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Research of Real Driving Emissions (RDE) with E85 and Two Flex Fuel Vehicles (FFV)

Project BAFU (ResRDE)*), contract nbr: 15.0002.PJ/Q223-0515, 3rd report

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November - December 2017 B501

*) Abbreviations see at the end of report

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1. SUMMARY

The control of real driving emissions (RDE) by means of portable emission measuring systems (PEMS) is generally an accepted way to further reduce the air pollution of traffic.
In several research activities with different PEMS open questions resulted concerning the methodology of testing and of evaluation.
On the other hand, there are questions about RDE from specific types of vehicles, or alternative fuels.

In different working packages the project ResRDE considers the two objectives: PEMS Testing Methodology and RDE of interesting variants “vehicle – fuel – exhaust system”.

This 3rd report presents the results of:

- comparison of emission results obtained with two FFV’s with E0 & E85 on chassis dynamometer in $WLTC_{cold}$ and in RDE-circuit,
- example of comparison of results obtained on the same vehicle/fuel variant with two different evaluation methods MAW vs. integration,
- influence of considering the cold start values in the evaluation,
- influence of validation procedure.

The most important statements are:

E0 & E85

- The use of E85 fuel is advantageous for emission reduction: with E85 there is a reduction of NO_x and PN for both investigated vehicles in all driving conditions.

Evaluations with EMROAD

- The normality and weighing of the windows have an influence on the final emission results and the characteristic curve of the trip (CO_2 vs. speed) is recommended to be inside of the primary tolerance band of +/- 25% with WF=1.
- Including the cold start in the evaluation, generally increases the emission results, but in case of non-valid trip and weighing of the windows (MAW) this effect can be weakened or even inversed.

2. TEST VEHICLES, FUELS AND LUBRICANTS

The vehicles and their data are presented in Fig. 1 and Tab. 1.

Vehicle	① **Volvo V60 T4F FFV gasoline**	② **Audi A4 2.0 TFSI FFV gasoline**
Number and arrangement of cylinder	4 / in line	4 in line
Displacement cm^3	1596	1984
Power kW	132 @ 5700rpm	132@4000rpm
Torque Nm	240 @1600rpm	320@1500rpm
Injection type	Direct Injection (DI)	Direct Injection (DI)
Curb weight kg	1554	1570
Gross vehicle weight kg	2110	2065
Drive wheel	Front-wheel drive	Front-wheel drive
Gearbox	a6	m6
First registration	2012	2010
Exhaust	EURO 5a	Euro 5

Table 1: Data of tested vehicles

Vehicle ① Volvo V60 T4F FFV in the laboratory

Vehicle ② Audi A4

Fig. 1: The tested cars

Both vehicles were operated with the Swiss market fuels (also Swiss market E85) and with the lubricating oil, which was actually present in each vehicle.

3. TEST METHODS AND INSTRUMENTATION

3.1. Chassis dynamometer and standard test equipment

- roller dynamometer: AFHB GSA 200
- roller diameter: 502 mm
- driver conductor system: Tornado, version 3.3
- CVS dilution system: Control Sistem R03-700 with roots blower
- air conditioning in the hall automatic for intake- and dilution air
  temperature: 20 ÷ 30°C
  humidity: 5.5 – 12.2. g/kg

3.2. Test equipment for regulated exhaust gas emissions

This equipment fulfils the requirements of the Swiss and European exhaust gas legislation.

- regulated gaseous components:
  exhaust gas measuring system Horiba MEXA-7100
  CO, CO_2… infrared analysers (IR)
  HCFID... flame ionisation detector for total hydrocarbons
  CH_4FID... flame ionisation detector with catalyst for only CH_4
  NO/NO_X... chemoluminescence analyser (CLA)

The dilution ratio DF in the CVS-dilution tunnel is variable and can be controlled by means of the CO_2-analysis.

3.3. PEMS

Most important data of the used PEMS are given in the Table 2. Some pictures of PEMS assembling on the test vehicles are given in annex A1.

GAS PEMS

	HORIBA MEXA 7200	**HORIBA OBS ONE**
	4x4 chassis dyno CVS	PEMS① wet
CO	NDIR	heated NDIR
CO_2	NDIR	heated NDIR
NO_x	CLD	CLD
NO	CLD	CLD
NO_2	calculated	calculated
O_2	-	-
HC	FID	-
PN	not measured	-
OBD logger	-	yes
GPS logger	-	yes
ambient (p, T, H)	yes	yes
EFM	-	pitot tube

OBS - one H_2O monitored to compensate the H_2O interference on CO and CO_2 sample cell heated to 60°C

Table 2: Overview of used measuring systems.

PN PEMS

As PN PEMS for Real Driving Emissions the NanoMet3-PS from Matter Aerosol-TESTO (NM3) was used. The exhaust gas conditioning, as described below for chassis dynamometer, is integrated in this analyzer and it indicates the solid particle number concentration and geometric mean diameter in the size range 10-700 nm. TESTO NanoMet3 presents several advantages like compactness, robustness, fast on-line response and it has been considered in the preparatory activities of on-coming RDE type approval in EU as a "Golden Instrument". This instrument works on the diffusion charging classifier principle (DiSC).

3.4. Nanoparticle analysis

The measurements of summary particle counts in the size range 10-700nm were performed with the NanoMet3 (NM3), a recognized PN PEMS.

For the dilution and sample preparation an ASET system from Matter Aerosol was used (ASET … aerosol sampling and evaporation tube). This system contains:

- Primary dilution air - MD19 tunable minidiluter (Matter Eng. MD19-2E)
- Secondary dilution air – dilution of the primary diluted and thermally conditioned measuring gas on the outlet of evaporative tube.
- Thermoconditioner (TC) - sample heating at 300°C.

4. TEST PROCEDURES

The measurements of vehicles were performed on chassis dynamometer in $WLTC_{cold}$ and on-road in a circuit, which is valid for RDE-requirements. The chronological list of measurements, see annex A2.

4.1. Driving cycle on chassis dynamometer

The vehicles were tested on a chassis dynamometer in the dynamic driving cycles WLTC, Fig. 2.
The first WLTC of each test series was performed with cold start (20-25°C).
The braking resistances were set according to legal prescriptions; they were not increased i.e. responded to the horizontal road.

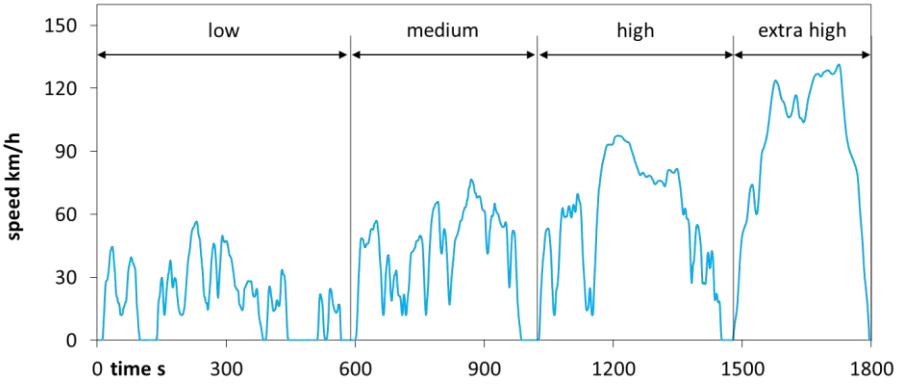

Fig. 2: WLTC driving cycle

4.2. On-road testing

With each vehicle several road tests were performed. The used road circuit was always the same, with approximately 1.5h duration and parts of urban, rural and highway roads, see annex A3.

Fig.3 shows an example of a driving cycle from the road circuit (RDE).

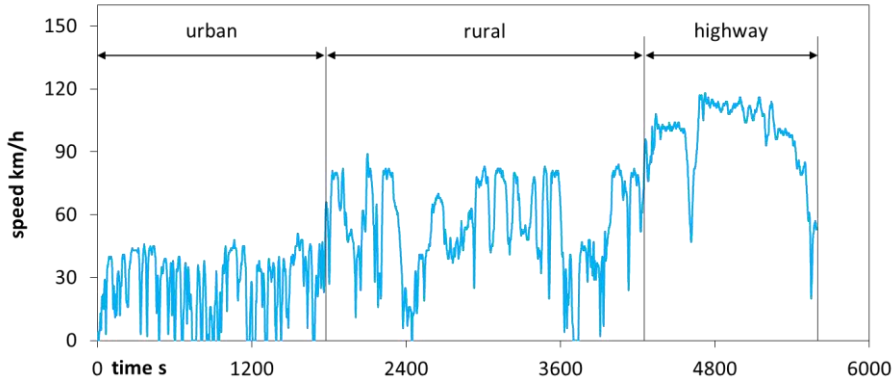

Fig. 3 Example of RDE cycle

5. RESULTS

The results are graphically represented in the attached figures.

5.1. Comparison of emissions with E0 & E85

The comparisons can be regarded from different points of view:

- Influence of fuel E0 – E85
- Influence of vehicle V1 – V2
- Measuring method on chassis dynamometer Bags (CVS) – PEMS
- WLTC – RDE

Fig. 4 represents the comparisons of NO_x, CO and CO_2 in $WLTC_{cold}$.
It can be stated that:

- NO_x is generally reduced with E85,
- for V1 NO_x diminishes stronger (with E85), than for V2,
- NO_x is in most cases underestimated with PEMS (relatively to CVS),

- CO is not influenced by E85 for V1, but CO is reduced with E85 for V2,
- V2 has higher level of CO than V1,
- the measuring method (CVS – PEMS) has nearly no influence on CO,

- CO_2 is normally decreased with E85,
- V2 has lower level of CO_2,
- the influences of measuring method (CVS – PEMS) are different and many of them opposite to each other; as average no tendency can be declared.

The cumulated emissions increase strongly in the last high-speed-phase of the cycle. In certain cases, cold starts or acceleration events contribute highly (or in majority) to the cumulated emission results.

Fig. 5 shows the gaseous emissions in road operation (RDE).

The tendencies depicted here are similar as in WLTC:
- E85 instead of E0: reduces NO_x, has no influence on CO and only slight reducing tendency on CO_2 for V2,
- Both vehicles attain similar levels of emissions at the end of RDE cycle, while the dispersion of results for each vehicle/fuel variant is much larger than on the chassis dynamometer (in WLTC).

Figures 6 and 7 confirm in $WLTC_{cold}$ and in RDE-circuit that E85 reduces the PN emissions of both vehicles in similar way. The PN emissions with E0 are for both vehicles at the same level.

Fig. 8 compares the fuel consumption measured with both fuels E0 & E85 on chassis dynamometer in $WLTC_{cold}$ with both sets of instruments (BAGS & PEMS). At the bottom of this figure, there are comparisons of fuel consumption measured in the road circuits (RDE) with PEMS.
It can be remarked, that the volumetric fuel consumption with E85 is generally higher, due to the lower heat value of this fuel. The results obtained with BAGS (CVS) and with PEMS on chassis dynamometer correlate well with each other. There is a stronger dispersion of the results from the RDE-circuit, than from chassis dynamometer.

5.2. Analyses of evaluation with EMROAD 5.96

Research of data evaluation was performed with the objective to indicate the influences of different evaluation ways on the results and their relationships.
All this research was performed for both vehicles, but only with the data from gasoline operation.

Fig. 9 shows the comparisons of results NO_x, CO & CO_2 in three RDE-attempts with vehicle V1. The results are evaluated with EMROAD MAW-method (moving averaging windows) and with integration (integral average values). The cold start results are considered, or excluded (as cold start & warm-up are considered, either the period from engine start to reach 70°C coolant temperature, or a time period in maximum 5 min).
The MAW-method offers no results of CO_2, since this component is used as reference quantity for the calculation and the normality of the windows, see annex A4.

Fig. 10 represents analogous results for vehicles V2.
The summary report of 6 RDE trips with both vehicles and gasoline is given in a table in annex A5.

5.2.1. Comparison of MAW- vs. integral results

Regarding the entire cycle for vehicle V1 (Fig. 9-1), it results higher NO_x- and CO-values with MAW. For vehicle V2 (Fig. 10-1), there are mostly no differences of NO_x and CO-values between MAW and INT (INT … integral average values).
Regarding the urban parts of the cycle with vehicle V1 (Fig. 9-2) and vehicle V2 (Fig. 10-2), it results, that the values indicated by MAW are in the most cases lower.

5.2.2. RDE with/without cold start

The integral values (INT) indicate higher emissions (NO_x, CO, CO_2) with cold start, than without cold start; this for both vehicles in the entire cycle and in the urban part. This is a usual very well-known result.
The MAW-method in contrary indicates much smaller differences "with/without cold start" for vehicle V2 and for vehicle V1 even lower CO- and NO_x-values with cold start. The main reason for that is in the weighing and validation of the windows (MAW), which is addressed in the next section.
Additionally, it must be remarked that the absolute values of the CO- and NO_x-emissions of vehicle V1 are very low and the differences "with/without cold start" are insignificant (Fig. 9-1 and Fig. 9-2).

5.2.3. Influence of weighing and validation on RDE results

The characterization of normality and completeness of a RDE trip is shortly described in annex A4.
The "normality" of the windows is concluded by comparing their CO_2 distance-specific emissions with a reference curve. The test is complete when the test includes enough normal windows, covering different speed areas (urban, rural, motorway).

The reference dynamic conditions of the test vehicle are set out from the vehicle CO_2 emissions versus average speed measured at type approval (WLTC) and referred to as "vehicle CO_2 characteristic curve".

During the MAW evaluation the following steps are performed:

Step 1 Segmentation of the data
Step 2 Calculation of emissions by sub-sets or "windows"
Step 3 Identification of normal windows
Step 4 Verification of test completeness and normality
Step 5 Calculation of emissions using the normal windows.

The following data are not considered for the calculation of the CO_2 mass, the emissions and the distance of the averaging windows:

- the periodic verification of the instruments and/or after the zero drift verifications
- the cold start emissions previously excluded are included in evaluation since September 2017
- vehicle ground speed < 1 km/h
- any section of the test during which the combustion engine is switched off.

In Fig. 11-1 such CO_2 characteristic curves are represented for three evaluated trips of vehicle V1. The trips and their dynamic conditions are not entirely normal, since the characteristic curves are exceeding the primary tolerance of +/- 25% (of the average WLTC-CO_2-values).
The operation of this vehicle V1 in the urban part (at lowest speeds) is not dynamic enough and the program sets for these windows weighting factors WF < 1. At the highest speeds, there are also windows passing over the primary tolerance, because of not sufficient engine load. (The maximum speed on Swiss highway is limited to 120 km/h and the last part of the highway in the RDE circuit is going downhill).

Fig. 11-2 shows an example of RDE1, where, additionally to the standard "weighed" evaluation a setting of all WF's inside of the secondary tolerance (+/-50%), was performed with WF=1. This setting (WF=1) provokes higher emission readings in the lowest and in the highest speed ranges.

Another example is given in Fig. 11-1, in the 3rd trip, "RDE3": in the highway part of cycle the automatic gear was limited to select only the 5th speed. This increased the fuel consumption and the CO_2 emission in this part of the cycle and it moved the characteristic curve (MAW CO_2 vs. MAW speed) in the primary tolerance domain of +/- 25%.

Summarizing these examples, it can be remarked that: the normality and weighing of the windows have an influence on the final emission results and the characteristic curve of the trip (CO_2 vs. speed) is recommended to be inside of the primary tolerance band of +/- 25% with WF=1.

Fig. 12 represents the characteristic curves of normality for the three trips with vehicle V2. The driving behaviour in the low-speed part is more dynamic with this vehicle with manual gears – the CO_2-speed-curve is in the primary tolerance. Nevertheless, there is a similar problem such as with the vehicle 1 in the highway part: to low maximum speed (120 km/h) and to low load (downhill) – the characteristic curve is below the -25% tolerance.

6. CONCLUSIONS

Following conclusions can be mentioned:

E0 & E85

- The use of E85 fuel is advantageous for emission reduction: with E85 there is reduction of NO_x and PN for both investigated vehicles in all driving conditions.
- The volumetric fuel consumption with E85 is generally higher, due to the lower heat value of this fuel.
- Both vehicles attain similar levels of emissions at the end of RDE cycle, while the dispersion of results for each vehicle/fuel variant is much larger than on the chassis dynamometer (in WLTC).

Evaluations with EMROAD

- The normality and weighing of the windows have an influence on the final emission results and the characteristic curve of the trip (CO_2 vs. speed) is recommended to be inside of the primary tolerance band of +/- 25% with WF=1.
- Including the cold start in the evaluation, generally increases the emission results, but in case of non-valid trip and weighing of the windows (MAW) this effect can be weakened or even inversed.

7. LIST OF FIGURES

Fig. 1 Vehicles used for the tests
Fig. 2 WLTC driving cycle
Fig. 3 Example of RDE cycle

E0 & E85

Fig. 4 Emissions in $WLTC_{cold}$, NO_x, CO, CO_2; V1 and V2
Fig. 5 RDE – NO_x, CO, CO_2; V1 and V2
Fig. 6 PN emissions in $WLTC_{cold}$; V1 and V2
Fig. 7 PN emissions in RDE circuit; V1 and V2
Fig. 8 Fuel consumption $WLTC_{cold}$ & RDE; V1 and V2

Evaluations with EMROAD

Fig. 9 Influence of cold start on emissions results, V1
Fig. 10 Influence of cold start on emissions results, V2
Fig. 11 RDE normality and MAW-weighing, V1
Fig. 12 RDE normality, V2

8. ANNEXES

A 1 PEMS assembling on the test vehicles
A 2 Chonological list of measurements
A 3 Road trip for RDE (example)
A 4 Characterization of the normality and completeness of RDE trip
A 5 Summary report of 6 RDE trips

9. ABBREVIATIONS

AFHB	Abgasprüfstelle FH Biel, CH
ASTRA	Amt für Strassen (CH)
BAFU	Bundesamt für Umwelt, (Swiss EPA)
BC	board computer
CADC	Common Artemis Driving Cycle
CAST	Combustion Aerosol Standard
CD	chassis dynamometer
CLA	chemiluminescence analyser
CLD	chemiluminescence detector
CPC	condensation particle counter
CVS	constant volume sampling
DAQ	data acquisition
DC	diffusion charging
DF	dilution factor
DI	Direct Injection
DiSC	diffusion charge size classifier
E0	gasoline (zero Ethanol)
E85	85% vol Ethanol
EC	European Commission
ECE	Economic Commission Europe
ECU	electronic control unit
EFM	exhaust flow meter

EMPA	Eidgenössische Material Prüf- und Forschungsanstalt
EMROAD	RDE emissions evaluation program
ETC	European Transient Cycle
EUDC	Extra Urban Driving Cycle
GDI	gasoline direct injection
GMD	geometric mean diameter
HC	unburned hydrocarbons
ILCE	Inter- Laboratory-Comparison-Exercise
INT	integral average values
JRC	Joint Research Centre (EC)
LFE	laminar flow element
MAW	moving averaging windows
MFS	mass flow sensor
NEDC	New European Driving Cycle (ECE+EUDC)
NM3	NanoMet3
NO	nitrogen monoxide
NO_2	nitrogen dioxide
N_2O	nitrous oxide
NO_x	nitric oxides
n.v.	non valid
OBD	on-board diagnostics
OP	operating point
PCRR	Particulate Counts Reduction Rate
PEMS	portable emission measuring systems
PF	Pitot flow meter
PMP	EC Particle Measuring Program
PN	particle number
PN-PEMS	PEMS with PN measuring device
RDE	real driving emissions
TFZ	Technologie- und Förderzentrum für Nachwachsende Rohstoffe, Straubing, D
TP	tailpipe
TWC	three way catalyst
V1	vehicle 1
V2	vehicle 2
ViPR	nanoparticle sample preparation with volatile particles remover
WLTC	worldwide harmonized light duty test cycle
WLTP	worldwide harmonized light duty test procedure
3WC	three way catalyst

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Figures

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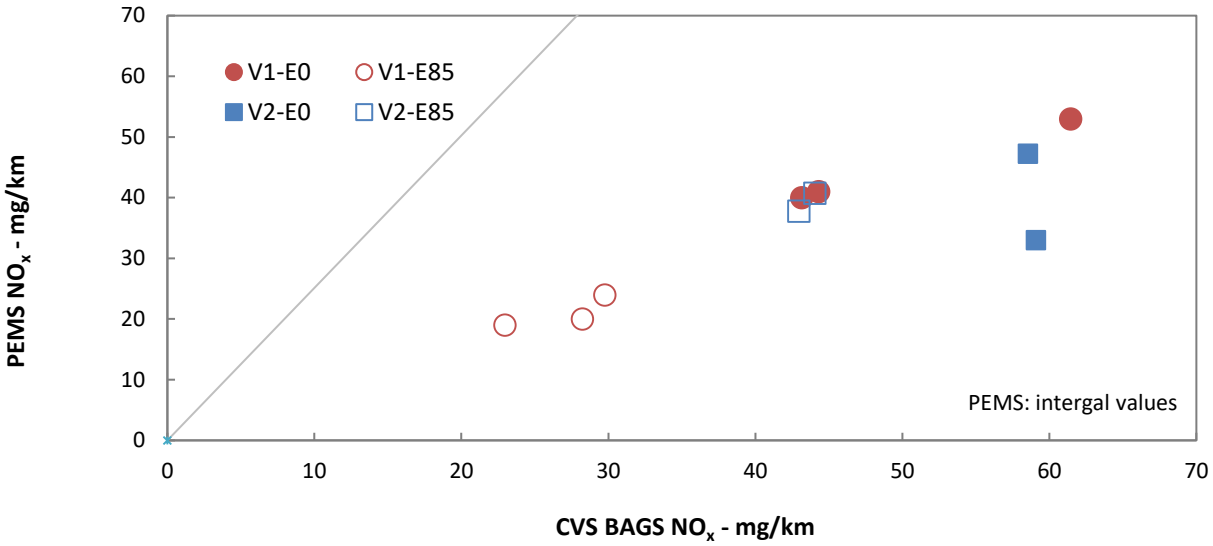
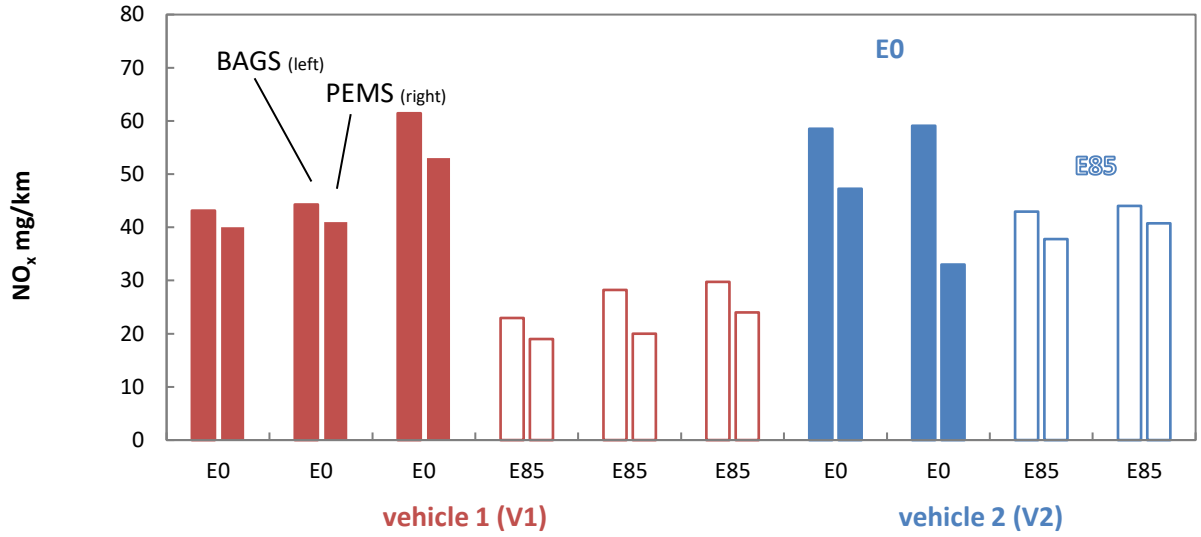
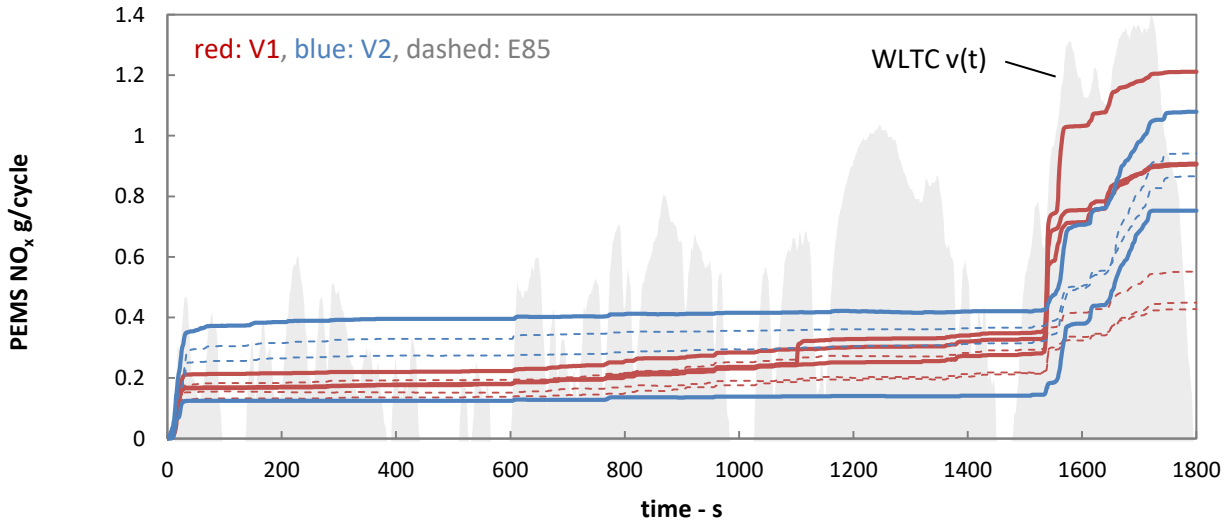
Chassis Dynamometer Measurements

NO_x - Emissions in WLTC cold with E0 and E85

Volvo V60 Flexfuel (V1); Audi A4 Flexifuel (V2)



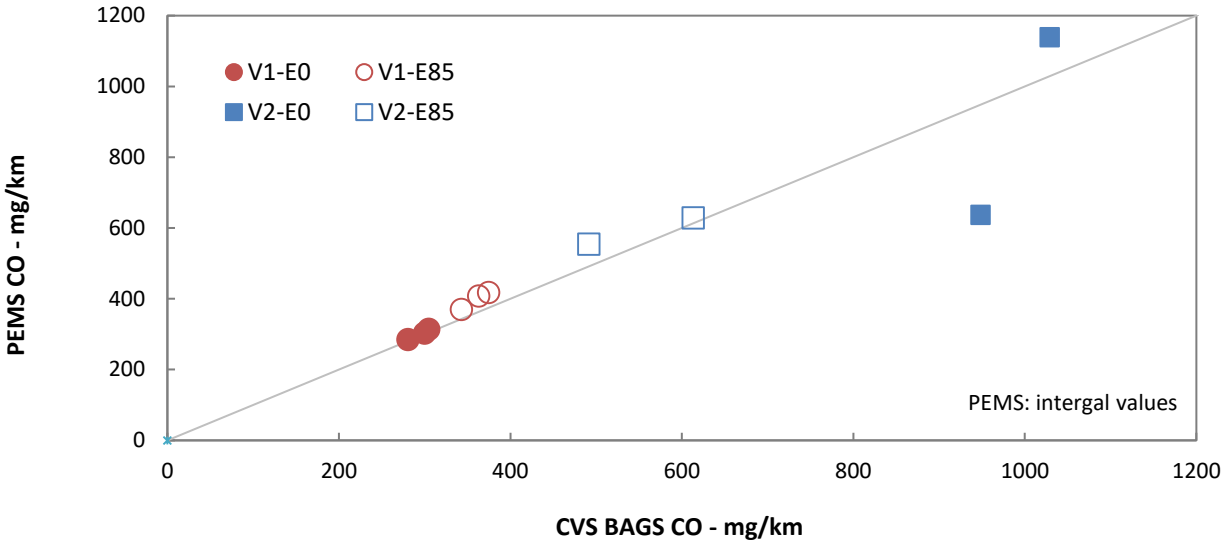


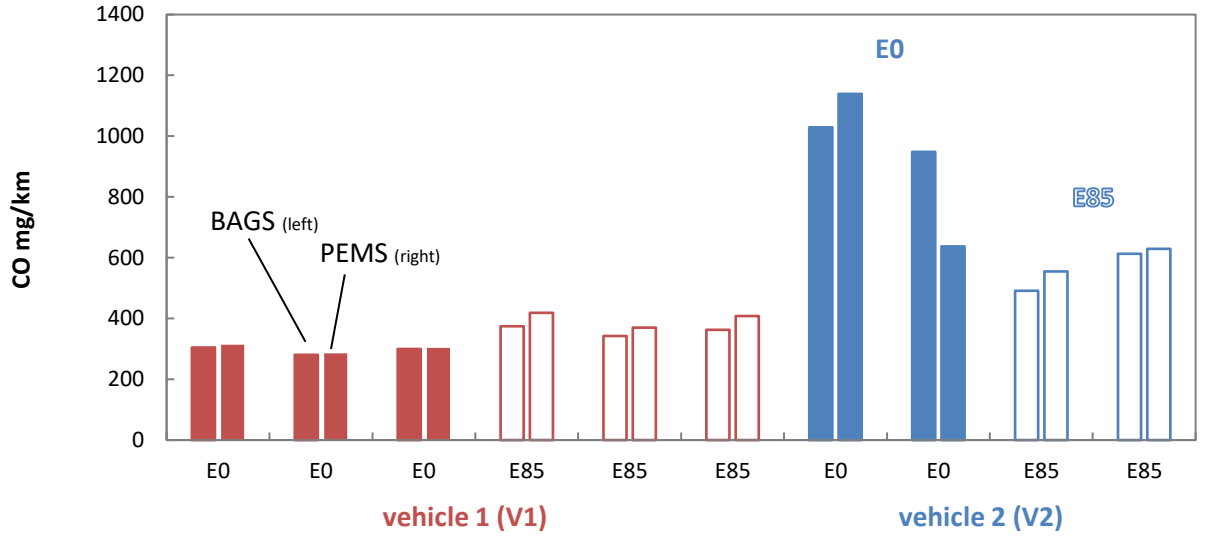


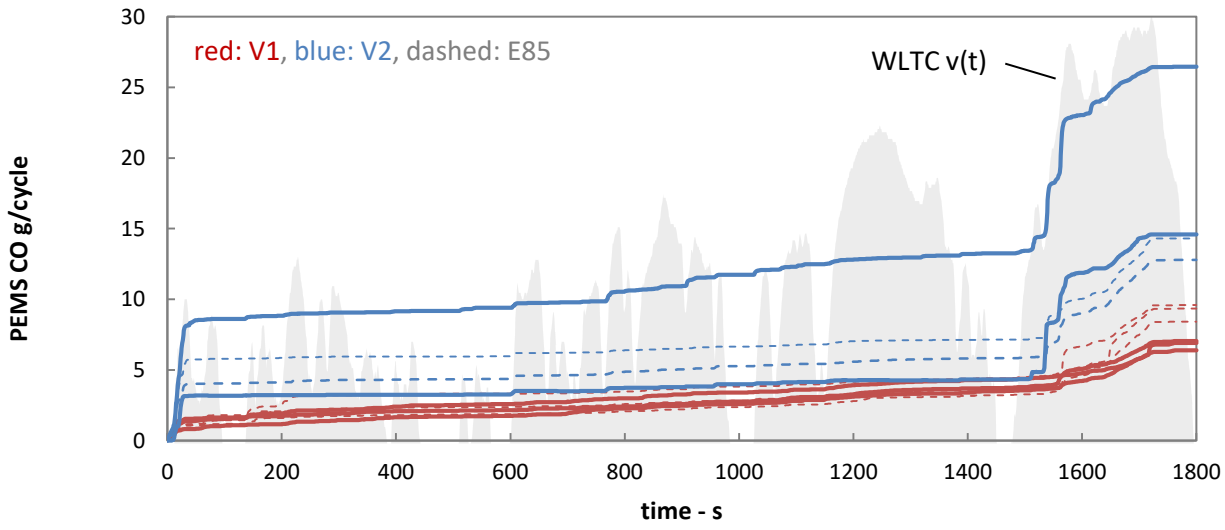
Chassis Dynamometer Measurements

CO - Emissions in WLTC cold with E0 and E85

Volvo V60 Flexfuel (V1); Audi A4 Flexifuel (V2)



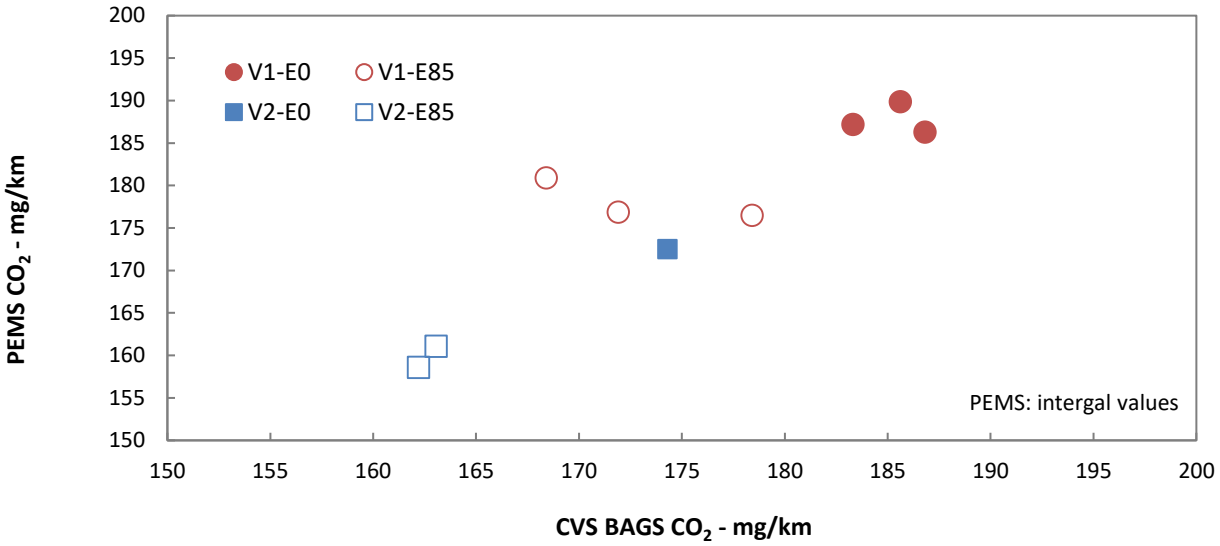


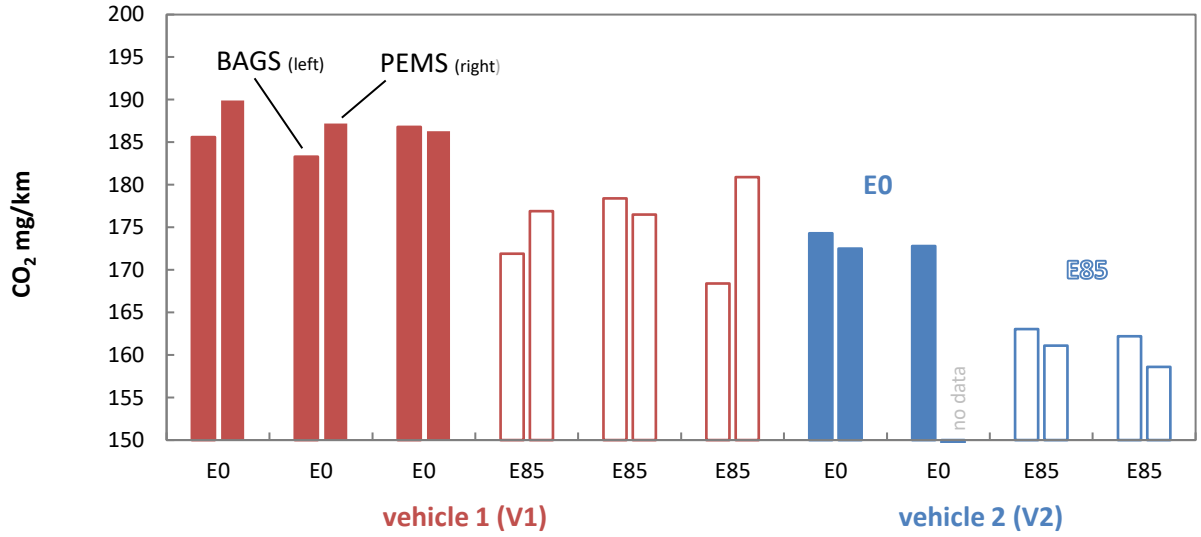


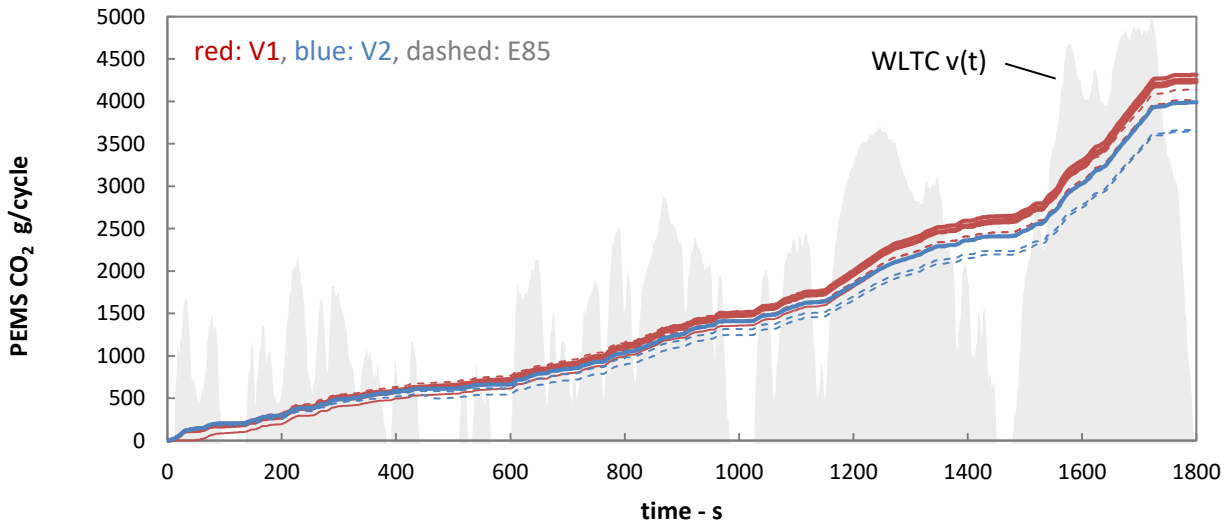
Chassis Dynamometer Measurements

CO_2 - Emissions in WLTC cold with E0 and E85

Volvo V60 Flexfuel (V1); Audi A4 Flexifuel (V2)



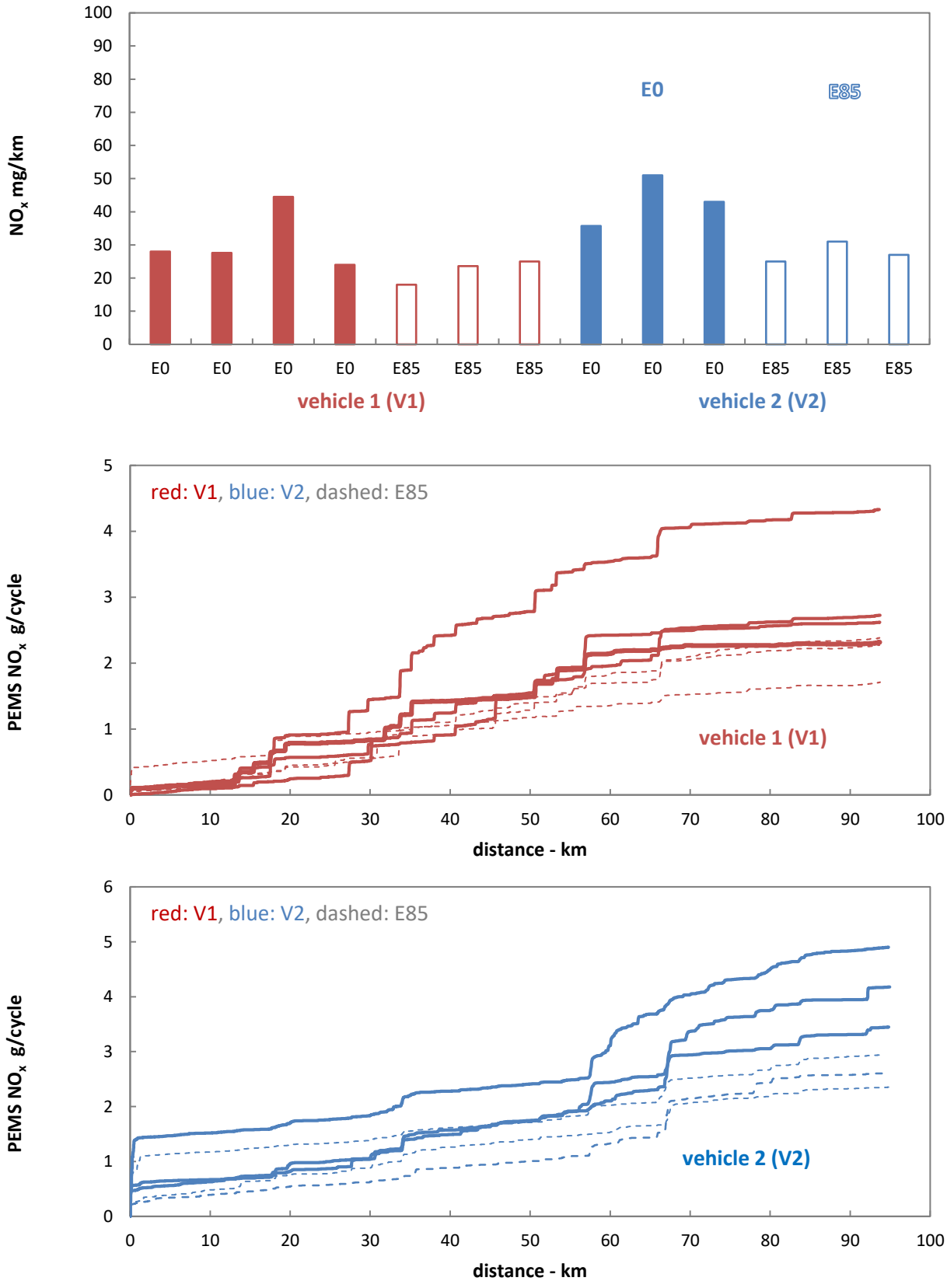




On-Road Measurements

NO_x - Emissions during RDE with E0 and E85

Volvo V60 Flexfuel (V1); Audi A4 Flexifuel (V2)



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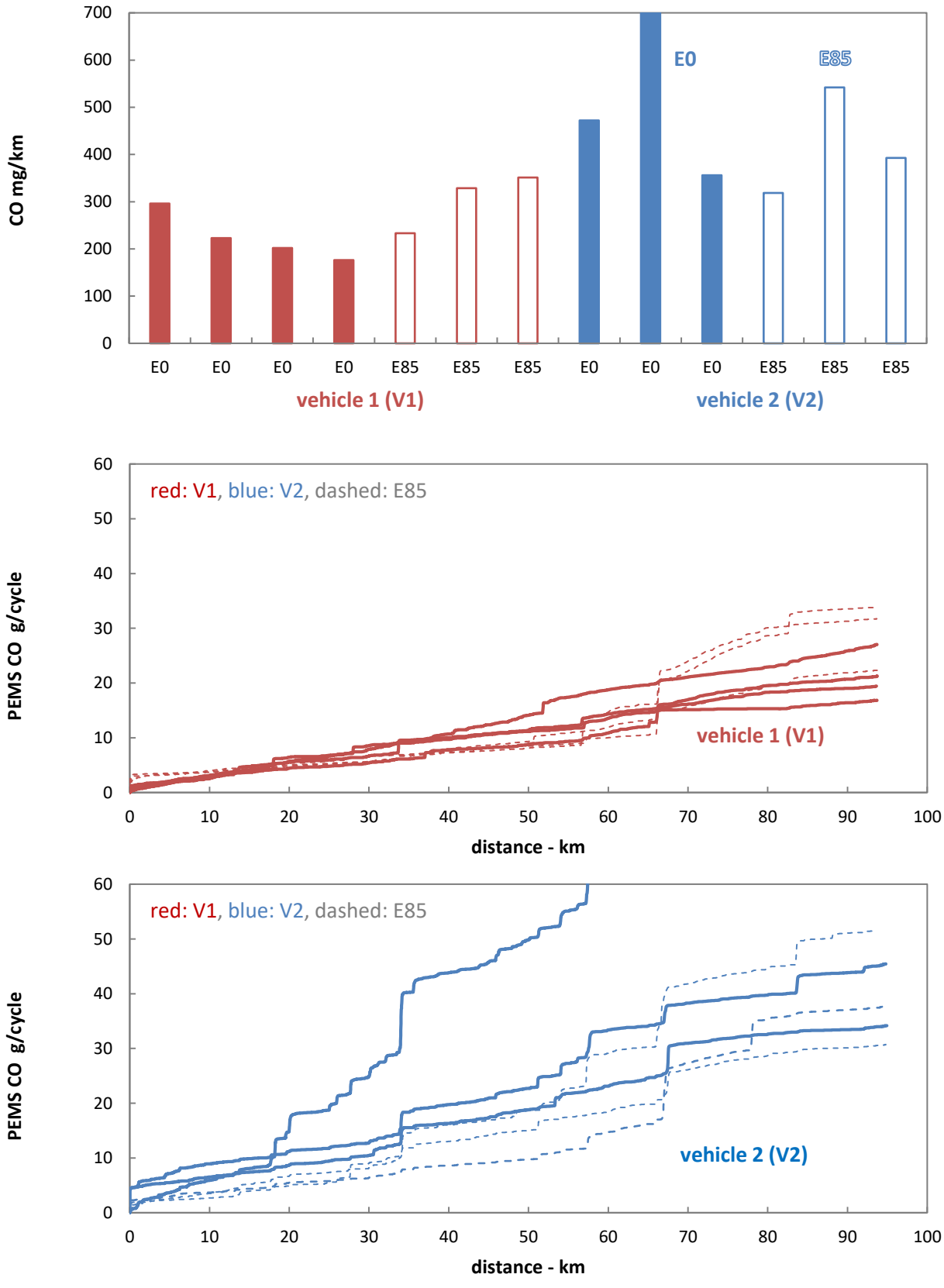

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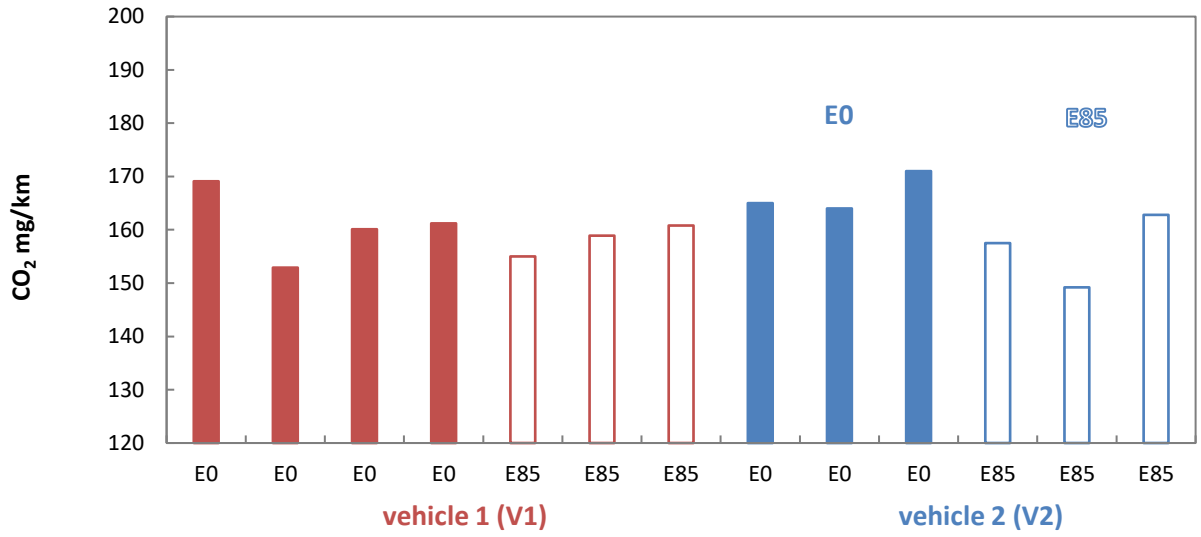
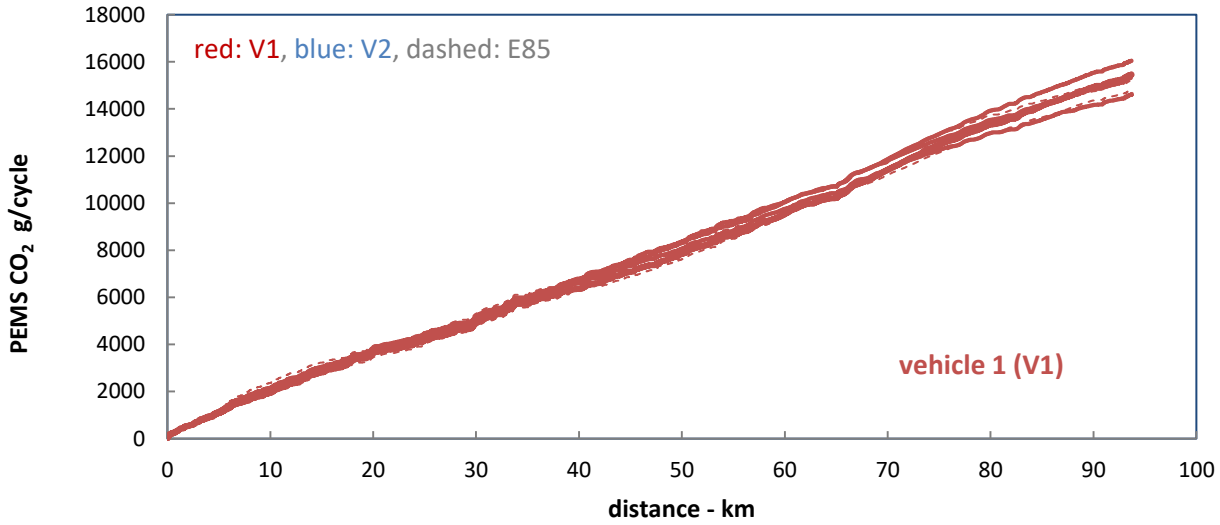
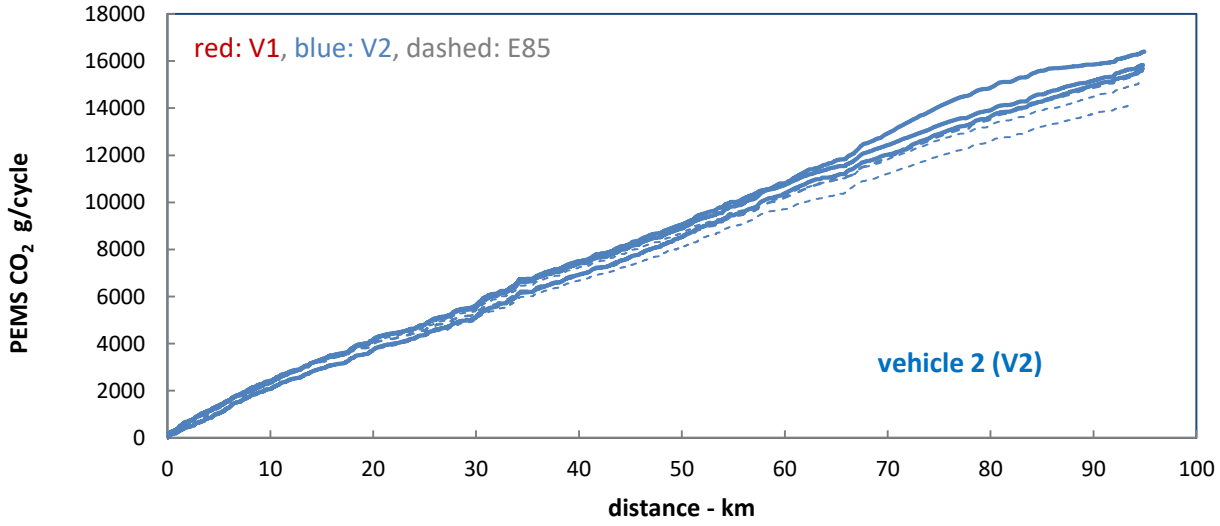


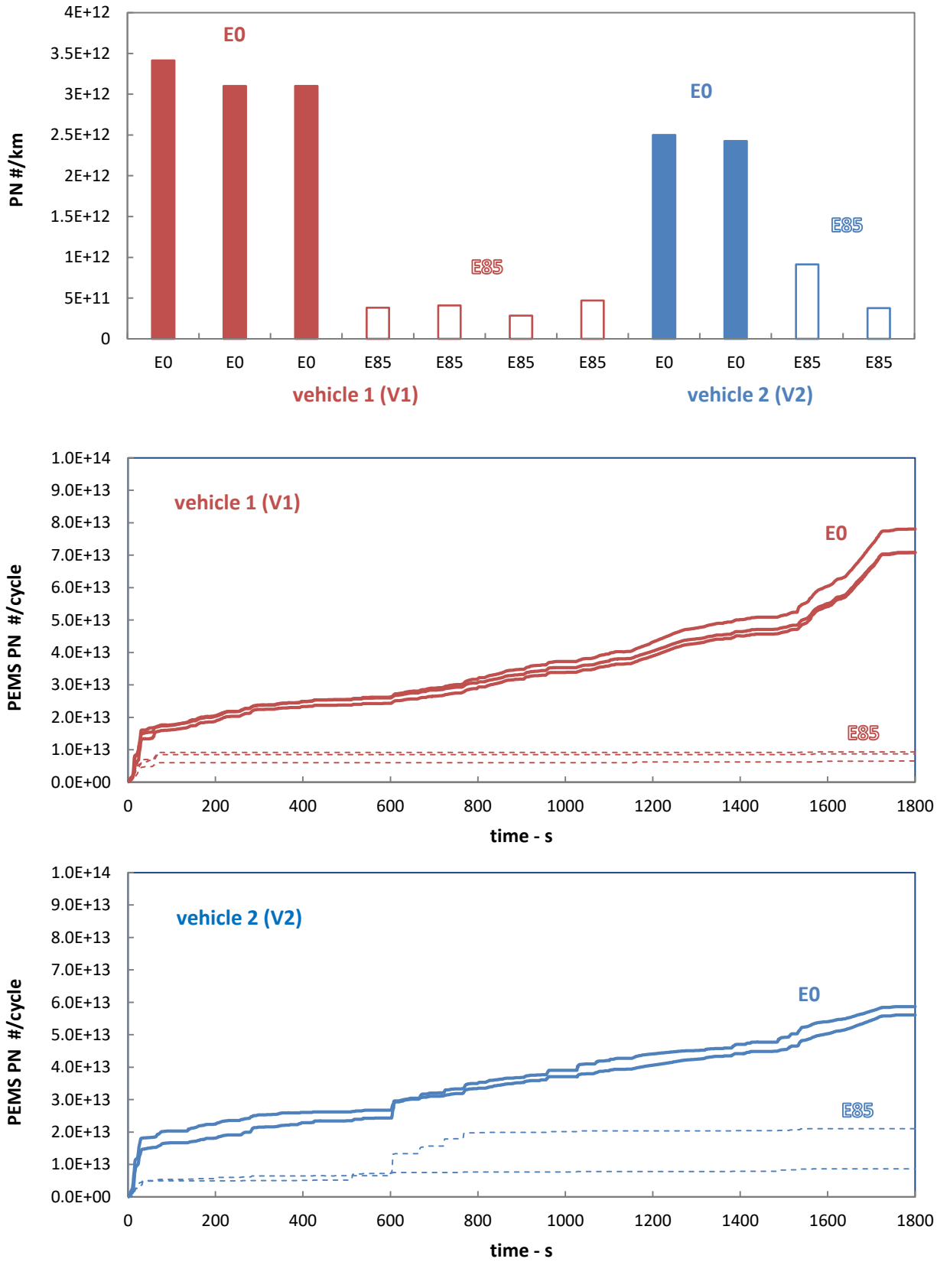




Chassis Dynamometers Measurements

PN - Emissions during WLTC cold with E0 and E85

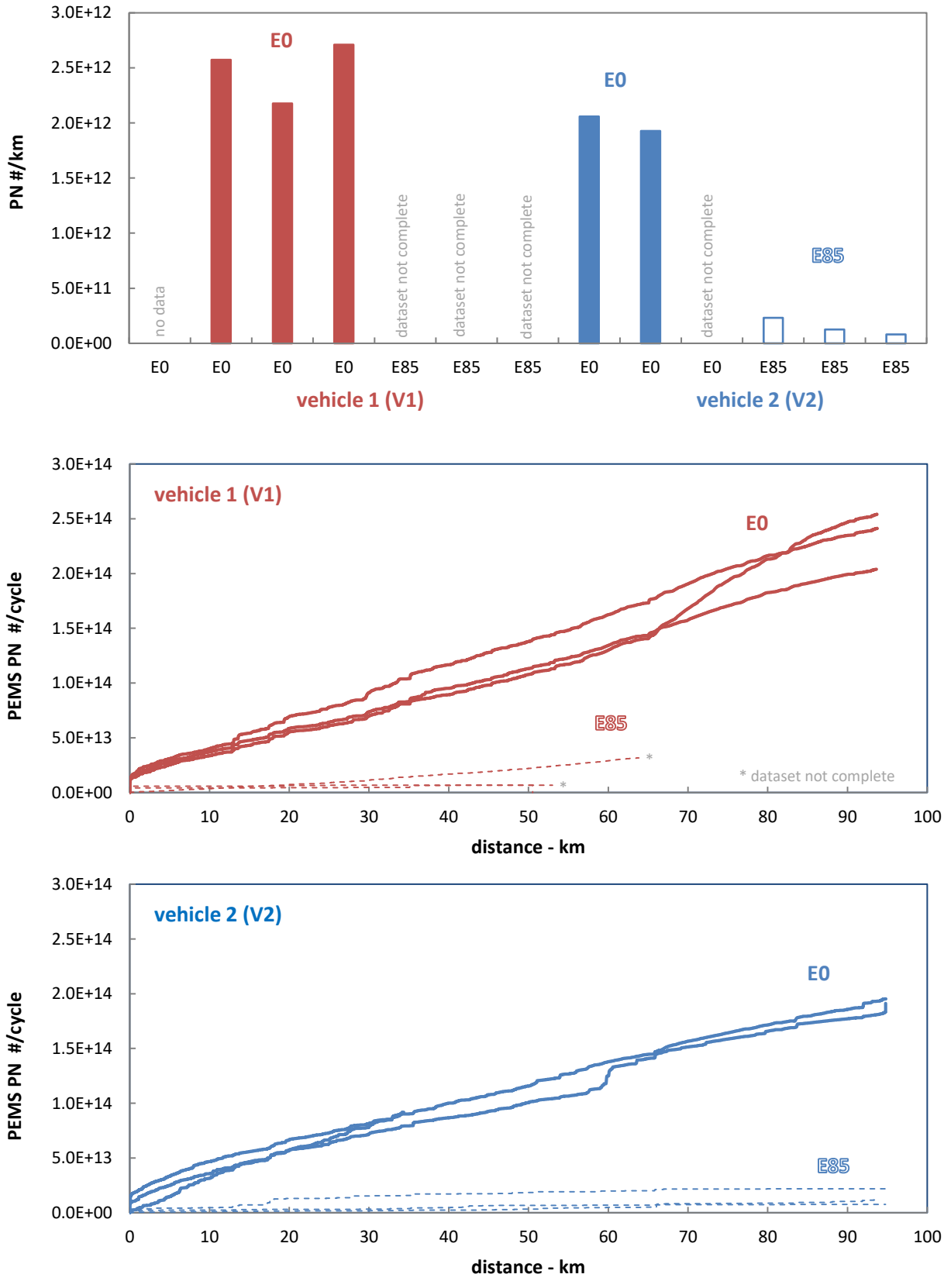
Volvo V60 Flexfuel (V1); Audi A4 Flexifuel (V2)



On-Road Measurements

PN - Emissions during RDE with E0 and E85

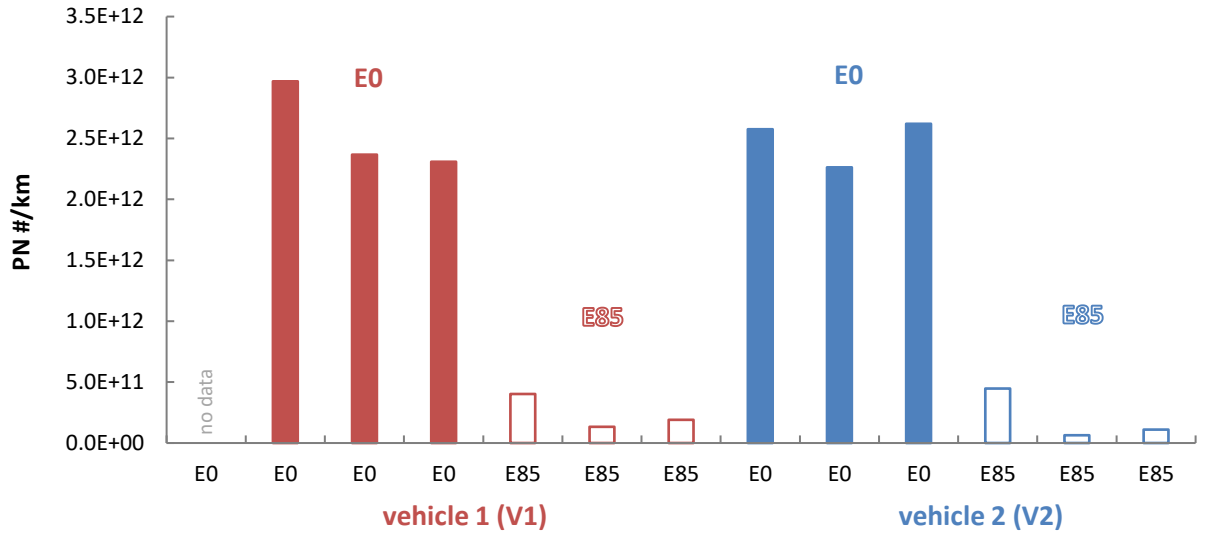
Volvo V60 Flexfuel (V1); Audi A4 Flexifuel (V2)

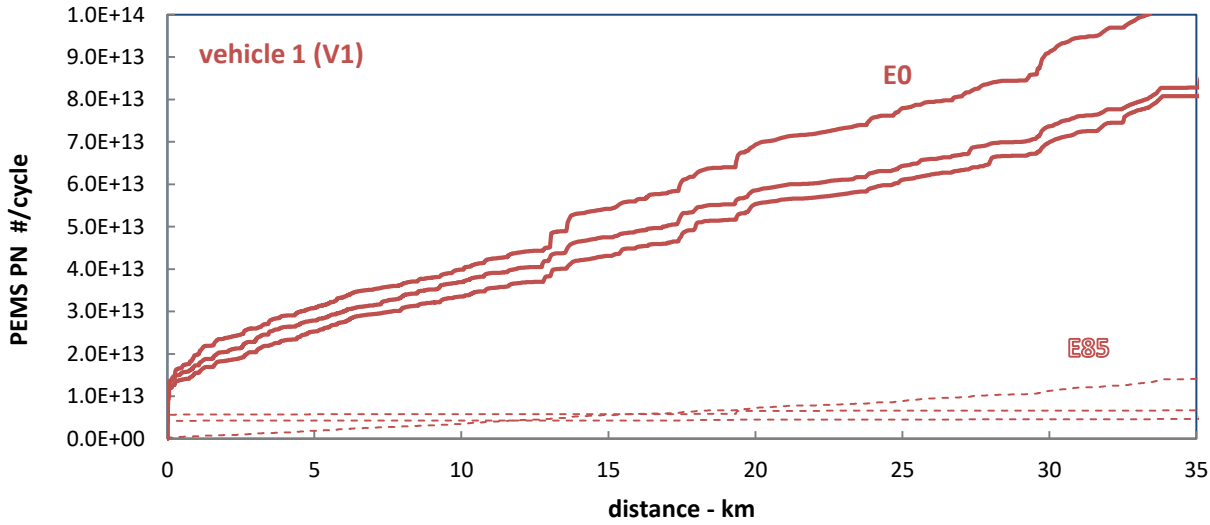


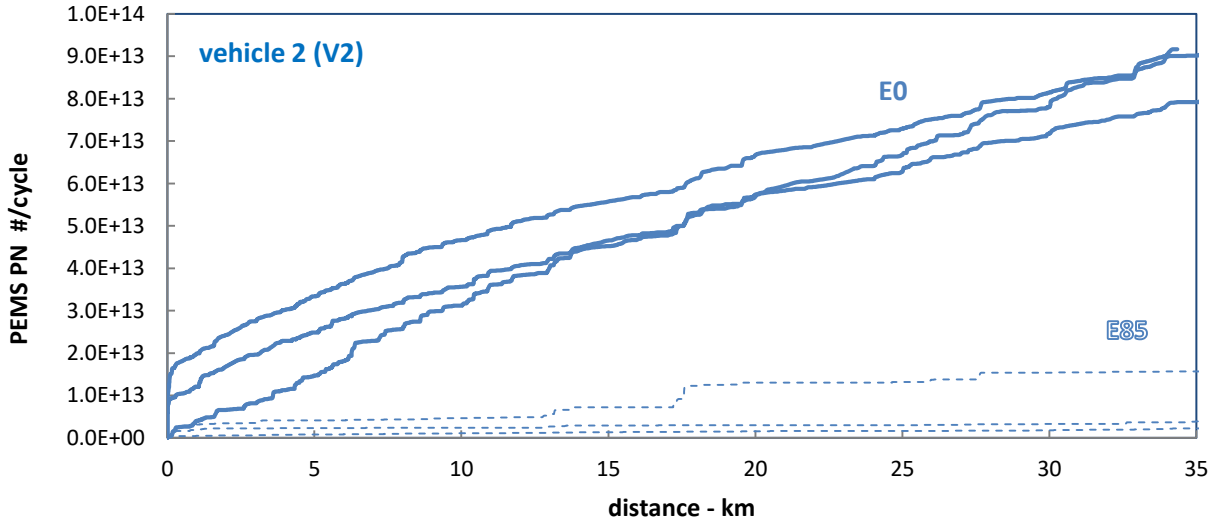
On-Road Measurements

PN - Emissions during RDE urban part with E0 and E85

Volvo V60 Flexfuel (V1); Audi A4 Flexifuel (V2)



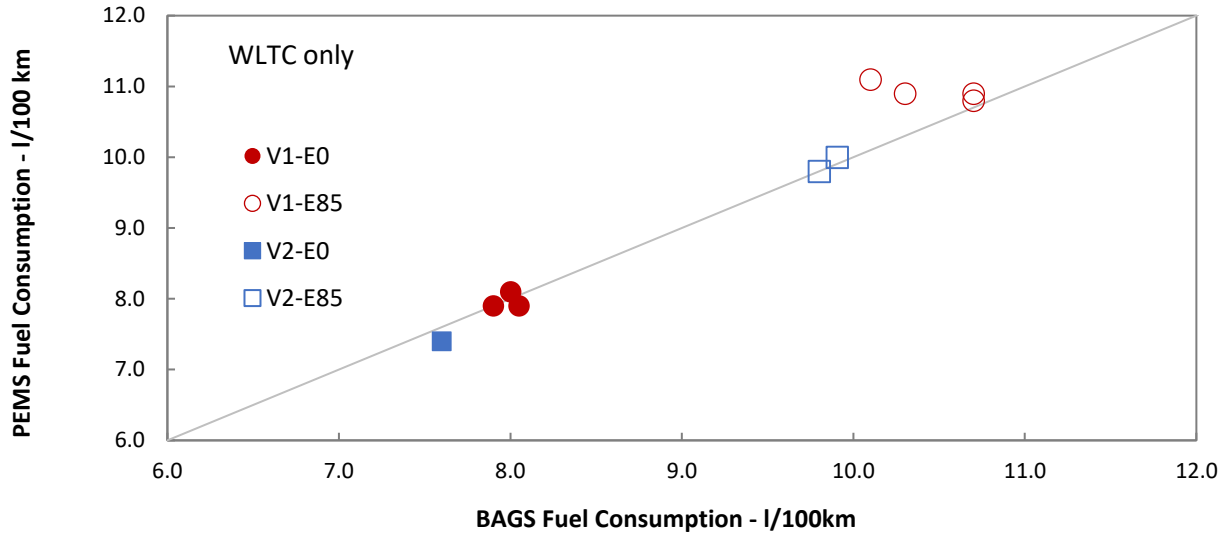


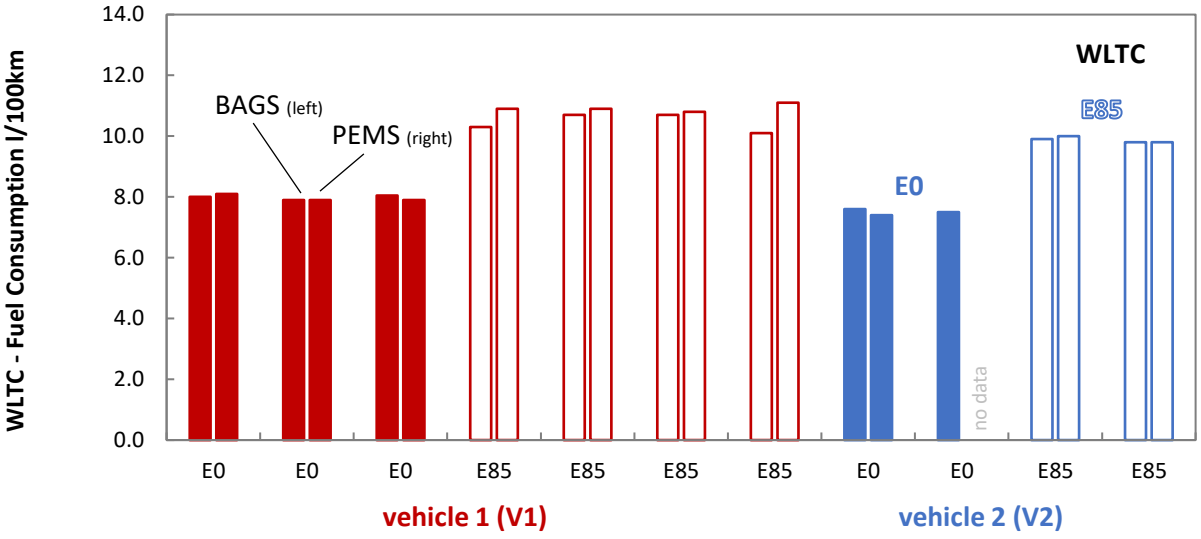


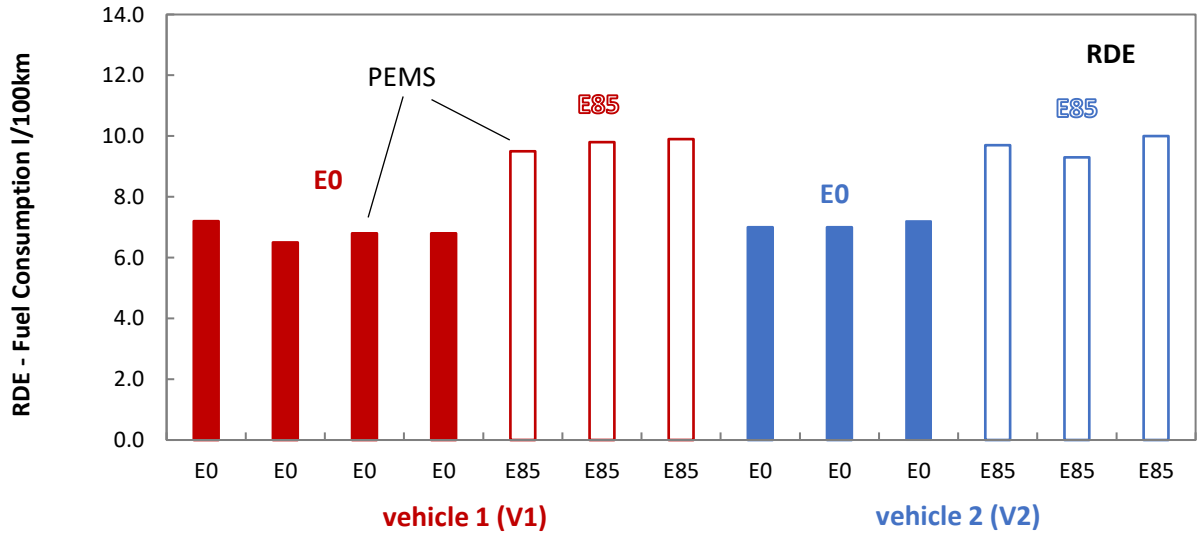
Chassis Dynamometer & On-Road Measurements

Fuel Consumption Averages for WLTC Cold and RDE with E0 and E85

Volvo V60 Flexfuel (V1); Audi A4 Flexifuel (V2)





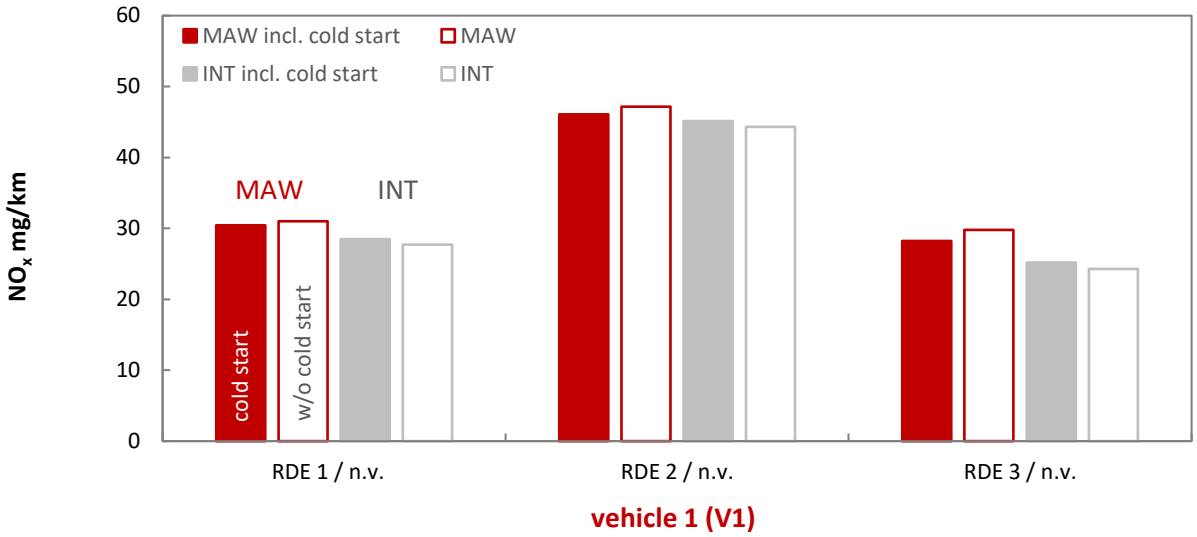


On-Road Measurements

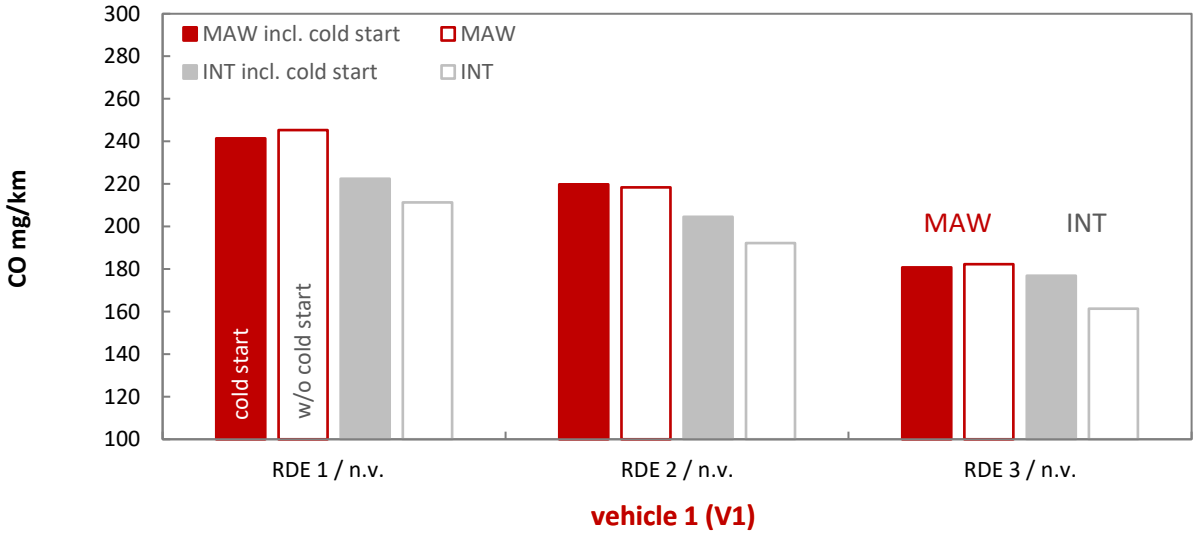
Influence of Cold Start on Emissions Results
RDE - MAW and Integral Values

Volvo V60 Flexfuel (V1), Gasoline

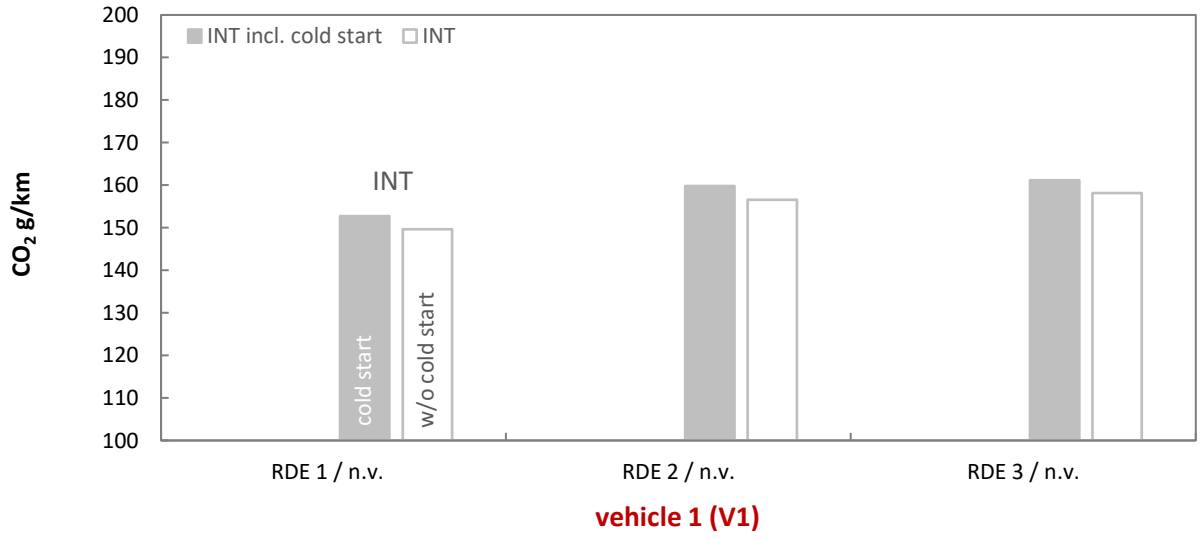
PEMS



vehicle 1 (V1)



vehicle 1 (V1)



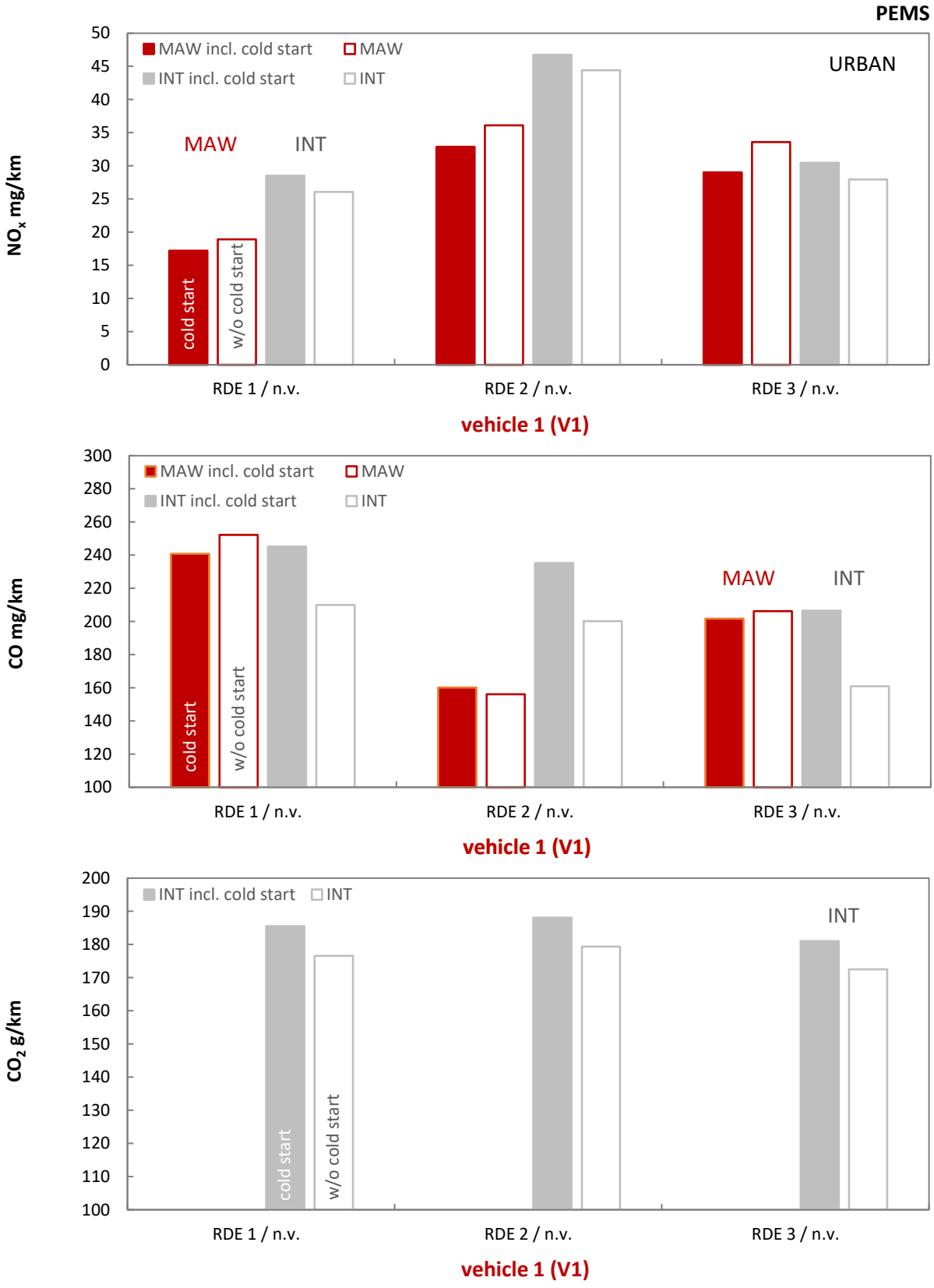
vehicle 1 (V1)

MAW	… Moving Average Windows
INT	… Integral Values
n.v.	… RDE test is not valid regarding normality (see Annex A4,A5)

On-Road Measurements

Influence of Cold Start on Emissions Results
RDE Urban Part - MAW and Integral Values

Volvo V60 Flexfuel (V1), Gasoline



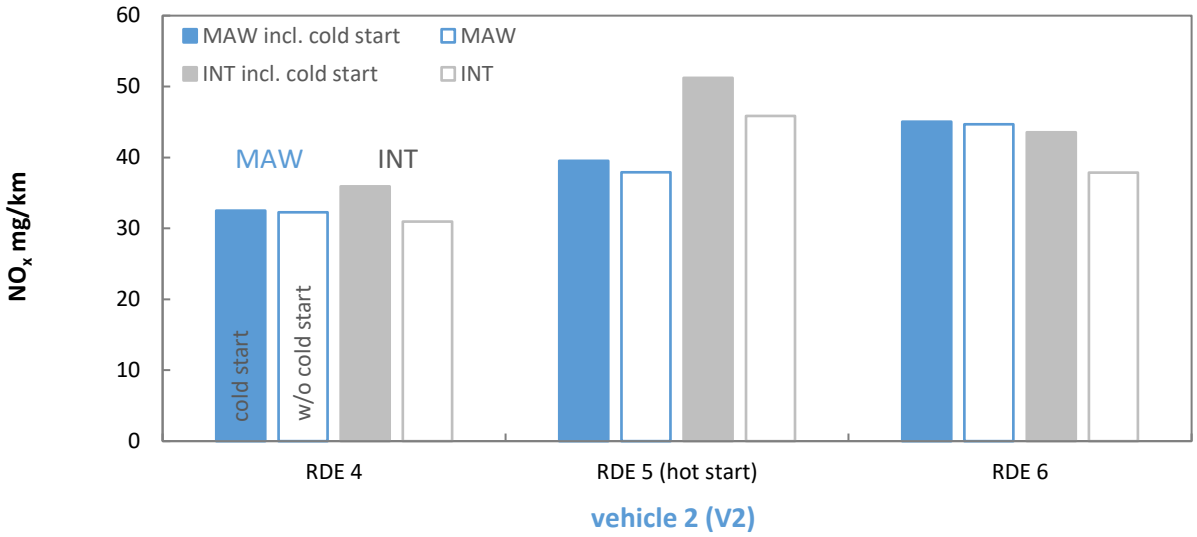
MAW … Moving Average Windows
INT … Integral Values
n.v. … RDE test is not valid regarding normality (see annex A4,A5)

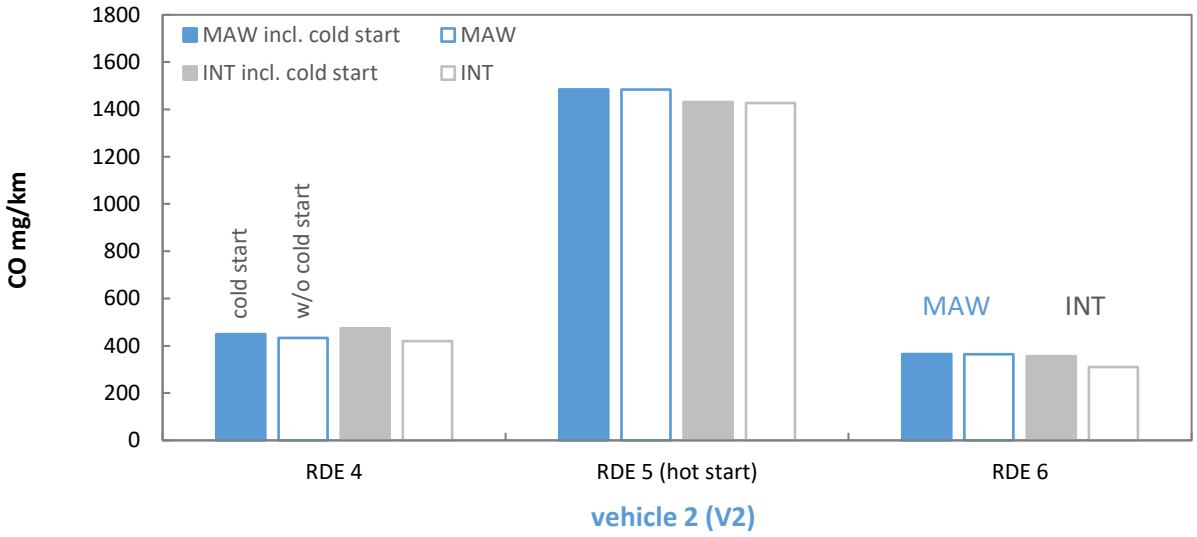
On-Road Measurements

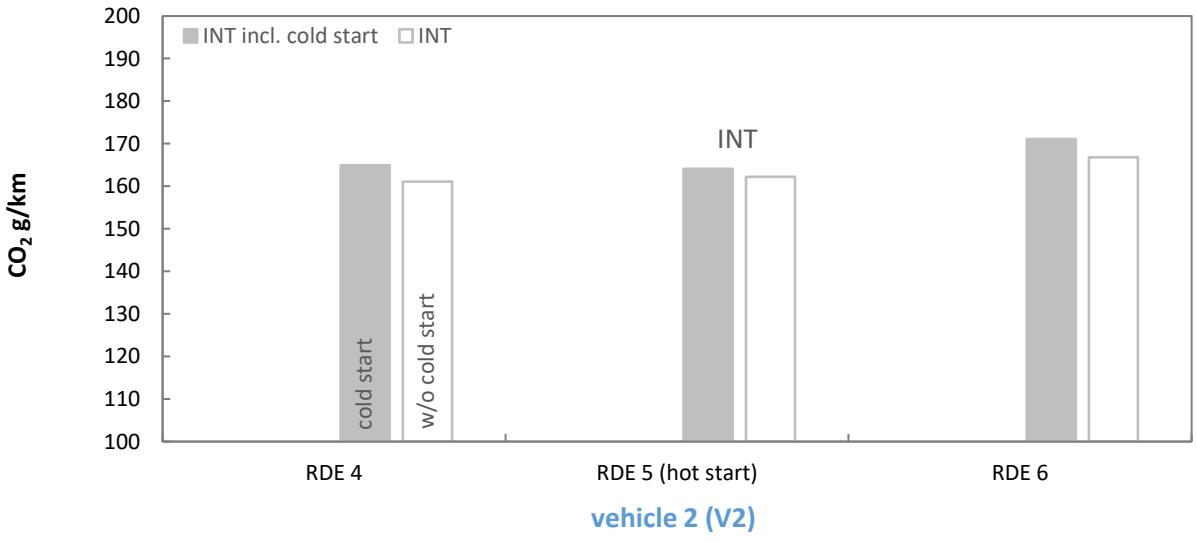
Influence of Cold Start on Emissions Results
RDE - MAW and Integral Values

Audi A4 Flexifuel (V2), Gasoline

PEMS





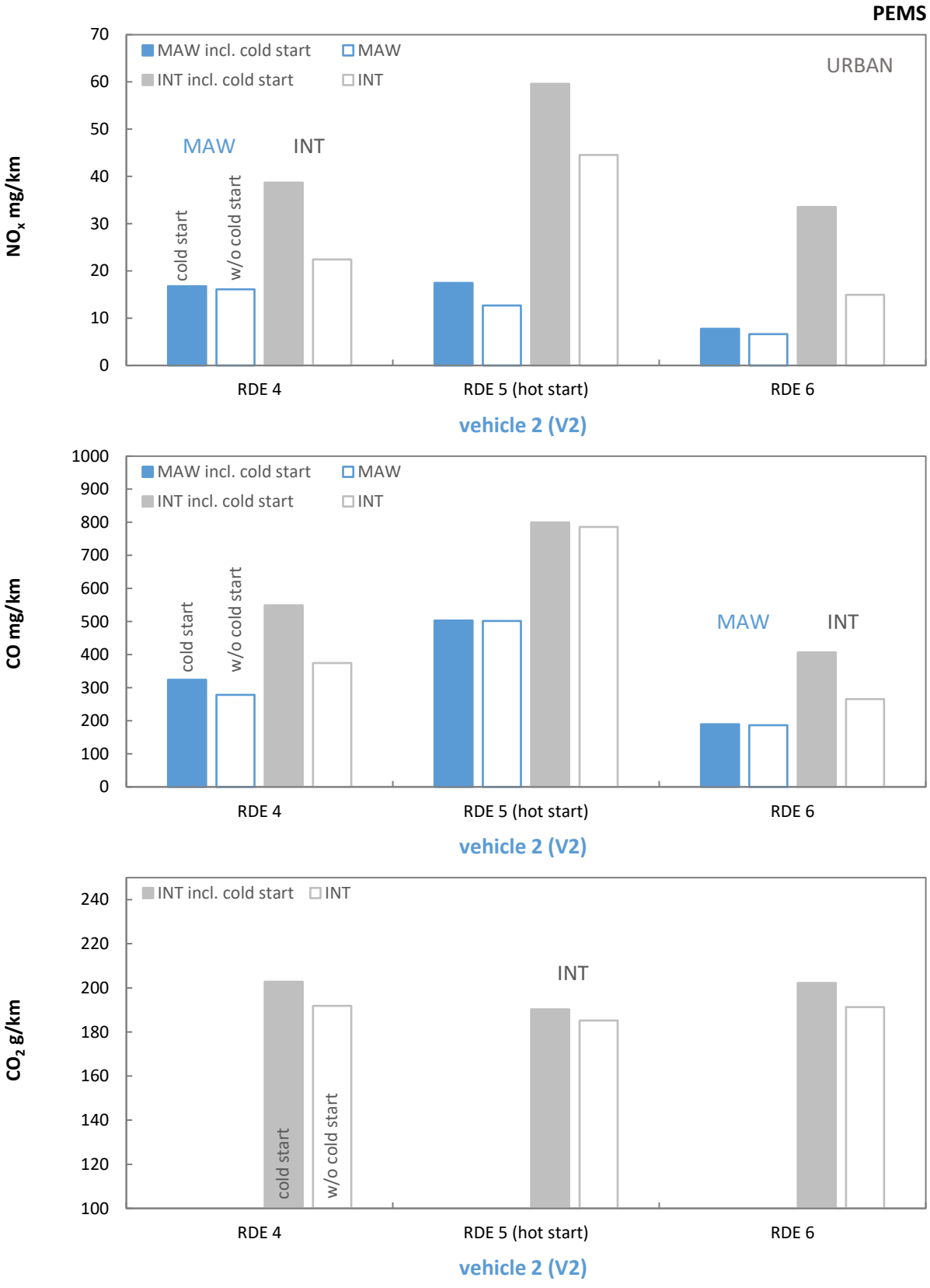


MAW … Moving Average Windows
INT … Integral Values

On-Road Measurements

Influence of Cold Start on Emissions Results
RDE Urban Part - MAW and Integral Values

Audi A4 Flexifuel (V2), Gasoline

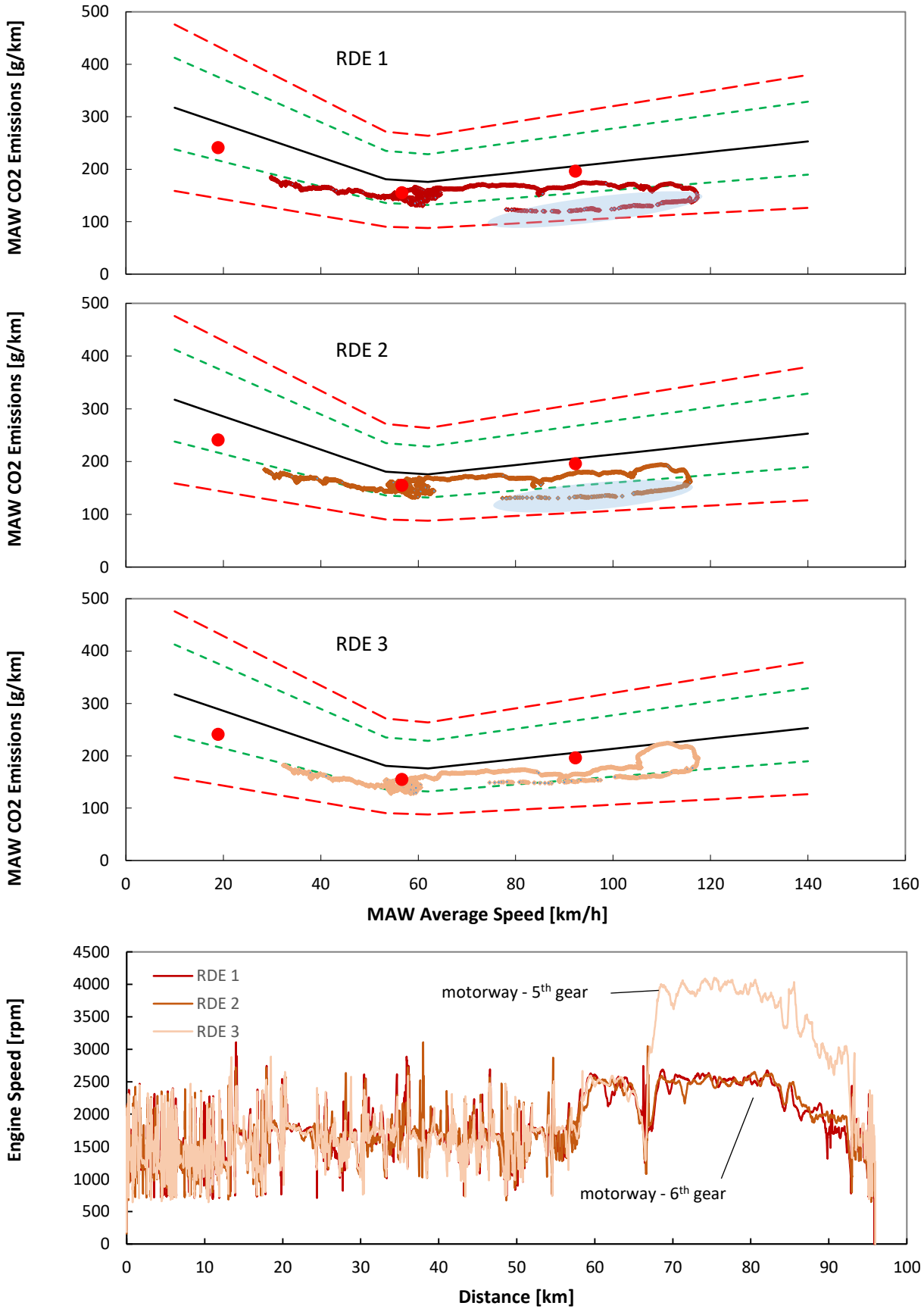


MAW … Moving Average Windows
INT … Integral Values

On-Road Measurements

RDE Normality Results and Vehicle Engine Speed

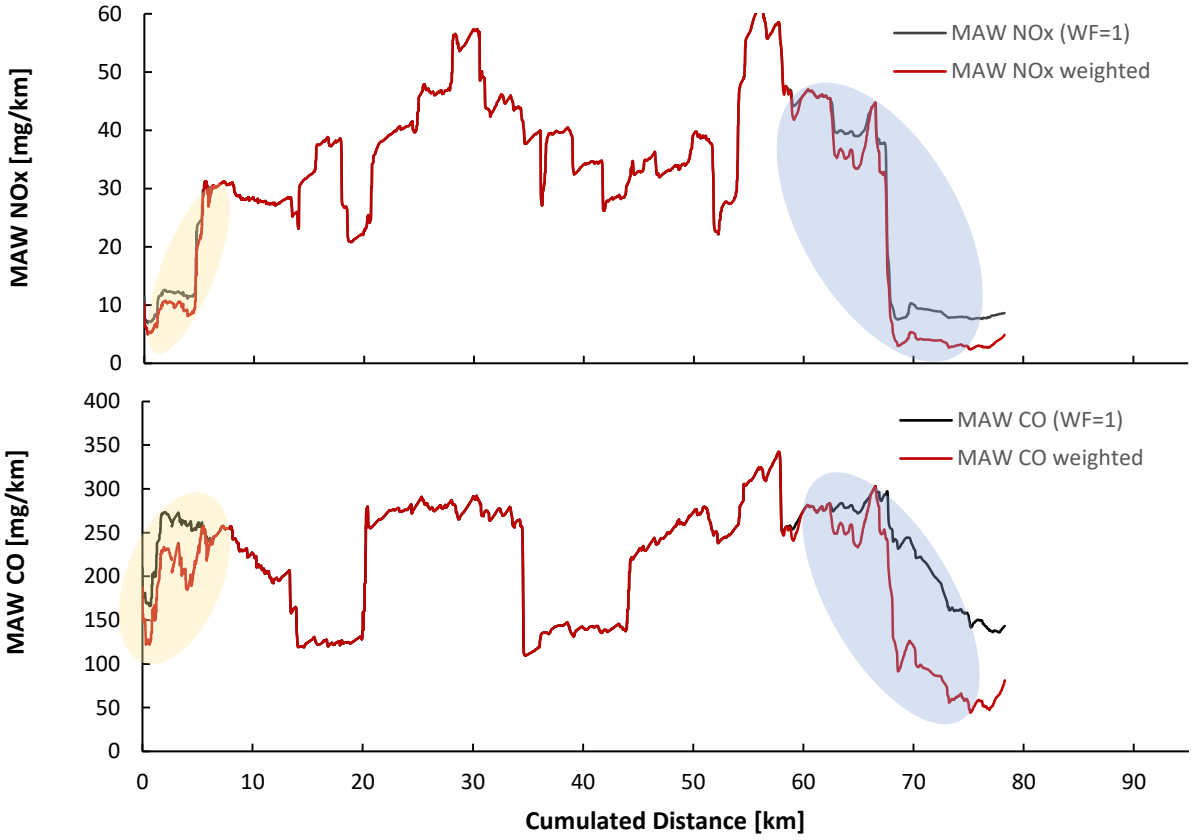
Volvo V60 Flexfuel (V1), Gasoline

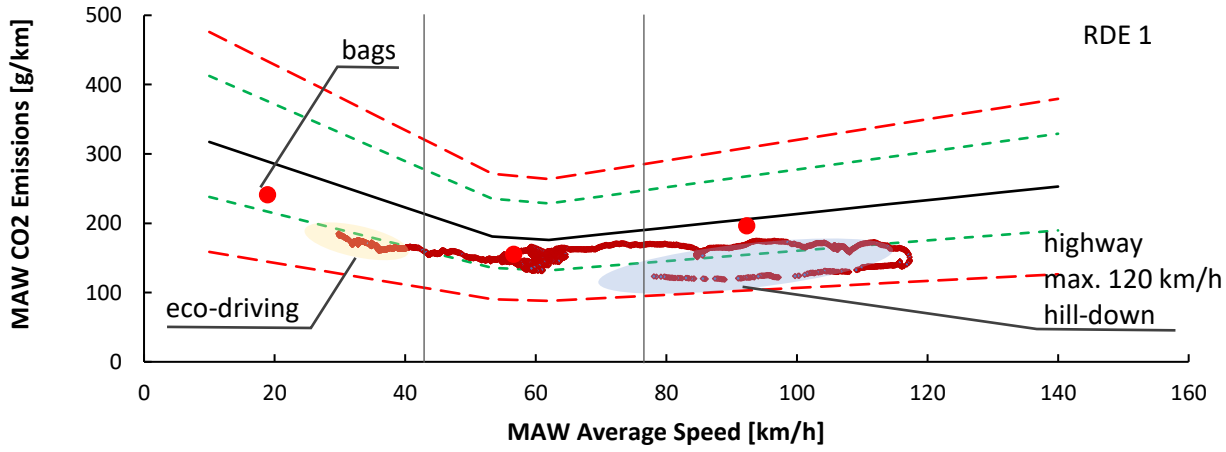


On-Road Measurements

Influence of MAW - Weighing
RDE 1

Volvo V60 Flexfuel (V1), Gasoline





Weighing formula for MAW:

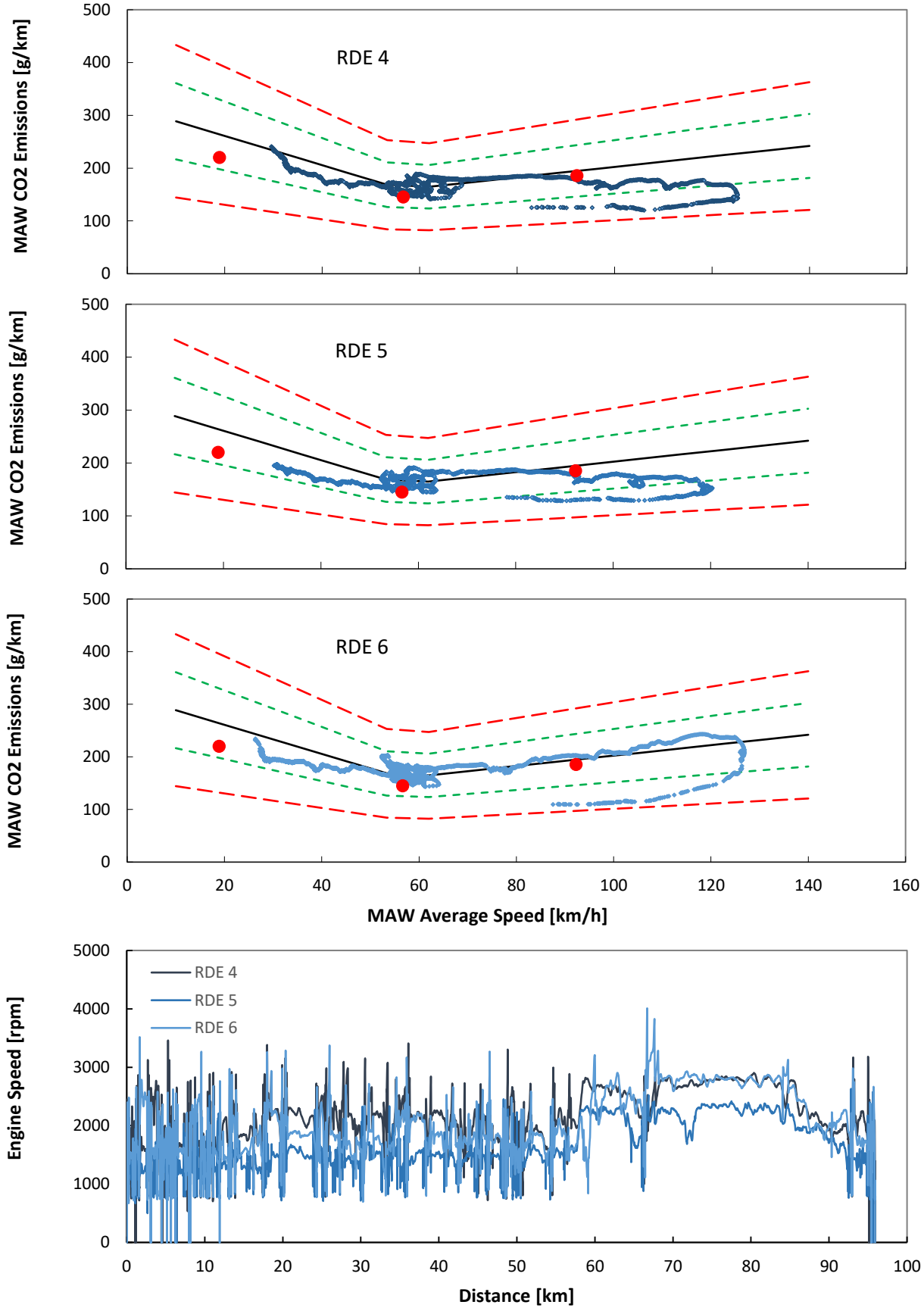
$$M_{gas,d,k} = \frac{\sum(w_j M_{gas,d,j})}{\sum w_j}$$

$M_{gas,d,j}$ ... distance-specific emission for the exhaust component in window j

On-Road Measurements

RDE Normality Results and Vehicle Engine Speed

Audi A4 Flexifuel (V2), Gasoline



B501_Fig12_comparison_RDE4-6

Berner Fachhochschule
Haute école spécialisée bernoise
Technik und Informatik
Technique et informatique

Abgasprüfstelle (AFHB)
Contrôle des gaz d'échappement
Gwerdtstrasse 5
CH-2560 **Nidau**
Tel./Tél. +41 (0)32 321 66 80

Research of Real Driving Emissions (RDE) with E85 and Two Flex Fuel Vehicles (FFV)

Project BAFU (ResRDE)*), contract nbr: 15.0002.PJ/Q223-0515, 3rd report

Annexes

November - December 2017 B501

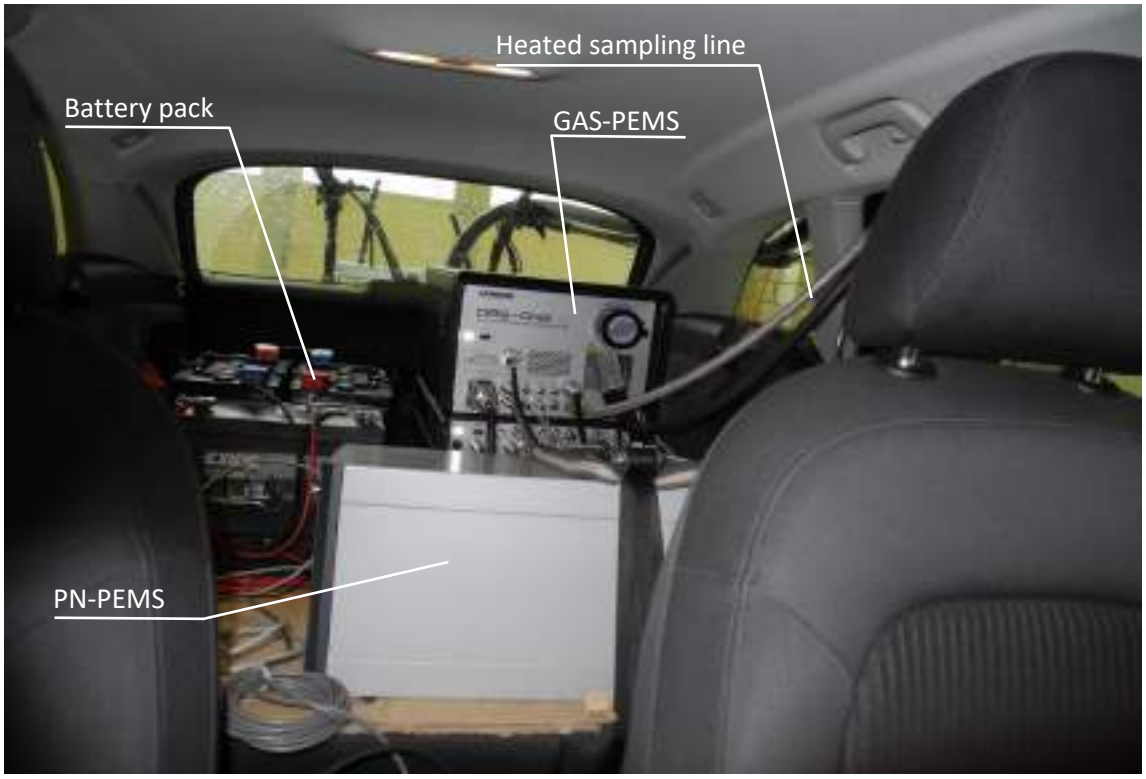
PEMS assembling on the Test Vehicles

Volvo V60 Flexfuel (V1)

Tailpipe attachment:
EFM Exhaust flow measurement
an sample probe.

PEMS assembling on the Test Vehicles

Audi A4 Flexifuel (V2)



Chronological List of Measurements

Chassis Dynamometer and Road

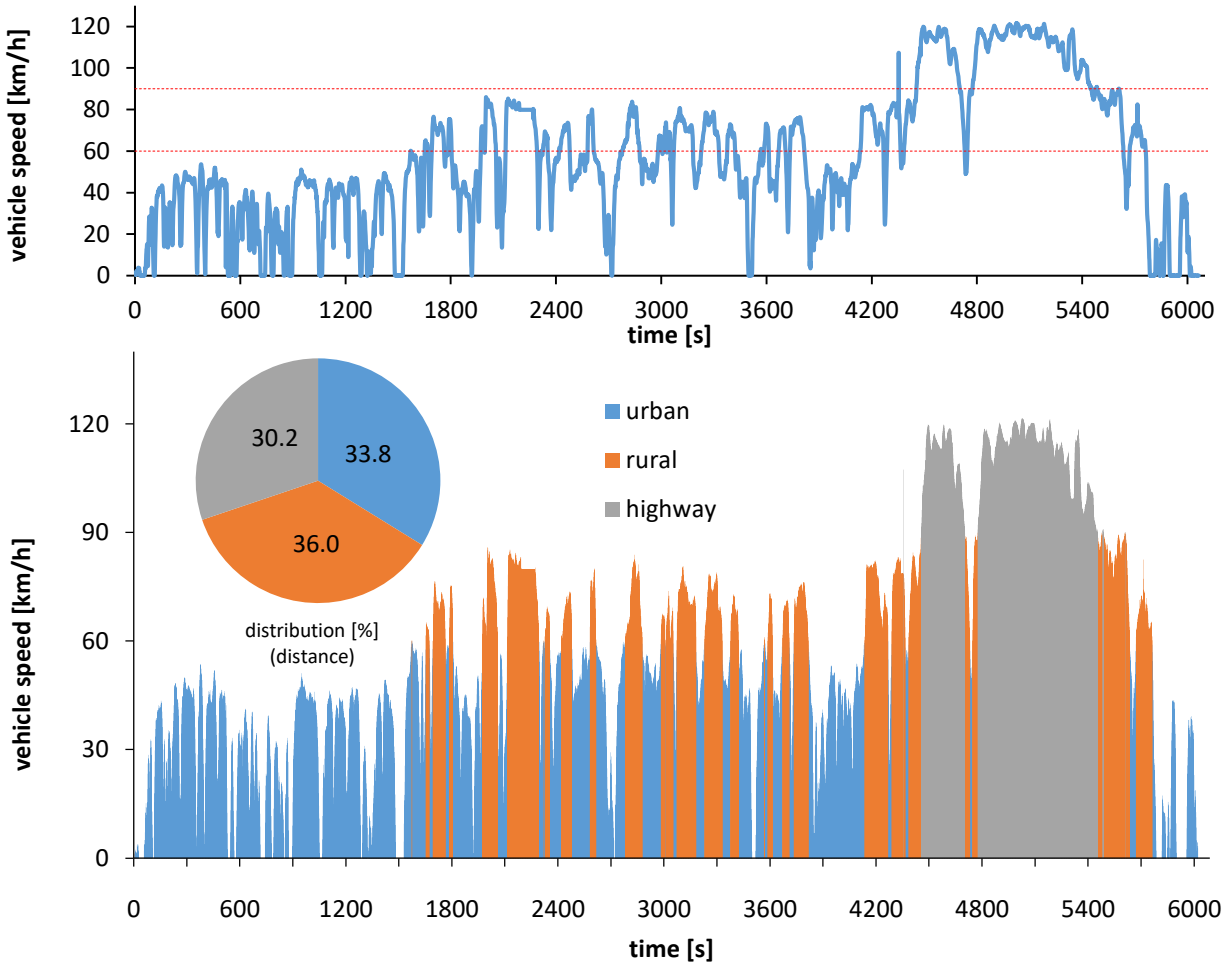
test nr.	date	vehicle	kilo-metrage	cycle	engine state	comments
001-VoE0RDE	05.05.17	Volvo V60 Flexfuel	28642	AFHB06f *)	cold	
002-VoE0Wc	08.05.17	Volvo V60 Flexfuel	28737	WLTC	cold	not valid
003-VoE0Wc	09.05.17	Volvo V60 Flexfuel	28763	WLTC	cold	
004-VoE0RDE	09.05.17	Volvo V60 Flexfuel	28786	AFHB06f	cold	
005-VoE0Wc	10.05.17	Volvo V60 Flexfuel	28881	WLTC	cold	
006-VoE0RDE	10.05.17	Volvo V60 Flexfuel	28904	AFHB06f	cold	
007-VoE0Wc	11.05.17	Volvo V60 Flexfuel	29021	WLTC	cold	
008-VoE0RDE	11.05.17	Volvo V60 Flexfuel	29044	AFHB06f	cold	
009-AuE85Wc	16.05.17	Audi A4 Flexifuel	207468	WLTC	cold	
010-AuE85RDEc	16.05.17	Audi A4 Flexifuel	207492	AFHB06f	cold	
011-AuE85RDEw	16.05.17	Audi A4 Flexifuel	207588	AFHB06f	warm	
012-AuE85Wc	17.05.17	Audi A4 Flexifuel	207684	WLTC	cold	
013-AuE85RDEc	17.05.17	Audi A4 Flexifuel	207707	AFHB06f	cold	
014-AuE0Wc	18.05.17	Audi A4 Flexifuel	207844	WLTC	cold	
015-AuE0RDEc	18.05.17	Audi A4 Flexifuel	207867	AFHB06f	cold	
016-AuE0RDEw	18.05.17	Audi A4 Flexifuel	207063	AFHB06f	warm	
017-AuE0Wc	19.05.17	Audi A4 Flexifuel	208060	WLTC	cold	
018-AuE0RDE	19.05.17	Audi A4 Flexifuel	208083	AFHB06f	cold	
030-VoE85Wc	06.06.17	Volvo V60 Flexfuel	29263	WLTC	cold	
031-VoE85RDEc	06.06.17	Volvo V60 Flexfuel	29286	AFHB06f	cold	

*) AFHB06f … actual version of AFHB RDE circuit (see annex A3)

Road Trip for RDE

RDE at 11.05.2017

VolvoV60 FlexFuel| Horiba OBS One & NanoMet 3

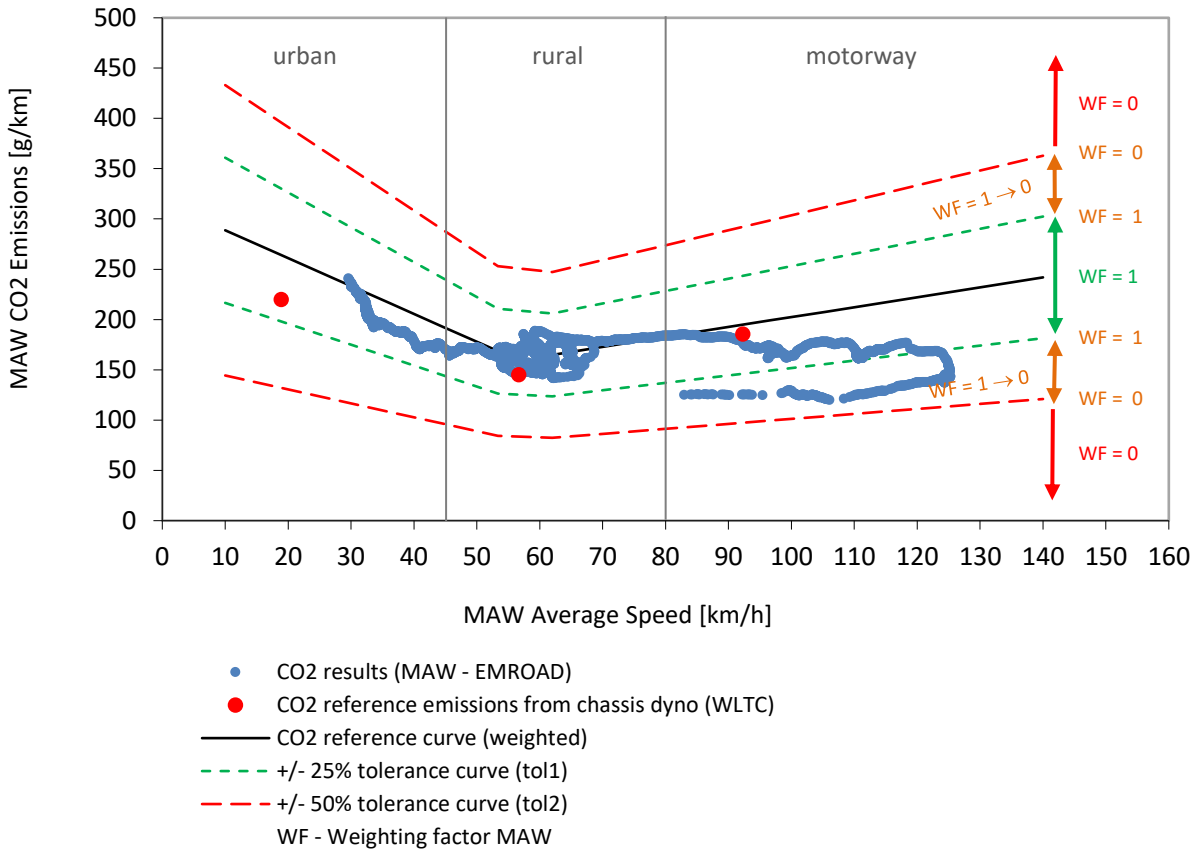


distance		
urban	32.4	km
rural	34.6	km
highway	29.0	km
total	**96.0**	**km**
time		
urban	51.1	min
rural	27.9	min
highway	15.6	min
stops	6.5	min
total	**101.1**	**min**
average speed		
urban	38.1	km/h
rural	74.2	km/h
highway	111.7	km/h
max	121.0	km/h

AFHB road-test route (AFHB06f)

On-Road Measurements

Characterization of the Normality and Completeness of a RDE Trip



source: COMMISSION REGULATION (EU) 2017/1151 of 1 June 2017 Annexe IIIa | Appendix 5

Verification of trip dynamic conditions and calculation of the final RDE emissions result with method 1 (Moving Averaging Window)

1. INTRODUCTION
The Moving Averaging Window method provides an insight on the real-driving emissions (RDE) occurring during the test at a given scale. The test is divided in sub-sections (windows) and the subsequent statistical treatment aims at identifying which windows are suitable to assess the vehicle RDE performance.
The 'normality' of the windows is conducted by comparing their CO_2 distance-specific emissions with a reference curve. The test is complete when the test includes a sufficient number of normal windows, covering different speed areas (urban, rural, motorway).

5.1. **Tolerances around the vehicle CO 2 characteristic curve**
The primary tolerance and the secondary tolerance of the vehicle CO 2 characteristic curve are respectively *tol* 1 = 25 % and *tol* 2 = 50 %.

⇨ *If the window is normal in the primary tolerance +/- 25%, its results are included in the evaluation with the weighing factor WF=1. The windows in secondary tolerance +/- (25% - 50%) are considered with continuously diminishing WF and the windows with tolerance outside of +/- 50% are neglected (WF=0).*

5.2. **Verification of test completeness**
The test shall be complete when it comprises at least 15 % of urban, rural and motorway windows, out of the total number of windows.

5.3. **Verification of test normality**

Table

RDE Report Summary

EMROAD version 5.96

Evaluated cold start		Volvo V60			Audi A4		
Test ID	BT17_	004	006	008	015	016	018
EMISSIONS RESULTS							
Test Valid	[Yes/No]	NO	NO	NO	YES	YES	YES
CO RDE emissions - Total	mg/km	241.4	219.8	180.8	449.3	1484.6	365.1
NOx RDE emissions - Total	mg/km	30.4	46.1	28.2	32.5	39.5	45.0
PN RDE emissions - Total	#/km	-	-	-	-	-	-
CO RDE emissions - Urban	mg/km	240.8	160.2	201.7	324.0	503.0	189.4
NOx RDE emissions - Urban	mg/km	17.2	32.9	29.0	16.8	17.5	7.8
PN RDE emissions - Urban	#/km	-	-	-	-	-	-
TRIP CHARACTERISTICS		VALID	VALID	VALID	VALID	VALID	VALID
Total trip distance	km	95.8	95.9	96.0	95.9	95.7	95.9
Total trip duration	min. [90-120]	101.7	104.5	100.9	97.1	100.9	104.1
Cold start duration	min. [<5]	3.7	3.2	3.2	4.7	0.4	4.8
Urban distance	km [>16]	30.2	33.3	32.5	29.8	34.1	32.1
Rural distance	km [>16]	36.1	32.6	34.5	34.0	30.7	38.5
Motorway distance	km [>16]	29.5	30.1	29.0	32.1	31.0	25.3
Urban distance share	% [29-44]	31.6	34.7	33.8	31.1	35.6	33.5
Rural distance share	% [23-43]	37.8	34.0	36.0	35.5	32.0	40.1
Motorway distance share	% [23-43]	30.8	31.3	30.2	33.5	32.4	26.4
Urban average speed	km/h [15-40]	32.2	32.4	33.9	33.3	34.8	31.9
Rural average speed	km/h	73.8	74.1	74.2	76.1	74.0	76.5
Motorway average speed	km/h	111.0	110.1	111.7	115.9	113.8	116.2
Total trip average speed	km/h	56.5	55.1	57.1	59.3	57.4	55.3
Motorway speed above 145 km/h	% [<3% mot. time]	0.0	0.0	0.0	0.0	0.0	0.0
Motorway speed above 100 km/h	min [>=5]	12.8	13.2	13.8	13.5	14.1	10.5
Urban stop time	% [6-30]	11.3	10.5	11.0	9.5	8.2	9.7
Start and end points elevation absolute difference	m [<=100m]	36.0	35.9	30.0	2.3	0.4	9.0
Cumulative positive elevation gain	m/100km	664.1	670.6	669.3	660.7	662.5	666.4
Operation under extended ambient boundary cond.	% of trip duration	0.0	0.0	0.0	0.0	0.0	0.0
MOVING AVERAGING WINDOW RESULTS		INVALID	INVALID	INVALID	VALID	VALID	VALID
[Settings] - Reference CO2 mass	kg	2.16	2.16	2.16	2.03	2.03	2.03
[Settings] - Primary tolerance	%	25	25	25	25	25	25
[Settings] - Secondary tolerance	%	50	50	50	50	50	50
Upper-primary tolerance percentage points increa	%	5	5	5	0	0	0
Total number of windows		4910	5099	4971	4814	5009	5111
Number of urban windows		886	1071	813	910	1003	1193
Number of rural windows		2979	2934	3006	2842	2891	3132
Number of motorway windows		1045	1094	1152	1062	1115	786
Share of urban windows	% [>15]	18.0	21.0	16.4	18.9	20.0	23.3
Share of rural windows	% [>15]	60.7	57.5	60.5	59.0	57.7	61.3
Share of motorway windows	% [>15]	21.3	21.5	23.2	22.1	22.3	15.4
Share of normal urban windows	% [>50]	7.8	12.2	3.1	100.0	100.0	100.0
Share of normal rural windows	% [>50]	99.5	99.8	94.4	100.0	99.8	100.0
Share of normal motorway windows	% [>50]	48.3	67.7	81.2	65.2	63.5	81.7
Urban severity index	%	-28.7	-28.7	-28.1	-9.5	-17.0	-13.8
Rural severity index	%	-15.3	-12.8	-17.5	-1.3	-0.8	2.0
Motorway severity index	%	-27.6	-22.4	-18.0	-23.7	-21.8	-6.3
CO MAW urban emissions	mg/km	240.8	160.2	201.7	324.0	503.0	189.4
CO MAW rural emissions	mg/km	214.2	148.7	197.0	446.8	1340.9	341.6
CO MAW motorway emissions	mg/km	269.3	352.4	143.1	578.8	2639.5	569.6
NOx MAW urban emissions	mg/km	17.2	32.9	29.0	16.8	17.5	7.8
NOx MAW rural emissions	mg/km	35.9	66.1	38.7	32.8	27.0	30.2
NOx MAW motorway emissions	mg/km	38.6	37.6	16.9	48.4	74.7	98.3
PN MAW urban emissions	#/km	-	-	-	-	-	-
PN MAW rural emissions	#/km	-	-	-	-	-	-
PN MAW motorway emissions	#/km	-	-	-	-	-	-
CO MAW RDE emissions	mg/km	241.4	219.8	180.8	449.3	1484.6	365.1
NOx MAW RDE emissions	mg/km	30.4	46.1	28.2	32.5	39.5	45.0
PN MAW RDE emissions	#/km	-	-	-	-	-	-
OVERALL TRIP DYNAMICS		VALID	VALID	VALID	VALID	VALID	VALID
Urban RPA	m/s2	0.17	0.17	0.17	0.18	0.18	0.15
Rural RPA	m/s2	0.09	0.10	0.08	0.10	0.10	0.10
Motorway RPA	m/s2	0.05	0.04	0.04	0.04	0.05	0.06
Urban 95th percentile Speed*Acc	m2/s3	11.6	11.8	10.9	11.8	10.7	10.8
Rural 95th percentile Speed*Acc	m2/s3	16.8	19.1	15.6	18.9	15.2	16.8
Motorway 95th percentile Speed*Acc	m2/s3	13.4	13.8	13.5	17.1	21.8	18.1