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CO2 In-Service Verification test campaign and methodology development for light-duty vehicles

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Summary

The project **"CO_2 in-service verification test campaign and methodology development for light-duty vehicles"** is aimed at supporting the European Commission in the development of a methodology for an in-service test and verification procedure for CO_2 emissions of light duty vehicles. The project has been carried out by TNO as part of service contract 2018/003 under framework contract No. CLIMA.001/FRA/2015/0014. For the vehicle testing, support was provided by the Commission's Joint Research Centre (JRC) in Ispra.

The objectives of this project are:
- to build experience with in-service testing of CO_2 emissions in order to establish an empirical and analytical basis;
- to explore options for the key elements of an ISV statistical procedure;
- to facilitate the elaboration by the Commission of the principles and details of an ISV procedure for CO_2.

The project contained the following tasks:
- Task 1: Vehicle sourcing;
- Task 2: In-service road load testing;
- Task 3: In-service chassis-dynamometer testing and "complete" WLTP in-service testing;
- Task 4 & 5: Uncertainty and sensitivity analysis, and options for pass/fail criteria for ISV CO_2 testing of individual models and IP families.

Six vehicles of two IP families have been tested: three variants of an IP family for a large diesel-fuelled vehicle model with automatic gearbox and three vehicles from an IP family for a small petrol-fuelled model with manual gearbox from a different manufacturer group. In this way a basic coverage of the spectrum of vehicles sizes and fuels in the fleet was obtained.

The measurement program has provided insight in the practicality of independent execution of WLTP tests, including both the coast down test for determining road load and the chassis dynamometer test for measuring CO_2 emissions. Analysis of the test results has provided insight in the type and size of variations occurring in both tests, related e.g. to specifics of the test track, weather conditions, details of the way in which the test is executed, the operation of the vehicle, differences between vehicles, and correction methods. Also the impacts of changes in vehicle mass or resistance on road load, cycle energy demand and CO_2 emissions have been quantified.

Based on this experience and on additional available information and insights recommendations have been formulated for working out an In-Service Verification procedure, relating to the test protocol as well as to the statistical procedure and pass/fail criteria. For the development of an ISV procedure that aims to safeguard the environmental effectiveness of the CO_2 standards, a number of general principles are identified.

For ISV testing these general principles include:

- It should be possible to execute an ISV test with no or minimal prior instructions from the manufacturer with respect to test conditions, vehicle state or vehicle adjustments, and with minimal need for extra information to be obtained from the manufacturer.
- The vehicles selected for ISV testing should be restored to their original state at registration, as specified in the CoC[1]. After-market modifications affecting emissions (e.g. different wheels / tyres or spoilers) should not be present.
- It should be acceptable to test on any track which satisfies the WLTP requirements, and under all conditions stipulated in the WLTP.
- The vehicles to be tested should be in a normal state and not tuned towards low test results. The vehicles should be made suitable to perform in the same manner on the WLTP test as in normal use. Adjustments of vehicle settings, which may be required to enable (safe) performance of a WLTP test, should not alter aspects of the vehicle's performance that affect CO_2 emissions.
- The operation of auxiliaries, including e.g. adjustable grills and energy consuming devices (affecting alternator current), in the test should match the operation of these auxiliaries under normal use conditions. It should be possible to correct for systematic and unexplained deviations.
- Where significant deviations are found between ISV road load values and the CoC values, these might be used to calculate the associated deviation in CO_2 emissions (which can be estimated from the IP family line) without a need to carry out chassis dynamometer tests.

For the ISV statistical procedure and pass/fail criteria, the identified general principles include:

- The starting point for ISV is that the results of any test carried out in accordance with Commission Regulation (EU) 2017/1151 (WLTP) are valid within the observed and expected variations in the testing. "Natural" variations in test results, which may be caused by e.g. the use of different test tracks or different ways in which the test can be executed within the specifications of the WLTP, are not to be considered in this respect as they define the inherent and accepted bandwidth of the tests.
  - Provided that tests are carried out in full accordance with the WLTP procedures, the fact that one lab or test track may have systematically higher or lower results than other labs, is part of the natural bandwidth of the WLTP.
- As a result, the full bandwidth of "natural" variations in test results does not have to be taken into account for the statistical procedure of the In-Service Verification, and neither is it necessary to quantify the different elements causing these variations.
- The statistical procedure and associated criteria should only consider the "normal" variations between repeat tests on the same vehicle under similar test conditions as observed in road load and chassis dynamometer tests. These "normal" variations relate to the accuracy with which a lab can carry out a test. The statistical procedure should contain a "base margin", representing the minimal "natural" variation, to cater for situations in which incidentally coinciding repeat tests do not yield a realistic estimate of a lab's test accuracy.

[1] The possibly undesired impacts of aftermarket modifications on in-use CO_2 emissions may need to be tackled by alternative means.

- The results obtained for different models in the same IP family could be combined by making the CO_2 results relative to the declared value, i.e. $CO_{2,ISV}/CO_{2,CoC}$. This makes it possible to apply a similar statistical approach both for In-Service Verification of single vehicle models and for In-Service test results obtained from testing different vehicle models (with different CoC CO_2 values) in the same IP family. Where absolute CO_2 values are needed, the average of the relative values can be multiplied by the average of the declared values.

In case of deviations found during ISV testing, the European Commission in the context of the CO_2 regulation will need to take into account the size of the deviation for calculating a manufacturer’s average specific emissions (new vehicles sales in a given year) and, hence, for assessing the manufacturer’s compliance with its specific emissions target. The statistical procedure used for the verification therefore needs to provide both a pass/fail decision and a statistical approach to determine the deviation to be applied for adjusting the average specific emissions. Existing statistical procedures used in other types of vehicle legislation may provide a basis for In-Service Verification of CO_2, but cannot be used directly in view of the different nature of the applicable targets. A delicate balance will have to be found between statistical principles and the need for a practical procedure which leads to a meaningful and robust outcome based on testing a limited number of vehicles.

Acronyms

ATCT	Ambient Temperature Correction Test
CED	Cycle Energy Demand
CoC	Certificate of Conformity
CoP	Conformity of Production
DPF	Diesel Particulate Filter
f0	Constant road load coefficient
f1	First order road load coefficient
f2	Second order road load coefficient
FCF	Family Correction Factors
GTAA	Granting Type Approval Authority
IMU	Inertial Management Unit
IP	Interpolation Family
IS-CD-CO_2	In-Service Chassis Dynamometer CO_2 emissions
IS-CED	In-Service Cycle Energy Demand
IS-RL	In-Service Road Loads
IS-TM	In-Service Test Mass
IS-WLTP-CO_2	In-Service WLTP CO_2 emissions
ISC	In-Service Conformity (of pollutant emissions)
ISV	In-Service Verification (of CO_2 emissions)
JRC	Joint Research Centre
LNT	Lean NO_x Trap
OBD	On-board diagnostics
OEM	Original Equipment Manufacturer
PG	Proving Ground
RCB	REESS energy charged based
RDW	Dutch vehicle and Type Approval Authority
REESS	Rechargeable Electric Energy Storage System
RRC	Rolling Resistance Coefficient
TA-IP	Type Approval Interpolation Line
TNO	the Netherlands Organisation for Applied Scientific Research
TPMS	Tyre Pressure Monitoring System
WLTC	Worldwide harmonized Light vehicles Test Cycles
WLTP	Worldwide harmonized Light vehicles Test Procedure

Contents

1 Introduction

The project **“CO_2 in-service verification test campaign and methodology development for light-duty vehicles”** is aimed at supporting the European Commission in the development of a methodology for an in-service test and verification procedure for CO_2 emissions of light duty vehicles. The project has been carried out by TNO as part of service contract 2018/003 under framework contract No. CLIMA.001/FRA/2015/0014. For the vehicle testing, support was provided by the Commission’s Joint Research Centre (JRC) in Ispra.

1.1 Legislative context

In the period 2007-2017 the difference between the type approval CO_2 values, based on the NEDC test, and the real-world CO_2 emissions of passengers cars as determined from fuel consumption, has increased from a few g/km to close to 50 g/km. The introduction of the Worldwide harmonized Light vehicles Test Procedure (WLTP) was intended to reduce this gap. Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles foresees the development of an In-Service Verification (ISV) procedure, to assess the extent to which CO_2 emission and fuel consumption values recorded in the certificates of conformity (CoC) correspond to the emissions and fuel consumption of vehicles in-service as determined in accordance with Commission Regulation (EU) 2017/1151 (WLTP).

Commission Regulation (EU) 2017/1151 (WLTP)
The WLTP regulation consists of a procedure to determine the CO_2 emissions of a vehicle for the purpose of Type Approval. The parts of the procedure that are related to the determination of CO_2 contain several crucial parts, in particular the determination of the road load, the measurement of emissions on a chassis dynamometer, and an interpolation (IP) method for determining the CO_2 emissions of individual vehicles within IP families.

The road load test can be a coast-down test on a test track, a test with torque meters on a test track, or a test in a wind tunnel, and is needed to provide input for simulating the driving resistances on the chassis dynamometer. CO_2 is measured in the lab on a chassis dynamometer which simulates the mass and road-load of the vehicle. Procedures are defined for control of the road loads on the chassis dynamometer. On the test results corrections are applied for ambient temperature, regenerations, and battery state of charge.

To be able to take account of specifics of individual vehicles in a cost-effective way the procedure contains a family approach in combination with an interpolation method. This interpolation method correlates CO_2 emissions to cycle energy demand (CED) for a family of related vehicle variants, and allows every individual vehicle to be assigned its own specific CO_2 emission value without having to test each variant within a model family.

Using the impact on the cycle energy demand of actual mass and other specifics of the vehicle, including options installed on the vehicle at the moment of registration in the European Union, the vehicle's CO_2 value is derived by means of linear interpolation between the WLTP test results for a "low" and a "high" vehicle (VL respectively VH) of the IP family to which the vehicle belongs. The interpolated CO_2 value is recorded in the vehicle's certificate of conformity.

Any procedure to validate that CO_2 value must take into consideration the IP family approach, as the link between the type-approval tests and individual vehicle registrations. Instead of using the actual CO_2 values measured on the WLTP, manufacturers are also allowed to use declared values for determining the IP family line and the specific CO_2 emissions of individual vehicles.

Regulation (EU) 2019/631

Regulation (EU) 2019/631 sets CO_2 emission performance standards for new passenger cars and for new light commercial vehicles. The targets set for the EU-wide new vehicle fleet average are translated into manufacturer specific targets using a mass-based target function. Manufacturers are required to make sure that the sales-weighted average CO_2 emissions of all their vehicles registered in the target year do not exceed the specific emissions target. A monitoring mechanism is in place to assess compliance of manufacturers with the regulation. For this monitoring mechanism the type approval CO_2 values, as recorded in the Certificate of Conformity (CoC), are collected for all new vehicles sold within the European Union.

To ensure that the type approval CO_2 value of a vehicle as recorded in the CoC is, and will remain, a proper representation of the actual emission performance of the vehicle in service, Regulation (EU) 2019/631 sets out a new governance framework including the following measures:

- Article 12: collection of real-world CO_2 emissions and fuel or energy consumption data using On-Board Fuel Consumption Monitoring devices (OBFCM).
- Article 13: verification by type approval authorities on the basis of appropriate and representative vehicle samples of vehicles in-service of:
  - the correspondence between the CoC CO_2 emissions/fuel consumption and the CO_2 emissions/fuel consumption of vehicles in-service as determined by using WLTP emission tests;
  - the presence of strategies on-board or relating to the vehicles, which are artificially improving the vehicle's performance in the emissions tests.

Furthermore, according to Article 7(9), type-approval authorities shall report to the Commission the deviations found in the CO_2 emissions of vehicles in-service during the tests referred to in Article 13 as compared to the emissions indicated in the CoC. The Commission shall take those deviations into account for the purpose of calculating the average specific CO_2 emissions of a manufacturer.

The procedures for the in-service verification tests and for how to deal with the deviations found shall be set out in a delegated act (establishing the guiding principles) and implementing acts (detailed rules and procedures). The current report is intended to provide support for the Commission for working out those delegated and implementing acts.

1.2 Objectives

The objectives of this project are:

- to build experience with in-service testing of CO_2 emissions in order to establish an empirical and analytical basis;
- to explore options for the key elements of an ISV statistical procedure;
- to facilitate the elaboration by the Commission of the principles and details of an ISV procedure.

1.3 Overview of tasks

The project contained the following tasks:

Task 1: Vehicle sourcing

- Sourcing and selection of six vehicles, type approved under the WLTP legislation and belonging to two distinct CO_2 interpolation families.

Results of this task are reported in Chapter 2.

Task 2: In-service road load testing

- Determination of in-service test mass and in-service road loads by coast-down testing;
- Calculation of both the CoC and in-service WLTP cycle energy demand, for linking the road load results to the effects on CO_2 via the interpolation line for the IP family.

Results of this task are reported in Chapter 3.

Task 3: In-service chassis-dynamometer testing and “complete” WLTP in-service testing

- Determination of in-service CO_2 emissions based chassis dynamometer tests using the CoC road load as well as in-service road loads determined in Task 2;
- Quantification of any difference between the type approval CO_2 interpolation line and the in-service CO_2 emission values and interpolation lines.

Results of this task are reported in Chapter 4.

Task 4 & 5: Uncertainty and sensitivity analysis, and options for pass/fail criteria for ISV CO_2 testing of individual models and IP families

- Determination of variations in the in-service WLTP CO_2 value and CoC CO_2 value from the uncertainties in the test results and the allowed test variations in the WLTP, and aspects associated with the interpolation method;
- Exploration of options for an ISV statistical procedure, pass/fail criteria and correction mechanisms for an individual model and for a CO_2 interpolation family.
- Use of the variations in the outcome and the underlying uncertainties to explore options for a statistical pass/fail procedure, for various combinations of test data.

Results of the first part of these tasks, related to determining variations in test results, are reported in Chapters 5 (road load) and 6 (chassis dynamometer tests). Results of the second part of these tasks, related to exploring options for the statistical procedure and pass/fail criteria, are reported in Chapters 7 (lessons learned) and 8 (general principles for the ISV procedure). Additional background and supporting information derived during the execution of the project can be found in the annexes.

2 Vehicle sourcing for ISV testing

2.1 Introduction

This chapter reports the results of the work carried out under Task 1 of the project. The objective of task 1 was to source six vehicles from two different vehicle IP families (three vehicles per IP family) for testing in task 2 and 3. All six test vehicles, type approved under the WLTP legislation (passenger vehicles registered after 1 September 2018), were sourced by TNO through rental agencies, company fleets or private owners. The six vehicles have been selected taking (as much as possible) account of the requirements for current In-service Conformity with respect to pollutant emissions, as set out in Regulation 2017/1151 (WLTP) Annex II and Annex XXI, as well as its predecessor, i.e. UNECE Regulation 83:

- The test vehicle shall be suitably run-in for at least 10,000 but no more than 80,000 km (2 vehicles selected with lower mileage);
- The tyres used shall not be older than 2 years after the production date, be run-in on a road for at least 200 km and have a constant tread depth between 100 and 80 percent of new.

By selecting one IP family of large diesel-fuelled vehicle models and one IP family of small petrol-fuelled models, from a different manufacturer group, a basic coverage of the spectrum of vehicles sizes and fuels in the fleet was obtained. Within each IP family vehicle model variants with different CO_2 values were selected in order to have different points on the interpolation line. From the most common vehicle model two almost identical vehicles (same CO_2 emissions and CoC specifications) were selected to investigate the reproducibility of test results with different vehicles of the same model and variant.

2.1.1 Considerations on the state of selected vehicles

Vehicles with a WLTP CoC were selected for testing. The CoC describes the characteristics / state of the vehicle at registration. For relatively new in-service vehicles the expectation would be that the vehicle is still in the same state as at registration, with the original tyres and no after-market adaptations. As much as possible the obtained vehicles were checked against the CoC. However, this is limited mainly to tyres, wheel size, and weight, as no further details on e.g. aerodynamic body parts or aerodynamic properties of wheel covers are provided in the CoC. In order to perform testing and obtain IP Family details the type-approval documents for the two selected vehicle families were obtained. In particular, the vehicles were selected on the basis of having different road load values for both rolling resistance and air drag. The air drag is the result of differences in body and wheels. The differences in body styles were indeed observed (e.g. spoilers and side trims). However, it could not be verified whether they were consistent with the respective CoCs as the body is not described in such detail.

2.2 Vehicle and interpolation family information

2.2.1 Vehicles selected for interpolation (IP) family 1

For the first CO_2 IP family, diesel vehicles representative of a higher middle segment and with automatic transmission were sought.

Makes and models considered during the selection procedure were: Ford Focus, Skoda Octavia, Mercedes Benz A180d and B220d, Peugeot 3008 and 308, Volvo V40 and XC60 and BMW 320d. For these makes and models vehicles were found on the market that were registered after September 2018, when the WLTP legislation was introduced (EURO-6d-TEMP vehicles).

Based on the availability of variants with three different test masses, the Volvo XC60 diesel was selected. Due to the limited availability, one of the vehicles had a mileage below 10,000 km.

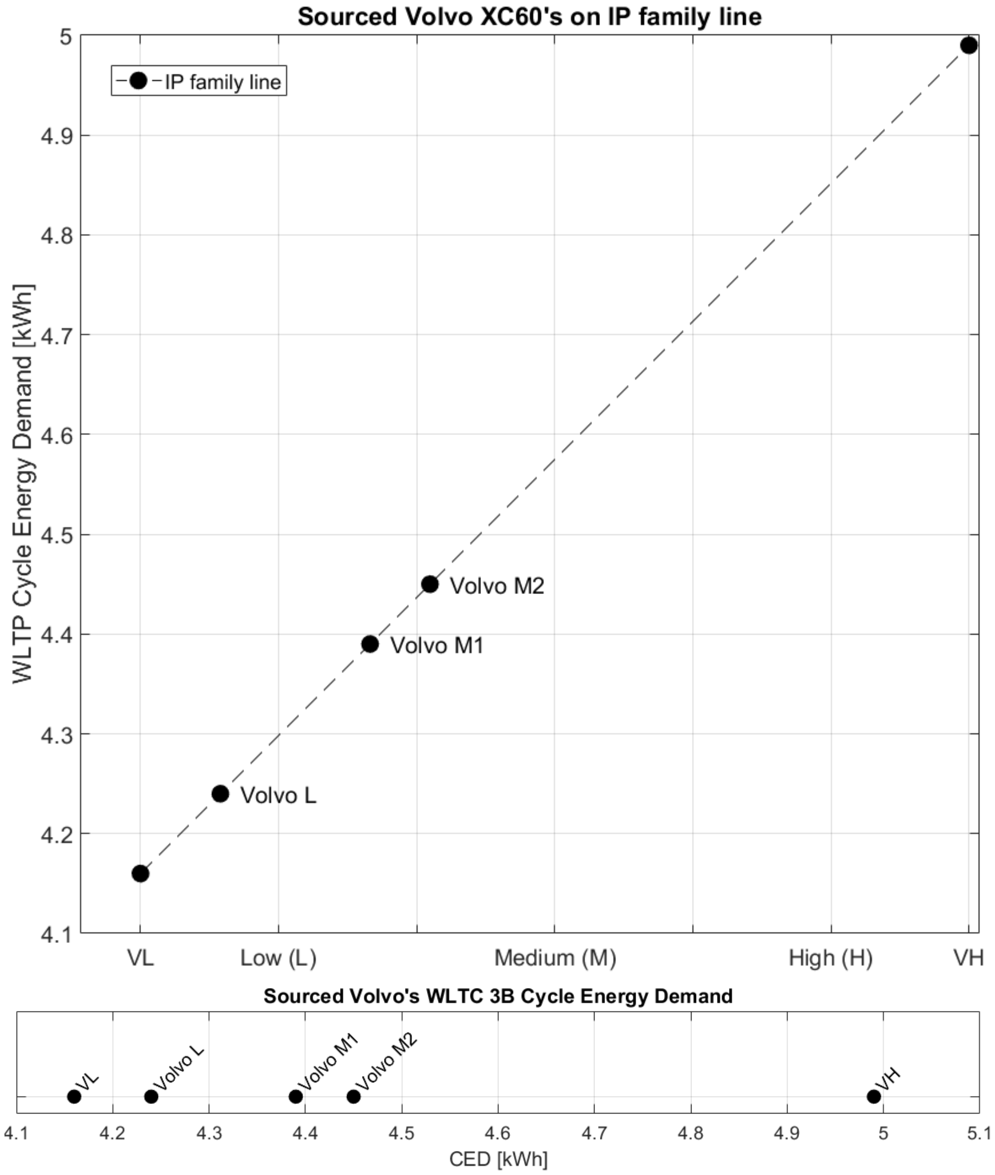

Figure 2.1: WLTP Cycle Energy Demand (CED) of the sourced Volvo XC60s relative to the Vehicle Low (VL) and Vehicle High (VH) of the IP family 1.

Table 2.1: IP family 1, vehicle low and high.

	Vehicle Low (VL)	Vehicle High (VH)	
Test mass:	1976	2172	kg
f0:	105.60	198.30	N
f1:	1.348	1.348	N/(km/h)
f2:	0.03683	0.04167	$N/(km/h)^2$
RRC:	5.9	8.4	-
Cycle Energy Demand			
Low:	0.45	0.54	kWh
Medium:	0.78	0.93	kWh
High:	1.15	1.40	kWh
Extra high:	1.78	2.12	kWh
Combined:	4.16	4.99	kWh
WLTP CO_2			
Low:	214	234	g/km
Medium:	181	202	g/km
High:	153	175	g/km
Extra high:	185	211	g/km
Combined:	178	201	g/km

Table 2.2: IP family 1, most relevant information for the three sourced diesel vehicles.

	Volvo M1	Volvo M2	Volvo L
Type	U	U	U
Variant	UZA8	UZA8	UZA8
Version	UZA8UC??	UZA8UC??	UZA8VC??
VIN	YV1UZA8UCJ1109080	YV1UZA8UCJ1085986	YV1UZA8VCJ1121025
Tyre	235/55R19 105V	255/45R20 105V	235/60R18 103V
Wheel	7.5Jx19x50.5	8Jx20x52.5	7.5Jx18x50.5
RRC	B	B	A
Mileage	18,000 km	13,500 km	6,500 km
Test mass	2021 kg	2058 kg	2018 kg
f0	143.5 N	147.2 N	109.1 N
f1	1.348 N/(km/h)	1.348 N/(km/h)	1.348 N/(km/h)
f2	0.03683 $N/(km/h)^2$	0.03712 $N/(km/h)^2$	0.03750 $N/(km/h)^2$
WLTP CO_2			
Low	220 g/km	222 g/km	216 g/km
Medium	188 g/km	189 g/km	183 g/km
High	159 g/km	161 g/km	155 g/km
Extra high	191 g/km	193 g/km	187 g/km
Combined	184 g/km	186 g/km	180 g/km

The vehicles are part of IP family IP-04-YV1-2017-0011 and the Type Approval (TA) number is e4*2007/46/1220*01 (Dutch whole-vehicle type approval). The vehicles are distinguished in this report as medium 1 (M1) medium 2 (M2) and low (L), based on their cycle energy demand (CED) relative to the WLTP Vehicle Low (VL) and Vehicle High (VH) from the IP family, as shown in Figure 2.1. The most relevant specifications of the IP family and the three selected vehicles can be found in Table

2.1 and Table 2.2, respectively. More detailed CoC information is presented in Appendix A.

Regarding Table 2.1 and Table 2.2:

- Test mass is as defined in 2017/1151 Annex XXI;
- f0, f1 and f2 are the road load coefficients;
- RRC is the tyre Rolling Resistance Coefficient;
- For both the cycle energy demand and the WLTP CO_2 the values are displayed for all four parts of the WLTC cycle, i.e. low, medium, high and extra high, as well as the total of the full cycle, combined.

2.2.2 Vehicles selected for interpolation (IP) family 2

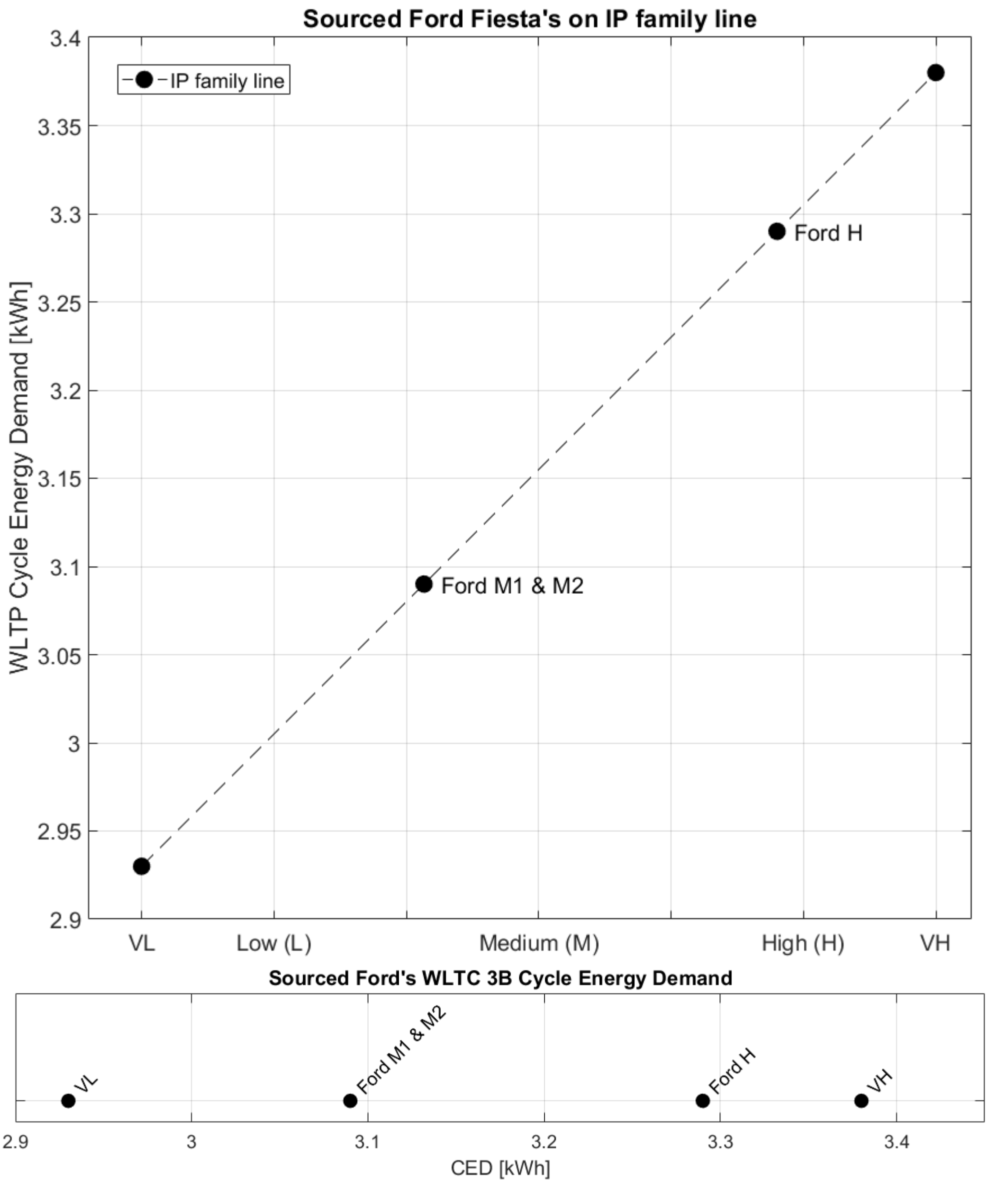

Figure 2.2: WLTP Cycle Energy Demand (CED) of the sourced Ford Fiesta's relative to the Vehicle Low (VL) and Vehicle High (VH) of the IP family 2.

Table 2.3: IP family 2, vehicle low and high.

	Vehicle Low (VL)	Vehicle High (VH)	
Test mass:	1239	1375	kg
f0:	98.80	138.20	N
f1:	0.601	0.601	N/(km/h)
f2:	0.02980	0.03330	$N/(km/h)^2$
RRC:	7.4	9.2	-
Cycle Energy Demand			
Low:	0.30	0.35	kWh
Medium:	0.52	0.61	kWh
High:	0.81	0.95	kWh
Extra high:	1.29	1.49	kWh
Combined:	2.93	3.38	kWh
WLTP CO_2			
Low:	152	155	g/km
Medium:	117	130	g/km
High:	105	120	g/km
Extra high:	131	149	g/km
Combined:	123	137	g/km

Table 2.4: IP family 2, most relevant information for the three sourced petrol vehicles.

	Ford M1	Ford M2	Ford H
Type	JHH	JHH	JHH
Variant	SFJN1JX	SFJN1JX	SFJN1JX
Version	5CDPZNABDAX	5CDPZNABDAX	5CDPZNABDAX
VIN	WF0JXXGAHJJU 05477	WF0JXXGAHJJU 20545	WF0JXXGAHJJU 29009
Tyre	195/55R16 87V	195/55R16 87V	205/40R18 86W
Wheel	6.5Jx16H2OS47.5	6.5Jx16H2OS47.5	7.0Jx18H2OS47.5
RRC	C	C	E
Mileage	8,500 km	17,500 km	14,500 km
Test mass	1313 kg	1312 kg	1325 kg
f0	119.85362 N	119.76967 N	142.03532 N
f1	0.601 N/(km/h)	0.601 N/(km/h)	0.601 N/(km/h)
f2	0.02952 $N/(km/h)^2$	0.02952 $N/(km/h)^2$	0.03138 $N/(km/h)^2$
WLTP CO_2			
Low	154 g/km	154 g/km	155 g/km
Medium	123 g/km	123 g/km	128 g/km
High	111 g/km	111 g/km	117 g/km
Extra high	137 g/km	137 g/km	145 g/km
Combined	129 g/km	129 g/km	134 g/km

For the second CO_2 IP family a low segment petrol vehicle with manual transmission was sought. Makes and models considered during the selection procedure were: Ford C-Max and Fiesta, Renault Clio and Twingo, Citroën C3 and Volkswagen Polo.

For these makes and models vehicles were found on the market that were registered after September 2018, when the WLTP legislation was applicable.

Based on the availability of three vehicles of the same model and variant, necessary for checking reproducibility between two on paper identical vehicles and the availability of a vehicle with a higher CED, the Ford Fiesta has been selected. Also in this case, a limited number of vehicles were available, so that one Ford Fiesta had to be selected with a mileage below 10,000 km.

The vehicles are part of IP family IP-9-WF0-2018-0003 and the TA is registered under e9*2007/46*3142*07 (Spanish whole-vehicle type approval). The vehicles are distinguished in this report as medium 1 (M1) and 2 (M2), with these vehicles having almost the same CED and CO_2 value, and high (H), based on their CED relative to the WLTP Vehicle Low (VL) and Vehicle High (VH) from the IP family, as shown in Figure 2.2. The most relevant specifications of the IP family and the three selected vehicles can be found in Table 2.3 and Table 2.4, while more detailed CoC information is presented in Appendix A.

2.3 Vehicle state compared to the Certificate of Conformity

The vehicles were checked prior to testing to identify any malfunctions and to find out whether the vehicles differed in any way from the CoC. Furthermore, a more thorough inspection was performed on the vehicles by an official dealership. The results of those checks are summarized in this section.

2.3.1 CO_2 IP family 1

For all three Volvo's the engine oil, coolant, brake fluid and power steering fluid were at the correct levels. An OBD scan, using a professional Autel MaxiSys diagnostics tool revealed multiple error codes stored in the vehicles. For two vehicles errors were found related to the emission performance of the vehicle.

The Volvo M1 had two errors related to the NO_x emissions, namely P2BA700 (NO_x exceedance) and P2BA77B (empty reagent tank), and the Volvo M2 had an error, P200200 (efficiency of diesel particulate filter under threshold). These errors turned out to be old errors and they did not return during the testing programme.

All three vehicles were thoroughly inspected by an official Volvo dealership with the following results:

- For all three vehicles the latest software was installed;
- For all three vehicles a recall was organized for a malfunction in the tailgate lift/support struts. This malfunction/recall was not considered to have an influence on the test results and therefore repair was postponed to after the test period;
- Volvo M1 had a bent left front disk brake rotor, causing vibrations under braking. The dealership recommended no action since this was considered to be only a driving comfort issue and not to affect the safety of the vehicle. On request of TNO, the disk brake rotor was replaced to reduce parasitic brake to a minimum, which may have affected coast down tests;
- Volvo L had a malfunctioning air-conditioning unit because of lack of pressure in the system. The proper functioning of the air-conditioning unit is, however, not required for the testing program, since it must be turned off;

- The wheel alignment for all vehicles was adjusted to the mid-value of range to meet the provisions of Regulation 2017/1151, Annex XXI Sub-Annex 4;
- All vehicles passed the general inspection of the dealership.

2.3.2 *CO_2 IP family 2*

For all three Ford vehicles the engine oil, coolant, brake fluid and power steering fluid were at the correct levels. An OBD scan, using a professional Autel MaxiSys diagnostics tool revealed multiple error codes stored in the vehicles. These errors turned out to be old errors, unrelated to emission performance, and did not return during the testing program.

All three vehicles were thoroughly inspected by an official Ford dealership with the following results:

- For all three the latest software was installed;
- No malfunctions were found that needed repair;
- The wheel alignment for all vehicles was set to meet the provisions of Regulation 2017/1151 Annex XXI Sub-Annex 4;
- All vehicles passed the general inspection of the dealership.

2.3.3 *Wheels and tyres*

After a license plate number has been assigned to a newly sold vehicle, the owner of the vehicle is free to change wheels and tyres of the vehicle. Mounting different wheels and tyres generally leads to a different rolling resistance, and some change in the air drag. Therefore, TNO checked if the wheels and tyres fitted to the vehicles, selected for testing, corresponded to the wheel and tyre specifications in the CoCs. In the CoC the tyre and wheel sizes are specified, together with the RRC label value of the tyre. In some cases alternatives of wheel and tyre sizes are listed under Miscellaneous item 52 of the CoC.

For some of the vehicles it was found that the tyres were replaced with different (higher) RRC label spec tyres.
The Volvo L and the Ford M2 were found to be fitted with tyres having a RRC label of two classes higher than mentioned in the CoC. The Volvo L had an alternative wheel and tyre size combination fitted.

For both the Volvo M2 and Volvo L, tyres were found to be fitted that seem to be intended for Volvo, indicated by ‘VOL’ in the tyre name, which was also confirmed by the tyre distributor. These tyres are fitted with an inlay of foam that reduces tyre noise. These tyres have a higher RRC than similar tyres without the ‘VOL’ indication. This is an example showing that WLTP certified vehicles driving on the road may be fitted with tyres with a higher RRC than the value mentioned on the CoC. The Volvo dealership where the vehicles were checked confirmed that when buying a brand new vehicle, the client always has the choice to have the vehicle fitted with different tyres (and thus also different RRC).

For the above-mentioned vehicles tyres had to be replaced for this project to meet the CoC specifications. See also Table 2.5 for specification of the wheels and tyres as found on the sourced vehicles and as used in the test programme.

For some vehicles the tyres have been replaced by TNO with new ones to comply with the requirement that tyre thread depth should be at least 80% of new tyres, as specified in Regulation 2017/1151 Annex XXI Sub-Annex 4. All tyres of all vehicles were checked for damage and were pressurized according to the specifications of the vehicle. In case new tyres were fitted, these were run in for more than 200 kilometres.

Table 2.5: Vehicle wheels and tyres.

Vehicle	On vehicle retrieval	Meeting CoC specs
Volvo M1		
Make/Model:	Continental ContiSport Contact 5	Continental ContiSport Contact 5
Tyre:	235/55R19 105V XL ContiSilent SUV VOL	235/55R19 105V XL ContiSilent SUV VOL
Wheel:	7.5Jx19x50.5	7.5Jx19x50.5
RRC:	B	B
Volvo M2		
Make/Model:	Michelin Latitude Sport 3	Michelin Latitude Sport 3
Tyre:	255/45R20 105V XL Acoustic VOL	255/45R20 105V XL
Wheel:	8Jx20x52.5	8Jx20x52.5
RRC:	C	B
Volvo L		
Make/Model:	Michelin Latitude Sport 3	Goodyear Eagle F1 Asymmetric 3
Tyre:	235/55R19 105V XL Acoustic VOL	235/55R19 105W XL J LR SUV
Wheel:	7.5Jx19x50.5	7.5Jx19x50.5
RRC:	C	A
Ford M1		
Make/Model:	Michelin Primacy 3	Michelin Primacy 3
Tyre:	195/55R16 87V	195/55R16 87V
Wheel:	6.5Jx16H2OS47.5	6.5Jx16H2OS47.5
RRC:	C	C
Ford M2		
Make/Model:	Vredestein Quatrac 5	Michelin Primacy 3
Tyre:	195/55R16 87V	195/55R16 87V
Wheel:	6.5Jx16H2OS47.5	6.5Jx16H2OS47.5
RRC:	E	C
Ford H		
Make/Model:	Michelin Pilot Sport 4	Michelin Pilot Sport 4
Tyre:	205/40ZR18 86W XL	205/40ZR18 86W XL
Wheel:	7.0Jx18H2OS47.5	7.0Jx18H2OS47.5
RRC:	E	E

2.3.4 *Coast down mode*

TNO has asked Ford and Volvo if the selected vehicles were equipped with a coast down mode. Ford indicated that no coast down mode is available. Volvo did not respond at the time. All Volvo coast down tests were therefore performed without bringing the vehicles in any mode specially designed for coast down testing.

2.3.5 *Active grill*

Both the Volvos and Fords were equipped with an active grill: a row of adjustable vanes behind the visible grill of the vehicle that can be closed or opened depending on the amount of air that needs to flow through the radiator and condenser. In normal operation this grill is opening and closing actively, in response to cooling demands for the engine. This is not desired during coast down testing, since the aerodynamics of the vehicle are thereby changing. Air drag may increase up to 10%[2] from fully closed to fully open.

TNO was instructed by Ford on how to handle the active grill during coast down testing. Ford's method, which was approved by the TA authority and was used during TA coast down tests, was shared with TNO. Due to confidentiality this method is not described further in this report.

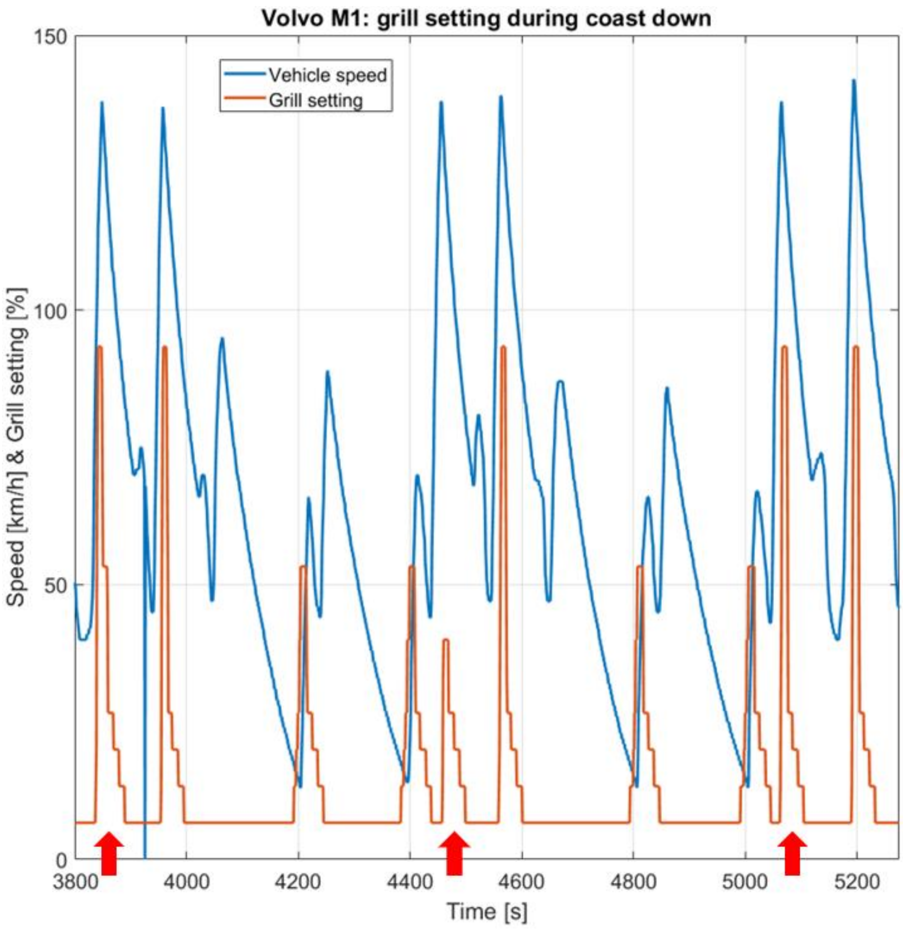

Figure 2.3: Volvo active grill behaviour during coast down testing.

[2] TNO 2015 R10955, *Correction algorithms for WLTP chassis dynamometer and coast-down testing*, p. 93

Volvo did not provide any information on how to handle the active grill. Trial coast down tests revealed that the operation of the active grill was inconsistent. In Figure 2.3 it can be seen (red arrows) that in some instances the active grill does not open as far as in most other, comparable instances. During acceleration the grill opens partially, but once the coast-down commences it closes quickly, such that most of the coast down was with a closed grill. Because of this inconsistency it was decided to keep the grill permanently open during coast down testing.

It should be noted for both the Ford Fiesta and Volvo XC60, that disengaging of the active grill did not result in any visible (malfunction) warnings on the dashboard of the vehicles. However, an error code was stored in the OBD systems of the vehicles, but without specialised tools to read those error codes the driver itself is not able to identify problems with this active grill.

3 Road load determination via coast down testing

3.1 Introduction

The coast down is the standard method to determine the road load or driving resistance of a vehicle to be replicated in the chassis dynamometer laboratory test. Higher driving resistance leads to additional work and additional CO_2. The results from the coast down testing activities performed under Task 2 of the project are presented in this chapter.

The objectives of task 2 were:

- to gain experience with independent execution of the coast down test as part of the WLTP;
- to determine the in-service road loads (IS-RL) and in-service test mass (IS-TM) for the different vehicles sourced;
- to calculate the WLTC energy demand (IS-CED) for each set of IS-RL in order to compare it with the certified cycle energy demand (CoC-CED) using the CoC data.

Important elements of the first objective were to assess:

- the statistics of repeat testing, with extended runs and repeat runs;
- the reproducibility with different vehicles of the same model and variant;
- the basic vehicle-related dependencies underlying the WLTP, such as effects of test mass, tyre label, etc.;
- systematic differences from different test tracks and different conditions such as wind and temperature.

Therefore, the testing according to CoC on the Ford Lommel Proving Ground has been the reference case for each vehicle. In tests deviating from the CoC conditions in many cases only one parameter of the coast down test has been varied, to determine the separate influence of each parameter.

To gain insight in potential impacts on the CO_2 result from the chassis dynamometer test, the results for Cycle Energy Demand (CED) in this chapter are also translated to their effect on CO_2 values, using the TA CO_2 Interpolation line (TA-IP).

For road load determination, several possible approaches are described in Regulation 2017/1151 Annex XXI Sub-Annex 4. This includes, e.g., coast down measurements on road, a wind tunnel method and calculation based on vehicle parameters. This project focuses on road load determination by performing coast downs on test tracks meeting the requirements of Regulation 2017/1151 Annex XXI Sub-Annex 4, point 4.

In this section the road load determination of the selected test vehicles is explained and the results are presented, together with an explanation on corrections that have been applied to the results. Detailed test results can be found in Appendix B.

3.2 Test procedure witnessing by Type Approval Authority

The test track of the RDW, the Dutch Vehicle Type Approval Authority, in Lelystad (The Netherlands), was used to get familiar with the vehicle preparation, warm-up and coast down procedures, according to type-approval requirements. Several coast downs were performed on the 720 meter straights and were being witnessed by the RDW. The expert RDW personnel approved the preparations and measures taken by TNO to ensure the execution of the coast downs according to the legislation.

As the Lelystad test track does not comply with the requirements in the legislation (the track is tilted sideways), it was not used later on for the actual coast down tests.

3.3 Test tracks

3.3.1 Lommel Proving Ground[3]

The test facility in Lommel, Belgium is commonly used for performing coast down tests. The facility is owned by Ford, but open for third parties. The tracks used at the facility were the Highway Track (#10), a six kilometre long two-lane highway, for the vehicle warm-up and the Straight Away (#3), a 2.3 kilometre straight for the coast downs themselves. The surface of track 10 was relatively old with different patches of asphalt of common structure. This track has a circular shape, and because of the one-way direction only right turns are made. The surface of track 3 had been replaced with new tarmac in December 2018. Directly next to track 3 a weather station is located. One side of the track 3 is well sheltered by trees, the south side however is more open. During the tests it occasionally happened that a south wind with speeds close to the allowed maximum according to Regulation 2017/1151 Annex XXI Sub-Annex 4 was recorded at the location of the Lommel weather station (at 8 m height from the ground) on the south side of the track, while this was not the case at the location of the TNO weather station (at 1.5 m height from the ground) next to the track.

In total of 21 coast down tests were performed, both during the morning and afternoon. Although no exclusive usage for the test tracks was requested, all tests could be performed successfully in accordance with the method described in Regulation 2017/1151, without interference of other vehicles on the track.

[3] https://www.fordlpg.com/en/

Figure 3.1: Lommel Proving Ground, Belgium (source: Google Maps, © Google, 2020).

3.3.2 *Applus+ IDIADA Proving Ground Spain*[4]

The test facility in Tarragona, Spain is a facility commonly used by manufacturers and third parties. The track used for both the vehicle warm-up and coast downs was the high speed circuit (#1), which is an oval with four lanes, each having a different minimum and maximum speed limit. Coast downs were only performed on the straights with lengths of around 2000 metres. The overall longitudinal gradient of the straights is 0.3%, which comes down to around 6 metres height difference along the full straights, in west direction positive and east direction negative. Only one-way clockwise traffic is allowed. The track surface consists of even and relatively dense asphalt. Directly next to both straights two separate weather stations are located. Especially the north straight of the track is well sheltered by a hill and/or trees. Wind speeds can be very low especially on that side of the track.

Figure 3.2: Applus+ IDIADA proving ground, Spain (source: Google Maps, © Google, 2020).

In total 12 coast down tests were performed at IDIADA, all tests during the evening and night because of the minimum speed limits during daytime. Although no exclusive usage for the test tracks was requested, all tests could be performed successfully according the method described in Regulation 2017/1151.

[4] https://www.applusidiada.com/global/en/what-we-do/services/proving-ground

3.4 Test equipment

Unless specifically stated otherwise, the measuring equipment complied with Regulation 2017/1151 Annex XXI Sub-Annex 4, point 3.

3.4.1 TNO test equipment

To obtain comparable data for all tests, the most important test equipment was provided by TNO. Care was taken to ensure all equipment used was properly calibrated.

3.4.2 GPS equipment

Time and the speed of the vehicle during the coast down tests were logged by a 100Hz GPS data logger combined with an Inertial Measurement Unit (accelerometer) to improve the quality of parameters measured in case the GPS signal is temporarily lost. Heading, altitude, and location are also recorded but not used. The GPS equipment is well-known and commonly used for performing coast-down tests. The software included is specifically designed for coast-down tests and updated to the latest WLTP requirements.

Table 3.1: GPS equipment specifications.

GPS equipment	
Model	Racelogic VBOX 3i v2, with IMU
Time accuracy	0.01 s
Time resolution	0.01 s
Velocity accuracy	0.1 km/h
Velocity resolution	0.01 km/h
Distance accuracy	0.05%
Distance resolution	1 cm
Update rate	100 Hz
Latency	6.75 ms

3.4.3 Tyre pressure gauge

The tyres of all vehicles were pressurized and pressure checked using a hand calibrated Förch PCL tyre pressure gauge with a reading accuracy of 1 kPa.

3.4.4 Handheld thermometer

Regular checks for parasitic braking have been performed over the course of the test program by monitoring the disk brake temperatures. A significant difference (left and right) between disk brake temperatures could indicate that either one of the disk brake rotors runs excessively against the brake pads. For this equipment no requirements are specified in the WLTP legislation since measurement of the brake temperature is not incorporated in the legislation.

Table 3.2: Handheld thermometer specifications.

Handheld thermometer	
Model	Powerfix Profi IAN 271160
Range	-50ºC to +380ºC
Accuracy	± 1.5ºC

3.4.5 Weather monitoring equipment

The weather monitoring equipment owned by TNO was used as back-up at the Lommel location. This equipment does not meet the standards from the WLTP legislation. The data is used to double check the weather data provided by the test facilities.

Table 3.3: Weather monitoring system specifications.

Weather monitoring system	
Model	Davis Vantage Vue, with datalogger
Atmospheric temperature accuracy	0.5 ºC
Atmospheric pressure accuracy	1.0 mbar (1000 Pa)
Wind speed accuracy	5%
Wind direction accuracy	3º
Logging interval	1 minute
Height of the station	0.7 m above road surface

3.4.6 Air drag pressure sensors

All vehicles have been equipped with pressure sensors to measure the actual air drag of the vehicle, as an alternative method for correcting for wind. Each vehicle is fitted with three identical pressure sensors, one at the front, one at the back and one underneath. In this way more detailed background information can be gained on the pressure difference over the vehicle due to its speed and the influence of the wind.

Table 3.4: Air drag pressure sensor specifications.

Air drag pressure sensor	
Model	BMP180 Barometric Pressure/ Temperature/ Altitude Sensor
Pressure range	300 – 1100 hPa
Resolution	0.03 hPa / 0.25m resolution
Accuracy	± 0.12 hPa
Frequency	1 Hz
Temperature range	-40ºC - 85ºC

3.4.6.1 Tyre Pressure Monitoring System

To monitor the tyre temperature and pressure during the entire coast down procedure the Volvo L and Ford L2 were fitted with a Tyre Pressure Monitoring System (TPMS).

Table 3.5: Tyre pressure monitoring system specifications.

Tyre pressure monitoring system	
Model	ALBI TPMS kit
Pressure range	0 – 5.375 mbar
Resolution	25 mbar/bit
Accuracy	± 25.0 mbar
Frequency	1 Hz
Temperature range	-40ºC - 175ºC

3.4.6.2 *TNO datalogger*

TNO developed a datalogger that has been used to log the vehicle OBD data and TPMS data. The OBD/CAN signals were logged at 1Hz and include:

- Active grill setting
- Ambient air temperature
- Battery voltage
- Brake disk temperatures
- Engine coolant temperature
- Vehicle speed

3.4.7 *Test facilities equipment*

The equipment provided by both testing facilities included the weather monitoring equipment and vehicle weighing scales. Care was taken to ensure all equipment used was properly calibrated.

3.4.7.1 *Vehicle weighing scales*

Table 3.6: Lommel PG weighing scales specifications.

Vehicle weighing scales	
Make/model	Mettler Toledo ID7 – 3000kg
Range	0 – 3000 kg
Accuracy	1 kg

Table 3.7: IDIADA PG weighing scales specifications.

Vehicle weighing scales	
Make/model	Moincasa SxS
Range	0 – 8000 kg
Accuracy	1 kg

3.4.7.2 *Weather monitoring equipment*

Table 3.8: Lommel PG weather monitoring equipment specifications at 8 metres high above Ground level.

Weather monitoring equipment	
Make/model	Vaisala WXTPTU
Atmospheric temperature accuracy	-
Atmospheric pressure accuracy	-
Wind speed accuracy	-
Wind direction accuracy	-
Humidity accuracy	-
Logging interval	1 second
Altitude of station	-

Table 3.9: IDIADA PG north straight weather monitoring equipment specifications next to the track at 1.5 metres high.

Weather monitoring equipment	
Make/model wind monitor	R.M. Young Company Wind Monitor Model 05103
Make/model data logger	Campbell Scientific CR800
Make/model pressure sensor	Vaisala BAROCAP Barometer PTB110
Atmospheric temperature accuracy	-
Atmospheric pressure accuracy	± 0.3 hPa
Wind speed accuracy	± 0.3 m/s
Wind direction accuracy	± 3º
Humidity accuracy	-
Logging interval	1 second
Altitude of station	-

Table 3.10: IDIADA PG south straight weather monitoring equipment specifications next to the track at 1.5 metres high above ground level.

Weather monitoring equipment	
Make/model wind monitor	Gill Instruments WindSonic option 1
Make/model data logger	Campbell Scientific CR800
Wind speed range	0 – 60 m/s
Wind speed accuracy	± 2% @ 12 m/s
Wind direction range	0 – 359º (no dead band)
Wind direction accuracy	± 2º @ 12 m/s
Wind direction resolution	1º
Logging interval	1 second
Height of station	-

3.5 Test matrix

TNO performed a total of 33 valid coast down tests, using the WLTP procedure in WLTP legislation 2017/1151 Annex XXI Sub-Annex 4, resulting in close to 500 coast downs. Table 3.11 gives an overview of all the tests that have been performed. Each of these tests is described in more detail in the following sections.

At the IDIADA PG all tests have been performed with the vehicles' test mass, aerodynamic shape, wheel size and tyre label in accordance with the CoC specifications. At the Lommel PG changes have been made to the weight, active grill setting (affecting the aerodynamics), wheels and tyres of the vehicles.
The detailed description of each test variation is described below.

Table 3.11: Test matrix coast down tests.

Test specification	Lommel PG			IDIADA PG		
Ford Fiesta	L1	L2	M	L1	L2	M
Default	1	1	1	1	1	1
Extended	1	1	1	1	1	1
Added weight	-	1	1	-	-	-
Different tyres	-	1	-	-	-	-
Combination high	-	-	-	-	-	-
Aerodynamics	-	-	2	-	-	-
Volvo XC60	M1	M2	L	M1	M2	L
Default	1	1	1	1	1	1
Extended	1	1	1	1	1	1
Added weight	-	-	1	-	-	-
Different tyres	-	-	1	-	-	-
Combination high	-	-	1	-	-	-
Aerodynamics	-	-	-	-	-	-

3.5.1 *Default test*

The default coast down tests have been performed with the vehicles according to ‘CoC specification’. The coast down tests were carried out until a statistical precision, as defined in the WLTP Regulation 2017/1151 Annex XXI Sub-Annex 4, Section 4.3.1.4.2, between individual coast down pairs was obtained. Coast down tests have to be repeated until the required accuracy of 3% for pairs of runs is met for all the velocity ranges.

3.5.2 *Extended test*

The extended coast down tests have been performed with the vehicle according to ‘CoC specification’, similar to the Default test. To capture the influence of the length of the test (expressed in terms of the number of pairs, with a pair being a set of two coast downs performed in opposite directions), the length of these tests was fixed at twenty pairs of measurement runs, regardless of whether the statistical precision criterion was met earlier with less pairs of runs. By extending the coast down test to a number of pairs of runs that typically is about twice the number of pairs needed to meet the statistical precision criterion, possible environmental changes during the tests and their effects on the coast down could be monitored more closely.

3.5.3 *Added weight test*

For this test the vehicle weight was raised up to the weight of the VH (Vehicle High) of the WLTP IP family, maintaining the weight distribution of the unraised vehicle weight. The test was completed upon reaching the required statistical precision.

3.5.4 *Different tyres test*

For these tests, wheels and tyres were exchanged between the vehicles of each family. This resulted in two coast down tests: the Ford M2 with the wheels and tyres of the Ford H and the Volvo L with the wheels and tyres of the Volvo M2. The test was completed upon reaching the required statistical precision.

3.5.5 *Combination high test*

For these tests, a combination of the added weight and different tyres test configuration was used, in order to end up as high as possible on the IP line. The test was completed upon reaching the required statistical precision.

The Volvo L was tested with the wheels and tyres of the Volvo M2 and with the vehicle weight raised to the VH test weight.

Since the Ford M vehicle was equipped with the wheels and tyres with the highest RRC of the three Fords, a configuration higher on the IP than the added weight configuration for the Ford M could not be reached. Therefore it was decided to perform two additional tests with the Ford L2, applying the added weight and different tyres configuration.

3.5.6 Aerodynamics test

During these tests, the grill of the vehicles was permanently closed in order to look into the effect of the active grills,. The test was completed upon reaching the required statistical precision.

3.6 Practical issues experienced with coast down testing

3.6.1 Split runs during coast down

As described in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.3.1.3.4 and 4.3.2.4.3, split runs may be performed if data cannot be collected in a single run for all the reference speed points. In practice finding a testing facility where the coast down can be performed without splitting is difficult. Typically, a length of four kilometres is needed to perform such coast down in a single run. The test tracks used in this project are about half as long. Therefore, split runs were inevitable. At the same time, this allowed some freedom in the order of execution and this will also affect the tyre pressure over the course of the test, within the requirements of the WLTP, as described below. Furthermore, the IDIADA PG speed limits also forced the coast down tests to be split since for different lanes different speed limits are in place, as seen in Figure 3.3.

Section 4.3.1.3.4 and 4.3.2.4.3 of Regulation 2017/1151 Annex XXI Sub-Annex 4 prescribe that care be taken so that vehicle conditions remain as stable as possible at each split point. No mention is made of possible variations in ambient conditions (e.g., wind) between different elements of split coast down tests. By varying the order in which different elements of split coast down test were carried some insight in this influencing factor was obtained.

Figure 3.3: IDIADA PG speed limits.

3.6.2 *Tyre pressure fluctuations*

The warm up, or preconditioning of the coast down procedure is designed to bring the vehicle to operating temperatures. During the warm up also the tyre temperatures increase, resulting in an increase in tyre pressure, reducing the rolling resistance of the tyres. In the WLTP Regulation, the time between warm-up and coast down is not specified. Immediately after warm up the tyres cool down, reducing the tyre pressure slightly, since typically the tyres are put under less stress during coast down than during warm-up. The time between warm-up and coast down also depends on the track layout. For example, at the Lommel PG a track change needs to be made while at IDIADA this is not the case.
Furthermore, at IDIADA a higher average speed can be maintained because of the oval shape of the track in comparison to the Lommel PG layout where a U-turn has to be made for each consecutive run.

To illustrate the effect of these conditions on the tyre pressure, Figure 3.4 plots the tyre pressure against the vehicle speed for two extended tests performed with the Volvo L at both the Lommel PG and IDIADA PG.

The following observations can be made based on this figure:

- A different time interval is seen between warm-up and coast down between the two tests, due to the layout and usage of test tracks at the different facilities;
- The drop in tyre pressure after completing the warm-up is twice as much at the Lommel PG.

A more detailed analysis of the impact of tyre temperature is presented in section 5.6.

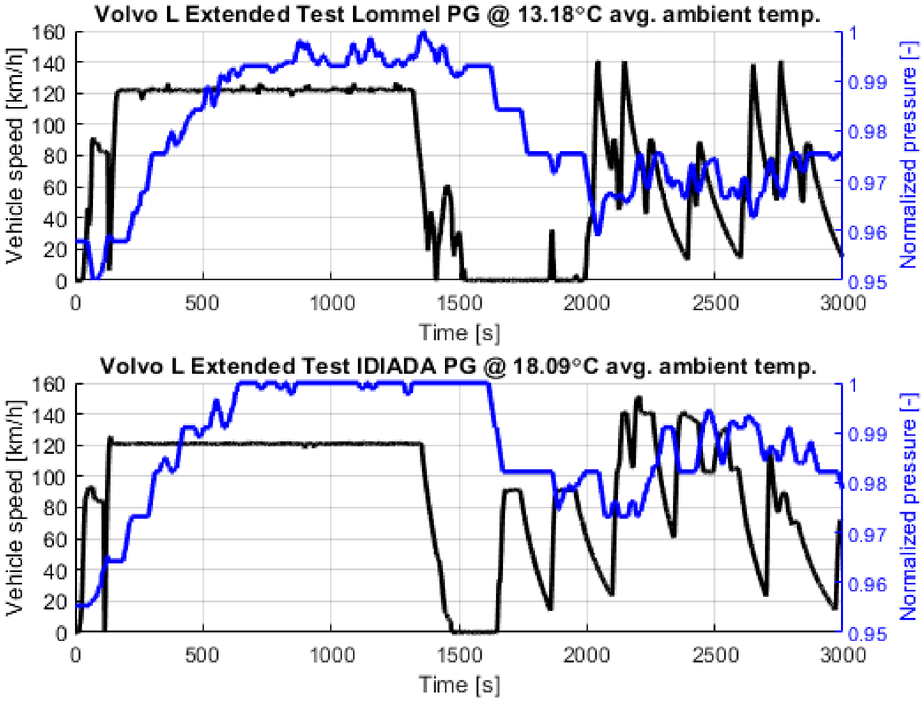

Figure 3.4: Tyre pressure fluctuations in between warm-up and coast down for comparable tests at the Lommel and IDIADA PG.

3.6.3 GPS reception

Upon analysis of the coast down tests at the IDIADA PG some irregularities were found in the speed traces. These irregularities can be seen in Figure 3.5 and are caused by the loss of GPS signal of the Racelogic VBOX equipment due to the passing of a bridge. A thorough analysis has been performed on both the VBOX data and the vehicle data and it was concluded that no influence on the outcomes of the coast downs was found since the road load determination is done by looking at the speed intervals only. Location data is not used in road load determination.

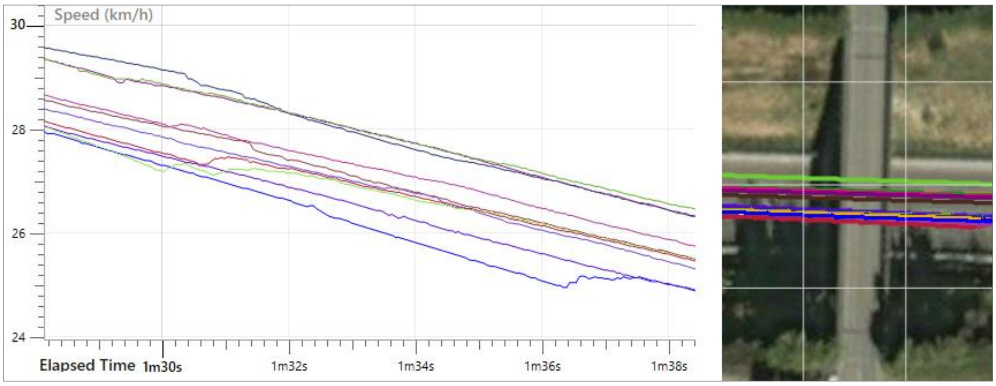

Figure 3.5: Screenshot VBOX software showing irregularities in speed traces and aerial footage.

3.6.4 Braking during coast down testing

During the completion of the testing program an impracticality regarding braking actions after vehicle warm-up was experienced. Especially at the Lommel PG it is practically impossible not to brake since a change in test track is made between warm-up and coast down testing and the track is laid out such that sharp U-turns at both ends have to be made. Therefore, braking is needed to reduce speed sufficiently. Next to that, both at the Lommel PG and IDIADA PG, situations frequently occurred where a small braking correction had to be made because of other traffic or other external influences resulting in an invalid run.

Braking actions during coast down testing may cause parasitic braking, having an influence on the vehicle's rolling resistance. See, for example, TNO Report 2015 R10955, *Correction algorithms for WLTP chassis dynamometer and coast-down testing*. Presumably for this reason Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.3.1.3.2 states that 'the vehicle brakes shall not be operated during coast down'. Regarding vehicle warm-up it is also stated in Section 4.2.4.1.1 that after the initial braking action prior to vehicle warm-up 'there shall be no further *actuation* or manual adjustment of the braking system'. [Emphasis added]

As explained from experience during testing it is, however, practically impossible to meet the requirements regarding braking after vehicle warm-up from the WLTP legislation. However, Section 4.2.4.1.1 of the legislation also states that 'at the request of the manufacturer and upon approval of the approval authority, the brakes may also be activated after the warm-up (…) if necessary'. This raises the question why it is in the first place not allowed to brake after warm-up and in between coast down runs.

3.6.5 *Other traffic on the test track*

During coast down testing on a test track without exclusive usage it might occur that other vehicles are also using the track. It can even occur that vehicles driving in other lanes of the track are being overtaken or vice versa, without making any steering corrections. How to deal with these kind of situations is not clearly addressed in the legislation. A remark is made in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.3.1.4.3 ‘on external factors or driver actions that influence the road load test’, but without specification this is freely interpretable.

At both facilities situations occurred where other vehicles got in the way because of unforeseen braking actions or lane changes that could not be anticipated at the start of a coast down. Situations where other traffic possible influenced the results, are marked as fail and discarded from the analysis. Runs were repeated until at least the regulatory accuracy was met.

3.7 Test results

From the coast down tests the road load of the vehicles was determined using the test reports exported from the VBOX software and the weather station data from both PGs. For each coast down test the road load forces per speed bin, the road load curve and road load coefficients were determined from the coast down time averages per speed bin using the method described in 2017/1151 Annex XXI Sub-Annex 4 Section 4.3.1.4.4. The road load curves and road load coefficients were corrected to reference conditions and measurement conditions as described in Regulation 2017/1151 Annex XXI Sub-Annex 4 Sections 4.5 to 4.5.5.2.

An additional correction on the road load coefficients was performed for all Ford results to correct for the way the active grill was handled during the coast down tests. This correction procedure was determined and approved by the GTAA according to Ford. These tests can be used to verify the manufacturer's instructions.

Considerations on test mass

In the road load tests presented here, all vehicles were tested with a test mass matching the CoC value. Weight was added to the vehicle to reach this test mass, so that the tests could be focussed on assessing the impact of resistance factors on in-service verification of road load. However, besides rolling resistances and air drag, vehicle mass influences the road load and is an important determinant of the CO_2 emissions measured on the chassis dynamometer. Checking the in-service vehicle mass and comparing this with the CoC test mass is therefore in principle relevant. But this comparison is difficult in practice. The test mass includes the weight of the driver and a default load, but is not necessarily equal to the empty vehicle mass, mentioned on the CoC, plus the weight of the driver and default load. In addition the in-service vehicle may contain elements (e.g. spare tyre, tyre pump, floor mats) of which it cannot not be determined whether they are included in the CoC test mass. Checking the in-service vehicle mass against the CoC test mass therefore cannot be done exactly. A rough check is possible by comparing the COC value with the tested empty vehicle mass plus a reasonable bandwidth for driver weight and load.

Considerations on comparing road load coefficients

The corrected road load coefficients obtained for all default and extended coast down tests can in theory be compared with the road load coefficients reported in the vehicles' CoCs. The regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.3.1.4.4. prescribes the method for obtaining the road load coefficients from the coast down results. However this is done by fitting of the test results and can, as is seen in Figure 3.6, yield polynomial fits with similar accuracy and forces in the velocity range but very different values for especially the coefficients f1 and f2. A direct comparison of the road load coefficients is therefore hard in practice.[5] The results of the coast down tests are therefore presented graphically (Figure 3.7 to Figure 3.10) as the cycle energy demand (CED) calculated from the road load coefficients and test mass, according to Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5 and applying the corresponding WLTC speed trace for all vehicles (see also section 4.3.1).

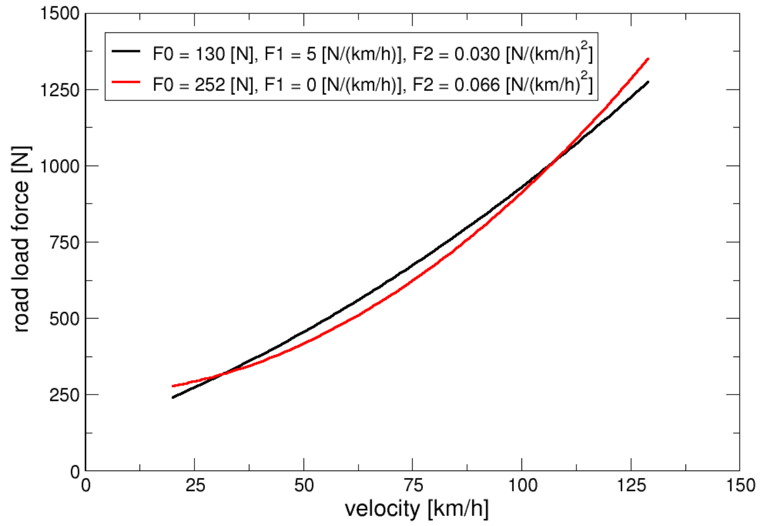

Figure 3.6: An example of about 100% variations in the road load coefficients leading only to minor variations, less than 10%, in the actual road load, in the coast down velocity range.

In tables accompanying the graphs (Table 3.12 to Table 3.15) the road load forces at 25 and 100 km/h, called F25 and F100 respectively, are presented. These forces are calculated by application of the road load equation (Regulation 2017/1151 Annex XXI, Sub-Annex 4 Section 2.4) and using the corrected road load coefficients. Furthermore the road load results are converted to corresponding CO_2 emissions by application of the Interpolation Method, as described in Paragraph 4.4.

3.7.1 *Ford Fiesta: all coast down tests*

Table 3.12 presents the coast down test results of all test with the Ford Fiesta's, next to CoC reference values. All Default and Extended tests (according CoC specification) per vehicle are combined. The average outcomes and corresponding variations for those tests are presented.

[5] See also TNO Report 2015 R10955 *Correction algorithms for WLTP chassis dynamometer and coast-down testing*, Appendix D.2.

Table 3.12: Overview of coast down test results for the Ford Fiesta's to determine the IS-RL. For the tests with the vehicles according to CoC specification results of all default and extended tests per vehicle M1, M2 and H are combined and results are presented as average, absolute standard deviation and standard deviation as percentage of the average. The velocities of 25 km/h and 100 km/h are taken as reference.

GENERAL INFORMATION				ROAD LOAD: F25*		ROAD LOAD: F100*	
#	Test #	Veh.	Description	CoC	Measured	CoC	Measured
[-]	[-]	[-]	[-]	[N]	[N]	[N]	[N]
1	-	M1	CoC Specification	153.33	150.30 ± 3.73 (2.5%)	475.15	475.91 ± 6.05 (1.3%)
2	-	M2	CoC Specification	153.24	145.19 ± 6.91 (4.8%)	475.07	473.49 ± 17.02 (3.6%)
3	-	H	CoC Specification	176.67	165.59 ± 6.22 (3.8%)	515.94	512.59 ± 9.08 (1.8%)
4	L15	M2	Added Weight	159.23	147.41	481.05	470.45
5	L16	M2	Different Tyres	174.02	148.62	495.85	486.70
6	L19	H	Added Weight	182.17	169.11	521.44	519.27
7	L20	H	Aero. Grill normal	176.67	155.76	515.94	499.78
8	L21	H	Aero. Grill closed	176.67	150.99	515.94	479.74

GENERAL INFORMATION				CYCLE ENERGY DEMAND**		CO_2 emission***	
#	Test #	Veh.	Description	CoC	Measured	CoC	Measured
[-]	[-]	[-]	[-]	[kWh]	[kWh]	[g/km]	[g/km]
1	-	M1	CoC Specification	3.09	3.09 ± 0.03 (0.9%)	129	127.89 ± 0.82 (0.6%)
2	-	M2	CoC Specification	3.09	3.07 ± 0.07 (2.4%)	129	127.36 ± 2.30 (1.8%)
3	-	H	CoC Specification	3.29	3.26 ± 0.04 (1.3%)	134	133.16 ± 1.34 (1.0%)
4	L15	M2	Added Weight	3.17	3.12	130.48	128.70
5	L16	M2	Different Tyres	3.20	3.13	131.25	129.03
6	L19	H	Added Weight	3.36	3.33	136.21	135.34
7	L20	H	Aero. Grill normal	3.29	3.20	134	131.21
8	L21	H	Aero. Grill closed	3.29	3.11	134	128.65

* Road load values in blue are hypothetical reference values (in absence of a CoC reference), which have been calculated based on the known change in test mass and RRC. Variations in aerodynamic effects, e.g. the active grill or the effect of tyres on the aerodynamic drag, have not been taken into account, as they were unknown.

** The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5.

*** CO_2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

The coast down results of the combined Default and Extended test per vehicle, see rows #1 to #3 in Table 3.12, show a typical variation less than 5%, less than 2.5% and less than 2% for the road load force, CED and CO_2 respectively. On average the measured road load forces at 25 and 100 km/h are in the order of 1 to 11 N lower than the reference values from the CoC, for all three Fords. This slightly lower road load force translates on average to CO_2 values in the order of 1 to 2 g/km lower than the reference CoC CO_2 values. The CED results are presented in more detail in Figure 3.7.

In Table 3.12 the measured road load, expressed in the forces F25 and F100 and CED, for the tests with vehicles according to CoC specifications, are compared to the reference values reported in the CoC. For the variation tests, i.e. the Added weight, Different tyres and Aerodynamics tests in which modifications were made to the vehicles, the measured road loads and CED values are compared against hypothetical reference values, calculated from the known change in test mass and RRC. In that calculation impacts on aerodynamics, e.g. from the active grill or the effect of tyres on the aerodynamic drag, have not been taken into account.

The CED results for all coast down tests of the Ford Fiesta's, as presented in Table 3.12, are visualized in Figure 3.7. The reference CED values and measured CED values are plotted on the x- and y-axis respectively. The combined repeat tests are presented as a group per vehicle with the whiskers presenting the variation.

To clarify the difference between the CED results and the CoC and hypothetical reference CED values, the IP family line has been displayed in the figure (dashed black line), as well as the Vehicle Low (VL) and Vehicle High (VH) of the IP family. Any test results below this line indicates the measured road load is below the (CoC or estimated) reference road load and vice versa.

The relative difference of the displayed CED for each test compared to the value on the CED IP family line is displayed in the smaller bottom figure. For example a CED located directly on the CED IP family line would be displayed in the bottom graph on the 0% line.

From Figure 3.7 it is seen that for the Ford's on average the road load expressed in CED for the repeat tests (Default and Extended tests) is below the IP family line, between 0 and 1% lower. The displayed variation in repeat tests, however, shows that some tests yielded road load values above the IP family line. A more in dept analysis of the repeat tests is found in the following section.

The measured CED values for the added weight and different tyres tests are between 1 and 2% lower compared to the estimated reference CED values. A more in dept analysis of the results of the aerodynamics tests is presented in section 3.8.3.

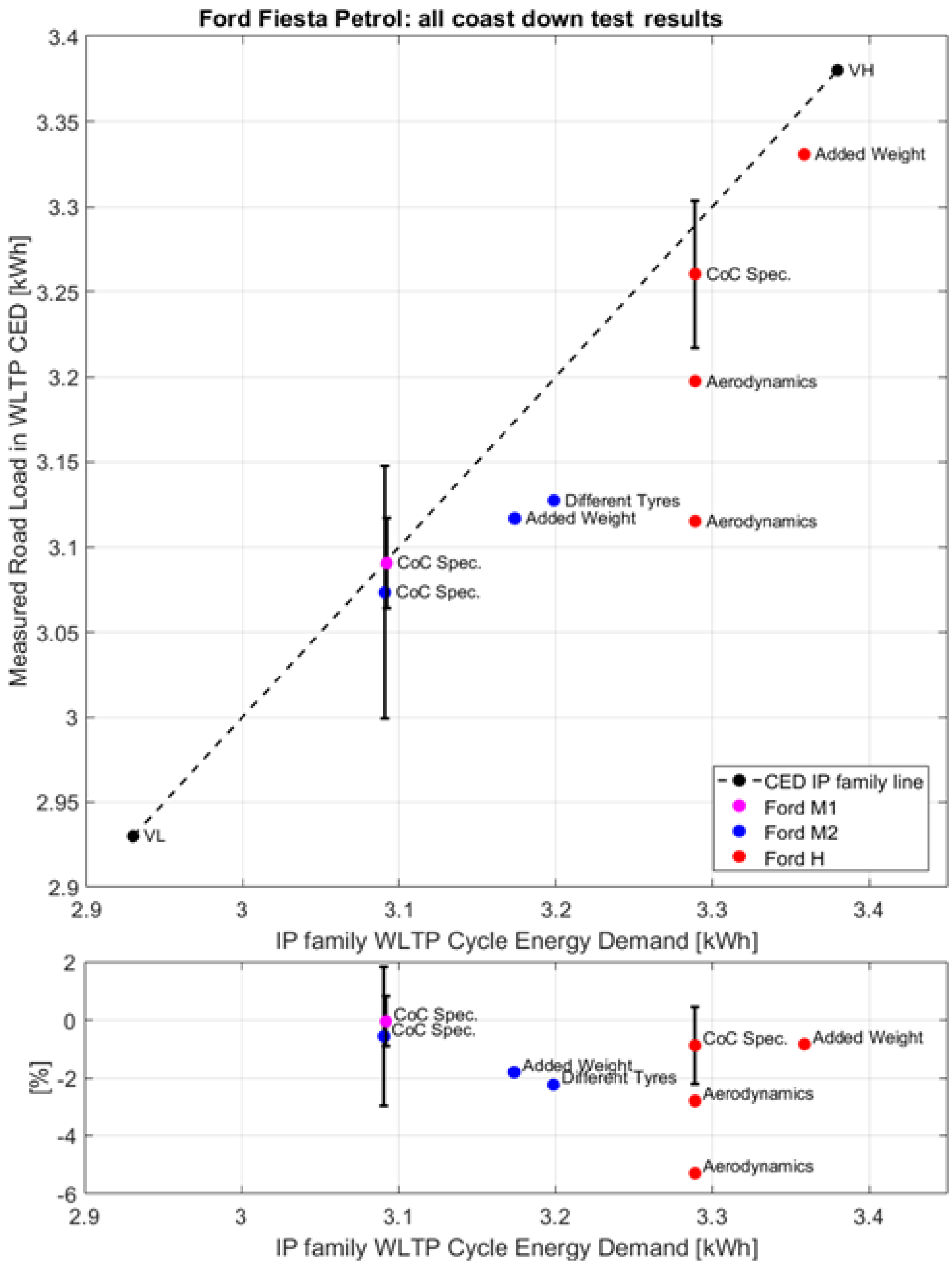

Figure 3.7: Ford Fiesta: all WLTP road-load test results translated into WLTP Cycle Energy Demand. The different circles of the same colour are measurements performed on the same vehicle but with different mass, tyres, or aerodynamics. The error bars indicate the standard deviation in the measurements with the vehicles according to CoC specifications. The upper graph presents the absolute measured values. The lower graph indicates the relative difference of the measured CEDs from the CEDs according to the IP family line.

3.7.2 *Ford Fiesta: repeat tests*

In Table 3.13 the individual test results of the repeat tests (Default and Extended test) for the three Ford vehicles are presented, in a fashion similar to Table 3.12.

Table 3.13: Individual coast-down test results of all default and extended tests (CoC Specification) for the Ford Fiesta's sorted by vehicle and test configuration. A distinction is made between the proving grounds.

GENERAL INFORMATION					RL FORCE: F25		RL FORCE: F100	
#	Test #	Veh.	Description	Test track	CoC	Measured	CoC	Measured
[-]	[-]	[-]	[-]	[-]	[N]	[N]	[N]	[N]
1	L11	M1	Default	LOMMEL	153.33	153.97	475.15	472.77
2	I7	M1	Default	IDIADA	153.33	152.16	475.15	481.84
3	L12	M1	Extended	LOMMEL	153.33	145.36	475.15	469.00
4	I8	M1	Extended	IDIADA	153.33	149.70	475.15	480.05
5	L13	M2	Default	LOMMEL	153.24	138.17	475.07	463.06
6	I9	M2	Default	IDIADA	153.24	152.81	475.07	495.02
7	L14	M2	Extended	LOMMEL	153.24	140.68	475.07	457.10
8	I10	M2	Extended	IDIADA	153.24	149.11	475.07	478.77
9	L17	H	Default	LOMMEL	176.67	162.10	515.94	506.95
10	I11	H	Default	IDIADA	176.67	165.40	515.94	507.30
11	L18	H	Extended	LOMMEL	176.67	160.46	515.94	510.06
12	I12	H	Extended	IDIADA	176.67	174.40	515.94	526.04

GENERAL INFORMATION					CED*		CO_2 emissions**	
#	Test #	Veh.	Description	Test track	CoC	Measured	CoC	Measured
[-]	[-]	[-]	[-]	[-]	[kWh]	[kWh]	[g/km]	[g/km]
1	L11	M1	Default	LOMMEL	3.09	3.08	129	127.66
2	I7	M1	Default	IDIADA	3.09	3.12	129	128.69
3	L12	M1	Extended	LOMMEL	3.09	3.06	129	126.85
4	I8	M1	Extended	IDIADA	3.09	3.11	129	128.38
5	L13	M2	Default	LOMMEL	3.09	3.02	129	125.81
6	I9	M2	Default	IDIADA	3.09	3.17	129	130.23
7	L14	M2	Extended	LOMMEL	3.09	3.00	129	125.22
8	I10	M2	Extended	IDIADA	3.09	3.10	129	128.17
9	L17	H	Default	LOMMEL	3.29	3.23	134	132.33
10	I11	H	Default	IDIADA	3.29	3.24	134	132.53
11	L18	H	Extended	LOMMEL	3.29	3.24	134	132.61
12	I12	H	Extended	IDIADA	3.29	3.32	134	135.15

* The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5.

** CO_2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

As seen from Table 3.13 the variation between repeat tests can be significant. There are several comparisons possible: repeat test with the same vehicle on the same track, the same vehicle on different tracks, different vehicles of the same model on the same track and on different tracks. The most comparable tests, i.e. the same vehicle on the same track (default and extended), show already substantial variation. For each vehicle and each track, there are two tests available; six pairs in total. This variation results in a difference in road load force at 25 km/h between -16 and +1N, and at 100 km/h between -18 and +20N, compared to the reference CoC road load. This difference in road load compared to CoC values is translated into differences in CED bandwidth and CO_2 of -0.09 kWh to +0.08 kWh and -3.8 to +1.2 g/km respectively.

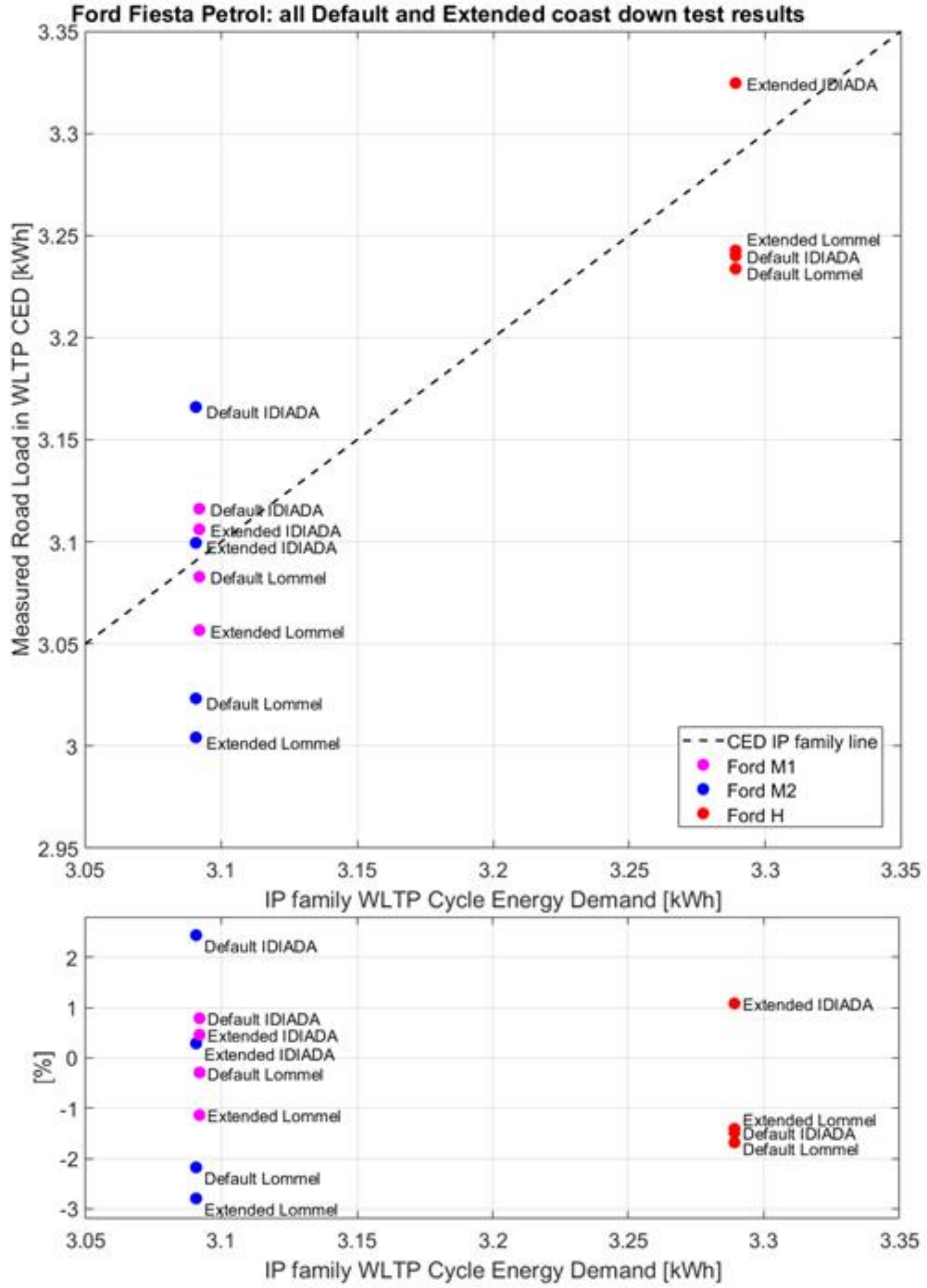

Figure 3.8: Ford Fiesta: Results of coast down tests, expressed in WLTP Cycle Energy Demand, with vehicles according to their CoC specifications. Different tests relate to different numbers of test repetitions and different test tracks. The upper graph presents the absolute measured values. The lower graph indicates the relative difference of the measured CEDs from the CEDs according to the IP family line.

In a similar fashion to Figure 3.7 the CED values of Table 3.13 have been plotted in Figure 3.8. In this way the difference between tests performed at different test tracks and with a different test length, i.e. Default and Extended tests, is visualized clearly.

From Figure 3.8 it is seen that in general for the Ford vehicles the Default and Extended tests performed at the Lommel PG result in a lower road load (expressed in CED) than the tests performed at the IDIADA PG. Next to that the Extended tests give a lower CED for the Ford M1 and M2 than the Default test, however, this is not the case for the Ford H.
Finally, from the bottom graph it is concluded that over all repeat coast down tests with the Ford Fiesta's the road load results vary between -3 and +2.5% compared to the reference CoC road load, both expressed in CED. This corresponds to the earlier mentioned rounded of -0.09 kWh to +0.08 kWh bandwidth and -3.8 to + 1.2 g/km CO_2 respectively.

3.7.3 *Volvo XC60: all coast down tests*

Table 3.14 presents the coast down test results of all test with the Volvo's, next to CoC reference values. All Default and Extended tests (according CoC specification) per vehicle are combined. The average outcomes and corresponding variations for those tests are presented.

Table 3.14: Overview of coast down test results for the Volvo XC60's. For the tests with the vehicles according to CoC specification results of all default and extended tests per vehicle M1, M2 and L are combined and results are presented as average, absolute standard deviation and standard deviation as percentage of the average.

GENERAL INFORMATION				ROAD LOAD: F25*		ROAD LOAD: F100*	
#	Test #	Veh.	Description	CoC	Measured	CoC	Measured
[-]	[-]	[-]	[-]	[N]	[N]	[N]	[N]
1	-	M1	CoC Specification	200.2	233.59 ± 8.21 (3.5%)	646.6	681.25 ± 22.46 (3.3%)
2	-	M2	CoC Specification	204.1	230.16 ± 11.0 (4.8%)	653.2	697.20 ± 24.27 (3.5%)
3	-	L	CoC Specification	166.2	200.80 ± 5.62 (2.8%)	618.9	648.20 ± 9.01 (1.4%)
4	L7	L	Added Weight	179.01	205.67	631.68	641.94
5	L8	L	Different Tyres	200.31	215.97	652.97	690.15
6	L9	L	Combination High	215.70	222.32	668.36	681.73

GENERAL INFORMATION				CYCLE ENERGY DEMAND**		CO_2 emission***	
#	Test #	Veh.	Description	CoC	Measured	CoC	Measured
[-]	[-]	[-]	[-]	[kWh]	[kWh]	[g/km]	[g/km]
1	-	M1	CoC Specification	4.39	4.57 ± 0.10 (2.1%)	184	189.30 ± 2.67 (1.4%)
2	-	M2	CoC Specification	4.45	4.65 ± 0.11 (2.3%)	186	191.70 ± 2.98 (1.6%)
3	-	L	CoC Specification	4.24	4.40 ± 0.04 (0.9%)	180	184.52 ± 1.15 (0.6%)
4	L7	L	Added Weight	4.44	4.51	185.70	187.71
5	L8	L	Different Tyres	4.41	4.57	185.03	189.46
6	L9	L	Combination High	4.62	4.68	190.87	192.48

* Road load values in blue are hypothetical reference values (in absence of a CoC reference), which have been calculated based on the known change in test mass and RRC. Variations in aerodynamic effects, e.g. the active grill or the effect of tyres on the aerodynamic drag, have not been taken into account, as they were unknown.
** The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5.
*** CO_2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

The coast down results of the combined Default and Extended test per vehicle, see rows #1 to #3 in Table 3.14, show a typical variation less than 5%, less than 2.5% and less than 2% for the road load force, CED and CO_2 respectively. On average the measured road load forces at 25 and 100 km/h are in the order of 25 to 45N higher than the reference values according to the CoC, for all three Volvo's. This significant higher road load force translates on average to CO_2 values in the order of 5 g/km higher than the reference CoC CO_2 values. The CED results are presented in more detail in Figure 3.9.

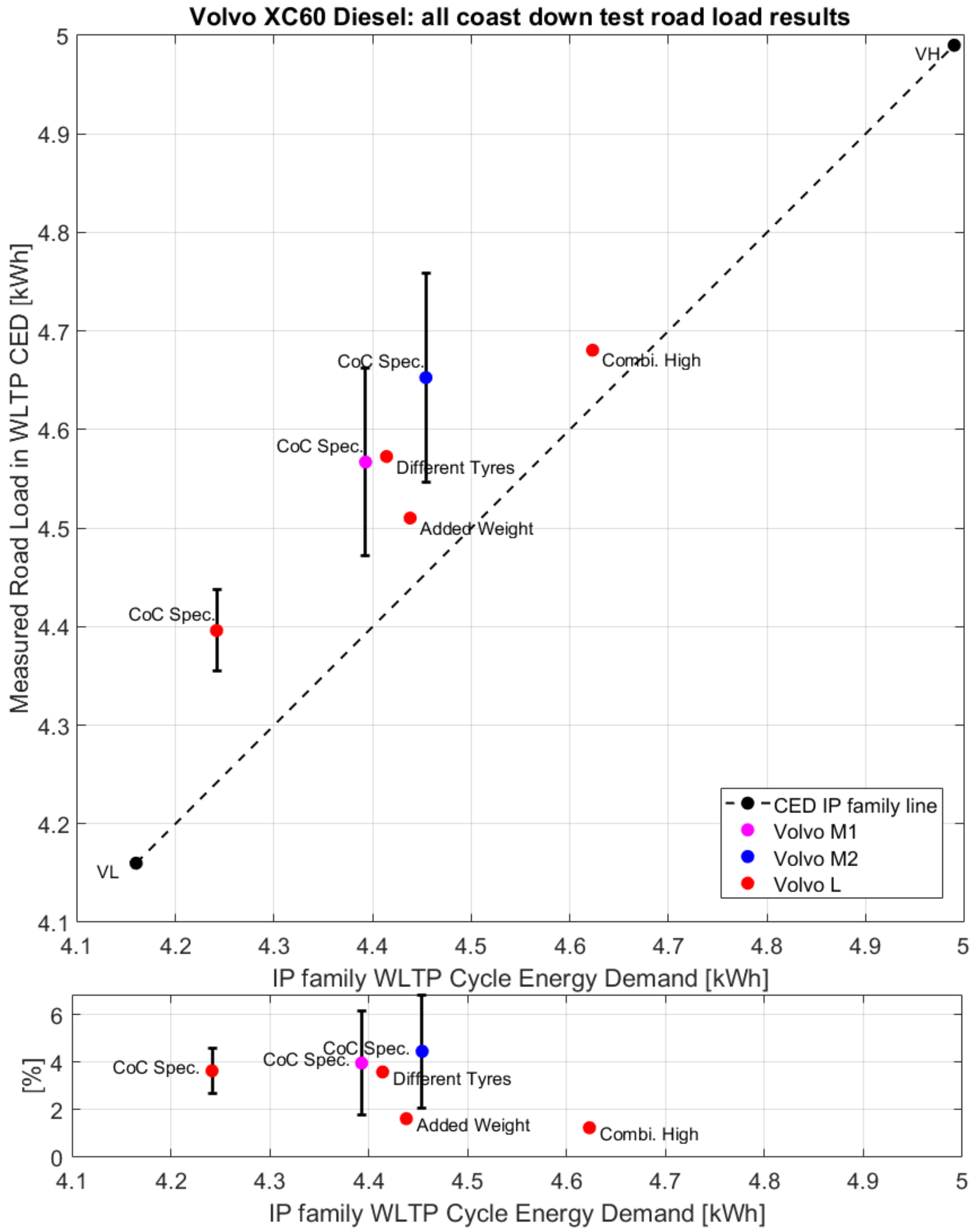

Figure 3.9: Volvo XC60: all WLTP road-load test results translated into WLTP Cycle Energy Demand. The different circles of the same colour are measurements performed on the same vehicle but with different mass, tyres, or aerodynamics. The error bars indicate the standard deviation in the measurements with the vehicles according to CoC specifications. The upper graph presents the absolute measured values. The lower graph indicates the relative difference of the measured CEDs from the CEDs according to the IP family line.

As previously explained in paragraph 3.7.1 the measured road load, expressed in the forces F25 and F100 and CED, for the tests with vehicles according to CoC specifications, are compared to the reference values reported in the CoC. For the variation tests, i.e. the Added weight, Different tyres and Aerodynamics tests in which modifications were made to the vehicles, the measured road loads and CED values are compared against hypothetical reference values, calculated from the known change in test mass and RRC. In that calculation impacts on aerodynamics, e.g. from the active grill or the effect of tyres on the aerodynamic drag, have not been taken into account.

The CED results for all coast down tests of the Volvo's, as presented in Table 3.14, are visualized in Figure 3.9. This is done in similar fashion as Figure 3.7.

From Figure 3.9 it is seen that on average the road load expressed in CED for the repeat tests (Default and Extended tests) is around 4% ± 2% above the IP family line. A more in depth analysis of the repeat tests is found in the following section. The measured CED for the added weight and different tyres tests is between 1 and 2% higher compared to the estimated reference CED values. A more in depth analysis of the results of these tests is found in section 3.8.

3.7.4 Volvo XC60: repeat tests

In Table 3.15 the individual test results of the repeat tests (Default and Extended test) for the three Volvo vehicles are presented, in a similar fashion to Table 3.12.

As seen from Table 3.15 the variation between repeat tests can be significant. This variation results in a difference in road load force at 25 km/h of 12 to 40N and at 100 km/h of 7 to 64N higher compared to the reference CoC road load. This difference in road load compared to CoC values is translated into differences in CED up to 0.3 kWh higher and differences in CO_2 between 1.5 to 8 g/km higher compared to the reference CoC values.

In similar fashion to Figure 3.9 the CED values of Table 3.15 have been plotted in Figure 3.10. In this way the difference between tests performed at different test tracks and with a different test length, i.e. Default and Extended tests, is visualized clearly.

Table 3.15: Individual coast down test results of all default and extended tests (CoC Specification) for the Volvo XC60's, sorted by vehicle and test configuration. A distinction is made between the proving grounds.

GENERAL INFORMATION					RL FORCE: F25		RL FORCE: F100	
#	Test #	Veh.	Description	Test track	CoC	Measured	CoC	Measured
[-]	[-]	[-]	[-]	[-]	[N]	[N]	[N]	[N]
1	L3	M1	Default	LOMMEL	200.22	236.68	646.60	672.63
2	I3	M1	Default	IDIADA	200.22	238.55	646.60	704.02
3	L4	M1	Extended	LOMMEL	200.22	221.32	646.60	653.91
4	I4	M1	Extended	IDIADA	200.22	237.79	646.60	694.43
5	L1	M2	Default	LOMMEL	204.10	226.33	653.20	694.70
6	I1	M2	Default	IDIADA	204.10	241.20	653.20	716.87
7	L2	M2	Extended	LOMMEL	204.10	216.56	653.20	663.84
8	I2	M2	Extended	IDIADA	204.10	236.55	653.20	713.37
9	L5	L	Default	LOMMEL	166.24	200.67	618.90	643.63
10	I5	L	Default	IDIADA	166.24	204.30	618.90	655.85
11	L6	L	Extended	LOMMEL	166.24	192.92	618.90	637.72
12	I6	L	Extended	IDIADA	166.24	205.32	618.90	655.58

GENERAL INFORMATION					CED*		CO_2 emissions**	
#	Test #	Veh.	Description	Test track	CoC	Measured	CoC	Measured
[-]	[-]	[-]	[-]	[-]	[kWh]	[kWh]	[g/km]	[g/km]
1	L3	M1	Default	LOMMEL	4.39	4.54	184	188.48
2	I3	M1	Default	IDIADA	4.39	4.66	184	191.92
3	L4	M1	Extended	LOMMEL	4.39	4.45	184	185.93
4	I4	M1	Extended	IDIADA	4.39	4.62	184	190.87
5	L1	M2	Default	LOMMEL	4.45	4.64	186	191.27
6	I1	M2	Default	IDIADA	4.45	4.74	186	194.21
7	L2	M2	Extended	LOMMEL	4.45	4.51	186	187.67
8	I2	M2	Extended	IDIADA	4.45	4.72	186	193.65
9	L5	L	Default	LOMMEL	4.24	4.38	180	184.04
10	I5	L	Default	IDIADA	4.24	4.43	180	185.47
11	L6	L	Extended	LOMMEL	4.24	4.35	180	183.12
12	I6	L	Extended	IDIADA	4.24	4.43	180	185.47

* The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5.

** CO_2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

From Figure 3.10 it is seen that for the Volvo's the Default and Extended tests performed at the Lommel PG result in a lower road load (expressed in CED) than the tests performed at the IDIADA PG. Next to that the Extended tests give a lower CED for the Volvo M1 and M2 than the Default test, however this is not the case for the Volvo L. Both observations are in line with the observations for the Ford repeat tests. Finally from the bottom graph it is concluded that over all repeat coast down tests with the Volvo's the road load results are between 1 and 6.5% higher than the reference CoC road load, both expressed in CED. This corresponds to the earlier mentioned rounded 0.3 kWh increase in CED and 1.5 to 8 g/km higher CO_2 values respectively.

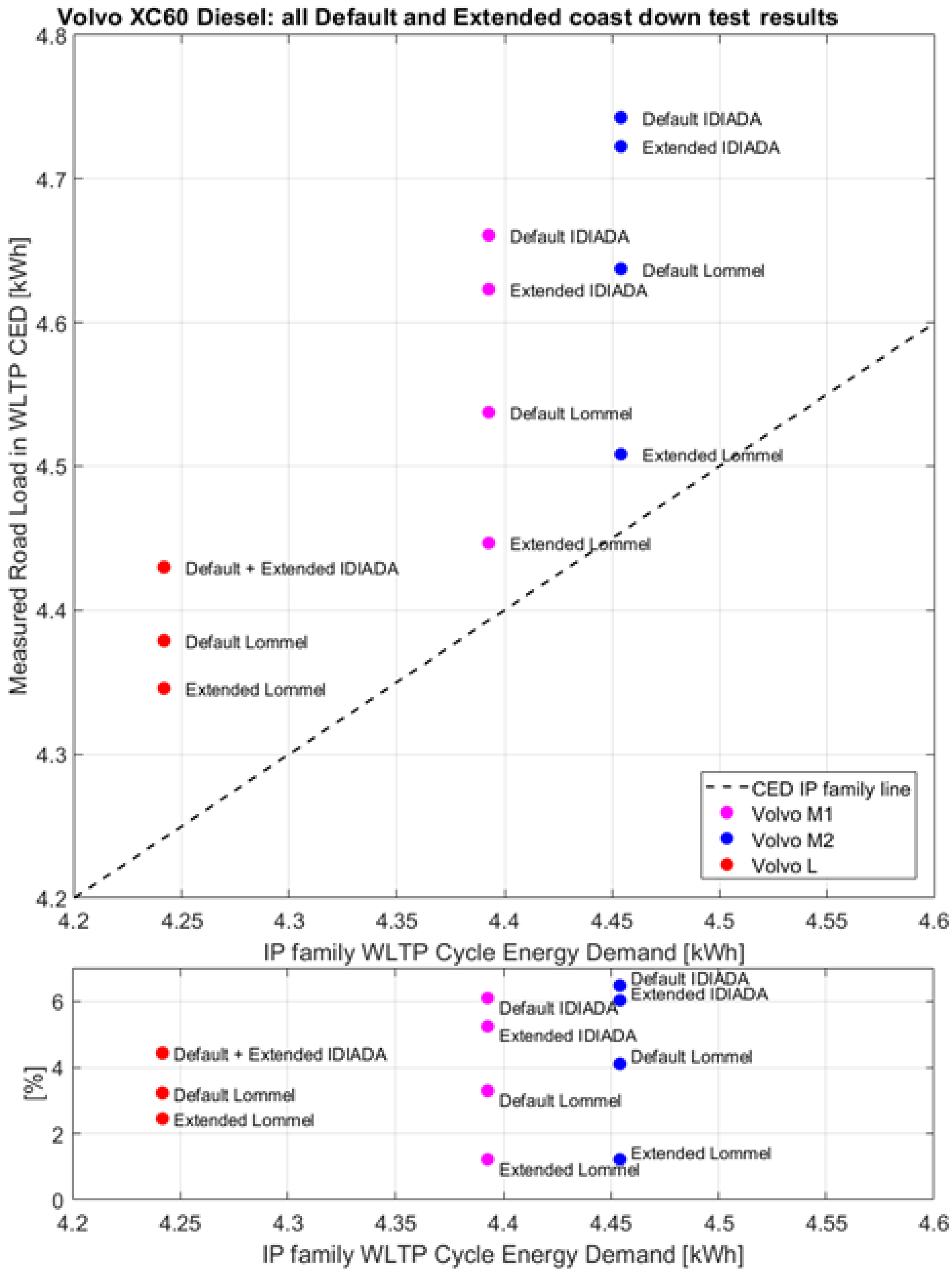

Figure 3.10: Volvo XC60: Results of coast down tests, expressed in WLTP Cycle Energy Demand, with vehicles according to their CoC specifications. Different tests relate to different numbers of test repetitions and different test tracks. The upper graph presents the absolute measured values. The lower graph indicates the relative difference of the measured CEDs from the CEDs according to the IP family line.

3.8 Impact of variation of vehicle parameters

In the WLTP physical principles are used to relate vehicle parameters like test mass and rolling resistance to CO_2 emissions for different vehicles in an interpolation family. Therefore, these vehicle parameters and the deviations from the one-to-one relation are investigated as it may affect the uncertainty.

3.8.1 Effect of test mass

The effect of the test mass on the road load force determined using the coast down test procedure, as described in Regulation 2017/1151 Annex XXI Sub-Annex 4, has been investigated by performing coast down tests with increased vehicle test weight. The road load force and cycle energy demand outcomes of these Added weight tests (see Paragraph 3.5.3) have been compared to the Default and Extended test results.

In total three Added weight tests were performed at the Lommel PG with the Volvo L and Ford M2 and H vehicles, as shown in Table 3.11. The results are compared to the average of the Default and Extended Tests performed at the same test facility to rule out the effect of the test track surface texture and layout as a source of variation.

The corrected (final) test masses (TM), road load forces at 25 and 100 km/h (F25 and F100) and cycle energy demands (CED) of the average of the Default and Extended Tests and Added weight tests of the three vehicles are shown in Table 3.16, Table 3.17 and Table 3.18.

Table 3.16: Volvo L 'CoC specification' test average vs. Added weight test, all performed at the Lommel test location. ΔCED/ΔTM is the ratio of the relative difference in CED and the relative difference in test mass.

Test description	TM [kg]	F25 [N]	F100 [N]	CED [kWh]	ΔCED/ΔTM
Avg. of Default and Extended test	2018.00	196.80	640.68	4.36	
Added weight test	2172.00	205.67	641.94	4.51	
Difference	7.6%	4.5%	0.2%	3.4%	0.44

Table 3.17: Ford M2 'CoC specification' test average vs. Added weight test, all performed at the Lommel test location.

Test description	TM [kg]	F25 [N]	F100 [N]	CED [kWh]	ΔCED/ΔTM
Avg. of Default and Extended test	1312.00	139.43	460.08	3.01	
Added weight test	1375.00	147.41	470.45	3.12	
Difference	4.8%	5.7%	2.3%	3.4%	0.71

Table 3.18: Ford H 'CoC specification' test average vs. Added weight test, all performed at the Lommel test location.

Test description	TM [kg]	F25 [N]	F100 [N]	CED [kWh]	ΔCED/ΔTM
Avg. of Default and Extended test	1325.00	161.28	508.50	3.24	
Added weight test	1375.00	169.11	519.27	3.33	
Difference	3.8%	4.9%	2.1%	2.9%	0.76

For the Volvo L an increase of test mass of 7.6% resulted in an increase in CED of 3.4%, as shown in Table 3.16. A relative increase in test mass translates to less than half as much relative increase in CED (ΔCED/ΔTM = factor 0.44).

For the Ford M2 and H the increase of TM with 4.8 and 3.8% respectively resulted in an increase in CED of 3.4 and 2.9% respectively, as can be seen in Table 3.17 and Table 3.18. A relative increase in test mass translates to around three quarters as much relative increase in CED for both Ford's (factors 0.71 and 0.76).

The observed relation between increase in CED and increase in TM is different for the two vehicle types (Ford and Volvo). The different vehicle characteristics of the two families are assumed to be the reason for that. This assumption is confirmed by the two Fords, where the observed relation is in line.

Furthermore the relative increase of road load force due to an increase in test weight at a low speed of 25 km/h is significantly higher than at a high speed of 100 km/h. This can be explained from the fact that test mass has an influence on the rolling resistance of the vehicle and not on the air drag resistance. Therefore the effect of increased test mass is relatively stronger at low driving speeds.

3.8.2 Effect of tyres

The effect of the tyre rolling resistance on the road load determined using the coast down test procedure, as described in Regulation 2017/1151 Annex XXI Sub-Annex 4, has been investigated by performing coast down tests with different tyres fitted to the vehicles. Similar to the method in section 3.8.1, the road load force and cycle energy demand outcomes of these Different tyres tests (see Paragraph 3.5.4) have been compared to the average of the Default and Extended test results. In total two Different tyres tests were performed at the Lommel PG with the Volvo L and Ford M2 vehicles, as shown in Table 3.11.

Table 3.19 presents the Energy Efficiency Class (Tyre Label) of the tyres fitted to the vehicle during the different tests as well as the corresponding Rolling Resistance Coefficient (RRC), as stated in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.2.2.1. Together with the test mass of the vehicle during coast down testing the theoretical rolling resistance force (RR) of the tyres is determined.

It should be mentioned that the exact RRC of the tyres fitted to the vehicles was not known since only the Tyre Label of the tyres is publicly available. The fixed RRC values corresponding to the Tyre Labels are derived from RRC intervals defined in Regulation (EC) No 1222/2009.

Table 3.19: Fitted tyres at default, extended and different tyres tests.

Vehicle	Test Description	LABEL	RRC	TM	RR
[-]	[-]	[-]	[kg/tonne]	[kg]	[N]
Volvo L	Default	A	5.9	2018	117
Volvo L	Extended	A	5.9	2018	117
Volvo L	Different Tyres	B	7.1	2018	141
Ford M2	Default	C	8.4	1312	108
Ford M2	Extended	C	8.4	1312	108
Ford M2	Different Tyres	E	9.8	1312	126

The RR, road load forces at 25 and 100 km/h (F25 and F100) and cycle energy demands (CED) of the Default and Extended tests were averaged and compared with the Different tyres tests, ending up in the overviews of Table 3.20 and Table 3.21.

Table 3.20: Volvo L ‘CoC specification’ test average vs. Different Tyres test, all performed at the Lommel test location. ΔCED/ΔRR is the ratio of the relative difference in CED and the relative difference in rolling resistance.

Test description	RR [N]	F25 [N]	F100 [N]	CED [kWh]	ΔCED/ΔRR
Avg. of Default and Extended test	117.00	196.80	640.68	4.36	
Different Tyres test	141	215.97	690.15	4.57	
Difference	20.5%	9.7%	7.7%	4.8%	0.24

Table 3.21: Ford M2 'CoC specification' test average vs. Different Tyres test, all performed at the Lommel test location.

Test description	RR [N]	F25 [N]	F100 [N]	CED [kWh]	ΔCED/ΔRR
Avg. of Default and Extended test	108.00	139.43	460.08	3.01	
Different Tyres test	126	148.62	486.70	3.13	
Difference	16.7%	6.6%	5.8%	3.8%	0.23

For the Volvo L an increase of RR of 20.5% results in an increase in CED of 4.8%, as seen in Table 3.20. A relative increase in rolling resistance force translates to just less than a quarter as much relative increase in CED (ΔCED/ΔRR = factor 0.24).

For the Ford M2 an increase of RR of 16.7% results in an increase in CED of 3.8%, as seen in Table 3.21. A relative increase in rolling resistance force translates to just less than a quarter as much relative increase in CED (factor 0.23).

The observed relation between increase in CED due to an increase in RR is equal for the two vehicle types (Ford and Volvo). In contrast to the effect of test mass on the cycle energy demand, the effect on the cycle energy demand of changed rolling resistance due to different tyres is observed to be independent of the vehicle family characteristics.

The relatively large increase of the theoretically determined RR force is not reflected in a similar increase of the measured road load force at a low speed of 25 km/h, although it could be argued that it should, since the rolling resistance of the tyres should ideally have a one-to-one effect on f0. The fact that the exact RRC of the tyres is not known could give an explanation for this inconsistency.

3.8.3 *Effect of active aerodynamics*

The effect of the active grill on the road load determination has been investigated by performing coast down tests with the active grill of the Ford Fiesta H vehicle in fixed open, normal (as-is) and fixed closed operating position. The relevance of the grill setting is clear from these results. The results from those tests are presented in Table 3.22 and Table 3.23.

Table 3.22: Ford H Extended and Aerodynamics tests results.

Grill Setting	Test Mass CoC	Test Mass Average	F25	F100	CED	ΔCED vs. NORMAL GRILL	ΔCED vs. NORMAL GRILL
[-]	[kg]	[kg]	[N]	[N]	[kWh]	[kWh]	[%]
OPEN	1325	1330.5	160.46	510.06	3.24	0.04	1.4%
NORMAL	1325	1331.5	155.76	499.78	3.20	-	-
CLOSED	1325	1324.5	150.99	479.74	3.11	-0.09	-2.6%

Table 3.23: Ford H Extended and Aerodynamics tests conditions.

Grill Setting	Asphalt Temp Average	Ambient Temp Average	Humidity Average	Pressure Average	Air density Average	Wind Average	Tyre Temp. Avg.	Tyre Press. Avg.
[-]	[°C]	[°C]	[%]	[kPa]	[kg/m^3]	[m/s]	[°C]	[bar]
OPEN	13.8	8.70	65.41	101.29	1.23	1.43	26.0	2.2
NORMAL	19.6	12.09	46.29	101.02	1.22	1.62	29.6	2.2
CLOSED	23.6	13.74	38.34	100.86	1.21	1.62	27.1	2.2

All three tests, consisting of 10 pairs of coast down runs each, have been performed on the Lommel PG, back to back on the same day, under relatively similar environmental conditions. Next to that the tyre conditions were constant.

From both the road load forces at 25 and 100 km/h (F25 and F100) and the determined road load expressed in CED, as described in section 3.7, a clear difference is seen for the different active grill settings. Compared to a normally operating active grill (during the coast down test) a permanently open active grill results in a 0.04 kWh (1.4%) increase in CED. A permanently closed active grill results in a 0.09 kWh (2.6%) decrease in CED, compared to normal operation.

3.9 Conclusions regarding experiences with, and results from ISV road load testing

- Vehicles sourced from the market may not be in the state as described in the CoC. For ISV testing vehicles should be brought back to the state that is specified in the CoC.
  - For example, some vehicles were found to be fitted with tyres having a higher RCC than the value mentioned on the CoC. The dealership, where the vehicles were checked, confirmed that when buying a brand new vehicle, the client always has the choice to have the vehicle fitted with different tyres. For the purpose of this project alternative tyres had to be mounted to bring these vehicles back in the state specified by the CoC.
- A direct comparison of the road load coefficients from the ISV coast down test with the CoC values is difficult in practice as very different road load coefficients may lead to very similar road load curves. Results of the coast down tests can therefore be better compared on the basis of the road load force at a specific vehicle speed or the resulting cycle energy demand (CED) calculated from the road load coefficients and test mass, according to Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5 and applying the corresponding WLTC speed trace.
- Over all repeat coast down tests the road load results varied between -3 and +6.5% compared to the reference CoC road load, both expressed in CED.
- The impact of changes in test mass was very different for the two vehicle models tested:
  - For the Ford Fiestas a given relative increase in mass results in a relative increase in CED that is about three quarters of the relative mass increase.
  - For the Volvos a given relative increase in mass only results in a relative increase in CED of about one quarter of the relative mass increase.
- The impact of changes in tyre rolling resistance is very similar for the two vehicle models tested. A given relative increase in rolling resistance force results in a relative increase in CED that is about one quarter of the relative increase in rolling resistance.

In relation to the above a general the following general observations relate to the availability of information and transparency:

- Not all vehicle conditions specified in the CoC can be checked by the Type Approval Authority or independent parties.
  - Vehicle mass e.g. influences the road load and is an important determinant of the CO_2 emissions measured on the chassis dynamometer. Checking the in-service vehicle mass and comparing this with the CoC test mass is therefore highly relevant but often difficult in practice.

The test mass includes the weight of the driver and a default load, but is not necessarily equal to the empty vehicle mass, mentioned on the CoC, plus the weight of the driver and default load. In addition the in-service vehicle may contain elements (e.g. spare tyre, tyre pump, floor mats) for which it cannot not be determined whether they are included in the CoC test mass.

- Also checking vehicles for aftermarket modifications is difficult as not all vehicle characteristics that may be altered by these modifications are described in the CoC.

4 Chassis Dynamometer tests

4.1 Introduction

In the WLTP chassis dynamometer testing is used to determine the CO_2 emissions of a vehicle in the laboratory. For In-Service Verification of the CO_2 emissions of a vehicle the results of WLTP chassis dynamometer tests, with applicable corrections, are to be compared with the CO_2 value on the CoC. Account should be taken of variations in test conditions that may influence the measured CO_2 value.

The main aspects that influence the results of a chassis dynamometer test are:
- the road load and mass settings of the dynamometer;
- the execution of the procedure for setting and checking of the correct road load settings of the chassis dynamometer;
- the execution of the test by driving a WLTC driving cycle;
- the corrections applied to the results, based on monitored change in the battery state of charge and other factors.

Variations in these different elements may cause variations in the test results as well as systematic deviations. Analysis of the test results and recorded test parameters can partly establish causal relations. Other aspects may remain part of a general source of uncertainty. Carrying out multiple tests, with multiple vehicles, and with different ways to determine effects are all useful to decompose the underlying causes of variations in test results.

This chapter presents results from the chassis dynamometer testing activities performed under Task 3 of the project.

The objectives of task 3 were:
- to gain experience with independent execution of the chassis dynamometer test as part of the WLTP;
- measure the in-service chassis-dynamometer CO_2 emissions (IS-CD-CO_2);
- to calculate the in-service WLTP CO_2 emissions (IS-WLTP-CO_2);
- to analyse the differences between those CO_2 values and the CoC CO_2 values, and
- to quantify any difference between the TA-IP line and the in-service interpolation (IS-IP) line.

Performing chassis dynamometer tests is not simple, especially not if all elements of the procedure must be checked and complied with. Test results must always be reviewed in detail. In order to collect sufficient statistics, a large number of tests have been done with a hot engine. A type-approval WLTP test, starting with a cold engine, requires soaking for at least 6 hours at 23 °C. This may limit the number of tests that can be done per day. Hot tests can be repeated one after another and provide much more data in a limited time. Most of the variations of test parameters, such as mass and road load, have been done with hot start tests. The fully WLTP-compliant cold start tests were reserved for measurements using dynamometer settings according to the vehicles' road load values found on the CoC.

Detailed test results can be found in Appendix B.

4.2 Test matrix

A total of 56 successful chassis-dyno tests were performed of which 29 tests with the Fords and 27 tests with the Volvo's. In Table 4.1 the test matrix is presented indicating the test configurations and number of repetitions per configuration. The different configurations are in detail explained in the following paragraphs.

The CoC, RLVL and RLVH tests are intended to explore deviations for the chassis-dyno measurement only (based on CoC road load settings, see also section 2.2), while differences for all other tests reflect the combined effect of differences in road load determination and chassis-dyno measurement.

It is important to note that for both the Fords and the Volvo's chassis-dyno tests were performed on only two of the three physical vehicles but for all three vehicle specifications, i.e. the Ford M1, M2 and H and the Volvo M1, M2 and L vehicles. Chassis-dyno tests were performed with the Ford M1 and M2 vehicles and the Volvo M1 and M2 vehicles. The tests with dynamometer settings corresponding to the vehicle specifications of the Ford H and Volvo L were performed using the Ford M1 and Volvo M1 vehicles respectively and adjusting the chassis-dyno settings to replicate the required vehicle specifications.

For all chassis-dyno tests with the Volvo's the chassis-dyno mode of the vehicles was engaged. The instructions for enabling the chassis-dyno mode of the vehicles were communicated by Volvo. All chassis-dyno tests with the Ford's, except for the CoC-DYNO-COLD and CoC-DYNO-HOT tests (see below), were performed without the vehicles being in any kind of chassis-dyno mode.

For the Ford M1 and Volvo L vehicles in total 6 CoC-COLD tests were performed. For each of the vehicles a set of 3 tests at 2 different chassis-dyno labs. Ths impact of testing in different labs is discussed in more detail in paragraph 6.5.

All repeat tests (CoC-COLD) per vehicle are performed by the same driver.

Table 4.1: Test matrix for chassis-dyno tests.

Test configuration	Ford Fiesta			Volvo XC60		
Vehicle specification	M1	M2	H	M1	M2	L
CoC-COLD	6	3	3	3	3	6
CoC-HOT	1	1	1	1	1	1
CoC-MINUS7	1	-	1	1	-	1
CoC-DYNO-COLD	1	-	-	X	X	X
CoC-DYNO-HOT	1	-	-	X	X	X
RLVL-HOT	1	-	-	1	-	-
RLVH-HOT	1	1	-	1	1	-
RLHM-HOT	1	-	-	1	-	-
TNOVH-HOT	1	-	-	1	-	-
RL-GRILL-HOT	1	-	-	1	-	-
RL-TYRE-HOT	1	-	-	1	-	-
RLm-HOT	1	1	1	1	1	1

4.2.1 CoC-COLD configuration

The CoC-COLD chassis-dyno tests have been performed in accordance with the legislation for determining the WLTP CO_2 emissions at type approval (Regulation

2017/1151 Annex XXI Sub-Annex 6) with the dynamometer settings corresponding to the road load specifications listed in the CoC of the vehicles. ‘COLD’ indicates a cold start of the engine and drive train. The tests were performed at an ambient temperature of 23 degrees Celsius, i.e. according the WLTP legislation. In this test no chassis-dyno mode of the vehicles was engaged.

4.2.2 CoC-HOT configuration

The CoC-HOT chassis-dyno tests are identical to the CoC-COLD tests except for the fact that the tests were started with the engine and drivetrain at normal operating conditions, a hot start.

4.2.3 CoC-MINUS7

The CoC-MINUS7 chassis-dyno tests are identical to the CoC-COLD tests except for the fact that the tests were performed at an ambient temperature of minus 7 degrees Celsius for preconditioning and during the test.

4.2.4 CoC-DYNO-COLD

This test configuration only applies to the Ford’s. The CoC-DYNO-COLD test is identical to the CoC-COLD tests apart from the fact that in the CoC-DYNO-COLD test the chassis-dyno mode was engaged. Additional information about this test configuration is found in 4.6.1.

4.2.5 CoC-DYNO-HOT

The CoC-HOT-DYNO test is identical to the CoC-DYNO-COLD test, except for the test commencing with a hot start, instead of cold start.

4.2.6 RLVL-HOT

The RLVL-HOT chassis-dyno tests have been performed with the dynamometer settings corresponding to the road load specifications of the type-approval Vehicle Low (VL) of the IP family, meaning the vehicle family configuration with the lowest Cycle Energy Demand. The test was initiated with a hot start and performed at an ambient temperature of 23 degrees Celsius.

4.2.7 RLVH-HOT

The RLVH-HOT tests were performed using the Vehicle High (VH) road load specifications of the IP family, meaning the vehicle family configuration with the highest Cycle Energy Demand. The test was performed at a 23 degrees ambient temperature and with a hot start.

4.2.8 RLHM-HOT

The chassis-dyno test RLHM-HOT has been performed with the chassis-dyno settings corresponding to the CoC road load settings of the Ford and Volvo M1 but with a test mass equal to the test mass of the VH of the corresponding IP family. This configuration was tested to get insights in the effect of the test mass on the WLTP CO_2 values. The test was performed at 23 degrees Celsius ambient temperature and with a hot start.

4.2.9 TNOVH-HOT

The TNOVH-HOT test has been performed with chassis-dyno road load settings corresponding to the highest outcome of the coast down tests, performed by TNO.

The test was performed at 23 degrees Celsius ambient temperature and with a hot start.

4.2.10 RL-GRILL-HOT

The RL-GRILL-HOT test has been performed with chassis-dyno settings corresponding to the road load settings outcome of the “aerodynamics” coast down tests (closed grill, see section 3.5). The test was performed at 23 degrees Celsius ambient temperature and with a hot start.

4.2.11 RL-TYRE-HOT

The RL-TYRE-HOT test has been performed with chassis-dyno settings corresponding to the road load settings outcome of the “different tyres” coast down tests (see section 3.5). The test was performed at 23 degrees Celsius ambient temperature and with a hot start.

4.2.12 RLm-HOT

The RLm-HOT test has been performed with chassis-dyno settings corresponding to the road load settings outcome of selected Default coast down tests, which provide an appropriate span of the coast down test results. The default tests are the coast down tests with the vehicle according to CoC specification which is stopped once the required accuracy is reached. The test is performed at 23 degrees Celsius ambient temperature and with a hot start.

4.3 Dynamometer settings

4.3.1 Speed trace

All six vehicle were able to follow the prescribed WLTP test cycle belonging to the Class 3b vehicles, as defined in Regulation 2017/1151 Annex XXI Sub-Annex 1.

4.3.2 Gear shift calculation

For the Volvos no gear shift calculation was necessary since they had an automatic transmission.

For the Fords the gear shift calculation was performed by JRC using the so-called ‘Heinz-Steven Tool’ version 29/10/2018[6], which complies with Regulation 2017/1151 Annex XXI Sub-Annex 2. The full load power curve necessary as input for this tool was provided by Ford to TNO. A default safety margin (SM) of 10% was used, in accordance with Regulation 2017/1151 Annex XXI Sub-Annex 2 Section 3.4, to account for the difference between the stationary full load condition power curve and the power available during transition conditions.

4.3.3 Coast downs on chassis-dyno

Setting the chassis-dyno to the correct road load specification was done by performing a coast down on the dyno. This method is described in Regulation 2017/1151 Annex XXI Sub-Annex 4 section 7. The chassis-dyno settings for all tests can be found in Appendix B.

[6] See https://github.com/JRCSTU/wltp and https://wltp.readthedocs.io/en/latest/

4.4 Check of CoC CO_2 value with the IP family line

Prior to performing the chassis-dyno tests the CoC road load, WLTP CO_2 and fuel consumption information of each vehicle was checked to see if it was in line with the results that are derived from the corresponding IP family and application of the interpolation method as described in Regulation 2017/1151 Annex XXI Sub-Annex 7 section 3.

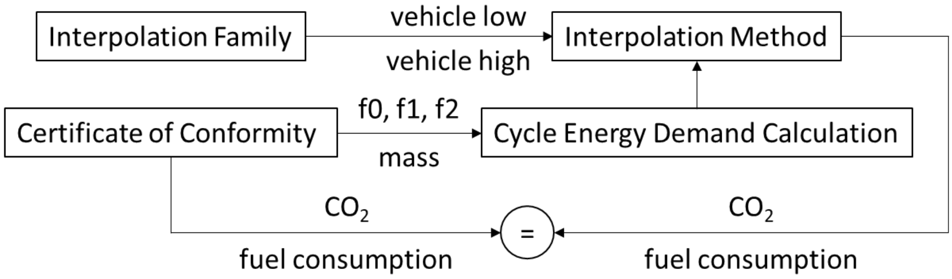

Figure 4.1: Application of interpolation method.

Figure 4.1 shows the comparison made between the CO_2 and fuel consumption listed in the CoC for the tested vehicles and the CO_2 and fuel consumption derived from the road load and type approval documentation. For all six vehicles the results of this comparison are shown in Table 4.2.

Table 4.2: CoC CO_2 value check by application of the interpolation method, as described in Regulation 2017/1151 Annex XXI Sub-Annex 7 section 3. Test numbers 1.L, 1.H and 2.L, 2.H show the IP family information for the VL and VH of the Volvo and Ford respectively.

#	Vehicle	f0	f1	f2	TM	CED WLTC 3b	CoC CO_2	IP Check CO_2	ΔCO_2
[-]	[-]	[N]	[Nh/km]	[Nh^2/km^2]	[kg]	[kWh]	[g/km]	[g/km]	[g/km]
1.L	Volvo VL	105.60	1.348	0.03683	1976	4.16	178	178	0.00
1.1	Volvo L	109.10	1.348	0.03750	2018	4.24	180	180.21	-0.21
1.2	Volvo M1	143.50	1.348	0.03683	2021	4.39	184	184.43	-0.43
1.3	Volvo M2	147.20	1.348	0.03712	2058	4.45	186	186.14	-0.14
1.H	Volvo VH	198.30	1.348	0.04167	2172	4.99	201	201	0.00
2.L	Ford VL	98.80	0.601	0.02980	1239	2.93	123	123	0.00
2.1	Ford M1	119.85	0.601	0.02952	1313	3.09	129	127.94	1.06
2.2	Ford M2	119.77	0.601	0.02952	1312	3.09	129	127.90	1.10
2.3	Ford H	142.04	0.601	0.03138	1325	3.29	134	134.05	-0.05
2.H	Ford VH	138.20	0.601	0.03330	1375	3.38	137	137	0.00

For the Volvos it is seen that the declared CO_2 values of the vehicles CoC's are slightly below the CO_2 IP family line, in the range of 0.14 to 0.43 g/km. For the Fords the declared CO_2 value of the Ford H meets the CO_2 value determined from the interpolation method. However for the Ford M1 and M2 their declared CO_2 values are over 1 g/km higher than the CO_2 IP family line.

It should be mentioned that in this report for all tests performed according the CoC specification of each vehicle, i.e. CoC road load and test mass, the declared CoC CO_2 value is used as comparison. Since, as shown in Table 4.2, these values do not always align with the interpolation method, misalignment between the determined CED values and presented CO_2 values is unavoidable.

Next to this, the interpolation method was also used to calculate the CO_2 emission and fuel consumption according to the CoC IP line for the CED outcomes derived from the coast down tests. All these values can be found in Appendix B.

4.5 Corrections to the test results

The direct measurement results from the chassis dynamometer test are not the final outcome of the WLTP procedure for determination of a vehicle's CO_2 emissions. Several further steps are taken to correct the measurement results for relevant aspects and uncontrolled variations in the test. The final CO_2 test results were obtained after application of several correction steps, as described in Regulation 2017/1151 Annex XXI, Sub-Annex 7 Section 1.4. These correction steps are described below, in order of application.

4.5.1 RCB correction

The REESS energy charge-based (RCB) correction is applied to normalise for the different battery states of charge, before and after the tests, for different tests as described in Regulation 2017/1151 Annex XXI Sub-Annex 6 Appendix 2.

For two CoC-COLD tests with the Volvo L specification and two CoC-COLD test with the Ford M2 specification the RCB correction had to be performed to correct for the relatively lower battery state of charge over the duration of the tests.

In six cases a RCB correction was applied, three tests for each vehicle model, because the difference in battery state of charge was above the threshold. The effects are significant. Up to 7 g/km downward correction was applied for the Volvo, and 6 g/km for the Ford. RCB corrections start at around 2-3 g/km. Below the threshold no correction is applied. Such variations in the final results affect any statistical method. The typical variation in raw test results is only a few gram per kilometre. In cases where the raw results would vary around the threshold value the sudden jump, resulting from the applied correction when the RCB threshold is exceeded, increases the spread in the corrected results significantly compared to the spread in the raw results.

4.5.2 Ki correction

The Ki correction is applied in order to take account of the extra fuel consumption during periodic regeneration events of an aftertreatment system, as described in Regulation 2017/1151 Annex XXI Sub-Annex 6 Appendix 1.

A Ki factor of 1.0126 was applied to the test results for the Volvo's since these are fitted with a Diesel Particulate Filter. The Ki factor was provided by the OEM. The Ki factor is determined according the Ki factor determination procedure, see Regulation 2017/1151 Annex XXI Sub-Annex 6 Appendix I. Repetition of this process to confirm the factor provided by the OEM was outside the scope of this project.

Tests with regenerations are excluded, the effect represents the average effect of regenerations in normal use. Checking the Ki would require typically running a vehicle over long distances on the chassis dynamometer in successive WLTP tests, to encounter two regenerations, to determine the number of regenerations per kilometre and the extra emissions associated with this regeneration, when it occurs.

The Ki correction was not applied (i.e. Ki=1) to the Ford vehicles since these petrol vehicles were not equipped with periodically regenerating after-treatment systems.

4.5.3 ATCT correction

The Ambient Temperature Correction Test (ATCT), see Regulation 2017/1151 Annex XXI Sub-Annex 6a Section 3.8.2, is used in order to normalise CO_2 emissions to a temperature of 14ºC (considered in the regulation as being the average EU ambient temperature) rather than the regulatory ambient temperature in the labs of 23ºC, under which the WLTP test is performed. This compulsory correction increases CO_2 emissions and this is due to higher fuel consumption during a test at 14ºC vs. 23ºC. Only the effects of the WLTC tests are included here and not the effect of in road load tests, which is set at an ambient temperature of 20º C, affecting the air drag and the rolling resistance. The CO_2 emission values found on the vehicles' CoC's are ATCT corrected (expressed as emissions at 14 ºC). Therefore the CO_2 values measured in the laboratory for ISV purposes also require correction before they can be compared with the value on the CoC. The ATCT family correction factors (FCF) used for all tests of the Fords and the Volvo's were respectively 1.032 and 1.016. These values are recorded in type-approval documentation of these vehicles.

4.6 Practical issues experienced during the chassis-dyno testing

4.6.1 Chassis dyno mode activation

Some vehicles have a chassis dyno mode which needs to be activated to properly run a chassis dyno test. This mode shuts off, for example, the safety features. An examples of that is collision prevention, which needs to be disabled since there is a big fan in front of the vehicle during testing.

To enter the chassis dyno mode an operator must perform a certain sequence of operations, which is provided by the manufacturer. For repeatable testing it is important to have traceable test settings.

The Volvo XC60 gives the operator a continuous indication on the dashboard display whether the vehicle is in dyno mode during testing.

The Ford Fiesta, however, only gives such indication directly after following the procedure for chassis dyno mode activation. This indication consist of a short blinking of the start/stop button. During the test it is not clear whether this vehicle is still in chassis dyno mode. Therefore, it is difficult to assess with sufficient certainty what the effect of the (in)active chassis dyno mode on the test results is.

4.7 Test results

4.7.1 Ford Fiesta: all chassis-dyno tests

For the Ford Fiesta's the CO_2 emission outcomes for all chassis-dyno tests, corrected for the factors described in section 4.5, are presented in Table 4.3 and Figure 4.2. All repeat tests (CoC-COLD) per vehicle are combined. The average outcomes and corresponding variations for those tests are presented.

Table 4.3: Ford chassis-dyno test results. For all repeat tests (CoC-COLD) results per vehicle M1, M2 and H are combined and results are presented as an average and standard deviation.

#	Test #	Veh.	Test Description	CED Target*	CO_2 CoC**	CO_2 Measured	ΔCO_2	ΔCO_2
[-]	[-]	[-]	[-]	[kWh]	[g/km]	[g/km]	[g/km]	[%]
1	-	M1	CoC-COLD	3.09	129	151.80 ± 2.17	22.80 ± 2.17	17.7 ± 1.7
2	-	M2	CoC-COLD	3.09	129	153.70 ± 0.44	24.70 ± 0.44	19.1 ± 0.3
3	-	H	CoC-COLD	3.29	134	159.26 ± 0.64	25.26 ± 0.64	18.9 ± 0.5
4	F5	M1	CoC-HOT	3.09	129	148.15	19.15	14.8
5	F15	M1	CoC-MINUS7	3.09	129	170.99	41.99	32.6
6	F8	M1	RLm-HOT	3.17	130.23	151.45	21.22	16.3
7	F7	M1	RL-TYRE-HOT	3.13	129.03	146.32	17.29	13.4
8	F9	M1	RL-GRILL-HOT	2.97	124.16	142.30	18.14	14.6
9	F10	M1	RLVL-HOT	2.90	123	139.43	16.43	13.4
10	F12	M1	RLHM-HOT	3.33	135.32	158.68	23.37	17.3
11	F13	M1	RLVH-HOT	3.38	137	158.76	21.76	15.9
12	F14	M1	TNOVH-HOT	3.12	128.70	151.48	22.78	17.7
13	F16	M1	CoC-DYNO-HOT	3.09	129	149.96	20.96	16.2
14	F20	M1	CoC-DYNO-COLD	3.09	129	150.93	21.93	17.0
15	F24	M2	CoC-HOT	3.09	129	147.13	18.13	14.1
16	F25	M2	RLm-HOT	3.02	125.81	145.13	19.32	15.4
17	F26	M2	RLVH-HOT	3.38	137	157.88	20.88	15.2
18	F30	H	CoC-HOT	3.29	134	155.37	21.37	15.9
19	F33	H	CoC-MINUS7	3.29	134	173.63	39.63	29.6
20	F31	H	RLm-HOT	3.24	132.53	152.81	20.28	15.3

* The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5.

** CO_2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

The chassis-dyno results of the combined repeat tests (CoC-COLD) per vehicle, see rows #1 to #3 in Table 4.3, show a typical variation around the average in the order of 1 to 3 g/km CO_2. On average the measured CO_2 emission is in the order of 20 to 30 g/km (i.e. close to 20%) higher than the reference CoC CO_2 for all three Ford's.

The measured CO_2 emissions for the CoC-HOT tests are slightly lower than the CoC-COLD tests, as expected, and are typically around 20 g/km (15%) higher than CoC reference value. As these tests are carried out with chassis dyno road load settings according to CoC specifications, this difference is entirely attributable to factors that influence the chassis dynamometer test.

In fact results of all HOT tests (with vehicle HOT-start) are in the range of 16 to 23 g/km higher than the reference CoC values. This is also clearly seen in Figure 4.2. The results show a strong linear relation between CED and CO_2.

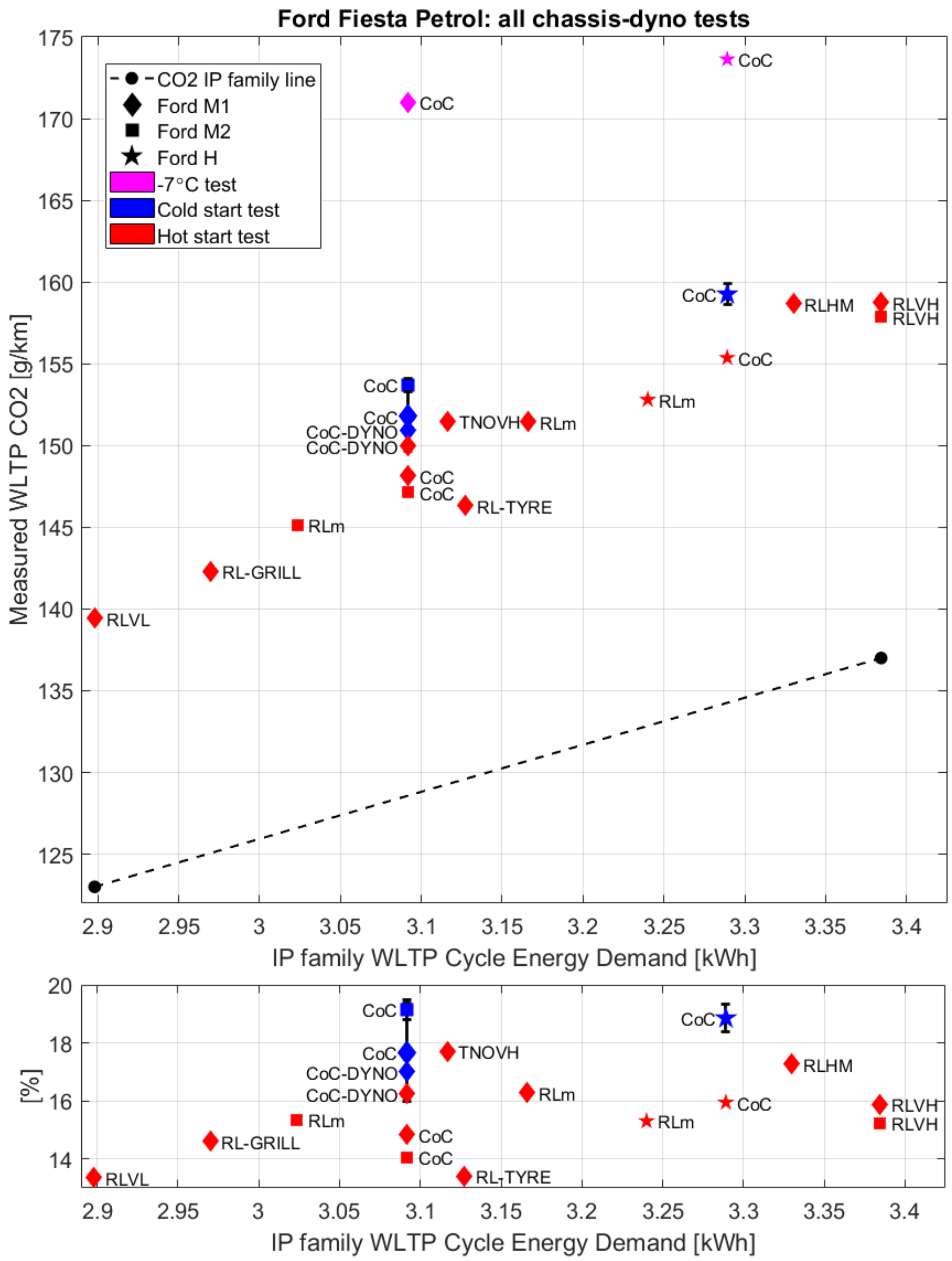

Figure 4.2: Ford Fiesta: CO_2 emission results of all chassis-dyno tests carried out on the WLTC test cycle with different mass and road load settings and temperatures for pre-conditioning and test.

To visualize the difference between the CO_2 results and the reference CoC CO_2 values, the IP family line has been displayed in Figure 4.2 (dashed black line), as well as the Vehicle Low (VL) and Vehicle High (VH) of the IP family. Any test results below this line indicates the measured CO_2 emissions at a certain CED is below the reference CoC CO_2 value at an equal CED and vice versa.

The relative difference of the displayed CO_2 results for each test compared to the CO_2 IP family line is displayed in the smaller bottom figure. For example a CO_2

value located directly on the CO_2 IP family line would be displayed in the bottom graph on the 0% line.

From Figure 4.2 it is clearly seen that the CO_2 results of the CoC-MINUS7 tests are about another 15 to 20 g/km higher than the outcomes of the CoC-COLD and -HOT tests.

Furthermore it is seen that the same tests performed on the two identical vehicles (Ford M1 and M2) result in relatively similar outcomes.

4.7.2 *Ford Fiesta: tests based on CoC chassis dyno settings*

In Table 4.4 the individual test results of the repeat tests (CoC-COLD) for the three Ford vehicles are presented, as well as the other CoC road load based chassis-dyno tests.

Comparing the repeat tests per vehicle with each other it is seen that the lowest and highest CO_2 outcomes differ 5.9, 0.75 and 1.3 g/km for the Ford M1, M2 and H respectively. This corresponds to a difference in CO_2 emission between the test outcome and reference CoC value of 20.6 to 26.5 g/km, 24.2 to 25.0 g/km and 24.7 to 26.0 g/km for the Ford M1, M2 and H respectively. For both the CoC-HOT and RLVH tests, the results are about 1 g/km CO_2 apart.

Table 4.4: Ford chassis-dyno tests based on CoC road load: CoC-COLD and -HOT, CoC-DYNO, RLVL and RLVH.

#	Test #	Veh.	Test Description	CED Target*	CO_2 CoC	CO_2 Measured	ΔCO_2	ΔCO_2
[-]	[-]	[-]	[-]	[kWh]	[g/km]	[g/km]	[g/km]	[%]
1	F1	M1	CoC-COLD-TEST1	3.09	129	152.67	23.67	18.3
2	F2	M1	CoC-COLD-TEST2	3.09	129	150.38	21.38	16.6
3	F4	M1	CoC-COLD-TEST4	3.09	129	152.18	23.18	18.0
4	F17	M1	CoC-COLD-TEST5	3.09	129	155.53	26.53	20.6
5	F18	M1	CoC-COLD-TEST6	3.09	129	149.62	20.62	16.0
6	F19	M1	CoC-COLD-TEST7	3.09	129	150.43	21.43	16.6
7	F5	M1	CoC-HOT	3.09	129	148.15	19.15	14.8
8	F10	M1	RLVL-HOT	2.90	123	139.43	16.43	13.4
9	F13	M1	RLVH-HOT	3.38	137	158.76	21.76	15.9
10	F16	M1	CoC-DYNO-HOT	3.09	129	149.96	20.96	16.2
11	F20	M1	CoC-DYNO-COLD	3.09	129	150.93	21.93	17.0
12	F21	M2	CoC-COLD-TEST1	3.09	129	153.95	24.95	19.3
13	F22	M2	CoC-COLD-TEST2	3.09	129	153.20	24.20	18.8
14	F23	M2	CoC-COLD-TEST3	3.09	129	153.95	24.95	19.3
15	F24	M2	CoC-HOT	3.09	129	147.13	18.13	14.1
16	F26	M2	RLVH-HOT	3.38	137	157.88	20.88	15.2
17	F27	H	CoC-COLD-TEST1	3.29	134	158.68	24.68	18.4
18	F28	H	CoC-COLD-TEST2	3.29	134	159.15	25.15	18.8
19	F29	H	CoC-COLD-TEST3	3.29	134	159.96	25.96	19.4
20	F30	H	CoC-HOT	3.29	134	155.37	21.37	15.9

* The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5.

The CoC-DYNO-COLD and -HOT tests (with the chassis-dyno mode engaged) have inconclusive results, with a CO_2 outcome slightly below and above the outcomes of the same tests with chassis-dyno mode not engaged. Together with the description of the issue of engaging the chassis-dyno mode for the Fords in paragraph 4.6.1, the exact effect of the chassis-dyno mode on the CO_2 emission outcome remains inconclusive.

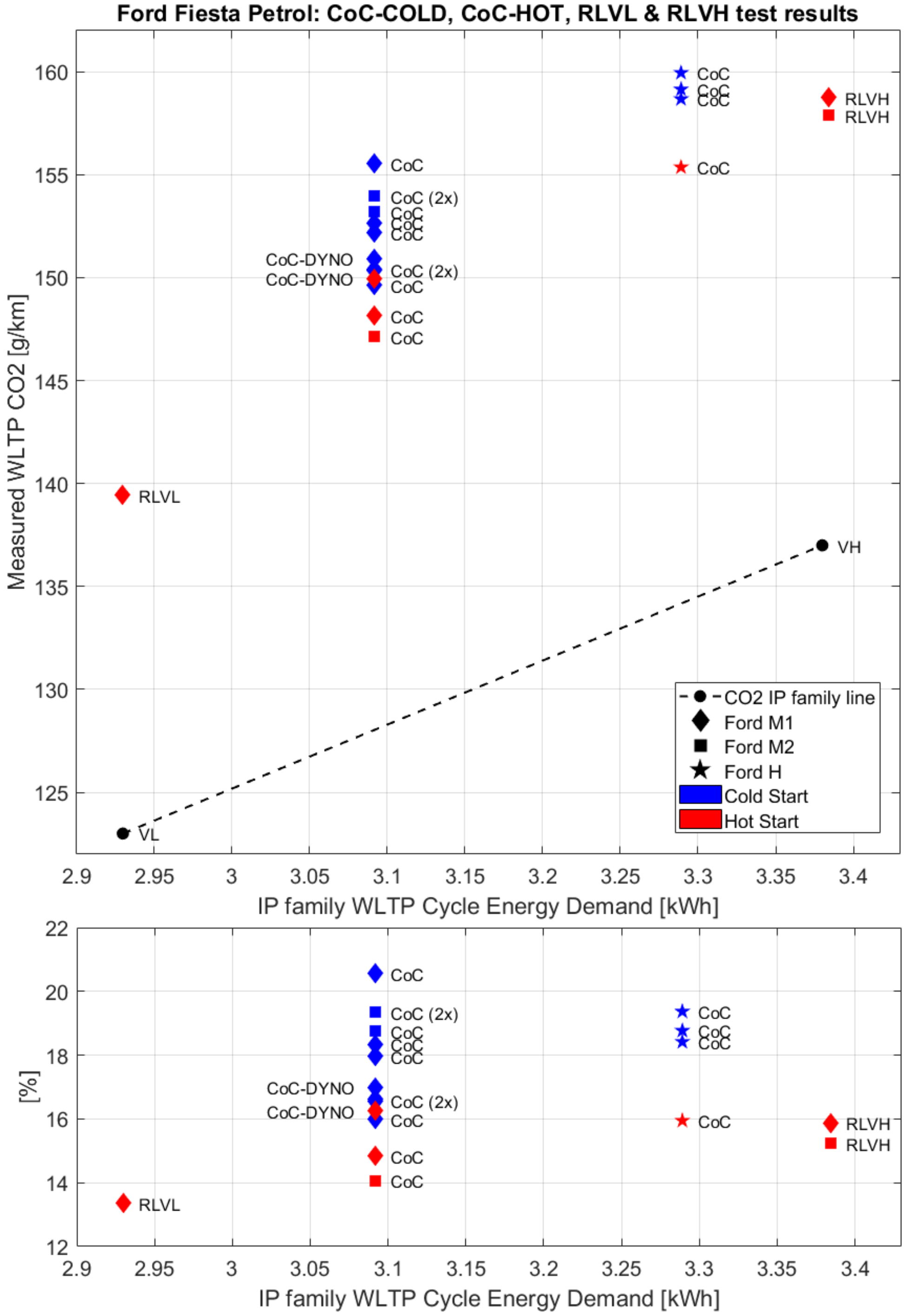

Figure 4.3: Ford Fiesta: CO_2 emission results of all chassis-dyno tests carried out with road load settings according to CoC specifications.

As already mentioned in the previous section the CO_2 emissions on the CoC-COLD tests are around 16% to 21% above the IP family line, with an uncertainty margin of 5%. As these tests are carried out with chassis dyno road load settings according to

CoC specifications, this difference is entirely attributable to factors that influence the chassis dynamometer test.

The impact of engaging the chassis dyno mode on the Ford Fiesta appears limited to around 2%.

The spread observed in repetitions of the same test on the same vehicle is 1 to 2%, except for one test with the Ford M1 vehicle. This confirms that the observed large differences between the results of individual tests with different road loads and the IP family line are significant and cannot be attributed to uncertainties in the execution of the chassis dyno tests.

4.7.3 *Volvo XC60: all chassis-dyno tests*

The CO_2 emission outcomes for all chassis-dyno tests, corrected for the factors described in section 4.5, are presented in Table 4.5, Table 4.3 and Figure 4.4. All repeat tests (CoC-COLD) per vehicle are combined. The average outcomes and corresponding variations for those tests are presented.

Table 4.5: Volvo chassis-dyno test results. All repeat tests (CoC-COLD) per vehicle M1, M2 and L are combined and results are presented as an average and standard deviation.

#	Test #	Veh.	Test Description	CED Target*	CO_2 CoC**	CO_2 Measured	ΔCO_2	ΔCO_2
[-]	[-]	[-]	[-]	[kWh]	[g/km]	[g/km]	[g/km]	[%]
1	-	M1	CoC-COLD	4.45	186	180.12 ± 2.20	-5.88 ± 2.20	-3.2 ± 1.2
2	-	M2	CoC-COLD	4.45	186	175.80 ± 1.38	-10.20 ± 1.38	-5.5 ± 0.7
3	-	L	CoC-COLD	4.24	180	174.53 ± 2.99	-5.47 ± 2.99	-3.0 ± 1.7
4	V4	M1	CoC-HOT	4.45	186	173.48	-12.52	-6.7
5	V12	M1	CoC-MINUS7	4.45	186	222.20	36.20	19.5
6	V5	M1	RLm-HOT	4.74	194.21	178.37	-15.85	-8.2
7	V6	M1	RLVH-HOT	4.99	201	186.74	-14.26	-7.1
8	V7	M1	RLVL-HOT	4.16	178	157.92	-20.08	-11.3
9	V8	M1	RLHM-HOT	4.55	188.86	173.20	-15.66	-8.3
10	V9	M1	TNOVH-HOT	4.51	187.71	170.83	-16.88	-9.0
11	V10	M1	RL-TYRE-HOT	4.73	193.98	175.42	-18.56	-9.6
12	V11	M1	RL-GRILL-HOT	4.27	180.88	161.46	-19.41	-10.7
13	V17	M2	CoC-HOT	4.45	186	168.42	-17.58	-9.5
14	V18	M2	RLm-HOT	4.64	191.27	174.25	-17.02	-8.9
15	V19	M2	RLVH-HOT	4.99	201	178.61	-22.39	-11.1
16	V24	L	CoC-HOT	4.24	180	167.77	-12.23	-6.8
17	V26	L	CoC-MINUS7	4.24	180	196.45	16.45	9.1
18	V27	L	RLm-HOT-TEST2	4.43	185.47	171.84	-13.63	-7.3

* The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5.

** CO_2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

The chassis-dyno results of the combined repeat tests (CoC-COLD) per vehicle, see rows #1 to #3 in Table 4.5, show a typical variation around the average in the order of 1.4 to 3 g/km CO_2. On average the measured CO_2 emissions are in the order of 5 to 10 g/km (i.e. 3 to 5%) lower compared to the reference CoC CO_2, for all three Volvo's.

The measured CO_2 emissions for the CoC-HOT tests are lower than the CoC-COLD tests, as expected, by around 7 g/km, and are typically around 15 g/km

(8%) lower than the CoC values. As these tests are carried out with chassis dyno road load settings according to CoC specifications, this difference is entirely attributable to factors that influence the chassis dynamometer test.
All results of HOT tests (with vehicle HOT-start) are in the range of 15 to 20 g/km lower than the reference CoC values. This is also clearly seen in Figure 4.4. The results show a strong linear relation between CED and CO_2. Tests with CoC road loads are slightly above the line that can be drawn through results from tests using road loads determined independently in this project.

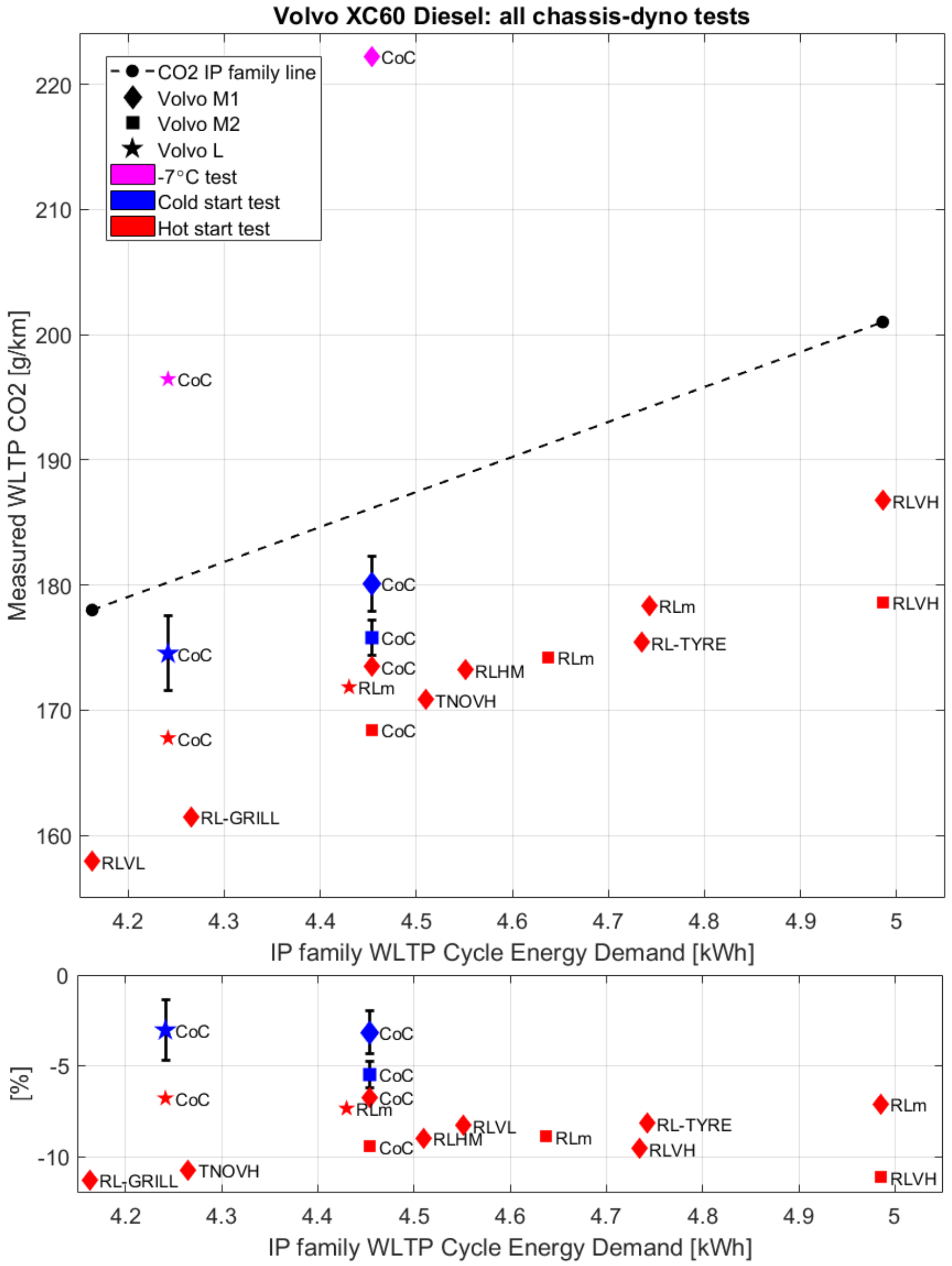

Figure 4.4: Volvo XC60: CO_2 emission results of all chassis-dyno tests carried out on the WLTC test cycle with different mass and road load settings and temperatures for pre-conditioning and test.

To visualize the difference between the CO_2 results and the reference CoC CO_2 values, the IP family line has been displayed in Figure 4.4 (dashed black line), as well as the Vehicle Low (VL) and Vehicle High (VH) of the IP family. Any test results below this line indicates the measured CO_2 emission at a certain CED is below the reference CoC CO_2 value at an equal CED and vice versa.

The relative difference of the displayed CO_2 results for each test compared to the CO_2 IP family line is displayed in the smaller bottom figure. For example a CO_2 value located directly on the CO_2 IP family line would be displayed in the bottom graph on the 0% line.

As expected, the chassis-dyno tests performed at an ambient temperature of -7ºC (CoC-MINUS7) show significantly higher CO_2 emission results compared to the cold and hot start tests at normal test temperature. For the Volvo M1 vehicle the impact of this test, in terms of additional g/km compared to the CoC test with cold start, is twice as high as for the L vehicle.

The results are discussed in more detail in the sections below.

4.7.4 *Volvo XC60: tests based on CoC chassis dyno settings*

In Table 4.6 the individual test results of the repeat tests (CoC-COLD) for the three Volvo vehicles are presented, as well as the other CoC road load based chassis-dyno tests.

Comparing the repeat tests per vehicle with each other it is seen that the lowest and highest CO_2 outcomes differ 4.3, 2.4 and 8.3 g/km for the Volvo M1, M2 and L respectively. This corresponds to a difference in CO_2 emission between the test outcome and reference CoC value of -3.5 to -7.8 g/km, -8.6 to -11 g/km and 0.2 to -8 g/km for the Volvo M1, M2 and L respectively.

Table 4.6: Volvo chassis-dyno tests based on CoC road load: CoC-COLD and -HOT, CoC-DYNO, RLVL and RLVH.

#	Test #	Veh.	Test Description	CED Target*	CO_2 CoC	CO_2 Measured	ΔCO_2	ΔCO_2
[-]	[-]	[-]	[-]	[kWh]	[g/km]	[g/km]	[g/km]	[%]
1	1	M1	CoC-COLD-TEST1	4.45	186	182.54	-3.46	-1.9
2	2	M1	CoC-COLD-TEST2	4.45	186	178.24	-7.76	-4.2
3	3	M1	CoC-COLD-TEST3	4.45	186	179.59	-6.41	-3.4
4	4	M1	CoC-HOT	4.45	186	173.48	-12.52	-6.7
5	6	M1	RLVH-HOT	4.99	201	186.74	-14.26	-7.1
6	7	M1	RLVL-HOT	4.16	178	157.92	-20.08	-11.3
7	13	M2	CoC-COLD-TEST1	4.45	186	177.39	-8.61	-4.6
8	15	M2	CoC-COLD-TEST3	4.45	186	175.01	-10.99	-5.9
9	16	M2	CoC-COLD-TEST4	4.45	186	175.00	-11.00	-5.9
10	17	M2	CoC-HOT	4.45	186	168.42	-17.58	-9.5
11	19	M2	RLVH-HOT	4.99	201	178.61	-22.39	-11.1
12	20	L	CoC-COLD-TEST1	4.24	180	174.11	-5.89	-3.3
13	22	L	CoC-COLD-TEST3	4.24	180	174.94	-5.06	-2.8
14	23	L	CoC-COLD-TEST4	4.24	180	173.47	-6.53	-3.6
15	28	L	CoC-COLD-TEST5	4.24	180	180.23	0.23	0.1
16	29	L	CoC-COLD-TEST6	4.24	180	171.97	-8.03	-4.5
17	30	L	CoC-COLD-TEST7	4.24	180	172.45	-7.55	-4.2
18	24	L	CoC-HOT	4.24	180	167.77	-12.23	-6.8

* The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5.

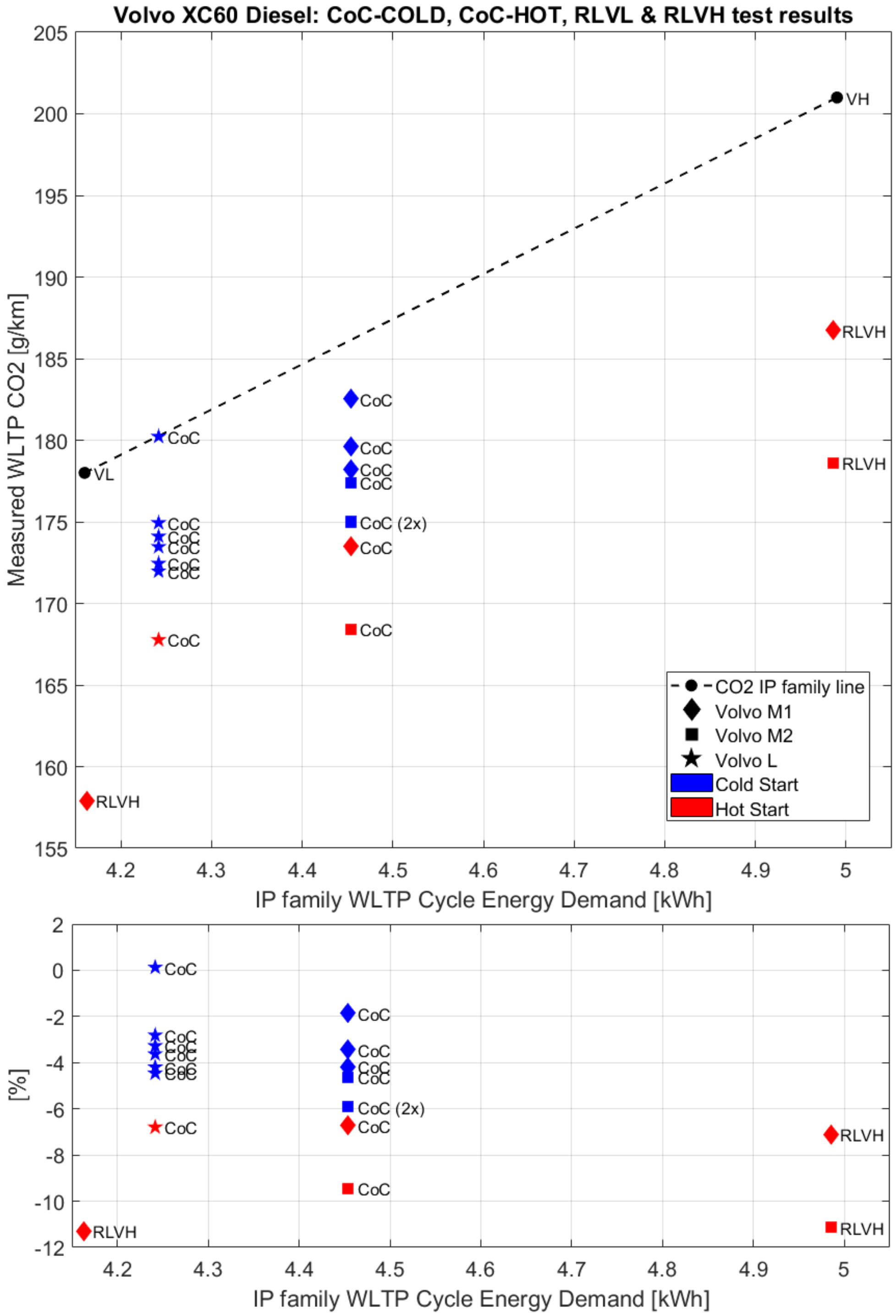

Figure 4.5: Volvo XC60: CO_2 emission results of all chassis-dyno tests carried out with road load settings according to CoC specifications.

Furthermore, it is seen that the repetition of tests between the two identical vehicles (Volvo M1 and M2) result in different outcomes, on average about 5 g/km. This is also true for the CoC-HOT and RLVH tests. The results for the RLVH tests vary even more, about 8 g/km.

As already mentioned in the previous section the CO_2 emissions on the CoC-COLD tests are around 3 to 6% below the IP family line. As these tests are carried out with chassis dyno road load settings according to CoC specifications, this difference is entirely attributable to factors that influence the chassis dynamometer test.

The spread observed in repetitions of the same test on the same vehicle is around 2%, except for one test with the Volvo L vehicle. This confirms that the observed large differences between the results of individual tests with different road loads and the IP family line are significant and cannot be attributed to uncertainties in the execution of the chassis dyno tests.

4.8 Impact of variations in road load testing and mass on WLTP CO_2 test results

The RLm-HOT tests have been performed with chassis-dyno settings corresponding to the road load settings outcome of default coast down tests without variations in vehicle or test parameters. For the Ford M1 this yields higher CO_2 emissions than the test with chassis dyno settings according to CoC, while for the M2 and H vehicles CO_2 emissions in this test are lower than in the CoC test, consistent with the differences in measured CED values for all three vehicles with the value based on CoC. For all three Volvo's it yields significantly higher CED values than those based on CoC specifications. The resulting higher CO_2 emissions compared to the tests with chassis dyno settings according to CoC, are consistent with the slope of the IP family line.

The strong linear relation between the results of tests carried out with different road load and mass settings confirms the applicability of the interpolation method for the IP family line.

In terms of their absolute and relative distance to the family IP line, the results of hot tests using measured road load settings are in a narrow bandwidth. Results of tests with CoC road loads are slightly higher and appear to be outside the mentioned bandwidth to a significant extent.

In the following paragraphs the impact of specific variations in road load and mass on the WLTP CO_2 test results are analysed. Despite the strong linear relation that is observed between the overall results, the variation in the results, as discussed in more detail in paragraph 6.3, brings with it the difficulty of comparing individual results. This is also seen for the analyses that follow in the coming paragraphs. It should therefore be kept in mind that the strong linear relation observed over all chassis-dyno test results confirms the applicability of the interpolation method.

4.8.1 Effect of test mass

The result of the RLHM-HOT test with the Ford, performed with the chassis-dyno road load settings corresponding to the CoC but with a test mass equal to the test mass of the VH of the IP family, is close to the VH test results, in terms of CO_2 as well as CED. This indicates that test mass is a strong determinant for CED and WLTP CO_2 with regards to the road load. For the Volvo RLHM-HOT test this effect is not as strong as for the Ford. These observations are in line with the effect of test mass on the CED as seen from the coast down tests in paragraph 3.8.1.

In Table 4.7 and Table 4.8 the outcomes of the added weight coast down tests and comparable chassis-dyno tests are presented. For the Ford it is seen that the difference in CO_2 value due to the increased test mass turns out to be larger for the actual chassis-dyno measurement, 3.8% in comparison to the estimated 2.1%. For the Volvo the opposite is observed. For this vehicle the measured difference in CO_2 value due to the increased test mass is less than expected from the coast down test.

Table 4.7: Ford H effect of test mass on road load, expressed in cycle energy demand (CED) and CO_2 value. On the left as determined from the coast down tests and presented in paragraph 3.8.1. On the right as determined from two hot-start chassis-dyno test results with comparable difference in CED as on the left.

Test #	TM	CED	CO_2*
[-]	[kg]	[kWh]	[g/km]
CoC Spec.	1325.00	3.24	132.53
Added weight	1375.00	3.33	135.32
Difference	3.8%	2.9%	2.1%

Test #	CED	CO_2
[-]	[kWh]	[g/km]
F31 (RLm)	3.24	152.81
F12 (RLHM)	3.33	158.68
Difference	2.9%	3.8%

* CO_2 emissions determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

Table 4.8: Volvo L effect of test mass on road load, expressed in cycle energy demand (CED) and CO_2 value. On the left as determined from the coast down tests and presented in paragraph 3.8.1. On the right as determined from two hot-start chassis-dyno test results with comparable difference in CED as on the left.

Test #	TM	CED	CO_2*
[-]	[kg]	[kWh]	[g/km]
CoC Spec.	2018.00	4.36	183.52
Added weight	2172.00	4.51	187.71
Difference	7.6%	3.4%	2.3%

Test #	CED	CO_2
[-]	[kWh]	[g/km]
V27 (RLm)	4.43	171.84
V8 (RLHM)	4.55	173.20
Difference	2.7%	0.8%

* CO_2 emissions determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

4.8.2 *Effect of tyres*

As seen in paragraph 3.8.2 the coast down tests performed with an increased rolling resistance, by fitting of different tyres, resulted in an increased road load expressed in CED of 3.8 and 4.8% for the Ford M2 and Volvo L respectively. By application of the interpolation method, as described in paragraph 4.4, the corresponding increase in CO_2 values for those increases in CED are 3.0 and 3.2% respectively.

To check if a similar relative difference in CED of the chassis-dyno road load settings also results in a similar relative difference in CO_2 value, two performed chassis-dyno tests are compared with the results from the coast down tests. This comparison is presented in Table 4.9 and Table 4.10 for the Ford and Volvo respectively.

As can be seen from Table 4.9 and Table 4.10 the actual measured increase in CO_2 value from a similar relative increase in road load (CED) as determined during the coast down test program is 0.8 and 1.4% for the Ford and Volvo respectively. This is lower than the determined increase of around 3% using the interpolation method.

Table 4.9: Ford M2 effect of tyres on road load, expressed in cycle energy demand (CED) and CO_2 value. On the left as determined from the coast down tests and presented in paragraph 3.8.2. On the right as determined from two hot-start chassis-dyno test results with comparable difference in CED as on the left.

Test	CED	CO_2*
[-]	[kWh]	[g/km]
CoC spec.	3.01	125.40
Different Tyres	3.13	129.12
Difference	3.8%	3.0%

Test #	CED	CO_2
[-]	[kWh]	[g/km]
F25	3.02	145.13
F7	3.13	146.32
Difference	3.6%	0.8%

* CO_2 emissions determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

Table 4.10: Volvo L effect of tyres on road load, expressed in cycle energy demand (CED) and CO_2 value. On the left as determined from the coast down tests and presented in paragraph 3.8.2. On the right as determined from two hot-start chassis-dyno test results with comparable difference in CED as on the left.

Test	CED	CO_2*
[-]	[kWh]	[g/km]
CoC spec.	4.36	183.52
Different Tyres	4.57	189.39
Difference	4.8%	3.2%

Test #	CED	CO_2
[-]	[kWh]	[g/km]
V27	4.43	171.84
V18	4.64	174.25
Difference	4.7%	1.4%

* CO_2 emissions have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

4.8.3 Effect of active aerodynamics

The result of the RL-GRILL-HOT tests, performed with chassis-dyno road load settings corresponding to the outcome of the “Aerodynamics” coast down tests with a closed grill (see section 3.5), show a large difference with the results from tests with chassis dyno settings according to CoC. A closed grill reduces the CO_2 emissions by around 6 and 12 g/km for the Ford and Volvo respectively.

4.9 Conclusions regarding experiences with, and results from ISV chassis dynamometer testing

- The chassis dynamometer test, which takes place under well specified and controlled laboratory conditions, is expected to have smaller uncertainties and variations in test results than the road load test, which has a larger amount of variable ambient and other test conditions beyond the control of the tester. In our measurements, however, the largest part of the observed deviations between measured CO_2 emissions and the CoC values were related to the chassis dynamometer test. These deviations are largely unexplained.
  - For the Ford Fiestas CO_2 emissions measured on the chassis dynamometer with road load settings according to the CoC and a cold start are around 16% to 21% above the IP family line, with a uncertainty margin of 5%. This difference is entirely attributable to factors that influence the chassis dynamometer test. The impact of engaging the chassis dyno mode on the Ford Fiesta appears limited to around 2%.
  - For the Volvo XC60s CO_2 emissions measured on the chassis dynamometer with road load settings according to the CoC and a cold start tests are around 3 to 6% below the IP family line. Also this difference is entirely attributable to factors that influence the chassis dynamometer test.

- The CO_2 emissions in tests with a cold start are typically 3-6% higher than in tests with a hot start. CO_2 emissions in tests at -7 °C are typically 10% higher than in tests with a cold start, with one exception of over 20%.
- From chassis dynamometer tests carried out with the VH test mass and road load settings derived from coast-down tests with vehicles having a mass equal to the VH of the IP family the impact of mass appears different for the two tested models. For the Ford it is seen that the difference in CO_2 value due to the increased test mass turns out to be larger than the value estimated on the basis of the calculated CED. For the Volvo the opposite is observed.
- The actual measured increase in CO_2 value from the same relative increase in road load (CED), as determined during the coast down test program, is quite similar for both vehicle models, but lower than the determined increase using the interpolation method.
- For each vehicle model the measured CO2 values are roughly on a line parallel to the CoC IP family line. The strong linear relation between the results of tests carried out with different road load and mass settings confirms the applicability of the interpolation method using an IP family line.

5 Analysis of elements determining variations between road load tests

5.1 Introduction

The total uncertainty in determining the WLTP CO_2 value of an individual vehicle is composed of variations in the different elements in the determination of the CO_2 value. Information on elements determining uncertainty can be obtained from (i) the verification of the CoC road-load values, (ii) the CO_2 results obtained from roller bench testing of an individual vehicle, and (iii) the results obtained on a sample of vehicles from an IP family.

The analysis presented in this chapter is part of task 4 of the project. It aims to identify from practice (in particular from task 2) and complementary theory the factors affecting the result of the WLTP road-load determination, and corresponding impacts on CED and CO_2 emission determination, for in service verification of an individual vehicle placed on the market.

In this chapter, actual values and relations for the different sources of uncertainties in road load tests are derived. They are used later in the analysis of the combined uncertainty of the CO_2 results.

Many of the observed effects are based on the experience of the test engineers who carried out the tests for this project, and were asked to keep detailed records.

5.2 Different types of variations in ISV testing

In analyzing variations in the results of ISV testing, in particular of road load testing, different types of variations in the results can be distinguished:

- “Natural” variations in test results are related to variations in test conditions and test execution within the bandwidths allowed by the WLTP. These variations include both random aspects and systematic differences:
  - Random variations in tests on the same track or in the same lab may result from variations in ambient conditions or differences in the way in which the test is executed, including influences of the driver, provided these are within the allowed bandwidth. Variations outside these bandwidths lead to invalid tests.
  - Systematic differences in test results from different test tracks or labs may result from, e.g., differences in the track surface or in (calibration of) equipment used, or form details in the laboratory protocol not specified within the WLTP.

  These variations are not to be considered as measurement inaccuracies, but as natural variations inherent to the prescribed test procedure. As a consequence these variations do not need to be taken into account in assessing the statistical significance of the result of ISV testing.

- “Normal” variations are differences in results of tests carried out under the same test conditions. These typical test-to-test variations on the same test track or in the same laboratory indicate the accuracy or reproducibility with which a result

can be established. This spread or margin is relevant for determining the statistical significance of the result of ISV testing.
  - These normal variations also contain random and systematic elements. The latter e.g. relate to testing different vehicles of the same model, or repeat testing by a different team or with different equipment in the same laboratory.

- "Base margin": A quantification of the lowest expected variation in repeat testing is necessary, and needs to be included as a base margin in the statistical procedure for ISV to cater for situations where repeat testing within the ISV activity does not yield a realistic spread. The latter may occur when accidentally a small number of tests yields identical results.

The base margin is likely to be smaller than the normal variations for a given laboratory. In turn these normal variations, related to test accuracy, are much smaller than the natural variations in test results, which are related to variations in test conditions and test execution within the bandwidths allowed by the WLTP.

In defining the statistical procedure for ISV the determination of which variations are to be considered "natural variations", associated with the bandwidths of the procedure, and which are "normal variations", that are to be included in the statistical procedure, deserves further study. For some elements, such as impacts of specific variations in ambient conditions that are not compensated by correction methods included in the WLTP, it is not a priori clear to which category they belong.

5.3 Variations related to repetition of tests

In the coast down test program with all vehicles, multiple tests (Default and Extended) have been performed at both test tracks with the vehicles conforming with CoC specifications. The variations found in road load are presented here and are translated into the theoretical variation in CED and CO_2, the latter derived from the CED in combination with the IP family line.

5.3.1 Repetition at same test track

For all six vehicles a Default and Extended test was performed at both PGs. Table 5.1 presents the variation in road load force at 25 and 100 km/h, the CED and the derived CO_2 value for each vehicle and test track separately.

The results of the Default and Extended tests for each vehicle at both test tracks have been averaged. Table 5.1 presents these average values, absolute standard deviations and standard deviations expressed as percentage of the averages.
The CED values are calculated from the RL coefficients using the method described in section 3.7. The theoretical CO_2 value is calculated from the CED value using a similar approach as described in section 4.4 (application of interpolation method using family information). In this way the variation in road load can be translated to an expected impact on CO_2 value.

The blue shaded cells indicate the coast down outcomes with the highest relative variation for F25, F100, CED and CO_2 each. The largest observed variation in road load is 4.7% and 3.2% at 25 and 100 km/h respectively. The largest observed variation in CED is 2.0%, and in CO_2 it is 1.4%. It should be noted that the largest relative CO_2 variation does not correspond with the largest absolute variation, which is 2.55 g/km CO_2.

Relative variations in road load are found to translate into relative CO_2 variations of half the size. In absolute terms, about 5 N change in road load force translates into 1 g/km variation in CO_2. This is a rule-of-thumb[7]. More appropriately, the actual road load and the interpolation line between VL and VH for the WLTP test cycle is used to derive the CO_2 value. The cited CO_2 effects in the following paragraphs are derived from this interpolation line.

Table 5.1: Variations observed in Default and Extended coast down tests, performed on vehicles that conform with CoC specifications.

Lommel	F25 [N]	F100 [N]	CED [kWh]	CO_2 [g/km]
Volvo M1	229.00 ± 10.86 (4.7%)	663.27 ± 13.24 (2.0%)	4.49 ± 0.06 (1.4%)	187.21 ± 1.80 (1.0%)
Volvo M2	221.44 ± 6.91 (3.1%)	679.27 ± 21.82 (3.2%)	4.57 ± 0.09 (2.0%)	189.47 ± 2.55 (1.3%)
Volvo L	196.80 ± 5.48 (2.8%)	640.68 ± 4.18 (0.7%)	4.36 ± 0.02 (0.5%)	183.58 ± 0.65 (0.4%)
IDIADA	F25 [N]	F100 [N]	CED [kWh]	CO_2 [g/km]
Volvo M1	238.17 ± 0.53 (0.2%)	699.22 ± 6.78 (1.0%)	4.64 ± 0.03 (0.6%)	191.40 ± 0.74 (0.4%)
Volvo M2	238.88 ± 3.29 (1.4%)	715.12 ± 2.47 (0.3%)	4.73 ± 0.01 (0.3%)	193.93 ± 0.40 (0.2%)
Volvo L	204.81 ± 0.72 (0.3%)	655.72 ± 0.19 (0.0%)	4.43 ± 0.00 (0.0%)	185.47 ± 0.01 (0.0%)
Lommel	F25 [N]	F100 [N]	CED [kWh]	CO_2 [g/km]
Ford M1	149.67 ± 6.09 (4.1%)	470.88 ± 2.67 (0.6%)	3.07 ± 0.02 (0.6%)	127.25 ± 0.57 (0.5%)
Ford M2	139.43 ± 1.78 (1.3%)	460.08 ± 4.22 (0.9%)	3.01 ± 0.01 (0.4%)	125.51 ± 0.42 (0.3%)
Ford H	161.28 ± 1.16 (0.7%)	508.50 ± 2.20 (0.4%)	3.24 ± 0.01 (0.2%)	132.47 ± 0.20 (0.1%)
IDIADA	F25 [N]	F100 [N]	CED [kWh]	CO_2 [g/km]
Ford M1	150.93 ± 1.74 (1.2%)	480.95 ± 1.26 (0.3%)	3.11 ± 0.01 (0.2%)	128.53 ± 0.22 (0.2%)
Ford M2	150.96 ± 2.62 (1.7%)	486.89 ± 11.49 (2.4%)	3.13 ± 0.05 (1.5%)	129.30 ± 1.46 (1.1%)
Ford H	169.90 ± 6.36 (3.7%)	516.67 ± 13.26 (2.6%)	3.28 ± 0.06 (1.8%)	133.84 ± 1.85 (1.4%)

5.3.2 *Repetition at different test tracks*

In addition to the overall observed variations in road load, CED and CO_2 derived from repeated coast down tests according to CoC specifications on the same test track, also possible differences in the variation observed on different test tracks can be analyzed from Table 5.1.

For all Volvo's the observed variations in F25 and F100 road loads are significantly higher at the Lommel PG than at the IDIADA PG. For the Fords this distinction is not so clear. For the Ford M2 and H the observed variations in F25 and F100 road loads at the Lommel PG are lower than at the IDIADA PG. This is the other way around for the Ford M1. In the combined impact on CED and theoretical CO_2 this leads to the highest variations for the Volvo vehicles on the Lommel PG, while for the Fords the highest variations occur at the IDIADA PG.

[7] See for example TNO 2016 R10419v3, *Supporting analysis on real world light duty vehicle CO_2 emissions*

The largest observed relative variations for the CoC specification tests performed at the Lommel and IDIADA PGs are framed in red and green respectively. Both the largest observed absolute and relative variations in road load and CED are from tests performed at the Lommel PG. The largest observed relative variation of the theoretically determined CO_2 value is about the same for both PGs.

With the statistics collected, the vehicles showing the highest variations in all coast-down tests are the Ford H vehicle at IDIADA and the Volvo M2 vehicle at Lommel. At low velocities the variations are larger, but at 100 km/h variations are often below 1%. The road load at 100 km/h is more relevant for the overall energy demand and the derived CO_2.

The large variations found with the Ford H vehicle at IDIADA could be explained by the fact that the default and extended test were performed at the same day, but with significantly different environmental conditions especially with respect to temperature and humidity, as can be seen in Table 5.2.

Table 5.2: Ford H, vehicle and environmental conditions for the default and extended tests performed at IDIADA PG.

	Vehicle conditions				Environmental conditions					
Test	TM CoC	TM Test	Tyre Temp	Tyre Pressure	Asphalt Temp	Ambient Temp	Humidity	Pressure	Air density	Wind
[-]	[kg]	[kg]	[°C]	[bar]	[°C]	[°C]	[%]	[kPa]	[kg/m³]	[m/s]
Default	1325	1342	43.5	2.13	32.94	22.67	31.02	101.08	1.1785	0.97
Extended	1325	1327	39.1	2.12	23.09	16.28	61.15	101.00	1.1842	0.82

In the end the results of the repetition tests show differences in the variation in road load force between the different test tracks, as is clearly seen for the Volvo's. But it is also shown that changing weather conditions have a significant influence on test outcomes, as is seen for the Ford H IDIADA repeat tests. Although these effects are clearly identified, quantifying their effect on the determined road load is difficult since the test program could not be performed at both test locations under exactly similar environmental conditions.

5.4 Variations in a single coast down test

Next to the variation in results between complete sets of coast down tests for road load determination, also the variation between pairs of coast down runs within a single test is analyzed. This is done by determination of the vehicle's road load per valid coast down pair separately. A typical example of a pair of coast down runs is shown in Table 5.3.

Table 5.3 gives an example of the coast down times of a complete pair of coast down runs. In this case the runs are split in three parts. Per speed bin and heading the individual and average coast down times are given. From these average coast down times per speed bin the road load force can be determined and corrected with the method described in section 3.7, using the correction coefficients prescribed for correcting the outcomes, for wind, temperature, and mass, of the entire test.
By doing this the individual complete pairs, that together make up the complete coast down test, can be compared.

Table 5.3: Example of a complete coast down pair (with split runs) and the derived average coast down times per speed bin.

Heading	+	-	+	-	+	-	
Split Run	1	2	3	4	5	6	Average
25 - 15 km/h	39.2	22.35					30.775
35 - 25 km/h	29.7	18.95					24.325
45 - 35 km/h	25.83	17.53					21.680
55 - 45 km/h	21.77	15.15					18.460
65 - 55 km/h	18.9	13.61	19.01	13.7			16.305
75 - 65 km/h			15.87	11.87			13.870
85 - 75 km/h			13.09	10.29			11.690
95 - 85 km/h			11.35	9.2	11.58	9.07	10.300
105 - 95 km/h					9.9	7.86	8.880
115 - 105 km/h					8.57	7.12	7.845
125 - 115 km/h					7.57	6.31	6.940
135 - 125 km/h					6.49	5.48	5.985

5.4.1 *Extended test analysis*

The variation between individual complete coast down pairs is compared for four Extended tests. The Extended test was selected since each test consists of a significant amount of complete runs, namely 20. The extended tests of the Volvo L and Ford H vehicles performed at both the Lommel and IDIADA PG were analyzed, giving the following results. Note that all presented results are corrected according the WLTP legislation as explained in section 3.7.

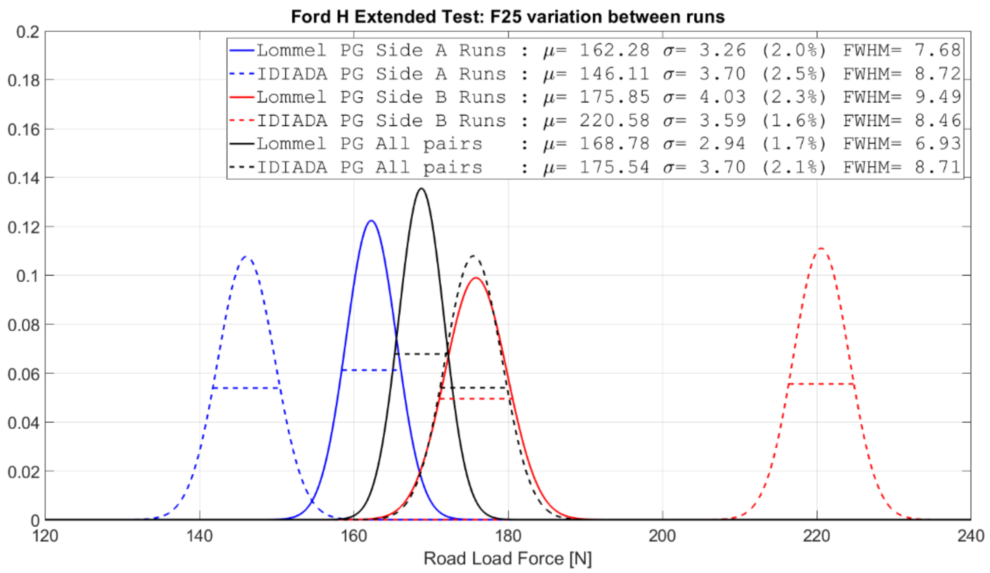

Figure 5.1: Ford H Extended test: variation in F25 between individual runs, the spread in the results of different runs plotted as gaussian distributions based on the average and the variation. The y-axis represents the density of probability. In the box the mean (μ), standard deviation (σ), σ/μ as percentage (relative variation) and full width at half maximum (FWHM) for each road load force distribution are presented.

In Figure 5.1 the average road load force at 25 km/h (F25) and the variation between runs is plotted for the Ford H Extended test performed at both the Lommel and IDIADA PGs. A distinction is made between separate results for all runs in the same direction (Side A and B) and the average road load and variation at 25 km/h for the entire test (all pairs).

The overall relative variation (σ/μ) in road load force observed at 25 km/h is around 2%. On individual runs the absolute variation is in the order of 3.5 N, from the figure above. For a pair that will lead to an uncorrelated variation of about 5%. This would mean that with about 4 runs the required accuracy of 3% could be reached.

The average road load at 25 km/h over all pairs is lower at Lommel than at IDIADA, as already highlighted in section 3.7. The difference in road load averages between the two driving directions is partly explained from the effect of the wind. The fact that the road load values of both driving directions at IDIADA are more apart than at Lommel is due the slope of the test track, resulting in an asymmetrical distribution of the RL force around the mean of the complete test. For this test, the mass of 1325 kg, the gravitational acceleration of 9.81 m/s^2 and the slope of 0.3% lead to a 39 Newton difference in force compared to a level track. This is very close to the observed 2 x 37 Newton difference in force between the A and B runs at IDIADA in the figure above. This force is independent of speeds (i.e., it remains equal at 25 and 100 km/h), and therefore at higher velocities this gravitational force has a smaller relative effect on the total road load force. However, the observed difference in F100 between A and B runs at IDIADA, as displayed in Figure 5.2 below, is found to be 2 x 54 N. Possibly, the wind significantly influenced this result as well.

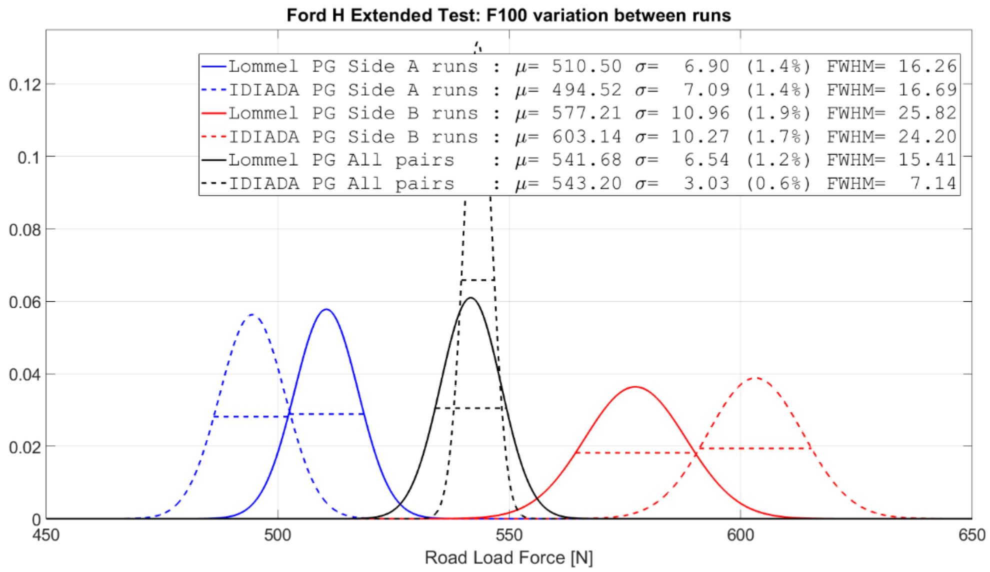

Figure 5.2: Ford H Extended test: variation in F100 between individual runs, the spread in the results of different runs plotted as gaussian distributions based on the average and the variation. The y-axis represents the density of probability. In the box the mean (μ), standard deviation (σ), σ/μ as percentage (relative variation) and full width at half maximum (FWHM) for each road load force distribution are presented.

Figure 5.2 presents results in a similar fashion as Figure 5.1, but in this case for the road load force at 100 km/h. Again the average road load force of the entire test is lower at Lommel than at IDIADA and the difference in road load force between both driving directions is larger at IDIADA due to the slope effect. However, this effect is less in relative size at this higher speed and also less asymmetrical, as explained before. The overall relative variations (σ/μ) in road load force are below 2%, slightly lower than at the lower speed of 25 km/h.

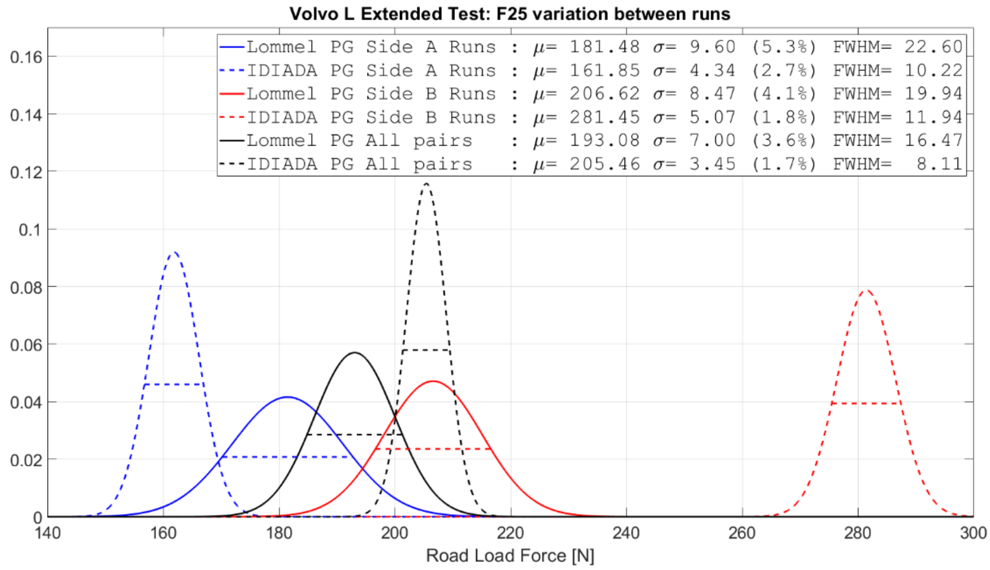

Figure 5.3: Volvo L Extended test: variation in F25 between individual runs, the spread in the results of different runs plotted as gaussian distributions based on the average and the variation. The y-axis represents the density of probability. In the box the mean (μ), standard deviation (σ), σ/μ as percentage (relative variation) and full width at half maximum (FWHM) for each road load force distribution are presented.

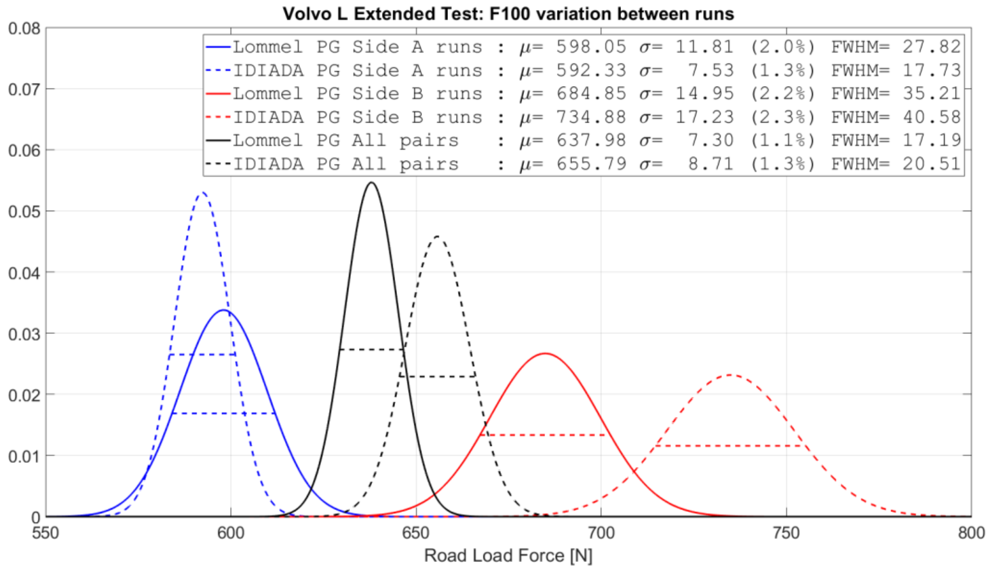

Figure 5.4: Volvo L Extended test: variation in F100 between individual runs, the spread in the results of different runs plotted as gaussian distributions based on the average and the variation. The y-axis represents the density of probability. In the box the mean (μ), standard deviation (σ), σ/μ as percentage (relative variation) and full width at half maximum (FWHM) for each road load force distribution are presented.

In Figure 5.3 and Figure 5.4 the same kind of results are presented for the Extended tests performed on the Volvo L vehicle at both test tracks. Similar observations regarding the difference in road load between both test tracks can be made as for the Ford H results. However, for the Volvo L the overall relative variation (σ/μ) in road load force at both speeds is somewhat higher than for the

Ford H, namely on average slightly above 3% at 25 km/h and around 2% at 100 km/h.

5.4.2 *Estimated variation in coast down times*

In the previous paragraph the variation between the individual complete coast down pairs was determined for four Extended coast down tests. Variation in the road load results derived from such sets is the result of the underlying variation between individual pairs of coast down runs. This variation can be assessed by composing different sets of coast down runs, meeting the statistical precision criteria, from a larger set of pairs of coast down runs.

In the WLTP a valid determination of road load is based on a set of coast down runs, of which for each speed bin the combined pairs of coast down times meet the statistical precision criteria as defined in the WLTP Regulation 2017/1151 Annex XXI Sub-Annex 4, Section 4.3.1.4.2.

The estimated variation in the coast down test is derived from possible combinations of pairs of coast down times per speed bin to form a complete speed trace (see Table 5.3) from a larger number of runs available from the extended testing.

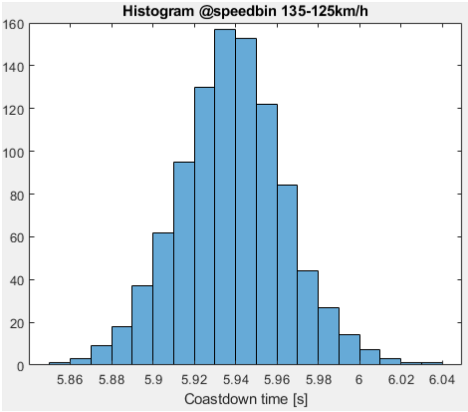

Figure 5.5: Histogram of all theoretically possible coast times in the 135-125 km/h speed bin from the test data of an extended test.

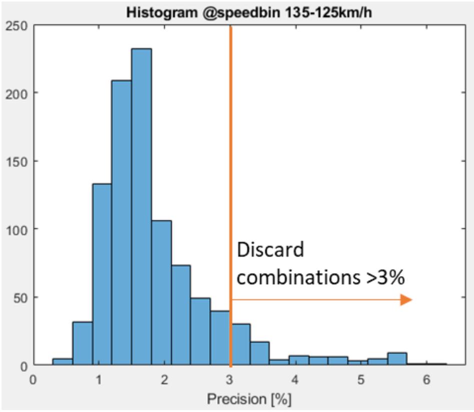

Figure 5.6: Histogram of the statistical precision corresponding to the coast down times of Figure 5.5

To clarify this approach Figure 5.5 shows the histogram of the average coast down time of all possible, statistically valid combinations of pairs of coast down times in the 135-125 km/h speed bin. There are in this case 968 random combinations of at least 3 pairs that meet the statistical precision criteria. In Figure 5.6 also the statistical precision histogram corresponding to Figure 5.5 is plotted. Here it is indicated that the combinations with a statistical precision above 3% should be discarded as described in Regulation 2017/1151 Annex XXI Sub-Annex 4, Section 4.3.1.4.2. For this particular speed bin this results in 879 possible valid combinations of coast down time pairs derived from the 10 pairs that were recorded during the coast down test.

As seen in Figure 5.5 the coast down times for all valid possible combinations are normally distributed. For all speed bins the distribution of possible combinations can therefore be expressed in a mean coast down time and corresponding standard deviation, from which the road load curve can be determined.

Two Extended tests of the Volvo L (one at Lommel and one at IDIADA) were analyzed in this way, meaning all possible complete coast down pairs were constructed from all theoretically possible coast times per speed bin. In that way the theoretical variation in the coast down test was retrieved. The road load force values derived from the coast down times and the variation per speed bin are given in Table 5.4 and Table 5.5.

In both tables the average road load force and standard deviation are presented, determined from taking all valid possible combinations of pairs of coast down times per speed bin. The standard deviation expressed as a percentage of the average road load indicates the theoretical spread in road load force when determining the road load of a vehicle using the coast down test procedure. The largest observed variation within a speed bin is 1.0%.

Table 5.4: Volvo L Extended test at IDIADA PG road load force [N] and theoretical variation.

Speed	20	30	40	50	60	70	80	90	100	110	120	130
Mean	192.49	220.85	257.62	302.81	356.41	418.43	488.86	567.7	654.95	750.62	854.7	967.2
Stdev	0.94	1.36	1.74	2.11	2.44	2.75	3.03	3.29	3.52	3.72	3.9	4.05
Stdev	0.49%	0.61%	0.68%	0.70%	0.68%	0.66%	0.62%	0.58%	0.54%	0.50%	0.46%	0.42%

Table 5.5: Volvo L Extended test at Lommel PG road load curve [N] and theoretical variation.

Speed	20	30	40	50	60	70	80	90	100	110	120	130
Mean	182.17	207.73	242.29	285.85	338.4	399.95	470.49	550.03	638.57	736.1	842.63	958.15
Stdev	1.82	1.85	1.98	2.21	2.52	2.93	3.44	4.04	4.73	5.52	6.4	7.38
Stdev	1.00%	0.89%	0.82%	0.77%	0.75%	0.73%	0.73%	0.73%	0.74%	0.75%	0.76%	0.77%

In Table 5.6 the effect of a 1% variation in road load is translated into a variation in CO_2 value for all 6 tested vehicles by determining the CED and using the interpolation method, as described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3 and 5 respectively. Averaged over all vehicles a 1% variation in road load force results in a 0.7 g/km or 0.45% variation in CO_2 value.

Table 5.6: Theoretical variation in road load from coast down testing, expressed in a CO_2 variation for all 6 vehicles.

	CoC CO_2 [g/km]	+1% RL CO_2 [g/km]	ΔCO_2 [g/km]	ΔCO_2 [%]
Volvo M1	184.43	185.19	0.75	0.41%
Volvo M2	186.14	186.91	0.77	0.41%
Volvo L	180.21	180.94	0.73	0.40%
Ford M1	127.94	128.54	0.60	0.47%
Ford M2	127.90	128.50	0.60	0.47%
Ford H	134.05	134.75	0.70	0.52%
		Average	0.69	0.45%

5.5 Variation related to the active grill setting

As was shown from the coast down test results in section 3.8.3 different settings of the active grill lead to variations in road load values and corresponding CED values. The resulting theoretical implications on CO_2 emissions are presented in Table 5.7.

Table 5.7: Ford H coast down test results with variations in active grill setting, expressed in CED and CO_2 values.

Grill Setting	CED	ΔCED vs. NORMAL GRILL	ΔCED vs. NORMAL GRILL	CO_2	ΔCO_2 vs. NORMAL GRILL	ΔCO_2 vs. NORMAL GRILL
[-]	[kWh]	[kWh]	[%]	[g/km]	[g/km]	[%]
OPEN	3.24	0.04	1.4%	132.61	1.40	1.1%
NORMAL	3.20	-	-	131.21	-	-
CLOSED	3.11	-0.09	-2.6%	128.65	-2.55	-1.9%

Translating the total observed variation in vehicle road load due to the active grill setting into a variation in CO_2 emissions, derived using the interpolation method, a variation of almost 4 g/km CO_2, between grill fixed open and fixed closed, is observed.

5.6 Variation related to tyre temperature

The tyre temperatures of all vehicles were monitored at all coast down tests using the handheld thermometer described in section 3.4.4. The tyre temperatures were monitored at three instances: right before warm-up, right before coast down and directly after coast down.
Next to that the track surface temperature was measured right before and directly after the coast down procedure. The following results are obtained from those measurements.

Table 5.8: Tyre, track surface and ambient air temperature average and spread over all coast down tests per test location.

	Before warm-up		Before coast down		After coast down	
Test track	Mean [°C]	Stdev [°C]	Mean [°C]	Stdev [°C]	Mean [°C]	Stdev [°C]
Lommel PG	15.81	5.52 (34.9%)	26.20	5.37 (20.5%)	26.31	4.33 (16.4%)
IDIADA PG	29.50	2.28 (7.7%)	39.54	2.84 (7.2%)	35.36	3.41 (9.7%)

	Track surface		Ambient air	
Test track	Mean [°C]	Stdev [°C]	Mean [°C]	Stdev [°C]
Lommel PG	17.81	5.94 (33.4%)	12.30	4.26 (34.6%)
IDIADA PG	26.34	2.79 (10.6%)	17.83	(10.5%)

In Table 5.8 the average tyre temperature, over all coast down tests of all vehicles per test location, over all four wheels is presented (mean) for each of the three instances (before warm-up, before and after coast down). Also the spread (stdev) in averaged tyre temperature between the tests is displayed, in absolute terms and relative to the mean. The displayed track surface temperature is the average track surface temperature over all tests per test location, and over the two instances (before and after coast down). The displayed ambient air temperature is the average ambient air temperature during each coast down test, averaged over all tests per test location.

Due to different weather conditions the recorded temperatures at the IDIADA PG were higher than at the Lommel PG. The average ambient air and track surface temperatures were respectively 5.5°C and 8.5°C higher at the IDIADA PG. This difference is also seen in the average tyre temperatures at Lommel and IDIADA.

The average tyre temperature increase due to the warm-up procedure before coast down are very similar for both test tracks, with 10.4°C for the Lommel tests and 10.0°C for the IDIADA tests.

Looking into the average tyre temperature before and after coast down, the results from both test tracks are different. At the Lommel PG the tyre temperature remained fairly constant (+0.11°C), related to friction during the sharp turns (incl. associated steep decelerations and accelerations) that have to be made there. At IDIADA the temperature decreased over the coast down test relative to the initial values after preconditioning (-4.17°C), as a result of intermediate speed driving, at the same speed as the coast-down tests, on the wide bends of that track. This means that with the normal execution of tests on different tracks the actual tyre temperature is already observed to vary 4 degrees.

A variation in tyre temperature results in a variation in road load force, as is described by the rolling resistance correction factor, see Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.5.2, which gives a relation for this effect. A 4°C variation in tyre temperature results in a variation in rolling resistance (f0) of 3%. In Table 5.9 the impact has been expressed in absolute terms for rolling resistance, CED and CO_2.

Table 5.9: Impact of tyre temperature variation expressed in f0, CED and CO_2. All CED values have been determined as described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 5. All CO_2 values have been determined as described in Regulation 2017/1151 Annex XXI Sub-Annex 7 section 3.

	f0	f0 (+3%)	Δf0		CED	CED (+3%)	ΔCED
	[N]	[N]	[N]		[kWh]	[kWh]	[kWh]
Volvo M1	143.50	147.81	4.31		4.393	4.415	0.022
Volvo M2	147.20	151.62	4.42		4.454	4.476	0.022
Volvo L	109.10	112.37	3.27		4.242	4.258	0.016
Ford M1	119.85	123.45	3.60		3.092	3.111	0.019
Ford M2	119.77	123.36	3.59		3.091	3.109	0.019
Ford H	142.04	146.30	4.26		3.289	3.311	0.022
Average			3.91				0.020

	CO_2	CO_2 (+3%)	ΔCO_2
	[g/km]	[g/km]	[g/km]
Volvo M1	184.432	185.045	0.613
Volvo M2	186.143	186.771	0.628
Volvo L	180.207	180.668	0.461
Ford M1	127.938	128.515	0.577
Ford M2	127.899	128.476	0.577
Ford H	134.050	134.743	0.693
Average			0.591

As seen in Table 5.9 the 3% variation in rolling resistance translates on average over all six vehicles to a variation in rolling resistance of 3.9 N, in CED of 0.02 kWh and in CO_2 of 0.59 g/km.

5.7 Variations related to uncertainties in the corrections for wind

5.7.1 Location of weather station

The two coast down test facilities (Lommel and IDIADA) have weather monitoring equipment placed differently alongside the track. At the Lommel PG the weather station is located at one end of the test track and fitted to a high tower, at 10 m above the track surface. At this test location TNO was allowed to place its own weather monitoring equipment alongside the track as well, at about 1.5 m height. The locations of the weather stations at the Lommel PG are shown in Figure 5.7.

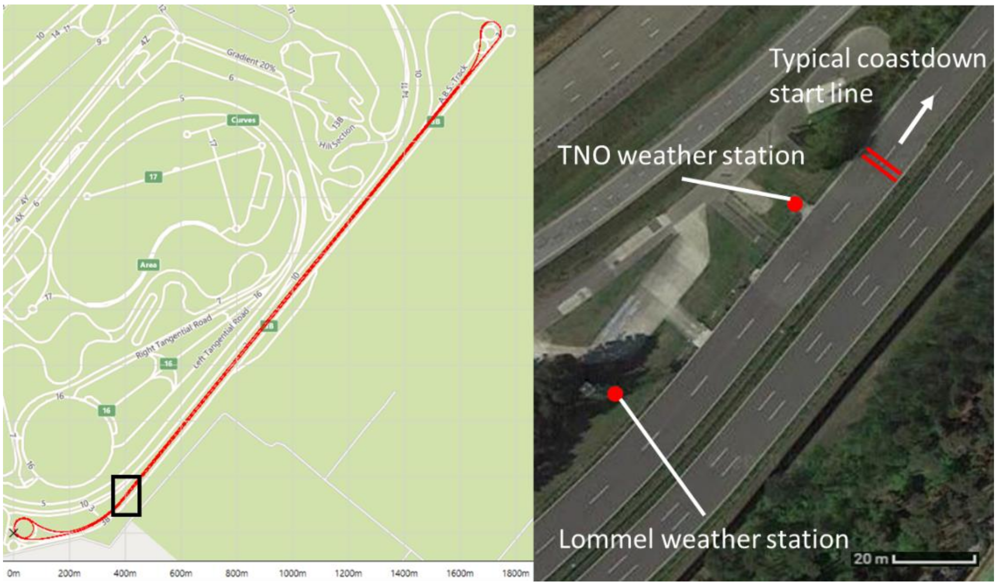

Figure 5.7: Lommel Proving Ground weather station location. The white arrow indicates the driving direction from the coast down start line (one of the driving directions).

The weather data from both weather stations is compared thoroughly for two tests. These tests are L14 and L1 (see Annex B), with an average wind speed of 3.40 and 1.04 m/s, the highest and lowest recorded wind speeds respectively.

Table 5.10: Lommel PG coast down test 14 (L14) average wind speed and direction. The interval (±) indicates the standard deviation. The Lommel PG weather data averages are determined from 1Hz data with 60 sec. moving average. The TNO weather data averages are determined from minute data.

Weather station	Average wind speed	Average wind direction
[-]	[m/s]	[degrees]
Lommel PG	3.40 ± 0.92	200.81 ± 16.11
TNO	2.91 ± 0.88	205.12 ± 23.85

Table 5.11: Lommel PG coast down test 1 (L1) average wind speed and direction. The interval (±) indicates the standard deviation. The Lommel PG weather data averages are determined from 1Hz data with 60 sec. moving average. The TNO weather data averages are determined from minute data.

Weather station	Average wind speed	Average wind direction
[-]	[m/s]	[degrees]
Lommel PG	1.04 ± 0.31	11.00 ± 20.88
TNO	0.50 ± 0.39	7.35 ± 37.70

For both tests the average wind speed and direction at both weather stations are listed in Table 5.10 and Table 5.11. It is seen that for both tests the measured wind speed at the TNO weather station is about 0.5 m/s lower.

Based on this lower wind speed also the downward correction on the determined road load force is less, as is described by the wind correction resistance, w_1, in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.5.3.1.2. In Table 5.12 the effect of this 0.5 m/s lower wind speed at both low and high wind speeds is seen for both the Fords and Volvo's.

Table 5.12: Effect of different placement of weather station on recorded wind speed and its corresponding effect on the wind correction resistance, w_1, and translated into its effect on the WLTP CO_2 value. Effects presented for both high and low wind speeds and as average over the 3 tested vehicles per IP family.

Vehicle	Wind speed	Reduction in wind correction resistance w_1	Effect on WLTP CO_2 emissions*
[-]	[m/s]	[N]	[g/km]
Ford	3.40 to 2.91	1.21	+ 0.19
Ford	1.04 to 0.50	0.40	+ 0.06
Volvo	3.40 to 2.91	1.49	+ 0.21
Volvo	1.04 to 0.50	0.40	+ 0.06

* Effects on CO_2 emissions have been determined from the change in cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

From Table 5.12 it can be seen that for the Fords and Volvo's a 0.5 m/s lower recorded wind speed at high wind speeds, due to a different placement of the weather station alongside the track, results in a 1.21 and 1.49 N higher road load force, respectively. This translates to a 0.2 g/km increase in CO_2 emissions. For low wind speeds a lower recorded wind speed does not lead to a significant increase in CO_2 emissions.

At the IDIADA PG two weather stations are located at either straight part of the oval test track at a height of 1.5 m above the track surface. TNO was not allowed to place its own weather station alongside this test track. The locations of the weather stations at the IDIADA PG are seen in Figure 5.8.

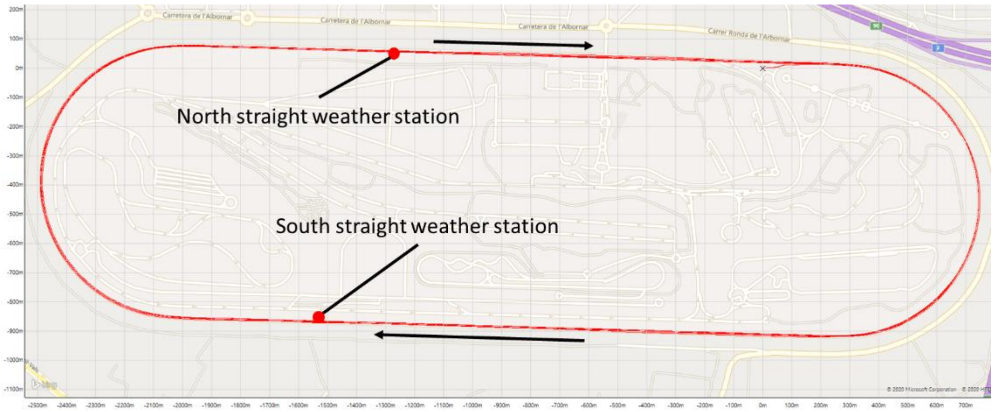

Figure 5.8: IDIADA Proving Ground weather station location. The black arrow indicates the driving direction on the oval.

The weather data from both weather stations is compared thoroughly for two tests. These tests are I3 and I8 (see Annex B). For both tests the average wind speed and direction at both weather stations are listed in Table 5.13 and Table 5.14. It is seen that for both tests the measured wind speed by the south straight weather station is lower. At the highest recorded average wind speed during a test of 1.04 m/s this difference is 0.4 m/s. At the lowest recorded average wind speed during a test of 0.28 m/s this difference is 0.2 m/s.

Table 5.13: IDIADA PG coast down test 3 (I3) average wind speed and direction. The interval (±) indicates the standard deviation. The IDIADA PG weather data averages are determined from 1Hz data with 60 sec. moving average.

Weather station	Average wind speed	Average wind direction
[-]	[m/s]	[degrees]
North straight	0.84 ± 0.38	74.95 ± 47.51
South straight	1.24 ± 0.55	84.35 ± 11.30

Table 5.14: IDIADA PG coast down test 8 (I8) average wind speed and direction. The interval (±) indicates the standard deviation. The IDIADA PG weather data averages are determined from 1Hz data with 60 sec. moving average.

Weather station	Average wind speed	Average wind direction
[-]	[m/s]	[degrees]
North straight	0.18 ± 0.19	101.96 ± 126.73
South straight	0.38 ± 0.28	153.35 ± 65.21

Again this difference in recorded wind speed at the two weather stations is translated into its potential effect on the wind correction resistance and thereby the road load force and CO_2 emissions. In Table 5.15 it is shown that the difference in recorded wind speeds between the north and south straight weather stations has no significant influence on the road load force and CO_2 emissions. At an average wind speed of 1.04 m/s the difference translates into a 0.40 N difference in road load force and 0.06 g/km difference in CO_2 emissions. At an even lower average wind speed of 0.28 m/s this is even lower with 0.05 N and 0.01 g/km.

Table 5.15: Effect of different placement of weather station on recorded wind speed and its corresponding effect on the wind correction resistance, w_1, and translated into its effect on the WLTP CO_2 value. Effects presented for both high and low wind speeds and as average over the 3 tested vehicles per IP family.

Vehicle	Wind speed	Reduction in wind correction resistance w_1	Effect on WLTP CO_2 emissions*
[-]	[m/s]	[N]	[g/km]
Ford	1.24 to 0.84	0.32	+ 0.06
Ford	0.38 to 0.18	0.05	+ 0.01
Volvo	1.24 to 0.84	0.40	+ 0.05
Volvo	0.38 to 0.18	0.05	+ 0.01

* Effects on CO_2 emissions have been determined from the change in cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in Regulation 2017/1151 Annex XXI Sub-Annex 7 Section 3.

Despite the correction an uncertainty remains at higher wind speeds. As stated in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.1.1.1.1., average wind speeds up to 5 m/s are allowed during coast down testing. At such wind speeds the observed difference in measured wind speeds at different locations of the weather station will have a significant influence on the determined road load force (≥ 1.5 N) and thereby the CO_2 emissions (≥ 0.2 g/km).

5.7.2 *Changing wind conditions between coast down runs*

The described wind correction, as stated in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.5.3.1.2., takes into account the average wind speed over the entire test. Changing wind conditions during a test could however result in different average wind speeds for the different driving directions.

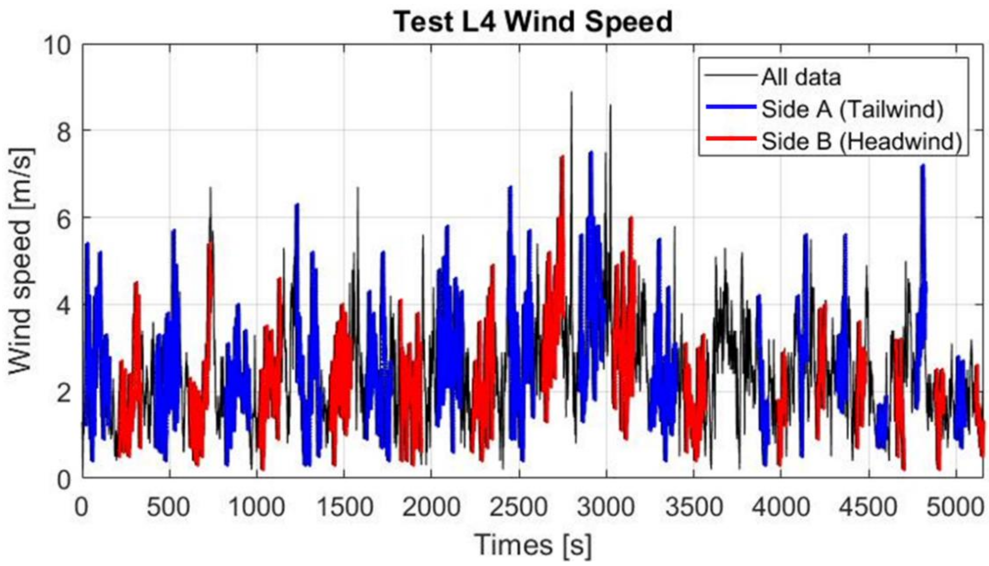

Figure 5.9: Lommel PG coast down test 4 (L4) wind speed. The wind speed data highlighted in blue and red corresponds to both driving directions during coast down testing.

In Figure 5.9 the recorded wind speed over the entire test time is displayed. In blue and red the wind speed data at the moment of coasting of the vehicle, in both directions, is highlighted. This means that the unhighlighted parts of the data was recorded when the vehicle was driving on connecting roads in between runs.

The data from Figure 5.9 is presented as a Gaussian distribution in Figure 5.10. The average wind speed over the entire test is 2.42 ± 1.15 m/s. The average wind speed during coast down is 2.54 ± 2.79 and 2.21 ± 2.54 m/s for the different driving directions respectively. The average wind speed during coasting is found to be different for both directions. The average wind speed at Side A differs by 0.12 m/s from the total test average. For Side B this difference is 0.21 m/s. The wind speeds at both driving directions are asymmetrically distributed around the average wind speed that is used for the WLTP correction.

In this example this asymmetrical effect results in an uncertainty of 1 N wind correction resistance w_1, and 0.15 g/km CO_2. In the least favourable case of wind speeds up to 5 m/s, this effect can result in an uncertainty of up to 3 N and 0.45 g/km CO_2.

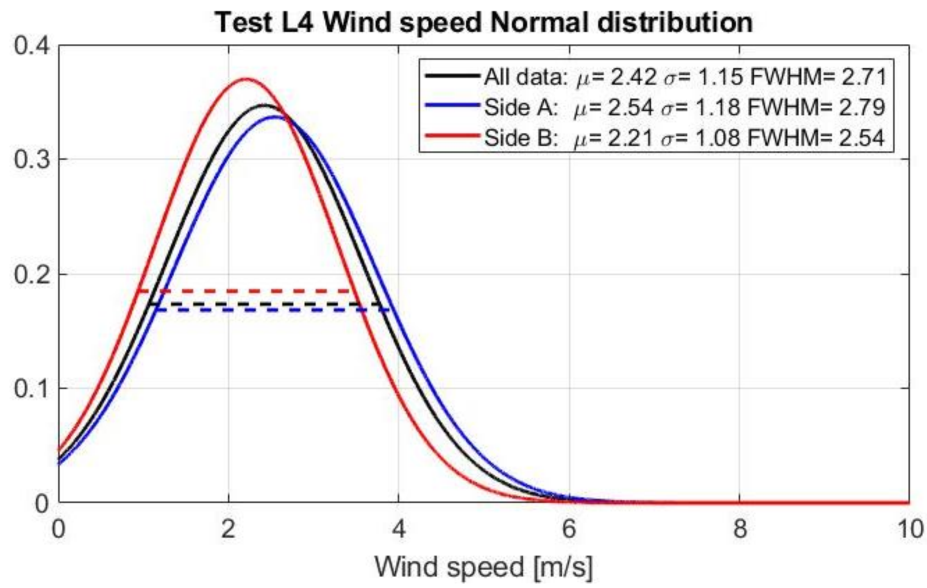

Figure 5.10: Lommel PG coast down test 4 (L4) wind speed plotted as gaussian distributions based on the average and the variation. The y-axis represents the density of probability. In the box the mean (μ), standard deviation (σ), σ/μ as percentage (relative variation) and full width at half maximum (FWHM) for each road load force distribution are presented.

5.8 Base margin representing a general measurement accuracy

Besides variations in test results originating from identifiable variations in test conditions, there is also a general measurement accuracy related to the accuracy of the equipment used and the accuracy with which the prescribed procedure can be followed. This general measurement accuracy can be established from repeat testing of the same vehicle under comparable test circumstances, and can be translated into a base margin that needs to be taken into account in de statistical procedure and pass/fail criteria (see Chapter 8).

5.9 Conclusions regarding uncertainties / variations in CO_2 testing related to coast down tests

- Due to the characteristics of available test tracks it is inevitable to carry out coast down tests using split runs. This creates some freedom in the order of execution of the split runs. Together with track-specific vehicle movements between runs, this affects the tyre pressure over the course of the test and therefore is a source of variation in test results.
- The difference between coast-down test results obtained on the IDIADA and Lommel test tracks translates into an average 2.3 g/km CO_2. The uncertainty in the road load derived from coast-down testing is less than 0.5%, which leads to a 0.7 g/km variation in CO_2 value on the chassis dynamometer test. Therefore, the systematic difference between the test tracks is much larger than the uncertainty from the tests.
- The standard deviation in road load forces, derived from pairs (test in both directions) of repeated coast down tests, is typically around 2%.

- The setting of an active grill has a large impact on the road load measured in a coast down test. The difference in resulting CED between an open and a closed grill is around 4%.
- The location of the weather station, relative to the test track, is found to have a significant impact on the recorded wind speed and the resulting wind correction. This most prominent at higher wind speeds.
- The wind correction, as stated in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 4.5.3.1.2., takes into account the average wind speed over the entire test. Changing wind conditions during a test, however, are seen to result in different average wind speeds for the different driving directions. In the analysed test, the wind speeds at both driving directions were found to be asymmetrically distributed around the average wind speed that is used for the WLTP correction. Ignoring this asymmetry may lead to impacts on measured CO_2 of 0.15-0.45 g/km.

5.10 Options for reducing uncertainties / variations in the coast down test

Uncertainties associated with the road load testing as part of In-Service Verification may be reduced by different measures, for which some suggestions are listed below. It is noted that some of these would require changes to the applicable legislation, in particular Commission Regulation (EU) 2017/1151 (WLTP) and Regulation (EU) 2019/631 (CO_2 regulation):

- The different test track layouts of the Lommel and IDIADA PGs resulted in differences in the coast down test results obtained at both locations. These differences are, amongst others, related to variations in tyre temperature and to differences in weather station placement for wind condition determination at both tracks. Degrees of freedom in the coast down test procedure due to the test track layout can only be brought under control (or their impacts understood) by extensive control and reporting, transparency, and comparative testing.
- Current practice is that the execution of a WLTP test generally requires information from the manufacturer and/or instructions on how to enable the vehicle to function safely or at all during the test on a track or chassis dynamometer. This remains a source of uncertainty, especially with respect to the extent to which the vehicle on the test as under normal real-world driving conditions. The need for special test modes should therefore be mitigated or it should be made sure that the operation of the vehicle's powertrain and energy using auxiliaries in test mode do not deviate from that in normal use.
  - An important source of variation in coast down test results was found in the active grill setting of the vehicles. The vehicle-family specific instructions provided by the OEM on how to handle the active grill during coast down testing might raise concern regarding the extent to which the vehicles operate "normally" during coast-down testing.
  - More transparency may allow more scrutiny of the differences between coast down modes and normal operation. The manufacturer could be required to provide a general procedure beforehand. If these instructions are followed, and the necessary elements are recorded, a test is valid. While this does not allay the concerns about the differences in active grill operation between coast down testing and normal operation, it would provide more insight in this difference for independent parties and in the necessity for using a coast down mode, or specifically for adjusting the grill setting during coast down testing.

  - Harmonization and improved visibility of indicators, indicating that the vehicle is in test mode, and the availability of guidance tools during the test mode setting procedure are recommended. This will help to prevent disputes on test results.
- In some cases results deviate because certain thresholds for the application of a WLTP correction are reached. The discrete nature of applying a correction only if a threshold is exceeded may generate larger variations in the test results than the underlying factors themselves.
  - Besides the option of excluding these corrections in the ISV procedure, an alternative option is to adapt the WLTP in such a way that this type or corrections is not used at all or replaced by corrections with a more gradual, rather than discrete effect on the resulting test value.
- The possibility of separate evaluation of parts of the WLTP (i.e., road load values and CO_2 values) relies on appropriate reporting. Currently, it seems that the manufacturers already include margins relative to the TA test result in the declared CoC values for the VL and VH cases. Whether the road load values for these two chassis dynamometer tests, as also reported in the CoC, also include these margins is unclear. Harmonization may be needed with respect to the definition of reported values (including margin vs. actual) to make sure that the result of a separate evaluation of the road load is compared to the appropriate reference value.

The Transparency List will most likely bring improvements to the availability of information and settings required to be able to perform a CO_2 In-service Validation test.

6 Analysis of elements determining variations between chassis dynamometer tests

6.1 Introduction

The analysis presented in this chapter is part of task 4 of the project. It aims to identify from practice (in particular from task 3) and complementary theory the factors possibly affecting the result of the WLTP chassis dynamometer test and, in turn, the CO_2 result for in service verification of an individual vehicle placed on the market or the interpolation line for a family of vehicles.

Chassis dynamometer testing is more of a black box test than coast down testing. In coast down testing, a limited number of uncontrolled elements, like wind and temperature determine the largest part of the uncertainty. With chassis dynamometer testing, much more of the conditions are controlled and less prone to change (e.g. the ambient conditions), but the result may still vary for reasons more difficult to identify.

Repeatability with the same vehicle in consecutive tests is generally good, with occasional outliers. Repeat testing on different vehicles of the same model generally shows more variation in results. In the UNECE Task Force on Conformity of Production, JRC has analyzed Conformity of Production data collected after the introduction of the WLTP in 2018, from France (611 vehicles from the 11 families which have at least 16 vehicles) and Germany (987 vehicles from the 186 families which have at least 3 vehicles), which showed 2.31% and 1.70% variation in WLTP IP family results for CO_2 emissions , if these dataset are shifted to the average of each IP family[8]. The datasets contain measured CoP values that are on average 5% below the declared values. These variations incorporate all elements of the chassis dynamometer testing, and they are based on measurements using the CoC road load and mass values of the individual vehicles.

6.2 Different types of variations in ISV testing

In section 5.2 a general categorization is given of different types of variations that can be observed in ISV testing. Due to the larger bandwidths in both controlled and uncontrolled variations in ambient and other test conditions, the variations in road load testing are expected to be higher than in chassis dynamometer testing.
The variations in chassis dynamometer testing can generally be separated in (i) true variations, which can be identified by repeat tests, (ii) systematic effects from test execution, which cannot be identified from repeat testing in the same laboratory, and (iii) effects from variations in vehicle and engine control strategy. Causes for the latter effects are occasionally observed, when lights remain on or when stop-start will not engage in the test. But in other cases such effects may be untraceable.

After typically 15,000 km of normal use, systematic differences between test results of different vehicles of the same model are to be expected as a result of the use of the vehicles. Differences may be related to, e.g., the soot loading of the DPF, wear,

[8] www.unece.org, WLTP Task Force on Conformity of Production (CoP TF), 9th session

or tyre choice. In as far as these differences are not associated with malfunctioning, they are to be considered as associated with the normal state of the specific vehicles, similar to differences resulting from variation in the production. The systematic variation between different vehicles, typically lies in the same order as the test-by-test variation on the same vehicle in the same laboratory. But the true cause is generally unknown, and very difficult to trace back. It is therefore essential that enough vehicles are tested, especially when the inter-vehicle variation of the test results is large.

6.3 Variations related to repetition of tests

From the chassis dynamometer measurements undertaken for this project, the variation related to the repetition of tests is decomposed in two elements: the variation in coast down control tests and the variation in chassis dynamometer tests.

6.3.1 Coast down control tests

The coast down control test on the chassis dynamometer is made up of two parts: the iterative setting of road load parameters of the chassis dyno to meet the target road load prior to the test, and a coast down check after the test to assess if the road load settings of the chassis-dyno are still in line. The iterative procedure to correctly set the chassis-dyno road load parameters is described in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 8.1. The procedure to check the road load settings of the chassis-dyno after a test is common practice, but does not exist in regulation.

In Table 6.1 the results of the road load setting on the chassis-dyno are presented. The target road load for each vehicle is the CoC road load, translated here in CO_2 emissions using the interpolation method. For both the Fords and Volvo's the road load setting was below the target road load, on average over all vehicles 0.2 g/km lower with a 0.5 g/km variation.

Table 6.1: Difference in road load between chassis-dyno setting and target, expressed in CO_2 [g/km].

Test vehicle	Target CO_2	CO_2 Setting	Delta	
[-]	[g/km]	[g/km]	[g/km]	
Ford M1	127.94	127.83	-0.11	
Ford M2	127.94	127.76	-0.18	Ford delta and variation
Ford H	134.05	133.93	-0.12	-0.13 ± 0.04 g/km
Volvo M1	186.14	185.10	-1.04	
Volvo M2	186.14	186.74	0.59	Volvo delta and variation
Volvo L	180.21	179.77	-0.44	-0.30 ± 0.83 g/km
All vehicles delta and variation				-0.21 ± 0.53 g/km

It should be noted that the coast downs performed for road load setting have been done by bringing the vehicle and dyno up to speed using the vehicle, i.e. the vehicle was driving the chassis-dyno. For comparison the road load of the chassis-dyno was also set by doing coast downs were the dyno was driving the vehicle. This was done with the Volvo M2. Both methods are allowed according the WLTP legislation, as is described in Regulation 2017/1151 Annex XXI Sub-Annex 4 Section 8.1.3.4.

The result of this additional test is presented in Table 6.2 and is in line with the results of Table 6.1.

Table 6.2: Difference in road load between chassis-dyno setting and target, expressed in CO_2 [g/km], of the comparison road load setting test were the chassis-dyno was driving the vehicle.

Test vehicle	Target CO_2	CO_2 Setting	Delta
[-]	[g/km]	[g/km]	[g/km]
Volvo M2	186.14	185.76	-0.38

In Table 6.3 the results of the comparison between the road load setting of the chassis-dyno and the road load checks performed after the CoC-COLD, CoC-HOT and CoC-MINUS7 tests are presented. Depending on the number of chassis-dyno tests that were performed per vehicle the number of checks varies. It should be noted that since this road load settings check procedure is not regulated the impact of time passed between the end of test and start of coast down check is crucial. Instructions given to the labs were to perform coast down checks within 120 seconds after end of test, as for practical reasons this is not possible directly after end of test. This might result in some coast down checks having been done after 30 seconds and some other after 120 seconds. As different vehicles cool down with different speeds this also effects the road load of these vehicles differently. For example the effect is higher for vehicles with AT such as the Volvo.

Table 6.3: Average difference and variation in road load between chassis-dyno check and setting, expressed in CO_2 [g/km], for the CoC-COLD, CoC-HOT and CoC-MINUS7 tests, performed with CoC-specification for the road load.

Vehicle	Average Delta CO_2 Check vs. Setting	Variation in Delta CO_2 Check vs. setting	Number of checks
[-]	[g/km]	[g/km]	[-]
Ford M1	0.27	0.49	7
Ford M2	0.10	0.33	6
Ford H	0.27	0.49	7
Volvo M1	0.73	3.21	7
Volvo M2	2.62	2.88	8
Volvo L	1.17	1.35	6
All Ford's	0.22	0.43	20
All Volvo's	1.57	2.68	21
All vehicles	0.91	2.04	41

Overall it is seen that after the emission tests the measured road load, expressed in CO_2 emissions, is on average 0.22 g/km and 1.57 g/km higher than the road load setting prior to testing for all Fords and Volvo's respectively, with variations in CO_2 of 0.43 g/km and 2.68 g/km respectively. Combining the results of all vehicles, the road load, expressed in CO_2 emissions, measured at the coast down checks is on average 0.91 g/km higher than the set road load, with a variation of 2.04 g/km.

Comparing the results between road load target setting (and check) for the CoC-COLD, CoC-HOT and CoC-MINUS7 tests, the variation in coast down control is in the order of 0.5 g/km. In some cases a 3 g/km deviation is observed, without clear underlying cause observable in, e.g., a variation in test conditions. The chassis dynamometer setting was varied with a small but fixed amount, so this result is related to the coast-down test procedure and vehicle performance.

For the chassis-dyno tests described in paragraphs 4.2.6 to 4.2.12 the chassis-dyno road load was not set by iteratively matching the target road load setting, but by offsetting the found chassis-dyno settings for the vehicle's CoC-COLD, CoC-HOT and CoC-MINUS7 tests. A coast down check was performed after each emissions test. The road loads measured in these checks in some case deviated significantly from the values expected on the basis of the adjustment made to the CoC chassis-dyno settings. The results are presented in Table 6.4.

Table 6.4: Difference in road load setting of the chassis-dyno, expressed in CO_2 emissions, before and after the test for the chassis-dyno tests described in paragraphs 4.2.6 to 4.2.12.

Test vehicle	Chassis-dyno test	Target CO_2	CO_2 Check	Delta	
[-]	[-]	[g/km]	[g/km]	[g/km]	
Ford M1	RLVL-HOT	121.93	121.51	-0.42	
Ford M1	RLVH-HOT	136.64	136.15	-0.49	
Ford M1	RL-TYRE-HOT	129.03	128.55	-0.49	
Ford M1	TNOVH-HOT	128.70	128.08	-0.62	
Ford M1	RLm-HOT	130.25	129.65	-0.60	
Ford M1	RLHM-HOT	135.32	134.59	-0.73	
Ford M1	RL-GRILL-HOT	124.16	123.81	-0.34	
Ford M1	RLm-HOT	130.26	129.80	-0.47	
Ford M1	RLHM-HOT	135.32	134.73	-0.59	
Ford M2	RLm-HOT	125.83	125.22	-0.61	Ford delta and variation
Ford M2	RLVH-HOT	137.01	136.23	-0.78	-0.56 ± 0.13 g/km
Volvo M1	RL-GRILL-HOT	180.88	177.84	-3.04	
Volvo M1	RLm-HOT	194.21	189.68	-4.53	
Volvo M1	RL-TYRE-HOT	193.98	190.13	-3.85	
Volvo M1	RLm-HOT	185.48	183.77	-1.70	
Volvo M1	RLm-HOT	185.48	183.18	-2.30	
Volvo M1	RLVH-HOT	201.00	196.46	-4.54	
Volvo M1	RLVL-HOT	178.00	173.30	-4.70	
Volvo M1	TNOVH-HOT	187.71	182.84	-4.87	
Volvo M1	RLHM-HOT	188.86	184.16	-4.70	
Volvo M2	RLm-HOT	191.27	191.14	-0.13	Volvo delta and variation
Volvo M2	RLVH-HOT	201.00	206.77	5.77	-2.60 ± 3.17 g/km
All vehicles delta and variation					-1.58 ± 2.42 g/km

The results in Table 6.4 display a difference in road load measured during the coast down check compared to the target road load of -0.56 g/km and -2.60 g/km CO_2 for the Fords and Volvo's respectively. The variation in delta CO_2 between the different tests is 0.13 g/km and 3.17 g/km CO_2 for the Fords and Volvo's respectively.

It was observed that for the Volvo the chassis dynamometer setting adjustments for the change in road load force (when checked after a test) were much larger than for the Ford. This means that the deviation between estimated and measured road load value was larger for the Volvo than for the Ford. A possible explanation for this might be found in differences in test execution and test setup, e.g. the fact that the Fords were tested on a 4WD dyno in 2WD mode while the Volvo's were tested on a 4WD dyno in 4WD mode. Also the earlier mentioned time between end of test and chassis-dyno road load check and its effect on the road load could be an explanation.

In the end in each sequence of testing the variation in coast-down values is small, except for some outliers, causing up to 5 g/km variation. But between different sequences there seem to be changes in execution that shift the average, around which the results vary.

6.3.2 *Chassis dynamometer tests*

The variation in chassis dynamometer tests is investigated by performing repeat tests for all six vehicles with CoC road load configurations. These are the CoC-COLD tests from Table 4.1. The CO_2 emissions results of these tests are presented in Table 6.5. The CO_2 values are the 'final' values determined according to the WLTP legislation and are equal to the CO_2 values presented in Figure 3.8 and Figure 3.10.

Table 6.5: CO_2 emissions results of chassis-dyno repeat tests (all CoC-COLD tests), measured and corrected according Regulation 2017/1151.

#	Test #	Reference vehicle	CO_2	Mean and variation		#	Test #	Reference vehicle	CO_2	Mean and variation
[-]	[-]	[-]	[g/km]	[g/km]		[-]	[-]	[-]	[g/km]	[g/km]
1	F27	Ford H	158.68	159.26 ± 0.64		1	V1	Volvo M1	182.54	180.12 ± 2.20
2	F28	Ford H	159.15			2	V2	Volvo M1	178.24	
3	F29	Ford H	159.96			3	V3	Volvo M1	179.59	
1	F21	Ford M2	153.95	153.70 ± 0.44		1	V13	Volvo M2	177.39	175.80 ± 1.38
2	F22	Ford M2	153.20			2	V15	Volvo M2	175.01	
3	F23	Ford M2	153.95			3	V16	Volvo M2	175.00	
1	F1	Ford M1	152.67	151.80 ± 2.17		1	V20	Volvo L	174.11	174.53 ± 2.99
2	F2	Ford M1	150.38			2	V22	Volvo L	174.94	
3	F4	Ford M1	152.18			3	V23	Volvo L	173.47	
4	F17	Ford M1	155.53			4	V28	Volvo L	180.23	
5	F18	Ford M1	149.62			5	V29	Volvo L	171.97	
6	F19	Ford M1	150.43			6	V30	Volvo L	172.45	

From Table 6.5 it is seen that repeat testing for some vehicles shows outliers of 3 g/km and above, e.g. Ford M1 Test F17 or Volvo L Test V28, that cause large variances. If these outliers are removed, a typical variation around 1 to 2 g/km remains.

One source of variation can be the control strategy or state of the vehicle. Already for many years parties report the failure to engage stop-start systems, or shut down lights, during tests as a possible cause for variations.[9] It is therefore not automatically the test execution that cause differences. Moreover, the soot loading of the DPF, LNT regenerations, and other emission control and vehicle state related elements can cause differences in the test results. An additional source of variation and outliers may be the RCB correction, which is only applied if the change in battery state of charge exceeds a threshold.

This last indicated source of variation, i.e., the RCB correction, is actually part of the reason for the earlier mentioned tests F17 and V28 to appear as outliers. Table 6.6 presents the RCB factors and the correction of the CO_2 emission results of the Ford M1 and Volvo L, in case a correction was applied. An RCB correction was

[9] For example in European testing for the development of CO2MPAS by JRC, LAT, TNO, and other laboratories. Furthermore, TNO WLTP development testing (with NEDC vehicles): TNO Report 2016 R11285: *WLTP-NEDC comparative testing*.

performed on two of the tests presented in Table 6.6, having a significant influence on the CO_2 emission value of -7.1 and -3.4 g/km respectively for tests V22 and V30.

Table 6.6: CO_2 emissions results of chassis-dyno repeat tests (all CoC-COLD tests) for the Ford M1 and Volvo L, measured and corrected according Regulation 2017/1151. The RCB factor and applied correction are presented to indicate the effect of the RCB correction.

#	Test #	Reference vehicle	CO_2	RCB Correction	RCB factor	Effect of RCB correction on CO_2
[-]	[-]	[-]	[g/km]	[-]	[-]	[g/km]
1	F1	Ford M1	152.67	NO	0.001	-
2	F2	Ford M1	150.38	NO	0.001	-
3	F4	Ford M1	152.18	NO	0.002	-
4	F17	Ford M1	155.53	NO	0.004	-
5	F18	Ford M1	149.62	NO	0.001	-
6	F19	Ford M1	150.43	NO	0.001	-
1	V20	Volvo L	174.11	NO	0.000	-
2	V22	Volvo L	174.94	YES	0.012	-7.1
3	V23	Volvo L	173.47	NO	0.001	-
4	V28	Volvo L	180.23	NO	0.004	-
5	V29	Volvo L	171.97	NO	-0.001	-
6	V30	Volvo L	172.45	YES	0.006	-3.4

As explained in paragraph 4.5.1, the RCB correction is applied when a certain threshold is exceeded. In Regulation 2017/1151 Annex XXI Sub-Annex 6 Appendix 2 Section 3.4.4 this is defined by means of an RCB factor and a threshold 0.005. For an RCB factor equal to or above 0.005 the correction is applied. For the two chassis-dyno tests that have relatively high CO_2 results (tests F17 and V28) the RCB factor was 0.004, just below the threshold. Had a correction been applied, the CO_2 results would have been 2 to 2.5 g/km lower (at best 153.3 and 177.7 g/km for tests F17 and V28 respectively), bringing them more in line with the other repeat tests.

6.4 Variations in CO_2 values between vehicles

Unlike the CoP data mentioned in Paragraph 6.1, there are some substantial differences observed between different vehicles tested with the same CoC values, i.e., the Volvo M1 and M2 and Ford M1 and M2 (see Figure 2.1 and Figure 2.2). As seen in Table 6.5 the difference in measured CO_2 values between the identical Fords is on average 1.9 g/km and for the almost identical Volvo's this difference is 4.3 g/km.

In many cases the outliers affect these results, i.e., Volvo LTest V28, with 180.23 g/km against a 174.53 g/km average and Ford M1 Test F17 with 155.53 g/km against a 151.80 g/km average. In the larger picture, the different tests with the different vehicles follow the interpolation line quite closely, albeit at a parallel offset. Therefore, it can be concluded that from time to time an outlier occurs, which cannot be traced back to an error or fault during the test.

6.5 Variations in CO_2 values between test labs

As mentioned in paragraph 4.2 for 2 vehicles chassis-dyno tests were performed at 2 different test labs. The results of the two vehicles that were tested in the different test labs are presented in Table 6.7.

Table 6.7: CO_2 emissions results of chassis-dyno repeat tests (all CoC-COLD tests) for the Ford M1 and Volvo L, performed at 2 different test labs.

#	Test #	Reference vehicle	Test lab	CO_2*
[-]	[-]	[-]	[-]	[g/km]
1	F1	Ford M1	Vela 2	152.67
2	F2	Ford M1	Vela 2	150.38
3	F4	Ford M1	Vela 2	152.18
4	F17	Ford M1	Vela 8	155.53 *(153.3)*
5	F18	Ford M1	Vela 8	149.62
6	F19	Ford M1	Vela 8	150.43
1	V20	Volvo L	Vela 2	174.11
2	V22	Volvo L	Vela 2	174.94
3	V23	Volvo L	Vela 2	173.47
4	V28	Volvo L	Vela 8	180.23 *(177.7)*
5	V29	Volvo L	Vela 8	171.97
6	V30	Volvo L	Vela 8	172.45

* The CO_2 values in italic are the values determined in paragraph 6.2.2, in case the RCB correction would have been applied to these tests.

For both the Ford M1 and Volvo L the tests performed in the Vela 8 lab result in similar or mainly lower CO_2 outcome compared to the tests performed in the Vela 2 lab. This is however not the case for tests F17 and V28. These two tests have been discussed before and their outcome is not in line because of the way the RCB correction is applied (see paragraph 6.3.2). Nevertheless even when the RCB correction is applied to these tests their outcomes (at best 153.3 and 177.7 g/km for tests F17 and V28 respectively) remain the highest of all 6 tests per vehicle.

JRC is familiar with the effect that a first test of a series often results in slightly different outcomes than all the subsequent tests and thus this might also be the case for the tests performed in the Vela 8 lab. For the tests performed in the Vela 2 lab this effect is not observed.

6.6 Base margin for general measurement accuracy

If unnecessary variance is removed by a proper outlier treatment, the base margin for chassis dynamometer testing can be in the order of 2%. The margin is therefore intertwined with outlier treatment, and repetitive testing. The coast down control testing yields a variation of 0.5 g/km, repeat testing yields a variation of another 1 g/km, but the testing of different vehicles of the same family yields variations in the order of 3 g/km. In In-Service Verification testing, the same variations will occur.

The lowest values should be the basis where the variation provides a margin for comparisons.

6.7 Conclusions regarding uncertainties / variations in CO_2 testing related to chassis dynamometer tests

- Checks of the simulated road load, carried out after execution of a chassis dynamometer test, reveal a significant change compared to the initial settings before the test. Combining the results of all vehicles, the road load, expressed in CO_2 emissions, measured at the coast down checks is on average 0.9 g/km higher than the set road load, with a variation of 2.0 g/km.
- Except for a limited number of tests, which can be considered as outliers, the spread observed in repetitions of the same test on the same vehicle is 1 to 2%. This confirms that the large differences between the results of individual tests with different road loads and the IP family line, observed for both vehicle models, are significant and cannot be attributed to uncertainties in the execution of the chassis dyno tests.
- The result of tests, performed with chassis-dyno road load settings corresponding to the outcome of coast down tests with a closed grill, show a large difference with the results from tests with chassis dyno settings according to CoC. A closed grill reduces the CO_2 emissions by around 6 and 12 g/km for the Ford and Volvo respectively.
- The RCB correction, applied when the change in battery state-of-charge exceeds a certain threshold, is found to be a significant source of variations. The correction of results for tests, that just exceed the threshold, is larger than the difference between the uncorrected CO_2 test results for tests that are just above and just below the threshold.
- When apparent outliers are excluded, tests performed on the same vehicle in two different labs at JRC do not show large differences in measured CO_2 emissions (typically 1-2 g/km).

6.8 Options for reducing uncertainties / variations in the chassis dynamometer test

The different options and margins in the coast down control test, as described in Paragraph 6.3.1, are a clear source of variations. At the moment it is unclear what are the underlying causes of these variations. These variations can only be brought under control by extensive control and reporting, transparency, and comparative testing.

Uncertainties associated with the chassis dynamometer testing as part of In-Service Verification may be reduced by different measures, for which some suggestions are listed below. It is noted that some of these would require changes to the applicable legislation, in particular Commission Regulation (EU) 2017/1151 (WLTP) and Regulation (EU) 2019/631 (CO_2 regulation):

- Current practice is that the execution of a WLTP test generally requires information from the manufacturer and/or instructions on how to enable the vehicle to function safely or at all during the test on a track or chassis dynamometer. Vehicle-family specific instructions provided by the OEM to engage a dyno-mode for the chassis dynamometer test will always raise concern regarding the extent to which the vehicle operates “normally” on the chassis dynamometer test, and as a consequence on the representativeness of the WLTP laboratory test for real-world emissions of CO_2 and pollutants. More transparency may allow more scrutiny of the differences between dyno-modes and normal operation.

  - If the use of a test mode cannot be avoided, a minimum requirement should be that manufacturers provide clear instructions, preferably as part of the information on the CoC or otherwise upon request of any qualified third party, on how to engage test modes. If these instructions are followed, and the necessary elements recorded, a test is valid. In the end, however, this does not allay the concerns about the difference between normal and dyno-mode. Therefore a second requirement could be that manufacturers provide clear information on the extent to which test modes alter the characteristics, functioning or performance of the vehicle.
  - Harmonization and improved visibility of indicators, indicating that the vehicle is in test mode, and the availability of guidance tools during the test mode setting procedure are recommended. This will help to prevent any disputes on test results.
  - The need for special test modes should be mitigated or it should be made sure that the operation of the vehicle’s powertrain and energy using auxiliaries in test mode do not deviate from that in normal use.
- Furthermore, it was shown that the application of correction methods could result in significant variations. The way the RCB correction is applied, from a predefined change in the battery state of charge over a test, set as threshold, results in a difference of at the least 2 to 2.5 g/km CO_2 between tests that exceed this threshold and tests staying just below it. Reconsidering the RCB correction method, e.g. avoiding the use of a threshold, could remove this artificial variation.

The Transparency List will most likely bring improvements to the availability of information and settings required to be able to perform a CO_2 In-service Validation test.

7 Lessons learned from the test program

Below we discuss a number of examples from the test results obtained in the project that provide indications of issues that should be taken into consideration in the development of the ISV procedure.

Additional considerations on the WLTP procedure for CO_2 determination, based on the experience gained in this project, can be found in Appendix C.

7.1 ISV relevant issues related to the vehicle

7.1.1 Issues w.r.t. vehicle settings required for testing

Tests according to the official WLTP test procedures have been performed on several in-service vehicles within two IP families from two different randomly selected brands, Ford and Volvo. The road load tests were supervised by a Type Approval Authority. The chassis-dyno tests were performed by JRC, having a lot of experience from earlier WLTP test campaigns. Nevertheless, the execution of the tests turned out to be difficult. Involvement of manufacturers was inevitable in order to get the information required to perform the tests, in particular to get the vehicle setting (active grill setting, coast down mode and chassis-dyno mode) right. Obtaining this information from the OEM took significant efforts and time. And it appears questionable if this information could be systematically obtained at all by parties that may not have the same level of industry contacts as TNO.

This leads to the conclusion that for facilitating ISV testing, and particularly for enabling independent testing, it should be made possible to execute the coast down and chassis-dyno tests according to the WLTP procedures without interference by the OEM. Preferably, no additional information from the OEM should be necessary, or, where inevitable, such information should be easy to obtain and understand beforehand.

The Volvo vehicles provided a clear confirmation of successful chassis-dyno mode activation after the chassis dyno mode selection process. In the case of Ford, on the other hand, despite having followed the manufacturer's procedures, it was still uncertain if the right chassis dyno mode was selected properly. This leads to the recommendation that the ISV procedures should require OEMs to equip vehicles with a clear and well-described indicator which signals when a test mode is switched on.

7.1.2 Issues w.r.t. tyres mounted on in-service vehicles

For half of the selected vehicles the fitted tyres did not correspond to the tyres on the CoC, and they typically had higher RRC values. Dealers confirmed that other tyres, and wheels, are offered to the customer as a 'service' when buying a new car. Such practice strongly hampers the execution of CO_2 In-Service Verification tests as new tyres (and wheels) have to be sourced, fitted and removed again. This experience contributes to the recommendation in chapter 8 that vehicles to be tested for ISV must be restored to a state that corresponds to the CoC. The CoC should contain sufficient information to do so. At the same time this means that ISV testing does not take account of all vehicle characteristics that determine the CO_2 emissions of in-use vehicles.

7.1.3 Electric power consumption and battery charging strategies.

The Ford Fiesta tests results were about 20 g/km higher than the value on the CoC. Measured CO_2 values were systematically higher over the whole set of tests. Ford explained that an electric windscreen heater may have possibly been operating continuously during the test. They illustrated this with data from one of their own WLTP tests, which showed large spikes in alternator currents. In their view, these could explain the difference in CO_2 results. In the tests in this program alternator current was not measured and a direct comparison was not possible. In the test results presented by Ford the observed large spikes in alternator current were associated with dips in battery voltage. Battery voltage was measured in our tests but did not show these dips, suggesting the absence of a large electric consumer as suggested by Ford. A second indication of the difference between the Ford data and our test results is the battery current measured with the engine-off (in stop-start) and no alternator power supply. The battery current measured in that situation corresponded to a continuous power usage of about 200 Watt.

The expected additional CO_2 from the auxiliary power consumption during our lab test, as derived from extrapolation over the whole test of the battery current measured during engine-off periods, is 5.3 g/km, which would leave a remaining 15.7 g/km average difference unexplained. In principle it is possible that, during the tests performed by Ford to establish the CoC value, the vehicle was in a special state on the chassis dynamometer, with specific instructions for decoupling auxiliary equipment, etc.. If this would reduce the CO_2 emissions by 20 g/km it could first of all be argued that it is a special optimization for the WLTP, of which the legality is questionable. But based on our tests the observed deviation cannot even be explained by such optimisation. With the average load of auxiliaries during the tests being responsible for 5.3 g/km, switching off these auxiliaries cannot reduce CO_2 emissions by more than that.

This issue, and the problems to find the underlying causes of CO_2 differences, has contributed to the recommendation that the criteria for a valid ISV test do not lie in the correspondence with the test conditions and execution used by the OEM or TAA during type approval testing, but in the formal correspondence of the test conditions and execution, as used in the ISV testing, with the requirements of the WLTP.

7.1.4 Grill operation and instructions

The road load values obtained from coast down tests with different grill settings translate into a 1.4 g/km variation in CO_2 values. It is observed that the grill setting can vary significantly between coast-downs tests, and, moreover, with grill settings observed in normal driving at the same velocities. This difference between normal operation and operation during testing is not considered in detail in the procedures. Parties conducting ISV testing must either collect evidence that the grill setting during coast down testing is appropriate or should be allowed to determine appropriate grill settings from normal use data in similar ambient conditions and apply these during coast down testing.

7.2 ISV relevant issues related to the test track for coast down testing

7.2.1 Test circuits differences

The driving resistance factors obtained on the Lommel test track were significantly lower than those obtained at IDIADA.

The difference between coast-down test results obtained on the IDIADA and Lommel test tracks translates into an average 2.3 g/km CO_2. The uncertainty in the road load derived from coast-down testing is less than 0.5%, which leads to a 0.7 g/km variation in CO_2 value on the chassis dynamometer test. Therefore, the systematic difference between the test tracks is much larger than the uncertainty from the tests.

The fact that the wind conditions at Lommel were less favourable during testing, suggests that the systematic difference between these two example test tracks can even be bigger, in idealized ambient conditions.

This issue provides additional motivation for the recommendation that the criteria for a valid ISV test do not lie in the correspondence with the test conditions and execution used by the OEM or TAA during type approval testing, but in the formal correspondence of the test conditions and execution, as used in the ISV testing, with the requirements of the WLTP.

7.2.2 Wind measurement specifics

Different coast down test facilities use different methods to measure wind velocity. Measuring higher wind velocities will lead to a larger downward correction of the road load. Meteorological wind measurements are typically at 10 metres above ground level, with higher and more constant wind than at the test track itself. Wind varies both with height above the surface, location along the test track, locations of the different straights on an oval track, and with time. With a large wind correction, say 7 Newton or more, comes the responsibility to ensure this wind speed is representative of the wind speeds at the test track at the time and location of the tests.

Given the current specification of the WLTP the influence of the location of the weather station, as long as it is within the bandwidths allowed by the WLTP, is to be considered as causing an inherent, “natural” variation in test results, which does not need to be taken into account in the ISV statistical procedure. The influence of this factor can, however, be reduced by amending the specifications in the WLTP for the weather station location and details of the wind correction.

7.2.3 Combined A- and B- runs

With the current A- and B-run averaging approach in the WLTP approach it is essential that the A-run and B-run conditions are either equal or opposite. Initially designed for a single track, traversed in both directions, where indeed conditions like wind, slope, or tarmac, are equal or opposite, most modern tracks have separate parts for the A- and B-run. Wind conditions may be different. If the head wind run track is less exposed to the wind than the tail-wind run, this may lead to an impact that cannot be identified in any other way than with a wind meter at each location at the time of the tests. To avoid dispute over high road loads measured in coast down tests, it is therefore recommendable that parties, carrying out ISV testing using an oval track for the coast down test, measure wind speed separately along both tracks. Moreover, independent reporting of A- and B-results can provide indications if the assumed wind effect is in line with the observed differences in driving resistance.

7.2.4 *Tyre temperature during coast-down tests*

The temperature correction of rolling resistance depends substantially on the ambient temperature. The ambient temperature is expected to affect the tyre temperature by the same degree across tests. The measured temperature varies between tests on different tracks, and over the tests, depending on the test execution. At Lommel the tyre temperature remained fairly constant, related to friction during the sharp turns (including associated hard decelerations and accelerations) that have to be made there. At IDIADA the temperature decreased over the coast down test relative to the initial values after preconditioning, as a result of intermediate speed driving, at the same speed as the coast-down tests, on the wide bends of that track. With the normal execution of tests on different tracks the actual tyre temperature is already observed to vary 4 degrees, which -based on the WLTP correction method- leads to a variation in rolling resistance of 3% and a 0.6 g/km variation in CO_2 emissions on the chassis dyno. It is expected that much larger effects can be achieved when the test execution is optimized (within the limited test execution boundaries and procedures prescribed by the WLTP) to maximize this difference. For example, pressurizing the tyres at the coldest moment of the day, will lead to higher pressures when the ambient temperature rises during the day. Also, the velocities, accelerations and decelerations occurring during the lengthy coast-down test influence tyre temperature. The order in which elements of the test are performed may be used as a means to optimize the test. A party conducting ISV testing can be expected to execute a coast down test in a more random and less optimized order and pace. This should be appropriate to have a proper road load determination.

Given the current specification of the WLTP the influence on tyre temperature of the order in which elements of the test are performed, as long as it is within the bandwidths allowed by the WLTP, is to be considered as causing an inherent, “natural” variation in test results, which does not need to be taken into account in the ISV statistical procedure. The influence of this factor can, however, be reduced by amending the specifications in the WLTP for the test execution.

7.3 ISV relevant issues related to the chassis dynamometer test

7.3.1 *Coast down check on the chassis dynamometer*

The check of the road load on the chassis dynamometer with a coast down test can be seen as a variant of the same issues of the coast down procedure on the test track. In particular conditioning may affect the results. The tests showed both a variation and a systematic deviation, within the boundaries of the WLTP, that translates into a typical spread in CO_2 of 0.9 g/km. Apart from this variation, the average measured road load after the WLTP tests was lower than the setting, leading to -0.2 g/km difference in CO_2. This may indicate a possible effect of a specific test protocol difference between the determination of the dynamometer setting and the control test.

A small change in chassis dynamometer settings is expected to give rise to a similar change in the coast down road load values on the chassis dynamometer. Only a minor effect is to be expected from additional heating up or cooling down resulting from the change in force on the tyres. In the testing, minor changes in chassis dynamometer settings were only checked afterwards, to collect additional results with limited additional test effort.

For the Ford vehicle the different elements that determine the total cycle energy are consistent with the interpolation line. The CO_2 values from the coast-down are on the same line as the CO_2 values from the target road-loads. For the Volvo vehicles, there are some large deviations from the road load, mainly caused by a single test, the type-approval vehicle high test, on the second vehicle only. This would result in 5.8 g/km higher CO_2 results.

However, and more importantly, for the Volvo a large systematic, but unexplained effect was observed in all other tests, related to the variation in chassis dyno settings. Small changes in the chassis dyno setting applied prior to the test did not result in equivalent changes in the road load measured in the coast down test on the chassis dynamometer after execution of the test. This systematic effect would cause on average 2.6 g/km lower CO_2 values. As this effect is systematic for both high road load settings and low road load settings, it cannot be attributed to compensating effects from the forces on the tyres. Instead the systematic deviation suggests that there may be flexibilities in the test protocol for execution of the coast down test on the chassis dynamometer that give rise to 2.6 g/km or more variation in CO_2 results.

This observation does not directly lead to recommendations for ISV testing, but does warrant further examination. Given the size of the possible impact, the results of that examination could motivate an adaptation of the specifications in the WLTP for the road load check on the chassis dynamometer.

8 Outline of general principles for In-Service Verification of CO_2 emissions

8.1 Introduction

As stated in Article 13 of Regulation (EU) 2019/631, In-Service Verification of CO_2 emissions is to be carried out by type approval authorities using appropriate and representative samples of vehicles in-service in order to verify the correspondence between the CoC CO_2 emissions/fuel consumption and the CO_2 emissions/fuel consumption as determined by using WLTP emission tests, as well as the possible presence of strategies on-board or relating to the vehicles, which are artificially improving the vehicle's performance in the emissions tests. Quantified deviations between the ISV CO_2 test values and the CoC values can be used by the European Commission to adjust a manufacturer's monitored fleet average CO_2 emissions. This will require a statistical approach to decide whether there are deviations justifying remedial action.

The chapter starts with an elaboration on general principles that can be used as a basis for defining the ISV CO_2 test procedure. The second part of the chapter sketches the general principles for a statistical procedure and pass/fail criteria that can be used for deciding on whether CO_2 values of in-service vehicles and vehicle families correspond with the CoC values and IP line.

According to the Regulation, Granting Type Approval Authorities have the responsibility to verify emissions of in-service vehicles for which they provided type approval. The principles discussed here are however also relevant for tests executed by third parties.

The work reported in this chapter relates to Task 4 and Task 5 of the Terms of Reference.

8.2 General principles for the ISV CO_2 test procedure

Based on the experience gained in this project as well as on general considerations related to the purpose of In-Service Verification, the overarching principle determining the general approach for ISV testing should be that any test carried out in accordance with Commission Regulation (EU) 2017/1151 (WLTP) is a valid ISV test. This means that, in case of deviations found, the burden of proof regarding the underlying reasons thereof should lie with the manufacturer concerned. This also means that the manufacturer should ensure that possible issues that can lead to deviating results are avoided or reported.

The above is in line with Article 13(1) of Commission Regulation (EU) 2019/631, which states that manufacturers shall ensure that the CO_2 emission and fuel consumption values recorded in the certificates of conformity correspond to the CO_2 emissions from, and fuel consumption of, vehicles in-service as determined in accordance with Regulation (EU) 2017/1151. This implies that the responsibility to account for deviations also lies with the OEM.

A second consequence of this general principle is that any “pass/fail” criteria associated with the statistical procedure would not need to take account of variations in test results that relate to allowed bandwidths for vehicle state, test conditions and test execution as specified in Commission Regulation (EU) 2017/1151, but only of the normal measurement accuracy associated with a WLTP test (see sections 5.2, 6.2 and 8.3).

Furthermore, the following general principles have been identified as a basis for defining the ISV CO_2 test procedure:

- It should be possible to execute an ISV test with no or minimal prior instructions from the manufacturer with respect to test conditions, vehicle state or vehicle adjustments, and with minimal need for information to be obtained from the manufacturer.
- The vehicles selected for ISV testing should be restored to their original state at registration, as specified in the CoC[10]. After-market modifications affecting emissions (e.g. different wheels / tyres or spoilers) should not be present.
- It is acceptable to test on any track which satisfies the WLTP requirements, and under all conditions stipulated in the WLTP.
- The vehicles to be tested should be in a normal state. This can be obtained by, e.g., applying servicing and maintenance prior to the test in the same manner as would be done for a private owner for normal use. Vehicles should not be tuned towards low test results. The vehicles must be suitable to perform in the same manner on the WLTP test as in normal use. Adjustments of vehicle settings, which may be required to enable (safe) performance of a WLTP test, should not alter aspects of the vehicle’s performance that affect CO_2 emissions.
- The operation of auxiliaries, including e.g. adjustable grills and energy consuming devices (affecting alternator current), in the test should match the operation of these auxiliaries under normal use conditions. This relates to the "justification" of positions of movable parts as hinted at in Regulation 2017/1151, section 4.2.1.5. on “Movable aerodynamic body parts”. It should be possible to correct for systematic and unexplained deviations.
- Where significant deviations are found between ISV road load values and the CoC values, these might be used to calculate the associated deviation in CO_2 emissions (which can be estimated from the IP family line) without a need to carry out chassis dynamometer tests.
- The level of statistical confidence in the laboratory results follows from the spread observed in the test results, relative to the difference between measured values and the CoC (declared) values which are verified. The obtained level of statistical confidence is the basis for conclusions drawn from the ISV test results (a pass/fail decision and value for the deviation to be used for correcting the monitoring results). The procedure for ISV testing should therefore contain repeat tests performed on the same vehicle.

Given the high impact of possible observed deviations in road load, it is appropriate to examine different elements of the WLTP procedure independently. Separate ISV procedures for road-load values and for CO_2 values should be developed. The significance of discrepancies between in-service road-load values and CoC values can be determined by translating the difference in road load into a difference in cycle energy demand and combining that with the slope of the CoC family IP line.

[10] The possibly undesired impacts of aftermarket modifications on in-use CO_2 emissions may need to be tackled by alternative means.

- A first screening of the CoC road load values can be done by comparing the available CoC data with the tyre label results. This could be complemented by a screening test, measuring road load at low speed only.
- In addition a screening test could be included for the road load test. If the result of a single, specific measurement is sufficiently in line with the road load from the CoC, one could proceed with lab testing based on the CoC road load values. If the screening result differs significantly from the CoC values, detailed road load testing is justified.

In this project gaining experience with, and insight in variations associated with, road load determination was done by carrying out coast down tests as described in Regulation 2017/1151 Annex XXI Sub-Annex 4. The Regulation also allows other methods, specifically the use of wind tunnels. This means that:

- For defining an appropriate ISV procedure also insight needs to be gained in the variations associated with wind tunnel testing;
- It should be allowed to use coast down testing for In-Service verification of CoC values that have been obtained on the basis of road loads determined in wind tunnel testing, and vice versa.

8.3 General principles for the ISV statistical procedure and pass/fail criteria

A statistical procedure is needed to prove that the final results of In-Service Verification testing meet set requirements with respect to statistical confidence. It should bring to light issues with the results and set minimum standards for the results of ISV tests to be fit for drawing legally binding conclusions and trigger legal consequences, such as those set out in CO_2 Regulations.

In defining a statistical procedure for ISV testing of CO_2 emissions, procedures developed for other types of legislation, in particular the vehicle pollutant emissions legislation, could be used as a basis. However, account should be taken of the different nature of the CO_2 emission legislation compared to the one for pollutants as there is no limit value applying to the CO_2 emissions of individual vehicles. Existing procedures are targeted towards pass/fail decisions for individual vehicles and therefore make no distinction between an exceedance by 1% or by 100%, in each of the separate tests. However, in the context of the CO_2 regulation, the size of the deviation is very relevant as it will be used to adjust the average specific emissions of a manufacturer. The statistical procedure therefore needs to provide a statistical approach allowing to determine this deviation.

The statistical procedure for ISV CO_2 tests should take account of possible random variations in CO_2 emissions determined in accordance with the WLTP. However, it should not be tuned to reflect systematic optimisation of WLTP testing towards the lower end of the full bandwidth of the uncertainty range. Such optimisation could be achieved by, e.g., choosing the best test circuit, the best weather conditions, the best battery charging strategy, the best test driver, etc.. Accounting for the bandwidth from the extremes from optimization on many elements of the test procedure would result in a large margin, causing the ISV tests to become irrelevant in practice.

For the development of an ISV procedure that helps to safeguard the environmental effectiveness of the CO_2 standards, the following general principles and issues are identified with respect to the statistical procedure and pass/fail criteria:

- The starting point for ISV is that the results of any test carried out in accordance with Commission Regulation (EU) 2017/1151 (WLTP) are valid results within the observed and expected variations in the testing.
- "Natural" variations in test results (see sections 5.2 and 6.2), which may be caused by e.g. the use of different test tracks, different ways in which the test can be executed within the specifications of the WLTP, or variations in test conditions that are not corrected for in the elaboration of test results, define the inherent and accepted bandwidth of the tests.
- As a result, the full bandwidth of "natural" variations in test results does not have to be taken into account for the statistical procedure of the in-service verification, and neither is it necessary to quantify the different elements causing the variations. The statistical procedure and associated criteria should therefore only consider the variations between repeat tests, i.e., the accuracy with which a specific laboratory can repeat road load and chassis dynamometer tests on the same vehicle. The minimum expected level of these variations can be expressed as a "base margin" for the purpose of defining statistical significance.
  - Nevertheless it is useful to have insight in the size of these "natural" variations, as deviations between ISV results and CoC values that exceed these variations may be an indication of the presence of strategies on-board or relating to the vehicles, which are artificially improving the vehicle's performance in the emissions tests. The various tests performed in this project provide a first indication of the magnitude of several elements and issues that contribute to these variations. However, a broader range of variations may occur in practice as the tests carried out in this project did not cover all allowed variations in vehicle and test conditions.
- The bandwidth to be taken into account can be determined from repeat tests on the same vehicle as part of the ISV testing. However, the margin to be included in the pass/fail criteria cannot simply be based on results of these repeat tests. If the test values for e.g. three or more consecutively tested vehicles accidentally are identical or very similar, this would give a very small or no spread. For this reason it is necessary to include a fixed "base margin" in the statistical procedure and pass/fail criteria.
  - First inputs for determining this inherent, minimal spread are provided by the results from the extended test program performed in this study. Further repeat tests will be necessary to determine the fixed base margin.
- It may be assumed that vehicles will be optimized for low CO_2 emissions on the WLTP type approval test. Therefore, the underlying causes of deviations in the test results will more likely increase than decrease the CO_2 emissions. The distribution of CO_2 emissions will thus be skewed with a median below the average, because of the longer tail of higher CO_2 values. The average is a more appropriate reference for the declared value than the median, as it relates more to the fleet average. In any statistical analysis it is important to make this distinction.
- Differences in test results between different in-use vehicles may be related to the impacts of use. Provided these are not associated with malfunctions, they are to be considered as associated with the normal state of the specific vehicles, similar to differences resulting from variation in the production.

- In the tests, carried out for this project, occasional outlier results can be observed, i.e., single test results that strongly deviate from results of repeat test or other similar tests. In order for the above-mentioned “base margin” to remain limited, an additional approach could be added for dealing with outliers, prior to applying the statistical procedure and determining pass/fail.
  - Typically, both the coast down tests and the chassis dynamometer tests show a spread of less than 2 g/km. The observed outliers, typically 4 g/km, are not explained or understood. As all other tests are in a much smaller bandwidth, it is likely that they are not the result of the vehicle itself, but rather of the test execution and procedure. A simple way to limit the effect of such outliers is to test every vehicle twice, and use the lowest result of both tests as input for the statistical procedure. With an expected chance, based on current testing, of a significant outlier of 1 in 10, the chance that it occurs twice for one vehicle is 1 in 100. Moreover, in an average of 3 or more tests, the effect of a single test outlier on the overall outcome will be negligible with each vehicle tested twice.
- In order for ISV to be effective the statistical procedure should at the same time provide sufficient confidence in the test results and be practical. The latter requires that decisions can be derived on the basis of results obtained from testing a limited number of vehicles. Considerations on the practicality of the statistical procedure are further elaborated in section 8.3.1.
- Indications of deviations may already be detected from the coast down test. In addition to a statistical procedure and pass/fail criteria for the CO_2 result from the chassis dynamometer test, similar procedures will be needed for the comparison of results from road load testing.
  - Besides comparing measured road load indicators to CoC values, the road load results may also be translated into CO_2 values using the associated work on the WLTC and the interpolation method for CO_2 determination, using the family interpolation line available from the CoC.

8.3.1 Considerations on the practicality of the statistical procedure

Different statistical procedures for vehicle emission testing exist, each having their specific advantages and drawbacks.

The UNECE Regulation 83 Appendix 4 has been the touchstone for In-Service Conformity testing of pollutant emissions for a long time. This statistical procedure is based on establishing with 95% confidence that 40% of the vehicles exceed the limit. A decision is forced at 20 vehicles tested. In many borderline cases 20 vehicles need to be tested.The prescribed statistical procedures were never really applied, because of their impractical nature. Instead the procedures were compared with the manufacturer’s own quality control. If the internal procedures were more stringent, these were accepted as alternative. Based on the fact that the existing procedure was impractical and rarely used, a new procedure was proposed and adopted for WLTP CoP. With the WLTP, CO_2 test values were included for the first time in the pass fail/decisions for the Conformity of Production of newly produced vehicles, when the Granting Type Approval Authority inspects the production process. For WLTP a CoP statistical procedure was included in Regulation (EC) 2017/1151 ANNEX I Appendix 1. It allows for a quicker decision based on the average value of the Type 1 tests and the spread in the results.

For ISC RDE a procedure is used with a maximum of 10 vehicles to be tested. This procedure, described in ANNEX II of Regulation (EC) 2018/1832, is closer to the original Regulation 83. The minimum number of vehicles tested in this kind of statistical procedures has always been 3, but with the procedure in Regulation 83 no fail decision can be reached, even with all 3 vehicles failing the test. ISC RDE is the first procedure where independent parties will be testing vehicles, and incorporates practical issues for independent parties.

Ideally, a statistical procedure should be defined in such a way that there is a high probability that a pass/fail decision can be reached with a limited number of vehicles tested. As a first estimate, in line with the RDE ISC procedure a range of 3 to 10 vehicles could be appropriate. To avoid undue test burden, the statistical procedure should be such that only in a limited number of cases the maximum number of vehicle tests are needed. This constrains the confidence level that can be reached. The average result of all vehicles tested should be the basis for the evaluation of the deviation. The variation in test results is the basis of the uncertainty / confidence in the average results.

8.4 Considerations on the ISV procedure for a CO_2 interpolation family

In the WLTP CoP procedure, the testing across the IP family has been made possible by combining and comparing the relative CO_2 value, i.e. $CO_{2,ISV}/CO_{2,CoC}$. This relative number makes it possible to apply a similar statistical approach for determining pass/fail both for single vehicle models, and for different vehicle models within the same IP family (with different COC CO_2 values). The absolute deviation, which may be relevant for correcting the fleet average emissions is thereby lost in first instance. A good proxy for the absolute deviation, however, can be obtained by applying the average measured relative deviation to the IP line for the vehicle family.

9 Conclusions and recommendations

To build experience with in-service testing of CO_2 emissions, and to provide an empirical basis for the development of a methodology for an in-service test and verification procedure for CO_2 emissions of light duty vehicles, six vehicles of two IP families have been tested: three variants of an IP family for a large diesel-fuelled vehicle model with automatic gearbox and three vehicles from an IP family for a small petrol-fuelled model with manual gearbox from a different manufacturer group. In this way a basic coverage of the spectrum of vehicles sizes and fuels in the fleet was obtained.

The measurement program has provided insight in the practicality of independent execution of WLTP tests, including both the coast down test for determining road load and the chassis dynamometer test for measuring CO_2 emissions. Analysis of the test results has provided insight in the type and size of variations occurring in both tests, related e.g. to specifics of the test track, weather conditions, details of the way in which the test is executed, the operation of the vehicle, differences between vehicles, and correction methods. Also the impacts of changes in vehicle mass or resistance on road load, cycle energy demand and CO_2 emissions have been quantified.

Based on this experience and on additional available information and insights recommendations have been formulated for working out an In-Service Verification procedure, relating to the test protocol as well as to the statistical procedure and pass/fail criteria. For the development of an ISV procedure that aims to safeguard the environmental effectiveness of the CO_2 standards, a number of general principles and issues are identified.

For ISV testing these general principles and issues include:
- It should be possible to execute an ISV test with no or minimal prior instructions from the manufacturer with respect to test conditions, vehicle state or vehicle adjustments, and with minimal need for information to be obtained from the manufacturer.
- The vehicles selected for ISV testing should be restored to their original state at registration, as specified in the CoC[11]. After-market modifications affecting emissions (e.g. different wheels / tyres or spoilers) should not be present.
- It must be acceptable to test on any track which satisfies the WLTP requirements, and under all conditions stipulated in the WLTP.
- The vehicles to be tested should be in a normal state and not tuned towards low test results. The vehicles must be made suitable to perform in the same manner on the WLTP test as in normal use. Adjustments of vehicle settings, which may be required to enable (safe) performance of a WLTP test, should not alter aspects of the vehicle's performance that affect CO_2 emissions.
- The operation of auxiliaries, including e.g. adjustable grills and energy consuming devices (affecting alternator current), in the test should match the operation of these auxiliaries under normal use conditions. It should be possible to correct for systematic and unexplained deviations.

[11] The possibly undesired impacts of aftermarket modifications on in-use CO_2 emissions may need to be tackled by alternative means.

- Where significant deviations are found between ISV road load values and the CoC values, these might be used to calculate the associated deviation in CO_2 emissions (which can be estimated from the IP family line) without a need to carry out chassis dynamometer tests.

For ISV statistical procedure and pass/fail criteria the identified general principles and issues include:

- The starting point for ISV is that the results of any test carried out in accordance with Commission Regulation (EU) 2017/1151 (WLTP) are valid within the observed and expected variations in the testing. “Natural” variations in test results, which may be caused by, e.g., the use of different test tracks or different ways in which the test can be executed within the specifications of the WLTP, are not to be considered in this respect as they define the inherent and accepted bandwidth of the tests.
  - Provided that tests are carried out in full accordance with the WLTP procedures, the fact that one lab or test track may have systematically higher or lower results than other labs, is part of the natural bandwidth of the WLTP.
- As a result, the full bandwidth of “natural” variations in test results does not have to be taken into account for the statistical procedure of the In-Service Verification, and neither is it necessary to quantify the different elements causing these variations.
- The statistical procedure and associated criteria should only consider the “normal” variations between repeat tests on the same vehicle under similar test conditions as observed in road load and chassis dynamometer tests. These “normal” variations relate to the accuracy with which a lab can carry out a test. The statistical procedure should contain a “base margin”, representing the minimal “natural” variation, to cater for situations in which incidentally coinciding repeat tests do not yield a realistic estimate of a lab’s test accuracy.
- The results obtained for different models in the same IP family could be combined by making the CO_2 results relative to the declared value, i.e. $CO_{2,ISV}/CO_{2,CoC}$. This makes it possible to apply a similar statistical approach both for In-Service Verification of single vehicle models and for In-Service test results obtained from testing different vehicle models (with different CoC CO_2 values) in the same IP family. Where absolute CO_2 values are needed, the average of the relative values can be multiplied by the average of the declared values.

In case of deviations found during ISV testing, the European Commission in the context of the CO_2 regulation will need to take into account the size of the deviation when assessing the manufacturer’s compliance with its specific emissions target, which applies at fleet level (new vehicles sales in a given year). The statistical procedure used for the verification therefore needs to provide both a pass/fail decision and a statistical approach to determine the deviation to be applied for adjusting the average specific emissions. Existing statistical procedures used in other types of vehicle legislation may provide a basis for In-Service Verification of CO_2, but cannot be used directly in view of the different nature of the applicable targets. A delicate balance will have to be found between statistical principles and the need for a practical procedure which leads to a meaningful and robust outcome based on testing a limited number of vehicles.

10 Signature

The Hague, 17 August 2020

TNO

S. van Goethem
Project leader

N.E. Ligterink
Author

A CoC information of tested vehicles

Table A.1: IP family 1, vehicle-medium 1 (Volvo M1)

General		
Make:	Volvo	
Model:	XC60	
Type:	U	
Variant:	UZA8	
Version:	UZA8UC??	
Vehicle Category	M1G	
Code of body	AC Wagon	
Vehicle Identification Number (VIN):	YV1UZA8UCJ1109080	
Type Approval (TA):	e4*2007/46*1220*01	
TA issued on:	2017-10-27	
Power plant		
Manufacturer of engine:	Volvo	
Engine code as marked on engine:	D4204T14	
Working principle:	Compression ignition, 4 stroke	
Number and arrangement of cylinders:	4 in line	
Engine capacity:	1969	cm^3
Fuel:	Diesel	
Maximum power:	140	kW
Powered axles:	2, front and rear	
Wheels and tyres		
Tyre:	235/55R19 105V	
Wheel combination:	7.5Jx19x50.5	
Rolling Resistance Class:	B	
Environmental performance		
Exhaust emission level:	Euro 6 AG	
Number of regulatory act:	715/2007*2017/1347AG	
Test mass:	2021	kg
f0:	143.5	N/(km/h)
f1:	1.348	N/(km/h)
f2:	0.03683	$N/(km/h)^2$
CO_2 emissions under Regulation (EU) 2017/1151 (WLTP values)		
Low:	220	g/km
Medium:	188	g/km
High:	159	g/km
Extra high:	191	g/km
Combined:	184	g/km
Vehicle Registration		
First registration	16-APR-2018	

Dutch registration	28-MAR-2019
License plate	XK-461-J
MOT expire date	16-APR-2021
Status	Imported to The Netherlands in 2019

Table A.2: IP family 1, vehicle-medium 2 (Volvo M2)

General		
Make:	Volvo	
Model:	XC60	
Type:	U	
Variant:	UZA8	
Version:	UZA8UC??	
Vehicle Category	M1G	
Code of bodywork	AC Wagon	
Vehicle Identification Number (VIN):	YV1UZA8UCJ1085986	
Type Approval (TA):	e4*2007/46*1220*01	
TA issued on:	2017-10-27	
Power plant		
Manufacturer of engine:	Volvo	
Engine code as marked on engine:	D4204T14	
Working principle:	Compression ignition, 4 stroke	
Number and arrangement of cylinders:	4 in line	
Engine capacity:	1969	cm^3
Fuel:	Diesel	
Maximum power:	140	kW
Powered axles:	2, front and rear	
Wheels and tyres		
Tyre:	255/45R20 105V	
Wheel combination:	8Jx20x52.5	
Rolling Resistance Class:	B	
Environmental performance		
Exhaust emission level:	Euro 6 AG	
Number of regulatory act:	715/2007*2017/1347AG	
Test mass:	2058	kg
f0:	147.2	N/(km/h)
f1:	1.348	N/(km/h)
f2:	0.03712	$N/(km/h)^2$
CO_2 emissions under Regulation (EU) 2017/1151 (WLTP values)		
Low:	222	g/km
Medium:	189	g/km
High:	161	g/km
Extra high:	193	g/km
Combined:	186	g/km

Vehicle Registration		
First registration	23-FEB-2018	
Dutch registration	28-FEB-2019	
License plate	XN-452-J	
MOT expire date	23-FEB-2021	
Status	Imported to The Netherlands in 2019	

Table A.3: IP family 1, vehicle-low (Volvo L)

General		
Make:	Volvo	
Model:	XC60	
Type:	U	
Variant:	UZA8	
Version:	UZA8VC??	
Vehicle Category	M1G	
Code of bodywork	AC Wagon	
Vehicle Identification Number (VIN):	YV1UZA8VCJ1121025	
Type Approval (TA):	e4*2007/46*1220*01	
TA issued on:	2017-10-27	
Power plant		
Manufacturer of engine:	Volvo	
Engine code as marked on engine:	D4204T14	
Working principle:	Compression ignition, 4 stroke	
Number and arrangement of cylinders:	4 in line	
Engine capacity:	1969	cm^3
Fuel:	Diesel	
Maximum power:	140	kW
Powered axles:	2, front and rear	
Wheels and tyres		
Tyre:	230/60R18 103V	
Wheel combination:	7.5Jx18x50.5	
Rolling Resistance Class:	A	
Environmental performance		
Exhaust emission level:	Euro 6 AG	
Number of regulatory act:	715/2007*2017/1347AG	
Test mass:	2018	kg
f0:	109.1	N/(km/h)
f1:	1.348	N/(km/h)
f2:	0.0375	$N/(km/h)^2$
CO_2 emissions under Regulation (EU) 2017/1151 (WLTP values)		
Low:	216	g/km
Medium:	183	g/km

High:	155	g/km
Extra high:	187	g/km
Combined:	180	g/km
Vehicle Registration		
First registration	7-SEP-2018	
Dutch registration	29-MAR-2019	
License plate	TZ-273-V	
MOT expire date	7-SEP-2021	
Status	Imported to The Netherlands in 2019	

Table A.4: IP family 2, vehicle-medium 1 (Ford M1)

General		
Make:	Ford	
Model:	Fiesta	
Type:	JHH	
Variant:	SFJN1JX	
Version:	5CDPZNABDAX	
Vehicle Category	M1	
Code of body	AB	
Vehicle Identification Number (VIN):	WF0JXXGAHJJU05477	
Type Approval (TA):	E9*2007/46*3142*07	
TA issued on:	5-7-2018	
Power plant		
Manufacturer of engine:	Ford	
Engine code as marked on engine:	SFJN	
Working principle:	Positive Ignition	
Number and arrangement of cylinders:	3 in line	
Engine capacity:	998	cm^3
Fuel:	Petrol	
Maximum power:	73.5	kW
Powered axles:	1, front	
Wheels and tyres		
Tyre:	195/55R16 87V	
Wheel combination:	6.5Jx16H2OS47.5	
Rolling Resistance Class:	C	
Environmental performance		
Exhaust emission level:	Euro 6 AG	
Number of regulatory act:	715/2007*2017/1347AG	
Test mass:	1313	kg
f0:	119.85362	N/(km/h)
f1:	0.601	N/(km/h)
f2:	0.02952	$N/(km/h)^2$
CO_2 emissions under Regulation (EU) 2017/1151 (WLTP values)		

Low:	154	g/km
Medium:	123	g/km
High:	111	g/km
Extra high:	137	g/km
Combined:	129	g/km
Vehicle Registration		
First registration	31-AUG-2018	
Dutch registration	31-AUG-2018	
License plate	TL-532-R	
MOT expire date	31-AUG-2022	
Status	-	

Table A.5: IP family 2, vehicle-medium 2 (Ford M2)

General		
Make:	Ford	
Model:	Fiesta	
Type:	JHH	
Variant:	SFJN1JX	
Version:	5CDPZNABDAX	
Vehicle Category	M1	
Code of body	AB	
Vehicle Identification Number (VIN):	WF0JXXGAHJJU20545	
Type Approval (TA):	E9*2007/46*3142*07	
TA issued on:	5-7-2018	
Power plant		
Manufacturer of engine:	Ford	
Engine code as marked on engine:	SFJN	
Working principle:	Positive Ignition	
Number and arrangement of cylinders:	3 in line	
Engine capacity:	998	cm^3
Fuel:	Petrol	
Maximum power:	73.5	kW
Powered axles:	1, front	
Wheels and tyres		
Tyre:	195/55R16 87V	
Wheel combination:	6.5Jx16H2OS47.5	
Rolling Resistance Class:	C	
Environmental performance		
Exhaust emission level:	Euro 6 AG	
Number of regulatory act:	715/2007*2017/1347AG	
Test mass:	1312	kg
f0:	119.76967	N/(km/h)
f1:	0.601	N/(km/h)
f2:	0.02952	$N/(km/h)^2$

CO_2 emissions under Regulation (EU) 2017/1151 (WLTP values)		
Low:	154	g/km
Medium:	123	g/km
High:	111	g/km
Extra high:	137	g/km
Combined:	129	g/km
Vehicle Registration		
First registration	31-AUG-2018	
Dutch registration	31-AUG-2018	
License plate	TL-852-H	
MOT expire date	31-AUG-2022	
Status	-	

Table A.6: IP-family 2, vehicle-high (Ford H)

General		
Make:	Ford	
Model:	Fiesta	
Type:	JHH	
Variant:	SFJN1JX	
Version:	5CDPZNABDAX	
Vehicle Category	M1	
Code of body	AB	
Vehicle Identification Number (VIN):	WF0JXXGAHJJU29009	
Type Approval (TA):	E9*2007/46*3142*07	
TA issued on:	5-7-2018	
Power plant		
Manufacturer of engine:	Ford	
Engine code as marked on engine:	SFJN	
Working principle:	Positive Ignition	
Number and arrangement of cylinders:	3 in line	
Engine capacity:	998	cm^3
Fuel:	Petrol	
Maximum power:	73.5	kW
Powered axles:	1, front	
Wheels and tyres		
Tyre:	205/40R18 86W	
Wheel combination:	7.0Jx18H2OS47.5	
Rolling Resistance Class:	E	
Environmental performance		
Exhaust emission level:	Euro 6 AG	
Number of regulatory act:	715/2007*2017/1347AG	
Test mass:	1325	kg
f0:	142.03532	N/(km/h)
f1:	0.601	N/(km/h)
f2:	0.03138	$N/(km/h)^2$

CO_2 emissions under Regulation (EU) 2017/1151 (WLTP values)		
Low:	155	g/km
Medium:	128	g/km
High:	117	g/km
Extra high:	145	g/km
Combined:	134	g/km
Vehicle Registration		
First registration	24-SEP-2018	
Dutch registration	24-SEP-2018	
License plate	TP-542-R	
MOT expire date	24-SEP-2022	
Status	-	

B Detailed test results

Note: The tables on the following pages are also available as a separate pdf-file.

Table B.1: Coast down test results: Overview of all Default and Extended tests (according CoC specification)

GENERAL INFORMATION											MASSES			ROAD LOAD COEFFICIENTS															CYCLE ENERGY DEMAND*		CO2 EMISSION**	
														CoC					COASTDOWN UNCORRECTED					COAST DOWN CORRECTED					CoC	COAST DOWN	CoC	IP METHOD
Index number	Test #	Vehicle		Test Description	Location	Driver	Test date	Number of Runs	Grill Setting	Achieved	CoC TM	Average Test Mass	Rotating Mass	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	WLTC 3B	WLTC 3B	total	total
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[kg]	[kg]	[kg]	[N]	[Nh/km]	$[Nh^2/km^2]$	[N]	[N]	[N]	[Nh/km]	$[Nh^2/km^2]$	[N]	[N]	[N]	[Nh/km]	$[Nh^2/km^2]$	[N]	[N]	[kWh]	[kWh]	[g/km]	[g/km]
1	L11	FORD	M1	Default	LOMMEL	J	25-4-2019	8	OPEN	OK	1313	1325	36,45	119,85	0,601	0,02952	153,33	475,15	147,59	0,098	0,03659	172,92	523,32	130,94	0,089	0,03329	153,97	472,77	3,09	3,08	129	127,66
2	L12	FORD	M1	Extended	LOMMEL	D	25-4-2019	20	OPEN	OK	1313	1320	36,45	119,85	0,601	0,02952	153,33	475,15	134,55	0,119	0,03668	160,46	513,28	121,59	0,110	0,03364	145,36	469,00	3,09	3,06	129	126,85
3	L13	FORD	M2	Default	LOMMEL	D	29-4-2019	16	OPEN	OK	1312	1314	36,45	119,77	0,601	0,02952	153,24	475,07	125,61	-0,068	0,03842	147,92	502,97	117,80	-0,065	0,03517	138,17	463,06	3,09	3,02	129	125,81
4	L14	FORD	M2	Extended	LOMMEL	D	24-4-2019	20	NORMAL	OK	1312	1350	36,45	119,77	0,601	0,02952	153,24	475,07	127,51	-0,172	0,03604	145,74	470,70	123,16	-0,179	0,03518	140,68	457,10	3,09	3,00	129	125,22
5	L17	FORD	H	Default	LOMMEL	D	6-5-2019	10	OPEN	OK	1325	1324	36,45	142,04	0,601	0,03138	176,67	515,94	151,31	0,442	0,03781	185,99	573,62	131,38	0,387	0,03369	162,10	506,95	3,29	3,23	134	132,33
6	L18	FORD	H	Extended	LOMMEL	J	7-5-2019	20	OPEN	OK	1325	1331	36,45	142,04	0,601	0,03138	176,67	515,94	150,48	0,156	0,03988	179,30	564,84	134,34	0,141	0,03616	160,46	510,06	3,29	3,24	134	132,61
7	I7	FORD	M1	Default	IDIADA	J	30-5-2019	8	OPEN	OK	1313	1315	36,45	119,85	0,601	0,02952	153,33	475,15	115,77	1,006	0,03000	159,67	516,35	110,85	0,966	0,02744	152,16	481,84	3,09	3,12	129	128,69
8	I8	FORD	M1	Extended	IDIADA	J	30-5-2019	20	OPEN	OK	1313	1322	36,45	119,85	0,601	0,02952	153,33	475,15	110,33	1,032	0,02944	154,54	507,97	107,44	1,012	0,02714	149,70	480,05	3,09	3,11	129	128,38
9	I9	FORD	M2	Default	IDIADA	D	29-5-2019	8	OPEN	OK	1312	1329	36,45	119,77	0,601	0,02952	153,24	475,07	114,16	0,984	0,03098	158,12	522,32	110,66	0,967	0,02877	152,81	495,02	3,09	3,17	129	130,23
10	I10	FORD	M2	Extended	IDIADA	D	29-5-2019	20	OPEN	OK	1312	1321	36,45	119,77	0,601	0,02952	153,24	475,07	111,61	1,003	0,02973	155,27	509,17	107,65	0,974	0,02737	149,11	478,77	3,09	3,10	129	128,17
11	I11	FORD	H	Default	IDIADA	D	31-5-2019	10	OPEN	OK	1325	1342	36,45	142,04	0,601	0,03138	176,67	515,94	131,61	0,494	0,03417	165,32	522,72	132,50	0,505	0,03243	165,40	507,30	3,29	3,24	134	132,53
12	I12	FORD	H	Extended	IDIADA	D	31-5-2019	20	OPEN	OK	1325	1327	36,45	142,04	0,601	0,03138	176,67	515,94	140,45	0,800	0,03376	181,55	558,06	135,47	0,774	0,03132	174,40	526,04	3,29	3,32	134	135,15
13	L1	VOLVO	M2	Default	LOMMEL	D	30-4-2019	10	OPEN	OK	2058	2057	56,73	147,20	1,348	0,03712	204,10	653,20	209,68	0,195	0,05106	246,48	739,82	191,53	0,179	0,04853	226,33	694,70	4,45	4,64	186	191,27
14	L2	VOLVO	M2	Extended	LOMMEL	D	29-4-2019	20	NORMAL	OK	2058	2022	56,73	147,20	1,348	0,03712	204,10	653,20	192,50	-0,030	0,04945	222,66	683,99	187,32	-0,029	0,04794	216,56	663,84	4,45	4,51	186	187,67
15	L3	VOLVO	M1	Default	LOMMEL	J	25-4-2019	14	NORMAL	OK	2021	1989	56,73	143,50	1,348	0,03683	200,22	646,60	221,93	-0,071	0,04828	250,32	697,55	208,95	-0,066	0,04703	236,68	672,63	4,39	4,54	184	188,48
16	L4	VOLVO	M1	Extended	LOMMEL	D	25-4-2019	18	NORMAL	OK	2021	2041	56,73	143,50	1,348	0,03683	200,22	646,60	204,71	-0,138	0,04752	230,95	666,05	195,19	-0,135	0,04723	221,32	653,91	4,39	4,45	184	185,93
17	L5	VOLVO	L	Default	LOMMEL	D	2-5-2019	14	OPEN	OK	2018	2019	56,73	109,10	1,348	0,03750	166,24	618,90	176,74	0,735	0,04387	222,54	688,96	157,86	0,664	0,04193	200,67	643,63	4,24	4,38	180	184,04
18	L6	VOLVO	L	Extended	LOMMEL	D	30-4-2019	20	OPEN	OK	2018	2016	56,73	109,10	1,348	0,03750	166,24	618,90	168,99	0,294	0,04710	205,77	669,38	157,74	0,276	0,04523	192,92	637,72	4,24	4,35	180	183,12
19	I1	VOLVO	M2	Default	IDIADA	J	27-5-2019	10	OPEN	OK	2058	2065	56,73	147,20	1,348	0,03712	204,10	653,20	193,64	0,946	0,04341	244,42	722,32	190,77	0,936	0,04325	241,20	716,87	4,45	4,74	186	194,21
20	I2	VOLVO	M2	Extended	IDIADA	J	27-5-2019	20	OPEN	OK	2058	2054	56,73	147,20	1,348	0,03712	204,10	653,20	195,83	0,673	0,04557	241,12	718,80	191,62	0,657	0,04560	236,55	713,37	4,45	4,72	186	193,65
21	I3	VOLVO	M1	Default	IDIADA	D	28-5-2019	10	OPEN	OK	2021	2064	56,73	143,50	1,348	0,03683	200,22	646,60	190,15	1,365	0,03954	248,99	722,04	180,91	1,330	0,03901	238,55	704,02	4,39	4,66	184	191,92
22	I4	VOLVO	M1	Extended	IDIADA	D	28-5-2019	20	OPEN	OK	2021	2056	56,73	143,50	1,348	0,03683	200,22	646,60	192,47	1,223	0,03981	247,93	712,92	183,59	1,188	0,03920	237,79	694,43	4,39	4,62	184	190,87
23	I5	VOLVO	L	Default	IDIADA	D	4-6-2019	8	OPEN	OK	2018	2028	56,73	109,10	1,348	0,03750	166,24	618,90	151,95	1,209	0,03856	206,28	658,48	150,18	1,201	0,03856	204,30	655,85	4,24	4,43	180	185,47
24	I6	VOLVO	L	Extended	IDIADA	J	3-6-2019	20	OPEN	OK	2018	2040	56,73	109,10	1,348	0,03750	166,24	618,90	163,76	0,823	0,04189	210,52	665,00	159,11	0,809	0,04155	205,32	655,58	4,24	4,43	180	185,47

GENERAL INFORMATION											CORRECTION COEFFICIENTS				ENVIRONMENTAL CONDITIONS						TYRE CONDITIONS										LINKED TO CHASSIS-DYNO	
																					AVERAGE TEMPERATURE					AVERAGE PRESSURE						
Index number	Test #	Vehicle		Test Description	Location	Driver	Test date	Number of Runs	Grill Setting	Achieved	K0	K1	K2	W1	Asphalt Temp Average	Ambient Temp Average	Humidity Average	Pressure Average	Air density Average	Wind Average	FL	FR	RL	RR	ALL	FL	FR	RL	RR	ALL	Selected for CD test	Chassis-dyno test Reference
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	$[K^{-1}]$	[N]	[-]	[N]	[°C]	[°C]	[%]	[kPa]	$[kg/m^3]$	[m/s]	[°C]	[°C]	[°C]	[°C]	[°C]	[bar]	[bar]	[bar]	[bar]	[bar]	[-]	[-]
1	L11	FORD	M1	Default	LOMMEL	J	25-4-2019	8	OPEN	OK	0,0086	1,337	0,957	1,469	11,85	8,88	86,23	100,62	1,20	1,76	23,9	24,8	22,0	22,0	23,2	2,2	2,2	1,9	1,9	2,1	NO	-
2	L12	FORD	M1	Extended	LOMMEL	D	25-4-2019	20	OPEN	OK	0,0086	0,663	0,964	2,314	16,65	11,17	77,13	100,70	1,20	2,21	24,6	24,6	22,2	21,9	23,3	2,2	2,3	1,9	1,9	2,1	NO	-
3	L13	FORD	M2	Default	LOMMEL	D	29-4-2019	16	OPEN	OK	0,0086	0,191	0,960	0,694	23,85	13,54	54,26	101,94	1,22	1,18	29,3	29,1	25,5	25,0	27,2	2,3	2,3	2,0	2,0	2,1	YES	FO-M2-RLm-HOT
4	L14	FORD	M2	Extended	LOMMEL	D	24-4-2019	20	NORMAL	OK	0,0086	3,543	1,024	5,392	32,30	24,50	32,21	99,25	1,15	3,40	41,1	40,7	37,7	38,0	39,4	2,4	2,3	1,9	1,9	2,1	NO	-
5	L17	FORD	H	Default	LOMMEL	D	6-5-2019	10	OPEN	OK	0,0086	-0,171	0,936	1,272	7,85	5,43	80,38	101,56	1,24	1,61	23,4	20,2	23,8	22,2	22,4	2,5	2,4	2,0	1,9	2,2	NO	-
6	L18	FORD	H	Extended	LOMMEL	J	7-5-2019	20	OPEN	OK	0,0086	0,622	0,950	1,061	13,75	8,70	65,41	101,29	1,23	1,43	25,5	25,8	26,8	25,9	26,0	2,5	2,4	1,9	1,9	2,2	NO	-
7	I7	FORD	M1	Default	IDIADA	J	30-5-2019	8	OPEN	OK	0,0086	0,132	0,972	0,218	23,23	15,40	66,36	101,37	1,19	0,75	39,2	38,3	38,4	33,5	37,3	2,1	2,1	1,8	1,8	2,0	NO	-
8	I8	FORD	M1	Extended	IDIADA	J	30-5-2019	20	OPEN	OK	0,0086	0,710	0,980	0,030	26,89	17,71	70,09	101,31	1,17	0,28	42,0	39,0	38,5	36,8	39,0	2,2	2,2	1,9	1,9	2,0	NO	-
9	I9	FORD	M2	Default	IDIADA	D	29-5-2019	8	OPEN	OK	0,0086	1,436	0,984	0,148	28,24	18,02	65,99	101,02	1,17	0,61	41,1	34,7	38,8	37,7	38,0	2,3	2,2	1,9	1,9	2,1	YES	FO-M1-RLm-HOT
10	I10	FORD	M2	Extended	IDIADA	D	29-5-2019	20	OPEN	OK	0,0086	0,736	0,978	0,052	25,00	16,67	73,52	101,12	1,17	0,37	37,7	36,2	36,3	35,4	36,4	2,2	2,2	1,9	1,9	2,0	NO	-
11	I11	FORD	H	Default	IDIADA	D	31-5-2019	10	OPEN	OK	0,0086	1,667	0,999	0,416	32,94	22,67	31,02	101,08	1,18	0,97	43,6	42,2	45,4	42,6	43,5	2,4	2,4	1,9	1,9	2,1	YES	FO-H-RLm-HOT
12	I12	FORD	H	Extended	IDIADA	D	31-5-2019	20	OPEN	OK	0,0086	0,212	0,978	0,293	23,09	16,28	61,15	101,00	1,18	0,82	39,9	38,7	40,2	37,7	39,1	2,4	2,4	1,9	1,9	2,1	NO	-
13	L1	VOLVO	M2	Default	LOMMEL	D	30-4-2019	10	OPEN	OK	0,0086	-0,153	0,950	0,718	12,70	10,22	81,14	101,76	1,21	1,04	24,4	25,6	22,4	21,4	23,4	2,8	2,8	2,8	2,8	2,8	YES	VO-M2-RLm-HOT
14	L2	VOLVO	M2	Extended	LOMMEL	D	29-4-2019	20	NORMAL	OK	0,0086	-3,427	0,970	1,889	25,65	15,97	44,47	101,78	1,21	1,72	34,0	32,1	31,6	29,4	31,8	2,9	2,9	2,8	2,8	2,8	NO	-
15	L3	VOLVO	M1	Default	LOMMEL	J	25-4-2019	14	NORMAL	OK	0,0086	-3,627	0,974	1,033	13,30	11,93	67,55	99,87	1,19	1,29	27,0	28,1	24,3	24,4	25,9	2,9	2,9	2,9	2,8	2,9	NO	-
16	L4	VOLVO	M1	Extended	LOMMEL	D	25-4-2019	18	NORMAL	OK	0,0086	1,956	0,994	3,605	23,95	17,69	51,51	99,87	1,17	2,42	33,3	35,5	31,1	31,8	32,9	2,9	2,9	2,8	2,9	2,9	NO	-
17	L5	VOLVO	L	Default	LOMMEL	D	2-5-2019	14	OPEN	OK	0,0086	0,044	0,956	1,949	14,55	8,76	82,97	100,65	1,21	1,85	23,1	23,3	23,1	22,5	23,0	2,9	2,9	2,9	2,8	2,9	NO	-
18	L6	VOLVO	L	Extended	LOMMEL	D	30-4-2019	20	OPEN	OK	0,0086	-0,210	0,960	1,633	22,55	13,18	62,24	101,76	1,21	1,64	26,9	27,8	25,6	24,0	26,1	2,8	2,8	2,8	2,8	2,8	NO	-
19	I1	VOLVO	M2	Default	IDIADA	J	27-5-2019	10	OPEN	OK	0,0086	0,676	0,996	0,145	27,90	18,76	62,59	99,99	1,16	0,51	37,6	40,2	37,2	33,6	37,1	2,8	2,8	2,8	2,8	2,8	YES	VO-M1-RLm-HOT
20	I2	VOLVO	M2	Extended	IDIADA	J	27-5-2019	20	OPEN	OK	0,0086	-0,361	1,001	0,108	24,97	17,35	72,47	99,08	1,14	0,43	33,2	37,8	33,8	31,6	34,1	2,8	2,8	2,8	2,8	2,8	NO	-
21	I3	VOLVO	M1	Default	IDIADA	D	28-5-2019	10	OPEN	OK	0,0086	3,972	0,987	0,552	26,08	17,05	72,42	100,39	1,16	1,04	36,8	38,4	32,9	34,9	35,7	2,8	2,8	2,8	2,8	2,8	NO	-
22	I4	VOLVO	M1	Extended	IDIADA	D	28-5-2019	20	OPEN	OK	0,0086	3,241	0,985	0,264	23,94	16,69	73,93	100,47	1,16	0,72	37,0	39,2	34,8	34,7	36,4	2,8	2,8	2,8	2,9	2,8	NO	-
23	I5	VOLVO	L	Default	IDIADA	D	4-6-2019	8	OPEN	OK	0,0086	0,712	1,000	0,072	28,53	19,24	76,16	99,81	1,13	0,38	32,6	35,2	33,4	33,4	33,7	2,7	2,8	2,7	2,7	2,7	YES	VO-L-RLm-HOT
24	I6	VOLVO	L	Extended	IDIADA	J	3-6-2019	20	OPEN	OK	0,0086	1,766	0,992	0,229	25,25	18,09	62,85	100,21	1,16	0,65	35,1	35,9	34,6	33,6	34,8	2,8	2,8	2,8	2,8	2,8	NO	-

*The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in 2017/1151 Annex XXI Sub-Annex 7 Section 5.

**CO2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in 2017/1151 Annex XXI Sub-Annex 7 Section 3.

Table B.2: Coast down test results: Overview of all variation tests, i.e., Added Weight, Different Tyres, Combination High and Aerodynamic tests

GENERAL INFORMATION											MASSES			ROAD LOAD COEFFICIENTS															CYCLE ENERGY DEMAND**		CO2 EMISSION***	
														CoC*					COASTDOWN UNCORRECTED					COAST DOWN CORRECTED					CoC	COAST DOWN	CoC	IP METHOD
Index number	Test #	Vehicle		Test Description	Location	Driver	Test date	Number of Runs	Grill Setting	Achieved	CoC TM	Average Test Mass	Rotating Mass	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	WLTC 3B	WLTC 3B	total	total
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[kg]	[kg]	[kg]	[N]	[Nh/km]	[Nh^2/km^2]	[N]	[N]	[N]	[Nh/km]	[Nh^2/km^2]	[N]	[N]	[N]	[Nh/km]	[Nh^2/km^2]	[N]	[N]	[kWh]	[kWh]	[g/km]	[g/km]
1	L15	FORD	M2	Added Weight	LOMMEL	J	29-4-2019	12	OPEN	OK	1375	1378	36,45	125,75	0,601	0,02952	159,23	481,05	136,49	0,061	0,03763	161,53	518,88	124,76	0,056	0,03401	147,41	470,45	3,17	3,12	130,48	128,70
2	L16	FORD	M2	Different Tyres	LOMMEL	J	10-5-2019	14	OPEN	OK	1312	1317	36,45	140,55	0,601	0,02952	174,02	495,85	132,86	0,220	0,03703	161,49	525,12	121,92	0,208	0,03440	148,62	486,70	3,20	3,13	131,25	129,03
3	L19	FORD	H	Added Weight	LOMMEL	J	6-5-2019	6	OPEN	OK	1375	1381	36,45	147,54	0,601	0,03138	182,17	521,44	159,23	0,142	0,03997	187,76	573,09	143,18	0,129	0,03632	169,11	519,27	3,36	3,33	136,21	135,34
4	L20	FORD	H	Aerodynamics	LOMMEL	J	7-5-2019	20	NORMAL	OK	1325	1332	36,45	142,04	0,601	0,03138	176,67	515,94	137,83	0,331	0,03729	169,41	543,82	126,65	0,309	0,03423	155,76	499,78	3,29	3,20	134	131,21
5	L21	FORD	H	Aerodynamics	LOMMEL	J	7-5-2019	20	CLOSED	OK	1325	1325	36,45	142,04	0,601	0,03138	176,67	515,94	134,61	0,150	0,03671	161,31	516,71	126,23	0,142	0,03393	150,99	479,74	3,29	3,11	134	128,65
6	L7	VOLVO	L	Added Weight	LOMMEL	J	24-4-2019	12	NORMAL	OK	2172	2164	56,73	121,88	1,348	0,03750	179,01	631,68	175,58	0,166	0,04500	207,86	642,18	173,30	0,164	0,04522	205,67	641,94	4,44	4,51	185,70	187,71
7	L8	VOLVO	L	Different Tyres	LOMMEL	J	3-5-2019	10	OPEN	OK	2018	2015	56,73	143,17	1,348	0,03750	200,31	652,97	197,77	0,281	0,05064	236,45	732,31	179,25	0,256	0,04853	215,97	690,15	4,41	4,57	185,03	189,46
8	L9	VOLVO	L	Combination High	LOMMEL	J	3-5-2019	12	OPEN	OK	2172	2170	56,73	158,56	1,348	0,03750	215,70	668,36	198,47	0,674	0,04605	244,12	726,46	179,46	0,612	0,04411	222,32	681,73	4,62	4,68	190,87	192,48

GENERAL INFORMATION											CORRECTION COEFFICIENTS				ENVIRONMENTAL CONDITIONS						TYRE CONDITIONS										LINKED TO CHASSIS-DYNO	
																					AVERAGE TEMPERATURE					AVERAGE PRESSURE						
Index number	Test #	Vehicle		Test Description	Location	Driver	Test date	Number of Runs	Grill Setting	Achieved	K0	K1	K2	W1	Asphalt Temp Average	Ambient Temp Average	Humidity Average	Pressure Average	Air density Average	Wind Average	FL	FR	RL	RR	ALL	FL	FR	RL	RR	ALL	Selected for CD test	Chassis-dyno test Reference
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[K^{-1}]	[N]	[-]	[N]	[°C]	[°C]	[%]	[kPa]	[kg/m^3]	[m/s]	[°C]	[°C]	[°C]	[°C]	[°C]	[bar]	[bar]	[bar]	[bar]	[bar]	[-]	[-]
1	L15	FORD	M2	Added Weight	LOMMEL	J	29-4-2019	12	OPEN	OK	0,0086	0,297	0,949	0,159	14,70	10,36	76,63	101,92	1,22	0,57	25,7	26,1	25,1	24,7	25,4	2,3	2,3	2,0	2,0	2,1	YES	FO-M1-TNOVH-HOT
2	L16	FORD	M2	Different Tyres	LOMMEL	J	10-5-2019	14	OPEN	OK	0,0086	0,504	0,975	3,524	18,35	13,77	61,30	100,43	1,19	2,71	26,3	25,3	24,3	24,2	25,0	2,4	2,4	1,9	1,9	2,2	YES	FO-M1-RL-TYRE-HOT
3	L19	FORD	H	Added Weight	LOMMEL	J	6-5-2019	6	OPEN	OK	0,0086	0,692	0,952	1,276	11,30	9,59	52,50	101,41	1,23	1,57	24,9	23,1	22,4	21,0	22,8	2,4	2,4	1,9	1,9	2,1	NO	-
4	L20	FORD	H	Aerodynamics	LOMMEL	J	7-5-2019	20	NORMAL	OK	0,0086	0,673	0,964	1,264	19,60	12,09	46,29	101,02	1,22	1,62	31,3	30,0	29,3	27,9	29,6	2,5	2,5	2,0	1,9	2,2	NO	-
5	L21	FORD	H	Aerodynamics	LOMMEL	J	7-5-2019	20	CLOSED	OK	0,0086	-0,051	0,971	1,249	23,60	13,74	38,34	100,86	1,21	1,62	29,1	26,0	26,1	27,2	27,1	2,5	2,4	1,9	1,9	2,2	NO	-
6	L7	VOLVO	L	Added Weight	LOMMEL	J	24-4-2019	12	NORMAL	OK	0,0086	-0,649	1,005	1,344	18,90	18,94	52,58	99,21	1,16	1,52	30,8	32,4	28,1	28,7	30,0	2,9	2,9	2,9	2,9	2,9	YES	VO-M1-TNOVH-HOT
7	L8	VOLVO	L	Different Tyres	LOMMEL	J	3-5-2019	10	OPEN	OK	0,0086	-0,294	0,958	0,891	11,75	9,43	71,37	100,63	1,21	1,16	23,1	22,9	20,9	20,1	21,7	2,8	2,9	2,8	2,8	2,8	NO	-
8	L9	VOLVO	L	Combination High	LOMMEL	J	3-5-2019	12	OPEN	OK	0,0086	-0,183	0,958	0,730	18,25	9,15	69,69	100,59	1,22	1,11	23,1	24,0	20,8	21,5	22,3	2,8	2,8	2,8	2,8	2,8	NO	-

*Road load coefficients in blue have been determined based on the known change in test mass and RRC. Variations in aerodynamic effects, e.q. the active grill or the effect of tyres on the aerodynamic drag, have not been taken into account, as they were unknown.

**The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in 2017/1151 Annex XXI Sub-Annex 7 Section 5.

***CO2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in 2017/1151 Annex XXI Sub-Annex 7 Section 3.

Table B.3a: Chassis-dyno tests: Overview of all CoC-COLD, CoC-HOT, CoC-MINUS7, CoC-DYNO-COLD and CoC-DYNO-HOT tests

GENERAL											MASSES		CHASSIS-DYNO ROAD LOAD SETTINGS																				DYNO COEFF		
													TARGET					SETTING					CHECK 1					CHECK 2							
Index number	Test #	Vehicle		Test Description	Dyno Number	Driver	Test date	Chassis-dyno mode	Start condition	Achieved	Test Mass	Rotating Mass	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	a	b	c
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[kg]	[kg]	[N]	[Nh/km]	$[Nh^2/km^2]$	[N]	[N]	[N]	[Nh/km]	$[Nh^2/km^2]$	[N]	[N]	[N]	[Nh/km]	$[Nh^2/km^2]$	[N]	[N]	[N]	[Nh/km]	$[Nh^2/km^2]$	[N]	[N]	[N]	[Nh/km]	$[Nh^2/km^2]$
1	V1	VOLVO	M1	VO-M1-CoC-COLD-TEST1	Vela 2	PL	10-7-2019	ON	Cold	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	148,38	1,157	0,03803	201,07	644,38	133,72	1,974	0,03279	203,56	659,02	169,22	1,621	0,03584	232,16	689,75	-71,97	0,690	0,03868
2	V2	VOLVO	M1	VO-M1-CoC-COLD-TEST2	Vela 2	PL	11-7-2019	ON	Cold	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	148,38	1,157	0,03803	201,07	644,38	127,19	1,480	0,03650	187,00	640,22	138,76	2,059	0,03331	211,06	677,79	-71,97	0,690	0,03868
3	V3	VOLVO	M1	VO-M1-CoC-COLD-TEST3	Vela 2	PL	12-7-2019	ON	Cold	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	148,38	1,157	0,03803	201,07	644,38	128,60	1,379	0,03682	186,08	634,68	130,84	1,314	0,03758	187,17	638,00	-71,97	0,690	0,03868
4	V4	VOLVO	M1	VO-M1-CoC-HOT	Vela 2	GP	10-7-2019	ON	Hot	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	148,38	1,157	0,03803	201,07	644,38	130,96	1,011	0,03934	180,82	625,46	-	-	-	-	-	-71,97	0,690	0,03868
5	V12	VOLVO	M1	VO-M1-CoC-MINUS7	Vela 2	GP	19-7-2019	ON	Cold	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	148,38	1,157	0,03803	201,07	644,38	182,15	2,122	0,03400	256,45	734,36	-	-	-	-	-	-71,97	0,690	0,03868
6	V13	VOLVO	M2	VO-M2-CoC-COLD-TEST1	Vela 2	PL	4-7-2019	ON	Cold	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	150,47	1,291	0,03785	206,40	658,07	159,50	1,768	0,03377	224,82	674,05	167,92	1,763	0,03526	234,03	696,81	-48,25	0,695	0,03732
7	V14	VOLVO	M2	VO-M2-CoC-COLD-TEST2	Vela 2	PL	5-7-2019	ON	Cold	NOK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	150,47	1,291	0,03785	206,40	658,07	-	-	-	-	-	-	-	-	-	-	-48,25	0,695	0,03732
8	V15	VOLVO	M2	VO-M2-CoC-COLD-TEST3	Vela 2	PL	5-7-2019	ON	Cold	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	150,47	1,291	0,03785	206,40	658,07	128,73	1,678	0,03454	192,26	641,86	135,70	2,670	0,03068	221,61	709,42	-48,25	0,695	0,03732
9	V16	VOLVO	M2	VO-M2-CoC-COLD-TEST4	Vela 2	PL	8-7-2019	ON	Cold	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	150,47	1,291	0,03785	206,40	658,07	159,88	1,145	0,03734	211,84	647,77	169,21	1,603	0,03547	231,46	684,28	-48,25	0,695	0,03732
10	V17	VOLVO	M2	VO-M2-CoC-HOT	Vela 2	PC	5-7-2019	ON	Hot	OK	2058	56,73	147,20	1,348	0,03712	204,10	653,20	150,47	1,291	0,03785	206,40	658,07	168,58	2,208	0,03003	242,55	689,68	-	-	-	-	-	-48,25	0,695	0,03732
11	V20	VOLVO	L	VO-L-CoC-COLD-TEST1	Vela 2	PL	17-7-2019	ON	Cold	OK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	105,88	1,317	0,03784	162,46	615,98	109,81	1,439	0,03674	168,75	621,09	-	-	-	-	-	-82,55	0,701	0,03855
12	V21	VOLVO	L	VO-L-CoC-COLD-TEST2	Vela 2	PL	18-7-2019	ON	Cold	NOK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	105,88	1,317	0,03784	162,46	615,98	-	-	-	-	-	-	-	-	-	-	-82,55	0,701	0,03855
13	V22	VOLVO	L	VO-L-CoC-COLD-TEST3	Vela 2	PL	18-7-2019	ON	Cold	OK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	105,88	1,317	0,03784	162,46	615,98	114,50	1,298	0,03751	170,39	619,34	104,18	1,414	0,03772	163,10	622,76	-82,55	0,701	0,03855
14	V23	VOLVO	L	VO-L-CoC-COLD-TEST4	Vela 2	PL	22-7-2019	ON	Cold	OK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	105,88	1,317	0,03784	162,46	615,98	120,76	1,613	0,03616	183,70	643,69	107,53	1,494	0,03713	168,09	628,20	-82,55	0,701	0,03855
15	V28	VOLVO	L	VO-L-CoC-COLD-TEST5	Vela 8	PL	24-7-2019	ON	Cold	OK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	-	-	-	-	-	122,53	1,805	0,03314	188,38	634,48	140,91	1,436	0,03738	200,18	658,31	-85,72	0,428	0,04035
16	V29	VOLVO	L	VO-L-CoC-COLD-TEST6	Vela 8	PL	25-7-2019	ON	Cold	OK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	-	-	-	-	-	110,66	1,949	0,03377	180,49	643,29	129,65	1,536	0,03712	191,24	654,36	-85,72	0,428	0,04035
17	V30	VOLVO	L	VO-L-CoC-COLD-TEST7	Vela 8	PL	26-7-2019	ON	Cold	OK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	-	-	-	-	-	111,74	1,367	0,03668	168,85	615,24	130,64	1,128	0,03951	183,54	638,60	-85,72	0,428	0,04035
18	V24	VOLVO	L	VO-L-CoC-HOT	Vela 2	PL	17-7-2019	ON	Hot	OK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	105,88	1,317	0,03784	162,46	615,98	108,60	1,306	0,03735	164,58	612,64	-	-	-	-	-	-82,55	0,701	0,03855
19	V26	VOLVO	L	VO-L-CoC-MINUS7	Vela 2	GP	19-7-2019	ON	Cold	OK	2018	56,73	109,10	1,348	0,03750	166,24	618,90	105,88	1,317	0,03784	162,46	615,98	147,30	1,424	0,03780	206,52	667,66	-	-	-	-	-	-82,55	0,701	0,03855
20	F1	FORD	M1	FO-M1-CoC-COLD-TEST1	Vela 2	PL	4-9-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	118,95	0,622	0,02933	152,83	474,45	120,76	0,650	0,02940	155,37	479,67	118,75	0,615	0,02951	152,57	475,34	67,40	0,113	0,03055
21	F2	FORD	M1	FO-M1-CoC-COLD-TEST2	Vela 2	PL	5-9-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	118,95	0,622	0,02933	152,83	474,45	122,13	0,647	0,02943	156,71	481,21	119,83	0,573	0,02982	152,79	475,30	67,40	0,113	0,03055
22	F3	FORD	M1	FO-M1-CoC-COLD-TEST3	Vela 2	PL	6-9-2019	OFF	Cold	NOK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	118,95	0,622	0,02933	152,83	474,45	-	-	-	-	-	-	-	-	-	-	67,40	0,113	0,03055
23	F4	FORD	M1	FO-M1-CoC-COLD-TEST4	Vela 2	PL	12-9-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	118,95	0,622	0,02933	152,83	474,45	120,15	0,629	0,02947	154,28	477,69	117,61	0,654	0,02921	152,22	475,16	67,40	0,113	0,03055
24	F17	FORD	M1	FO-M1-CoC-COLD-TEST5	Vela 8	PL	17-9-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	-	-	-	-	-	119,31	0,519	0,03003	151,07	471,58	118,44	0,507	0,02994	149,83	468,57	68,50	0,042	0,03080
25	F18	FORD	M1	FO-M1-CoC-COLD-TEST6	Vela 8	PL	17-9-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	-	-	-	-	-	119,35	0,553	0,02969	151,73	471,53	120,70	0,560	0,02967	153,24	473,35	68,50	0,042	0,03080
26	F19	FORD	M1	FO-M1-CoC-COLD-TEST7	Vela 8	PL	18-9-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	-	-	-	-	-	119,24	0,561	0,02973	151,84	472,59	121,64	0,594	0,02953	154,96	476,38	68,50	0,042	0,03080
27	F5	FORD	M1	FO-M1-CoC-HOT	Vela 2	PL	4-9-2019	OFF	Hot	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	118,95	0,622	0,02933	152,83	474,45	118,19	0,556	0,02969	150,65	470,74	-	-	-	-	-	67,40	0,113	0,03055
28	F15	FORD	M1	FO-M1-CoC-MINUS7	Vela 2	PL	13-9-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	118,95	0,622	0,02933	152,83	474,45	-	-	-	-	-	-	-	-	-	-	67,40	0,113	0,03055
29	F16	FORD	M1	FO-M1-CoC-DYNO-HOT	Vela 2	PL	12-9-2019	ON	Hot	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	-	-	-	-	-	142,67	0,553	0,03146	176,17	512,64	-	-	-	-	-	67,40	0,113	0,03055
30	F20	FORD	M1	FO-M1-CoC-DYNO-COLD	Vela 8	PL	19-9-2019	ON	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	-	-	-	-	-	117,51	0,566	0,02978	150,27	471,91	-	-	-	-	-	68,50	0,042	0,03080
31	F21	FORD	M2	FO-M2-CoC-COLD-TEST1	Vela 2	PL	24-7-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	119,32	0,603	0,02942	152,78	473,82	118,11	0,614	0,02948	151,89	474,31	120,38	0,598	0,02969	153,89	477,08	69,12	0,082	0,03067
32	F22	FORD	M2	FO-M2-CoC-COLD-TEST2	Vela 2	PL	25-7-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	119,32	0,603	0,02942	152,78	473,82	120,51	0,546	0,02989	152,84	474,01	121,49	0,581	0,02979	154,63	477,49	69,12	0,082	0,03067
33	F23	FORD	M2	FO-M2-CoC-COLD-TEST3	Vela 2	PL	25-7-2019	OFF	Cold	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	119,32	0,603	0,02942	152,78	473,82	120,68	0,532	0,03001	152,74	473,98	-	-	-	-	-	69,12	0,082	0,03067
34	F24	FORD	M2	FO-M2-CoC-HOT	Vela 2	AB	24-7-2019	OFF	Hot	OK	1313	36,45	119,85	0,601	0,02952	153,33	475,15	-	-	-	-	-	119,70	0,527	0,02986	151,54	471,00	-	-	-	-	-	69,12	0,082	0,03067
35	F27	FORD	H	FO-H-CoC-COLD-TEST1	Vela 2	PL	10-9-2019	OFF	Cold	OK	1325	36,45	142,04	0,601	0,03138	176,67	515,94	140,94	0,643	0,03098	176,38	515,04	142,07	0,637	0,03103	177,40	516,12	141,25	0,611	0,03101	175,90	512,43	91,52	0,131	0,03216
36	F28	FORD	H	FO-H-CoC-COLD-TEST2	Vela 2	PL	11-9-2019	OFF	Cold	OK	1325	36,45	142,04	0,601	0,03138	176,67	515,94	140,94	0,643	0,03098	176,38	515,04	141,46	0,638	0,03109	176,84	516,16	143,65	0,649	0,03109	179,31	519,44	91,52	0,131	0,03216
37	F29	FORD	H	FO-H-CoC-COLD-TEST3	Vela 2	PL	11-9-2019	OFF	Cold	OK	1325	36,45	142,04	0,601	0,03138	176,67	515,94	140,94	0,643	0,03098	176,38	515,04	141,28	0,683	0,03080	177,59	517,55	144,86	0,609	0,03136	179,70	519,43	91,52	0,131	0,03216
38	F30	FORD	H	FO-H-CoC-HOT	Vela 2	PL	10-9-2019	OFF	Hot	OK	1325	36,45	142,04	0,601	0,03138	176,67	515,94	140,94	0,643	0,03098	176,38	515,04	133,47	0,443	0,03260	164,92	503,76	133,47	0,443	0,03260	164,92	503,76	91,52	0,131	0,03216
39	F32	FORD	H	FO-H-CoC-MINUS7-TEST1	Vela 2	-	16-9-2019	OFF	Cold	NOK	1325	36,45	142,04	0,601	0,03138	176,67	515,94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	F33	FORD	H	FO-H-CoC-MINUS7-TEST2	Vela 2	PL	16-9-2019	OFF	Cold	OK	1325	36,45	142,04	0,601	0,03138	176,67	515,94	140,94	0,643	0,03098	176,38	515,04	155,64	0,795	0,03080	194,76	543,12	155,64	0,795	0,03080	194,76	543,12	91,52	0,1308	0,03216

Table B.3b: Chassis-dyno tests: Overview of all CoC-COLD, CoC-HOT, CoC-MINUS7, CoC-DYNO-COLD and CoC-DYNO-HOT tests

GENERAL											CYCLE ENERGY DEMAND*				CO2**		DRIVE TRACE INDICES						ERRORS AND VIOLATIONS				CO2 CORRECTION FACTORS				CO2 INTERIM VALUE	
Index number	Test #	Vehicle		Test Description	Dyno Number	Driver	Test date	Chassis-dyno mode	Start condition	Achieved	Target	Setting	Check 1	Check 2	CoC	Measured Final	ER	DR	EER	ASCR	IWR	RMSSE	Error count	Error time	Violation count	Violation time	RCB yes/no?	RCB correction factor	ATCT FCF	Ki factor	CO2 raw	RCB corrected
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[kWh]	[kWh]	[kWh]	[kWh]	[g/km]	[g/km]	[-]	[-]	[-]	[-]	[-]	[km/h]	[-]	[s]	[-]	[s]	[-]	[-]	[-]	[-]	[g/km]	[g/km]
1	V1	VOLVO	M1	VO-M1-CoC-COLD-TEST1	Vela 2	PL	10-7-2019	ON	Cold	OK	4,45	4,42	4,48	4,63	186	182,54	0,71%	0,06%	0,65%	1,74%	1,75%	0,42	0	0,0	0	0,0	NO	0,002	1,016	1,0126	177,43	-
2	V2	VOLVO	M1	VO-M1-CoC-COLD-TEST2	Vela 2	PL	11-7-2019	ON	Cold	OK	4,45	4,42	4,38	4,56	186	178,24	0,59%	0,14%	0,45%	1,12%	1,16%	0,39	0	0,0	0	0,0	NO	0,001	1,016	1,0126	173,25	-
3	V3	VOLVO	M1	VO-M1-CoC-COLD-TEST3	Vela 2	PL	12-7-2019	ON	Cold	OK	4,45	4,42	4,36	4,37	186	179,59	0,26%	0,12%	0,14%	1,09%	0,87%	0,43	0	0,0	0	0,0	NO	0,002	1,016	1,0126	174,56	-
4	V4	VOLVO	M1	VO-M1-CoC-HOT	Vela 2	GP	10-7-2019	ON	Hot	OK	4,45	4,42	4,32	-	186	173,48	1,62%	0,19%	1,41%	3,89%	5,68%	1,18	5	11,2	2	9,8	NO	0,001	1,016	1,0126	168,62	-
5	V12	VOLVO	M1	VO-M1-CoC-MINUS7	Vela 2	GP	19-7-2019	ON	Cold	OK	4,45	4,42	4,83	-	186	222,20	0,76%	0,20%	0,56%	3,21%	4,04%	0,72	0	0,0	0	0,0	NO	0,001	1,016	1,0126	215,98	-
6	V13	VOLVO	M2	VO-M2-CoC-COLD-TEST1	Vela 2	PL	4-7-2019	ON	Cold	OK	4,45	4,48	4,56	4,66	186	177,39	0,67%	0,16%	0,50%	1,70%	1,68%	0,42	0	0,0	0	0,0	NO	0,002	1,016	1,0126	172,42	-
7	V14	VOLVO	M2	VO-M2-CoC-COLD-TEST2	Vela 2	PL	5-7-2019	ON	Cold	NOK	4,45	4,48	-	-	186	-	-	-	-	-	-	-	-	-	-	-	NO	0,003	1,016	1,0126	184,59	-
8	V15	VOLVO	M2	VO-M2-CoC-COLD-TEST3	Vela 2	PL	5-7-2019	ON	Cold	OK	4,45	4,48	4,40	4,69	186	175,01	0,17%	0,06%	0,11%	1,73%	1,78%	0,41	0	0,0	0	0,0	YES	0,005	1,016	1,0126	173,19	170,11
9	V16	VOLVO	M2	VO-M2-CoC-COLD-TEST4	Vela 2	PL	8-7-2019	ON	Cold	OK	4,45	4,48	4,44	4,44	186	175,00	0,31%	0,13%	0,17%	1,60%	1,71%	0,49	0	0,0	0	0,0	NO	n/a	1,016	1,0126	170,10	-
10	V17	VOLVO	M2	VO-M2-CoC-HOT	Vela 2	PC	5-7-2019	ON	Hot	OK	4,45	4,48	4,64	-	186	168,42	-0,82%	0,05%	-0,88%	-1,10%	-1,02%	0,71	1	1,7	1	1,7	NO	0,001	1,016	1,0126	163,70	-
11	V20	VOLVO	L	VO-L-CoC-COLD-TEST1	Vela 2	PL	17-7-2019	ON	Cold	OK	4,24	4,23	4,25	-	180	174,11	0,65%	0,15%	0,50%	1,67%	1,73%	0,43	0	0,0	0	0,0	NO	0,000	1,016	1,0126	169,24	-
12	V21	VOLVO	L	VO-L-CoC-COLD-TEST2	Vela 2	PL	18-7-2019	ON	Cold	NOK	4,24	4,23	-	-	180	-		-	-	-	-	-	-	-	-	-	-	-	1,016	1,0126	167,05	-
13	V22	VOLVO	L	VO-L-CoC-COLD-TEST3	Vela 2	PL	18-7-2019	ON	Cold	OK	4,24	4,23	4,25	4,25	180	174,94	0,57%	0,09%	0,47%	1,54%	1,14%	0,47	2	2,2	1	2,0	YES	0,012	1,016	1,0126	177,14	170,04
14	V23	VOLVO	L	VO-L-CoC-COLD-TEST4	Vela 2	PL	22-7-2019	ON	Cold	OK	4,24	4,23	4,36	4,28	180	173,47	0,85%	0,16%	0,68%	1,74%	1,98%	0,44	0	0,0	0	0,0	NO	0,001	1,016	1,0126	168,61	-
15	V28	VOLVO	L	VO-L-CoC-COLD-TEST5	Vela 8	PL	24-7-2019	ON	Cold	OK	4,24	-	4,33	4,43	180	180,23	0,39%	0,08%	0,31%	1,73%	2,34%	0,53	-	-	0	0,0	NO	0,004	1,016	1,0126	175,18	-
16	V29	VOLVO	L	VO-L-CoC-COLD-TEST6	Vela 8	PL	25-7-2019	ON	Cold	OK	4,24	-	4,35	4,41	180	171,97	0,91%	0,21%	0,69%	1,51%	2,82%	0,51	-	-	0	0,0	NO	-0,001	1,016	1,0126	167,16	-
17	V30	VOLVO	L	VO-L-CoC-COLD-TEST7	Vela 8	PL	26-7-2019	ON	Cold	OK	4,24	-	4,23	4,34	180	172,45	0,39%	0,08%	0,31%	1,72%	2,49%	0,49	-	-	0	0,0	YES	0,006	1,016	1,0126	171,04	167,62
18	V24	VOLVO	L	VO-L-CoC-HOT	Vela 2	PL	17-7-2019	ON	Hot	OK	4,24	4,23	4,22	-	180	167,77	0,36%	0,14%	0,22%	1,03%	1,25%	0,41	0	0,0	0	0,0	NO	0,001	1,016	1,0126	163,08	-
19	V26	VOLVO	L	VO-L-CoC-MINUS7	Vela 2	GP	19-7-2019	ON	Cold	OK	4,24	4,23	4,48	-	180	196,45	1,23%	0,17%	1,05%	3,13%	3,43%	0,77	1	0,3	0	0,0	NO	0,001	1,016	1,0126	190,95	-
20	F1	FORD	M1	FO-M1-CoC-COLD-TEST1	Vela 2	PL	4-9-2019	OFF	Cold	OK	3,09	3,09	3,11	3,09	129	152,67	0,45%	0,02%	0,43%	2,97%	3,83%	0,64	1	0,4	0	0,0	NO	0,001	1,032	1	147,93	-
21	F2	FORD	M1	FO-M1-CoC-COLD-TEST2	Vela 2	PL	5-9-2019	OFF	Cold	OK	3,09	3,09	3,12	3,09	129	150,38	0,12%	0,03%	0,09%	2,12%	2,84%	0,62	2	1,3	0	0,0	NO	0,001	1,032	1	145,71	-
22	F3	FORD	M1	FO-M1-CoC-COLD-TEST3	Vela 2	PL	6-9-2019	OFF	Cold	NOK	3,09	3,09	-	-	129	-	-	-	-	-	-	-	-	-	-	-	NO	0,001	1,032	1	138,57	-
23	F4	FORD	M1	FO-M1-CoC-COLD-TEST4	Vela 2	PL	12-9-2019	OFF	Cold	OK	3,09	3,09	3,10	3,09	129	152,18	0,38%	0,10%	0,28%	1,67%	2,33%	0,45	0	0,0	0	0,0	NO	0,002	1,032	1	147,46	-
24	F17	FORD	M1	FO-M1-CoC-COLD-TEST5	Vela 8	PL	17-9-2019	OFF	Cold	OK	3,09	-	3,08	3,06	129	155,53	0,57%	-0,09%	0,66%	2,46%	4,95%	0,69	-	-	0	0,0	NO	0,004	1,032	1	150,71	-
25	F18	FORD	M1	FO-M1-CoC-COLD-TEST6	Vela 8	PL	17-9-2019	OFF	Cold	OK	3,09	-	3,08	3,08	129	149,62	53,49%	0,21%	34,71%	29,85%	123,77%	4,99	-	-	0	0,0	NO	0,001	1,032	1	144,98	-
26	F19	FORD	M1	FO-M1-CoC-COLD-TEST7	Vela 8	PL	18-9-2019	OFF	Cold	OK	3,09	-	3,08	3,10	129	150,43	0,05%	-0,10%	0,14%	2,05%	3,23%	0,61	-	-	0	0,0	NO	0,001	1,032	1	145,76	-
27	F5	FORD	M1	FO-M1-CoC-HOT	Vela 2	PL	4-9-2019	OFF	Hot	OK	3,09	3,09	3,07	-	129	148,15	-0,03%	0,08%	-0,10%	2,54%	3,70%	0,60	0	0,0	0	0,0	NO	0,001	1,032	1	143,56	-
28	F15	FORD	M1	FO-M1-CoC-MINUS7	Vela 2	PL	13-9-2019	OFF	Cold	OK	3,09	3,09	-	-	129	170,99	0,69%	0,11%	0,57%	3,08%	3,25%	0,46	0	0,0	0	0,0	NO	0,001	1,032	1	165,69	-
29	F16	FORD	M1	FO-M1-CoC-DYNO-HOT	Vela 2	PL	12-9-2019	ON	Hot	OK	3,09	-	3,27	-	129	149,96	0,22%	0,10%	0,13%	1,93%	2,42%	0,50	0	0,0	0	0,0	NO	0,002	1,032	1	145,31	-
30	F20	FORD	M1	FO-M1-CoC-DYNO-COLD	Vela 8	PL	19-9-2019	ON	Cold	OK	3,09	-	3,08	-	129	150,93	0,09%	-0,11%	0,20%	2,13%	0,64%	3,43	-	-	0	0,0	NO	0,001	1,032	1	146,25	-
31	F21	FORD	M2	FO-M2-CoC-COLD-TEST1	Vela 2	PL	24-7-2019	OFF	Cold	OK	3,09	3,09	3,09	3,10	129	153,95	0,72%	0,04%	0,67%	3,00%	3,68%	0,53	0	0,0	0	0,0	YES	0,011	1,032	1	155,29	149,18
32	F22	FORD	M2	FO-M2-CoC-COLD-TEST2	Vela 2	PL	25-7-2019	OFF	Cold	OK	3,09	3,09	3,09	3,10	129	153,20	0,21%	0,08%	0,13%	2,23%	31,13%	0,59	1	2,3	1	2,3	YES	0,011	1,032	1	154,53	148,45
33	F23	FORD	M2	FO-M2-CoC-COLD-TEST3	Vela 2	PL	25-7-2019	OFF	Cold	OK	3,09	3,09	3,09	-	129	153,95	0,29%	0,07%	0,22%	3,27%	4,18%	0,56	0	0,0	0	0,0	YES	0,005	1,032	1	151,09	149,18
34	F24	FORD	M2	FO-M2-CoC-HOT	Vela 2	AB	24-7-2019	OFF	Hot	OK	3,09	-	3,07	-	129	147,13	-0,53%	-0,19%	-0,34%	1,38%	2,75%	0,83	1	1,1	1	1,1	NO	0,003	1,032	1	142,57	-
35	F27	FORD	H	FO-H-CoC-COLD-TEST1	Vela 2	PL	10-9-2019	OFF	Cold	OK	3,29	3,29	3,29	3,27	134	158,68	0,47%	0,04%	0,42%	2,84%	3,42%	0,47	0	0,0	0	0,0	NO	0,001	1,032	1	153,76	-
36	F28	FORD	H	FO-H-CoC-COLD-TEST2	Vela 2	PL	11-9-2019	OFF	Cold	OK	3,29	3,29	3,29	3,31	134	159,15	0,42%	0,17%	0,25%	2,64%	2,93%	0,52	0	0,0	0	0,0	NO	0,001	1,032	1	154,22	-
37	F29	FORD	H	FO-H-CoC-COLD-TEST3	Vela 2	PL	11-9-2019	OFF	Cold	OK	3,29	3,29	3,30	3,31	134	159,96	0,15%	0,14%	0,01%	2,33%	3,25%	0,51	0	0,0	0	0,0	NO	0,003	1,032	1	155,00	-
38	F30	FORD	H	FO-H-CoC-HOT	Vela 2	PL	10-9-2019	OFF	Hot	OK	3,29	3,29	3,23	-	134	155,37	0,18%	0,13%	0,05%	1,82%	2,46%	0,52	0	0,0	0	0,0	NO	0,001	1,032	1	150,55	-
39	F32	FORD	H	FO-H-CoC-MINUS7-TEST1	Vela 2	-	16-9-2019	OFF	Cold	NOK	3,29	-	-	-	134	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	F33	FORD	H	FO-H-CoC-MINUS7-TEST2	Vela 2	PL	16-9-2019	OFF	Cold	OK	3,29	3,29	3,42	-	134	173,63	0,39%	0,02%	0,37%	3,05%	3,63%	0,45	0	0,0	0	0,0	NO	0,001	1,032	1	168,25	-

*The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in 2017/1151 Annex XXI Sub-Annex 7 Section 5.

**CO2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in 2017/1151 Annex XXI Sub-Annex 7 Section 3.

Table B.4: Chassis-dyno test results: Overview of all variation tests, i.e., RLVL-HOT, RLVH-HOT, RLHM-HOT, TNOVH-HOT, RL-GRILL-HOT, RL-TYRE-HOT and RLm-HOT

GENERAL											MASSES		CHASSIS-DYNO ROAD LOAD SETTINGS: TARGET				
Index number	Test #	Vehicle		Test Description	Dyno Number	Driver	Test date	Chassis-dyno mode	Start condition	Achieved	Test Mass	Rotating Mass	f0	f1	f2	F25	F100
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[kg]	[kg]	[N]	[Nh/km]	[Nh²/km²]	[N]	[N]
1	V5	VOLVO	M1	VO-M1-RLm-HOT	Vela 2	GP	10-7-2019	ON	Hot	OK	2058	56,73	190,77	0,936	0,04325	241,20	716,87
2	V6	VOLVO	M1	VO-M1-RLVH-HOT	Vela 2	GP	10-7-2019	ON	Hot	OK	2172	56,73	198,30	1,348	0,04167	258,04	749,80
3	V7	VOLVO	M1	VO-M1-RLVL-HOT	Vela 2	GP	11-7-2019	ON	Hot	OK	1976	56,73	105,60	1,348	0,03683	162,32	608,70
4	V8	VOLVO	M1	VO-M1-RLHM-HOT	Vela 2	GP	11-7-2019	ON	Hot	OK	2172	56,73	147,20	1,348	0,03712	204,10	653,20
5	V9	VOLVO	M1	VO-M1-TNOVH-HOT	Vela 2	GP	11-7-2019	ON	Hot	OK	2172	56,73	173,30	0,164	0,04522	205,67	641,94
6	V10	VOLVO	M1	VO-M1-RL-TYRE-HOT	Vela 2	GP	12-7-2019	ON	Hot	OK	2119	56,73	192,00	1,348	0,03712	248,90	698,00
7	V11	VOLVO	M1	VO-M1-RL-GRILL-HOT	Vela 2	GP	12-7-2019	ON	Hot	OK	2018	56,73	141,17	1,129	0,03620	192,02	616,07
8	V18	VOLVO	M2	VO-M2-RLm-HOT	Vela 2	PL	5-7-2019	ON	Hot	OK	2058	56,73	191,53	0,179	0,04853	226,33	694,70
9	V19	VOLVO	M2	VO-M2-RLVH-HOT	Vela 2	PC	5-7-2019	ON	Hot	OK	2172	56,73	198,30	1,348	0,04167	258,04	749,80
10	V25	VOLVO	L	VO-L-RLm-HOT-TEST1	Vela 2	GP	17-7-2019	ON	Hot	NOK	2018	56,73	150,18	1,201	0,03856	204,30	655,85
11	V27	VOLVO	L	VO-L-RLm-HOT-TEST2	Vela 2	PL	22-7-2019	ON	Hot	OK	2018	56,73	150,18	1,201	0,03856	204,30	655,85
12	F6	FORD	M1	FO-M1-RLm-HOT-TEST1	Vela 2	PL	4-9-2019	OFF	Hot	NOK	1313	36,45	110,66	0,967	0,02877	152,81	495,02
13	F8	FORD	M1	FO-M1-RLm-HOT-TEST2	Vela 2	CB	6-9-2019	OFF	Hot	OK	1313	36,45	110,66	0,967	0,02877	152,81	495,02
14	F7	FORD	M1	FO-M1-RL-TYRE-HOT	Vela 2	MC	6-9-2019	OFF	Hot	OK	1312	36,45	121,92	0,208	0,03440	148,62	486,70
15	F9	FORD	M1	FO-M1-RL-GRILL-HOT	Vela 2	CB	6-9-2019	OFF	Hot	OK	1313	36,45	112,66	0,565	0,02770	144,10	446,15
16	F10	FORD	M1	FO-M1-RLVL-HOT	Vela 2	PL	6-9-2019	OFF	Hot	OK	1239	36,45	98,80	0,601	0,02890	131,89	447,90
17	F11	FORD	M1	FO-M1-RLHM-HOT-TEST1	Vela 2	PL	6-9-2019	OFF	Hot	NOK	1375	36,45	142,04	0,601	0,03138	176,67	515,94
18	F12	FORD	M1	FO-M1-RLHM-HOT-TEST2	Vela 2	PL	12-9-2019	OFF	Hot	OK	1375	36,45	142,04	0,601	0,03138	176,67	515,94
19	F13	FORD	M1	FO-M1-RLVH-HOT	Vela 2	PL	9-9-2019	OFF	Hot	OK	1375	36,45	138,20	0,601	0,03330	174,04	531,30
20	F14	FORD	M1	FO-M1-TNOVH-HOT	Vela 2	PL	9-9-2019	OFF	Hot	OK	1375	36,45	124,76	0,056	0,03401	147,41	470,45
21	F25	FORD	M2	FO-M2-RLm-HOT	Vela 2	AB	24-7-2019	OFF	Hot	OK	1313	36,45	117,80	-0,065	0,03517	138,17	463,06
22	F26	FORD	M2	FO-M2-RLVH-HOT	Vela 2	AB	24-7-2019	OFF	Hot	OK	1375	36,45	138,20	0,601	0,03330	174,04	531,30
23	F31	FORD	H	FO-H-RLm-HOT	Vela 2	PL	10-9-2019	OFF	Hot	OK	1325	36,45	132,50	0,505	0,03243	165,40	507,30

Index number	CHASSIS-DYNO ROAD LOAD SETTINGS: SETTING					CHECK 1					CHECK 2					DYNO COEFF		
	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	f0	f1	f2	F25	F100	a	b	c
[-]	[N]	[Nh/km]	[Nh²/km²]	[N]	[N]	[N]	[Nh/km]	[Nh²/km²]	[N]	[N]	[N]	[Nh/km]	[Nh²/km²]	[N]	[N]	[N]	[Nh/km]	[Nh²/km²]
1	-	-	-	-	-	178,20	0,352	0,04697	216,37	683,13	-	-	-	-	-	-28,40	0,278	0,04481
2	-	-	-	-	-	174,97	0,980	0,04451	227,28	718,07	-	-	-	-	-	-20,87	0,690	0,04323
3	-	-	-	-	-	92,32	0,720	0,04086	135,87	572,91	-	-	-	-	-	-113,57	0,690	0,03839
4	-	-	-	-	-	132,94	0,720	0,04129	176,75	617,81	-	-	-	-	-	-71,97	0,690	0,03868
5	-	-	-	-	-	158,10	-0,461	0,04931	177,40	605,10	-	-	-	-	-	-45,87	-0,495	0,04678
6	-	-	-	-	-	170,51	1,267	0,03726	225,47	669,80	-	-	-	-	-	-27,17	0,690	0,03868
7	-	-	-	-	-	119,54	1,196	0,03550	171,62	594,07	-	-	-	-	-	-78,00	0,471	0,03776
8	-	-	-	-	-	188,34	0,388	0,04659	227,16	693,05	-	-	-	-	-	-3,92	-0,474	0,04873
9	-	-	-	-	-	218,21	1,589	0,04175	284,03	794,60	-	-	-	-	-	2,85	0,695	0,04187
10	-	-	-	-	-	136,94	1,212	0,03784	190,88	636,50	-	-	-	-	-	-41,47	0,554	0,03961
11	-	-	-	-	-	137,19	1,240	0,03828	192,10	643,95	-	-	-	-	-	-41,47	0,554	0,03961
12	-	-	-	-	-	110,29	0,905	0,02910	151,11	491,80	-	-	-	-	-	58,21	0,479	0,02980
13	-	-	-	-	-	108,69	0,942	0,02879	150,24	490,81	-	-	-	-	-	58,21	0,479	0,02980
14	-	-	-	-	-	119,68	0,188	0,03451	145,95	483,57	-	-	-	-	-	69,47	-0,280	0,03543
15	-	-	-	-	-	111,65	0,541	0,02780	142,56	443,78	-	-	-	-	-	60,21	0,077	0,02873
16	-	-	-	-	-	98,27	0,534	0,02934	129,96	445,08	-	-	-	-	-	46,35	0,113	0,02993
17	-	-	-	-	-	141,01	0,535	0,03173	174,22	511,84	-	-	-	-	-	89,59	0,113	0,03241
18	-	-	-	-	-	141,15	0,520	0,03176	174,01	510,78	-	-	-	-	-	89,59	0,113	0,03241
19	-	-	-	-	-	136,06	0,532	0,03362	170,37	525,43	-	-	-	-	-	85,75	0,113	0,03433
20	-	-	-	-	-	123,24	0,012	0,03416	144,89	466,02	-	-	-	-	-	72,31	-0,432	0,03504
21	-	-	-	-	-	118,86	-0,191	0,03586	136,50	458,36	-	-	-	-	-	67,07	-0,584	0,03632
22	-	-	-	-	-	137,64	0,504	0,03377	171,36	525,78	-	-	-	-	-	87,47	0,082	0,03446
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81,98	0,035	0,03321

GENERAL											CYCLE ENERGY DEMAND*				CO2**	
Index number	Test #	Vehicle		Test Description	Dyno Number	Driver	Test date	Chassis-dyno mode	Start condition	Achieved	Target	Setting	Check 1	Check 2	CoC	Measured
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[kWh]	[kWh]	[kWh]	[kWh]	[g/km]	[g/km]
1	V5	VOLVO	M1	VO-M1-RLm-HOT	Vela 2	GP	10-7-2019	ON	Hot	OK	4,74	-	4,58	-	194,21	178,37
2	V6	VOLVO	M1	VO-M1-RLVH-HOT	Vela 2	GP	10-7-2019	ON	Hot	OK	4,99	-	4,82	-	201	186,74
3	V7	VOLVO	M1	VO-M1-RLVL-HOT	Vela 2	GP	11-7-2019	ON	Hot	OK	4,16	-	3,99	-	178	157,92
4	V8	VOLVO	M1	VO-M1-RLHM-HOT	Vela 2	GP	11-7-2019	ON	Hot	OK	4,55	-	4,38	-	188,86	173,20
5	V9	VOLVO	M1	VO-M1-TNOVH-HOT	Vela 2	GP	11-7-2019	ON	Hot	OK	4,51	-	4,34	-	187,71	170,83
6	V10	VOLVO	M1	VO-M1-RL-TYRE-HOT	Vela 2	GP	12-7-2019	ON	Hot	OK	4,73	-	4,60	-	193,98	175,42
7	V11	VOLVO	M1	VO-M1-RL-GRILL-HOT	Vela 2	GP	12-7-2019	ON	Hot	OK	4,27	-	4,16	-	180,88	161,46
8	V18	VOLVO	M2	VO-M2-RLm-HOT	Vela 2	PL	5-7-2019	ON	Hot	OK	4,64	-	4,63	-	191,27	174,25
9	V19	VOLVO	M2	VO-M2-RLVH-HOT	Vela 2	PC	5-7-2019	ON	Hot	OK	4,99	-	5,19	-	201	178,61
10	V25	VOLVO	L	VO-L-RLm-HOT-TEST1	Vela 2	GP	17-7-2019	ON	Hot	NOK	4,43	-	4,34	-	185,47	-
11	V27	VOLVO	L	VO-L-RLm-HOT-TEST2	Vela 2	PL	22-7-2019	ON	Hot	OK	4,43	-	4,37	-	185,47	171,84
12	F6	FORD	M1	FO-M1-RLm-HOT-TEST1	Vela 2	PL	4-9-2019	OFF	Hot	NOK	3,17	-	3,15	-	130,23	-
13	F8	FORD	M1	FO-M1-RLm-HOT-TEST2	Vela 2	CB	6-9-2019	OFF	Hot	OK	3,17	-	3,15	-	130,23	151,45
14	F7	FORD	M1	FO-M1-RL-TYRE-HOT	Vela 2	MC	6-9-2019	OFF	Hot	OK	3,13	-	3,11	-	129,03	146,32
15	F9	FORD	M1	FO-M1-RL-GRILL-HOT	Vela 2	CB	6-9-2019	OFF	Hot	OK	2,97	-	2,96	-	124,16	142,30
16	F10	FORD	M1	FO-M1-RLVL-HOT	Vela 2	PL	6-9-2019	OFF	Hot	OK	2,90	-	2,88	-	123	139,43
17	F11	FORD	M1	FO-M1-RLHM-HOT-TEST1	Vela 2	PL	6-9-2019	OFF	Hot	NOK	3,33	-	3,31	-	135,32	-
18	F12	FORD	M1	FO-M1-RLHM-HOT-TEST2	Vela 2	PL	12-9-2019	OFF	Hot	OK	3,33	-	3,31	-	135,32	158,68
19	F13	FORD	M1	FO-M1-RLVH-HOT	Vela 2	PL	9-9-2019	OFF	Hot	OK	3,38	-	3,36	-	137	158,76
20	F14	FORD	M1	FO-M1-TNOVH-HOT	Vela 2	PL	9-9-2019	OFF	Hot	OK	3,12	-	3,10	-	128,70	151,48
21	F25	FORD	M2	FO-M2-RLm-HOT	Vela 2	AB	24-7-2019	OFF	Hot	OK	3,02	-	3,00	-	125,81	145,13
22	F26	FORD	M2	FO-M2-RLVH-HOT	Vela 2	AB	24-7-2019	OFF	Hot	OK	3,38	-	3,36	-	137	157,88
23	F31	FORD	H	FO-H-RLm-HOT	Vela 2	PL	10-9-2019	OFF	Hot	OK	3,24	-	-	-	132,53	152,81

Index number	DRIVE TRACE INDICES						ERRORS AND VIOLATIONS				CO2 CORRECTION FACTORS				CO2 INTERIM VALUE	
	ER	DR	EER	ASCR	IWR	RMSSE	Error count	Error time	Violation count	Violation time	RCB yes/no?	RCB correction factor	ATCT FCF	Ki factor	CO2 raw	RCB corrected
[-]	[-]	[-]	[-]	[-]	[-]	[km/h]	[-]	[s]	[-]	[s]	[-]	[-]	[-]	[-]	[g/km]	[g/km]
1	1,19%	0,31%	0,87%	3,70%	4,86%	0,77	0	0,0	0	0,0	NO	0,001	1,016	1,0126	173,37	-
2	1,15%	0,25%	0,90%	4,11%	5,97%	0,79	0	0,0	0	0,0	NO	0,001	1,016	1,0126	181,51	-
3	-0,19%	0,03%	-0,22%	0,85%	0,69%	0,54	0	0,0	0	0,0	NO	0,002	1,016	1,0126	153,50	-
4	1,58%	0,21%	1,34%	3,66%	5,17%	0,82	1	0,8	0	0,0	NO	0,001	1,016	1,0126	168,36	-
5	1,25%	0,18%	1,05%	3,80%	6,88%	0,84	1	0,5	0	0,0	NO	0,001	1,016	1,0126	166,05	-
6	0,53%	0,13%	0,40%	2,04%	2,81%	0,86	1	0,9	0	0,0	NO	0,001	1,016	1,0126	170,51	-
7	1,43%	0,19%	1,22%	3,79%	5,42%	0,83	0	0,0	0	0,0	NO	0,001	1,016	1,0126	156,94	-
8	0,46%	0,15%	0,30%	1,48%	1,33%	0,44	0	0,0	0	0,0	NO	0,001	1,016	1,0126	169,37	-
9	-0,31%	-0,01%	-0,30%	0,05%	0,35%	0,62	0	0,0	0	0,0	NO	0,000	1,016	1,0126	173,61	-
10		-	-	-	-	-	-	-	-	-	-	-	1,016	1,0126	165,87	-
11	0,74%	0,09%	0,65%	1,55%	1,33%	0,37	0	0,0	0	0,0	NO	0,001	1,016	1,0126	167,03	-
12	-	-	-	-	-	-	-	-	-	-	NO	0,002	1,032	1	136,20	-
13	0,27%	0,10%	0,18%	2,57%	3,39%	0,48	0	0,0	0	0,0	NO	0,001	1,032	1	146,75	-
14	-0,53%	0,15%	-0,69%	1,69%	2,85%	0,72	0	0,0	0	0,0	NO	0,001	1,032	1	141,78	-
15	-0,25%	0,08%	-0,33%	2,04%	2,87%	0,63	0	0,0	0	0,0	NO	0,001	1,032	1	137,89	-
16	0,49%	0,17%	0,31%	1,85%	2,55%	0,55	0	0,0	0	0,0	NO	0,001	1,032	1	135,11	-
17	-	-	-	-	-	-	-	-	-	-	NO	0	1,032	1	150,08	-
18	0,21%	0,07%	0,14%	1,96%	2,73%	0,41	0	0,0	0	0,0	NO	0,001	1,032	1	153,76	-
19	0,09%	0,06%	0,03%	2,47%	3,58%	0,47	0	0,0	0	0,0	NO	0,001	1,032	1	153,83	-
20	-0,03%	-0,03%	-0,01%	2,45%	2,82%	0,60	0	0,0	0	0,0	NO	0,001	1,032	1	146,79	-
21	0,60%	-0,12%	0,71%	3,28%	4,42%	0,77	1	0,5	0	0,0	NO	0,002	1,032	1	140,63	-
22	0,06%	-0,08%	0,15%	2,86%	4,63%	0,74	0	0,0	0	0,0	NO	0,001	1,032	1	152,98	-
23	0,25%	0,09%	0,16%	2,22%	3,07%	0,54	0	0,0	0	0,0	NO	0,001	1,032	1	148,07	-

*The cycle energy demand has been determined from the test mass and road load coefficients by application of the method described in 2017/1151 Annex XXI Sub-Annex 7 Section 5.

**CO2 emissions displayed in blue have been determined from the cycle energy demand and IP family information (Vehicle Low and High) by application of the interpolation method described in 2017/1151 Annex XXI Sub-Annex 7 Section 3.

C Considerations on the WLTP procedure for CO_2 determination

C.1 Treatment of wind as major source of uncertainty in road load determination

C.1.1 Certified meteorological measurements and weather station location

The requirements in the WLTP on wind measurements are unrealistic. In particular a 1 Hz signal, and higher, is generally not available with the required accuracy. Certification of wind measuring equipment is with stationary wind conditions in a small wind tunnel. Given that the presence of wind will always lead to a downward correction of the road load value, measuring the wind speed at a more windy location near the track will have benefits to achieve lower road loads. Furthermore, the “average wind speed” and “peak wind speed” are not properly defined mathematical operations on these wind signals. The period to average over, and the method of averaging (i.e., absolute values or vectoral) is not described in the WLTP.

In the WLTP text, 4.1.1.1.1: “In addition, the average vector component of the wind speed across the test road shall be less than 2 m/s during each valid run pair.” It is virtually impossible to comply with this unless the crosswind is always lower than 2 m/s. Matching meteorological data with run data cannot be done in this manner, possibly only with great effort in postprocessing to drop results, as described in the WLTP. But during the runs statistics need to be kept, to reach the required accuracy.

C.1.2 Wind along the test track, differences between the A-run and B-run

The purpose of an A-run and a B-run is to ensure that effects that work differently in opposite directions are averaged over (The underlying assumption seems that the A- and B-run are on the same road stretch in opposite directions.). The typical examples are slope and wind effects. In particular, wind effects that can be large, should lead only to minor corrections w1 if the simple mathematics is applicable. With allowable wind speeds up to 5 m/s, effects on a single A-run or B-run forces can be as high as 50%. There are three major caveats in the assumptions underlying the WLTP:

1. The wind in the A-run and B-run are not necessarily the same. The tail wind can be larger than the head wind, if one side of the track is less exposed to wind.
2. A typical track is 2 kilometers long (to limit the number of split runs to 2), in which the wind conditions can vary greatly, for example, by banks or slopes and trees. The wind speed at the location of the wind measurement system is then just an example of the wind conditions that can occur along the whole track.
3. As is clear from the anemometer method, with the yaw angle (Y in 4.3.2.5.4), in the WLTP side wind effects on the air drag are more related to disturbances of the flow pattern around the vehicle than the additional flow. Therefore, side winds may have double the effect on the air-drag compared to head or tail wind. Moreover, from measurements it is apparent that the reduction of air drag with tail wind is limited, while the increase with head wind is larger, compared to the additional velocity.

Given the size and direction of the wind correction to the road load it is important to ensure the wind measurement is more representative of conditions along the whole track, than currently described in the WLTP.

C.1.3 Differences in parallel and perpendicular wind directions

It is observed, and also confirmed by the functional form with the yaw angle of the on-board anemometer method, that crosswind has a more detrimental effect on the air-drag than head or tail wind. Currently, only the vectoral effect, i.e., the addition of the longitudinal wind increase with crosswind is accounted for in the WLTP procedure. This is very likely not the most important effect of the crosswind. The maximum allowed crosswind of 2 m/s may ensure a limited effect. A higher factor for crosswind in w_1 and w_2 corrections may be appropriate, if evidence can be provided. For example, on-board anemometry results can provide such evidence.

C.2 Examples of wind effects

The difference in wind speed for the A and the B run gives the largest effect on the air-drag. A higher measured wind velocity at the weather station with respect to the wind around the vehicle still gives a nonnegligible effect on the road load values.

If the head wind is 4 m/s and the tail wind is 5 m/s, due to different locations of the A and B lane on test track, the difference in air-drag is:

$$F_{air\text{-}drag} = ½ * f2 * ((v + 4 * 3.6)^2 + (v – 5 * 3.6)^2) = f2*(v^2 - 3.6 * v + 265.7)$$

If the air-drag is corrected according to the highest wind velocity, i.e. 5 m/s, the downward correction is: $w_1 = f2 * 324$:

$$F_{air\text{-}drag}^{corrected} = f2 * (v^2 - 3.6 * v – 58.3)$$

At 50 km/h the corrected air drag is 9.6% lower than the actual value $f2*v^2$, at 100 km/h it is 4.2% lower, and at 130 km/h the air drag is 3.1% lower.

Generally, if the measured wind speed is 1 m/s higher at the weather station than encountered at the vehicle location on the track, the wind correction w_1 yields a lowering of the air drag equal to:

$$\Delta F = f2 * (v_{wind} + 3.6)^2 – f2 * v_{wind}^2 = f2 * (7.2 * v_{wind} + 13.0)$$

For a typical velocity of 100 km/h, the maximal effect on the air drag given $v_{wind} < 5$ m/s is 0.5%, at 50 km/h it is 2%.

C.3 WLTP test procedures

C.3.1 No definition of “straight” coasting (“movement of the steering wheel”), with presence of other traffic on the track.

In practice, multiple users are on a test track during coast down tests. Manoeuvring around other vehicles and wind gusts from passing vehicles are quite normal experiences. A description in terms of the maximal change in heading angle over a given distance (i.e. < [1°/100] metres) should ensure a common understanding of valid driving. Common vehicle instrumentation (e.g. VBOX from Racelogic) for coast down logs the necessary heading signal (4.3.2.4.2 and 4.4.2.3).

C.3.2 The need for braking on specific test tracks

Instructions on "moderate braking" in coast down tests turned out to be impractical on some test tracks. In particular straight tracks with a small turning cycle at the end need some significant braking in the high velocity test, if the coast down tests are to be performed in 2 split runs. Moreover, the use of the word "actuation" in 4.2.4.1 ("there shall be no further actuation or manual adjustment of the braking system") is deemed wrong with the common meaning of this word.

C.3.3 Tyre pressure variations depending on runs

The dynamic tyre pressure varies over the coast down test program. Effects will vary with the test track layout and the test executions. For example, braking and split run order may result in differences. Without any special optimization the execution of the tests on different tracks led to a few percent observed differences in tyre pressure (and thus tyre temperature). Effects on the road load are unknown, but some variations may be expected.

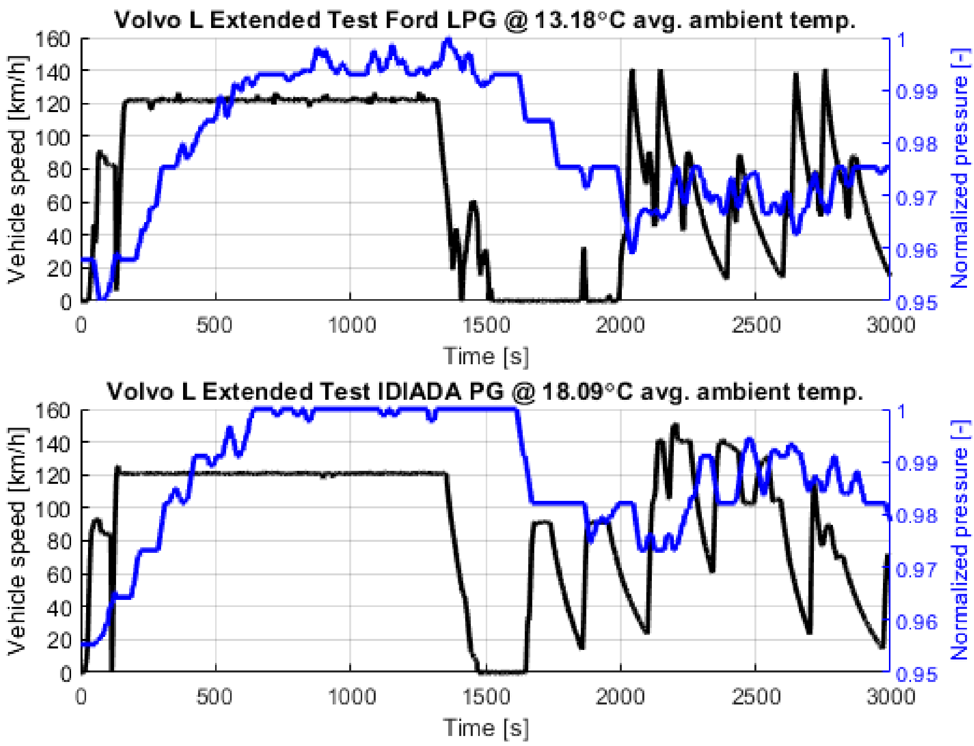

Figure C.1: The tyre pressure monitoring throughout the conditioning and the first part of the cost down tests, with the same vehicle on different test tracks.

C.3.4 Order in the execution of split runs

Split runs can be performed in different order. For example, the high velocity runs first, or alternating high and low velocity runs. This is linked to tyre pressure effects throughout the test program. It is possible to optimize for the lowest rolling resistance, although yet unclear what order leads to the lowest results.

C.4 Statistics, equations and corrections

C.4.1 The rolling resistance correction K1 for coast-down test mass

The rolling resistance is corrected for the test mass, proportional with the test mass, while not all resistance is related to the test mass. Testing for the road load matrix family method for N1 vehicles has shown that part of the rolling resistance is not affected by changes in the mass, and the effect is less than proportional (i.e. 95%, 5.1.1.1). This correction overestimates the effect of mass, and may lead to a larger than real downward correction with higher coast down test masses.

C.4.1 Skewed distributions will shift the outcome systematically down with continued coast-down runs

The minimal number of coast down runs to meet the required statistics will lead to higher road load values than if the test program is extended with more runs. Contrary to normal statistics of a single skewed probability distribution, where the average of a limited draw is closer to the modal than the mean with a small sample, the method in the WLTP leads to the opposite bias. More appropriate statistical methods may remove some of the small sample size bias.

C.4.2 Rolling resistance (rubber viscosity?) temperature correction K0 has limited validation

The ambient temperature correction of the rolling resistance K_0 has limited validation, given the fact that the tyre pressure, and with that the average inner-tyre temperature, can easily vary several degrees from test to test. This variation translates directly into a few percent correction of the rolling resistance if the actual tyre temperature variation rather than the ambient temperature proxy is used. This correction, although acting in the right direction, is difficult to validate for different types of tyres, different test tracks, and freedom in coast-down test execution. Very likely, the temperature of the road surface, for example, due to sunlight, is affecting this result. Validating the true effect of temperature on rolling resistance of tyres in coast down tests, and its dependencies, should not be underestimated.

C.5 Deviations from the parabolic force curve between 135 and 130 km/h

The generic assumption in the WLTP is that road-load force as function of speed can be described by a parabolic curve (coefficients f0,f1,f2). It is noted that in practice there are substantial deviations from this functional form, particular at high velocities. It seems that the vehicles are not “stable” in coasting at 135 km/h and the observed forces between 135 km/h and 130 km/h (the top half of the highest velocity bin) are higher than would be expected on the basis of the extrapolation of the parabolic curve derived from lower speeds. Alternatively, large scale flow eddies at the onset turbulence at these velocities may cause and increase in air drag. The same effect is observed for different vehicles.

Likewise, the lack of low velocity data in the coast down does not uniquely fit the parabolic curve. See section 3.7. This may affect the CED value as well. It is expected that f1 will play only a minor part in the total road load, compared to rolling resistance (f0) and air drag (f2), but in the fitting f1 may compensate limitations of the coast down and deviations from the assumed parabolic curve.

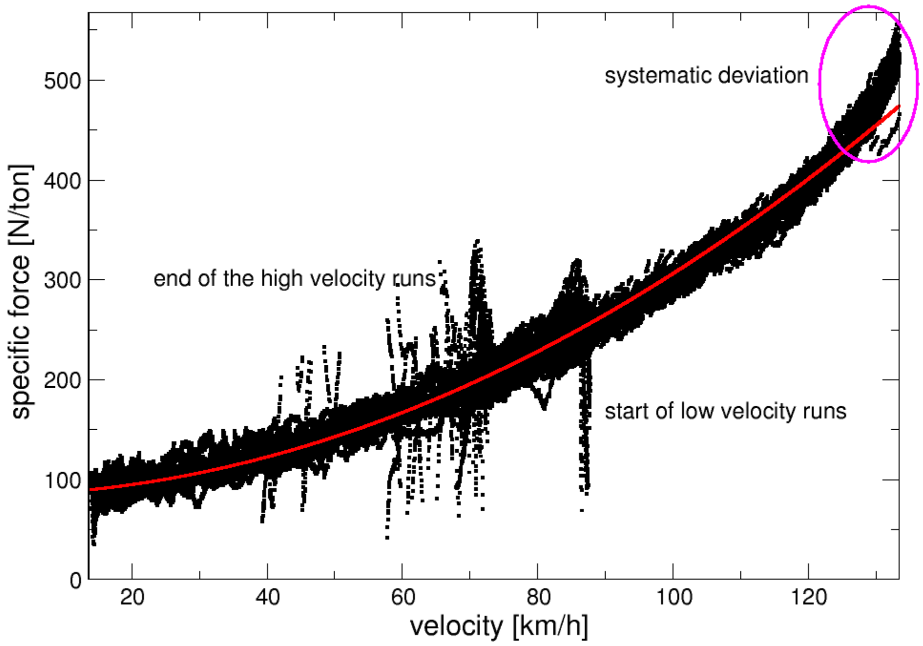

Figure C.2: The forces based on 2 seconds differences, showing a systematic deviation from the parabolic curve at high velocities.

C.6 General principles of applying corrections

If results need to be corrected for variations in the conditions, beyond the control of the test execution, these corrections should hopefully be small. If corrections are small there is no need to combine corrections, as 1% of 1% is 0.01%. However, several corrections are much larger than 1%, and the combination may lead to substantial additional effects.

The order and combinations in which the corrections are applied in the WLTP seem somewhat arbitrary. The wind correction is applied before the rolling resistance correction. But the air resistance correction is not applied to the wind correction. Moreover, the relation of f1 with rolling resistance correction, as suggested by the correction equation in the WLTP, is hard to motivate from the origin of f1 resistance, which may be transmission or driveline related. If corrections are to be combined, it should follow from a master equation which shows the actual interdependencies of the different factors. The sensitivity analyses for the variations in test circumstances and parameters should then provide the true interdependencies of correction factors.

However, there are good reasons not to combine any corrections, but linearize the corrections to separate, independent terms. Any nonlinearity or product of terms in the correction may lead to a correction even if there is no systematic effect, but just measurement noise. For example, the wind correction w_1/w_2 is a quadratic function of the wind speed. If there is no wind, but just measurement noise, it will still lead to a downward correction of the road load, because the square of any signal will be non-negative. This is also an important aspect in the way the average wind speed is determined.

The general functional form of the different corrections (represented by coefficients that sum together close to 1) is:

$$F = f0 * (driveline_0 + tyre_0 + slope * tyre_{slope}) + f1 *(driveline_1 + tyre_1) * v_{vehicle} + f2 * (v_{vehicle} + v_{wind})^2 * \rho_{air}$$

with:

- **$driveline_0$**: Will limit the tyre corrections somewhat. It is expected to be in the order of 5% of f0. This may be affected by ambient temperature. If $driveline_0$ ~5%, it would mean that $tyre_0$ ~ 95% as reference value.
- **$tyre_0$**: Composed of K_0 rolling resistance temperature correction * K_1 mass correction (* RRC correction)
- **slope** correction: Not needed with A and B run combined with opposite slopes. Small differences in forces on the $tyre_{slope}$ can be expected, but are unknown and not included.
- **$driveline_1$**: Can be dominant in f1. Ambient temperature corrections (e.g., lubricants) can be expected. In the determination of K_0 the effects of temperature on driveline resistance must be considered.
- **$tyre_1$**: The single constant RRC is measured on a flat steel drum at 80 km/h. Deviations are expected with velocity and road surface, partly compensated by the drum radius leading to surface curvature. Only relevant for correcting towards tyre label class value.
- **ρ_{air}**: Air density varies with temperature, barometric pressure, combined in K_2 (and slightly with humidity).
- **$(v_{vehicle} + v_{wind})^2$**: The simple vectoral addition of the A and B run, the net effect is $v_{vehicle}^2 + v_{wind}^2$, where $\rho_{air} * v_{wind}^2$ is a constant factor to correct the measured f0. Currently, ρ_{air} is absent in this correction.

Deriving the f0, f1, and f2 from the coast-down measurements should, most appropriately, be done by inserting all known corrections, and subsequently fit the values of f0, f1, and f2 directly from the corrected measured values. Instead, the A run and B run are combined to limit the variation and this average is fitted. This removes also any check on the validity of the actual corrections for wind and the absence of a slope correction.

In the mixed order in which the calculations are performed in the WLTP the determination of f0, from the measurements, contains the wind effect $f2 * v_{wind}^2$ (not, more appropriately: $\rho_{air} * f2 * v_{wind}^2$):

$$f0_{measured} = f0 * (driveline_0 + tyre_0) + f2 * v_{wind}^2$$

Inverting this relation yields a variant of the current form of the approximate correction:

$$f0 = (f0_{measured} - f2 * v_{wind}^2) / (driveline_0 + tyre_0) \sim (f0_{measured} - f2 * v_{wind}^2) * (2 - driveline_0 - tyre_0)$$

In the current legislation the total f0 is assigned to rolling resistance ($driveline_0$ = 0%), with corrections on the rolling resistance accounted for fully in f0, and the last factor reduces to $(1-tyre_0) = (1 + K_0*(T-20))$, where T is temperature in degrees Celsius, not Kelvin.

C.7 Ambiguous mathematics

Given Newton's second law **F = m * a**, some of the equations in the WLTP seem erroneous, as the details are hidden in inappropriate definitions. The velocity v[m/s] = v[km/h]/3.6. If the differences (Δ) in velocity and time are defined in the same manner, as is usual in infinitesimal calculus, the factor 2 should be out of place in the WLTP text:

$$F_j = \frac{1}{3{,}6} \times (m_{av} + m_r) \times \frac{2 \times \Delta v}{\Delta t_j}$$

This kind of alternative formulations of existing equations causes much confusion and they may lead to errors.

C.8 Unexplained variations in road loads

Test engineers have observed that during coast down measurements the conditions change significantly, without being recorded by the weather stations as a dramatic change. For example, during sunset such changes were observed. Within the course of a fraction of an hour the coast down runs became significantly longer, indicating a lower road load. Such effects may be used by some OEMs, but are not recorded as the effect is hidden in the limited reporting on coast down tests. In principle, some redundancy in reporting may be used to examine actual statistics and variations now outside the scope of the WLTP.

C.9 Reporting, traceability and transparency

Not all contracting parties under UNECE require procedural details to ensure that different parties follow comparable procedures. The items below are mainly of concern for the European situation.

Information from the manufacturer needed for testing or determining the CO_2 value. TNO had difficulty to obtain the necessary information to repeat tests according to manufacturer's specification and to validate the corrections or test methods suggested by the manufacturers:

- The coast down mode (or disabling of safety devices interfering with coast-down testing) was not readily available from one OEM. Part of the testing had to be done based on the judgement and experience of the test engineers.
- Both vehicle families had an active grill. Information on the grill operation was only available for one vehicle model from one OEM. For the other vehicle model the testing was not consistent with the OEM procedures. This was discovered only afterwards, when results were discussed with the OEM.
- The dyno mode was not readily available from one OEM. Ambiguous responses of one OEM led to testing inconsistent with OEM specifications. Effect of dyno mode was only tested afterwards, with no repeated testing.
- Torque curve and further details needed to determine the gear shift locations in the chassis dynamometer tests were not readily available. The freedom of the OEM to adapt the gear shift locations makes it essential that the actual gear shift points information is shared, rather than that the gear shift locations are to be derived independently.
- Correction factors such as K_i and ATCT were not readily available, to obtain the final CO_2 values. It is also not easily possible to verify these values.

- Limited information is available to examine the root cause of observed differences between independent testing, type-approval results, and declared values.

Moreover, it is generally impossible to validate procedures of the manufacturer for corrections and grill settings. Grill operation in normal use has been observed to vary greatly. It is not a priori clear what would be the most appropriate grill setting, or correction, in coast down testing.

C.9.1 Limited information to ensure that the body shape and wheels are consistent with CoC

A number of vehicles with low mileages obtained from the market had wheel and tyre sizes and labels inconsistent with CoC documents, where appropriate tyre size and labels are provided. Given the low mileages, these wheels and tyres were likely mounted on the new vehicle. Other elements, such as body shape differences, could not be checked against the CoC, because little detail is available on the original bodywork. With different F2 in the CoCs, differences in bodywork and wheel sizes are observed, but it is not possible to determine if this is according to registration and CoC.

C.9.2 WLTP options "at the request of the manufacturer"

Variations in testing and evaluation "at the request of the manufacturer" and without any record available to independent parties will make comparison with OEM results difficult. This includes, non-exhaustively, different cycle energy, fuel choice, chassis test preconditioning, OBD signals, application of correction factors such as wind correction, gear exclusion, gear changes, power safety margin, coast-down preconditioning, weight distribution, use of wind tunnel and flat belt results, details of the interpolation method, run-in distance, wheel alignment, inter-runs stabilization driving in coast-down tests, inter-test times, cooling fan location, battery state prior to preconditioning, driver mode, use of default K_i factor, and the details of the ATCT procedure.

Given the fact that currently both a low as well as a high declared CO_2 value can be favourable for the manufacturer in the transition from NEDC to WLTP, these kind of details make it very difficult to find fault with the manufacturer's CO_2 results on the basis of independent test results.

C.9.3 The lack of RRC values for tyres used in coast-down testing

Although actual RRC values are used in the type-approval, it has proven so far impossible to obtain the actual RRC values of tyres for independent testing.
The CoC and the interpolation method use the class value, but with coast down testing it is relevant to correct the actual RRC value to the class value for a fair comparison. This has not been possible, although tyre manufacturers were contacted. The variation in RRC values is quite large, and it may cause a significant deviation of the measured rolling resistance from the RRC class-value based CoC value

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