Methods of converting the type-approval CO_2 emission values of light vehicles for Australia's New Vehicle Efficiency Standard

Prepared by The International Council on Clean Transportation

1 Introduction

Australia's measurement of fuel consumption and emissions of light-duty vehicles (LDVs) has been based on the New European Driving Cycle (NEDC; Australian Government, 2021). Regulatory agencies use these values to determine compliance with emission standards and to show fuel consumption and carbon dioxide (CO_2) emission values on the fuel consumption label mandated by Australian Design Rule (ADR) 81/02.

In April 2024, Australia's Minister for Infrastructure, Transport, Regional Development, and Local Government adopted Australian Design Rule (ADR) 79/05, mandating Euro 6d-equivalent emission standards for newly approved light vehicle models imported from December 2025 and all new vehicles imported from July 2028 (Australian Government, 2024b).[1] To comply with ADR 79/05, vehicles must be tested in accordance with either the 4-phase Worldwide harmonized Light vehicle Test Procedure (4p-WLTP), the 3-phase WLTP (3p-WLTP), or the U.S. 2-cycle test procedures.

As existing vehicle models may continue to comply with NEDC testing requirements until July 2028, Australia's New Vehicle Efficiency Standard (NVES), which commenced on January 1, 2025, defines LDV CO_2 targets for 2025–2029 based on the NEDC (Australian Government, 2024a). To enable newly approved vehicle models tested to the stricter standards mandated by ADR 79/05 comply with the NVES, the government advised it would develop a conversion procedure to enable an NEDC equivalent CO_2 value to be calculated for these vehicles. With this conversion procedure, new models complying with ADR 79/05 under the WLTP or U.S. standards would not require physical vehicle testing to the NEDC to comply with the NVES.

The Department of Infrastructure, Transport, Regional Development, Communications and the Arts engaged the International Council on Clean Transportation (ICCT) in December 2024 to develop a detailed methodology for the conversion of official type-approval CO_2 emissions between regulatory test cycles. The methodology will be used to convert the CO_2 emission values of vehicles type-approved under the 4-phase and 3-phase WLTP and the U.S. 2-cycle test to the equivalent g CO_2/km emissions under the NEDC. Due to the inherent uncertainty in such calculations, manufacturers of vehicle models complying with ADR 79/05 will still be able to comply with the NVES by performing physical vehicle testing if preferred.

[1] Light vehicles covered under ADR 79/05 are defined as passenger vehicles and light commercial vehicles up to 3,500 kg of gross weight.

This report develops a series of conversion factors that Australia can adopt to determine compliance with the NVES for light vehicles on an NEDC CO_2-equivalent basis. The report is organized as follows. Section 2 provides an overview of the selected test cycles and cycle conversion methodologies. Section 3 analyzes the current Australian light-duty vehicle market by vehicle category, fuel and powertrain type, and brand, and assesses trends in CO_2 emissions. Section 4 describes the methods and data used for developing the conversion protocol. Section 5 summarizes the final sets of cycle conversion algorithms and examines the robustness of the conversion algorithms through verification exercises.

2 Overview of test cycles and conversion methodologies

2.1 Geographic coverage

Table 1 shows the list of countries and regions that use the WLTP or the U.S. 2-cycle type approval test procedures as of 2024 (ICCT, n.d.). These test cycles cover all major vehicle manufacturing markets that have adopted mandatory CO_2 emission regulations.[2] This includes most of the top markets from which Australia imports vehicles, including China, the European Union, Japan, South Korea, and the United States.[3]

Table 1
Test procedures used for light-duty vehicle CO_2 emissions compliance in selected countries

Test procedure	Country/region
4p-WLTP	China, European Union, Iceland, Norway, Switzerland, United Kingdom
3p-WLTP	Japan, New Zealand
U.S. 2-cycle	Brazil, Canada, Mexico, South Korea, United States

2.2 Review of selected test cycles

2.2.1 Worldwide harmonized Light vehicle Test Procedure

Under the WLTP, defined in U.N. Economic Commission for Europe (UNECE) Regulation No 154 (2021), the CO_2 emissions and fuel consumption of cars and vans are determined by performing the Worldwide harmonized Light vehicle Test Cycle (WLTC) on a chassis dynamometer. The WLTC consists of four phases—low, medium, high, and extra-high—that represent different driving conditions. China and the European Union follow the Level 1A provision of UN Regulation 154, which requires emissions testing on all four phases of the WLTC. Japan and New Zealand follow the Level 1B provision, which entails driving the first three phases (low, medium, and high).

Under the NEDC, all vehicles of the same vehicle type receive the same CO_2 emissions value for the purpose of emissions classification; under the WLTP, however, each vehicle receives a specific CO_2 emission value.[4] The WLTP CO_2 emissions value considers the vehicle's rolling resistance, aerodynamic resistance, and test mass, which under the WLTP includes not only the mass in running order (used under the NEDC) but also the mass of any optional equipment and a representable payload. To minimize the test burden, vehicles are grouped into CO_2 families and no

[2] Chile and India use the NEDC cycle for CO_2 emission standards.
[3] Top importing countries are discussed in section 3 (see Figure 9).
[4] Vehicles of the same type for the purpose of emission classification under NEDC must be in the same equivalent inertia class and have the same engine and vehicle characteristics, as defined in Regulation (EC) No 692/2008.

more than three vehicle configurations of each family are tested in the laboratory. The CO_2 emissions of all other vehicles in the family are then determined by linear interpolation between the emission values of the tested vehicles. The interpolation is based on the vehicles' cycle energy demand—that is, the mechanical energy required to drive the WLTC. The WLTC is performed at an ambient temperature of 23 °C.

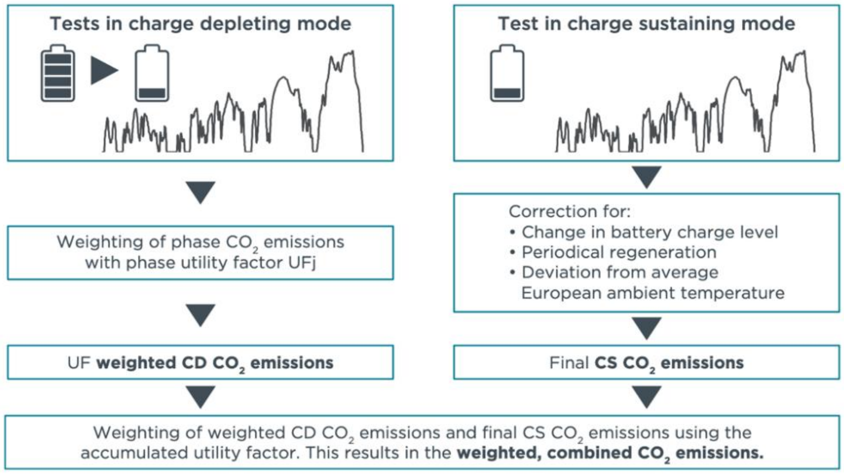
Emissions are continuously sampled during each phase of the laboratory test. Measured CO_2 emissions are corrected for changes in battery charge level and emissions during the periodic regeneration of aftertreatment devices. For Level 1A type-approvals, corrections are applied for differences in ambient temperature in addition to deviations between actual driven speed and distance and the reference values.

During the type-approval process, manufacturers declare CO_2 values for the vehicles tested. If the measured CO_2 emission value (after correction) is equal to or lower than the value declared by the manufacturer, the declared value becomes the official type-approval value. The declared value contains a margin to ensure that the CO_2 emissions of vehicles measured during conformity of production tests are below the declared value, as the vehicle would otherwise not be compliant. However, as manufacturers aim for official CO_2 emission values to be as low as possible, the declared value is usually only slightly higher than the expected measured value.

For vehicles registered in 2020, the NEDC CO_2 emissions were still used to determine manufacturer CO_2 performance, and the WLTP CO_2 values were only used to determine each manufacturer's WLTP CO_2 target in the period 2021–2024. For this purpose, the manufacturer's 2020 NEDC CO_2 target was multiplied with the ratio of average WLTP CO_2 emissions and average NEDC CO_2 emissions of all vehicles sold by the manufacturer in 2020. This meant that the higher the WLTP-to-NEDC ratio was in 2020, the higher the target value would be in the following years. Consequently, manufacturers had an incentive to declare higher WLTP values to lessen compliance burden. To counteract this potential loophole, the European Commission decided to also collect the measured WLTP CO_2 emission values. The Commission published the measured and declared WLTP values collected in 2020, aggregated by manufacturer (European Commission, 2023a). On average, the declared values exceeded the measured values by 4.8% for passenger cars and 5.1% for light commercial vehicles. This over-declaration ranged from 1% to 11% for passenger cars and from 0% to 12% for light commercial vehicles across the manufacturers. We corrected for these differences in over-declaration as explained in Section 4.

Plug-in hybrid vehicles (PHEVs), referred to as off-vehicle charging hybrid electric vehicles in the WLTP regulation (UNECE Regulation No 154, 2021), are tested in two operating modes to determine their official CO_2 emission value, as shown in Figure 1. The first test, performed in charge-depleting mode, is cold started with a fully charged battery, and consecutive WLTCs are performed until the battery is depleted. In this mode, the vehicle primarily uses the electric motor to power the vehicle, but the combustion engine can also be used; consequently, the measured CO_2 emissions are very low. The second test, in charge-sustaining mode, is a cold started WLTC performed with an empty battery. In this mode, the vehicle can operate as a conventional hybrid vehicle, with similar CO_2 emissions.

Figure 1
Determination of plug-in hybrid type-approval CO_2 emission values under the WLTP

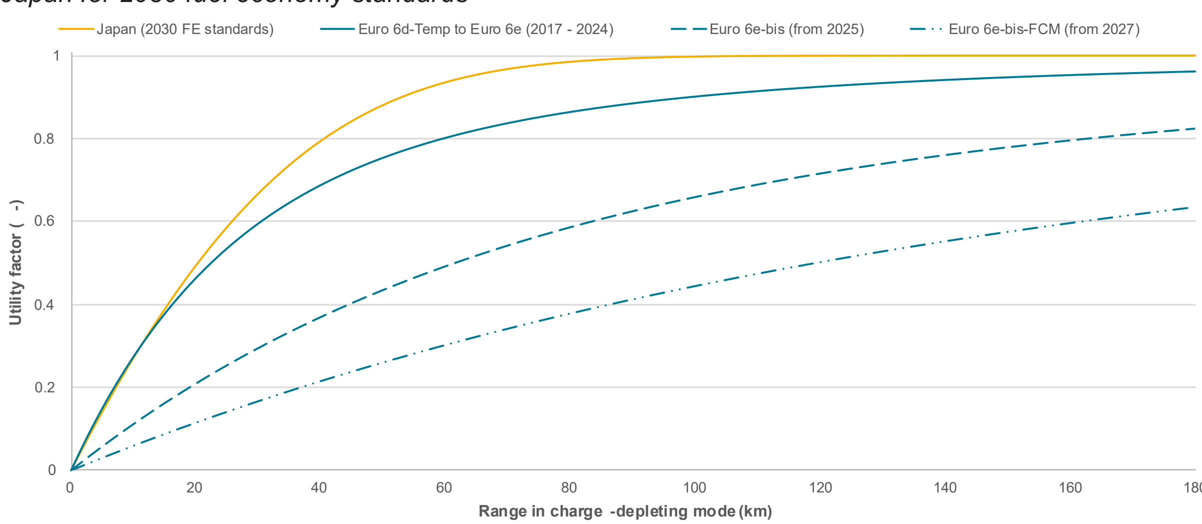


To calculate official PHEV WLTP CO_2 type-approval values ($CO_{2,type\text{-}approval,WLTP}$), the CO_2 emissions determined in charge-depleting mode ($CO_{2,charge\text{-}depleting}$) and charge-sustaining mode ($CO_{2,charge\text{-}sustaining}$) are weighted using a utility factor (UF), as shown in Equation 1.

$$CO_{2,type-approval,WLTP} = UF \cdot CO_{2,charge-depleting,WLTP} + (1 - UF) \cdot CO_{2,charge-sustaining,WLTP} \quad (1)$$

The UF ranges from 0 to 1 and describes the distance share a PHEV is expected to be operated in charge-depleting mode. The higher the UF, the longer the range that the PHEV can operate in charge-depleting mode and the lower the official PHEV CO_2 emission value. Figure 2 shows the UF curves used in the European Union for WLTP type-approval of light-duty PHEVs and the UF curve used in Japan for its 2030 fuel economy standards.

Figure 2
Utility factor curves used in the European Union for WLTP type-approval of plug-in hybrid vehicles and in Japan for 2030 fuel economy standards



Before switching to WLTP, official PHEV CO_2 emission values were calculated under the NEDC type-approval procedure using equation (2) (UNECE R 101, 2013):

$$CO_{2,type-approval,NEDC} = CO_{2,charge-sustaining,NEDC} \cdot \frac{25km}{Range_{charge-depleting} + 25km} \quad (2)$$

Where $CO_{2,charge-sustaining,NEDC}$ is g CO_2/km emissions measured in charge sustaining mode and $Range_{charge-depleting}$ is the electric range in charge depleting mode (equivalent all electric range) in kilometers.

Since the introduction of WLTP, the European Union used the same UF curve for PHEV type-approval through 2024. However, research has shown that the UF curve for the Euro 6d-Temp standards significantly overestimates the real-world driving share in charge-depleting mode and thereby underestimates the actual CO_2 emissions of PHEVs, which have been estimated to be more than 3 times higher than the type-approval values (Plötz et al., 2022; European Environment Agency, n.d.). The large gap between real-world and type-approval CO_2 emissions was found to be mainly caused by the following factors:

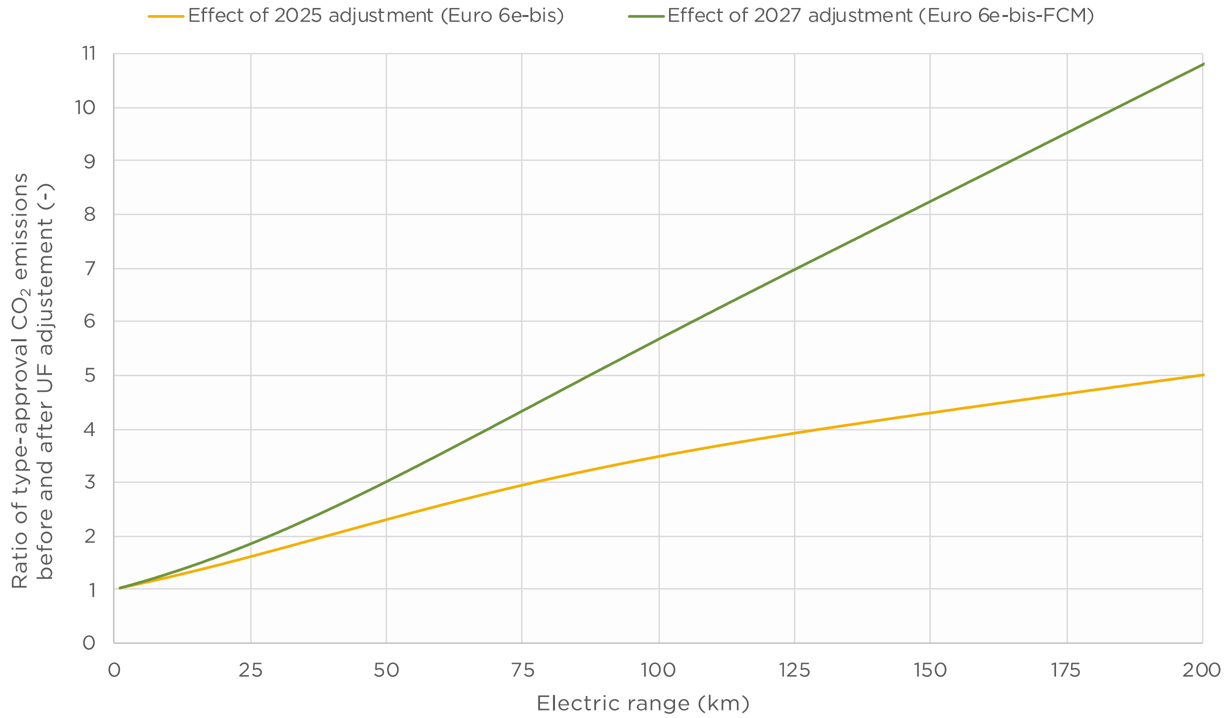
- The real-world electric range is shorter than the value measured during type-approval.
- When driving long distance trips, the electric range is exceeded, and large portions of the total distance are driven using the combustion engine.
- Vehicles are not fully charged every day, as assumed when defining the UF curve.
- As for other combustion engine vehicles, the real-world CO_2 emissions in charge-sustaining mode are higher than the type-approval values.

The effects of less charging, long distance driving, and higher fuel consumption in charge-sustaining mode have been found to be more pronounced for company cars than for privately owned vehicles. This is largely due to adverse fiscal incentives that favored PHEVs over combustion engine vehicles, even though PHEVs are not suited for many company car use cases, which are associated with frequent long-distance driving. Furthermore, company cars often come with fuel cards, which allows free refueling for both private and work purposes, and thereby disincentivizes the operation on electricity.

To obtain more representative type-approval CO_2 emissions for PHEVs, the European Commission introduced revised UF curves for cars type-approved under Euro 6e-bis emission standards and Euro 6e-bis-FCM by 2025 and 2027, respectively (Dornoff, 2022). The Euro 6e-bis-FCM curve is currently under review, considering real-world CO_2 emission data collected by the European Commission. As the introduction of Euro 7 for light-duty vehicles is now expected by the end of 2026—that is, before Euro 6e-bis-FCM would have gone into effect—the UF curve developed for Euro 6e-bis-FCM is expected to apply to Euro 7 vehicles.

Figure 3 shows the estimated effect of the adjusted UF curves on the official WLTP CO_2 emission values, depending on the range a PHEV can drive in charge-depleting mode. It shows that the same vehicle type-approved under Euro 6e-bis and Euro 6e-bis-FCM would have higher official WLTP CO_2 emission values due to the new UF curves, thereby reducing the gap between real-world and type-approval values.

Figure 3
Estimated effect of utility factor adjustment on official plug-in hybrid vehicle CO_2 emission values



2.2.2 U.S. 2-cycle

The U.S. 2-cycle tests are used to determine compliance with U.S. greenhouse gas standards and corporate average fuel economy standards (U.S. Environmental Protection Agency, 2024). The tests consist of emission measurements on two separate drive cycles: the Federal Test Procedure (FTP), referred to as the “city” test, and the Highway Fuel Economy Test (HWFET), referred to as the “highway” test.

The FTP comprises three phases (“bags”) of emission measurements (U.S. Environmental Protection Agency, 2015). Bag 1 begins with a cold start preceded by a 12- to 36-hour soak period, during which the vehicle engine is off (Exhaust emission test procedures, 2023). Bag 2 is conducted immediately after Bag 1 and is referred to as the “hot stabilized” phase. The engine is then shut off for 9–11 minutes prior to the Bag 3 test, which is referred to as the “hot start” phase. Bags 1 and 3 have identical durations and speed versus time traces, differing only in their start condition (cold or hot). The FTP emission rates are based on a weighted combination of emissions measured in each of the three bags.

The HWFET cycle represents highway driving. It consists of a hot-start test, whereby measurements start after a preconditioning cycle of the same schedule with a break of not more than 17 seconds (DieselNet, n.d.; U.S. Environmental Protection Agency, 2015). The combined 2-cycle CO_2 values are derived by weighting the emission measurements at 55% for city and 45% for highway driving.

At the time of certification, manufacturers may use the CO_2 emissions level from the ‘‘worst case’’ vehicle as a surrogate for all of the models in the test group. A test group typically includes model variants that share critical emission-related features.[5] As a condition of the certificate, this surrogate CO_2 emissions value will generally be replaced with actual, model-level CO_2 values based on results from Corporate Average Fuel Economy (CAFE) testing that occurs later in the model year.[6]

To calculate PHEV CO_2 type-approval values for compliance assessment, PHEVs are tested in both charge-depleting and charge-sustaining operation to determine CO_2 emissions in each mode and the electrical range of the vehicle. The methodology for determining the UF for PHEVs in the United States is very similar to that used in Europe, apart from differences in the test cycle and UF curve equation coefficients. The United States has two sets of utility factors: one for the FTP and one for the HWFET.

2.3 Review of test cycle conversion methods

2.3.1 CO_2MPAS

With the introduction of the WLTP in the European Union in 2017, an increasing number of new vehicles were type-approved under the WLTP instead of the NEDC. However, the regulatory CO_2 targets through 2020 remained based on the NEDC. To monitor and enforce the NEDC CO_2 targets, and to determine the NEDC-equivalent WLTP CO_2 targets for 2021 and onwards, new vehicles were required to have both a WLTP and an NEDC CO_2 type-approval value.

To avoid double testing for WLTP and NEDC CO_2 emissions, the European Commission defined a conversion procedure based on the CO_2 Model for PAssenger and commercial vehicles Simulation (CO_2MPAS), their in-house simulation tool (Regulation (EU) 2017/1152, 2017; Regulation (EU) 2017/1153, 2017). CO_2MPAS was released in 2017 and used until 2020 for determining NEDC CO_2 emission values for WLTP-tested vehicles. Its development was continued until 2023. The CO_2MPAS source code is publicly available, and its use is free of charge (European Commission, 2023b).

CO_2MPAS uses vehicle characteristics, time-series data measured during WLTP testing, and pre-calibrated vehicle component models to simulate the test vehicle. Based on the input data, CO_2MPAS identifies CO_2-relevant operating strategies like gear shifting and alternator control to optimize the model calibration and minimize the error between simulated and measured WLTP phase CO_2 emissions. Once optimized, the calibrated model is used to simulate the CO_2 emissions of the vehicle operating under NEDC type-approval conditions (Fontaras et al., 2018). The model simulates second-by-second CO_2 emission values, and, therefore, can be used to calculate the average CO_2 emissions for both the full NEDC and separately for the two NEDC phases (urban and extra-urban). To validate the modeled emissions, 10% of the simulated vehicles are randomly selected and physically tested under NEDC conditions. While CO_2MPAS predicts NEDC CO_2 emissions with a high accuracy, it also requires extensive vehicle information and time-series measurement data from the WLTP: As shown in Annex I of the correlation procedure implementing regulation, 66 parameters are required as input data for the correlation tool (Regulation (EU) 2017/1153, 2017).

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[5] The factors considered for determining test groups include combustion cycle, engine type, engine displacement, number of cylinders and cylinder arrangement, fuel type, fuel metering system, catalyst construction, and precious metal composition.
[6] CAFE testing requires manufacturers to submit laboratory test data representing at least 90% of the manufacturer's model year production, by configuration.

In principle, the CO_2MPAS methodology can also be used to convert CO_2 emissions between test procedures other than the WLTP and NEDC. This would require adjusting the model parameters to reflect the differences in the test procedure (e.g., road load parameters, tire pressure, and ambient temperature). Moreover, the calibration of CO_2MPAS sub-modules for engine and exhaust temperature prediction, gear-shifting prediction, and power losses calculation is based on CO_2-affecting technologies used in vehicles sold in the European Union. Using CO_2MPAS for vehicles type-approved elsewhere (e.g., under the U.S. 2-cycle procedure) therefore requires an extension or recalibration of some sub-modules, which in turn requires detailed test data from a large number of vehicles.

2.3.2 Statistical regression approach

Since 2007, the ICCT has contributed to developing conversion methods for CO_2 emissions between regulatory test cycles (An et al., 2007). The ICCT's methodology is based on statistical regression using g CO_2/km emissions of the same vehicles generated under different test cycles. An ICCT study published in 2014 used a simulation modeling tool developed by Ricardo, Inc (Kühlwein et al., 2014; Yang, 2014). The model, referred to as the Data Visualization Tool, predict CO_2 emissions and fuel efficiency for a mix of vehicle powertrains and advanced engine technologies on a series of test cycles, including the U.S. 2-cycle, WLTP, NEDC, and Japanese JC08. The simulation accounted for a range of existing petrol, diesel, and hybrid electric vehicle technologies and projected technologies for 2020 and later.

Using the modeled CO_2 emissions, various regression analyses requiring different levels of information on installed vehicle technologies or road load characteristics were developed and evaluated to describe the relationship for each pair of driving cycles. A "universal approach" was derived for the conversion of fleet-average CO_2 emission values between test cycles that combines linear regressions of petrol and diesel vehicles while accounting for the share of petrol and diesel vehicles in the fleet for each pair of driving cycles.

More recently, in 2021, the ICCT developed a set of conversion protocols for LDV CO_2 emissions between test cycles for the New Zealand Government to support the implementation of their CO_2 standards (Yang & Bandivadekar, 2021). The least square regression approach applied for the conversion was the same as that used for the ICCT's 2014 study to develop the best-fitting curve to the given database. However, instead of modeled CO_2 emissions, the analysis was based on the measured or reported CO_2 data available for pairs of test cycles. This included the United Kingdom's 2019 certification database, containing the WLTP type-approval CO_2 emissions values of nearly 5,500 vehicles, including emission values for each of the four WLTP phases. The conversion relations were developed to generate equivalent g CO_2/km emissions in the 3-phase WLTP (the regulatory cycle used in New Zealand) from various other test procedures, including the 4p-WLTP, NEDC, U.S. 2-cycle, JC08, and the Japanese 10–15 mode cycle. For each pair of cycles, a separate linear relation was developed, including statistically significant slope and intercept values. The relations were developed separately for petrol and diesel vehicles. The European Commission Joint Research Center also has conducted several studies exploring the relationships between reported NEDC and simulated 4p-WLTP values using the same regression approach (Tsiakmakis et al., 2017). In general, any regression relation will have inherent uncertainty. The power required to run a test cycle, and the resulting emissions, are functions of not only the test procedure itself but also of the design and propulsion characteristics of the vehicle being tested. Thus, while it is possible to derive general relations, the errors and hence, the predictive power, can vary depending on the vehicle. As with any statistical regression, the general relations will be accurate on average, as they reflect the average relation of the universe of possible relations, but there will always be some errors of prediction for a given vehicle.

3 Australian market analysis

The purpose of this analysis is to generate insights into the composition of the current Australian vehicle market, top-selling brands, and respective trends in CO_2 emissions, by vehicle type and fuel and powertrain.

3.1 Data sources and processing

This market analysis is primarily based on the database underpinning the official Australian Green Vehicle Guide (GVG; Australian Government, n.d.-a). The GVG database includes basic information on LDVs sold in Australia reported voluntarily by vehicle importers, including make, model, variant, vehicle type, fuel and powertrain type, engine displacement, and 2024 g CO_2/km emissions under the NEDC as declared by the manufacturer.

The Federal Chamber of Automotive Industries (FCAI) provided sales data for 2022–2024 that matched the vehicle make and model information in the GVG database. The total sales of LDVs in 2024 reported by FCAI covered by the merged FCAI–GVG dataset was 985,359, which accounted for 80% of the national 2024 LDV sales reported in the FCAI's VFACTS database (CarExpert, 2025).[7] Similarly, for 2022 and 2023, the total sales reported in the merged dataset represented 88% and 89%, respectively, of the actual sales reported by the National Transport Commission (NTC). Thus, the sales-weighted analyses of parameters provided in the merged data cover the majority of LDVs sold to the Australia market.

We combined the merged FCAI-GVG data with data from Blue Flag, a commercial database shared by the Australian government that includes such information as vehicle power, gross vehicle mass, and country of origin. Due to a lack of unique identifier information to link the GVG and Blue Flag databases, we merged the data based on multiple composite criteria, including make, model, and electric range for battery electric vehicles (BEVs) and make, model, engine size, fuel consumption, and CO_2 emissions for non-BEVs. The merged Blue Flag data match 85% of the 2024 LDVs sales reported in the FCAI-GVG database. This represents 68% of the 2024 sales reported in the VFACTS database. Given data limitations, we used this merged data from Blue Flag only for analyzing the country of origin, which we consider illustrative, rather than representative, of the Australian market.

The available data include most of the vehicle classes that fall under the scope of the NVES: passenger cars defined as regulatory class "MA," off-road passenger vehicles defined as class "MC," and light goods vehicles defined as class "NA" (Australian Government, 2024a, n.d.-b). Under the NVES, LDVs are categorized as either Type 1, comprising cars and light off-road passenger vehicles, or Type 2, comprising heavy off-road vehicles, light goods vehicles, and some medium goods vehicles. Type 1 vehicles have relatively more stringent g CO_2/km targets than Type 2. In this market analysis, we refer to Type 1 vehicles as passenger cars (PCs) and Type 2 vehicles as light commercial vehicles (LCVs).[8]

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[7] We further added up the 2024 sales numbers reported by the EV Council of Australia for Tesla and Polestar that were missing from the FCAI's reported volume in the GVG database. These additional BEV sales volumes–omprising 15,231 sales for Tesla and 1,449 for Polestar–slightly increased the total estimated 2024 sales, which subsequently accounted for 81% of the actual national 2024 sales volume reported in the VFACTS database.

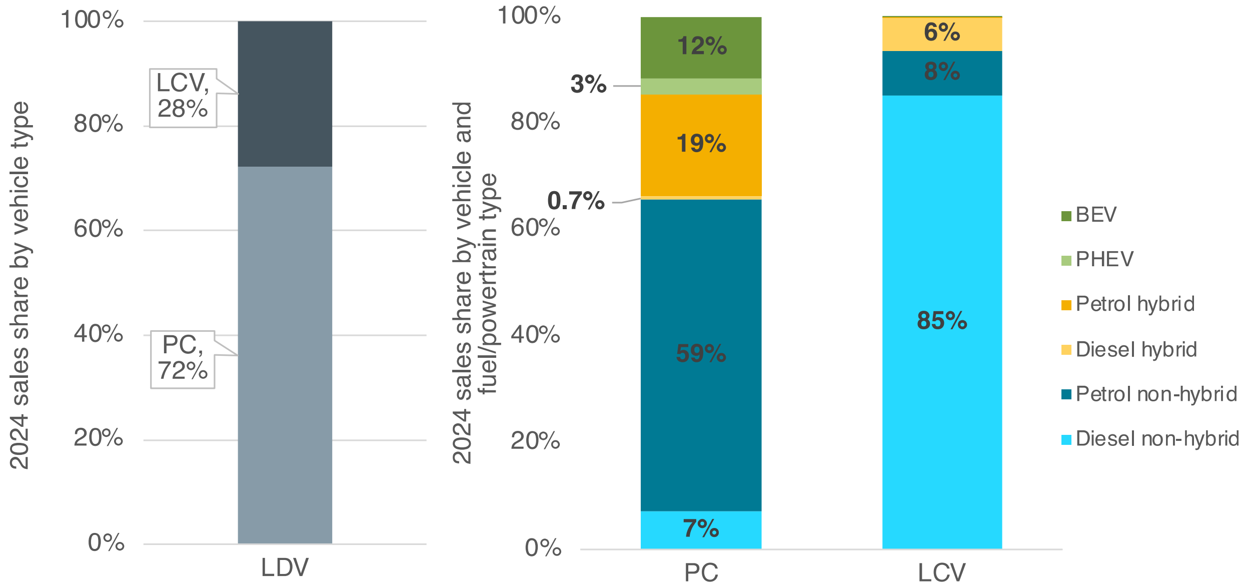
[8] The GVG database does not provide information on NB1 (medium goods) vehicles, which are classified as Type 2.

3.2 Market composition

Figure 4 shows that PCs accounted for about 72% of the 2024 LDV market. While the PC market is dominated by petrol powertrains, the LCV market is dominated by diesel vehicles, which accounted for about 91% of LCV sales. Figure 5 charts the annual growth of the PC and LCV fleet by fuel and powertrain type. From 2022 to 2024, sales of non-hybrid cars declined, while sales of less-emitting powertrains increased significantly: by 63% for petrol hybrids, nearly 200% for BEVs, and 400% for PHEVs. The LCV market, in contrast, has remained mostly unchanged since 2022 in terms of fuel and powertrain composition.

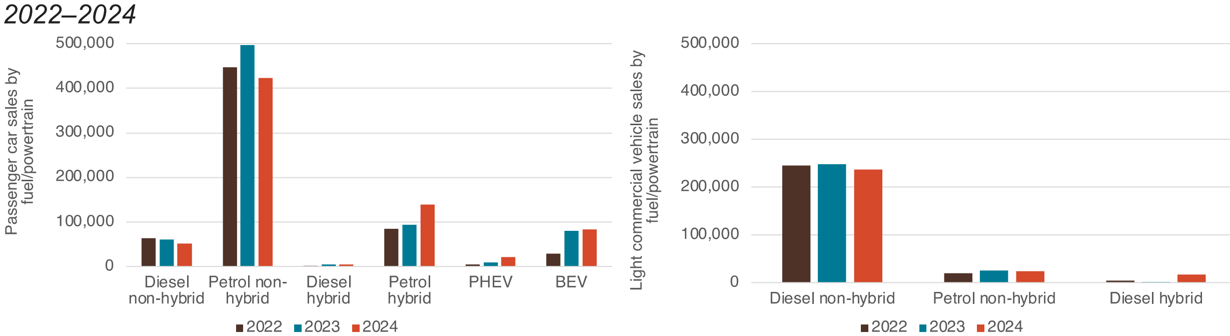
This market segmentation will inform the conversion factor development in Section 4.

Figure 4
Australian market composition by type of vehicle and fuel and powertrain in 2024



Note: Figure does not show limited shares of petrol hybrid (0.2%) and battery electric (0.03%) light commercial vehicles.

Figure 5
Annual sales growth in the passenger car and light commercial vehicle fleet by fuel and powertrain type, 2022–2024

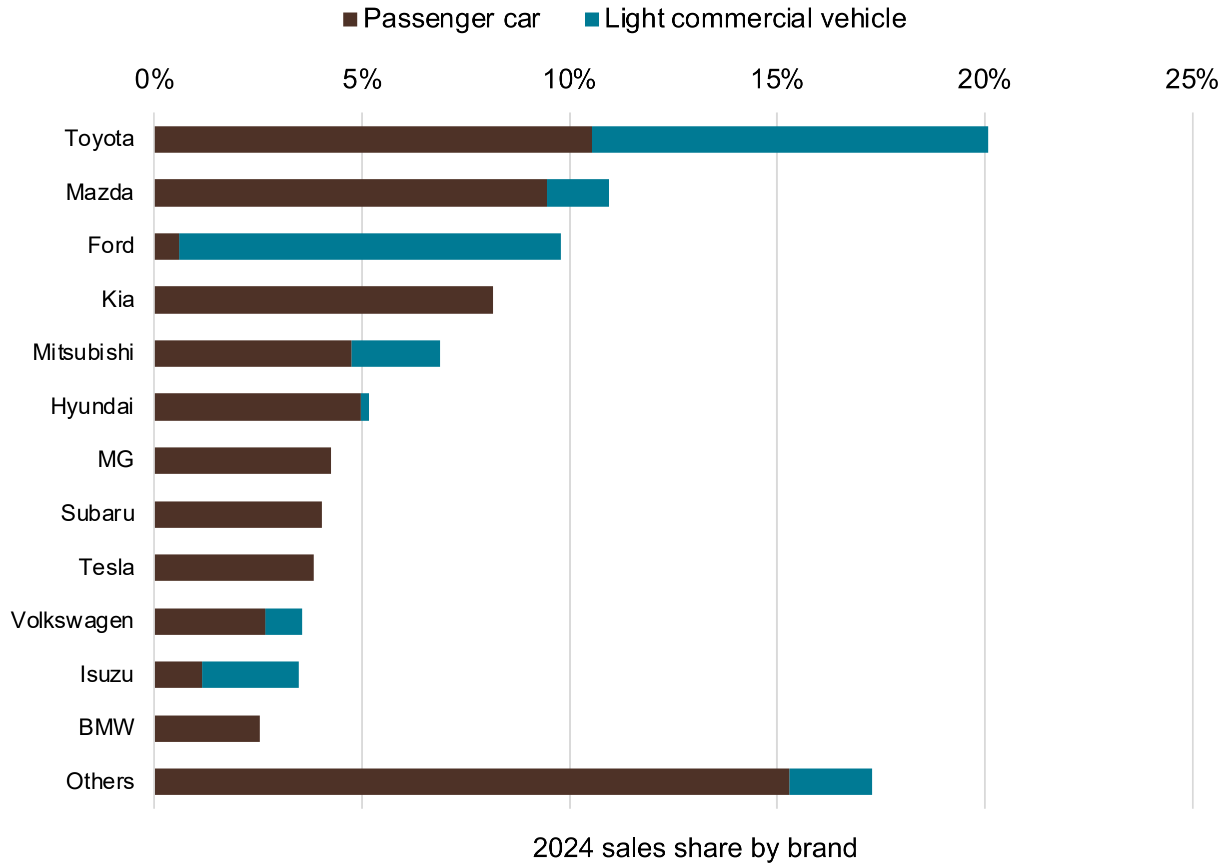


Note: Figure does not show limited sales of petrol hybrid (385 sales in 2024) and battery electric (49 sales in 2022, 18 sales in 2023, and 64 sales in 2024) light commercial vehicles.

3.3 Top-selling brands

Figure 6 reflects the 2024 LDV sales shares by brand. The top 12 brands by sales accounted for nearly 83% of the market in 2024. The most popular brand, Toyota, had more than a 20% market share in 2024, roughly equally distributed between PCs and LCVs. Mazda, Ford, Kia, Mitsubishi, and Hyundai were the other top-selling brands, each making up more than 5% of the market. Almost of all of Ford's sales in 2024 were LCVs, while PCs comprised the majority or entirety of sales for most other brands. This list of top-selling brands is considered in the brand-specific verification analysis of the proposed conversion factors in Section 5.

Figure 6
Australian light duty vehicle market share by brand in 2024



3.4 Trends in CO_2 emissions

Figure 7 shows the estimated sales-weighted average CO_2 emissions of LDVs sold in Australia in 2022–2024 by vehicle type, while Figure 8 shows the emissions for internal combustion engine (ICE) vehicles only, by vehicle and fuel type. These estimates are based on the merged FCAI-GVG data. In the absence of official CO_2 data at the model variant level for 2022 and 2023 in the GVG database, we apply the 2024 g CO_2/km values for these years.

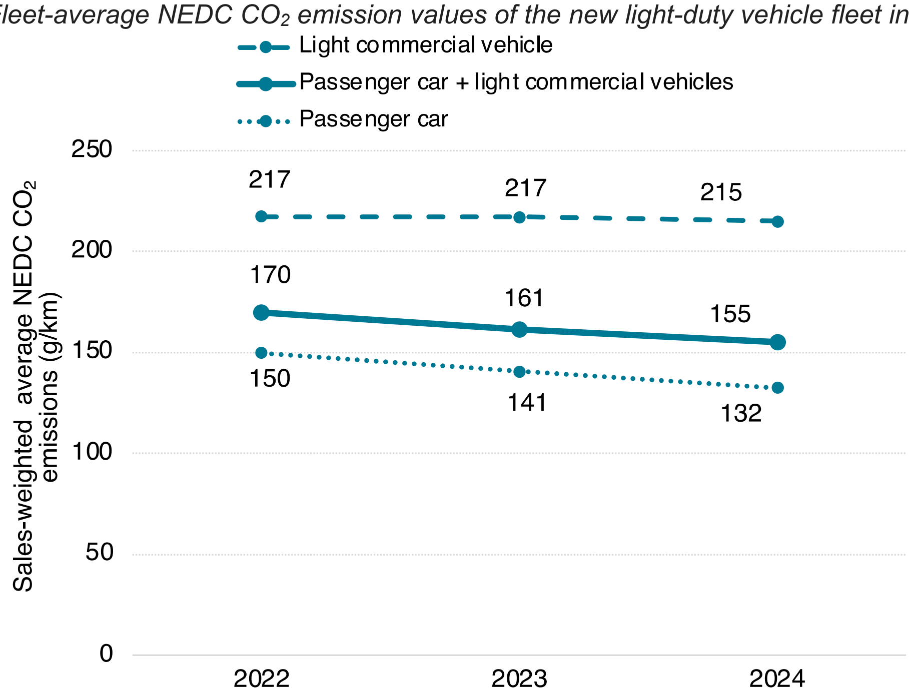
Based on the data drawn from the National Transport Commission (2024), fleet-average emissions for new sales were 174 g CO_2/km in 2022 and 165 g CO_2/km in 2023.[9] Sales-weighted emissions estimates in this analysis—170 g CO_2/km for 2022 and 161 g CO_2/km for 2023—are slightly lower than the NTC reported values, each by a margin of less than 2.5%. That the difference from the official reported data is minor, confirms that this analysis is representative of the fleet.

The fleet-average CO_2 emissions of LDVs decreased from 170 g/km in 2022 to 155 g/km in 2024. This reduction was largely underpinned by a decline in PC fleet CO_2 emissions of nearly 12% over this period, from 150 g/km to 132 g/km. CO_2 emissions from the ICE PC fleet only slightly decreased by 3% over the three years, from 158 g/km to 153 g/km. This modest emissions reduction in ICE PCs happens despite the substantial increase in petrol hybrid vehicle sales, as shown in Figure 5. Further, reduction in fleet-average emissions can be attributed to the growth of BEV and PHEV sales.

In contrast, fleet-average emissions from the LCV fleet remained mostly flat over the years with a 1% reduction from 217 g/km in 2022 to 215 g/km in 2024. In 2024, fleet-average emissions for LCVs were 62% higher than for PCs. Due to low electric vehicle uptake for the segment as shown in Figures 4 and 5, the fleet-average LCV emissions are mainly attributable to the ICE vehicle and LCV emissions, with the same numerical emission values (in whole numbers) over the years.

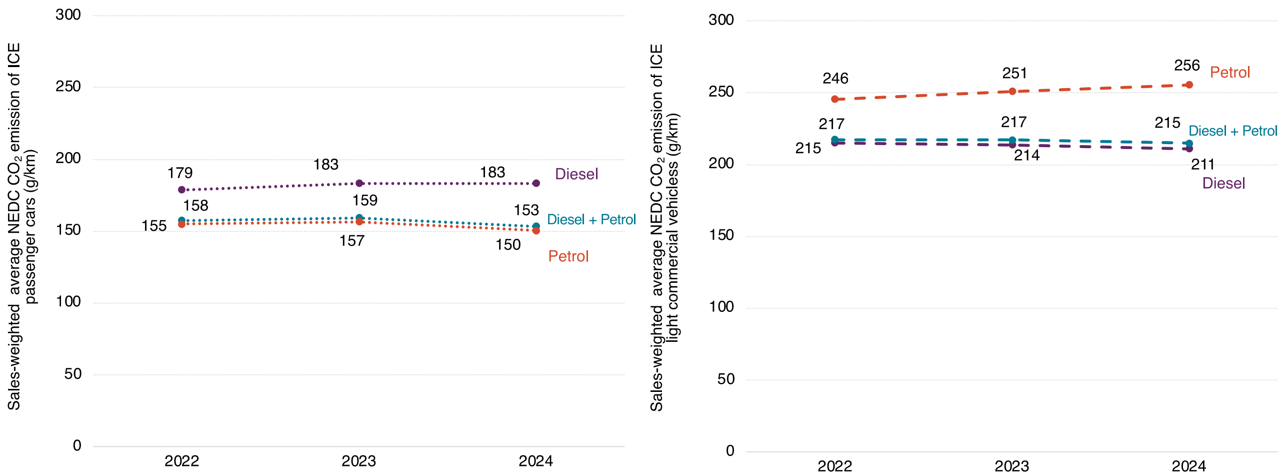
The difference in vehicle CO_2 performance by vehicle type will inform the conversion factor development in Section 4.

Figure 7
Fleet-average NEDC CO_2 emission values of the new light-duty vehicle fleet in Australia, by vehicle type



[9] Inclusive of the various technology credits adopted in the FCAI voluntary standard in 2020.

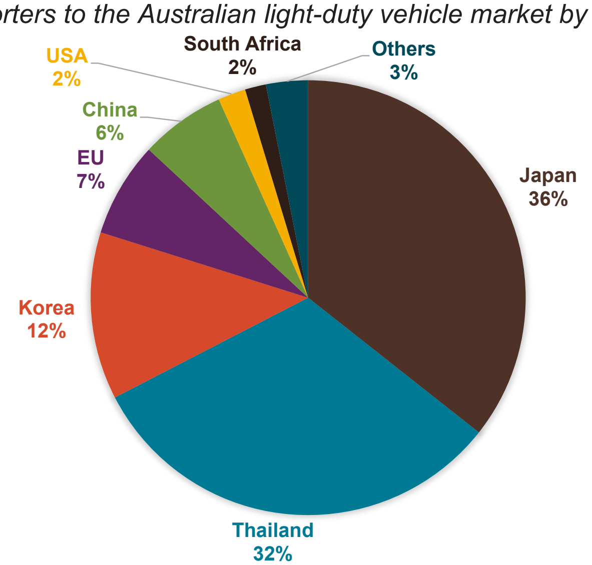
Figure 8
Average NEDC CO_2 emission values of the new ICE LDV fleet in Australia, by vehicle and fuel type



3.5 Countries of origin

Figure 9 shows the major exporting countries to the Australian LDV market based on 2024 market shares. As noted above, this information is for illustrative purposes, as the data coverage is low compared with total LDV sales. Vehicles imported from Japan, South Korea, and Thailand together represented nearly 80% of the Australian market. The European Union (7%), China (6%), the United States (2.1%), and South Africa (1.6%) were other key exporters. This list is consistent with that reported by other independent sources (Observatory of Economic Complexity, 2025). As shown in Table 1, most of these countries, except for South Africa and Thailand, have their own fuel efficiency or CO_2 regulations and use either the WLTP or the U.S. 2-cycle tests for type-approval and compliance determination. Vehicles imported from these countries are thus likely already type-approved based on their domestic procedures.

Figure 9
Exporters to the Australian light-duty vehicle market by market share in 2024



4 Methodology and results

This analysis applies the statistical regression method described in Section 2.3.2 to develop cycle conversion parameters. This approach has been widely adopted by other analyses and is functional and convenient in implementation.

To determine the appropriate method of analysis, we compared several regression approaches—including sales-weighted linear regression, exponential regression, and multivariate regression—comparing each with a simple equal-weighted univariate linear regression. There are limitations to each approach. The sales-weighted regression accounts for the sales of each vehicle model or model variant in the database, and is thus biased toward brands with higher sales. In contrast, the equal-weight linear regression considers the relative performance of each vehicle model in different test cycles equally. Exponential regression shows a good fit for the central data points, but the error of prediction increases substantially for vehicles with CO_2 values lying outside of the major data clouds (see Appendix A). For the multivariate regression, we considered the vehicle characteristics in the dataset, such as engine displacement, engine power, and vehicle mass, as additional independent variables, as they are typically correlated with vehicle fuel consumption and CO_2 performance (U.S. Environmental Protection Agency, 2024). The multivariate regression showed only minor improvements in predictive power compared with the simple univariate linear regression, such that we deemed that it did not justify the additional data requirements (see Appendix B).

Based on this assessment, we selected the simple univariate linear regression approach for converting original type-approval CO_2 emission values to NEDC g CO_2/km emission values using non-sales-weighted vehicle model data as input, as it offered a better balance of simplicity and accuracy compared with the other alternatives.

4.1 4-phase WLTP to NEDC conversion

4.1.1 Data source

We developed conversion algorithms from the 4-p WLTP to the NEDC based on comprehensive CO_2 emissions data published annually by the European Environment Agency (EEA; EEA, n.d.-b, n.d.-c). The EEA data contain the CO_2 emission values for each LDV registered in the European Union that is subject to the EU CO_2 standards (Regulation (EU) 2019/631, 2019). This is the basis for determining manufacturer compliance with annual CO_2 targets. As noted in section 2.2.1, during the EU transition from the NEDC to the WLTP, vehicles registered in 2020 were required to report CO_2 type-approval values under both test procedures, and the European Commission used the NEDC values to determine compliance with EU CO_2 emission standards for 2020 and the WLTP values to determine the future CO_2 targets of each manufacturer under the WLTP. These data (hereinafter referred to as EEA 2020) form the basis for our cycle conversion from the 4-p WLTP to the NEDC. In addition to CO_2 emission data, the EEA 2020 database contains vehicle characteristics like make, model name, type-variant-version code, fuel and powertrain type, engine capacity and power, and vehicle masses.

The EEA 2020 database is more updated as well as more comprehensive covering the entire EU market compared to the database used in the study for New Zealand, which included emissions data from 2019 and only for a single market, i.e., United Kingdom (Yang & Bandivadekar, 2021). Furthermore, a detailed data screening procedure was conducted for the EEA 2020 database as discussed in the following section, which is more updated and different from the procedure done in the New Zealand study. Hence, the results of the NEDC-WLTP regression in this study are expected to be different from the one derived in the New Zealand study.

4.1.2 Data processing and quality assurance

We performed the following steps to process and check the quality of the EEA 2020 data.

Step 1: Data clean-up. We removed records with blank or missing values, implausible or suspicious values, or irrelevant or extreme values that could bias the analysis. [10] This includes:

- Records with missing vehicle make, model, or NEDC or WLTP g CO_2/km values.
- Records with a fuel type other than petrol or diesel.
- Records with missing entries for mass in running order, WLTP test mass, or gross vehicle weight. The 2020 EU reporting guidelines describe these data fields as mandatory and explicitly highlight their importance of reporting in 2020 (European Commission, 2020).
- Records with missing entries for vehicle segment.
- Records where the reported NEDC CO_2 emissions are identical to the WLTP values.
- Records where mass in running order is greater than the test mass, where the test mass is greater than the gross vehicle weight, or where the gross vehicle weight exceeds 3,500 kg. The test mass by definition is greater than the mass in running order, and the EU LDV CO_2 standards only cover vehicles with a gross vehicle mass up to 3,500 kg (UNECE R 154, 2021).
- Records where segment is not consistent with the vehicle category. This means only non-car derived vans, car-derived vans, and pickup vehicles are categorized as light commercial vehicles, and all other segments are considered passenger cars.
- Records of PHEVs with WLTP CO_2 emissions of more than 111 g/km. This threshold is based on the CO_2 emission values of PHEVs available in the German market in 2020 (Allgemeiner Deutscher Automobil-Club, 2021).[11]
- Vehicle type-approved as national small series or that were approved individually, as these vehicles are not type-approved following the full test procedure and, therefore, WLTP and NEDC CO_2 emission values are considered less reliable.

This led to the removal of 9.3% of PC records and 22% of LCV records in the original database prior to analysis.[12]

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[10] We define a record as a row in the original database with a unique combination of make, model, segment type, variant, version, fuel type, powertrain type, vehicle power, engine displacement, and CO_2 values in the WLTP and NEDC.

[11] The Allgemeiner Deutscher Automobil-Club database contains records of all vehicle models offered in the German market. Germany is considered a fair representation of the EU market as it is the biggest vehicle market in the EU. According to this database, 99.5% of PHEV models available in Germany in both 2019 and 2020 had WLTP g CO2/km values of 110 g/km or less. The maximum reported value was 111 g/km in 2019 and 169 g/km in 2020.

[12] For this analysis, the definition of PC and LCV follows the EU vehicle categorization, where PCs are M1 vehicles and LCVs are N1 vehicles.

Step 2: WLTP values adjustment. WLTP values were adjusted to address the wide range of over-declaration of WLTP CO_2 values across manufacturers, as explained in Section 2.2.1. To ensure that the WLTP to NEDC CO_2 conversion was not distorted by differences stemming from different levels of over-declaration, we used Equation 2 to adjust the declared WLTP values based on the margin between declared and measured WLTP values, averaged across the fleet.[13] The manufacturer-average and fleet-average ratio of declared to measured WLTP emissions is taken from the European Commission (2023a). The adjustment factors range from 95% to 104% for PCs and from 94% to 105% for LCVs across the vehicle makes.

$$CO_{2,\,WLTP,adjusted,OEM,v} = CO_{2,\,WLTP,declared,OEM,V} \cdot \frac{r_{declared\ to\ measured,\ fleet,v}}{r_{declared\ to\ measured,\ OEM,v}} \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:

$r_{declared\ to\ measured,\ fleet,v}$ is the ratio of declared to measured WLTP values, averaged over the 2020 fleet by vehicle category v—that is, 4.8% for PCs and 5.1% for LCVs; and

$r_{declared\ to\ measured,\ OEM,v}$ is the ratio of declared to measured WLTP values by manufacturer and vehicle category v, as listed in European Commission (2023a).

We used these adjusted WLTP values for generating the regression relations after performing the data condensation and outlier removal steps described below.

Step 3: Data condensation. We selected unique combinations of make, model, segment type, variant, version, fuel type, powertrain type, vehicle power, and engine displacement. We refer to each such unique combination as a “model” for the purpose of this analysis. For these models, we calculated the sales-weighted average of NEDC and WLTP CO_2 emission values. We performed this data condensation to reduce bias that could be introduced for manufacturers with large sales volumes and for models that have multiple records with the same information. This condensation process yielded an aggregated database with 65,308 unique records: 48,862 for PCs and 16,446 for LCVs.

Step 4: Removing statistical outliers. We defined outliers as vehicles with an NEDC-to-WLTP g CO_2/km emissions ratio outside $\pm$ 3 standard deviations of the mean ratio for all samples in a vehicle group subject to the regression. This is a standard statistical rule for determining outliers, based on 99.7% of values being within +/- 3 standard deviations where data is normally distributed. The vehicle groupings used for the conversions are discussed later in this section. Through this process, we removed 393 outliers for the PV-only analysis, 250 outliers for the LCV-only analysis, and 974 outliers for the combined PV and LCV analysis.

4.1.3 4p-WLTP to NEDC conversion relations by type of vehicle and powertrain

We generated the regression relations using the screened EEA 2020 database obtained after performing the data processing and clean up steps described above. After evaluating a series of regressions for various vehicle groups, we determined the 4p-WLTP to NEDC CO_2 emissions for five vehicle groups, shown in Figures 10–14:

1. PCs and LCVs with internal combustion engines using petrol

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[13] Please note that this adjustment was done to address the over-declaration issue, however, this adjustment does not reflect the actual measured values.

2. PCs with internal combustion engines using diesel
3. LCVs with internal combustion engines using diesel
4. PHEV PCs and LCVs using petrol
5. PHEV PCs and LCVs using diesel

Figure 10
Regression between NEDC and 4p-WLTP CO_2 emissions for petrol internal combustion engine passenger cars and light commercial vehicles, including hybrid vehicles, in the EEA 2020 database

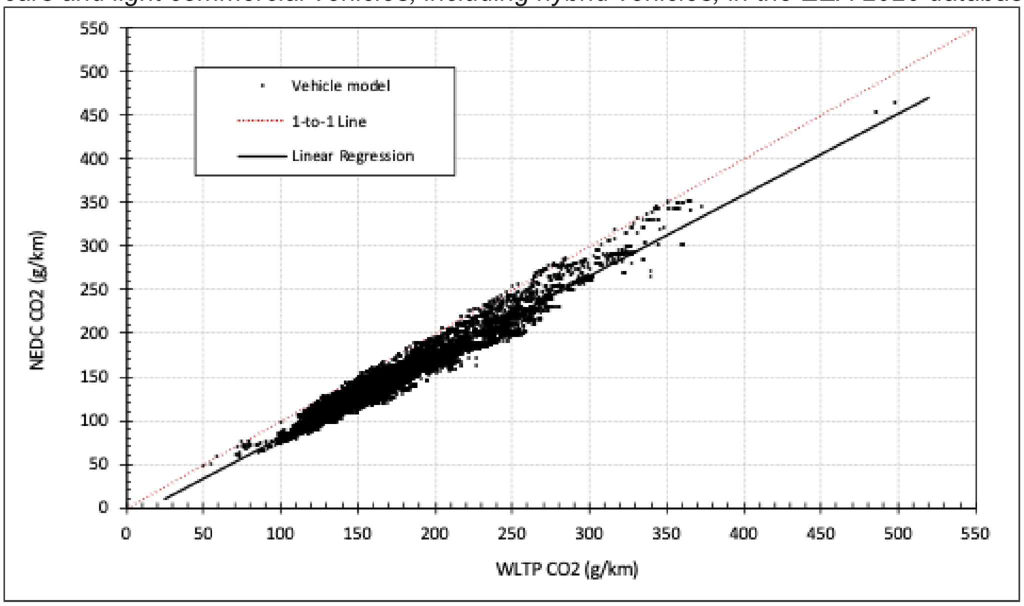


Figure 11
Regression between NEDC and 4p-WLTP CO_2 emissions for diesel combustion engine passenger cars, including hybrid vehicles, in the EEA 2020 database

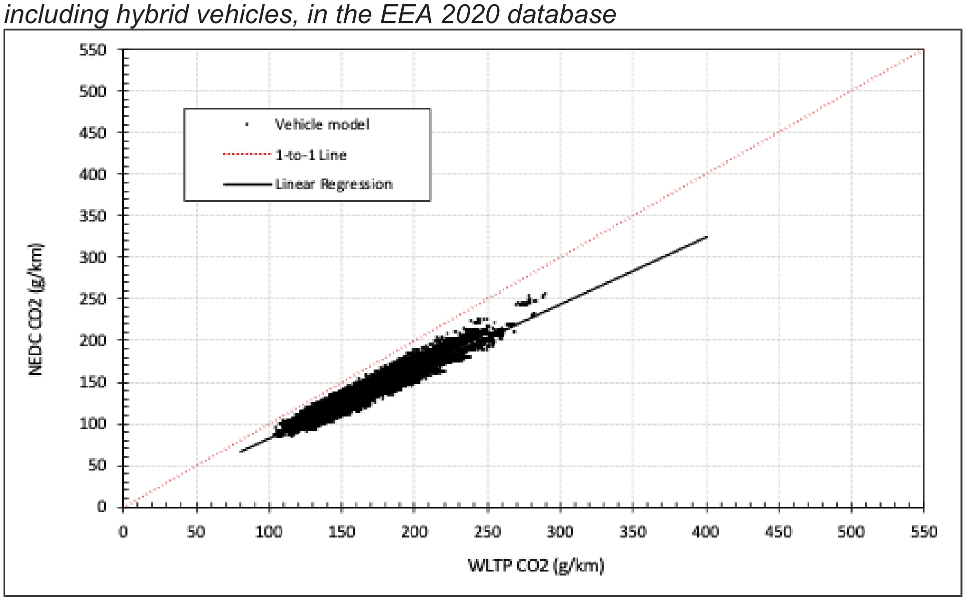


Figure 12
Regression between NEDC and 4p-WLTP CO_2 emissions for diesel combustion engine light commercial vehicles, including hybrid vehicles, in the EEA 2020 database

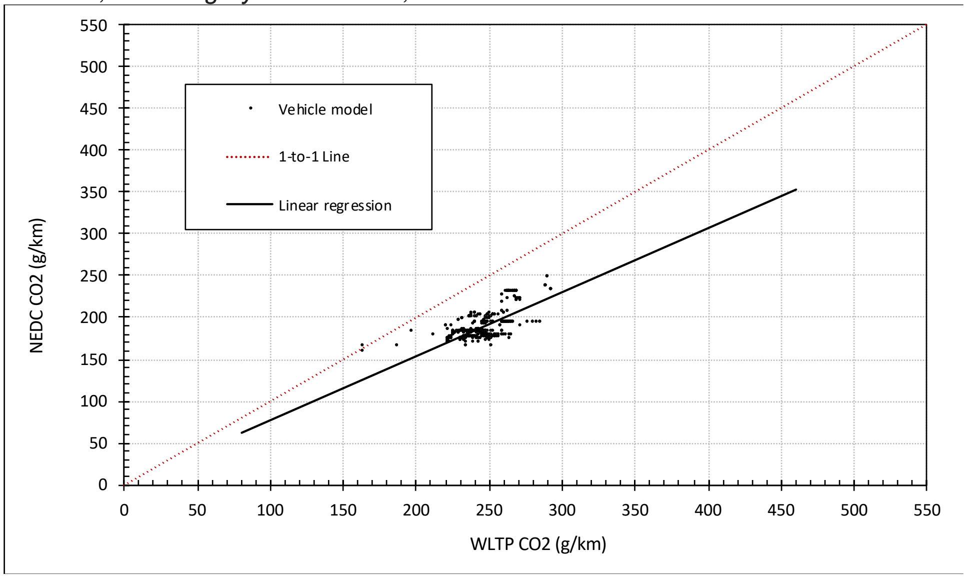


Figure 13
Regression between NEDC and 4p-WLTP CO_2 emissions for petrol plug-in hybrid passenger cars and light commercial vehicles in the EEA 2020 database

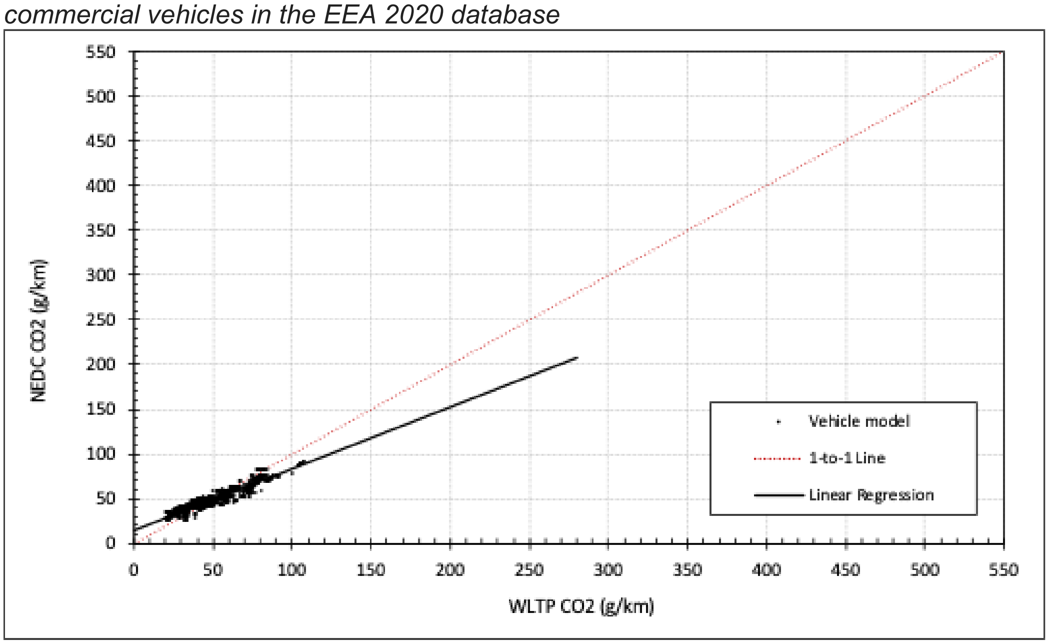
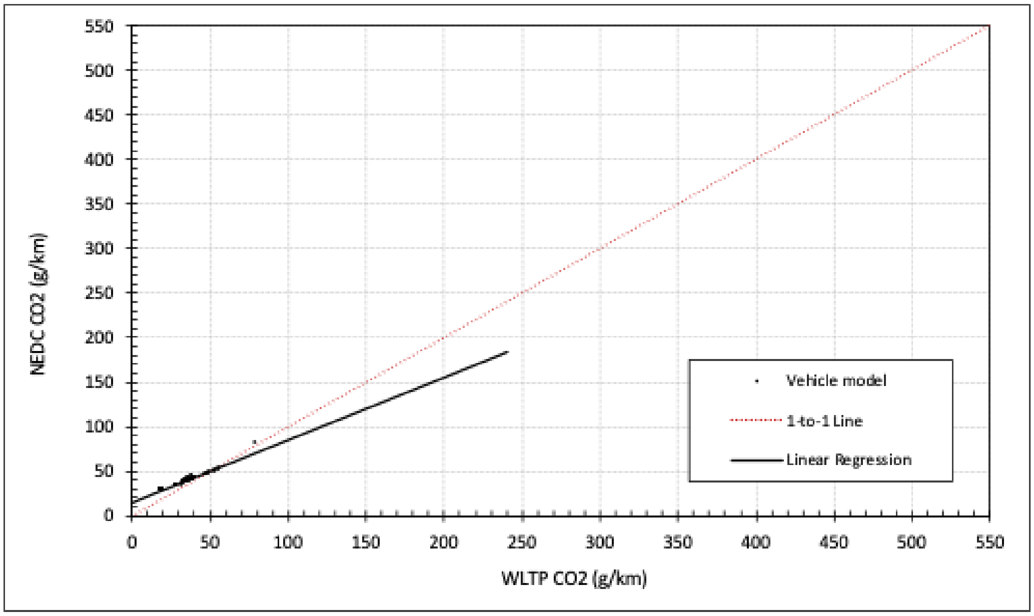


Figure 14
Regression between NEDC and 4p-WLTP CO_2 emissions for diesel plug-in hybrid passenger cars and light commercial vehicles in the EEA 2020 database



The results showed noticeable differences between diesel and petrol vehicles and between ICE vehicles and PHEVs. We therefore developed separate regression curves for each of these vehicle and powertrain types. The data clouds are similar between PCs and LCVs of a given fuel type; yet we generate separate conversion curves for diesel PCs and diesel LCVs considering that diesel PCs have sizable sale volumes according to Australia's 2024 market data (Figure 5).

Almost all SUVs in the EEA database are type approved under the PC class. Since those SUVs align with other non-SUV PCs in the WLTP–NEDC data cloud and the WLTP type procedure follows the same procedure as for PCs, the conversion relations for SUVs refer to the respective PC relations in this analysis.

Hybrid electric vehicles (HEVs) were grouped with conventional ICE vehicles for the regressions. The differentiation of hybrid and non-hybrid vehicles has blurred with the widespread adoption of micro- and mild-hybrid technologies. We evaluated HEVs separately, based on the category in the EEA 2020 database, and found that the regression curves of HEVs and non-HEVs were not significantly different from each other (see Appendix C). In addition, the HEV-only regression did not increase the predictive power compared with the HEV-inclusive ICE data regression.

For the diesel LCV segment, we generate the relation based on the diesel pickups. This decision is based on two justifications. The first is that pickup and utility vehicles dominate Australia's LCV market (excluding SUVs) comprising 86% of LCV sales in 2024. As shown in Table 2, the GVG 2024 dataset lists diesel pickup and utility vehicles separately from cab-chassis vehicles, which account for 44% and 23% of new vehicle sales in 2024, respectively. However, most cab-chassis vehicles are essentially derivatives or variants of the pickup models. Thus, the actual pickup market share after including the cab-chassis variants is 66% of the diesel LCV market. Most wagons in the GVG database are SUVs that have been historically classified as wagons in the Australian registration and certification systems, and therefore are not representative as diesel LCVs in the EEA data and should refer to the respective PC conversion curves developed in this analysis. After excluding SUVs and wagons, the pickup and utility vehicles account for 86% of the Australian diesel LCV market.

Table 2
Composition of Australia's 2024 diesel light commercial vehicle market by body style

Market shares based on the body style classification in GVG database		Market shares based on the primary body style	
Body style	**%sales share, 2024**	**Body style**	**%sales share, 2024**
Utility vehicle	44%	Utility vehicle / Cab-chassis	66%
Cab-chassis	23%	SUV / Wagon	23%
SUV	13%	Vans	11%
Wagon	10%		
Van	11%		

Second, the top-selling pickup models are the same in the EEA database and in Australian market, which provides the justification for using the EEA 2020 dataset for pickups to generate the relation for Australia. The pickup samples in the EEA database are composed of two major models, the Toyota Hilux and the Ford Ranger, which are also the two top-selling pickup models in Australia. In contrast, the van models are very different between the two markets. Except for a few shared models such as Mercedes-Benz Vito, Peugeot Expert, and Renault Trafic, most brands with reported van sales in the EEA dataset do not sell vans in the Australian market. Likewise, few brands selling vans in Australia, do not have van sales data in the EEA dataset.

Considering pickup vehicles dominate the Australian diesel LCV market and their similarity with the EU pickup models, it is reasonable to derive the conversion relation for Australia's diesel LCVs based on the diesel pickups rather than the entire diesel-LCV sample in the EEA dataset.[14] In addition, the relation we generate for diesel pickups closely approximated the average NEDC g CO_2/km emissions for vans in the EEA 2020 dataset.[15] Therefore, the conversion relation for pickups covers the van segment as well and there is no need to generate an additional relation for vans.

Table 3 summarizes the 4p-WLTP to NEDC regression line parameters, including the slope and intercept, and the respective statistics of the regression, including the coefficient of determination, R^2 value, and standard error of prediction for each vehicle group.[16] The 4p-WLTP to NEDC CO_2 values are highly correlated, as indicated by coefficient of determination, or R^2, values of 0.9 or higher, and the prediction errors are all well below 9 g CO_2/km for each vehicle group, except for

[14] The initial regression analysis based on the entire diesel LCV sample from EEA dataset yielded a higher standard error of 17.4 g/km, which led to a test of developing conversion factors based on the sub-segments of diesel LCVs and a comparison of popular models sold in each segment between the two markets. The EEA database allows us to segment the diesel LCVs into pickup, car-derived vans, and non-car-derived vans. The reasons listed in the text led to the decision of using the regressions generated with pickup data.

[15] Using the diesel LCV regression relation given in Table 3, that we derived based on the diesel pickups, we converted the WLTP g CO2/km values reported in the EEA 2020 dataset to NEDC values for each van model. On average, the predicted NEDC value of 185.8 g CO_2/km)for the vans is within 0.3% of the declared NEDC value of 185.2 g CO_2/km.

[16]The coefficient of determination, or R^2, is defined as the proportion of variability in the dependent variable that can be explained from the independent variable. R^2 is the square of the Pearson's correlation coefficient, r, and is considered a measure of correlation. The standard error of prediction is calculated as the square root of the sum of squared residuals divided by (sample size – 2) and is also referred to as the root mean squared error.

the diesel LCV class. The regression for the diesel LCV group has a standard error of 12.6 g CO_2/km with an R^2 value of 0.48. The low R^2 value indicates relatively lower degree of explainability between the two test cycles compared with other vehicle groups. However, we find this R^2 value is very sensitive to the LCV data selected from the EEA database and can increase significantly when removing some data samples that do not report data on vehicle weight, power, or engine displacement information (see Appendix B for details). Hence, the low R^2 in this case does not necessarily indicate a statistically weak relation or less accuracy.

Table 3
4-p WLTP to NEDC regression parameters and statistics

Vehicle group	Sample size	Slope	Intercept (g CO_2/km)	Coefficient of determination, R^2	Standard error of prediction (g CO_2/km)
Petrol	25,148	0.9294	-13.2248	0.95	8.1172
Diesel PC	22,280	0.8075	1.8475	0.94	6.5759
Diesel LCV	518	0.7633	1.0199	0.48	12.5823
Petrol PHEV	1,331	0.6879	13.9135	0.90	4.2770
Diesel PHEV	101	0.7084	14.5883	0.96	1.5554

Note: Relations are of the form: NEDC = slope (4p-WLTP) + intercept, where NEDC and 4p-WLTP values are in g CO_2/km.

Separate regression relations were derived for diesel and petrol PHEVs. The WLTP CO_2 emissions in the EEA 2020 database were derived using the Euro 6d utility factor (see Figure 2). However, as noted above, the Euro 6e-bis utility factor curve has been used for PHEV type-approval in the European Union since January and a second adjustment of the curve is foreseen for 2027. Therefore, as discussed in Section 2.2.1, the effect of the adjusted utility factor curves on PHEV WLTP CO_2 emissions must be addressed for PHEVs type-approved in the European Union after January 2025 and exported to Australia. This will be discussed in Section 5.

4.2 3-phase WLTP to NEDC conversion

4.2.1 Data source

While the EEA 2020 database is the most comprehensive publicly available source for WLTP and NEDC values for same set of vehicles, it does not contain CO_2 emission values for the individual phases of the WLTP, or for a 3-phase composite. Therefore, we used an alternative dataset published by the UK Department for Transport Vehicle Certification Agency (2019) that was also used for determining cycle conversion factors for New Zealand in 2021 (Yang & Bandivadekar, 2021). It contains fuel consumption values for 5,492 vehicle models from 36 makes available in the UK market in 2019, both for the entire WLTC and separately for the low, medium, high, and extra-high speed phases of the test. This dataset (referred to here as the UK 2019 dataset) was used to determine the relation between WLTP 3-phase and 4-phase CO_2 emissions.

4.2.2 Data processing and quality assurance

Since fuel consumption and CO_2 emissions are directly correlated, the fuel consumption was first converted to an equivalent CO_2 emission value using emission factors of 2,631 g CO_2 per liter of diesel and 2,278 g CO_2 per liter of petrol, in accordance with EU type-approval fuel properties

(European Commission, 2024). After this conversion, we calculated the composite 3-phase and 4-phase-WLTP emission values for each vehicle by weighting the phase-specific emission value with the distance driven in each of the applicable phases.

The UK 2019 database contains declared NEDC g CO_2/km values. However, given that the EEA 2020 database we used for the 4p-WLTP conversion includes more updated NEDC data, we decided to use that relation and follow a 2-step conversion: first generating the conversion algorithm from 3p-WLTP to 4p-WLTP and then following the 4p-WLTP to NEDC conversion parameters (Table 3). We mathematically combined the steps so that the two conversions involve a single set of regression parameters. It should be emphasized that this does not result in a loss in precision and is thus consistent with directly converting from the 3p-WLTP to the NEDC.

Like the 4p-WLTP to NEDC conversion, we followed a step-by-step procedure for data screening and quality assurance of the UK 2019 database.

Step 1: Data clean-up. We eliminated the following:

- Records with no phase-specific data.
- Records with reported composite fuel consumption less than the lowest fuel consumption of any component phase.
- Records with reported composite fuel consumption greater than the highest fuel consumption of any component phase.
- Records with reported composite fuel consumption equal to reported composite fuel economy.[17]
- Records where reported composite fuel consumption varied from the estimated composite fuel consumption by more than 0.1 liters per 100 km (i.e., the level of round-off error).

This process resulted in a database of 5,345 records.

Step 2: Data condensation. We condensed the data using the database fields: manufacturer, model, vehicle description, transmission, engine capacity, fuel type, engine power, testing scheme, Euro standard, real-driving emission standard(Vehicle Excise Duty supplement), electric energy consumption, and maximum electric range.[18] For each unique value, we aggregated the 4-phase-specific fuel consumption and reported composite fuel consumption values. We then recalculated the composite 4-phase fuel consumption from the aggregated individual phase values and compared that with the aggregated reported 4-phase fuel consumption to verify that all condensed records agreed to within 0.1 L/100 km. This resulted in a condensed database of 3,209 records (1,292 diesel and 1,917 petrol).

Step 3: Statistical outlier removal. We identified and eliminated the records for which the ratio of 3p-WLTP to 4p-WLTP reported composite fuel consumption was outside $\pm$ 3 standard deviations of the mean ratio. This resulted in the identification of three diesel record outliers, so that the final analysis database contained 3,206 records (1,289 diesel and 1,917 petrol).

[17] Fuel consumption refers to l/100 km while fuel economy refers to miles per gallon values. This step was performed to screen for any data entry error.

[18] For diesel vehicles not certified to the real-driving emissions standards, a Vehicle Excise Duty supplement was applied in the UK.

4.2.3 3p-WLTP to NEDC conversion relations by type of vehicle and powertrain

Using the screened UK 2019 dataset, we generated the 3p-WLTP to 4p-WLTP regressions separately for petrol and diesel vehicles. As shown in Figure 15, the data trends appear highly consistent across both regressions, thus we did not further split the regression by vehicle type. We then algebraically combined the two regressions with the 4p-WLTP to NEDC relations to derive the 3p-WLTP to NEDC relations for petrol PCs and LCVs, diesel PCs, and diesel LCVs.

Figure 15
Correlation between 4p-WLTP and 3p-WLTP CO_2 emissions in the UK 2019 database

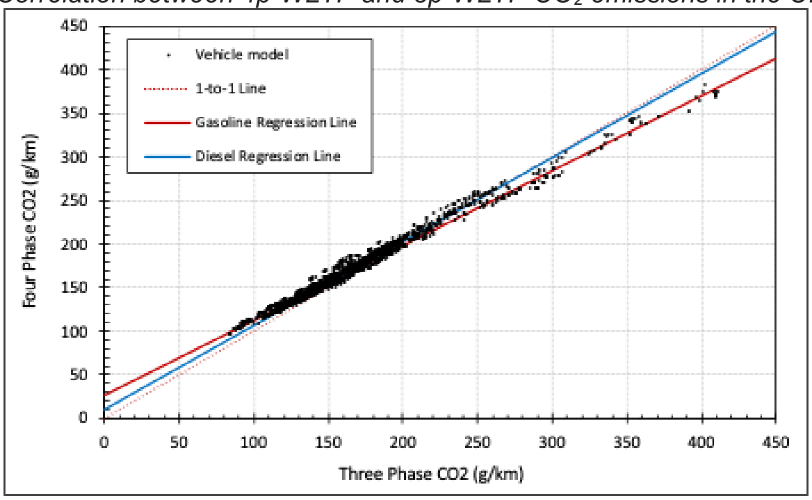


Table 4 lists the 3p-WLTP to NEDC regression parameters and statistics by vehicle type. The regressions demonstrate similar effects to those observed in the 4p-WLTP to NEDC relations: strong correlations and prediction errors of less than 10 g CO_2/km across vehicle groups except diesel LCVs, which exhibited relatively larger prediction errors. We did not generate the relations for PHEVs, because Japan, where the 3p-WLTP vehicles are likely type-approved, uses a different UF curve than the European Union, which would create inconsistencies with the 4p-WLTP to NEDC relations that we developed based on the EU utility factors. Section 5 discusses the proposed method for converting the CO_2 emissions of PHEVs.

Table 4
3 phase-WLTP to NEDC regression parameters and statistics

Vehicle group	Sample size	Slope	Intercept (g CO_2/km)	Coefficient of determination, R^2	Error of prediction (g CO_2/km)
Petrol	1,917	0.7946	11.8702	0.94	9.7676
Diesel PC	1,289	0.7773	10.0080	0.92	7.6972
Diesel LCV	1,289	0.7347	8.7332	0.47	13.2030

Notes: Relations are of the form: NEDC = a (3p-WLTP) + b, where a is the slope, b is the intercept, and NEDC and 3p-WLTP values are in gCO_2/km. The underlying 4p-WLTP = a1(3p-WLTP) + b1 analysis was algebraically combined with a separate NEDC = a2(4p-WLTP) + b2 analysis (the statistics for which are reported in Table 3). The aggregated statistics are developed as follows: a = (a1)(a2), b = (a2)(b1) + b2, and standard error = $[(\text{standard error1})^2 + (\text{standard error2})^2]^{0.5}$.

4.3 U.S. 2-cycle to NEDC conversion

4.3.1 Data source

In the absence of public data containing both the U.S. 2-cycle CO_2 emission values and NEDC or WLTP CO_2 emission measurements for the same vehicle, we used the simulation model results from ICCT (2014), as discussed in Section 2.3.2. This simulation model dataset was also used in Yang & Bandivadekar (2021) for New Zealand, albeit for a different conversion (U.S. 2-cycle to 3p-WLTP).

Use of the simulation data from ICCT (2014) offers several benefits. First, the data cover the U.S. 2-cycle and NEDC procedures. Developed through rigorous methodologies consistent with industry practice, they are based on well-researched, established analytical methods. They also account for advanced ICE vehicle technology data through 2025. However, the database does not account for PHEVs.

4.3.2 Data processing and quality assurance

The simulation data did not require much cleaning or merging. We compared the U.S. 2-cycle and NEDC data in terms of technology timeframe (2014-era versus 2025-era technology), technology type (PC versus LCV), and fuel type (petrol versus diesel). Significant relational differences were only observed between 2014-era and 2025-era technology data. As the 2025-era technology is current and the emissions data for the 2014-era technology were on the high end of the expected ranges for current certification values, we focused our analysis on the 2025-era technology only.

Like the 4p-WLTP and 3p-WLTP databases, we applied the same $\pm$ 3 standard deviation outlier screening criteria to the 2025-era data based on the ratios of NEDC to U.S. 2-cycle g CO_2/km emissions. This resulted in the exclusion of three petrol PV records and one diesel PV record. The final analysis database contained 752 records (669 petrol and 83 diesel).

4.3.3 U.S. 2-cycle to NEDC conversion relations by type of vehicle and powertrain

Figures 16 and 17 show that the NEDC and U.S. 2-cycle trends are almost perfectly linear and highly consistent across vehicle groups. However, to be consistent with the other cycle conversions, we generated the U.S. 2-cycle to NEDC conversion relations for the same set of vehicle groups: petrol PCs and LCVs, diesel PCs, and diesel LCVs.

Figure 16
Correlation between NEDC and U.S. 2-cycle CO_2 emissions for petrol passenger cars and light commercial vehicles

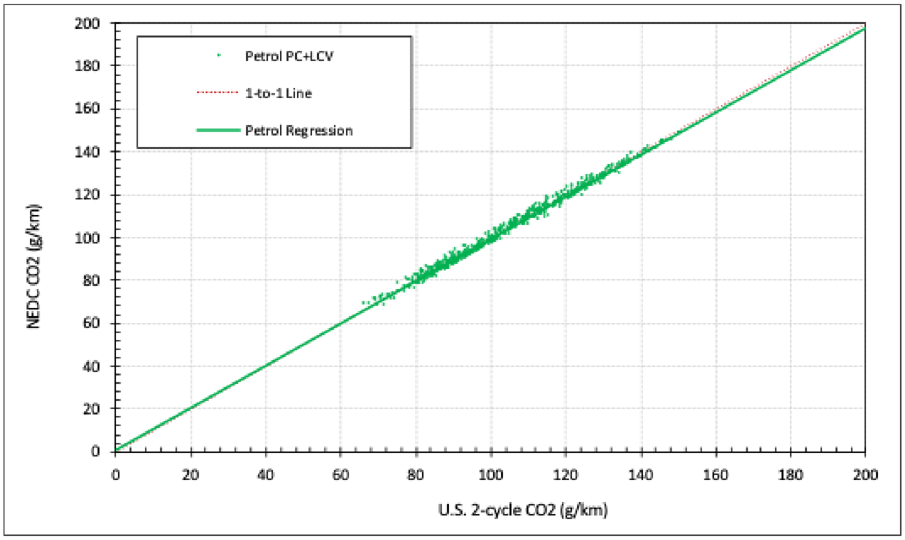


Figure 17
Correlation between NEDC and U.S. 2-cycle CO_2 emissions for diesel passenger cars and light commercial vehicles

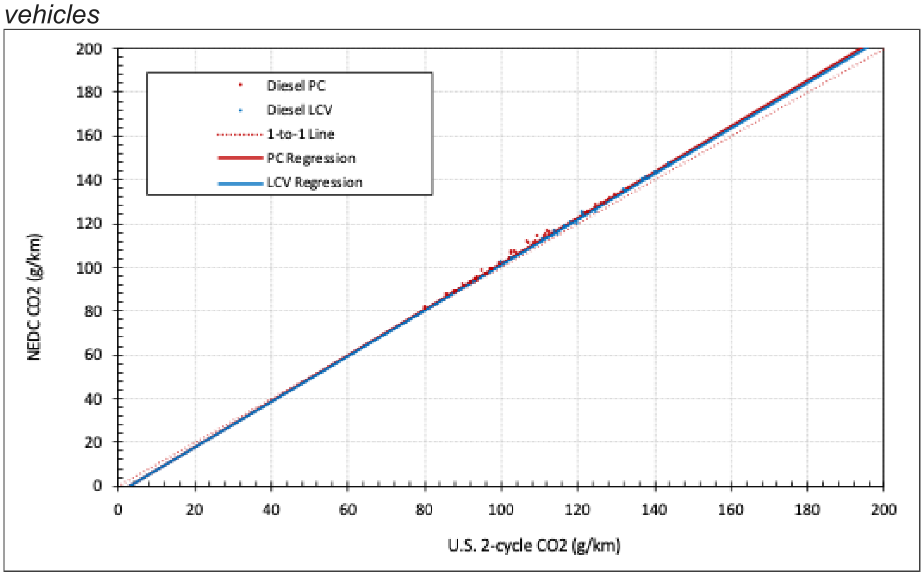


Table 5 shows the respective regression line parameters and statistics by vehicle group. The R^2 values for these regressions are almost 1.0, indicating a perfect linear fit across all vehicle groups, and prediction errors are very low (less than 2 g CO_2/km for petrol vehicles and 1 g CO_2/km for diesel vehicles). This is due to the more controlled and systematic behavior of the simulated data compared with the large range of variability in actual vehicle samples.

Table 5: U.S. 2-cycle to NEDC regression parameters and statistics

Vehicle group	Sample size	Slope	Intercept (gCO_2/km)	Coefficient of determination, R^2	Error of prediction (gCO_2/km)
Petrol PC and LCV	669	0.9849	0.9819	0.99	1.6204
Diesel PC	55	1.0478	-3.0061	0.99	0.8978
Diesel LCV	28	1.0419	-3.2551	0.99	0.8609

Relations are of the form: NEDC = a (U.S. 2-cycle) + b, where a is the slope, b is the intercept, and NEDC and U.S. 2-cycle values are in gCO2/km.

In the absence of simulation data for PHEVs, we cannot determine a direct U.S. 2-cycle to NEDC conversion relation for these vehicles. The next section discusses the conversion for PHEVs.

5 Summary and verification

Table 6 provides a summary of the conversion relations for the specified pairs of test cycles by type of fuel, vehicle, and powertrain. As mentioned in Section 4, the conversion relations are of the form:

NEDC = a x (From cycle) + b

Where NEDC and "From cycle" are in g CO_2/km, a is the slope, and b is the intercept (g CO_2/km) of the regression line.

Table 6
Summary of test cycle conversion parameters for Australia

From cycle	To cycle	Fuel	Vehicle and powertrain type	Slope	Intercept (g CO_2/km)
4p-WLTP	NEDC	Petrol	ICE PCs and LCVs (including HEVs)	0.9294	-13.2248
3p-WLTP	NEDC	Petrol	ICE PCs and LCVs (including HEVs)	0.7946	11.8702
U.S. 2-cycle	NEDC	Petrol	ICE PCs and LCVs (including HEVs)	0.9849	0.9819
4p-WLTP	NEDC	Diesel	ICE PCs (including HEVs)	0.8075	1.8475
3p-WLTP	NEDC	Diesel	ICE PCs (including HEVs)	0.7773	10.0080
U.S. 2-cycle	NEDC	Diesel	ICE PCs (including HEVs)	1.0478	-3.0061
4p-WLTP	NEDC	Diesel	ICE LCVs (including HEVs)	0.7633	1.0199

From cycle	To cycle	Fuel	Vehicle and powertrain type	Slope	Intercept (g CO_2/km)
3p-WLTP	NEDC	Diesel	ICE LCVs (including HEVs)	0.7347	8.7332
U.S. 2-cycle	NEDC	Diesel	ICE LCVs (including HEVs)	1.0419	-3.2551
4p-WLTP	NEDC	Petrol	PHEV PCs and LCVs	0.6879	13.9135
4p-WLTP	NEDC	Diesel	PHEV PCs and LCVs	0.7084	14.5883

For PHEVs, if the original test cycle is 4p-WLTP, the parameters listed in the last two rows of Table 6 can be used for the conversion for each respective fuel type. For PHEVs type-approved to Euro 6e-bis or later emission standards, 3p-WLTP or U.S. 2-cycle, emission values can be estimated by first converting the charge-sustaining mode emissions using ICE conversion relations from Table 6 and then using the NEDC rule shown in Equation 2 in section 2.2.1, to generate the combined NEDC CO_2 emission values.

The following sub-sections provide details on the results of residual distribution and verification exercises assessing the robustness of the developed conversion relations.

5.1 Residual distribution

Table 7 presents the percentile distribution of the regression residuals—that is, the absolute difference between predicted and observed values, in g CO_2/km, for the 4p-WLTP and U.S. 2-cycle to NEDC conversions. The prediction errors are low for the majority of vehicle samples in the distribution across most vehicle groups.

For instance, for the 4p-WLTP to NEDC conversion, except for the diesel LCV class, differences between the predicted and observed values are well below 10 g CO_2/km for 80% of the vehicle records. For the diesel LCV class, 60% of vehicles have prediction errors below 10 g CO_2/km and 70% of the vehicles have a difference well below the standard error of prediction of 12.6 g CO_2/km.

Table 2
Percentile distribution of regression residuals (g CO_2/km) for cycle conversions

	Standard error	10th Percentile	20th Percentile	30th Percentile	40th Percentile	50th Percentile	60th Percentile	70th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile	100th Percentile
4p-WLTP to NEDC													
Petrol PC and LCV	8.1172	1.0	2.0	3.0	4.0	5.1	6.3	7.6	9.5	12.8	16.6	24.0	39.5
Diesel PC	6.5759	0.9	1.7	2.4	3.3	4.4	5.4	6.7	8.4	10.9	13.0	17.0	27.2
Diesel LCV	12.5833	2.9	3.7	4.9	6.2	7.9	9.7	12.1	16.4	21.1	26.2	29.9	41.6
Petrol PHEV	4.2770	0.4	0.9	1.5	2.0	2.8	3.3	4.0	5.3	6.7	9.7	11.9	13.7
Diesel PHEV	1.5554	0.3	0.4	0.4	0.4	0.6	0.9	1.1	1.4	1.7	1.9	2.7	11.4
U.S. 2-cycle to NEDC													
Petrol PC and LCV	1.6204	0.2	0.4	0.6	0.8	1.1	1.4	1.7	2.1	2.7	3.2	4.0	4.7
Diesel PC	0.8978	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.5	1.8	2.3	2.5

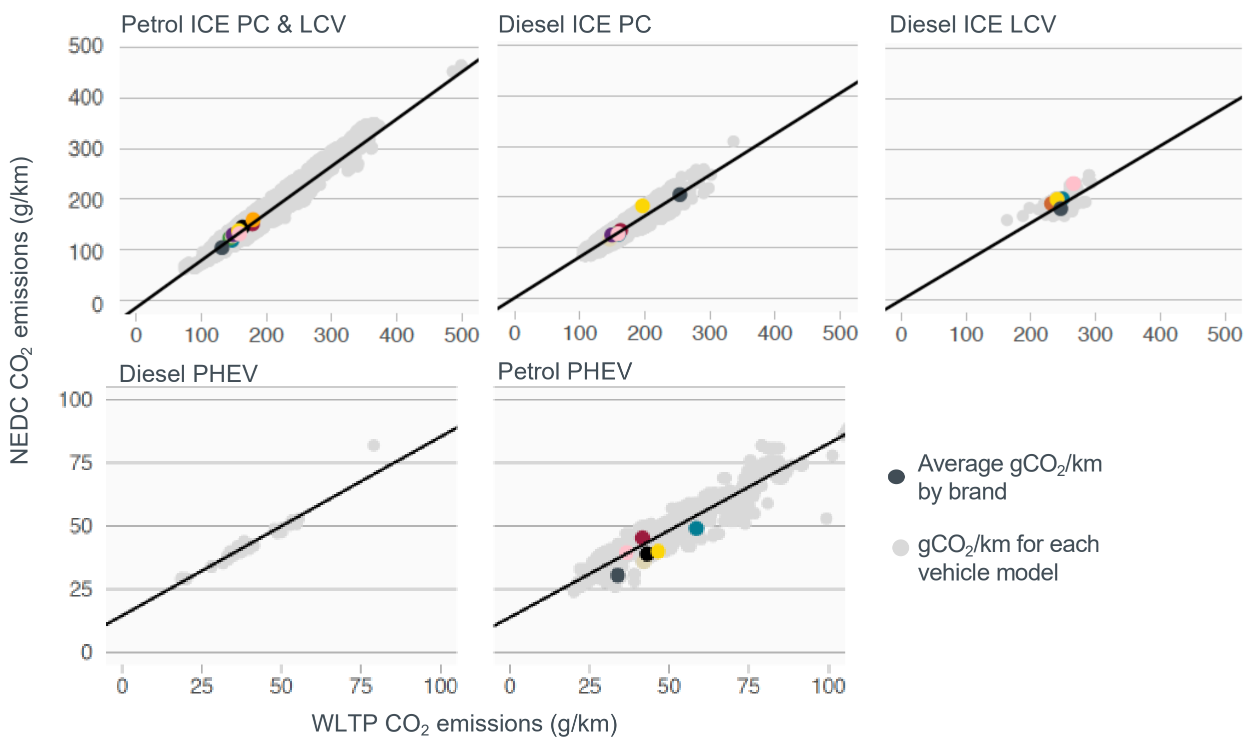
	Standard error	10th Percentile	20th Percentile	30th Percentile	40th Percentile	50th Percentile	60th Percentile	70th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile	100th Percentile
Diesel LCV	0.8609	0.1	0.3	0.4	0.6	0.6	0.8	0.9	1.0	1.4	1.6	1.7	1.7

5.2 Verification exercise for top-selling brands

To test the robustness of the conversion algorithms, we also performed a verification exercise for 4p-WLTP to NEDC conversions considering the top selling 11 ICE vehicle brands in the Australian market (see Section 3.3).[19] We identified these brands in the EEA 2020 database and calculated the fleet-average g CO_2/km emissions for each brand in both the NEDC and 4p-WLTP. Figure 18 shows the fleet-average NEDC and 4p-WLTP emissions of the selected brands compared with the 4p-WLTP to NEDC regression lines we generated for each vehicle group based on the observed WLTP values.

Average emissions for most brands, shown as data points in color, are close to (if not exactly on) the regression lines. This indicates that the errors from the conversion do not bias against brands and that the predictions are very close to manufacturers' actual average emissions.

Figure 18
Average WLTP and NEDC CO_2 emissions for the 11 manufacturers with the highest market share in Australia in 2024



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[19] For this verification analysis, we selected 11 of the top 12 selling brands in Australia shown in Section 3.3. We excluded Tesla, which sells all electric vehicles.

6 Additional considerations

The power required to run a drive cycle is affected not only by the test procedure itself but also by the design characteristics of the vehicle being tested. Adopting any cycle conversion algorithm will thus be necessarily imprecise. The conversions developed in this analysis hold on average, but the variability or error of these relations for any given vehicle can be significant. As alternative options to using these conversion relations, importers will have the choice to either run the emission tests under the NEDC at certified testing laboratories or use the CO2MPAS model to estimate the emissions in NEDC.

While the NVES is intended to regulate specified vehicles with a gross vehicle weight of up to 4,500 kg, the databases used for this analysis only have data for PCs and LCVs with a gross vehicle weight of up to 3,500 kg. Given the lack of relevant CO_2 emissions data available for vehicles between 3,500 kg and 4,500 kg to develop or verify the conversion algorithms, Australian authorities could consider using the LCV conversion factors to convert the CO_2 values of these vehicles, as well as allowing an alternative for the importers of these vehicles to conduct physical CO_2 testing under the NEDC if preferred. If importers choose to conduct physical testing for this heavier LCV segment, they should report the CO_2 emission values in both the original test cycle and NEDC, and authorities could then consider developing a separate set of conversion factors for these LCVs as data become available to justify such adjustment.

Lastly, given that new models sold in Australia will comply with at least WLTP-based Euro 6d-equivalent pollutant emission standards (or equivalent U.S. standards) starting from December 2025, with all models required to comply by July 2028, an increasing number of vehicles entering the Australian market will be tested under 4p-WLTP. This would place most importers and models on a level field for compliance with the standards by 2028 and reduce inaccuracies in converting the CO_2 and fuel consumption values from different test cycles.

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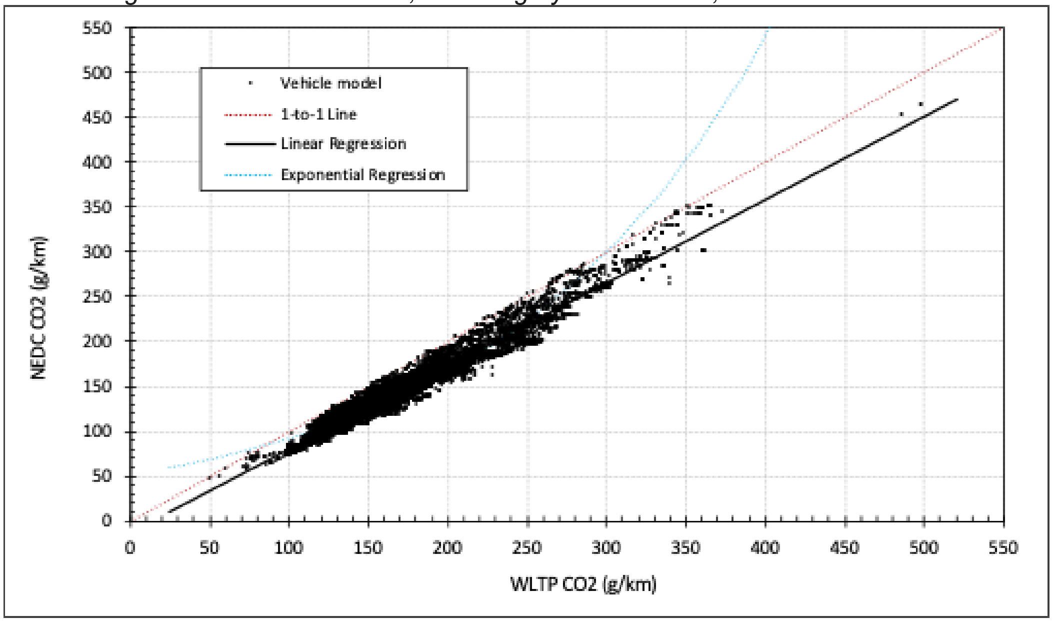
Appendix A. Example of exponential regression

Figure A1
Regression between NEDC and 4p-WLTP CO_2 emissions for petrol internal combustion engine passenger cars and light commercial vehicles, including hybrid vehicles, in the EEA 2020 database



Appendix B. Example of multivariate regression

This comparison is based on the set of records that includes all information needed for the multivariate regression. Therefore, the sample sizes and the resulting regression parameters of univariate approach are different from those listed in Table 3, for each vehicle type.

Table B1
4 phase-WLTP to NEDC regression parameters and statistics, univariate versus multivariate regression

Vehicle group	Regression type	Sample size	a_WLTP	a_weight	a_power	a_displacement	b (gCO_2/km)	R^2	Standard error (gCO_2/km)
Petrol PC and LCV	Univariate	21,010	0.9274	/	/	/	-12.8377	0.95	8.1508
Petrol PC and LCV	Multivariate	21,010	0.8755	-0.0152	0.0746	0.0018	5.6700	0.96	7.4323
Diesel PC	Univariate	19,512	0.7992	/	/	/	3.2817	0.94	6.5013
Diesel PC	Multivariate	19,512	0.6879	0.0071	0.0237	0.0032	-0.8097	0.95	6.0611
Diesel LCV	Univariate	430	0.5069	/	/	/	40.6006	0.94	6.5005
Diesel LCV	Multivariate	430	0.2952	0.0273	-0.0188	0.0140	9.9573	0.97	5.0466

Note that although the multivariate regression of diesel LCVs shows a much lower standard error and much higher R^2 compared to the findings in the report, the univariate regression with the same dataset also shows similar statistics. Those changes come from the removal of sample data without vehicle weight, power, or displacement data in the database rather than the change in regression methods.

With the multivariate approach, it is necessary to consider collinearity between the independent variables to better reflect the potential importance of each independent variable. However, our primary exercise was to assess the potential predictability of the multivariate approach compared to the univariate approach. Since the multivariate approach generally does not much improve the predictive power compared to the univariate model, we did not further closely examine the collinearity issue, as this does not affect our decision to use the univariate model approach.

Appendix C. Regression comparisons of non-hybrid and hybrid vehicles

Figure C1
Linear regressions of petrol non-hybrid and hybrid passenger cars and light commercial vehicles