ISSN 1831-9424

European Commission

JRC SCIENCE FOR POLICY REPORT

2025 and 2030 CO_2 emission targets for Light Duty Vehicles

Suarez, J., Komnos, D., Ktistakis, M.A., Fontaras, G.

2023

Joint Research Centre

EUR 31509 EN

Contact information
Name: Georgios Fontaras
Address: European Commission, Joint Research Centre (JRC), Via E. Fermi, 2749, 21027 Ispra VA, Italy
Email: georgios.fontaras@ec.europa.eu
Tel.: +39 033278-6425

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC133502

EUR 31509 EN

PDF ISBN 978-92-68-03448-4 ISSN 1831-9424 doi:10.2760/901734 KJ-NA-31-509-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: Suarez, J., Komnos, D., Ktistakis, M.A., Fontaras, G., *2025 and 2030 CO_2 emission targets for Light Duty Vehicles*, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/901734, JRC133502.

Contents

Abstract

Road transport is the main contributor to transport emissions of carbon dioxide (CO_2) in the European Union (EU), with passenger cars and light commercial vehicles (LCVs) accounting for almost 15% of the total emissions. In order to gradually decarbonise the fleet, the EU has established fleet-wide CO_2 targets for annually registered vehicles, assigning manufacturer specific targets based on their average vehicle mass. From 2025, new EU fleet-wide targets will be established applying a percentage reduction to a reference 2021 EU fleet-wide target. This value is calculated from the vehicles' CO_2 emissions for 2020 and the mass and registration figures of 2021. In 2025, the reduction will be 15% for both passenger cars and LCVs, while for 2030 it will increase to 55% and 50%, respectively, following the recent adoption of the more ambitious targets. This report provides the robust method used to calculate the EU fleet-wide targets in 2025 and 2030 and the parameters that will define the manufacturers' specific target line from 2025 onwards. The EU fleet-wide targets calculated for 2025 are 93.6 g/km for passenger cars and 153.9 g/km for LCVs. For 2030, the EU fleet-wide targets will be reduced to 49.5 g/km for passenger cars and 90.6 g/km for LCVs. The slope of the target line for 2025 will be -0.0144 g/(km· kg) for passenger cars and 0.0848 g/(km· kg) for LCVs, while for 2030 the slope will be -0.0076 g/(km· kg) and 0.0499 g/(km· kg), respectively. An indicative 2025 average test mass of 1,609.6 kg for cars and 2,163.0 kg for LCVs, was calculated.

Acknowledgements

The views expressed here are purely those of the authors and may not, under any circumstances, be regarded as an official position of the European Commission.

The authors are grateful to the European Commission's colleagues from the Directorate General for Climate Action (DG CLIMA) in particular Filip François, Victor Bormand, Katalin Lakatos and Samuel Timmers, and to the colleagues from the European Environment Agency (EEA), especially Cinzia Pastorello and Stephanie Schilling, for their support, supplying the data and the valuable comments provided.

Authors

Suarez J., Komnos, D., Ktistakis, M.A., Fontaras, G.

Executive summary

Policy context

This report has been prepared on request of the Directorate-General for Climate Action (DG CLIMA) in order to calculate the **2025 and 2030 European Union (EU) fleet-wide targets for passenger cars and light commercial vehicles**, as mandated in Regulation (EU) 2019/631. Once they are established by Commission Decision, the parameters calculated in this study will be utilised for the determination of the manufacturers' future targets that will apply in the run-up to the 2035 zero-emission targets for new vehicles registered in the EU.

Key conclusions

The EU-fleet wide targets applying from 2025 onwards are expressed as a percentage reduction with respect to a 2021-based EU fleet-wide emissions target: a 15% reduction from 2025 for both passenger cars and light commercial vehicles, and a 55% and 50% reduction from 2030 for passenger cars and light commercial vehicles, respectively. This report calculates the 2021 EU fleet-wide target as set out in the Regulation. This target is based on the 2020 manufacturers' measured (Worldwide harmonized Light vehicles Test Procedure) WLTP emissions, the average mass in running order of the vehicles registered in 2021 and the number of registrations per manufacturer in 2021. For this purpose, a database combining the measured-WLTP and NEDC emissions of the new vehicles registered in the EU in 2020 has been built from the data submitted by the manufacturers and the Member States authorities.

Applying the agreed reduction factors to the 2021 fleet-wide target, the EU fleet-wide targets for passenger cars and light commercial vehicles in 2025 and 2030 are calculated and provided. The manufacturers' specific emission targets for 2025 onwards will be calculated from those EU fleet-wide targets, taking into account the average mass of their registered vehicles. The slopes of the target lines are also calculated in this exercise.

Main findings

Passenger cars.

- The database containing the measured-WLTP emissions of passenger cars registered in 2020 has been subjected to the gap-filling procedure set out in Regulation (EU) 2017/1153 and to data cleansing, with a final total number of **11,382,143** vehicles considered.
- The calculated EU fleet-wide target$_{2021}$ for passenger cars is **110.1** g/km, resulting in EU fleet-wide targets for 2025 and 2030 of **93.6** g/km and **49.5** g/km, respectively.
- The slope of the regression line a_{2021} in passenger cars is **-0.0175** g/(km· kg), yielding a slope (a_{2025}) of **-0.0144** g/(km· kg) for 2025 and a slope (a_{2030}) of **-0.0076** g/(km· kg) for 2030.
- The indicative fleet-wide average test mass value for 2025 (TM_0), calculated based on the 2021 new registered cars, has been calculated as **1,609.6** kg.

Light commercial vehicles.

- The database containing the measured-WLTP emissions of light commercial vehicles registered in 2020 has been subjected to the gap-filling procedure set out in Regulation (EU) 2017/1152 and to data cleansing, with a final total number of **1,198,214** vehicles considered.
- The calculated EU fleet-wide target$_{2021}$ for light commercial vehicles is **181.1** g/km, resulting in EU fleet-wide targets for 2025 and 2030 of **153.9** g/km and **90.6** g/km, respectively.
- The slope of the regression line a_{2021} in light commercial vehicles is **0.1064** g/(km· kg), yielding a slope (a_{2025}) of **0.0848** g/(km· kg) for 2025 and a slope (a_{2030}) of **0.0499** g/(km· kg) for 2030.
- The indicative fleet-wide average test mass value for 2025 (TM_0), calculated based on the 2021 new registered light commercial vehicles, has been calculated as **2,163.0** kg.

Related and future JRC work

Following a close collaboration between the Joint Research Centre (JRC), DG Climate Action and the European Environment Agency, this report provides a detailed description of the procedure followed for the determination

of the EU fleet-wide CO_2 targets for the period of 2025 to 2034. The Commission will formally adopt the targets and associated parameters.

Quick guide

This report analyses CO_2 emissions data reported by countries and manufacturers for the new passenger cars and light commercial vehicles (together referred to as "light-duty vehicles") registered in the EU (and Norway and Iceland) in the years 2020 and 2021.

The introduction establishes the background of this report, explaining the role of the targets in reducing the CO_2 emissions of light-duty vehicles.

Section 2 (CO_2 emission calculations and targets' background) explains how targets are calculated for the different periods since they were first established.

Section 3 (Material) provides an analysis of the emission databases used in this exercise for both passenger cars and light commercial vehicles and the data cleaning procedure.

Section 4 (Calculation of the parameters for determining 2025 and 2030 targets) presents the calculation of the parameters relevant for defining the 2025 and 2030 target lines, in particular the EU fleet-wide $target_{2021}$ and the a_{2021} slope.

In the conclusions, the main outcomes of this work are presented.

1 Introduction

The transport sector contributes one-fourth of the greenhouse gas emissions in the European Union (EU) (European Environment Agency, 2022a), and it has shown the slowest carbon dioxide (CO_2) emission reduction pace among all the sectors of the economy (European Environment Agency, 2022b). To achieve climate neutrality by 2050, a 90% reduction of the transport sector's greenhouse emissions is needed, compared to 1990. Currently, approximately 15% of the total CO_2 emissions are attributed to passenger cars (M1 fleet) and light commercial vehicles (N1 fleet - vans) due to fossil fuels being their primary propulsion fuel (Wang et al., 2022). Hence, the EU needs to substantially reduce road vehicle CO_2 emissions to meet its commitments.

Until 2009, the essential measure addressing road transport CO_2 emissions in Europe was a voluntary agreement between the European Commission (EC) and the three major car manufacturer associations: European Automobile Manufacturers' Association (ACEA), Japan Automobile Manufacturers Association (JAMA) and Korea Automobile Manufacturers' Association (KAMA). This agreement set a target of 140 g/km in average CO_2 emissions from new passenger cars by 2008-2009. The failure to achieve this target revealed that more action was needed and in 2007, the EC proposed the first Regulation setting CO_2 targets for new passenger cars (European Commission, 2009). This Regulation was adopted by the European Parliament and the Council in 2009. The EU fleet-wide CO_2 target in the period 2015-2019 was 130 g /km. From 2020, the EU fleet-wide target was set at 95 g CO_2/km, and the implementation modalities for this target were adopted in 2014 (European Union, 2014a). CO_2 emission standards for new light commercial vehicles were first introduced in 2011 (European Union, 2011a), setting for 2017 a fleet-wide target of 175 g/km. The 2020 fleet target for light commercial vehicles was set to 147 g/km, with the implementation modalities agreed in 2014 (European Union, 2014b). All of the above target values are based on the New European Driving Cycle (NEDC). For determining the binding manufacturer targets, the EU fleet targets have to be adjusted to the average vehicle mass of the manufacturer's fleet.

To ensure the proper functioning of the emission performance standards, the Regulation requires Member States to record the technical characteristics of each new passenger car and van registered in their territory, including the specific CO_2 emissions. Since 2011, the European Environment Agency (EEA) keeps a central register of these data (European Environment Agency, 2023), which will be referred to in this report as the annual EU registrations monitoring datasets. On this basis, the Commission calculates the annual average CO_2 emissions and targets for all car and van manufacturers and assesses their compliance.

During the certification of the vehicles, their fuel consumption and CO_2 emissions are determined following a specific testing protocol that has evolved throughout the years under Regulation (EC) No 715/2007. Commission Regulation (EC) No 692/2008 set the NEDC (European Commission, 2007), originally designed in the 1970's, as the emission Type Approval procedure. However, as several studies showed (Fontaras et al., 2017; Tietge, 2019), there was a significant and increasing disparity between the (understated) NEDC official figures and the real-world CO_2 emissions, reaching almost 40% in 2017. The gap was attributed to the loose boundary conditions assumed in the official test (Pavlovic et al., 2020). In 2017, the new Worldwide harmonized Light vehicles Test Procedure (WLTP) was introduced in the EU via Regulation (EU) 2017/1151 (European Union, 2017a), substituting the outdated NEDC with the objective to provide a more robust test-basis that would better represent the actual on-road vehicle operation (Dornoff et al., 2020; Ktistakis et al., 2022). Among other significant differences, the WLTP includes a longer and more dynamic driving cycle than the NEDC, and consequently, the Cycle Energy Demand (CED) and the corresponding CO_2 emissions are expected to be higher. In WLTP, the Type Approval certification involves the definition of vehicle families, which are sets of vehicles with similar characteristics, which may share the same reference physical tests. The official emission values of each vehicle registered in the EU are derived from the Type Approval physical tests performed on reference vehicles of their family.

Regulation (EU) 2017/1151 established a transition period (2017-2020) during which the Certificate of Conformity (CoC) of the newly registered vehicles included both the WLTP emission values and the equivalent (verified with measurements or vehicle simulation) NEDC values (European Union, 2017b, 2017c). At the same time, it was ensured that from 2021 onwards the existing targets were translated into WLTP compatible values (Commission Delegated Regulations (EU) 2017/1502 (cars) and (EU) 2017/1499 (light commercial vehicles)). The targets were renormalized to reflect the increased CO_2 emissions under WLTP compared to NEDC. The NEDC-to-WLTP conversion factors were to be based on the manufacturer declared emissions of the vehicles registered in 2020.

The CO_2 emission standards for new passenger cars and light commercial vehicles were revised with the adoption in 2019 of Regulation (EU) 2019/631 (European Union, 2019), which replaced and repealed

Regulations (EC) No 443/2009 and (EU) No 510/2011. The new Regulation preserves the fundamentals of its predecessors, such as the methodology to calculate the manufacturer emission targets, the modalities for implementing them and the annual collection of monitoring data on the new EU vehicle registrations. It also maintains the target levels set for 2020 in NEDC terms, and specific WLTP-based targets for each manufacturer in the period 2021-2024. For passenger cars, new reduction targets of 15% and 37.5% were introduced for the years 2025 and 2030, respectively. These reductions are calculated based on a 2021 EU fleet-wide target, which is taking into account the *measured*-WLTP emissions for 2020 and the mass and registration figures of 2021. For light commercial vehicles, the new reduction targets set for 2025 and 2030 were 15% and 31%, respectively, using the same approach for calculating the 2021 EU fleet-wide target, which serves as the reference.

In 2023, Regulation (EU) 2019/631 was amended through Regulation (EU) 2023/851 (European Union, 2023), reflecting the EU's increased climate ambition for 2030 and 2050. The EU fleet-wide target levels for 2030 were tightened to 55% (passenger cars) and 50% (light commercial vehicles). The calculation method for determining those values remained unchanged. For 2035, a 100% reduction (i.e., 0 g/km) target was introduced for both passenger cars and light commercial vehicles.

The 2020 EU registrations monitoring dataset includes CO_2 emission values determined according to both the NEDC and WLTP. These data have been used so far for the following calculations, as reflected in Commission Implementing Decision (EU) 2022/2087 (European Union, 2022):

— The average NEDC 2020 CO_2 emission values for each manufacturer or pool of manufacturers, which had to be compared to the respective CO_2 emission targets for 2020 (either derived from the EU fleet-wide target or derogation targets).

— The ratios, per manufacturer or pool of manufacturers, between the average WLTP (2020) and NEDC (2020) emissions, which will be used for defining each manufacturer's 2021 WLTP *specific emissions reference target*, which in turn is the basis for defining the manufacturers' targets for the years 2021 until 2024 using the applicable mass corrections.

The main purpose of this report is to calculate the reference values$_{2021}$ and the EU fleet-wide target$_{2021}$ for both passenger cars and light commercial vehicles, which are the basis for determining the 2025 and 2030 EU fleet-wide reduction targets. As set out in point 6.0 of Annex I, part A (passenger cars) or B (light commercial vehicles) of Regulation (EU) 2019/631, the EU fleet-wide target$_{2021}$ is obtained by sales-weighting, with the number of new registrations in 2021, the reference values for each manufacturer or pool of manufacturers. These reference values are calculated by rescaling the 2020 fleet-wide CO_2 targets with the ratio between the 2020 average *measured* WLTP emissions and the 2020 average NEDC emissions of each manufacturer or pool of manufacturers.

One critical difference between the 2021 specific emissions targets (used to assess manufacturers' compliance) and the EU fleet-wide target$_{2021}$ (used as a reference for calculating the 2025 and 2030 fleet-wide targets) is that the first is determined using the manufacturers' *declared* WLTP CO_2 values in 2020, while the latter is based on the measured WLTP CO_2 values in 2020. The manufacturers were obliged to transmit those measured emission values to the EC according to the provisions of Regulations (EU) 2017/1153 (passenger cars) and (EU) 2017/1152 (light commercial vehicles). The use of the *measured* WLTP values guards against a potential artificial inflation of the WLTP declared values in 2020 and, thus, of the future targets.

The report provides a comprehensive description of the Regulation's provisions regarding the EU fleet CO_2 emissions calculation and the targets, separated in 4 sub-sections: pre-2020, 2020, 2021-2024 and 2025 onwards. Following that, the data sources are introduced, and the necessary data curation steps for applying the Regulation's provisions on the available data are detailed. In the results section, the datasets produced by the study team for passenger cars and light commercial vehicles are presented. Furthermore, insights about the composition of 2020 EU fleet are demonstrated. The final part of the results section presents the calculation of the parameters to determine the future 2025 and 2030 targets for both passenger cars and light commercial vehicles. These parameters are the *EU fleet-wide target$_{2021}$*, the parameter a_{2021} used to calculate the slope of the target lines from 2025 onwards and the indicative TM_0 value, taken as the average test mass of the vehicles in 2021. Finally, the main conclusions and future implications are summarised.

2 CO_2 emission calculations and targets' background

This section includes a glossary of some relevant terms. Then it describes how the certification of CO_2 emissions of individual vehicles evolved over the last two decades, and the evolution of the fleet targets, split in four chronological periods: before 2020, 2020, 2021-2024, and from 2025 onwards.

2.1 Glossary

In this section, a description of essential elements of the CO_2 certification procedure is provided, so that the reader has a better understanding of specific principles:

— *Chassis-dyno test (CDM test)*: A CDM refers to a test bench on top of which the vehicle is placed. It can simulate different road conditions within a controlled environment. This type of testing is used in the CO_2 certification process of light-duty vehicles. Depending on the protocol followed, specific rules need to be followed, such as the velocity profile, the temperature of the cell, and the vehicle pre-conditioning. The load transferred through the test-bench rollers to the vehicle's wheels changes according to the instantaneous vehicle speed and the Road Load (RL) coefficients. In this way, different resistances that apply during on-road driving can be simulated (e.g., air drag), as the vehicle follows the predefined speed profile.

— *Type Approval procedure*: The procedure whereby an approval authority certifies that a type of vehicle, system, component, or separate technical unit satisfies the relevant administrative provisions and technical requirements (Regulation (EU) 2018/858) (European Union, 2018). Concerning the CO_2 emissions, this report will refer to the NEDC and the WLTP Type Approval procedures set out under Regulation (EC) 715/2007.

— *Certificate of Conformity*: The document issued by the manufacturer which certifies that a produced vehicle conforms to the approved type of vehicle and complies with all regulatory acts that were applicable at the time of its production (Regulation (EU) 2018/858).

— *Road load*: The force resisting the forward motion of a vehicle as measured with the coast down method or methods that are equivalent regarding the inclusion of frictional losses of the drivetrain (Reg. (EU) 2017/1151).

— *Road load coefficients*: An essential part of the CDM testing is the insertion of the RL coefficients that will accurately replicate inside the laboratory the load a specific vehicle would realise according to its speed. According to the certification procedure, these coefficients are obtained in proving grounds, using a representative test vehicle. Several methodologies are described and used to obtain the RL coefficients (Komnos et al., 2021), with the most popular to be the coast down method: the vehicle is left to decelerate from a high speed (130 km/h for passenger cars). The times intervals the vehicle needs to decelerate through pre-specified speed bins are translated into forces, as function of the vehicle speed. The coefficients are produced by applying a second order fit in the pairs of (speed, forces).

— *Cycle energy demand (CED)*: Is the calculated positive energy required by the vehicle to drive the prescribed cycle (Reg. (EU) 2017/1151). It is calculated as the integral of the instantaneous positive motive power to overcome the vehicle inertia, the inclination, and the resistances opposing the vehicle movement (air drag, tyre rolling resistance, etc.) over a predefined velocity profile.

— *Actual mass*: The vehicle's mass in running order plus the mass of the fitted optional equipment to an individual vehicle (Reg. (EU) 2017/1151).

— *Mass in running order*: The mass of the vehicle, with its fuel tank(s) filled to at least 90 per cent of its or their capacity/capacities, including the mass of the driver, fuel and liquids, fitted with the standard equipment in accordance with the manufacturer's specifications and, when they are fitted, the mass of the bodywork, the cabin, the coupling and the spare wheel(s) as well as the tools (Reg. (EU) 2017/1151).

— *Mass representative of the vehicle load*: means x per cent of the maximum vehicle load where x is 15 per cent for category M vehicles and 28 per cent for category N vehicles (Reg. (EU) 2017/1151).

— *Maximum vehicle load*: The technically permissible maximum laden mass minus the mass in running order, 25 kg and the mass of the optional equipment (Reg. (EU) 2017/1151).

— *Mass of the optional equipment*: Maximum mass of the combinations of optional equipment which may be fitted to the vehicle in addition to the standard equipment in accordance with the manufacturer's specifications (Reg. (EU) 2017/1151).

— *Test mass*: Is the sum of the actual mass of the vehicle, 25 kg and the mass representative of the vehicle load (Reg. (EU) 2017/1151).

— *Measured* CO_2 *emissions value*: CO_2 emissions combined value as determined and reported in accordance with Article 7a of Implementing Regulation (EU) 2017/1153 for passenger cars and with Article 6a of Implementing Regulation (EU) 2017/1152 for light-commercial vehicles. Under the WLTP, Regulation (EU) 2017/1151, the measured CO_2 value includes the correction for the difference in the speed profile followed on the CDM test versus the theoretical speed profile (speed and distance correction), and for the difference in the electric energy flowing from and to the rechargeable electric energy storage system (REES). Furthermore, the test results are renormalised to the average European ambient temperature (14°C).

— *Declared* CO_2 *emissions value*: CO_2 emissions value declared by the manufacturer and stated in the Certificate of Conformity. According to Regulation (EU) 2017/1151, the declared value cannot be lower than the value measured (and corrected) in the Type Approval emission test.

— *WLTP specific emissions reference target*: Value calculated in accordance with Point 3 of Annex I, Part A and B, to Regulation (EU) 2019/631, as an intermediate to calculate the WLTP specific emissions targets for each manufacturer (or pool of manufacturers) for the calendar years 2021 to 2024.

— *WLTP specific emissions target*: CO_2 emissions target for the specific manufacturer, calculated in accordance with Points 4 (2021-2024) and 6.3 (2025 onwards) of Annex I, Part A and B, to Regulation (EU) 2019/631.

— *Reference-value*$_{2021}$: Value calculated for each manufacturer's (or pool of manufacturers) fleet in accordance with Point 6.0 of Annex I, Part A and B, to Regulation (EU) 2019/631, as an intermediate to calculate the EU fleet-wide target$_{2021}$.

— *EU fleet-wide target*$_{2021}$: Reference target value used to calculate the EU fleet-wide targets for 2025 and 2030, calculated in accordance with Point 6.0 of Annex I, Part A and B, to Regulation (EU) 2019/631.

— a_{2021}: The slope of the best fitting straight line established by applying the linear squares fitting method to the test mass (independent variable) and the specific emissions of CO_2 (dependent variable) of each new vehicle registered in 2021.

2.2 Type Approval CO_2 calculation

Every car or light commercial vehicle of the EU fleet is assigned CO_2 emissions and fuel consumption values following a specific certification process, as established in Regulation (EC) 715/2007. Until 2017, the process was performed following the NEDC protocol detailed in Regulation (EC) 692/2008 (NEDC) (European Union, 2011b), where a physical CDM test was carried out on a representative parent vehicle. The final CO_2 emissions value declared by the manufacturer could be extended to vehicles with up to 4% higher CO_2 emissions, resulting to CO_2 values biased towards lower values by a factor ranging from 0-4% (Fontaras et al., 2017). Several procedural flexibilities and instrumentation tolerances allowed during the tests led to non-representative lower declared CO_2 values (Tietge et al., 2017). For example, the vehicle RL coefficients applied during the CDM test were obtained in optimised conditions, while the mass attributed to the vehicle was lower than the one occurring in actual operation, even considering a single driver occupancy (Fontaras et al., 2017). These lower declared values could be extended to vehicles sharing similar powertrain characteristics belonging to the same family. Thus, the same low values were assigned to many of the model variants in the family.

Since 2017, the transition from NEDC to the WLTP test protocol has led to a significant improvement of the situation. The introduction of the CO_2 Interpolation (IP) family allowed the attribution of vehicle-specific CO_2 values for each individual model. Under WLTP, manufacturers can group their vehicles into IP families, which include vehicles with the same technical powertrain characteristics (European Union, 2017a). Vehicle variants belonging to the same IP family may differ in terms of mass, optional equipment and body shape, tyre dimensions and tyre energy class, which affect the vehicle resistances and energy demand over the WLTP, but do not directly influence powertrain efficiency. These vehicle resistances determine the cycle energy demand (CED). For the same speed profile, changes in the CED among the members of the same IP family have a linear impact on CO_2 emissions. Consequently, each IP family is characterised by a linear function of CO_2 with respect to CED. This linear relationship is determined by testing two vehicle variants: the variants for which the equipment combination results in the highest (vehicle-High) and lowest (vehicle-Low) CED. Optionally, the manufacturers can characterise all the vehicles in the family with the CO_2 value of vehicle-High.

Regarding the vehicle motion resistances, referred to as RL, two enhancements in WLTP resulted in values more representative of real-world conditions. Firstly, the mass of the vehicle used is the "test mass", as defined in Regulation (EU) 2017/1151, which is higher and more representative of the real-world operation than the equivalent NEDC mass since it takes into account optional equipment fitted to the vehicle and the vehicle payload. Secondly, similarly to IP families, RL families are constructed, and RL determination tests are performed for the variants with highest and lowest CED. The CED of individual vehicles are determined by linear interpolation of the vehicle-High and -Low. It should be noted that the members of the IP families and RL families may overlap but are not necessarily the same; hence an IP family may contain members of several RL families.

Thus, according to the specifications and CED value of the individual vehicle, the WLTP-based certification results in a unique CO_2 value for each vehicle. **Figure 1**(a) shows a graphical representation of the procedure for determining the WLTP and NEDC CO_2 emission values. The procedures can be summarised as follows:

Step 1. At least one CDM test is performed for vehicle-High according to WLTP. If no other test is performed, the same vehicle-High CO_2 value applies to all members of the IP family. In most cases, manufacturers also test vehicle-Low, and the IP line is established. The measured CO_2 values (blue line in **Figure 1**(a)) include the necessary corrections according to the WLTP provisions.

Step 2. The manufacturer needs to declare a WLTP CO_2 value for vehicle-High, and vehicle-Low that is equal or higher than the measured values (corrections applied) of the tests performed plus a margin for the test uncertainty. The margin is 1% in case of one single test performed and it is reduced to 0% in case of three tests. A new line for the IP family declared CO_2 is formed (red line in **Figure 1**(a)).

Step 3. The manufacturer registers the individual vehicles that will be sold in the EU, assigning to each vehicle a declared CO_2 value that is calculated from a linear interpolation formula between vehicle-Low and vehicle-High declared values and the specific CED of the vehicle (open red square in **Figure 1**(a)). These are the CO_2 emission values included in the annual monitoring databases.

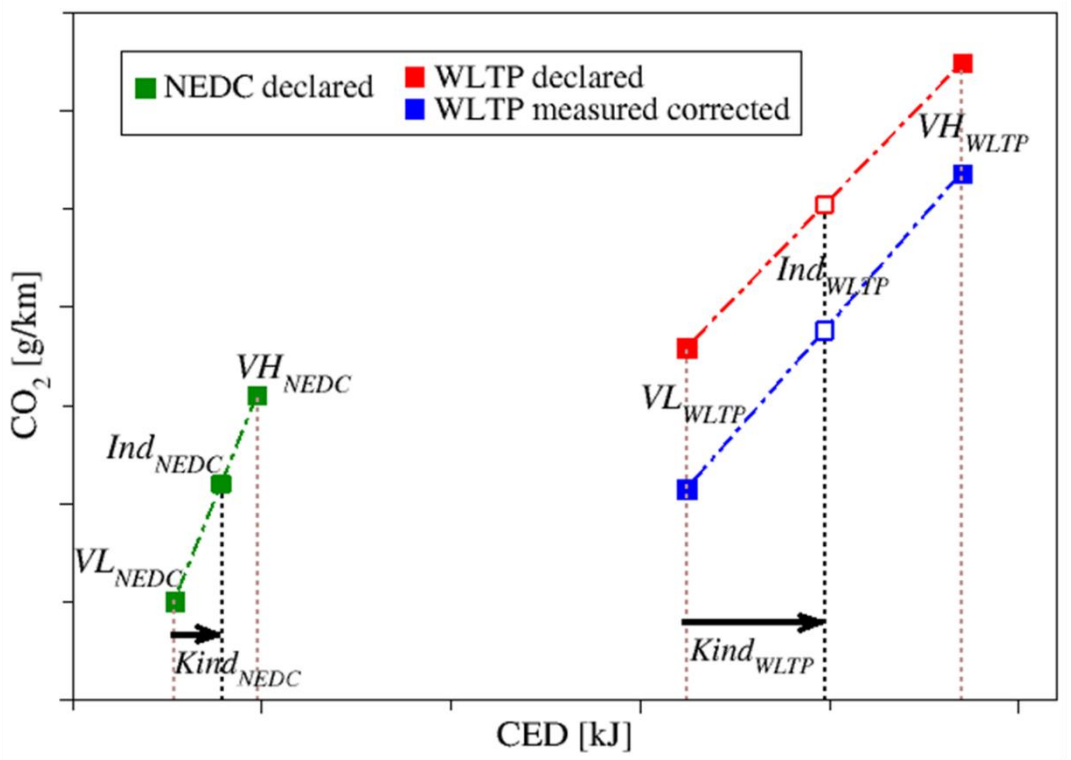
Step 4. Only for the year 2020, the manufacturer calculates the measured CO_2 emission value for the individual vehicle (open blue square in **Figure 1**(a)) using the same CED as in Step 3 and a linear interpolation procedure from the measured CO_2 values of vehicle-Low and vehicle-High. The procedure is established in the correlation provisions of Regulation (EU) 2017/1153 for passenger cars and Regulation (EU) 2017/1152 for light-commercial vehicles. The individual measured values, together with the measured values of vehicle-High (and vehicle-Low), are submitted to the EC.

Correlation steps (period 2017-2020). For the period 2017-2020, the WLTP certification method applied for defining both RL and CO_2 IP families. However, the correlation Regulations (EU) 2017/1153 and (EU) 2017/1152 set provisions for determining the correlated NEDC CO_2 values. First, the individual vehicles would get a CED for NEDC derived from the WLTP CED. The NEDC declared CO_2 value of the individual vehicle (white-filled green square in Figure 1) was derived from the interpolation line defined from the NEDC vehicle-High and vehicle-Low values (green line in **Figure 1**(a)).

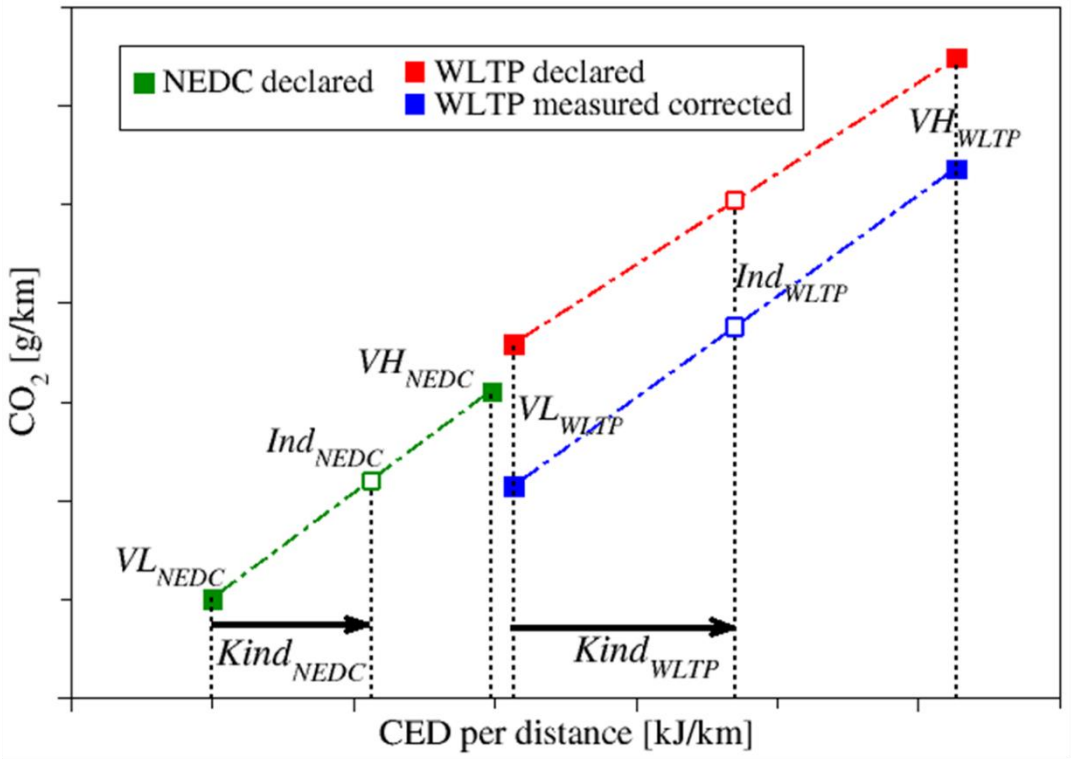
To reduce the cost of both physically testing under WLTP and NEDC while assuring the stringency of the out coming estimates, the option was provided to undertake the verification of the NEDC declared CO_2 values for the high- and low-variants by using the CO2MPAS (CO_2 Model for Passenger and commercial vehicles Simulation) vehicle simulation tool provided by the EC (Fontaras et al., 2018). CO2MPAS performs accurate simulation of vehicle fuel-consumption and CO_2 emissions under different operating conditions using mainly physical models.

Figure 1. Example case of construction of vehicle families in the transition period from 2017 to 2020, both for WLTP and NEDC cases, representing: (a) CO_2 emissions versus CED; (b) CO_2 emissions versus CED normalised to distance. The steps are detailed in section 2.2. The labels denote the CED of the Vehicle-Low, Vehicle-High and Individual vehicle for NEDC and WLTP. Black arrows represent the interpolation factors ($Kind_{NEDC}$ and $Kind_{WLTP}$) for each procedure.

(a)



(b)



Source: JRC analysis, 2023

It should be noted that, for the construction of a CO_2 IP family from low and high CO_2 values, certain restrictions are defined: an IP family should have a range of CO_2 values between 5 g/km and 30 g/km (which means that the vehicle-High CO_2 should be at least 5 g/km higher than the vehicle-Low CO_2). Due to the lower limit, but also

at the manufacturer's request, a CO_2 family could consist of only one vehicle, with no intermediate variants, and thus no interpolation line; in such a case, the configuration type approved is defined as the vehicle-High, and all the different variants sold in Europe will share the same CO_2 emissions value.

Figure 1 shows an example of realistic WLTP and NEDC values for the family and the individual vehicle. While the WLTP declared and measured (corrected) interpolation lines shown in the upper panel encompass the same CED range, the NEDC interpolation line spans a different energy domain, significantly lower than the WLTP one. The shorter length of the NEDC cycle (11 km against the 23.25 km in WLTP) only partially explains the difference in the energy required to move the vehicle. In the distance-normalised representation of the CED (**Figure 1**(b)), the abscissae of the NEDC line are still lower than for the WLTP, this is a consequence of the more favourable or loose RLs testing conditions in NEDC. For the same reason, the depicted interpolation factors $Kind_{NEDC}$ and $Kind_{WLTP}$, corresponding to the normalised energy distance of the individual vehicle, are not necessarily equal in both cases. In contrast, the slope of the interpolation lines in the distance-normalised CED representation is very similar in both three cases, since the slope represents the engine's efficiency, which is similar in both WLTP and NEDC tests.

2.3 Definition of CO_2 targets

The Commission determines each year the average specific CO_2 emissions and the CO_2 emissions targets for every manufacturer and pool of manufacturers responsible for new passenger cars and light commercial vehicles registered in the EU (including the UK up to 2020), Iceland (since 2018) and Norway (since 2019) in order to assess compliance.

2.3.1 Targets for passenger cars and light commercial vehicles before 2020

Regulation (EC) No 443/2009 defined the first fleet CO_2 targets for the new passenger cars registered in the EU each calendar year (European Commission, 2009). For the period 2012-2019, the EU fleet-wide target was 130 g CO_2/km. Acknowledging the diversity in the market, the manufacturers' annual CO_2 emissions targets were defined based on the average mass of the vehicles in their fleet during the target year (see points 1 and 2 of Annex I in Regulation (EC) No 443/2009):

2012-2019:
$$target_{m_i,NEDC}^{(yy)} = 130 + a\left(M_i^{(yy)} - M_0^{(yy)}\right) \quad (1)$$

where:

yy is the year (2012-2019);

$a = 0.0457$;

$M_i^{(yy)}$ is the average mass in running order of all passenger cars of manufacturer i in kg in the year yy;

$M_0^{(yy)}$ is the EU-fleet average mass value a priori defined in the Regulation for the year yy.

For each manufacturer or pool of manufacturers, the average CO_2 emissions obtained during NEDC Type Approval procedures were assessed against the target values $target_{m_i,NEDC}^{(yy)}$. In order to support a smooth transitional period between 2012-2015 to meet the 2015 target of 130 g/km, phase-in, super-credits, pooling, eco-innovations and derogations provisions were introduced in the Regulation.

For light-commercial vehicles, Regulation (EU) No 510/2011 set target values for manufacturers for the years 2014 to 2019 according to:

2014-2019:
$$target_{m_i,NEDC}^{(yy)} = 175 + a\left(M_i^{(yy)} - M_0^{(yy)}\right) \quad (2)$$

where:

yy is the year (2014-2019);

$a = 0.093$;

$M_i^{(yy)}$ is the average mass in running order of all light commercial vehicles of manufacturer i in kg in the year yy;

$M_0^{(yy)}$ is the EU-fleet average mass value a priori defined in the Regulation for the year yy.

2.3.2 2020 targets for passenger cars and light commercial vehicles

Regulation (EC) No 443/2009 also set an EU fleet-wide target of 95 g CO_2/km for passenger cars from 2020 onwards. Through the amendments introduced by Regulation (EU) No 333/2014, this target was confirmed, and its implementation modalities were introduced (see below). Compared to the previous period, the slope of the mass-based limit value curve was lowered from 0.0457 to 0.0333 in order to account for the lower fleet target (reduction by 27%). It should also be noted that 2020 was the last year in which the target assessment was performed with respect to the NEDC protocol.

2020: $$\text{Specific emissions target [g/km]} = (95 + 0.0333 \cdot (M_i - 1379.88)) \quad (3)$$

where:

M_i is the average mass in running order of all passenger cars of manufacturer i in kg in 2020.

Similarly, Regulation (EU) No 510/2011 set an EU fleet-wide target value of 147 g CO_2/km for 2020 for light-commercial vehicles, with the formula to calculate the manufacturer's specific emission targets:

2020: $$\text{Specific emissions target [g/km]} = (147 + 0.096 \cdot (M_i - 1766.4)) \quad (4)$$

The evaluation of the manufacturers' performance is achieved by assessing the average specific emissions of CO_2 against the targets defined in eq. (3) for passenger cars and eq. (4) for light commercial vehicles. The calculation methodology for the average specific emissions is illustrated in Commission Notice C/2017/3563 ("Guidance on the monitoring and reporting of data on new light-duty vehicles") (European Commission, 2017), and the results for the 2020 monitoring exercise have been adopted and published (European Union, 2022).

A number of provisions have been introduced in Regulations (EC) No 443/2009 and (EU) 510/2011 to facilitate the implementation of the manufacturer targets from 2020 (and these were maintained under Regulation (EU) 2019/631:

1. Phase-in (2020 only, passenger cars only): For the purpose of evaluating the average specific CO_2 emissions of each car manufacturer, only 95% of the manufacturer's 2020-registered passenger cars – those with the lowest CO_2 emission levels - are considered (Article 4(3), Regulation (EU) 2019/631).
2. Super-credits (2020-2022, passenger cars only): Every new passenger car with NEDC emissions below 50 g CO_2/km is counted more than once for the purpose of calculating the manufacturer's average specific CO_2 emissions, with a maximum emission reduction of 7.5 g CO_2/km per manufacturer over the period 2020-2022. For 2020, the multiplier was 2 (1.66 in 2021 and 1.33 in 2022). (Article 5, Regulation (EU) 2019/631).
3. Pooling: Manufacturers can form pools of manufacturers to jointly achieve the targets of each calendar year (Article 6, Regulation (EU) 2019/631).
4. Eco-innovations: CO_2 savings (by reference to the NEDC until 2020) accomplished by using innovative technologies that make a verified/approved CO_2 reduction in real world are deducted (up to a total contribution of 7 g/km) during the calculation of the manufacturer's (pool's) average CO_2 emissions. (Article 11, Regulation (EU) 2019/631)
5. Derogations: Manufacturers (or pools) responsible for less than 10,000 new passenger car or light commercial vehicles registrations can apply for a "small volume" **derogation**. Manufacturers (or pools) with between 10,000 and 300,000 new passenger cars registered in the Union per calendar year can apply for a **niche derogation**. Specific derogation targets are established for each case. (Article 10, Regulation (EU) 2019/631)
6. Exemptions: Manufacturers with less than 1,000 registrations in the **previous** calendar year are **exempted** from the targets. However, it should be noted that if a manufacturer is granted a derogation, it should comply with its **derogation target** even if it would be eligible for the exemption.

2.3.3 2021-2024 targets for passenger cars and light commercial vehicles

Passenger cars and light commercial vehicles registered from 2021 onwards are type approved under the WLTP. The manufacturer's emission targets for the period 2021-2024 are established on the WLTP procedure, by renormalizing the NEDC manufacturer-specific targets with ratios calculated from the average (declared) WLTP and NEDC emissions of the manufacturer in 2020. In other words, to account for the higher CO_2 emissions in the WLTP cycle compared to NEDC, the WLTP-based emissions targets are proportionally increased. The same procedure, described below, applies for both passenger cars and light commercial vehicles.

First, Regulation (EU) 2019/631 establishes a 2021 WLTP specific emissions reference target for each manufacturer (see point 3 of Annex I):

2021-2024:
$$\mathrm{ref}_{m_j,\mathrm{WLTP}}^{(2021)} = \frac{WLTP_{m_j}^{(2020)}}{NEDC_{m_j}^{(2020)}} \cdot \mathrm{target}_{m_j,\mathrm{NEDC}}^{(2020)} \quad (5)$$

where:

$\mathrm{target}_{m_j,\mathrm{NEDC}}^{(2020)}$ is m_j manufacturer's specific emissions target 2020, as defined in equations (3) and (4);

$WLTP_{m_j}^{(2020)}$ is the average WLTP CO_2 emission value of m_j manufacturer's 2020 fleet;

$NEDC_{m_j}^{(2020)}$ is the average NEDC CO_2 emission value of m_j manufacturer's 2020 fleet.

For cases where the above approach is not applicable, specific rules are set out in points 3a-3c of Annex I of Regulation (EU) 2019/631.

The 2021 WLTP specific emissions reference targets have been calculated by the Commission and are set out in Annex II of Commission Implementing Decision (EU) 2022/2087 (European Union, 2022).

Then, the 2021-2024 targets per manufacturer are calculated by adjusting the specific emissions reference targets taking into account the deviations of the manufacturer's average mass from the EU-fleet average mass in 2020 and in the target year (see point 4 of Annex I to Regulation (EU) 2019/631):

2021-2024:
$$\mathrm{target}_{m_j,\mathrm{WLTP}}^{(yy)} = \mathrm{ref}_{m_j,\mathrm{WLTP}}^{(2021)} + a\left[\left(M_{m_j}^{(yy)} - M_0^{(yy)}\right) - \left(M_{m_j}^{(2020)} - M_0^{(2020)}\right)\right] \quad (6)$$

where:

yy is the year (2021, 2022, 2023, 2024);

a is 0.0333 for passenger cars; and 0.096 for light commercial vehicles;

$M_{m_j}^{(yy)}$ is the average mass in running order of the manufacturer's vehicles in the yy year;

$M_0^{(yy)}$ is 1,379.88 in 2021 and 1,398.50 in 2022, 2023 and 2024 for passenger cars;

and 1,825.23 in 2021, 2022 and 2023 and 1,875.07 in 2024 for light commercial vehicles.

$M_{m_j}^{(2020)}$ is the average mass in running order of manufacturer m_j in 2020;

$M_0^{(2020)}$ is 1,379.88 for passenger cars and 1,766.4 for light commercial vehicles.

For manufacturers (same applies for pools) that have been granted a (NEDC based) derogation target in 2021, that year's target is calculated as follows (see point 5 of Annex I to Regulation (EU) 2019/631):

2021-2024:
$$\mathrm{target}_{m_j,\mathrm{WLTP}}^{(yy)} = \frac{WLTP_{m_j}^{(2020)}}{NEDC_{m_j}^{(2020)}} \cdot \mathrm{target}_{m_j}^{(2021),\mathrm{spec}} \quad (7)$$

where:

yy is the year (2021, 2022, 2023, 2024);

$WLTP_{m_j}^{(2020)}$ and $NEDC_{m_j}^{(2020)}$ are defined in eq. (5);

$\text{target}_{m_j}^{(2021),\text{spec}}$ is the derogation target 2021 (NEDC) granted by the Commission.

2.3.4 2025 onward targets

Regulation (EU) 2019/631 introduced new fleet-wide targets for 2025 and 2030, which are determined applying reduction percentages to the 2021 emission targets. For 2025, the reduction will be 15% for passenger cars and light commercial vehicles, while for 2030, following the amendments introduced by Regulation (EU) 2023/851, the reduction will be 55% and 50%, respectively.

As the new targets were adopted at a time when the NEDC-to-WLTP transition was still ongoing, it was necessary to provide for a translation of the NEDC based 2021 targets into WLTP. For this, a similar approach as used for the 2021-2024 targets was applied. However, in order to guard against an over-inflation in the (WLTP/NEDC) ratio, Regulation (EU) 2019/631 requires the use of the *measured*, instead of the declared, 2020 WLTP values for calculating the 2021 fleet target and the corresponding 2025-onwards targets. Since the measured values are by mandate lower than the declared ones, this should result in lower EU fleet-wide target values when compared to a calculation based on declared WLTP values.

1. Calculation of the EU fleet-wide targets

   (a) A specific reference value ($\text{ref}_{m_i,\text{WLTP}_{\text{meas}}}^{(2021)}$) is calculated for each manufacturer mi, based on its 2020 CO_2 emissions (the declared NEDC and the measured WLTP values) and the 2021 average mass in running order (see *point 6.0 of Annex I, Part A in Regulation (EU) 2019/631*):

$$\text{ref}_{m_i,\text{WLTP}_{\text{meas}}}^{(2021)} = \frac{WLTP_{m_i}^{(2020),\text{meas}}}{NEDC_{m_i}^{(2020)}} \cdot \text{target}_{EU-fleet,\text{NEDC}}^{(2020)} + \text{a}\left(M_{m_i}^{(2021)} - M_0^{(2021)}\right) \quad (8)$$

   where:

   $a = 0.0333$ for passenger cars and 0.096 for light commercial vehicles;

   $\text{target}_{EU-fleet,\text{NEDC}}^{(2020)}$ is 95 g/km for passenger cars; and 147 g/km for light commercial vehicles;

   $M_{m_i}^{(2021)}$ is the average mass in running order of the manufacturer's vehicles in 2021;

   $M_0^{(2021)}$ is the average mass in running order of all new passenger cars (or light commercial vehicles) registered in 2021, excluding the manufacturers benefiting from an exemption or derogation in 2021;

   $NEDC_{m_i}^{(2020)}$ is as defined in eq. (5), section 2.3.3;

   $WLTP_{m_i}^{(2020),\text{meas}}$ is the average **measured** WLTP CO_2 emissions for each manufacturer.

   (b) The **EU fleet-wide target$_{2021}$** $\left(\text{ref}_{EU-fleet,\text{WLTP}_{\text{meas}}}^{(2021)}\right)$, which is the reference for calculating the 2025 and 2030 EU fleet-wide targets, is then calculated as the weighted average of the above reference values in eq. (8). The weighting is based on the 2021 number of registrations of each manufacturer ($w_{m_i}^{(2021)}$) – again excluding the manufacturers benefiting from an exemption or derogation in 2021 (see *point 6.0 of Annex I, Part A in Regulation (EU) 2019/631*).

   As the manufacturers included are the same as the ones used for the calculation of the average mass ($M_0^{(2021)}$), this value is independent of the mass of the vehicles and the EU fleet-wide target$_{2021}$ becomes:

$$\begin{aligned} \text{ref}_{EU-fleet,\text{WLTP}_{\text{meas}}}^{(2021)} &= \sum_{m_i} w_{m_i}^{(2021)} \text{ref}_{m_i,\text{WLTP}_{\text{meas}}}^{(2021)} \\ &= \sum_{m_i} w_{m_i}^{(2021)} \frac{WLTP_{m_i}^{(2020),\text{meas}}}{NEDC_{m_i}^{(2020)}} \cdot \text{target}_{EU-fleet,\text{NEDC}}^{(2020)} \end{aligned} \quad (9)$$

(c) The **EU fleet-wide targets** from 2025 onwards (*point 6.1 of Annex I, Part A in Reg. (EU) 2019/631*) are then calculated by applying the reduction factors to the EU fleet-wide target_{2021}.

For years 2025 to 2029:

2025-2029: $$\text{target}^{(yy)}_{EU-fleet,\text{WLTP}} = \text{ref}^{(2021)}_{EU-fleet,\text{WLTP}_{\text{meas}}} \cdot \left(1 - r_{(2025)}\right) \quad (10)$$

where the reduction factor is 15% ($r_{(2025)} = 0.15$) for both passenger cars and light commercial vehicles.

From 2030 onwards:

2030-2034: $$\text{target}^{(yy)}_{EU-fleet,\text{WLTP}} = \text{ref}^{(2021)}_{EU-fleet,\text{WLTP}_{\text{meas}}} \cdot \left(1 - r_{(2030)}\right) \quad (11)$$

where the reduction is 55% ($r_{(2030)} = 0.55$) for passenger cars and 50% ($r_{(2030)} = 0.5$) for light commercial vehicles (Regulation (EU) 2023/851.

2. Calculation of M1 manufacturer specific targets

(a) **Specific emissions reference targets** for the M1 manufacturers are calculated based on a linear correlation with the average *test mass* of the manufacturer's fleet and the CO_2 emissions reference targets. From 2025 to 2029, the manufacturer's reference targets are:

2025-2029: $$\text{ref}^{(yy)}_{m_i,\text{WLTP}} = \text{target}^{(2025)}_{EU-fleet,\text{WLTP}} + \text{a}_{2025}\left(TM^{(yy)}_{m_i} - TM^{(yy)}_{0}\right) \quad (12)$$

and for 2030 to 2034:

2030-2034: $$\text{ref}^{(yy)}_{m_i,\text{WLTP}} = \text{target}^{(2030)}_{EU-fleet,\text{WLTP}} + \text{a}_{2030}\left(TM^{(yy)}_{m_i} - TM^{(yy)}_{0}\right) \quad (13)$$

where:

$TM^{(yy)}_{m_i}$ is the average **test mass** of all new passenger cars of the manufacturer registered in year yy

$TM^{(yy)}_{0}$ is the EU-fleet average reference test mass (in kg), which shall be determined in accordance with point *d,* Article 14(1) of Regulation (EU) 2019/631.

The parameters a_{2025} and a_{2030} employed in eq. (12) and (13), respectively, are the slope of the lines used for determining the manufacturer's specific reference target according to the manufacturer's fleet-averaged test mass. These parameters are obtained from the slope (a_{2021}) of the best fitting linear regression in the CO_2 versus test mass representation of all the M1 vehicles registered in 2021, renormalised with the ratio between the 2025 and 2030 fleet-wide targets, respectively, and the average CO_2 emissions of M1 vehicles in registered in 2021 from non-derogated manufacturers:

$$\text{a}_{yy} = \text{a}_{2021}\frac{\text{target}^{(yy)}_{EU-fleet,\text{WLTP}}}{\text{CO}_2{}^{(2021)}_{EU-fleet,\text{WTLP}}} \quad (14)$$

where:

$\text{CO}_2{}^{(2021)}_{EU-fleet,\text{WTLP}}$ is the average emissions of the EU-fleet in 2021, excluding the manufacturers benefiting from an exemption or derogation in 2021 (see point 6.2 of Annex I, Part A in Regulation (EU) 2019/631).

a_{2021} is the slope of the best fitting straight line for the CO_2 emissions versus test mass representation obtained for the whole EU fleet registered in 2021.

(b) Finally, the **specific emissions targets** are calculated taking into account until 2029 a *ZLEV factor*, which reflects the share of zero- and low-emission vehicles in a manufacturer's fleet, as:

2025-2029:
$$\text{target}_{m_i,\text{WLTP}}^{(yy)} = \text{ref}_{m_i,\text{WLTP}}^{(yy)} \cdot ZLEV_{m_i}^{(yy)} \quad (15)$$

2030-2034:
$$\text{target}_{m_i,\text{WLTP}}^{(yy)} = \text{ref}_{m_i,\text{WLTP}}^{(yy)} \quad (16)$$

where:

$ZLEV_{m_i}^{(yy)}$ is a factor ranging from 1.00 to 1.05 introduced to increase the targets according to the percentage of zero- and low-emission vehicles in the manufacturer's fleet in case that exceeds the benchmark values set in the Regulation (see *Point 6.3*, *Annex I, part A, Regulation (EU) 2019/631)*.

3. Calculation of N1 manufacturer specific targets

(a) **Specific emissions reference targets** for the N1 manufacturers are calculated based on a similar correlation with the average *test mass* of the manufacturer's fleet and the CO_2 emissions reference targets. However, the values are now calculated based on a regression formula with two different slopes below and above the fleet-wide average mass $TM_0^{(yy)}$, respectively.

From 2025 to 2029, the manufacturer's specific reference targets are:

$$\text{ref}_{m_i,\text{WLTP}}^{(yy)} = \text{target}_{EU-fleet,\text{WLTP}}^{(2025)} + \alpha_{\text{yy}}\left(TM_{m_i}^{(yy)} - TM_0^{(yy)}\right) \quad (17)$$

$$\text{with } \alpha_{yy} = \begin{cases} \text{a}_{2025} \; for \; TM_{m_i}^{(yy)} \leq TM_0^{(yy)} \\ \text{a}_{2021} \; for \; TM_{m_i}^{(yy)} > TM_0^{(yy)} \end{cases} \quad (18)$$

and for 2030 to 2034:

$$\text{ref}_{m_i,\text{WLTP}}^{(yy)} = \text{target}_{EU-fleet,\text{WLTP}}^{(2025)} + \alpha_{\text{yy}}\left(TM_{m_i}^{(yy)} - TM_0^{(yy)}\right) \quad (19)$$

$$\text{with } \alpha_{yy} = \begin{cases} \text{a}_{2025} \; for \; TM_{m_i}^{(yy)} \leq TM_0^{(yy)} \\ \text{a}_{2021} \; for \; TM_{m_i}^{(yy)} > TM_0^{(yy)} \end{cases} \quad (20)$$

where:

$TM_{m_i}^{(yy)}$ is the average **test mass** of all new light commercial vehicles of the manufacturer registered in year yy

$TM_0^{(yy)}$ is the EU-fleet average reference test mass (in kg), which shall be determined in accordance with point *d,* Article 14(1) of Regulation (EU) 2019/631.

a_{2025} and a_{2030} are calculated as explained in eq. (14), with the corresponding values referring to N1 vehicles.

(b) Finally, the **specific emissions targets** are calculated taking into account until 2029 a *ZLEV factor*, which reflects the share of zero- and low-emission vehicles in a manufacturer's fleet and a parameter $\Phi_{\text{targets}}^{(yy)}$, which is introduced as a safe-guard to ensure that the average value of the specific emissions reference targets coincides with the EU fleet-wide target, as:

2025-2029:
$$\text{target}_{m_i,\text{WLTP}}^{(yy)} = \left(\text{ref}_{m_i,\text{WLTP}}^{(yy)} - \left(\Phi_{\text{targets}}^{(yy)} - \text{target}_{EU-fleet,\text{WLTP}}^{(yy)}\right)\right) \cdot ZLEV_{m_i}^{(yy)} \quad (21)$$

2030-2034:
$$\text{target}_{m_i,\text{WLTP}}^{(yy)} = \text{ref}_{m_i,\text{WLTP}}^{(yy)} - \left(\Phi_{\text{targets}}^{(yy)} - \text{target}_{EU-fleet,\text{WLTP}}^{(yy)}\right) \quad (22)$$

where:

$ZLEV_{m_i}^{(yy)}$ is a factor ranging from 1.00 to 1.05 introduced to increase the targets according to the percentage of zero- and low-emission vehicles in the manufacturer's fleet in case that exceeds the benchmark values set in the Regulation (see *Point 6.3*, *Annex I, part B, Regulation (EU) 2019/631)*.

$\Phi_{\text{targets}}^{(yy)}$ is the average, weighted by the number of light commercial vehicles of each manufacturer, of all the specific emissions reference targets determined according to eq. (17) for the year (yy) in the period [2025,2029] and eq. (19) for the year (yy) in the period [2030,2034].

3 Material

This chapter introduces the data sources used in the present analysis and the data cleaning performed. Manufacturers and their corresponding pools have been assigned with an acronym that will be used in the following sections. The correlation between the manufacturer names and the acronyms can be found in **Table 5** and **Table 7** of Annex 2, for passenger cars and light commercial vehicles, respectively.

3.1 Data sources

The main datasets considered in the present study have been collected by the EEA on behalf of the EC, according to Regulations (EU) 2019/631 and (EU) 2021/392. First, this concerns the official EU registration datasets collected and published by EEA for the years 2020 and 2021, hereafter called **EEA monitoring datasets** (European Environment Agency, 2023). The **2020 EEA measured WLTP dataset**, as provided by EEA, contains the measured WLTP values of the vehicles registered in 2020, which have to be combined with the 2020 EEA monitoring data for calculating the EU fleet-wide $target_{2021}$ and the 2025 and 2030 EU fleet-wide emission targets. The **Database for In-service verification of CO_2 Emissions (DICE)** which incorporates Type Approval information per CO_2 IP family, as provided by the Type Approval Authorities (TAAs), and the **European Type Approval Exchange System (ETAES)** were utilised to supplement these datasets.

3.1.1 EEA monitoring datasets

Regulation (EU) 2019/631 sets the requirements for collecting every calendar year information on each light-duty vehicle registered in EU. The EEA operates the central register that collects all the data from each Member State. The dataset contains information about the CO_2 emissions from each vehicle (NEDC until 2017, both NEDC and WLTP for the period 2017-2020, and only WLTP from 2021 onwards), as well as other relevant information about the vehicle's specifications and the Type Approval information. Further details about the published data can be found in the dedicated EEA webpage (European Environment Agency, 2023); details of the available variables can be found in **Table 4** of Annex 1.

Additionally, for the calculation of the EU fleet-wide $target_{2021}$ and the fleet targets from 2025 onwards, an extended 2020 dataset including also the WLTP measured CO_2 emissions was used. This dataset, the **2020 EEA measured WLTP dataset**, is filled according to the specifications in (EU) 2017/1153 for passenger cars and (EU) 2017/1152 for light commercial vehicles: For the calendar year 2020, manufacturers had to calculate the combined or, for plug-in-hybrid vehicles, weighted combined CO_2 emissions for each new passenger car and van registered, and submit all these values to Commission. In more detail, the reported information had to contain:

— **VIN**: Vehicle Identification Number, as specified in the CoC.

— **MC02**: Measured CO_2 emissions value [g/km] (including corrections) for the individual vehicle, calculated according to the WLTP procedure (see Step 4 in section 2.2).

— **MC02VL**: (where applicable) Measured CO_2 emissions value [g/km] (including corrections) according to the WLTP test for the vehicle-Low of the IP family.

— **MC02VH**: Measured CO_2 emissions value [g/km] (including corrections) according to the WLTP test for the vehicle-High of the IP Family.

— **Kind**: (for Off Vehicle Charging Hybrid Electric Vehicles (OVC-HEVs, i.e., plug-in hybrid electric vehicles) - and Not Off Vehicle Charging hybrid electric vehicles (NOVC-HEV)) Interpolation Factor for the Cycle Energy Demand

The 2020 EEA monitoring and the 2020 EEA measured WLTP datasets were combined to produce the **EEA combined 2020 datasets,** detailed in 3.2 (passenger cars) and in 3.3 (light commercial vehicles), used to calculate the parameter EU fleet-wide $target_{2021}$.

3.1.2 DICE dataset

During the Type Approval transition period from NEDC to WLTP (from September 2017 to the end of 2020), the EC implemented a correlation framework to monitor the compliance of the manufacturer's average CO_2 emissions with the NEDC-based targets. In this way, for each vehicle, the WLTP-CO_2 emission values were translated into equivalent NEDC levels, either on the basis of duplicate measurements or by using a vehicle

simulation tool (Fontaras et al., 2018) specifically developed for the purpose of this correlation exercise. By collecting the input and output data of this schema, a database was created that contains, for each CO_2 IP family, the Type Approval data for the vehicles with highest energy demand (vehicle-High) and, where applicable, lowest energy demand (vehicle-Low) including:

— General information on vehicle characteristics.

— Relevant recordings during the WLTP CDM tests (Type 1 test in Regulation (EU) 2017/1151).

— Measured CO_2 emissions (before and after corrections) during WLTP test.

— Declared WLTP and NEDC CO_2 values.

These data are safely encrypted and stored in DICE for every new IP family. When an IP family CO_2 extension was performed according to the certification Regulation, or when a correction was needed in the Type Approval documentation, the DICE database was also updated.

3.1.3 ETAES dataset

The ETAES is an electronic platform that contains Type Approval documents from different Member States, as reported by the corresponding Granting Type Approval Authority and/or the Technical Service. This platform was established in Regulation (EU) 2020/1812 (European Union, 2020), laying down rules on the notification of EU Type Approvals, as the common secure electronic exchange system for the purposes of notifying EU type Approvals. The submission of documents to this platform is performed voluntarily and therefore it does not include all the IP families type approved. The ETAES dataset is not publicly available, but the Commission has access to it.

3.2 EEA combined 2020 dataset for M1 vehicles (passenger cars)

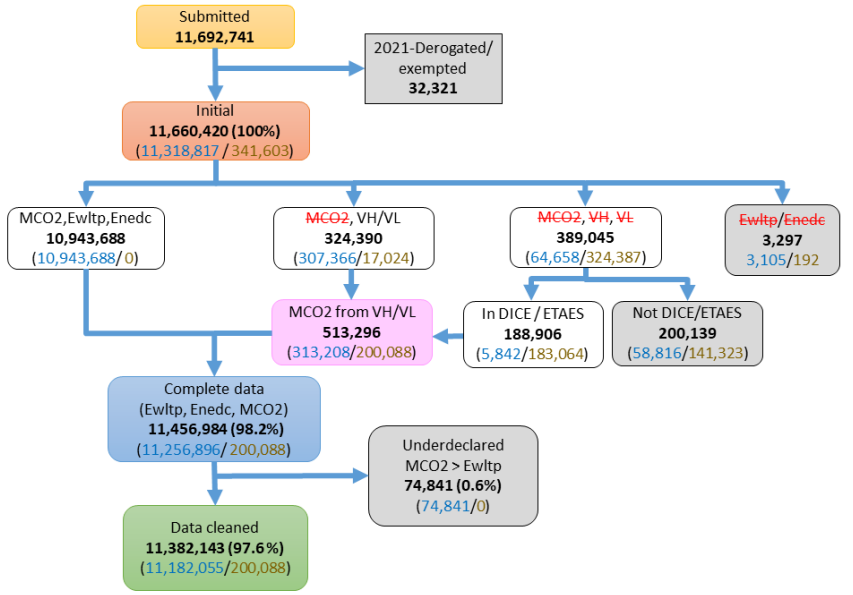
For the purpose of calculating the EU fleet-wide target 2021, the ratios per manufacturer/pool of the average measured-WLTP values against the average declared NEDC values need to be determined. As a first step, a combined dataset is created by merging the 2020 EEA measured WLTP dataset provided by the manufacturers with the 2020 EEA monitoring one (containing the declared WLTP and NEDC values that the Granting Type Approval Authorities (GTAAs) submitted and later manufacturers ratified). Then, a cleaning and gap-filling procedure is applied in order to obtain a complete set of **measured**, **declared-WLTP** and **declared-NEDC** values for each vehicle. In case of missing measured-WLTP values, the gap-filling procedure detailed in Article 7a of Regulation (EU) 2017/1153 determines how to calculate it from the vehicle-High and vehicle-Low measured-WLTP emissions. As a final verification, a comparison between the measured- and the declared-WLTP value was established to assure that no vehicle with a measured value above the declared one was considered, as this would not be consistent with the requirements for vehicle-Low and vehicle-High in Regulation (EU) 2017/1151. The gap-filling/cleaning procedure for passenger cars is illustrated **Figure 2**.

The original EEA combined 2020 dataset contains **11,692,741** passenger cars registered in the year 2020. From this set, **32,321** cars correspond to manufacturers that were exempted or have been granted a (NEDC based) derogation target in 2021, and which therefore will not be used for the calculation of the EU fleet-wide $target_{2021}$. The remaining **11,660,420** cases are considered the initial set for the cleaning/gap-filling process (100%). For deeper analysis, **Figure 2** specifies the number of cases belonging to non-derogated manufacturers and derogated or exempted manufacturers in 2020. Both sets should be considered for the calculation of the specific reference value ($\mathrm{ref}^{(2021)}_{m_i,\mathrm{WLTP_{meas}}}$), but derogated/exempted manufacturers in 2020 were not obliged to report their emissions, and therefore the gap-filling provision is more relevant (**324,387** out of **341,603** cases did not report any of the three measured values, and gap-filling with DICE and ETAES was necessary to obtain a final fair share of **200,088** vehicles).

Concerning the data cleaning process, three main issues were identified. The first one, previously mentioned, regards the manufacturers exempted or with derogation targets in 2021, which according to Point 6 of Annex I in Regulation (EU) 2019/631 shall not be considered for the calculation of the EU fleet-wide $target_{2021}$. The other two issues, missing data and underdeclared CO_2 emission values, will be discussed in the two following sub-sections.

The **11,382,143** vehicles at the end of the cleaning process (green box) are **97.6 %** of the initial vehicles and are the set of data on which the specific reference values will be calculated[1].

Figure 2. EEA combined 2020 dataset cleaning procedure for passenger cars. Pink cells represent gap-filling cases, grey cells represent cleaned (discarded) cases. Numbers in bracket refer to number of cases (not-derogated/derogated) in 2020. Red strikethrough are missing parameters in the submissions.



Source: JRC analysis, 2023.

3.2.1 Missing data in M1 fleet

There were some gaps in the declared-NEDC (Enedc), declared-WLTP (Ewltp), and measured-WLTP CO_2 emissions (MCO2) values reported. A step-by-step approach was followed to produce a final dataset which includes the complete set of MCO2, Enedc and Ewltp values for each vehicle. The following cases were identified and dealt with as explained below:

1. **Missing declared values** ("*Ewltp/Enedc missing*" in **Figure 2**): For **3,297** cars, at least one of the two declared values (Enedc and Ewltp) was missing. These vehicles were discarded. Details on the number of discarded vehicles per manufacturer are presented in **Table 9** of Annex 3.

2. **Missing measured values** ("*MCO2 & VH & VL missing*" in **Figure 2**): For **389,045** vehicles (**64,658** from not-derogated$_{2020}$ and **324,387** from derogated$_{2020}$, all measured-WLTP values were missing: for the individual vehicle, vehicle-High and vehicle-Low. As foreseen in the correlation regulation (EU) 2017/1153, using the IP family identifier (Vehicle Family Number, VFN) to make the link with the Interpolation family information collected in DICE, two different cases were identified:

   (a) **188,906** vehicles (**5,842** not-derogated$_{2020}$ and **183,064** derogated$_{2020}$) could be linked to IP families present in the DICE database, which allowed to determine the measured CO_2 for vehicle-High (MCO2VH) and –optionally- for vehicle-Low (MCO2VL). These values were processed to provide a reference MCO2 for the individual vehicles as explained below ("*MCO2 from VH/VL*" in **Figure 2**).

   (b) **200,139** vehicles (**58,816** not-derogated$_{2020}$ and **141,323** derogated$_{2020}$) could not be linked to any family reported in DICE, either because of a wrong reporting of the VFN code or because the family had been registered in DICE before 2019, when reporting CO_2 values started to be mandatory. Since there was no way to fill the missing values, these vehicles were discarded (**Table 10** of Annex 3).

[1] The manufacturers' names and the corresponding pools have been anonymised throughout the following sections. The correspondence between manufacturers and pools and the number of vehicles registered in 2020 for each case before and after the cleaning process is detailed in Part A of Annex 2.

3. **Missing individual measured (MCO2) values but with VH or VL measured values** ("*MCO2 missing, VH/VL present*" in **Figure 2**): in **324,390** cases (**307,366** not-derogated$_{2020}$ and **17,024** derogated$_{2020}$), the measured-WLTP value of the individual vehicle (MCO2) was missing, while either the VH or VL (or both) measurements were available. These values were later processed to provide a reference MCO2 for the individual vehicles as explained below ("*Calculate MCO2 from VH/VL*" in **Figure 2**).

For the **513,296** cases (**313,208** not-derogated$_{2020}$ and **200,088** for derogated$_{2020}$) where the MCO2 was missing but MCO2VH and/or MCO2VL was/were present or could be identified in DICE (merge of cases 2a and 3), the gap-filling strategy for calculating the MCO2 was as follows, based on Regulation (EU) 2017/1153:

— For the cases with only MCO2VH available, MCO2 is taken from MCO2VH.

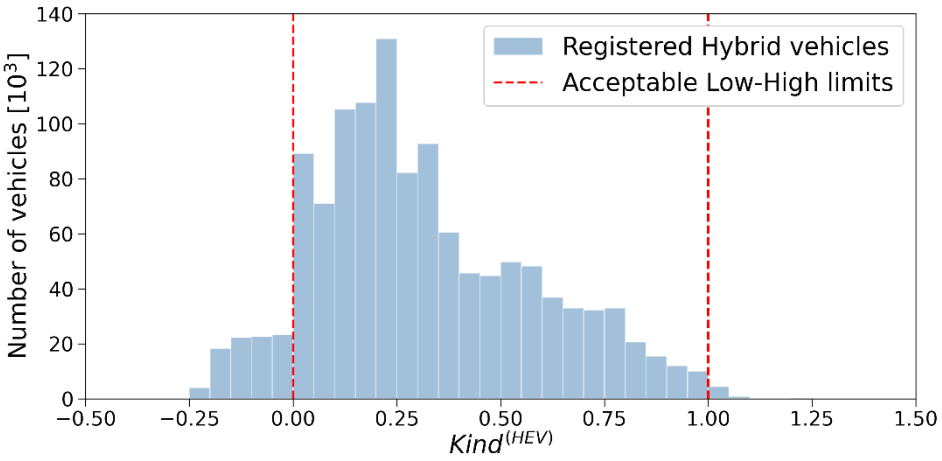
— For the cases with both MCO2VH and MCO2VL available, or only MCO2VL, MCO2 is taken from MCO2VL.

- In the case of OVC-HEVs and NOVC-HEVs, when both MCO2VH and MCO2VL were available, the MCO2 value was calculated according to the following formula:

$$MCO2 = MCO2VL + Kind * (MCO2VH - MCO2VL) \quad (23)$$

where $Kind$ must be defined in the interval [0,1]. As seen in **Figure 3**, there were 96,019 cases where the $Kind$ value reported was outside these limits. For those cases, $Kind$ was taken as 0 for negative values and 1 for values above 1.

Figure 3 $Kind$ values distribution as reported in the 2020 registrations dataset.



Source: JRC analysis, 2023.

As a result of this step, 1.5% of the vehicles were discarding, keeping **11,456,984** passenger cars (98.5%) for further data cleaning.

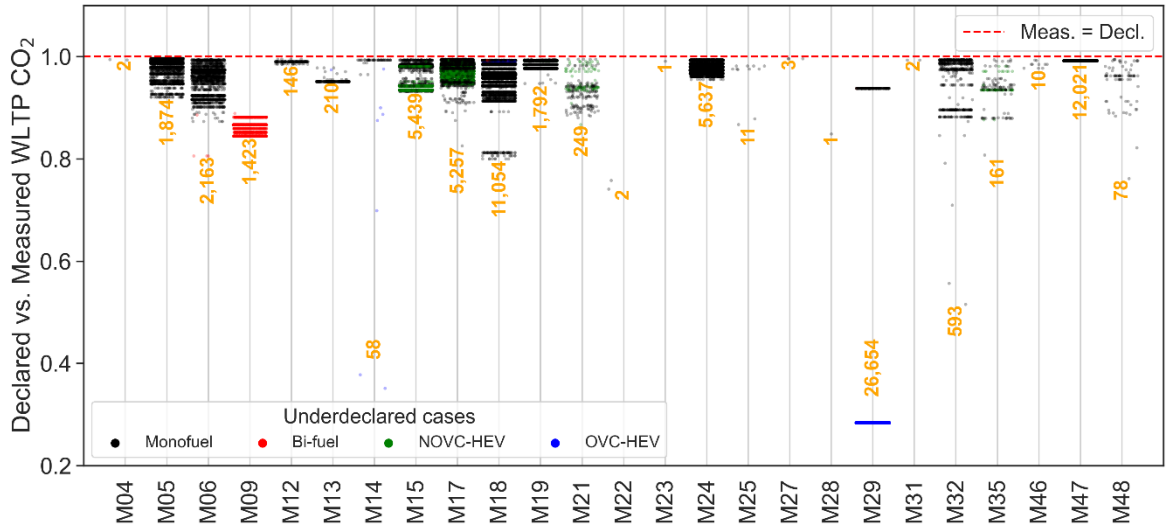
3.2.2 Underdeclared WLTP CO_2 values in M1 fleet

For a total of **74,841** vehicles, the measured WLTP CO_2 value reported was higher than the one declared by the manufacturer. However, it is explicitly established in Paragraph 1.2.3.8 of Sub-Annex 6, Annex XX1 to Regulation (EU) 2017/1151 that the manufacturer should declare a WLTP-CO_2 value for both vehicle-Low and vehicle-High of the IP family which cannot be lower than the values measured. The margin depends on the number of test repetitions performed in the Type Approval WLTP test: In case of one single test, the declared value should be at least 1% higher than the measured (corrections included) value; for two tests, the margin is reduced to 0.5%, taking the average of both measurements, while for three or more tests any declared value above or equal to the measured one is valid. Consequently, these **74,841** vehicles have been excluded from the further calculations.

The **74,841** cases are shown in **Figure 4** split by manufacturer, plotting the underdeclaration ratio (declared WLTP / measured WLTP) in addition to the fuel mode. The number of cases per manufacturer is both in the figure and in **Table 11** of the Annex 3. One-third of the cases stem from **Mitsubishi (M29)**, involving only 2

IP families. One of the families represents PHEV vehicles, and in view of the magnitude of the underdeclaration, the discrepancy seems to stem from considering a combined declared value while the measured one might be reflecting only the Charge Sustaining part. The manufacturers **Skoda (M47)**, with one single family, and **Kia (M18)** account for another third of the cases, while manufacturers **Opel (M24)**, **Hyundai (M15)** and **Hyundai Czech (M17)** account for less than 7% each. The rest of manufacturers have a marginal contribution to the underdeclared values. As regards the fuel types, 40,488 vehicles are mono-fuels (diesel and gasolines) followed by OVC-HEVs (26,672 vehicles).

Figure 4. CO_2 declared vs measured in 2020 combined dataset, by M1 manufacturer. Black, red, green, blue dots represent the vehicles that are mono-fuel, bi-fuel, NOVC-HEV, and OVC-HEVs, respectively, and their declared value was found lower than their measured. Yellow numbers represent the number of vehicles affected by underdeclarations per manufacturer.



Source: JRC analysis, 2023.

3.2.3 Pools and derogation situation in M1 fleet

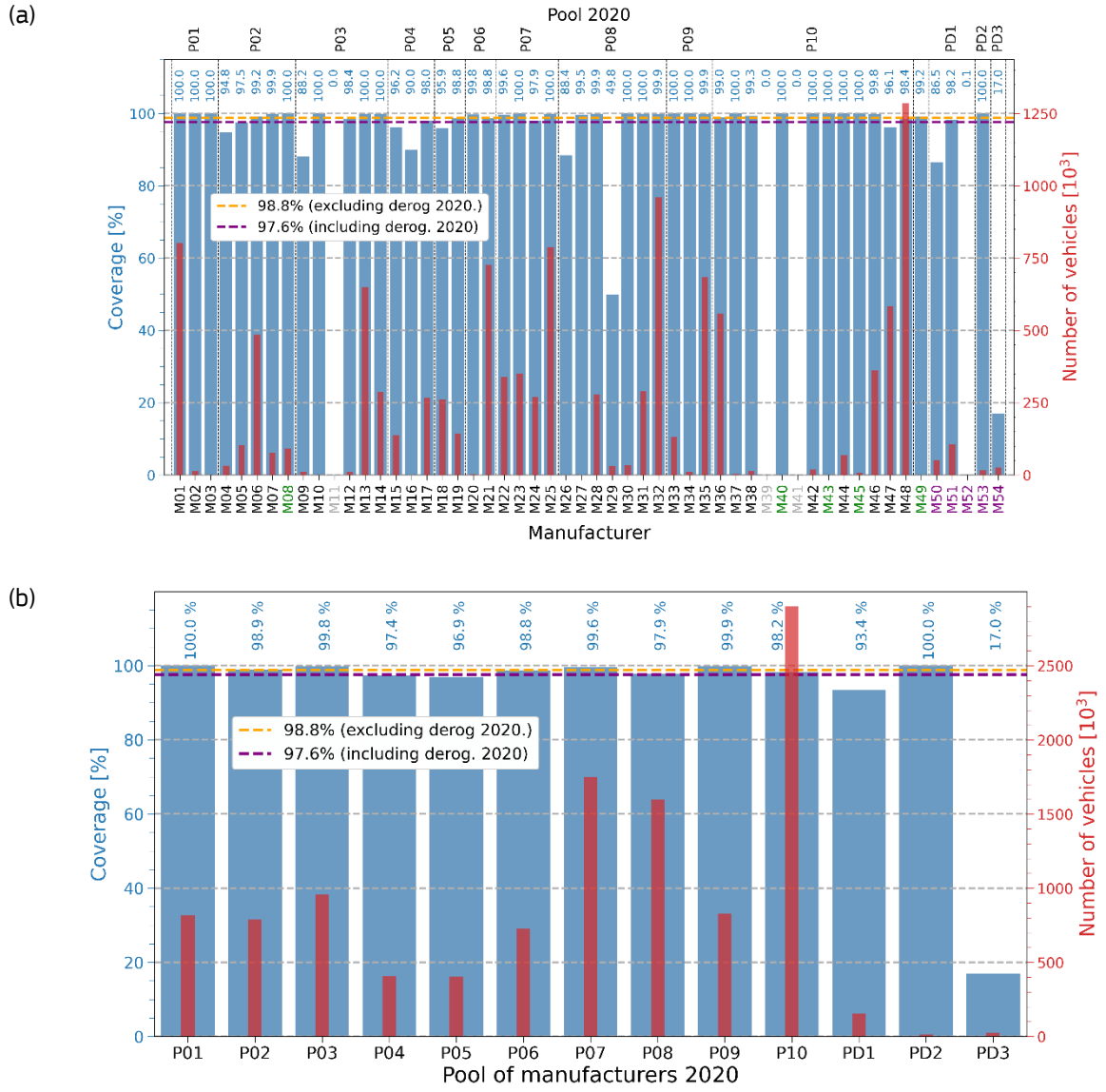
There were 11 pools of M1 manufacturers in 2020, one of them (**SUZUKI** pool) benefitting from a derogation in 2020. In 2021, a rearrangement of manufacturers into different pools resulted in 10 pools of manufacturers, none of them derogated. Five individual car manufacturers (**M50, M51, M52, M53, M54**) benefited from a derogation in 2020, but not anymore in 2021. Therefore, the reference values for 2021 of all these manufacturers should be calculated and taken into account for the determination of the EU fleet-wide target$_{2021}$. However, reporting measured-WLTP values was not required from manufacturers, which were benefitting from a derogation in 2020. For the **341,603** vehicles of the concerned manufacturers, no measured-WLTP values (MCO2) were reported. Consequently, the gap-filling procedure set out in Regulation (EU) 2017/1153 was applied, as illustrated in **Figure 2** (figures in brackets). **Subaru (M53)** submitted the measured WLTP values of vehicle-High (MCO2VH) for almost all the vehicles. For the other manufacturers, no vehicle-Low or vehicle-High values were reported, and gap-filling with the DICE and the ETAES databases based on the IP family identification allowed to approximately cover half of the vehicles.

After the whole cleaning procedure, **141,957** vehicles (**41.5%** of the 341,603 vehicles) had to be discarded (**192** because the declared WLTP/NEDC value was missing and **141,765** because the data for the Interpolation Family concerned was not reported in DICE/ETAES), so in the end **200,124** vehicles (**58.5%** of the 341,603 vehicles) could be included in the final cleaned database 2020.

Three manufacturers present in the cleaned 2020 database did not register any vehicle in 2021: **Ford India (M10)**, with 53 vehicles in the cleaned 2020 database; **Avtovaz (M27)**, with 880 vehicles; and **MG Motor (M42)**, with 18,459 vehicles. Finally, **Saic Maxus (M49)** did not belong to a pool in 2020 or 2021 and had only pure-electric vehicles registered, with zero average NEDC and measured-WLTP CO_2 emissions. Therefore, it is also excluded from the calculation of the EU fleet-wide target$_{2021}$.

3.2.4 Data coverage in M1 fleet

Figure 5. (a) Coverage by M1 manufacturer in % (blue) and number of vehicles (red) after the gap-filling and data cleaning procedure. Purple labels for manufacturers derogated in 2020, green labels for manufacturers of pure electric vehicles, grey labels for manufacturers for which all vehicles have been excluded during the data curation. (b) Same as (a) but expressed per pool of manufacturers. The average coverage is calculated in both cases, with and without considering derogated manufacturers in 2020 to illustrate their impact in data completeness.



Source: JRC analysis, 2023.

Figure 5(a) shows the result of the data cleaning and gap filling procedure for the generation of the EEA combined 2020 dataset, grouped by manufacturer. Most manufacturers have close to 100% representation (one fifth have 100% coverage, and almost half of the manufacturers have coverage above 99.9%). Overall, the average coverage of the non-derogated$_{2020}$ manufacturers is 98.8%. When including the derogated$_{2020}$ manufacturers **M50**, **M51**, **M52**, **M53** and **M54**, the coverage ratio drops mainly due to the remaining gaps for **M54 (Jaguar and Land Rover)**, but remains very high at 97.6%, There are three manufacturers, **M11 (Ford Australia)**, **M39 (Bugatti)** and **M41 (LEVC)** that belong to a pool in 2020, but for which all the vehicles were excluded during the cleaning procedure and consequently are not considered for the EU fleet-wide target$_{2021}$ determination. Apart from the two derogated$_{2020}$ manufacturers **M50** and **M54,** a few other manufacturers

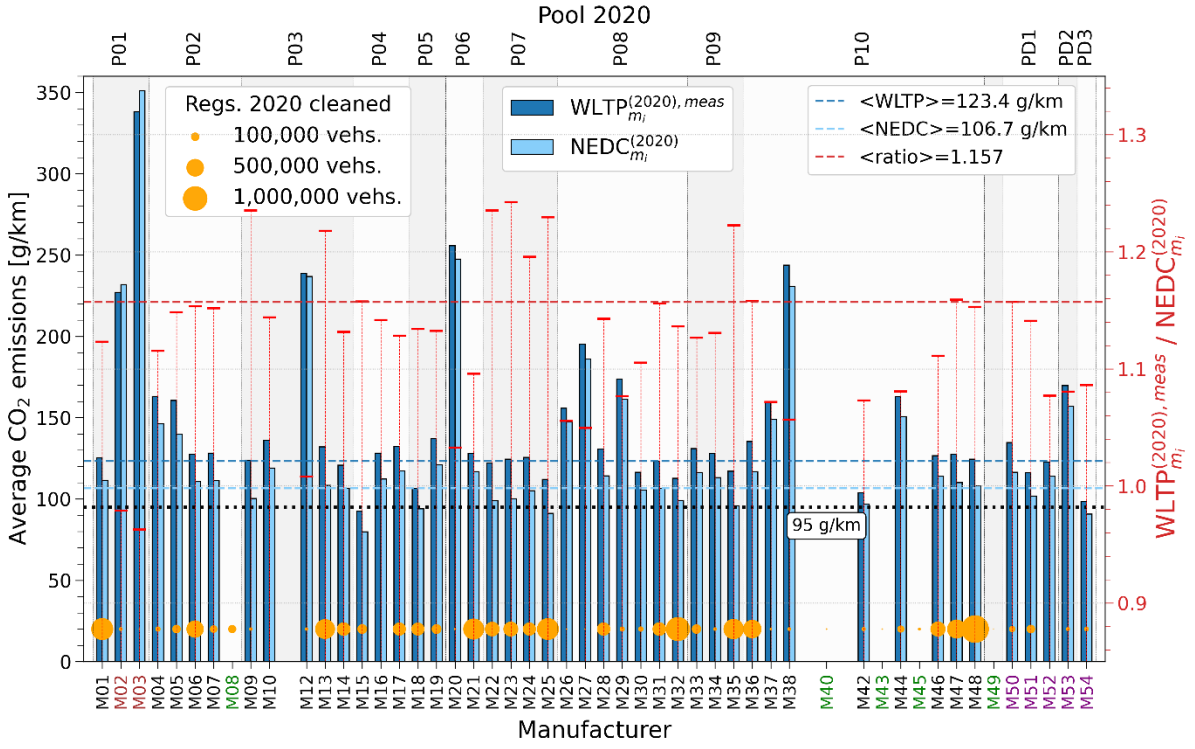
have significantly lower coverage than the average (**M09**, **M16**, **M26**, **M29**). However, all of them have less than 50,000 registrations and the impact on the calculation of the EU fleet-wide target$_{2021}$ is small.

The coverage per pool of manufacturers is presented **Figure 5**(b), including the pools **PD1**, **PD2** and **PD3** derogated in 2020 (the last two representing the individual manufacturers **M53** and **M54**). The pool percentage coverage ranges from 96.9 % to 100 %, except for **PD3** (**Jaguar Land Rover, M54**). Overall, the representativeness of all pools is considered satisfactory for the next steps of the exercise.

3.2.5 Average measured-WLTP and NEDC emissions per M1 manufacturer

Figure 6 depicts the average measured-WLTP and NEDC-declared emissions in 2020 per manufacturer in the EEA combined 2020 database, which were used for determining the reference values$_{2021}$ that will be calculated at pool (2021) level. The average values per M1 manufacturer and the number of vehicles in the EEA combined 2020 dataset are provided in **Table 6** of Annex 2, Part A. For better benchmarking each manufacturer's contribution, the ratio between the WLTP and the NEDC average emissions is also shown, excluding the manufacturers of exclusively electric vehicles. The fleet-averaged measured-WLTP and NEDC values are displayed in horizontal dashed lines. The average measured-WLTP value in 2020 is 123.4 g/km, while the average NEDC-declared value is 106.7 g/km, yielding an average measured-WLTP to NEDC ratio of 1.157.

Figure 6. 2020 WLTP measured and NEDC (cleaned) average values grouped per M1 manufacturer (blue bars) and their corresponding ratio (red dashes). The pool of the manufacturer in 2020 is indicated in the upper axis. Brown manufacturer labels represent cases where the average measured WLTP (MCO2) is lower than the average NEDC, green labels for manufacturers producing exclusively electric cars, and purple labels for manufacturers derogated in 2020.



Source: JRC analysis, 2023.

There are two cases, **BMW GMBH (M02)** and **Rolls Royce (M03)**, where the NEDC value is higher than the measured-WLTP value and the ratio lower than 1. These are cases of high-consumption vehicles, for which the usual benefits of the favourable testing conditions in NEDC may not be so evident. **Ford M.C. (M12)** presents measured-WLTP average very close to NEDC, with a ratio very close to 1, same as **Mercedes AMG**. Four manufacturers registered exclusively zero-emission vehicles: **Tesla (M08)**, **Jiangling Motor (M40)**, **NEXT EGO Mobile (M43)** and **Saic M.C (M45)**, displayed in green in the figure.

The measured-WLTP to NEDC ratio is notably higher than the rest for all the manufacturers from the pool **PSA-OPEL (P07)**, which will be in the **STELLANTIS** pool in 2021. Another manufacturer with a high ratio of 1.22 is

Toyota (M35), showing a distinctive higher ratio than the rest of manufacturers in the **P09 pool (TOYOTA-MAZDA)**. Interestingly, the magnitude of the ratio does not seem to be related to the number of cases with only vehicle-High declared. In fact, the manufacturers declaring only vehicle-High values have a rather low ratio (**Alpine (M26)**, **Avtovaz (M27)**, **Mitsubishi Motor (M29)**, **MG Motor (M42)** and **Subaru (M53)**) or at least lower than the fleet-wide average value (**Mazda M33**, **Mazda Europe M34** and **Mitsubishi Thailand M30**).

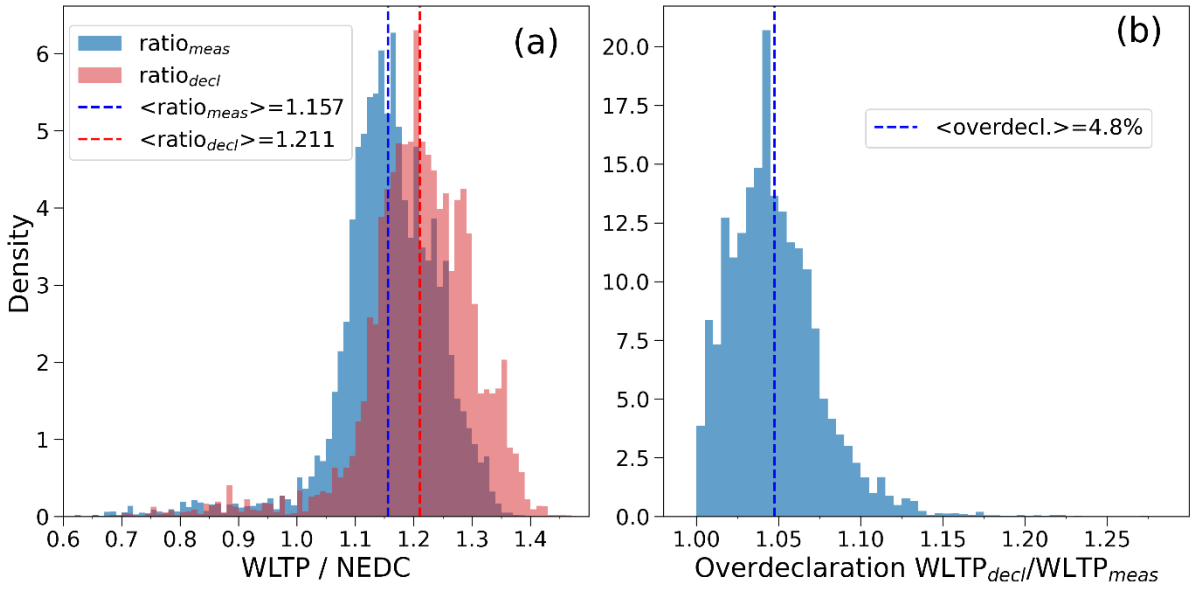
3.2.6 Analysis of 2020 WLTP overdeclaration in M1 fleet

Overdeclaration is a concept intrinsically linked to the WLTP procedure. As explained in **section 2.2** and illustrated in **Figure 1**, the CO_2 emissions reported in the CoC of each vehicle are interpolated from the **values declared** after the Type Approval tests, according to Regulation (EU) 2017/1151. Similarly, a measured CO_2 emissions value can be defined for the individual vehicle by interpolating from the **values measured** for the vehicle-High and vehicle-Low (or alternatively only vehicle-High, in case the vehicle-Low is not defined). The declared values should never be lower than the measured counterparts, but there are no upper bounds in the Type Approval legislation. Consequently, the magnitude of the overdeclaration for the individual vehicles is variable and determined by the manufacturer.

Overdeclaration is an issue that occurred in the past and may still occur to some extent for justifiable reasons. Manufacturers overdeclare the CO_2 emission values in order to avoid failure during the CoP testing of new vehicles. However, the overdeclaration in 2020 had quantifiable implications on the targets' baseline definition from 2021 to 2024, since the translation from NEDC based targets to WLTP based ones relied on the 2020 data. Indeed, a transitional high overdeclaration during the NEDC to WLTP transition period, with the targets still based on NEDC, would increase the future targets and could thus facilitate the target compliance from 2021 onwards without bringing any negative consequence to the manufacturer. To safeguard against the effects of a possible undue degree of inflation, the measured WLTP values instead of the declared values were used for determining the 2025 and 2030 targets. Using the combination of measured and declared WLTP values reported in 2020, the magnitude of the overdeclaration can be established for 2020 at a complete fleet-wide level, considering all the registered vehicles in that year.

Even before the WLTP certification procedure entered into force, several studies (Pavlovic et al., 2018; Tsiakmakis et al., 2016) tried to predict its impact on the CO_2 emissions and energy efficiency declaration. Two main questions were raised. The first question was on the difference between the CO_2 emissions under the NEDC procedure and under WLTP. Literature (Chatzipanagi et al., 2022) quantified this increase in declared official CO_2 emissions being 21% (the ratio being 1.21), which coincides with the ratio of **1.211** found for the non-electric vehicles included in the EEA combined 2020 dataset – see **Figure 7**(a). The distribution of the ratio among the EU fleet is quite broad, ranging from 0.8 to 1.4. This ratio is related to the renormalisation used to calculate the 2021-2024 targets, and therefore the higher it is, the higher will be the EU fleet-wide targets for those four years.

Figure 7. Distributions as calculated from the EEA combined 2020 dataset of M1 vehicles for: (a) the ratio between WLTP and NEDC CO_2 values, considering measured-WLTP (blue) and declared-WLTP (red). (b) the overdeclaration (ratio between the declared-WLTP and the measured-WLTP CO_2 values). Vertical lines denote the average ratios in both figures.

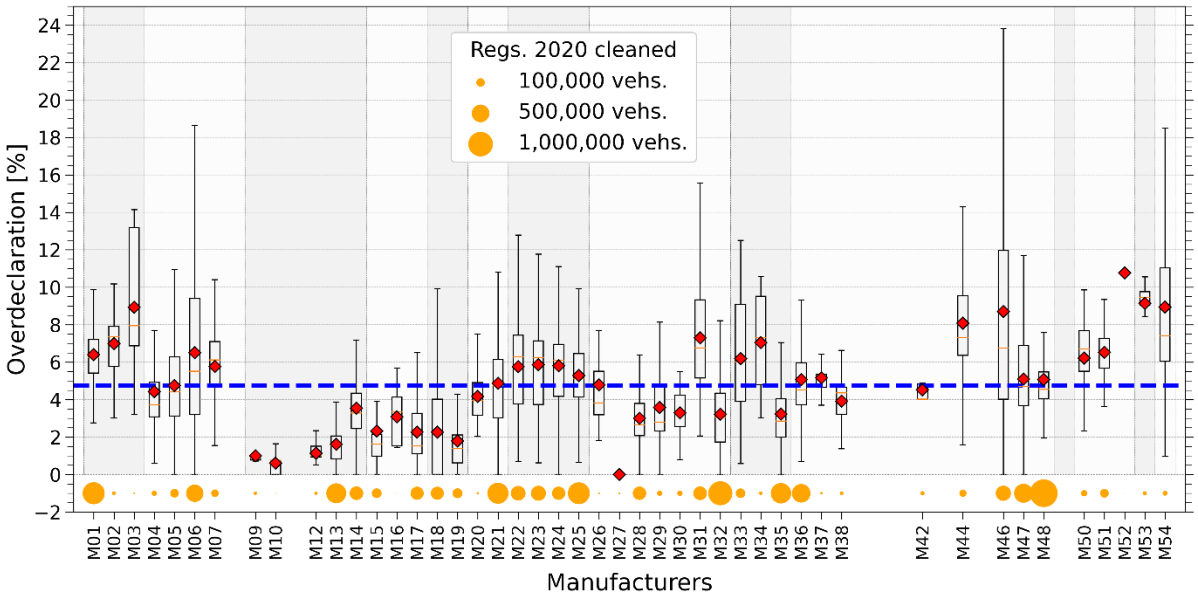


Source: JRC analysis, 2023.

The second question was to estimate the overdeclaration in WLTP, and how it might evolve over the following years. For the same set of vehicles as in the previous figure, **Figure 7**(b) shows an average overdeclaration at EU fleet level of 4.8% in 2020, with a standard deviation of 3.0%. The distribution shows a cut-off at 1 due to the impossibility to declare lower values than those measured. In line with this overdeclaration pattern, the measured-WLTP to NEDC ratios are lower – see **Figure 7**(a) – than the declared-WLTP to NEDC ratios, moving in average from **1.211 to 1.157**. This last value, calculated from the measured-WLTP, is the one to be used for calculating the 2025 and 2030 targets, which means that the 2025 onwards targets are established safeguarding against the **4.8% WLTP overdeclaration** in 2020.

Figure 8 represents the distribution of the overdeclaration in WLTP CO_2 values obtained for each manufacturer (a) and each pool (b) in 2020. Combining the analysis of this figure with the fleet-wide one presented above, we try to determine what could be considered as reasonable values for the overdeclaration of each manufacturer. The average observed overdeclaration for the whole fleet is 4.8%. Manufacturers **Ford India (M10)**, **Hyundai (M15)**, **Hyundai Czech (M17)**, **Kia (M18)** and **Kia Slovakia (M19)** exhibit the lowest average overdeclaration, below 2%. On the opposite side, manufacturers **Rolls Royce (M3)**, **Ford Werke (M13)**, **Mazda Europe (M34)**, **Seat (M46) and Suzuki Thailand (M52)** are overdeclaring on average by more than 6%. From these cases, only **Mazda Europe (M34)** and **Subaru (M53)** are manufacturers declaring vehicle-High only, so it cannot be established a direct link between the overdeclaration and the share of vehicle-High only declarations. Finally, **Fiat (M06)**, **Seat (M46)** and **Jaguar Land Rover (M54)** show a much higher variability than other manufacturers, reaching for some of their vehicles an overdeclaration above 15%.

Figure 8. Overdeclaration of M1 non-electric registered vehicles for each 2020 manufacturer. Each box represents the 1st and 3rd quartile; red diamond is the average value; whiskers quantify the 1.5*IQR (interquartile range). The number of registrations in 2020 for each manufacturer/pool is correlated to the size of the orange bullet. The average fleet-wide overdeclaration of 4.8% obtained excluding electric vehicles is shown with a blue dashed line.



Source: JRC analysis, 2023

3.3 EEA combined 2020 dataset for N1 vehicles (light commercial vehicles)

This section details the procedure followed for the calculation of the EU fleet-wide target 2021 for light commercial vehicles (light commercial vehicles), also referred in the regulation as N1 category vehicles. For this purpose, the data curation and gap-filling procedure is presented, followed by the analysis of the emissions reported.

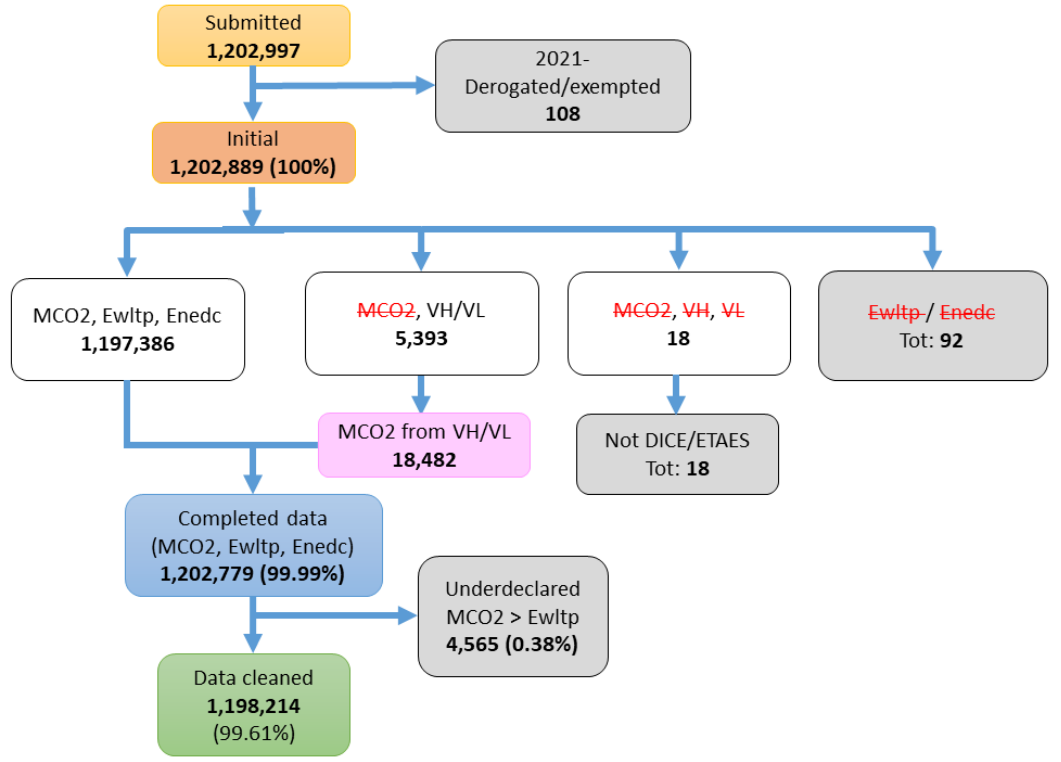
3.3.1 Missing data in N1 fleet

The first step to obtain the EEA combined 2020 dataset involves the data curation and gap-filling process as shown in **Figure 9**. In the case of light commercial vehicles, all the pools of manufacturers derogated in 2020 were also derogated in 2021, and consequently there is no distinction between derogated$_{2020}$ and not-derogated$_{2020}$ cases in the figure, as there was for M1 vehicles.

The original 2020 combined EEA dataset contained data for **1,202,997** light commercial vehicles. Out of this set, **92** vehicles, either NEDC or WLTP (see **Table 9** of Annex 3). For **5,393** vehicles (1.53%) where the measured-WLTP value was missing, the value could be gap-filled from the measured values for the Vehicle-High and/or Vehicle-Low. For **18** vehicles identified, also not when using the DICE database as an auxiliary source (see **Table 10** of Annex 3 for identification of the manufacturers). With this, a total of **1,202,779** light commercial vehicles with all necessary data (measured-WLTP, declared-WLTP and declared-NEDC) were considered for further data cleaning.

The majority (99.2%) of the vehicles for which measured WLTP data was received are coming from defined IP families using both on vehicle-Low and vehicle-High. Only **Fiat (N05)** with 1.6%, **Opel (N06)** with 2.6% and **Renault-Trucks (N25)** with 27%, presented a certain share of vehicles registered based exclusively on vehicle-High measurements.

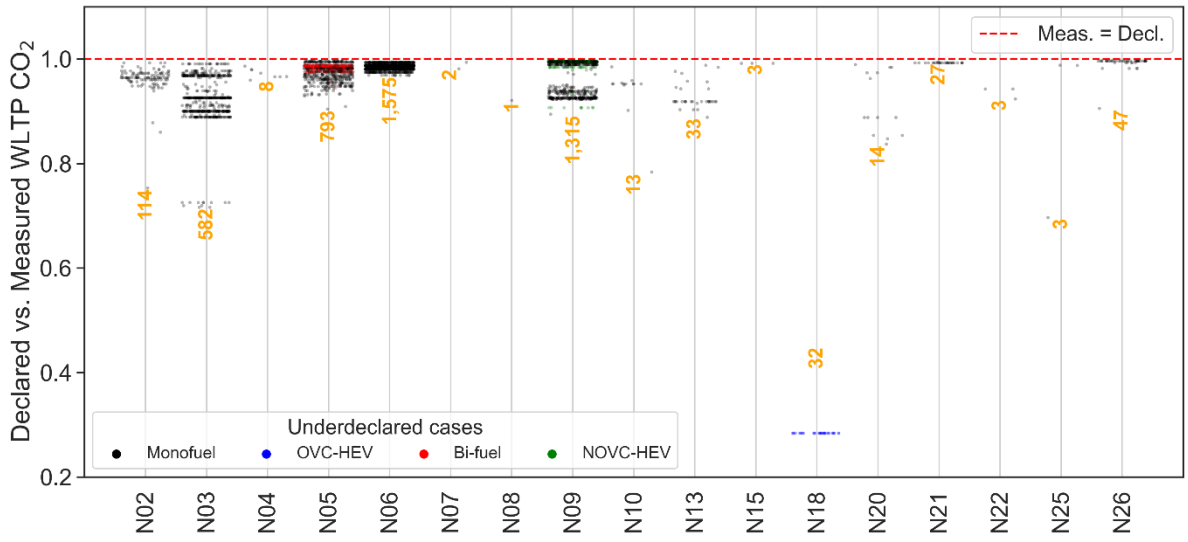
Figure 9. EEA combined 2020 dataset cleaning procedure for light commercial vehicles. Pink cells represent gap-filling cases, grey cells represent cleaned (discarded) cases. Red strikethrough are missing parameters in the submissions.



Source: JRC analysis, 2023

3.3.2 Underdeclared WLTP CO_2 values in N1 fleet

Figure 10. CO_2 declared vs measured in 2020 combined dataset, by N1 manufacturer. Black, red, green, blue dots represent the vehicles that are mono-fuel, bi-fuel, NOVC-HEV, and OVC-HEVs, respectively, and their declared value was found lower than their measured. Yellow numbers represent the number of vehicles affected by underdeclarations per manufacturer.



Source: JRC analysis, 2023

The presence of a declared-WLTP value was required in order to identify and exclude from the dataset vehicles for which the WLTP CO_2 emissions had been incorrectly underdeclared (the declared value should always be

higher than the one measured –and corrected- during the WLTP test). On this basis, **18,482** underdeclared cases, represented in **Figure 10**, were filtered out, resulting in a final total dataset of 1,198,214 vehicles (99.61% of the original dataset) on which the emission reference targets will be calculated. The number of underdeclared vehicles per manufacturer is detailed in **Table 11** of Annex 3.

3.3.3 Pools and derogation situation in N1 fleet

Two pools benefited from a derogation in 2020, **HYUNDAI** and **KIA**, and they were also derogated in 2021. Therefore, they were not considered for our calculations. The final cleaned database of the measured 2020 data contains vehicles from 27 manufacturers, which involved 5 different pools (**FCA-PSA**, **FORD-VW**, **MAN-SAIC**, **MERCEDES-BENZ** and **RENAULT-NISSAN-MITSUBISHI**) and 6 individual manufacturers not pooling: **Iveco (N22)**, **Jaguar Land Rover (N23)**, **Porsche (N24)**, **Renault Trucks (N25)**, **Toyota (N26)** and **Volvo (N27)**. Three manufacturers were not included in this measured 2020 database for different reasons and are therefore not considered either for the EU fleet-wide target$_{2021}$ calculation: **BMW AG** was exempted due to less than 1,000 vehicles registered in the previous year, while **Avtovaz** and **CNG** had no registrations in 2021.

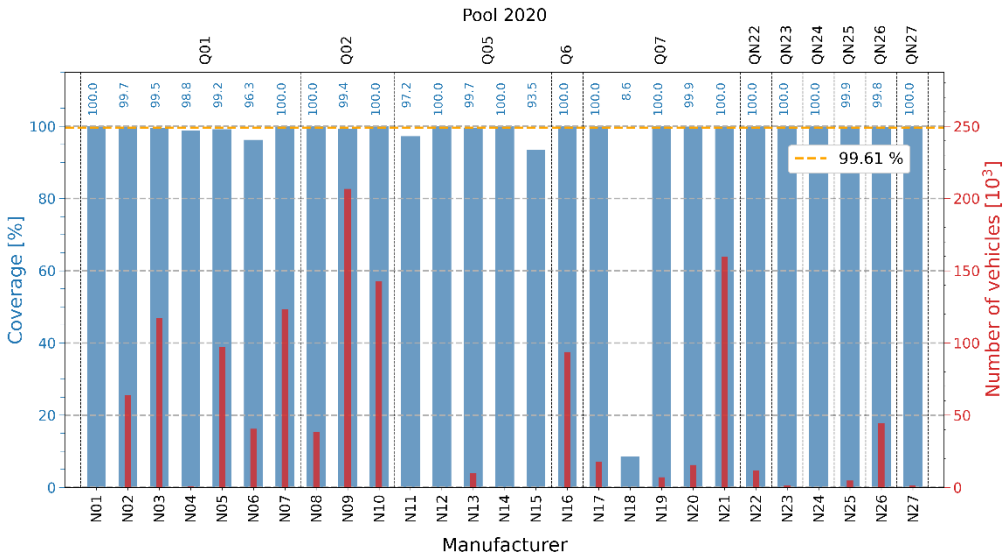
In addition, there was a rearrangement in 2021 of the pooling arrangements. **STELLANTIS** substituted **FCA-PSA**, the pool **VOLKSWAGEN-FORD-SAIC-GOUPIL** was formed from the merging of **FORD-VW** and **MAN-SAIC**, and **MERCEDES** did not pool and became an individual manufacturer.

3.3.4 Data coverage in N1 fleet

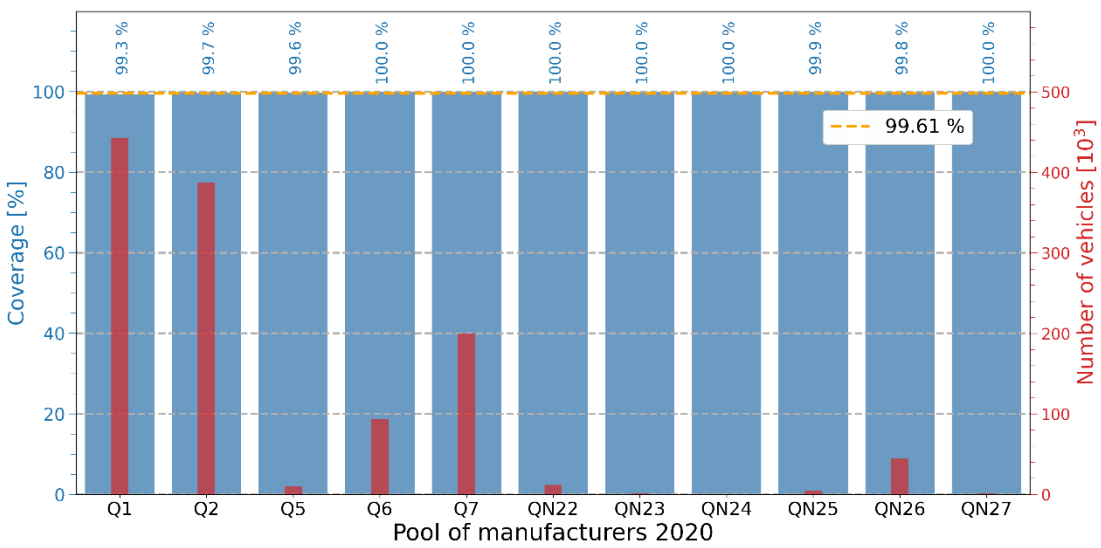
Figure 11 illustrates the cleaning procedure and the coverage per manufacturer. Figure 11 (a) displays a comparison of the percentage of vehicles for which the manufacturers reported the measured CO_2 emissions) with the number of records in the monitoring database. In total, the number of reported measured emissions in the whole 2020 N1-fleet (**1,202,997**) is **12% lower** than the number of registrations from the monitoring database (**1,368,395** declared emissions). The non-reported vehicles are distributed among the largest fleet's manufacturers, **Mercedes-Benz (N16)** takes the lion's share with almost one-third of the missing vehicles.

Figure 11. (a) Coverage by N1 manufacturer in % (blue) and number of vehicles (red) after the gap-filling and curation procedure. (b) Same as (a) but expressed per pool of manufacturers. The average coverage is displayed in both cases with a yellow dashed horizontal line.

(a)



(b)



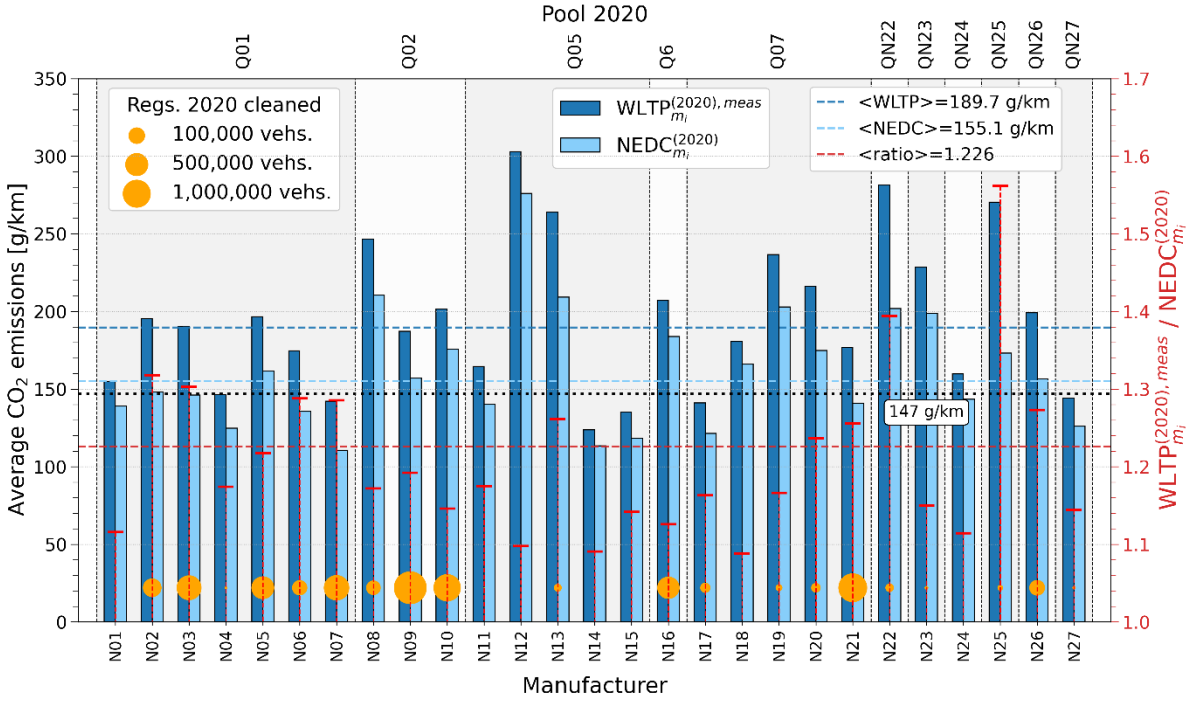
Source: JRC analysis, 2023

3.3.5 Average measured-WLTP and NEDC emissions for N1 manufacturers

This section analyses the average measured-WLTP and declared-NEDC emissions, used in the determination of the EU fleet-wide target$_{2021}$. A detailed description of the average values per N1 manufacturer and of the number of cases considered is provided in **Table 8** of Annex 2, Part B.

The average measured-WLTP value across the whole N1 fleet is **189.7 g/km**, while the average-NEDC value is **155.1 g/km**, which leads to a ratio of **1.226** between the two values. The average emissions from each manufacturer are displayed in **Figure 12**.

Figure 12. 2020 WLTP measured and NEDC average values grouped per N1 manufacturer (blue bars) and their corresponding ratio (red dashes). The pool of the manufacturer in 2020 is indicated in the upper axis.

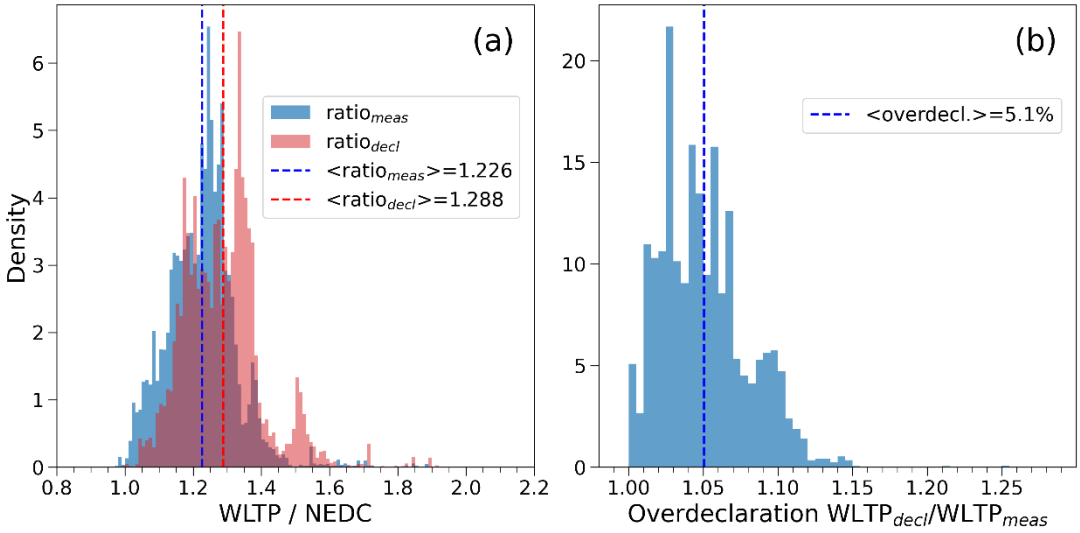


Source: JRC analysis, 2023.

3.3.6 Analysis of 2020 WLTP overdeclaration in N1 fleet

Figure 13(a) shows the WLTP to NEDC ratio per vehicle in the N1 fleet, according to the cleaned 2020 EEA combined database (excluding the 8,631 electric vehicles). The distributions are broader than for the M1 fleet. For the ratio of the declared WLTP value over the declared NEDC value, the range extends from ca. 1.05 to 1.6, with an average of 1.29. For the ratio of the measured WLTP value over the declared NEDC value, the average is 1.226, which is reflecting the effect of a **5.1%** overdeclaration – see **Figure 13**(b).

Figure 13. Distributions as calculated via the 2020 EU fleet registrations of N1 vehicles for: (a) the ratio between WLTP and NEDC CO_2 values, considering measured-WLTP (blue) and declared-WLTP (red). (b) the overdeclaration (ratio between the declared-WLTP and the measured-WLTP CO_2 values). Vertical lines denote the average ratios in both figures.

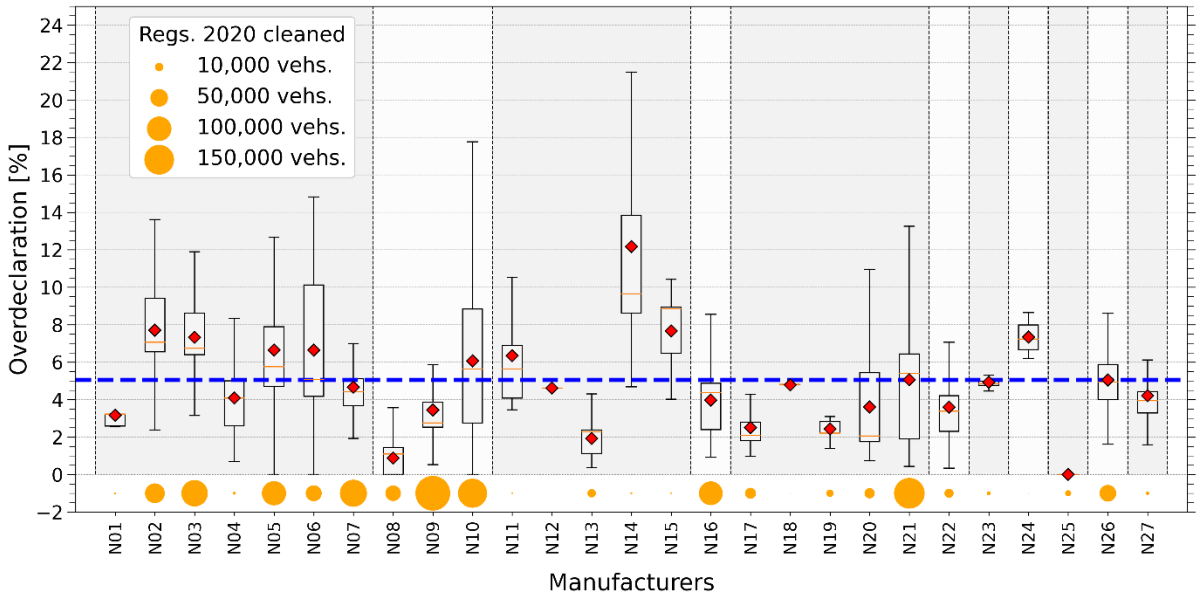


Source: JRC analysis, 2023

Figure 14 depicts a representation of the overdeclaration in terms of the individual manufacturers considered in the 2020 cleaned measured dataset. Manufacturers with exclusively pure electric vehicles have been excluded. Most of the larger manufacturers have an overdeclaration close to the 5.1% average value, with values slightly below the average for **Ford Werke (N09)** and **Mercedes-Benz (N16)**.

Manufacturer **Renault Trucks (N25)** stands as a particular case, with a zero overdeclaration, which means that the declared values are exactly equal to the measured emissions for the 4,687 vehicles in the fleet, stemming from 10 different interpolation families. This indicates that each of those families must have been approved on the basis of three vehicle tests.

Figure 14. Overdeclaration in the EEA combined 2020 database for N1 non-electric vehicles per 2020 manufacturer. Each box represents the 1st and 3rd quartile; red diamond is the average value; whiskers represent 1.5*IQR (interquartile range). The number of registrations in 2020 for each manufacturer/pool is correlated to the size of the orange bullet. The average fleet-wide overdeclaration of 5.1%, excluding electric vehicles, is shown with blue dashed line.



Source: JRC analysis, 2023

4 Calculation of the parameters for determining 2025 and 2030 targets

This section presents the calculation of the parameters necessary for the determination of the 2025 and 2030 CO_2 emission targets for light-duty vehicles. These targets will be established for each manufacturer (or pool of manufacturers) based on a linear correlation with the average test mass of the corresponding manufacturer's vehicles fleet. To determine the target lines of 2025 and 2030 three parameters are needed: i) The fleet-wide target (EU fleet-wide $target_{2025}$ and EU fleet-wide $target_{2030}$), calculated as a % reduction of a reference 2021 value (EU fleet-wide $target_{2021}$); ii) the fleet-wide reference test mass (TM_0), calculated biannually from the average test mass of the vehicles registered in the preceding two years; and iii) the slope(s) of the target line (a_{2021}, a_{2025} and a_{2030}), with the latter two calculated from the slope of the best fitting straight line in a 2021 CO_2 emissions to test mass representation (a_{2021}). The following subsections are devoted to the calculation of the EU fleet-wide $target_{2021}$, a_{2021} and to the indicative TM_0 value for 2025 for both passenger cars and light commercial vehicles.

4.1 General procedure for the determination of the EU fleet-wide $target_{2021}$

The procedure used for the determination of the EU fleet-wide $target_{2021}$ involved three steps that are illustrated in the schema of **Figure 15**. According to Article 6(7) of Regulation (EU) 2019/631, manufacturers which are part of a pool "shall be considered as one manufacturer for the purposes of meeting their obligations under Article 4". Therefore, the determination of the specific individual 2021 reference values is done at pool level.

The combination of 2020 and 2021 data involves the consideration of several issues regarding the determination of the EU fleet-wide $target_{2021}$, which are:

— The configuration of a pool might change from one year to another (in the example in Figure15, e.g., $POOL_2^{20}$ and $POOL_3^{20}$ are differently composed than $POOL_2^{21}$ and $POOL_3^{21}$). In fact, for passenger cars only the pools **P01**, **P04**, **P05**, **P06**, **P08** and **P10** existed both in 2020 and 2021, while pools **P12**, **P13**, **P14** and **P15** were new in 2021. For light commercial vehicles, only pool **Q03** exists in both years.

— Manufacturers which did not form a pool in 2021 and were not derogated or exempted, must be considered at individual level: **Volvo (PM14)**, and **Suzuki Thailand (PM52)** for passenger cars. **Saic Maxus (PM49)** is a particular individual case which has been excluded for the EU fleet-wide $target_{2021}$ calculation exercise as all the individual vehicles registered are electric, and therefore the corresponding $reference\text{-}value_{2021}$ could not be calculated. In the case of light commercial vehicles, the individual manufacturers not pooling are: **Mercedes-Benz (QN16)**, **Iveco (QN22)**, **Jaguar Land Rover (QN23)**, **Porsche (QN24)**, **Renault Trucks (QN25)**, **Toyota (QN26)** and **Volvo (QN27)**.

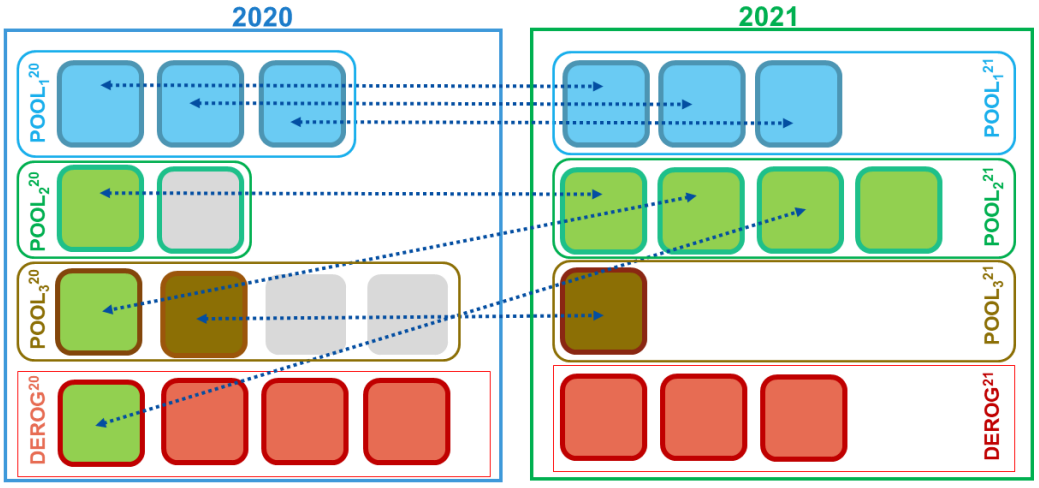
— A manufacturer or pool might have registered vehicles in 2020 but not in 2021 (light-brown cases in $POOL_3^{20}$ in the example figure). Consequently, the corresponding 2021 reference values will not be considered for the calculation of the EU fleet-wide $target_{2021}$. These cases are **Ford India (M10)**, **Avtovaz (M27)** and **MG Motor (M42)**.

— Some manufacturers present in 2021 did not register any vehicle in the final EEA 2020 combined dataset (e.g., last green box of $POOL_2^{21}$ in the example), either because the manufacturer did not exist in 2020 (such as **Geely** and **Polestar**), or because no registrations were left after the cleaning process (**Ford Australia (M11)**, **Bugatti (M39)** and **LEVC (M41)**). In both cases, these manufacturers are not considered for the calculation of the specific reference value or the weighting factor.

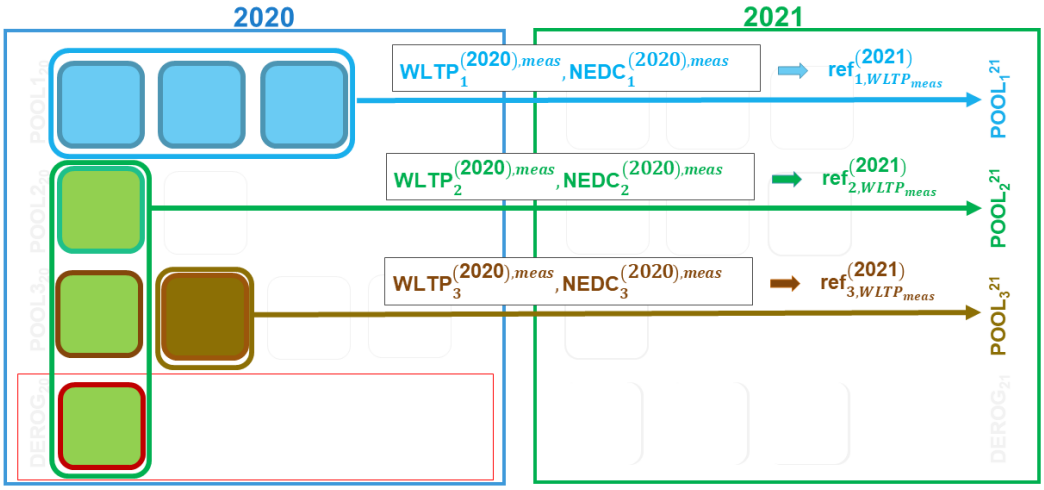
— Finally, those manufacturers derogated in 2020 but not in 2021 (**Magyar Suzuki (M50)**, **Suzuki Motor Corporation (M51)**, **Suzuki Thailand (M52)**, **Subaru (M53)** and **Jaguar Land Rover (M54)**) are fully considered in this exercise, in accordance with Point 4, Annex I to Regulation (EU) 2019/631, despite the fact that reporting the 2020 CO_2 values was not mandatory for them

Figure 15. Schematic example of the three-step procedure for determining the EU fleet-wide target$_{2021}$.

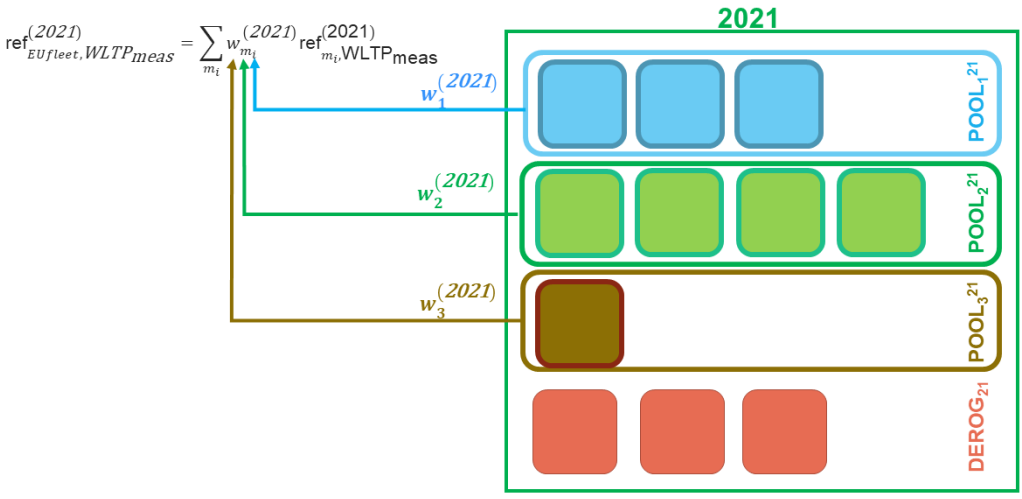
1.



2.



3.



Source: JRC analysis, 2023

Taken these considerations into account, the steps for determining the EU fleet-wide target$_{2021}$ are:

1. First, the 2021 pools or individual manufacturers, for which Point 4 of Annex I (Part A) of Regulation (EU) 2019/631 applies (not-derogated in 2021) are considered. All the manufacturers involved are identified also in 2020, establishing a link at manufacturer level between 2020 and 2021 (dotted arrows in Figure 15).

2. Secondly, average values of the 2020 measured-WLTP and NEDC emissions are calculated for each group of manufacturers that: i) have available data in 2020 and ii) are pooling together in 2021. These manufacturers are shown in the same color in **Figure 15**. Both the average measured-WLTP and the NEDC value are calculated on the EEA 2020 combined dataset. Combining the previous information with the number of registrations per pool in 2021 and the average mass in running order, the reference-value$_{2021}$ ($\mathrm{ref}^{(2021)}_{m_i,\mathrm{WLTP_{meas}}}$) is calculated for each 2021 pool/manufacturer according to equation (8).
3. Finally, these reference values are averaged weights according to the number of registrations of the pool/manufacturer in 2021 ($w^{(2021)}_{m_i}$) to yield the EU fleet-wide target2021 according to eq. (9).

4.2 Precision in the determination of the EU fleet-wide target$_{2021}$

The robustness of the procedure to calculate the EU fleet-wide target$_{2021}$ relies on the representativeness of the sample used to evaluate the measured-WLTP and NEDC average values. The maximum precision that can be achieved in the calculation is therefore affected by the missing data following the cleaning/gap-filling of the EEA combined 2020 datasets, as the value target value should be safeguarded against possible variations in the emission values reported. The quality of the procedure and the reliability of the value builds upon the high coverage of vehicles correctly reported, shown in **Figure 5** (97.6%) and **Figure 11** (99.61%) for the complete M1 and N1 fleets, respectively.

Nevertheless, for the M1 case there are significant differences in the coverage upon manufacturers. This issue particularly concerns the M1 manufacturer **Jaguar Land Rover (M54)**, with a poor 17% share of vehicles represented. To quantify the impact of these gaps on the precision of the EU fleet-wide target$_{2021}$ calculation, different scenarios were simulated exploring different WLTP to NEDC ratios for this manufacturer. The WLTP to NEDC ratio of the individual vehicles from M54 presents a quasi-normal statistical distribution.

Table 1 shows how different percentiles of such ratio affect the calculated EU fleet-wide target$_{2021}$, and therefore establishes a variability range for the latter. A maximum variation of ±0.04% in the EU fleet-wide target$_{2021}$ value is found between the 1% and the 99% percentile. This relative variation translates into ca. ±0.04 gCO_2/km in absolute terms when considering the approximately 110.1 gCO_2/km found in the next section (eq. (24)) for this parameter. Since the precision of the EU fleet-wide target$_{2021}$ must be in line with this variability range, a **precision of ±0.5%** can be established. In other words, the EU fleet-wide target$_{2021}$ must be given with one decimal figure. For the sake of consistency, the same precision will be applied to the value of the N1 fleet.

Table 1. Variation in the final EU fleet-wide ratio $\mathrm{ref}^{(2021)}_{EU\,fleet,\mathrm{WLTP_{meas}}}$ taking different percentiles of the reference-value$_{2021}$ ($\mathrm{ref}^{(2021)}_{M54,\mathrm{WLTP_{meas}}}$) distribution of Jaguar Land Rover (M54). The reference value for the variation is the final EU fleet-wide reference value as calculated in the next subsection.

Percentile	1%	10%	25%	75%	90%	99%
Variation	-0.04%	0%	0%	0.032%	0.041%	0.044%

Source: JRC analysis, 2023.

4.3 Calculation of parameters determining the 2025/2030 specific emissions targets for M1 vehicles

4.3.1 Calculation of EU fleet-wide target 2021 for M1 vehicles

The reference-value$_{2021}$ of each M1 pool (or individual manufacturer) in 2021 is shown in **Table 2.** Values used for determining the M1 reference values$_{2021}$ and EU fleet-wide target $_{2021}$ and illustrated in **Figure 16**.

Table 2. Values used for determining the M1 reference values$_{2021}$ and EU fleet-wide target $_{2021}$

Pools 2021 acronym	Pools 2021 name	<NEDC>$_{2020}$ (g/km)	<WLTP$_{meas}$>$_{2020}$ (g/km)	<MRO>$_{2021}$ (kg)	Reference Value2021 (g/km)	Registrations 2021
P01	BMW	113.790	127.185	1714.52	113.860	666,275
P04	HYUNDAI	104.374	118.567	1441.46	106.502	439,580
P05	KIA	103.454	117.260	1421.34	105.592	412,967
P06	MERCEDES-BENZ	117.395	128.570	1812.13	114.971	543,342
P08	RENAULT-NISSAN-MITSUBISHI	104.508	118.996	1331.74	103.100	1,302,737
P10	VW-SAIC	112.190	128.618	1530.75	110.468	2,490,908
P12	FORD	110.188	133.468	1553.29	117.379	426,013
P13	MAZDA-SUBARU-SUZUKI-TOYOTA	101.409	120.744	1367.90	109.248	922,651
P14	STELLANTIS	102.028	122.871	1326.50	109.163	2,139,576
P15	TESLA	56.352	64.098	1907.55	122.163	232,459
PM14	VOLVO	106.646	120.678	1941.33	122.729	241,475
PM52	SUZUKI THAILAND	114.000	122.780	890.00	82.537	12

Source: JRC analysis, 2023.

Combining the previously calculated reference-value$_{2021}$ for each manufacturer (at pool level where applicable) with the number of car registrations in 2021, the EU fleet-wide target$_{2021}$ for passenger cars is calculated according to the rules set out in **Section 2.3.4** as:

M1: $$\boxed{ref^{(2021)}_{EUfleet,WLTP_{meas}} = 110.1\ g/km} \quad (24)$$

The previous parameter has been determined with one decimal digit in view of the precision estimated in section 4.2.

The EU fleet-wide target for 2025 is a 15% reduction of the EU fleet-wide target$_{2021}$, i.e.:

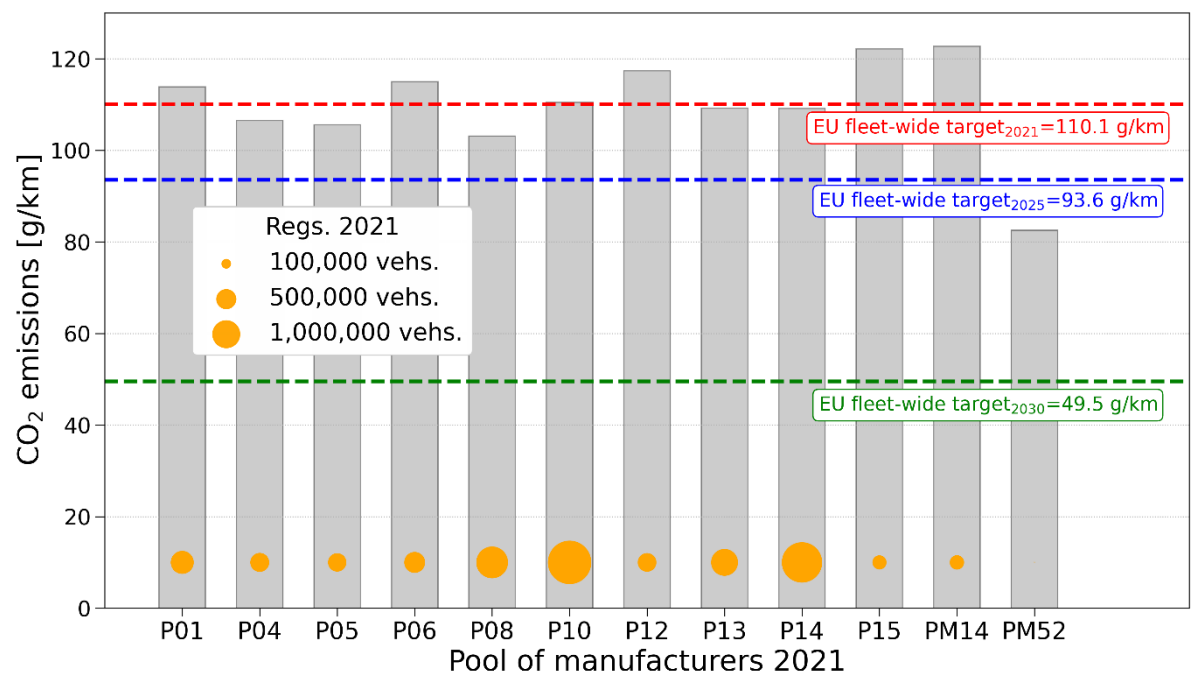
M1: $$\boxed{\text{target}^{(2025)}_{EU-fleet,\text{WLTP}} = 93.6\ g/km} \quad (25)$$

The EU fleet-wide target for 2030 is a 55% reduction of the EU fleet-wide target$_{2021}$, i.e.

M1: $$\boxed{\text{target}^{(2030)}_{EU-fleet,\text{WLTP}} = 49.5\ g/km} \quad (26)$$

Figure 16 displays the reference value 2021 for each pool/manufacturer in 2021. The calculated EU fleet-wide target$_{2021}$ of 110.1 g/km is shown in comparison to the specific values of manufacturers/pools, together with future EU fleet-wide targets for 2025 and 2030.

Figure 16. Reference-values$_{2021}$ per pools of M1 manufacturers in 2021 (grey bars) and EU fleet-wide target$_{2021}$=110.1 g/km (red dashed line). The size of the orange bullets reflects the number of registrations in 2021. The EU fleet-wide target$_{2025}$ (93.6 g/km, blue dashed line), taken as 15% reduction of EU fleet-wide target$_{2021}$, and the EU fleet-wide target$_{2030}$ (49.5 g/km, green dashed line), taken as 55% reduction, are also displayed.



Source: JRC analysis, 2023

4.3.2 Calculation of the target line slopes for M1 vehicles

The calculation of the a_{2021} parameter is performed according to a best fitting straight line established by applying the linear least squares fitting method to the test mass (independent variable) and CO_2 emissions of each new vehicle registered in 2021.

According to this calculation and as shown in **Figure 17**, the slope of the line for 2021 is:

M1: $$\boxed{a_{2021} = -0.0175 \frac{g}{km \cdot kg}} \quad (27)$$

The negative value of the slope is the result of the high number of heavy zero- and low-emission vehicles.

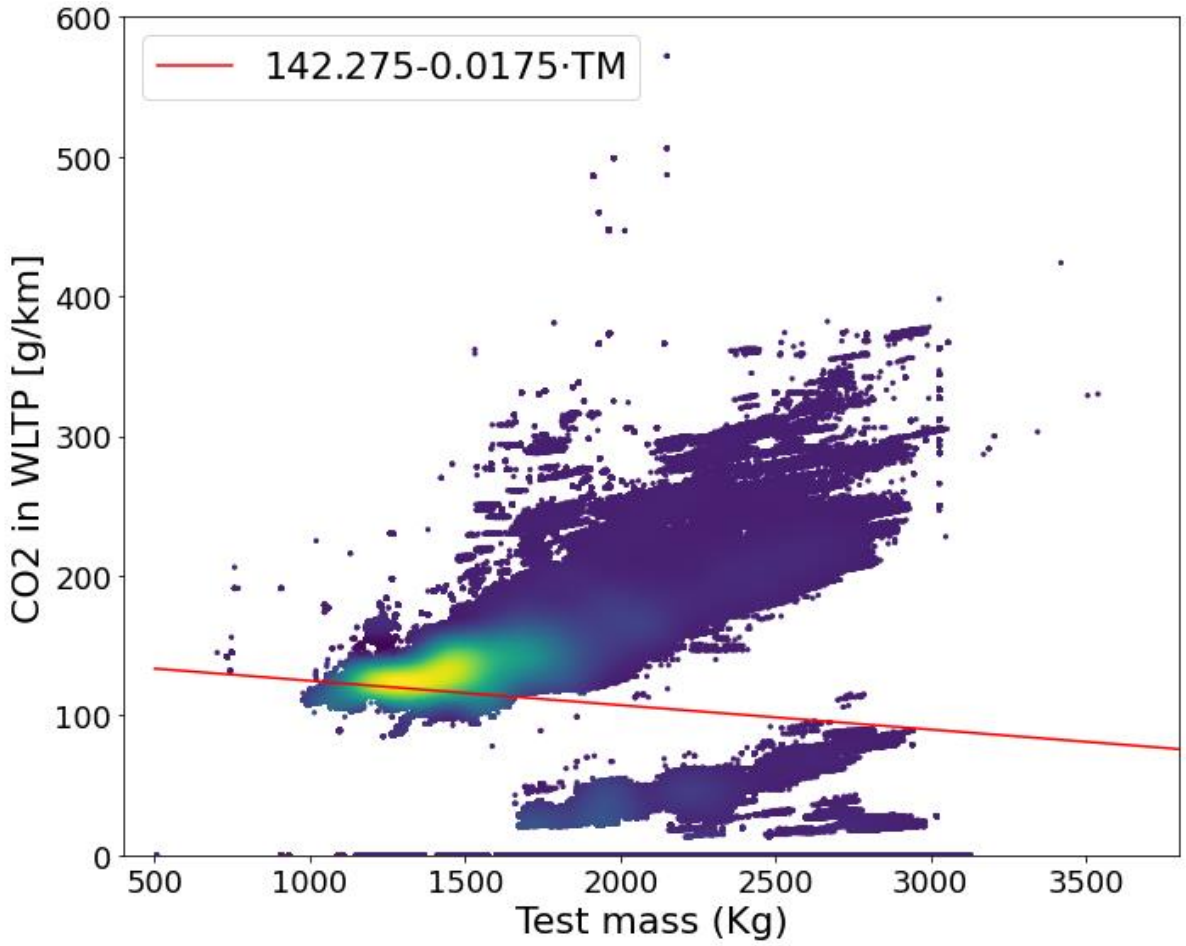
Following eq. (14), the a_{2025} parameter that determines the slope of the target line in 2025 is:

M1: $$\boxed{a_{2025} = -0.0144 \frac{g}{km \cdot kg}} \quad (28)$$

while the a_{2030} parameter, slope of the target line in 2030, is:

M1: $$\boxed{a_{2030} = -0.0076 \frac{g}{km \cdot kg}} \quad (29)$$

Figure 17. Best linear fitting of the WLTP CO_2 emissions for the fleet of new passenger cars (M1) registered in 2021, as a function of the test mass of the vehicle.



Source: JRC analysis, 2023

4.3.3 Calculation of the indicative TM0 value for M1 vehicles

The indicative TM_0 value for 2025, calculated from the average test mass of all new passenger cars registered in 2021 to be used in eq. (12) and (13), is:

M1: $$\boxed{TM_0 = 1{,}609.6\ kg} \quad (30)$$

4.3.4 Determination of the specific emissions reference target lines for 2025/2030 for M1 manufacturers

Combining the EU fleet-wide targets for the years 2025 and 2030 presented in section 4.3.1 and the slopes a_{2025}, a_{2030} for the CO_2 to test mass correlation and the indicative reference test mass TM_0 for the year 2025 presented in sections 4.3.2 and 4.3.3, the specific emissions reference target line for the years 2025 and 2030 for M1 manufacturers is determined according to:

2025-2029: $$\mathrm{ref}_{m_i,\mathrm{WLTP}}^{(yy)} = 93.6 - 0.0144\left(TM_{m_i}^{(yy)} - TM_0^{(yy)}\right) \quad (31)$$

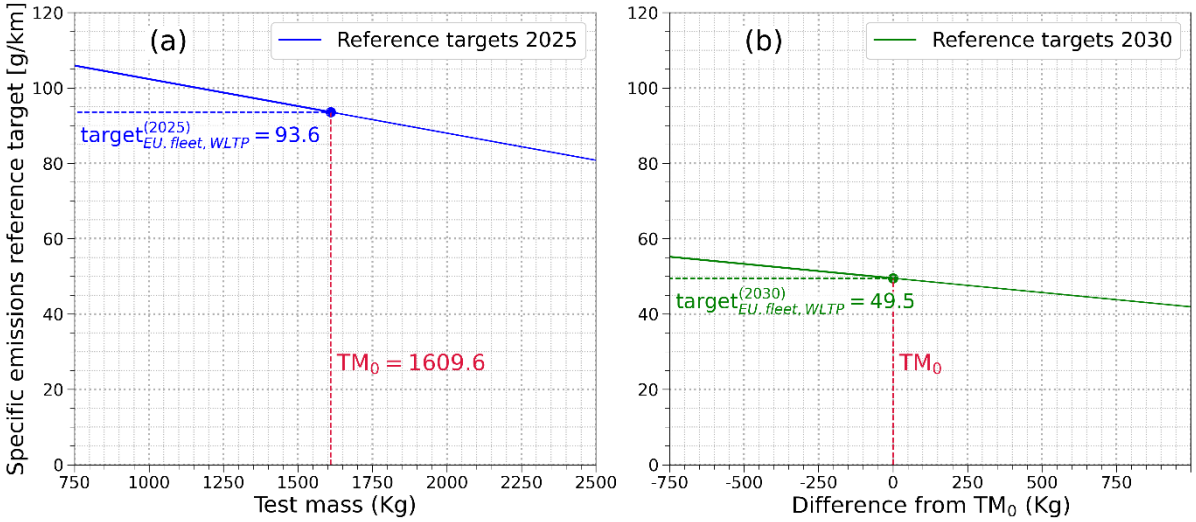
with (yy) from 2025 to 2029. The value $TM_0^{(2025)}$ is equal to 1,609.6 kg. (indicative value based on 2021 data).

2030-2034: $$\mathrm{ref}_{m_i,\mathrm{WLTP}}^{(yy)} = 49.5 - 0.0076\left(TM_{m_i}^{(yy)} - TM_0^{(yy)}\right) \quad (32)$$

with (yy) from 2030 to 2034. The value $TM_0^{(yy)}$ will be determined every second year starting from October 2024.

The target lines for both 2025 and 2030 are represented in **Figure 18**. For 2030, the position of the fleet target related to TM_0 (reference test mass) cannot be determined yet; however, the shape of the reference target formula in terms of slope is reflected in the figure.

Figure 18. Specific emissions reference target lines for (a) 2025 and (b) 2030 for passenger cars (M1) manufacturers. For 2025, the indicative fleet-wide average test mass TM_0 obtained in equation (30) has been used. For 2030, the abscissa refers to an undetermined reference TM_0.



Source: JRC analysis, 2023

4.4 Calculation of parameters for the 2025/2030 specific emissions targets for N1 vehicles

4.4.1 Calculation of the EU fleet-wide target$_{2021}$ for N1 vehicles

Similarly, to the previous section for passenger cars, the final EU fleet-wide target$_{2021}$ for **N1 category vehicles** is determined according to:

N1: $$\boxed{ref^{(2021)}_{EUfleet,WLTP_{meas}} = 181.1\ g/km} \quad (33)$$

The EU fleet-wide target for 2025 is a 15% reduction of the EU fleet-wide target$_{2021}$, i.e.

N1: $$\boxed{\text{target}^{(2025)}_{EU-fleet,\text{WLTP}} = 153.9\ g/km} \quad (34)$$

The EU fleet-wide target for 2030 is a 50% reduction of the EU fleet-wide target$_{2021}$, i.e.

N1: $$\boxed{\text{target}^{(2030)}_{EU-fleet,\text{WLTP}} = 90.6\ g/km} \quad (35)$$

An overview of the data used to calculate the targets is given in **Table 3** and illustrated **Figure 19**, displaying the reference-value$_{2021}$ for each pool of manufacturers in 2021. The calculated EU fleet-wide target$_{2021}$ of 181.1 g/km is shown in comparison to the specific values of manufacturers/pools, together with future EU fleet-wide targets for 2025 and 2030.

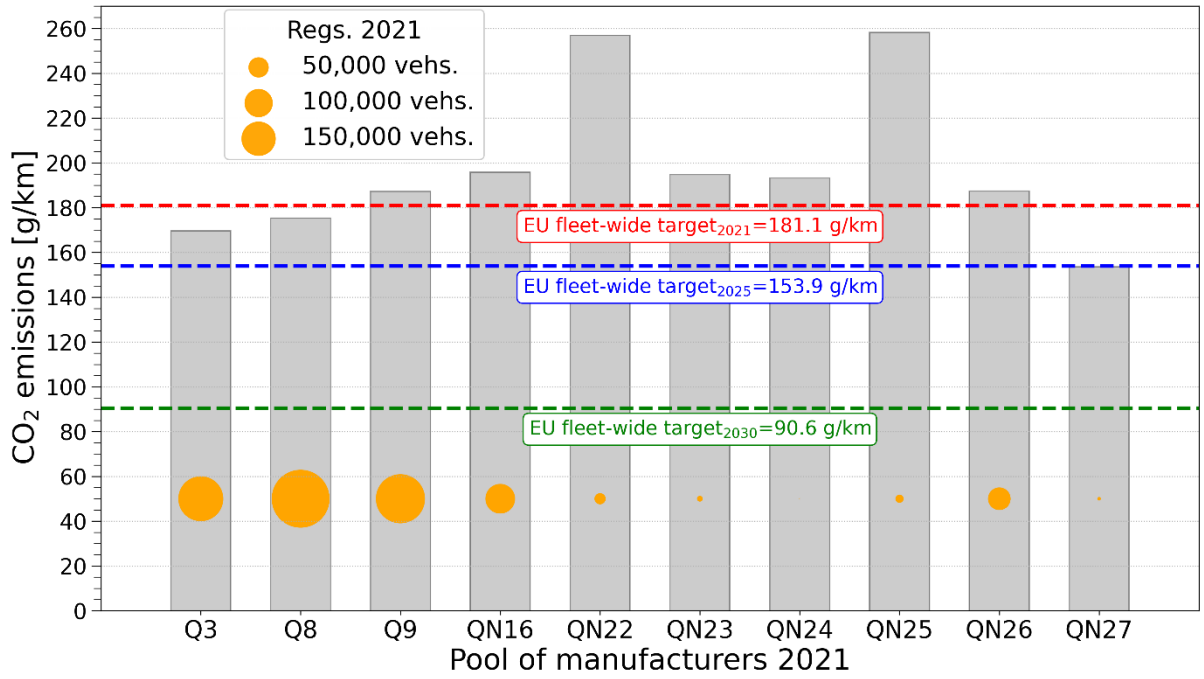
The measured-WLTP and NEDC-declared average emissions and corresponding reference-values$_{2021}$ for the 3 pools and 7 individual manufacturers used in the calculation of the final EU fleet-wide target$_{2021}$ for N1 vehicles are included in **Table 3**, respectively.

Table 3. Values used for determining the N1 reference values$_{2021}$ and EU fleet-wide target $_{2021}$

Pools 2021 acronym	Pools 2021	<NEDC>$_{2020}$ (g/km)	<WLTP$_{meas}$>$_{2020}$ (g/km)	<MRO>$_{2021}$ (kg)	Reference Value (g/km)	Registrations 2021
Q3	RENAULT-NISSAN-MITSUBISHI	143.981	178.886	1,745.71	169.580	261,926
Q8	STELLANTIS	138.951	177.586	1,751.59	175.381	440,185
Q9	VOLKSWAGEN-FORD-SAIC-GOUPIL	170.154	199.872	2,040.03	187.258	308,159
QN16	MERCEDES-BENZ AG	183.867	207.011	2,196.88	195.759	11,1042
QN22	IVECO	201.863	281.422	2,423.59	256.956	13,506
QN23	JAGUAR LAND ROVER LIMITED	198.758	228.477	2,149.70	194.706	2,810
QN24	PORSCHE	143.400	159.800	2,187.50	193.167	2
QN25	RENAULT TRUCKS	173.172	270.496	2,180.09	258.259	6,584
QN26	TOYOTA	156.450	199.144	1,884.85	187.416	6,3019
QN27	VOLVO	126.986	144.139	1,729.83	153.599	725

Source: JRC analysis, 2023.

Figure 19. Reference-values$_{2021}$ for light commercial vehicles (N1), calculated per 2021 pools, in comparison with the EU fleet-wide target$_{2021}$=181.1 g/km (red dashed line). The size of the orange bullets reflects the number of registrations in 2021. The EU fleet-wide targets for 2025 (153.9 g/km) and 2030 (90.6 g/km), introduced as a 15% and 50% reduction of the EU fleet-wide target$_{2021}$ are displayed in blue and green dashed lines, respectively.



Source: JRC analysis, 2023

4.4.2 Calculation of the target line slopes for N1 vehicles

The calculation of the a_{2021} parameter is performed according to a best fitting straight line method to the test mass (independent variable) and CO_2 emissions of each new light commercial vehicle registered in 2021.

According to this calculation and as shown in **Figure 20** the slope of the line for 2021 has a value of:

N1: $$\boxed{a_{2021} = 0.1064 \frac{g}{km \cdot kg}} \quad (36)$$

In the case of light commercial vehicles, where the number of zero- and low-emission vehicles is quite limited, the slope of the line is positive and slightly higher than the 0.096 slope of the target lines in 2020-2024.

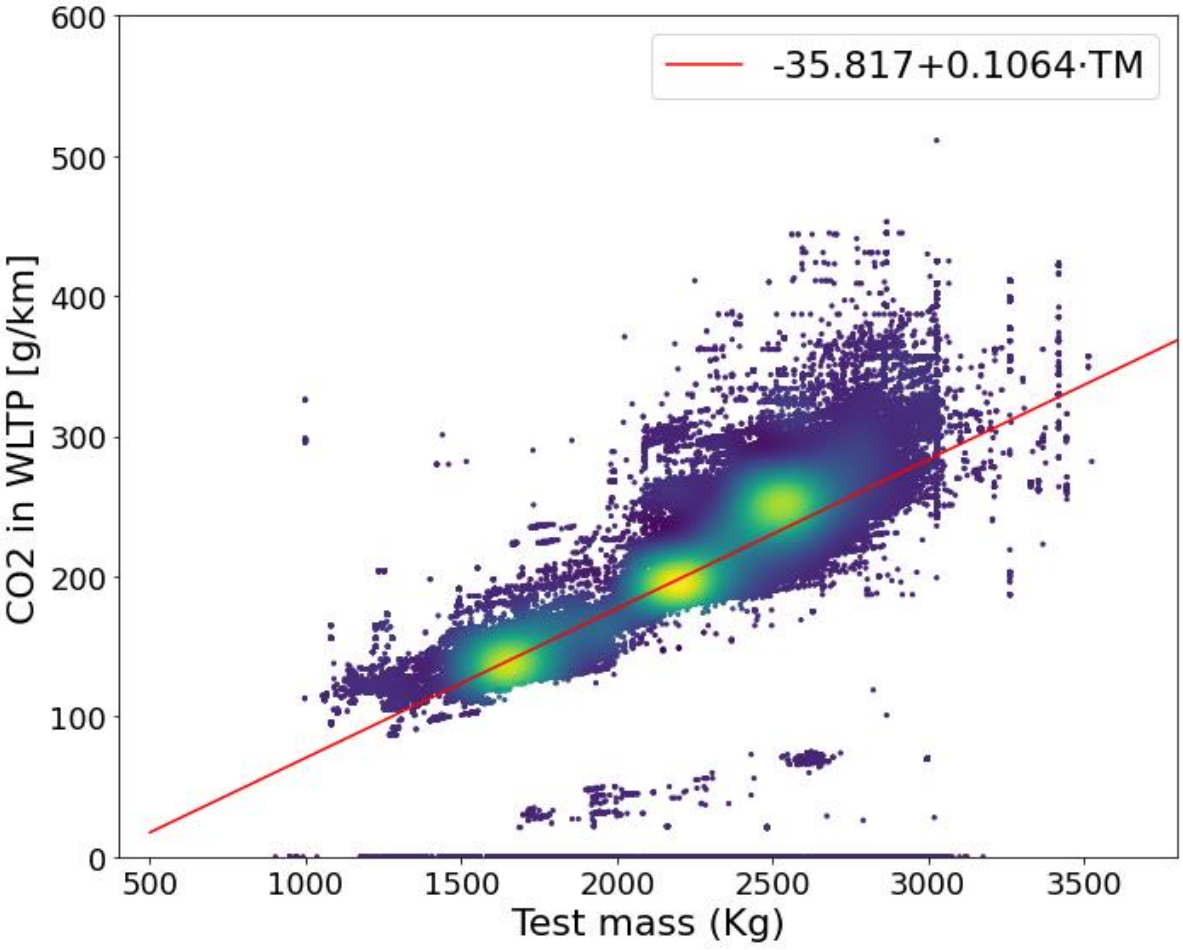
Using the expression in eq. (14), the a_{2025} used to calculate the slope of the target line in 2025 becomes:

N1: $$\boxed{a_{2025} = 0.0848 \frac{g}{km \cdot kg}} \quad (37)$$

while the parameter a_{2030}, calculated according to eq. (14) as well, is:

N1: $$\boxed{a_{2030} = 0.0499 \frac{g}{km \cdot kg}} \quad (38)$$

Figure 20. Best linear fitting of the WLTP CO_2 emissions for the fleet of new light commercial vehicles (N1) registered in 2021, as a function of the test mass of the vehicle.



Source: JRC analysis, 2023

4.4.3 Calculation of the indicative TM0 value for N1 vehicles

The indicative TM_0 value for 2025, calculated from the average test mass of all new light commercial vehicles registered in 2021 to be used in eq. (17) and (19), is:

N1: $$\boxed{TM_0 = 2{,}163.0\ kg} \quad (39)$$

4.4.4 Determination of the specific emissions reference target lines for 2025/2030 for N1 manufacturers

Combining the EU fleet-wide targets for the years 2025 and 2030 presented in section 4.4.1 and the slopes a_{2025}, a_{2030} for the CO_2 to test mass correlation and the reference test mass TM_0 for the year 2025 presented in sections 4.4.2 and 4.4.3, the specific emissions reference target lines for the years 2025 and 2030 for N1 manufacturers are determined according to:

2025-2029: $$\mathrm{ref}_{m_i,\mathrm{WLTP}}^{(yy)} = 153.9 + 0.0848\left(TM_{m_i}^{(yy)} - TM_0^{(yy)}\right) \quad (40)$$

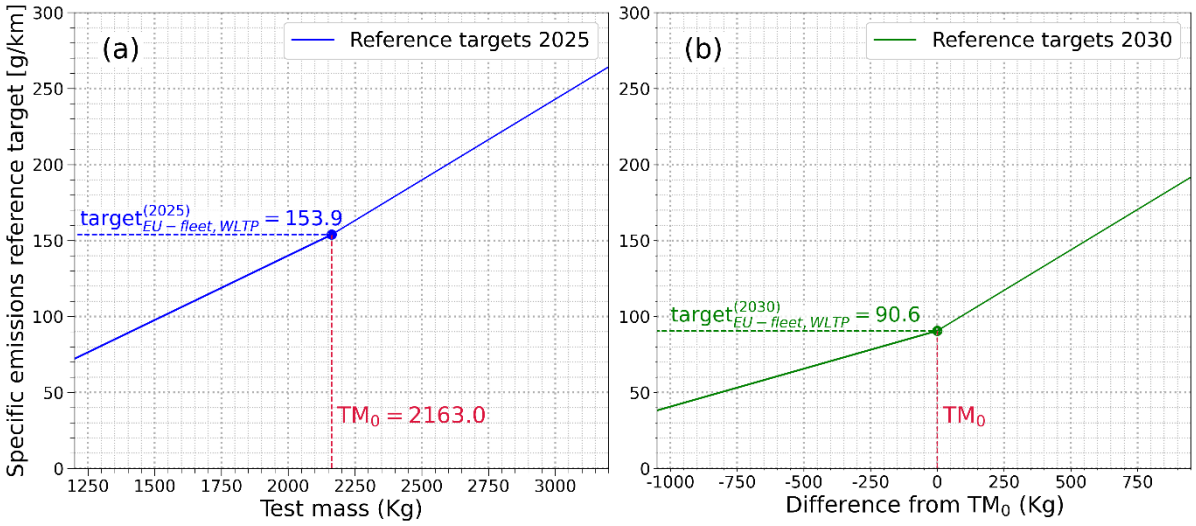
with (yy) from 2025 to 2029. The value $TM_0^{(2025)}$ is equal to 2163,0 kg (indicative value based on 2021 data).

2030-2034: $$\mathrm{ref}_{m_i,\mathrm{WLTP}}^{(yy)} = 90.6 + 0.0499\left(TM_{m_i}^{(yy)} - TM_0^{(yy)}\right) \quad (41)$$

with (yy) from 2030 to 2034.

The target lines for both 2025 and 2030 are represented in **Figure 21**, showing the two different slopes, for lower and higher average test mass values. For 2030, the position of the merging point TM_0 (reference test mass) cannot be determined yet; however, the shape of the reference target formula in terms of slope is reflected in the figure.

Figure 21. Specific emissions reference target lines for (a) 2025 and (b) 2030 for light commercial vehicles (N1) manufacturers. For 2025, the indicative fleet-wide average test mass TM_0 obtained in eq. (39) has been used. For 2030, the abscissa refers to an undetermined reference TM_0.



Source: JRC analysis, 2023

5 Conclusions

The average CO_2 emissions of new passenger cars and light commercial vehicles registered in the EU (and Iceland and Norway) are assessed annually by the Commission for each manufacturer against the targets set out in Regulation (EU) 2019/631. The year 2020 was highly important concerning light-duty vehicle CO_2 emissions for four main reasons. Firstly, new and stricter EU fleet-wide targets entered into effect for both passenger cars and light commercial vehicles. Secondly, it was the last year that the average CO_2 emissions were assessed based on the NEDC Type Approval procedure. As a third point, the 2020 CO_2 emission data are also utilised for the calculation of the 2021 to 2024 targets. Finally, the 2020 WLTP emission values measured during the WLTP tests are used as the basis for determining the 2025 onwards targets.

This report presents the calculation of the relevant parameters for determining the CO_2 emissions targets to be applied from 2025 to 2034 for passenger cars (M1) and light commercial vehicles (N1) in the EU (and Iceland and Norway) in the run-up to the zero-emission targets agreed for 2035. The relevant parameters specified in Regulation (EU) 2019/631 are the EU fleet-wide targets for 2025 and 2030 (EU fleet-wide $target_{2025}$ and EU fleet-wide $target_{2030}$, respectively), the slopes of the reference target lines used to determine each manufacturer's target (a_{2025} and a_{2030}), and the average test mass of the EU fleet (TM_0) to be used as reference. For the latter, an indicative value should be determined based on the 2021 data.

The calculation of the above-mentioned parameters follows a solid scientific procedure, where the calculation of the EU fleet-wide $target_{2021}$ is the keystone. The robustness of the procedure relies on the quality of the emissions data used. To calculate the EU fleet-wide $target_{2021}$, the 2020 and 2021 CO_2 emissions data for the new passenger cars and light commercial vehicles, received by the Commission from countries and manufacturers, have been thoroughly and meticulously processed. As a preliminary step, a comprehensive data cleaning and gap-filling process, involving the Type Approval related datasets DICE and ETAES, was carried out for the emissions data from 2020 registered vehicles (compiled in the **EEA 2020 combined dataset**). Based on this processed dataset, an EU fleet-wide target for 2021, reference for the future targets in 2025 and 2030, is calculated. The main issues found during the cleaning process were vehicles with missing CO_2 values (1.7% for M1 and only 0.001% for N1 vehicles) and cases, where the declared WLTP CO_2 value was lower than the measured one (0.67% in M1 and 0.28% in the N1 dataset). On the other hand, five M1 manufacturers belonged to a pool that was derogated in 2020 but not anymore in 2021, some of them showing a low reporting share. These issues are overcome by adopting the gap-filling strategy foreseen in the regulations (EU) 2017/1153 for passenger cars and (EU) 2017/1152 for light commercial vehicles.

The high representativeness of the sample following the cleaning and gap-filling process for both passenger cars and light commercial vehicles enhances the consistency, accuracy and reliability of the calculated values. A sample of **11,382,143** passenger cars was finally considered for the calculations, representing **97.6%** of the initially reported vehicles. This sample involved 54 different manufacturers, grouped in 10 non-derogated pools and 2 individual manufacturers in 2021. The sample representativeness is excellent also for light commercial vehicles, with **1,198,214** registrations representing a **99.61%** share of the initially reported cases. The sample in this case covered 27 different manufacturers, grouped into 3 pools and 7 individual manufacturers in 2021.

The analysis of the 2020 combined dataset for M1 vehicles shows an average declared-WLTP of 129.3 g/km, while the average measured-WLTP was 123.4 g/km and the average NEDC emissions were 106.6 g/km. This means an overdeclaration in WLTP (against measured WLTP) of 4.8% and a measured-WLTP to NEDC ratio of 1.157. For N1 vehicles, the average declared-WLTP was 199.4 g/km, the average measured-WLTP was 189.7 g/km and the average NEDC 155.1 g/km, yielding an average overdeclaration of 5.1% and a measured-WLTP to NEDC ratio of 1.226.

For the determination of the post-2025 EU fleet-wide targets, first the reference value EU fleet-wide $target_{2021}$ was calculated. This value is determined by sales-weighting (with the number of 2021 registrations) the reference values calculated for each manufacturer (or, where applicable, pool of manufacturers) that is not benefitting from an exemption or derogation in 2021. The EU fleet-wide $target_{2021}$ calculated is **110.1 g/km** for M1 and **181.1 g/km** for the N1-category fleet. Applying the amended reduction factors for 2025 and 2030 as established by Regulation (EU) 2023/851, the corresponding EU fleet-wide targets will be **93.6** and **49.5 g/km** for passenger cars, and **153.9 g/km** and **90.6 g/km**, respectively, for light commercial vehicles. Concerning the slopes of the reference targets line, the a_{2021} parameter is calculated based on the slope of the best linear fitting for the CO_2 emissions versus test mass representation of all the vehicles registered in 2021. The regression line has a negative slope for M1 vehicles ($\mathbf{a_{2021} = -0.0175}$ **g/km/kg**), yielding a slope

$\mathbf{a_{2025}} = \mathbf{-0.0144}$ g/km/kg for 2025 and $\mathbf{a_{2030}} = \mathbf{-0.0076}$ g/km/kg for 2030. For the case of N1 vehicles, the slope is positive ($\mathbf{a_{2021}} = \mathbf{0.1064}$ **g/km/kg**) and slightly above the slope of the NEDC target line in 2020 ($a = 0.096$ g/km/kg). The slope of the future target lines for 2025 and 2030 will be $\mathbf{a_{2025}} = \mathbf{0.0848}$ g/(km· kg) for 2025 and $\mathbf{a_{2030}} = \mathbf{0.0499}$ g/km/kg, respectively. Finally, an indicative test mass fleet-wide average value for the 2025 specific target determination has been calculated based on the 2021 new registered cars, with $\boldsymbol{TM_0} = \mathbf{1,609.6}$ kg for M1 and $\boldsymbol{TM_0} = \mathbf{2,163.0}$ kg for N1 vehicles. Combining the previous calculated parameters, expressions for the determination of the 2025 and 2030 specific reference targets per manufacturer have been generated.

References

Chatzipanagi, A., Pavlovic, J., Ktistakis, M.A., Komnos, D., Fontaras, G., 2022. Evolution of European light-duty vehicle CO2 emissions based on recent certification datasets. Transportation Research Part D: Transport and Environment 107, 103287. https://doi.org/10.1016/j.trd.2022.103287

Dornoff, J., Tietge, U., Mock, P., 2020. On the way to "real-world" CO2 values: The European passenger car market in its first year after introducing the WLTP.

European Commission, 2017. Commission Notice — Guidance on the monitoring and reporting of data on the registration of new light duty vehicles. Publications Office of the European Union.

European Commission, 2009. 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.

European Commission, 2007. Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 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 (Text with EEA relevance), OJ L.

European Environment Agency, 2023. Datasets — European Environment Agency [WWW Document]. URL https://www.eea.europa.eu/data-and-maps/data/#c0=5&c11=l3fwryepgj&c5=all&b_start=0 (accessed 4.19.23).

European Environment Agency, 2022a. Greenhouse gas emissions from transport in Europe [WWW Document]. URL https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-transport (accessed 5.19.23).

European Environment Agency, 2022b. Is Europe reducing its greenhouse gas emissions? — European Environment Agency [WWW Document]. URL https://www.eea.europa.eu/themes/climate/eu-greenhouse-gas-inventory (accessed 6.29.22).

European Union, 2023. 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 CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition (Text with EEA relevance).

European Union, 2022. COMMISSION IMPLEMENTING DECISION (EU) 2022/2087 of 26 September 2022 confirming or amending the provisional calculation of the average specific emissions of CO2 and the specific emissions targets for manufacturers of passenger cars and light commercial vehicles for the calendar year 2020 and informing manufacturers of the values to be used for the calculation of the specific emissions targets and derogation targets for the calendar years 2021 to 2024 pursuant to Regulation (EU) 2019/631 of the European Parliament and of the Council.

European Union, 2020. Commission Implementing Regulation (EU) 2020/1812 of 1 December 2020 laying down rules on the online data exchange and the notification of EU type-approvals under Regulation (EU) 2018/858 of the European Parliament and of the Council.

European Union, 2019. Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 (Text with EEA relevance.) (No. 32019R0631).

European Union, 2018. Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC (Text with EEA relevance.), OJ L.

European Union, 2017a. 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 (Text with EEA relevance) (No. 32017R1151).

European Union, 2017b. Commission Implementing Regulation (EU) 2017/1152 of 2 June 2017 setting out a methodology for determining the correlation parameters necessary for reflecting the change in the regulatory test procedure with regard to light commercial vehicles and amending Implementing Regulation (EU) No 293/2012 (Text with EEA relevance) (No. 32017R1152).

European Union, 2017c. Commission Implementing Regulation (EU) 2017/1153 of 2 June 2017 setting out a methodology for determining the correlation parameters necessary for reflecting the change in the regulatory test procedure and amending Regulation (EU) No 1014/2010 (Text with EEA relevance) (No. 32017R1153).

European Union, 2014a. Regulation (EU) No 333/2014 of the European Parliament and of the Council of 11 March 2014 amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO 2 emissions from new passenger cars, OJ L.

European Union, 2014b. Regulation (EU) No 253/2014 of the European Parliament and of the Council of 26 February 2014 amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO 2 emissions from new light commercial vehicles Text with EEA relevance, OJ L.

European Union, 2011a. 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 Text with EEA relevance, OJ L.

European Union, 2011b. Directive 2011/83/EU of the European Parliament and of the Council of 25 October 2011 on consumer rights, amending Council Directive 93/13/EEC and Directive 1999/44/EC of the European Parliament and of the Council and repealing Council Directive 85/577/EEC and Directive 97/7/EC of the European Parliament and of the Council Text with EEA relevance, OJ L.

Fontaras, G., Ciuffo, B., Zacharof, N., Tsiakmakis, S., Marotta, A., Pavlovic, J., Anagnostopoulos, K., 2017. The difference between reported and real-world CO2 emissions: How much improvement can be expected by WLTP introduction? Transportation Research Procedia, World Conference on Transport Research - WCTR 2016 Shanghai. 10-15 July 2016 25, 3933–3943. https://doi.org/10.1016/j.trpro.2017.05.333

Fontaras, G., Valverde, V., Arcidiacono, V., Tsiakmakis, S., Anagnostopoulos, K., Komnos, D., Pavlovic, J., Ciuffo, B., 2018. The development and validation of a vehicle simulator for the introduction of Worldwide Harmonized test protocol in the European light duty vehicle CO2 certification process. Applied Energy 226, 784–796. https://doi.org/10.1016/j.apenergy.2018.06.009

Komnos, D., Broekaert, S., Grigoratos, T., Ntziachristos, L., Fontaras, G., 2021. In Use Determination of Aerodynamic and Rolling Resistances of Heavy-Duty Vehicles. Sustainability 13, 974. https://doi.org/10.3390/su13020974

Ktistakis, M.A., Pavlovic, J., Fontaras, G., 2022. Developing an optimal sampling design to monitor the vehicle fuel consumption gap. Science of The Total Environment 832, 154943. https://doi.org/10.1016/j.scitotenv.2022.154943

Pavlovic, J., Ciuffo, B., Fontaras, G., Valverde, V., Marotta, A., 2018. How much difference in type-approval CO2 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

Pavlovic, J., Fontaras, G., Ktistakis, M., Anagnostopoulos, K., Komnos, D., Ciuffo, B., Clairotte, M., Valverde, V., 2020. Understanding the origins and variability of the fuel consumption gap: lessons learned from laboratory tests and a real-driving campaign. Environmental Sciences Europe 32, 53. https://doi.org/10.1186/s12302-020-00338-1

Tietge, U., 2019. From laboratory to road: A 2018 update of official and "real-world" fuel consumption and CO2 values for passenger cars in Europe.

Tietge, U., Mock, P., Franco, V., Zacharof, N., 2017. From laboratory to road: Modeling the divergence between official and real-world fuel consumption and CO2 emission values in the German passenger car market for the years 2001–2014. Energy Policy 103, 212–222.

Tsiakmakis, S., Ciuffo, B., Fontaras, G., Anagnostopoulos, K., Arcidiacono, V., Praksova, R., Marotta, A., 2016. Introducing a New Emissions Certification Procedure for European Light-Duty Vehicles: Monte Carlo Simulation of the Potential Effect on Fleet Carbon Dioxide Emissions. Transportation Research Record 2572, 66–77. https://doi.org/10.3141/2572-08

Wang, H., Asif Amjad, M., Arshed, N., Mohamed, A., Ali, S., Haider Jafri, M.A., Khan, Y.A., 2022. Fossil Energy Demand and Economic Development in BRICS Countries. Frontiers in Energy Research 10.

List of abbreviations and definitions

ACEA	European Automobile Manufacturers' Association
CO_2	Carbon dioxide
CO2MPAS	CO2 Model for Passenger and commercial vehicles Simulation
CoC	Certificate of Conformity
DICE	Database for In-service verification of CO_2 Emissions
EC	European Commission
EEA	European Environment Agency
EU	European Union
ETAES	European Type Approval Exchange System
GTAA	Granting Type Approval Authority
IP	Interpolation
JAMA	Japan Automobile Manufacturers' Association
KAMA	Korea Automobile Manufacturers' Association
NEDC	New European Driving Cycle
RL	Road Load
TAA	Type Approval Authority
VFN	Vehicle Family Number
VIN	Vehicle Identification Number
WLTP	Worldwide Harmonized Light Vehicles Test Procedure

List of figures

List of tables

Annexes

Annex 1. EEA monitoring dataset variables

Table 4. EEA monitoring datasets published per year. The table shows the available data for each vehicle registered in 2020.

Field name	Field Definition
ID	Identification number
MS	Member state
Mp	Manufacturer pooling
VFN	Vehicle family identification number
Mh	Manufacturer name (EU standard denomination)
Man	Manufacturer name (manufacturer declaration)
MMS	Manufacturer name (MS registry denomination)
TAN	Type Approval number
T	Type
Va	Variant
Ve	Version
Mk	Make
Cn	Commercial name
Ct	Category of the vehicle type approved
Cr	Category of the vehicle registered
m (kg)	Mass in running order (Completed/complete vehicle)
Mt	WLTP test mass
Enedc (g/km)	Specific CO_2 Emissions (NEDC)
Ewltp (g/km)	Specific CO_2 Emissions (WLTP)
W (mm)	Wheel Base
At1 (mm)	Axle width steering axle
At2 (mm)	Axle width other axle
Ft	Fuel type

Fm	Fuel mode
ec (cm3)	Engine capacity
ep (KW)	Engine power
z (Wh/km)	Electric energy consumption
IT	Innovative technology or group of innovative technologies
Ernedc (g/km)	Emissions reduction through innovative technologies (NEDC)
Erwltp (g/km)	Emissions reduction through innovative technologies (WLTP)
De	Deviation factor
Vf	Verification factor
R	Total new registrations
year	Reporting year
Zr	Electric range

Source: JRC analysis, 2023.

Annex 2. EEA 2020 combined dataset

Part A. Passenger cars (M1 vehicles)

Table 5. Correlation between acronyms used in this report for all the M1 manufacturer and pools in 2020 and 2021

Manufacturer		Pool 2020		Pool 2021	
BMW AG	M01	BMW	P01	BMW	P01
BMW GMBH	M02	BMW	P01	BMW	P01
ROLLS ROYCE	M03	BMW	P01	BMW	P01
ALFA ROMEO	M04	FCA	P02	STELLANTIS	P14
CHRYSLER	M05	FCA	P02	STELLANTIS	P14
FIAT GROUP	M06	FCA	P02	STELLANTIS	P14
HONDA MOTOR CO	M07	FCA	P02	TESLA	P15
TESLA	M08	FCA	P02	TESLA	P15
CNG TECHNIK	M09	FORD-VOLVO	P03	FORD	P12
FORD INDIA	M10	FORD-VOLVO	P03		
FORD MOTOR AUSTRALIA	M11	FORD-VOLVO	P03		
FORD MOTOR COMPANY	M12	FORD-VOLVO	P03	FORD	P12
FORD WERKE GMBH	M13	FORD-VOLVO	P03	FORD	P12
VOLVO	M14	FORD-VOLVO	P03	VOLVO	PM14
HYUNDAI	M15	HYUNDAI	P04	HYUNDAI	P04
HYUNDAI ASSAN	M16	HYUNDAI	P04	HYUNDAI	P04
HYUNDAI CZECH	M17	HYUNDAI	P04	HYUNDAI	P04
KIA	M18	KIA	P05	KIA	P05
KIA SLOVAKIA	M19	KIA	P05	KIA	P05
MERCEDES AMG	M20	MERCEDES-BENZ	P06	MERCEDES-BENZ	P06
MERCEDES-BENZ AG	M21	MERCEDES-BENZ	P06	MERCEDES-BENZ	P06
AUTOMOBILES CITROEN	M22	PSA-OPEL	P07	STELLANTIS	P14
AUTOMOBILES PEUGEOT	M23	PSA-OPEL	P07	STELLANTIS	P14
OPEL AUTOMOBILE	M24	PSA-OPEL	P07	STELLANTIS	P14

PSA	M25	PSA-OPEL	P07	STELLANTIS	P14
ALPINE	M26	RENAULT-MITSUBISHI	P08	RENAULT-NISSAN-MITSUBISHI	P08
AVTOVAZ	M27	RENAULT-MITSUBISHI	P08		
DACIA	M28	RENAULT-MITSUBISHI	P08	RENAULT-NISSAN-MITSUBISHI	P08
MITSUBISHI MOTORS CORP.	M29	RENAULT-MITSUBISHI	P08	RENAULT-NISSAN-MITSUBISHI	P08
MITSUBISHI MOTORS THAILAND	M30	RENAULT-MITSUBISHI	P08	RENAULT-NISSAN-MITSUBISHI	P08
NISSAN	M31	RENAULT-MITSUBISHI	P08	RENAULT-NISSAN-MITSUBISHI	P08
RENAULT	M32	RENAULT-MITSUBISHI	P08	RENAULT-NISSAN-MITSUBISHI	P08
MAZDA	M33	TOYOTA-MAZDA	P09	MAZDA-SUBARU-SUZUKI-TOYOTA	P13
MAZDA EUROPE	M34	TOYOTA-MAZDA	P09	MAZDA-SUBARU-SUZUKI-TOYOTA	P13
TOYOTA	M35	TOYOTA-MAZDA	P09	MAZDA-SUBARU-SUZUKI-TOYOTA	P13
AUDI AG	M36	VW-SAIC	P10	VW-SAIC	P10
AUDI HUNGARIA	M37	VW-SAIC	P10	VW-SAIC	P10
AUDI SPORT	M38	VW-SAIC	P10	VW-SAIC	P10
BUGATTI	M39	VW-SAIC	P10	VW-SAIC	P10
JIANGLING MOTOR	M40	VW-SAIC	P10	VW-SAIC	P10
LEVC	M41	VW-SAIC	P10	VW-SAIC	P10
MG MOTOR	M42	VW-SAIC	P10		
NEXT EGO MOBILE	M43	VW-SAIC	P10	VW-SAIC	P10
PORSCHE	M44	VW-SAIC	P10	VW-SAIC	P10
SAIC MOTOR CORPORATION	M45	VW-SAIC	P10	VW-SAIC	P10
SEAT	M46	VW-SAIC	P10	VW-SAIC	P10
SKODA	M47	VW-SAIC	P10	VW-SAIC	P10
VOLKSWAGEN	M48	VW-SAIC	P10	VW-SAIC	P10
SAIC MAXUS	M49	SAIC MAXUS	PM1	SAIC MAXUS	PM49

MAGYAR SUZUKI	M50	SUZUKI	PD1	MAZDA-SUBARU-SUZUKI-TOYOTA	P13
SUZUKI MOTOR CORPORATION	M51	SUZUKI	PD1	MAZDA-SUBARU-SUZUKI-TOYOTA	P13
SUZUKI THAILAND	M52	SUZUKI	PD1	SUZUKI THAILAND	PM52
SUBARU	M53	SUBARU	PD2	MAZDA-SUBARU-SUZUKI-TOYOTA	P13
JAGUAR LAND ROVER LIMITED	M54	JAGUAR LAND ROVER LIMITED	PD3	TESLA	P15

Source: JRC analysis, 2023.

Table 6. Values calculated for each M1 manufacturer from the EEA database to be used in the determination of the EU fleet-wise target 2021

A	B	C	D	E	F	G	H	I
Manufacturer	Pools 2020	Registrations 2020 cleaned	<Enedc>	<MCO2>	<Ewltp>	Pools 2021	Registrations 2021	M.R.O 2021
M01	P01	801,922	111.503	125.245	133.352	P01	656,243	1710.36
M02	P01	14,510	231.883	227.026	242.690	P01	9,790	1969.35
M03	P01	508	351.008	337.957	367.717	P01	242	2672.02
M04	P02	32,690	146.167	163.034	170.419	P14	23,210	1704.15
M05	P02	102,755	139.800	160.527	168.104	P14	69,747	1605.31
M06	P02	484,389	110.612	127.594	135.703	P14	491,207	1231.23
M07	P02	78,221	111.295	128.180	135.763	P15	38,558	1454.83
M08	P02	92,526	0.000	0.000	0.000	P15	127,791	1912.45
M09	P03	10,636	100.237	123.817	125.044	P12	1,021	1713.00
M10	P03	53	118.981	136.132	136.925			
M11	P03							
M12	P03	10,058	236.866	238.739	241.469	P12	3,010	1847.61
M13	P03	648,706	108.387	131.994	134.230	P12	421,982	1550.81
M14	P03	286,552	106.646	120.678	124.973	PM14	241,475	1941.33
M15	P04	138,742	79.855	92.435	94.557	P04	111,362	1585.98

M16	P04	9	112.222	128.111	132.000	P04	120,572	1086.61
M17	P04	267,202	117.105	132.136	135.058	P04	207,646	1569.99
M18	P05	261,929	93.911	106.509	109.119	P05	237,103	1373.94
M19	P05	143,043	120.928	136.946	139.548	P05	175,864	1485.25
M20	P06	3,243	247.558	255.683	265.968	P06	805	1670.54
M21	P06	726,313	116.814	128.003	134.038	P06	542,537	1812.34
M22	P07	339,444	98.893	122.156	129.237	P14	288,043	1166.56
M23	P07	351,477	100.155	124.427	131.626	P14	271,525	1487.73
M24	P07	271,063	105.055	125.612	132.756	P14	185,952	1396.75
M25	P07	788,483	91.145	112.070	117.969	P14	809,892	1336.15
M26	P08	994	147.622	155.830	163.244	P08	2,158	1177.27
M27	P08	880	185.970	195.167	195.167			
M28	P08	278,629	114.306	130.634	134.530	P08	252,389	1176.07
M29	P08	31,999	161.314	173.678	179.964	P08	31,099	1805.62
M30	P08	33,956	105.381	116.469	120.279	P08	34,027	950.89
M31	P08	289,655	106.477	123.077	132.137	P08	179,976	1386.09
M32	P08	960,438	99.104	112.618	116.128	P08	803,088	1366.69
M33	P09	132,704	116.238	130.958	138.885	P13	108,477	1438.04
M34	P09	11,822	113.180	127.966	136.949	P13	16,868	1412.22
M35	P09	683,778	95.762	117.083	120.941	P13	612,548	1409.40
M36	P10	558,808	116.823	135.279	142.444	P10	444,872	1724.69
M37	P10	3,824	148.954	159.628	167.871	P10	2,953	1463.30
M38	P10	13,412	230.791	243.848	253.557	P10	11,077	1942.13
M39	P10					P10	13	2070.00
M40	P10	697	0.000	0.000	0.000	P10	1,060	1835.92
M41	P10					P10	1	2305.00
M42	P10	18,459	96.696	103.759	108.368			
M43	P10	490	0.000	0.000	0.000	P10	131	1255.46
M44	P10	68,113	150.696	162.858	175.832	P10	58,891	2039.29

M45	P10	7,209	0.000	0.000	0.000	P10	22,311	1703.27
M46	P10	363,229	113.996	126.650	137.183	P10	339,380	1391.26
M47	P10	583,027	110.071	127.578	134.128	P10	511,393	1444.29
M48	P10	1,285,458	107.971	124.481	130.928	P10	1,090,431	1497.21
M49	PM1	120	0.000	0.000	0.000	PM49	368	1884.54
M50	PD1	50,946	116.411	134.702	142.992	P13	78,841	1305.30
M51	PD1	105,299	101.814	116.168	123.821	P13	90,409	999.21
M52	PD1	1	114.000	122.780	136.000	PM52	12	890.00
M53	PD2	17,024	157.032	169.682	185.195	P13	15,508	1657.68
M54	PD3	26,698	90.670	98.489	106.560	P15	66,110	2162.14

Source: JRC analysis, 2023.

Description of columns in **Table 6**:

A. **Manufacturer:** Vehicle manufacturer

B. **Pools 2020:** Pools formed in 2020 pursuant to Article 6 of Regulation (EU) 2019/631.

C. **Registrations 2020 clean:** Number of M1 vehicles in the EEA 2020 combined dataset, obtained after the cleaning process. All registers have defined values for MCO2, Ewltp and Enedc

D. **<Enedc>:** Average CO_2 emissions in 2020 for a manufacturer according to the NEDC procedure

E. **<MCO2>:** Average measured CO_2 emissions in 2020 for a manufacturer according to the WLTP procedure

F. **<MCO2>:** Average declared CO_2 emissions in 2020 for a manufacturer according to the WLTP procedure

G. **Pools 2021:** Pools formed in 2021 pursuant to Article 6 of Regulation (EU) 2019/631.

H. **Registrations 2021:** Number of registrations per manufacturer in 2021

I. **M.R.O 2021:** Average mass in running order of the manufacturer's fleet of vehicles registered in 2021.

Part B. Light Commercial Vehicles (N1 vehicles)

Table 7. Correlation between acronyms used in this report for all the N1 manufacturer and pools in 2020 and 2021

Manufacturer		Pool 2020		Pool 2021	
ALFA ROMEO	N01	FCA-PSA	Q1	STELLANTIS	Q8
AUTOMOBILES CITROEN	N02	FCA-PSA	Q1	STELLANTIS	Q8
AUTOMOBILES PEUGEOT	N03	FCA-PSA	Q1	STELLANTIS	Q8
CHRYSLER	N04	FCA-PSA	Q1	STELLANTIS	Q8
FIAT GROUP	N05	FCA-PSA	Q1	STELLANTIS	Q8
OPEL AUTOMOBILE	N06	FCA-PSA	Q1	STELLANTIS	Q8
PSA	N07	FCA-PSA	Q1	STELLANTIS	Q8
FORD MOTOR AUSTRALIA	N08	FORD-VW	Q2	VOLKSWAGEN-FORD-SAIC-GOUPIL	Q9
FORD WERKE GMBH	N09	FORD-VW	Q2	VOLKSWAGEN-FORD-SAIC-GOUPIL	Q9
VOLKSWAGEN	N10	FORD-VW	Q2	VOLKSWAGEN-FORD-SAIC-GOUPIL	Q9
AUDI AG	N11	MAN-SAIC	Q5	VOLKSWAGEN-FORD-SAIC-GOUPIL	Q9
AUDI SPORT	N12	MAN-SAIC	Q5	VOLKSWAGEN-FORD-SAIC-GOUPIL	Q9
MAN	N13	MAN-SAIC	Q5	VOLKSWAGEN-FORD-SAIC-GOUPIL	Q9
SEAT	N14	MAN-SAIC	Q5	VOLKSWAGEN-FORD-SAIC-GOUPIL	Q9
SKODA	N15	MAN-SAIC	Q5	VOLKSWAGEN-FORD-SAIC-GOUPIL	Q9
MERCEDES-BENZ AG	N16	MERCEDES-BENZ	Q6		QN16
DACIA	N17	RENAULT-NISSAN-MITSUBISHI	Q7	RENAULT-NISSAN-MITSUBISHI	Q3
MITSUBISHI MOTORS CORPORATION	N18	RENAULT-NISSAN-MITSUBISHI	Q7	RENAULT-NISSAN-MITSUBISHI	Q3
MITSUBISHI MOTORS THAILAND	N19	RENAULT-NISSAN-MITSUBISHI	Q7	RENAULT-NISSAN-MITSUBISHI	Q3
NISSAN	N20	RENAULT-NISSAN-MITSUBISHI	Q7	RENAULT-NISSAN-MITSUBISHI	Q3

RENAULT	N21	RENAULT-NISSAN-MITSUBISHI	Q7	RENAULT-NISSAN-MITSUBISHI	Q3
IVECO	N22	IVECO	QN22		QN22
JAGUAR LAND ROVER	N23	JAGUAR LAND ROVER	QN23		QN23
PORSCHE	N24	PORSCHE	QN24		QN24
RENAULT TRUCKS	N25	RENAULT TRUCKS	QN25		QN25
TOYOTA	N26	TOYOTA	QN26		QN26
VOLVO	N27	VOLVO	QN27		QN27

Source: JRC analysis, 2023.

Table 8. Values calculated for each N1 manufacturer from the EEA database to be used in the determination of the EU fleet-wise target 2021

A	B	C	D	E	F	G	H	I
Manufacturer	Pools 2020	Registrations 2020 cleaned	<Enedc>	<MCO2>	<Ewltp>	Pools 2021	Registrations 2021	M.R.O 2021
N01	Q1	149	138.946	155.013	159.913	Q8	380	1745.37
N02	Q1	63,979	148.204	195.307	210.906	Q8	66,827	1886.15
N03	Q1	117,133	146.171	190.478	204.830	Q8	111,686	1884.09
N04	Q1	671	124.727	146.459	152.323	Q8	2,177	2124.06
N05	Q1	97,349	161.525	196.646	210.119	Q8	118,595	1820.12
N06	Q1	40,551	135.603	174.674	187.542	Q8	36,897	1738.23
N07	Q1	123,217	110.629	142.225	148.865	Q8	103,623	1440.51
N08	Q2	38,327	210.420	246.580	248.750	Q9	34,206	2376.18
N09	Q2	206,623	157.001	187.148	193.722	Q9	142,823	2028.56
N10	Q2	142,653	175.805	201.493	213.123	Q9	121,485	1948.18
N11	Q5	35	140.114	164.657	175.114	Q9	23	1854.57
N12	Q5	1	276.000	303.000	317.000	Q9	3	2041.67
N13	Q5	9,760	209.152	263.784	268.891	Q9	9,290	2203.11
N14	Q5	159	113.428	123.711	138.711	Q9	211	1468.15

N15	Q5	43	118.419	135.186	145.419	Q9	118	1261.76
N16	Q6	93,781	183.867	207.011	215.272	QN16	111,042	2196.88
N17	Q7	17,812	121.341	141.148	144.705	Q3	19,933	1308.26
N18	Q7	3	166.000	180.667	189.333	Q3	67	2083.19
N19	Q7	7,109	202.931	236.678	242.492	Q3	10,514	2071.06
N20	Q7	15,530	174.843	216.217	223.335	Q3	22,818	1971.18
N21	Q7	159,566	140.878	176.890	186.697	Q3	208,594	1746.34
N22	QN22	11,750	201.863	281.422	291.638	QN22	13,506	2423.59
N23	QN23	1,605	198.758	228.477	239.681	QN23	2,810	2149.70
N24	QN24	5	143.400	159.800	171.400	QN24	2	2187.50
N25	QN25	4,687	173.172	270.496	270.496	QN25	6,584	2180.09
N26	QN26	44,535	156.450	199.144	209.030	QN26	63,019	1884.85
N27	QN27	1,181	125.986	144.139	150.179	QN27	725	1729.83

Source: JRC analysis, 2023.

Description of columns in **Table 8**:

A. **Manufacturer:** Vehicle manufacturer

B. **Pools 2020:** Pools formed in 2020 pursuant to Article 6 of Regulation (EU) 2019/631.

C. **Registrations 2020 clean:** Number of N1 vehicles in the EEA 2020 combined dataset, obtained after the cleaning process. All registers have defined values for MCO2, Ewltp and Enedc

D. **<Enedc>:** Average CO_2 emissions in 2020 for a manufacturer according to the NEDC procedure

E. **<MCO2>:** Average measured CO_2 emissions in 2020 for a manufacturer according to the WLTP procedure

F. **<MCO2>:** Average declared CO_2 emissions in 2020 for a manufacturer according to the WLTP procedure

G. **Pools 2021:** Pools formed in 2021 pursuant to Article 6 of Regulation (EU) 2019/631.

H. **Registrations 2021:** Number of registrations per manufacturer in 2021

I. **M.R.O 2021:** Average mass in running order of the manufacturer's fleet of vehicles registered in 2021.

Annex 3. Data cleaning

Table 9. Number of registrations with missing Ewltp and/or Enedc for M1 (left) and N1 vehicles (right).

M1				N1	
Manufacturer	**Cases**	**Manufacturer**	**Cases**	**Manufacturer**	**Cases**
M21	2,222	**M25**	14	**N02**	55
M29	216	**M19**	12	**N26**	35
M46	201	**M44**	6	**N25**	1
M48	188	**M07**	6	**N11**	1
M54	103	**M22**	6		
M51	83	**M23**	5		
M35	56	**M15**	3		
M18	37	**M13**	3		
M24	30	**M47**	3		
M32	28	**M50**	3		
M17	27	**M53**	3		
M28	20	**M20**	2		
M14	19	**M12**	1		

Source: JRC analysis, 2023.

Table 10. Vehicles discarded due to MCO2, MCO2VH, MCO2VL missing values: M1 (left) and N1 vehicles (right).

M1				N1	
Manufacturer	**Cases**	**Manufacturer**	**Cases**	**Manufacturer**	**Cases**
M54	130,294	**M07**	50	**N21**	17
M48	21,303	**M17**	35	**N17**	1
M47	11,588	**M14**	31		
M50	7,935	**M13**	29		
M21	6,685	**M24**	28		
M36	5,787	**M17**	24		
M29	5,347	**M12**	15		
M51	1,943	**M44**	10		
M04	1,791	**M39**	7		
M06	1,787	**M20**	6		
M22	1,385	**M01**	3		
M52	1,149	**M18**	3		
M05	809	**M11**	2		
M32	608	**M30**	2		
M46	382	**M34**	1		
M25	328	**M09**	1		
M35	283	**M32**	1		
M28	164	**M45**	1		
M26	130	**M16**	1		
M38	93	**M41**	1		
M31	77	**M19**	1		
M23	64	**M27**	1		

Source: JRC analysis, 2023.

Table 11. Number of cases where the measured CO_2 value is higher than the declared one (MCO2>Ewltp) for M1 (left) and N1 vehicles (right).

M1			N1		
Manufacturer	**Cases**	**IP families**	**Manufacturer**	**Cases**	**IP families**
M29	26,654	2	**N06**	1,575	3
M47	12,021	1	**N05**	793	22
M18	11,054	21	**N03**	582	3
M24	5,637	11	**N09**	120	2
M15	5,439	14	**N02**	114	5
M17	5,257	47	**N26**	47	4
M06	2,163	20	**N13**	33	7
M05	1,874	12	**N18**	32	1
M19	1,792	19	**N21**	27	2
M09	1,423	1	**N20**	14	5
M40	593	16	**N10**	13	6
M32	249	34	**N04**	8	2
M13	210	2	**N08**	4	1
M35	161	11	**N22**	3	1
M12	146	1	**N15**	3	1
M48	78	12	**N25**	3	3
M14	58	9	**N07**	2	1
M25	11	4			
M46	10	2			
M27	3	1			
M04	2	2			
M22	2	1			
M31	2	1			
M23	1	1			
M28	1	1			

Source: JRC analysis, 2023.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

— at the following standard number: +32 22999696,

— via the following form: european-union.europa.eu/contact-eu/write-us_en.

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

Open data from the EU

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
joint-research-centre.ec.europa.eu

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

EU Science

Publications Office
of the European Union