

FROM LABORATORY TO ROAD

A 2014 UPDATE OF OFFICIAL AND “REAL-WORLD” FUEL CONSUMPTION AND CO₂ VALUES FOR PASSENGER CARS IN EUROPE

AUTHORS:

Peter Mock, Uwe Tietge, Vicente Franco, John German, Anup Bandivadekar (ICCT)

Norbert Ligterink (TNO)

Udo Lambrecht (IFEU)

Jörg Kühlwein (KISU)

Iddo Riemersma (Sidekick Project Support)



www.theicct.org

communications@theicct.org



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For additional information:

International Council on Clean Transportation Europe
Neue Promenade 6, 10178 Berlin
+49 (30) 847129-102
communications@theicct.org
www.theicct.org

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EXECUTIVE SUMMARY

Europe’s passenger-car efficiency regulation has very effectively driven down the official average CO₂ emissions and fuel consumption of new passenger cars in the EU. The 2015 target of 130 grams of CO₂ per kilometer (g/km) was met two years ahead of schedule and manufacturers are making good progress towards the 2020/21 target of 95 g/km.

But beneath this apparent success there is cause for concern. The basis for the regulation are results obtained under laboratory conditions using the New European Driving Cycle (NEDC)—the so-called certification or “type-approval” values. To make real progress, however, the results recorded in the laboratory must translate dependably into CO₂ reductions and fuel-consumption savings experienced on the road. This study, which builds on and extends the analysis begun in 2012 and continued in 2013, demonstrates that the year-over-year improvements reported via the type-approval tests are not reliably matched in everyday driving—and that the gap between the vehicle emissions testing laboratory and the real world of the road is getting wider.

A technically precise definition of real-world driving conditions is elusive because of the large variation in vehicle types and driving behavior. However, by aggregating large sets of on-road fuel consumption data, clear trends can be observed. This methodology is the basis for the analysis in this report. The data sources comprise eight different data sets covering as many as 13 model years, including both private and company cars, from various European countries. In total, these sources furnish fuel consumption and CO₂ emission data from more than half a million vehicles.

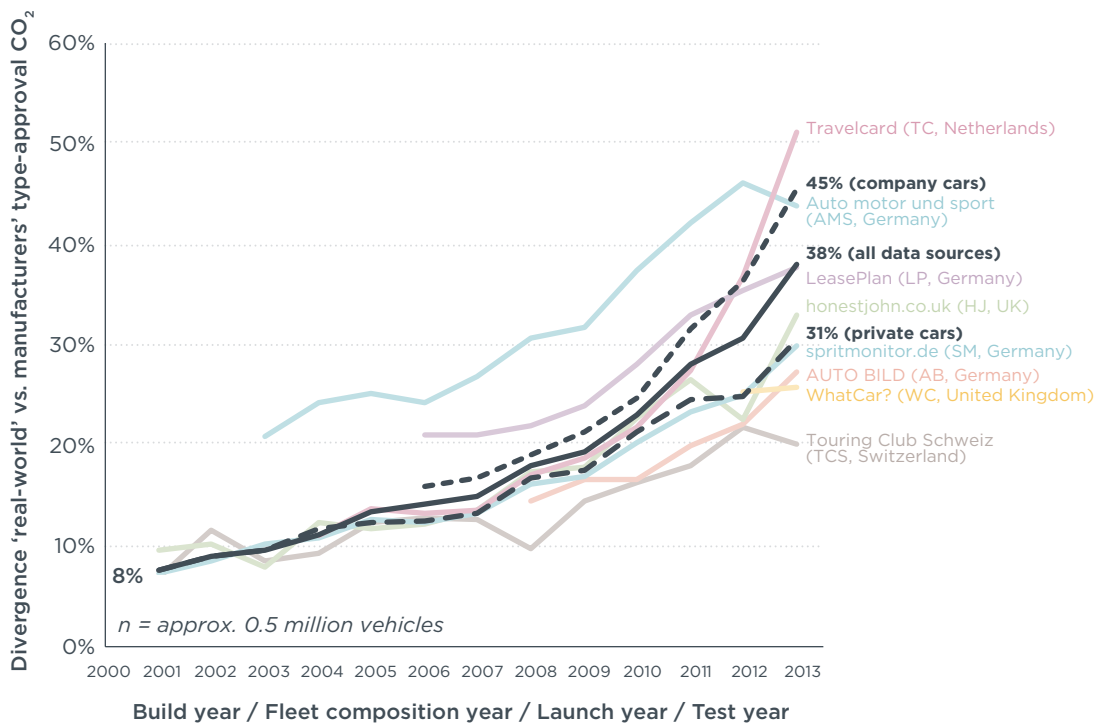


Figure 1. Divergence of real-world CO₂ emissions from manufacturers' type-approval CO₂ emissions for various on-road data sources, including an average estimate for private and company cars as well as all data sources.

All sources confirm one overarching trend: while the average discrepancy between type-approval and on-road CO₂ emissions was around 8 percent in 2001, by 2013 it had increased to about 38 percent. The increase in recent years was especially steep: since 2007 the gap grew by roughly one fifth per year. Methods of collecting on-road CO₂ emissions differ from source to source, as do fleet characteristics and driving styles; therefore, the absolute discrepancies found vary from one source to another. What is important to note, though, is that all evidence points towards a growing gap between type-approval and real-world values over time.

It is reasonable to assume that driving behavior has not changed appreciably over the past years. Instead, the observed increase of the gap is most likely due to a combination of the following factors:

- » Increasing application of fuel-saving technologies that show a higher benefit in type-approval tests than under real-world driving conditions (for example, stop-start technology).
- » Increasing exploitation of “flexibilities” (test tolerances and insufficiently defined aspects of the test procedure) in the type-approval procedure (for example, during coast-down testing).
- » External factors changing over time (for example, increased use of air conditioning)

The discrepancy observed in some cases differs among vehicle segments, vehicle manufacturers, and individual vehicle models. The greater discrepancy for low-CO₂ vehicles in the Netherlands is particularly remarkable. This development was likely driven by tax exemptions that provide a very strong incentive for vehicles that fall into the lowest tax category based on type-approval CO₂ values.

In general, differences in typical customer profiles may influence the comparison of manufacturers and vehicle models. Therefore, the analysis should not be viewed as a manufacturer ranking but rather as evidence that the observed increase in the gap constitutes a systemic problem.

The results of this study have significant implications for all stakeholders.

- » **For an average consumer**, the gap translates into increased fuel costs on the order of €450 per year¹.
- » **For society** as a whole, the gap *more than halves* the official CO₂ reductions achieved during the last ten years, making it more challenging to meet our CO₂ reduction and climate change mitigation objectives. Similarly, overall fuel consumption and thus also oil imports into the EU are not reduced to the same extent as suggested by the type-approval values.
- » **For governments**, the gap can mean significant loss of potential tax revenues, as most EU member states base their vehicle taxation schemes at least partly on type-approval CO₂ emissions. For the Netherlands, the loss in tax revenues could exceed €3.4 billion per year. For Germany, despite its relatively low vehicle taxes, the loss in annual vehicle ownership tax on a single year’s new car sales alone could be well over €240 million per year.
- » **For manufacturers**, the gap has the potential to undermine the credibility of individual companies, and even of the entire auto industry.

¹ This is due to the fact that CO₂ emissions and fuel consumption are directly proportional. Any discrepancy between type-approval and real-world CO₂ emissions therefore translates into an equivalent gap for fuel consumption figures.

It is important to clarify that this analysis is not intended to incriminate vehicle manufacturers. The NEDC was not originally designed to measure average fuel consumption or CO₂ emissions, and some of its features can be exploited to obtain artificially low results. Manufacturers appear to be taking advantage of permitted flexibilities in the NEDC, resulting in lower CO₂ emission values. The new Worldwide Harmonized Light Vehicles Test Procedure (WLTP), with its more dynamic test cycle and tightened test procedure, is expected to result in somewhat more realistic values. The WLTP was adopted in March 2014, and the European Commission is currently preparing its implementation for the type-approval of new cars in the European Union from 2017 on. A key aspect of the transition will be an appropriate conversion of existing CO₂ targets and CO₂ based taxation schemes from NEDC into WLTP. Unintended flexibilities that are currently part of the NEDC should not be accounted for when transitioning to WLTP. Otherwise there is a risk of undermining the introduction of WLTP and making most improvements achieved with the WLTP obsolete.

At the same time, the WLTP will not resolve all open issues, and the new procedure may itself have vulnerabilities that have not yet been identified. In light of this, it is important to complement the WLTP with additional measures, such as testing and regulating the efficiency of vehicle air conditioning systems. More importantly, some form of in-service conformity testing should be required to ensure that reasonable emission values are achieved not for a single test vehicle alone but for all cars sold to customers and driven on the road.

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ABBREVIATIONS

cm	Centimeter
CO ₂	Carbon dioxide
EPA	Environmental Protection Agency
EU	European Union
g/km	Grams per kilometer
HEV	Hybrid electric vehicle
ICCT	International Council on Clean Transportation
IFEU	Institute for Energy and Environmental Research Heidelberg
km	Kilometer
km/h	Kilometers per hour
MPG	Miles per gallon
NEDC	New European driving cycle
PEMS	Portable emissions measurement system
PHEV	Plug-in hybrid electric vehicle
RDE	Real driving emissions
TCS	Touring Club Switzerland
TNO	Netherlands Organisation for Applied Scientific Research
U.K.	United Kingdom
USA	United States of America
VW	Volkswagen
WLTP	World harmonized light vehicles test procedure

1. INTRODUCTION

The European Union (EU) was among the first regions in the world to introduce a mandatory regulation to reduce carbon dioxide (CO₂) emissions of new passenger cars. In 2009, when the EU CO₂ performance standards were adopted, there was considerable controversy as to whether the 2015 target of 130 grams per kilometer (g/km) of CO₂ could be achieved. As it turned out, the target was met in 2013 (Tietge and Mock, 2014), two years ahead of schedule. And car manufacturers are already preparing for the next target, the 95 g/km standard for 2020/21. There is no question that the EU CO₂ regulation for passenger cars has been a great success. Before the regulation took effect, the annual rate of reduction in CO₂ emissions from new cars was around one percent per year; afterward, the reduction rate increased to about four percent per year (Mock 2014).

The European Commission estimates that to limit the worst effects of climate change we must reduce average greenhouse gas emissions in the EU by 80-95 percent from 1990 levels by 2050 (EC 2011). Passenger cars, as a major contributor of CO₂ emissions, are an important source for those reductions, and mandatory performance standards are the key to realizing them. Moreover, as CO₂ emissions and fuel consumption are proportional, reducing CO₂ emissions also means fuel cost savings for consumers and less need to import oil into the EU². Last but not least, efforts to reduce vehicle emissions and improve fuel efficiency drive technological development, which creates and sustains jobs in the EU (Summerton et al. 2013).

But those benefits depend on regulations that deliver real reductions in CO₂ emissions, not merely reductions on paper. It is important to understand that the vehicle performance standards set by the EU only affect the “type-approval” values for individual vehicles. These values are laboratory measurements of vehicle emissions, obtained over a test cycle and via a test procedure specified in the regulation. (Currently in the EU, the New European Driving Cycle, or NEDC, is used for this purpose.) This approach should in principle ensure that manufacturers certify their vehicles in a reproducible manner and that all vehicles are held to the same standard. However, to achieve real CO₂ emission improvements, reductions in the level of CO₂ emissions measured in the laboratory through type-approval testing must be matched by reductions under “real-world” driving conditions.

The term “real-world” (or, similarly, “on-road”) relates to the practical experience of car owners in their everyday driving. As every driver has a distinct way of driving and driving conditions vary widely, especially seasonally, a precise technical definition of real-world driving is elusive. Still, as will be discussed in more detail later, by aggregating large amounts of in-use fuel consumption data, clear trends can be observed and analyzed.

In 2012, the International Council on Clean Transportation (ICCT) carried out the first attempt to quantify the historical relationship between type-approval and real-world CO₂ values of passenger cars (Mock et al. 2012). That study analyzed 28,000 user entries from the spritmonitor.de vehicle database, and found that the discrepancy between the two values had increased from about 7 percent in 2001 to 21 percent in 2010, and that the increase had been particularly pronounced since 2007.

In 2013, the ICCT, the Netherlands Organisation for Applied Scientific Research (TNO), and the Institute for Energy and Environmental Research Heidelberg (IFEU) jointly published a follow-up report (Mock et al. 2013). That report included many

² For reasons of clarity and simplicity, only CO₂ values are reported in this paper, with CO₂ being an excellent proxy for fuel consumption.

more data sources, with data from around half a million vehicles altogether. It mirrored the findings of the 2012 ICCT report, noting a considerable increase in the gap between official and real-world CO₂ emissions, in particular since 2007, for various vehicle types and usage patterns. The 2013 report also presented results for individual manufacturers and explored the differences in the level of discrepancy among different vehicle brands.

This document continues and extends the research begun in those two earlier reports. The objectives are to update the analysis of the gap between type-approval and real-world CO₂ emissions and to carry out additional analyses with updated and supplemental data. ICCT again collaborated with TNO and IFEU to collect and analyze various data sets, including those from car magazines and leasing companies. In addition, this report also analyzes data trends for individual vehicle models, thereby providing more insights into the underlying reasons for the increasing discrepancy between official and real-world emissions.

As in previous years, we make use of the “law of large numbers” in our analysis: while everyone drives differently, large sets of driving data generally resemble a normal distribution. Figure 2 illustrates this effect using the spritmonitor.de database as an example. Looking at the 2001 curve, it becomes clear that there was a significant variation in real-world CO₂ emission levels for different drivers, and that the distribution resembles a bell curve. While some managed to emit less than the official type-approval value (those on the left of the 100 percent line), others exceeded the official CO₂ emissions value by 20 percent or more. On average, the drivers achieved emission values that are about 7 percent higher than type-approval CO₂ measurements. Looking—for example—at the 2011 and 2013 curves, an approximately normal distribution (bell curve) of results can still be observed. However, the average level of the gap increases from 7 percent in 2001 to 23 percent in 2011 and 30 percent in 2013. These average gap values are the focus of this report; however, it should always be kept in mind that each of the average values is based on a distribution curve, as shown in this figure.

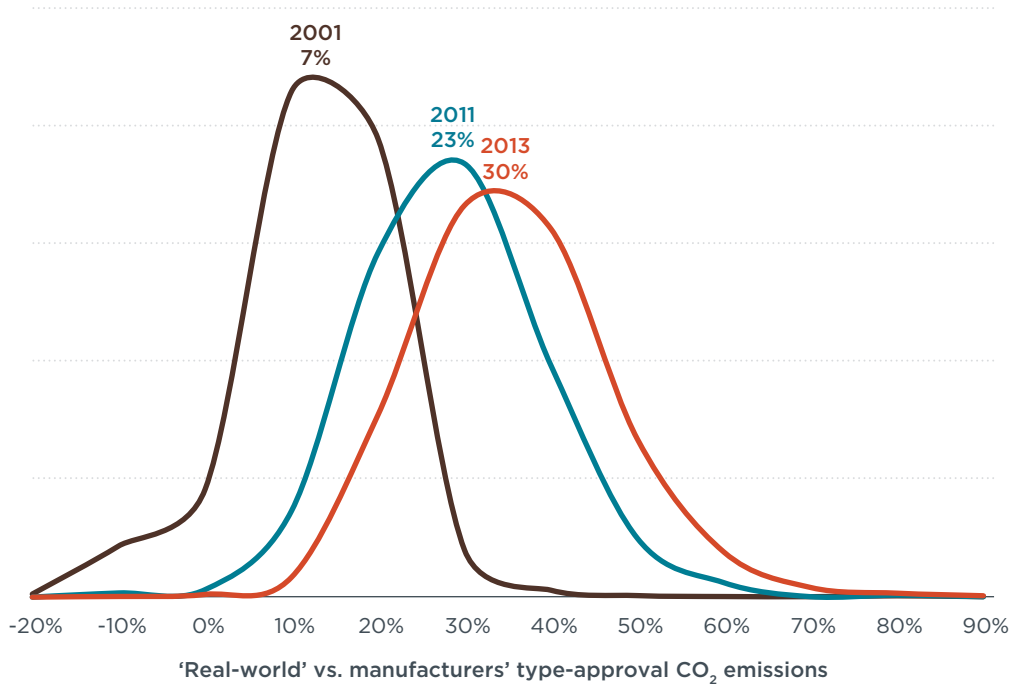


Figure 2. Estimated probability density function of reported real-world emission values as a percentage of type-approval figures in spritmonitor.de, comparison for the years 2001, 2011 and 2013.

The remainder of this report is divided into four parts. In section 2 we describe and analyze a number of different data sources. Where the data will permit it, we present results not only for that vehicle fleet as a whole but also for individual vehicle segments, manufacturers, and models. In section 3, we compare different data sources and discuss trends. Sections 4 and 5 summarize the findings and put them in a policy context.

Potential reasons for the increasing gap were discussed in detail in our 2013 report. That discussion is not reproduced in detail in this 2014 update. Similarly, while details on a comparable U.S. data set were included in 2013, this report focuses on EU data sources only. Finally, this report focuses on on-road driving data only. Laboratory data from tests performed outside of type-approval, such as the ADAC EcoTest results³, were included and analyzed in detail in our 2012 and 2013 reports.

While the focus of this report is on CO₂ emissions and fuel consumption, there is growing evidence of a similar discrepancy in test measurements versus on-road emissions of air pollutants, in particular emissions of nitrogen oxides from diesel cars. This issue will be addressed in a forthcoming report by the ICCT.

³ <http://www.adac.de/infotestrat/tests/eco-test/default.aspx>

2. DATA ANALYSIS

2.1. SPRITMONITOR.DE (GERMANY)

Data type	On-road, user-submitted
Data availability	2001–2013, approximately 6,000 vehicles per year
Data collection	Fuel consumption data, entered by vehicle drivers into a publicly available online database
Fleet structure, driving behavior	Mostly private cars, urban and extra-urban driving, no details on driving style

Description

Spritmontitor.de⁴ is an online database with more than 300,000 users that provides on-road fuel consumption figures for cars in Germany. Anyone can register for free, choose a vehicle model, year of manufacture (build year), and exact configuration, and enter data on fuel consumption as well as distance travelled. The reported values are freely accessible to everyone.

As spritmonitor.de relies on user-submitted data, consumers' attitudes and behaviors could affect the data. On the one hand, those consumers reporting their experience to the website are likely to pay more attention to the fuel efficiency of their vehicles and may drive in a more fuel-conserving manner than others. One might therefore posit that the difference between real-world and type-approval CO₂ values is actually higher than what is suggested by the spritmonitor.de analysis. The gap between type-approval and spritmonitor.de fuel consumption rates may thus be viewed as a conservative estimate. On the other hand, consumers who are particularly frustrated with their cars' fuel consumption may be more likely to engage with websites such as spritmonitor.de than other consumers. This bias could lead to an overestimation of the gap between spritmonitor.de and type-approval values. In any case, even if the data are biased in either direction, this bias should be consistent over time and should not affect the observed trends in the relationship between the spritmonitor.de values and the type-approval values. As was shown in our 2013 analysis, spritmonitor.de data provides a good representation of the German car market.

Methodology

Data from 85,000 vehicles manufactured between 2001 and 2013 were analyzed for the following car manufacturers/brands: BMW (BMW, Mini), Daimler (Mercedes-Benz, smart), Fiat, Ford, General Motors (Opel), PSA (Peugeot, Citroën), Renault-Nissan (Renault, Nissan), Toyota, Volkswagen (Audi, Škoda, VW), and Volvo. The models included in the study account for about 75 percent of annual sales in Germany.

For every vehicle variant on spritmonitor.de, the average fuel consumption value was collected and divided by the corresponding type-approval value. Quality checks, such as outlier detection and correction, were performed on the data. The relative difference was then weighted by sales of the respective vehicle variant in the German market in order to accurately represent the new car fleet in Germany.

Results

As shown in Figure 3, the average discrepancy between fuel consumption values reported on spritmonitor.de and vehicle type-approval values increased from 7 percent

⁴ See <http://www.spritmonitor.de>. The data set used for this analysis was collected from the website during May–June 2014.

in 2001 to 30 percent in 2013. It is also noteworthy that the compound annual growth rate increased from 10 percent between 2001 and 2007 to 15 percent between 2007 and 2013.

While a systematic difference between gasoline and diesel vehicles was not observable between 2001 and 2010, the increase in the deviation of diesel vehicles after 2010 appears to persist. Hybrid vehicles exhibit significantly higher deviations from official fuel consumption figures than gasoline or diesel cars. In the case of the spritmonitor.de data set, the discrepancy found for hybrid cars in 2010–2013 is around 35–40 percent. It should be taken into account, though, that hybrid vehicles generally have automatic transmissions; the higher gap may, to some extent, be attributable to the automatic transmission (see next paragraph), not the hybrid technology itself. There are not enough hybrid cars in the data set for a meaningful analysis of vehicles built before 2010. The number of plug-in hybrid electric vehicles (PHEV) is still too low in Germany to support any conclusions about their average discrepancy.

Lastly, as shown in Figure 4, the disparity between manual and automatic transmission vehicles continues to increase. On average, automatic transmission vehicles now consume 36 percent more fuel under real-world conditions than under type-approval testing, while vehicles with manual transmissions deviate by 27 percent. The disparity between the two transmission types has doubled since 2011. This observation is in line with the general expectation that the introduction of the new World-Harmonized Light-Duty Vehicles Test Procedure (WLTP) will result in more favorable CO₂ type-approval values for vehicles with manual transmissions compared to manual transmissions under the current NEDC test procedure. In the current NEDC, there are fixed gear shift points for manual transmissions that need to be followed, whereas manufacturers can adjust gear shift points for vehicles with automatic transmissions. The WLTP will include flexibility in the selection of shift points for both transmission types (Mock 2013b).

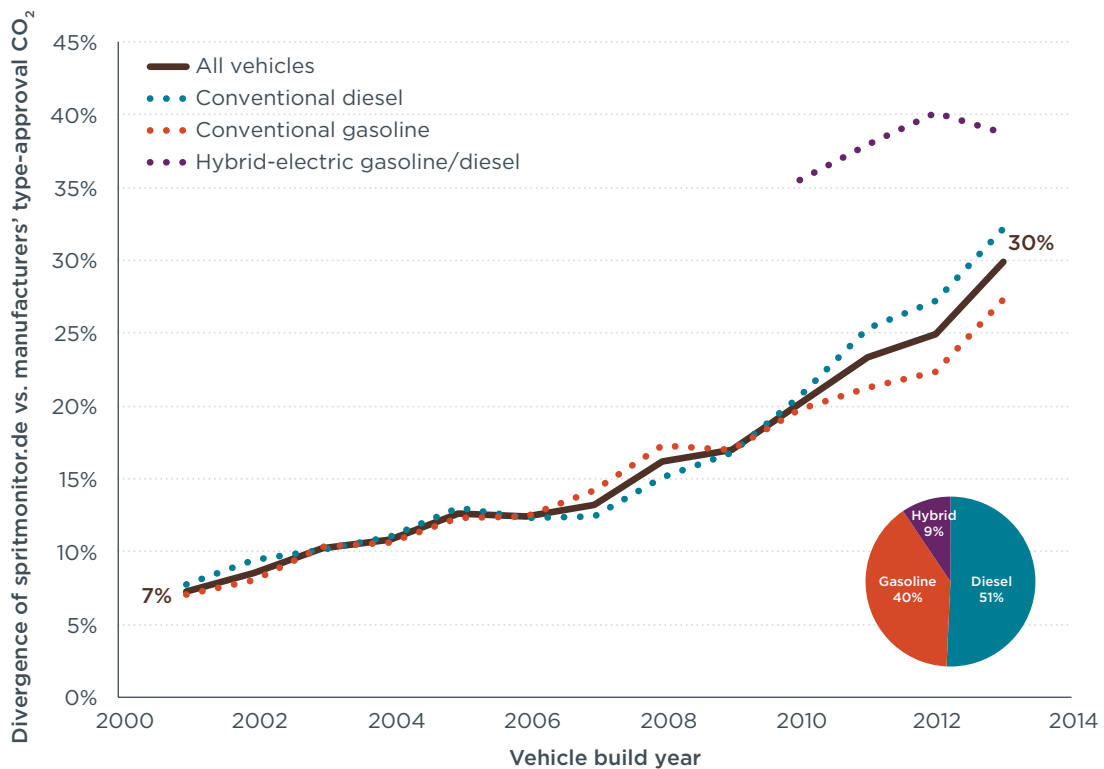


Figure 3. Divergence of spritmonitor.de vs. manufacturers' type-approval CO₂ emissions by engine type (pie chart indicates number of vehicles per engine type in the data set for 2013)

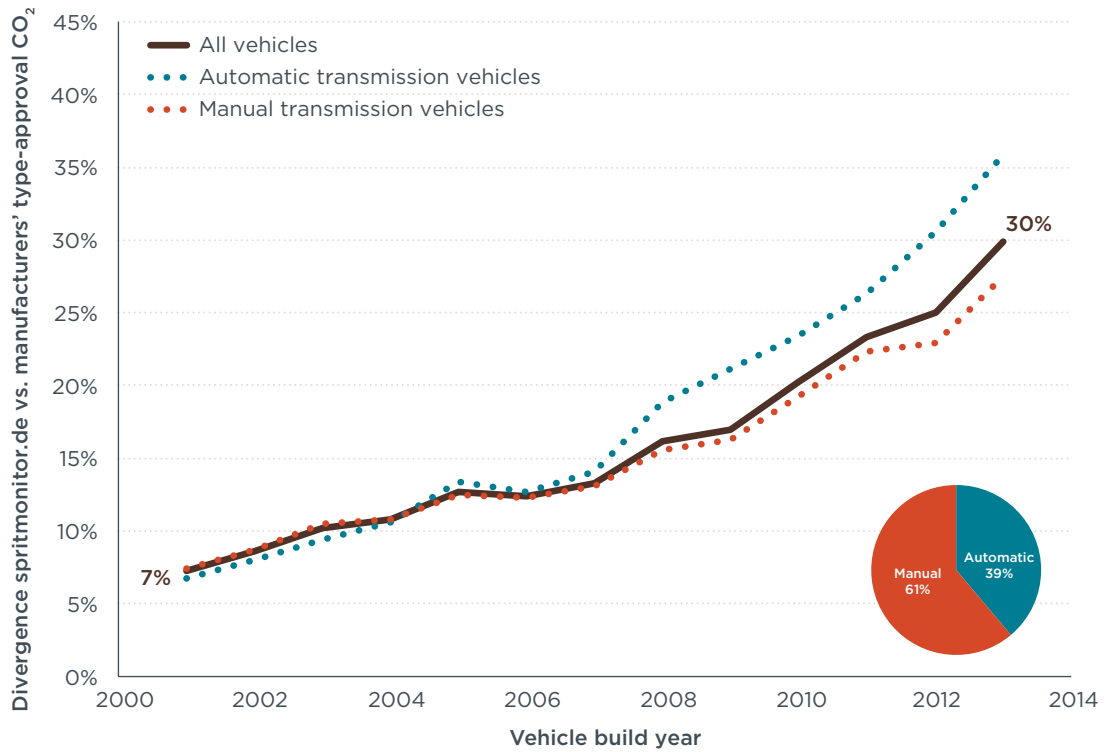


Figure 4. Divergence of spritmonitor.de vs. manufacturers' type-approval CO₂ emissions by transmission type (pie chart indicates number of vehicles per transmission type in the data set for 2013).

(Ed. note: The figure has been altered from the original to correct an editorial error; the manual and automatic transmission trend lines were inadvertently reversed.)

Figure 5 shows the divergence of spritmonitor.de CO₂ emissions from type-approval values for different vehicle segments. While the lower segments follow the market trend, the upper-medium and sport segments exhibit significant and rapid increases in this divergence.



Figure 5. Divergence of spritmonitor.de vs. manufacturers' type-approval values by vehicle segment (pie chart indicates number of vehicles per segment in the data set for 2013).

The spritmonitor.de data also allows for an analysis of individual brands and manufacturers (Figure 6). As indicated in the foregoing discussion, technical characteristics and driving behavior vary across different vehicle segments. Comparisons of car manufacturers/brands with similar customer bases—for example, Audi, BMW, and Daimler—are therefore more even-handed than comparisons across brands with dissimilar customer bases. However, it should again be noted that driving behavior and vehicle use cannot account for the overall increase of the divergence over time.

While some manufacturers, such as Ford and General Motors, steadily follow the market trend, other manufacturers went through more abrupt changes. Two German premium car makers, BMW and Daimler, exceeded the market-wide average gap during recent years. BMW's deviation in real-world CO₂ emissions increased rapidly from 2006 to 2008; this increase coincides with the introduction of EfficientDynamics technologies, a package of fuel-saving technologies such as start-stop systems and aerodynamic

improvements.⁵ Daimler only began to deviate from the market average in 2010, with the difference continuing and increasing through 2013.

In contrast to these manufacturers, the French and Franco-Japanese partnerships PSA and Renault-Nissan remain below the market average for discrepancies between real-world and type-approval CO₂ emissions. However, starting in 2010 and 2011, spritmonitor.de data reveals a steep increase in the deviations of both car makers.

As indicated in Figure 3, hybrid vehicles generally have a higher divergence than gasoline or diesel vehicles. This observation is reflected in Toyota's development: spritmonitor.de data reveals lower deviations for Toyota's conventional vehicles (excluding hybrids) than for the manufacturer's entire portfolio of vehicles (including hybrids). This difference indicates that Toyota's hybrid vehicles have higher deviations than its diesel and gasoline vehicles, and that sales of hybrid cars (about 26 percent in Germany in 2013) were sufficiently high to significantly impact the manufacturer's overall deviation. In this context it should be noted that hybrid vehicles generally have automatic transmissions, and if compared to automatic transmission conventional gasoline and diesel vehicles only, the difference in the gap is lower than compared to the average for all gasoline and diesel vehicles.

Within the Volkswagen Group, Audi has continuously exceeded the market average deviation in real-world CO₂ emissions. In contrast to premium manufacturers BMW and Daimler, Audi already exceeded the market trend in 2003, and has continued to do so. The other Volkswagen Group brands considered in this analysis, Škoda and VW, have consistently remained below the market average, with the result that the overall deviation of the Volkswagen group closely tracks the market trend.

⁵ <http://www.bmwarchiv.de/artikel/2007-06-26-zum-herbst-2007-bereits-rund-40-prozent-des-bmw-group-absatzes-in-europa-mit-maximal-140g-co2-pro-km-bmw-efficient-dynamics-jetzt-auch-fuer-alle-bmw-3er.html>

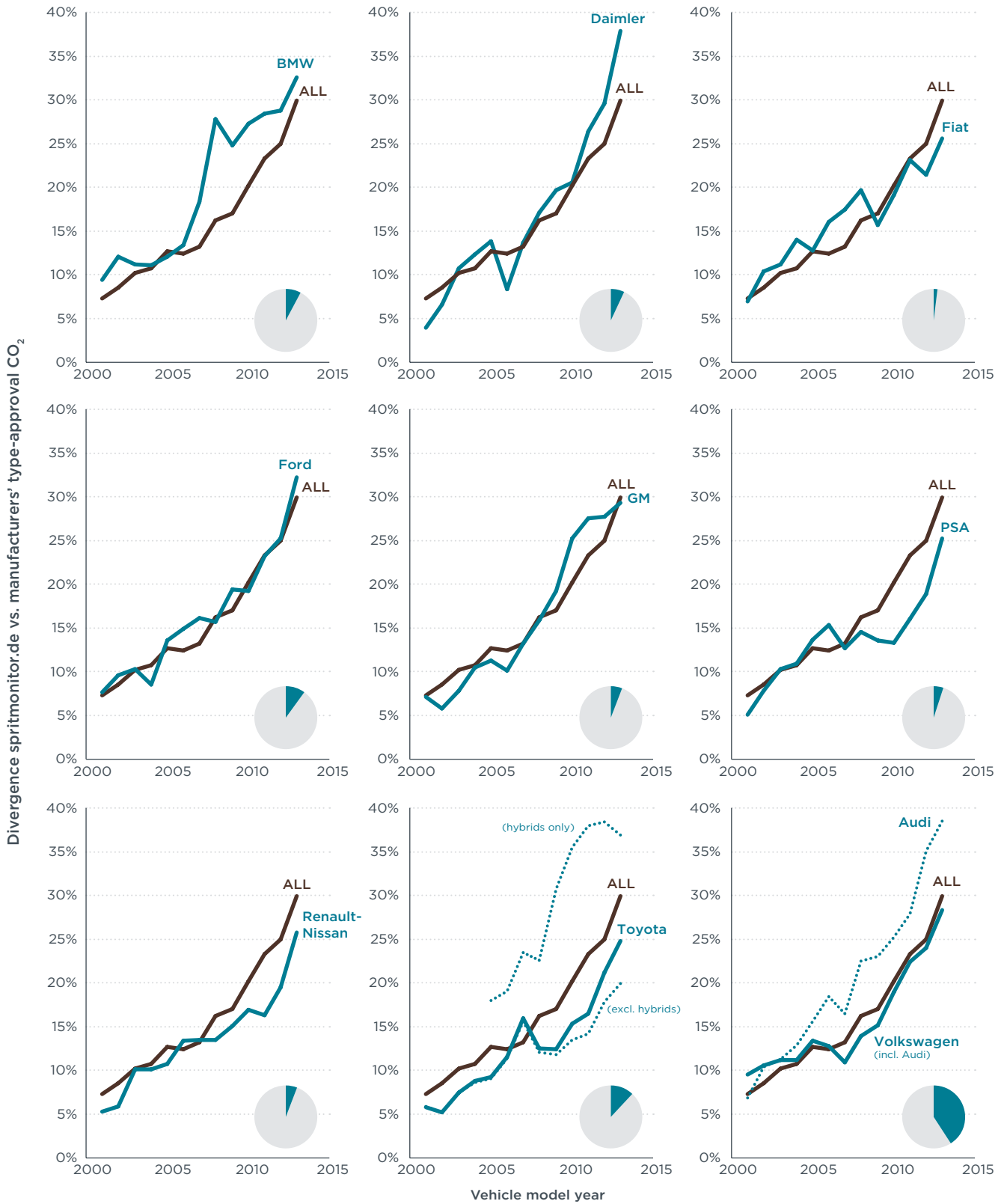


Figure 6. Divergence of spritmonitor.de vs. manufacturers' type-approval CO₂ emissions by brands/manufacturers.⁶

⁶ Manufacturers (brands) included are: BMW (BMW, Mini), Daimler (Mercedes-Benz, smart), Fiat (Fiat), Ford (Ford), GM = General Motors (Opel), PSA (Peugeot, Citroën), Renault-Nissan (Renault, Nissan), Volkswagen (Audi, Škoda, VW), Volvo (Volvo). Due to limited space, the deviation for Volvo (5% in 2001 to 29% in 2013) was not presented in the figure.

Because spritmonitor.de includes such a large number of vehicles, it is also possible to examine developments in the divergence of real-world CO₂ values from type-approval values for individual vehicle models.

Figure 7 depicts the divergence of CO₂ values for the three top-selling models produced by BMW, Mercedes-Benz, Peugeot, Renault, Toyota, and VW. In addition to the evolution of the discrepancy between real-world and type-approval CO₂ emission values for each model, the graphs also display sales-weighted average deviations for entire brands, for comparison. The minimum and maximum number of annual entries for models (not for entire brands) is shown in the bottom-right corner. Each model's contribution to its respective brand's sales in 2013 is also presented. The arrowheads on the trend lines indicate the introduction of a new model generation or a major facelift affecting fuel consumption. It should be noted that gasoline, diesel and hybrid-electric vehicle model sales are averaged here.

As shown in these graphs, divergence of real-world CO₂ emissions from all models, regardless of brand, increased between 2001 and 2013. Since the three top-selling models typically account for 50 to 70 percent of each brand's sales, the divergence of a brand's top models is usually in line with the divergence of the brand's overall fleet.

The divergence of BMW's top three models, accounting for approximately 71 percent of its sales, increased rapidly during 2006 and 2008. The 1-series' deviation increased from 17 to 36 percent during this time. This increase coincided with the introduction of EfficientDynamics, a package of fuel-saving technologies.⁷ More recently, after introduction of the sixth generation in 2010, the 5-series has shown the highest deviation, which is consistent with the sharp increase observed in the upper-medium segment (Figure 5).

The A-, C-, and E-Class models account for roughly 54 percent of Mercedes-Benz sales, and have generally exhibited uniform developments in the divergence of real-world CO₂ emissions. The A-Class, however, lay significantly below the brand average in 2011 and increased by 25 percent in the last two years. This upsurge followed the introduction of a new generation of the A-Class in early 2012⁸. The E-Class now has the highest deviation of the top-selling Mercedes-Benz vehicles after a sharp rise in its divergence between 2012 and 2013, which is consistent with the upper medium segment's development (Figure 5).

For Peugeot, sufficient spritmonitor.de entries for all years were only available for two series of models. Other models, such as the Peugeot 2008, significantly contribute to the brand's sales, but they have only recently been introduced, so an inter-annual analysis would not be meaningful. Both the 206-208 and the 306-308 models closely follow the brand average. The data reveals a rapid increase in the models' divergence between 2011 and 2013, about at the same time as the introduction of the 208 in 2012.

This sudden increase is also noticeable for two Renault models, the Mégane and Clio. While the Mégane underwent a facelift with the introduction of more fuel-efficient engines in 2012, an entirely new generation of the Clio was introduced in the same year⁹. In the absence of significant technical overhauls, the Renault Twingo's divergence remains fairly stable after 2006.

Two of Toyota's top-selling models, the Yaris and Auris, are available as hybrid and non-hybrid vehicles. While the non-hybrid variants deviate less from type-approval CO₂ values, the hybrid variants have a significantly higher divergence. This considerable

7 Katalog der Automobile Revue 2013, <http://katalog.automobilrevue.ch>

8 Katalog der Automobile Revue 2013, <http://katalog.automobilrevue.ch>

9 Katalog der Automobile Revue 2013, <http://katalog.automobilrevue.ch>

discrepancy between hybrid and non-hybrid vehicles is consistent with trends in the overall market (see Figure 3) and with the discrepancy between manual versus automatic transmissions, as all Toyota hybrids use automatic transmissions (see Figure 3).

For VW, the Passat shows a rapid increase in the divergence of CO₂ emissions; from 9 percent in 2010 to 31 percent in 2011. This upswing occurred after the seventh generation of the Passat was introduced in 2010.¹⁰ In contrast to the Passat, the Golf and Polo exhibit a more gradual increase in these years; however, the divergence of the Golf increased steeply last year. As the Golf accounts for 30 percent of all VW sales, this increase has a significant effect on the brands' overall deviation.

¹⁰ Katalog der Automobile Revue 2013, <http://katalog.automobilrevue.ch>

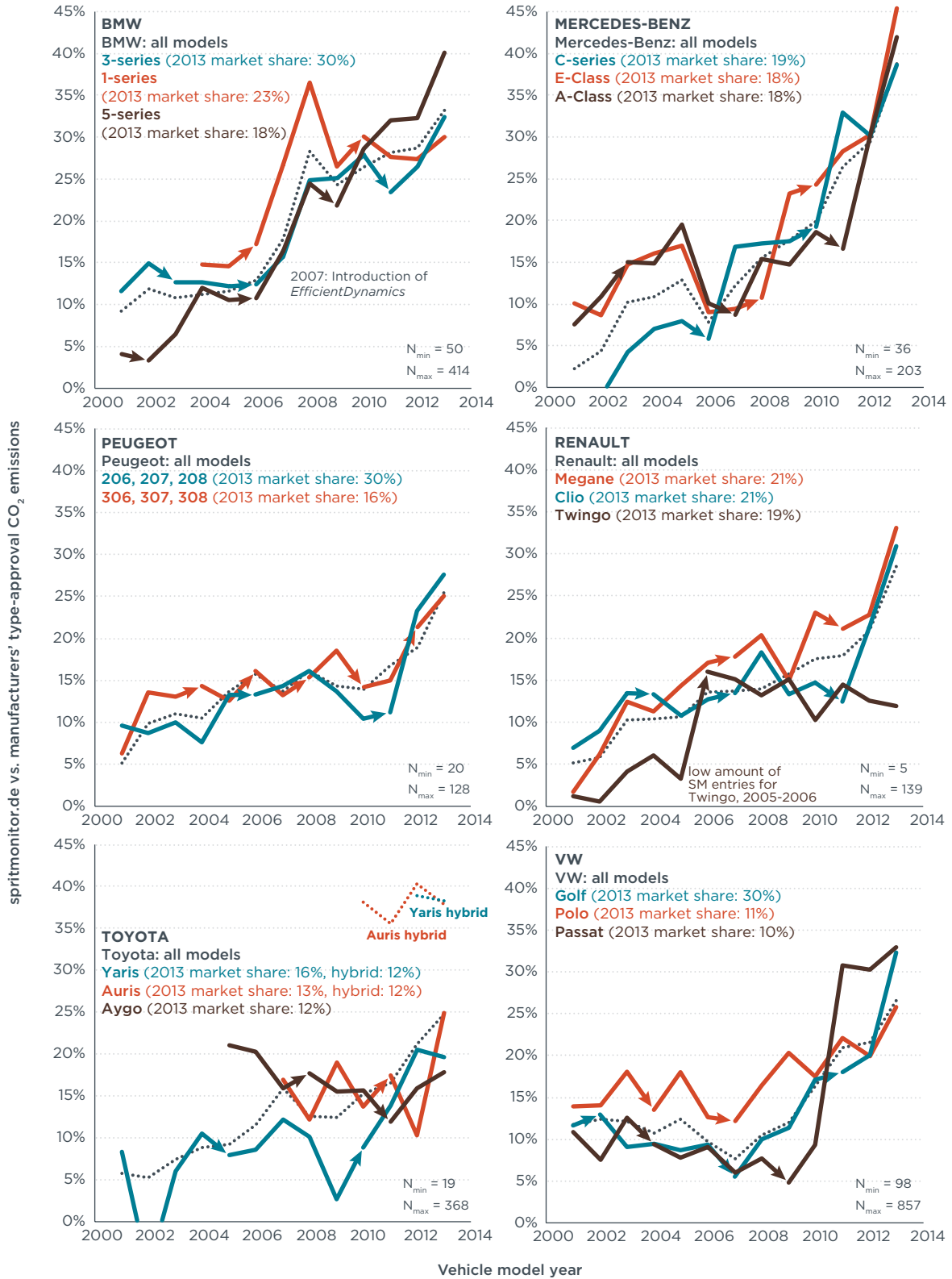


Figure 7. Divergence of spritmonitor.de data from manufacturers' type-approval CO₂ emissions by brand and by top-selling models.¹¹

¹¹ 2013 market share: models' contribution to the sales of their respective brands in Germany (source: European Commission CO₂ monitoring database); N_{min}/N_{max} : minimum and maximum number of vehicles per model for all years; Toyota models separated into gasoline/diesel and hybrid models.

Figure 8 presents the divergence of fuel consumption for the three top-selling models of different vehicle segments. These graphs are especially interesting, as the impacts of driver behavior and automatic versus manual transmissions should be minimized for these comparisons of similar vehicles. The graphs are delineated according to vehicle segments (small, lower medium, medium, and upper medium) as well as target market (mass market or premium market)¹². In addition to the annual discrepancy between real-world and type-approval CO₂ emission values for each model, the graphs also display sales-weighted average deviations for entire market segments for comparison. The minimum and maximum number of annual entries for all models (not for the entire segment) is displayed in the lower-right corner. Each model's contribution to sales in its respective segment in 2013 is also presented. As in figure 7, arrowheads on the trend lines indicate the introduction of a new model generation or a major facelift affecting fuel consumption.

A universal increase in the divergence between spritmonitor.de and type-approval emissions values can again be observed. However, while the increase in the discrepancy is fairly constant and homogeneous for some segments, this development is more abrupt and fragmented in other classes.

The small, mass-market segment is characterized by fairly uniform, steady increases in the divergence between real-world and type-approval CO₂ values. Merely a sharp increase in the Ford Fiesta's deviation between 2012 and 2013 is notable, following a major facelift of the model series.

The lower-medium, mass-market models appear to be more divergent. The Opel Astra's deviation surged after 2006 and peaked by 2010. In contrast to the Astra, the Škoda Octavia underwent only minor technical overhauls in 2006–2012, but rapidly caught up to the segment average in 2013 after the introduction of the third-generation model in late 2012¹³.

In the lower-medium, premium market segment, the BMW 1-series was first to reach a divergence above 30 percent. The Audi A3 saw a rapid increase in its deviation during 2012 to 2013 after a facelift in 2012.¹⁴ As noted earlier, the Mercedes-Benz A-Class similarly went through a period of rapid increase in the divergence of real-world and type-approval CO₂ emissions during this time, following a facelift in early 2012.

In the medium, mass-market segment, the Opel Insignia closely tracked the segment average. Similar to the Škoda Octavia, the Škoda Superb lagged behind other models but then saw a rapid increase in its deviation from type-approval values after a facelift in 2013. As noted above, the spritmonitor.de data indicate that the VW Passat's divergence in real-world fuel consumption surged between 2010 and 2011, after the seventh generation of the Passat was introduced in 2010.

The medium, premium market segment is characterized by a relatively stable and uniform upwards trend in the divergence between real-world and type-approval CO₂ emission values. A notable exception is the 20-percentage-point increase in the Audi A4's divergence between 2011 and 2012, following a facelift in November 2011¹⁵.

In the upper-medium, premium market segment, the three top-selling models (Mercedes-Benz E-Class, BMW 5-series, and Audi A6) accounted for 90 percent of sales in Germany during 2013. These models show a steep incline in real-world CO₂ emissions from roughly 10 percent in 2006 to 45 percent in 2013. According to spritmonitor.de data, the Audi A6 is now the most divergent model in this segment, after an overhaul of the model in 2011.¹⁶

12 Classification of target market by ICCT. No suitable premium models could be identified in the small vehicle segment. Conversely, no mass-market models were included in the upper-medium segment analysis.

13 Katalog der Automobile Revue 2013, <http://katalog.automobilrevue.ch>

14 Katalog der Automobile Revue 2013, <http://katalog.automobilrevue.ch>

15 Katalog der Automobile Revue 2013, <http://katalog.automobilrevue.ch>

16 Katalog der Automobile Revue 2013, <http://katalog.automobilrevue.ch>

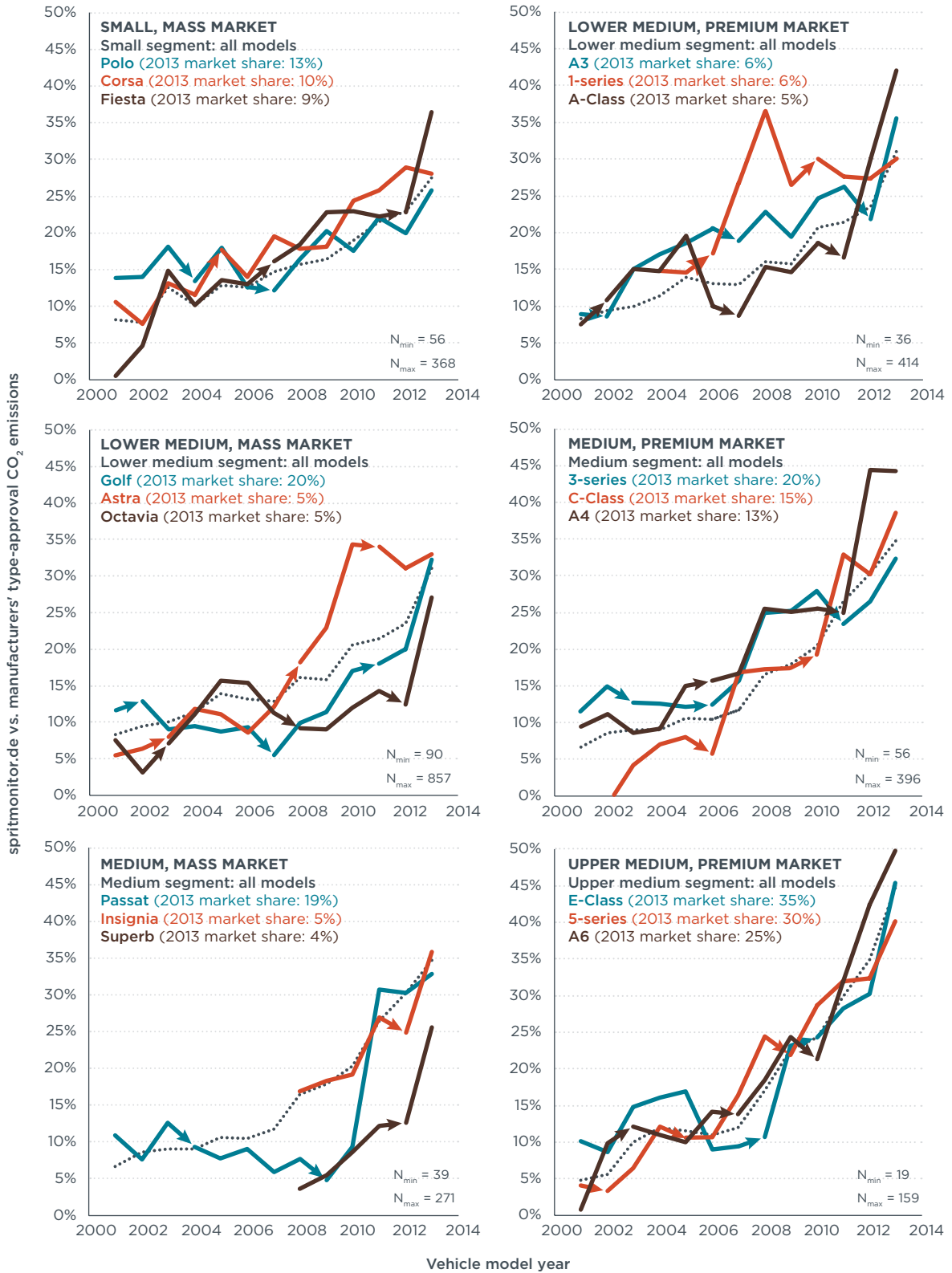


Figure 8. Divergence of spritmonitor.de data from manufacturers' type-approval CO₂ emissions by vehicle segment and their top-selling mass-market (left) and premium-market (right) models.¹⁷

¹⁷ 2013 market share: models' contribution to their respective segments in 2013; $N_{min/max}$: minimum and maximum annual amount of data entries for vehicle models.

The trend lines for individual vehicle models in Figure 7 and Figure 8 point towards the conclusion that changes in the gap tend to happen at the same time as the introduction of a new vehicle model generation or a major facelift. Figure 9 aggregates the data for the 26 top-selling vehicle models analyzed here. For each vehicle model, the discrepancy in the year immediately before and the year immediately after introduction of a new generation or a major facelift were taken into account, and a simple average (no sales weighting) was calculated for all 26 models. Model changes that took place before the year 2009 and those that occurred in 2009 or later are also differentiated.

The result confirms that the average gap was higher after 2009 (18 and 29 percent) than before 2009 (12 and 17 percent). More importantly, it demonstrates that the observed increase in the gap did not happen smoothly over time but instead is the result of many step-wise increases for individual vehicle models. After 2009, on average the gap increased from 18 percent to 29 percent for every introduction of a new vehicle generation or facelift; i.e., it increased rapidly within the two years around a model change. This finding is a strong indication that changes in driving behavior and/or in external factors (such as increased use of air conditioning) cannot be the underlying reasons for the increasing gap. Instead, changes in technology (for example, the introduction of stop-start technology) and increased exploitation of “flexibilities” (test tolerances and insufficiently defined aspects of the test procedure) are the most likely explanation.

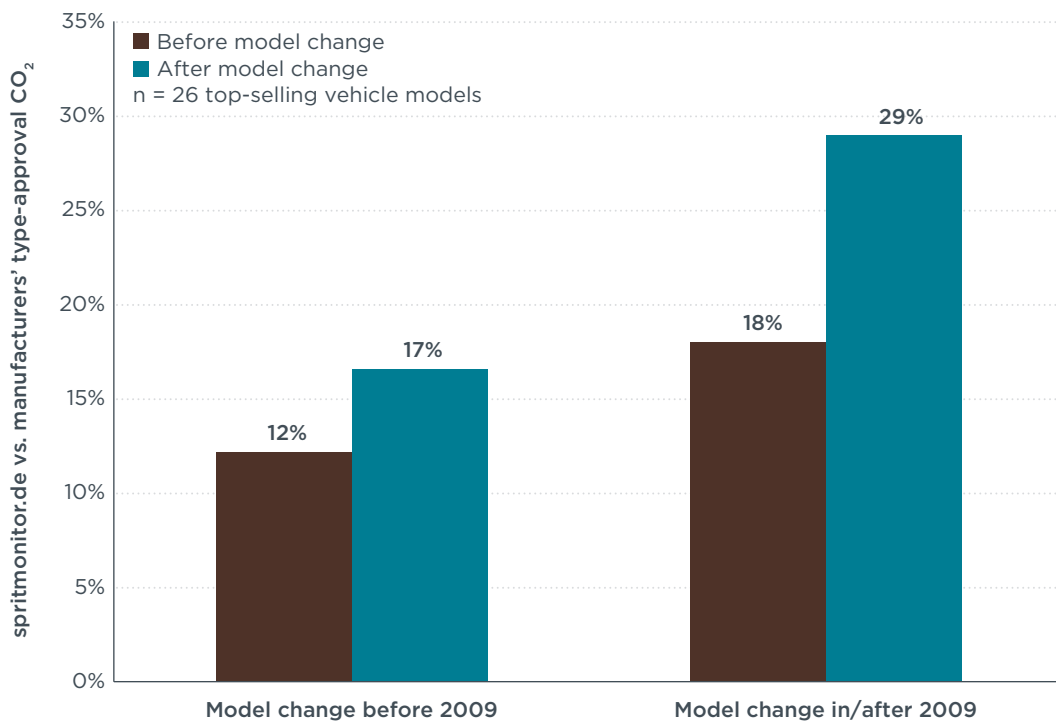


Figure 9. Average divergence of spritmonitor.de data from manufacturers' type-approval CO₂ emissions for 26 top-selling vehicle models. For ease of comparison, the years immediately before and after introduction of a new model generation or major facelift are put next to each other—on the left for model changes that occurred before 2009, on the right for changes in/after 2009.

2.2. TRAVELCARD (NETHERLANDS)

Data type	On-road, automatically recorded
Data availability	2004–2013, approximately 20,000 vehicles per year
Data collection	Fuel-consumption data, recorded using a tank card when refueling at gas stations
Fleet structure, driving behavior	Company cars, urban and extra-urban driving; fuel is usually paid for by the employer

Description

Travelcard¹⁸ is a fuel-card system introduced in the Netherlands that can be used at any gas station in the Netherlands and at more than 33,000 filling stations across Europe. Travelcard is part of LeasePlan Corporation N.V. About 200,000 vehicles out of the eight million cars registered in the Netherlands are regularly fueled using Travelcard. The fuel is typically paid for by employers, since many employees in the Netherlands receive a company car as part of their job benefits.

For this study, detailed fuel consumption data for more than 300,000 Travelcard vehicles from 2004 to 2013 were analyzed by TNO (Ligterink, N.E., Eijk A., R.A 2014). Following a thorough quality check, about 20 million individual filling events were used for the analysis. The following brand/manufacturer classification was applied: BMW (BMW, Mini), Daimler (Mercedes-Benz, smart), Fiat (Alfa Romeo, Fiat), Ford, General Motors (Opel), PSA (Peugeot, Citroën), Renault (Renault, Nissan), Toyota (Toyota, Lexus), Volkswagen (Audi, Seat, Škoda, VW).

In the discussion of Travelcard data in our 2013 report we differentiated between gasoline/diesel and hybrid electric vehicles, but here we differentiate between gasoline/diesel and plug-in hybrid electric vehicles. In the Travelcard data, (conventional) hybrid electric vehicles are no longer considered separately, as hybrid technology is ubiquitous in the Netherlands and included in the data for conventional gasoline/diesel vehicles for this analysis.

As with spritmonitor.de data, fuel consumption reported by Travelcard is not based on laboratory measurements, but instead reflects the in-use consumption experience of a large number of customers. The values are therefore considered a good representation of real-world CO₂ emission values of company cars in the Netherlands.

On the one hand, since fuel expenses are usually covered by the employer, Travelcard users may have weaker incentives to conserve fuel. On the other hand, the driving behavior of business customers, typically consisting of longer driving distances and limited urban driving, may counteract this bias. For a detailed comparison of Travelcard data and the Dutch vehicle market averages, see our 2013 report (Mock et al. 2013).

Methodology

The Travelcard data include manufacturers' type-approval fuel consumption figures for every vehicle, as well as the real-world fuel consumption rates determined by analyzing pairs of consecutive fueling events. The distance travelled between each pair of fueling events is recorded by the driver. The data set can therefore be analyzed without needing to reference other data sources. When aggregating individual vehicle data to fleet-wide averages, the Travelcard vehicle count was used to weight the results.

¹⁸ <http://www.travelcard.nl/>

Results

As shown in Figure 10, the discrepancy between CO₂ emission values reported by Travelcard and type-approval values increased from 11 percent in 2004 to 51 percent in 2013. The rapid acceleration of this increase occurred during the period when the mandatory passenger-car CO₂ emission regulation was introduced at the EU level and when the Dutch government introduced economic incentives for low-carbon vehicles and increased CO₂-based taxation of vehicles. For example, since 2009 fuel-efficient vehicles have been exempted from the Dutch registration tax. (The threshold values for this exemption were made more stringent in 2012 and 2013.)

A consistent difference between gasoline and diesel vehicles could not be observed for the Travelcard data for most years. However, it is noteworthy that the average discrepancy level of all vehicles built in 2012 was greater than the average discrepancy of diesel and gasoline vehicles in the same year (see Figure 9). This coincides with the fact that sales of new plug-in hybrid vehicles in the Netherlands increased from less than 0.5 percent of the overall market in 2012 to close to 5.0 percent in 2013, then decreased again to around 3.5 percent in the first part of 2014. Thus, the market share of plug-in hybrid electric vehicles built in 2012 was sufficient to significantly affect the 2013 fleet's overall average discrepancy level.¹⁹ Given the comparably high divergence from type-approval values for plug-in hybrid vehicles this led to a higher average gap in 2012 model year vehicles.²⁰ It should be noted that, according to TNO, the proportion of plug-in hybrid vehicles in the Travelcard data set is somewhat higher than in the Dutch national vehicle fleet, and therefore the effect of plug-in hybrid vehicles on the national average market in the Netherlands should be smaller than shown here (see also Ligterink et al., 2013). In 2013, for the first time in the Travelcard data, a significant difference between the divergence of gasoline and diesel vehicles can be seen. Interestingly, the discrepancy is higher for gasoline vehicles, while in the spritmonitor.de data the discrepancy is higher for diesel vehicles (compare Figure 4).

¹⁹ Plug-in hybrid electric vehicles accounted for more than four percent of new vehicles in the Netherlands in 2013 (Tietge, Mock 2014). See also <http://www.theicct.org/blogs/staff/electric-vehicle-markets-have-their-ups-and-downs-2014-ytd-update>

²⁰ In the current test procedure, fuel consumption and emissions of plug-in hybrid vehicles decrease drastically with increasing electrical range. In that regard, the procedure may not adequately reflect real-world driving behavior. For details on the test procedure, see UNECE R101, Annex 8, par. 3.4 and Ligterink et al., 2013.

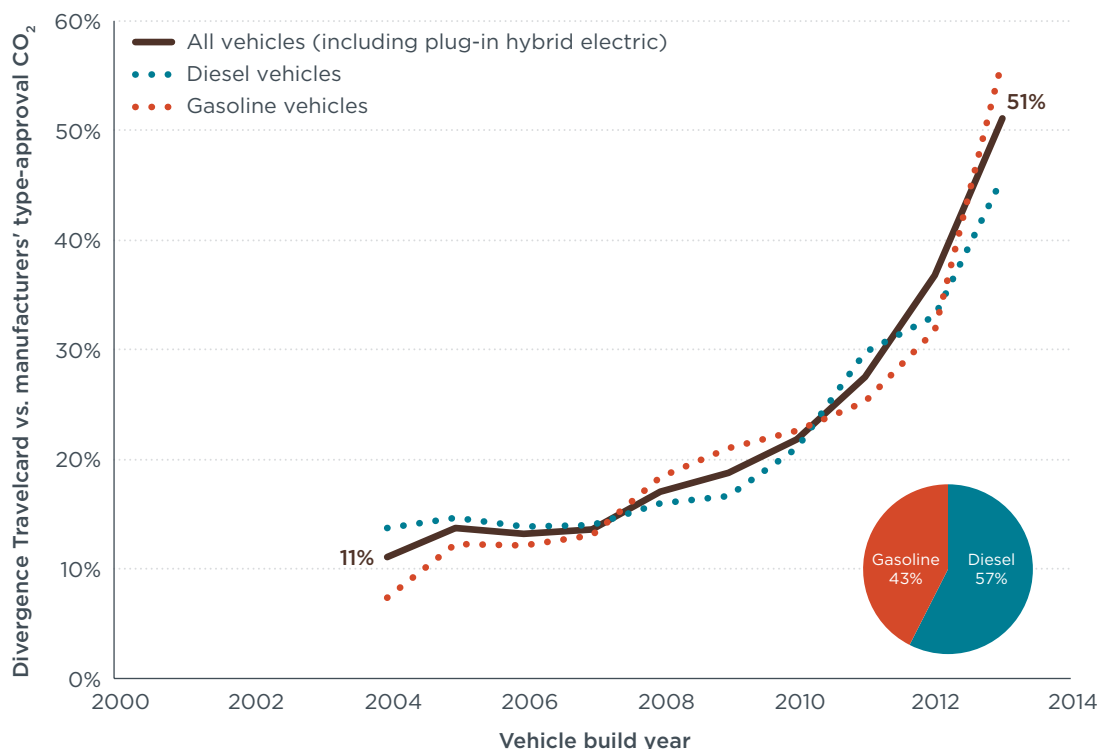


Figure 10. Divergence of Travelcard data from manufacturers' type-approval CO₂ emissions by engine type (pie chart indicates number of vehicles per engine type in the data set for 2013).

Because the Travelcard data set includes a sufficiently large number of vehicles, it is also possible to investigate the divergence of CO₂ values for car manufacturers or brands (see Figure 11). An analysis of individual vehicle models from Travelcard data can be found in section 3.4.

While BMW and Volkswagen, as well as VW's Audi brand, remain below the fleet average, for most manufacturers the discrepancy between real-world and type-approval emissions increased rapidly from 2011 to 2013. Most notably, the deviation of CO₂ values of Ford, General Motors, PSA, and Renault-Nissan remained below the fleet average in 2011, but increased by as much as 32 percentage points by 2013. This increase coincides with the Dutch government tightening the CO₂-based vehicle taxation system in the Netherlands.²¹

For Toyota and Volvo, plug-in hybrid electric vehicles clearly affected the manufacturers' average deviation. In 2013, PHEVs accounted for roughly 9 percent of the Toyota brand's sales; at the same time, 25 percent of all Volvos sold in the Netherlands were plug-in hybrid vehicles. Including these vehicles in the calculation of the brands' average deviation increases the divergence by more than 20 percent. This observation again underscores the above-average deviation in CO₂ emissions of plug-in hybrid electric vehicles.

²¹ For example, the CO₂ emissions thresholds for taxation of private use of company vehicles were lowered in 2012 and 2013 (ACEA 2013).

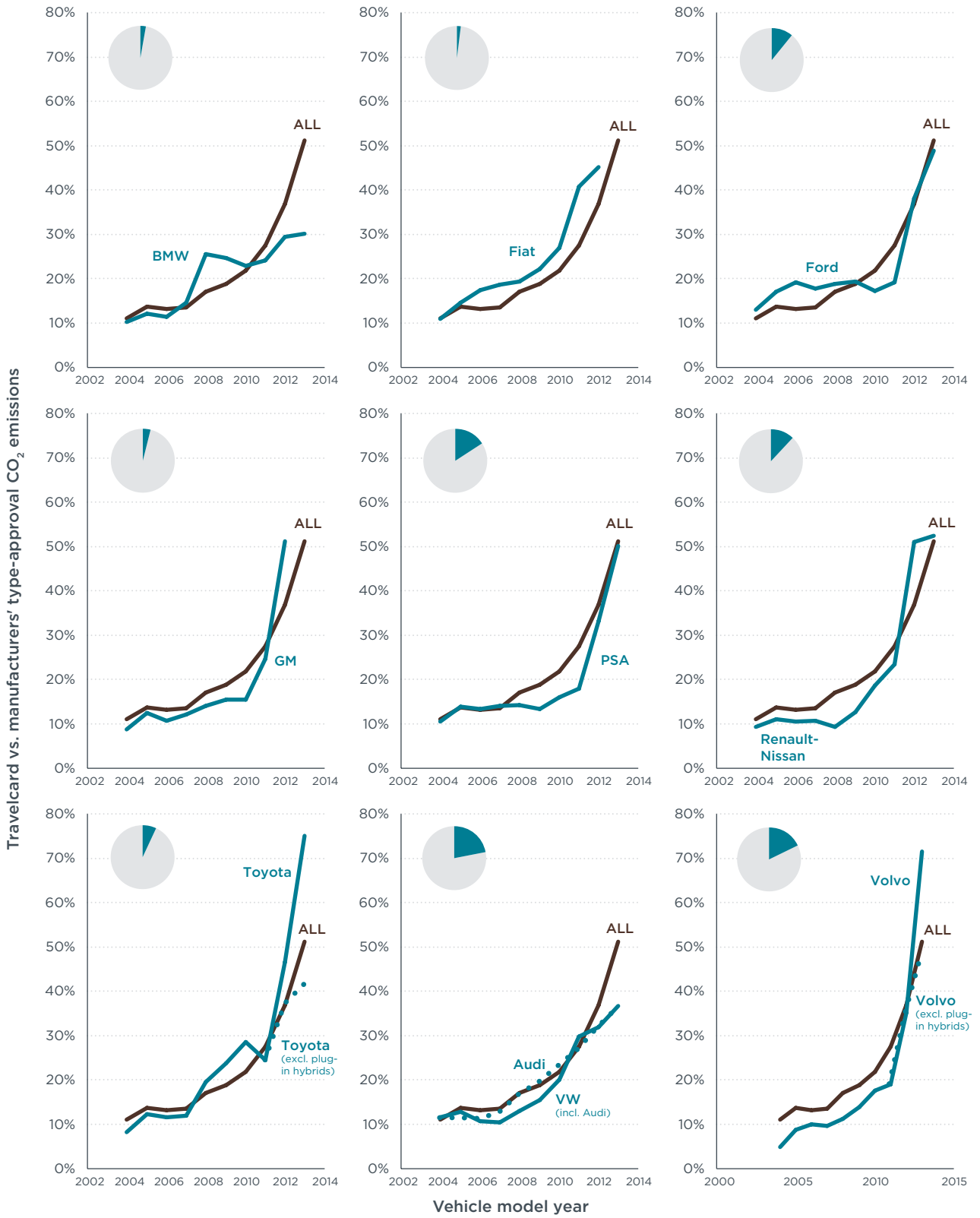


Figure 11. Divergence of Travelcard data from manufacturers' type-approval CO₂ emissions by brand/manufacturer (pie chart indicates number of vehicles per brand/manufacturer in the data set for 2013).²²

²² Daimler was not included in this analysis due to an insufficient number of data points. For Fiat and GM no data available for 2013 (pie chart data shown is for 2012).

2.3. LEASEPLAN (GERMANY)

Data type	On-road, automatically recorded
Data availability	2006–2013, more than 15,000 new vehicles per year
Data collection	Fuel-consumption data, automatically recorded using a fuel card when refueling at gas stations
Fleet structure, driving behavior	Company cars, mostly extra-urban and highway driving; fuel is usually paid for by the employer

Description

LeasePlan,²³ which offers Travelcard as one of its lines of business, is a global fleet- and vehicle-management company of Dutch origin. Established more than 50 years ago, LeasePlan has grown to become the world's leading fleet- and vehicle-leasing company. The company manages over 1.3 million vehicles of multiple brands and provides financing and operational fleet and vehicle management services in 32 countries. LeasePlan is located in the Netherlands and is owned by the Volkswagen Group (50%) and Fleet Investments B.V. (50%).

For the analysis in this section, only passenger car data from LeasePlan Germany²⁴ were analyzed. LeasePlan Germany is a wholly-owned subsidiary of LeasePlan Corporation and oversees 85,500 vehicles. Its data set is similar to that compiled by Travelcard; only the geographic range is different (Germany rather than the Netherlands). The following brand/manufacturer classification was applied to the LeasePlan data: BMW (BMW, Mini), Daimler (Mercedes-Benz, smart), Fiat (Alfa-Romeo, Chrysler, Dodge, Fiat, Jeep, Maserati), Ford, General Motors (Chevrolet, Opel), PSA (Peugeot, Citroën), Renault-Nissan (Dacia, Nissan, Renault), Toyota (Lexus, Toyota), Volkswagen (Audi, Porsche, Seat, Škoda, VW).

For the LeasePlan data, the build year of vehicles is not known. The LeasePlan averages therefore represent a fleet-wide average rather than new vehicle data. According to LeasePlan, the average holding period for a lease is about three years. This turnover rate implies that the values presented for LeasePlan should be viewed as the three-year running average of the fleet's fuel consumption.

Like spritmonitor.de and Travelcard, fuel consumption reported by LeasePlan does not depend on laboratory measurements. Instead, it reflects the actual experience of a substantial customer base. However, possible sources of biases in these data should be acknowledged. In particular, the cars managed by LeasePlan are company cars, and thus differ from typical vehicles in the German market in a number of respects. Notable differences include a high share of diesel vehicles (94 percent in 2013) and an over-representation of cars from medium and upper-medium segments. In terms of individual companies, BMW, Daimler, Ford, and Volkswagen account for 87 percent of all vehicles used in the analysis. For a more detailed comparison of LeasePlan data and German vehicle market statistics see our 2013 report (Mock et al. 2013).

Furthermore, LeasePlan drivers generally do not have to pay for fuel, as this expense is covered by the employer. It is therefore likely that LeasePlan customers have weaker incentives to drive in a fuel-efficient manner. According to LeasePlan, many customers drive long distances on the Autobahn, often at speeds exceeding 130 km/h, at which point CO₂ emissions increase drastically. However, as with the spritmonitor.de and Travelcard data, any bias in the data set from driving behavior is expected to be consistent over time.

²³ <http://www.leaseplan.com>

²⁴ <http://www.leaseplan.de>

Methodology

The LeasePlan data include type-approval fuel-consumption figures for each vehicle as well as the real-world consumption measurements determined by summing up the fueling events for each vehicle. It was therefore possible to analyze the LeasePlan data without supplemental information from other data sets. The aggregation of individual vehicle data to fleet-wide averages was based on the LeasePlan vehicle count; in other words, the aggregated data is representative of the LeasePlan fleet but does not reflect the composition of the German market.

LeasePlan data are available from 2006 onward. Data for 2006 to 2010 were provided by LeasePlan in aggregated form.²⁵ Data for 2011 and 2013 were available at a level of detail that allowed an analysis by segment and individual manufacturers. Values for 2012 were not available to the ICCT.

Results

The discrepancy between real-world and type-approval CO₂ emissions increased from 21 percent in 2006 to 38 percent in 2013 (see Figure 11). Before slowing down after 2011, the deviation grew at an increasing pace between 2007 and 2011.

As noted above, only the fleet-wide average for a given year is reported. Considering that the deviation of real-world CO₂ emissions is increasing each year, new vehicles are likely to exhibit a higher deviation than indicated by Figure 12.

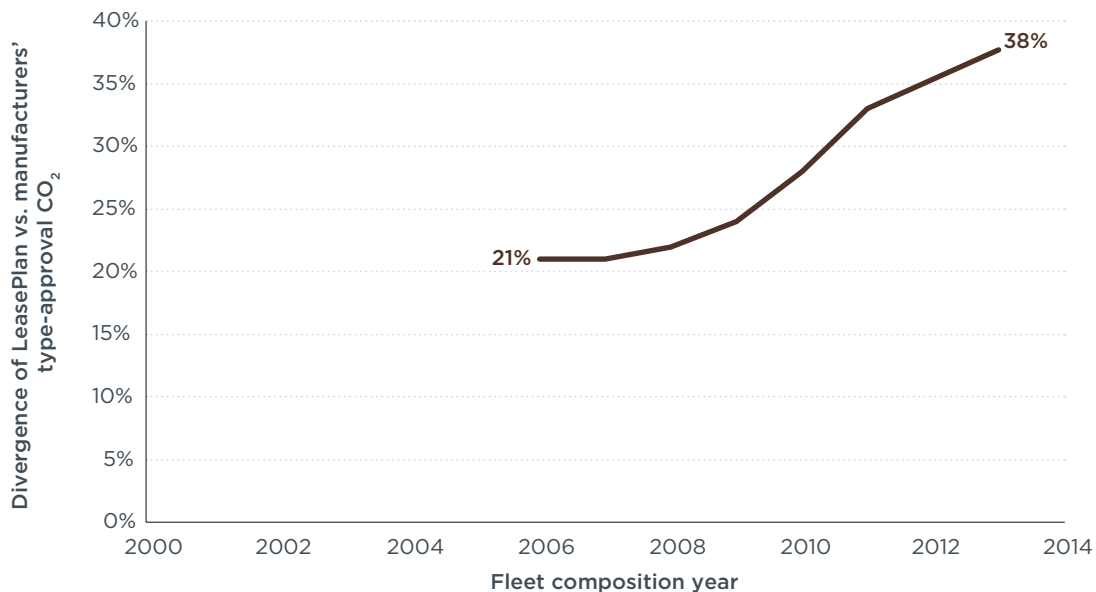


Figure 12. Annual divergence of LeasePlan data from manufacturers' type-approval CO₂ emissions.²⁶

Figure 13 presents the divergence between LeasePlan and type-approval CO₂ emission values for different vehicle segments in 2011 and 2013. Notably, the deviation has increased for all segments during this period. The mini, luxury, sport, off-road, and multi-purpose segment consistently lie below the fleet average; however, as these segments together accounted for roughly 12 percent of the LeasePlan fleet in 2013, the effect on the fleet-wide, annual averages is insignificant. Only the small and upper-medium segments consistently exceed the fleet average.

²⁵ Since these data was provided directly by LeasePlan, they could not be verified by the ICCT.

²⁶ The data point for 2012 was linearly interpolated from the 2011 and 2013 data points.

Figure 14 presents the divergence between LeasePlan and type-approval CO₂ emission values for different manufacturers in 2011 and 2013. All manufacturers except Fiat show an increase in the deviation of their vehicles during this time. Toyota, General Motors, and PSA exhibit the largest increase. In terms of relative performance, Daimler, Ford, General Motors, and Volvo consistently lie above the fleet average while Fiat and PSA show the lowest deviations in 2013.

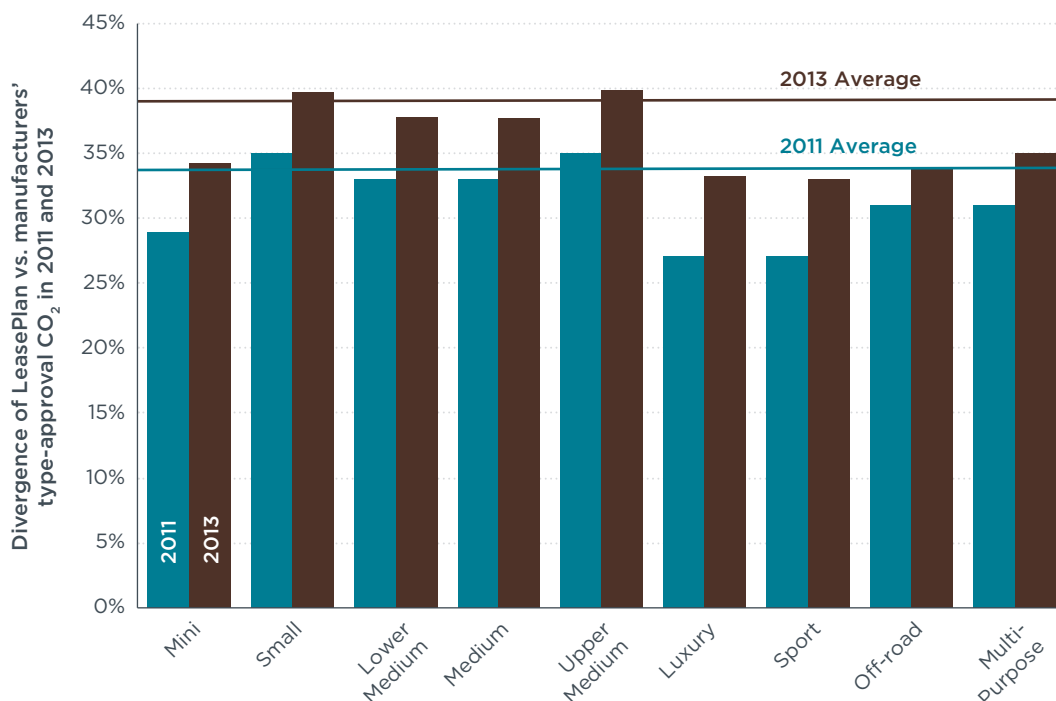


Figure 13. Divergence of LeasePlan data from manufacturers' type-approval CO₂ emissions by segments for 2011 and 2013.

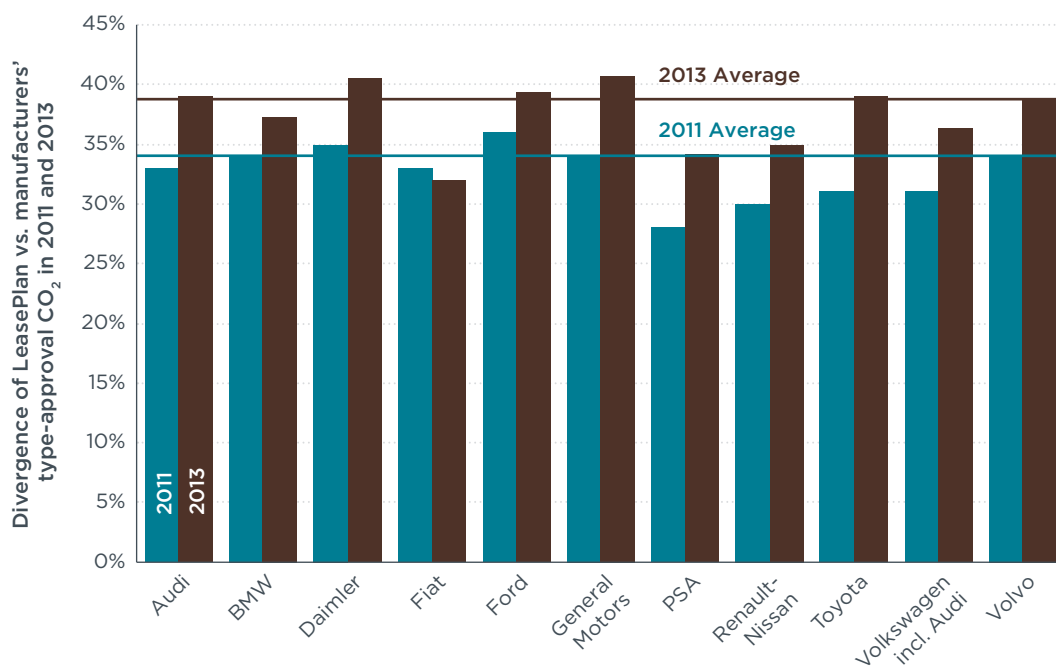


Figure 14. Divergence of LeasePlan data from manufacturers' type-approval CO₂ emissions by manufacturer/brand for 2011 and 2013.²⁷

²⁷ Manufacturers (brands) included are: BMW (BMW, Mini), Daimler (Mercedes-Benz, smart), Fiat (Alfa-Romeo, Chrysler, Dodge, Fiat, Jeep, Maserati), Ford (Ford), GM (Chevrolet, Opel), PSA (Citroën, Peugeot), Renault-Nissan (Dacia, Nissan, Renault, Infiniti), Toyota (Lexus, Toyota), Volvo (Volvo), Volkswagen (Audi, Porsche, Seat, Škoda, VW)

2.4. HONESTJOHN.CO.UK (UNITED KINGDOM)

Data type	On-road, user-submitted
Data availability	2001–2013, approximately 3,500 vehicles per year
Data collection	Fuel consumption data, entered by vehicle drivers into a publicly available online database
Fleet structure, driving behavior	Mostly private cars, urban and extra-urban driving, no details on driving style

Description

Honestjohn.co.uk²⁸ is a consumer motoring website in the United Kingdom that allows anyone to submit real-world fuel consumption data. Users can select a vehicle model and engine configuration and enter fuel consumption data based on their everyday driving experience. In contrast to spritmonitor.de, fuel consumption data are entered directly by the user in miles per gallon (MPG) and not calculated by the website based on the amount of fuel purchased and the odometer readings. It should also be noted that honestjohn.co.uk dates models based on the introduction of new generations (launch year) whereas spritmonitor.de uses vehicles' year of manufacture (build year).

In total, more than 50,000 readings have been submitted to date. Details on the driving style of users were not available, but any biases are assumed to be consistent over time and should not affect the observed trend. Honestjohn.co.uk data include slightly more diesel vehicles and slightly lower average CO₂ emission levels than are typical for the U.K. market; see our 2013 report (Mock et al. 2013).

Methodology

Real-world and type-approval fuel consumption values (in miles per gallon) from honestjohn.co.uk were converted to CO₂ values.²⁹ A submissions-weighted average of the discrepancy of real-world and type-approval emission values was then calculated for each model. These values were weighted by sales of the respective model in the British vehicle market in order to ensure representative results. While this sales-weighting was not performed in our 2013 report, the effect on annual, fleet-wide deviations was smaller than four percent per year.

Results

The discrepancy between real-world and type-approval values increased from 10 percent in 2001 to 33 percent in 2013 (Figure 15). According to honestjohn.co.uk, the temporary dip in 2012 resulted from the launch of a number of vehicle models with low discrepancies and substantial market shares. No persistent difference between diesel and gasoline vehicles can be observed.

²⁸ <http://www.honestjohn.co.uk>

²⁹ For the conversion from MPG to g CO₂/km, the following factors were applied: 1 imperial gallon = 4.55 liters; 1 mile = 1.61 km; 2.43 kg CO₂ per liter of gasoline and 2.65 kg CO₂ per liter of diesel fuel.

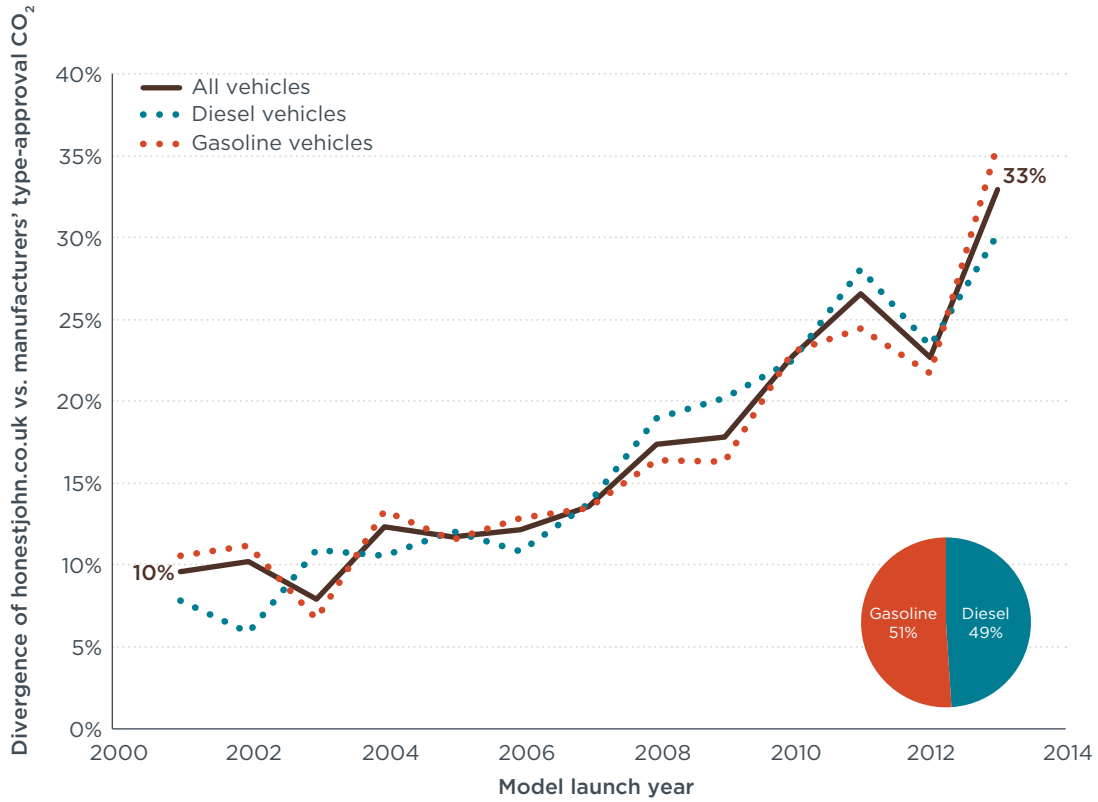


Figure 15. Divergence of honestjohn.co.uk data from manufacturers' type-approval CO₂ emissions by fuel type (pie chart indicates number of vehicles per fuel type in the data set for 2013).

As honestjohn.co.uk employs the launch year to date vehicles, data points are less evenly distributed across time than for sources that employ the build year. Consequently, there are insufficient data entries to allow a more detailed analysis of different vehicle segments. This is only possible for the small, lower-medium, and medium segments (see Figure 16). While these segments generally follow the trend for all vehicles, the deviation of small vehicles drastically increased from 19 to 41 percent between 2011 and 2013.

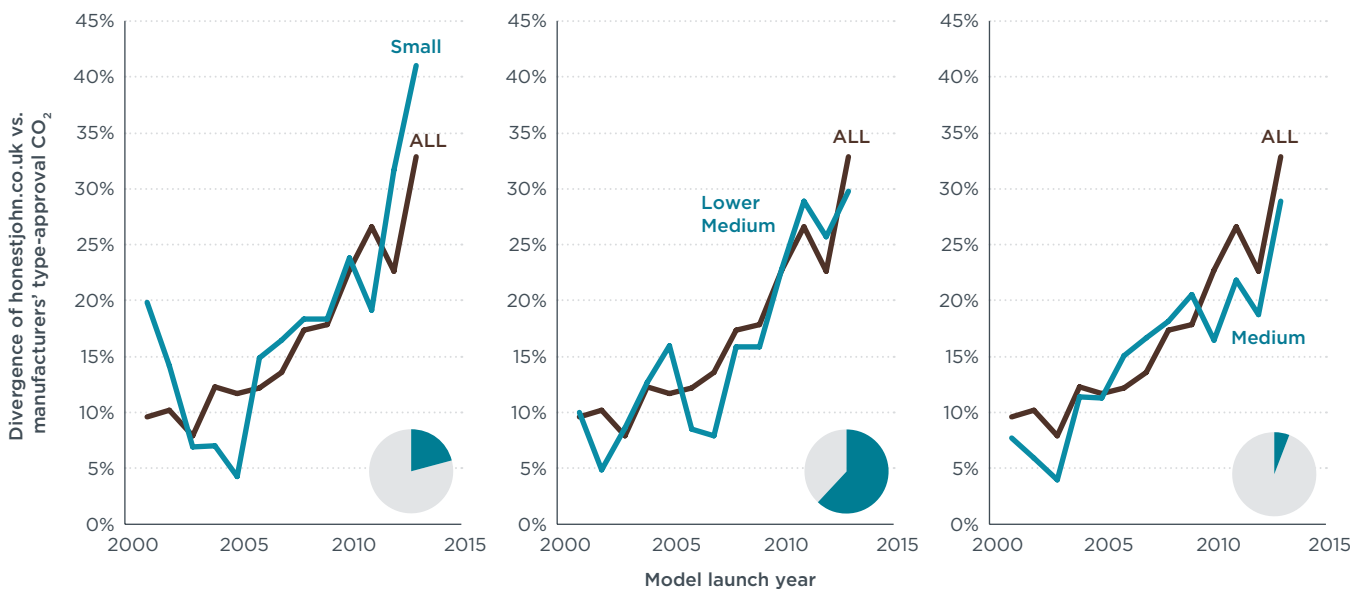


Figure 16. Divergence of honestjohn.co.uk data from manufacturers' type-approval CO₂ emissions by vehicle segment (pie chart indicates number of vehicles per segment in the data set for 2013).

2.5. AUTO BILD (GERMANY)

Data type	On-road, test route
Data availability	2008–2013, approximately 250 vehicles per year
Data collection	Fuel consumption data, measured before and after a 155 km test drive
Fleet structure, driving behavior	Vehicles selected for testing by AUTO BILD; urban, extra-urban, and highway driving; professional drivers; strict adherence to speed limits and normal engine speed

Description

AUTO BILD³⁰ is a German automobile magazine first published in 1986. The magazine frequently measures fuel consumption during car tests. This measurement relies on a test drive on German roads, including 61 km of extra-urban, 54 km of highway (20 km without speed limit), and 40 km of urban driving. According to AUTO BILD, test drivers strictly adhere to speed limits while keeping the engine speed within normal limits. Each vehicles' fuel tank is filled to capacity before and after the test³¹. The amount of fuel added after the test is the basis for the calculation of the car's fuel consumption.

Methodology

Data ranging from 2008 to 2013 were provided by AUTO BILD. These data include fuel consumption figures from the test drive as well as type-approval values. From the ratio of these two figures, the annual unweighted average divergence of real-world and type-approval CO₂ values was calculated.

Results

Figure 17 shows the annual divergence of real-world and type-approval CO₂ emission levels for the *AUTO BILD* data. These values increased at a fairly constant pace from 14 percent in 2008 to 27 percent in 2013.

While no unambiguous difference between diesel and gasoline vehicles can be observed, the average deviation of all vehicles is higher than both diesel and gasoline vehicles in 2011 and 2013. This is due to the effect of a small number of hybrid and plug-in hybrid electric vehicles (between two and five cars per year) with especially high deviations (100 percent and more) in CO₂ emissions. Despite the high deviations, these vehicles were included in the study; however, Figure 16 also depicts the average divergence for all cars *excluding hybrid vehicles* (both hybrid and plug-in hybrid) to demonstrate the significant effect of the few tested hybrid electric vehicles.

³⁰ <http://www.autobild.de/>

³¹ It should be noted that a consistent refill of a fuel tank is challenging, especially for gasoline vehicles, due to the volatility of the fuel. This might have some minor effect on the results, but should not affect the overall observed trends over time. Similarly, ambient temperature varies for the individual vehicle tests, which has some effect on the results, but if vehicle tests are carried out in a similar way each year the effect should not be great enough to significantly influence the overall trends observed.

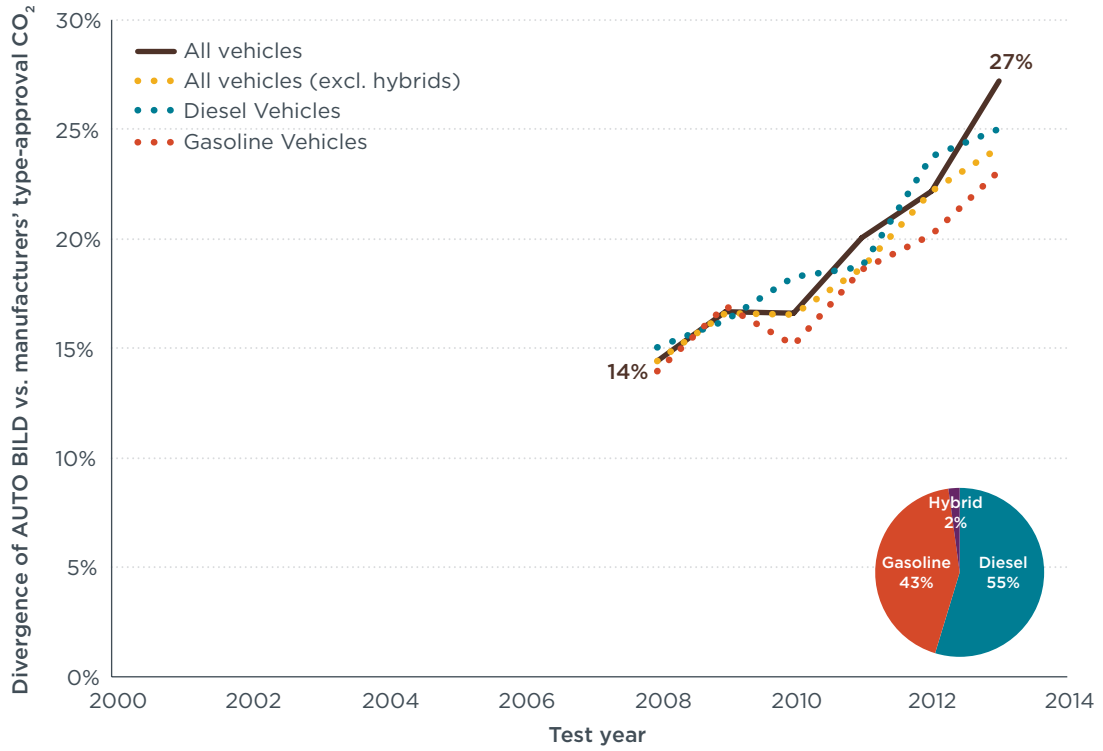


Figure 17. Divergence of *AUTO BILD* data from manufacturers' type-approval CO₂ emissions by fuel type (pie chart indicates number of vehicles per fuel type in the data set for 2013).

2.6. AUTO MOTOR UND SPORT (GERMANY)

Data type	On-road, test route
Data availability	2003–2013, approximately 150 vehicles per year
Data collection	Fuel-consumption data, measured before and after a test drive
Fleet structure, driving behavior	Vehicles selected for testing by Auto motor und sport; urban, extra-urban, and highway driving; professional drivers; adherence to speed limits, low engine speeds

Description

*Auto motor und sport*³² is a German automobile magazine first published in 1946. As part of its vehicle tests, *Auto motor und sport* measures the fuel consumption of cars. These measurements include driving on the German Autobahn, strong acceleration when overtaking other vehicles, uphill driving, rush-hour driving, turning on the air conditioning, as well as taking into account additional payload. *Auto motor und sport* describes their test conditions as “representative of real-world driving but not extreme.”³³ The resulting fuel consumption values³⁴, along with type-approval figures, are published in the magazine’s vehicle tests.

Methodology

Data on type-approval and real-world fuel consumption, as well as other technical parameters, were collected from *Auto motor und sport* vehicle tests. From the ratio of these two figures, the annual unweighted average divergence of real-world and type-approval CO₂ values was calculated.

Results

Figure 17 shows the annual deviation of real-world CO₂ values from type-approval figures. This deviation has increased from 21 percent in 2003 to 44 percent in 2013. While diesel vehicles exhibit a higher divergence than gasoline cars for some years, no consistent difference was observed. In contrast to the *AUTO BILD* data analyzed, the *Auto motor und sport* data set does not include any plug-in hybrid vehicles.

In addition to the foregoing results, *Auto motor und sport* also attempts to determine the minimum feasible real-world fuel consumption of tested vehicles (*Normverbrauchsrunde*). As expected, the deviation between these values and type-approval values (not shown here) is significantly lower than the results presented in Figure 18; however, the deviation between the auto motor sport minimum fuel consumption and type-approval values are increasing over time and at a similar rate as the normal deviations in Figure 17. This simultaneous increase under both test conditions is a strong indication that the growth of real-world CO₂ deviations is occurring independently of driving behavior.

³² <http://www.auto-motor-und-sport.de/>

³³ <http://www.auto-motor-und-sport.de/so-testet-auto-motor-und-sport-den-kraftstoffverbrauch-22-696942.html>

³⁴ Like *AUTO BILD*, *Auto motor und sport* measures fuel consumption by refilling the tank following a road test; see n. 31 above on the risks of inconsistency with that method.

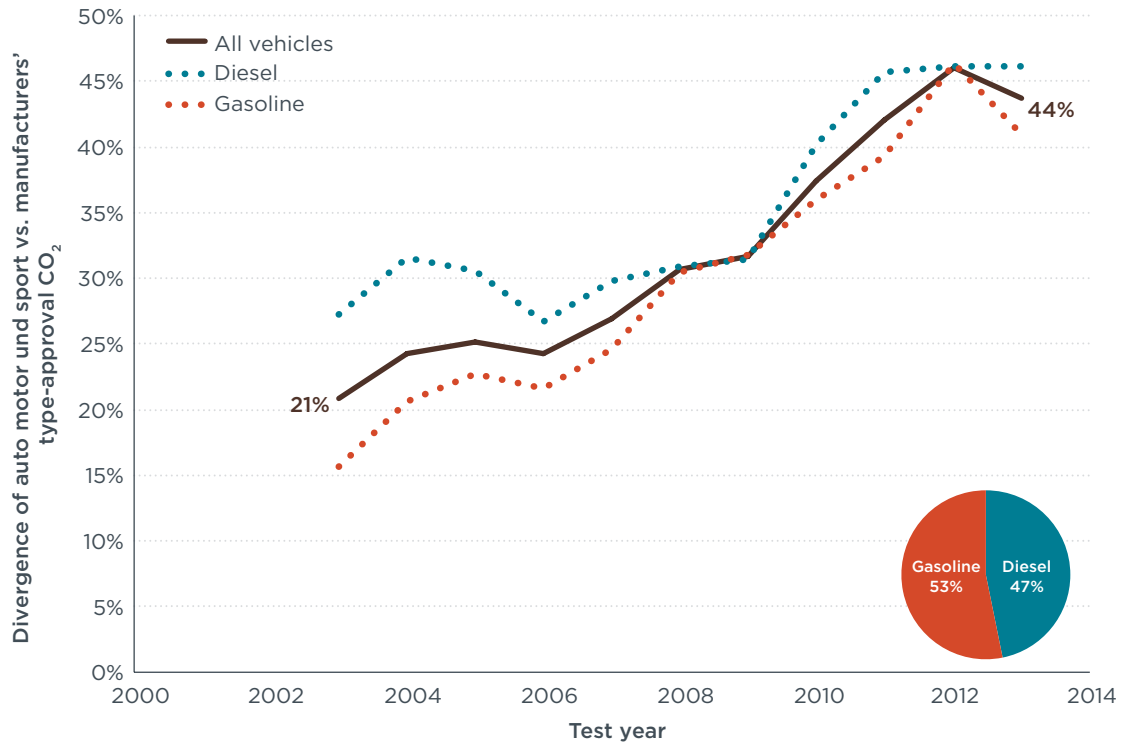


Figure 18. Divergence of *Auto motor und sport* data from manufacturers' type-approval CO₂ emissions by fuel type.

2.7. WHATCAR? (UNITED KINGDOM)

Data type	On-road, test route
Data availability	2011–2013, approximately 150 vehicles per year
Data collection	Portable Emissions Measurement System (PEMS) testing on urban and extra-urban roads
Fleet structure, driving behavior	Mixed vehicle fleet; professional drivers always using the same test route

Description

*WhatCar?*³⁵ is a British automobile magazine targeted at consumers intending to purchase vehicles. Since 2012, *WhatCar?* has published real-world fuel consumption data from its True MPG tests. The underlying data source is a series of on-road vehicle tests using Portable Emission Measurement System (PEMS) equipment, which is generally accepted as a very accurate way of measuring emissions and fuel consumption.³⁶ These tests are carried out by Emissions Analytics,³⁷ a vehicle emissions analysis firm, on behalf of the magazine.

The vehicles are driven on a test route that encompasses urban and extra-urban roads and takes about two hours in total. The average speed during the test is approximately 60 km/h. The urban section consists of driving at an average speed of approximately 24 km/h, whereas the average speed for the extra-urban and highway portion is about 97 km/h. According to Emissions Analytics, the test route is more demanding than the NEDC, as it has been selected to reflect typical U.K. driving patterns. Vehicles are tested in the default state from the manufacturer. Any alternative driving setting, such as “econ” modes, are therefore left switched off. Air conditioning and other non-essential on-board systems are left switched off as well. Emissions Analytics ensures that engines are warmed up before testing begins.

According to *WhatCar?*, test drivers hold a “steady pace, avoiding heavy acceleration and braking whenever possible”.³⁸ During the vehicle test, sensors measure various parameters, including vehicle speed, which allows subsequent adjustment of the CO₂ emissions for traffic flow and other conditions such as ambient temperature. This adjustment ensures that the final CO₂ emission figures are as consistent as possible when comparing the results from different test drives.

Methodology

Data for the years 2012 and 2013 was received from *WhatCar?* These data included measured CO₂ emission levels during the True MPG test and type-approval CO₂ values. From the ratio of these two figures, the annual unweighted average divergence of real-world and type-approval CO₂ values was calculated. While a sales-weighted average was used in our 2013 report, this procedure was not deemed appropriate in this 2014 update due to the inherent unrepresentativeness of small data sets. The difference between the sales-weighted and unweighted average deviation of all *WhatCar?* tests in 2012 was less than one percent.

³⁵ <http://www.whatcar.com/>

³⁶ In this case, SEMTECH-DS from Sensors Inc.

³⁷ <http://emissionsanalytics.com>

³⁸ *WhatCar?*, True MPG—how we do it, <http://www.whatcar.com/truempg/how-we-did-it>

Results

Figure 19 shows the annual discrepancy between real-world and type-approval CO₂ values for all vehicles and for fuel and transmission types. According to *WhatCar?* data, the deviation of all vehicles increased marginally from 2012 to 2013. Diesel vehicles generally exhibit lower discrepancies than gasoline vehicles; however, while the deviation of diesel vehicles increased from 2012 to 2013, gasoline vehicles showed a slight decrease. Lastly, deviations in real-world CO₂ emissions were consistently lower for vehicles with automatic transmissions.

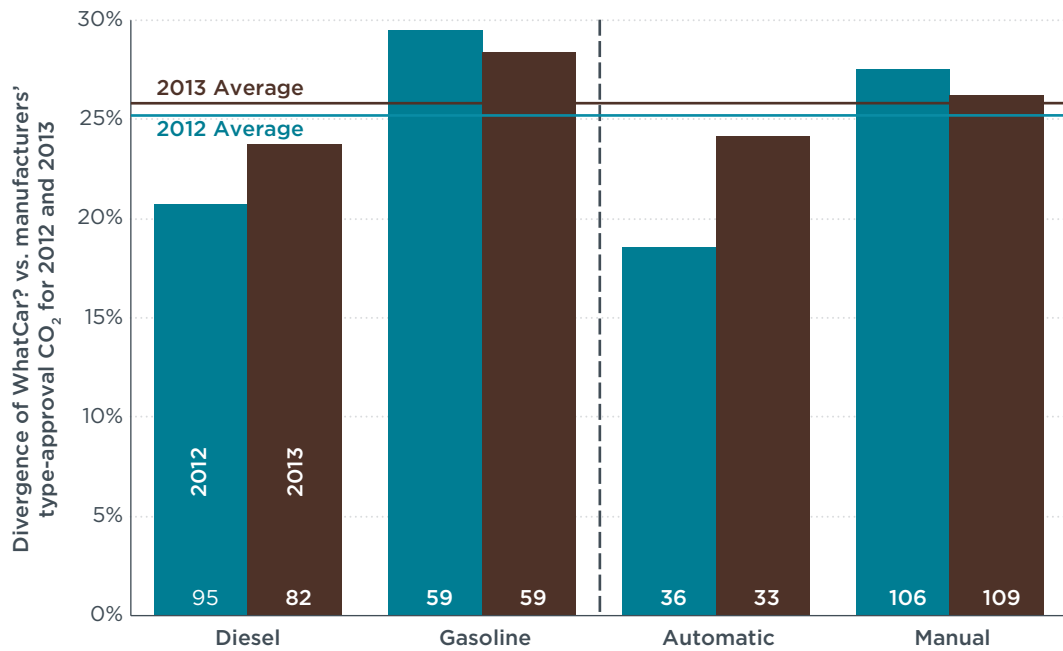


Figure 19. Divergence of *WhatCar?* data from manufacturers' type-approval CO₂ emissions by fuel and transmission type for 2012 (blue) and 2013 (brown). The number of entries for each category is shown at the base of each bar.

2.8. TCS (SWITZERLAND)

Data type	On-road
Data availability	1996–2013, approximately 20 vehicles per year
Data collection	On-road driving, roughly 3,000 km for each vehicle
Fleet structure, driving behavior	Most popular vehicle models in Switzerland; professional drivers

Description

With about 1.6 million members, Touring Club Schweiz (TCS) is Switzerland's largest car club.³⁹ Since 1996, TCS has carried out vehicle tests to compare real-world fuel consumption with type-approval values. According to TCS, a key criterion for selecting test vehicle models is their popularity among Swiss car buyers. In total, about 15–20 vehicles, provided directly by the manufacturers, are tested each year. While gasoline cars were more prevalent in the early years, the proportion of gasoline and diesel vehicles is now roughly even.

For the on-road test, each vehicle is driven for about 3,000 km and the fuel consumption is recorded. According to TCS, these on-road tests are usually carried out by the same drivers, whose driving behavior has not changed over the years. In addition to the on-road test, TCS also carries out chassis dynamometer tests in a laboratory. While these dynamometer data were considered in our 2013 report, this 2014 update focuses on the on-road data only.

Methodology

The data set provided by TCS includes type-approval values, as well as TCS on-road test results for each tested vehicle. The proportion of these values yields the divergence for a vehicle. The annual divergence was calculated as the unweighted average of these values for each test year.

Results

Figure 20 summarizes the annual average discrepancy between real-world and type-approval CO₂ emissions from TCS for test years 1996 to 2013. This divergence increased from 0 percent in 1996 to 20 percent, respectively from 0 to 1.1 l/100km, in 2013. While a clear upward trend is discernible, the year-to-year development is fairly erratic due to the small number of vehicles tested each year. A differentiated analysis of gasoline and diesel vehicles was not deemed meaningful for this reason.

³⁹ see <http://www.tcs.ch>

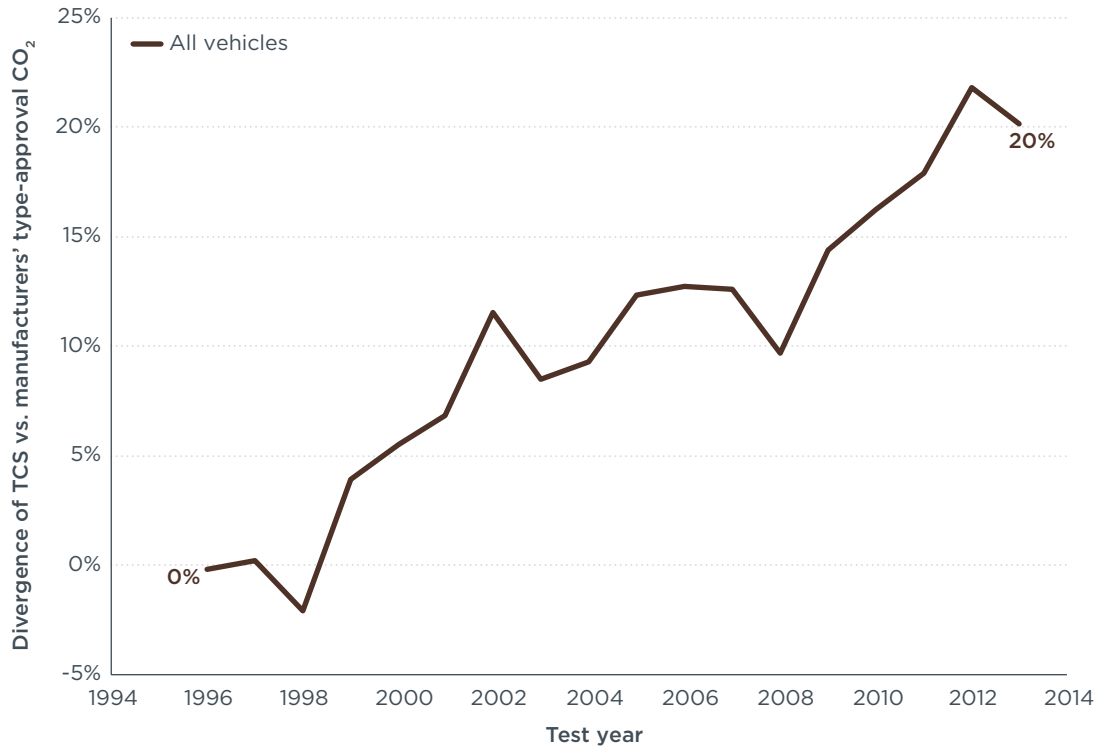


Figure 20. Divergence of TCS vs. type-approval CO₂ values.

3. DATA COMPARISON

Table 1 summarizes the data sources used for the analyses in this report. In total, data for about 540,000 private and company vehicles from eight data sources and four countries were evaluated. The number of vehicles per year is around 45,000.

Table 1. Summary of data sources used for this report.

Source	Country	Total vehicles	Vehicles per year	Mostly company cars	Dating convention
spritmonitor.de	Germany	85,666	~6,000		Build year
Travelcard	Netherlands	311,611	~20,000	X	Build year
LeasePlan	Germany	~90,000	~15,000	X	3-year avg.
honestjohn.co.uk	U.K.	50,332	~3,500		Launch year
AUTO BILD	Germany	1,978	~250		Test date
Auto motor sport	Germany	1,660	~150		Test date
WhatCar?	U.K.	284	~150		Test date
TCS	Switzerland	332	~20		Test date
Total	-	~540,000	~45,000		-

3.1. FLEET-WIDE AVERAGES OVER TIME

Annual average divergence

Figure 21 presents the divergence of real-world CO₂ emission levels for all data sources. Taken together, the data sets considered in the analysis exhibit an unambiguous upward trend in the discrepancy between real-world and type-approval CO₂ values. In 2001, estimates of the gap ranged from 4 to 10 percent. By 2013, the lowest estimate for the gap was 20 percent while the highest estimate exceeded 50 percent.

The two large data sets of private cars, namely spritmonitor.de and honestjohn.co.uk, generally exhibit very similar developments. In 2001, both sources indicated a divergence of less than 10 percent which increased to approximately 30 percent in 2013. The largest discrepancy between these two data sets was observed in 2011 and amounted to only about three percent.

In comparison with private cars, the data sets that predominantly consist of company cars, namely Travelcard and LeasePlan, show higher discrepancies between real-world and type-approval CO₂ emissions. While Travelcard data initially was in line with spritmonitor.de and honestjohn.co.uk in 2006, the discrepancy in real-world CO₂ emission values increased at a rapid pace between 2010 and 2013. This increase coincides with the Dutch government's lowering the exemption thresholds for the CO₂-based vehicle taxes.

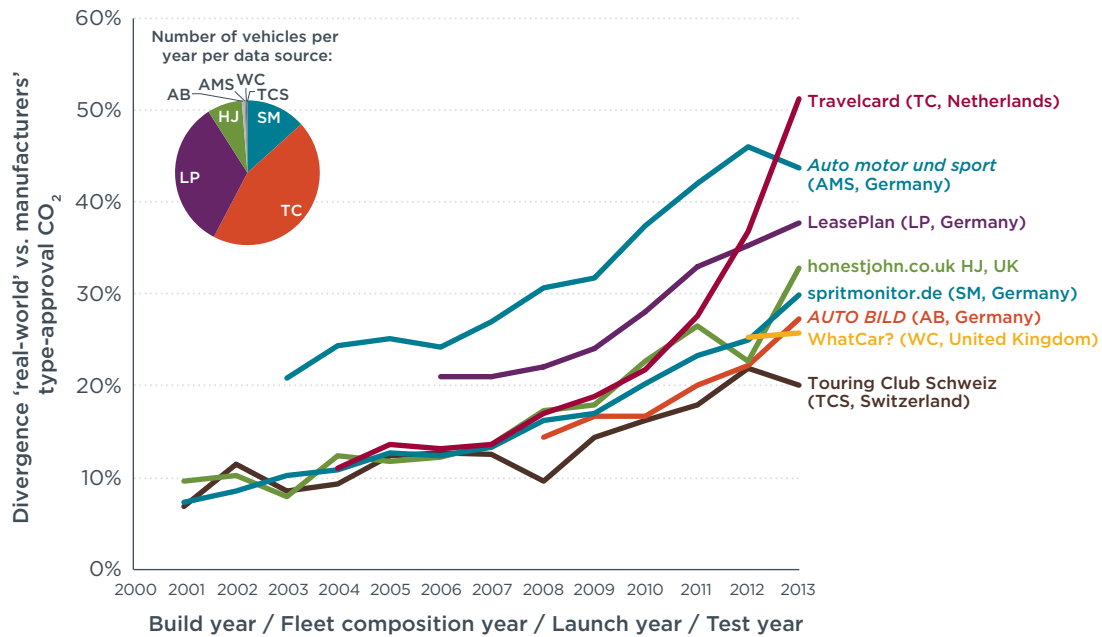


Figure 21. Divergence of real-world from manufacturers' type-approval CO₂ emissions for various on-road data sources.

For LeasePlan data, the average deviation in 2006 was well above the other large data sets and has increased at a similar pace as private vehicle average deviations. Driving behavior may be one explanation for the difference between LeasePlan and spritmonitor.de. While both fleets are predominantly used in Germany, the LeasePlan fleet consists of company vehicles. As employers typically bear fuel costs, drivers have lower incentives to conserve fuel. In addition, according to LeasePlan, highway driving accounts for a large proportion of its fleet's mileage. As CO₂ emissions increase rapidly at high speeds, the high proportion of highway driving may also account for the difference between spritmonitor.de and LeasePlan data.

Compared with these large, user-sourced data sets, vehicle tests by *AUTO BILD*, *Auto motor und sport*, TCS, and *WhatCar?* accounted for a small proportion of the data included in this study. Due to the smaller numbers of vehicles, and possible incongruities between real-world driving and test procedures, these data sets were not expected to prove representative of large vehicle markets. These data sets were not sales-weighted for this reason. Nonetheless, a clear upward trend in the average divergence of these data sets from type-approval values was observed. While *AUTO BILD*, TCS, and *WhatCar?* fell within ten percent of honestjohn.co.uk and spritmonitor.de, *Auto motor und sport* exhibited a significantly higher divergence, most likely due to relatively demanding driving during the fuel consumption testing.

Dating conventions

As discussed for each data source, different dating conventions for vehicles were applied to the data sets (see Table 1). For example, while spritmonitor.de dates vehicles based on the cars' build year, honestjohn.co.uk uses major technical overhauls such as the introduction of a new model generation (launch year). As a result, honestjohn.co.uk has fewer data points for more recent years while spritmonitor.de has a more uniform number of data points for each year.

In contrast to all other data sources, annual values for LeasePlan refer to the average of its entire fleet rather than only new vehicles. Due to the vehicle turnover observed for LeasePlan, this is roughly equivalent to a three-year running average.

For vehicle tests conducted by car magazines, the test date is used in the analysis. As car magazines are likely to test new vehicles, this dating convention should yield results similar to the launch year.

Taken together, the use of dissimilar dating conventions impedes comparisons of different data sources. Consequently, care should be taken in comparing absolute values from different sources. Nonetheless, the increase in the divergence between real-world and type-approval CO₂ values is unaffected by the use of different dating conventions.

Central estimate

Based on the available data, a central estimate for the divergence of real-world and type-approval CO₂ emissions was constructed (see Figure 22). For this, in a first step spritmonitor.de, honestjohn.co.uk, as well as *AUTO BILD*, *Auto motor und sport*, *What-Car?*, and TCS data were weighted by the number of vehicles in each source to arrive at an average trend line for the private car segment. The estimated average divergence for private cars increased from about 8 percent in 2001 to 31 percent in 2013. Similarly, Travelcard and LeasePlan data was weighted to derive a trend line for the company car market. As LeasePlan data is only available since 2006, this year was selected as the starting point. The divergence for company cars rose from around 13 percent in 2006 to 45 percent in 2013. In a final step, an average of both lines was calculated, using the assumption that the ratio of private to company cars in Europe is around fifty-fifty. The resulting central estimate for all data sources examined shows an increase from 8 percent in 2001 to 38 percent in 2013.

A number of limitations of this estimate should be acknowledged. First, as driving behavior, geographic coverage, and fleet structure vary across the sources, the central estimate combines data from diverse markets. Second, the number of vehicles in a data set is not necessarily a proxy for the quality or representativeness of its data. Third, as discussed in the previous section, the data sources employ different dating conventions, making a direct comparison of annual averages difficult.

In light of these limitations, the central estimate should primarily be viewed as an indication that the divergence of real-world CO₂ is increasing and only to a lesser degree as a precise estimate of the divergence in the European market. It should also be noted that the divergence for the overall vehicle stock is likely lower than for the new-vehicle fleet, given the time required for fleet turnover.

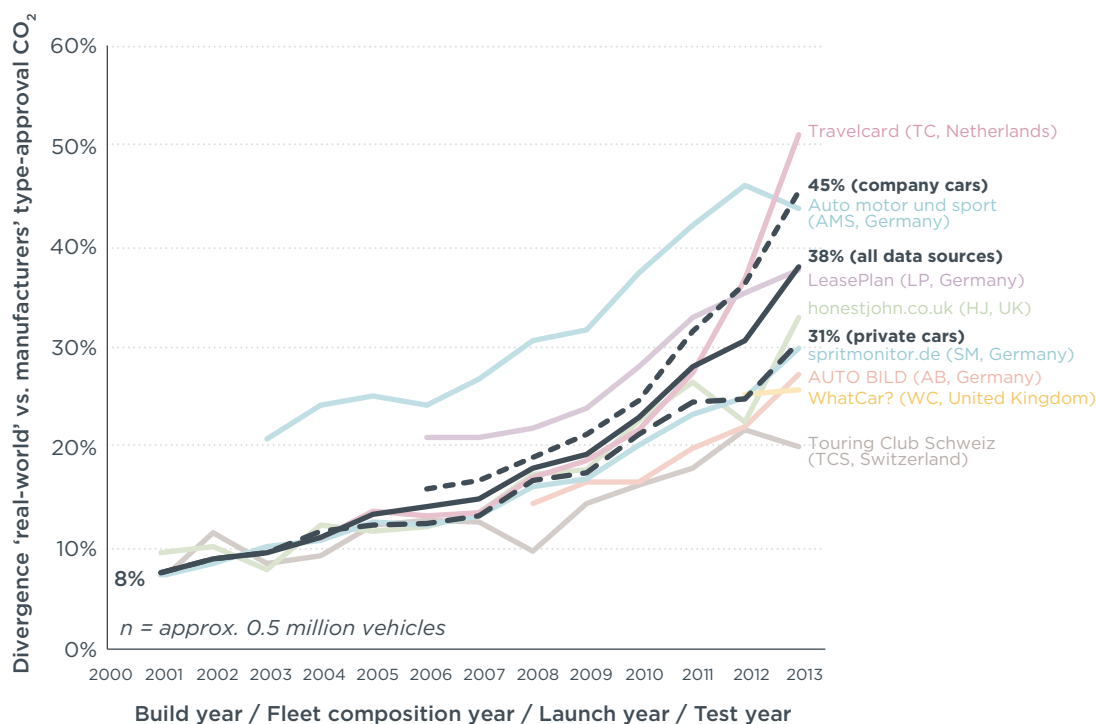


Figure 22. Central estimate for the divergence of real-world from manufacturers' type-approval CO₂ emissions for various on-road data sources.

3.2. COMPARISON BY MANUFACTURER

A more detailed analysis provides some insight into the trends shown in Figure 21. Figure 23 compares trends in the data from spritmonitor.de and Travelcard for selected manufacturers and brands.

As noted in section 3.1, comparisons between data sources should take into consideration differences in fleet composition, driving behavior, geographic coverage, and vehicle dating conventions. Similarly, comparisons of manufacturers should acknowledge possible differences in the driving behavior of their customer bases. It should also be noted that the definition of manufacturers (in terms of brands) varies slightly among the data sources used in this study.

As Figure 23 shows, in general the divergence of real-world from type-approval CO₂ emissions has increased for all manufacturers and brands over time.

While in the past the divergence of real-world CO₂ values was similar for Travelcard and spritmonitor.de data, in recent years a stronger increase is observed for the Dutch Travelcard dataset. A likely explanation for this rapid incline in the divergence of several manufacturers is the tightening of CO₂-based vehicle taxes in the Netherlands in recent years. This is investigated in more detail in the following section.

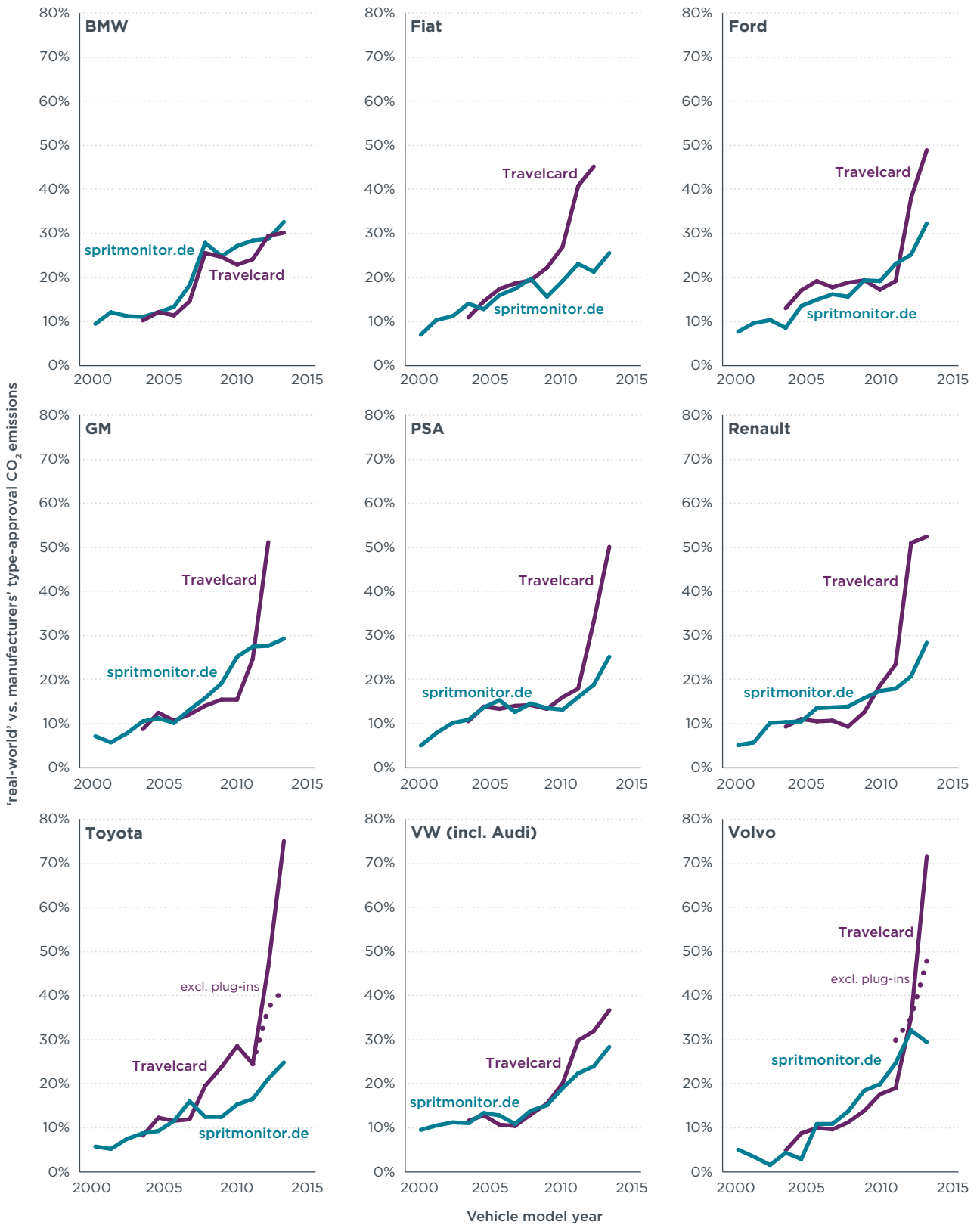


Figure 23. Comparison of spritmonitor.de and Travelcard results by manufacturer/brand.⁴⁰

⁴⁰ Daimler was not included in this analysis due to an insufficient number of data points. For Fiat and GM, no data are available for 2013.

3.3. EFFECTS OF CO₂-BASED VEHICLE TAXATION

Dutch CO₂-based vehicle taxes may account for some of the differences between the German (spritmonitor.de) and the Dutch Travelcard data. In the Netherlands, income tax is levied on the monetary value of company cars if the private use of the vehicle exceeds 500 km per year. The level of this tax is contingent on the CO₂ emissions of the vehicle. The tax brackets for gasoline and diesel vehicles for 2013 are presented in Table 2. In Germany, private use of a company car is also taxed based on the monetary value of the vehicle. However, the amount subject to income tax is independent of CO₂ emissions and is always 1 percent of the gross catalogue value⁴¹. In addition to the company car tax, in the Netherlands a vehicle registration tax applies. A CO₂-based annual ownership tax is also levied in both countries.

Table 2. Income taxes for private use of company cars in the Netherlands and Germany in 2013 (ACEA 2013).

Tax categories [gCO ₂ /km]		Taxable benefit	
Gasoline vehicles	Diesel vehicles	Netherlands	Germany
≤ 50	≤ 50	0%	1%
51-95	51-88	14%	1%
96-124	89-112	20%	1%
≥125	≥113	25%	1%

Figure 24 presents three metrics for each of the Dutch tax categories.⁴² First, the share of vehicles within each tax bracket is presented for spritmonitor.de and Travelcard fleets. Second, the cost impact of German and Dutch registration taxes, ownership taxes, and taxes on the private use of company cars for 2013 is compared.⁴³ Third, the divergence of real-world CO₂ emissions is presented for these data sets.

Several differences between spritmonitor.de and Travelcard are notable. For one thing, the Travelcard fleet had a high share (45 percent) of vehicles with type-approval CO₂ values between 51 and 95 g/km. This segment only accounted for 9 percent of the spritmonitor.de fleet. Conversely, vehicles with more than 125 g CO₂/km accounted for 57 percent of the spritmonitor.de fleet, while only 16 percent of all Travelcard vehicles in 2013 exceeded this value. Considering that Travelcard predominantly consists of Dutch company cars, it appears very likely that Dutch income taxes on private use of company cars explain a large portion of this difference between the two data sets.

The comparison of Dutch and German vehicle taxes reveals a stark difference between the countries in terms of the effect of CO₂ emissions on the level of taxation. In Germany, the difference in tax costs between the highest and lowest tax bracket merely amounts to €92 over a four-year period; in the Netherlands, the difference between the highest and lowest tax bracket amounts to more than €12,000. Consequently, while Dutch and German vehicle taxes are comparable for the lowest tax bracket, vehicle taxes in the Netherlands are more than three times higher than in Germany for a vehicle emitting more than 125 g/km.

In line with the tax levels, the difference in the deviations of the two data source is also notable. While spritmonitor.de and Travelcard exhibit a very similar divergence for vehicles with more than 125 g CO₂/km, the discrepancy between real-world and type-approval emission levels increased much more steeply for Travelcard than for spritmoni-

⁴¹ In addition, 0.03 percent of the gross catalogue price per km of the distance between the residence and the office of the employee applies.

⁴² A comparison of the < 50 g/km was not possible due to the insufficient number of vehicles in this bracket.

⁴³ Assumptions for the calculation of vehicles taxes: vehicle price: €25,000; engine displacement: 1,600 cm³; CO₂ emissions in each bracket: 95, 125, and 140 g/km; duration of ownership: 4 years; income tax rate: 40 percent; discount rate: 0 percent. Taxation thresholds and rates based on 2013 (ACEA, 2013).

tor.de. More specifically, while the German data set shows a deviation of 37 percent in the 51 to 95 g CO₂/km category, the Dutch data has a divergence of 56 percent.

In order to further investigate the effect of German and Dutch vehicle taxes, the next section compares a number of individual vehicle models from the spritmonitor.de and Travelcard data sets.

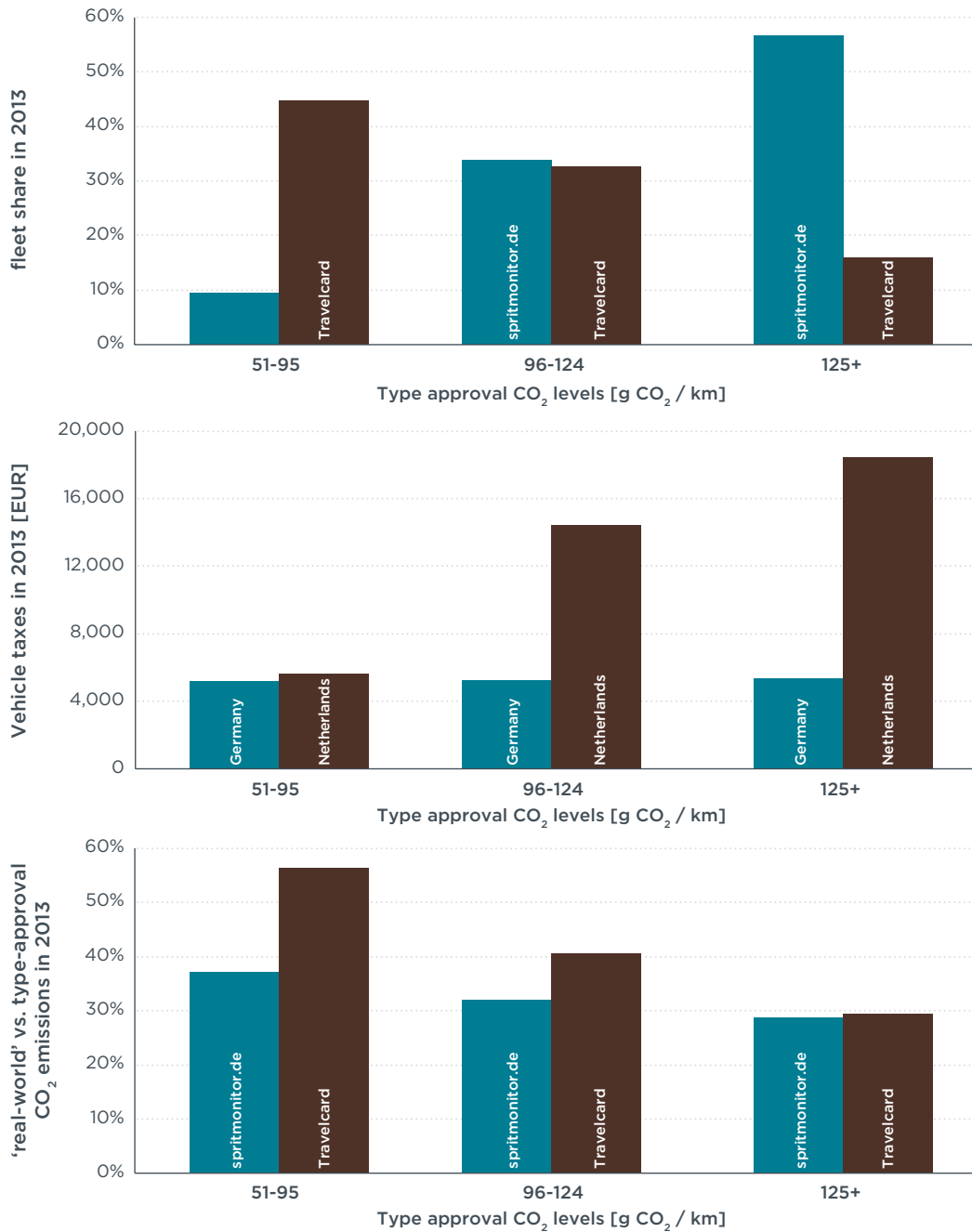


Figure 24. Comparison of spritmonitor.de vs. Travelcard data and German vs. Dutch vehicle taxes.

3.4. COMPARISON BY VEHICLE MODEL

Figure 25 and Figure 26 compare spritmonitor.de and Travelcard CO₂ emission data to type-approval CO₂ emissions for individual models in the Netherlands and Germany. These annual averages were weighted by the number of vehicles of each model in the respective fleet. In addition, the Dutch 14% income tax threshold is also presented for gasoline and diesel vehicles (dotted lines). The number of vehicles per year and data source is above 80 for all models.

Figure 25 presents these data for vehicles which generally fell within the Dutch 14% tax bracket. For this group of models, the fleet-weighted average of type-approval CO₂ values unambiguously decreased between the base year and 2013. At the same time, all models exhibited a smaller decrease in the real-world values, resulting in increasing divergence in the values. Moreover, the change in type-approval values and divergence between the base year and 2013 was smaller in the German data set in almost all cases.

For the Ford Fiesta and Renault Mégane, a marked decrease in type approval CO₂ emissions and increase in divergence is notable after the tightening of tax regulations in 2012. Similarly, the VW Polo fell within the 14% tax bracket by 2010 and exhibited a steep increase in its divergence between 2009 and 2010. In the case of the Renault Mégane, it is noteworthy that there seems to be an 88 g/km vehicle variant that is only available to customers in the Netherlands. In all other EU member states, the lowest-CO₂ Mégane in 2013 was a 90 g/km variant.⁴⁴ 88 g/km is at the same time the threshold above which a 20 percent taxable benefit applies, instead of 14 percent. The estimated difference for a Renault Mégane is an approximately €600 lower company tax per year (about €1,400 instead of €2,000 per year)⁴⁵.

Figure 26 presents the same data for models that typically do not meet the 14% income tax threshold. While all models underwent a decrease in type-approval CO₂ emissions, this reduction was less pronounced in the spritmonitor.de data. However, in contrast to Figure 25, spritmonitor.de and Travelcard type-approval and real-world values generally develop in unison. The difference between annual averages of the two data sources is less extreme. At the same time, the similar development of the spritmonitor.de and Travelcard trend lines is more pronounced for vehicles with higher type-approval CO₂ values. For example, the BMW 1-series only exhibits minor changes in its real-world and type-approval CO₂ values in the German and Dutch data sets. Similarly, while the relative change in the Passat's deviation is large due to small divergence in the base year (2008), the co-movement of the spritmonitor.de and Travelcard data is notable.

Overall, Figure 25 and Figure 26 demonstrate that the differences between spritmonitor.de and Travelcard data appear to be far greater for vehicles within the Dutch 14% tax bracket than outside of it. With respect to Figure 25 these model comparisons provide further insight into why the divergence of low-carbon models (≤ 95 g CO₂/km) is much greater for Travelcard vehicles than for spritmonitor.de cars. Moreover, since the 14% tax bracket accounts for 45% of Travelcard vehicles in 2013, the analysis of tax brackets and models also offers an explanation for the divergence of Travelcard and German data sources after 2011.

⁴⁴ See EEA CO₂ monitoring database, as well as technical specifications provided on <http://www.renault.de> and <http://www.renault.nl>

⁴⁵ Assumptions for the calculation of vehicles taxes: vehicle price, €25,000; income tax rate, 40 percent.

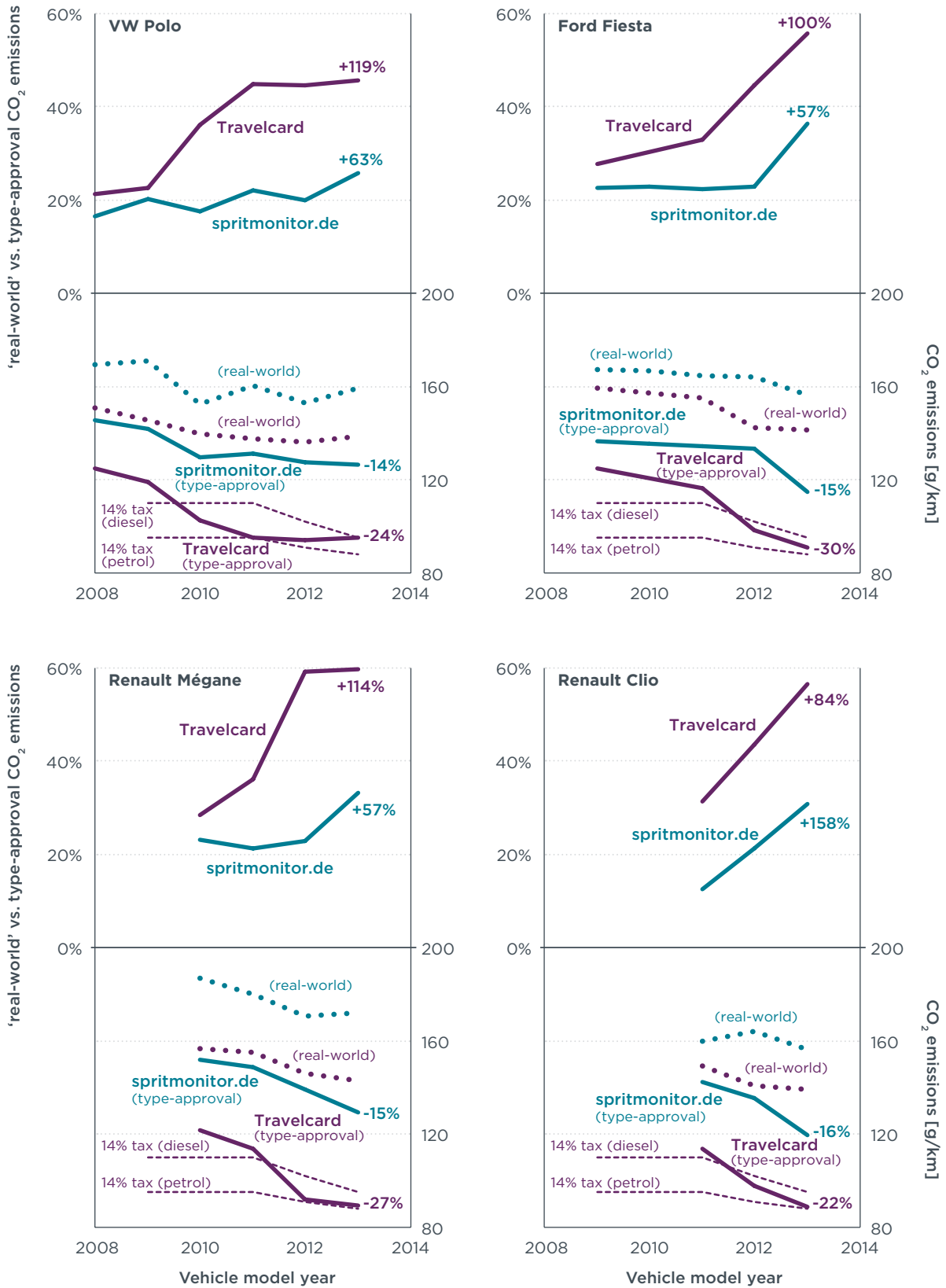


Figure 25. Comparison of spritmonitor.de and Travelcard data by vehicle model (models within the Netherlands' 14 percent tax threshold)



Figure 26. Comparison of spritmonitor.de and Travelcard data by vehicle model (models outside the Netherlands' 14 percent tax threshold).

4. DISCUSSION OF RESULTS

After the EU introduced a mandatory CO₂-emissions regulation for passenger cars, type-approval emissions and fuel consumption levels decreased considerably. The annual rate of reduction in CO₂ emissions increased from around 1 percent before 2007 to about 4 percent after 2007. In 2013, new passenger cars emitted on (fleet) average 127 g/km of CO₂—less than what was required under the regulation, which set a target of 130 g/km in 2015 (Mock 2014).

Nonetheless, there is a problem with this success story: the regulation only applies to type-approval CO₂ emission values, as measured over the NEDC procedure during the vehicle type-approval procedure. To make real progress, reductions under “real-world” driving conditions must match or approximate those recorded in the laboratory during type-approval testing.

Everyone drives differently, so a precisely accurate technical definition of real-world driving is elusive. However, when we aggregated large amounts of on-road driving data, we found clear patterns and trends. When we started our first analysis in 2012, we only had two German data sets available, totalling around 30,000 vehicles (Mock et al. 2012). In 2013, our analysis included data for nearly 500,000 vehicles (Mock et al. 2013). Now, in 2014, we can draw upon eight credible data sets from various EU member states and Switzerland. Altogether, the data encompass more than half a million vehicles, including both private and company cars.

All data sets we examined demonstrate the same over-arching trend: the discrepancy between type-approval and real-world CO₂ emissions is increasing. While in 2001 this gap was just 8 percent, it grew to 18 percent by 2008 and then to 38 percent in 2013. The increase in recent years was especially steep. Since our first analysis, the gap has been growing by about one fifth per year.

Each of our data sources has its own distinct characteristics. For example, company cars, on average, tend to be driven on different roads and in a different style than private cars. Therefore, it is not surprising that the absolute level of the gap was different for the various data sets. However, what is striking is the *increase* in the gap, which was observed in all data sources.

It appears reasonable to assume that driving behavior has not changed appreciably over the past years. This assumption is supported by looking at historical trends for individual vehicle models, where we found sudden increases in the discrepancy level that cannot be attributed to changes in driving behavior. Thus, the increasing gap is most likely a result of a combination of the following developments:

- » Increasing application of technologies that show a higher benefit in type-approval tests than under real-world driving conditions (for example, start-stop technology)
- » Increasing use of flexibilities in the type-approval procedure (for example, during coast-down testing)
- » External factors changing over time, which are unaccounted for in the type approval test (for example, increased use of air conditioning)

Some influencing factors may have an *absolute* impact in terms of grams of CO₂ per kilometer, i.e., they remain constant regardless of the fuel efficiency of the vehicle.⁴⁶ As CO₂ emission levels of new cars decrease, this would result in a proportionately higher impact of these factors and would explain part of the increasing gap. However, this effect cannot explain the magnitude of the increase, as the following simple calculation shows: in 2001, the type-approval CO₂ emission level for new cars in the EU was 170 g/km and the discrepancy level observed was 8 percent, i.e., 14 g/km in absolute terms. In 2013, the type-approval CO₂ emission level was 127 g/km. Assuming that the absolute level of the gap remained constant, i.e., at 14 g/km, the percentage gap in 2013 would have been 11 percent. In reality however, we find that the gap was 38 percent in 2013. In other words, even if the assumption that some influencing factors remain constant with increasing efficiency of vehicles was correct, this effect would only explain a very small fraction of the increasing gap.

The higher level of discrepancy for low-CO₂ vehicles in the Netherlands is particularly remarkable. This development was most likely driven by tax exemptions that provide a very strong incentive for vehicles that fall into a lower tax category.

As our analysis shows, the level of discrepancy observed in some cases differs notably between vehicle segments and vehicle manufacturers/brands. However, differences in typical customer profiles, technologies, and exogenous factors may all have influenced that outcome. Therefore, the analysis should not be viewed as a manufacturer ranking; instead, the analysis by manufacturer/brand demonstrates that the observed increase in the gap is a universal, systematic problem for the entire industry.

⁴⁶ One example of such a factor is the state of charge of the vehicle's battery. The effect of fully charging the battery before the test and using the battery's energy to reduce CO₂ emissions from the vehicle is largely independent of vehicle size. Another example could be air conditioning, where the load on the engine is relatively independent of vehicle size and powertrain efficiency.

5. POLICY IMPLICATIONS

The observed increase over time in the gap between real-world CO₂ emissions and official, type-approval emissions has implications for all key stakeholders:

From a **government's perspective**, the increasing gap can result in significant losses in tax revenues. Most EU member states base their vehicle-taxation schemes at least partly on type-approval CO₂ emissions. With an increasing discrepancy between type-approval and real-world emissions, there is a risk that low-carbon vehicles could benefit from tax breaks even though they did not perform better under real-world driving conditions than vehicles that do not fall into low tax brackets. The loss in tax revenues could be dramatic, especially for a country that has a strong CO₂-based vehicle taxation system.

For example, in the Netherlands, every g CO₂/km above a threshold of 88 g/km (for diesel cars) or 95 g/km (for gasoline-powered cars) is taxed by at least €125 at the time of vehicle registration (ACEA 2013). A gap of about 50 percent (55 g/km in absolute terms), as indicated by Travelcard data for the Netherlands, would therefore result in a registration tax that is more than €6,800 lower than a tax based on real-world CO₂ emissions. With about half a million new vehicles per year, the resulting effect on Dutch tax revenues would exceed €3.4 billion per year. The effects on the Netherlands' annual circulation and company car taxes would be similar.

Even in a country like Germany, where vehicle taxes are low compared to other EU member states, the estimated tax deficit is remarkable. The annual ownership tax is partly based on CO₂; in 2014 that tax was assessed a rate of €2 per g CO₂/km above a threshold of 95 g/km (ACEA 2013). Assuming a discrepancy of about 30 percent (40 g/km in absolute terms), as indicated by spritmonitor.de data, and about 3 million new vehicle registrations, lost tax revenues from new vehicles alone would be around €240 million per year.⁴⁷ And since annual ownership taxes are collected not just on newly purchased vehicles but on all vehicles, the actual tax revenues forgone are obviously much higher.

From a **customer's perspective**, every gram of CO₂ that is saved under type-approval conditions but not under real-world driving conditions results in unexpected fuel costs. A gap of 38 percent, as found for the central case of our analysis, translates into about 50 g/km of additional CO₂ emissions—or 2 liters per 100 kilometers if expressed in terms of fuel consumption. The resulting additional fuel cost for an average consumer is around €450 per year.⁴⁸ Given these additional, unexpected expenditures on fuel, there is a risk that customers will lose trust in manufacturers' claims about the latest fuel-efficient vehicles and simply not buy them—a dangerous development that could potentially undermine future attempts to reduce CO₂ emissions from the EU's vehicle fleet.

From a **societal perspective**, the increasing gap suggests we are making good progress in meeting CO₂ reduction targets when in actuality we are not. In the EU, the CO₂ emission level (according to type-approval) of new cars decreased from 170 g/km in 2001 to 127 g/km in 2013, a reduction of 25 percent. Taking the spritmonitor.de data as an example, this gap would translate into a real-world reduction from about 182 g/km (8 percent gap in 2001) to 165 g/km (30 percent gap in 2013). This reduction (equivalent to 9 percent) is much lower than anticipated based on laboratory test data (see Figure 27 and Figure 28). Similarly, overall fuel consumption and thereby also oil imports into the EU are not reduced to the same extent as suggested by the type-approval values.

⁴⁷ In 2013, 2 percent of new vehicles in Germany were below the 95 g/km threshold. The proportion of cars that would remain below the 95 g/km threshold in terms of real-world CO₂ emissions is deemed negligible.

⁴⁸ Assuming a fuel price of €1.5 per liter and an average annual driving range of 15,000 km.

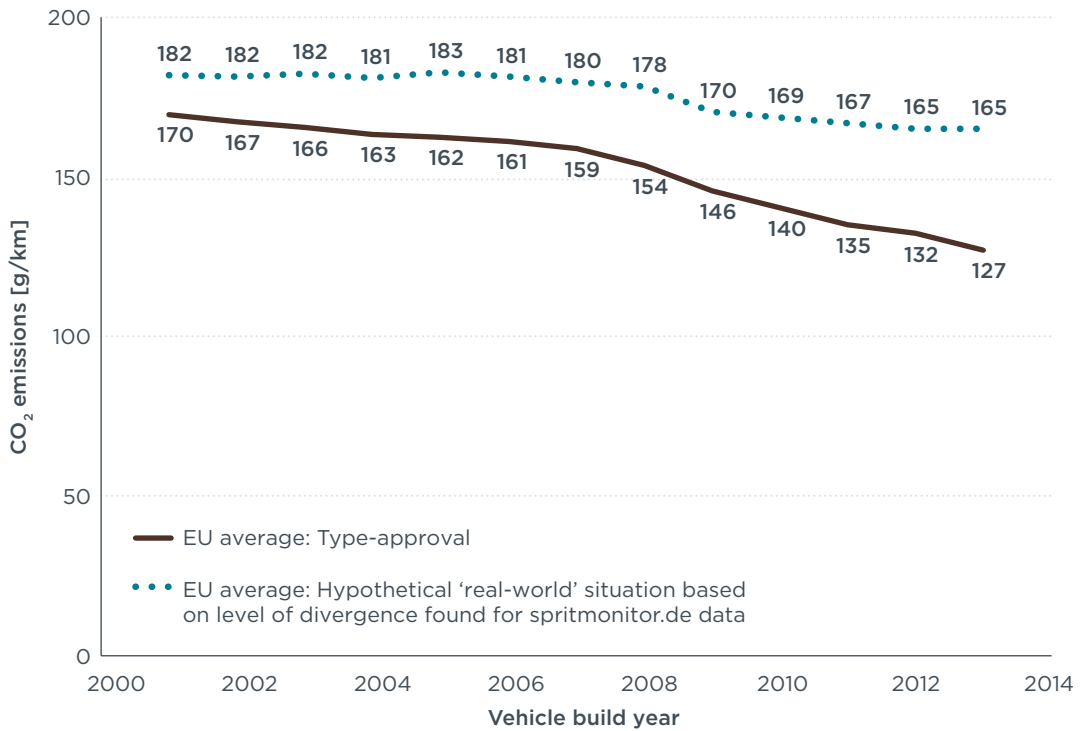


Figure 27. 2001–2013 real-world vs. type-approval CO₂ emissions, based on spritmonitor.de data estimates.

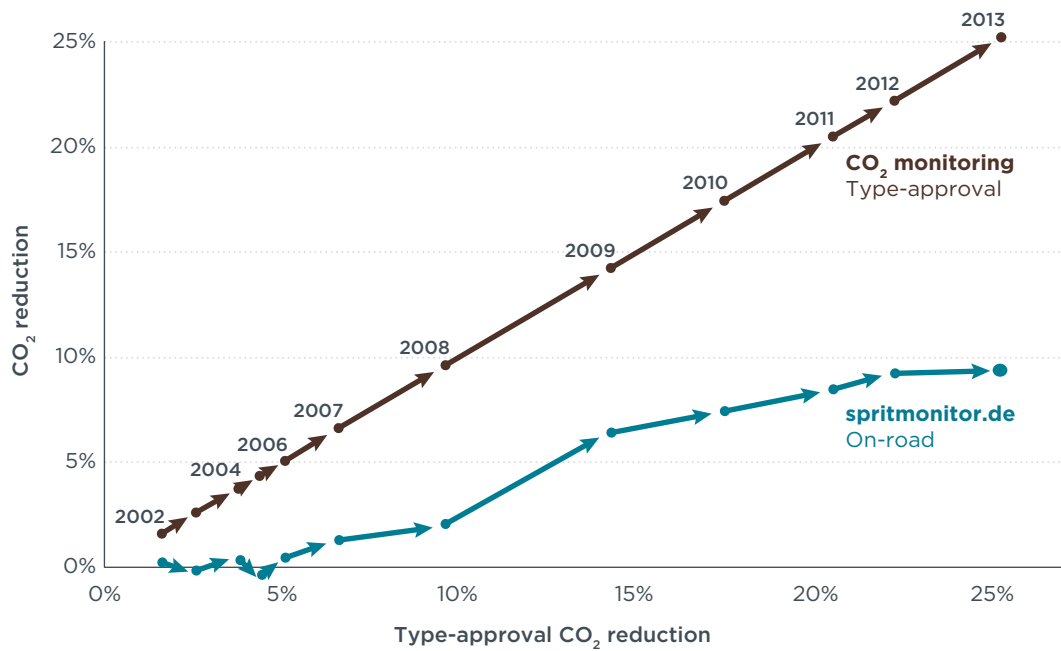


Figure 28. 2002–2013 real-world vs. type-approval CO₂ reductions in the EU, based on spritmonitor.de data estimates.

From a **manufacturer's point of view**, in the short run, the most economical pathway is to ensure that each company meets its respective CO₂ emission target as measured under the NEDC procedure, thereby avoiding any penalty payments for exceeding the target value. In the long run, however, an increasing gap can potentially undermine the credibility of single manufacturer or even the entire car industry. Customers and regulators may ultimately doubt the accuracy and representativeness of type-approval values. Individual carmakers are faced with a dilemma, though: if one company were to focus on the real-

world performance of its vehicles instead of optimizing cars for a particular laboratory test cycle, it would be subject to tax penalties and its competitive position would suffer—in particular if only some manufacturers were to move in this direction and others did not. From this perspective, official measures to establish a more realistic test cycle and procedure would help to create a more level playing field for car manufacturers.

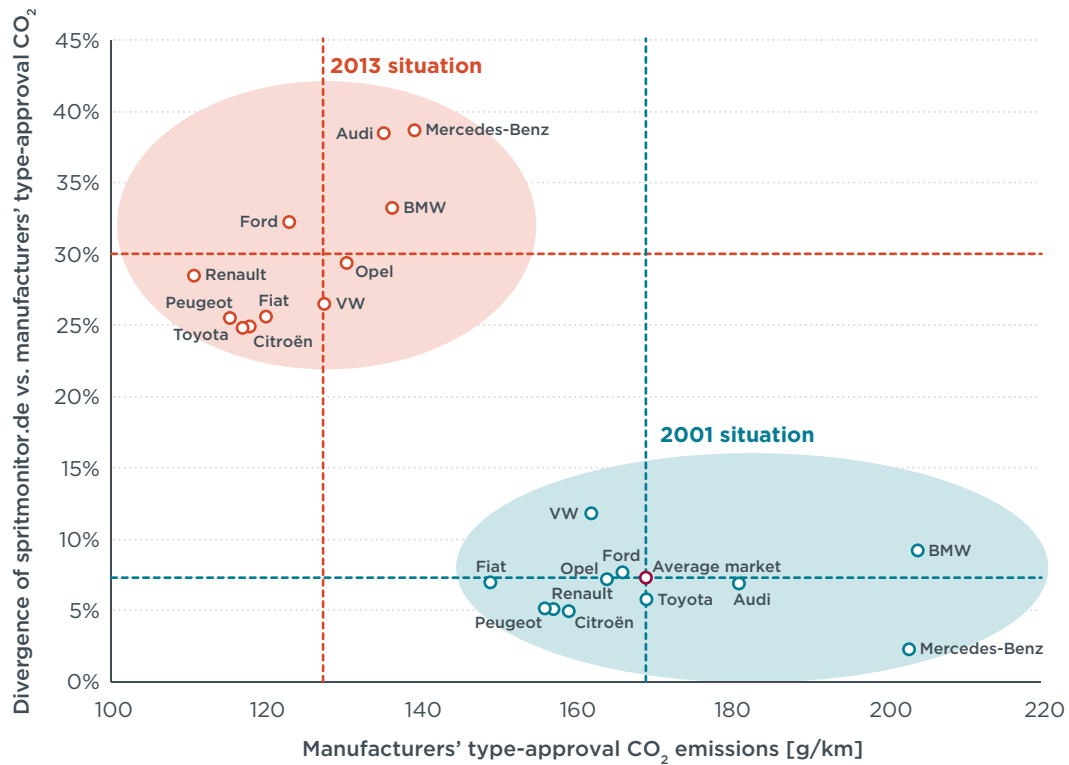


Figure 29. Sales-weighted CO₂ emission levels and spritmonitor.de vs. type-approval discrepancy for selected brands/manufacturers in 2001 and 2013.

It is important to clarify that nothing in our analysis suggests that manufacturers have done anything illegal. However, the NEDC was not originally designed to measure fuel consumption or CO₂ emissions, and many of its features can be exploited to influence these test results. Manufacturers appear to be taking advantage of permitted flexibilities in the NEDC, resulting in unrealistically low CO₂ emission levels (see Figure 29 for a comparison of different manufacturers in the EU in 2001 and 2013). The new Worldwide Harmonized Light Vehicles Test Procedure (WLTP), with its more realistic test cycle and tightened test procedure, is expected to result in more realistic CO₂ emission values. The WLTP could therefore narrow the gap between type-approval and real-world values. It is therefore in the interest of all stakeholders to introduce the WLTP in the EU as soon as possible. The UN-sponsored World Forum for Harmonization of Vehicles Regulations (WP.29) adopted the WLTP in March 2014, and the European Commission is currently working on its implementation, with the expectation that it will apply for type-approval of new cars in the EU from 2017 on (Mock 2013).

However, the WLTP will not resolve all known issues with the current procedure. In addition, it may itself have vulnerabilities that have not yet been identified. For example, it remains to be seen how plug-in hybrid electric vehicles and other electrified vehicles will perform in the WLTP as compared to on-road driving. Under the current test procedure (the NEDC), when determining CO₂ emissions for plug-in hybrid vehicles, the maximum electrical driving range is taken into account for calculating an average emission value. As a result, the type-approval CO₂ emission level decreases drastically with an increasing elec-

trical range⁴⁹—a procedure that may not adequately reflect real-world driving behavior, as can also be seen from the Dutch Travelcard data with its especially high divergence for plug-in hybrid vehicles.

In addition to a prompt introduction of WLTP, an appropriate conversion of existing CO₂ targets and taxation systems is needed. If the conversion were to allow testing vehicles in the NEDC and making use of any unintended flexibilities in the test procedure that are solved by the WLTP, the resulting new CO₂ values would implicitly include the same flexibilities. This would effectively undermine the introduction of WLTP and would make most of the improvements achieved with WLTP obsolete.

Furthermore, additional measures should be implemented in the near future to ensure more realistic CO₂ emission values. These measures should cover the emissions of current off-cycle technologies, like vehicle air conditioning systems (which are turned off during the NEDC and also during the WLTP test), as well as random re-testing of road-load data (which are a critical input factor for any laboratory test but are currently not available to the public in the EU).

From a long-term perspective, it is also important to add some form of in-service conformity check for CO₂ levels, to complement the existing type-approval laboratory test. This procedure would ensure that emission values are not only met for a so-called golden test vehicle, but for all cars that are sold to customers and are driven on the road. It might furthermore be advisable to develop a more efficient method of testing vehicle CO₂ emissions, done on the road instead of in a laboratory. The testing conditions could then more closely reflect the actual real-world driving behavior of the average customer and be less prone to exploitation of flexibilities. For tailpipe air pollutants, the European Commission is currently working on such an on-road testing approach, named Real-Driving Emissions (RDE), making use of portable emission measurement systems.

A rather simple but potentially very useful approach could be to develop a common European database on real-world fuel consumption values as reported by customers. Similar to spritmonitor.de, honestjohn.co.uk, and other private websites, such a database could provide consumers valuable information and advice on a particular vehicle model and its real-world behavior. In the United States, the Environmental Protection Agency (EPA) already hosts such a website, named “My MPG”,⁵⁰ containing data for about 30,000 vehicles. Ideally, existing websites would be integrated into a comparable European system, thereby ensuring that an already existing user base will not be lost. A desirable complementary measure would be the systematic collection of real-world data, making use of data loggers that can be installed on vehicles to record on-road CO₂ emissions (Posada, German 2013).

49 For details on the test procedure, see UNECE R101, Annex 8, par. 3.4 and Ligterink et al., 2013.

50 <https://www.fueleconomy.gov/mpg/MPG.do>

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