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Joint Research Centre 2018 light-duty vehicles emissions testing

Contribution to the EU market surveillance: testing protocols and vehicle emissions performance

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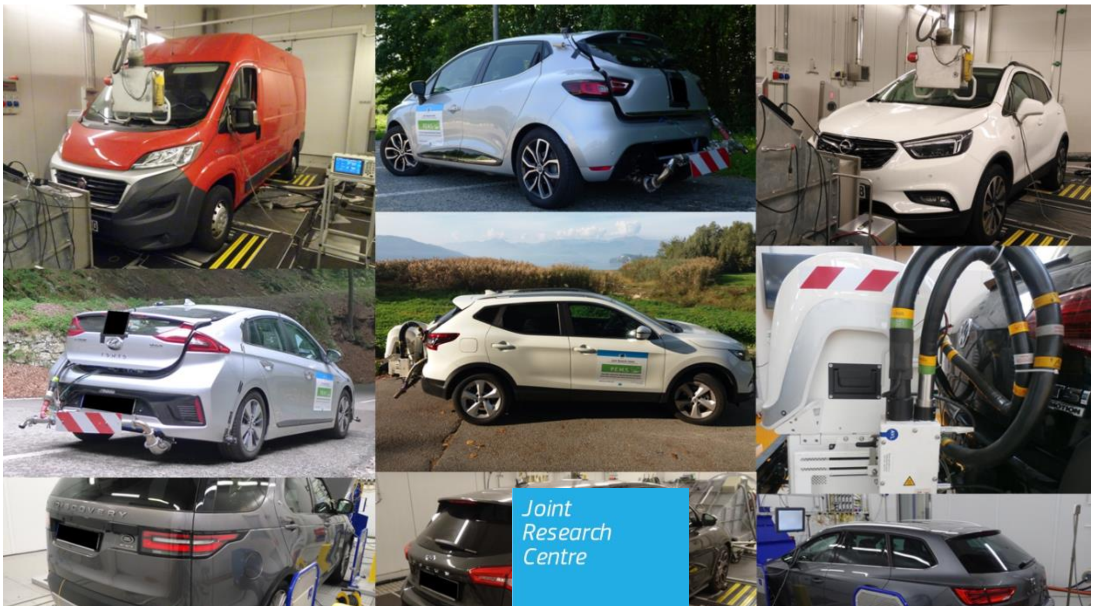

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Contents

Abstract

This report presents the activities of the JRC on tailpipe emissions compliance assessment of light-duty vehicles conducted throughout 2018. Criteria pollutant and CO_2 emissions of 19 vehicles were measured in the laboratory and on the road in a wide range of driving conditions. Distance-specific emissions for individual vehicles and per vehicle technologies and standards are presented. The methodology for emissions compliance defined in the *Guidance on the evaluation of Auxiliary Emission Strategies and the presence of Defeat Devices with regard to the application of Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6)* was applied and discussed.

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Executive summary

Every year, close to 500 000 premature deaths are attributed to poor air quality in the European Union. Currently, road transport is a major source of air pollutants, particularly in urban areas. In order to protect health and the environment, the European Commission aims at curbing emissions from motor vehicles by tightening the testing protocols and strengthening the enforcement of the emissions regulations. This report presents the tailpipe emissions of a set of 19 vehicles (7 gasoline, 1 gasoline/LPG, 9 diesel, 1 CNG, 1 gasoline/electric) tested by the JRC in laboratory conditions and on the road with portable emissions measurement systems in 2018. Emissions compliance and the presence of anomalous emissions control strategies are assessed based on the emissions measured on each vehicle under a wide range of conditions.

Policy context

Despite the fact that vehicles need to comply with specific emission limits at type-approval (i.e., before entering the EU market), and that manufacturers shall effectively limit the emissions of vehicles throughout their normal life under normal conditions of use (according to EC Regulation 715/2007), empirical data gathered by a variety of stakeholders has shown that on the road, NOx emissions of certain diesel vehicles are largely above their permissible laboratory limits. Inefficient after-treatment systems, the use of cycle-beating strategies (defeat devices) and tampering have been identified as the main causes of the difference between the emission values reported in the official tests and the real life figures. In order to secure low tailpipe emissions, several EU regulations have been approved since 2016 including the Real Driving Emissions regulation (EU regulations 2016/427, 2016/646, 2017/1154, 2018/1832); the implementation of the WLTP as the new regulatory test procedure that replaces the outdated NEDC (EU regulations 2017/1151, 2018/1832); an enhanced type-approval framework that includes Market Surveillance provisions to improve enforcement (EU regulation 2018/858); and the in-service conformity procedure which aims at checking emissions compliance of vehicles under normal conditions during their normal life (EU regulation 2018/1832).

Key findings and conclusions

The methodological approach for assessing vehicles emissions compliance includes testing vehicles in the laboratory, on the road (according to the RDE regulation), and the verification for the presence of Auxiliary Emissions Strategies (AES) which might affect the emissions under certain conditions. The latter is achieved by modifying certain test parameters (e.g., test cell temperature, driving cycle, load, etc.) as well as on-road tests within and beyond RDE boundaries. This comprehensive testing enables measuring emissions under a wide range of driving conditions and it proves to robustly assess emissions compliance. It is however an expensive and time consuming protocol, in particular when searching for AES. To efficiently make use of the available resources, it will be fundamental to make a proper vehicle selection based on a risk assessment performed upstream of the vehicle testing (i.e., test vehicles with suspicious behaviour).

Regarding NOx, gasoline vehicles of all tested Euro 6 stages (i.e., Euro 6b, 6c, and 6d-TEMP) met the emission limits in the laboratory (60 mg/km) as well as on RDE compliant tests (126 mg/km, considering the temporary conformity factor of 2.1) except one Euro 6b (to which the RDE requirements did not apply).

Euro 6b diesel vehicles emit on average 3.5 and 7.5 times as many NOx than gasoline Euro 6b vehicles in standard laboratory and road conditions, respectively. Under RDE conditions, diesel Euro 6b vehicles averaged 210 mg/km that is 2.6 times the NOx limit in the laboratory. Among those vehicles, those not equipped with a Selective Catalytic Reduction catalyst performed particularly poorly on the modified laboratory tests and on the road. Euro 6d-TEMP diesel vehicles averaged 46 mg/km and 75 mg/km under WLTP and RDE conditions, respectively confirming that the introduction of new regulatory texts has pushed manufacturers to produce diesel vehicles that emit low NOx under a wide range of conditions, which will ultimately help improving air quality. On non-RDE compliant tests, Euro 6d-TEMP diesel vehicles remained below the NTE NOx limit except on the dynamically-driven tests in which two out of three tested vehicles exceeded 225 mg/km. It is worth mentioning that certain diesel vehicles equipped with SCR exhibited NOx emissions consistently lower than the NTE limit on all on-road tests including dynamically-driven non-RDE compliant tests.

All tested diesel vehicles emitted less than half of the particle number (PN) laboratory limit under all testing conditions, which proves a good performance of diesel particle filters. On average on the road, Euro 6 diesel vehicles emitted ~1e10 #/km, two orders of magnitude less PN than their gasoline counterparts (~1e12 #/km). Gasoline vehicles with direct injection (GDI) and port-fuel injection (PFI) emitted similar amount of particles on the road although only PN from GDI vehicles are currently regulated. Four Euro 6b gasoline vehicles, two PFIs and two GDIs emitted more PN than the Not-to-exceed limit applicable for Euro 6d-TEMP vehicles. One of the Euro 6b GDI vehicles was equipped with a gasoline particle filter and it showed consistent emissions two orders of magnitudes lower than its applicable limit. On the road, the hybrid electric vehicle (GDI) emitted similar PN (5e11 #/km) when operated in charge sustaining and charge depleting mode, when most of the drive was done using the electric motor due to multiple engine-on situations.

All vehicles complied with the CO and HC emission limits in the laboratory. However on the road, most gasoline vehicles emitted more CO on the complete test than on the urban part alone, which indicates that cold-start emissions are not the main contributor to the CO emissions of these vehicles. When tested with a dynamic driving style on the road, the CO emissions on the motorway section of certain gasoline vehicles are particularly high (> 5 g/km).

As an outcome of the testing activities it has become clear that the current version of the Guidance note used for the identification of defeat devices needs to be updated to cover Euro 6d-TEMP vehicles and to consider other pollutants beyond NOx, namely PN and CO.

Related and future JRC work

In accordance with EU Regulations 2018/1832 and 2018/852, the European Commission will officially assess emissions compliance of light-duty vehicles in the context of in-service conformity (from September 2019) and Market Surveillance (from September 2020), respectively. The JRC is the EC service responsible for performing the emission tests in the laboratory and on the road. Using the experience of the present market surveillance pilot project as baseline, the JRC is working on improving its emissions testing capabilities and compliance assessment expertise by enhancing its human and technical resources and by accrediting its activity (ISO 17020/ISO 17025).

In addition, the JRC has started working on assessing the potential of remote sensing devices and simplified emissions measurement systems to screen the circulating vehicle fleet in order to properly identify and select potentially problematic vehicles upstream of the actual emissions testing.

Quick guide

The report is organised as follows. Chapter 1 introduces the policy context and defines the scope of the project. Chapter 2 describes the criteria used in the vehicle selection, the description of the testing methods and instruments, as well as the protocol to check for the presence of defeat devices. The tailpipe emissions of criteria pollutant retrieved during the laboratory and on-road tests on the 20 vehicles tested are presented in Chapter 3. Chapter 4 discusses the deviation between the measured CO_2 emissions and the type-approved CO_2 value. Chapter 5 presents the methodology to search for AES, the assessment being based on the emissions measured in the laboratory and on the road. Finally, chapter 6 provides the conclusions.

1 Introduction

This report presents the activities of the JRC on tailpipe emissions compliance assessment of light-duty vehicles conducted throughout 2018. It is the second report of its nature after the one discussing the activities carried out during the year 2017 [1]. As a consequence of the entry into force of new policy instruments aiming at curbing pollutant emissions, this report presents the environmental performance analysis of vehicles type-approved under different Euro standards: on one hand Euro 6b and Euro 6c vehicles, and on the other hand and for the first time, Euro 6d-TEMP vehicles. In 2018 in the European Union, several regulatory acts specified further the rules used to verify vehicle emissions before and after their introduction on the EU market (namely, at type-approval and during in-service conformity testing):

- The "4th RDE package" for light-duty vehicles and the WLTP second act (both in Regulation 2018/1832 [2]); the in-service conformity (ISC) provisions, that aim at ensuring that light-duty vehicles comply with their emission limits throughout their normal life (up to a mileage of 100 000 km or five years, whichever occurs first) was also introduced in Regulation 2018/1832. From September 1st 2019, the ISC provisions will be applicable to all new vehicles and it is applicable to all new types since January 1st 2019.
- The new Framework Regulation for type-approval and market surveillance (Regulation 2018/858 [3]).

To prepare for the Commission's obligations under the new Framework Regulation, the JRC kept running a Pilot activity including:

- Testing, both in the laboratory and on the road, a certain number of vehicles representative of the latest technologies appeared on the market applying the latest protocols used at type-approval (WLTP, RDE) to assess their emissions performance;
- Further assessment of the testing protocols that were proposed in 2016 following the emissions scandal to identify vehicles that exhibit emission patterns which could be caused by defeat devices.

1.1 Regulatory requirements, technology trends and their impact upon real pollutant emissions

The tests conducted in the project provided an insight on the pollutant emissions performance of the tested vehicles, relative to each other, as single vehicles or per technology classes, under comparable conditions (laboratory or same RDE routes). The questions which are tentatively addressed are:

- Are there significant differences in emissions performance among Euro 6 vehicles belonging to different stages (i.e., Euro 6b, Euro 6c, Euro 6d-TEMP)?
- Do the new or improved technologies (e.g., SCR, GPF) deliver the expected improvements, once assessed with the newest on-road test procedure (RDE)?
- Under comparable conditions, which technologies appear as the cleanest and/or most able to fulfil the latest environmental requirements?

1.2 Methodology to check the vehicles emissions compliance

The work of the authorities having the responsibility to enforce the requirements in the future can be classified in three main areas:

- Vehicle selection and risk assessment / Information gathering / Any additional information regarding the environmental performance of a given vehicle may be considered during the selection such as Remote Sensing or results from PEMS, or from simplified emission monitoring systems (SEMS).

— Vehicle testing according to the regulatory procedures for which performance requirements exist (e.g. the Type 1 WLTP, the Type 1a RDE test or even the Type 4 evaporative test, and the Type 6 cold temperature test);
— Assessment of Auxiliary Emissions Strategies (AES) and search for defeat devices in agreement with the Guidance on the evaluation of Auxiliary Emission Strategies and the presence of Defeat Devices with regard to the application of Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6).

During this Pilot activity, the above three pillars were addressed, with a view to build a robust basis for future official Market Surveillance activities performed by the European Commission in the context of the EU regulation 2018/858 Which will replace the current type-approval framework (Directive 2007/46/EC) from September 2020 [3]. The methodology is described in detail in below.

2 Methodology

2.1 Vehicle selection

2.1.1 Selection criteria and technologies

To assess the environmental performance of new vehicles and to check the suitability of the test protocol for the detection of defeat devices, a vehicle sample has been built that represents the market for 2018. The JRC laboratory had the capacity to test 20 vehicles that year. The following criteria were used to draw up the sample:

— Sales numbers;

— Vehicle manufacturer, to ensure a good coverage of various manufacturers present on the EU market;

— Vehicle segments as described in **Table 1** (the segmentation provides an indication on the size of the vehicle);

— Vehicle emissions control and powertrain technologies (**Table 1**).

Table 1: Vehicle size and technology selection (for acronyms see list of abbreviations and acronyms on page 79).

Vehicle segments	Vehicle Technologies
- A and B: Mini and Small cars	- Diesel (EGR+SCR+DPF, EGR+LNT+DPF, etc.)
- C: Medium cars	- Gasoline (PFI, GDI, GPF)
- D and E: Large and executive cars	- Compressed Natural Gas (CNG)
- Light Commercial Vehicles	- Liquefied petroleum gas (LPG)
	- Hybrid (including NOVC-HEVs and OVC-HEVs)

2.1.2 Sales numbers

The European Environment Agency's public dataset on EU vehicle sales in the year 2017 [4,5] was filtered and summarised, based on the type-approval number plus variant and version of the vehicle before being cross-checked with consolidated data from European Automobile Manufacturers Association (ACEA) registered in EU26 (Malta and Cyprus not included) plus Iceland, Norway and Switzerland [6]. **Figure 1** presents the number of newly registered passenger cars in the EU for 2017, broken down by main group of manufacturers as aggregated in the ACEA dataset.

The different geographical scope of the two datasets can explain the differences in registration numbers. In addition, the process to clean up data in the EEA original dataset may also result in discarded data (misspelt or wrongly annotated entries) which resulted in lower registration number in the final dataset. The total number of new registration of passenger car in 2017 obtained after data processing and excluding small-volume[1] manufacturers from the EEA and ACEA sources were 15.1M and 15.6M, respectively.

(1) Manufacturers responsible for fewer than 10 000 new vehicle registrations per year

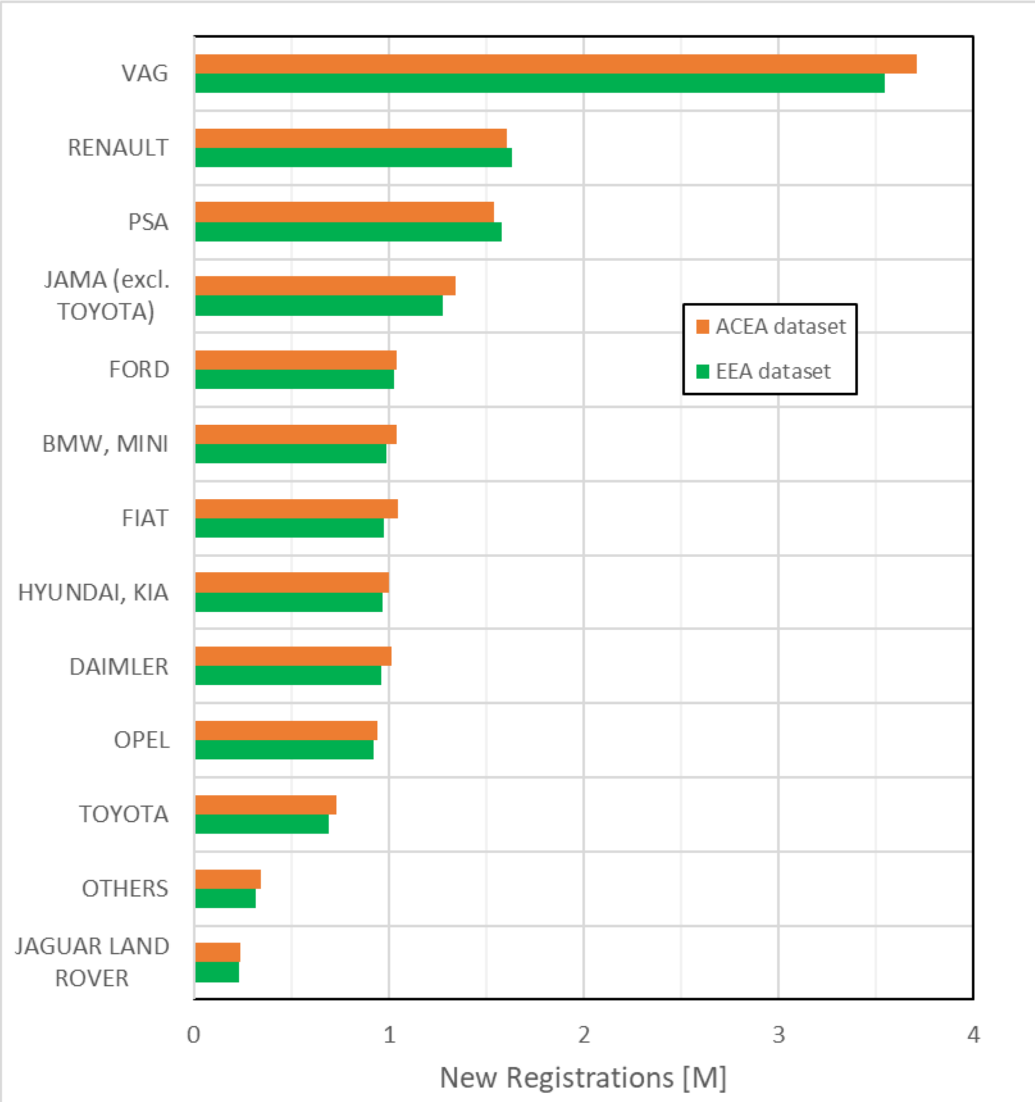

Figure 1: New passenger car registrations in EU28 (source EEA) and in EU 26 + Iceland, Norway and Switzerland (source ACEA) broken down by main vehicle manufacturer groups (following ACEA classification).

2.1.3 Vehicle manufacturers sales and cluster grouping

As the objective was to focus on high sales volume vehicles and technologies, small-volume manufacturers were excluded from the testing programme for 2018. The car manufacturer groups from **Table 2** were all included and considered for the entire selection process. The choice of the clusters and the grouping for the selected manufacturers was to ensure that vehicles are picked from the different world regions. The classification of the vehicle manufacturers is presented in **Table 2**.

Figure 2 presents the share of new registration of passenger cars in 2017 according to the consolidated data provided by ACEA for enlarged Europe, and broken down following the cluster classification defined in **Table 2**. According to these data and assuming a test fleet of 20 vehicles, **Table 3** presents the tentative number of vehicles to be tested by cluster, together with the vehicle actually tested in 2018.

Table 2: Cluster grouping of the main car manufacturers in EU

Cluster	Group	Country(ies) of origin	Brands
Cluster 1	VAG, Daimler, BMW	Germany, Spain, Czech Republic, United Kingdom	Volkswagen, Audi, Seat, Škoda, Porsche, Mercedes, Smart, BMW, Mini
Cluster 2	Ford, Opel[2]	Germany, United Kingdom	Ford, Opel, Vauxhall
Cluster 3	PSA, Renault[3]	France, Romania	Peugeot, Citroën, DS, Renault, Dacia
Cluster 4	FCA, Jaguar Land Rover, Volvo	Italy, United Kingdom, Sweden	Fiat, Alfa Romeo, Lancia, Chrysler, Jeep, Jaguar, Land Rover, Volvo
Cluster 5	Toyota, Honda, Mazda, Mitsubishi[3], Nissan[3], Subaru, Suzuki	Japan	Toyota, Honda, Mazda, Mitsubishi, Nissan, Subaru, Suzuki
Cluster 6	Hyundai, Kia, Ssangyong	South Korea	Hyundai, Kia, Ssangyong

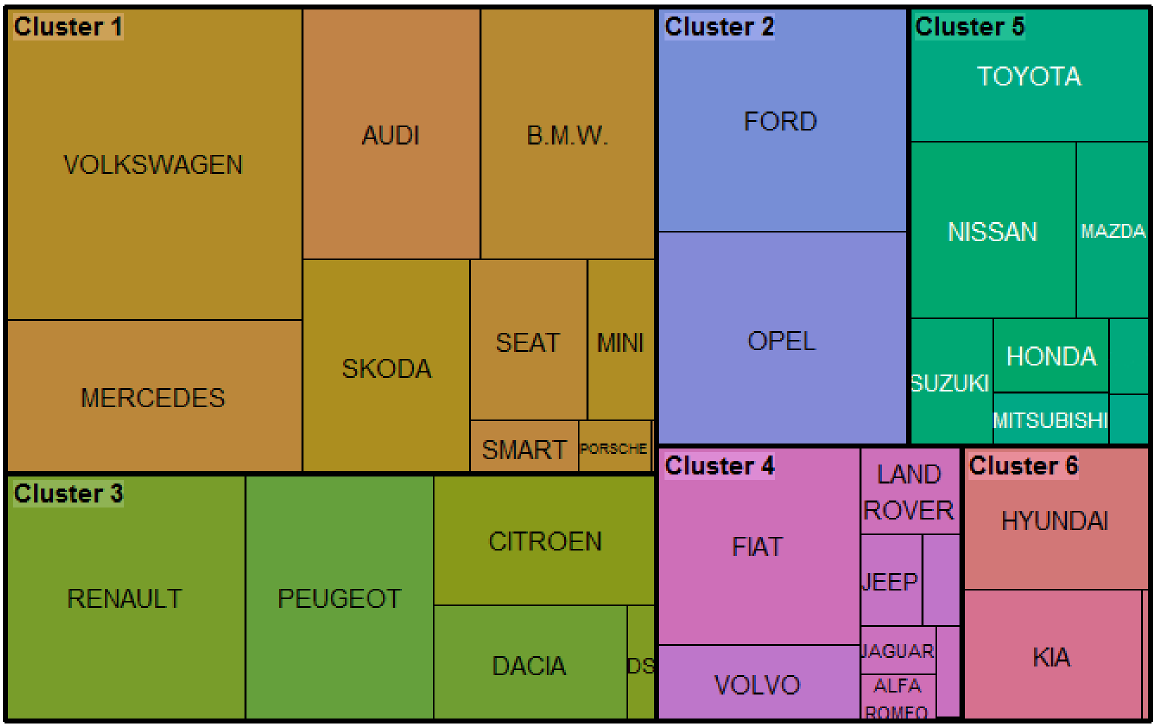

Figure 2: Shares of new passenger car registrations in Enlarged Europe, by cluster and brand (source: own visualization with ACEA data)

(2) Currently part of the PSA group
(3) Renault, Nissan and Mitsubishi form a strategic partnership

Table 3: Target and actual tested vehicles by main cluster

Cluster	Combined market share	Target no. of vehicles to be tested	Actual no. of vehicles tested
Cluster 1	37%	7	5
Cluster 2	13%	3	3
Cluster 3	20%	4	2
Cluster 4	11%	2	5
Cluster 5	13%	3	3
Cluster 6	6%	1	1

2.1.4 Selected vehicles

Table 4 presents the vehicles included in this Pilot study. Thirteen vehicles complying with Euro 6b standard, two vehicles complying with Euro 6c standard, and four vehicles complying with Euro 6d-TEMP standard were tested, totalizing nineteen vehicles. Vehicle FT060 is an OEM-fitted bi-fuel vehicle (Gasoline/LPG) that was fully tested on both fuels. The results of each fuel type are considered independently in the present report and therefore the tested fleet can be considered to be 20 vehicles. FT061 is a positive ignition, PFI commercial vehicle that runs on Compressed Natural Gas (CNG). FT061 can also run on gasoline over short distances although its use of gasoline is beyond the requirements of its emissions type-approval. The emissions of FT061 when fuelled with gasoline are briefly discussed in below7.

Regarding the technologies, gasoline vehicles were either Port Fuel Injection (PFI) or Direct Injection (GDI) and they were all equipped with a three-way catalyst (TWC). Only one gasoline vehicle (VW040) was equipped with a gasoline particle filter (GPF). All diesel vehicles were equipped with a diesel oxidation catalyst (DOC), an Exhaust Gas Recirculation (EGR) system, a diesel particle filter (DPF) and either Lean NOx Trap (LNT), Selective Catalytic Reduction (SCR) or both. More details on the vehicles tested can be found in **Annex 2**. The tested sample included one plug-in hybrid vehicle (HI002) that combined a 77.5 kW internal combustion gasoline GDI engine and a 44.5 kW electric motor.

Table 4: Final selection of test vehicles, all M1 category except FT061 which is N1 class III (vehicle categories as defined in Directive 70/156/EC).

Id.	Manufacturer	Model	Segment	Cluster	Euro class	Fuel	Emission Control Technologies
LA002	Lancia	Ypsilon 0.9l	B	4	6b	Gasoline PFI	TWC
VW040	Volkswagen	Tiguan 1.4l TSI	D	1	6b	Gasoline GDI	TWC + GPF
RT012	Renault	Clio 1.2l	B	3	6b	Gasoline GDI	TWC
NN009	Nissan	Qashqai 1.2l	C	5	6b	Gasoline GDI	TWC

Id.	Manufacturer	Model	Segment	Cluster	Euro class	Fuel	Emission Control Technologies
ST001	Seat	León ST 1.4l	C	1	6b	Gasoline GDI	TWC
FT060	Fiat	Tipo 1.4l	C	4	6b	Gasoline PFI /LPG	TWC
HI002	Hyundai	Ioniq PHEV 1.6l + 45 kW	C	6	6b	Hybrid Gasoline GDI /Electric	TWC + EGR
MB010	Mercedes	C220d	D	1	6b	Diesel	DOC + EGR + SCR + DPF
LR001	Land Rover	Discovery HSE Td6	E	4	6b	Diesel	DOC + EGR + SCR + DPF
OL002	Opel	Corsa 1.3l	B	2	6b	Diesel	DOC + EGR + LNT+ DPF
TA008	Toyota	Yaris 1.4l	B	5	6b	Diesel	DOC + EGR + LNT + DPF
OL003	Opel	Mokka X 1.6l	B	2	6b	Diesel	DOC + EGR + LNT + DPF
FT061	Fiat	Ducato 3.0l	LCV	4	6b	CNG	TWC
VW042	Volkswagen	Golf 1.5l TSI	C	1	6c	Gasoline GDI	TWC
SA002	Škoda	Superb 2.0l	D	1	6c	Diesel	DOC + EGR + LNT + SCR + DPF
SI001	Suzuki	Swift 1.2l	B	5	6d-TEMP	Gasoline PFI	TWC + EGR
VO006	Volvo	XC40 2.0l	D	4	6d-TEMP	Diesel	DOC + EGR + LNT + SCR + DPF
FD009	Ford	Focus 1.5l	C	2	6d-TEMP	Diesel	DOC + EGR + LNT + DPF
PT011	Peugeot	308 1.5l	C	3	6d-TEMP	Diesel	DOC + EGR + SCR+ DPF

2.2 Test methods

DISCLAIMER: As the declarations regarding the emissions control strategies are under the control of the vehicle Type-Approval Authority, the report cannot provide any judgement on the legality of the observed systems functioning. The findings are meant to assess the methods proposed in the Guidance on the evaluation of Auxiliary Emission Strategies and the presence of Defeat Devices [7] (hereinafter The Guidance). Furthermore, the report does not include either detailed information (e.g. functioning of the emissions control technologies and/or second-by-second data) to discuss the difference(s) which may appear between the emissions from tests conducted under different conditions.

In addition, vehicles which were part of the test program but became subject of investigations (resulting from an initiative from the Type-Approval Authority or an alert from the JRC) are not part of the report. The results from these vehicles will be presented once the investigations are completed.

2.2.1 Introduction

As a general principle, the vehicles are tested under their regulatory emissions test(s): compliance is verified according to the applicable regulatory methodologies, i.e. the Type 1 and Type 1a tests. This step is also important to ensure that the vehicle is free of malfunctioning, bad maintenance or other similar issues for which the vehicle manufacturer has no responsibility. For Euro 6b and Euro 6c vehicles, the Type 1 test follows the NEDC procedure as described in UN/ECE Regulation 83 [8], whereas for Euro 6d-TEMP vehicles, the applicable Type 1 test follows the Worldwide harmonised Light vehicles Test Procedures (as described in EU regulation 2017/1151 [9]). Type 1a corresponds to on-road testing with Portable Emissions Measurement Systems (PEMS) following the requirements of the Real Driving Emissions (RDE, [10 and its amendments]) regulation, which is applicable for Euro 6d-TEMP vehicles.

To detect the presence of defeat devices, the vehicles are tested under variations of the standard testing conditions referred to as "modified testing conditions" following the methodological schema introduced in the 2017 Pilot project activity [1] and verified by other researchers [11, 12, 13]. These general principles are illustrated in **Table 5** for the requirements varying between Euro 6b and Euro 6c, and Euro 6d-TEMP.

Table 5: Emissions standards, regulatory emissions tests and possible modified conditions

Emissions standards	Applicable regulatory emissions test(s)	Possible modified testing conditions for defeat device detection
Euro 6b Euro 6c	NEDC according to ECE R83	Modified NEDC, other cycles, on-road tests WLTP and RDE
Euro 6d-TEMP	WLTP according to EU Reg. 2017/1151 RDE	Steady High Speed (SHS) Cycle, Special lab cycles On-road tests outside the RDE "boundary conditions" (e.g. outside RDE altitude and temperature ranges)

2.2.2 Testing protocol to check for the presence of defeat devices

The Guidance proposed a testing protocol to screen for the presence of defeat devices for Euro 5 and Euro 6b vehicles. As a general principle, the vehicles are tested under variations of the standard testing conditions applied for type-approval–referred to as "modified testing conditions". By modifying one or several of the test parameters with respect to the emissions test, one might trigger one or more of the following:

— A defeat device[4]

— An Auxiliary Emission Strategy (AES) which becomes active and replaces the Base Emission Strategy (BES) for a specific purpose or purposes in response to a change of conditions (e.g., ambient temperature). Note that a vehicle can include several AES and that the use of AES is allowed as long as it is duly justified and the Type-Approval Authority authorises it.

— A modified physical response of the engine and/or emissions control technologies, naturally caused by the change of conditions (e.g., ambient temperature affecting the warm-up of components) but not controlled by software in response to sensed signals/parameters.

The combination of any of the above (the defeat device or AES and the physical effects) may result in a global change in tailpipe emissions. The protocol proposed to introduce 4 categories of procedures to cover the possible situations.

— In category 1, the test is conducted in a laboratory under a controlled environment with only limited changes when compared to the legislative cycle and the modified parameters can be controlled. The modification of the testing conditions should not lead to a significant change in the physical response of the engine system but may lead to a limited change of the vehicle emissions. Examples of such modifications include testing vehicles with an open door or rolled-down windows.

— In category 2, the test is conducted in a laboratory or on the road with conditions different than the legislative cycle and the value of the modified parameters can be controlled (e.g., driving a legislative cycle on a test track). The modification of the testing conditions may in some cases lead only to a limited change in the physical response of the engine system. Examples of such modifications include variations in the test temperature, the execution of hot-start tests, and the repetition of selected phases of the test cycle.

— In category 3, the test is conducted on the road and the values of the modified parameters are–to a large extent–uncontrolled (e.g., the vehicle speed due to the traffic, the temperature, etc.). The modification of the testing conditions may lead to a significant change in the physical response of the engine system(s). The magnitude in the change of the emissions may depend on the severity of the testing conditions. Examples of such modifications include testing at various test routes characterised by a distinct altitude profile, such as the RDE-compliant testing.

— A category 4 is added in order to cover what we call "surprise testing" to cover additional testing that does not fall into any of the above categories, but may still be needed in order to detect a possible defeat device.

The set of modified conditions is not fixed, but instead kept open due to the need to detect specific technology behaviours in response to a complex set of parameters and the need to keep a non-predictable character

For Euro 5 and Euro 6b vehicles, for which the main focus was on diesel, the following mechanism was proposed to identify anomalous vehicles:

Under category 1, emissions exceeding the recommended thresholds are a strong indication for a possible presence defeat device, since there can be no plausible explanation for an increase in pollutant emissions by simple modifications that do not affect the engine performance. In such a case, it is certain that the vehicle sensed that it is not tested in a regulatory cycle and therefore the change in emission level.

Under categories 2 to 4, emissions exceeding the recommended thresholds might result from the possible presence of a defeat device and/or the physical effects upon the emissions control of an AES. Therefore, further investigations and explanations from the manufacturers will be needed in order to identify if it is really a defeat device or an approved AES.

([4]) defeat device, defined in Article 3 (10) of Regulation (EC) 715/2007, means any element of design which senses temperature, vehicle speed, engine speed (RPM), transmission gear, manifold vacuum or any other parameter for the purpose of activating, modulating, delaying or deactivating the operation of any part of the emission control system, that reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use.

The typology of tests performed on Euro 6b and Euro 6c vehicles including their respective category and motivation are presented in **Table 6** .

For Euro 6d-TEMP and Euro 6d vehicles, the previous categorisation of tests and recommended emissions thresholds are no longer applicable: the tailpipe emissions have to comply with the applicable limits on the Type 1 (WLTP) and Type 1a (RDE) tests. Emissions exceeding the limits may occur outside the RDE boundary conditions or for non-compliant RDE tests. To determine whether elevated emissions are caused by a defeat device (i.e., an illegal Auxiliary Emissions Strategy) or by a modified physical response of the engine detailed investigations must be conducted including assessment of ambient and engine parameters. The typology of tests performed on Euro 6d-TEMP vehicles including their respective category and motivation are presented in **Table 7**. Section 5 presents an analysis of the methodology used to check emissions compliance.

Table 6: Tests and objectives (Euro 6b and Euro 6c vehicles)

Tests	Category[5]	Objectives
NEDC Cold	-	Vehicle emissions compliance under standard conditions
NEDC Hot	2	Emissions performance with hot engine, to check for a potential timer or vehicle conditioning triggering AES[6]
NEDC w/o preconditioning Cold	2	Emissions performance on a cold started NEDC driving cycle without pre-conditioning of the vehicle, to check for the potential vehicle conditioning triggering AES
NEDC Repeated Hot	2	Emissions performance with hot engine (without turning off the engine between the two tests), to check for a potential timer or distance windows triggering AES
Modified NEDC Cold +10% Speed	2	Vehicle emissions on a modified NEDC driving cycle, to check for a potential speed or distance windows triggering AES
NEDC hot with additional engine loads (AC and lights)	2	Emissions performance with hot engine and additional engine loads (AC and lights), to check for a potential use of vehicle systems triggering AES
NEDC +10°C Cold	2	Emissions performance at low ambient temperature, to check for a potential thermal window triggering AES
NEDC +30°C Cold	2	Emissions performance at high ambient temperature (higher than 30°C[7]), to check for a potential thermal window triggering AES
WLTC Cold	2	Emissions performance on cold started WLTC to check for a potential timer, vehicle conditioning, as well as speed or distance windows triggering AES.
WLTC Hot	2	Emissions performance on hot started WLTC to check for a potential timer, vehicle conditioning, as well as speed or distance windows triggering AES
RDE compliant	3	Emissions performance on road, to check for ECS functioning

(5) The categorisation of the various types of tests is made by the responsible testing entity and should be based on the lessons learned from its own testing activities and/or the publicly available information. It is subject to adaptations and revisions depending on the emissions control technology.

(6) In the following AES will stand for AES or Defeat Device. The decision on whether something can be considered an AES or a defeat device is always the responsibility of the Type-Approval Authority.

(7) These test were carried out at ca. 30°C due to laboratory facility limitation

Tests	Category[5]	Objectives
		under uncontrolled conditions, beyond the NEDC conditions
RDE non-compliant	3	Emissions performance on road outside the RDE boundary conditions. The non-compliance may result from the test altitude, temperature, driving dynamics and/or the trip urban-rural-motorway shares.

Table 7: Tests and objectives (Euro 6d-TEMP vehicles)

Tests	Objectives
WLTC Cold	Vehicle emissions compliance under standard conditions.
WLTC Hot	Emissions performance with hot engine and hot after treatment system, to check for a potential timer or vehicle conditioning triggering AES
Steady High Speed (SHS)	Emissions performance on cold started test including the first to phases of the WLTC and steady speed of 110 and 130 km/h respectively introduced in the modified 3rd and 4th phases of the driving cycle to check for potential AES during the steady speed driving.
WLTC +10°C Cold	Emissions performance at low ambient temperature, to check for a potential thermal window triggering AES
RDE compliant	Vehicle emissions compliance under moderate and extended RDE conditions
RDE non-compliant	Emissions performance on road outside the RDE boundary conditions. The non-compliance of the test with the RDE rules may result from the test altitude, temperature, driving dynamics and/or the trip urban-rural-motorway shares.

2.3 Tests conducted for each vehicle

All Euro 6b and Euro 6c vehicles were tested over the NEDC and WLTP cycles (both cold and hot) and at least over three different RDE compliant routes (named ESP, LAB and VIR), except for FT061, the only light-commercial vehicle of the tested fleet, which was tested only on ESP and VIR routes with additional (artificial) permissible payloads ranging 0% to 90%. HI002, plug-in-hybrid vehicle was tested on charge sustaining operation over NEDC, WLTP, and on ESP and VIR whereas an additional ESP test was done on charge depleting operation starting with fully loaded battery. The modified laboratory tests as well as the non-RDE compliant tests were performed on a case-by-case basis depending on the need and laboratory/PEMS availability.

All Euro 6d-TEMP vehicles were tested in the laboratory on WLTP (cold and hot engine conditions) as well as on the road over RDE compliant (ESP, LAB, VIR) and non-compliant tests (MIL, SAC, ESD, LAD, SMB). The main characteristics of the routes are presented in **Annex 1**. Regarding the RDE-non compliant tests, **Table 8** provides an exhaustive overview of the RDE boundary conditions that were not met for each test type. Note that all the RDE-compliant tests were performed respecting the regulatory minimum and maximum soak times whereas, on the non-RDE compliant tests, this was not always the case. **Table 9** indicates which non-RDE compliant tests were performed on each vehicle. Finally, **Table 10** summarises the tests conducted for each vehicle.

All PEMS tests were performed following the recommendations of the JRC Guidance note for light-duty vehicles [14] and fulfilling the RDE instrumentation requirements.

Table 8: Mandatory RDE conditions not fulfilled on RDE non-compliant tests, by test typology

Test type	Non-compliant conditions during tests
MIL	Total Trip Duration > 120 minutes Trip composition with urban share of the total distance < 29%, rural share < 23% and with motorway shares > 43% Rural distance <16 km
SAC	Altitude above 1300 meters above sea level Rural and motorway distance <16 km Trip composition with urban share of the total distance > 44% and with no rural and motorway shares (only urban test) Motorway speed above 100 km/h < 5 minutes. Total trip and urban cumulative positive elevation gain > 1200 m/100 km Share of normal urban windows < 50% Number of counts of acceleration points for rural and motorway sections < 100
ESP Dynamic (ESD)	95th percentile of the product of the vehicle velocity and positive acceleration above permitted limits defined in Appendix 7a, Section 4 of RDE regulation in at least one of the trip bins (Urban, rural or motorway).
LAB Dynamic (LAD)	
SMB	Urban cumulative positive elevation gain > 1200 m/100 km

Table 9: Non RDE-compliant tests conducted for each vehicle

Id.	MIL	SAC	ESD	LAD	SMB
LA002			X	X	X
VW040	X	X	X	X	X
RT012			X	X	X
NN009					X
ST001					X
FT060 (PFI)					X
FT060 (LPG)					X
HI002	X[8]	X	X[8]		
MB010	X		X	X	X
LR001			X	X	

(8) Test performed in charge-depleting operation

Id.	MIL	SAC	ESD	LAD	SMB
OL002					X
TA008					X
OL003					X
FT061					
VW042	X		X	X	X
SA002	X	X	X	X	X
SI001	X	X	X	X	X
VO006	X	X	X	X	X
FD009	X		X	X	X
PT011	X	X	X	X	X

Table 10: Chassis dynamometer tests conducted for each vehicle. Note that FT060 (bi-fuel vehicle) was tested on the same modalities in the laboratory and on the road on both fuels (Gasoline and LPG). The “SHS” modality corresponds to the test in which phases 3 and 4 are driven at steady speed (110 km/h and 130 km/h, respectively).

Id.	Make and model	Euro	Fuel	NEDC Cold	NEDC Hot	WLTC Cold	WLTC Hot	RDE Compliant	RDE non-compliant	NEDC w/o preconditioning Cold	NEDC Repeated Hot	NEDC +10% Speed Cold	NEDC with engine loads Hot	NEDC at +10°C Cold	NEDC at +30°C Cold	SHS Cold
Category				1	2	2	2	3	3	2	2	2	2	2	2	-
LA002	Lancia Ypsilon 0.9l	6b	Gasoline PFI	X	X	X	X	X	X	X	X	X	X	X		
VW040	Volkswagen Tiguan 1.4l TSI	6b	Gasoline GDI	X	X	X	X	X	X	X	X		X			X
RT012	Renault Clio 1.2l	6b	Gasoline GDI	X	X	X	X	X	X	X	X		X			X
NN009	Nissan Qashqai 1.2l	6b	Gasoline GDI	X	X	X	X	X	X	X	X		X			X
ST001	Seat Leon ST 1.4l	6b	Gasoline GDI	X	X	X	X	X	X	X	X		X			X
FT060	Fiat Tipo 1.4l	6b	Gasoline PFI/LPG	X	X	X	X	X	X	X	X	X	X			
HI002	Hyundai Ioniq PHEV 1.6l + 45 kW	6b	Hybrid Gasoline GDI /Electric	X	X	X	X	X	X				X			X
MB010	Mercedes C220d	6b	Diesel	X	X	X	X	X	X	X	X	X	X	X	X	
LR001	Land Rover Discovery HSE Td6	6b	Diesel	X	X	X	X	X	X	X	X	X	X	X	X	
OL002	Opel Corsa 1.3l	6b	Diesel	X	X	X	X	X	X	X	X	X	X	X	X	

Id.	Make and model	Euro	Fuel	NEDC Cold	NEDC Hot	WLTC Cold	WLTC Hot	RDE Compliant	RDE non-compliant	NEDC w/o preconditioning Cold	NEDC Repeated Hot	NEDC +10% Speed Cold	NEDC with engine loads Hot	NEDC at +10°C Cold	NEDC at +30°C Cold	SHS Cold
TA008	Toyota Yaris 1.4l	6b	Diesel	X	X	X	X	X	X	X	X	X	X	X		
OL003	Opel Mokka X 1.6l	6b	Diesel	X	X	X	X	X	X	X	X	X	X	X		
FT061	Fiat Ducato 3.0l	6b	CNG	X	X	X	X	X		X	X		X			X[9]
VW042	Volkswagen Golf 1.5l TSI	6c	Gasoline	X	X	X	X	X	X	X	X		X	X		X
SA002	Škoda Superb 2.0l	6c	Diesel	X	X	X	X	X	X	X	X	X	X	X	X	X
SI001	Suzuki Swift 1.2l	6d-TEMP	Gasoline PFI			X	X	X	X							X
VO006	Volvo XC40 2.0l	6d-TEMP	Diesel			X	X	X	X							X[10]
FD009	Ford Focus 1.5l	6d-TEMP	Diesel			X	X	X	X							X[10]
PT011	Peugeot 308 1.5l	6d-TEMP	Diesel			X	X	X	X							X[10]

(9) SHS Phase 3 steady at 85 km/h
(10) WLTP at 10 °C ambient temperature

2.4 Tests settings

2.4.1 Laboratory tests

The Laboratory tests were conducted at the European Commission Joint Research Centre (EC-JRC) Ispra, Italy, using two of the Vehicle Emission Laboratories (VELA):

- The first facility was composed of a chassis dynamometer (two rolls with 48" diameter, inertia range 454-4540 kg, MAHA Haldenwang, Germany), a Constant Volume Sampler (CVS, flow rate range 3 m^3 min-1 - 30 m^3 min^{-1}) with a critical flow Venturi, and gas analyzer benches (MEXA-7100 for the raw exhaust and MEXA-7400 for the dilution tunnel and bags, HORIBA, Japan).
- The second facility was composed of a chassis dynamometer (two rolls with 48" diameter, inertia range 250-4500 kg, ZÖLLNER GmbH, Bensheim, Germany), a CVS (CVS i60 LD, flow rate range 2 m^3 min^{-1} - 20 m^3 min^{-1}) with a critical flow Venturi, and gas analyzer benches (AMAi60 R1(D1) for both the raw exhaust and the dilution tunnel and bags, AVL, Graz, Austria).

For Euro 6b and Euro 6c vehicles, for which official road loads were not available, the resistances that were applied on the chassis dynamometer were calculated based on the vehicle characteristics (mass and dimensions). Formulas for calculation of these NEDC road load coefficients (F0, F1, and F2) were derived from a JRC database of vehicles for which road loads were known and provided by OEM's [15]. Road load coefficients for WLTP tests were calculated from NEDC road loads taking into consideration all procedural differences between NEDC and WLTP procedures that have an impact on road load [15]. The road loads applied in the laboratory for Euro 6d-TEMP vehicles were the ones used at type-approval, and were retrieved from each vehicle's Certificate of Conformity. The inertia, F0, F1, and F2 parameters used for each vehicle and test type are presented in **Annex 2**.

In addition, all WLTP tests have been done following the requirements of the new test procedure such as: increased and more realistic test mass, new gearshift strategy (for vehicles with manual transmission), test temperature, accuracy of the chassis dyno for the road load simulation, and vehicle preconditioning. In addition, the WLTP regulation requires the correction of measured CO_2 results for the vehicle's battery state of charge (SOC) at the end of the test. For Euro 6d-TEMP vehicles, the WLTP CO_2 results included in this report have been corrected for the State Of Charge of the battery (RCB correction as prescribed in the WLTP regulation) [9]. In addition, WLTP CO_2 values for Euro 6d-TEMP vehicles have been corrected for ambient temperature correction (ATCT) using ATCT correction factors retrieved from type-approval documentation.

2.4.2 On-road tests

To assess emissions performance of vehicle over on-road tests, three units of AVL-MOVE Gas PEMS (AVL, Graz, Austria – model 2016) were used. The PEMS measure separately NO and NO_2 with an ultra-violet analyser, and, CO and CO_2 with a non-dispersive infra-red analyser. Two PN-PEMS units (AVL M.O.V.E PN PEMS iS, and Horiba Nanoparticle Emission Tester NPET) were used during the test campaign to measure solid particle number with a 23 nm cut-off. The AVL PN-PEMS uses a diffusion charger as sensing principle to determine the particle number concentration, whereas the NPET uses a condensation particle counter. The exhaust mass flow was systematically measured with an exhaust flow meter (AVL M.O.V.E EFM) based on differential pressure measurement principle.

The PEMS fully comply with the RDE requirements and were validated on the chassis dynamometer on 11 passenger cars and 1 light commercial vehicle (5 Diesel + 2 Gasoline GDI + 3 Gasoline PFI + 1 LPG + 1 CNG) over NEDC & WLTC cycles on Cold and Hot engine conditions totalizing 26 validation tests [16]. The PEMS showed overall good performance of gas analysers in laboratory conditions with low number outside the permissible tolerances (< 5% for single analysers). The measurement uncertainty of PEMS has been discussed elsewhere [17].

2.5 Quality control and validation of test results

For the laboratory tests, a minimum of two repetitions per test type were carried out per vehicle. As the purpose of the testing protocol was to detect a potential AES rather than accurately reported an emission performance of the specific vehicle over modified testing condition, this screening approach was adopted. As a first quality check, the repeatability of the pollutant measurement was assessed for each type of test described in **Table 6** and **Table 7**. The quality check was considered successful when at least one of the two conditions defined in **Table 11** was fulfilled. When the indicated criteria were not fulfilled a third repetition was performed. In the case when the criteria in **Table 11** were not met but the emission values measured were well below the emission limits, the third repetition was not performed in the interest of time. The tolerances for repetition acceptance were based on the permissible tolerances defined in Appendix 3 of RDE regulation of the recommended validation of PEMS equipment as described in the 3rd RDE package [18].

For on-road tests, the requirements defined in the RDE regulation, including the amendments of RDE4 laid down in regulation 2018/1832 [2], were used and fulfilled on the RDE Compliant tests (altitude and temperature boundary limits, trip dynamicity, share of operation, cold start requirements, etc.). Pre-test and post-test were performed as requested by the regulation. Whenever the drift requirements of the regulation for zero and/or span were not met, the measured emissions were disregarded for the pollutant(s) beyond the permissible tolerances (e.g., in one RDE test PN and NOx are kept whereas CO is discarded for exceeding CO zero drift of 75 ppm). It is important to notice that four tests were performed on the LA002 and that all of them resulted invalid for not meeting the RDE Appendix 5 requirements (50% of moving averaging windows within the defined tolerances on the urban, rural, and motorway bins). LA002 averaged 193 gCO_2/km on the four complete road tests and its measured WLTP CO_2, which is used to set the tolerances, was 126 gCO_2/km and the type-approval value on NEDC was 97 gCO_2/km. Results presented on RDE compliant tests for LA002 are kept for illustration purposes despite not fully meeting all RDE requirements. FT061, which is a light commercial vehicle, was tested with no additional payload, and 50% and 90% additional payload (2 tests each). Only tests with 90% payload and one test with 50% payload fulfilled the Appendix 5 requirements. Emissions reported correspond only to the valid tests. The CO zero drift was systematically exceeded on all RDE tests performed on the sole Euro 6d-TEMP gasoline vehicle (SI001). As it is the only vehicle of its kind, the emissions are reported for illustration purposes.

The data evaluation and emissions calculations used in the report correspond to those described in Appendix 5 and Appendix 6 of the RDE4 regulation [2], respectively. EMROAD (version 6.02) was used to perform the ex-post evaluation and emissions calculations. For Euro 6b and Euro 6c vehicles, the WLTP CO_2 phases required to use the MAW Method were obtained from the WLTP Cold tests performed in-house. For Euro 6d-TEMP vehicles, the WLTP CO_2 figures were those reported in the CoC.

Both for laboratory and RDE, the tests in which a regeneration of the diesel particle filter (DPF) was identified were discarded and repeated. It is unclear if a regeneration occurred on one on-road test (ESD) done on the VW040 (gasoline vehicle with GPF) as discussed in [19]. During the end of the urban section and start of the rural section gaseous emissions were particularly high as compared to other road and laboratory tests done with this vehicle and therefore the test was voided and repeated.

Table 11: Conditions of acceptance of the laboratory test type experimental results

Pollutants	<u>Condition 1</u> Limit of the absolute difference between max and min values of the repetitions	<u>Condition 2</u> Limit of the coefficient of variation of the repetitions
THC	15 mg/km	15%
PN	1e11 #/km	50%
CO	15 mg/km	15%
CO_2	10 g/km	10%
NOx	15 mg/km	15%

3 Pollutant Emissions Results

3.1 Introduction

The primary objective of the section is to provide an insight on the emissions performance of the tested vehicles, relative to each other, as single vehicles or per technology classes, under comparable conditions (laboratory or same RDE routes). The emission limits applicable for each type of vehicle depending on its powertrain and segment are summarised in **Table 12**. With this analysis, the questions which are addressed are:

— Under comparable conditions, which technologies appear as the cleanest and/or able to fulfil the latest environmental requirements?

— With Euro 6b, Euro 6c and Euro 6d-TEMP, is there a significant trend towards an improvement or a worsening of the real-world emissions performance?

This chapter seeks to answer these questions based on the laboratory and PEMS emissions data collected by the JRC in 2017 and 2018. Sections 3.2 to 3.5 present the emissions of the vehicles tested in 2018 for NOx, CO, total hydrocarbons (HC) and PN, whereas section 3.6 integrates the results of 2017 and 2018.

The emissions values are presented for "reference situations", i.e., the NEDC and WLTP cold and hot tests and for the complete and urban RDE compliant tests. The results from tests conducted specifically to detect AES/defeat devices are presented in Section 5.

Table 12: Regulated pollutant Type 1 test limits for the vehicles included in this study

Pollutants	Positive ignition (Gasoline, LPG) M1 Euro 6	Compression ignition (Diesel) M1 Euro 6	Positive ignition (CNG) N1 Cl.III Euro 6
THC [mg/km]	100	-	160
NMHC [mg/km]	68	-	108
NOx [mg/km]	60	80	82
HC+NOx [mg/km]	-	170	-
CO [mg/km]	1000	500	2270
PM [mg/km]	4.5	4.5	4.5
PN [#/km]	6e11 [11]	6e11	- [12]

3.2 NOx emissions

NOx emissions obtained for the NEDC, WLTC and RDE tests for Euro 6b and Euro 6c vehicles are presented in **Figure 3** whereas WLTC and RDE tests for Euro 6d-TEMP vehicles are shown in **Figure 4**. **Table 13** shows the average emissions by main vehicle technologies and emissions standards. Please note that the names used for the various vehicles in all figures and tables below should be read as making reference to the identification code (Id.) in **Table 4**.

(11) Limit applicable for GDI powered vehicles only. A limit of 6e12 #/km was applicable for vehicles type-approved in the period September 2014 to September 2017 (Euro 6b).

(12) No PN limit applies to FT061 since it is a positive ignition engine with port fuel injection

The following observations can be made about the laboratory and on-road emissions (under RDE conditions):

- On the NEDC Cold test (i.e., type-approval conditions in the laboratory for Euro 6b and Euro 6c vehicles), the NOx applicable limits were met for all the vehicles except for OL003. For this diesel vehicle, four repetitions were made on NEDC Cold with average NOx emissions of 91 mg/km (emissions of each individual test being 72 mg/km, 83 mg/km 91 mg/km, and 116 mg/km). In order to reduce uncertainty on the measured value associated to the measurement instrumentation, the vehicle was tested on both laboratories participating in the test campaign yielding similar results.
- The average (±standard deviation) of Euro 6b gasoline vehicles (PFIs and GDIs) over the NEDC Cold test was 18 ± 7 mg/km, similar to the sole Euro 6c vehicle tested (17 mg/km).
- Within the gasoline vehicles, no apparent difference was found between PFI vehicles and GDI ones for the NEDC Cold tests.
- For diesel vehicles, the average of Euro 6b vehicles over the NEDC Cold test was 64 ± 16 mg/km whereas the Euro 6c (one vehicle only) was one third lower (48 mg/km).
- On the NEDC Cold, the NOx emission of diesel vehicles was on average 3.7 and 2.8 times the NOx emission of gasoline vehicles for Euro 6b and Euro 6c, respectively.
- The lowest NOx emissions on NEDC Cold corresponded to HI002 (plug-in hybrid vehicle, operated in charged sustaining operation), followed by FT060 on LPG.
- The NEDC Hot test yielded similar or slightly lower NOx emissions than the Cold test (performed back to back) for all powertrains except on Euro 6b diesel and CNG vehicles, where NOx was 1.4 and 2.3 times the cold-test value, respectively. OL003 performed particularly poorly on NEDC Hot test reaching 193 mg/km (more than twice the emission measured on the Cold test). Additional comments on this vehicle are discussed in section 5.3.
- Regarding WLTP Cold test, all gasoline vehicles except NN009 were below the 60 mg/km NOx limit (applicable to Euro 6d-TEMP vehicles). NN009 averaged 63 mg/km on the two repetitions of the WLTP Cold test performed. Euro 6b, 6c, and 6d-TEMP gasoline vehicles averaged 34 ± 18 mg/km, 14 mg/km, and 10 mg/km, respectively. On the WLTP Hot test, emissions were similar to those measured on the Cold test.
- The emissions performance of diesel vehicles improved alongside the Euro emissions standard step: Euro 6b vehicles averaged 143 ± 81 mg/km, which is 3 to 5 times the average of the Euro 6c and Euro 6d-TEMP vehicles. It is important to notice that the two Euro 6b vehicles with an SCR (LR001 and MB010) did not exceed the 80 mg/km limit on the WLTP tests (Cold or Hot), whereas the other three vehicles (TA008, OL002, and OL003) averaged 197 mg/km and 230 mg/km on WLTP Cold and WLTP Hot tests, respectively. The vehicle with lowest NOx emission on the WLTP Cold test was FD009 (19 mg/km, Euro 6d-TEMP) followed by SA002 (29 mg/km, Euro 6c).
- The NOx emissions of the CNG vehicle (FT061) were 3.6 and 7.5 times the 82 mg/km type-approval limit over the WLTP Cold and WLTP Hot tests, respectively. On the road, the vehicle emitted 4.3 and 5.9 times the type-approval limit on the complete trip and urban section, respectively.
- On the road under RDE compliant conditions, NOx emissions of all gasoline vehicles disregard their emission standard were below the Euro 6 limit of 60 mg/km, both on the complete trip and on the urban section except NN009. For all the gasoline vehicles (including the PHEV) and the LPG vehicle, NOx emissions on the RDE complete test were similar to those measured on the WLTP Cold test.
- Euro 6b diesel vehicles averaged 210 ± 206 mg/km on the complete RDE route, which is 2.6 times the Euro 6 limit applicable on the NEDC Cold test. However, NOx emission of diesel vehicles equipped with an SCR (MB010, and LR001) were below 80 mg/km on all RDE tests performed. NOx emissions were particularly high on one test (ESP) of TA008 and one test (LAB) of OL003 reaching 708 mg/km and 516 mg/km (8.8 and 6.5 times the limit, respectively). These two are diesel vehicles without an SCR.
- The diesel Euro 6c vehicle registered the lowest on-road NOx emissions with a maximum value of 19 mg/km (3 valid RDE tests performed). Among Euro 6d-TEMP diesel vehicles PT011 and VO006 (both

with SCR) averaged < 55 mg/km on the complete route whereas NOx emissions on FD009 (LNT) were 118 mg/km (still below the applicable NTE limit for Euro 6d-TEMP vehicles: 168 mg/km).

- For the gasoline, LPG, and CNG vehicles, the RDE urban emissions resulted higher when compared to the RDE emissions for the complete trip. The opposite trend was found for diesel vehicles (Euro 6b and Euro 6d-TEMP).

Table 13: Average NOx emissions in mg/km over NEDC, WLTP, and RDE-compliant tests by emissions standard and vehicle technology.

Cycle / **Vehicle Technology (#)**	**NEDC Cold**	**NEDC Hot**	**WLTP Cold**	**WLTP Hot**	**Complete RDE**	**Urban RDE**
Euro 6b Gasoline PFI (2)	16	10	17	17	13	18
Euro 6b Gasoline GDI (4)	18	20	43	49	52	80
Euro 6b PHEV (Gasoline GDI/Electric) (1)	2	2	8	9	7	1
Euro 6b Diesel (5)	65	91	143	156	210	176
Euro 6b LPG (1)	13	9	17	14	15	16
Euro 6b CNG (1)	56	130	294	614	181	645
Euro 6c Gasoline GDI (1)	17	6	14	7	10	14
Euro 6c Diesel (1)	48	45	29	20	15	21
Euro 6d-TEMP Gasoline non-GDI (1)	-	-	10	17	12	16
Euro 6d-TEMP Diesel (3)	-	-	46	44	75	47

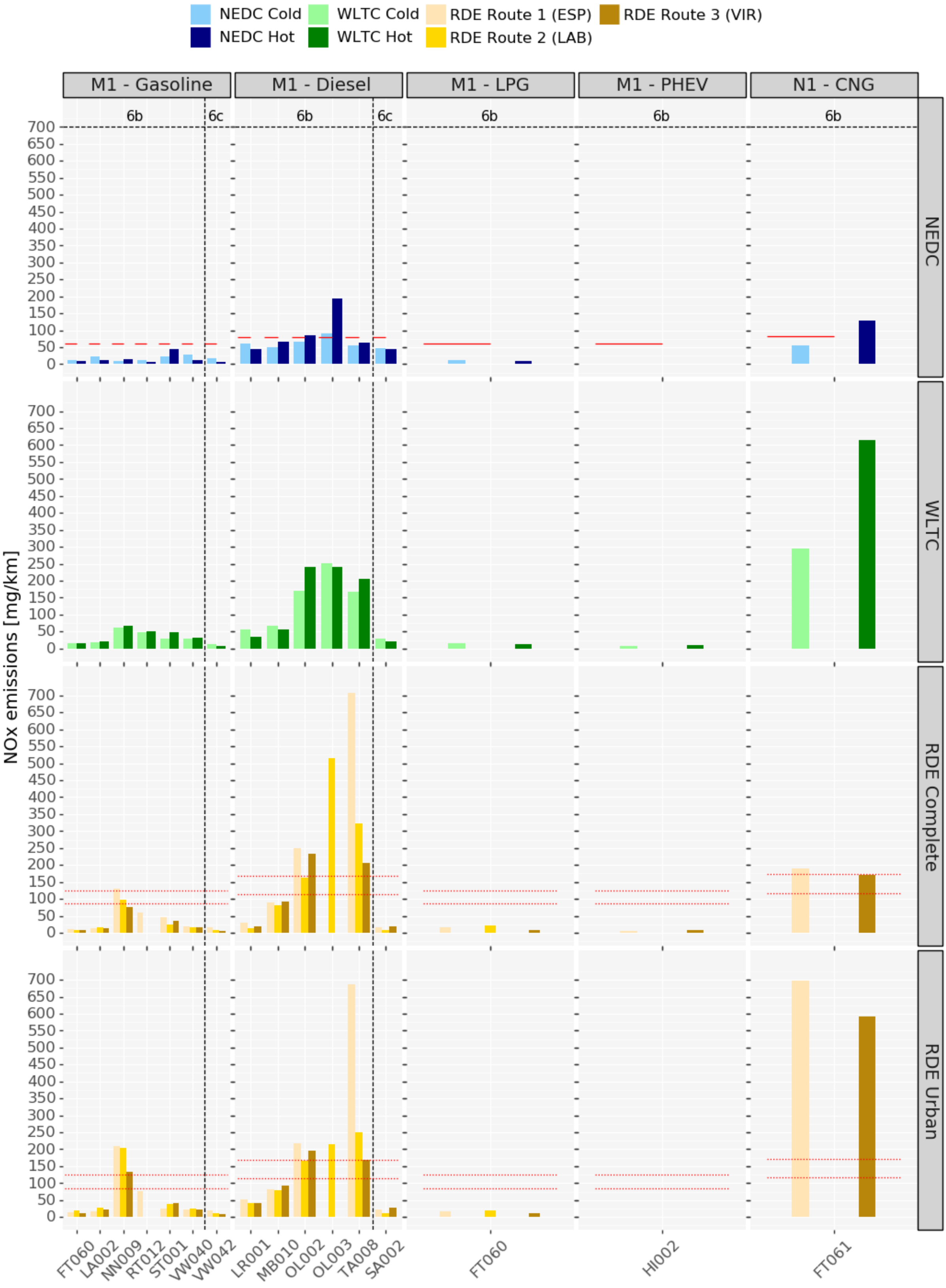

Figure 3: NOx emissions for Euro 6b and Euro 6c vehicles over the NEDC laboratory cold and hot tests (top panel), the WLTC laboratory cold and hot tests (second panel) and on-road tests (third panel for complete trip and bottom panel for urban section). On the top panel, horizontal red lines stand for the NOx limit applicable on the Cold NEDC test. On the third and fourth panels, dashed horizontal red lines stand for the NOx NTE limit including the conformity factor of 2.1 and 1.43 (not applicable to Euro 6b and Euro 6c vehicles, depicted for illustration purposes).

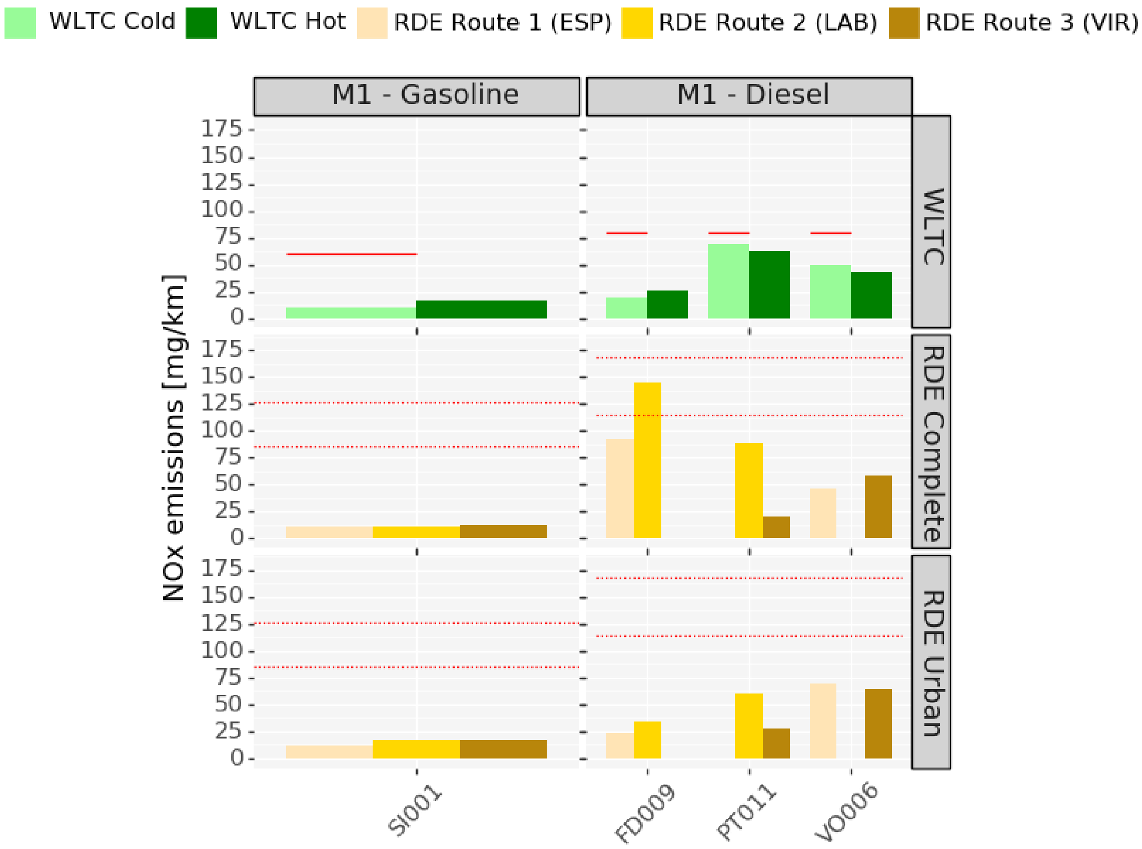

Figure 4: NOx emissions for Euro 6d-TEMP vehicles over the WLTP laboratory cold and hot tests (first panel) and RDE compliant tests (middle and bottom panels for complete and urban section, respectively). On the top panel, horizontal red lines stand for the NOx limit applicable on the Cold WLTC test. On the middle and bottom panels, dashed horizontal red lines stand for the NOx NTE limit including the conformity factor of 2.1 and 1.43.

3.3 CO emissions

The CO emissions obtained for the NEDC, WLTP, and RDE tests are presented in **Figure 5** (Euro 6b and Euro 6c) and **Figure 6** (Euro 6d-TEMP). **Table 14** shows the average emissions by main vehicle technologies and emissions standards. The following observations can be made for their laboratory and on-road emissions (under RDE conditions):

— All vehicles complied with the applicable limit on the laboratory Type 1 test (NEDC for Euro 6b and Euro 6c vehicles, and WLTP for Euro 6-dTEMP vehicles).

— Over the NEDC Cold test, gasoline Euro 6b vehicles emitted on average 277 ± 181 mg/km, which is 2.9 times the value for Euro 6b diesel vehicles (96 ± 63 mg/km).

— Euro 6b gasoline vehicles emitted 1.8 times as many CO over the NEDC Cold test than the Euro 6c. The opposite occurred for diesel vehicles, where the Euro 6c emitted 1.4 times the Euro 6b average.

— On the NEDC Cold test, the PHEV operated in charge-sustaining mode emitted half the CO of the gasoline GDI average, whereas the LPG and the CNG registered similar CO values as the gasoline PFI vehicles.

— As expected due to the catalyst light-off, the emissions over the cold NEDC cycle were systematically higher than those over the hot NEDC. The relative reduction in emissions on the hot test as compared to the cold one was higher on the diesel vehicles than on the gasoline ones (both for Euro 6b and Euro 6c).

— Among gasoline vehicles, those with PFI (FT060 and LA002) emitted 3.4 times as many CO than those with direct injection (VW040, RT012, NN009, ST001) on NEDC Cold and NEDC Hot, respectively.

— Over the WLTP Cold test, the Euro 6b gasoline vehicles (2 PFIs + 4 GDIs) averaged 373 ± 342 mg/km of CO, the Euro 6c gasoline vehicle (GDI) yielded 94 mg/km, and the Euro 6d-TEMP (PFI), 370 mg/km. The largest CO emissions over WLTP correspond to FT060 when operated with gasoline. In fact, emissions on the WLTP Cold test are 1.8 times higher than over the NEDC Cold test reaching 971 mg/km despite the fact that cold start effect is usually more noticeable on the NEDC cycle than on the WLTP due to the shorter distance covered by the cycle and its reduced dynamicity. On the hot tests, this vehicle emits 8 times as many CO on the WLTP than on the NEDC pointing to a poor operation under high load condition.

— CO emissions of diesel vehicles over WLTP Cold were 86 ± 107 mg/km (Euro 6b), 24 mg/km (Euro 6c), and 47 ± 26 mg/km (Euro 6d-TEMP).

— Regarding RDE tests, gasoline Euro 6b vehicles averaged 742 ± 674 mg/km, which is 3.4 and 3.1 times the emissions of the gasoline Euro 6c, and Euro 6d-TEMP vehicles. Note that the GDIs (with the exception of NN009) emitted less than 400 mg/km on the complete test, whereas NN009 and FT060 emitted more than 1000 mg/km (Type 1 test limit).

— For the on-road tests, the CO emissions from gasoline vehicles were found 2.5, 4.6, and 2.1 times higher over the complete Route than on the urban part, for Euro 6b, Euro 6c, and Euro 6d-TEMP, respectively. This finding is consistent with the recent RDE data provided by the manufacturers during the RDE monitoring phase and available at their websites [16,20,21]. It also indicates that, during on-road operation, cold-start emissions are not the main contributor to the CO emissions of the vehicles.

— The PHEV emitted on average 32 mg/km of CO on RDE-compliant tests (charge-sustaining and charge-depleting tests considered) which is two orders of magnitude lower than the Type 1 applicable limit (1000 mg/km).

— The on-road emissions were lower than those measured on the WLTP Cold test on the LPG and particularly on the CNG vehicle.

Table 14: Average CO emissions in mg/km over NEDC, WLTC, and RDE tests by emissions standard and vehicle technology

Cycle / Vehicle Technology (#)	NEDC Cold	NEDC Hot	WLTP Cold	WLTP Hot	Complete RDE	Urban RDE
Euro 6b Gasoline PFI (2)	556	170	704	413	1000	604
Euro 6b Gasoline GDI (4)	163	51	167	169	464	108
Euro 6b PHEV (Gasoline GDI/Electric) (1)	78	5	55	33	32	17
Euro 6b Diesel (5)	96	15	86	44	20	35
Euro 6b LPG (1)	659	167	542	228	404	486
Euro 6b CNG (1)	482	212	579	390	191	227
Euro 6c Gasoline GDI (1)	157	23	94	58	217	47
Euro 6c Diesel (1)	136	9	24	26	14	14
Euro 6d-TEMP Gasoline PFI (1)	-	-	370	241	241	113
Euro 6d-TEMP Diesel (3)	-	-	47	17	11	10

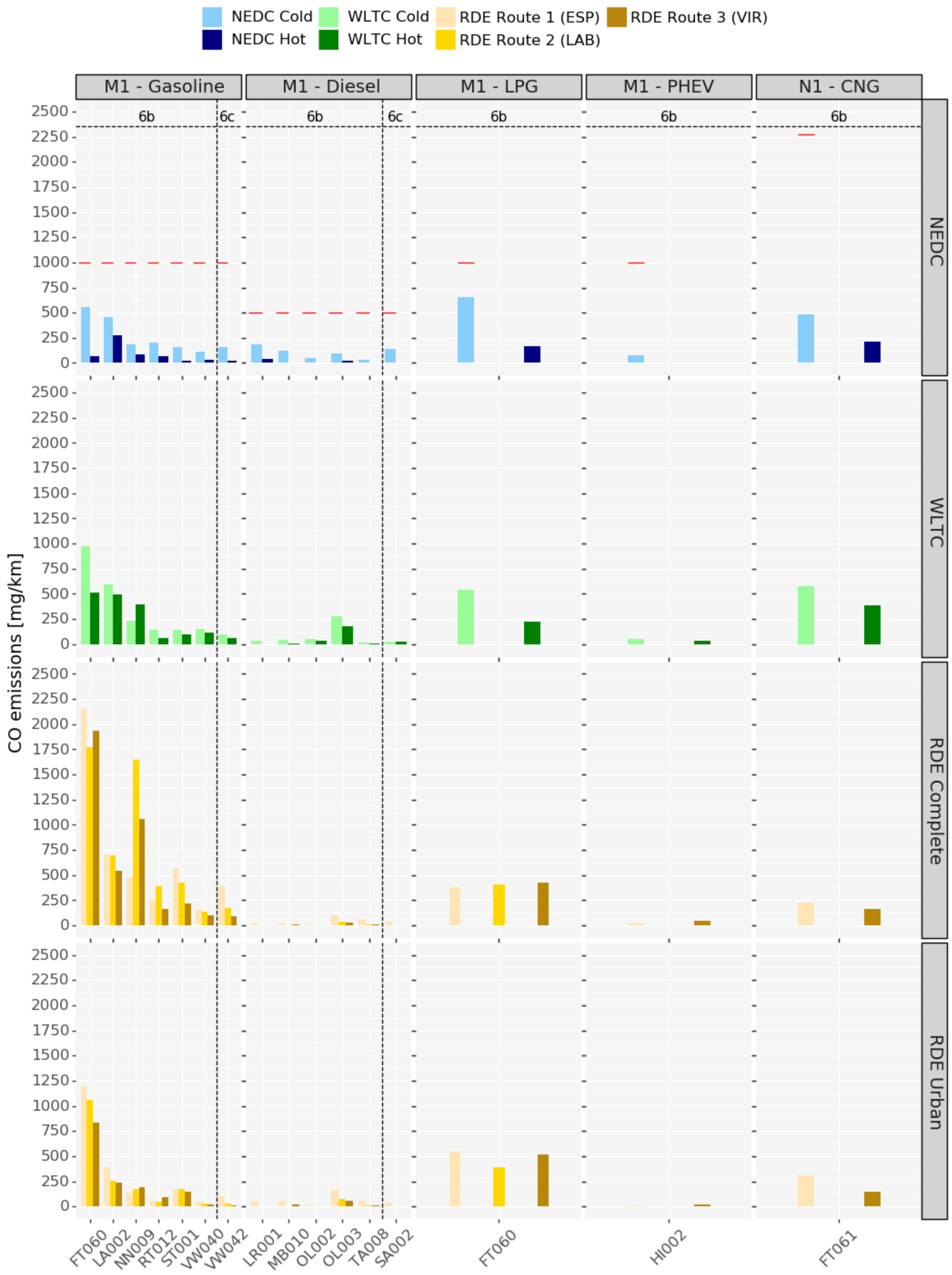

Figure 5: CO emissions for Euro 6b and Euro 6c vehicles over the NEDC laboratory cold and hot tests (top panel), the WLTC laboratory cold and hot tests (second panel) and on-road tests (third panel for complete trip and bottom panel for urban section). On the top panel, horizontal red lines stand for the CO limit applicable on the Cold NEDC.

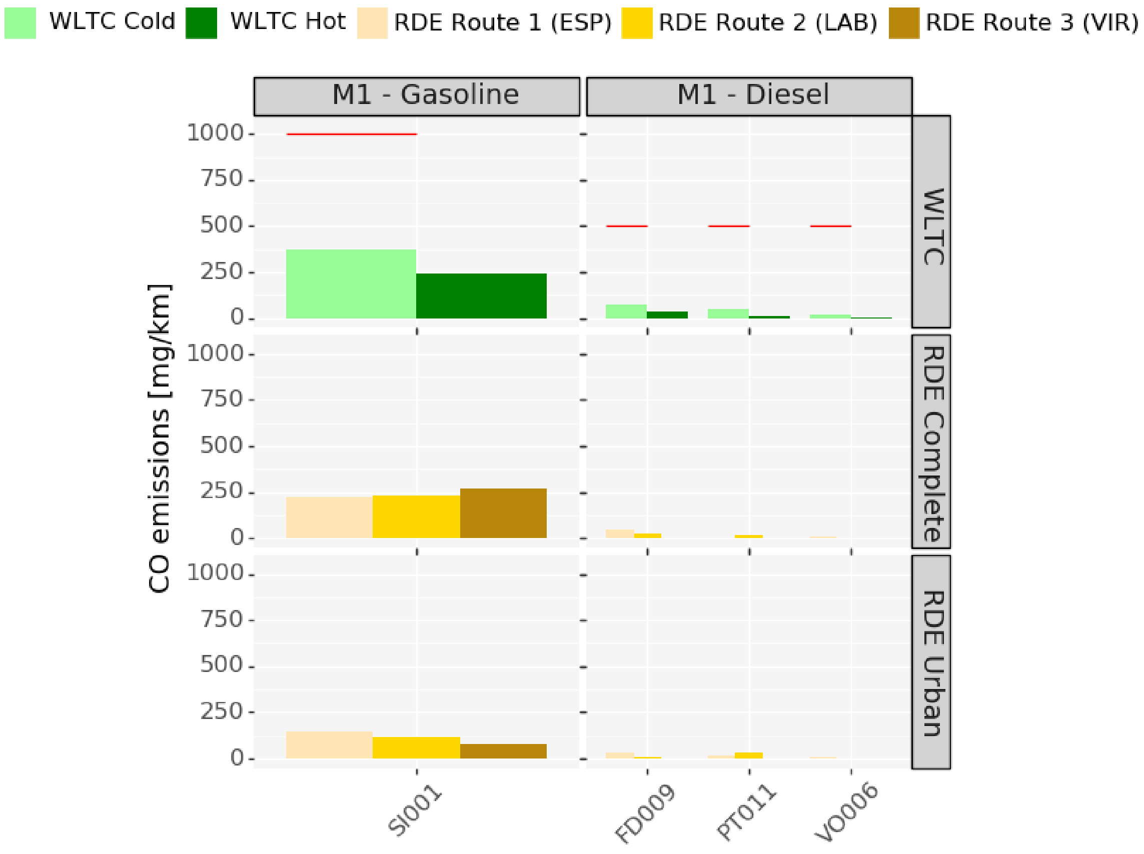

Figure 6: CO emissions for Euro 6d-TEMP vehicles over the WLTC laboratory cold and hot tests (first panel) and RDE compliant tests (middle and bottom panels for complete and urban section, respectively). On top panel, horizontal red lines stand for the CO limits applicable on the Cold WLTC test.

3.4 HC emissions

As hydrocarbons (HC) measurements were not conducted for the on-road tests, this section only informs on NEDC and WLTC. Currently, PEMS are able to measure HC on the road (compulsory requirement for Heavy-duty vehicles), and the measurement of HC on the road may be performed for LDVs in the near future. HC emissions of Euro 6b and Euro 6c are shown in **Figure 7**, while **Figure 8** corresponds to Euro 6d-TEMP vehicles HC emissions. **Table 15** shows the average emissions by main vehicle technologies and emissions standards. The following observations can be made:

— All spark ignition engines complied with the applicable HC limits on Type 1 test. Over both NEDC and WTLP cycles, the maximum HC emissions were not even half if the Type 1 limit for gasoline and LPG vehicles.

— On NEDC Cold test, gasoline vehicles emitted on average 36 ± 9 mg/km, same range as the PHEV and the LPG vehicles. Diesel vehicles averaged 23 ± 6 mg/km, roughly one third lower than the gasoline vehicles.

— NEDC Hot test resulted in lower HC emissions than NEDC Cold for all powertrains and Euro emission standards since HC emission are primarily released during the cold start phase.

— The gasoline Euro 6d-TEMP vehicle (PFI) emitted similar HC as Euro 6b PFIs on the WLTP Cold and Hot tests. Gasoline GDI vehicles (Euro 6b and Euro 6c) emit slighly lower HC than PFI vehicles both in cold and warm conditions.

— Noticeable differences are found among diesel Euro 6d-TEMP vehicles: while PT011 has HC emissions < 4 mg/km, FD009 emitted 83 mg/km on WLTP Cold. The observation is consistent with the operation of the LNT mounted on the FD009, which releases HC during its regeneration.

Table 15: Average HC emissions in mg/km over NEDC and WLTC tests by emissions standard and vehicle technology

Cycle / **Vehicle Technology (#)**	**NEDC Cold**	**NEDC Hot**	**WLTP Cold**	**WLTP Hot**
Euro 6b Gasoline PFI (2)	38	10	40	14
Euro 6b Gasoline GDI (4)	34	11	16	5
Euro 6b PHEV (Gasoline GDI/Electric) (1)	34	7	15	8
Euro 6b Diesel (5)	23	15	12	12
Euro 6b LPG (1)	35	7	42	2
Euro 6b CNG (1)	60	46	122	129
Euro 6c Gasoline GDI (1)	27	5	12	2
Euro 6c Diesel (1)	15	6	3	2
Euro 6d-TEMP Gasoline PFI (1)	-	-	33	22
Euro 6d-TEMP Diesel (3)	-	-	43	32

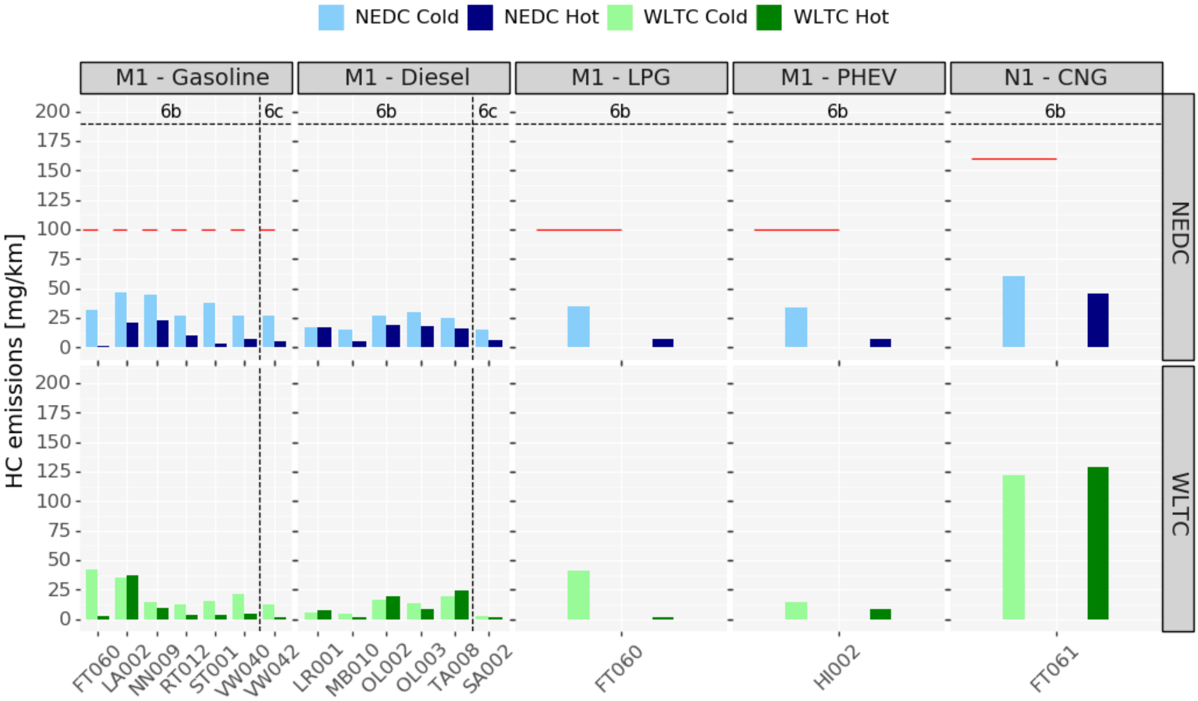

Figure 7: HC emissions for Euro 6b and Euro 6c vehicles over the NEDC cold and hot tests (top panel) and the WLTC laboratory cold and hot tests (bottom panel). On the top panel, horizontal red lines stand for the HC limit applicable on the Cold NEDC test.

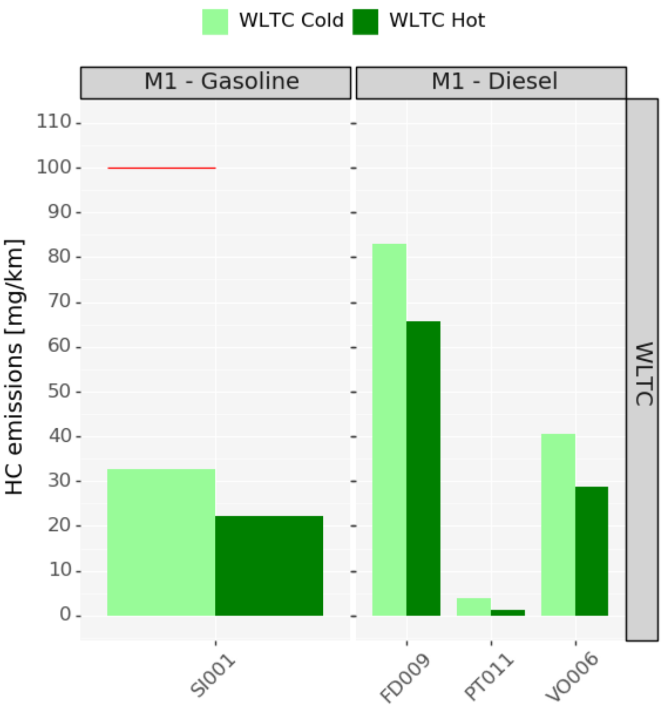

Figure 8: HC emissions for Euro 6d-TEMP vehicles over the WLTC laboratory cold and hot tests. The horizontal red lines stand for the HC limits applicable on the Cold WLTC test.

3.5 PN emissions

PN emissions obtained for the NEDC, WLTC, and RDE tests are presented in **Figure 9** (Euro 6 and Euro 6c vehicles) and **Figure 10** (Euro 6d-TEMP vehicles), while **Table 16** shows the average emissions by main vehicle technologies and emissions standards. The following observations can be made for their laboratory and on-road emissions (under RDE conditions):

- All vehicles complied with their PN emission limit, applicable on Type 1 test: gasoline GDI Euro 6b had a temporary limit of 6e12 #/km (including the PHEV), whereas for diesel vehicles the limit is 6e11 #/km.
- Among gasoline Euro 6b vehicles, GDIs emitted on average 2 times as many particulates than gasoline PFIs over the NEDC Cold test (without considering VW040, which mounted a GPF). The PN emissions from VW040 (GDI with GPF) were two orders of magnitude lower than the average of the other 3 GDIs without a GPF (RT012, ST001, and NN009).
- The PN emissions of the PHEV GDI vehicle (HI002) were in the order of 1e12 #/km when the vehicle was operated in the laboratory on charge sustaining operation.
- On average the Euro 6b diesel vehicles (1.2e11 ± 2.5e11 #/km) emitted one order of magnitude lower PN emission than gasoline vehicles on NEDC Cold (1.3e12 ± 1.0e12 #/km). However, among diesel vehicles, MB010 exhibited emissions close to the limit (5.7e11 #/km) whereas the other four Euro 6b diesels averaged 1.4e10 #/km.
- Euro 6c gasoline and diesel vehicles (one of each) exhibited systematically lower emissions than their Euro 6b counterparts on NEDC and WLTP tests (one order of magnitude lower for gasoline and two for diesel).
- Emissions measured on the Hot tests (NEDC and WLTP) were systematically lower than those of the Cold tests for all powertrains, which corroborates that the cold start is associated with increased release of particles.
- All diesel Euro 6d-TEMP vehicles tested over RDE tests with PN-PEMS equipment were systematically below the applicable NTE PN limit defined for RDE (CF of 1.5).
- The Euro 6d-TEMP gasoline vehicle is PFI and therefore no PN limit applies. However, its emissions on the road are above the NTE PN limit applicable for GDIs and diesel vehicles (i.e., > 9e11 #/km) on the Urban RDE (1e12 #/km).
- Four Euro 6b gasoline vehicles, two PFIs (LA002 and FT060) and two GDIs (NN009 and RT012) exceed the NTE limit for PN applicable for Euro 6d-TEMP vehicles.
- On the road, the PHEV was tested two times in charge sustaining operation with an average PN emission of 6.5e11 #/km and a driven distance share in electric mode of 33%. On the charge-depleting test (with 70% of the distance driven with the electric motor), the PN emission was 4.8 e11 #/km.

Table 16: Average PN emissions in e11 #/km over NEDC, WLTP, and RDE tests by emissions standard and vehicle technology. Standard limits over NEDC Cold are 6e11 #/km for diesel vehicles and Euro 6c and Euro 6d-TEMP GDIs, and 6e12 #/km for Euro 6b GDIs.

Cycle / Vehicle Technology (#)	NEDC Cold	NEDC Hot	WLTP Cold	WLTP Hot	Complete RDE	Urban RDE
Euro 6b Gasoline PFI (2)	8.5	2.8	14.7	8.3	16.7	16.7
Euro 6b Gasoline GDI (4)	13.2	9.0	21.2	19.4	10.4	11.3
Euro 6b PHEV (Gasoline GDI/Electric) (1)	11.2	10.3	14.7	13.1	8.5	5.0
Euro 6b Diesel (5)	1.2	1.2	1.9	1.3	1.2	1.9
Euro 6b LPG (1)	2.5	0.4	3.5	0.3	0.8	1.0
Euro 6b CNG (1)	14.1	10.6	5.0	4.5	1.3	5.2
Euro 6c Gasoline GDI (1)	1.1	0.6	1.5	0.8	0.8	0.9
Euro 6c Diesel (1)	0.02	0.03	0.04	0.02	0.1	0.3
Euro 6d-TEMP Gasoline PFI (1)	-	-	6.1	3.2	7.8	11.1
Euro 6d-TEMP Diesel (3)	-	-	0.2	0.2	0.2	0.2

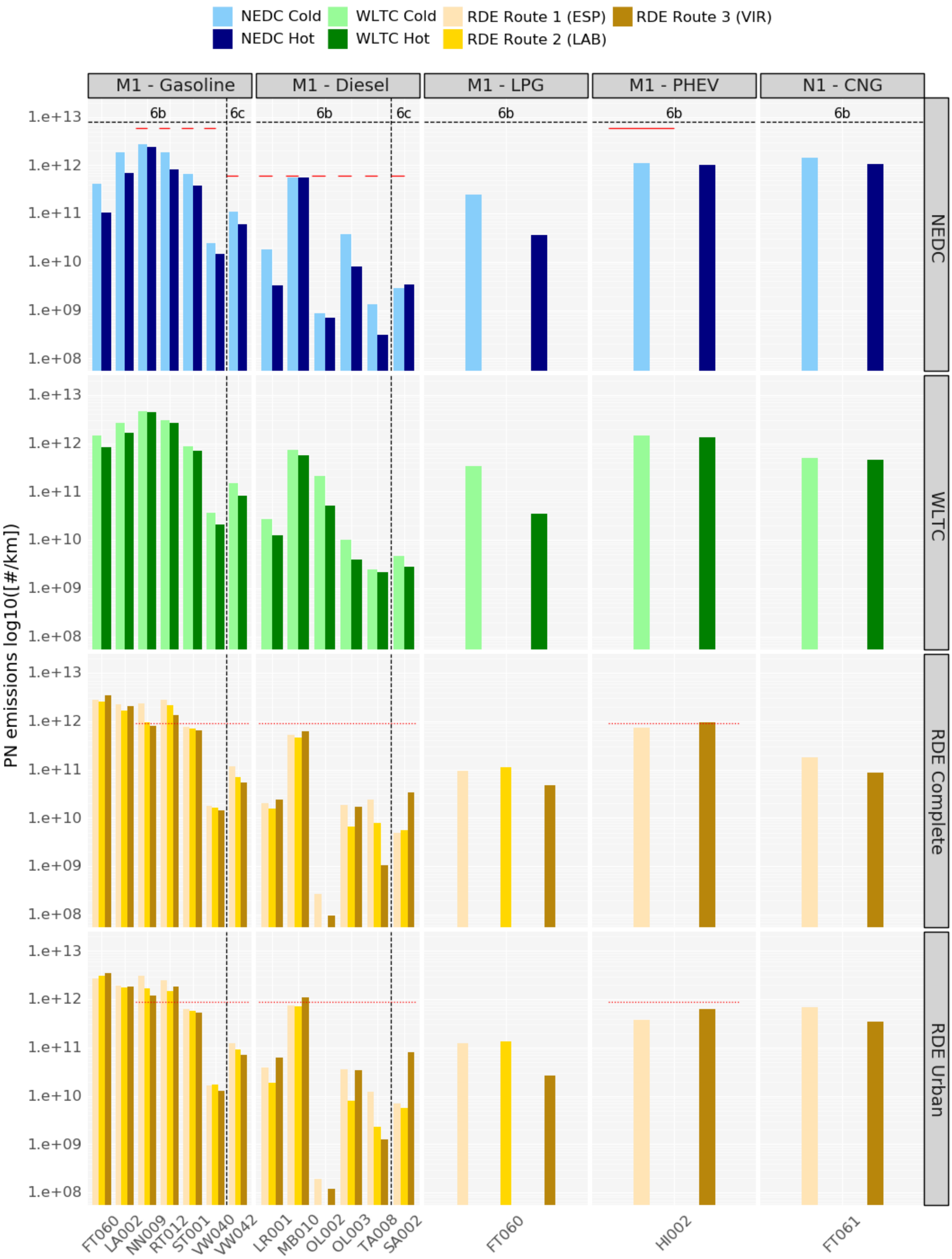

Figure 9: PN emissions for Euro 6b and Euro 6c vehicles over the NEDC laboratory cold and hot tests (top panel), the WLTP laboratory cold and hot tests (second panel) and on-road tests (third panel for complete trip and bottom panel for urban section). On the top panel, horizontal red lines stand for the PN limit applicable on the Cold NEDC test. On the third and fourth panels, dashed horizontal red lines stand for the PN NTE limit including the conformity factor of 1.5 (not applicable to Euro 6b and Euro 6c vehicles, depicted for illustration purposes).

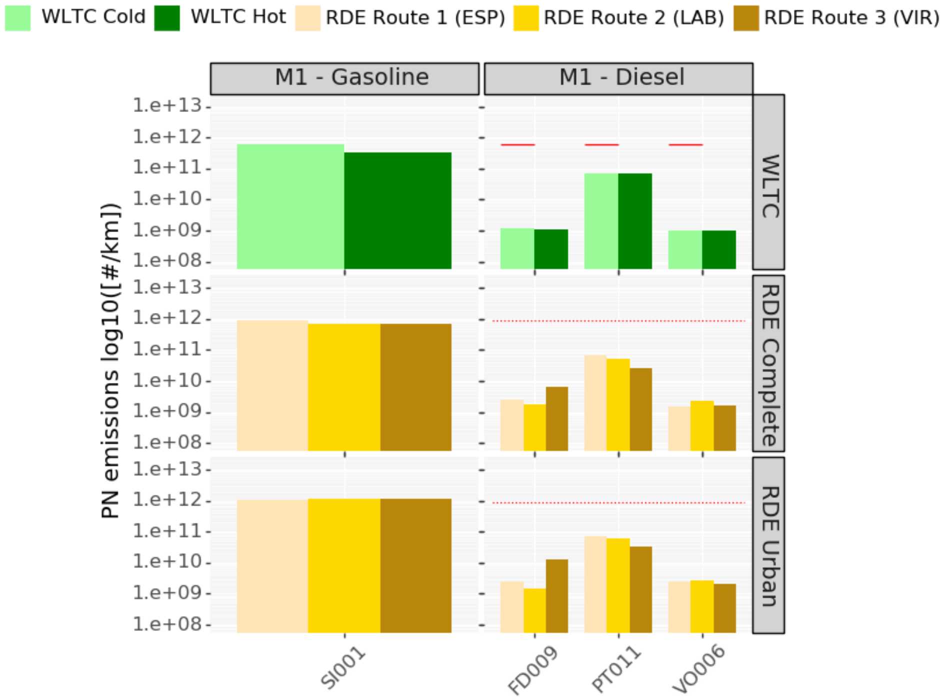

Figure 10: PN emissions for Euro 6d-TEMP vehicles over the WLTP laboratory cold and hot tests (first panel) and RDE compliant tests (middle and bottom panels for complete and urban section, respectively). On the top panel, horizontal red lines stand for the PN limit applicable on the Cold WLTP test. On the middle and bottom panels, dashed horizontal blue lines stand for the PN NTE limit including the conformity factor of 1.5.

3.6 Aggregated 2017 and 2018 data

This section provides an overview of the test results of JRC test campaigns performed in 2017 [1] and 2018 (this report) on Euro 6 vehicles to show trends on specific tests. The focus is on NOx and PN (pollutants currently regulated in the laboratory and on the road) and the results are aggregated by Euro standard (Euro 6 stages). **Figure 11** presents an overview of the considered fleet of 32 vehicles. Most of the vehicles tested in the context of the Market Surveillance Pilot project correspond to Euro 6b standard (81.2%). It is therefore important to note that the observations made on emissions trends are qualitative and not statistically significant considering the low number of vehicles fulfilling the Euro 6c (2 vehicles) and Euro 6d-TEMP (4 vehicles) standards. There is also only 1 LPG, 1 CNG and 2 PHEVs in the fleet, all of them meeting the Euro 6b standard. It is therefore not possible to establish emissions trends for those powertrains based on the data gathered by JRC.

The PEMS data for the 2017 fleet have been reprocessed with EMROAD version 6.02 so that the emissions are calculated in the same way as those of the 2018 fleet (using Appendix 6 of RDE4). For Euro 6b and Euro 6c vehicles for which no official WLTP CO_2 values were available, the CO_2 emissions used in EMROAD correspond to those measured in the VELA laboratories under WLTP Cold conditions (duplicates of Type 1 test). Euro 6b vehicles of the 2017 fleet for which tabulated road loads were used (VW035, FD007, and CN002) were not considered in the analysis as the emissions (pollutants and CO_2) are not directly comparable to all the other vehicles for which calculated or declared road loads were used. From a methodological point of view, it is important to notice that on the graphs of this section presenting RDE data, each dot represents an RDE test in order to show not only the individual vehicle performance on the road but also the trip-to-trip variability.

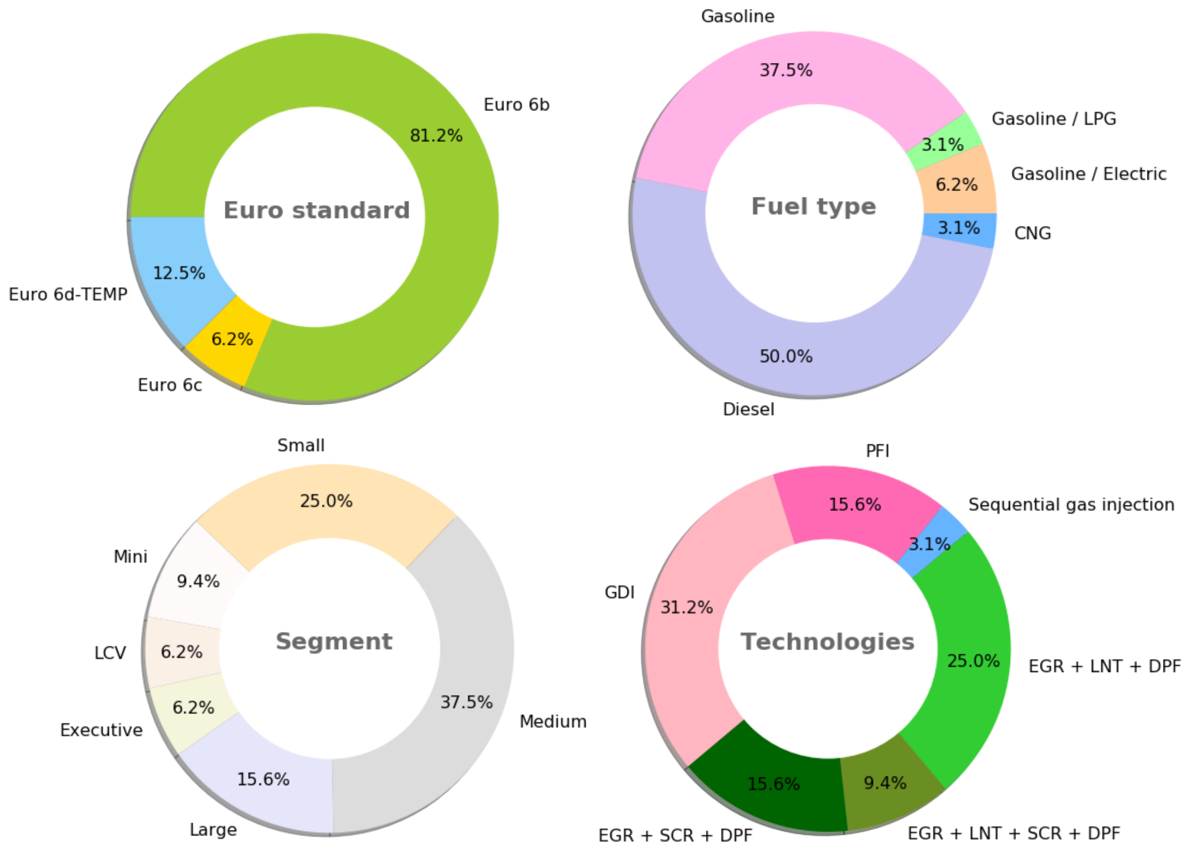

Figure 11: Main characteristics of the vehicles tested in the Market Surveillance pilot project during the 2017 and 2018 campaigns: Euro standard, Fuel type, Vehicle segment, and vehicle technologies (injection type for gasoline vehicles, and after-treatment systems for diesel vehicles).

NOx emissions results on NEDC Cold (**Figure 12**) and NEDC Hot (**Figure 13**) tests correspond to the emissions measured on Euro 6b and Euro 6c vehicles (26 and 2 vehicles, respectively). Except for OL003, which exceeds the applicable limit on the NEDC Cold test, all Euro 6b and Euro 6c vehicles meet their respective NOx thresholds on the Type 1 test. The gasoline vehicles (both PFIs and GDIs) have similar emissions performance among them with NOx emissions ranging from 7 mg/km to 28 mg/km on the Cold test. The NOx emission of the sole Euro 6c gasoline vehicle (17 mg/km) is similar to the median NOx of gasoline Euro 6b (12 mg/km). On the NEDC Hot test the Euro 6b gasoline vehicles have a median NOx emission of 9 mg/km and the Euro 6c emits 6 mg/km. Therefore, there is not a particular trend between gasoline vehicles of Euro 6b and Euro 6c stages on NEDC tests. Regarding diesel vehicles, the NOx emissions of Euro 6b vehicles are not homogeneous among individual vehicles, covering a range of 16 mg/km to 90 mg/km with a median of 49 mg/km on the NEDC Cold test (which is close to the Euro 6c diesel 48 mg/km). On the NEDC Hot test, the Euro 6b NOx emissions are even more spread than on the Cold test with a range of 8 mg/km to 193 mg/km, a median of 65 mg/km, and three vehicles exceeding 80 mg/km (OL002, RT011, and OL003). Half of the Euro 6b diesel vehicles have a NOx emission on the NEDC Hot test lower than the one measured on the Euro 6c diesel vehicle (SA002, 45 mg/km) so that no indication of better performance of the Euro 6c diesel is observed on NEDC tests.

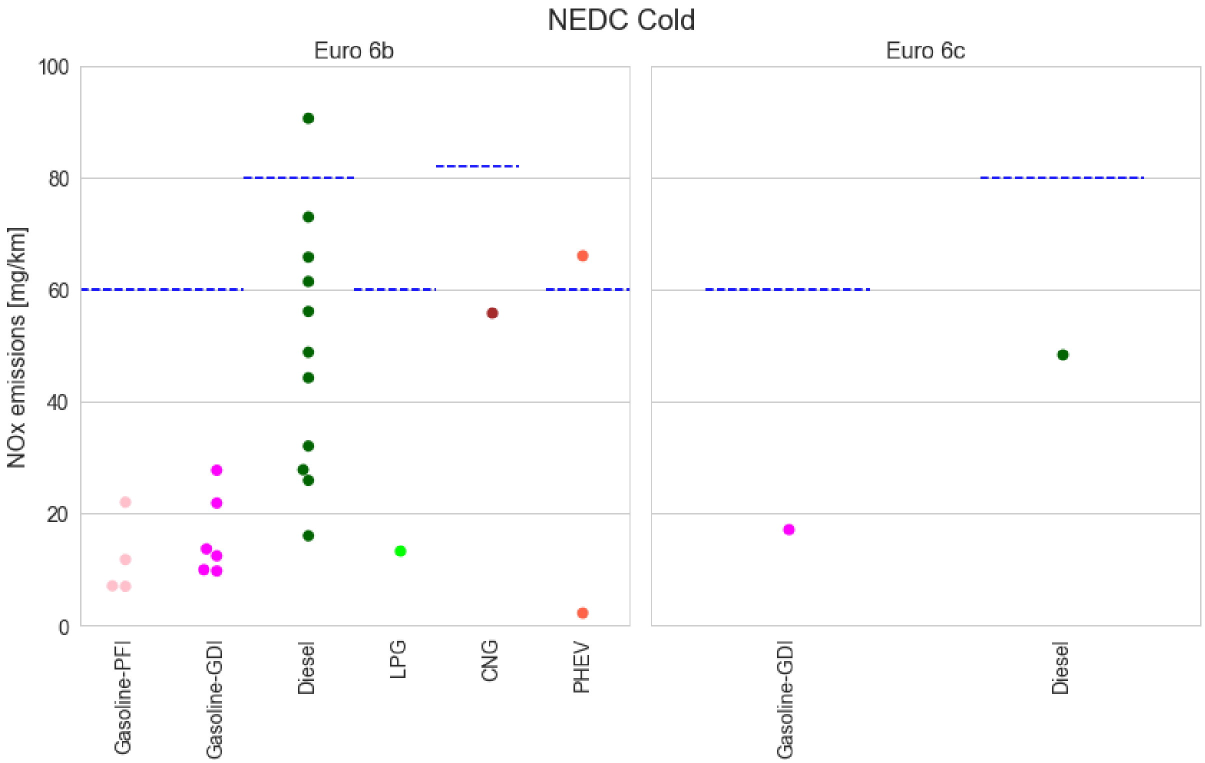

Figure 12: NOx emissions for Euro 6b and Euro 6c vehicles over the NEDC laboratory cold test per fuel type and Euro standard. The dotted blue lines stand for the NOx applicable limits on the NEDC Cold test. The CNG vehicle is a LCV (N1-class III) with emission limit of 82 mg/km

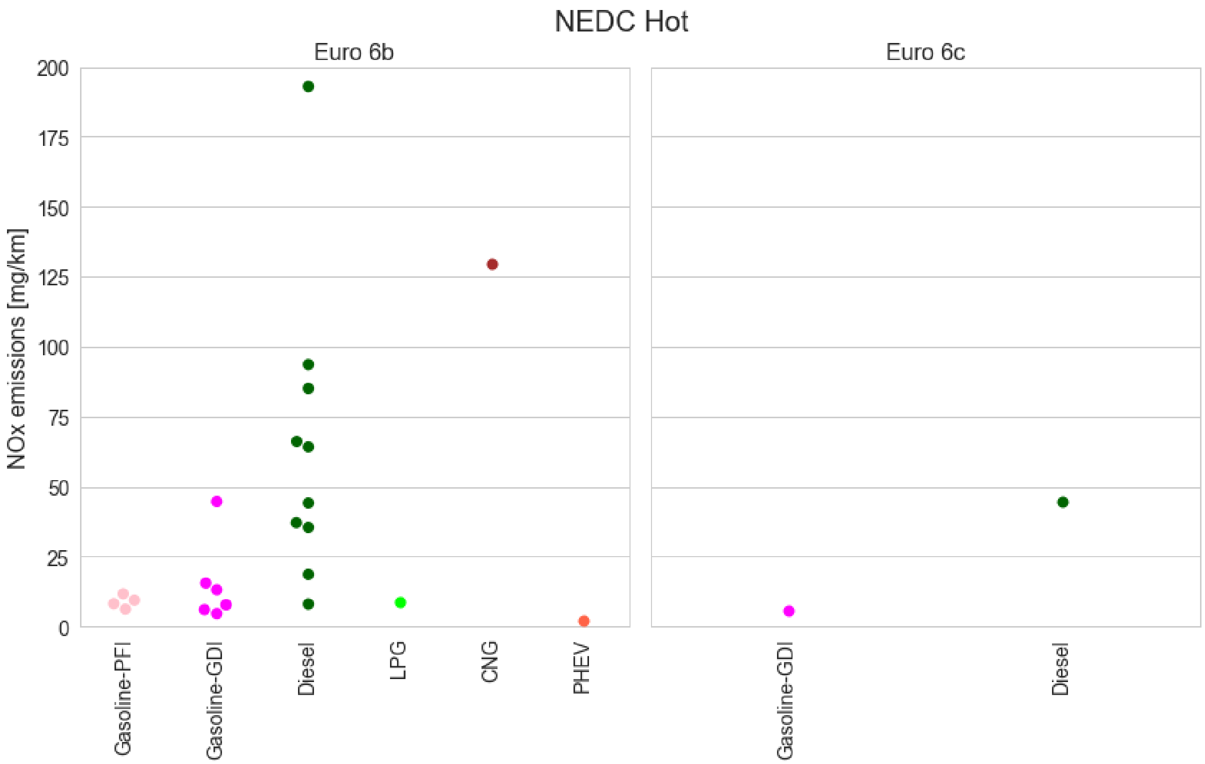

Figure 13: NOx emissions for Euro 6b and Euro 6c vehicles over the NEDC laboratory hot test per fuel type and Euro standard.

Figure 14 and **Figure 15**, showing the NOx emissions on the WLTP Cold and Hot tests, respectively, have a common pattern. On the gasoline vehicles side, Euro 6b PFI vehicles have lower NOx emissions than Euro 6b GDIs with median emission of 14 mg/km and 47 mg/km, respectively on the Cold test, and 17 mg/km and 50 mg/km, on the Hot one. The Euro 6c gasoline GDI presents low emissions on the WLTP Cold and Hot tests (14 mg/km and 7 mg/km, respectively) which represents 4 to 5 times lower NOx than its Euro 6b counterparts. The gasoline Euro 6d-TEMP PFI vehicle (SI001) shows similar NOx emissions on the WLTP Cold as the Euro 6b PFI vehicles. Regarding diesel vehicles, Euro 6b present a range of NOx emissions on the WLTP Cold test from 20 mg/km (BW014) up to 317 mg/km (RT011). All diesel vehicles exceeding 80 mg/km on the WLTP Cold test (5 out of 10 vehicles) use EGR in combination with LNT as after-treatment system. The diesel Euro 6b meeting the 80 mg/km limit use EGR + LNT, EGR + SCR or EGR + LNT + SCR. The diesel Euro 6c vehicle (EGR + LNT + SCR) NOx emission lays on the low end of values measured on the Euro 6b vehicles both on the Cold and Hot tests (29 mg/km and 20 mg/km). Finally, diesel Euro 6d-TEMP vehicles meet the 80 mg/km both on the Cold and Hot tests, ranging 19 mg/km to 69 mg/km and 25 mg/km to 63 mg/km, respectively. On the WLTP, NOx emissions of Euro 6d-TEMP vehicles are similar to those measured on the Euro 6c and on half of the Euro 6b vehicles.

The pattern described above for NOx emissions on WLTP tests is observed again on the road under RDE compliant conditions (**Figure 16**). The median NOx emissions of Euro 6b gasoline PFIs (9 mg/km) is lower than the one of Euro 6b GDIs (59 mg/km), although some Euro 6b GDIs have same level of NOx emissions than some PFIs on the road (e.g., LA002-PFI and VW040-GDI emit 15 mg/km over complete RDE tests). The gasoline Euro 6c GDI (VW042, averaging 10 mg/km) performs similarly than the best Euro 6b GDI (VW040). Again, the Euro 6d-TEMP PFI (SI001) performs similarly to its Euro 6b counterparts on the road averaging 10 mg/km. The Euro 6b diesel fleet exhibits important differences among individual vehicles. The fleet can be divided into one half for which NOx emissions on the road lay below the NTE limit of 168 mg/km and the other half exceeding this value. Vehicles like LR001 and BW014 average NOx emissions on the road < 30 mg/km, whereas the worst performers are RT011 (> 1.6 g/km) and KA001 (~0.7 g/km) although both vehicles were tested in wintertime. The diesel Euro 6c vehicle averages 15 mg/km on RDE tests and the Euro 6d-TEMP ~ 50 mg/km (VO006 and PT011, both equipped with SCR), and 118 mg/km (FD009, equipped with LNT). From the after-treatment point of view, diesel vehicles equipped with an SCR cope well with NOx emissions under most driving conditions in the laboratory and on the road, whereas those vehicles that mount only an LNT exhibit higher emissions in comparable test conditions. Those findings are in agreement with previous literature [22, 23].

The aggregated data of 2017 and 2018 tests regarding PN refer only to NEDC Cold (**Figure 17**), WLTP Cold (**Figure 18**) and the complete RDE (**Figure 19**) for the sake of brevity. The trends described for the Cold tests are also observable on the Hot ones with the important notice that on the Hot tests absolute emissions are lower than on the Cold tests since there is not contribution from cold start. It is important to notice that on the three figures, the Euro 6b GDI vehicle exhibiting lowest PN emissions correspond to VW040, which is the vehicle equipped with a GPF.

On the NEDC Cold test, the median PN emission of Euro 6b PFIs (3.2e11 #/km) is lower than the median of Euro 6b GDIs (1.9e12 #/km, excluding the vehicle with GPF) but the Euro 6c GDI (1.1e11 #/km) emits even lower than the most performant Euro 6b (1.8e11 #/km). Since the Euro 6c GDI does not wear a GPF, the reduction of PN emission as compared to Euro 6b GDIs points to a lower engine-out PN emission. On the diesel side, the Euro 6c PN emission (2.9e9 #/km) is slightly lower than the median PN emission of Euro 6b diesel vehicles (6.5e9 #/km) but up to four Euro 6b vehicles (OL002, TA008, VW037, KA001) emit lower PN on the NEDC Cold than the Euro 6c. There is not a measurable downward trend in PN emission on NEDC from Euro 6b to Euro 6c stages for diesel vehicles.

Similar observations as the ones made above can be made regarding PN emissions on the WLTP Cold and complete RDE tests. The Euro 6c gasoline GDI (1.5e11 #/km) has one order of magnitude lower emissions than the median Euro 6b GDIs (1.2e12 #/km, excluding the GPF vehicle). The PN emission of the Euro 6d-TEMP PFI (7.8e11 #/km) is slightly lower than the one of the Euro 6b PFIs on WLTP (1.0e12 #/km) and RDE complete test (1.1e12 vs 1.7e12 #/km). The results are in agreement with a recent review [24].

On the diesel side, both Euro 6c and Euro 6d-TEMP diesel (except for PT011) have PN emissions in the range of the most performant Euro 6b diesel (TA008 ~ 2.5e9 #/km) on the WLTP Cold test. The Euro 6c and Euro 6d-TEMP PN emissions do not show a particular improvement as compared to Euro 6b on the RDE test. The median PN emissions on the complete RDE test for the three stages are 7.8e9 #/km, 5.7e9 #/km, and 2.5e9 #/km respectively.

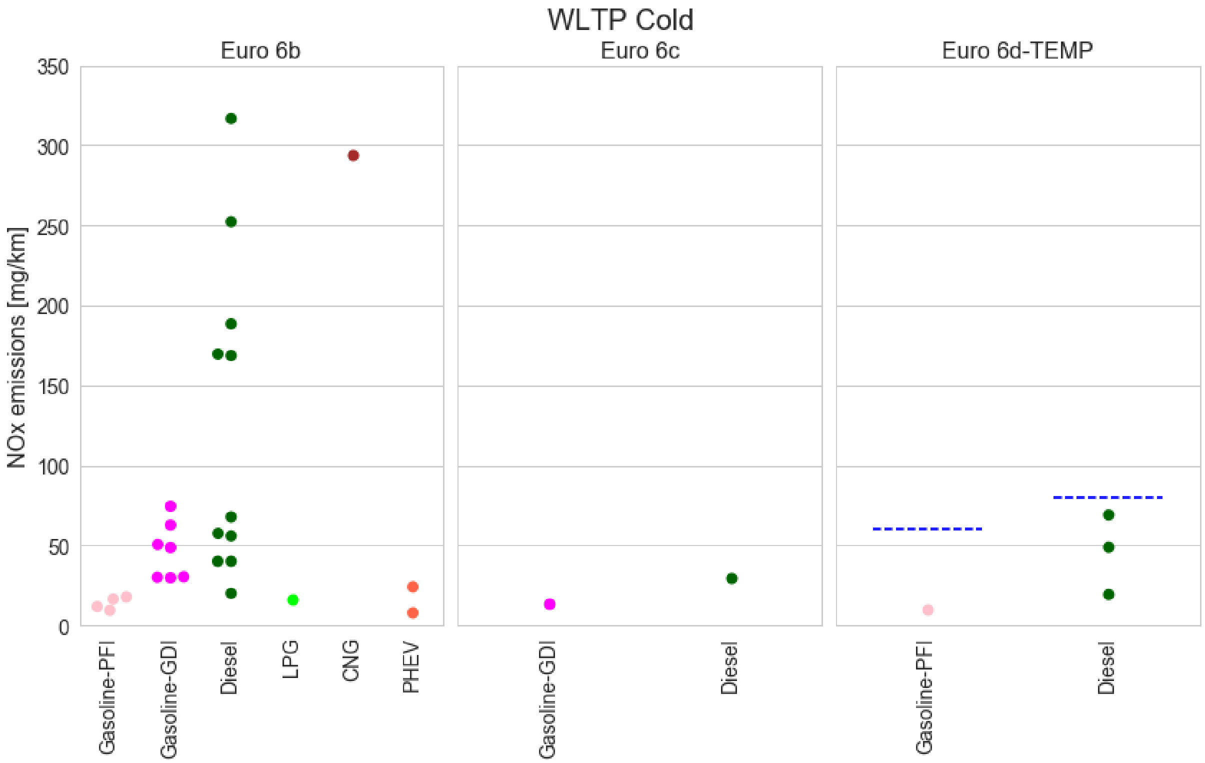

Figure 14: NOx emissions for Euro 6b, Euro 6c, and Euro 6d-TEMP vehicles over the WLTP laboratory cold test per fuel type and Euro standard. The dotted blue lines stand for the NOx applicable limits on the WLTP Cold test.

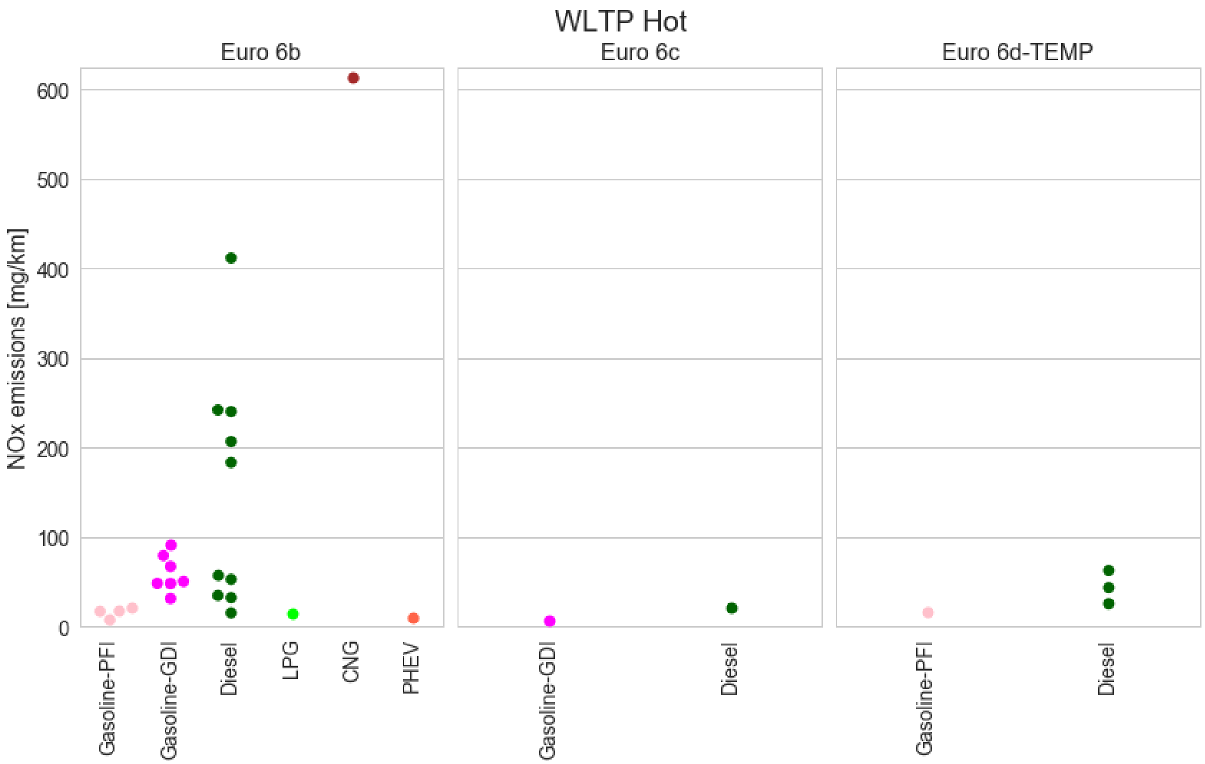

Figure 15: NOx emissions for Euro 6b, Euro 6c, and Euro 6d-TEMP vehicles over the WLTP laboratory hot test per fuel type and Euro standard.

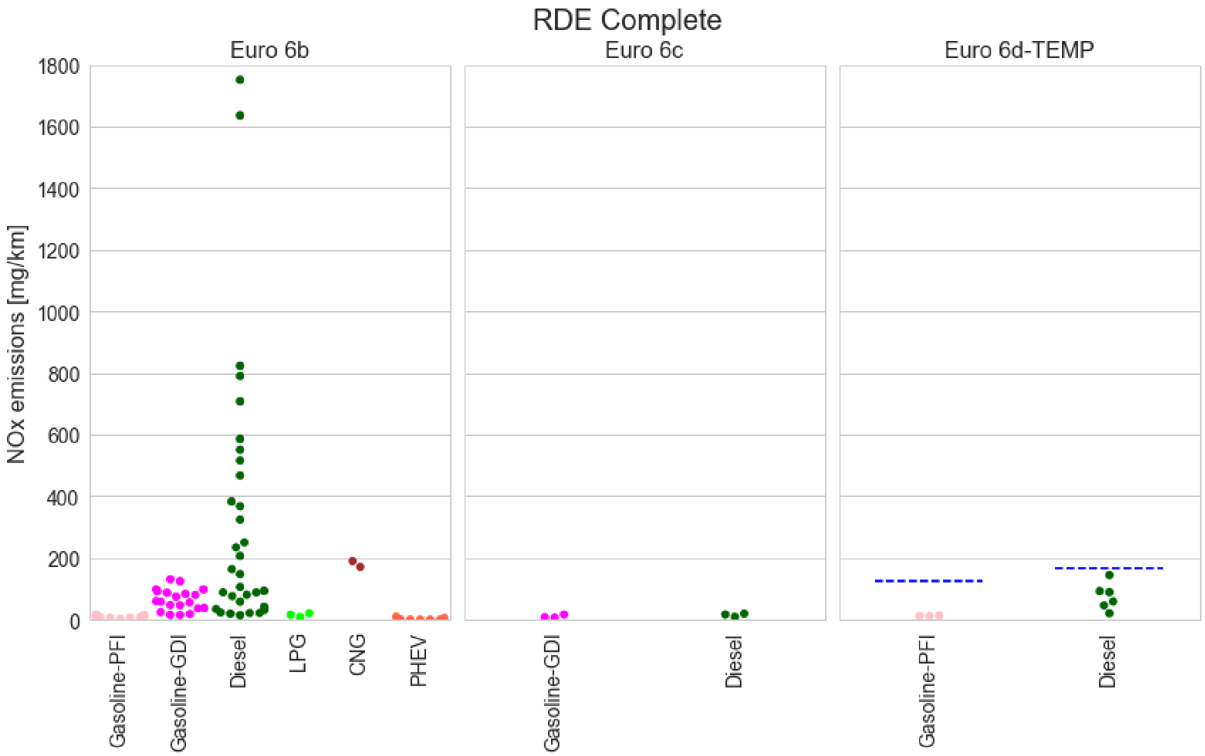

Figure 16: NOx emissions for Euro 6b, Euro 6c, and Euro 6d-TEMP vehicles over RDE compliant tests (Complete trip) per fuel type and Euro standard. The dotted blue lines stand for the NOx Not-To-Exceed limits applicable only to Euro 6d-TEMP vehicles (temporary conformity factor 2.1).

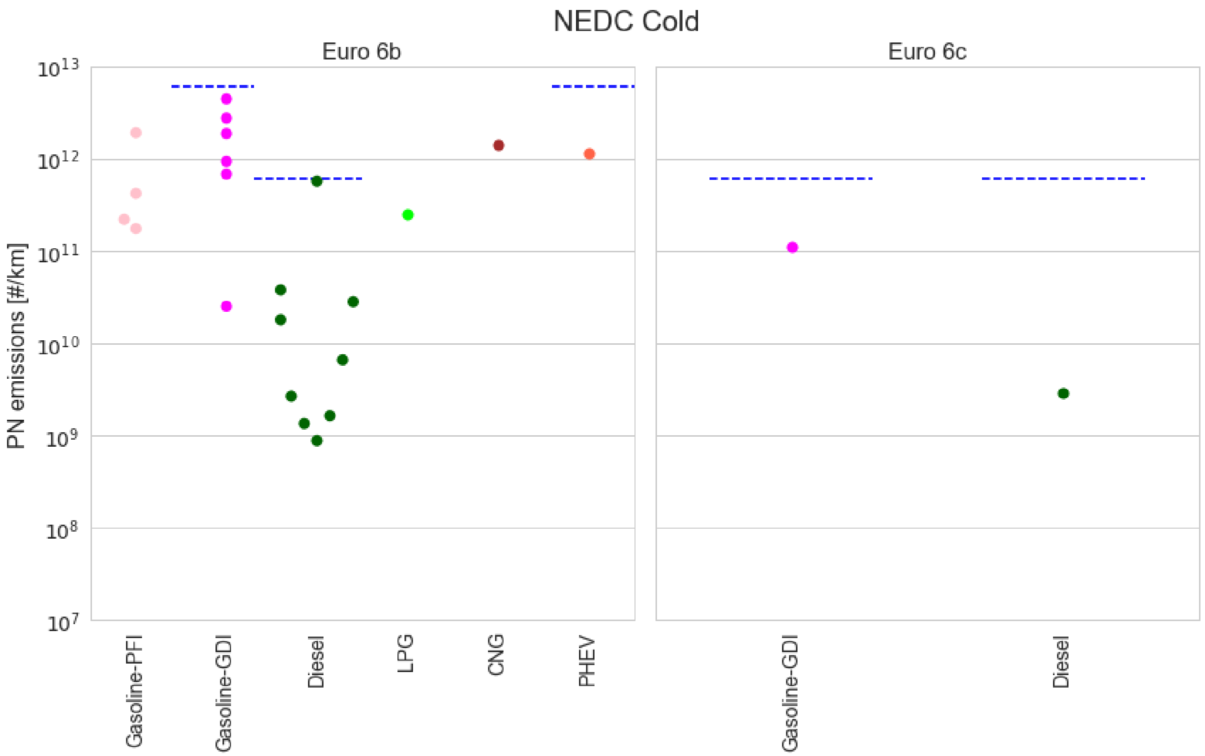

Figure 17: PN emissions for Euro 6b and Euro 6c vehicles over the NEDC laboratory cold test per fuel type and Euro standard. The dotted blue lines stand for the PN applicable limits on the NEDC Cold test.

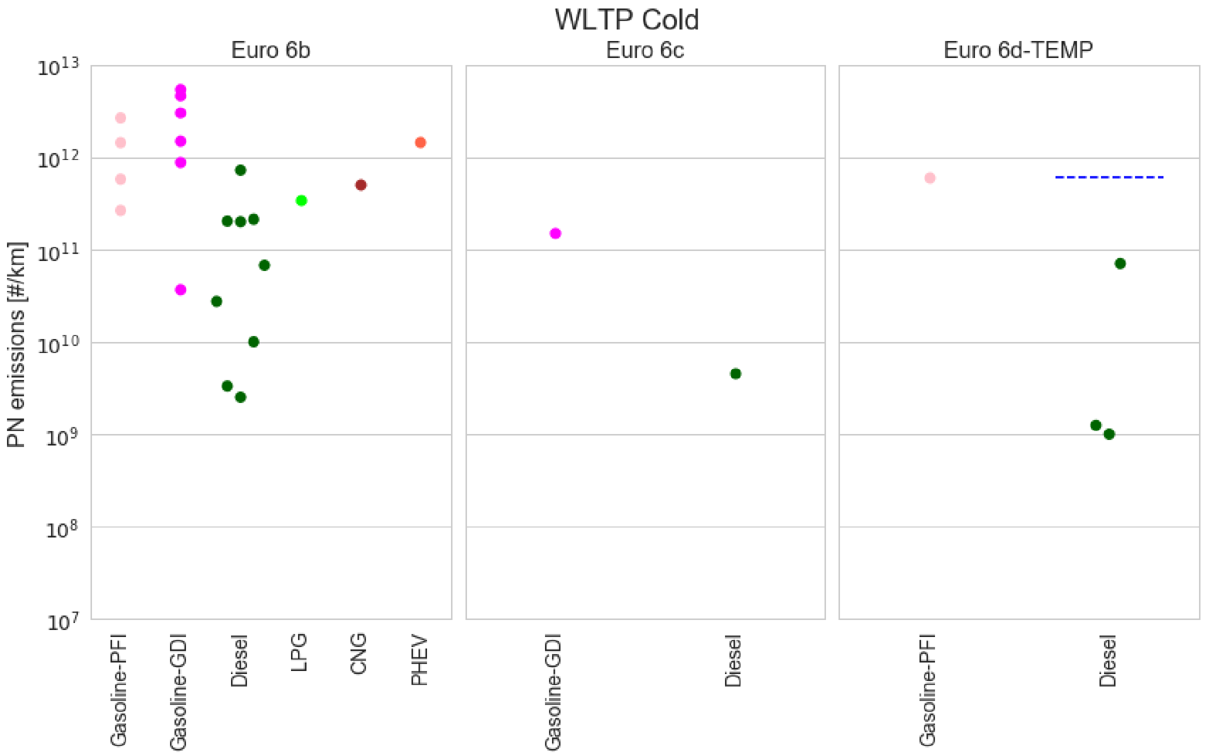

Figure 18: PN emissions for Euro 6b, Euro 6c, and Euro 6d-TEMP vehicles over the WLTP laboratory cold test per fuel type and Euro standard. The dotted blue lines stand for the PN applicable limits on the WLTP Cold test.

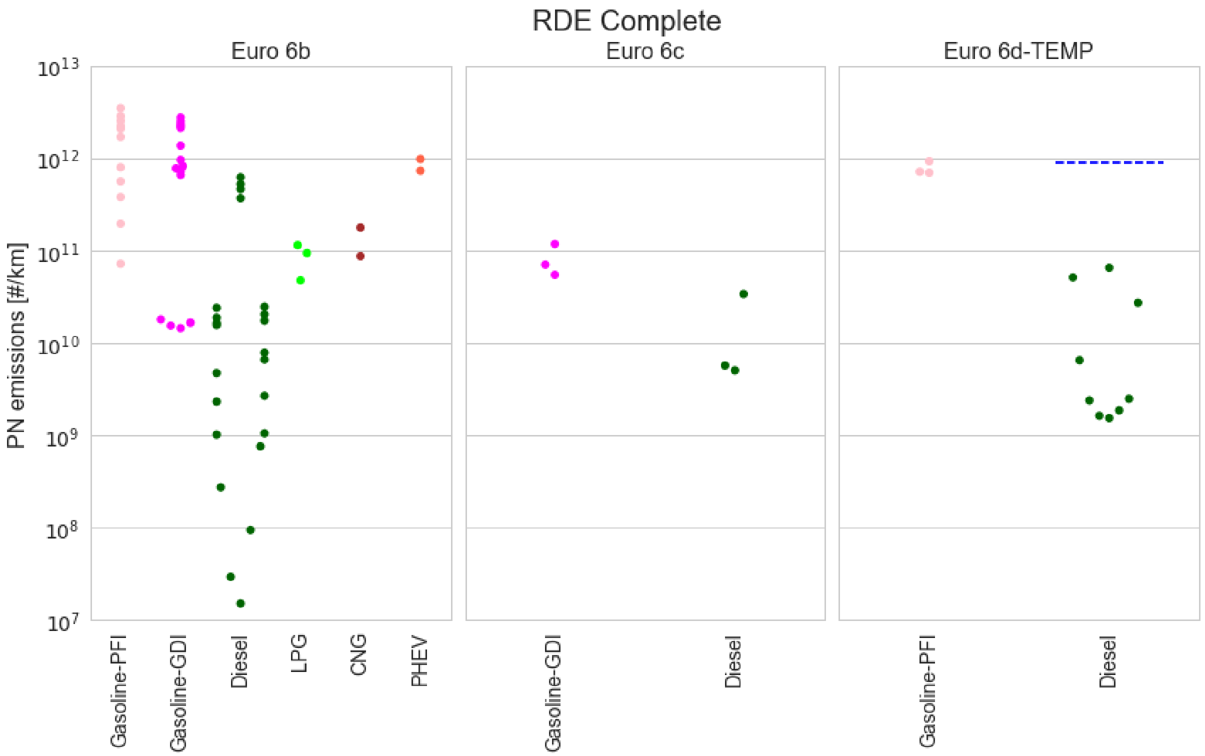

Figure 19: PN emissions for Euro 6b, Euro 6c, and Euro 6d-TEMP vehicles over RDE compliant tests (Complete trip) per fuel type and Euro standard. The dotted blue lines stand for the PN Not-To-Exceed limits applicable only to Euro 6d-TEMP diesel vehicles (conformity factor 1.5).

3.7 Discussion of pollutant emission results and technologies

This section summarises the emissions performance of the tested vehicles based on the laboratory and on-road data collected by the JRC in 2017 and 2018.

For the vehicles tested in 2018, the limits on the Type 1 test were fulfilled for all regulated pollutants in all cases but OL003 for NOx, thus strengthening the idea that the vehicles were properly functioning. Of the four NEDC Cold repetitions performed on OL003, only one was below the applicable limit. No signals of malfunctioning were identified on this vehicle after OBD and physical inspection.

NOx emissions

On the NEDC Cold test, all gasoline vehicles (GDIs and PFIs) emitted less than 20 mg/km of NOx. Under more transient conditions, in the laboratory (WLTP) and on the road (RDE), PFIs emitted also < 20 mg/km of NOx (all Euro 6b and the Euro 6d-TEMP vehicles). Regarding gasoline GDIs, Euro 6b vehicles registered similar NOx as PFIs on NEDC Cold but, on average, their emissions on WLTP Cold and RDE were 3.4 and 6.5 times higher, respectively. The best-performing Euro 6b GDI as well as the Euro 6c GDI had, however, low NOx emissions (< 20 mg/km) under all testing conditions. For most gasoline vehicles, NOx emissions on the Hot tests (NEDC and WLTP) were similar or slightly lower than those measured on the Cold tests, whereas emissions on the Urban RDE were higher than those registered on the Complete test. It is noticeable that OL001 had 1.8 times as much NOx emission on the NEDC Hot test than on the NEDC Cold one and that on the hot test emissions exceeded the type 1 test limit. Based on all results, no particular trend in NOx emissions is observed between Euro 6 stages. It is also important to notice that within vehicles of the same Euro 6 stage and injection type, a vehicle-to-vehicle emissions performance variability is observed. For example, among Euro 6b gasoline-GDI vehicles, NN009 emits ~ 60mg/km on WLTP test and ~ 100 mg/km on RDE tests whereas WV042 emits less than 20 mg/km on all situations.

In laboratory (NEDC and WLTP Cold tests) and road conditions (Complete RDE), Euro 6b diesel vehicles emit on average roughly 3.5 and 7.5 times more NOx than gasoline Euro 6b vehicles, respectively (50, 125, and 334 mg/km of NOx on NEDC, WLTP, and RDE respectively). Euro 6b diesel vehicles exhibited a large vehicle-to-vehicle variability with NOx emissions ranging from ~15 mg/km to ~315 mg/km in the laboratory, and ~15 mg/km to ~1750 mg/km on the road. Euro 6b diesel vehicles equipped with an EGR in combination with an LNT tend to emit more NOx than vehicles that mounted an SCR in combination with an EGR/EGR + LNT (4 and 6 times higher over WLTP Cold and RDE Complete, respectively). Euro 6c and Euro 6d-TEMP diesel vehicles emitted approximately two times more NOx than their gasoline counterparts both on laboratory and on road tests (42 and 26 mg/km of NOx on WLTP Cold test and 55 and 23 mg/km of NOx on RDE Complete, respectively). Euro 6b diesel vehicles emitted on average 4 times more NOx than Euro 6c and Euro 6d-TEMP over WLTP and RDE tests. However, the best Euro 6b diesel vehicles had a similar emission performance as the Euro 6c and Euro 6d-TEMP. It is believed that the Euro 6b/6c diesel vehicles that perform similarly to Euro 6d-TEMP ones were developed by manufacturers to meet RDE regulation but were type-approved before the entry into force of the RDE regulation.

The PHEV and the LPG vehicles tested in 2018 emitted NOx in the range of gasoline vehicles in all driving conditions (< 20 mgNOx/km). The CNG vehicle (FT061) complied with its NOx emission limit on the NEDC Cold test but it largely exceeded the 82 mg/km threshold on the WLTP and RDE tests (up to 613 mg/km on the WLTP Hot test).

CO emissions

Euro 6b gasoline PFI vehicles emitted on average 3.4, 4.2, and 2.2 times more CO than the gasoline GDIs over NEDC Cold, WLTP Cold, and Complete RDE tests (432, 933, 1153 mgCO/km). Euro 6b PFIs, in particular FT060, tended to emit larger amount of CO/km on the motorway drive than on any other section of RDE tests, which yielded a higher RDE CO emission on the complete trip than on the urban section (to which cold-start effect emissions are associated) (**Figure 20**). This behaviour was also observed on some Euro 6b GDIs (namely NN009) but not on vehicles with other powertrains. In fact, diesel vehicles of all Euro 6 stages emitted one order of magnitude lower CO than the Type 1 limit (500 mg/km) on all driving conditions and reached < 20 mgCO/km on the road. The Euro 6c GDI behaved similarly as the most performant Euro 6b GDI in terms of CO emissions when tested on the chassis dyno and on the road (~ 100 mg/km). The Euro 6d-TEMP PFI (SI001) averaged 266 mg/km of CO on the complete test but the emissions were voided since the permissible zero drift of CO was slightly exceeded on all three RDE compliant tests (CO zero drift of 81, 84, and 81 ppm on ESP, LAB, VIR tests > 75 ppm of permissible drift).

The PHEV emitted < 100 mg/km of CO on all test conditions (including on-road charge sustaining and charge depleting tests) which is close to 2 order of magnitude lower than the Type 1 applicable limit (1000 mg/km). On the other hand, the on-road CO emissions of LPG and CNG vehicles were lower than those measured on the respective WLTP Cold test, averaging 400 mg/km and 190 mg/km on the complete RDE test, respectively.

HC emissions

Regarding HC emissions, diesel vehicles averaged ~20 mg/km in the laboratory, roughly one third lower than what was measured from the gasoline vehicles (PFIs and GDIs), the PHEV and the LPG vehicle. It is noticeable that the CNG vehicle emitted two times more on the WLTP Hot test than on the Cold one (122 mg/km, still below the Type 1 test applicable limit). Also, the emissions of the diesel Euro 6d-TEMP FD009 (83 mgHC/km on WLTP Cold) were particularly high (highest value for a diesel vehicle considering all Euro stages and tests).

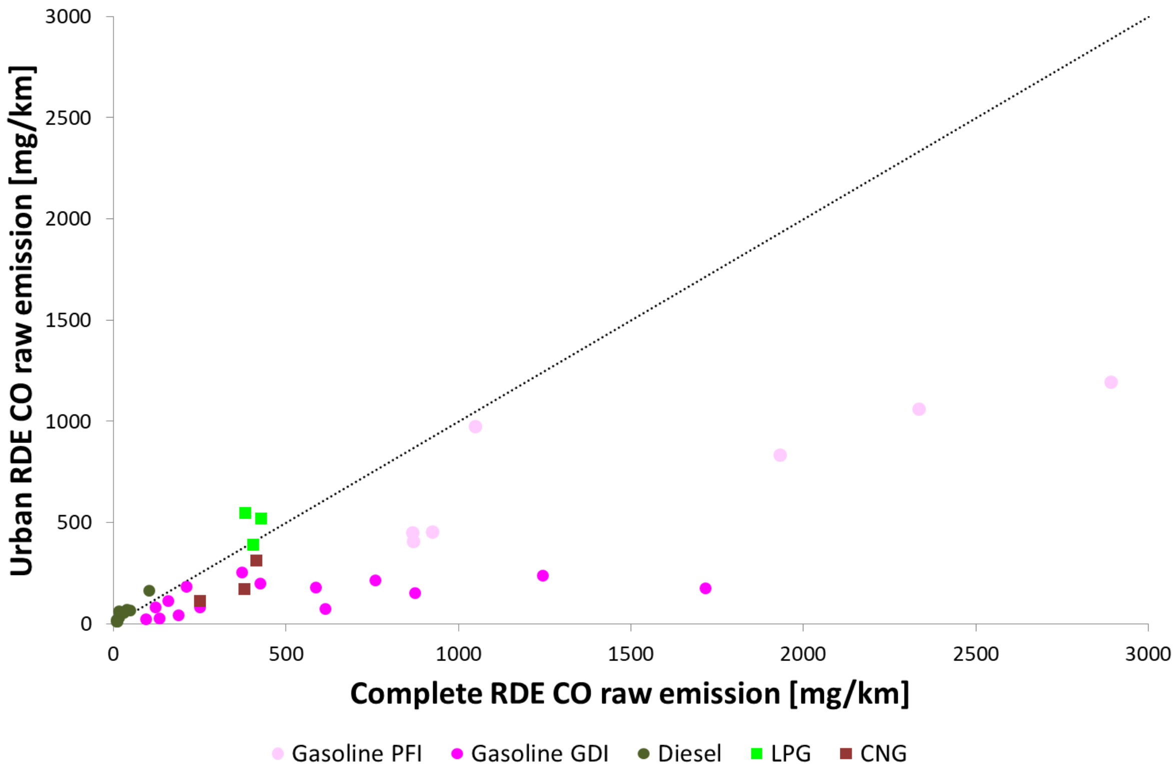

Figure 20: Complete versus urban CO RDE Euro 6b vehicles included in the 2018 JRC test campaign (raw emissions). The black dotted line stands for 1:1.

PN emissions

Considering the data gathered on 2017 and 2018 aggregating all Euro 6 stages, the median PN emission of diesel vehicles on the NEDC and WLTP Cold tests (combined) and on the complete RDE is 7e9 #/km and 6e9 #/km, respectively. Euro 6 diesel vehicles emit two orders of magnitude less particles than Euro 6 gasoline vehicles in the laboratory and on the road (8e11 #/km and 7e11 #/km, respectively). In turn, Euro 6 GDIs emit roughly 50% more particles than Euro 6 PFIs in laboratory conditions (9e11 #/km and 6e11 #/km). On the road however, GDIs and PFIs have a similar median emission ~7.5e11 #/km. The vehicle with highest PN emissions on the road is in fact a gasoline PFI (FT060) which averages 3e12 #/km (three times above the NTE limit established on the RDE regulation to diesel and GDI vehicles). The GPF helps keeping low PN emissions from the GDI vehicle in all driving conditions. The sole Euro 6c vehicle of the fleet (GDI) emits less than any of the Euro 6b GDIs pointing to a reduction in PN emission from Euro 6b to Euro 6c stages. Such a trend is not observed neither on gasoline PFIs nor on diesel vehicles from Euro 6b to Euro 6d-TEMP. The PN emissions of the PHEV in the laboratory and on the road are high (~ 1e12 #/km) even when the vehicle is operated mostly in electric mode. This value might be explained by the multiple internal combustion engine-on situations occurring during the drive that lead to numerous cold-starts [25].

4 CO_2 emissions results

4.1 Introduction and boundaries of the exercise

The objective of this chapter is to present the CO_2 emissions emitted by the vehicles tested within the project in 2018 (**Table 4**). As introduced in Chapter 2, the vehicles were tested under various modalities. Most of these modalities were designed to search for the presence of pollutant emissions (e.g. NOx) relevant defeat devices and were not applied to all the vehicles in the same way (**Table 10**). The CO_2 emissions are reported only for conditions that were applied to all of them, i.e. the NEDC (except for Euro 6d-TEMP), WLTP and the RDE compliant tests. For the RDE tests, it must be stressed that the testing conditions may vary significantly from one test to another, due to the selected route, the driver's behaviour, the traffic and the environmental conditions. The results may therefore not be representative of a European-wide average value of the vehicle and shall be taken as indicative given the intrinsic variability of the real-world fuel consumption and CO_2 emissions of a vehicle [26,27].

The results are all presented as "deviation ratio" (DR), i.e. the ratio of the measured CO_2 emissions (in the laboratory or in the road) and the type-approved CO_2 value reported in the vehicle specifications (Certificate of Conformity): NEDC-based for Euro 6b and Euro 6c vehicles, WLTP-based on Euro 6d-TEMP vehicles (**Table 17**).

As introduced in section 2, the Euro 6b and Euro 6c vehicles were tested on the chassis dynamometer applying road load coefficients and test masses that did not meet those used during the official NEDC type-approval test as those were not made available. For Euro 6d-TEMP vehicles, WLTP tests done in the laboratory used the official parameters used during the type-approval (retrieved from the CoC). While the road loads applied don't have significant effect on pollutant emissions results, it is not the case for CO_2 emissions (and fuel consumption). Therefore, it is important to highlight that despite the fact that the testing on Euro 6b and Euro 6c was performed using the best available information following a validated approach [15], the CO_2 values measured and reported in this project are not directly comparable to the type-approval ones. Regarding the WLTP, all the tests have been done following the requirements of the new test procedure such as: increased and more realistic test mass, vehicle-specific gearshift strategy (for vehicles with manual transmission, derived according to the WLTP procedure), test temperature, accuracy of the chassis dyno for the road load simulation, and vehicle preconditioning. The WLTP CO_2 results included in this report have been corrected for the SOC of the battery and for the ATCT conditions only for Euro 6d-TEMP vehicles. The battery current has been measured at 2 Hz frequency and properly down-sampled and time-aligned using internal tools. The Ki correction applicable for vehicles with periodically regenerating systems was not performed since Ki factors/Ki offsets are not available in the type-approval documentation.

Table 17: Type-approval CO_2 emission.

Id.	Declared CO_2 [g/km]
LA002	97
VW040	132
RT012	120
NN009	129
ST001	117
FT060 - LPG	135
FT060 - Gasoline	146

Id.	Declared CO_2 [g/km]
HI002	CS: 92 // Weighted CS+CD: 26*
MB010	117
LR001	189
OL002	107
TA008	91
OL003	114
FT061	234
VW042	113
SA002	113
SI001	115
VO006	172
FD009	143
PT011	128

*CS: charge-sustaining mode; CD: charge-depleting mode.

4.2 Discussion of CO_2 deviation ratios

CO_2 "deviation ratios" (DR) obtained for laboratory (NEDC and WLTP) and RDE (Complete and Urban) tests are presented in **Table 18**, while **Figure 21** and **Figure 22** show the average CO_2 DR broken down by primary vehicle technology for Euro 6b and Euro 6c vehicles, and Euro 6d-TEMP vehicles, respectively.

- For the NEDC Cold tests, the measured CO_2 always exceeded the declared value except for the Euro 6c GDI vehicle (VW042 CO_2 DR= 0.96) and two Euro 6b vehicles (ST001 and LR001, for which CO_2 DR= 0.99. The CO_2 DR ranged from 1.01 to 1.23 excluding the light-commercial vehicle (FT061) for which the exceedance of the declared value was 33%. The mean and median CO_2 DR for all vehicles were 1.07 and 1.03, respectively. A partial reason for this difference is already described in the previous section and concerns the NEDC road loads used during the JRC testing. In addition to this, deviation observed between the measured NEDC and the type-approval CO_2 numbers can come from flexibilities allowed in the old procedure[13] regarding the declaration of CO_2 results and Conformity of Production (CoP). Details about these flexibilities can be found elsewhere [26]. In summary, an OEM could systematically declare CO_2 results 4% lower than the ones achieved during the tests and vehicles coming from the production line could have up to 8% higher CO_2 results compared to the corresponding type-approval value. These 2 flexibilities, when combined together, could already result in up to 12% DR in CO_2 results.
- As expected, CO_2 emissions on the NEDC Hot tests were systematically lower than the respective Cold tests since the vehicles start with a warm engine (i.e., no extra fuel consumption needed for the stabilisation of the thermal engine). The mean and median CO_2 DR was 1.0 in both cases and the CO_2 DR ranged from 0.83 (HI002) to 1.17 (FT061).

([13]) These flexibilities have been minimised in the WLTP.

- On the WLTP Cold tests, Euro 6b and Euro 6c vehicles averaged a CO_2 DR of 1.16 with a slightly higher deviation for gasoline vehicles (1.17) as compared to diesel ones (1.14). The highest CO_2 DRs were measured on two gasoline vehicles: 1.29 on LA002, and 1.27 on NN009. The Euro 6d-TEMP vehicles, for which the type-approval CO_2 figure is based on the WLTP, averaged a CO_2 DR of 1.03 with two vehicles exceeding the type-approved value (FD009 1.07 and VO006 1.10) and the two other vehicles with same or lower CO_2 as the declared one (SI001 1.00 and PT011 0.98). On the WLTP Hot test, Euro 6b and Euro 6c averaged a CO_2 DR of 1.12 whereas the Euro 6d-TEMP 0.97. It is noteworthy that VO006 emitted 15% more CO_2 on the WLTP Cold test as compared to the WLTP Hot one when the mean and median for the whole fleet are 3.6% and 3.4%, respectively.
- For Euro 6b and Euro 6c vehicles, the average increase in CO_2 emission from the NEDC to the WLTP test is 9.5% for gasoline vehicles and 8.4% for diesel vehicles, which is in line with previous studies that concluded that the WLTP is likely to increase the type-approval CO_2 emissions [15,26]. It must be noted that the WLTP CO_2 emissions reported for Euro 6b and Euro 6c vehicles are those as measured, i.e., the results were not corrected for distance and speed, ATCT, RCB, Ki as requested by the WLTP regulation. If those aspects are considered the CO_2 emission increase from NEDC to WLTP could be larger than the one reported here.
- The CNG vehicle (FT061) emitted 10% lower CO_2 on the WLTP Cold test than on the NEDC Cold one. This fact could be an indication that the road loads applied for the NEDC test might not have been proper for this vehicle in particular.
- On the road, all vehicles of the tested fleet emitted more than their declared CO_2 values on all the RDE tests performed with the exception of the PHEV when tested in charge depleting operation (test started with 100% state of charge of the battery). The mean and median CO_2 DR on the complete RDE test for the whole fleet are 1.25 and 1.24, respectively. The average deviations for the different Euro 6 stages are 1.30 (6b), 1.32 (6c) and 1.09 (6d-TEMP). The maximum CO_2 DR over the RDE corresponds to LA002, which averaged 1.96 on the three tests performed in August 2018 (~30 °C ambient temperature, AC on during the tests). The vehicles registering lowest CO_2 DR on the complete RDE tests are PT011 (1.05, ~30 °C ambient temperature, AC on during the tests) and OL002 (1.06, ~22.5 °C ambient temperature, AC off during the tests). The CNG vehicle was the only one showing lower CO_2 DR on the road than in the laboratory.
- The urban section of an RDE test includes the emissions associated with the cold start, and it tends to include more stop and go traffic and transient operation than the rural and motorway sections. The CO_2 DR calculated for the Urban RDE section is therefore higher than that of the complete test for all vehicles operated on their combustion engine. The mean and median CO_2 DR on the urban RDE are 1.46 (excluding HI002). Again, the maximum CO_2 DR corresponds to LA002 (2.3) and the minimum (1.14) to OL002 and PT011.

Table 18: Average CO_2 deviation ratio over NEDC, WLTP and RDE tests broken down by main vehicle technology. Type-approved CO_2 emission factor was used as baseline.

Cycle / Vehicle Technology (#)	NEDC Cold	NEDC Hot	WLTP Cold	WLTP Hot	Complete RDE	Urban RDE
Euro 6b Gasoline PFI (2)	1.16	1.06	1.18	1.13	1.50	1.74
Euro 6b Gasoline GDI (4)	1.02	1.01	1.17	1.14	1.32	1.57
Euro 6b PHEV (Gasoline GDI/Electric) (1)	1.03	0.83	1.15	1.09	0.96[14]	0.84[14]
Euro 6b Diesel (5)	1.05	0.98	1.14	1.11	1.23	1.37
Euro 6b LPG (1)	1.11	1.02	1.11	1.05	1.22	1.41
Euro 6b CNG (1)	1.33	1.17	1.21	1.14	1.15	1.32
Euro 6c Gasoline GDI (1)	0.96	0.88	1.11	1.08	1.34	1.64
Euro 6c Diesel (1)	1.02	0.96	1.16	1.15	1.30	1.55
Euro 6d-TEMP Gasoline PFI (1)	-	-	1.00	0.96	1.10	1.27
Euro 6d-TEMP Diesel (3)	-	-	1.05	0.97	1.08	1.25

(14) CO_2 deviation ratio for PHEV, calculated using as denominator the Charge Sustaining CO_2 emission in WLTP (i.e., 92 k/km), both in the laboratory and on the road. From the 3 RDE compliant tests performed on this vehicle, 2 were done in charge sustaining and 1 was done in charge depleting mode.

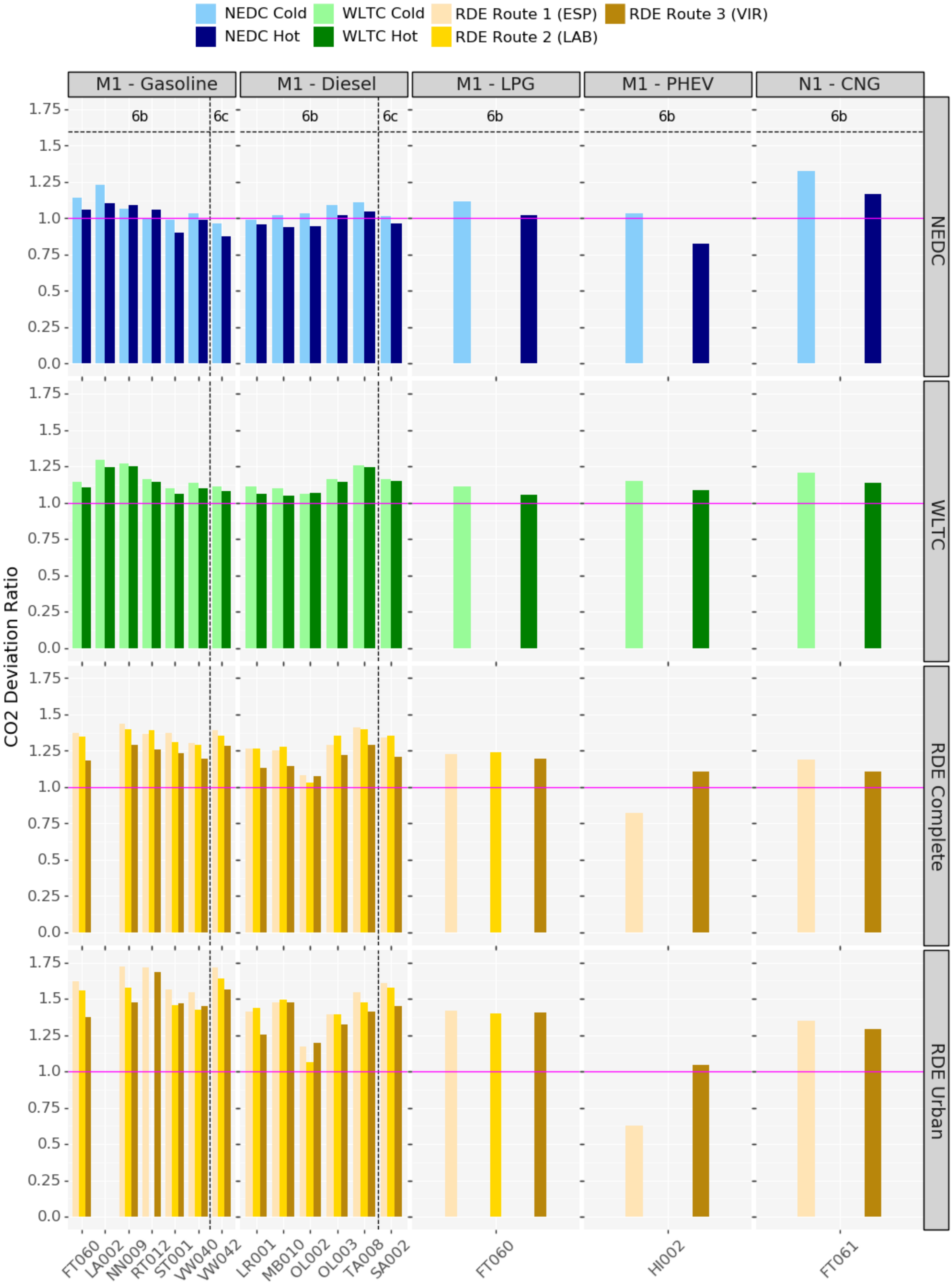

Figure 21: Euro 6b and Euro 6c vehicles CO_2 deviation ratios against the declared value over the laboratory (top panels for NEDC and WLTP) and on-road tests (bottom panels for Urban and Complete RDE). Horizontal solid lines indicate a deviation ratio of 1 (measured CO_2 equal to declared CO_2 emission).

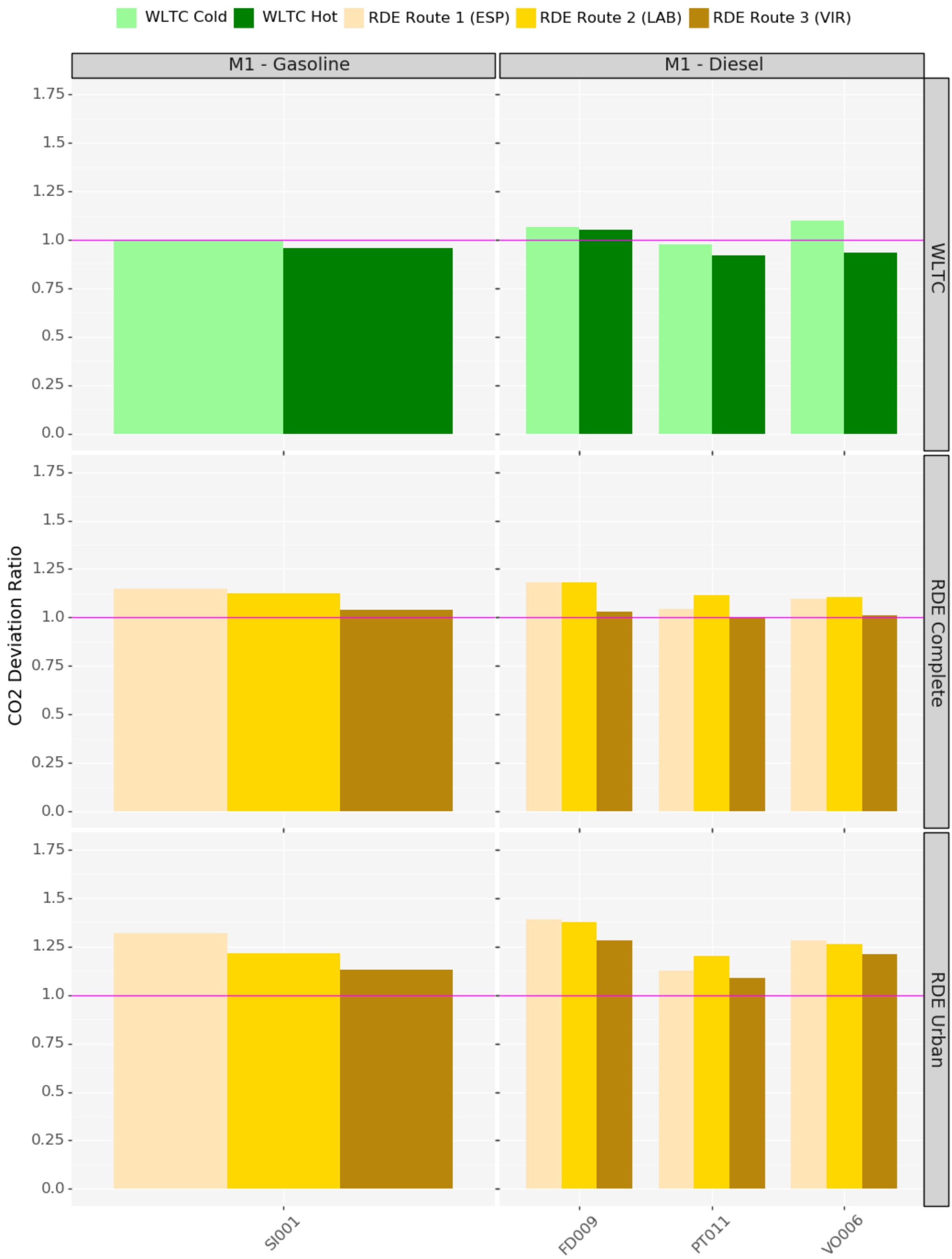

Figure 22: Euro 6d-TEMP vehicles CO_2 deviation ratios against the declared value over the WLTP laboratory (top panel) and on-road tests (bottom panels for Urban and Complete RDE). Horizontal solid lines indicate a deviation ratio of 1 (measured CO_2 equal to declared CO_2 emission).

5 Assessing the methodologies for vehicle compliance checks

5.1 Boundaries of the exercise

The objective of this section is to assess the potential of the test methods to detect anomalous[15] emissions control strategies using the experience and knowledge accumulated during the 2017 and 2018 Pilot studies. The main questions which are addressed are:

— Was the testing protocol able to detect anomalous emissions control strategies in a satisfactory manner?

— Which combinations of pollutants, test modalities and/or technologies are more prone to lead anomalous emissions control strategies (and are or will they ultimately be included in the future mandatory requirements)?

The protocol was applied to the entire vehicle sample considering Euro 6b and Euro 6c vehicles on the one hand (type-approved under NEDC), and Euro 6d-TEMP vehicles on the other hand (type-approved under WLTP and RDE).

DISCLAIMER: As the declarations regarding the emissions control strategies are under the control of the vehicle Type-Approval Authority, the report cannot provide any judgement on the legality of the observed systems functioning. The findings are only useful to test the consistency of the Guidance and further develop it. Furthermore, the report does not include either detailed information (e.g., functioning of the emissions control technologies and/or second-by-second data) to discuss the difference(s) which may appear between the emissions from tests conducted under different conditions.

Before performing any test, vehicles were inspected physically and through the OBD to discard performance issues related to the engine and after-treatment systems. Results reported here correspond to vehicles that are believed to operate properly.

Only one vehicle per model was tested. Anomalous emission control strategies identified in this project on a given model shall be confirmed by the testing of additional vehicle(s) of the same nature.

In addition, vehicles which were part of the test program but became subject of investigations (resulting from an initiative from the Type-Approval Authority or an alert from the JRC) are not part of the report. The results from these vehicles will be presented once the investigations are completed.

5.2 Present methodology

In this chapter, the vehicle tailpipe emissions are expressed as "Emissions Compliance Factors" (ECF). The ECF is defined as the vehicle emissions divided by the applicable emissions limit. The ECF is compared to the mandatory limits (for the Type 1 test) and the recommended thresholds proposed in the Guidance (for NOx and for the various categories of modified testing conditions herewith referred to as "modalities"). The modalities are defined in **Table 6** together with their purpose for Euro 6b and Euro 6c vehicles. With the exception of OL003 for NOx, all vehicles complied with their emission limits for all pollutants in their regulatory tests: NEDC Cold for Euro 6b and Euro 6c vehicles, and WLTP Cold and RDE for the Euro 6d-TEMP. These results ensure to a large extent that the vehicles were free of malfunctioning, bad maintenance or other similar issues.

For the vehicles in this study which were type-approved before the RDE rules came into force (Euro 6b and Euro 6c), the useful comparison is how high do they emit compared to similar vehicles, since at the time there was no Not-To-Exceed limit for these vehicles. This was one of the reasons for setting the recommended thresholds in the Guidance [7]. The other reason was to prioritise further testing, i.e., the vehicles that emit higher amounts should be the ones checked first. For Euro 6d-TEMP vehicles, the on-

([15]) In this paragraph, "anomalous" means that this project was not meant to assess the legality of the AES. In other words, the thresholds recommended in the Guidance were exceeded, the underlying cause was identified but the case is not necessarily statistically significant and should be investigated by the responsible authorities.

road emissions are compared against the applicable Not-To-Exceed limits (considering a Conformity Factor of 2.1 for NOx and 1.5 for PN as defined in the RDE regulation).

For the rest of the data, the average NOx, CO and PN Emissions Compliance Factors were calculated for each vehicle and each modality. The ECFs of on-road test presented in this section correspond to the emissions measured during the complete and urban section of the tests.

In the following figures:

- Each data point stands for the average ECF of the vehicle in the modality reported in the x axis.
- The grey boxplots show the distribution of the ECF values of the vehicles tested within the modality. The median value is displayed as horizontal black line. The upper and lower parts of the grey box display the 25th and 75th percentiles values.

The Guidance also highlighted examples of situations that require particular attention [7]:

- Strategies that lead to higher emissions when starting the engine in hot start than cold start;
- "Thermal windows" where emissions increase below or above certain ambient temperature ranges;
- Parameters such as a timer or the vehicle's speed that are used to modulate emission control systems.

The analysis conducted in the present chapter addresses these emissions strategies, to determine whether the methodology proposed in the Guidance [7] is able to properly detect problematic cases.

5.3 NOx emissions

5.3.1 General findings

The average ECF values calculated for Euro 6b and Euro 6c gasoline (**Figure 23**) and diesel (**Figure 24**) vehicles over each test modality tested are reported in **Table 19**. Regarding Euro 6d-TEMP vehicles, the NOx ECFs are shown in **Figure 25** for gasoline vehicles and **Figure 26** for diesel vehicles. **Table 20** reports the ECFs of all test modalities on all Euro 6d-TEMP vehicles. Colour code in the table is based on the following rules:

- Green when the ECF is lower than the applicable limit or the recommended threshold;
- Red when the ECF exceeds the applicable limit or the recommended threshold by more than 25%;
- Orange for the other cases.

Results overview for gasoline vehicles:

- All Euro 6b and Euro 6c gasoline vehicles complied with the applicable NOx limit for the Type 1 test (NEDC Cold).
- No exceedance of the NOx threshold was observed on any of the gasoline vehicles on any of the test modalities performed in the laboratory and on the road, which illustrates that gasolines vehicles tend to manage properly their NOx emissions.
- However, NN009 (Euro 6b GDI) emitted 63 mg/km and 67 mg/km on the WLTP Cold and WLTP Hot tests, respectively. This was the only Euro 6b gasoline vehicle emitting more than the Type 1 limit (60 mg/km) on some laboratory test modality. This particular vehicle (model year 2017) would not have passed the WLTP Type 1 test procedure.
- In addition, on the road over the RDE compliant tests, NN009 stands out as the Euro 6b gasoline vehicle with largest NOx emissions averaging 101 mg/km and 182 mg/km on the complete and urban RDE sections. Again, this vehicle would not have meet the NTE limit applicable on the urban section of RDE tests (126 mg/km). The maximum NOX ECF of this vehicle on an individual test is 3.5.

— All other Euro 6b and Euro 6c vehicles have a NOx ECF lower than 1 on all test conditions including the non-compliant RDE tests, with the exception of RT012 (GDI Euro 6b) which slightly exceeds this value on the urban section of an RDE test (1.3) and a non-compliant RDE test (1.1).

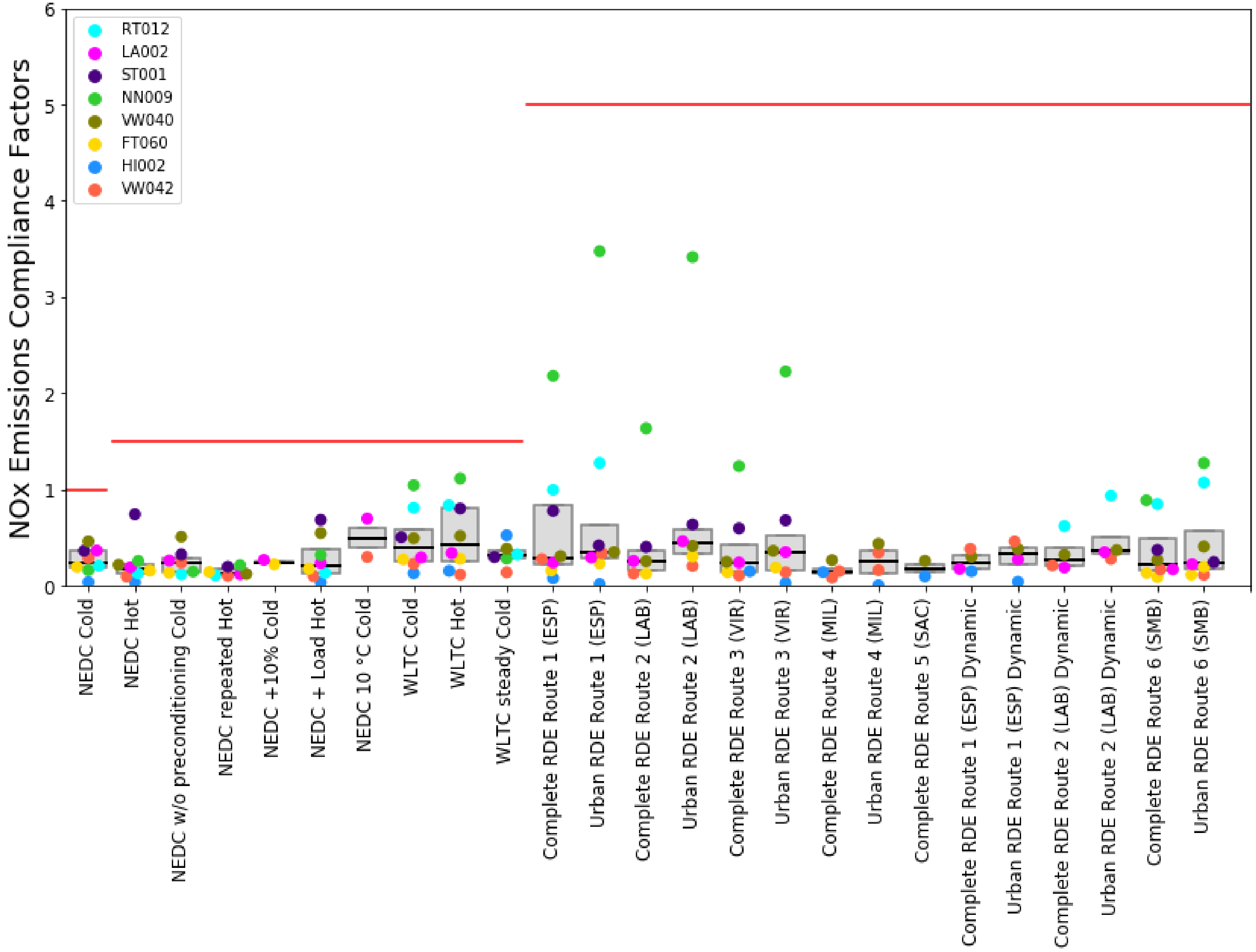

Figure 23: NOx Emissions Compliance Factors for Euro 6b and Euro 6c gasoline vehicles over the laboratory and on-road tests. Horizontal red lines stand for limits or recommended thresholds proposed in the Guidance.

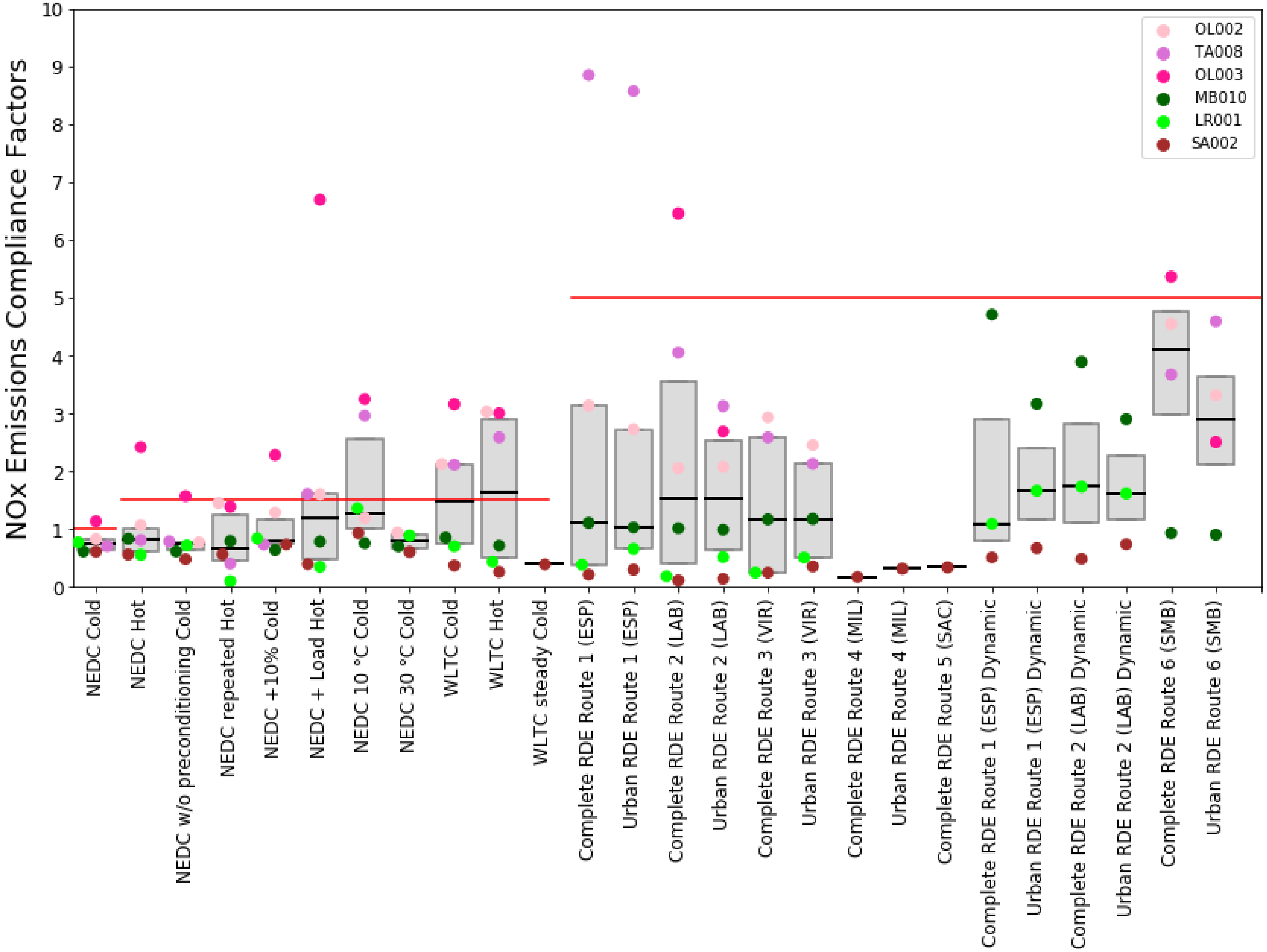

Figure 24: NOx Emissions Compliance Factors for Euro 6b and Euro 6c diesel vehicles over the laboratory and on-road tests. Horizontal red lines stand for limits or recommended thresholds proposed in the Guidance.

Table 19: NOx Emissions Compliance Factors of the tested Euro 6b and Euro 6c vehicles. For vehicle HI002, laboratory emissions correspond to tests in charge sustaining operation, whereas on the road two charge sustaining tests and one charge depleting test were considered.

Id.	Euro	Fuel	NEDC Cold	NEDC Hot	WLTC Cold	WLTC Hot	RDE Compliant (Min-Max)	RDE non-compliant (Min-Max)	NEDC w/o preconditioning Cold	NEDC Repeated Hot	NEDC +10% Speed Cold	NEDC with engine loads Hot	NEDC at +10°C Cold	NEDC at +30°C Cold	SHS Cold
	Category		-	2	2	2	3	3	2	2	2	2	2	2	2
	Recommended Threshold		1	1.5	1.5	1.5	5	5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LA002	6b	Gasoline PFI	0.4	0.2	0.3	0.3	0.2-0.3	0.2-0.2	0.3	0.1	0.3	0.2	0.7		
VW040	6b	Gasoline GDI	0.5	0.2	0.5	0.5	0.2-0.3	0.3-0.3	0.5	0.1		0.5			0.4
RT012	6b	Gasoline GDI	0.2	0.1	0.8	0.8	1.0	0.6-0.8	0.1	0.1		0.1			0.3
NN009	6b	Gasoline GDI	0.2	0.3	1.0	1.1	1.2-2.2	0.9	0.1	0.2		0.3			0.3
ST001	6b	Gasoline GDI	0.4	0.7	0.5	0.8	0.4-0.8	0.4	0.3	0.2		0.7			0.3
FT060	6b	Gasoline PFI	0.2	0.2	0.3	0.3	0.1-0.2	0.1-0.1	0.1	0.1	0.2	0.2			
FT060	6b	LPG	0.2	0.1	0.3	0.2	0.1-0.3	0.2	0.1	<0.1	0.2	0.1			
HI002	6b	GDI /Electric	<0.1	<0.1	0.1	0.2	0.1-0.1	0.1-0.2				<0.1			0.5
MB010	6b	Diesel	0.6	0.8	0.8	0.7	1.0-1.2	0.9-4.7	0.6	0.8	0.6	0.8	0.8	0.7	
LR001	6b	Diesel	0.8	0.6	0.7	0.4	0.2-0.4	1.1-1.7	0.7	0.1	0.8	0.3	1.4	0.9	
OL002	6b	Diesel	0.8	1.1	2.1	3.0	2.0-3.1	4.5	0.8	1.4	1.3	1.6	1.2	0.9	
TA008	6b	Diesel	0.7	0.8	2.1	2.6	2.6-8.8	3.7	0.8	0.4	0.7	1.6	3.0		
OL003	6b	Diesel	1.1	2.4	3.2	3.0	6.5	5.4	1.6	1.4	2.3	6.7	3.2		
FT061	6b	CNG	0.7	1.6	3.6	7.5	2.1-2.3		0.7	1.3		2.0			4.2[16]
VW042	6c	Gasoline	0.3	0.1	0.2	0.1	0.1-0.3	0.1-0.4	0.2	0.1		0.1	0.3		0.1
SA002	6c	Diesel	0.6	0.6	0.4	0.3	0.1-0.2	0.2-0.5	0.5	0.6	0.7	0.4	0.9	0.6	0.4

([16]) SHS Phase 3 steady at 85 km/h

— Regarding the gasoline Euro 6d-TEMP, SI001 performed well emitting < 18 mg/km of on all laboratory and RDE compliant tests. Even on some of the non-RDE compliant tests (MIL, SAC) the vehicle coped well with NOx. It is worth mentioning than when the vehicle was driven in a dynamic way (ESD, LAD), NOx emissions increased to 60 mg/km.

Results overview for diesel vehicles:

— Diesel vehicles from all Euro 6 stages met the Type 1 test NOx emission limit with the exception of OL003. As mentioned previously, 4 NEDC Cold repetitions were performed on this vehicle using two independent laboratories within the JRC with consistent results. No proof of malfunctioning was found during the inspection of the vehicle.

— In the laboratory, OL003 exceeded the 1.5 threshold on seven out of eight modalities tested, with a maximum NOx emission of 535 mg/km (NOx ECF = 6.7) on the NEDC Hot test performed with AC and lights on (NEDC load). On the road two of the three RDE compliant tests performed on this vehicle were voided for not meeting the span drift requirements and therefore only 1 test is valid (LAB). On the valid test, NOx ECF was 6.5 on the complete route and 2.7 on the urban section.

— Among diesel Euro 6b, other two vehicles (OL002 and TA008) exceeded the 1.5 indicative threshold established in the Guidance on certain laboratory test modalities: NEDC + Load Hot, NEDC +10°C Cold, WLTP Cold, and WLTP Hot. On the road, the emissions of OL002 were systematically below the indicative threshold (NOx ECF = 5), whereas TA008 exceeded the threshold on one of the three RDE compliant tests (ESP) with a NOx ECF = 8.8 and 8.6, on the complete and urban sections, respectively.

— The diesel Euro 6c (SA002) exhibited low NOx emissions consistently on all test conditions. The maximum NOx emissions of this vehicle in the laboratory and on the road were 74 mg/km (NEDC +10°C Cold) and 59 mg/km (urban section of LAD), respectively.

— For what regards Euro 6d-TEMP diesel vehicles, FD009 (equipped with LNT) performed better in all laboratory tests than the other two vehicles that mounted an SCR (VO006 and PT011). The opposite trend was observed over the on-road tests. This result is in agreement with [22] that pointed out that on short distances (WLTP 23 km) the LNT can cope better with the NOx emissions than the SCR since it is efficient at low exhaust temperature. In addition, during the test the LNT operates at its best capabilities as it gets properly conditioned during the precedent preconditioning cycle. Over long-distances however, SCRs are very efficient in NOx conversion and the tailpipe emissions remain low. It is noteworthy that on one of the RDE compliant tests (LAB), the NOx emission of FD009 (144 mg/km) was slightly lower than the applicable NTE limit (168 mg/km).

— On the non-RDE compliant tests all vehicles remained below the NTE NOx limit except on the dynamic-driven tests. In particular, on the ESD and LAD tests FD009 and VO006 averaged 338 mg/km and 227 mg/km, respectively. PT011 performed much better on the dynamic tests registering an average of 87 mg/km.

Results overview for LPG/CNG/PHEV vehicles:

— Only one vehicle per powertrain was tested in 2018 and it is not possible to draw conclusions on the emissions performance of LPG/CNG/PHEV vehicles. With this in mind, the LPG and PHEV vehicles did not show anomalous behaviours for what regards NOx emissions with maximum values < 20 mg/km and < 35 mg/km, respectively.

— On the other hand, the CNG vehicle exceeded the 1.5 threshold defined in the Guidance on most of the laboratory modalities (e.g., NOx ECF = 7.5 on the WLTC Hot test) and on the urban section of RDE tests (e.g. NOx ECF = 8.5 on the VIR route).

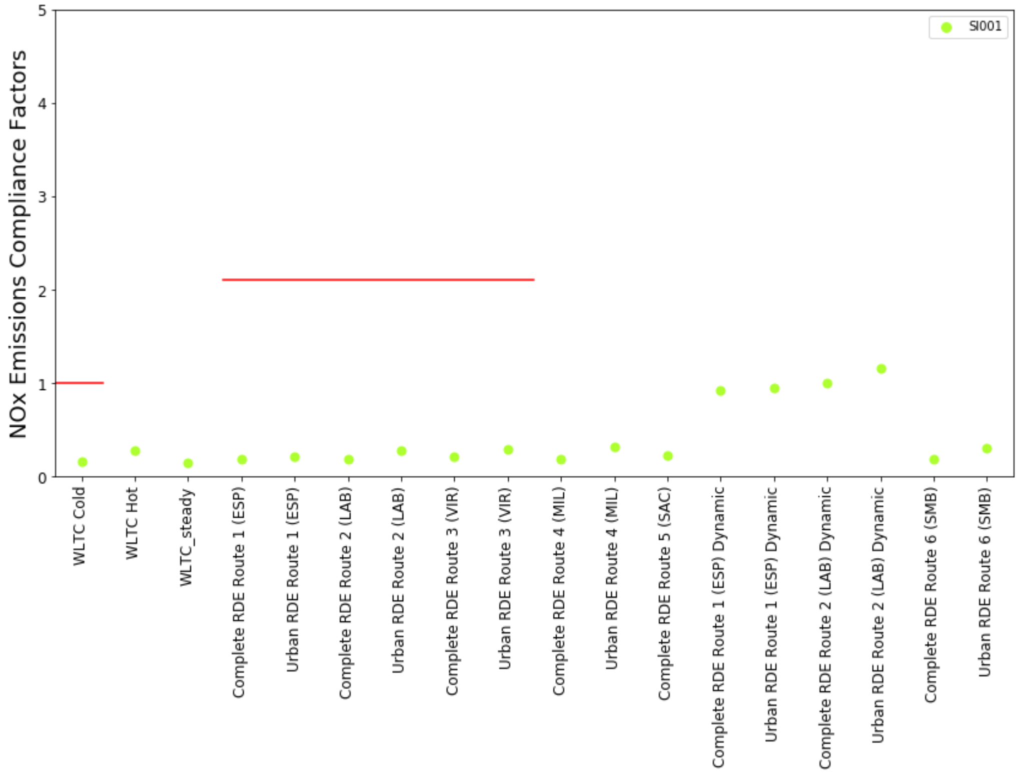

Figure 25: NOx Emissions Compliance Factors for SI001 Euro 6d-TEMP gasoline vehicle over the laboratory and on-road tests. Horizontal red lines represent applicable limits on Type 1 test (60 mg/km) and on the road (126 mg/km corresponding to NTE with CF = 2.1)

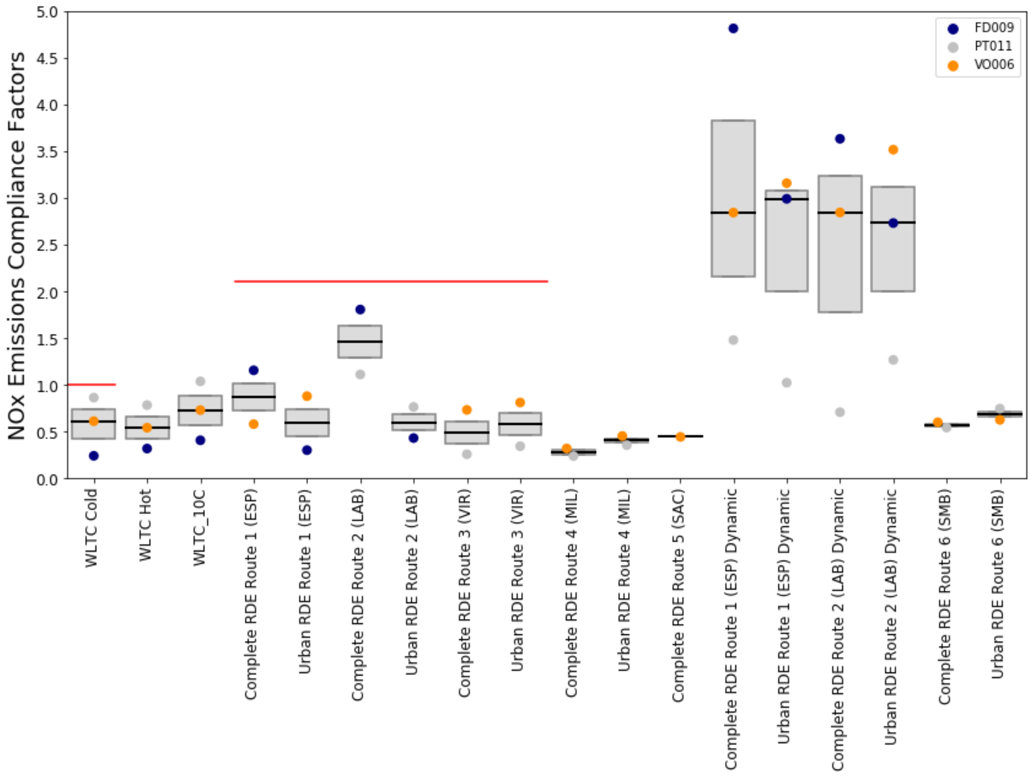

Figure 26: NOx Emissions Compliance Factors for Euro 6d-TEMP diesel vehicles over the laboratory and on-road tests. Horizontal red lines represent applicable limits on Type 1 test (80 mg/km) and on the road (168 mg/km corresponding to NTE with CF = 2.1).

Table 20: NOx Emissions Compliance Factors of the tested Euro 6d-TEMP vehicles. No recommended thresholds have been yet defined for these vehicles and they did not have to comply with the Not-to-Exceed limits under non-RDE compliant conditions. The color is therefore shown as orange for the highest values.

Id.	Euro	Fuel	WLTC Cold	WLTC Hot	RDE Compliant (Min-Max)	RDE non-compliant (Min-Max)	Modified WLTP
	Category		-	-	-	-	-
	Recommended Threshold		1		2.1		
SI001	6d-TEMP	Gasoline PFI	0.2	0.3	0.2-0.2	0.2-1.0	0.1
VO006	6d-TEMP	Diesel	0.6	0.5	0.6-0.7	0.3-2.8	0.7[17]
FD009	6d-TEMP	Diesel	0.2	0.3	1.2-1.8	3.6-4.8	0.41[17]
PT011	6d-TEMP	Diesel	0.9	0.8	0.3-1.1	0.2-1.5	1.0[17]

5.3.2 Anomalous cases identified with the methodology

The application of the methodology defined in the Guidance on Euro 6b and Euro 6c vehicles [7] has led to the identification of OL003 and FT061 as anomalous since their NOx emissions are systematically higher than the proposed thresholds. Additional vehicles of the same type, variant, and version are foreseen to be tested at JRC to confirm or not the findings presented above. In addition, OL002 and TA008 have been identified as high-emitters as compared to the other vehicles in the fleet on certain modalities (WLTP Cold and WLTP Hot, NEDC + Load).

Despite not exceeding the proposed thresholds, NOx emissions of NN009 on several modalities are high as compared to the rest of gasoline vehicles and its emissions performance shall be further assessed.

Regarding Euro 6d-TEMP vehicles, FD009 (diesel) seems to be a transitional vehicle from Euro 6c to Euro 6d: its NOx emissions are close to the applicable limits and it is expected that emissions could fail under more demanding RDE tests but it will not undergo ISC testing as the provisions were not in force at the time of its type-approval.

5.4 CO emissions

5.4.1 General findings

As the focus of the first Guidance was primarily on NOx for diesel engines, no thresholds were defined for CO. The CO ECFs, calculated based on the Type 1 applicable limits, are therefore not verified against thresholds.

Figure 27 and **Figure 28** show the CO ECFs for the Euro 6b and Euro 6c gasoline and diesel vehicles, respectively. Moreover, **Figure 29** and **Figure 30** show the CO ECFs for the Euro 6d-TEMP gasoline and diesel vehicles, respectively. The actual CO ECFs for each vehicle on each tested modality are reported in **Table 21** (Euro 6b and Euro 6c) and **Table 22** (Euro 6d-TEMP). For Euro 6d-TEMP vehicles, only a limited number of vehicles is considered. Therefore, the approach using a relative comparison of vehicles is not applicable

([17]) WLTP at 10 °C ambient temperature

Results overview for gasoline vehicles:

- All gasoline vehicles met the CO emission limit on their respective Type 1 test and had a mean and median CO ECF of 0.24 and 0.17, respectively.
- Gasoline vehicles had a CO ECF ≤ 1 on all laboratory modalities with the exception of the "WLTP steady test" (standard WLTC cycle where phases 3 and 4 are driven at steady speed of 110 km/h and 130 km/h). On this modality, four out of ten gasoline vehicles (RT012, ST001, VW040, and SI001) had a CO ECF close to or exceeding 1. CO emissions were large during the accelerations from 0 km/h to 110 km/h and 0 km/h to 130 km/h but also remarkable on steady speed conditions (additional discussion in section 5.4.3).
- On the RDE compliant tests, gasoline vehicles tend to emit more CO on the complete test than on the urban part alone (**Figure 20**). In fact, the highest CO emissions are measured in the motorway section which could be explained by fuel enrichment occuring at high engine loads. All vehicles had a CO ECF < 1 on the RDE compliant tests except FT060 and NN009, which average a CO ECF of 1.9 and 1.1, respectively.
- On the dynamic on-road tests (non-RDE compliant ESD and LAD), gasoline Euro 6b vehicles have a CO ECF largely above 1 (average CO ECF: LA002 = 5.2; VW040 = 2.8; RT012 = 2.4). The raw CO emissions (i.e., not processed according to RDE regulation) on the motorway section of the ESD test are particularly high, reaching 12.8 g/km (LA002), 7.5 g/km (VW040) and, 5.4 g/km (RT012).
- It is noteworthy that VW042 (Euro 6c GDI) had consistently low CO emission on all test modalities (average CO ECF = 0.1). Only in the dynamic on-road test (complete ESD), the CO emission was slightly above 1 g/km (1079 mg/km).
- The Euro 6d-TEMP gasoline vehicle SI001 reaches CO ECF of 1.9 on one of the dynamic tests (ESD).

Results overview for diesel vehicles:

- Diesel vehicles from all Euro 6 stages had low CO ECFs on all test modalities, which is a proof of good operation of the engine and/or the DOC technology. In particular, Euro 6d-TEMP vehicles have a maximum CO ECF of 0.2 (i.e., 20% of the permissible emission on Type 1 test). The maximum CO emission of a diesel vehicle corresponds to LR001 on the "NEDC +10°C Cold" modality (319 mg/km).
- In fact, the test modalities done at 10°C (either NEDC for Euro 6b and Euro 6c, and WLTP for Euro 6d-TEMP) were the ones that led to higher CO values on most of the diesel vehicles. The median CO ECF was 0.43 for the NEDC 10°C, and 0.10 for the WLTP 10°C.
- Although having a CO ECF < 1 TA008 tend the exhibit the highest CO emissions among diesel vehicles on all test modalities.

Results overview for LPG/CNG/PHEV vehicles:

- The LPG (FT060) and the CNG vehicles (FT061) did not exceed a CO ECF of 1 in any of the test modalities either in the laboratory or on the road. The median CO ECF was 0.41 and 0.12 for the LPG and CNG vehicles, respectively. The maximum CO emission of FT060 was measured over the NEDC Cold (657 mg/km) and "NEDC without conditioning Cold" modality (690 mg/km) which points to a large contribution of cold start on the total emission. For FT061, the maximum CO emission corresponded to 579 mg/km on the WLTC Cold test. It must be stressed that none of these vehicles was tested in the dynamic on-road tests (ESD or LAD).
- FT061 can be fuelled with gasoline as a back-up for the CNG tank (maximum mileage ~ 55 km and maximum speed ~ 80 km/h). When operated with gasoline NOx emissions are lower than 10 mg/km (NEDC Cold test and RDE) but the emissions of other pollutants are extremely high: ~20gCO/km, ~460 mgHC/km, and PN ~1e13 #/km.
- The PHEV (HI002) had a median CO ECF of 0.03. The CO emission on all modalities was < 100 mg/km (one order of magnitude lower than the applicable limit on Type 1 test). However, on the dynamic on-road test, CO emissions reached 2.4 g/km (CO ECF = 2.4). Most of the CO emission was measured in high accelerations starting from stopped condition (in the rural and motorway sections).

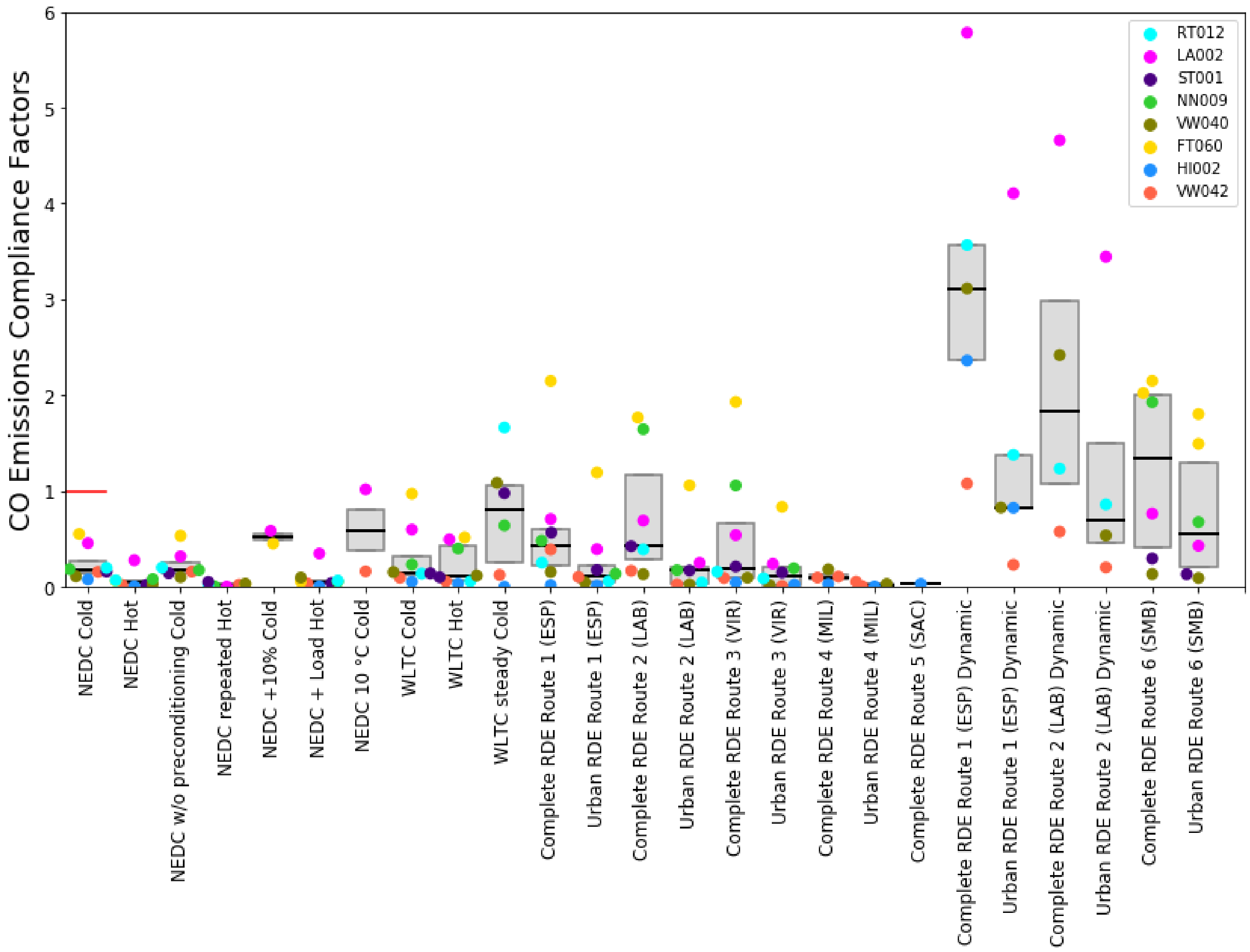

Figure 27: CO Emissions Compliance Factors for Euro 6b and Euro 6c gasoline vehicles over the laboratory and on-road tests. The horizontal red line corresponds to the Type 1 test applicable limit for gasoline vehicles (1000 mg/km).

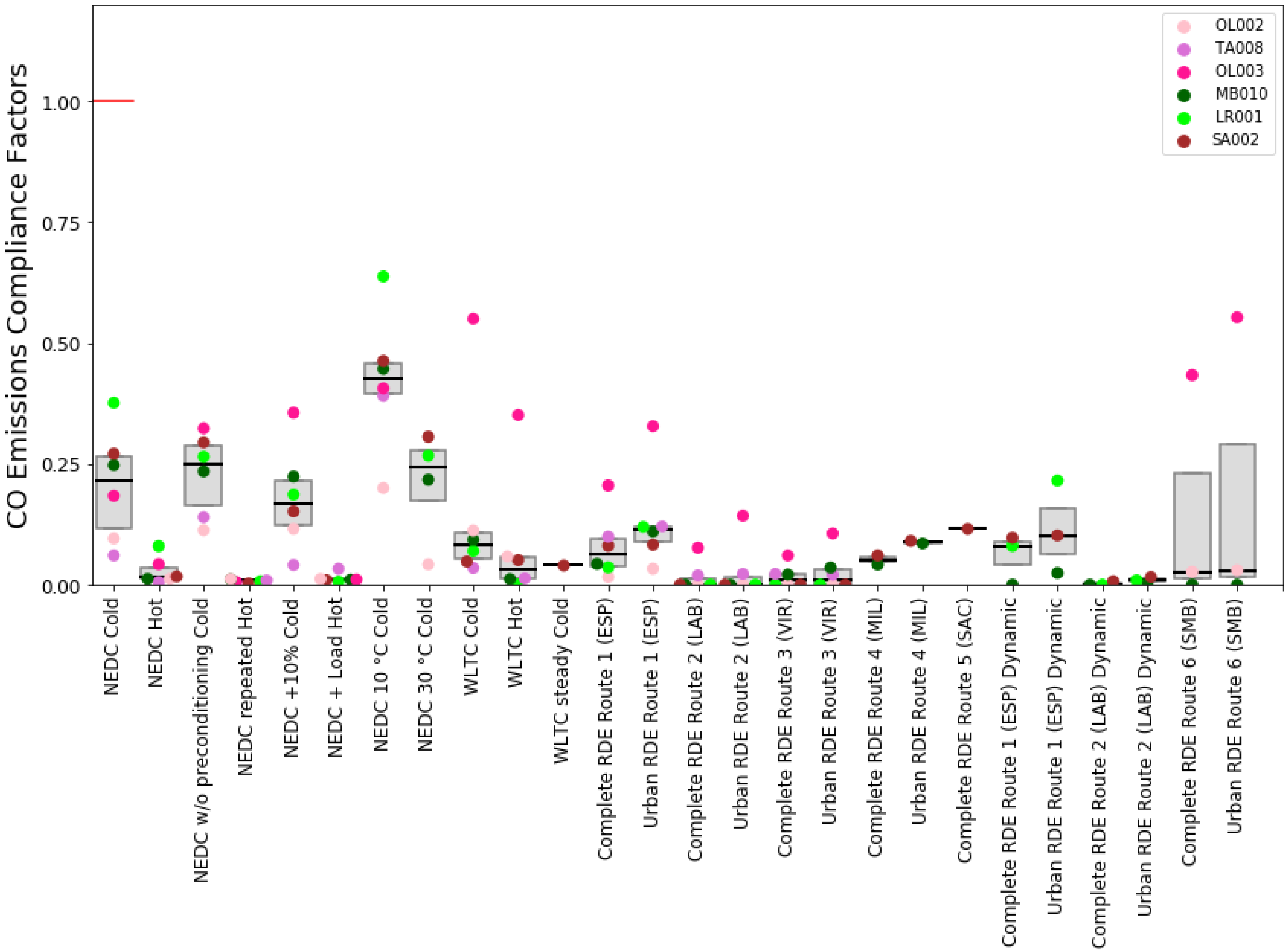

Figure 28: CO Emissions Compliance Factors for Euro 6b and Euro 6c diesel vehicles over the laboratory and on-road tests. The horizontal red line corresponds to the Type 1 test applicable limit for diesel vehicles (500 mg/km).

Table 21: CO Emissions Compliance Factors of the tested Euro 6b and Euro 6c vehicles. For vehicle HI002, laboratory emissions correspond to tests in CS operation, whereas on the road two CS tests and one CD test were considered. In bold, CO ECF > 1. "NA" stands for "not available". The "SHS" modality corresponds to the test in which phases 3 and 4 are driven at steady speed (110 km/h and 130 km/h, respectively).

Id.	Euro	Fuel	NEDC Cold	NEDC Hot	WLTC Cold	WLTC Hot	RDE Compliant (Min-Max)	RDE non-compliant (Min-Max)	NEDC w/o preconditioning Cold	NEDC Repeated Hot	NEDC +10% Speed Cold	NEDC with engine loads Hot	NEDC at +10°C Cold	NEDC at +30°C Cold	SHS Cold
	Category		-	2	2	2	3	3	2	2	2	2	2	2	2
	Recommended Threshold		1	-	-	-	-	-	-	-	-	-	-	-	-
LA002	6b	Gasoline PFI	0.5	0.3	0.6	0.5	0.5-0.7	0.8-**5.8**	0.3	<0.1	0.6	0.3	**1.0**		
VW040	6b	Gasoline GDI	0.1	<0.1	0.2	0.1	0.1-0.2	0.1-**3.1**	0.1	<0.1		0.1			**1.1**
RT012	6b	Gasoline GDI	0.2	0.1	0.1	0.1	0.2-0.4	**1.2-3.6**	0.2	<0.1		0.1			**1.7**
NN009	6b	Gasoline GDI	0.2	0.1	0.2	0.4	0.5-**1.6**	**1.9**	0.2	<0.1		0.1			0.6
ST001	6b	Gasoline GDI	0.2	<0.1	0.1	0.1	0.2-0.6		0.1	0.1		<0.1			**1.0**
FT060	6b	Gasoline PFI	0.6	0.1	**1.0**	0.5	**1.8-2.1**	**2.0-2.1**	0.5	<0.1	0.5	0.1			
FT060	6b	LPG	0.7	0.2	0.5	0.2	0.4-0.4	0.4	0.7	<0.1	0.7	0.2			
HI002	6b	GDI/Electric	0.1	<0.1	0.1	<0.1	<0.1	<0.1-**2.4**				<0.1			<0.1
MB010	6b	Diesel	0.2	<0.1	0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.2	<0.1	0.4	0.2	
LR001	6b	Diesel	0.4	0.1	0.1	<0.1	<0.1	<0.1-0.1	0.3	<0.1	0.2	<0.1	0.6	0.3	
OL002	6b	Diesel	0.1	<0.1	0.1	0.1	<0.1	<0.1	0.1	<0.1	0.1	<0.1	0.2	<0.1	
TA008	6b	Diesel	0.1	<0.1	<0.1	<0.1	<0.1-0.1	NA	0.1	<0.1	<0.1	<0.1	0.4		
OL003	6b	Diesel	0.2	<0.1	0.5	0.4	0.1-0.2	0.4	0.3	<0.1	0.4	<0.1	0.4		
FT061	6b	CNG	0.2	0.1	0.3	0.2	0.1-0.1		0.2	0.1		0.1			0.2[18]
VW042	6c	Gasoline	0.2	<0.1	0.1	0.1	0.1-0.4	0.1-**1.1**	0.2	<0.1		<0.1	0.2		0.1
SA002	6c	Diesel	0.3	<0.1	<0.1	0.1	<0.1-0.1	<0.1-0.1	0.3	<0.1	0.2	<0.1	0.5	0.3	<0.1

(18) SHS Phase 3 steady at 85 km/h

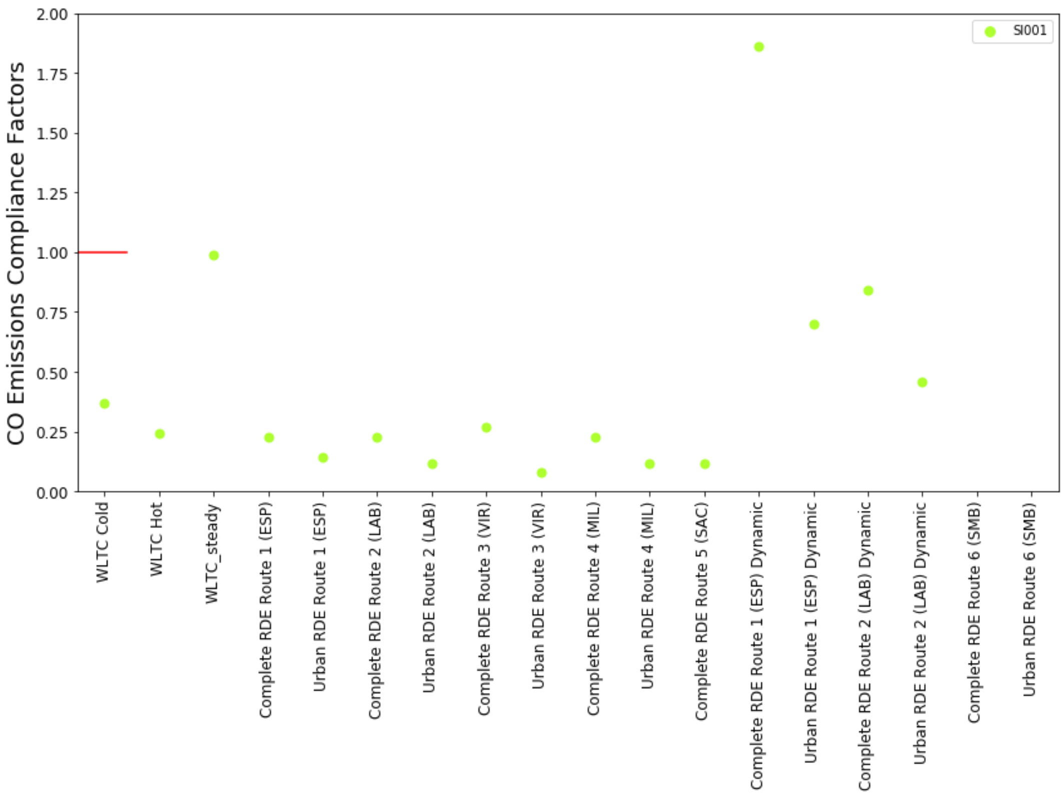

Figure 29: CO Emissions Compliance Factors for SI001 Euro 6d-TEMP gasoline vehicle over the laboratory and on-road tests. The horizontal red line corresponds to the Type 1 test applicable limit for gasoline vehicles (1000 mg/km). Results on RDE compliant tests displayed for illustration purposes.

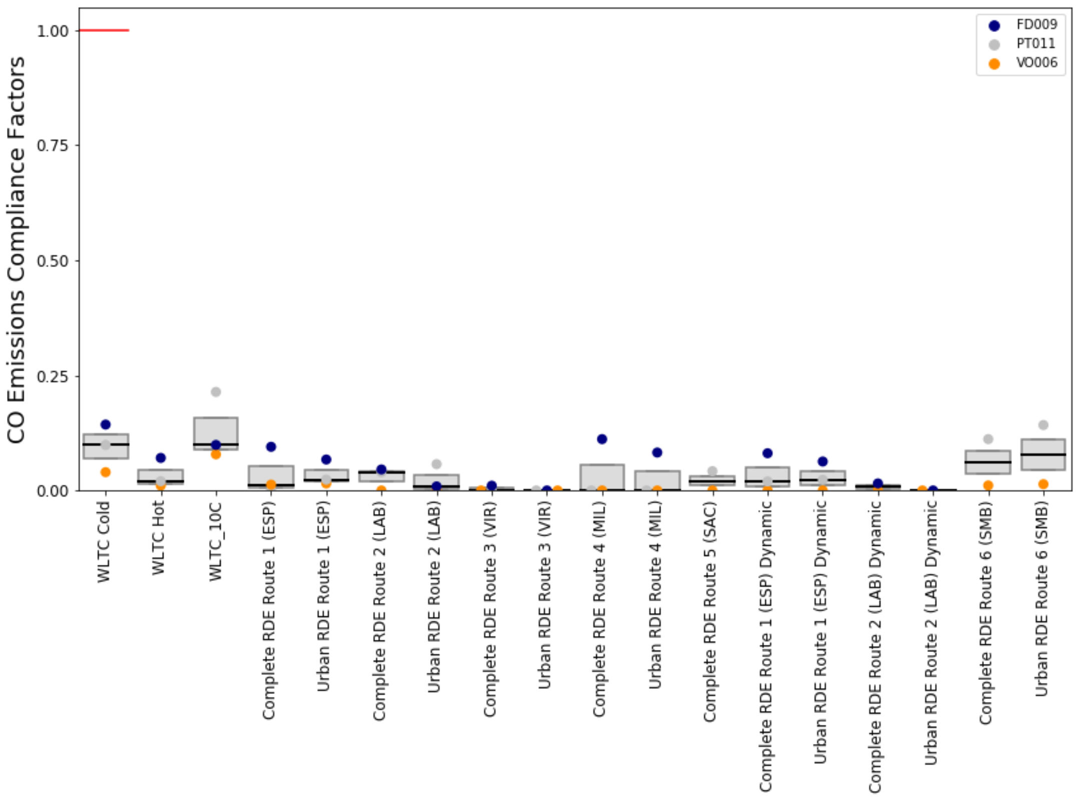

Figure 30: CO Emissions Compliance Factors for Euro 6d-TEMP diesel vehicles over the laboratory and on-road tests. The horizontal red line corresponds to the Type 1 test applicable limit for diesel vehicles (500 mg/km).

Table 22: CO Emissions Compliance Factors of the tested Euro 6d-TEMP vehicles. In bold, CO ECF > 1. "NA" stands for "not available". The "Modified WLTP" modality corresponds to WLTP test performed at 10 °C.

Id.	Euro	Fuel	WLTC Cold	WLTC Hot	RDE Compliant (Min-Max)	RDE non-compliant (Min-Max)	Modified WLTP
	Category		-	-	-	-	-
	Recommended Threshold		1	-	-	-	-
SI001	6d-TEMP	Gasoline PFI	0.4	0.2	NA	0.1-**1.9**	**1.0**
VO006	6d-TEMP	Diesel	<0.1	<0.1	<0.1	<0.1	0.1[19]
FD009	6d-TEMP	Diesel	0.1	0.1	<0.1-0.1	<0.1-0.1	0.1[19]
PT011	6d-TEMP	Diesel	0.1	<0.1	<0.1	<0.1-0.1	0.2[19]

5.4.2 Anomalous cases identified with the methodology

The methodology defined in the Guidance on Euro 6b and Euro 6c focuses on NOx from diesel vehicles and therefore its application to investigate CO emissions is not particularly suitable. However, the addition of the "WLTP steady" test performed in the laboratory on gasoline vehicles appears to be appropriate to identify high CO emissions on high load operation. In addition, the dynamic tests on the road have proven to be useful to identify different operation of the engine and/or the after-treatment systems in gasoline vehicles (including Euro 6d-TEMP). The next section discusses in more detail the methodological approach and the findings.

SI001, LA002, RT012 and VW040 emit on 8.0, 8.2, 14.2, and 20.0 as many CO on the ESP route when driven in a dynamic way (ESD) than when driven on a standard RDE-compliant way (ESP).

5.4.3 Additional considerations regarding CO emissions

Considering the elements presented in the previous sections, it is not straightforward to propose absolute thresholds for CO that could be used to indicate that the emissions behaviour of vehicles change in specific situations, caused by AESs or any physical response of the system.

Still, due to the presence of "borderline" gasoline vehicle cases (also in the 2017 report, vehicle C), further attention was given to the CO emissions of gasoline vehicles and AES that might occur under specific conditions.

The work in this section was conducted without any preliminary assumption regarding the cause behind the elevated CO emissions, which could be physical limitations of the vehicle systems (e.g., after-treatment systems not being able to abate emissions beyond a certain threshold) or a voluntary modulation of the emissions control strategy (on the engine or after-treatment).

Other approaches (more detailed than the methodology using absolute thresholds) were followed to identify AESs affecting CO emissions from gasoline vehicles:

— The first approach is based on the comparison of the RDE compliant motorway CO emissions relative to the urban ones, as they represent very different engine load and after-treatment thermal conditions. This analysis searches for general trends of elevated CO emissions at high engine

([19]) WLTP at 10 °C ambient temperature load/motorway. Since all gasoline vehicles have the same after-treatment system, the approach is appropriate to make vehicle-to-vehicle comparisons.

— The second approach looks more in detail at the emissions over the WLTP phases and compares the emissions over phases 3 and 4 of the standard (“WLTC Cold”) and the SHS Cycle (“WLTP steady”). In particular, it searches for a trend to elevated CO emissions at high engine load at constant vehicle speed.

5.4.3.1 Approach 1 - Urban vs. Motorway CO emissions for RDE compliant routes

For the considered gasoline vehicles, the CO emissions (in g/km) were found on average 5 times higher on the motorway when compared to their urban counterpart: The elevated CO emissions for the complete RDE tests are therefore a result of the significant contribution from their motorway part.

Figure 31 shows the average CO RDE over the different sections of the RDE tests for most of the Euro 6 gasoline and diesel vehicles tested in 2017 (vehicles 3 to 16) and 2018 (vehicles 22 to 26). As a general trend, CO emissions tend to increase at high speeds/high engine loads. This increase is by far much higher for one of the vehicles (#16 - RT010 from the 2017 campaign), the latter exhibiting higher CO motorway/urban emissions ratios when compared to the other vehicles.

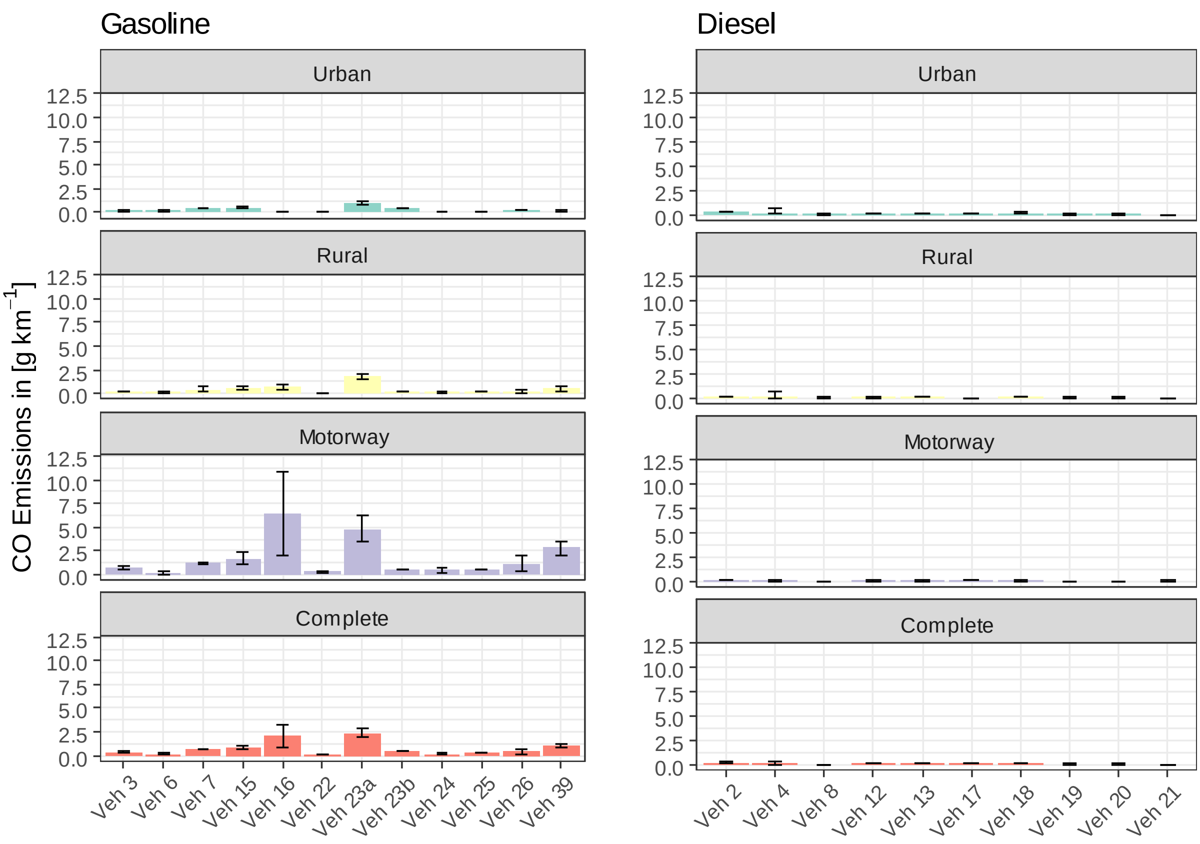

Figure 31: RDE CO emissions over the different sections of the RDE tests for all the gasoline (left column) and diesel (right column) Euro 6 vehicles tested in 2017 (vehicles 2 to 18) and 2018 (vehicles 19 to 26). Vehicle 23 (FT060) was tested in gasoline (labelled “Veh 23a”) and with LPG (labelled “Veh 23b”). Error bars stand for min and max values.

5.4.3.2 Approach 2 - CO emissions for the WLTP and SHS Cycle

The WLTP cycle has been modified driving the cycle with its 3rd and 4th phases at constant speeds of respectively 110 and 130 km/h. The results are reported in **Table 23**, which summarizes the average CO emission by phase for the seven Euro 6 gasoline vehicles tested with the SHS Cycle.

The higher CO emissions during phase 1 are caused by the cold start effects. The low emissions during phase 2 show that the three-way catalytic converter has reached its light-off temperature whereas the higher values during phases 3 and 4 have to be attributed mainly to the acceleration events at the beginning of each phase. During the steady-speed phases, it was therefore not expected to observe a significant and steady-increase of the emissions. VW040 and SI001 show the highest CO emission rates at steady 130 km/h.

Table 23: CO emission by phase on the WLTP steady test for gasoline vehicles. – For Phase 1 to 4, the results are the bags values whereas the emissions for "Constant CO emission rate at 130 km/h" exclude the emissions from the acceleration.

Id.	Phase 1 – Low [mg/km]	Phase 2 – Medium [mg/km]	Phase 3 – Steady 110 km/h [mg/km]	Phase 4 – Steady 130 km/h [mg/km]	Constant CO emission rate at 130 km/h [mg/km]
VW040	789	16	333	2555	570
RT012	774	10	773	3684	150
VW042	444	10	62	159	63
ST001	375	53	812	3220	100
NN009	609	62	546	586	110
SI001	1477	259	903	1277	415

5.5 PN emissions

Figure 32 and **Figure 33** show the PN ECFs for Euro 6b and Euro 6c gasoline GDI and diesel vehicles, respectively. PN ECFs for diesel Euro 6d-TEMP vehicles are presented in **Figure 34**. The calculated values for each vehicle over each test modality tested are reported in **Table 24** (Euro 6b and Euro 6c) and **Table 25** (Euro 6d-TEMP). It is important to notice that for Euro 6b GDI vehicles the temporary limit of 6e12 #/km has been used to calculate the PN ECF and that no PN ECF have been calculated for gasoline PFI vehicles since any PN emission limit currently applies to those vehicles. The PN emissions of those vehicles have been presented in Sections 3.5 and 3.6 (aggregated 2017 and 2018 data).

The main results are as follows:

- All gasoline GDI vehicles complied with Type 1 emission limit with PN ECF ranging from 0.0 to 0.5.
- NN009 was the GDI vehicle which tended to present the highest PN emissions on all modalities followed by RT012. However, in the laboratory and most of the on-road tests, PN ECFs were systematically lower than 1 for all vehicles.
- The vehicle equipped with a GPF (VW040, Euro 6b) consistently showed good performance on all testing conditions with emissions two order of magnitudes lower than the applicable limit for Euro 6b (ECF = 0.0).
- On one of the dynamic road tests (ESD), RT012 emitted twice as much PN that on the corresponding ESP test driven in normal conditions.

— On the non-RDE compliant tests, Euro 6b and Euro 6d-TEMP PFIs ranged 2e12 #/km to 7e12 #/km and 8e11 #/km to 1e12 #/km, respectively which are PN emissions mostly above the NTE limits applicable for diesel and GDI vehicles. The Euro 6d-TEMP PFI emitted on average 1e12 #/km on the urban section of the RDE compliant tests.

— With the exception of MB010, all diesel Euro 6b and Euro 6c vehicles had PN ECFs < 0.4 on all test modalities, which proves a good performance of DPFs. MB010 consistently emitted more PN than any other diesel vehicle both in laboratory and on-road conditions. The maximum PN ECF (1.8) corresponded to the urban section of the VIR RDE compliant test. For this particular test, the vehicle would not have met the PN NTE limit in force for Euro 6d-TEMP vehicles (1e12 #/km when the limit is 9e11 #/km).

— All Euro 6d-TEMP diesel vehicles had PN ECFs < 0.1 on all test modalities. The maximum PN emission (9e10 #/km on the urban section of SMB test) is one order of magnitude lower than the RDE NTE limit.

— The LPG vehicle ranged PN emissions from 3e10 #/km to 4e11 #/km in the laboratory and on the road with PN ECF systematically ≤ 0.1.

— The PHEV (HI002, GDI), that was tested on several non-RDE compliant routes exceeded the NTE limit applicable for Euro 6d-TEMP GDIs on the prolonged motorway test (MIL 9.6e11 #/km) and on the dynamic driven test (ESD 9.7e11 #/km), both driven in charge depleting operation (share of electric drive: 50% and 65% on MIL and ESD, respectively).

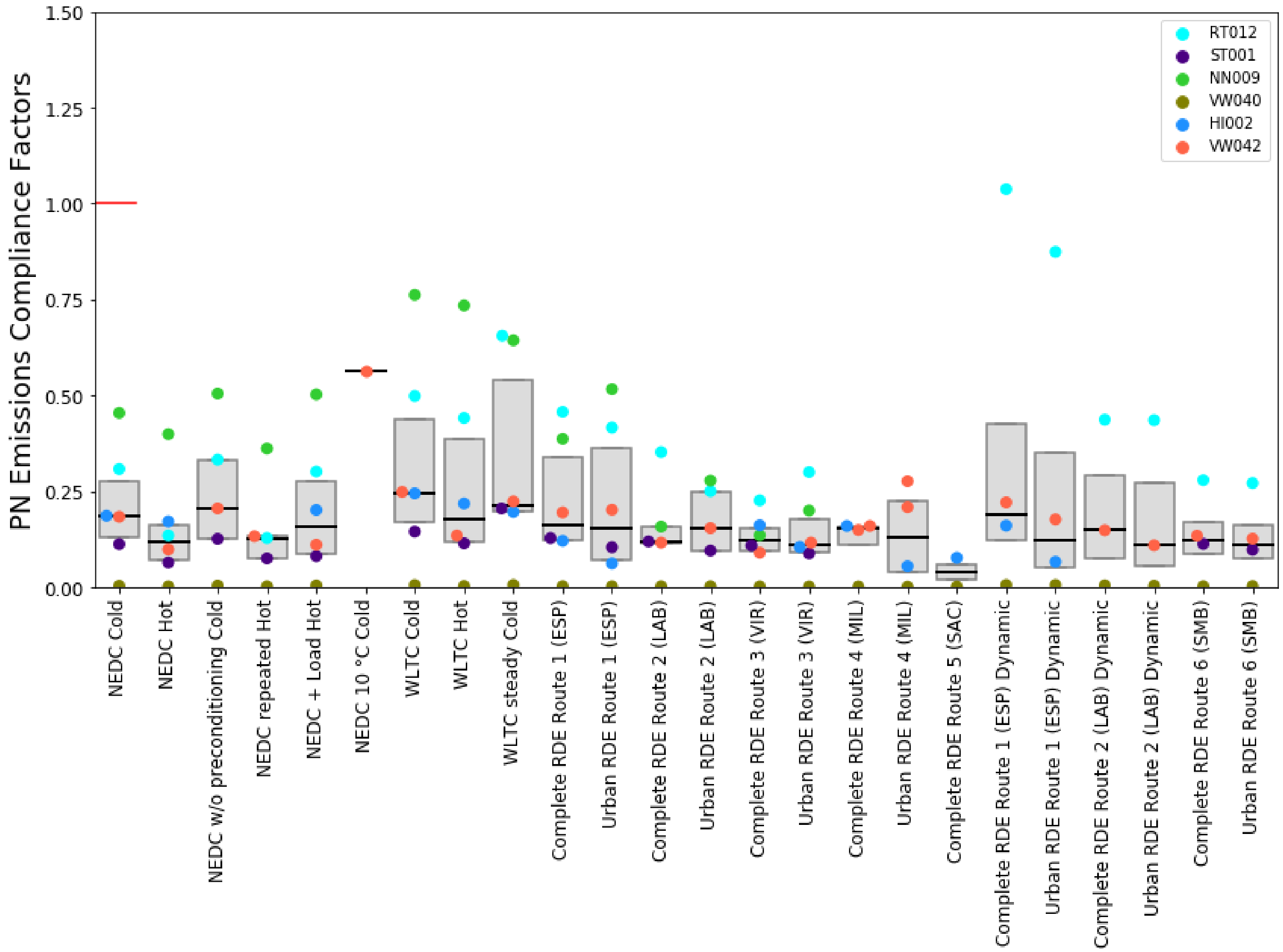

Figure 32: PN Emissions Compliance Factors for Euro 6b and Euro 6c gasoline vehicles over the laboratory and on-road tests. The horizontal red line corresponds to the Type 1 test applicable limit for gasoline Euro 6b vehicles (6e12 #/km). NB Emissions Compliance Factors were calculated assuming PN limit of 6e12 #/km for all the gasoline vehicles. Gasoline-PFI vehicles, for which no PN limit exists, are not represented.

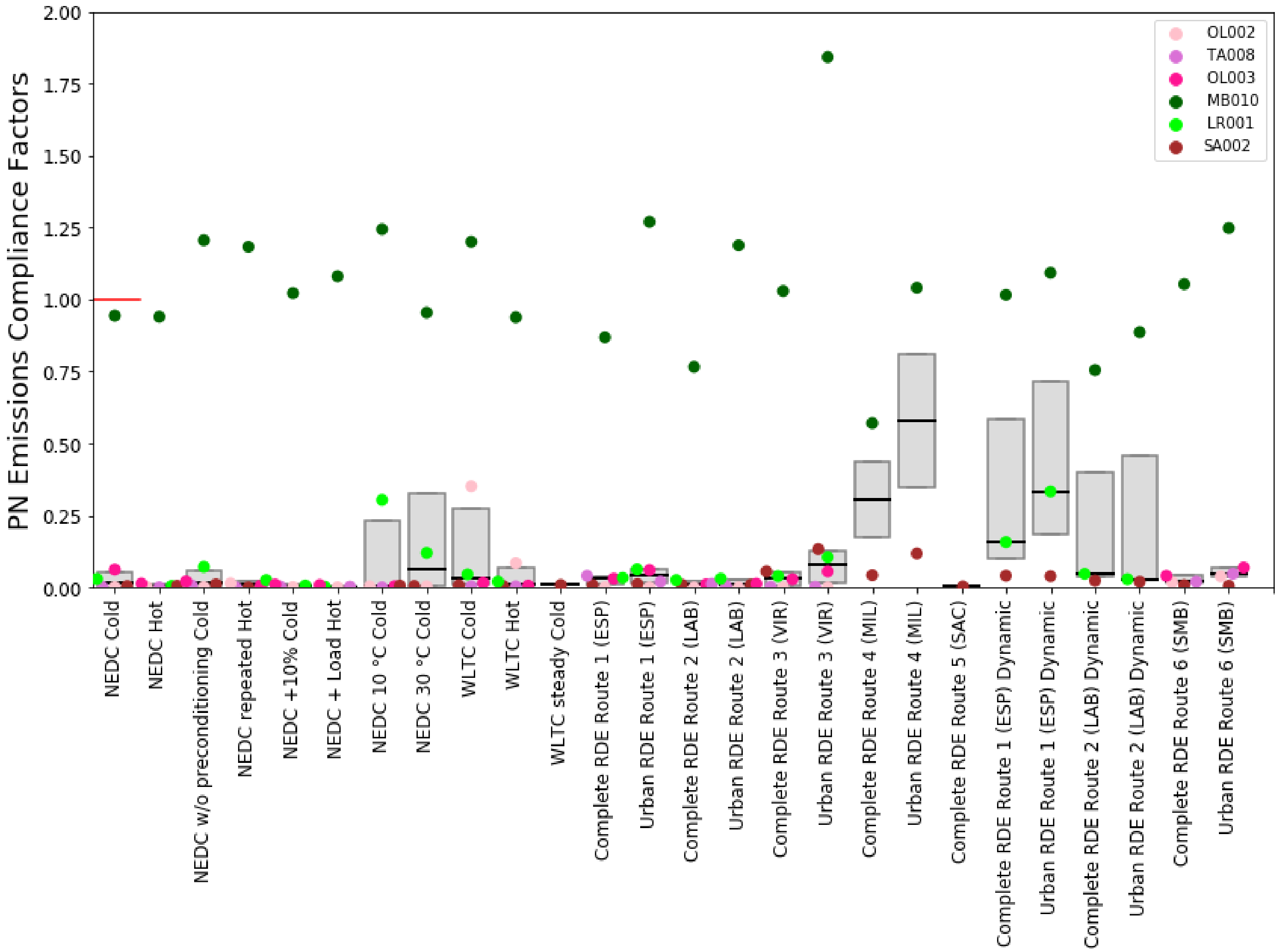

Figure 33: PN Emissions Compliance Factors for Euro 6b and Euro 6c diesel vehicles over the laboratory and on-road tests. The horizontal red line corresponds to the Type 1 test applicable limit for diesel vehicles (6e11 #/km).

Table 24: PN Emissions Compliance Factors of the tested Euro 6b and Euro 6c vehicles. For vehicle HI002, laboratory emissions correspond to tests in charge sustaining operation, whereas on the road two charge sustaining tests and one charge depleting test were considered. For Euro 6b Gasoline GDI vehicles PN Emissions Compliance Factors were calculated assuming a PN limit of 6e12 #/km. NB there is no PN limit applicable to gasoline PFI engines. In bold, PN ECF > 1. "NA" stands for "not available". The "SHS" modality corresponds to the test in which phases 3 and 4 are driven at steady speed (110 km/h and 130 km/h, respectively).

Id.	Euro	Fuel	NEDC Cold	NEDC Hot	WLTC Cold	WLTC Hot	RDE Compliant (Min-Max)	RDE non-compliant (Min-Max)	NEDC w/o preconditioning Cold	NEDC Repeated Hot	NEDC +10% Speed Cold	NEDC with engine loads Hot	NEDC at +10°C Cold	NEDC at +30°C Cold	SHS Cold
	Category		-	2	2	2	3	3	2	2	2	2	2	2	2
	Recommended Threshold		1	-	-	-	-	-	-	-	-	-	-	-	-
LA002	6b	Gasoline PFI	-	-	-	-	-	-	-	-	-	-	-		
VW040	6b	Gasoline GDI	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1			<0.1
RT012	6b	Gasoline GDI	0.3	0.1	0.5	0.4	0.2-0.5	0.3-**1.0**	0.3	0.1		0.3			0.7
NN009	6b	Gasoline GDI	0.5	0.4	0.8	0.7	0.1-0.4	NA	0.5	0.4		0.5			0.6
ST001	6b	Gasoline GDI	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1			0.2
FT060	6b	Gasoline PFI	-	-	-	-	-	-	-	-	-	-			
FT060	6b	LPG	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1			
HI002	6b	Hybrid Gasoline – GDI/Electric	0.2	0.2	0.2	0.2	0.1-0.2	0.1-0.2				0.2			0.2
MB010	6b	Diesel	0.9	0.9	**1.2**	0.9	0.8-**1.0**	0.6-**1.1**	**1.2**	**1.2**	**1.0**	**1.1**	**1.2**	1.0	
LR001	6b	Diesel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1-0.2	0.1	<0.1	<0.1	<0.1	0.3	0.1	
OL002	6b	Diesel	<0.1	<0.1	0.4	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
TA008	6b	Diesel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
OL003	6b	Diesel	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
FT061	6b	CNG	-	-	-	-	-		-	-		-			-
VW042	6c	Gasoline	0.2	0.1	0.2	0.1	0.1-0.2	0.1-0.2	0.2	0.1		0.1	0.6		0.2
SA002	6c	Diesel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	NA	NA	<0.1	<0.1	<0.1

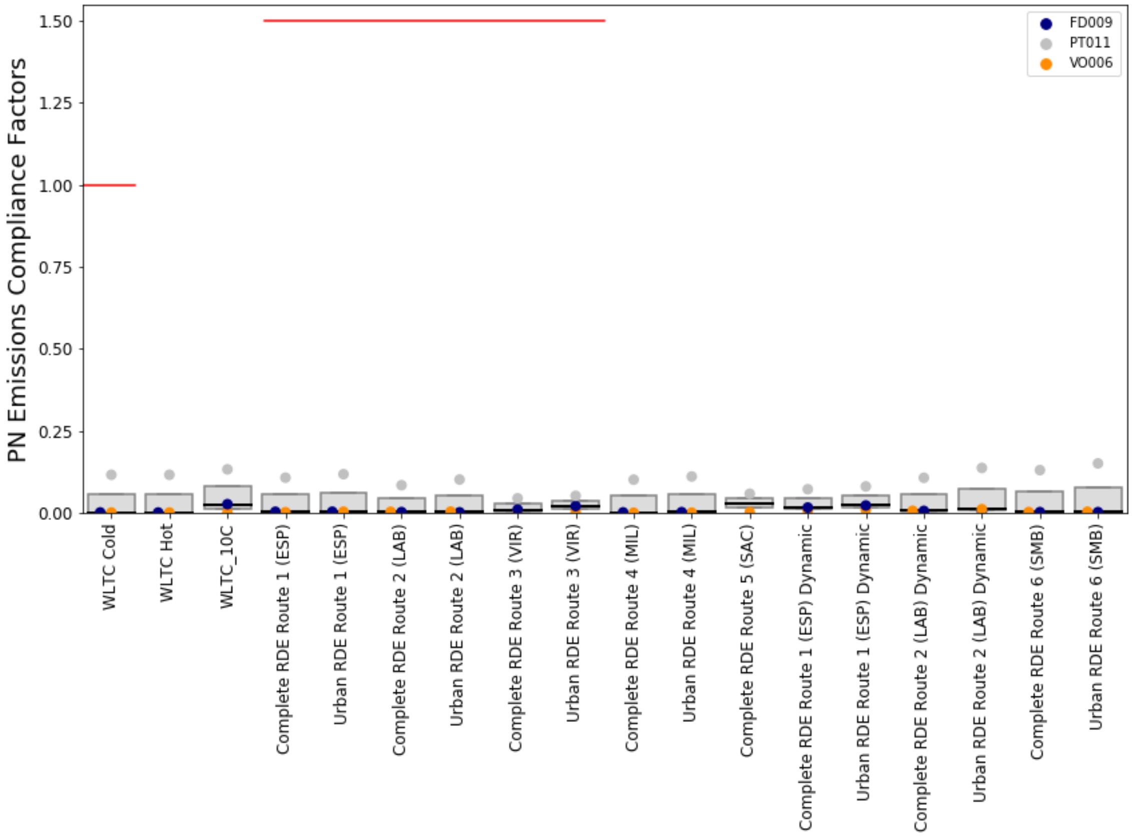

Figure 34: PN Emissions Compliance Factors for Euro 6d-TEMP diesel vehicles over the laboratory and on-road tests. The horizontal red line corresponds to the Type 1 test applicable limit for diesel vehicles (6e11 #/km).

Table 25: PN Emissions Compliance Factors of the tested Euro 6d-TEMP vehicles. NB there is no PN limit applicable to gasoline PFI engines. In bold, PN ECF > 1. “NA” stands for “not available”. The “Modified WLTP” modality corresponds to WLTP test performed at 10 °C.

Id.	**Euro**	**Fuel**	**WLTC Cold**	**WLTC Hot**	**RDE Compliant (Min-Max)**	**RDE non-compliant (Min-Max)**	**Modified WLTP**
	Category		-	-	-	-	-
	Recommended Threshold		1	-	-	-	-
SI001	6d-TEMP	Gasoline PFI	-	-	-	-	-
VO006	6d-TEMP	Diesel	<0.1	<0.1	<0.1	<0.1	<0.1[20]
FD009	6d-TEMP	Diesel	<0.1	<0.1	<0.1	<0.1	<0.1[20]
PT011	6d-TEMP	Diesel	0.1	0.1	<0.1-0.1	0.1-0.1	0.1[20]

(20) WLTP at 10 °C ambient temperature

6 Conclusions

6.1 Regulatory requirements, technology trends and their impact on real pollutant emission

The vehicles tested during the program (primarily Euro 6b and some Euro 6c and Euro 6d-TEMP light-duty vehicles) fulfilled the limits on the applicable certification conditions (Type 1 test (cold NEDC or WLTP) and Type 1a (RDE, when applicable) for all regulated pollutants (except one vehicle for NOx), confirming the idea that the vehicles were correctly functioning.

No exceedance of the NOx threshold was observed on any of the gasoline vehicles on any of the test modalities performed in the laboratory and on the road, which shows that gasolines vehicles tend to manage properly their NOx emissions. However, one Euro 6b vehicle (NN009, GDI) was found to emit higher NOx as compared to other equivalent gasoline vehicles in specific laboratory and on-road tests, particularly under high load operation (NN009: 63 and 101 mg/km of NOx on WLTP Cold and RDE complete, respectively).

Among diesel Euro 6b vehicles, OL002, OL003 and TA008 showed NOx emissions above the recommended thresholds of the Guidance on laboratory (170, 169, and 252 mg/km of NOx over WLTP Cold test) or on-road tests (216, 516, and 413 mg/km of NOx over RDE Complete) proving a poor operation of their after-treatment systems or the use of an AES.

When compared to the previous generations (Euro 5 or 6b), Euro 6d-TEMP diesel vehicles showed a different performance on the road. The vehicle equipped with an LNT only (FD009) was found to have NOx emissions close to the NTE (maximum emission on an RDE compliant test: 144 mg/km of NOx) and it is believed that this vehicle could not meet the limit under demanding RDE conditions (close to the RDE boundaries). Since the vehicle was type-approved in 2018, it is exempted from ISC procedure and therefore emissions on the road were just challenged during the type-approval procedure. The other two diesel Euro 6d-TEMP vehicles, operating an SCR proved to have low NOx emissions in real life conditions.

The CNG vehicle (FT061) exceeded the 1.5 threshold defined in the Guidance on most of the laboratory modalities and on the urban section of RDE tests.

The aggregation of the 2017 and 2018 data (presented in section 3.6) shows the first trend of emissions and for the various stages of the Euro 6 standard (6b, 6c and 6d-TEMP) and for the main technologies present on the market. The main and positive outcome (though preliminary as it is based on a limited number) is the significant reduction of NOx emissions for the Euro 6d-TEMP diesel vehicles under RDE conditions.

Diesel vehicles of all Euro 6 stages coped well with CO and PN emissions in all test modalities and on-road routes proving a good operation of the DOC and the DPF. However, certain gasoline vehicles perform poorly for what regards CO in high load operation reaching emission values of several grams per kilometre. Gasoline vehicles emit one order of magnitude more PN than diesel vehicles equipped with a DPF. From the results of the sole GDI that mounted a GPF in the tested fleet, the use of particle filter for gasoline vehicles looks promising to properly abate PN emissions in real-life operation.

The PN emission of the PHEV (HI002) was high (ranging from 4e11 #/km to 1e12 #km) when tested in charge sustaining and charge depleting operation. It is noteworthy that PN emissions are close to the PN NTE limit even if the test is driven with the electric motor for more than 70% of the distance.

6.2 Methods to support the EU authorities conducting AES investigations

The "current methodology" [7] developed during the European national investigations (launched after the diesel gate and largely focusing on Euro 5 and 6b diesel vehicles) was still applied during this project. It was primarily designed to deal with AESs affecting NOx emissions on diesel vehicles. It resulted as insufficient to address other emissions and technologies where AESs might be found under very specific and short operating conditions (e.g. accelerations).

Some new approaches and conditions were proposed and applied to the CO emissions. They were successful in identifying vehicles whose behaviour deviate from the majority of vehicles with the same emissions standard and technologies.

These approaches should pave the way for a revision of the methodology in the Guidance and the following elements shall be considered and could be developed specifically per technology/pollutant/emissions standard combination:

— Test and operating situations under which AESs are likely to be activated;

— Establishment of a benchmark for emissions performance of the vehicles within these operating situations and - in a more general way - proposal for "emissions signatures" of properly functioning vehicles;

— Development of absolute or relative thresholds for the identification of AES activations and/or anomalous emissions behaviours. Instead of comparing the emissions of a vehicle during a given test against a fixed threshold, compare its emissions against the signature of correctly functioning vehicles within the same bin (same Euro standard, powertrain, after-treatment system, and test type).

References

[1] M. Clairotte, V. Valverde, P. Bonnel, B. Giechaskiel, M. Carriero, M. Otura, G. Fontaras, J. Pavlovic, G. Martini, A. Krasenbrink, R. Suarez-Bertoa, Joint Research Centre, 2017 Light-Duty Vehicles Emissions Testing; Publications Office of the European Union: Luxembourg, (2018). doi: 10.2760/83327

[2] Commission Regulation (EU) 2018/1832 of 5 November 2018 amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) 2017/1151 for the purpose of improving the emission type-approval tests and procedures for light passenger and commercial vehicles, including those for in-service conformity and real-driving emissions and introducing devices for monitoring the consumption of fuel and electric energy. Off. J. Eur. Union. OJ L 301 (2018) 1–314.

[3] 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. Off. J. Eur. Union. OJ L 151 (2018) 1–218.

[4] EC, 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 CO2 emissions from light-duty vehicles, Off. J. Eur. Union. OJ L 140 (2009) 1–15.

[5] EEA, Monitoring of CO2 emissions from passenger cars - Data 2017 - Provisional data, (2018). https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-14#tab-european-data.

[6] ACEA, Year 2017 Consolidated Registrations in Western Europe – by Manufacturer, (2018). http://www.acea.be/statistics/article/consolidated-registrations-by-manufacturer.

[7] Commission Notice of 26.1.2017. Guidance on the evaluation of Auxiliary Emission Strategies and the presence of Defeat Devices with regard to the application of Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6). C(2017) 352 final 1-18.

[8] Regulation No 83 of the Economic Commission for Europe of the United Nations (UN/ECE) – Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements. Off. J. Eur. Union. OJ L 375 (2006) 223–495.

[9] 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. Off. J. Eur. Union. OJ L 175 (2017) 1–643.

[10] Commission Regulation (EU) 2016/427 of 10 March 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6). Off. J. Eur. Union. OJ L 82 (2016) 1–98.

[11] M. Contag, G. Li, A. Pawlowski, F. Domke, K. Levchenko, T. Holz, S. Savage, How They Did It: An Analysis of Emission Defeat Devices in Modern Automobiles, in: IEEE, 2017: pp. 231–250. doi:10.1109/SP.2017.66.

[12] Y. Bernard, J. German, A. Kentroti, R. Muncrief, Catching defeat devices. How systematic vehicle testing can determine the presence of suspicious emissions control strategies. International Council on Clean Transportation White paper, 2019. https://theicct.org/sites/default/files/publications/ICCT_catching_defeat_devices_20190710.pdf

[13] MV. Prati, MA. Costagliola, A. Zuccheroso, P. Napolitano, Assessment of Euro 5 diesel vehicle NOx emissions by laboratory and track testing, Environ Sci Pollut Res 26 (2019) 10576. doi: 10.1007/s11356-019-04486-7.

[14] V. Valverde, P. Bonnel, On-road testing with Portable Emissions Measurement Systems (PEMS) - Guidance note for light-duty vehicles, EUR 29029 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-77345-7, doi:10.2760/08294, JRC109812

[15] S. Tsiakmakis, G. Fontaras, B. Ciuffo, Z. Samaras, A simulation-based methodology for quantifying European passenger car fleet CO2 emissions, Appl. Energy. 199 (2017) 447–465. doi:10.1016/j.apenergy.2017.04.045.

[16] V. Valverde, B. Giechaskiel, JRC 2018 PEMS margin review. Outlook of experimental campaigns, 2019. https://circabc.europa.eu/ui/group/f4243c55-615c-4b70-a4c8-1254b5eebf61/library/9af94e94-21c1-4679-a3c4-8923871c1346/details

[17] B. Giechaskiel, M. Clairotte, V. Valverde, P. Bonnel, Z. Kregar, V. Franco, P. Dilara, Framework for the assessment of PEMS (Portable Emissions Measurement Systems) uncertainty, 166 (2018) 251-260. doi: 10.1016/j.envres.2018.06.012.

[18] Commission Regulation (EU) 2017/1154 of 7 June 2017 amending Regulation (EU) 2017/1151 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 Regulation (EC) No 692/2008 and Directive 2007/46/EC of the European Parliament and of the Council as regards real-driving emissions from light passenger and commercial vehicles (Euro 6) Off. J. Eur. Union. OJ L 175 (2017) 708–732.

[19] R. Suarez-Bertoa, T. Lähde, J. Pavlovic, V. Valverde, M Clairotte, B. Giechaskiel, Laboratory and On-road Evaluation of a GPF-equipped Gasoline Vehicle, 9 (2019), 678. doi: 10.3390/catal9080678

[20] ACEA, Access to Euro 6 RDE data, (2017). http://www.acea.be/publications/article/access-to-euro-6-rde-monitoring-data (accessed July 11, 2019).

[21] JAMA, Access to Euro 6 RDE data, (2018). http://www.jama-english.jp/europe/publications/rde.html (accessed July 11, 2019).

[22] R. Williams, J. Andersson, H. Hamje, P. Ziman, et al., Impact of Demanding Low Temperature Urban Operation on the Real Driving Emissions Performance of Three European Diesel Passenger Cars, SAE Technical Paper 2018-01-1819 (2018) doi: 10.4271/2018-01-1819.

[23] V. Valverde, B. Adria-Mora, M. Clairotte, J. Pavlovic, et al., Emission Factors Derived from 13 Euro 6b Light-Duty Vehicles Based on Laboratory and On-Road Measurements, atmosphere 10(5), (2019) 243. doi: 10.3390/atmos10050243

[24] B. Giechaskiel, A. Joshi, L. Ntziachristos, P. Dilara, European Regulatory Framework and Particulate Matter Emissions of Gasoline Light-Duty Vehicles: A Review, catalysts, 9 (2019), 586. doi: 10.3390/catal9070586.

[25] Z. Yang, Y. Ge, D. Thomas, X. Wang, S. Su, H Li, H. He, Real driving particle number (PN) emissions from China-6 compliant PFI and GDI hybrid electrical vehicles, Atmos. Env. 199 (2019) 70-79. doi: 10.1016/j.atmosenv.2018.11.037.

[26] J. Pavlovic, B. Ciuffo, G. Fontaras, V. Valverde, A. Marotta, How much difference in type-approval CO_2 emissions from passenger cars in Europe can be expected from changing to the new test procedure (NEDC vs. WLTP)?, Transp. Res. Part Policy Pract. 111 (2018) 136–147. doi:10.1016/j.tra.2018.02.002.

[27] G. Fontaras, N.-G. Zacharof, B. Ciuffo, Fuel consumption and CO_2 emissions from passenger cars in Europe – Laboratory versus real-world emissions, Prog. Energy Combust. Sci. 60 (2017) 97–131. doi:10.1016/j.pecs.2016.12.004.

List of abbreviations and acronyms

AC	Air conditioning
AES	Auxiliary Emission Strategy
BES	Base Emission Strategy
CD	Charge depleting
CoC	Certificate of Conformity
CoP	Conformity of Production
CS	Charge sustaining
CVS	Constant Volume Sampler
ECF	Emission Compliance Factor
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
DR	Deviation Ratio
ECE	Economic Commission for Europe
ECS	Emissions Control Systems
ECU	Engine Control Unit
EGR	Exhaust Gas Recirculation
EUDC	Extra-Urban Driving Cycle
GDI	Gasoline Direct Injection
GPF	Gasoline Particulate Filter
ISC	In-service conformity
IQR	Inter-Quartile Range
JRC	Joint Research Centre
LNT	Lean NOx Trap
MAW	Moving Average Window
NEDC	New European Driving Cycle
NOVC-HEV	Not off-vehicle charging hybrid electric vehicle
OEM	Original Equipment Manufacturer
OVC-HEV	Off-vehicle charging hybrid electric vehicle
PEMS	Portable Emissions Measurement Systems
PFI	Port Fuel Injection
RDE	Real-Driving Emissions
RL	Road Load
RT	Recommended Threshold
SCR	Selective Catalytic Reduction
SOC	State of Charge
WLTC	Worldwide harmonised Light vehicles Test Cycle
WLTP	Worldwide harmonised Light vehicles Test Procedure

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Annexes

Annex 1. Testing conditions for AES detection on in-service vehicles

Application of the European testing protocol: JRC test settings

Document version: 10/08/2016

A. Vehicle preparation

In preparation for future JRC in-service conformity testing, the criteria for vehicle selection defined in Appendix 1 of EU regulation 2018/1832 have been applied to all vehicles reported. The vehicle preparation activity records a set of items that support that tested vehicles were properly maintained and used prior to the emissions testing. In particular the following elements were checked/ information was gathered.

- Recording mileage;
- Recording vehicle data;
- Recording inspection and maintenance information (if any);
- Visual inspection for rebuilds, modifications and leaks of the exhaust and after-treatment system;
- Checking for OBD faults (Scan tool);
- Checking for tyres damage;
- Checking for any anomaly which might affect the emissions performance;
- Adaption of tailpipe to use an exhaust mass flowmeter for PEMS installation and for connection to CVS.

B. Laboratory Tests Settings

Variations of the test settings were also applied changing the driving cycle (WLTP instead of NEDC) and/or the road load settings.

Standard NEDC According to ECE R83

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values
Vehicle pre-conditioning	• EUDC • Soak of min. 6 hours between 20 and 30°C
Driving cycle	• NEDC
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

NEDC Hot Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values
Vehicle pre-conditioning	• None, check coolant and oil temperatures
Driving cycle	• NEDC
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

NEDC @ 10°C - Cold Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values
Vehicle pre-conditioning	• EUDC • Soak of min. 6 hours between 20 and 30°C
Driving cycle	• NEDC
Test temperature	• 10°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

NEDC @ 30°C - Cold Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values
Vehicle pre-conditioning	• EUDC • Soak of min. 6 hours between 20 and 30°C
Driving cycle	• NEDC
Test temperature	• 30°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

NEDC with speeds +10% - Cold Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values
Vehicle pre-conditioning	• EUDC • Soak of min. 6 hours between 20 and 30°C
Driving cycle	• Modified NEDC, speeds +10%
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

NEDC with engine loads – Hot Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values
Vehicle pre-conditioning	• None, check coolant and oil temperatures
Driving cycle	• NEDC
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal
Engine loads	• Air conditioning and lights on

NEDC without preconditioning – Cold vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values
Vehicle pre-conditioning	• Soak of min. 4 hours
Driving cycle	• NEDC
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

NEDC repeated – Hot Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values
Vehicle pre-conditioning	• None, cycle driven back to back with a Cold NEDC cycle without switching off the engine in between the cycles
Driving cycle	• NEDC
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

WLTP Cold Vehicle according to EU Regulation 2017/1151

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values / CoC values for Euro 6d-TEMP
Vehicle pre-conditioning	• Battery charge • WLTC • Soak of min. 6 hours between 20 and 30°C without battery charge
Driving cycle	• WLTC
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

WLTP Hot Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values / CoC values for Euro 6d-TEMP
Vehicle pre-conditioning	• None, check coolant and oil temperatures
Driving cycle	• WLTC
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

SHS Cycle - Cold Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values / CoC values for Euro 6d-TEMP
Vehicle pre-conditioning	• Battery charge • WLTC • Soak of min. 6 hours between 20 and 30°C without battery charge
Driving cycle	• WLTC phases 1 and 2 • Then for the duration of phase 3, accelerate from 0 to 110 km/h and drive steady 110 km/h • Then for the duration of phase 4, accelerate from 0 to 130 km/h and drive steady 130 km/h
Test temperature	• 22 to 24°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

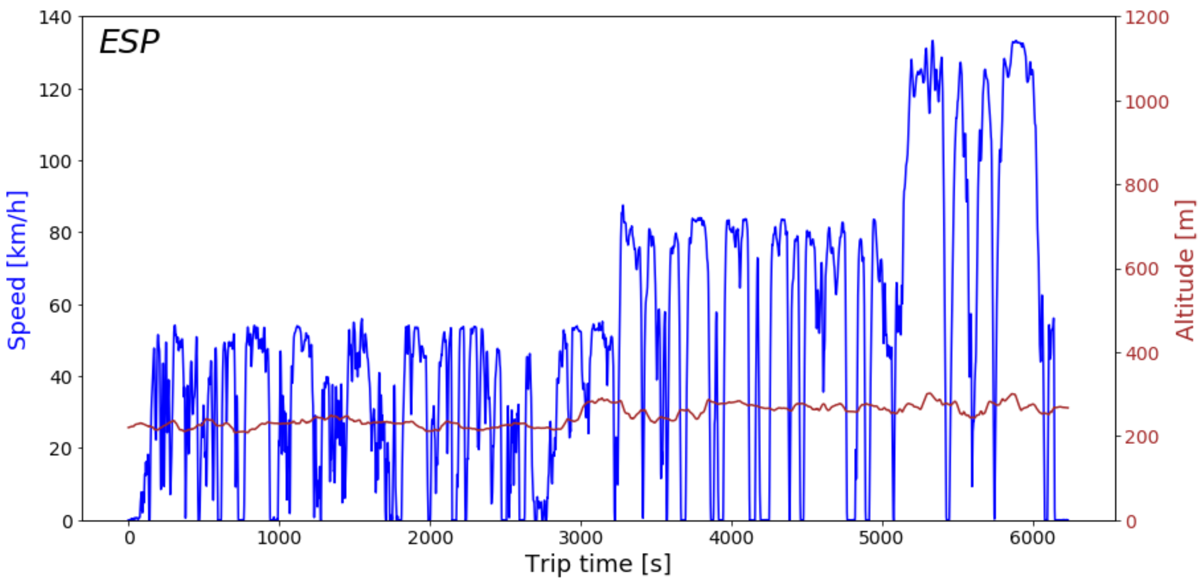
WLTP @ 10°C - Cold Vehicle

Type	• Chassis dynamometer 2WD mode
Fuel	• Market
Road Load	• calculated values / CoC values for Euro 6d-TEMP
Vehicle pre-conditioning	• Battery charge • WLTC • Soak of min. 6 hours between 20 and 30°C without battery charge
Driving cycle	• WLTC
Test temperature	• 10°C
Emissions measurement	• Gaseous emissions, PN • CVS (bags) and modal

C. On-Road Tests

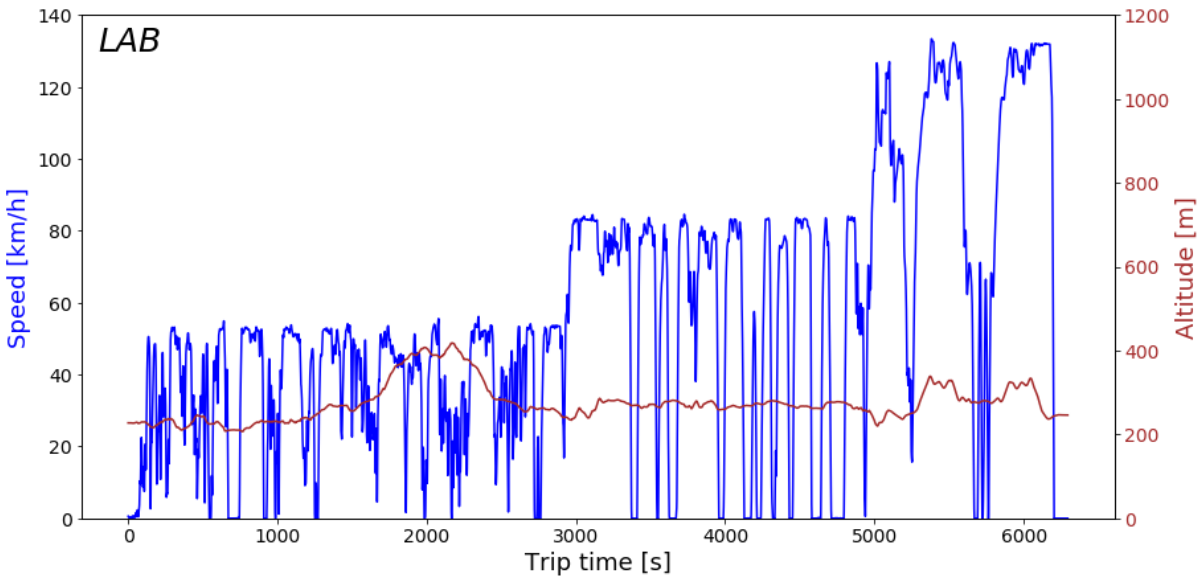
RDE Route # 1 –ESP

Type	• On-road
Fuel	• Market
Vehicle pre-conditioning	• 30 minute drive + overnight soak • For 2nd to last RDE test, the RDE test of the previous day is used as pre-conditioning
Driving cycle	• JRC RDE route #1 - ESP
Test temperature	• Depending on day/time, measured
Emissions measurement	• Gaseous and solid particle number emissions • PEMS
Data evaluation	• As defined in RDE regulation fulfilling al requirements up to RDE4 package. Calculations done with EMROAD v6.02
Total Distance [km]	• Ca. 79
Urban Rural Motorway Distance Shares [%]	• 40.5 – 32.5 – 27
Average speed [km/h]	• 49.0
Average urban speed [km/h]	• 29.3
Average urban stop time [%]	• 18.8
Cumulative altitude gain [m/100km] for complete trip and urban section	• 610 / 655



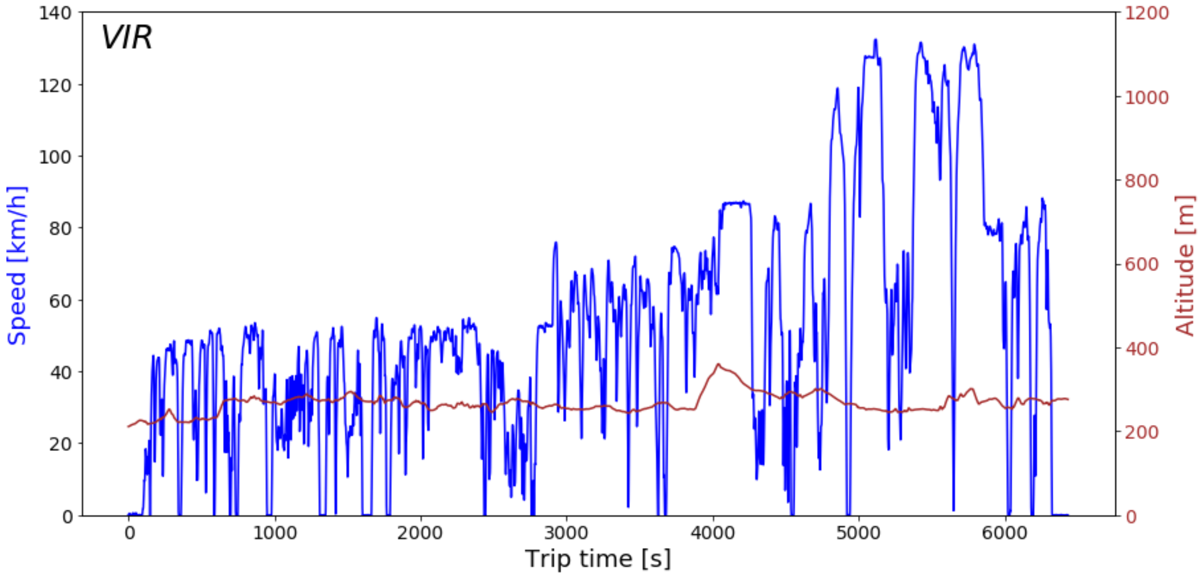
RDE Route # 2 –LAB

Type	•	On-road
Fuel	•	Market
Vehicle pre-conditioning	• •	30 minute drive + overnight soak For 2nd to last RDE test, the RDE test of the previous day is used as pre-conditioning
Driving cycle	•	JRC RDE route #2 - LAB
Test temperature	•	Depending on day/time, measured
Emissions measurement	• •	Gaseous and solid particle number emissions PEMS
Data evaluation	•	As defined in RDE regulation fulfilling al requirements up to RDE4 package. Calculations done with EMROAD v6.02
Total Distance [km]	•	Ca. 94
Urban Rural Motorway Distance Shares [%]	•	38.6 – 28.2 – 33.2
Average speed [km/h]	•	52.4
Average urban speed [km/h]	•	30.5
Average urban stop time [%]	•	16.9
Cumulative altitude gain [m/100km] for complete trip and urban section	•	719 / 832



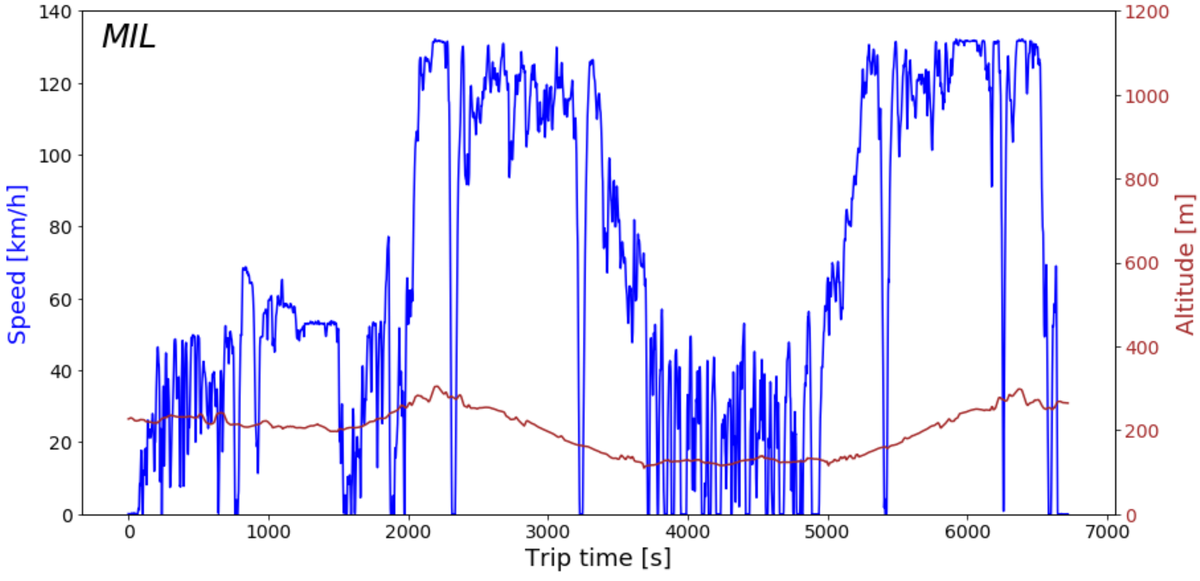
RDE Route # 3 –VIR

Type	•	On-road
Fuel	•	Market
Vehicle pre-conditioning	•	30 minute drive + overnight soak
	•	For 2nd to last RDE test, the RDE test of the previous day is used as pre-conditioning
Driving cycle	•	JRC RDE route #3 – VIR
Test temperature	•	Depending on day/time, measured
Emissions measurement	•	Gaseous and solid particle number emissions
	•	PEMS
Data evaluation	•	As defined in RDE regulation fulfilling al requirements up to RDE4 package. Calculations done with EMROAD v6.02
Total Distance [km]	•	Ca. 104
Urban Rural Motorway Distance Shares [%]	•	38.7 – 27.9 – 33.4
Average speed [km/h]	•	55.5
Average urban speed [km/h]	•	34.2
Average urban stop time [%]	•	9.0
Cumulative altitude gain [m/100km] for complete trip and urban section	•	516 / 727



RDE Route # 4 – MIL

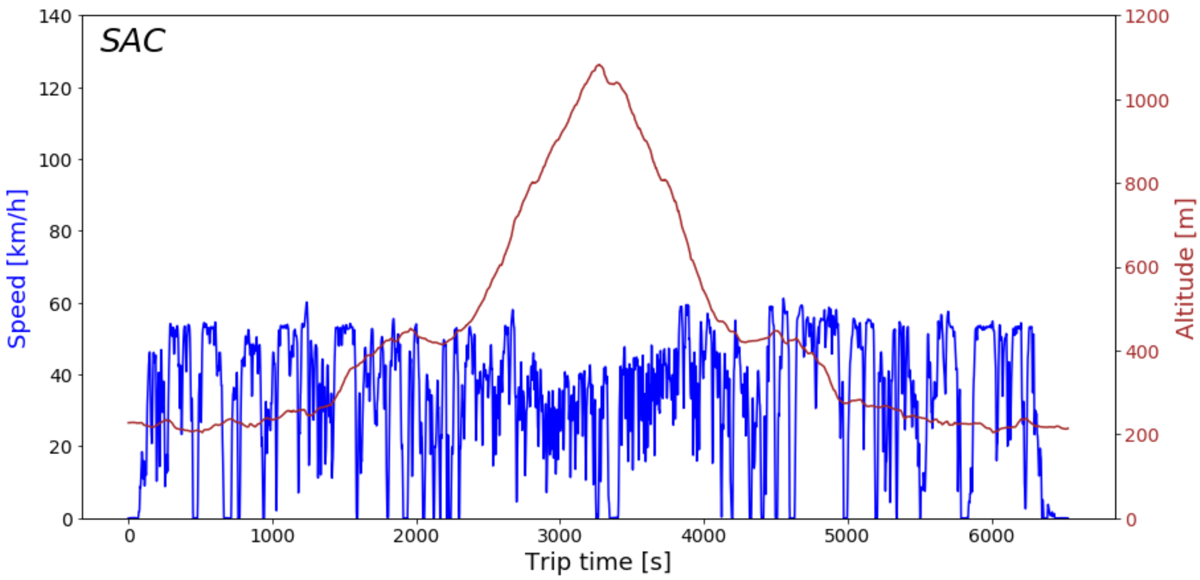
Type	• On-road
Fuel	• Market
Vehicle pre-conditioning	• None
Driving cycle	• JRC RDE route #4 – MIL
Test temperature	• Depending on day/time, measured
Emissions measurement	• Gaseous and solid particle number emissions • PEMS
Data evaluation	• As defined in RDE regulation fulfilling al requirements up to RDE4 package. Calculations done with EMROAD v6.02
Total Distance [km]	• Ca. 140
Urban Rural Motorway Distance Shares [%]	• 31.4 – 11.9 – 56.7
Average speed [km/h]	• 61.2
Average urban speed [km/h]	• 32.2
Average urban stop time [%]	• 14.3
Cumulative altitude gain [m/100km] for complete trip and urban section	• 371 / 443



RDE Route # 5 – SAC

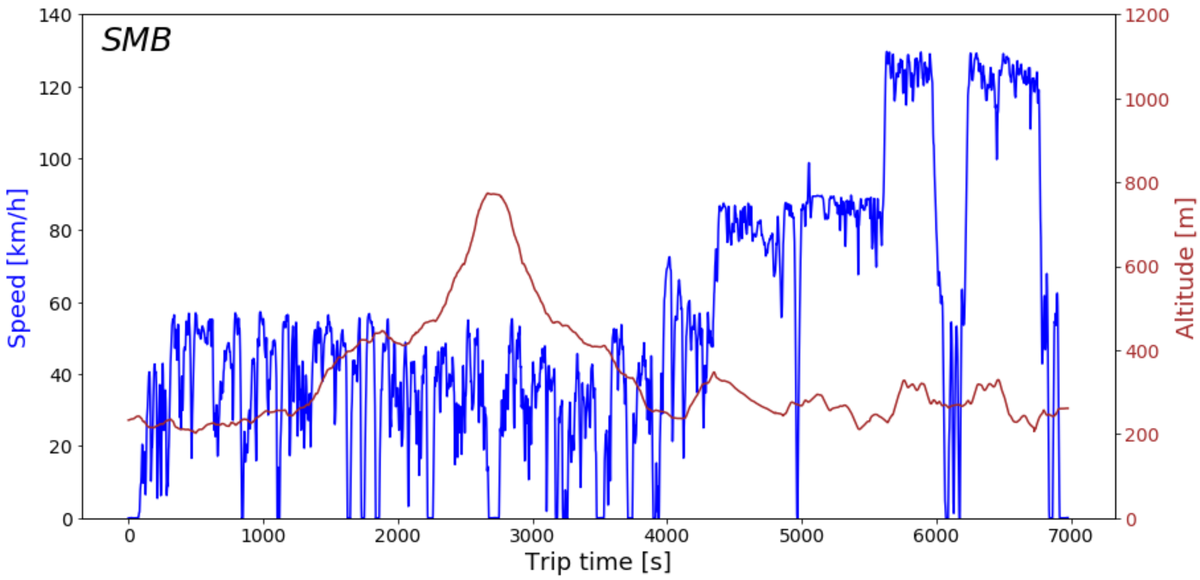
Type	•	On-road
Fuel	•	Market
Vehicle pre-conditioning	•	None
Driving cycle	•	JRC RDE route #5 – SAC
Test temperature	•	Depending on day/time, measured
Emissions measurement	• •	Gaseous and solid particle number emissions PEMS
Data evaluation	•	As defined in RDE regulation fulfilling al requirements up to RDE4 package. Calculations done with EMROAD v6.02

Total Distance [km]	•	Ca. 62
Urban Rural Motorway Distance Shares [%]	•	99.2 – 0.8 – 0
Average speed [km/h]	•	34.0
Average urban speed [km/h]	•	33.9
Average urban stop time [%]	•	7.2
Cumulative altitude gain [m/100km] for complete trip and urban section	•	1663 / 1673



RDE Route # 6 –SMB

Type	•	On-road
Fuel	•	Market
Vehicle pre-conditioning	•	None
Driving cycle	•	JRC RDE route #6 – SMB
Test temperature	•	Depending on day/time, measured
Emissions measurement	• •	Gaseous and solid particle number emissions PEMS
Data evaluation	•	As defined in RDE regulation fulfilling al requirements up to RDE4 package. Calculations done with EMROAD v6.02
Total Distance [km]	•	Ca. 104
Urban Rural Motorway Distance Shares [%]	•	39.8 – 30.2 – 30.0
Average speed [km/h]	•	34.1
Average urban speed [km/h]	•	55.7
Average urban stop time [%]	•	8.8
Cumulative altitude gain [m/100km] for complete trip and urban section	•	1041 / 1664



Annex 2. Vehicle characteristics

A. Vehicle LA002

Table 26: Vehicle LA002 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and $N/(km/h)^2$ respectively.

Vehicle OEM:	Lancia
Vehicle Model:	Ypsilon
Vehicle Class:	M1
Vehicle Code:	LA002
Fuel Type:	Gasoline
Injection Type:	Port Fuel Injection
Emissions Control Technologies:	TWC
Model Year:	2016
Vehicle Identification Number:	ZLA31200005283492
Homologation Number	e3*2007/46*0064*25
Emissions Standard:	Euro 6b
Odometer Reading:	14292
Transmission Type:	Automatic
Number of Gears:	5
Engine Capacity in cm^3:	875
Rated Power in kW:	62.5
Tyre Dimensions:	185/55/R15
RL coefficients NEDC:	Inertia: 1023, F0: 68.9, F1: 0.63, F2: 0.03
RL coefficients WLTP:	Inertia: 1200, F0: 105.2, F1: 0.34, F2: 0.032
Declared CO_2 value in g/km:	97

Figure 35: Vehicle LA002

B. Vehicle VW040

Table 27: Vehicle VW040 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	VW
Vehicle Model:	Tiguan
Vehicle Class:	M1
Vehicle Code:	VW040
Fuel Type:	Gasoline
Injection Type:	Gasoline Direct Injection
Emissions Control Technologies:	TWC + GPF
Model Year:	2018
Vehicle Identification Number:	WVGZZZ5NZJW382779
Homologation Number	e1*2001/116*0450*33
Emissions Standard:	Euro 6b
Odometer Reading:	4477
Transmission Type:	Manual
Number of Gears:	6
Engine Capacity in cm^3:	1395
Rated Power in kW:	110
Tyre Dimensions:	215/65/R17
RL coefficients NEDC:	Inertia: 1470, F0: 96.6, F1: -0.08, F2: 0.041
RL coefficients WLTP:	Inertia: 1678, F0: 148.3, F1: -0.08, F2: 0.044
Declared CO2 value in g/km:	132

Figure 36: Vehicle VW040

C. Vehicle RT012

Table 28: Vehicle RT012 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Renault
Vehicle Model:	Clio
Vehicle Class:	M1
Vehicle Code:	RT012
Fuel Type:	Gasoline
Injection Type:	Gasoline Direct Injection
Emissions Control Technologies:	TWC
Model Year:	2017
Vehicle Identification Number:	VF15RBU0D57745893
Homologation Number	e2*2007/116*0327*80
Emissions Standard:	Euro 6b
Odometer Reading:	7242
Transmission Type:	Automatic
Number of Gears:	6
Engine Capacity in cm^3:	1197
Rated Power in kW:	87
Tyre Dimensions:	195/55/R16
RL coefficients NEDC:	Inertia: 1130, F0: 75.9, F1: 0.35, F2: 0.029
RL coefficients WLTP:	Inertia: 1340, F0: 120.6, F1: 0.36, F2: 0.031
Declared CO2 value in g/km:	120

Figure 37: Vehicle RT012

D. Vehicle NN009

Table 29: Vehicle NN009 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Nissan
Vehicle Model:	Qashqai
Vehicle Class:	M1
Vehicle Code:	NN009
Fuel Type:	Gasoline
Injection Type:	Gasoline Direct Injection
Emissions Control Technologies:	TWC
Model Year:	2017
Vehicle Identification Number:	SJNFEAJ11U2128664
Homologation Number	e11*2007/46*0963*15
Emissions Standard:	Euro 6b
Odometer Reading:	3349
Transmission Type:	CVT
Engine Capacity in cm^3:	1197
Rated Power in kW:	85
Tyre Dimensions:	215/60/R17
RL coefficients NEDC:	Inertia: 1360, F0: 88.3, F1: -0.01, F2: 0.039
RL coefficients WLTP:	Inertia: 1512, F0: 132.3, F1: -0.01, F2: 0.042
Declared CO_2 value in g/km:	119

Figure 38: Vehicle NN009

E. Vehicle ST001

Table 30: Vehicle ST001 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and $N/(km/h)^2$ respectively.

Vehicle OEM:	Seat
Vehicle Model:	Leon ST
Vehicle Class:	M1
Vehicle Code:	ST001
Fuel Type:	Gasoline
Injection Type:	Gasoline Direct Injection
Emissions Control Technologies:	TWC
Model Year:	2017
Vehicle Identification Number:	VSSZZZ5FZJR118169
Homologation Number	e92007/46 0094*25
Emissions Standard:	Euro 6b
Odometer Reading:	11392
Transmission Type:	Automatic
Number of Gears:	7
Engine Capacity in cm^3:	1395
Rated Power in kW:	110
Tyre Dimensions:	225/45/R17
RL coefficients NEDC:	Inertia: 1360, F0: 84.3, F1: 0.36, F2: 0.028
RL coefficients WLTP:	Inertia: 1459, F0: 122.9, F1: 0.37, F2: 0.031
Declared CO_2 value in g/km:	117

Figure 39: Vehicle ST001

F. Vehicle FT060

Table 31: Vehicle FT060 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Fiat
Vehicle Model:	Tipo
Vehicle Class:	M1
Vehicle Code:	FT060
Fuel Type:	Gasoline / LPG
Injection Type:	Port Fuel Injection
Emissions Control Technologies:	TWC
Model Year:	2017
Vehicle Identification Number:	ZFA35600006F40588
Homologation Number	e3*2007/46*0373*04
Emissions Standard:	Euro 6b
Odometer Reading:	15493
Transmission Type:	Manual
Number of Gears:	6
Engine Capacity in cm^3:	1368
Rated Power in kW:	88
Tyre Dimensions:	225/45/R17
RL coefficients NEDC:	Inertia: 1360, F0: 90.5, F1: 0.26, F2: 0.031
RL coefficients WLTP:	Inertia: 1530, F0: 136.8, F1: 0.26, F2: 0.034
LPG Declared CO_2 value in g/km:	135
Gasoline Declared CO_2 value in g/km:	146

Figure 40: Vehicle FT060

G. Vehicle HI002

Table 32: Vehicle HI002 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Hyundai
Vehicle Model:	Ioniq PHEV
Vehicle Class:	M1
Vehicle Code:	HI002
Fuel Type:	Gasoline / Electric
Injection Type:	Gasoline Direct Injection
Emissions Control Technologies:	TWC + EGR
Model Year:	2017
Vehicle Identification Number:	KMHC751DGHV052883
Homologation Number	e4*2007/46*1157*03
Emissions Standard:	Euro 6b
Odometer Reading:	1581
Transmission Type:	Automatic DCT
Number of Gears:	6
Engine Capacity in cm^3:	1580
Rated Power in kW:	77.2
Tyre Dimensions:	205/55/R16
RL coefficients NEDC:	Inertia: 1590, F0: 101.7, F1: 0.29, F2: 0.031
RL coefficients WLTP:	Inertia: 1670, F0: 144.4, F1: 0.29, F2: 0.033
Declared CO_2 value in g/km:	CD: 0, CS: 92, Weighted CS+CD: 26

Figure 41: Vehicle HI002

H. Vehicle MB010

Table 33: Vehicle MB010 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Mercedes-Benz
Vehicle Model:	C 220 d
Vehicle Class:	M1
Vehicle Code:	MB010
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+SCR+DPF
Model Year:	2017
Vehicle Identification Number:	WDD2050041R269991
Homologation Number	e1*2001/116*0431*42
Emissions Standard:	Euro 6b
Odometer Reading:	18049
Transmission Type:	Automatic
Number of Gears:	9
Engine Capacity in cm^3:	2143
Rated Power in kW:	125
Tyre Dimensions:	225/50/R17
RL coefficients NEDC:	Inertia: 1590, F0: 101.7, F1: 0.34, F2: 0.029
RL coefficients WLTP:	Inertia: 1694, F0: 146.4, F1: 0.35, F2: 0.031
Declared CO_2 value in g/km:	117

Figure 42: Vehicle MB010

I. Vehicle LR001

Table 34: Vehicle LR001 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Land Rover
Vehicle Model:	Discovery HSE Td6
Vehicle Class:	M1
Vehicle Code:	LR001
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+SCR+DPF
Model Year:	2017
Vehicle Identification Number:	SALRA2BK4HA005862
Homologation Number	e11*2007/46*3784*01
Emissions Standard:	Euro 6b
Odometer Reading:	15167
Transmission Type:	Automatic
Number of Gears:	8
Engine Capacity in cm^3:	2993
Rated Power in kW:	190
Tyre Dimensions:	255/55/R20
RL coefficients NEDC:	Inertia: 2270, F0: 152.5, F1: -0.41, F2: 0.05
RL coefficients WLTP:	Inertia: 2526, F0: 227.6, F1: -0.42, F2: 0.053
Declared CO_2 value in g/km:	189

Figure 43: Vehicle LR001

J. Vehicle OL002

Table 35: Vehicle OL002 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and $N/(km/h)^2$ respectively.

Vehicle OEM:	Opel
Vehicle Model:	Corsa
Vehicle Class:	M1
Vehicle Code:	OL002
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+LNT+DPF
Model Year:	2017
Vehicle Identification Number:	W0V0XEP08J6000853
Homologation Number	e1*2001/116*0379*41
Emissions Standard:	Euro 6b
Odometer Reading:	4157
Transmission Type:	Manual
Number of Gears:	5
Engine Capacity in cm^3:	1248
Rated Power in kW:	55
Tyre Dimensions:	185/65/R15
RL coefficients NEDC:	Inertia: 1250, F0: 78, F1: 0.32, F2: 0.03
RL coefficients WLTP:	Inertia: 1285, F0: 109, F1: 0.33, F2: 0.032
Declared CO_2 value in g/km:	107

Figure 44: Vehicle OL002

K. Vehicle TA008

Table 36: Vehicle TA008 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Toyota
Vehicle Model:	Yaris
Vehicle Class:	M1
Vehicle Code:	TA008
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+LNT+DPF
Model Year:	2015
Vehicle Identification Number:	VNKJC3D370A108411
Homologation Number	e11*2007/46*0152*08
Emissions Standard:	Euro 6b
Odometer Reading:	19344
Transmission Type:	Manual
Number of Gears:	6
Engine Capacity in cm^3:	1364
Rated Power in kW:	66
Tyre Dimensions:	175/65/R15
RL coefficients NEDC:	Inertia: 1130, F0: 75.2, F1: 0.32, F2: 0.03
RL coefficients WLTP:	Inertia: 1254, F0: 112.2, F1: 0.33, F2: 0.032
Declared CO_2 value in g/km:	91

Figure 45: Vehicle TA008

L. Vehicle OL003

Table 37: Vehicle OL003 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Opel
Vehicle Model:	Mokka X
Vehicle Class:	M1
Vehicle Code:	OL003
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+LNT+DPF
Model Year:	2016
Vehicle Identification Number:	W0LJD7EC0HB127687
Homologation Number	e4*2007/46*0537*16
Emissions Standard:	Euro 6b
Odometer Reading:	5917
Transmission Type:	Manual
Number of Gears:	6
Engine Capacity in cm^3:	1598
Rated Power in kW:	100
Tyre Dimensions:	215/55/R18
RL coefficients NEDC:	Inertia: 1590, F0: 98.8, F1: -0.05, F2: 0.04
RL coefficients WLTP:	Inertia: 1639, F0: 138.3, F1: -0.05, F2: 0.043
Declared CO_2 value in g/km:	114

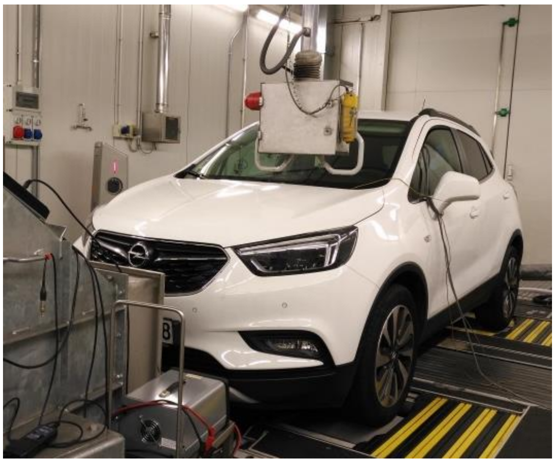


Figure 46: Vehicle OL003

M. Vehicle FT061

Table 38: Vehicle FT061 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Fiat
Vehicle Model:	Ducato
Vehicle Class:	N1, Cl. 3
Vehicle Code:	FT061
Fuel Type:	CNG
Emissions Control Technologies:	TWC
Model Year:	2018
Vehicle Identification Number:	ZFA25000002E78860
Homologation Number	e3*2007/46*0044*20
Emissions Standard:	Euro 6b
Odometer Reading:	307
Transmission Type:	Manual
Number of Gears:	6
Engine Capacity in cm^3:	2999
Rated Power in kW:	100
Tyre Dimensions:	225/70/R15
RL coefficients NEDC:	Inertia.: 2270, F0: 141.9, F1: 0.21, F2: 0.087
RL coefficients WLTP:	Inertia.: 2726, F0: 230.8, F1: 0.22, F2: 0.093
Declared CO_2 value in g/km:	234

Figure 47: Vehicle FT061

N. Vehicle VW042

Table 39: Vehicle VW042 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Volkswagen
Vehicle Model:	Golf TSI Bluemotion
Vehicle Class:	M1
Vehicle Code:	VW042
Fuel Type:	Gasoline
Injection Type:	Gasoline Direct Injection
Emissions Control Technologies:	TWC
Model Year:	2017
Vehicle Identification Number:	WVWZZZAUZJW076757
Homologation Number	e1*2007/46*0623*30
Emissions Standard:	Euro 6c
Odometer Reading:	11163
Transmission Type:	Automatic
Number of Gears:	7
Engine Capacity in cm^3:	1498
Rated Power in kW:	96
Tyre Dimensions:	225/45/R17
RL coefficients NEDC:	Inertia: 1360, F0: 87.3, F1: 0.31, F2: 0.03
RL coefficients WLTP:	Inertia: 1454, F0: 126.2, F1: 0.32, F2: 0.032
Declared CO_2 value in g/km:	113

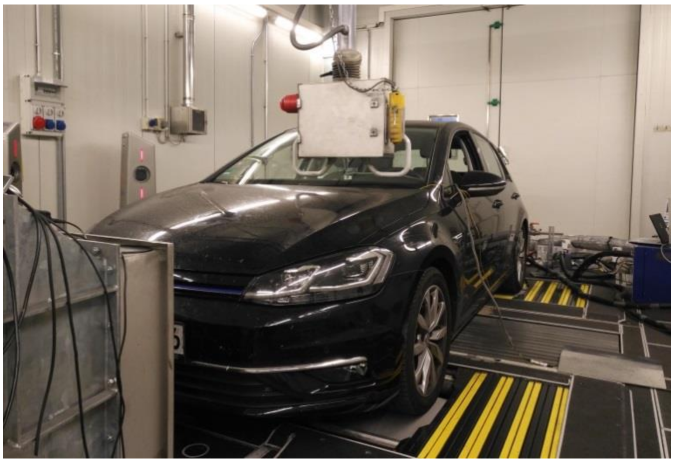


Figure 48: Vehicle VW042

O. Vehicle SA002

Table 40: Vehicle SA002 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and $N/(km/h)^2$ respectively.

Vehicle OEM:	Škoda
Vehicle Model:	Superb
Vehicle Class:	M1
Vehicle Code:	SA002
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+LNT+SCR+DPF
Model Year:	2017
Vehicle Identification Number:	TMBJH7NP0J7548858
Homologation Number	e11*2001/116*0326*45
Emissions Standard:	Euro 6c
Odometer Reading:	21000
Transmission Type:	Manual
Number of Gears:	6
Engine Capacity in cm^3:	1968
Rated Power in kW:	110
Tyre Dimensions:	215/55/R17
RL coefficients NEDC:	Inertia: 1590, F0: 102, F1: 0.32, F2: 0.03
RL coefficients WLTP:	Inertia: 1793, F0: 155.3, F1: 0.33, F2: 0.032
Declared CO_2 value in g/km:	113

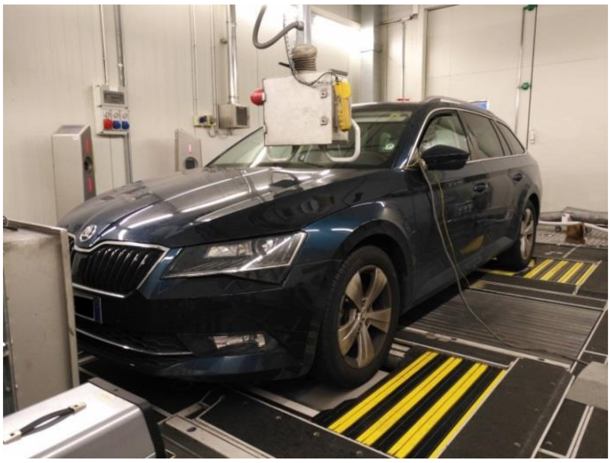


Figure 49: Vehicle SA002

P. Vehicle SI001

Table 41: Vehicle SI001 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Suzuki
Vehicle Model:	Swift
Vehicle Class:	M1
Vehicle Code:	SI001
Fuel Type:	Gasoline
Injection Type:	Port Fuel Injection
Emissions Control Technologies:	EGR+TWC
Model Year:	2018
Vehicle Identification Number:	JSAAZC83S0025458
Homologation Number	E4*2007/46*1205*02
Emissions Standard:	Euro 6d-TEMP
Odometer Reading:	1351
Transmission Type:	Manual
Number of Gears:	5
Engine Capacity in cm^3:	1242
Rated Power in kW:	66
Tyre Dimensions:	175/65/R15
RL coefficients WLTP:	Inertia: 1051, F0: 55.2, F1: 0.72, F2: 0.031
Declared CO_2 value in g/km:	115

Figure 50: Vehicle SI001

Q. Vehicle V0006

Table 42: Vehicle V0006 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and $N/(km/h)^2$ respectively.

Vehicle OEM:	Volvo
Vehicle Model:	XC40
Vehicle Class:	M1
Vehicle Code:	V0006
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+LNT+SCR+DPF
Model Year:	2018
Vehicle Identification Number:	YV1XZABCJ2002110
Homologation Number	e9*2007/46*3146*00
Emissions Standard:	Euro 6d-TEMP
Odometer Reading:	9192
Transmission Type:	Automatic
Number of Gears:	8
Engine Capacity in cm^3:	1969
Rated Power in kW:	140
Tyre Dimensions:	245/45/R20
RL coefficients WLTP:	Inertia: 1917, F0: 147.3, F1: 0.311, F2: 0.04162
Declared CO_2 value in g/km:	172

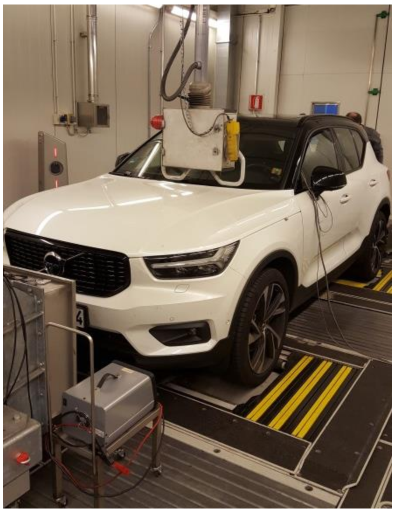


Figure 51: Vehicle V0006

R. Vehicle FD009

Table 43: Vehicle FD009 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Ford
Vehicle Model:	Focus
Vehicle Class:	M1
Vehicle Code:	FD009
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+LNT+DPF
Model Year:	2018
Vehicle Identification Number:	WF0NXXGCHNJM00726
Homologation Number	e13*2007/46*1911*01
Emissions Standard:	Euro 6d-TEMP
Odometer Reading:	1427
Transmission Type:	Automatic
Number of Gears:	8
Engine Capacity in cm^3:	1499
Rated Power in kW:	88
Tyre Dimensions:	235/40/R18
RL coefficients WLTP:	Inertia: 1543, F0: 151.07, F1: 0.151, F2: 0.03519
Declared CO_2 value in g/km:	143

Figure 52: Vehicle FD009

S. Vehicle PT011

Table 44: Vehicle PT011 specification. RL stands for road load, with Inertia, F0, F1 and F2 in kg, N, N/(km/h) and N/(km/h)^2 respectively.

Vehicle OEM:	Peugeot
Vehicle Model:	308
Vehicle Class:	M1
Vehicle Code:	PT011
Fuel Type:	Diesel
Emissions Control Technologies:	DOC+EGR+SCR+DPF
Model Year:	2018
Vehicle Identification Number:	VF3LBYHZPHS361402
Homologation Number	e2*2007/46*0405*18
Emissions Standard:	Euro 6d-TEMP
Odometer Reading:	9680
Transmission Type:	Manual
Number of Gears:	6
Engine Capacity in cm^3:	1499
Rated Power in kW:	96
Tyre Dimensions:	225/45/R17
RL coefficients WLTP:	Inertia: 1462, F0: 117.9, F1: 0.611, F2: 0.03194
Declared CO_2 value in g/km:	127.31

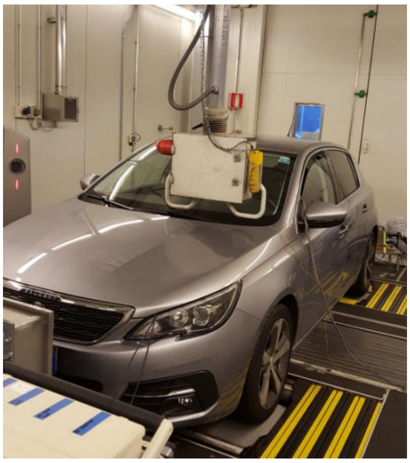


Figure 53: Vehicle PT011

KJ-NA-29897-EN-N

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