JUNE 2026

On the way to ‘real-world’ CO_2 values?

Evidence from 2021–2023 on-board fuel consumption monitoring data in the European passenger car market

SONSOLES DÍAZ, UWE TIETGE, JAN DORNOFF

ACKNOWLEDGMENTS

The authors express their gratitude to all reviewers of this paper for their guidance and constructive comments, with special thanks to Peter Mock, Rui Su, and María Vega Gonzalo. Their review does not imply an endorsement, and any errors are the authors' own. Funding for this work was generously provided by the European Climate Foundation.

International Council on Clean Transportation Europe
Fasanenstraße 85, 10623 Berlin, Germany
communications@theicct.org | www.theicct.org | @TheICCT

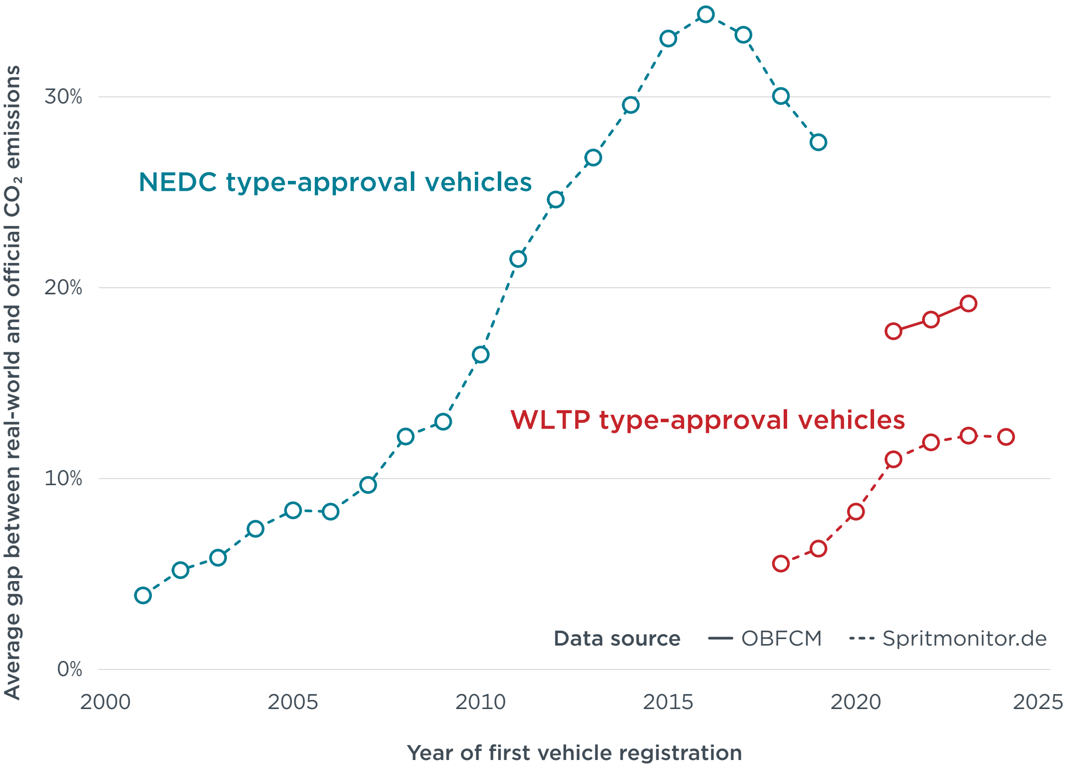
EXECUTIVE SUMMARY

This paper examines the gap between official and real-world tailpipe carbon dioxide (CO_2) emission values of European passenger cars registered since the introduction of the Worldwide harmonized Light vehicles Test Procedure (WLTP) in 2017. This study is the first International Council on Clean Transportation (ICCT) analysis to assess the gap using on-board fuel consumption meter (OBFCM) data submitted to the European Environment Agency for approximately 8 million cars newly registered between 2021 and 2023, the most recent data available. While earlier ICCT studies focused on internal combustion engine vehicles (ICEVs), including hybrid electric vehicles (HEVs) and mild hybrid electric vehicles (MHEVs), the OBFCM dataset enables analysis of plug-in hybrid electric vehicles (PHEVs) as well. We compare the results based on OBFCM data with user-reported fuel consumption data from the German website Spritmonitor.de, covering vehicles registered between 2001 and 2024.

Across both data sources, this study found that the gap between real-world and official CO_2 emissions continues to widen, most notably for PHEVs. For ICEVs, HEVs, and MHEVs, the OBFCM data showed a modest increase in the gap between WLTP type-approval values and real-world emissions—measured as the percentage by which real-world emissions exceeded official values—from 18% in 2021 to 19% in 2023, as illustrated by Figure ES1. Although Spritmonitor.de data indicated lower gap values of approximately 11%–12%, they revealed a similar upward trend over this period. Further, historic Spritmonitor.de data for 2001–2024 showed that WLTP values are substantially more representative of real-world driving than those determined under the previous test cycle, but a gradual increase in the gap continues to be observed.

Figure ES1

Average gap between real-world and type-approval CO_2 emission values for ICEVs (including MHEVs and HEVs) by data source

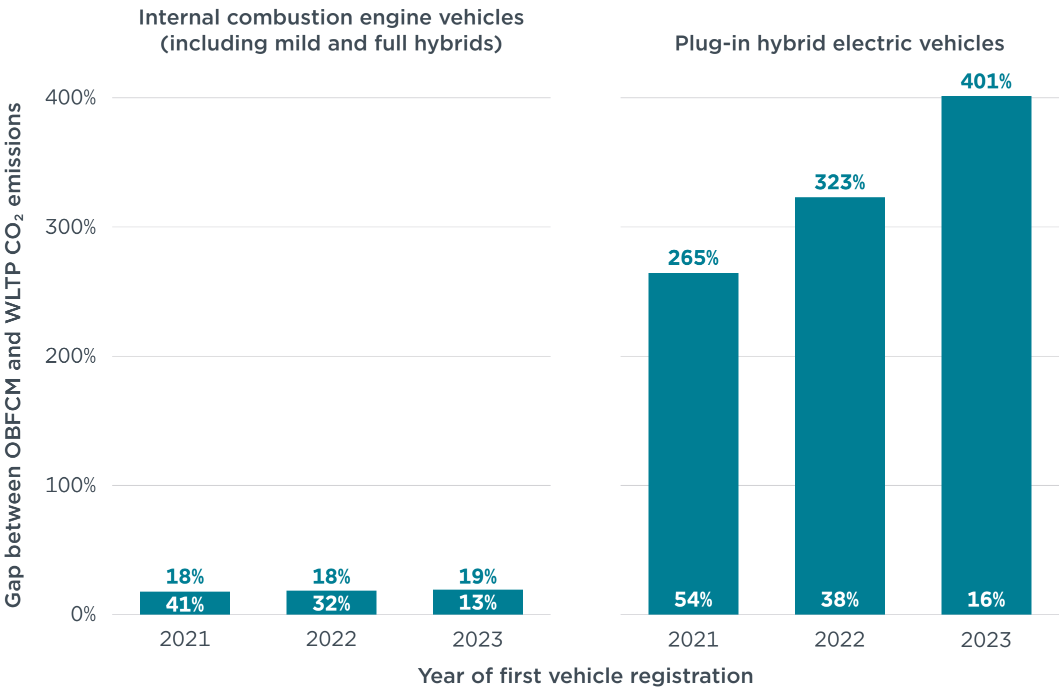


THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

In contrast to ICEVs, HEVs, and MHEVs, PHEVs exhibited a much larger and faster-growing gap, with average on-road CO_2 emissions about 5 times the official WLTP value in 2023 and a 50% increase in this gap from 2021, as shown in Figure ES2. This discrepancy mainly resulted from the overestimation of the electric driving share under real-world driving conditions in the WLTP.

Figure ES2

Average gap between real-world and type-approval CO_2 emission values for ICEVs and PHEVs



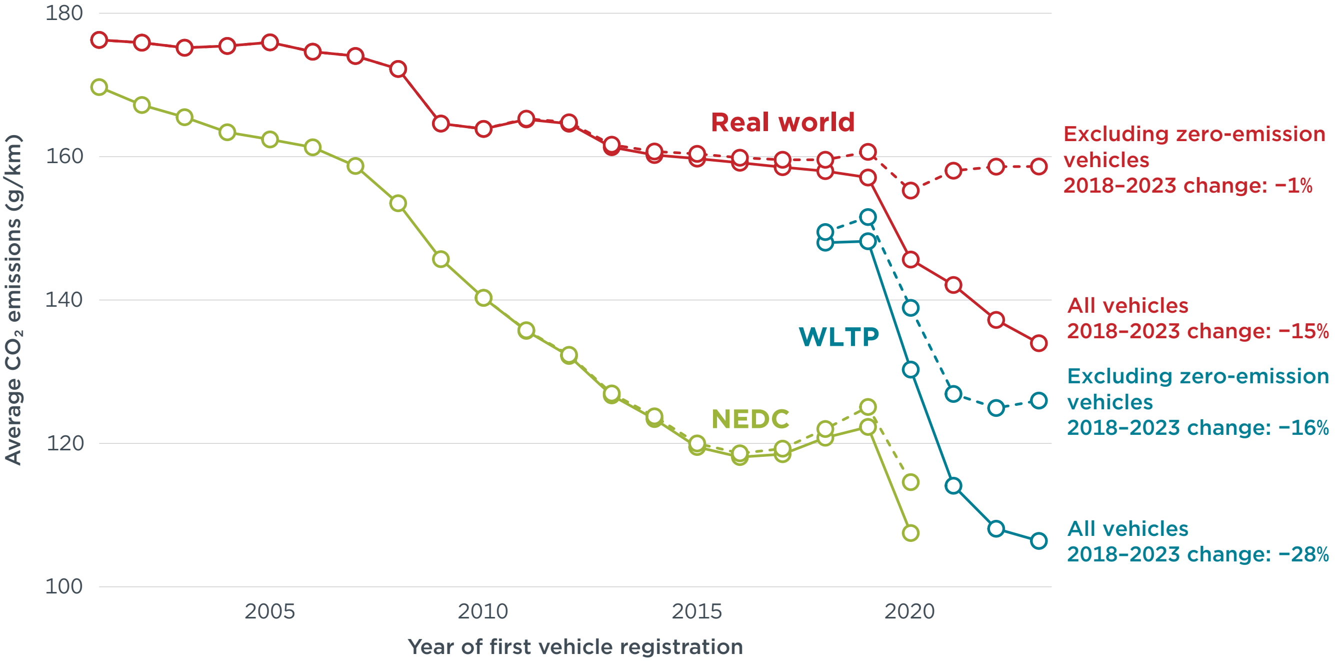
Note: The share of registered vehicles represented in the OBFCM data is presented at the bottom of each bar.

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

The growing gap between type-approval and real-world emissions, particularly for PHEVs, undermines CO_2 emission reduction targets, which currently solely rely on official values. As illustrated in Figure ES3, although official fleet-average CO_2 values decreased by 28% between 2018 and 2023, estimated real-world emissions declined by only 15%. Moreover, these real-world reductions were driven by the increasing uptake of battery electric vehicles (BEVs), not efficiency improvements in vehicles with combustion engines, whose estimated average real-world CO_2 emissions decreased by just 1% from 2018 to 2023.

Figure ES3

Fleet-average type-approval CO_2 emissions compared with estimated real-world emissions



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

Based on our findings, we offer the following policy recommendations:

- **Review the PHEV utility factor curve regularly.** The type-approval test procedure regulation calls for implementing a utility factor adjustment for PHEVs in 2027. Given the growing gap observed for PHEVs, the PHEV utility factor curve could be regularly reviewed and updated to reflect real-world PHEV usage, ensuring it remains representative over time.
- **Implement a correction mechanism to prevent further growth of the emissions gap.** Under the CO_2 standards, the European Commission is already tasked with publishing a methodology for a correction mechanism by 2026. This mechanism would proportionally lower manufacturers' CO_2 targets in future years to compensate for excess emissions resulting from a growing gap. The availability of OBFCM data could allow this correction mechanism to take effect as early as 2027. A detailed proposal for such a mechanism is provided in Dornoff et al. (2024).
- **Require OBFCM data collection for all Euro 7 BEVs.** BEVs are currently exempt from OBFCM reporting requirements during the first stage of Euro 7. Extending OBFCM reporting requirements to Euro 7 electric vehicles from November 29, 2026, would enable earlier collection of representative real-world energy consumption data.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Transport produces more greenhouse gas emissions than any other sector of the economy, with road transport responsible for over 70% of transport-related emissions (European Environment Agency, 2025). The EU adopted carbon dioxide (CO_2) emission standards for new passenger cars (PCs) in 2009 and for vans in 2011, launching a major effort to decarbonize the sector (Regulation [EC] No 443/2009, 2009; Regulation [EU] 510/2011, 2011). These initial standards were followed by a series of regulations that set progressively more ambitious targets for the decades ahead. This trajectory culminated in the requirement that all new cars and vans must have zero CO_2 emissions at the tailpipe from 2035 onward (Regulation [EU] 2023/851, 2023)—a milestone that placed the EU on a clear path toward zero-emission road transport (Dornoff, 2023; Mock, 2019).[1]

The European standards, however, regulate fleet-average CO_2 emissions of car and van manufacturers as measured in the laboratory during the type-approval procedure. Extensive research has shown that reductions in type-approval CO_2 emissions have not consistently translated into equivalent reductions on the road. Instead, a growing discrepancy has emerged between official and real-world emissions of PCs. This gap has been documented for internal combustion engine vehicles (ICEVs) and hybrid electric vehicles (HEVs) by previous International Council on Clean Transportation (ICCT) studies in the "From Laboratory to Road" series (Mock et al., 2012, 2013; Mock, Tietge, et al., 2014; Tietge et al., 2015, 2016, 2017, 2019) and the "On the Way to 'Real-World' CO_2 Values" series (Dornoff et al., 2020, 2024).

The gap was first observed for combustion engine vehicles type-approved under the New European Driving Cycle (NEDC), the test procedure in place when CO_2 standards were introduced in the EU. It grew steadily over time, peaking at around 37% for vehicles newly registered in 2016, compared with 4% in 2001. To make type-approval values more representative of real-world driving, the Worldwide harmonized Light vehicles Test Procedure (WLTP) gradually replaced the NEDC starting in 2017 (Mock, 2013; Mock, Kühlwein, et al., 2014; Pavlovic et al., 2018). Since 2020, all new cars and vans registered in the EU are required to be type-approved under the WLTP.

In 2020 and 2024, ICCT studies investigated the WLTP gap for ICEVs and HEVs using real-world CO_2 emissions data reported by consumers on the Spritmonitor.de website.[2] The results indicated that, although WLTP values are more representative of real-world emissions than those from the NEDC, the discrepancy grew from about 8% in 2018 to 14% in 2022 (Dornoff et al., 2020, 2024). In addition, separate analyses of plug-in hybrid electric vehicles (PHEVs) drawing on Spritmonitor.de data, company car datasets, and user surveys have shown that the gap between real-world and type-approval emissions for PHEVs is substantially higher, with actual emissions 3–5 times higher on average than WLTP type-approval values (Plötz et al., 2020, 2022, 2026; Navas Gohlke & Gimbert, 2025).

The negative impacts of this gap are manifold. The failure of real-world emissions to decline in line with regulatory requirements compromises CO_2 reduction goals and, therefore, undermines efforts to mitigate climate change. The gap leads to higher-than-expected vehicle operating costs for consumers because the advertised fuel economy is not in line with real-world consumption. Unrepresentative type-approval values

---

[1] The 100% CO_2 reduction target for cars and vans for 2035 is currently under revision following an amendment proposed by the European Commission in December 2025 (Dornoff et al., 2025).

[2] Spritmonitor.de is a crowdsourced, free-of-charge platform where users can voluntarily document their vehicles' fuel efficiency by logging both mileage and fuel consumption. The website covers hundreds of thousands of vehicles, and previous ICCT papers have shown that these data are consistent with data from other real-world sources (predominantly for privately owned cars).

also make it difficult for buyers to make informed vehicle purchase decisions. The gap leads to lost government revenue in CO_2-based taxation systems and misdirection of subsidies as these fiscal measures rely on official emission values.

To prevent a widening gap between WLTP and on-road emissions, the CO_2 regulation adopted in 2019—which set reduction targets for 2025 and 2030—also tasked the European Commission with monitoring the on-road fuel and electric energy consumption of PCs and vans. For this purpose, since 2021, all new vehicles registered in the EU have been required to have on-board fuel and energy consumption monitoring (OBFCM) devices. By 2026 at the latest, the Commission is required to use the OBFCM data to assess the feasibility of a mechanism to prevent the gap from growing by adjusting each manufacturer's annual CO_2 emission performance starting in 2030 (Dornoff, 2023).

This study provides an update on the gap between WLTP and real-world emissions for ICEVs, including mild hybrid electric vehicles (MHEVs) and HEVs, as well as for PHEVs registered between 2021 and 2023. It relies on OBFCM real-world CO_2 emissions data published by the European Environment Agency (EEA; EEA, 2024) for approximately 8 million vehicles. In addition, we analyze user-reported fuel consumption data from Spritmonitor.de for ICEVs, including MHEVs and HEVs, first registered up to and including 2024, extending our most recent Spritmonitor.de analysis by 2 years (Dornoff et al., 2024). The Spritmonitor.de sample also includes NEDC type-approved vehicles registered through 2019, the final year in which NEDC vehicles could be registered. Because they are not yet required to be equipped with OBFCM devices, battery electric vehicles (BEVs) and fuel-cell electric vehicles are outside the scope of this study.

The paper is organized as follows. First, we describe the datasets used and the methodology applied in this study. We then present the development of the gap between real-world and type-approval CO_2 emissions by powertrain type, fuel type, and manufacturer and estimate fleet-wide real-world CO_2 emissions based on this gap. We conclude by summarizing the findings and providing recommendations to support the reduction of real-world CO_2 emissions for cars and vans in Europe.

METHODOLOGY FOR CALCULATING THE CO_2 EMISSIONS GAP

This section describes the methodology used to calculate the CO_2 emissions gap between type-approval data and two sets of real-world data: OBFCM records published by the EEA and user-reported fuel consumption values from the consumer platform Spritmonitor.de. It also discusses the limitations of the study and the methodological differences compared with Suarez et al. (2025), which analyzed the CO_2 emissions gap based on the OBFCM data.

This study differentiates between ICEVs (including MHEVs and HEVs) and PHEVs. ICEVs could not further be subdivided into non-hybrid, mild hybrid, and full hybrid cars because the EEA data do not allow us to reliably differentiate between these powertrain types.[3] However, because hybrid vehicles are a form of efficient ICEVs and the share of MHEVs is continuously increasing, grouping hybrid vehicles with ICEVs was deemed reasonable for the purposes of this analysis (Dornoff et al., 2022). Because the vast majority of ICEVs, HEVs, and PHEVs operate on either diesel or gasoline, we only analyzed vehicles using those fuel types.

We excluded from the analysis WLTP type-approval values for cars registered in 2017 because they cover only a fraction of the 2017 fleet. The WLTP test procedure was introduced in the EU in September 2017 for the type approval of new models of cars and vans. Starting in September 2018, the WLTP test was required for all new cars and small vans, including models previously approved under the NEDC. For larger vans, the introduction dates were delayed by 1 year.

The analysis included the COVID-19 pandemic period from early 2020 to early 2022. Although these years saw a drop in new vehicle registrations, shifts in travel behavior, and reduced fuel prices (Ecke et al., 2021), we do not expect that the pandemic had a considerable effect on the study's results. German household survey data on car usage indicate that the pandemic had no significant effect on average fuel consumption (Vallée et al., 2022), suggesting the impact on gap estimates is likely modest.

DATA SOURCES

Type-approval data: European Environment Agency

We used the dataset on manufacturer CO_2 performance published annually by the EEA to supplement the OBFCM and Spritmonitor.de datasets with type-approval CO_2 emissions and new registration information (EEA, 2026). Both real-world datasets lacked new registration figures, and the Spritmonitor.de sample had incomplete type-approval CO_2 values. The type-approval CO_2 data, determined through laboratory testing, was needed for vehicle-level gap calculations, while new registration data served to compute registrations-weighted averages. Additional details on the EEA type-approval dataset can be retrieved from the an ICCT brief on manufacturers' CO_2 performance published in 2025 (Díaz et al., 2025). Because this dataset does not include vehicles registered before 2011, we obtained CO_2 emission values for these vehicles from an internal ICCT database.

Real-world data: On-board fuel consumption monitoring, European Environment Agency

Previous ICCT CO_2 gap analyses primarily relied on self-reported real-world fuel consumption values. This report focuses on the analysis of on-road CO_2 emissions data collected via OBFCM devices from 2021 to 2023 and published by the EEA (n.d.).

---

[3] Full HEVs can operate some distance in purely electric mode while the low voltage system and small battery of a MHEV only allows the electric motor to assist the internal combustion engine.

OBFCM devices have been mandatory for all new combustion engine and hybrid cars, plug-in hybrid cars, and most vans since 2021. For heavy vans, the requirement has been in place since 2022 (Dornoff et al., 2024). These devices automatically record lifetime fuel and energy consumption as well as the total mileage of a vehicle. Manufacturers must demonstrate OBFCM device accuracy during the type-approval process and regular conformity of production checks (Regulation [EU] 2017/1151, 2017). Since 2021, OBFCM data have been retrieved from vehicles during repair and maintenance and, starting in 2023, also during periodic technical inspections, provided the owner consents. Manufacturers and (since 2023) Member States collect and transmit all data from a given year to the European Commission in the following year. For vehicles already reporting OBFCM data wirelessly to the manufacturer IT systems, these data are also transferred annually to the Commission (Regulation [EU] 2021/392, 2021). With the Euro 7 standard, which applies to new PC models from November 29, 2026, all vehicles are required to transmit their OBFCM data wirelessly to manufacturers (Regulation [EU] 2025/1707, 2025). After this requirement goes into effect, the average time lag between a vehicle's registration date and the first OBFCM data reporting is therefore expected to decrease substantially, and the frequency of data reporting per vehicle is expected to increase from 2027 onward.

Based on the OBFCM data, the Commission then determines the lifetime average fuel consumption and the equivalent CO_2 emissions for each vehicle, using conversion factors of 22.78 g CO_2/km per L/100km for gasoline and 26.31 g CO_2/km per L/100km for diesel (Commission Staff Working Document, 2024).

To date, the EEA has released three batches of OBFCM data. The first, published in 2024, includes data collected by manufacturers from PCs first registered in 2021, while the two other datasets were published in 2025 and cover vehicles first registered from 2021–2022 and 2021–2023. No Member State-collected data have been published to date. This study analyzed all three datasets, which contain parameters for each vehicle, including a unique vehicle identifier, reporting year, total lifetime fuel consumption and mileage, country of registration, make and model name, vehicle category, technical specifications such as mass in running order and engine power, and type-approval CO_2 emissions. For PHEVs, additional parameters on mileage and fuel and electricity consumption in different operating modes are also included.

Real-world data: Spritmonitor.de

To complement the analysis of the OBFCM data, we also analyzed fuel consumption records from the German consumer platform Spritmonitor.de, providing a reference for comparison as well as historical context by extending the available time series to vehicles first registered from 2001 onward. Because of its alignment with other real-world sources, Spritmonitor.de data for Germany served as the sole source of real-world CO_2 emission data in the two previous ICCT studies analyzing the discrepancy between real-world and WLTP type-approval emissions data (Dornoff et al., 2024).

The Spritmonitor.de dataset, which we acquired in October 2025, includes gasoline and diesel ICEVs and HEVs but excludes PHEVs. For each vehicle, the dataset contained the country of registration, build year (year the vehicle was manufactured), make and model name, powertrain type, fuel type, engine power, transmission type, distance driven, and the amount of fuel consumed. The year of first registration was not included.

DATA PROCESSING

Type-approval data: European Environment Agency

We cleaned the EEA type-approval data to harmonize make and model names as well as powertrain and fuel types.

Real-world data: On-board fuel consumption monitoring, European Environment Agency

The OBFCM datasets published by the EEA cover a growing sample of PCs. For 2023, the most recent reporting year, the raw dataset included approximately 7,734,000 unique vehicles, compared with around 923,000 vehicles in reporting year 2021. For each vehicle, we calculated real-world fuel consumption as the total fuel consumption of the vehicle divided by its total mileage. We then estimated corresponding real-world CO_2 emissions using the same conversion factors used by the European Commission.

We applied several filters to the dataset to address quality issues before analysis. First, this study applied the same filters used in the European Commission's assessment of OBFCM CO_2 emissions: excluding vehicles with missing information on key parameters such as total distance or total fuel consumption, those with a total distance below 500 km, and those with invalid powertrain types (Commission Staff Working Document, 2024). These filters removed approximately 18% of records (see Table 1). Second, for HEVs and PHEVs, the total distance and fuel consumption values were required to be greater or equal to the sum values of the charge-depleting and charge-increasing modes.[4] This filter removed approximately 0.3% of records. Third, 0.2% of records had implausible on-road CO_2 emission values and were removed based on the thresholds defined in Suarez et al. (2025). Specifically, vehicles were excluded if their on-road CO_2 emission values exceeded 3 times the type-approval CO_2 value or fell below the type-approval value minus 30 g CO_2/km. For PHEVs, vehicles were excluded if on-road CO_2 emissions exceeded 440 g CO_2/km. Finally, for vehicles for which data were retrieved in multiple years, we retained only the record with the highest fuel and distance values. This filter removed approximately 19% of records. However, the effect was more pronounced for 2021 (29%) and 2022 (14%) than for 2023 (0.1%), because 2023 provided the most recent datum for many vehicles with multiple records. Overall, we included approximately 63% of all records in the raw datasets in this analysis.

Table 1

Number of OBFCM records removed by different filters by registration year

Number of records	2021	2022	2023	2021–2023
Raw data	6,138,082	4,214,719	2,120,615	12,473,416
Incomplete	–442,315	–846,594	–928,310	–2,217,219
Invalid hybrids	–30,127	–2,621	–230	–32,978
Implausible CO_2 emissions	–15,509	–9,901	–1,691	–27,101
Multiple records per vehicle	–1,796,687	–580,478	–1,307	–2,378,472
Remaining records	**3,853,444**	**2,775,125**	**1,189,077**	**7,817,646**

---

[4] Charge-depleting mode and charge-sustaining mode are the two primary modes for PHEVs. In charge-depleting mode, the vehicle draws energy from the battery, running on electricity alone or with combustion engine assistance, resulting in lower CO_2 emissions. Once the battery is depleted, it switches to charge-sustaining mode, in which the battery charge level is kept roughly constant, the combustion engine provides most of the propulsion, and CO_2 emissions are comparable to those of conventional vehicles. A third, user-selectable option (charge-increasing mode) also exists, which allows the driver to charge the battery by using the electric motor as an ICE-powered generator.

Real-world data: Spritmonitor.de

Spritmonitor.de provided anonymized data for approximately 1,014,100 vehicles registered in Germany between 2001 and 2025. As with the OBFCM dataset, for each vehicle, we calculated real-world fuel consumption as the total fuel consumption of the vehicle divided by its total mileage, while corresponding real-world CO_2 emissions were estimated using the above-mentioned conversion factors.

We only analyzed PCs with a minimum recorded mileage of 1,500 km. We excluded car-derived vans, non-car-derived vans, and pickups from the analysis because they are typically registered as vans. We also excluded vehicles if they were built before 2001 or used fuel types other than diesel or gasoline. Additionally, after supplementing the dataset with type-approval CO_2 values (see next section), we removed any vehicles with implausible on-road CO_2 emission values using the same criteria as those applied to the OBFCM dataset.

After cleaning the dataset, a sample of approximately 302,000 vehicles remained, equivalent to roughly 30% of the initial raw sample. The number of cars for each build year exceeded 8,000 through 2020, with sample sizes near or above 15,000 from 2007 onward. For build years 2021 to 2024, the number of vehicles gradually declined from about 5,200 in 2021 to roughly 3,500 in 2024.

Merging real-world with type-approval and new registration data

To enable gap calculations and registration-weighted analyses, we complemented the OBFCM and Spritmonitor.de cleaned datasets with type-approval CO_2 emission figures (for Spritmonitor.de) and new registration data (for both datasets) from the cleaned EEA type-approval dataset.

To merge the OBFCM and type-approval datasets, we first determined the number of new vehicles registered for each combination of registration year, make, commercial name, fuel type, fuel mode, engine power, engine capacity, and WLTP type-approval CO_2 emissions in the EEA type-approval dataset. These attributes provided a detailed vehicle definition while excluding extraneous columns, particularly those with missing values. We then joined the OBFCM and type-approval datasets on these grouping variables. Of the approximately 7,711,000 vehicles in the clean OBFCM dataset, 0.6% could not be assigned a number of newly registered vehicles.

To combine the Spritmonitor.de and type-approval datasets, we first calculated the mean type-approval CO_2 emission value and the number of new registrations for each combination of registration year, make, model, fuel type, and engine power in the EEA type-approval dataset, filtered for vehicles registered in Germany. Because each combination could have included multiple versions of a vehicle model with differing official CO_2 values—such as manual and automatic transmission variants—we computed the CO_2 value for each combination as the registration-weighted average of all vehicles within that combination. We then joined the Spritmonitor.de and type-approval datasets on these five grouping variables, requiring that the build year and registration year were equal. Compared with the OBFCM join, we used fewer grouping variables due to more limited data availability in the Spritmonitor.de dataset. For vehicles in the Spritmonitor.de dataset built before 2011, we performed the join using an ICCT internal type-approval database, following the same procedure.

Calculating the gap between real-world and type-approval CO_2 emissions

We used both the OBFCM and Spritmonitor.de datasets to estimate the fleet-average gap between real-world and official CO_2 emissions. For this purpose, we calculated the gap between the two values for each vehicle, expressed as a percentage of the official CO_2 emission value. We then calculated the fleet-average gap by registration year, powertrain type, fuel type, and manufacturer by weighting the per-vehicle gap with the number of new registrations.

Estimating fleet-wide real-world CO_2 emissions

Although the OBFCM sample covered millions of vehicles and the Spritmonitor.de sample hundreds of thousands, neither represented the entire fleet. To estimate fleet-wide real-world emissions over time from gap values, we combined results from the Spritmonitor.de and OBFCM data analyses. For vehicles registered between 2001 and 2010, we estimated fleet-average real-world CO_2 emissions by applying NEDC gap values derived from the Spritmonitor.de sample to fleet-average type-approval CO_2 emissions. For vehicles registered between 2011 and 2019, we estimated real-world CO_2 emissions separately for ICEVs (including MHEVs and HEVs) and PHEVs before weighting them by their respective fleet shares. For these vehicles, we calculated on-road ICEV emissions using NEDC gap values from Spritmonitor.de, while we assumed PHEV emissions to be equal to the average OBFCM CO_2 emissions of PHEVs registered in 2021. We applied the same approach to vehicles registered in 2020, using the WLTP gap value from Spritmonitor.de instead of the NEDC value. For vehicles registered between 2021 and 2023, we assumed fleet-average real-world CO_2 emissions to be equal to the corresponding fleet-average OBFCM CO_2 emissions.

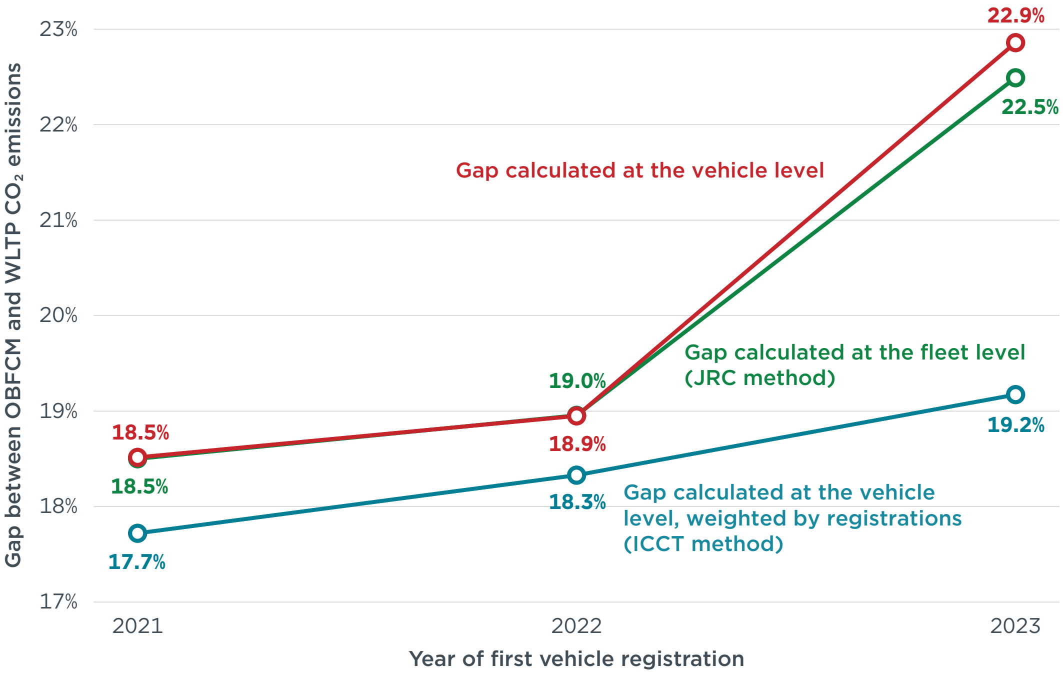
Methodological differences with the Joint Research Centre CO_2 emissions gap analyses

There are two significant methodological differences between our analysis and the study conducted by Suarez et al. (2025), which followed the European Commission's approach. First, Suarez et al. (2025) calculated the gap as the total fleet-wide OBFCM CO_2 emissions divided by the total WLTP CO_2 emissions. By contrast, our analysis computed the gap at the vehicle level before aggregating it to the fleet level. While the approach by Suarez et al. (2025) focused on assessing how much higher fleet-wide real-world CO_2 emissions were compared with type-approval values, our approach focused on the discrepancy at the vehicle level to evaluate how realistic the official fuel consumption values were from a driver's perspective. Second, Suarez et al. (2025) determined the gap as the average of all valid reported values. By contrast, our analysis calculated the registration-weighted gap.

These methodological differences had only a minimal impact on the average gap values. As shown in Figure 1, calculating the gap at the vehicle level before aggregating to the fleet level resulted in differences of less than 0.5 percentage points across all registration years relative to Suarez et al. (2025). Further, unweighted average gap values were higher than registration-weighted figures, although the difference remained below 1 percentage point for 2021 and 2022 and below 3 percentage points for 2023. The fact that registration-weighted and unweighted gap values were closely aligned for cars first registered in 2021 and 2022 indicates that the OBFCM sample was representative of the 2021 and 2022 fleets. The larger difference observed for 2023 vehicles was likely due to the lower number of vehicles for which OBFCM data were available.

Figure 1

Comparison of average gap values between OBFCM real-world and WLTP type-approval CO_2 emissions (excluding PHEVs) across three calculation methods



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

In this study, we harmonized previous methodological differences between the Joint Research Centre and ICCT analyses, including the use of different fuel-consumption-to-CO_2 conversion factors and alternative thresholds for outlier removal.

REPRESENTATIVENESS OF THE ANALYZED DATASETS

Representativeness of the OBFCM dataset for the EU car fleet

To evaluate how representative the analyzed OBFCM data were of EU-wide real-world CO_2 emission trends for PCs, the top panel of Figure 2 compares average type-approval CO_2 emission values, excluding zero-emission vehicles (ZEVs), across the EEA CO_2 monitoring dataset, the OBFCM dataset, and the registration-weighted OBFCM dataset per registration year. In the bottom panel, the figure compares the share of PHEVs relative to the total number of vehicles excluding ZEVs.

Figure 2

Average WLTP type-approval CO_2 emission values from EEA CO_2 monitoring data, OBFCM data, and registration-weighted OBFCM data (top) and PHEV share (bottom)

Note: Average WLTP type-approval CO_2 emission values and PHEV shares do not include ZEVs. The share of vehicle registrations covered by each sample is presented at the bottom of each bar.

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

The older the vehicle, the more likely it is to undergo repair and maintenance, providing opportunities to retrieve OBFCM data. As a result, the share of new car registrations included in the OBFCM sample increased with vehicle age, covering about 42% of new 2021 registrations (excluding ZEVs), 33% of 2022 registrations, and 13% of 2023 registrations. For PHEVs, the coverage was higher: about 54% of 2021 PHEV registrations, roughly 38% for 2022, and 16% for 2023 appeared in the OBFCM sample.

Figure 2 indicates that the weighted OBFCM sample was representative of the EU PC fleet. Annual average type-approval CO_2 emission levels in the registration-weighted OBFCM dataset differed from those in the EEA type-approval dataset by 1 g CO_2/km or less. At the same time, for vehicles first registered in 2021 and 2022, average type-approval CO_2 values in the unweighted OBFCM sample were closely aligned with those in the EEA type-approval dataset (with deviations of about 1 g CO_2/km), indicating that the OBFCM sample was highly representative for these registration years. The difference increased to 2 g CO_2/km for registration year 2023, likely due to the smaller vehicle sample.

Similarly, the powertrain-type distribution in the weighted OBFCM sample closely aligned with that of the EEA CO_2 monitoring dataset, with a maximum discrepancy of about 1 percentage point in registration year 2021. In comparison, PHEVs were slightly overrepresented in the unweighted OBFCM sample, with larger discrepancies of 2–3 percentage points relative to the EEA CO_2 monitoring dataset.

The OBFCM data were also representative for the individual vehicle makes. Tables A1 and A2 in the Appendix compare OBFCM samples of the largest 19 vehicle makes with EEA CO_2 monitoring data for registration years 2021–2023. Specifically, Table A1 shows the share of new ICEV registrations covered by the OBFCM sample for each make and registration year as well as the difference in type-approval CO_2 emissions between the OBFCM and the EEA monitoring datasets. Table A2 provides the same information for PHEVs. The results show that, on average, 28% of ICEV and 38% of PHEV registrations were covered by the OBFCM samples, although coverage varied by make and registration year. Moreover, average type-approval CO_2 emission values by make in the OBFCM samples were within ±1 g/km of the corresponding averages in the EEA monitoring dataset in the vast majority of cases.

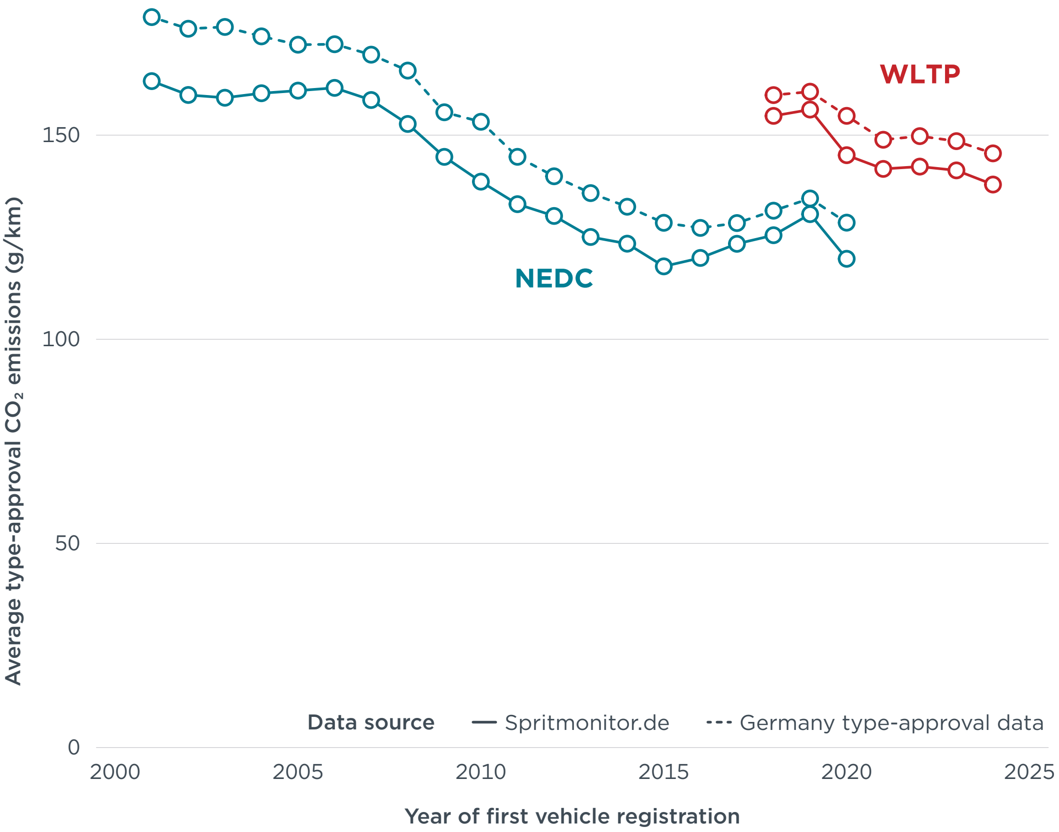
Overall, although the OBFCM data were not based on random sampling, the analysis showed that the analyzed sample was representative of the EU PC fleet, particularly for registration years 2021 and 2022. For vehicles first registered in 2023, the sample size was smaller and may have overrepresented certain fleet segments. For instance, telemetry data collected by manufacturers is more likely to be available for higher-end models.

Representativeness of the Spritmonitor.de dataset for the German car fleet

Figure 3 indicates that trends in average type-approval CO_2 emissions over time in the Spritmonitor.de sample mirrored those of the German vehicle fleet. The figure compares registrations-weighted average type-approval CO_2 emissions in the merged Spritmonitor.de dataset with those in the EEA CO_2 monitoring dataset for Germany (for registration years 2011–2024) and with the ICCT's internal type-approval database for vehicles registered before 2011. Across all years, average type-approval CO_2 values in the Spritmonitor.de sample were about 10 g CO_2/km lower than those of the German fleet. This discrepancy decreased for more recent registration years, narrowing to around 7 g CO_2/km for WLTP type-approved cars manufactured between 2021 and 2024. A likely explanation is the overrepresentation of private cars in the Spritmonitor.de data, as these vehicles tend to be smaller and have lower type-approval CO_2 values (Tietge et al., 2019; Wappelhorst et al., 2024). Overall, however, the trends in average type-approval CO_2 emissions over time were closely aligned between the two datasets. In summary, we estimate that real-world emissions in the Spritmonitor.de sample are representative of the German private car fleet but may underestimate fleet-wide emissions due to the omission of company cars, thus yielding a conservative estimate of the gap.

Figure 3

Comparison of fleet-average type-approval CO_2 emissions of ICE passenger cars (including MHEVs and HEVs) registered in Germany versus Spritmonitor.de vehicles



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

DEVELOPMENT OF THE CO_2 EMISSIONS GAP OVER TIME

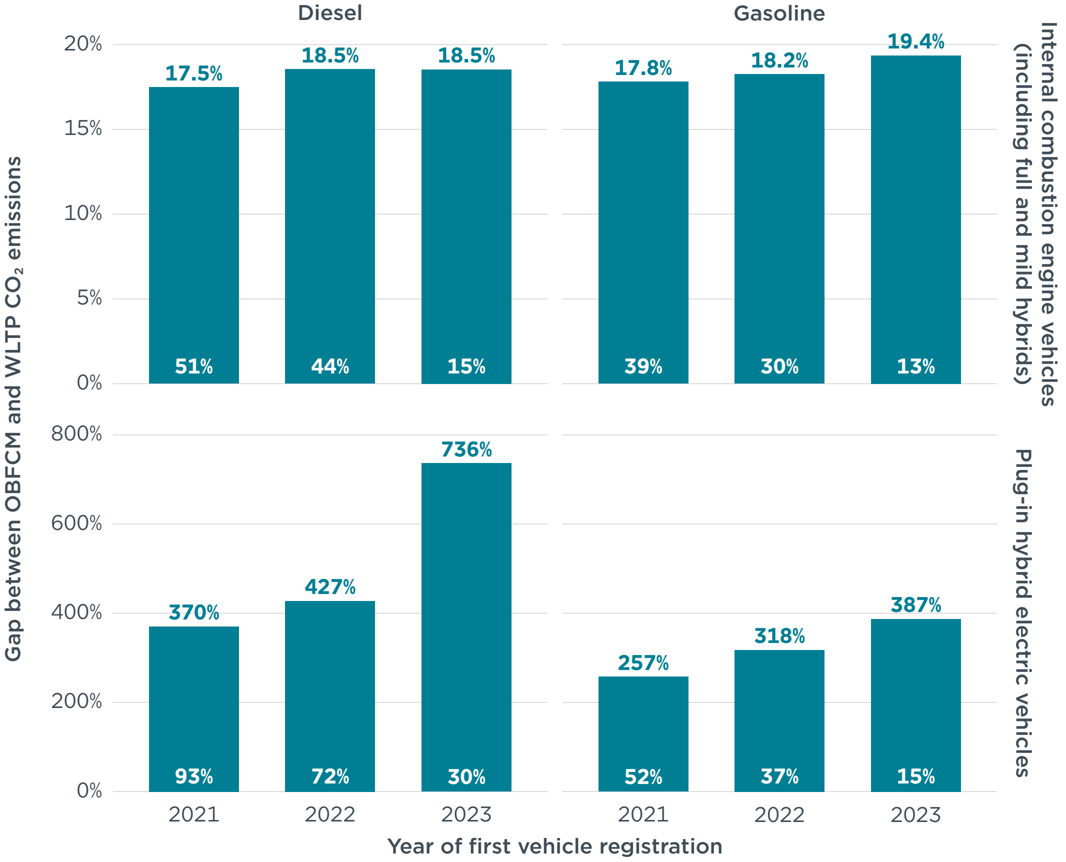
This section analyzes the development of the gap between real-world and WLTP type-approval CO_2 emissions, broken down by powertrain type, fuel type, and vehicle make, based on the OBFCM data for registration years 2021–2023. We examine differences in the gap for ICEVs and PHEVs, including the impact of PHEVs on the average gap per vehicle make. We also compare gap trends from OBFCM data with those derived from Spritmonitor.de. In addition to serving as a point of comparison, the Spritmonitor.de data provide a broader temporal scope, covering NEDC type-approved vehicles from build years 2001 to 2019 and WLTP type-approved vehicles for build years 2018 to 2024. Finally, the section estimates the development of fleet-wide real-world CO_2 emissions from the gap.

DEVELOPMENT OF THE GAP BY POWERTRAIN TYPE

The discrepancy between WLTP type-approval and on-road CO_2 emissions for ICEVs (including MHEVs and HEVs) increased slightly, from about 17% for diesel cars and 18% for gasoline cars in 2021 to approximately 19% for both fuel types in 2023, as shown in Figure 4. For both gasoline and diesel PHEVs, the gap values were much higher than those for ICEVs and grew steadily over the same period. For gasoline PHEVs, which made up roughly 90% of the PHEV sample, the gap rose sharply from about 260% in 2021 to roughly 390% in 2023. Diesel PHEVs exhibited even larger discrepancies, increasing from 370% in 2021 to about 740% in 2023.

Figure 4

Average gap between real-world and type-approval CO_2 emission values for ICEVs and PHEVs by fuel type



Note: The number at the top of the columns represents the average gap. The number at the bottom of the columns represents the share of new vehicle registrations included in the OBFCM data.

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

For ICEVs, these results were broadly consistent with results published by the EEA (n.d.) as well as by Suarez et al. (2025), despite methodological differences (see Figure 1). However, for PHEVs, the gap estimates presented here are somewhat higher than the PHEV gaps reported by Suarez et al. (2025), particularly for diesel models. Nonetheless, these estimates are of the same order of magnitude as those determined by Plötz et al. (2022), which identified the low real-world electric driving share of these vehicles relative to the values assumed in the regulation as the main reason for the large discrepancy.

DEVELOPMENT OF THE GAP BY MANUFACTURER

The CO_2 emissions gap of ICEVs (including MHEVs and HEVs) varied across makes, as illustrated in Figure 5, which depicts the gap for the 19 largest makes by new car registrations. Together, these makes accounted for about 89% of new PC registrations between 2021 and 2023, although average gap values were reported only for make and registration year combinations with at least 1,000 vehicles.

Figure 5

Average gap between real-world and type-approval CO_2 emission values for ICEVs (including MHEVs and HEVs) by make

Note: The number at the top of the columns represents the average gap. The number at the bottom of the columns represents the share of annual registrations represented in the OBFCM data. Columns are only presented for make and registration year combinations with at least 1,000 vehicles. Data are presented for the 19 largest vehicle makes by new registration volumes over the 2021–2023 period.

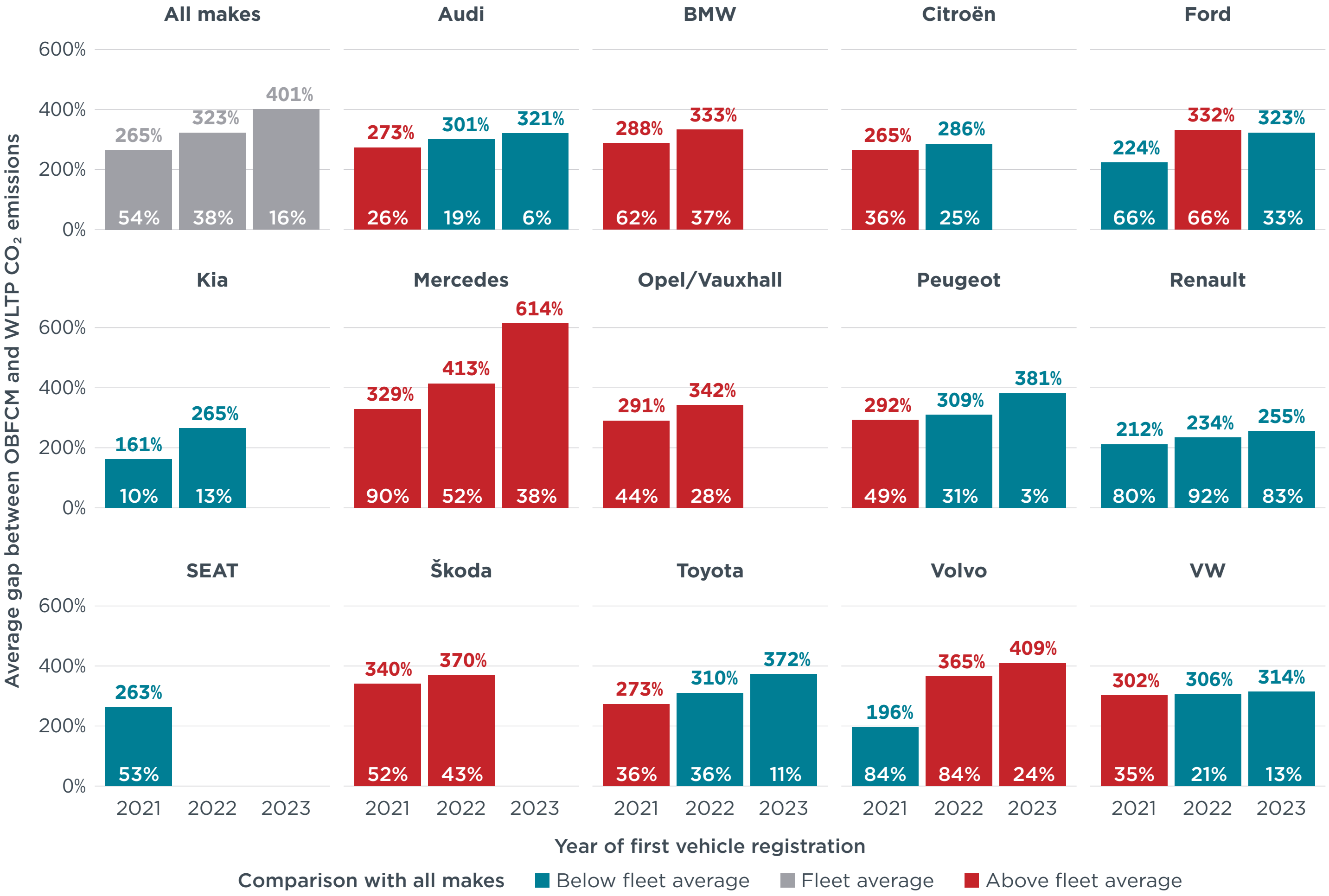
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

The gap increased over time for all makes except for Ford, Hyundai, Toyota, and Suzuki. Fiat recorded the largest gap increase (6 percentage points between 2021 and 2022), whereas the other makes had changes of 1–2 percentage points over the same period. Over the 2021–2023 period, Toyota and Suzuki showed the lowest average gap values, at 9% and 13%, respectively. Kia, along with Volvo, Citroën, and VW (all at approximately 16%), also exhibited below-average gap levels compared with the overall average of 18%–19%. Hyundai remained below the average in 2021 and 2022, although its 2023 gap level was unavailable due to insufficient data. By contrast, the highest average gap values over the 2021–2023 period were observed for Renault and Fiat (both at 26%), followed by BMW, Dacia, and Nissan (all at 23%).

As with the emissions gap for ICEVs, the PHEV gap also varied by vehicle make. Figure 6 shows results for 14 of the 19 largest makes with OBFCM sample sizes exceeding 1,000 vehicles in at least 1 registration year. Data for make and registration year combinations with 1,000 or fewer vehicles are not shown in the figure. Together, these 14 makes represent about 76% of new PHEV registrations between 2021 and 2023. Among the makes with sufficient data for all 3 registration years, the gap generally widened over time, except for the gap for Ford, which increased between 2021 and 2022 before slightly decreasing in 2023.

Figure 6

Average gap between real-world and type-approval CO_2 emission values for PHEVs by make



Note: The number at the top of the columns represents the average gap. The number at the bottom of the columns represents the share of annual registrations represented in the OBFCM data. Columns are only presented for make and registration year combinations with at least 1,000 vehicles. Data are presented for the 14 largest vehicle makes with sufficient OBFCM PHEV data.

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

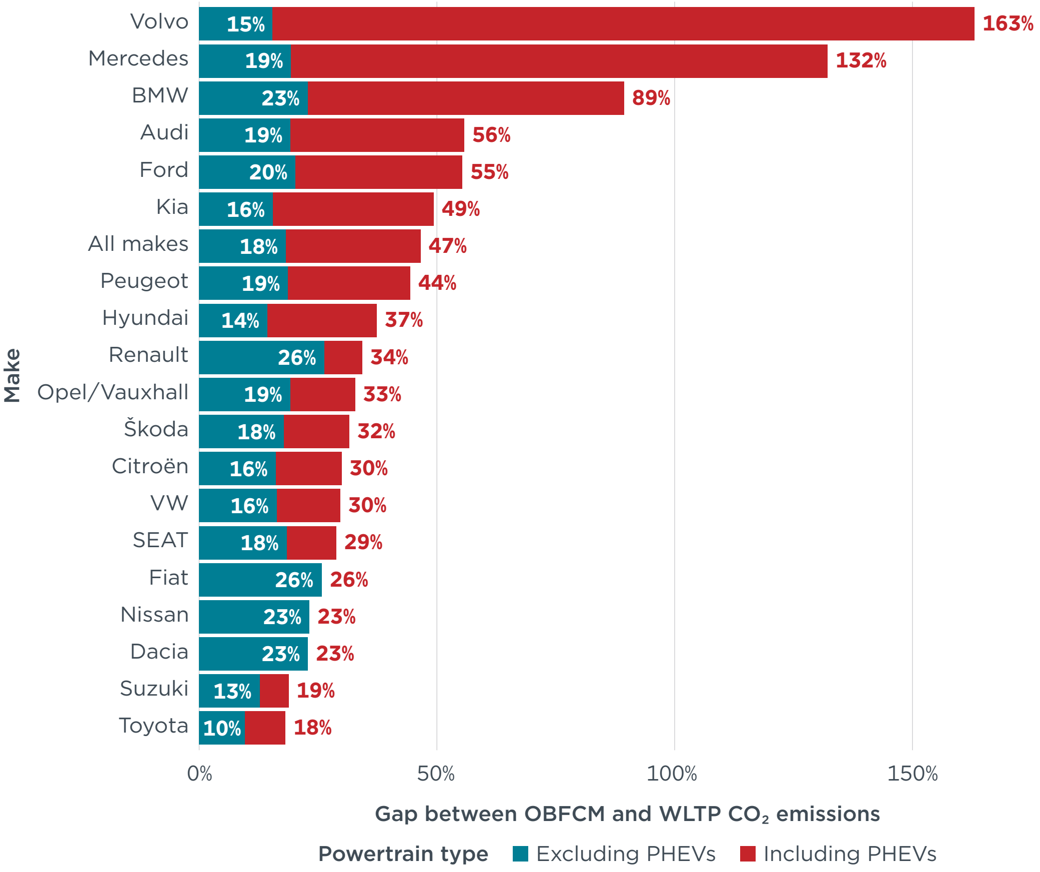
Among the makes shown in Figure 6, Mercedes displayed the largest gap by a wide margin. Mercedes accounts for the largest number of new PHEV registrations (about 14% of all PHEVs registered between 2021 and 2023) and the second-highest share of PHEV registrations (20% in 2023, not shown in the figure). The average PHEV gap for Mercedes vehicles first registered over the 2021–2023 period came to 452%. The brand also showed the largest increase in the gap, rising from 329% in 2021 to 614% in 2023. Virtually all diesel PHEVs registered in 2021 and 2022 and more than 90% of diesel PHEVs registered in 2023 were Mercedes vehicles, which, as shown in Figure 4, exhibited larger gap values than gasoline PHEVs.

With a 17% PHEV registration share in 2023, BMW also recorded above-average gap values in 2021 and 2022, although these were much closer to the fleet-wide mean compared with Mercedes. The 2023 gap values for BMW were not available due to insufficient data. Volvo, which holds the highest PHEV registration share among the makes included in Figure 6 (35% in 2023), exhibited gap levels close to the average but had the largest increase between 2021 and 2022.

For makes with high PHEV penetration, such as Volvo, Mercedes, and BMW, PHEVs had a substantial impact on the average gap between real-world and type-approval CO_2 emissions, as shown in Figure 7. The figure shows the average gap by make for 2021–2023, both including and excluding PHEVs. Across all makes, the average gap rose from 18% excluding PHEVs to 47% including them. When PHEVs were included, Volvo exhibited the largest average discrepancy at 163%, which is about 3.5 times the fleet-wide average gap (47%). Mercedes and BMW followed, with average gap values of 132% and 89%, respectively.

Figure 7

Impact of PHEVs on the average gap between real-world and type-approval CO_2 emission values by vehicle make



Note: Data are presented for the 19 largest vehicle makes.

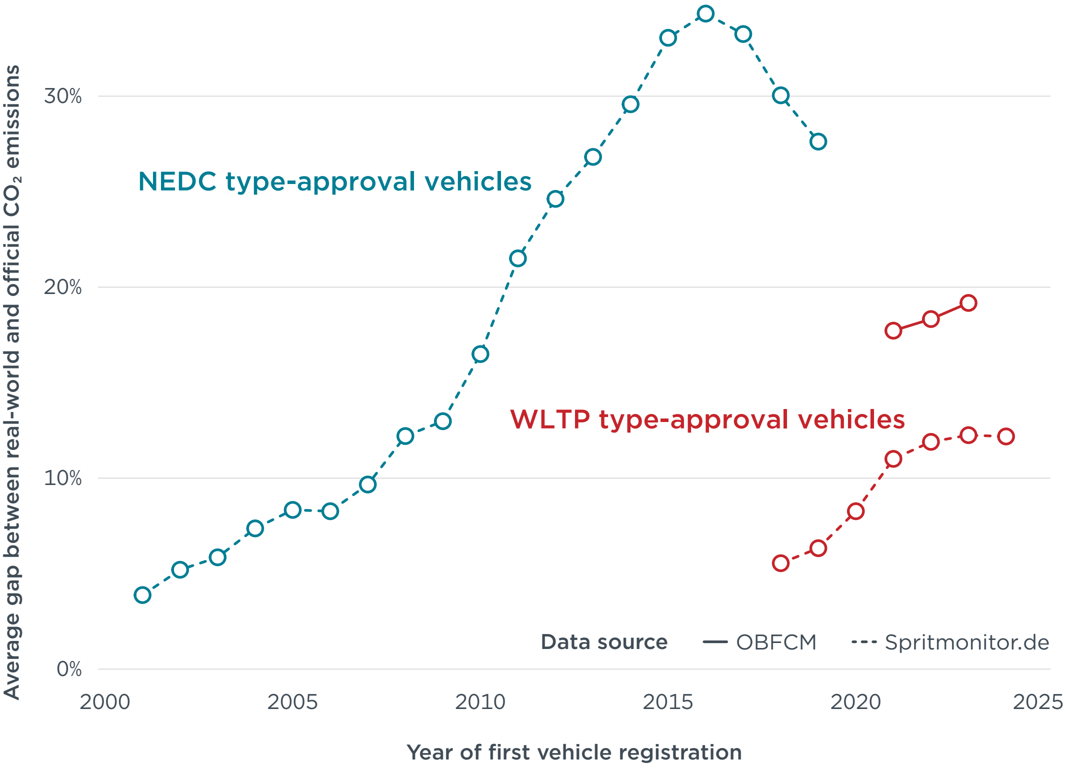
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

COMPARISON OF THE CO_2 EMISSIONS GAP BASED ON OBFCM DATA AND SPRITMONITOR.DE DATA

In this section, we compare the gap estimated from OBFCM data with that calculated from the Spritmonitor.de sample for registration years 2021 through 2023. We also present the evolution of the gap for WLTP type-approval vehicles before 2021 and up to 2024, as well as the evolution of the gap for NEDC type-approval vehicles (see Figure 8).

Figure 8

Average gap between real-world and type-approval CO_2 emission values for ICEVs (including MHEVs and HEVs) by data source



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

For registration years 2021 through 2023, the gap values derived from the Spritmonitor.de dataset were consistently lower than those based on the OBFCM sample, by roughly 5–7 percentage points. For 2023, the OBFCM data indicated a gap of 19%, compared with 12% according to the Spritmonitor.de data. Both datasets indicated a slight increase in the WLTP gap between 2021 and 2023, of approximately 1.5 percentage points. For 2024, however, Spritmonitor.de data suggested that the gap stabilized.

As mentioned above, the Spritmonitor.de dataset also provides a historical perspective on the gap's development since 2001. It showed that the average gap decreased substantially with the implementation of the WLTP. For vehicles registered in 2018, the average gap under the NEDC stood at 30%, but narrowed down to approximately 8% when using the WLTP type-approval values as reference.

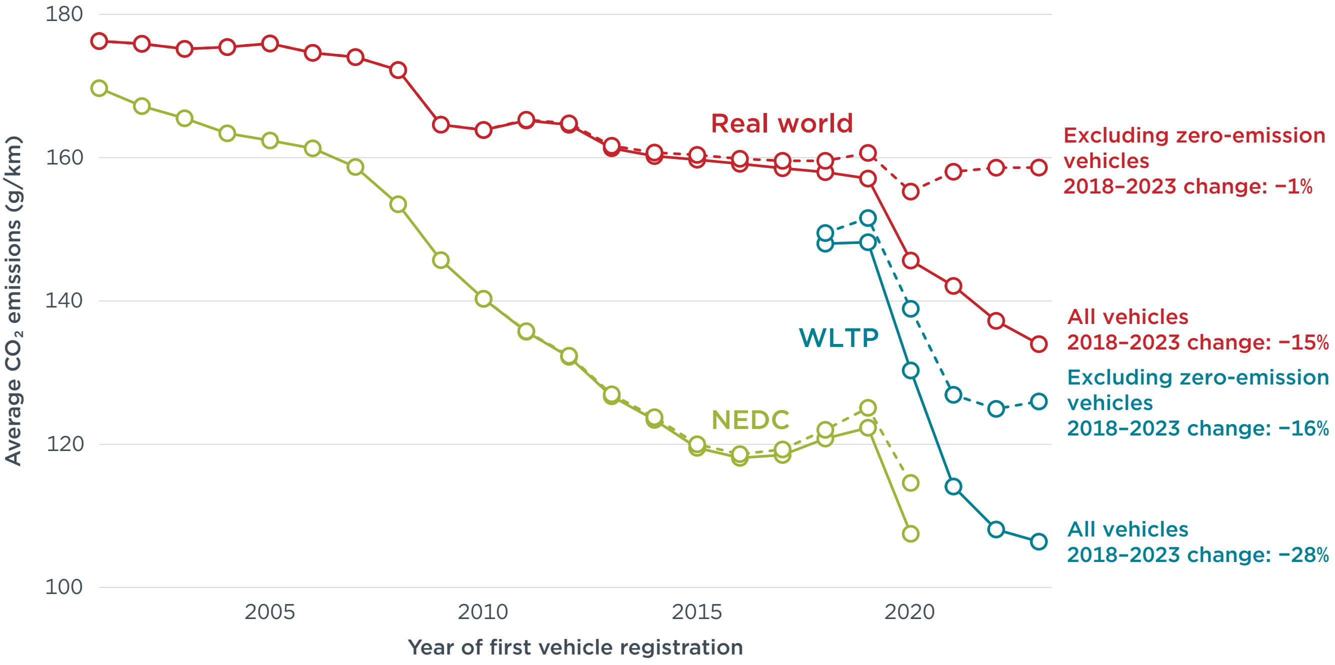
The reasons for the discrepancies between OBFCM and Spritmonitor.de results remain unclear, but differences in fleet composition between the Spritmonitor.de and OBFCM samples—particularly vehicle ownership—are likely a key factor. Previous gap analyses indicated that company cars typically exhibit higher gap values than private cars, with an average difference of about 8 percentage points (Tietge et al., 2019). The Spritmonitor.de sample primarily covered private cars, whereas the OBFCM data likely included a mix of corporate and private vehicles, reflecting the owner-type distribution among new registrations, with corporate cars typically representing around 60% of new registrations in Europe.

ESTIMATION OF REDUCTIONS IN REAL-WORLD CO_2 EMISSIONS OVER TIME

Due to the growing gap, reductions in type-approval CO_2 emissions since the adoption of CO_2 standards have translated into significantly smaller real-world reductions than intended by the regulations, as illustrated in Figure 9. Between 2009 and 2020, fleet-average NEDC emissions fell by 26%, whereas, at only 12%, real-world emissions declined by less than half. After the introduction of the WLTP, fleet-average official CO_2 emissions decreased by 28% from 147 g/km in 2018 to 106 g/km in 2023. Over the same period, however, real-world fleet-average emissions fell by only 15%. When ZEVs are excluded, official CO_2 emissions declined by 16% from 149 g/km in 2018 to 126 g/km in 2023, while real-world emissions decreased by 1% over the same period. The results indicate that real-world emission reductions between 2020 and 2023 resulted from the deployment of BEVs rather than efficiency improvements in vehicles with combustion engines. Between these years, average real-world emissions excluding ZEVs actually increased by 2%.

Figure 9

Fleet-average type-approval CO_2 emissions compared with estimated real-world emissions



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION **THEICCT.ORG**

CONCLUSIONS AND POLICY RECOMMENDATIONS

Although WLTP type-approval CO_2 values are more representative of real-world values than those determined under the previous NEDC procedure, our analysis indicates that a substantial and growing discrepancy remains. Drawing on EEA OBFCM data representing about 30% of PCs registered in the EU between 2021 and 2023 (excluding ZEVs), we found a slowly increasing gap between real-world and official CO_2 emissions for ICEVs, including HEVs and MHEVs: real-world emissions exceeded official values by 18% in registration year 2021, rising to 19% in 2023. For PHEVs, the gap was substantially larger and faster growing—with real-world emissions 265% higher than official values in 2021, rising to 401% higher in 2023. The analysis of the Spritmonitor.de dataset, which included only ICEVs, HEVs, and MHEVs registered in Germany, produced gap estimates that were lower by approximately 5–7 percentage points but revealed a similar relative increase over the 2021–2023 period.

As a result of the gap, reported reductions in official CO_2 emissions have not translated into equivalent reductions in real-world emissions. Following the introduction of the WLTP, official fleet-average CO_2 emissions declined from 147 g/km in 2018 to 106 g/km in 2023, a 28% reduction. Over the same period, however, real-world fleet-average emissions fell by only 15% and only due to the increasing share of BEV registrations. Without BEVs, real-world emissions would have decreased by just 1%, underscoring the critical role these vehicles play in achieving decarbonization targets.

These findings highlight the need for policy responses to achieve greater real-world CO_2 emission reductions from combustion vehicles, including for PHEVs. Based on our findings, we offer the following policy recommendations:

Reviewing the PHEV utility factor[5] curve regularly: The substantial and growing PHEV gap documented in this study largely reflects an overestimation of the real-world electric driving share in the type-approval procedure. The type-approval test procedure regulation calls for implementing a utility factor adjustment for PHEVs in 2027. Regular review and updating of the utility factor curve to reflect real-world PHEV usage could help ensure that type-approval values remain representative over time.

Implementing a correction mechanism to prevent further growth of the emissions gap: Under the current CO_2 standards, by 2026, the European Commission is tasked with publishing a methodology for a mechanism that adjusts manufacturer CO_2 targets using real-world data from 2030 onward, along with an assessment of that mechanism's feasibility. The Commission could implement a correction mechanism to ensure that the CO_2 reductions intended by the regulator translate into real-world emission reductions. Such a mechanism would proportionally lower manufacturers' CO_2 targets in future years to compensate for excess emissions resulting from a growing gap. The availability of OBFCM data could allow this correction mechanism to take effect as early as 2027, rather than from 2030 onward as currently foreseen under the CO_2 standards. A detailed proposal for a correction mechanism is outlined in Dornoff et al. (2024).

Requiring OBFCM data collection for all Euro 7 BEVs: BEVs are currently exempt from OBFCM reporting requirements during the first stage of Euro 7. OBFCM reporting requirements could be extended to all Euro 7 BEVs from November 29, 2026. The on-board technology to determine the energy consumption of electric powertrains exists, as evidenced by the energy consumption data reported for PHEVs, and earlier data collection would yield important insights into representative real-world electric range and driving costs.

---

[5] The share of the distance a vehicle is estimated to travel in charge-depleting (CD) mode is expressed by the utility factor, which is determined at type approval from a utility factor curve and depends on the range in CD mode.

REFERENCES

Commission Regulation (EU) 2017/1151 of 1 June 2017 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) No 1230/2012 and repealing Commission Regulation (EC) No 692/2008, OJ L 175, 1–643 (2017). http://data.europa.eu/eli/reg/2017/1151/oj

Commission Implementing Regulation (EU) 2021/392 of 4 March 2021 on the monitoring and reporting of data relating to CO_2 emissions from passenger cars and light commercial vehicles pursuant to Regulation (EU) 2019/631 of the European Parliament and of the Council and repealing Commission Implementing Regulations (EU) No 1014/2010, (EU) No 293/2012, (EU) 2017/1152 and (EU) 2017/1153 (Text with EEA relevance), OJ L 77/8, 8–25 (2021). http://data.europa.eu/eli/reg_impl/2021/392/oj

Commission Implementing Regulation (EU) 2025/1707 of 25 July 2025 laying down rules for the application of Regulation (EU) 2024/1257 of the European Parliament and of the Council as regards specific methods, requirements and tests, including compliance thresholds, for OBFCM devices and OBM systems, characteristics and performance of driver warning systems and inducement methods and methods to assess their operation, EVP format and data and methods of communication of EVP data of motor vehicles of categories M1 and N1, OJ L 2025/1707, 5.9.2025. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32025R1707&qid=1779183123317

Commission Staff Working Document accompanying the document Report from the Commission, Commission report under Article 12(3) of Regulation (EU) 2019/631 on the evolution of the real-world CO_2 emissions gap for passenger cars and light commercial vehicles and containing the anonymised and aggregated real-world datasets referred to in Article 12 of Commission Implementing Regulation (EU) 2021/392, COM (2024) 122(final) (March 18, 2024). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52024SC0059

Díaz, S., Tietge, U., Dornoff, J., & Mock, P. (2025). *CO_2 emissions from new passenger cars in Europe: Car manufacturers' performance in 2024*. International Council on Clean Transportation. https://theicct.org/publication/co2-emissions-from-new-passenger-cars-in-europe-car-manufacturers-performance-in-2024-dec25/

Dornoff, J. (2023). *CO_2 emission standards for new passenger cars and vans in the European Union*. International Council on Clean Transportation. https://theicct.org/publication/eu-co2-standards-cars-vans-may23/

Dornoff, J., Baldino, C., Díaz, S., Mulholland, E., Negri, M., & Vega Gonzalo, M. (2025). *Unwrapping the package: A review of the European Commission's CO_2 standards proposal*. International Council on Clean Transportation. https://theicct.org/publication/european-commissions-risks-and-opportunities-of-the-proposed-co2-standards-dec25/

Dornoff, J., German, J., Deo, A., & Dimaratos, A. (2022). *Mild-hybrid vehicles: A near term technology trend for CO_2 emissions reduction.* International Council on Clean Transportation. https://theicct.org/publication/mild-hybrid-emissions-jul22/

Dornoff, J., Morales, V. V., & Tietge, U. (2024). *On the way to "real world" CO_2 values? The European passenger car market after 5 years of WLTP.* International Council on Clean Transportation. https://theicct.org/publication/real-world-co2-emission-values-vehicles-europe-jan24/

Dornoff, J., Tietge, U., & Mock, P. (2020). *On the way to "real-world" CO_2 values: The European passenger car market in its first year after introducing the WLTP*. International Council on Clean Transportation. https://theicct.org/publication/on-the-way-to-real-world-co2-values-the-european-passenger-car-market-in-its-first-year-after-introducing-the-wltp/

Ecke, L., Magdolen, M., Chlond, B., & Vortisch, P. (2021). Tracing the effects of the Covid-19 pandemic on car usage in Germany—An analysis of the German Mobility Panel. *European Journal of Transport and Infrastructure Research*, *21*(3), 64–81. https://doi.org/10.18757/ejtir.2021.21.3.5467

European Environment Agency. (n.d.). *Real-world CO_2 emissions from new cars and vans* [Data]. Retrieved November 2, 2025, from https://climate-energy.eea.europa.eu/topics/transport/real-world-emissions/data

European Environment Agency. (2024, November 14). *Real-world monitoring—2024 reported data*: *Expert group meeting - CO_2 from road vehicles*. CIRCABC. https://circabc.europa.eu/ui/group/4cf23472-88e0-4a52-9dfb-544e8c4c7631/library/09779f26-940a-420f-857e-985b6ca62ad9/details

European Environment Agency. (2025, November 6). *Greenhouse gas emissions from transport in Europe*. https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-transport

European Environment Agency. (2026, January 6). *Monitoring of CO_2 emissions from passenger cars Regulation (EU) 2019/631* [Datasets]. https://www.eea.europa.eu/en/datahub/datahubitem-view/fa8b1229-3db6-495d-b18e-9c9b3267c02b

Navas Gohlke, S., & Gimbert, Y. (2025, October). *Smoke screen: The growing PHEV emissions scandal*. Transport & Environment. https://www.transportenvironment.org/articles/smoke-screen-the-growing-phev-emissions-scandal

Mock, P. (2013). *World-Harmonized Light-Duty Vehicles Test Procedure*. International Council on Clean Transportation. https://theicct.org/publication/world-harmonized-light-duty-vehicles-test-procedure/

Mock, P. (2019). *CO_2 emission standards for passenger cars and light-commercial vehicles in the European Union*. International Council on Clean Transportation. https://theicct.org/publication/co2-emission-standards-for-passenger-cars-and-light-commercial-vehicles-in-the-european-union/

Mock, P., German, J., Bandivadekar, A., & Riemersma, I. (2012). *Discrepancies between type-approval and real-world fuel consumption and CO_2 values in 2001–2011 European passenger cars*. International Council on Clean Transportation. https://theicct.org/publication/discrepancies-between-type-approval-and-real-world-fuel-consumption-and-co2-values-in-2001-2011-european-passenger-cars/

Mock, P., German, J., Bandivadekar, A., Riemersma, I., Ligterink, N., & Lambrecht, U. (2013). *From laboratory to road – A comparison of official and "real-world" fuel consumption and CO_2 values for cars in European and the United States*. International Council on Clean Transportation. https://theicct.org/publication/from-laboratory-to-road/

Mock, P., Kühlwein, J., Tietge, U., Franco, V., Bandivadekar, A., & German, J. (2014). *The WLTP: How a new test procedure for cars will affect fuel consumption values in the EU*. International Council on Clean Transportation. https://theicct.org/publication/the-wltp-how-a-new-test-procedure-for-cars-will-affect-fuel-consumption-values-in-the-eu/

Mock, P., Tietge, U., Franco, V., German, J., Bandivadekar, A., Ligterink, N., Lambrecht, U., & Riemersma, I. (2014). *From laboratory to road: A 2014 update of official and "real-world" fuel consumption and CO_2 values for passenger cars in Europe*. https://theicct.org/publication/from-laboratory-to-road-a-2014-update/

Pavlovic, J., Ciuffo, B., Fontaras, G., Valverde, V., & Marotta, A. (2018). How much difference in type-approval CO_2 emissions from passenger cars in Europe can be expected from changing to the new test procedure (NEDC vs. WLTP)? *Transportation Research Part A: Policy and Practice*, *111*, 136–147. https://doi.org/10.1016/j.tra.2018.02.002

Plötz, P., Gnann, T., Kasten, P., Steinbach, I., & Jöhrens, J. (2026). *Regulatory adjustments for plug-in hybrid vehicles in Europe*: *Report on the Project Scientific Support for Climate Policy and Action Program (14-BE-2203)*. Frauenhofer Institute for Systems and Innovation Research; Öko-Institut; Prognos AG Berlin; Institute for Energy and Environmental Research; IREES; Society for Economic Structural Research. https://publica.fraunhofer.de/entities/publication/ec906d31-8cf0-4cc8-a68a-283a0fd8912d

Plötz, P., Link, S., Ringelschwendner, H., Keller, M., Moll, C., Bieker, G., Dornoff, J., & Mock, P. (2022). *Real-world usage of plug-in hybrid vehicles in Europe: A 2022 update on fuel consumption, electric driving, and CO_2 emissions*. International Council on Clean Transportation. https://theicct.org/publication/real-world-phev-use-jun22/

Plötz, P., Moll, C., Li, Y., Bieker, G., & Mock, P. (2020). *Real-world usage of plug-in hybrid electric vehicles: Fuel consumption, electric driving, and CO_2 emissions*. https://theicct.org/publication/real-world-usage-of-plug-in-hybrid-electric-vehicles-fuel-consumption-electric-driving-and-co2-emissions/

Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles (Text with EEA relevance), OJ L 140, 1–15. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009R0443&qid=1779180980473

Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO_2 emissions from light-duty vehicles, OJ L 145/1, 1–18 (2011). http://data.europa.eu/eli/reg/2011/510/oj

Regulation (EU) 2023/851 of the European Parliament and of the Council of 19 April 2023 amending Regulation (EU) 2019/631 as regards strengthening the CO_2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition, OJ L 110/5, 5–20 (2023). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R0851&qid=1779180746772

Suarez, J., Tansini, A., Ktistakis, M. A., Marin, A. L., Komnos, D., Pavlovic, J., & Fontaras, G. (2025, October 25). Towards zero CO_2 emissions: Insights from EU vehicle on-board data. *Science of The Total Environment*, *1001*, Article 180454. https://doi.org/10.1016/j.scitotenv.2025.180454

Tietge, U., Díaz, S., Mock, P., Bandivadekar, A., Dornoff, J., & Ligterink, N. (2019). *From laboratory to road: A 2018 update of official and "real-world" fuel consumption and CO_2 values for passenger cars in Europe*. International Council on Clean Transportation. https://www.theicct.org/publications/laboratory-road-2018-update

Tietge, U., Díaz, S., Mock, P., German, J., Bandivadekar, A., & Ligterink, N. (2016). *From laboratory to road: A 2016 update of official and “real-world” fuel consumption and* CO_2 *values for passenger cars in Europe*. International Council on Clean Transportation. https://theicct.org/publication/from-laboratory-to-road-a-2016-update/

Tietge, U., Mock, P., German, J., Bandivadekar, A., & Ligterink, N. (2017). *From laboratory to road: A 2017 update of official and “real-world” fuel consumption and* CO_2 *values for passenger cars in Europe*. International Council on Clean Transportation. http://theicct.org/publications/laboratory-road-2017-update

Tietge, U., Zacharof, N., Mock, P., Franco, V., German, J., Bandivadekar, A., Ligterink, N., & Lambrecht, U. (2015). *From laboratory to road—A 2015 update of official and “real-world” fuel consumption and* CO_2 *values for passenger cars in Europe*. International Council on Clean Transportation. https://theicct.org/publication/from-laboratory-to-road-a-2015-update/

Vallée, J., Ecke, L., Chlond, B., & Vortisch, P. (2022, October 31). *Deutsches Mobilitätspanel (MOP) – Wissenschaftliche Begleitung und Auswertungen Bericht 2021/2022: Alltagsmobilität und Fahrleistung* [German mobility panel – scientific support and evaluation report 2021/2022: Everyday mobility and driving performance]. Bundesministerium für Verkehr und digitale Infrastruktur (BMVI). https://doi.org/10.5445/IR/1000154338

Wappelhorst, S., Morrison, K., Díaz, S., Plummer, A., Ehmsen, S., & Monteforte, M. (2024). *Monitor 2024: Elektromobilität und soziale Teilhabe – ein statistisches Porträt des Pkw-Markts in Deutschland aus sozialer Sicht* [Monitor 2024: Electric mobility and social participation – A statistical portrait of the passenger vehicle market in Germany from a social perspective]. International Council on Clean Transportation. https://theicct.org/publication/soziale-teilhabe-im-ubergang-von-verbrenner-zu-elektro-pkw-monitor-dec24/

APPENDIX

Table A1 and Table A2 compare OBFCM samples with EEA registration data for the largest 19 makes per vehicle registration year. The p-values represent one-sample t-tests that compared average WLTP CO_2 emissions of the weighted OBFCM sample with those of the fleet for each registration year and make.[6] The t-tests indicated statistically significant differences ($p < 0.05$) between the sample and population means for the majority of the make-year combinations. However, despite their statistical significance, the magnitude of these differences was generally small: in 82% of cases for ICEVs and 90% of cases for PHEVs, the difference between the sample and population mean lies within ±1 g/km. This suggests that while minor variations are statistically significant due to large sample sizes, their practical significance is negligible.

---

[6] A one-sample t-test is an inferential statistical test used to determine whether the mean of a sample differs significantly from the population mean. It tests a null hypothesis that the two means are equal and helps to decide whether observed differences are likely due to chance (the null hypothesis cannot be rejected) or are statistically significant (the null hypothesis can be rejected). The test yields a p-value, which indicates the probability of obtaining test results at least as extreme as the result actually observed, under the assumption that the null hypothesis is correct. A large p-value (typically greater than 0.05) suggest that the null hypothesis cannot be rejected.

Table A1

Comparison of ICEV OBFCM samples and registration data at the make and registration-year levels

Make	Registration year	Population	N	Coverage	M	SD	p	M - µ
Audi	2021	349,946	142,646	41%	154	32	<0.001	0
Audi	2022	363,310	107,320	30%	157	35	0.001	0
Audi	2023	441,603	32,631	7%	157	34	<0.001	0
BMW	2021	396,361	268,702	68%	152	28	<0.001	-1
BMW	2022	337,213	148,214	44%	155	29	0.704	0
BMW	2023	380,142	36	0%	152	34	<0.001	-2
Citroën	2021	398,807	82,276	21%	127	12	<0.001	0
Citroën	2022	308,121	37,387	12%	127	11	<0.001	0
Citroën	2023	297,089	4,605	2%	129	9	<0.001	0
Dacia	2021	363,016	139,267	38%	132	9	<0.001	5
Dacia	2022	399,750	91,350	23%	132	9	<0.001	5
Dacia	2023	469,557	133,107	28%	130	10	<0.001	6
Fiat	2021	346,712	165,273	48%	124	16	<0.001	-1
Fiat	2022	283,833	103,444	36%	116	15	<0.001	0
Fiat	2023	272,458	13,067	5%	114	12	<0.001	0
Ford	2021	362,395	210,518	58%	138	28	<0.001	0
Ford	2022	336,698	166,372	49%	138	28	<0.001	1
Ford	2023	329,419	86,060	26%	138	30	<0.001	2
Hyundai	2021	354,856	18,429	5%	131	16	<0.001	-1
Hyundai	2022	331,062	5,605	2%	132	16	0.002	0
Hyundai	2023	355,029	38	0%	133	19	<0.001	1
Kia	2021	316,738	48,398	15%	133	19	<0.001	-1
Kia	2022	321,140	47,356	15%	132	14	<0.001	0
Kia	2023	343,650	8,666	3%	131	15	<0.001	0
Mercedes	2021	347,501	277,891	80%	169	41	<0.001	0
Mercedes	2022	352,518	208,063	59%	168	44	<0.001	-1
Mercedes	2023	384,409	142,262	37%	166	46	<0.001	-1
Nissan	2021	153,614	37,226	24%	141	11	<0.001	-1
Nissan	2022	138,490	24,273	18%	139	11	<0.001	0
Nissan	2023	182,674	9,079	5%	134	14	<0.001	0
Opel/Vauxhall	2021	351,113	45,538	13%	128	14	<0.001	0
Opel/Vauxhall	2022	281,895	26,689	10%	127	14	0.033	0
Opel/Vauxhall	2023	283,380	4,397	2%	126	11	<0.001	0
Peugeot	2021	581,159	141,698	24%	127	13	<0.001	0
Peugeot	2022	473,415	78,394	17%	126	12	0.285	0
Peugeot	2023	470,637	10,737	2%	129	11	<0.001	0
Renault	2021	537,803	291,025	54%	125	16	<0.001	0
Renault	2022	459,165	311,911	68%	124	18	<0.001	1
Renault	2023	580,593	344,467	59%	122	19	<0.001	0
SEAT	2021	252,982	86,586	34%	133	15	<0.001	0
SEAT	2022	176,425	48,928	28%	133	17	<0.001	-1
SEAT	2023	202,437	15,955	8%	131	15	0.18	0
Suzuki	2021	167,527	40,603	24%	121	11	<0.001	0
Suzuki	2022	109,372	18,239	17%	122	10	0.101	0
Suzuki	2023	155,685	7,012	5%	120	8	0.73	0
Toyota	2021	581,628	224,547	39%	115	23	<0.001	-1
Toyota	2022	637,159	198,362	31%	115	25	0.039	0
Toyota	2023	678,897	51,814	8%	113	22	<0.001	0
VW	2021	891,989	489,912	55%	143	23	0.004	0
VW	2022	841,238	324,001	39%	142	23	0.383	0
VW	2023	940,398	67,027	7%	140	21	<0.001	0
Volvo	2021	123,861	92,662	75%	164	9	<0.001	0
Volvo	2022	86,426	58,862	68%	163	12	<0.001	-1
Volvo	2023	89,809	16,797	19%	162	11	<0.001	-1
Škoda	2021	441,095	198,818	45%	134	16	<0.001	0
Škoda	2022	412,895	156,863	38%	135	18	<0.001	1
Škoda	2023	509,664	38,296	8%	134	18	<0.001	0

Note: N = number of OBFCM vehicles; M = average OBFCM WLTP CO_2 emissions (g/km); SD = standard deviation of OBFCM CO_2 emissions (g/km); p = p-value; M - µ = difference between OBFCM and fleet-average WLTP CO_2 emissions (g/km).

Table A2

Comparison of PHEV OBFCM samples and registration data at the make and registration-year levels

Make	Registration year	Population	N	Coverage	M	SD	p	M - µ
Audi	2021	68,199	17,512	26%	38	11	<0.001	-1
Audi	2022	54,963	10,699	20%	36	8	0.005	0
Audi	2023	59,170	3,609	6%	37	8	<0.001	-4
BMW	2021	110,105	68,174	62%	38	6	0.145	0
BMW	2022	107,941	39,474	37%	37	8	0.972	0
BMW	2023	101,381	5	0%	19	5	<0.001	-12
Citroën	2021	14,503	5,190	36%	32	0	0.836	0
Citroën	2022	19,259	4,852	25%	31	1	0.489	0
Citroën	2023	18,839	714	4%	30	2	<0.001	0
Fiat	2023	4	2	50%	65	0	N/A	0
Ford	2021	45,040	29,596	66%	36	14	<0.001	0
Ford	2022	49,471	32,764	66%	26	10	0.001	0
Ford	2023	43,454	14,278	33%	24	8	0.22	0
Hyundai	2021	24,888	696	3%	31	3	<0.001	0
Hyundai	2022	33,135	194	1%	31	2	<0.001	0
Kia	2021	47,889	4,990	10%	33	4	0.016	0
Kia	2022	58,702	7,480	13%	29	6	0.878	0
Kia	2023	48,428	991	2%	28	6	0.996	0
Mercedes	2021	135,613	122,471	90%	34	12	<0.001	0
Mercedes	2022	126,200	65,708	52%	30	14	<0.001	-1
Mercedes	2023	120,662	45,525	38%	22	18	<0.001	-1
Opel/Vauxhall	2021	10,458	4,617	44%	31	1	<0.001	0
Opel/Vauxhall	2022	13,513	3,795	28%	28	3	0.335	0
Opel/Vauxhall	2023	16,349	431	3%	26	2	0.281	0
Peugeot	2021	48,333	23,706	49%	31	3	0.942	0
Peugeot	2022	44,809	13,722	31%	30	3	0.447	0
Peugeot	2023	46,699	1,630	4%	27	3	<0.001	0
Renault	2021	35,282	28,065	80%	32	2	0.962	0
Renault	2022	15,250	14,103	93%	30	1	0.164	0
Renault	2023	8,180	6,786	83%	30	1	1	0
SEAT	2021	17,065	9,089	53%	31	7	0.781	0
SEAT	2022	2,940	637	22%	34	8	0.091	0
SEAT	2023	5,356	545	10%	32	5	0.663	0
Suzuki	2021	1,951	415	21%	22	0	N/A	0
Suzuki	2022	2,338	336	14%	22	0	N/A	0
Suzuki	2023	2,417	55	2%	22	0	N/A	0
Toyota	2021	21,734	7,884	36%	22	1	0.002	0
Toyota	2022	16,565	6,030	36%	22	1	0.911	0
Toyota	2023	15,845	1,809	11%	21	2	0.532	0
VW	2021	59,159	20,675	35%	32	10	<0.001	-1
VW	2022	50,059	10,645	21%	32	8	<0.001	-2
VW	2023	36,809	4,696	13%	35	7	<0.001	-2
Volvo	2021	94,047	78,686	84%	52	8	<0.001	0
Volvo	2022	74,554	62,609	84%	34	18	0.284	0
Volvo	2023	79,760	18,796	24%	30	11	0.849	0
Škoda	2021	27,222	14,168	52%	26	3	<0.001	0
Škoda	2022	14,461	6,208	43%	26	4	0.535	0
Škoda	2023	14,952	914	6%	26	3	0.003	0

Note: N = number of OBFCM vehicles; M = average OBFCM WLTP CO$_2$ emissions (g/km); SD = standard deviation of OBFCM CO$_2$ emissions (g/km); p = p-value; M - µ = difference between OBFCM and fleet-average WLTP CO$_2$ emissions (g/km).

www.theicct.org

communications@theicct.org

@theicct.org

THE INTERNATIONAL COUNCIL
ON CLEAN TRANSPORTATION

BEIJING | BERLIN | NEW DELHI | SAN FRANCISCO | SÃO PAULO | WASHINGTON DC