SWEDISH TRANSPORT AGENCY

Swedish In-Service Testing Program

On Emissions from Heavy-Duty Vehicles

Report for the Swedish Transport Agency

Certification & Regulation Compliance
AVL

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Content

List of Abbreviations

BS	Brake Specific
CAN	Controller Area Network
CD	Chassis dynamometer
CF	Conformity Factor
CFV	Critical Flow Venturi
CH_4	Methane
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO_2	Carbon dioxide
COP	Conformity of Production
CPC	Condensation Particle Counter
CVS	Constant Volume Sampling
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
DS	Distance Specific
ECU	Engine Control Unit
ED95	Ethanol Diesel
EEV	Environmentally Enhanced Vehicle
EGR	Exhaust Gas Recirculation
ELR	European Load Response
ESC	European Stationary Cycle
ETC	European Transient Cycle
FC	Fuel consumption
FTIR	Fourier transform infrared spectroscopy
GFM	Gravimetric Filter Module
GVM	Gross Vehicle Mass (*technically permissible maximum laden mass of the vehicle)*
HC	Total hydrocarbons (THC)
HDV/HD	Heavy Duty Vehicle/ Heavy Duty
HFID	Heated Flame Ionization Detector
IUC	In Use Compliance
JRC	Joint Research Centre
MK1	Environmental class 1
MSS	Micro Soot Sensor
NDIR	Non-Dispersive Infrared
NDUV	Non-Dispersive Ultraviolet
NH_3	Ammonia
NMHC	Non Methane Hydrocarbons
NO	Nitrogen oxides
NO_2	Nitrogen dioxides
NOx	Nitrogen oxides
OBD	On board Diagnostics
PASS	Photo-Acoustic principle

PEMS	Portable Emission Measurement System
PLU	Fuel mass flow metering device
PM	Particulate Matter
PN	Particulate Number
SCR	Selective Catalytic Reduction
SEPA	Swedish Environmental Protection Agency
SRA	Swedish Road Administration
STA	Swedish Transport Agency
THC	Total Hydrocarbons
TWC	Three-way catalyst
WBW	Work Based Window
WHSC	World Harmonized Stationary Cycle
WHTC	World Harmonized Transient Cycle
WHVC	World Harmonized Vehicle Cycle

Introduction

In Europe as well as in USA methods for verifying emission performance have been developed using portable emission measurement system (PEMS), where emissions are measured on board a vehicle during real life operation. The main objective with on board measurement is to verify whether a HD vehicle is meeting set emission requirement during real driving conditions

In Europe, activities to develop suitable test methods for on-road measurements and associated test protocol have been organized and coordinated by EU Joint Research Centre (JRC). JRC launched a pilot project for measurements of gaseous emissions in 2006 where manufacturer of engines/vehicles, manufacturer of instrument, approval authorities and technical services was invited to participate. The activity was called EUPEMS project. The Swedish Road administration and then later, The Swedish Transport
Agency (STA) participated in the pilot project using data from the In-Service Testing Program as input. The EU-PEMS Pilot project is now finalized and findings, conclusions and comments from stakeholders have been considered and are now included in the European Euro VI emission requirements (Regulation No 595/2009 and EU Regulation No 582/2011). Further, a common way to calculate and present results from measurements have been introduced by JRC and a standardized test protocol has been established (EMROAD). The protocol is used to verify whether tested vehicles/engines meet the set requirements. The protocol also specifies the measurement points to be used for the calculation.

The result from national activities carried out 2016 is presented in this report.

Summary

AVL MTC AB has on the commission of The Swedish Transport Agency (STA) carried out The Swedish In-Service Testing Programme on Emissions from Heavy-Duty (HD) Vehicles. Seventeen vehicles were tested on road using Portable Emissions Measurement System (PEMS). In addition, ten of these were vehicles also tested on chassis dynamometer according to the Fige (chassis dynamometer version of European Transient Cycle (ETC)) and the WHVC (Worldwide Harmonized Vehicle Cycle, chassis dynamometer version of WHTC - Worldwide harmonized Transient Cycle). The emission measurement methods used in the programme meet the requirements of regulation (EU) NO. 582/2011 Annex II and (EU) No. 64/2012. The selection of the vehicles was mainly based on Euro VI standard.

The scope of the investigation was, beside in use compliance, to generate emission factors from commercial vehicles tested as commanded in the new directive for Euro VI vehicles.

For chassis dynamometer tests, there are no legal requirements for this type of vehicle but the WHTC engine test emission limits are in this investigation used as “fictive” pass/fail criteria. These emission limits are also used for evaluation of PEMS test results where all events have been evaluated. For PEMS testing is also the In-Service Conformity (ISC) pass/fail criteria used, where conformity factors limit for gaseous emissions have been established.

The selection of the test vehicle was done in cooperation with the Swedish Transport Agency.

Table 1 Vehicle selection

Vehicle	Emission standard	Fuel	Aftertreatment	Model year	Vehicle category	Mileage (km)	Power (kW)	Gross vehicle mass	NOx CF
A	Euro VI	Diesel	DOC.SCR.DPF	2014	N3	112 000	290	27 000	0.35
B	Euro VI	Diesel	SCRT	2014	N3	65 000	324	26 000	1.05
C	Euro VI	Diesel	DOC.SCR.DPF	2014	N3	40 600	550	80 000	0.77
D	Euro VI	Diesel	SCRT	2014	N3	50 000	184	15 500	0.23
E	Euro VI	CNG	TWC	2015	N3	40 000	206	16 000	0.8
F	Euro VI	Diesel	DOC.SCR.DPF	2014	N3	52 000	184	16 000	0.8
G	Euro VI	FAME	DOC.SCR.DPF	2015	M3	95 000	235	18 000	0.52
H	Euro VI	HVO	DOC.SCR.DPF	2014	M3	107 000	235	30 000	0.53
I	Euro VI	CNG	TWC	2014	M3	250 000	228	30 000	1.45
J	Euro III/VI	Diesel	Retrofit system	2005	M3	830 000	250	24 300	1.22
K	Euro VI	HVO/hybrid	DOC.SCR.DPF	2014	M3	40 000	186/150	19 000	-
L	Euro VI	Diesel	DOC.SCR.DPF	2014	N3	97 000	248	21 000	0.77
M	Euro VI	Diesel	DOC.SCR.DPF	2014	N2	60 000	175	12 000	2.6
N	Euro VI	Diesel	DOC.SCR.DPF	2014	N3	58 000	206	18 600	0.24
O	Euro VI	Diesel	DOC.SCR.DPF	2013	N3	140 000	345	27 000	1.18
P	Euro VI	Diesel	DOC.SCR.DPF	2014	N2	68 000	175	12 000	3.23
Q	Euro VI	Diesel	DOC.SCR.DPF	2015	N3	53 000	206	16 000	0.82

Vehicle A

A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions were a little high in the WHVC cold start, however very low in all warm start tests resulting in a weighted average below the Euro VI limit. The ammonia emissions measured were low.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, were below the limit.

Vehicle B

A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.
The In Service Conformity (ISC) pass/fail criteria with given conformity factors limits were assessed in the PEMS result analysis. All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

It can be concluded that measured emission levels of CO, THC, NH_3, PM and PN all meet the regulatory Euro VI WHTC limitations. However, NO_X emissions reach beyond the 0.46 g/kWh limit during all tests.

Vehicle C

A heavy duty truck Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. Testing was performed on Swedish roads using a portable emissions measurement system (PEMS). The vehicle was tested with and without load (24 400 – 80 000 kg). The vehicle was tested in 2015 and these results are included in present report as a comparison.

Emissions of THC, CO were below the detection limits for the used instrument. The NO_x emissions were passing the Euro VI emission limit with a conformity factor of 0.77 (work based) and 0.84 (CO_2 based). Fuel consumption increased with 1.9 litres with an extra load of 55 000 kg.

The conclusion is that no significant deterioration of the exhaust after treatment system can be seen.

Vehicle D

A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.

The In Service Conformity (ISC) pass/fail criteria with given conformity factors limits were assessed in the PEMS result analysis. All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions measured during the tests were very low in all warm start tests. The cold start generated a little higher NOx emissions however the weighted result was below the emission limit. The ammonia emissions measured were low.

Vehicle E

A heavy duty Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, THC, and PM well below the Euro VI emission limit. The NOx emissions measured during the tests were very low in all warm start tests. The cold start generated a little higher NOx emissions however the weighted result was below the emission limit. The PN result was higher than the WHTC PN limit in both the cold and the warm WHVC cycles however lower in the PEMS test. The ammonia emissions measured were low.

Vehicle F

A heavy duty delivery truck, Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.
All tests resulted in emissions of CO, THC, and PM well below the Euro VI emission limit. The NOx emissions measured during the tests were very low in all warm start tests. The cold start generated a little higher NOx emissions however the weighted result was below the emission limit. The PN result was higher than the WHTC PN limit in both the cold and the warm WHVC cycles however lower in the PEMS test. The ammonia emissions measured were low.
No fault codes were indicated by the OBD system.

Vehicle G

A bus, Euro VI, fuelled with RME and of model year 2015, has been tested for exhaust emissions and fuel consumption. A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.
All established conformity factors from the ISC evaluation, for work based windows, passed the criteria below 1.5 value.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions were higher in the WHVC cold start, however very low in all warm start tests resulting in a weighted average below the Euro VI limit. The ammonia emissions measured were low.

Vehicle H

A city bus, Euro VI, fuelled with HVO and of model year 2014, has been tested for exhaust emissions and fuel consumption. Tests were carried out on Swedish roads with a portable emissions measurement system (PEMS) on board.
For PEMS testing is the In Service Conformity (ISC) pass/fail criteria used, where conformity factors limits for gaseous and PM emissions have been established. Emissions from the entire PEMS tests have also been evaluated (all events) and the results are compared to the Euro VI WHTC emission limits which in this case only is a comparison and no legal pass/fail criteria.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, were below the limit.
All tests resulted in emissions of CO, THC, NOx and PM well below the Euro VI emission limit.

Vehicle I

A city bus, Euro VI, fuelled with CNG and of model year 2014, has been tested for exhaust emissions and fuel consumption. Tests were carried out on Swedish roads with a portable emissions measurement system (PEMS) on board.

For PEMS testing is the In Service Conformity (ISC) pass/fail criteria used, where conformity factors limits for gaseous and PM emissions have been established. Emissions from the entire PEMS tests have also been evaluated (all events) and the results are compared to the Euro VI WHTC emission limits which in this case only is a comparison and no legal pass/fail criteria.

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, NMHC, CH4, PM and PN well below the Euro VI emission limit. The emissions of NOx were however higher than the limit. No malfunction was indicated by the OBD system.

Vehicle J

An articulated bus, retrofitted from Euro III to Euro V, fuelled with diesel and of model year 2005, has been tested for exhaust emissions and fuel consumption. Tests were carried out on Swedish roads with a portable emissions measurement system (PEMS) on board.

For PEMS testing is the In Service Conformity (ISC) pass/fail criteria used, where conformity factors limits for gaseous and PM emissions have been established. However, PEMS testing on Euro V vehicles is only optional and no mandatory testing method. Emissions from the entire PEMS tests have also been evaluated (all events) and the results are compared to the Euro V ETC emission limits which in this case only is a comparison and no legal pass/fail criteria.

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, THC, and PM well below the Euro V emission limit. The emissions of NOx were however higher than the limit. There is no PN emission limit for Euro V vehicles but the measured values were lower than the Euro VI limit.

Vehicle K

A diesel fuelled electric hybrid bus of model year 2014 and emission standard Euro VI has been tested for exhaust emissions and fuel consumption. Two different on-road measurement tests were carried out using a portable emissions measurement system (PEMS) mounted on board.

Measured brake specific emissions of NOx are below the Euro VI regulatory limit when taking the work of the electrical motor into account. The emission of CO and THC are close to or below the detection limit of the measurement system. PM emissions are in the order of 100 times below the regulatory limit.

Vehicle L

A heavy duty truck Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. In 2015, the vehicle was tested on a chassis dynamometer and on Swedish roads using a portable emissions measurement system (PEMS) (27 000 km). In 2016, the vehicle, which now had an odometer reading of 97 000 km, was retested only on the road, using the same test route as in 2015. This report presents the emission performance from the PEMS testing, in 2015 compared to in 2016.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value. Emissions of NOx has increased over the past year.

Vehicle M

A heavy duty truck, Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.
The established NOx conformity factors from the ISC evaluation, for both work and CO_2 based windows, were rather high and the vehicle did not pass the Euro VI emission limit. The particulate emissions where low, meeting the legislative criteria.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions measured during all tests were above the Euro VI limit for engine tests. The ammonia emissions measured were rather low.

Vehicle N

A heavy duty truck, Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions were a little high in the WHVC cold start, however very low in all warm start tests resulting in a weighted average below the Euro VI limit. The ammonia emissions measured were low.

Vehicle O

A truck Euro VI, model year 2013, has been tested for exhaust emissions and fuel consumption. In 2014, the vehicle was tested on a chassis dynamometer and on Swedish roads using a portable emissions measurement system (PEMS) (800 km). The vehicle was retested on the road in 2015 with an odometer reading of 28 000 km and now in 2016 (odometer reading of 140 000 km). This report presents the emission performance from the PEMS testing, in 2014 and 2015 compared to in 2016.

The PEMS test results are presented as “all events” as well as the pass/fail criteria for In Service Conformity (ISC) where conformity factors limits for gaseous emissions and PM have been established.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value. Emissions of NOx have increased over the past year. Emissions of PM were low.

Vehicle P
A delivery truck, Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.
The established NOx conformity factors from the ISC evaluation, for both work and CO_2 based windows, were rather high and the vehicle did not pass the Euro VI emission limit. The particulate emissions where low, meeting the legislative criteria.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions measured during all tests were above the Euro VI limit for engine tests. The ammonia emissions measured were rather low.

Vehicle Q
A delivery truck Euro VI, model year 2015, has been tested for exhaust emissions and fuel consumption. The vehicle was tested on Swedish roads using a portable emissions measurement system (PEMS).
The PEMS test results are presented as “all events” as well as the pass/fail criteria for In Service Conformity (ISC) where conformity factors limits for gaseous emissions and PM have been established.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

Test program

Seventeen vehicles have been tested on road with PEMS. In addition, ten of these vehicles have been tested on a chassis dynamometer. The aim of the study was not to pinpoint specific manufacturer thus, the vehicles in this report will be denoted A – Q and the engine power is presented as an approximate figure.

Selection of test vehicles

The vehicle selection has been performed in cooperation with the STA. The vehicle type chosen for testing was based on Euro VI technology. Vehicles tested have been served in accordance to the manufacturer specification on a regular basis.

Table 2 EU Emission Standards for HD Engines, transient testing

Emission standard Test cycle	**CO [g/kWh]**	**NMHC [g/kWh]**	**CH_4[1] [g/kWh]**	**NO_x [g/kWh]**	**PM [g/kWh]**	**$PN_{[3]}$ #/kWh**	**NH_3 ppm**
Euro V European Transient Cycle (ETC)	4.0	0.55	1.1	2.0	0.03	-	-
Euro VI Worldwide Harmonized Transient Cycle (WHTC)	4.0	0.16[2]	0.5	0.46	0.01	$6*10^{11}$	10

[1] For CNG engines only, [2] THC for Diesel engines, [3] for Diesel engines

Testing on chassis dynamometer

Chassis dynamometer test cell

The chassis dynamometer is a cradle dynamometer with 515 mm roller diameters. The maximum permitted axle load is 13 000 kg. Vehicle inertia is simulated by flywheels in steps of 226 kg from 2 500 kg to 20 354 kg. The maximum speed is 120 km/h without flywheels and 100 km/h with flywheels.

Two DC motors, each 200 kW maximum load, and separate control system serves as power absorption units. The DC motors and their computer-controlled software enable an excellent road load simulation capability. The software sets the desired road load curve through an iterative coast down procedure with test vehicle on the dynamometer.

An AVL PUMA computer system is used as a superior test cell computer for engine monitoring and also for the measurement and collection of all data emanating from the vehicle, emission measurement system and test cell.

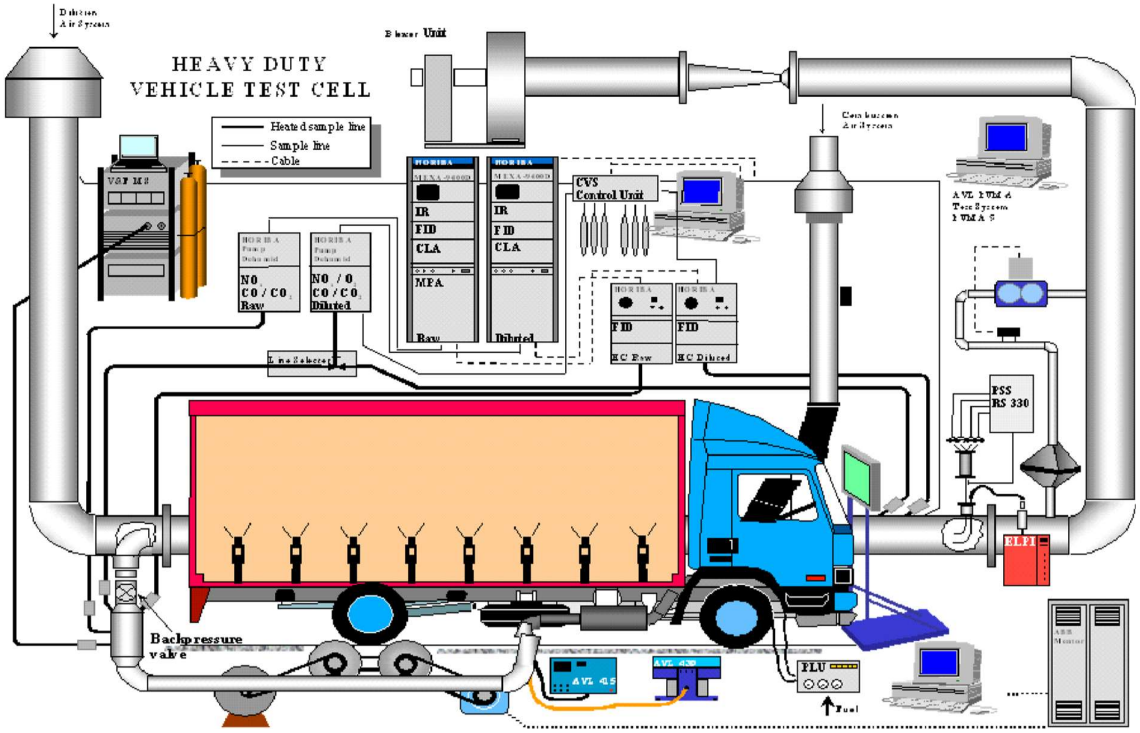


Figure 1 A schematic description of the test cell.

Engine power

The engine power was estimated by adding the integrated signals from measured acceleration force of the inertia used and the road load. No fan correction has been applied to the calculations. The integrated power is then used to calculate the total estimated work (kWh) during the test cycle which is used to calculate emissions in g/kWh. 18

Regulated gaseous emissions and CO_2

The sampling- and analysing equipment are based on full flow dilution systems, i.e. the total exhaust is diluted using the CVS (Constant Volume Sampling) concept. The total volume of the mixture of exhaust and dilution air is measured by a CFV (Critical Flow Venturi) system. For the subsequent collection of particulates, a sample of the diluted exhaust is passed to the particulate sampling system. The sample is here diluted once more in the secondary dilution tunnel, a system referred to as full flow double dilution.

According to the regulations for transient tests the diluted exhaust gases are both bagsampled and sent for further analysis *and* on-line sampled. Through the CVS system a proportional sampling is guaranteed.

The equipment used for analysing the gaseous regulated emissions consist of double Horiba 9400D systems. Hereby exists the possibility to measure both diluted and raw exhaust emissions on-line simultaneously. The sampling system fulfils the requirements of Regulation (EU) 582/2011 in terms of sampling probes and heated lines etc.

The measured components and measurement principles are specified in Table 3.

Table 3 Measured components and measurement principles.

Component	Measurement principle
Total hydrocarbons (THC)	HFID (heated flame ionization detector) (190°C)
Carbon monoxide (CO)	NDIR (non-dispersive infrared analyzer)
Carbon dioxide (CO_2)	NDIR
Nitrogen oxides (NO_X)	CL (chemiluminescence)
Ammonia (NH_3)	FTIR (Fourier Transform InfraRed)
Fuel consumption (FC)	Carbon balance of HC, CO and CO_2

Fuel consumption

The total fuel consumption (Fc) was calculated using the carbon balance method. The diesel consumption was also measured with a PLU (fuel mass flow meter measuring device).

Particulate emissions

The particulate emissions were analysed gravimetrically, by number and by size distribution.

Particulate mass

The particulate mass was measured gravimetrically by the use of glass fibre filters. For the collection of particle matter (PM), a sample of the diluted exhaust is passed to the particulate sampling system. The sample is then diluted once more in the secondary dilution tunnel, a system referred to as full flow double dilution. The particles are collected on Teflon-coated Pallflex™ filter and measured gravimetrically. The sampling of particle matter is in accordance with Directive 2005/55/EEC.

Particle number

The particle number is measured in a Condensation Particle Counter (CPC) with a size range of 23nm to 2.5µm. The particle number is limited for heavy duty diesel engines from emission standard Euro VI (limits for positive ignited engines are not yet decided).

In the counter, the particles are enlarged by condensation of butanol and are thereafter detected and counted using a light-scattering method.

Chassis dynamometer test cycles

The ETC/FIGE driving cycle

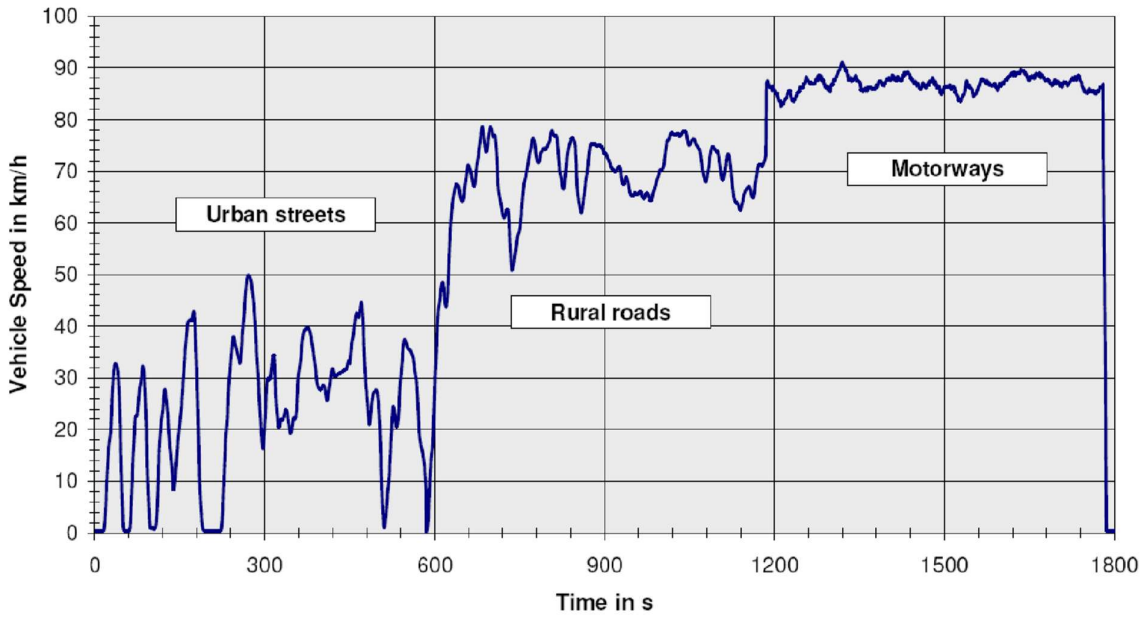


Figure 2 The FIGE driving cycle

The FIGE test cycle has been developed by the FIGE Institute, Aachen, Germany, based on real road cycle measurements of heavy duty vehicles. FIGE Institute developed the cycle in two variants: as a chassis and an engine dynamometer test. The engine dynamometer version of the test is the so called ETC cycle (European Transient Cycle) which today is used for certification purposes of diesel engines to be used in heavy duty vehicles. The chassis dynamometer version is normally referred to as the FIGE test cycle.

Different driving conditions are represented by three parts of the ETC/FIGE cycle, including urban, rural and motorway driving.

The duration of the entire cycle is 1800s. The duration of each part is 600s.

- Part one represents city driving with a maximum speed of 50 km/h, frequent starts, stops, and idling.
- Part two is rural driving starting with a steep acceleration segment. The average speed is about 72 km/h
- Part three is motorway driving with average speed of about 88 km/h.

The WHVC/WHTC test cycle

The WHTC (World Harmonized Transient Cycle) test cycle will become the future test cycle for certification of engines. The WHVC (World Harmonized Vehicle Cycle) test

cycle, which can be used for testing entire vehicles on a chassis dynamometer, is the test cycle from which the WHTC was developed. The WHVC is not identical to the WHTC since it was only an intermediate step from data collection to engine test bench cycle, but it is the closest there is today.

The test procedures for chassis dynamometer testing are not identical to the procedures used for engine dynamometer testing, but the results using the WHVC test cycle can be used in order to compare the emission levels from a vehicle with the emissions levels of an engine tested with the WHTC test cycle. The emission results are presented in g/km but also converted from g/km to g/kWh using estimations of executed work during the transient test cycle.

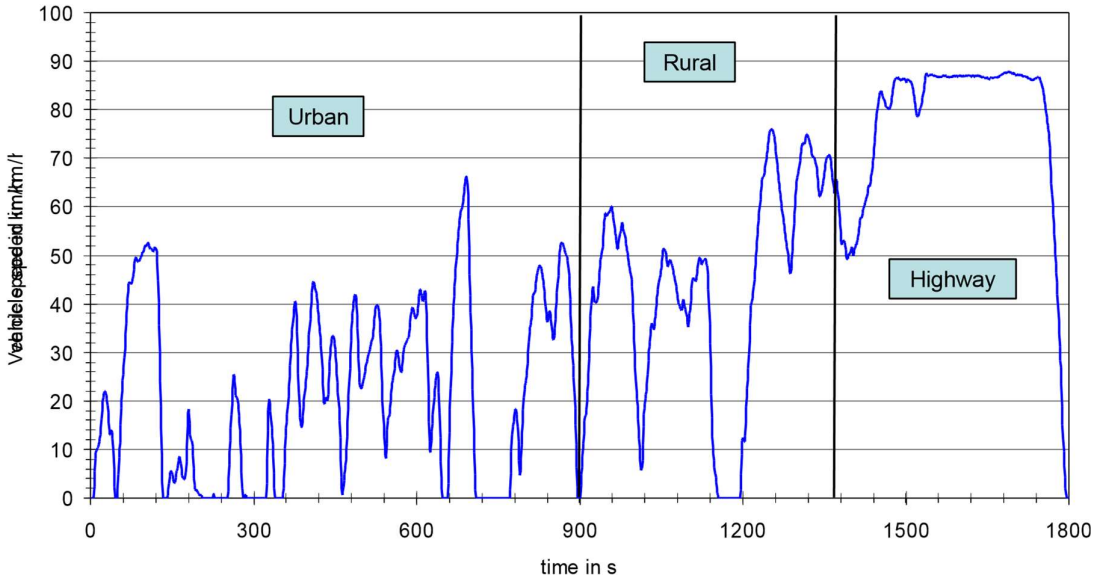


Figure 3 The WHVC test cycle

The transient cycle used in the test was the “WHVC” test cycle (unofficial).

The WHVC is a transient test of 1800 s duration, with several motoring segments.

Different driving conditions are represented by three parts of the WHVC cycle, including urban, rural and highway driving.

The duration of the entire cycle is 1800s.

- The first 900 seconds represents urban driving with an average speed of 21 km/h, maximum speed of 66 km/h. This part includes frequent starts, stops and idling.
- The following 468 seconds represents rural driving with an average speed of 43 km/h and maximum speed of 76 km/h.
- The last 432 seconds are defined as highway driving with average speed of about 76 km/h.

On-road measurement

Portable Emissions Measurement System (PEMS)

The M.O.V.E is developed by AVL for testing of vehicles and equipment under real-world operating conditions. The instrument is an on-board emissions analyzer which enables tailpipe emissions to be measured and recorded simultaneously while the vehicle/machine is in operation.
The following measurement subsystems are included in the AVL M.O.V.E GAS PEMS emission analyzer:

- Heated Flame Ionization Detector (HFID) for total hydrocarbon (THC) measurement.
- Non-Dispersive Ultraviolet (NDUV) analyzer for nitric oxide (NO) and nitrogen dioxide (NO_2) measurement.
- Non-Dispersive Infrared (NDIR) analyzer for carbon monoxide (CO) and carbon dioxide (CO_2) measurement.
- Electrochemical sensor for oxygen (O_2) measurement.

Table 4 AVL M.O.V.E GAS PEMS specification

An AVL M.O.V.E GAS PEMS 493	
Inputs/Outputs electrical	Heated line connectors (3 heating circles with 2 x PT100); 1 x Ethernet (TCP/IP); 1 x CAN (CAN bus monitoring); 8 x analog out; 4 x analog In, 4 x digital Out (DC-isolated); 5 x digital In (DC-isolated)
Measurement Range	**THC:** 0-30,000 ppmC1 **NO/ NO2:** 0-5000 ppm (NO) 0-2500 ppm (NO2) **CO/ CO2:** 0-5 vol% (CO), 0-20 vol% (CO2)
Zero Drift	**THC:** < 1,5 ppmC1/8h **NO/** **NO2:** 2ppm/8h **CO:** 20ppm/8h **CO2:** 0,1 vol%/8h
Sample flow rate	< 3.5l/min
Pneumatics Inputs/ Outputs	ZERO gas, SPAN gas, burner gas for HFID, sample gas IN, exhaust and drainage OUT

The AVL M.O.V.E PM PEMS combines the time resolved photo-acoustic soot measurement principle with a gravimetric PM measurement which operates with a gravimetric filter. The time-resolved particulate (PM) emissions are calculated by weighing the loaded gravimetric filter after the end of the test and using additionally the time resolved soot signal and the exhaust mass flow as inputs.
The instrument consists of below main components:

- The Micro Soot Sensor measuring unit (MSS) which is designed for continuous measurement of soot concentrations

Table 5 AVL Micro Soot Sensor specification

AVL 483 Micro Soot Sensor	
MEASURING UNIT	
Measured value:	Concentration of soot (mg/m3, µg/m3) in the diluted exhaust gas
Measuring range:	0 – 50 mg/m3
Display resolution:	0,001 mg/m3
Detection limit:	~ 5 µg/ m3
Turndown ratio:	1 : 5.000
Data rate:	Digital: 10 Hz Analog: 100 Hz
Rise time:	≤ 1 sec
Operation temperature:	5°C to 43°C
Probe/Bypass flow:	~ 2 + 2 l/min
Interfaces:	RS232, Digital I/O, Analog I/O, Ethernet
Laser class:	Class 1 laser product
CONDITIONING UNIT	
Dilution ratio (DR):	Adjustable from 2 – 10 and from 10 – 20
The actual DR will be displayed with the	accuracy noted below
Data rate:	Digital: max. 5 Hz Analog: 50 Hz
Accuracy (DR display):	max. ± 3% in the range of DR [2..10], max. ± 10 % in the range of DR [10..20]
Power supply:	90…230V, 50/60 Hz
Pressurized air:	Input pressure 1 ± 0,2 bar over pressure Flow: > 41/min
Exhaust gas temperature:	Up to 1000°C
Exhaust gas back pressure	Up to 2000 mbar
Pressure pulsation:	± 1000 mbar, but max. 50% of exhaust gas back pressure (intermediate pressure)
Blow by amount:	Dep. on pressure, ~ 20 l/min at 1000 mbar
Power supply:	90…240V AC, 50/60Hz, 500VA
Unit dimensions:	Measuring unit: W x H x D ~ 19” x 5HE x 530 mm Conditioning unit: W x H x D ~ 19” x 5HE x 530 mm
Unit weight:	Measuring unit: ~20 kg Conditioning unit: ~ 12 kg

- The Gravimetric Filter Module (GFM) which provides total PM using the gravimetric filter method.

Table 6 AVL M.O.V.E PM PEMS specification

AVL M.O.V.E PM PEMS 494	
Operating temperature	5 to 40°C
Storage temperature	-40 to +70°C
Ambient rel. humidity	Corr. max. humidity of 95% at 25°C
Dimensions	appr. 19"*430*540 mm (w*h*d*)

Weight	appr. 45 kg
Warm-up time at 20°C ambient temperature	<<1/2 hr
Power Demand/Operating Voltage	appr. 400W (after warm-up), the PM PEMS can be operated either with 24 VDC or 110 VAC
Exhaust inlet pressure tolerance:	-80 mbar to +60 mbar (for higher pressures an optional available high pressure reduction module is required)
Data logging frequency	1 Hz standard, 5 Hz for selected values
Interfaces	Analog (0 -10V, 4 Out/ 2 In), 4 Digital In, 4 Digital out, 1 TCP/IP
Dilution ratio (constant)	up to DR=20
Dilution ratio (proportional)	DR=2 to 100
Sample flow over filter	6 lpm
Filter holder	47mm, measurement and backup filter; Geometry acc. to CFR 40 §1056
Soot measuring range	up to 1000 mg/m3 (at DR=20)
Soot detection limit	~ 5 µg/m³
rise time of soot signal	≥ 1 sec

The instruments are operated in combination with an electronic vehicle exhaust flow meter, Sensors EFM-HS. The M.O.V.E. instrument uses the flow data together with exhaust component concentrations to calculate instantaneous and total mass emissions. The flow meter is available in different sizes depending on engine size of the tested machine.

On-road measurement test routes

Euro VI route for N3 vehicles

The test route used for N3 vehicles is designed to meet the requirements specified by the regulation. Depending on the engine power of the tested vehicle, each share of operation (urban, rural, motor way) can be varied in order to optimize the trip length.

According to the requirements shall the PEMS trip be long enough to complete five times the work performed during the WHTC or produce five times the CO_2 reference mass in kg/cycle from the WHTC.
For N3 vehicles, the shares of operation, expressed as a percentage of the total trip duration, shall be:

- Urban driving (0-50 km/h): 20 %
- Rural driving (50-75 km/h):25 %
- Motorway driving (> 75 km/h): 55 %

Figure 4 shows the approximate velocity and altitude profile.

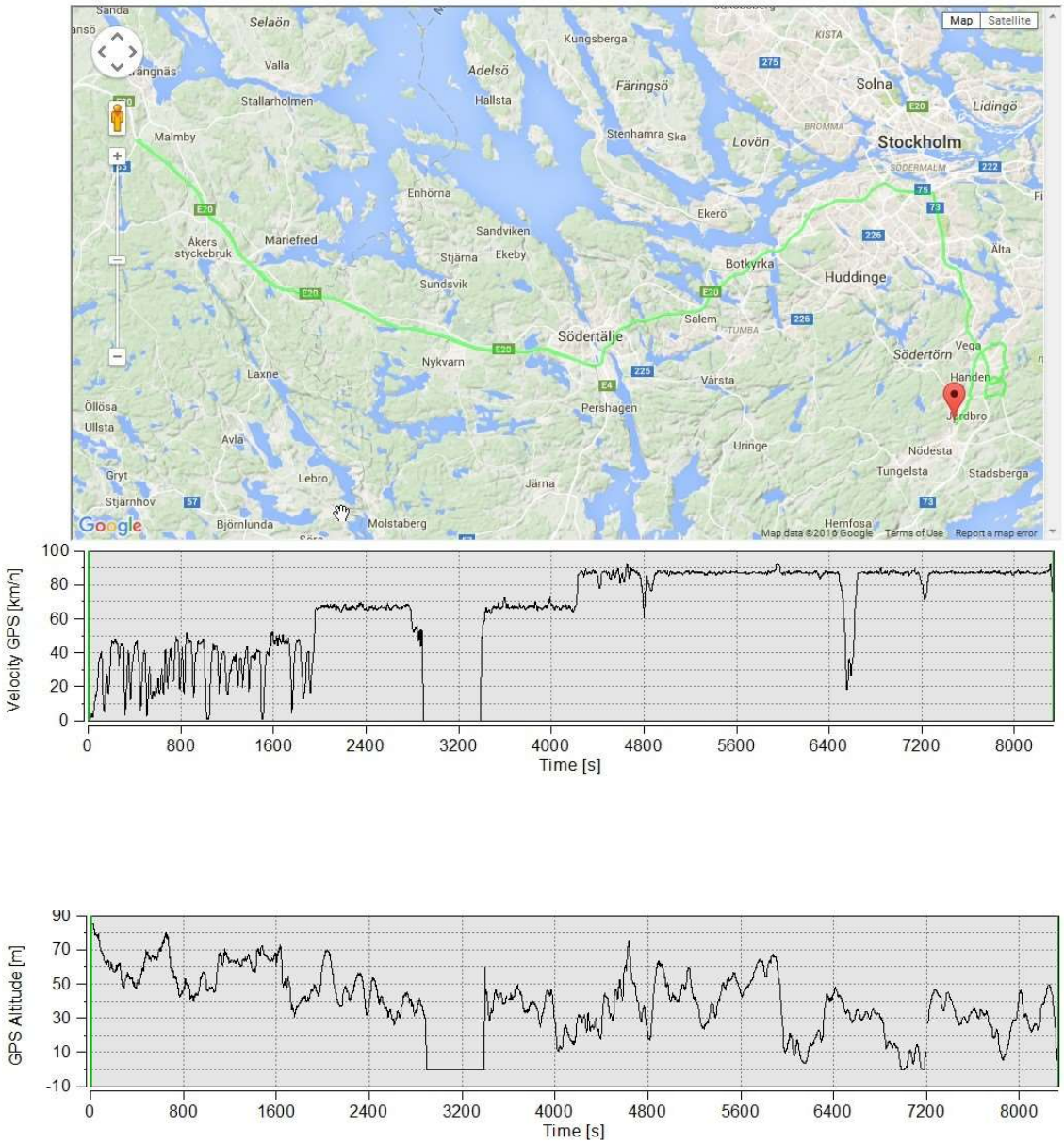


Figure 4 Characteristics of the Euro VI N3 route

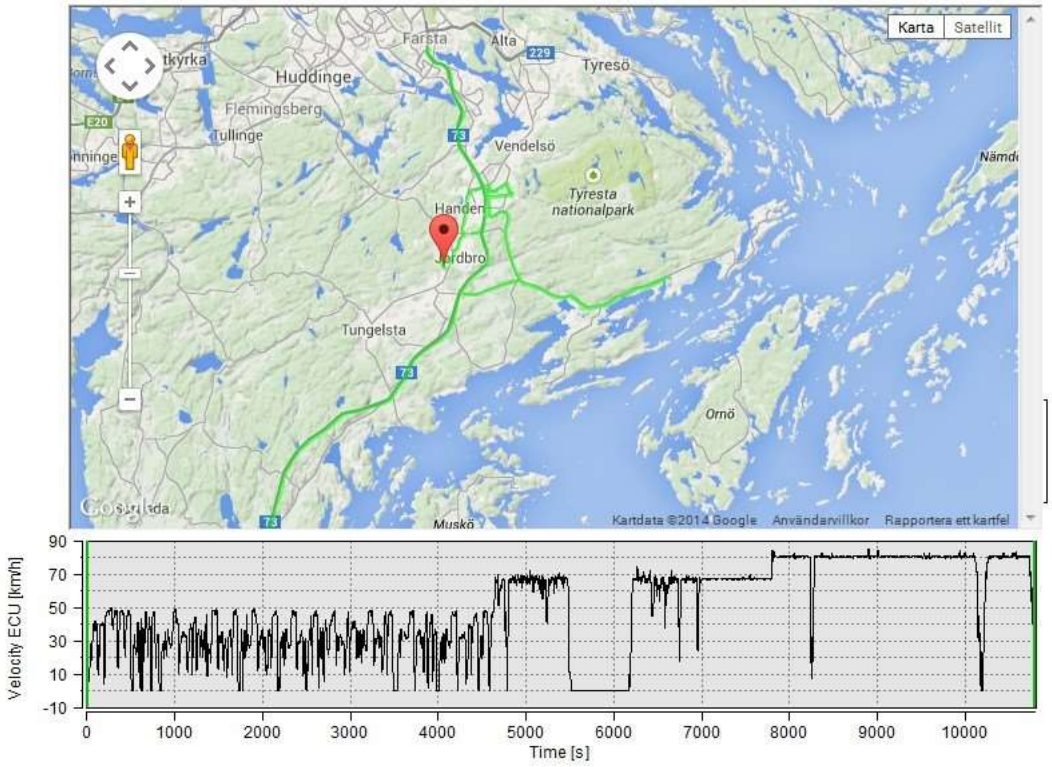
Euro VI route for N1, N2, M1, M2 and M3 vehicles

The test route used for N1, N2, M1, M2 and M3 vehicles is designed to meet the requirements specified by the regulation. Depending on the engine power of the tested vehicle, each share of operation (urban, rural, motor way) can be varied in order to optimize the trip length.

According to the requirements shall the PEMS trip be long enough to complete five times the work performed during the WHTC or produce five times the CO_2 reference mass in kg/cycle from the WHTC.
For N1, N2, M1, M2 and M3 vehicles, the shares of operation, expressed as a percentage of the total trip duration, shall be:

- Urban driving (0-50 km/h): 45 % ○ Rural driving (50-75 km/h):25 %
- Motorway driving (> 75 km/h): 30 %

Figure 5 shows the approximate velocity and altitude profile.



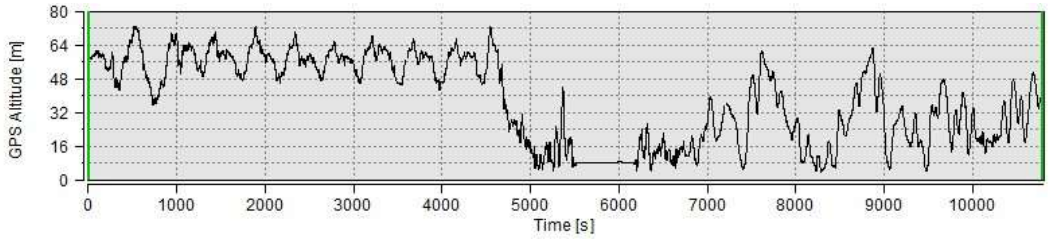


Figure 5 Characteristics of the Euro VI route for N1, N2, M1, M2 and M3 vehicles

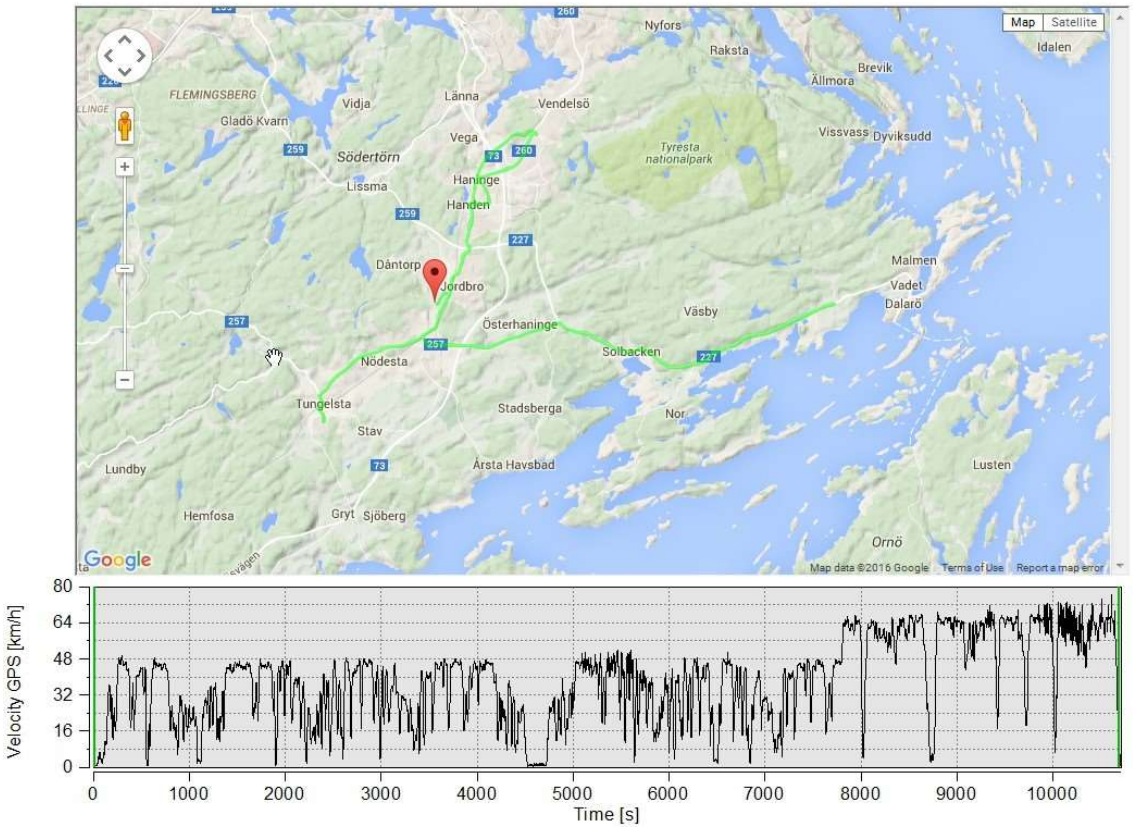
Euro VI route for M2 and M3 vehicles of class I, II, or A

The test route used for M2 and M3 vehicles of class I, II, or A is designed to meet the requirements specified by the regulation. Depending on the engine power of the tested vehicle, each share of operation (urban, rural, motor way) can be varied in order to optimize the trip length.

According to the requirements shall the PEMS trip be long enough to complete five times the work performed during the WHTC or produce five times the CO_2 reference mass in kg/cycle from the WHTC.
For M1 and M2 vehicles of class I, II, or A, the shares of operation, expressed as a percentage of the total trip duration, shall be:

- Urban driving (0-50 km/h): 70 % ○ Rural driving (50-75 km/h):30 %
- Motorway driving (> 75 km/h): 0 %

Figure 6 shows the approximate velocity and altitude profile.



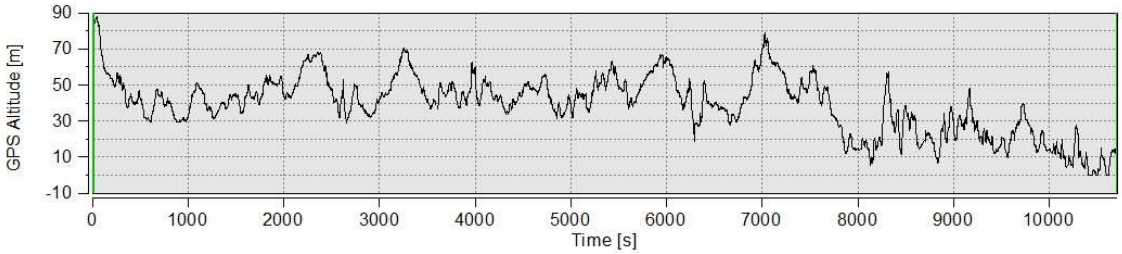


Figure 6 Characteristics of the Euro VI route for M2 and M3 vehicles of class I, II, or Class A

Test Fuel

For all diesel vehicles, commercially available fuels fulfilling the specification of Environmental class 1 diesel (Mk1) has been used. Swedish MK1 fuel is a low sulphur diesel i.e. less than 10 ppm, and has a boiling point interval of 180-290°C. The fuel consists of 50-70% parafines, 30-45% naphtenes and 3-5% aromatics.

Two vehicles were fuelled with CNG (Compressed Natural Gas). The CNG used was commercially available CNG which consists of approximately 80 % methane. CNG has an energy content of 13 kWh/kg.

One vehicle was fuelled with hydrogenated vegetable oil diesel (HVO).

Vehicle A

A delivery truck, Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.
For chassis dynamometer tests, there are no legal requirements for this type of vehicle but the WHTC engine test emission limits are in this investigation used as “fictive” pass/fail criteria. These emission limits are also used for evaluation of PEMS test results where all events have been evaluated. For PEMS testing is also the In Service Conformity (ISC) pass/fail criteria used, where conformity factors limits for gaseous emissions have been established.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions were a little high in the WHVC cold start, however very low in all warm start tests resulting in a weighted average below the Euro VI limit. The ammonia emissions measured were low.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, were below the limit.

Experimental

Vehicle

Model year:	2014
Vehicle category:	N3
Vehicle type:	Delivery truck
Mileage:	112 000 km
Engine:	6-cylinder
Displacement:	10 700 cm^3
Fuel:	Diesel
Power:	~ 300 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	27 000 kg
Mass in running order (vehicle):	12 200 kg
Maximum payload:	14 800 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 21st and 29th of April 2016.

Table A1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	20 354	(≈8 200)
WHVC	2	3	20 354	(≈8 200)
PEMS Euro VI N3 route	3	-	-	8 000

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 1150 N
- A1: 63 N/(km/h)
- A2: 1.85 N/(km/h)^2

The simulated vehicle payload during the tests on the chassis dynamometer made 55% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 54 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors was performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

During the first PEMS test, no PM was measured.

Ambient conditions during PEMS testing

Test 1 (2016-04-21):

- Trip average RH: 48 %
- Trip average ambient temperature: 13 °C

Test 2 (2016-04-22):

- Trip average RH: 67 %
- Trip average ambient temperature: 9 °C

Test 3 (2016-04-23):

- Trip average RH: 60 %
- Trip average ambient temperature: 9 °C

On Board Diagnostics (OBD)

No diagnostic trouble codes from the OBD system.

Emission test results

The ISC NO_X and PM results for both PEMS tests are presented in Figure A1 and Figure A1 respectively. CO and THC conformity factors are insignificantly small. NO_X conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows in all tests. Calculated PM conformity factors also meet the legislative criteria.

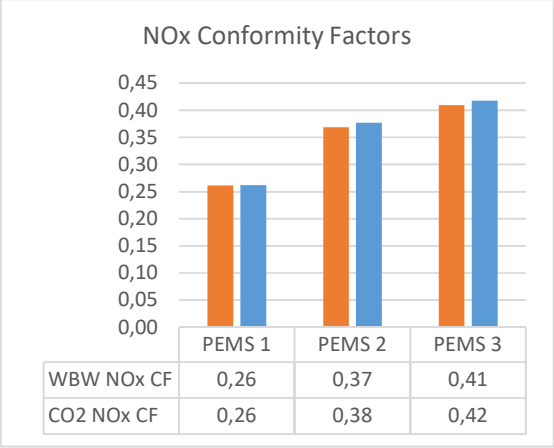


Figure A1. Work and CO2 based NOx conformity factors for the PEMS tests.

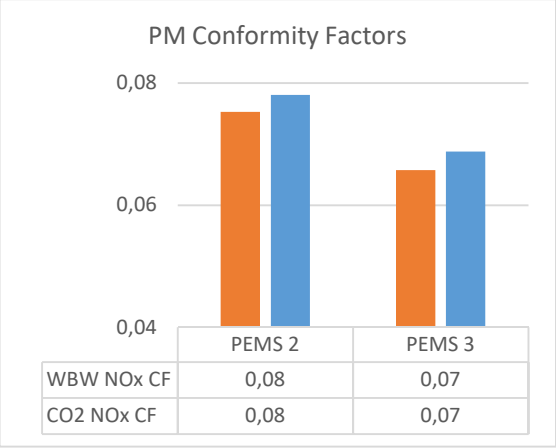


Figure A1. Work and CO2 based PM conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are below the Euro VI limit of 4 g/kWh. No CO was detected during the PEMS tests.

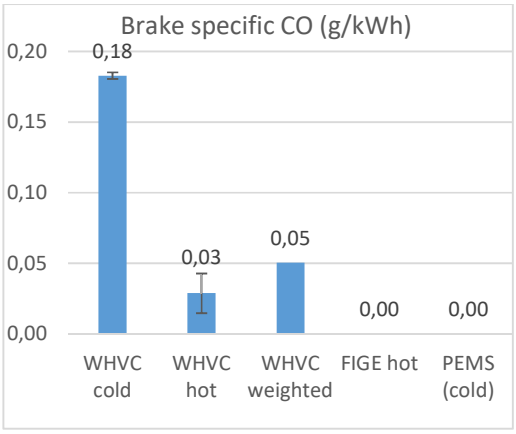


Figure A2. Avg. brake specific CO emissions (g/kWh)

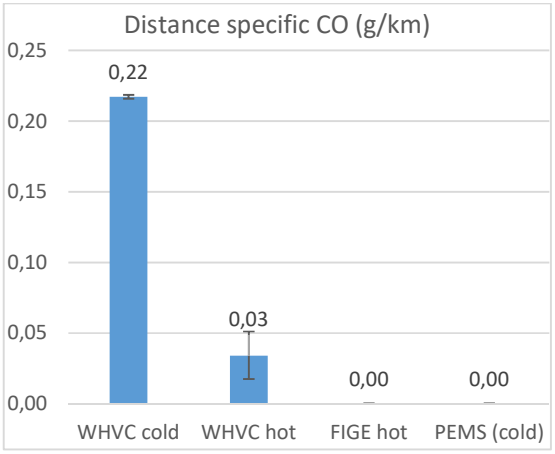


Figure A3. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure A4 and Figure A5. Emitted THC is way below the Euro VI legislative limit of 0.16 g/kWh.

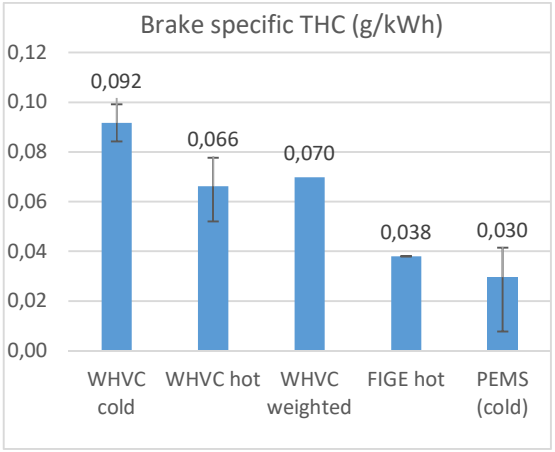


Figure A4. Avg. brake specific THC emissions (g/kWh)

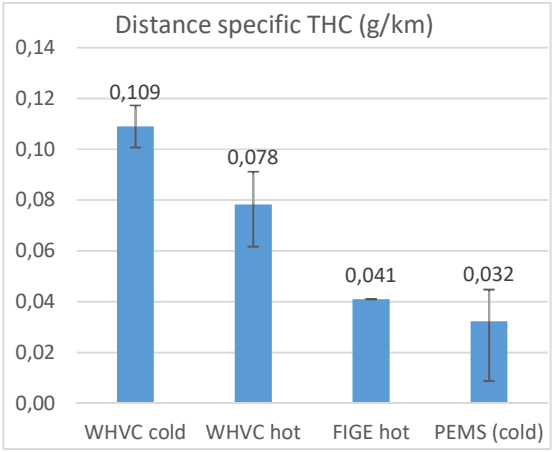


Figure A5. Avg. distance specific THC emissions (g/km)

Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS tests. Results indicate raised emissions of NO_X for the WHVC cold start however, the weighted average, is below the Euro VI limit.

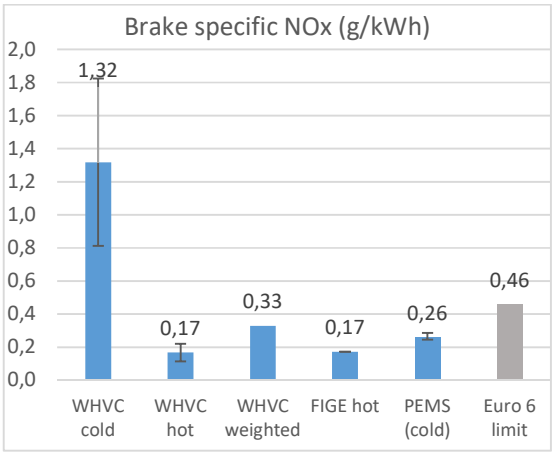


Figure A6. Avg. brake specific NO_x emissions (g/kWh)

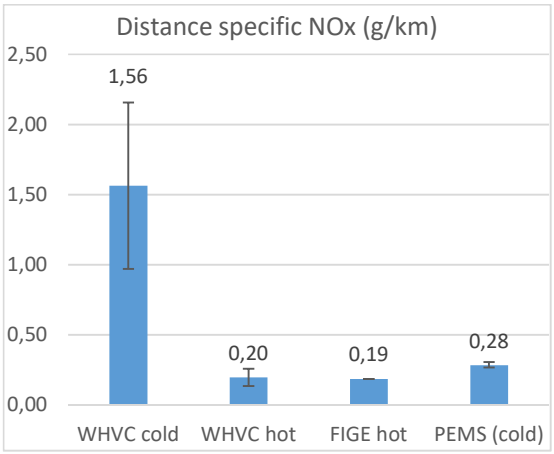


Figure A7. Avg. distance specific NO_x emissions (g/km)

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. As stated previously, PEMS PM measurement was carried out only during the second and third trip. Particle emissions are within the same ranges for the different tests, and well below the legislative limits.

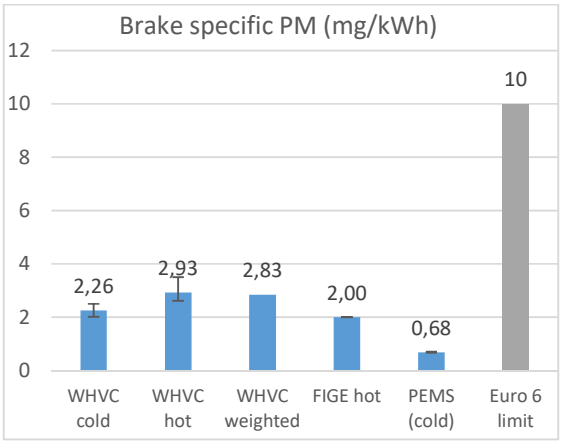


Figure A8. Avg. brake specific PM emissions (mg/kWh)

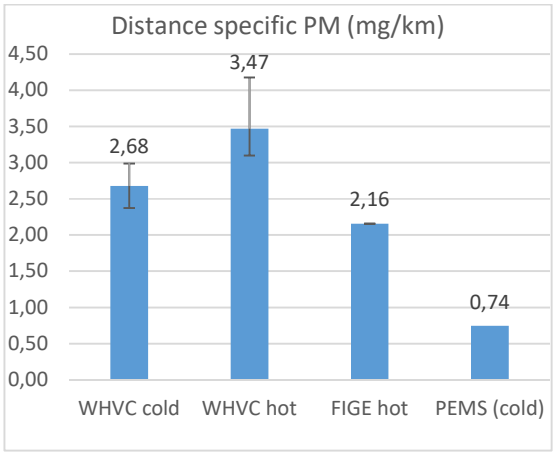


Figure A9. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. All results are lower than the Euro VI particle number limit. The number of emitted particles are higher for WHVC cold start tests.

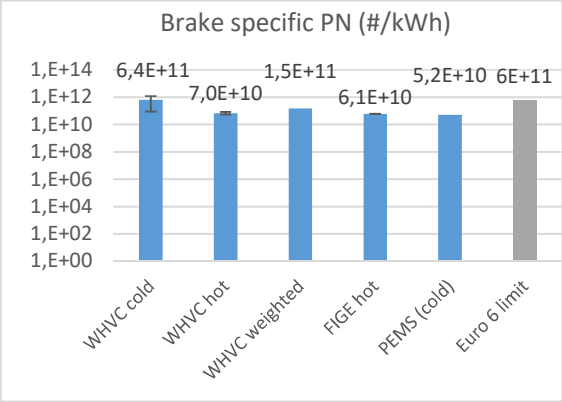


Figure A10. Avg. brake specific PN emissions (#/kWh)

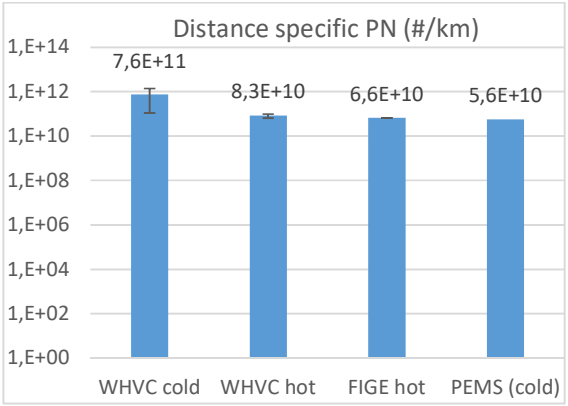


Figure A11. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to Figure A15.

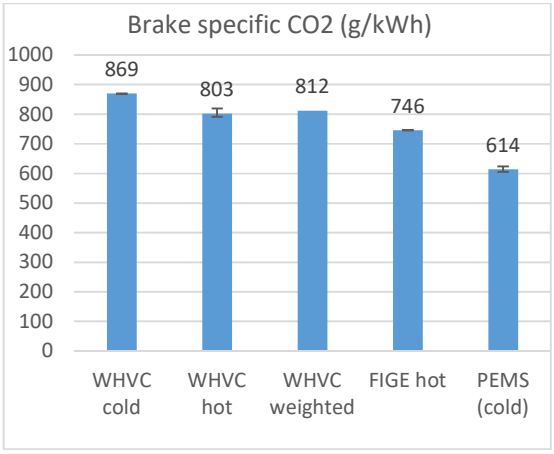


Figure A12. Avg. brake specific CO_2 emissions (g/kWh)

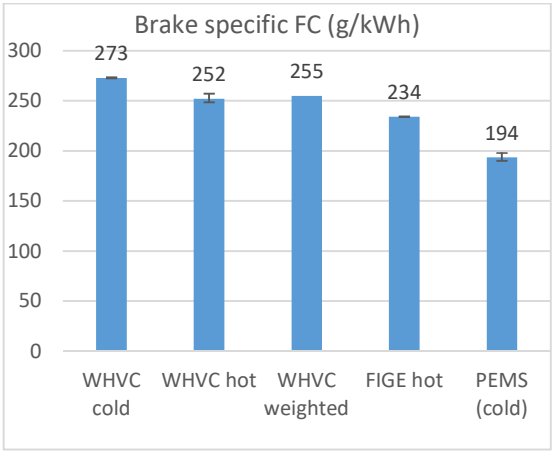


Figure A13. Avg. brake specific FC (g/kWh)

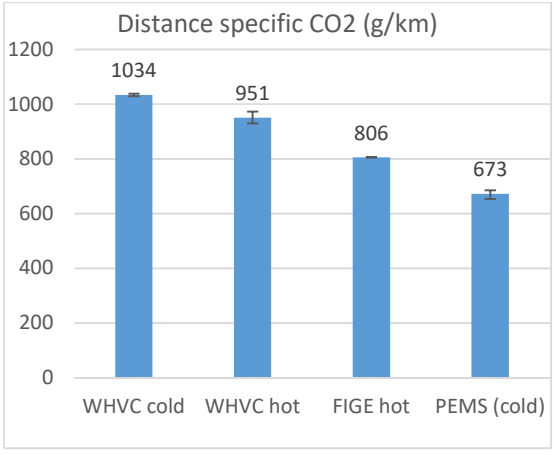


Figure A14. Avg. distance specific CO_2 emissions (g/km)

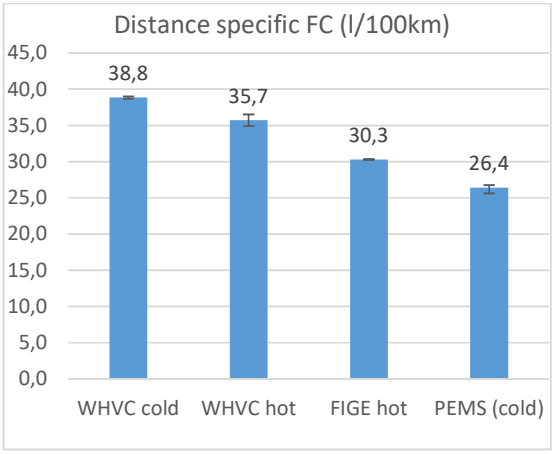


Figure A15. Avg. distance specific FC (l/100km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure A16.

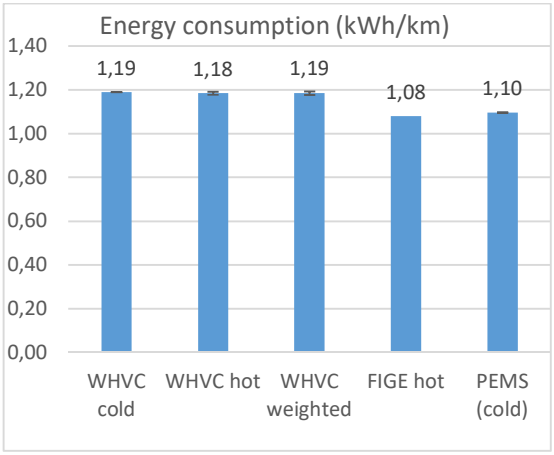


Figure A16. Avg. energy consumption (kWh/km)

Finally, Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are well below the Euro VI regulatory limit of 10 ppm.

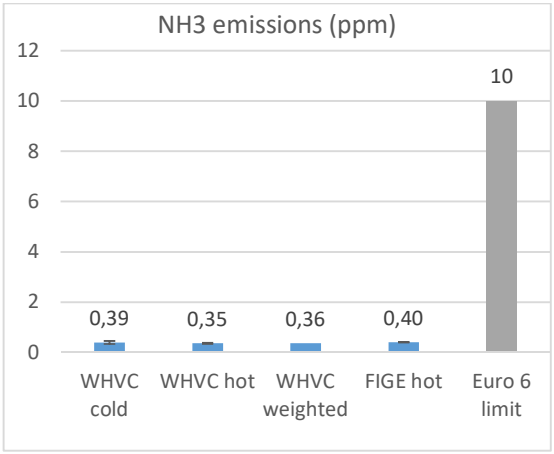


Figure A17. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions were a little high in the WHVC cold start, however very low in all warm start tests resulting in a weighted average below the Euro VI limit. The ammonia emissions measured were low.

No malfunction was indicated by the OBD system.

Vehicle B.

A delivery truck, Euro VI, model year 2014, has been tested for exhaust emissions and fuel consumption. A series of tests were carried out by both driving pre-defined cycles on chassis dynamometer and driving on Swedish roads with a portable emissions measurement system (PEMS) on board.

There are no emission regulations on heavy duty chassis dynamometer tests, hence, the WHTC engine test emission limits are used in this investigation as “fictive” pass/fail criteria. The same emission limits are also applicable for PEMS test results where all events have been evaluated. Furthermore, the In Service Conformity (ISC) pass/fail criteria with given conformity factors limits were assessed in the PEMS result analysis. All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

It can be concluded that measured emission levels of CO, THC, NH_3, PM and PN all meet the regulatory Euro VI WHTC limitations. However, NO_X emissions reach beyond the 0.46 g/kWh limit during all tests.

Experimental

Vehicle

Model year:	2014
Vehicle category:	N3
Vehicle type:	Delivery truck
Mileage:	65 000 km
Engine:	6-cylinder
Displacement:	12 419 cm^3
Fuel:	Diesel
Power:	~ 320 kW
Exhaust after treatment:	SCRT
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	26 000 kg
Mass in running order (vehicle):	10 000 kg
Maximum payload:	16 000 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 3d and 12th of May 2016.

Table B 1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
WHVC	2	1	18 094	(≈8 050)
PEMS Euro VI N3 route	2	-	-	8 250

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 1150 N
- A1: 63 N/(km/h)
- A2: 1.85 N/(km/h)^2

The simulated vehicle payload during the tests on the chassis dynamometer made 50% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 52 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors were performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-05-03):

- Trip average RH: 34 %
- Trip average ambient temperature: 20 °C

Test 2 (2016-05-04):

- Trip average RH: 41 %
- Trip average ambient temperature: 19 °C

On Board Diagnostics (OBD)

The ABS sensor configuration of the vehicle caused problems during the chassis dynamometer testing and assistance from the manufacturer was needed in order to perform the testing. The ABS-related fault codes set by the OBD system where deleted by the manufacturer.

Emission test results

The ISC NO_X and PM results for both PEMS tests are presented in Figure A1 and Figure A1 respectively. CO and THC conformity factors are insignificantly small. NO_X conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows. Calculated PM conformity factors also meet the legislative criteria.

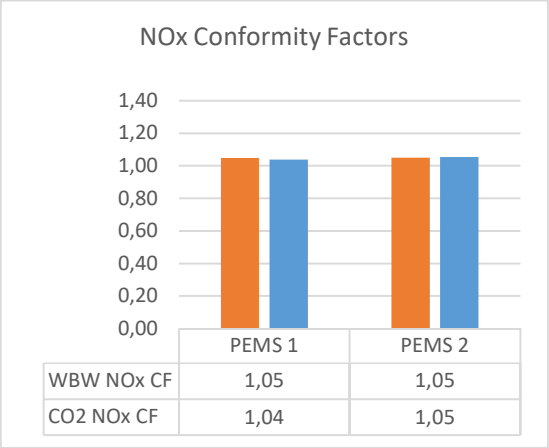


Figure 18. Work and CO2 based NOx conformity factors for the PEMS tests.

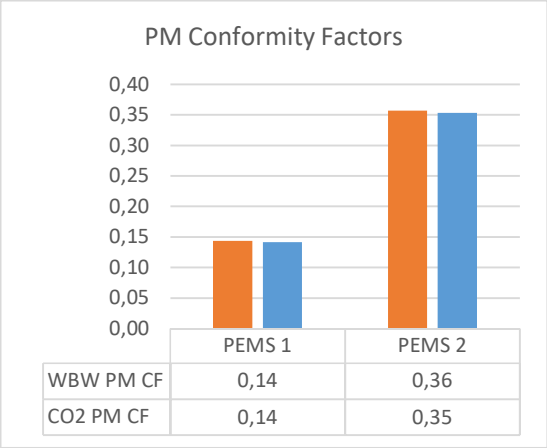


Figure 19. Work and CO2 based PM conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are far below the Euro VI limit of 4 g/kWh.

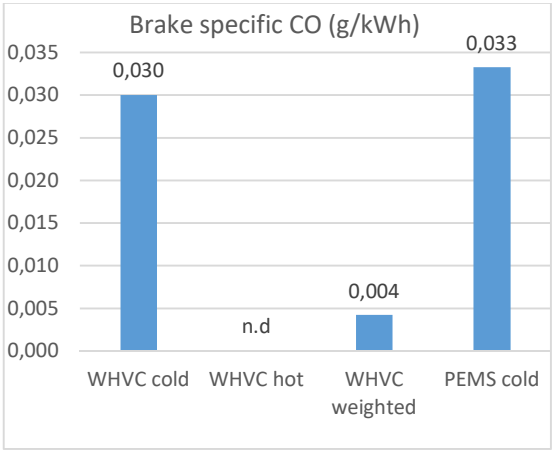


Figure B3. Avg. brake specific CO emissions (g/kWh)

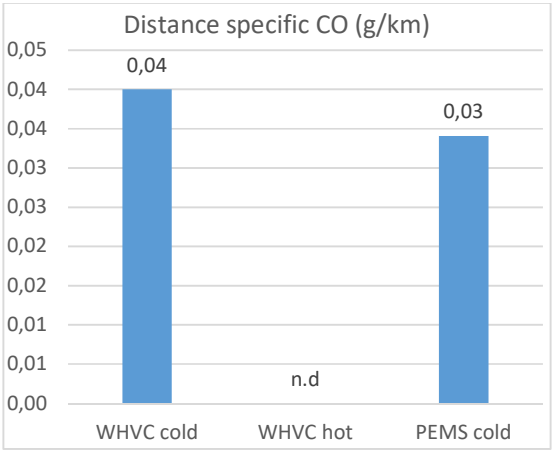


Figure 20. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure A4 and Figure A5. Emitted THC is below the Euro VI legislative limit of 0.16 g/kWh.

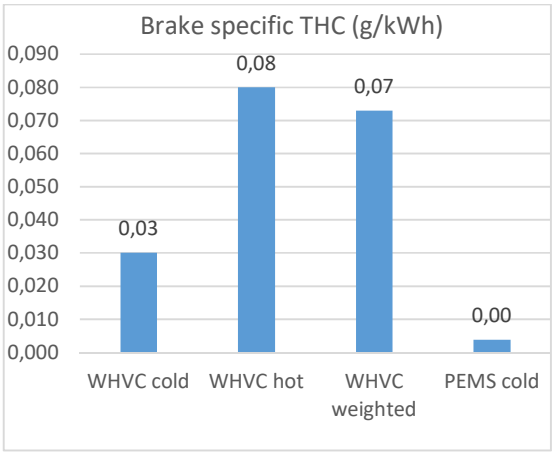


Figure B5. Avg. brake specific THC emissions (g/kWh)

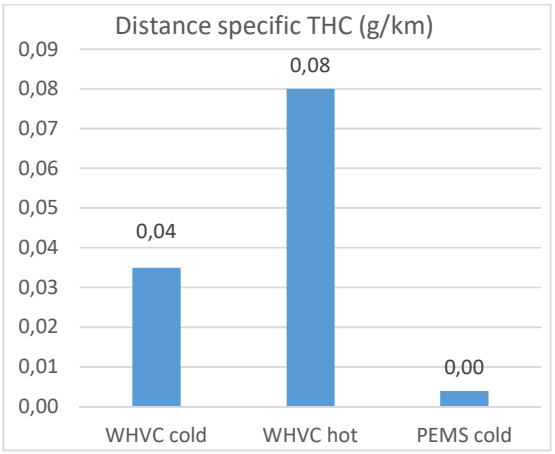


Figure 21. Avg. distance specific THC emissions (g/km)

Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS tests. Results indicate relatively high emissions of NO_X, exceeding the Euro VI limit during all tests.

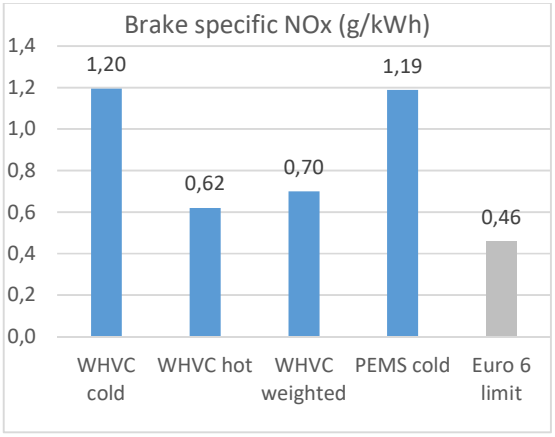


Figure 22. Avg. brake specific NO_X emissions (g/kWh)

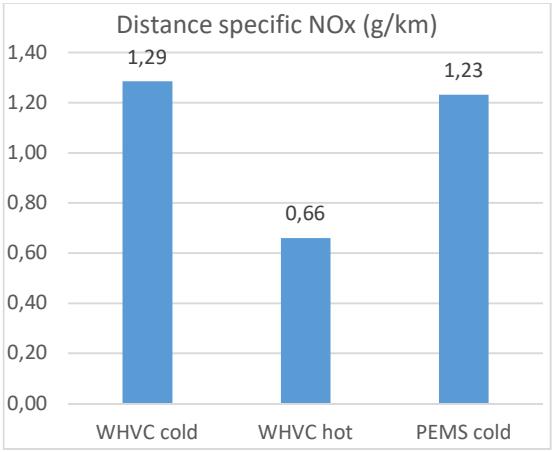


Figure B8Avg. distance specific NO_X emissions (g/km)

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. Particle emissions are within the same ranges for the different tests, and safely under the legislative limits.

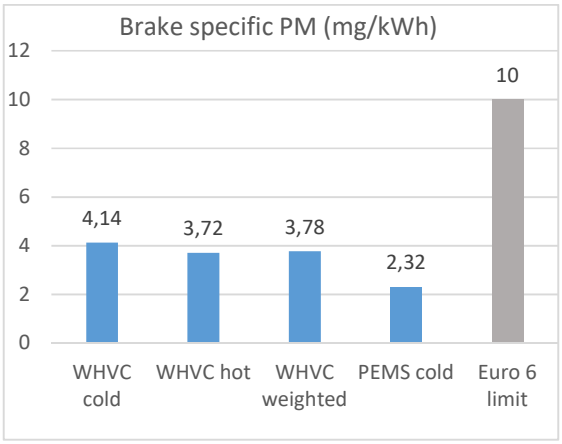


Figure 23. Avg. brake specific PM emissions (mg/kWh)

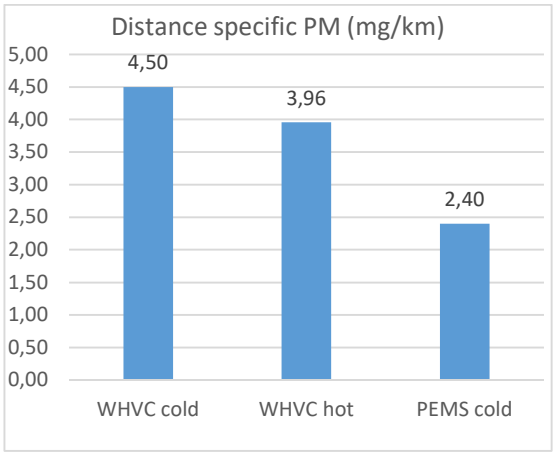


Figure 24. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. The number of emitted particles are higher for WHVC cold start tests, however the weighted result is below the Euro VI particle number limit

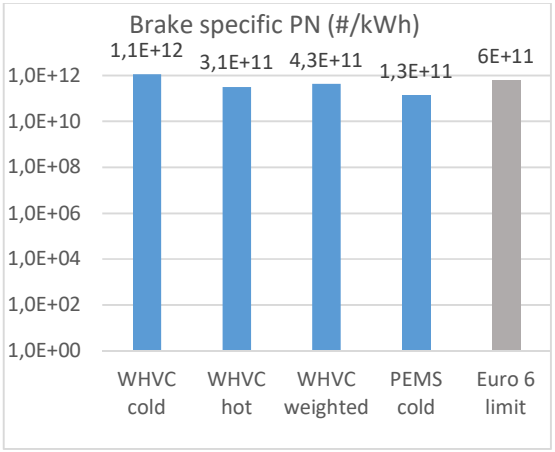


Figure 25. Avg. brake specific PN emissions (#/kWh)

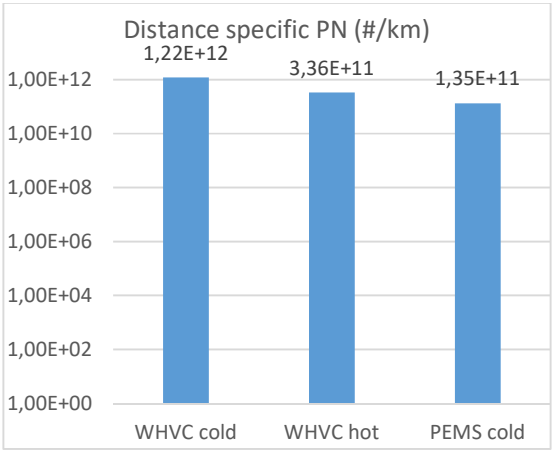


Figure 26. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to Figure A15.

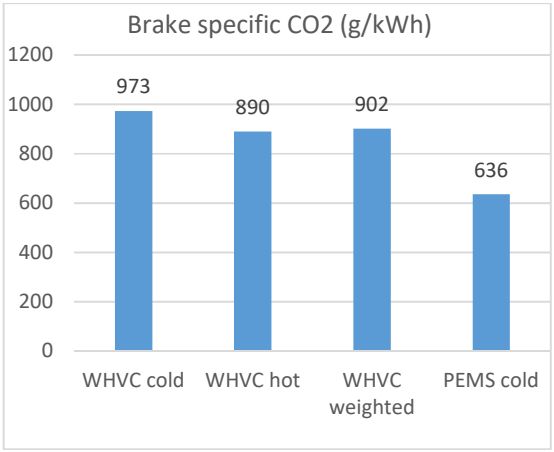


Figure 27. Avg. brake specific CO_2 emissions (g/kWh)

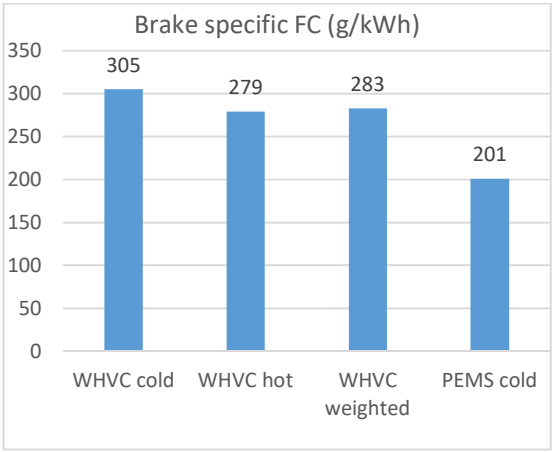


Figure B14. Avg. brake specific FC (g/kWh)

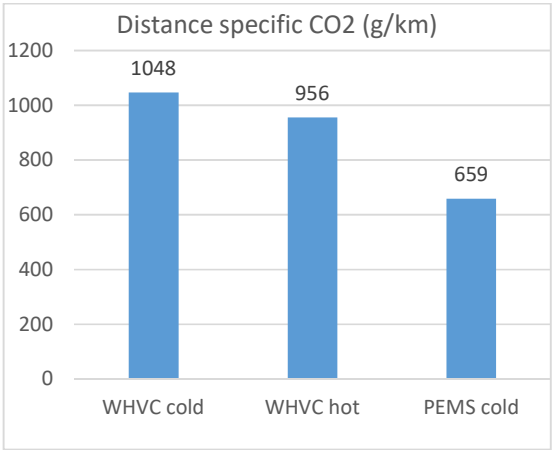


Figure B15. Avg. distance specific CO_2 emissions (g/km)

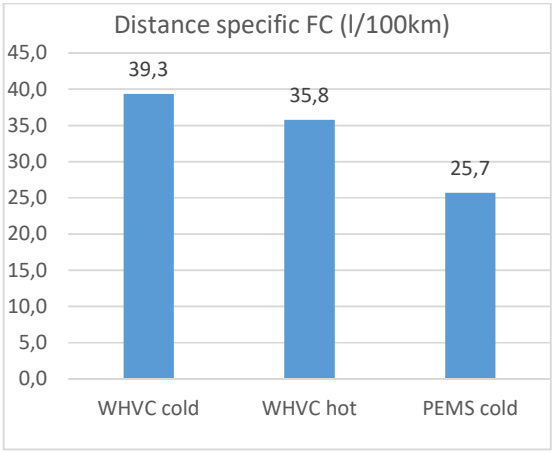


Figure 28. Avg. distance specific FC (l/100km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure A16. Energy consumption for the chassis dynamometer tests agree very well while the slightly higher result for the PEMS tests is mainly a consequence of added vehicle payload.

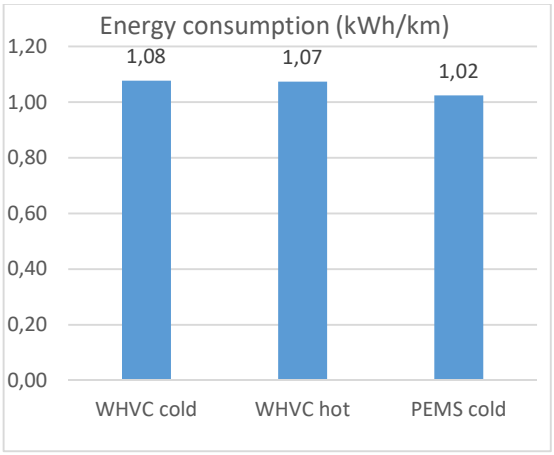


Figure 29. Avg. energy consumption (kWh/km)

Finally, Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are well below the Euro VI regulatory limit of 10 ppm.

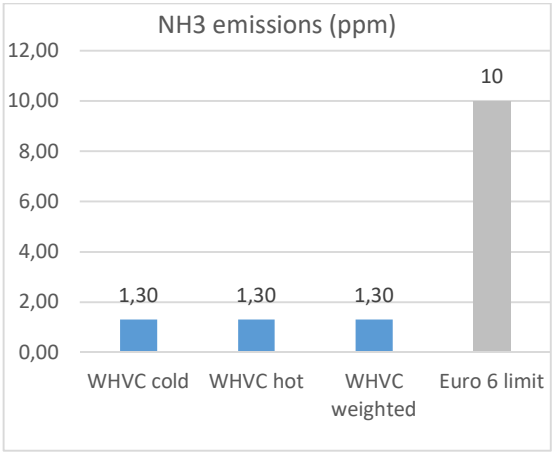


Figure 30. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.
All measured emission levels of CO, THC, NH_3, PM and PN meet the regulatory Euro VI WHTC limitations. However, NO_X emissions reach beyond the 0.46 g/kWh limit during all tests.
ABS-related fault codes were indicated by the OBD system.

Vehicle C

Vehicle

Model year:	2014
Vehicle category:	N3
Vehicle type:	Heavy duty truck
Mileage:	40600 km (116000 km in 2015)
Engine:	8-cylinder
Displacement:	16 litres
Fuel:	Diesel
Power:	~ 550 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF
Transmission:	Automatic
Gross Vehicle Mass (GVM):	14 100 kg + 10 300 (trailer)
Maximum payload:	55 000 kg
Test weight:	24 400 – 80 000 kg
Emission standard:	Euro VI

Fuel

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1).

On-road test route

The on-road testing was performed the 15th of May 2016 at an average temperature and humidity of 7 °C and RH 80 % respectively. The vehicle were driven between Edsvära and Övertorp, Skaraborg, Sweden. However, it must be emphasised that the vehicle were tested during a normal working day. Thus, the driving pattern and load does not fulfil the requirements of an Euro VI test route. Presented results originates from the total test route consisting of cold start with no load (24 400 kg), hot start with load and hot start with no load. In addition the sub trip emissions has been calculated.

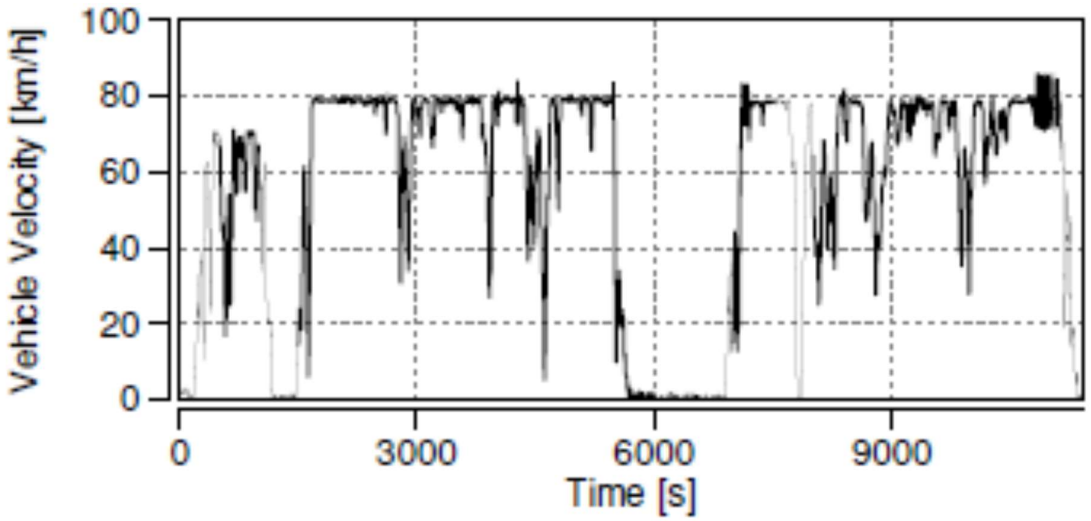


Figure C1. Test trip driving pattern.

Main characteristics of the test route:

- Approximate trip duration: 11 400 seconds (approx. 3h, 25 min)
- Average trip distance: 175 km
- Average speed: 55 km/h
- Average trip composition:
  - Urban driving: 1 %
  - Rural driving: 63 %
  - Highway driving: 36 %
  - Idle: 15 %

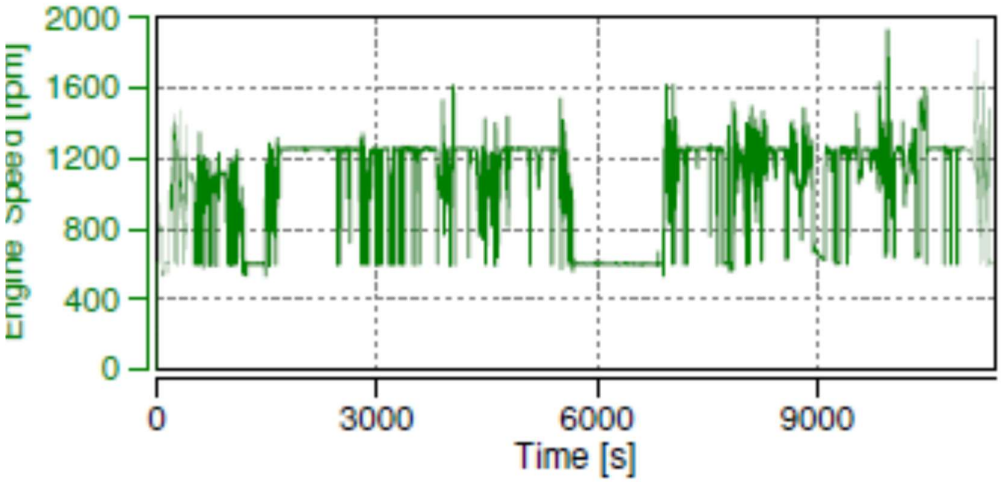


Figure C2. Test trip engine speed.

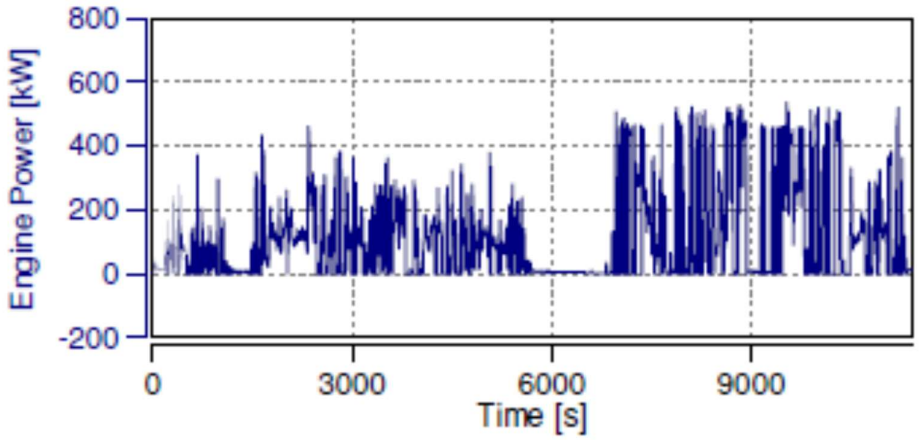


Figure C3. Test trip engine power.

No trouble code from the OBD system were detected. However, during the 2015 test there was an Exhaust sensor trouble code.

Results and conclusions

The test results from the on-road driving measurements are presented in Figure C4 – C6. The emissions of CO and HC were below the detection limit. PM and soot were not measured. During the complete test cycle the confirmatory factors of NOx varies from 0.77 to 0.84 for work based window and CO2 window respectively (maximum allowed value, 1.5).The NO_x emissions during the cold start phase were 3.9 g/kWh due to low SCR catalyst temperature but comparing with the result from 2015, 64 % lower emission were detected. When the exhaust after treatment system were fully warmed up the NO_x emission levels varies from 0.41 to 0.66 g/kWh i.e in the same order of magnitude compared to 2015 data. When comparing the fuel consumption it can be noted that 55 000 kg extra weight increases the consumption with 1.9 litres / 10 km (2.6 litres in the 2015 study)

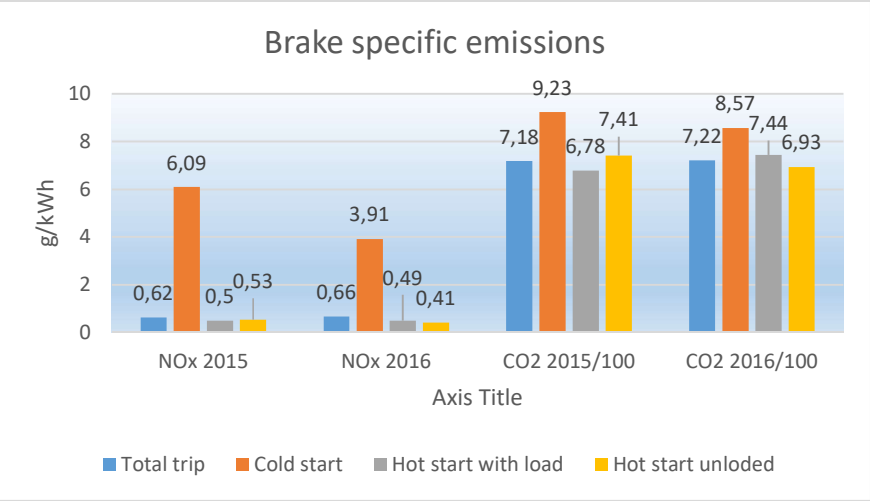


Figure C4. Brake specific emissions for the complete test and sub trips.

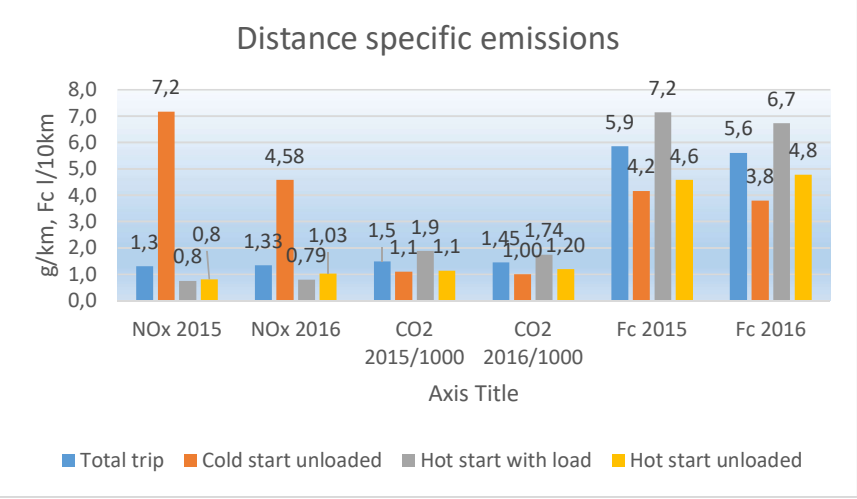


Figure C5. Distance specific emissions for the complete test and sub trips.

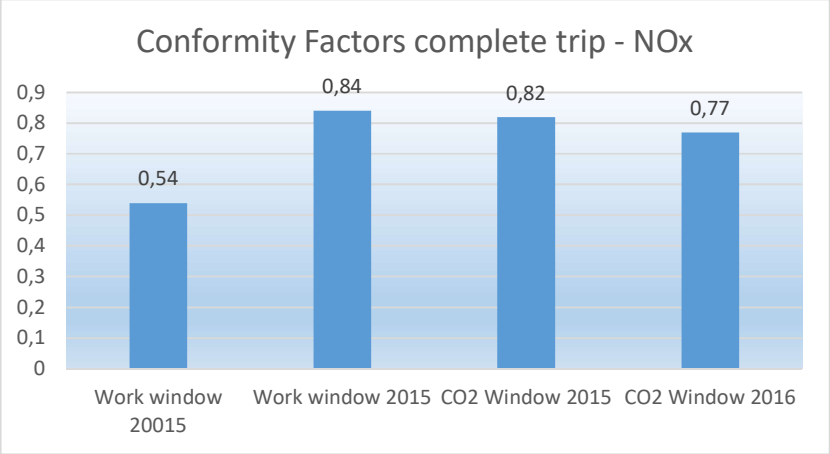


Figure C6. Conformity factors.

Vehicle D

Vehicle

Model year:	2014
Vehicle category:	N3
Vehicle type:	Delivery truck
Mileage:	50 000 km
Engine:	6-cylinder
Displacement:	6 900 cm^3
Fuel:	Diesel
Power:	~ 180 kW
Exhaust after treatment:	SCRT
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	15 500 kg
Mass in running order (vehicle):	8 500 kg
Maximum payload:	7 000 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 16th and 26th of May 2016.

Table D1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	12 670	(≈4 200)
WHVC	2	2	12 670	(≈4 200)
PEMS Euro VI N3 route	2	-	-	4 000

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 843 N
- A1: 59 N/(km/h)
- A2: 1.85 $N/(km/h)^2$

The simulated vehicle payload during the tests on the chassis dynamometer made 60% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 57 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors was performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

No PM was measured during the PEMS tests.

Ambient conditions during PEMS testing

Test 1 (2016-05-25):

- Trip average RH: 57 %
- Trip average ambient temperature: 16°C

Test 2 (2016-05-26):

- Trip average RH: 89 %
- Trip average ambient temperature: 11 °C

On Board Diagnostics (OBD)

The ABS sensor configuration of the vehicle caused problems during the chassis dynamometer testing. Assistance from the manufacturer was needed in order to perform the testing and ABS-related fault codes were set by the OBD system.

Emission test results

The ISC NO_X results for both PEMS tests are presented in Figure A1. CO and THC conformity factors are insignificantly small. NO_X conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows.

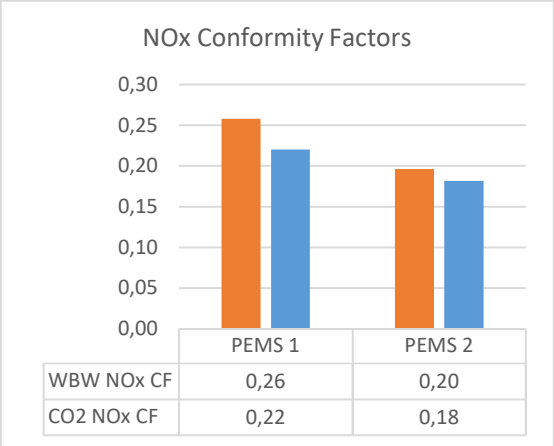


Figure 31. Work and CO2 based NOx conformity factors for PEMS tests.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are far below the Euro VI limit of 4 g/kWh. No CO was detected during the FIGE and the PEMS tests.

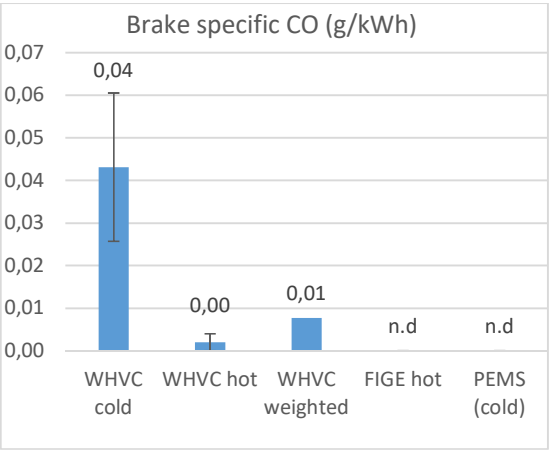


Figure 32. Avg. brake specific CO emissions (g/kWh)

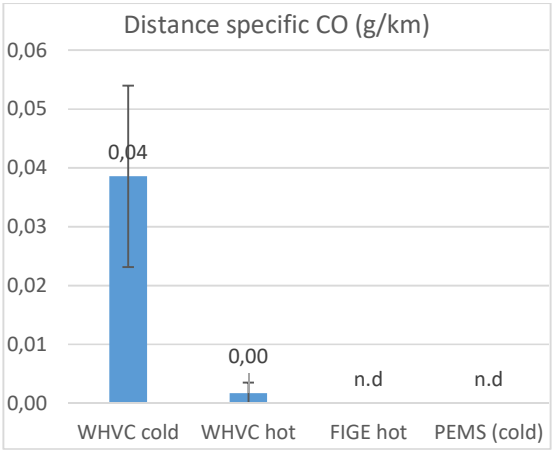


Figure 33. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure A4 and Figure A5. Emitted THC is below the Euro VI legislative limit of 0.16 g/kWh.

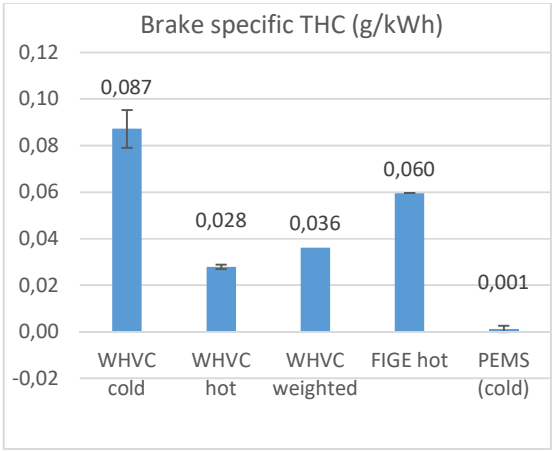


Figure 34. Avg. brake specific THC emissions (g/kWh)

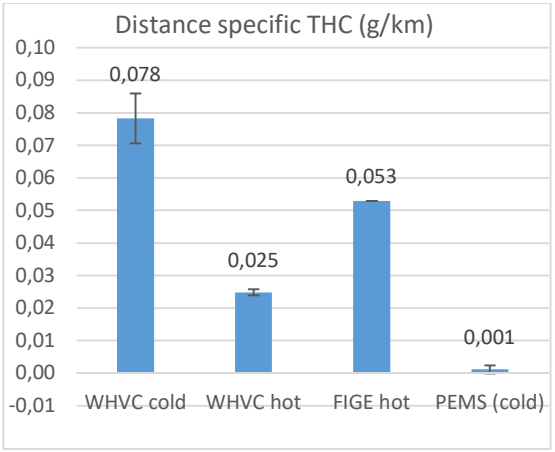


Figure D5. Avg. distance specific THC emissions (g/km)

Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS tests. Results indicate elevated emissions of NO_X for the WHVC cold start, however the weighted average and all other tests are below the Euro VI limit.

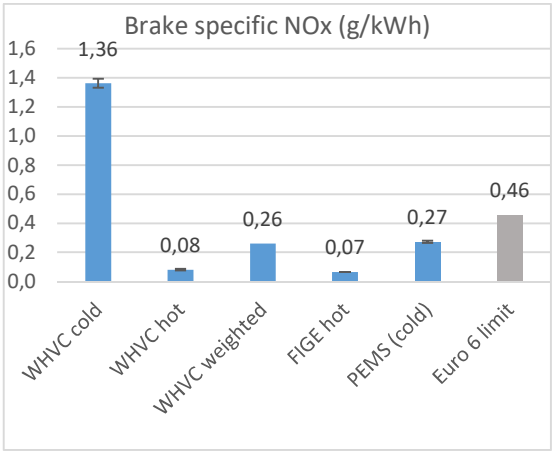


Figure 35. Avg. brake specific NO_X emissions (g/kWh)

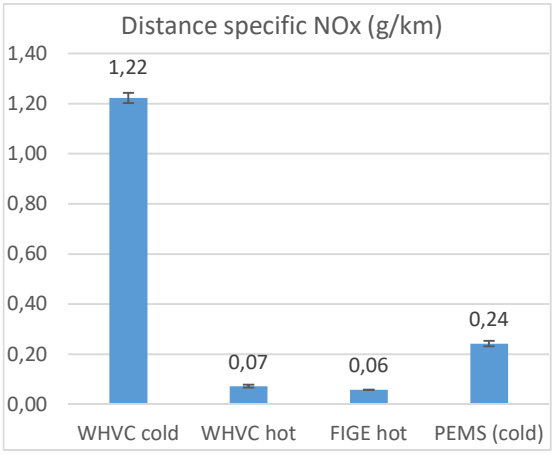


Figure 36. Avg. distance specific NO_X emissions (g/km)

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. Particle emissions are within the same ranges for the different tests, and safely under the legislative limits.

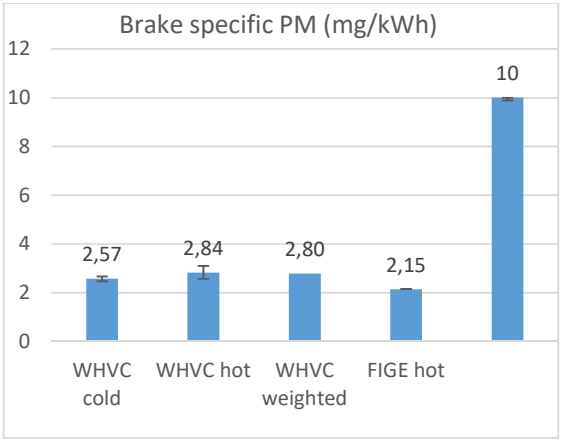


Figure 37. Avg. brake specific PM emissions (mg/kWh)

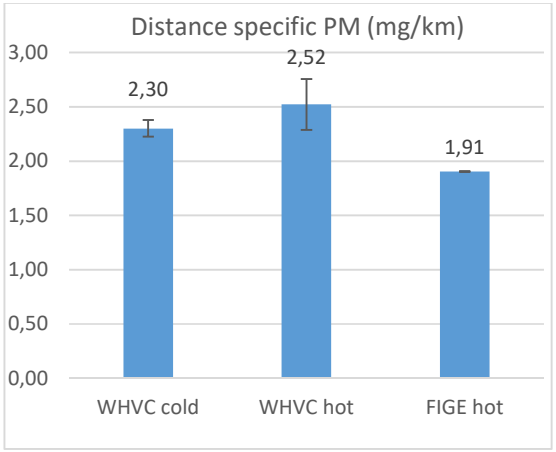


Figure 38. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. All results are lower than the Euro VI particle number limit. The number of emitted particles are higher for WHVC cold start tests.

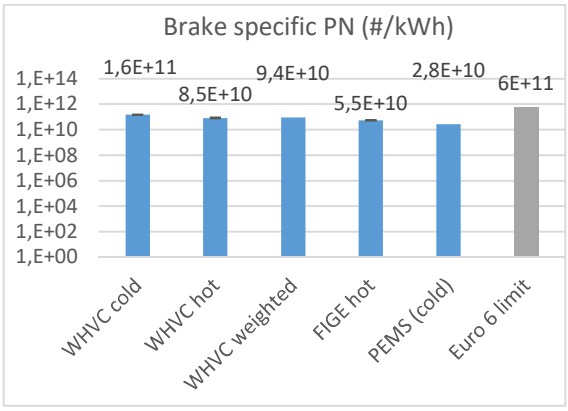


Figure 39. Avg. brake specific PN emissions (#/kWh)

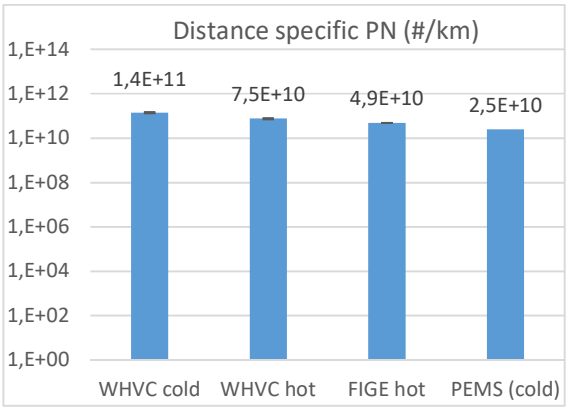


Figure 40. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to Figure A15.

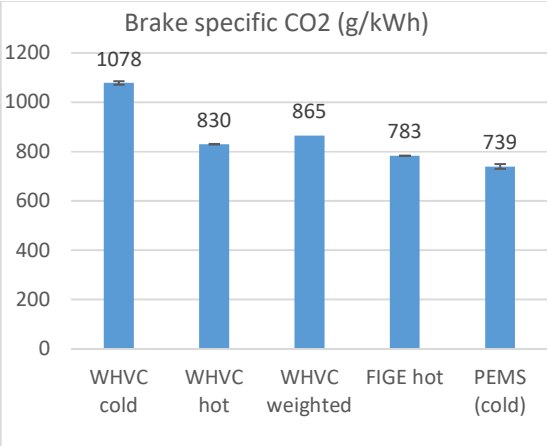


Figure 41. Avg. brake specific CO_2 emissions (g/kWh)

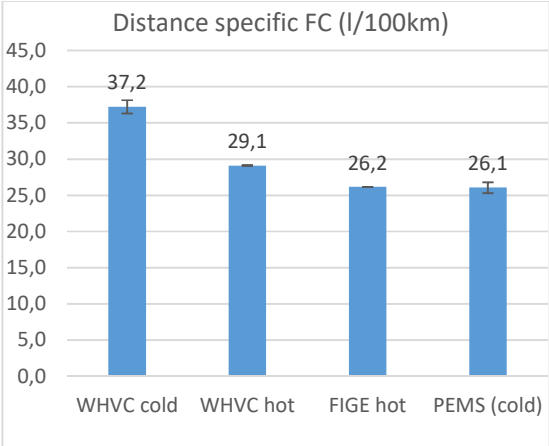


Figure 44. Avg. distance specific FC (l/100km)

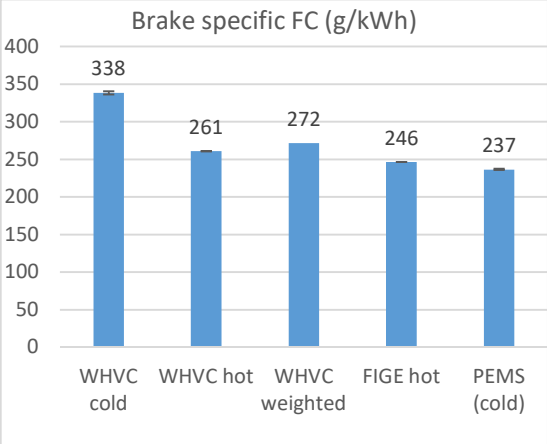


Figure 42. Avg. brake specific FC (g/kWh)

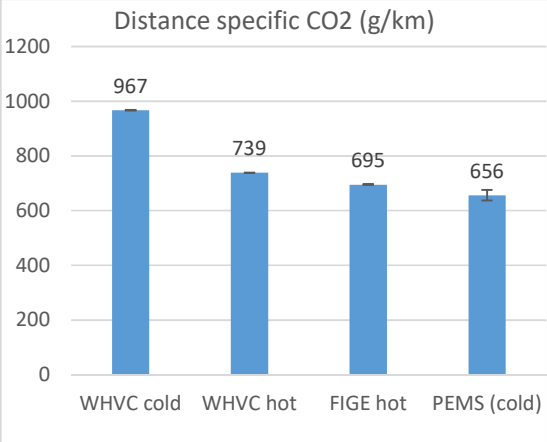


Figure 43. Avg. distance specific CO_2 emissions (g/km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure A16. Energy consumption for the chassis dynamometer tests and the PEMS test agree very well.

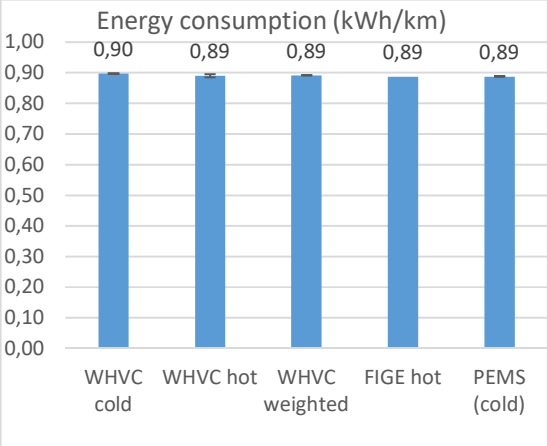


Figure 45. Avg. energy consumption (kWh/km)

Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are well below the Euro VI regulatory limit of 10 ppm.

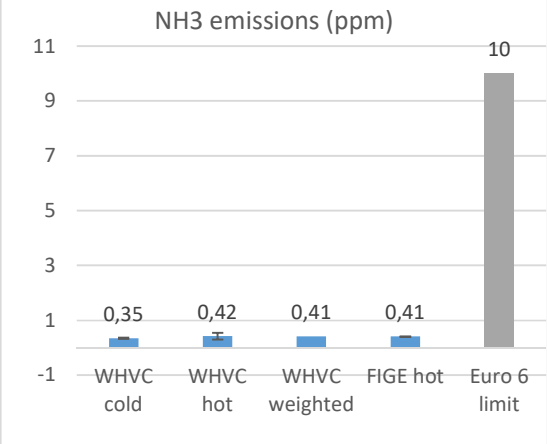


Figure 46. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions measured during the tests were very low in all warm start tests. The cold start generated a little higher NOx emissions however the weighted result was below the emission limit. The ammonia emissions measured were low.
ABS-related fault codes were indicated by the OBD system.

Vehicle E

Vehicle

Model year:	2015
Vehicle category:	N3
Vehicle type:	Delivery truck
Mileage:	40 000 km
Engine:	5-cylinder
Displacement:	~ 9 300 cm^3
Fuel:	CNG
Power:	206 kW
Exhaust after treatment:	TWC
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	19 000 kg
Mass in running order (vehicle):	9 900 kg
Maximum payload:	8 100 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 2^{d} and 14th of June 2016.

Table E1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	14 026	(≈4 100)
WHVC	2	2	14 026	(≈4 100)
PEMS Euro VI N3 route	1	-	-	4 200

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 843 N
- A1: 59 N/(km/h)

- A2: 1.85 N/(km/h)^2

The simulated vehicle payload during the tests on the chassis dynamometer made 51% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 52 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors were performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with commercially available CNG during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-06-02):

- Trip average RH: 30 %
- Trip average ambient temperature: 24 °C

On Board Diagnostics (OBD)

No diagnostic trouble codes from the OBD system.

Emission test results

The ISC NO_X and CH4 results for the PEMS test are presented in Figure A1 and Figure A1 respectively. CO and PM conformity factors are insignificantly small. Both NO_X and CH4 conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows in all tests.

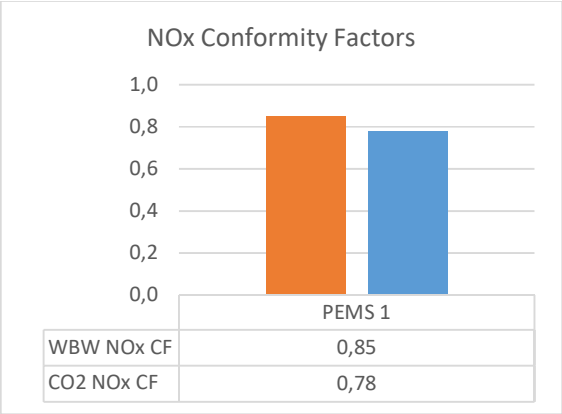


Figure 47. Work and CO2 based NOx conformity factors for the PEMS test.

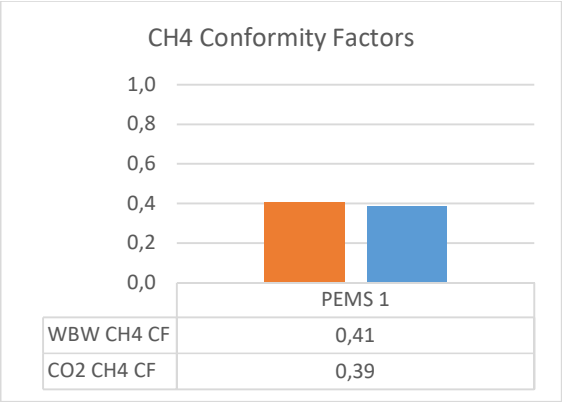


Figure 48. Work and CO2 based CH4 conformity factors for the PEMS test.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are below the Euro VI limit of 4 g/kWh.

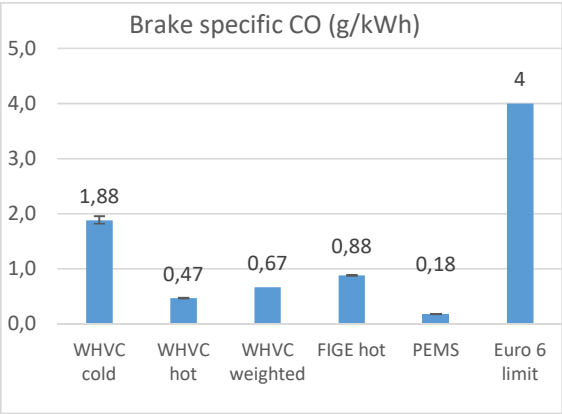


Figure 49. Avg. brake specific CO emissions (g/kWh)

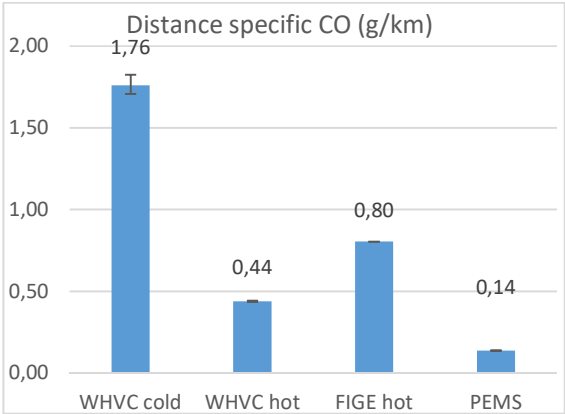


Figure 50. Avg. distance specific CO emissions (g/km)

Average CH_4 emissions are presented in Figure A4 and Figure A5. Emitted CH_4 is below the Euro VI legislative limit of 0.50 g/kWh.

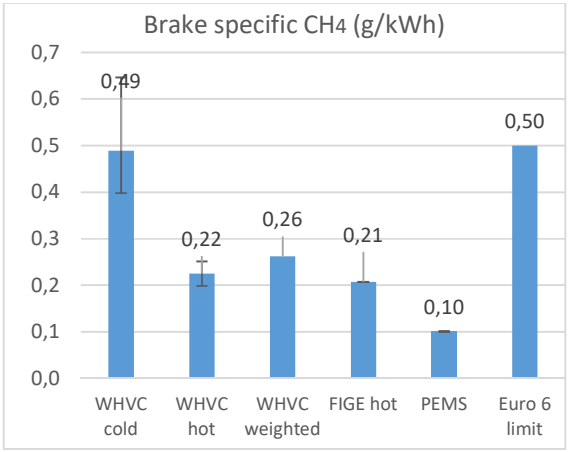


Figure 51. Avg. brake specific THC emissions (g/kWh)

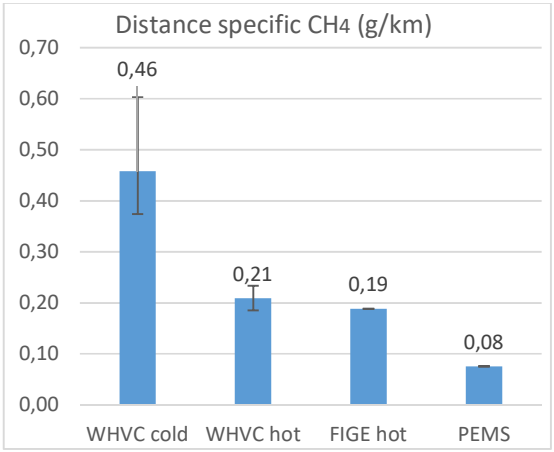


Figure 52. Avg. distance specific THC emissions (g/km)

Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS test. Results indicate raised emissions of NO_X for the WHVC cold start however, the weighted average, is below the Euro VI limit.

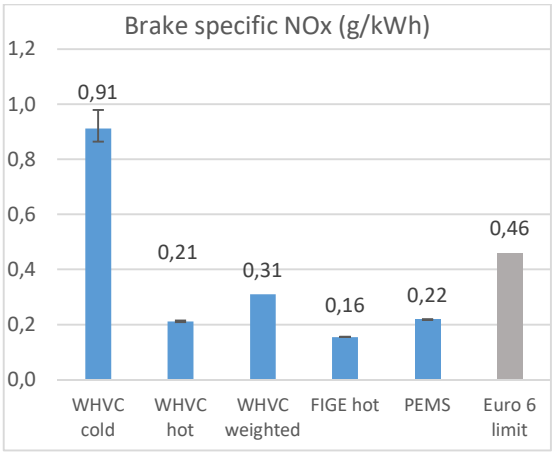


Figure 53. Avg. brake specific NO_X emissions (g/kWh)

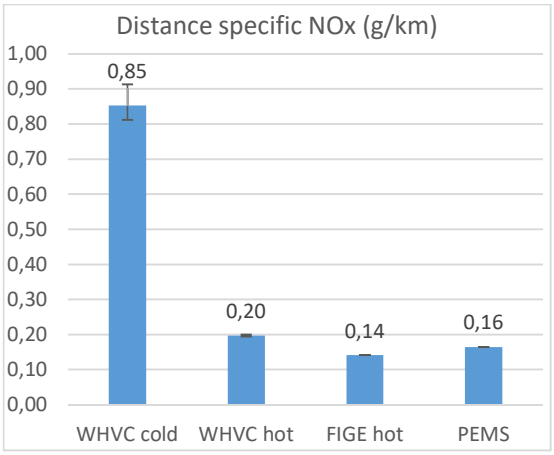


Figure 54. Avg. distance specific NO_X emissions (g/km)

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. Particle emissions are well below the legislative limits.

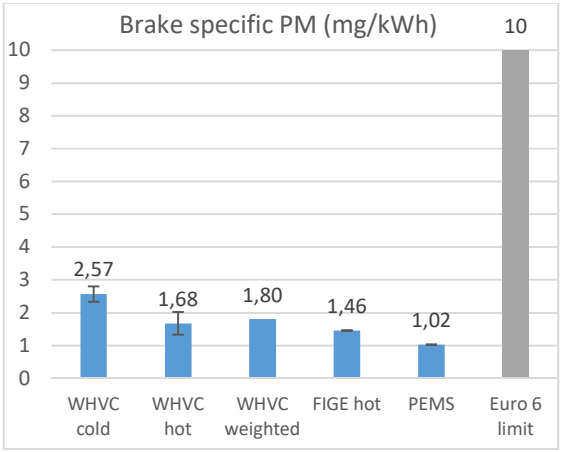


Figure E9. Avg. brake specific PM emissions (mg/kWh)

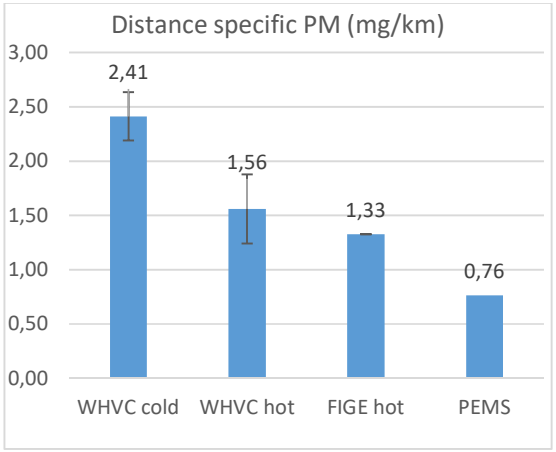


Figure 1E10. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. All CD results are lower than the Euro VI particle number limit. The number of emitted particles are higher for WHVC cold start tests. The PEMS test show results above the Euro VI particle number limit.

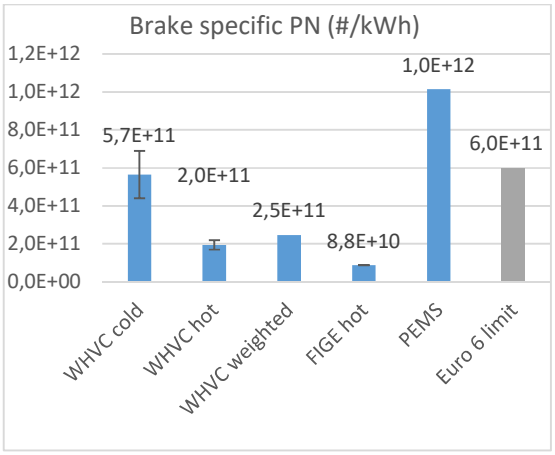


Figure 55. Avg. brake specific PN emissions (#/kWh)

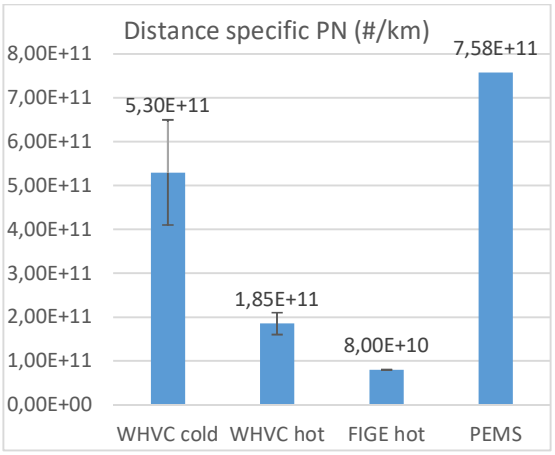


Figure 56. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to Figure A15.

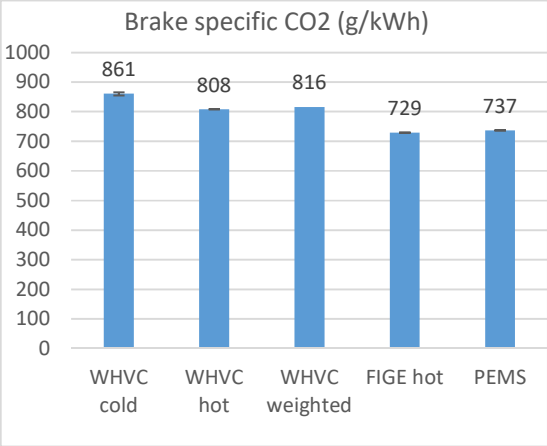


Figure 57. Avg. brake specific CO_2 emissions (g/kWh)

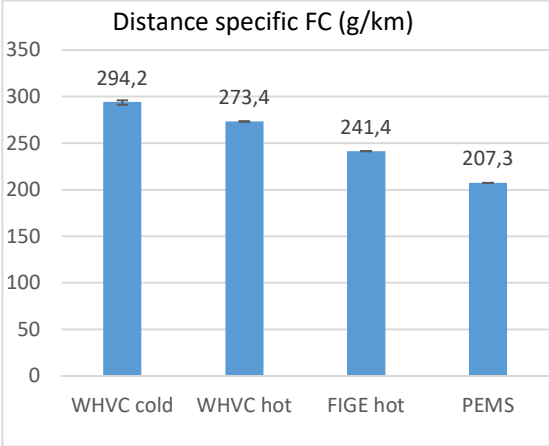


Figure 60. Avg. distance specific FC (l/100km)

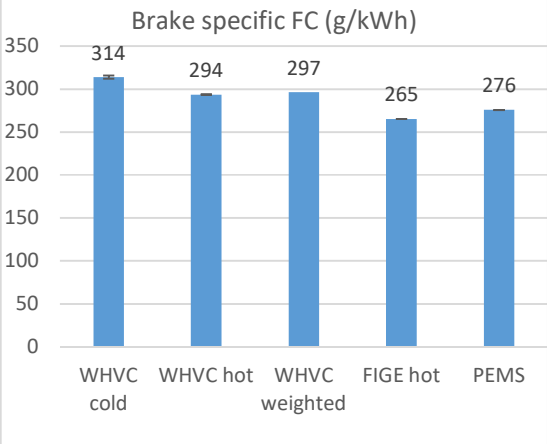


Figure 58. Avg. brake specific FC (g/kWh)

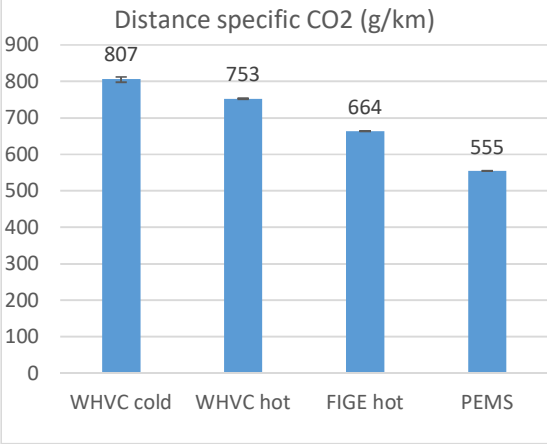


Figure 59. Avg. distance specific CO_2 emissions (g/km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure A16.

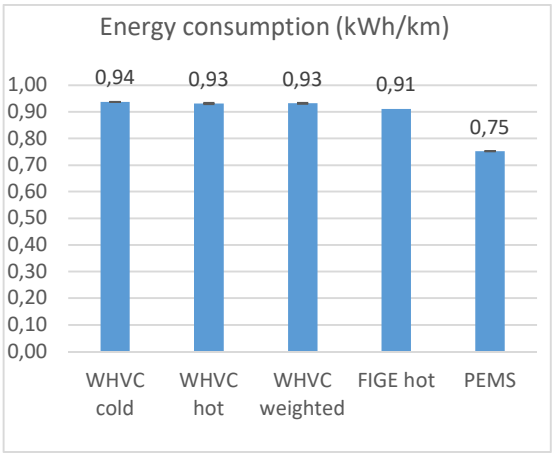


Figure 61. Avg. energy consumption (kWh/km)

Finally, Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are above the Euro VI regulatory limit of 10 ppm as test average.

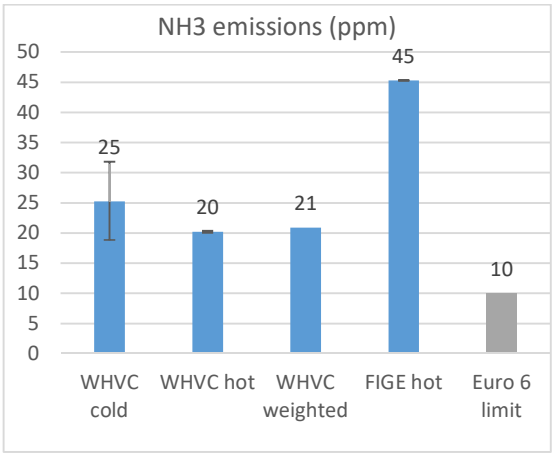


Figure 62. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.
All tests resulted in emissions of CO, CH4, and PM well below the Euro VI emission limit. The NOx emissions were a little high in the WHVC cold start, however very low in all warm start tests resulting in a weighted average below the Euro VI limit.

The PN results during the CD tests are lower than the Euro VI particle number limit. The PEMS test show results above the Euro VI limit.

The ammonia emissions measured were rather high, not passing the limit of 10 ppm average over the cycle. Vehicles with a positive ignited engine and a three-way catalyst often produce ammonia as a secondary pollutant during the NOx reduction process in the three-way catalyst.
No malfunction was indicated by the OBD system.

Vehicle F

Vehicle

Model year:	2014
Vehicle category:	N3
Vehicle type:	Delivery truck
Mileage:	52 000 km
Engine:	6-cylinder
Displacement:	7 700 cm^3
Fuel:	Diesel
Power:	~ 180 kW
Exhaust after treatment:	DOC, DPF, SCR, ASC
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	16 000 kg
Mass in running order (vehicle):	8 400 kg
Maximum payload:	7 600 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 13th and 17th of June 2016.

Table F1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	12 444	(≈4 000)
WHVC	2	2	12 444	(≈4 000)
PEMS Euro VI N3 route	2	-	-	4 300

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 843 N
- A1: 59 N/(km/h)
- A2: 1.85 $N/(km/h)^2$

The simulated vehicle payload during the tests on the chassis dynamometer made 53% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 57 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors were performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-06-13):

- Trip average RH: 30 %
- Trip average ambient temperature: 23°C

Test 2 (2016-06-14):

- Trip average RH: 34 %
- Trip average ambient temperature: 22 °C

On Board Diagnostics (OBD)

No fault codes were indicated by the OBD system.

Emission test results

The ISC NO_X and PM results for both PEMS tests are presented in Figure A1 and Figure A1 respectively. CO and THC conformity factors are insignificantly small. NO_X conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows. Calculated PM conformity factors also meet the legislative criteria.

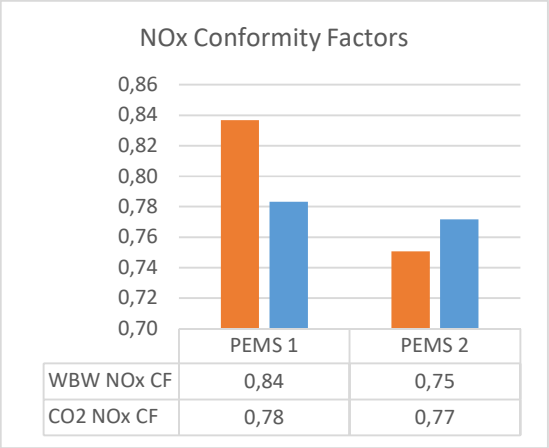


Figure F1. Work and CO2 based NOx conformity factors for PEMS tests.

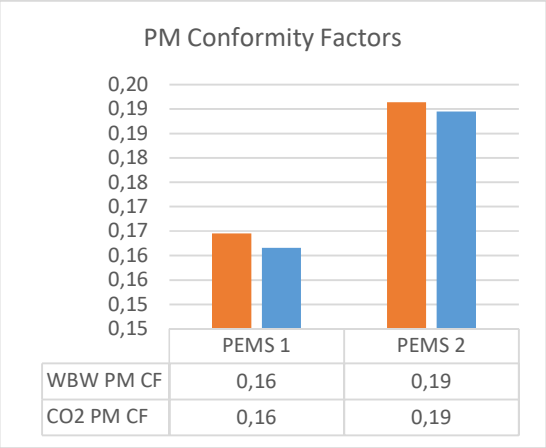


Figure 63. Work and CO2 based PM conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are far below the Euro VI limit of 4 g/kWh in all tests.

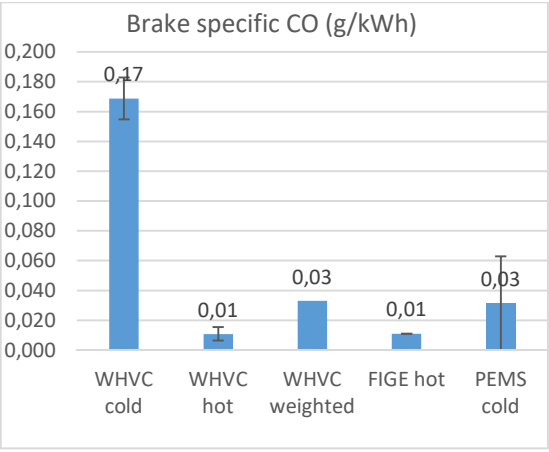


Figure 64. Avg. brake specific CO emissions (g/kWh)

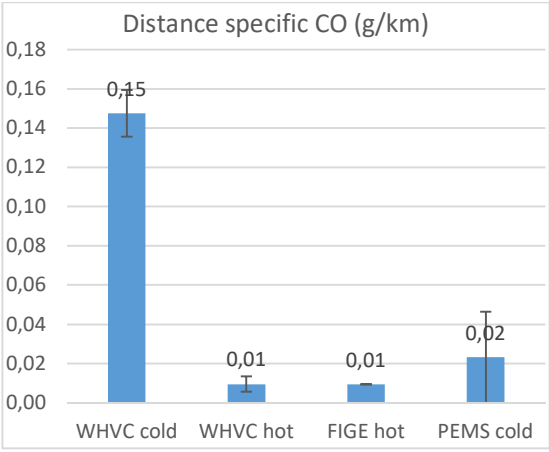


Figure 65. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure A4 and Figure A5. Emitted THC is below the Euro VI legislative limit of 0.16 g/kWh.

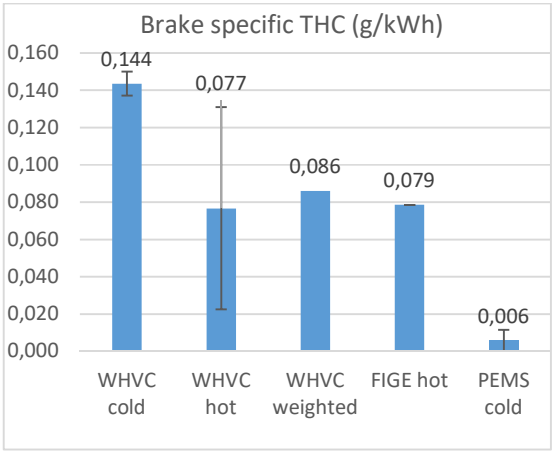


Figure 66. Avg. brake specific THC emissions (g/kWh)

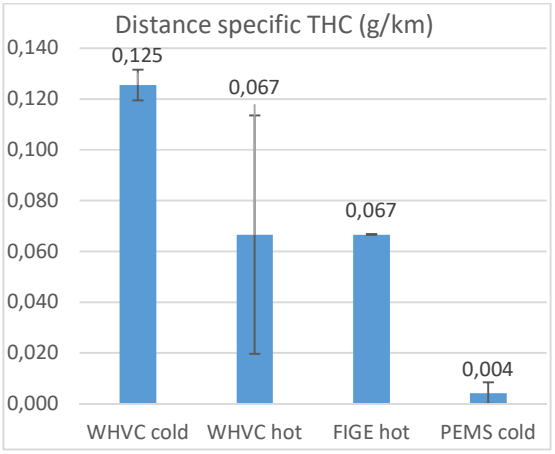


Figure 67. Avg. distance specific THC emissions (g/km)

Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS tests. Results indicate elevated emissions of NO_X for the WHVC cold start, however the weighted average and all other tests are below the Euro VI limit.

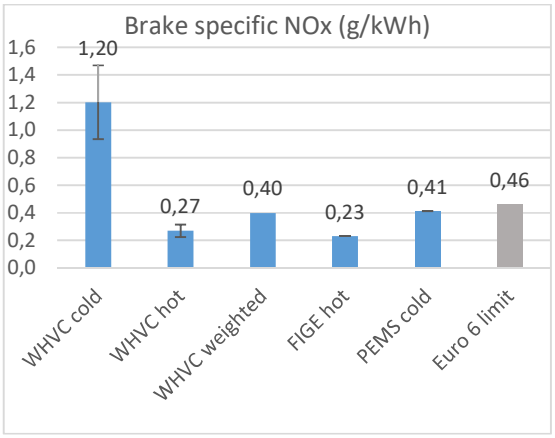


Figure 68. Avg. brake specific NO_X emissions (g/kWh)

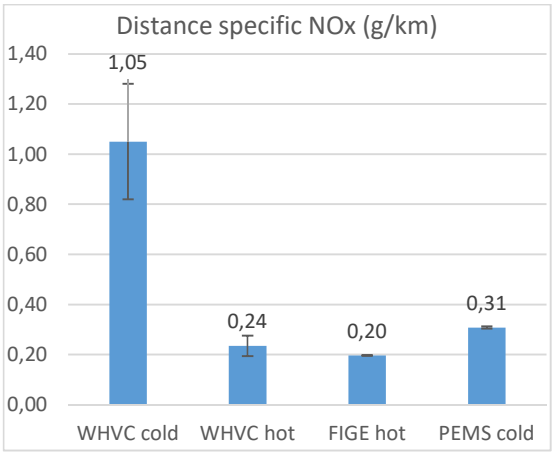


Figure 69. Avg. distance specific NO_X emissions (g/km)

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. Particle emissions are below the legislative limits.

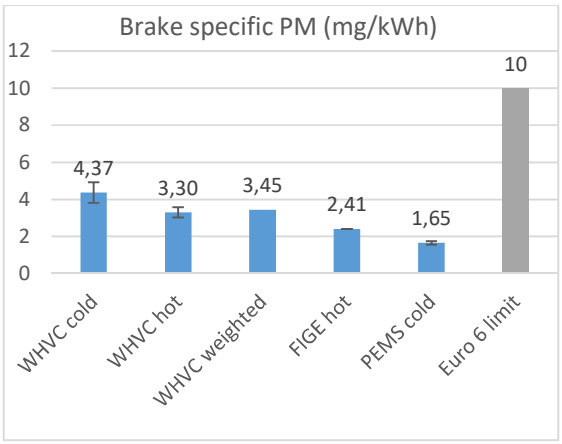


Figure F9. Avg. brake specific PM emissions (mg/kWh)

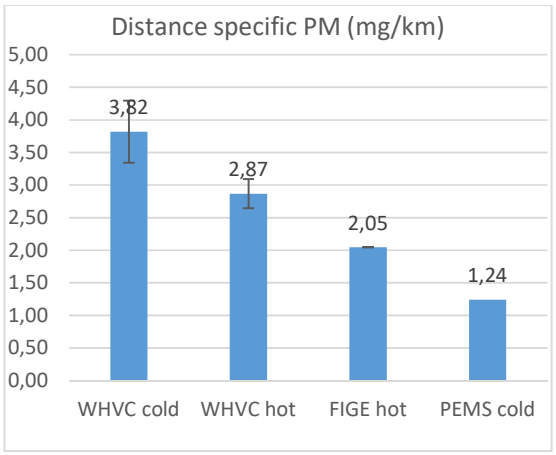


Figure 70. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. All results in the WHVC are higher than the Euro VI particle number limit. The results from the PEMS tests are lower.

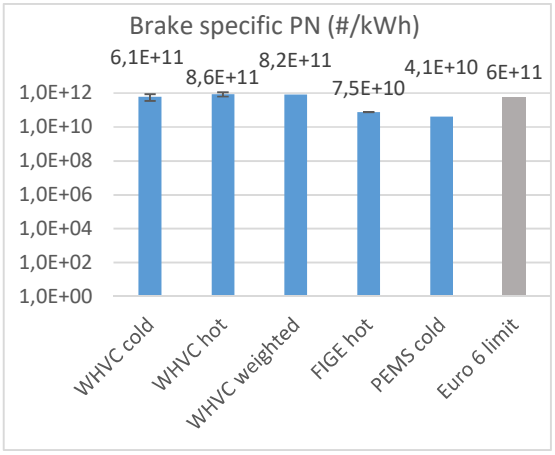


Figure 71. Avg. brake specific PN emissions (#/kWh)

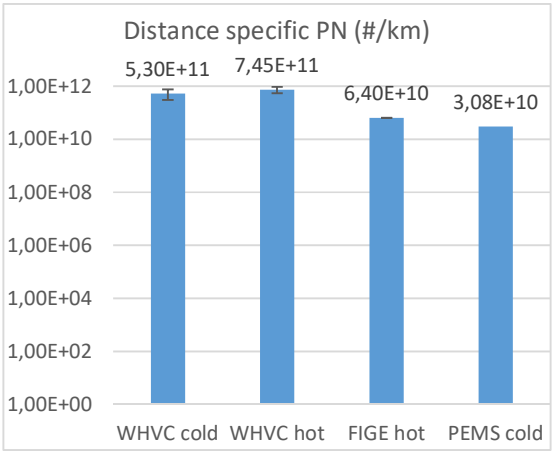


Figure 72. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to Figure A15.

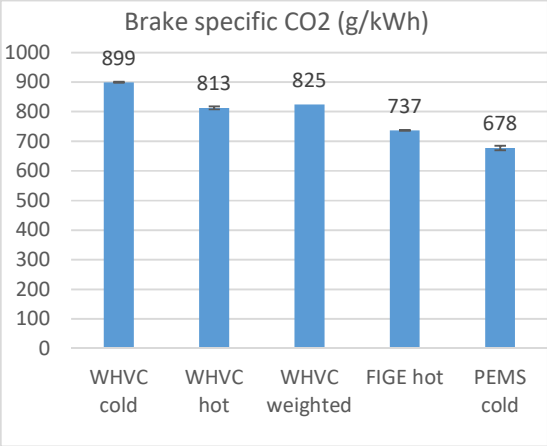


Figure 73. Avg. brake specific CO_2 emissions (g/kWh)

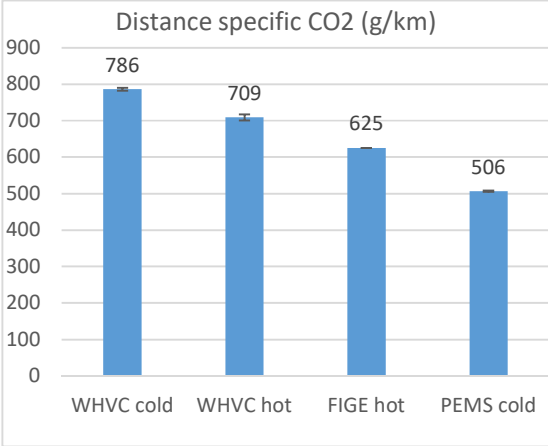


Figure 75. Avg. distance specific CO_2 emissions (g/km)

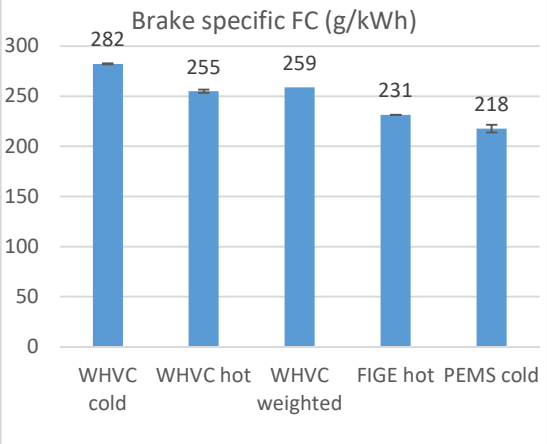


Figure 74. Avg. brake specific FC (g/kWh)

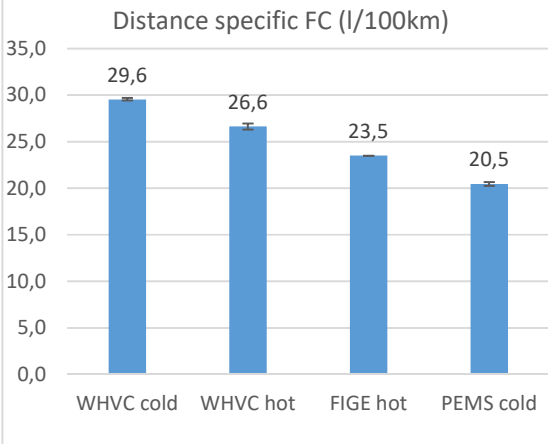


Figure 76. Avg. distance specific FC (l/100km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure A16.

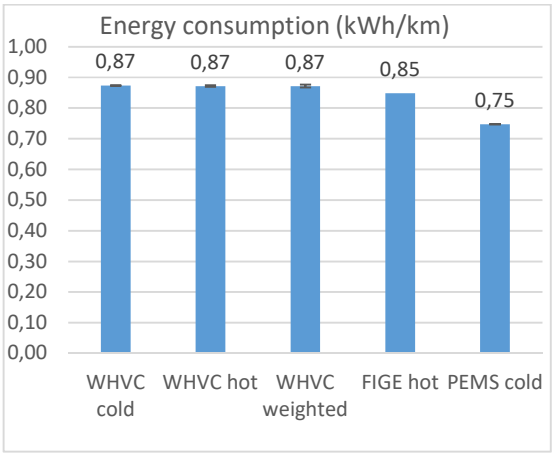


Figure 77. Avg. energy consumption (kWh/km)

Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are well below the Euro VI regulatory limit of 10 ppm.

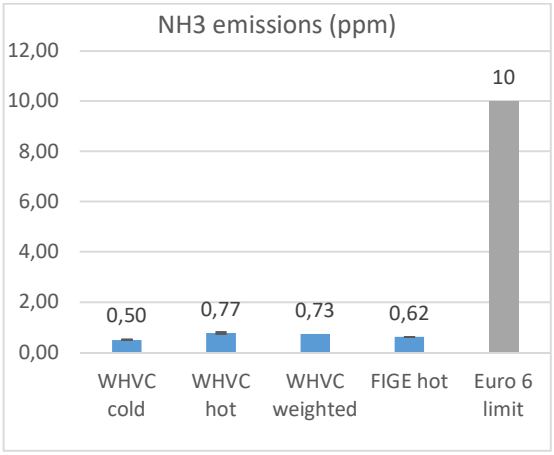


Figure 78. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.
All tests resulted in emissions of CO, THC, and PM well below the Euro VI emission limit. The NOx emissions measured during the tests were very low in all warm start tests. The cold start generated a little higher NOx emissions however the weighted result was below the emission limit. The PN result was higher than the WHTC PN limit in both the cold and the warm WHVC cycles however lower in the PEMS test. The ammonia emissions measured were low.
No fault codes were indicated by the OBD system.

Vehicle G

Vehicle

Model year:	2015
Vehicle category:	M3
Vehicle type:	Bus
Mileage:	95 000 km
Engine:	6-cylinder
Displacement:	7 700 cm^3
Fuel:	Biodiesel, RME
Power:	~ 230 kW
Exhaust after treatment:	DOC, DPF, SCR
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	18 000 kg
Mass in running order (vehicle):	12 200 kg
Maximum payload:	5 800 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 29st of June and 8th of July 2016.

Table G1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	15 156	(≈3 000)
WHVC	2	2	15 156	(≈3 000)
PEMS Euro VI N3 route	2	-	-	3 000

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 843 N
- A1: 59 N/(km/h)
- A2: 1.85 $N/(km/h)^2$

The simulated vehicle payload during the tests on the chassis dynamometer made 51% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 51 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors was performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with 100% biodiesel (RME) during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-06-29):

- Trip average RH: 27 %
- Trip average ambient temperature: 26 °C

Test 2 (2016-06-30):

- Trip average RH: 43 %
- Trip average ambient temperature: 25 °C

On Board Diagnostics (OBD)

No diagnostic trouble codes from the OBD system.

Emission test results

The ISC NO_X and PM results for both PEMS tests are presented in Figure A1 and Figure A1 respectively. CO and THC conformity factors are insignificantly small. NO_X conformity factors pass the ISC criteria (below 1.5) for work based windows in all tests. The amount of CO2 mass based windows were less than 50% and no conformity factor could be calculated. PM conformity factors also meet the legislative criteria.

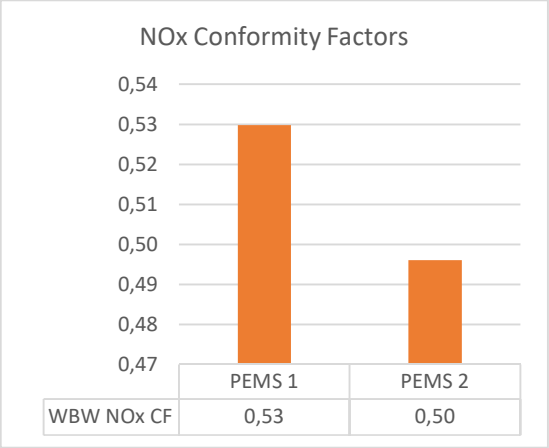
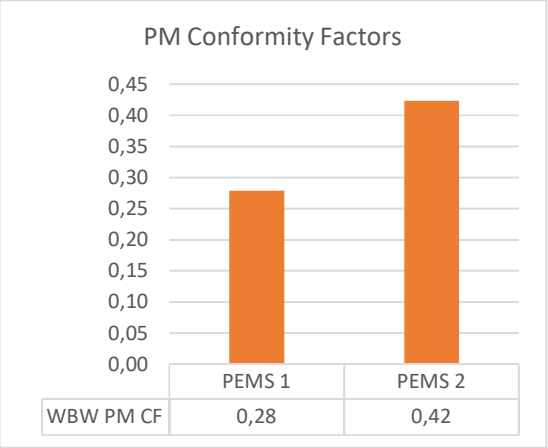


Figure 79. Work based NOx conformity factors for PEMS tests.



FigurG2. Work based PM conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are below the Euro VI limit of 4 g/kWh.

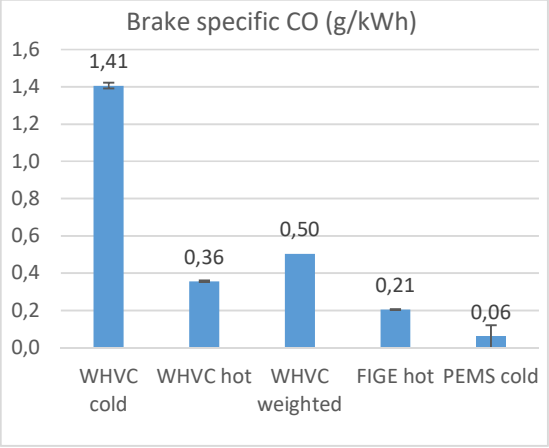


Figure 80. Avg. brake specific CO emissions (g/kWh)

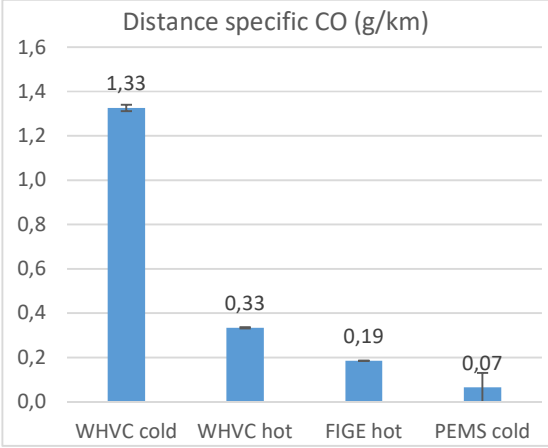


Figure 81. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure A4 and Figure A5. Emitted THC is far below the Euro VI legislative limit of 0.16 g/kWh. In the FIGE and the PEMS test, no THC was detected.

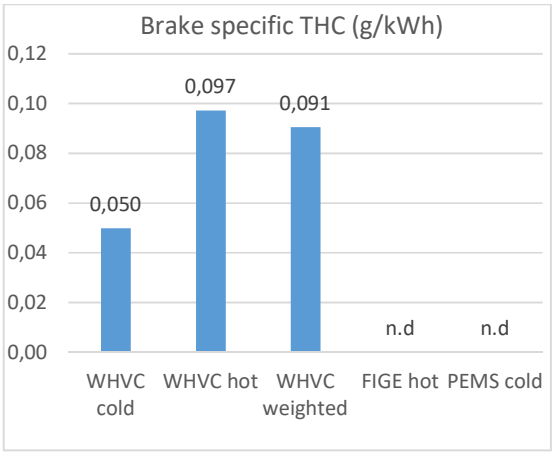


Figure 82. Avg. brake specific THC emissions (g/kWh)

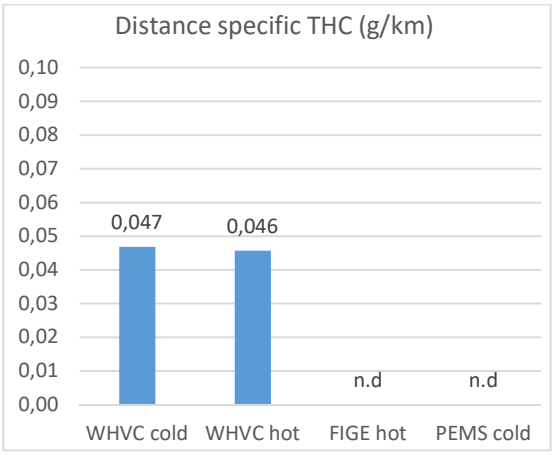


Figure 83. Avg. distance specific THC emissions (g/km)

Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS tests. Results indicate raised emissions of NO_X for the WHVC cold start however, the weighted average, is below the Euro VI limit.

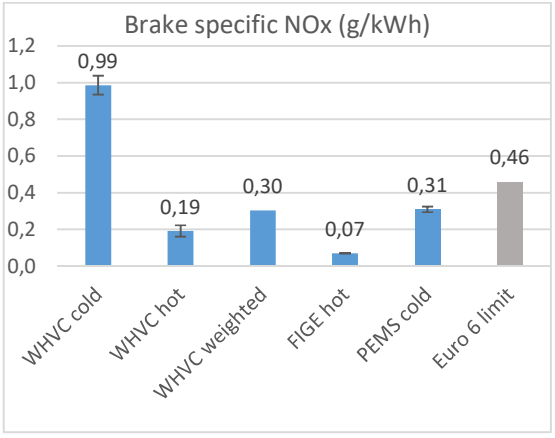


Figure G7. Avg. brake specific NO_X emissions (g/kWh)

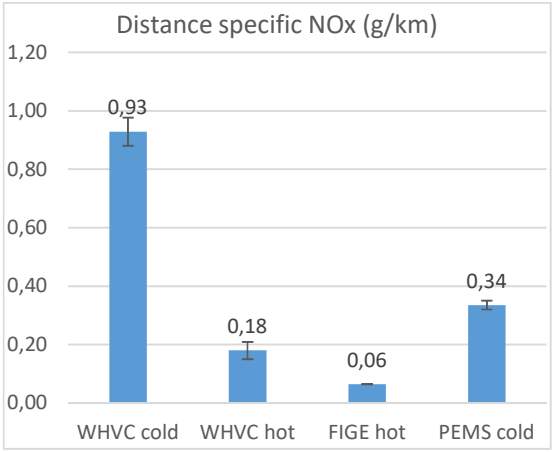


Figure 84. Avg. distance specific NO_X emissions (g/km)

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. Particle emissions are within the same ranges for the different tests, and well below the legislative limits.

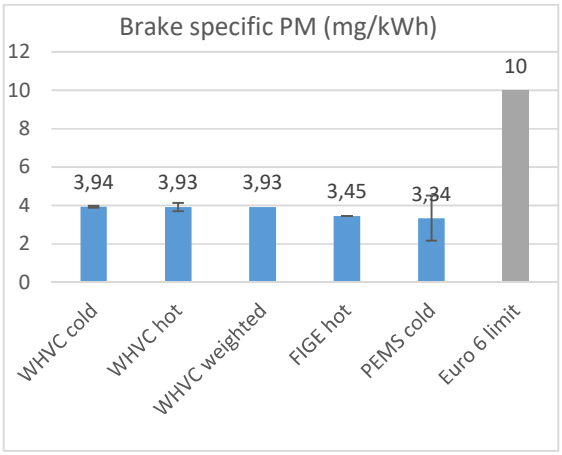


Figure 85. Avg. brake specific PM emissions (mg/kWh)

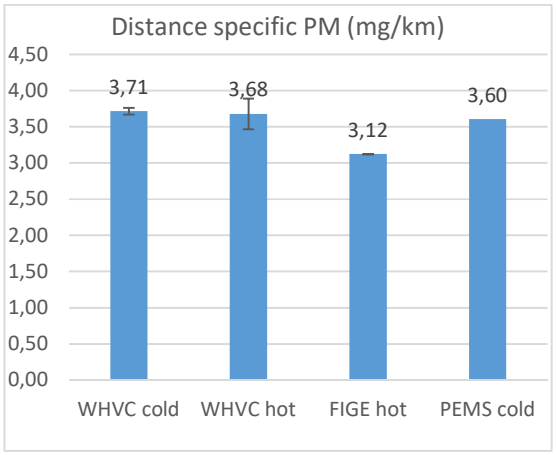


Figure 86. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. All results are lower than the Euro VI particle number limit. The number of emitted particles are higher for WHVC cold start tests.

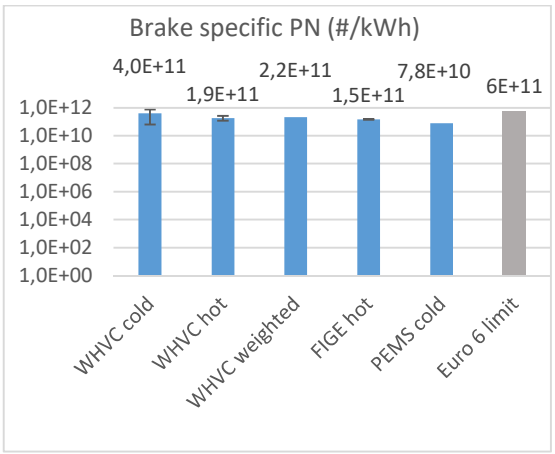


Figure 87. Avg. brake specific PN emissions (#/kWh)

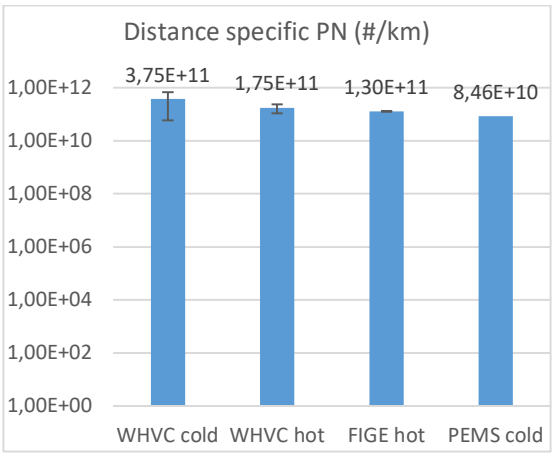


Figure 88. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to Figure A15.

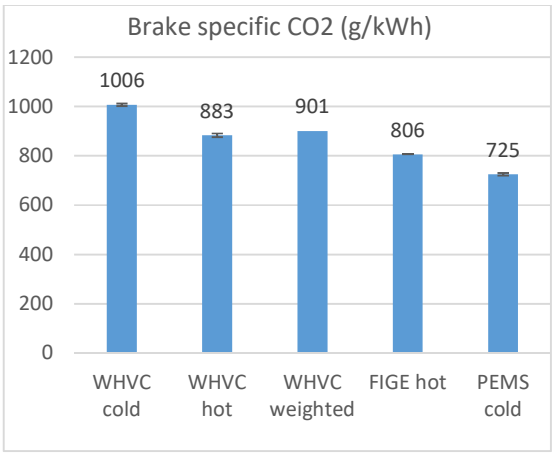


Figure 89. Avg. brake specific CO_2 emissions (g/kWh)

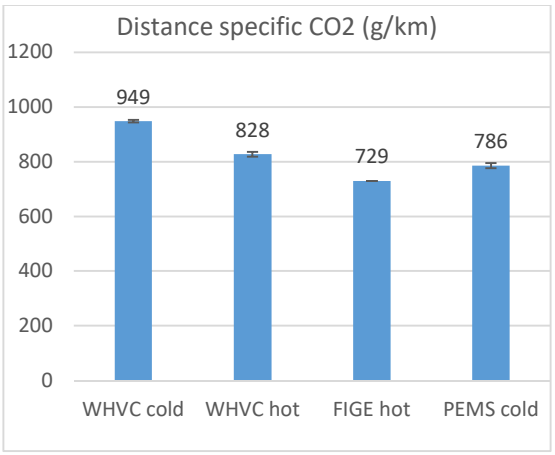


Figure 91. Avg. distance specific CO_2 emissions (g/km)

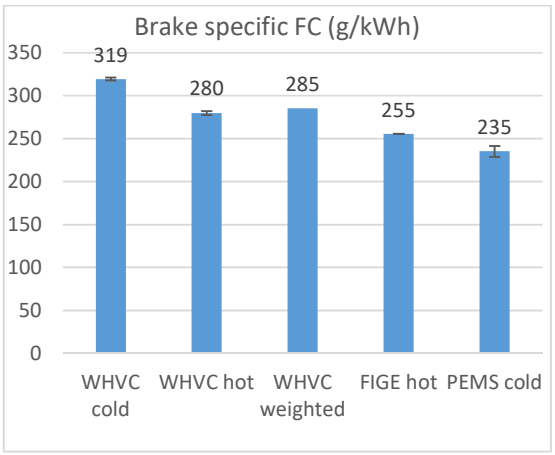


Figure 90. Avg. brake specific FC (g/kWh)

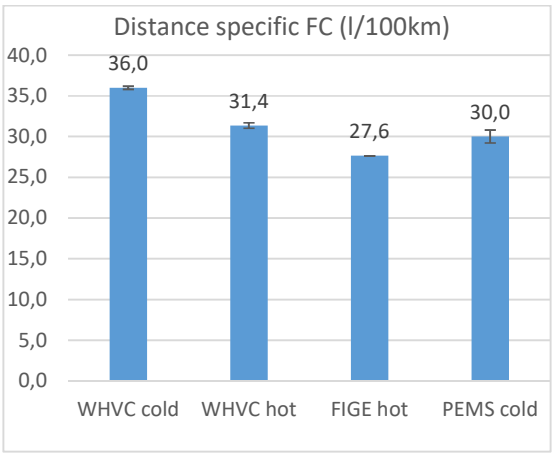


Figure 92. Avg. distance specific FC (l/100km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure A16.

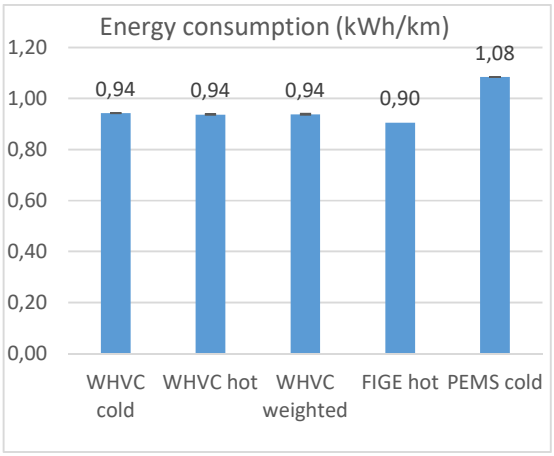


Figure 93. Avg. energy consumption (kWh/km)

Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are well below the Euro VI regulatory limit of 10 ppm.

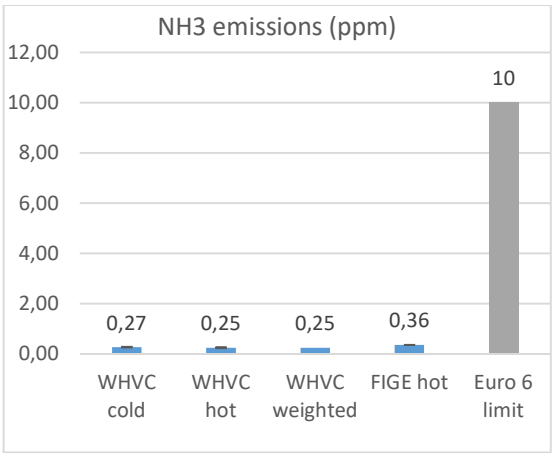


Figure 94. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

All established conformity factors from the ISC evaluation, for work based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions were higher in the WHVC cold start, however very low in all warm start tests resulting in a weighted average below the Euro VI limit. The ammonia emissions measured were low.

No malfunction was indicated by the OBD system.

Vehicle H

Vehicle

Model year:	2014
Vehicle category:	M3
Vehicle type:	Articulated bus
Mileage:	107 000 km
Engine:	6-cylinder
Displacement:	10 500 cm^3
Fuel:	Diesel/HVO
Power:	~ 230 kW
Exhaust after treatment:	SCRT®
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	30 000kg
Mass in running order (vehicle):	17 500kg
Maximum payload:	12 450 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 7th and 8th of July 2016.

Table H1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
PEMS Euro VI M3 route	2	-	-	6 200

Vehicle payload during the on-road tests using PEMS was 50 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors were performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with HVO fuel supplied by the vehicle owner.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-07-07):

- Trip average RH: 44 %
- Trip average ambient temperature: 20 °C

Test 2 (2016-07-08):

- Trip average RH: 36 %
- Trip average ambient temperature: 23 °C

On Board Diagnostics (OBD)

No diagnostic trouble codes from the OBD system.

Emission test results

The ISC NO_X and PM results for both PEMS tests are presented in Figure A1 and Figure A1 respectively. CO and THC conformity factors are insignificantly small. NO_X conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows in all tests. Calculated PM conformity factors also meet the legislative criteria.

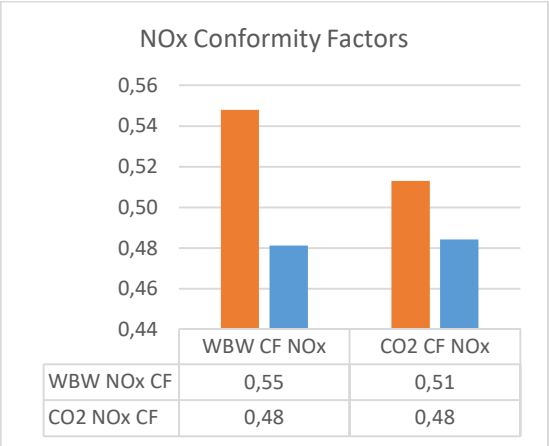


Figure 95. Work and CO2 based NOx conformity factors for PEMS tests.

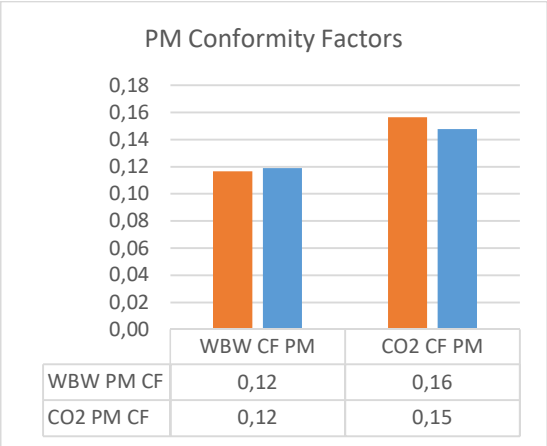


Figure 96. Work and CO2 based PM conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value.
Measured emissions, shown in Figure A2 and Figure A3, are all below the Euro VI limit of the respective emission. No CO was detected.

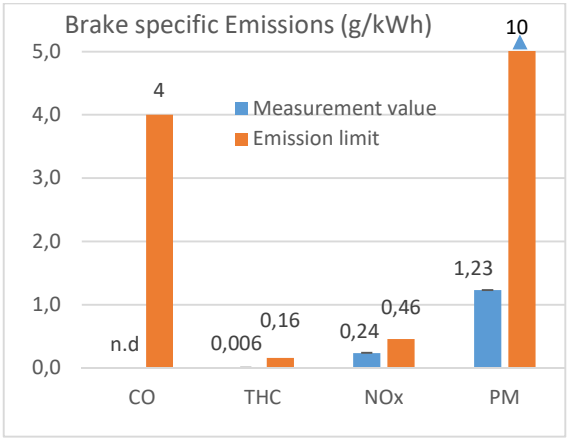


Figure 97. Avg. brake specific CO emissions (g/kWh)

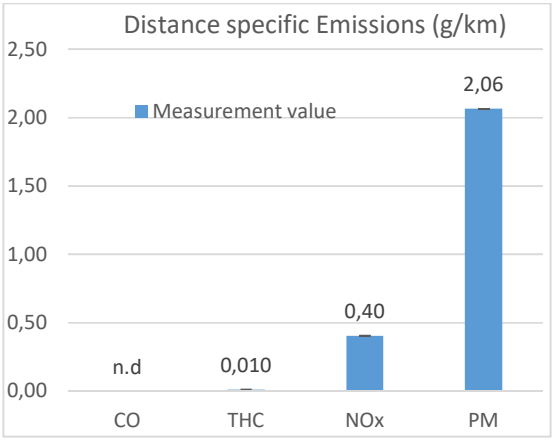


Figure 98. Avg. distance specific CO emissions (g/km)

CO_2 emissions results are presented in Figure A12 and calculated fuel consumption in Figure A15.

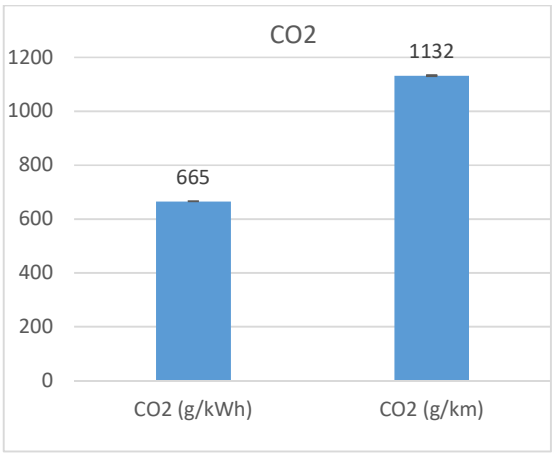


Figure 99. Avg. brake specific CO_2 emissions (g/kWh)

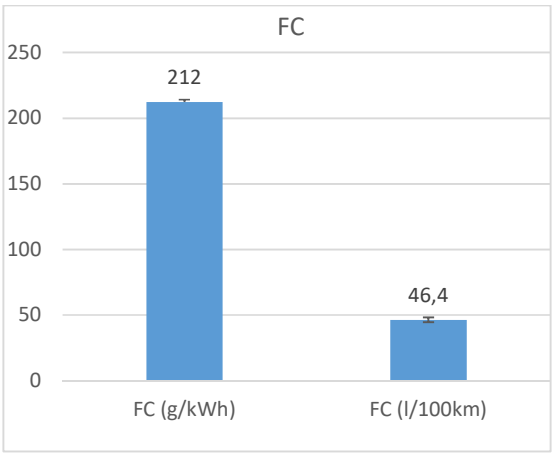


Figure 100. Avg. distance specific FC (l/100km)

Calculated energy consumption, specified in kWh per km, are presented in Figure A16.

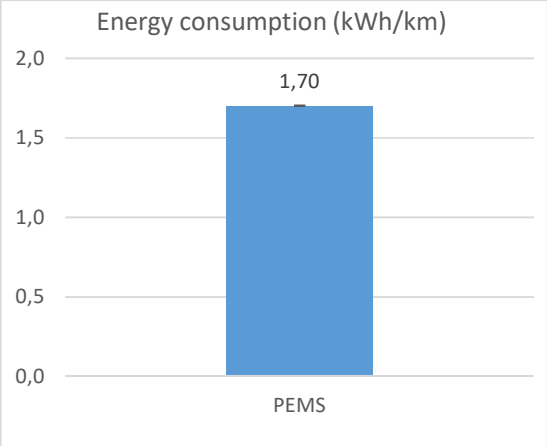


Figure 101. Avg. energy consumption (kWh/km)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, THC, NOx and PM well below the Euro VI emission limit.

No malfunction was indicated by the OBD system.

Vehicle I

Vehicle

Model year:	2014
Vehicle category:	M3
Vehicle type:	Articulated bus
Mileage:	250 000 km
Engine:	6-cylinder
Displacement:	12 800 cm^3
Fuel:	CNG
Power:	230 kW
Exhaust after treatment:	TWC
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	30 000 kg
Mass in running order (vehicle):	18 400 kg
Maximum payload:	11 600kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 12th and 14th of July 2016.

TableI1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
PEMS Euro VI M3 route	2	-	-	6 000

Vehicle payload during the on-road tests using PEMS was 52 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors were performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with commercially available CNG.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-07-13:

- Trip average RH: 71 %
- Trip average ambient temperature: 19 °C

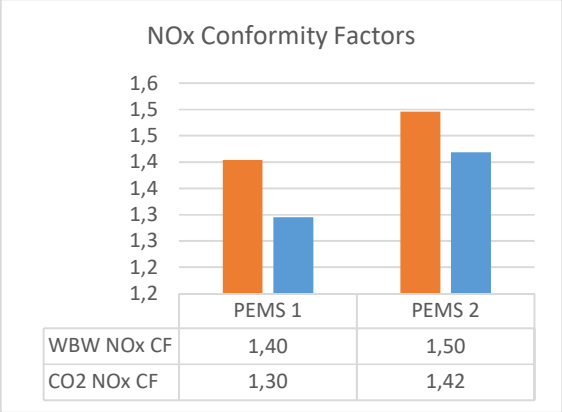
Test 2 (2016-07-14):

- Trip average RH: 55 %
- Trip average ambient temperature: 22 °C

On Board Diagnostics (OBD)

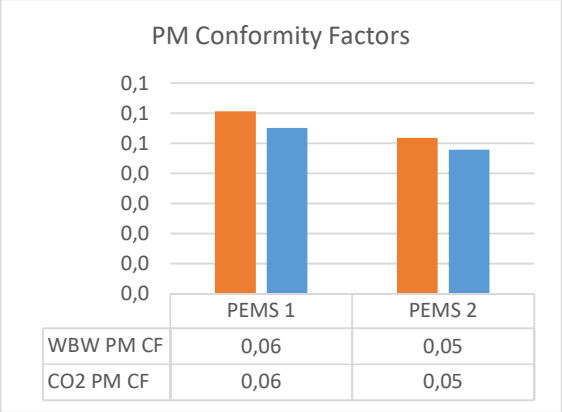
No diagnostic trouble codes from the OBD system.

Emission test results
The ISC emission results for both PEMS tests are presented in Figure A1 to Figure 105. The conformity factors for all emissions pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows in all tests.



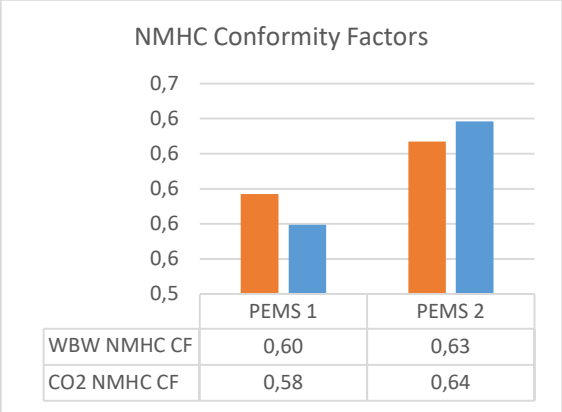
	PEMS 1	PEMS 2
WBW NOx CF	1,40	1,50
CO2 NOx CF	1,30	1,42

Figure 102. Work and CO2 based NOx conformity factors for the PEMS tests.



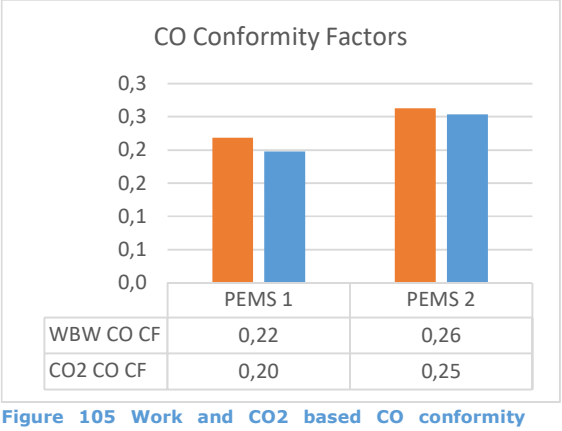
	PEMS 1	PEMS 2
WBW PM CF	0,06	0,05
CO2 PM CF	0,06	0,05

Figure 103. Work and CO2 based PM conformity factors for the PEMS tests.



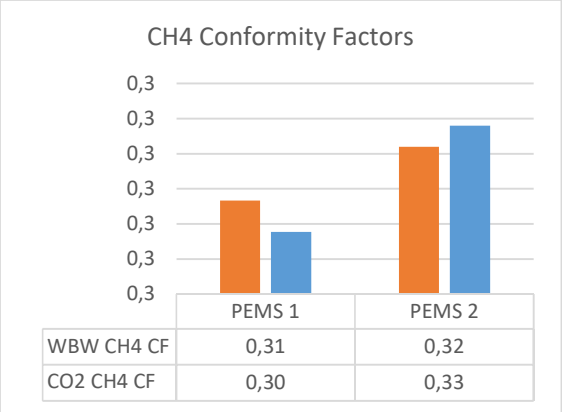
	PEMS 1	PEMS 2
WBW NMHC CF	0,60	0,63
CO2 NMHC CF	0,58	0,64

Figure 104 Work and CO2 based NMHC conformity factors for the PEMS tests.



	PEMS 1	PEMS 2
WBW CO CF	0,22	0,26
CO2 CO CF	0,20	0,25

Figure 105 Work and CO2 based CO conformity factors for both PEMS tests.



	PEMS 1	PEMS 2
WBW CH4 CF	0,31	0,32
CO2 CH4 CF	0,30	0,33

Figure 106 Work and CO2 based CH4 conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value.
Measured emissions, shown in Figure A2 and Figure A3 CO, CH4, NMHC and PM are below the Euro VI limit of the respective emission. Emissions of NOx are more than the limit.

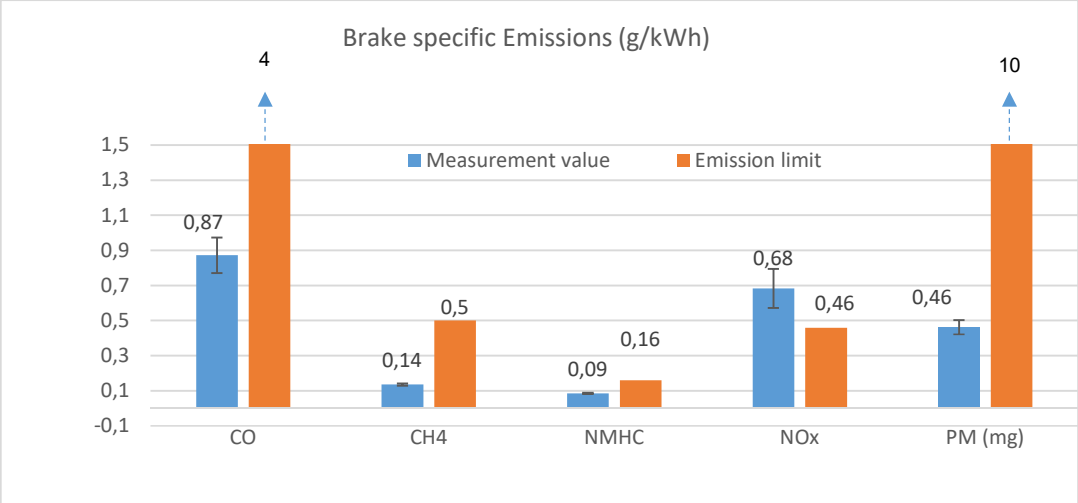


Figure 107. Avg. brake specific emissions (g/kWh)

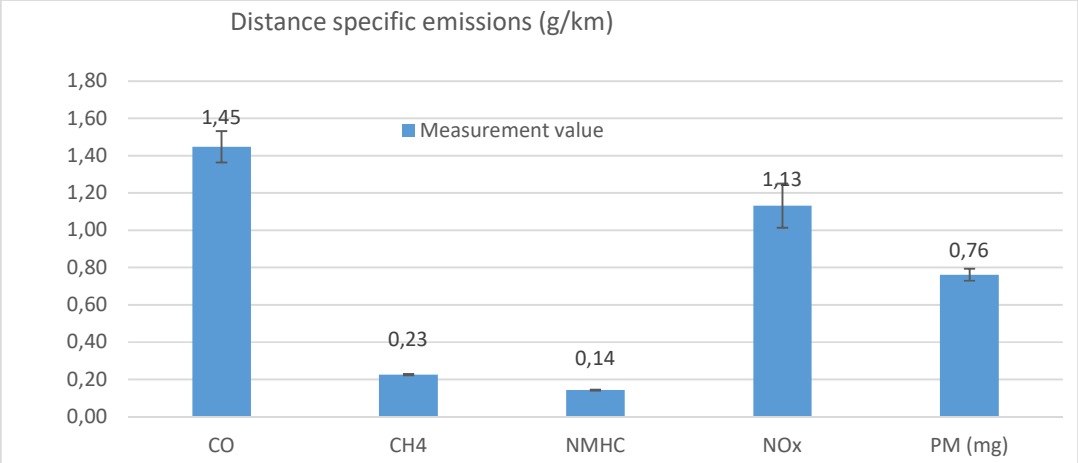


Figure 108. Avg. distance specific emissions (g/km)

Particle number emissions are presented in Figure A10. PN was measured during the last test and the result was lower than the Euro VI particle number limit.

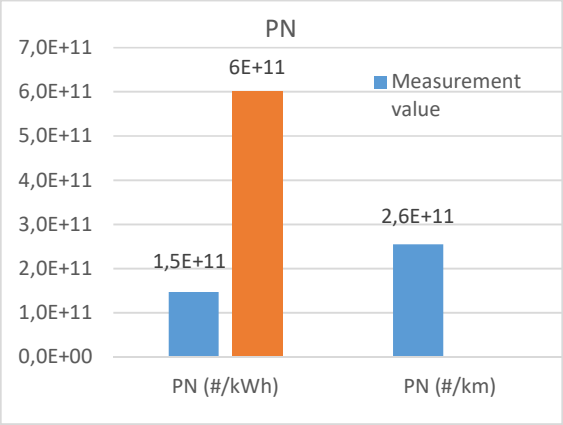


Figure 109. Avg PN emissions

CO_2 emissions results are presented in Figure A12 and calculated fuel consumption in Figure 111.

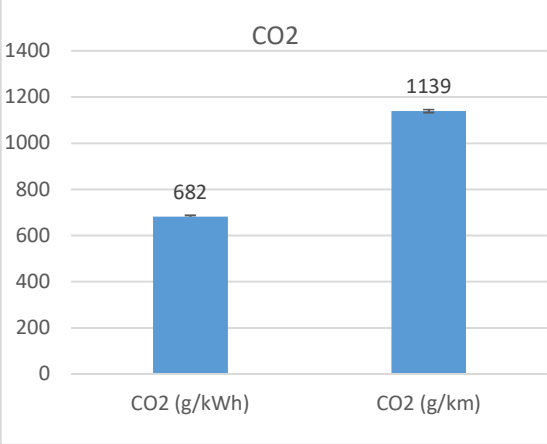


Figure 110. Avg. CO_2 emissions

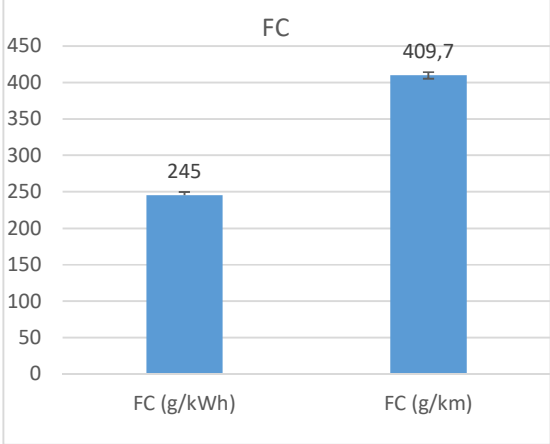


Figure 111. Avg. Fuel Consumption

Calculated energy consumptions, specified in kWh per km, is presented in Figure A16.

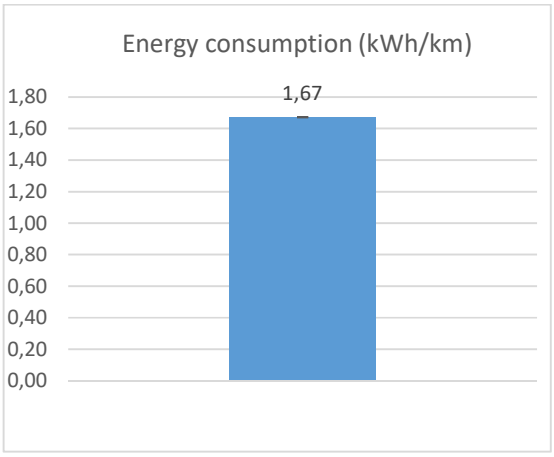


Figure 112. Avg. energy consumption (kWh/km)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, NMHC, CH4, PM and PN well below the Euro VI emission limit. The emissions of NOx were however higher than the limit.

No malfunction was indicated by the OBD system.

Vehicle J

Vehicle

Model year:	2005
Retrofitted in year:	2013
Mileage when retrofitted:	650 000 km
Mileage when tested:	830 000 km
Vehicle category:	M3
Vehicle type:	Articulated bus
Engine:	6-cylinder
Displacement:	9,4 dm^3
Fuel:	Diesel
Power:	~ 250 kW
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	24 300 kg
Mass in running order (vehicle):	17 500 kg
Maximum payload:	6 700 kg
Original emission standard:	Euro III
Emission standard after retrofitting:	Euro V

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 11th and 12th of August 2016.

Table J1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
PEMS Euro VI M3 route	2	-	-	3 400

Vehicle payload during the on-road tests using PEMS was 50 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors were performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the “all events result”, emissions released during cold start are included.

The vehicle was fuelled with commercially available Diesel.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-08-11):

- Trip average RH: 52 %
- Trip average ambient temperature: 16 °C

Test 2 (2016-08-12):

- Trip average RH: 51 %
- Trip average ambient temperature: 18 °C

On Board Diagnostics (OBD)

No diagnostic trouble codes from the OBD system.

Emission test results

The NOx and PM ISC emission results for both PEMS tests are presented in Figure A1 and Figure A1. The conformity factors for CO and THC are insignificantly small. The conformity factors for all emissions pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows in all tests.

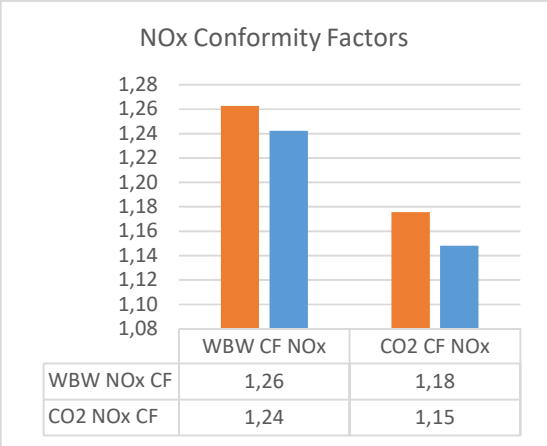


Figure 113. Work and CO2 based NOx conformity factors for the PEMS tests.

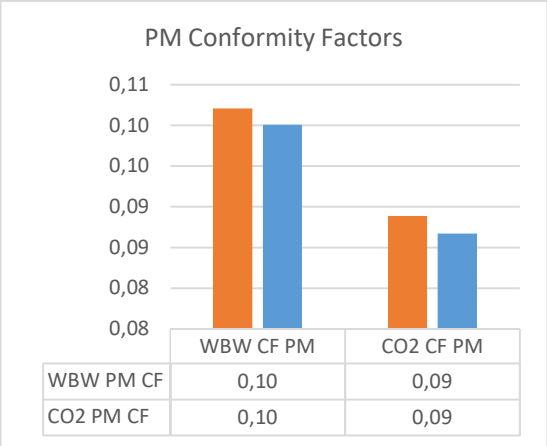


Figure 114. Work and CO2 based PM conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value.
Measured emissions, shown in Figure A2 and Figure A3 CO, THC and PM are below the Euro V limit of the respective emission. Emissions of NOx are more than the limit.

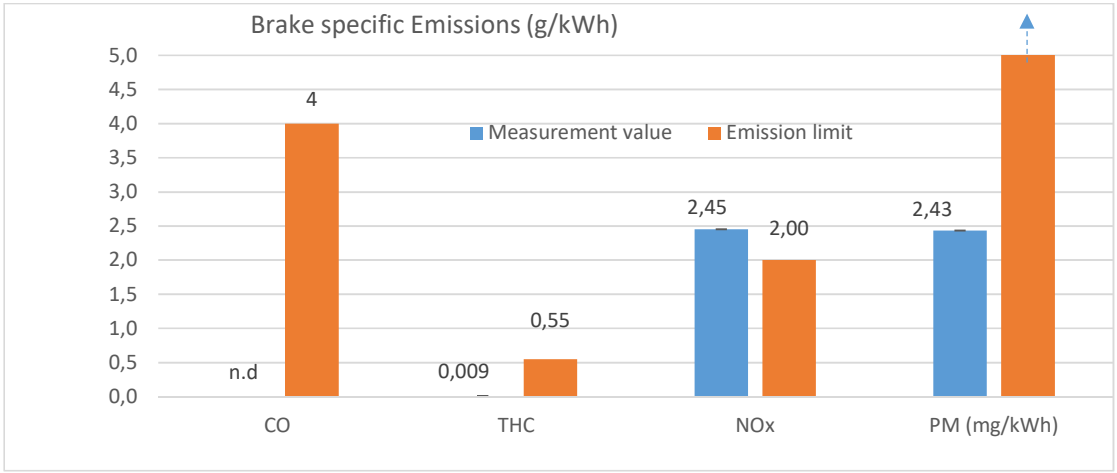


Figure 115. Avg. brake specific emissions (g/kWh)

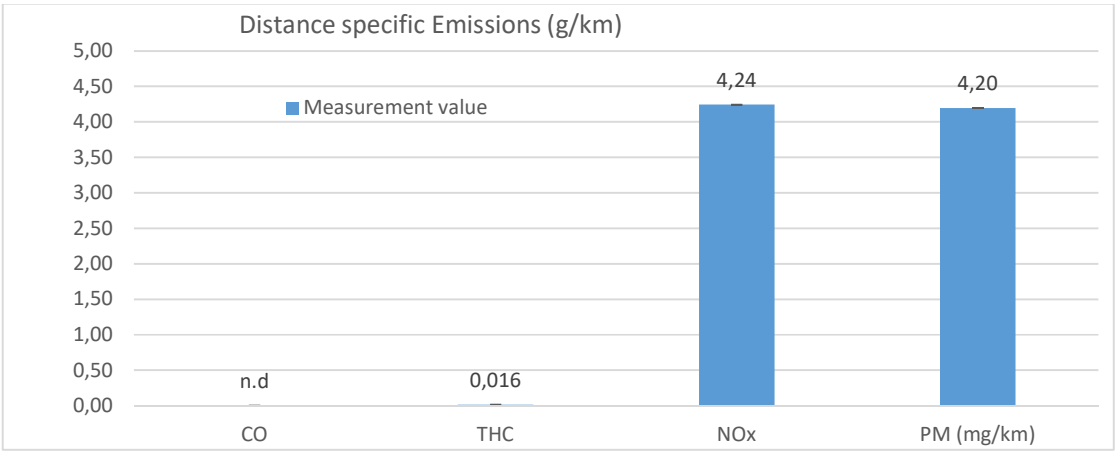


Figure 116. Avg. distance specific emissions (g/km)

Particle number emissions are presented in Figure A10.

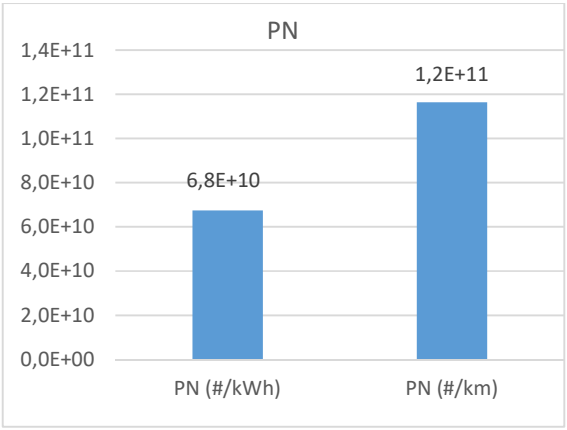


Figure 117. Avg PN emissions

CO_2 emissions results are presented in Figure A12 and calculated fuel consumption in Figure 111.

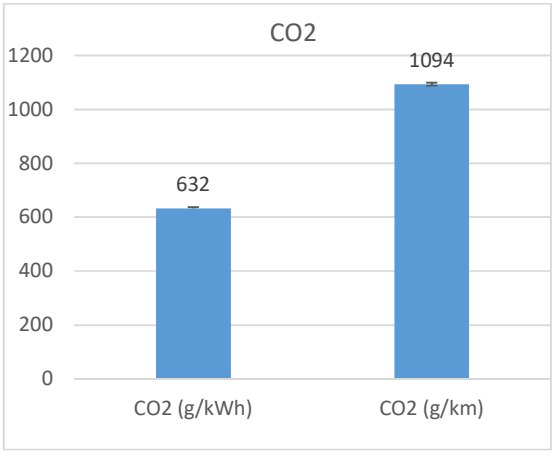


Figure 118. Avg. CO_2 emissions

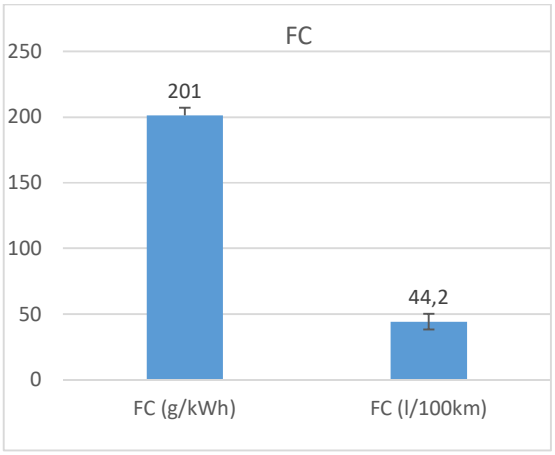


Figure 119. Avg. Fuel Consumption

Calculated energy consumptions, specified in kWh per km, is presented in Figure A16.

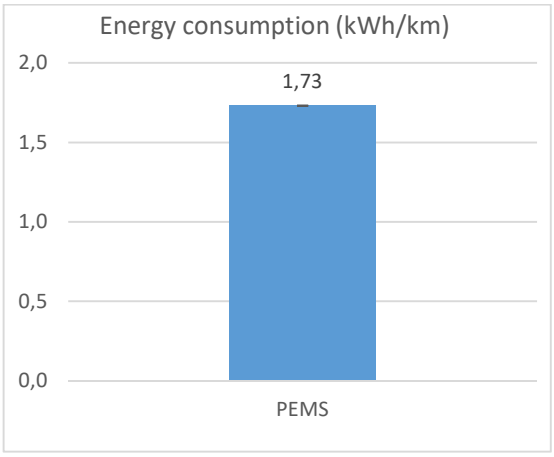


Figure 120. Avg. energy consumption (kWh/km)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

All tests resulted in emissions of CO, THC, and PM well below the Euro V emission limit. The emissions of NOx were however higher than the limit. There is no PN emission limit for Euro V vehicles but the measured values were lower than the Euro VI limit.

No malfunction was indicated by the OBD system.

Vehicle K

A diesel fuelled electric hybrid bus of model year 2014 and emission standard Euro VI has been tested for exhaust emissions and fuel consumption. Two different on-road measurement tests were carried out using a portable emissions measurement system (PEMS) mounted on board.
Measured brake specific emissions of NOx are below the Euro VI regulatory limit when taking the work of the electrical motor into account. The emission of CO and THC are close to or below the detection limit of the measurement system. PM emissions are in the order of 100 times below the regulatory limit.

Vehicle

Model year:	2014
Vehicle category:	M3
Vehicle type:	Bus
Mileage:	~ 40000 km
Diesel engine:	240 hp / 918 Nm, 5 132 cm^3
Electric motor:	150 kW / 1200 Nm
Diesel fuel:	HVO
Energy storage system:	High-capacity lithium-ion battery
Exhaust after treatment:	DPF/SCR/EGR
Transmission:	Automatic
Gross Vehicle Mass (GVM):	19 000 kg
Emission standard:	Euro VI

The charging of the bus starts automatically when the bus is in the right position at the end of the line. The vehicle can run 7 km on electricity and runs in electric mode on average for 70% of the route. The total energy saving can, according to the manufacturer, reach 60 %.

Test information

Euro VI route
The vehicle was driven according to a pre-defined route which was designed to meet the Euro VI requirements for M3 vehicles. In addition one test run during driving on the bus route 73 (Ropsten – Karolinska Institutet) was carried out.

The route of the initial PEMS trip has the following data summary:

- Approximate trip duration: 10 200 seconds
- Approximate trip distance: 106 km
- Average speed: 40 km/h
- Average trip share of operation:
    - Urban driving (0-50 km/h): 65 % (goal 70 %)
    - Rural driving (50-75 km/h): 35 % (goal 30 %)

Figure 121 depicts the velocity profile of the Euro VI trip.

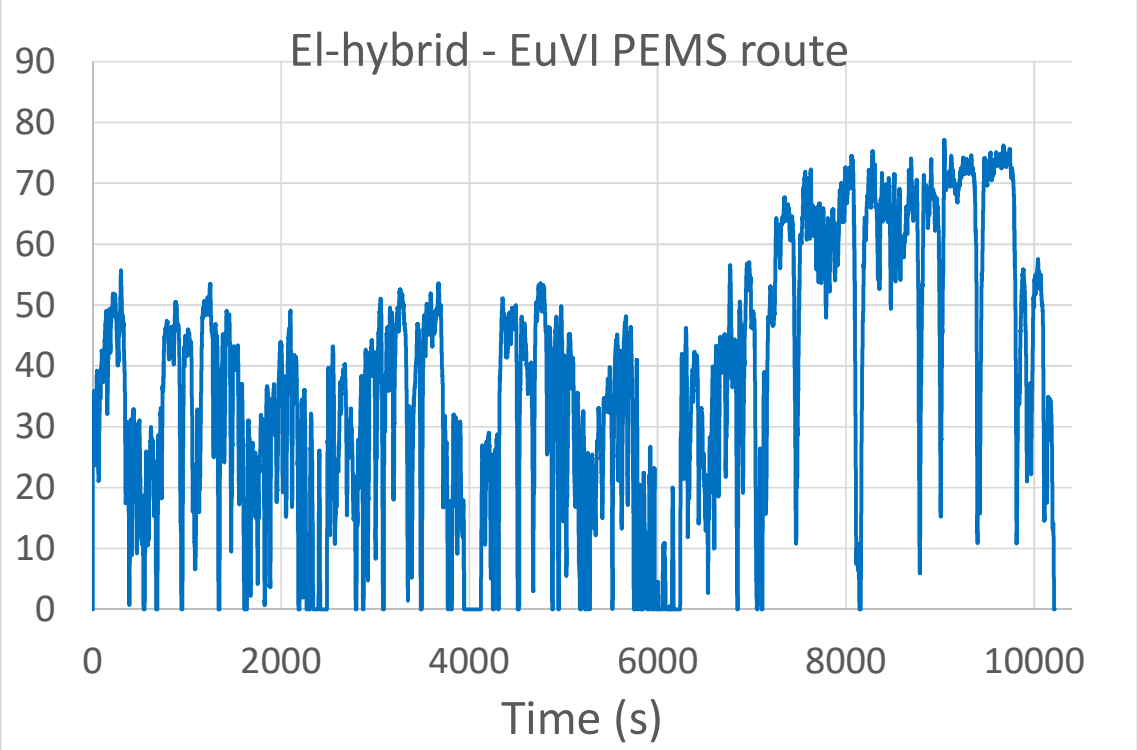


Figure 121. Velocity profile over the PEMS route. Speed in km/h.

Line 73 route

The route of the 73 test route has the following data summary:

- Approximate trip duration: 4300 seconds
- Approximate trip distance: 14.9 km
- Average speed: 12 km/h
- Average trip share of operation:
    - Urban driving (0-50 km/h): 100 %
    - Rural driving (50-75 km/h): 0 %

Figure K2 depicts the velocity profile of the trip. Note that test rout 73 does not fulfill the requirements of regulation (EU) NO. 582/2011 Annex II and (EU) No. 64/2012.

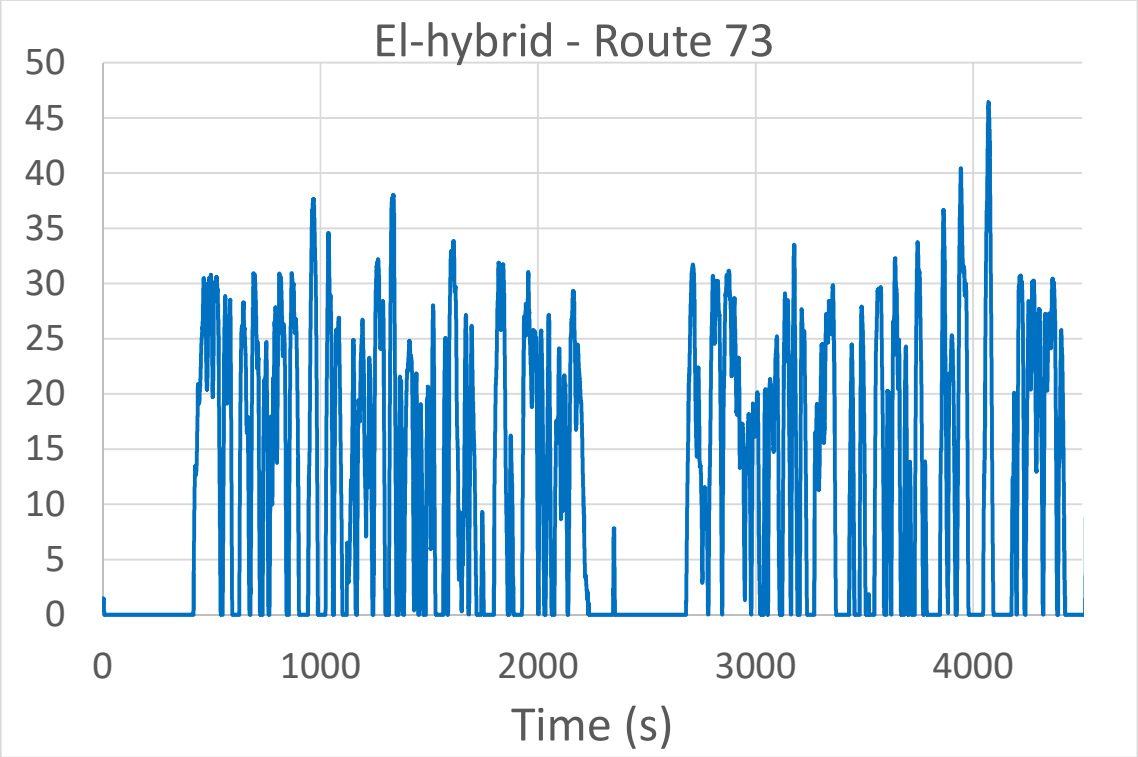


Figure K2. Velocity profile over the 73 route. Speed in km/h.

The PEMS tests were carried out during the 15th and 19th of August 2016.

Vehicle payload for the test series mark 50 % of the maximum permissible payload. Both PEMS trips were started after warming up the engine. In addition, one test on the Euro VI route was carried out with a cold start. No diagnostic trouble codes from the OBD system were detected.

Emission test results

The in service conformity emission testing results are presented in Figure K3 - K4. The results of CO and THC are not presented since all CO results were below the detection limit and all THC close to the detection limit.

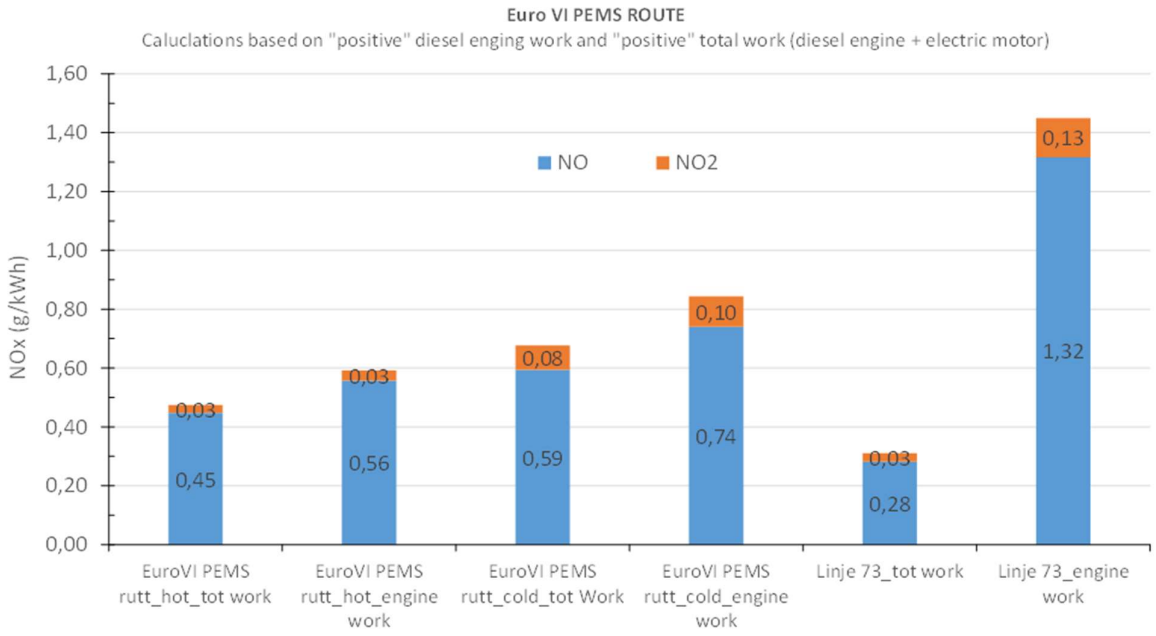


Figure K3. NO and NO2 emission results. ICE based as well as total work including electrical motor.

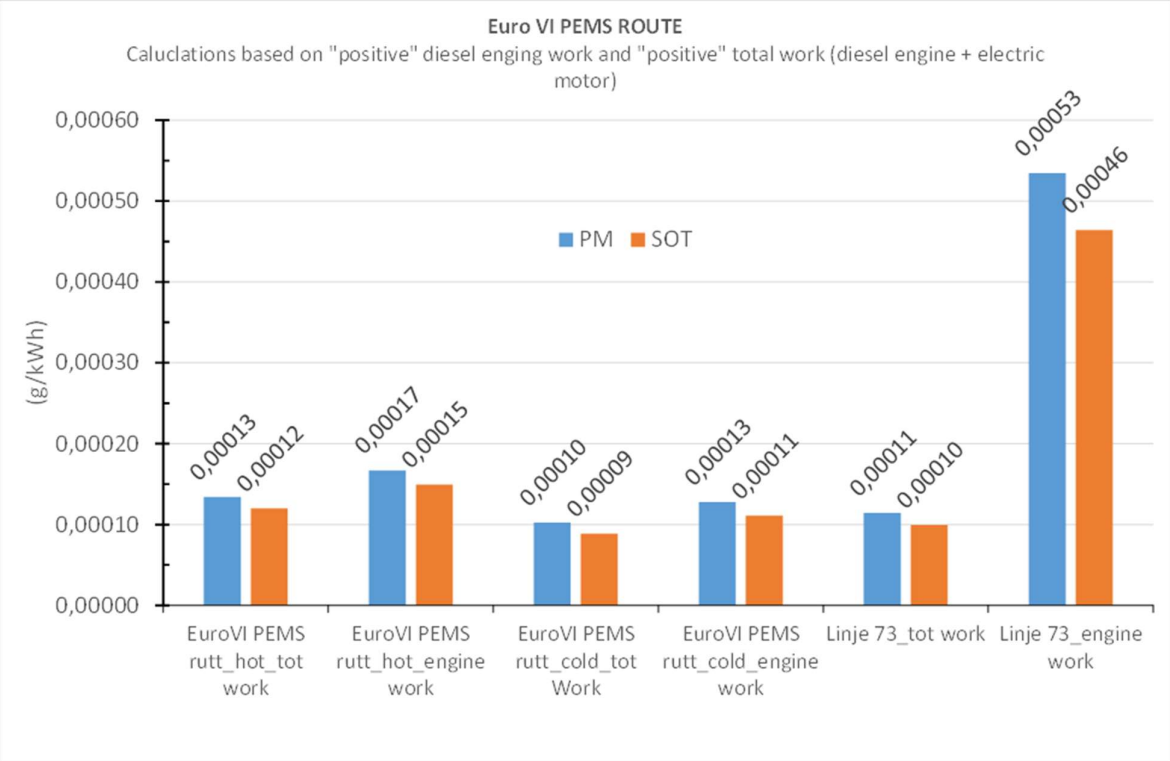


Figure K4. PM and soot emission results. ICE based as well as total work including electrical motor.

Table K1. Distance specific emissions, g/km.

	Route 73	Hot Euro VI	Cold Euro VI
Fuel Economy(l/100km)	9.61	27.1	26.6
CO2	251	672	670
CO	0	0	0
THC	0.0047	0.005	0
NO	0.42	0.5	0.87
NO2	0.042	0.058	0.12
NOx	0.46	0.56	0.99
Soot	0.00014	0.00012	0,00013
PM	0.00016	0.00014	0.00015

Conclutions

Measured brake specific emissions of NOx are below the Euro VI regulatory limit when taking the work of the electrical motor into account. The emission of CO and THC are close to or below the detection limit of the measurement instrument. PM emissions are in the order of 100 times below the regulatory limit. Relatively high NOx emissions can be seen on the 73 test route if the work from the electrical motor is omitted. This effect

is related to the fact that the temperature of the exhaust seldom reach the required light-off temperature of the SCR catalyst due to the city bus driving pattern.
Lastly, Table 1 shows the distance specific fuel consumption and emissions. The emissions of NOx are higher on the cold start test as an effect of the low temperature of the engine coolant and exhaust temperature. The measurement starts at an engine and ambient temperature of 15 ^{o}C. The calculations of the emissions are based on the complete test run in order to obtain real driving emissions factors. According to the regulation the calculation should omit values below engine temperatures of 70 ^{o}C.

Vehicle L

Vehicle

Model year:	2014
Vehicle category:	N3
Vehicle type:	Rigid truck
Mileage:	97 000 km
Engine:	6-cylinder
Displacement:	10 800 cm^3
Fuel:	Diesel
Power:	250 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF, ASC
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	21 000 kg
Mass in running order:	11 200 kg
Maximum payload:	9 800 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed on the 6th and 7th of October in 2016.

Table 2. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
PEMS Euro VI N3 route	2	-	-	5 000

The vehicle payload, during the on-road tests using PEMS, made 51% of the maximum payload. All tests where started with a cold engine but the evaluation of conformity factors has been performed according to the legislation where emissions emitted before the engine has reached 70°C are excluded. In the “all event result” are cold start emissions included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-10-06):

- Trip average RH: 63 %
- Trip average ambient temperature: 11 °C

Test 2 (2016-10-07):

- Trip average RH: 66 %
- Trip average ambient temperature: 11 °C

On Board Diagnostics (OBD)

No diagnostic trouble codes from the OBD system.

Emission test results

CO and THC conformity factors are insignificantly small. The ISC NO_X results for PEMS tests are presented in Figure A1. NO_X conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows in 2016 as well as in 2015 but have increased significantly over the past year.

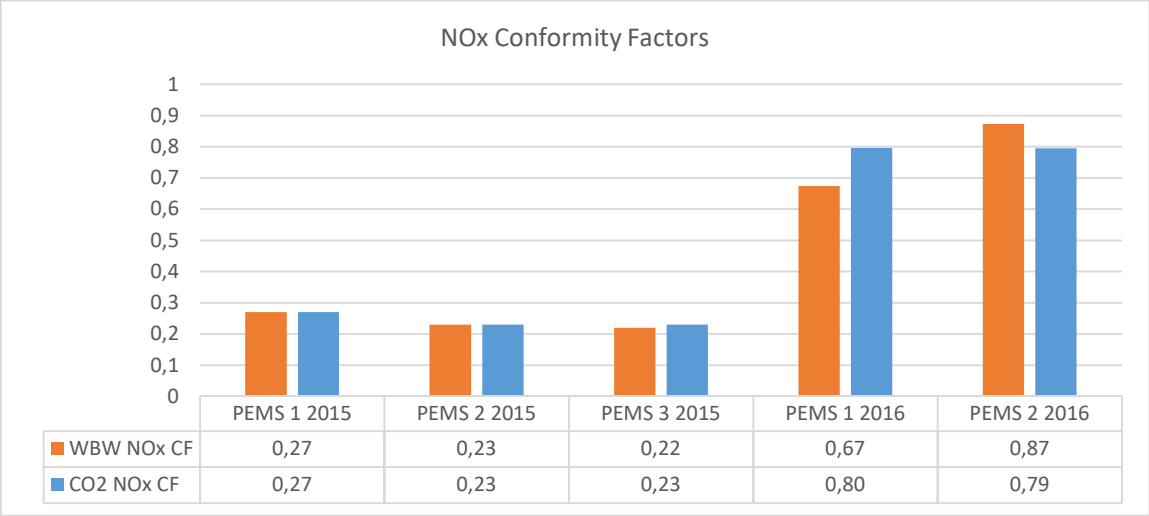


Figure 122. Work and CO2 based NOx conformity factors for the PEMS tests, in 2015 and in 2016.

PM was not measured in 2015, but is low and meet the legislative criteria in 2016, Figure A1.

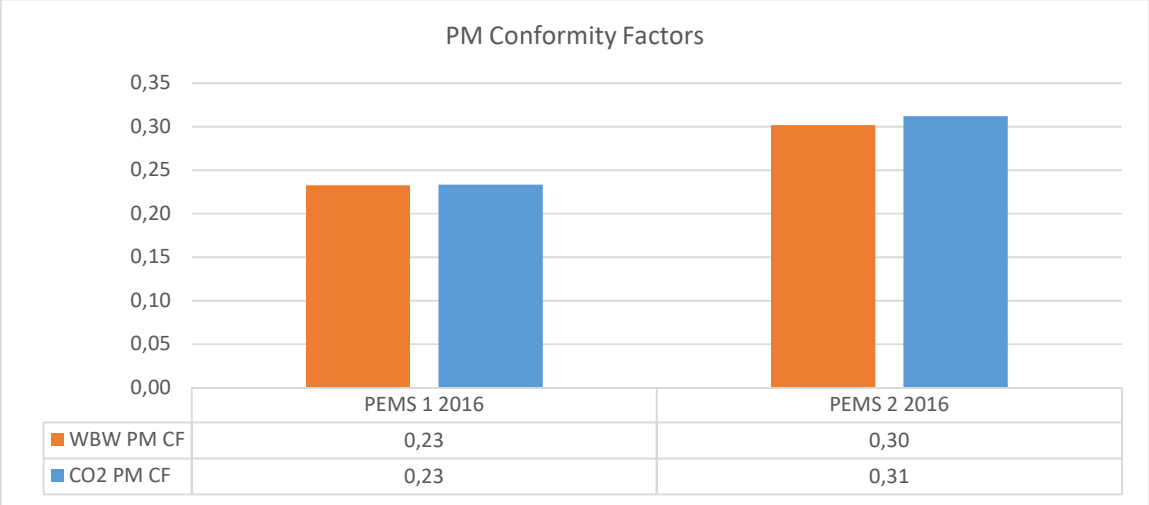


Figure 123. Work and CO2 based PM conformity factors in 2016.

PEMS tests when considering the complete route (all events) are summarized in both brake specific and distance specific units.

Both CO and THC emissions were either insignificantly small or not detected during the PEMS tests.

Figure A6 and Figure A7 show the measured NO_X emissions PEMS tests. Emissions of NOx has significantly increased over the past year.

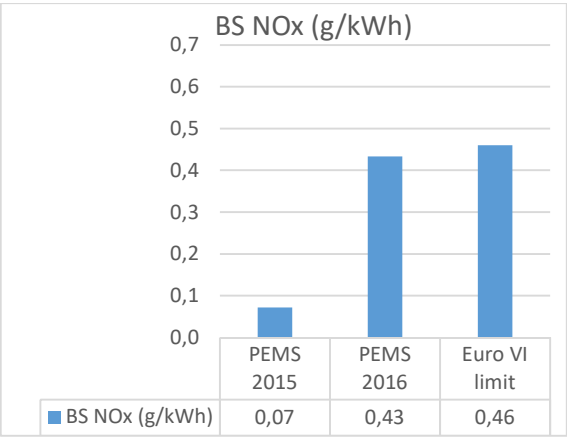


Figure 124. Avg. brake specific NO_X emissions (g/kWh)

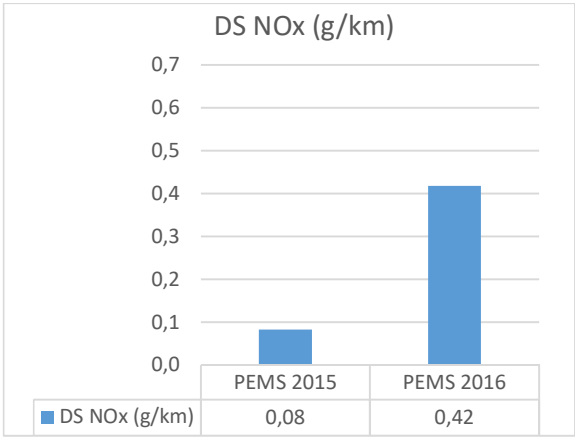


Figure 125. Avg. distance specific NO_X emissions (g/km)

PM and Particle number emissions (PN) are presented in Figure 126 and Figure 127. All results are lower than the Euro VI PM and PN limits.

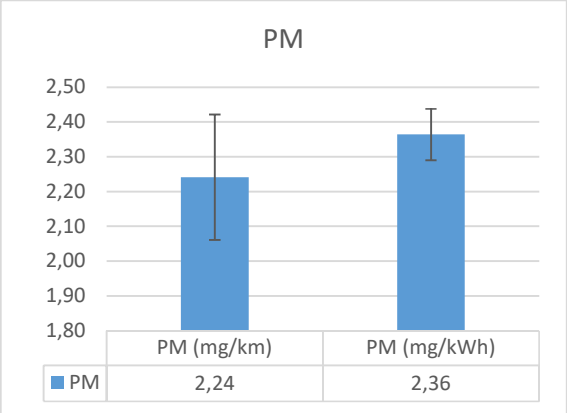


Figure 126. Avg. PM emissions

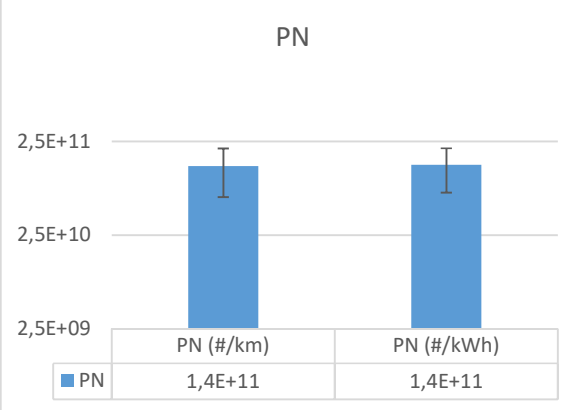


Figure 127. Avg. PN emissions

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value. Emissions of NOx have increased over the past year.

No malfunction was indicated by the OBD system.

Vehicle M

Vehicle

Model year:	2014
Vehicle category:	N2
Vehicle type:	Delivery truck
Mileage:	60 000 km
Engine:	6-cylinder
Displacement:	7 700 cm^3
Fuel:	Diesel
Power:	~ 180 kW
Exhaust after treatment:	DOC, DPF, SCR
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	12 000 kg
Mass in running order (vehicle):	7 600 kg
Maximum payload:	4 400 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 11th and 18th of October 2016.

Table 3. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	10 184	(≈2 600)
WHVC	2	3	10 184	(≈2 600)
PEMS Euro VI N3 route	2	-	-	2 500

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 843 N
- A1: 59 N/(km/h)
- A2: 1.85 $N/(km/h)^2$

The simulated vehicle payload during the tests on the chassis dynamometer made 59% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 57 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors were performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the "all events result", emissions released during cold start are included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-10-11):

- Trip average RH: 68 %
- Trip average ambient temperature: 9°C

Test 2 (2016-10-12):

- Trip average RH: 74 %
- Trip average ambient temperature: 8 °C

On Board Diagnostics (OBD)

No fault codes were indicated by the OBD system.

Emission test results

The ISC NOX and PM results for both PEMS tests are presented in Figure A1 and Figure A1 respectively. CO and THC conformity factors are insignificantly small. The emissions of NOx where rather high, not passing the conformity factor limit in any test. The particulate emissions where low meeting the legislative criteria.

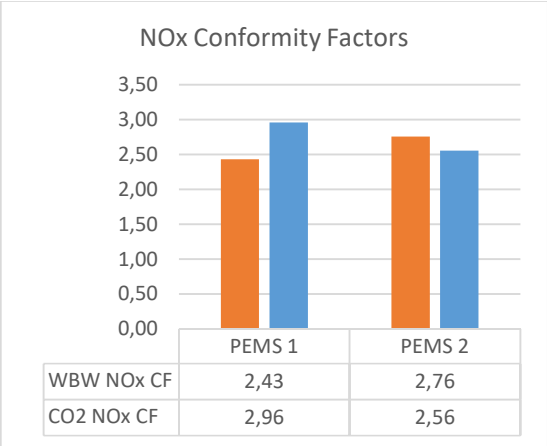


Figure 128. Work and CO2 based NOx conformity factors for the PEMS tests.

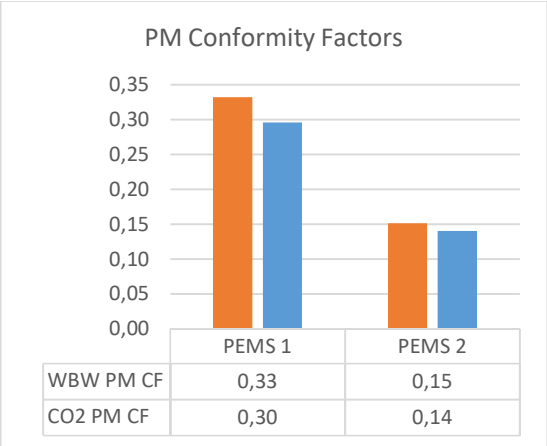


Figure 129. Work and CO2 based PM conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are far below the Euro VI limit of 4 g/kWh in all tests.

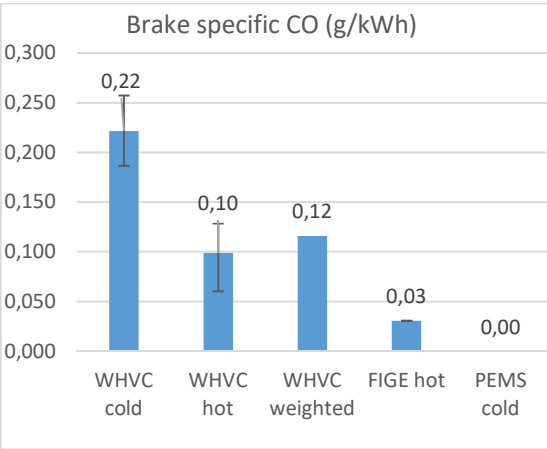


Figure 130. Avg. brake specific CO emissions (g/kWh)

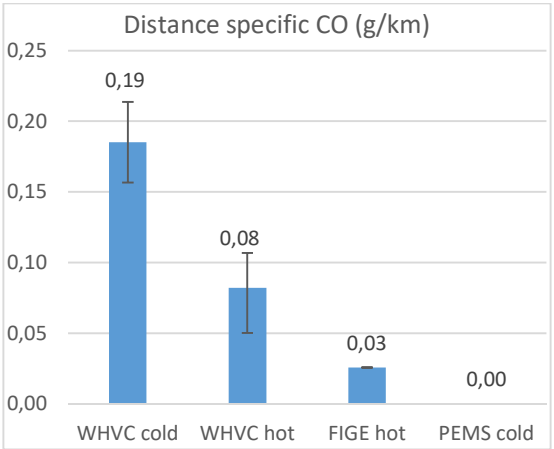


Figure 131. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure A4 and Figure A5. Emitted THC is below the Euro VI legislative limit of 0.16 g/kWh.

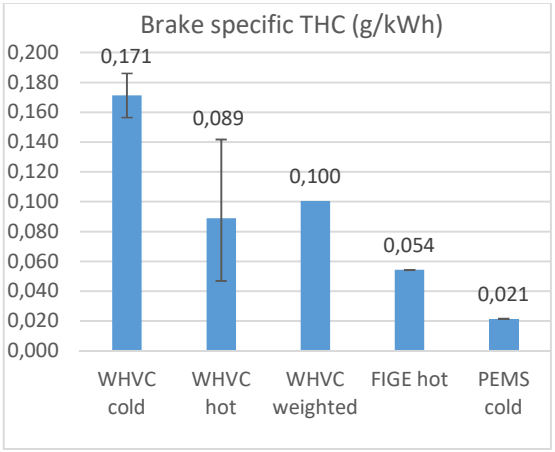


Figure 132. Avg. brake specific THC emissions (g/kWh)

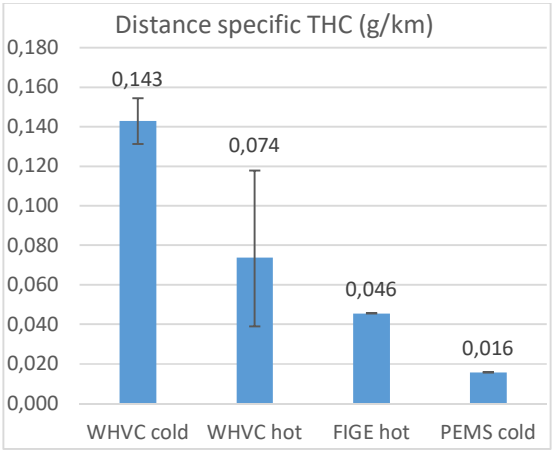


Figure 133. Avg. distance specific THC emissions (g/km)

The NOx emissions measured during the tests on the chassis dynamometer were in all cycles higher than the Euro VI emission limit. Also the "all events" results from the PEMS testing showed high NOx emissions. Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS tests.

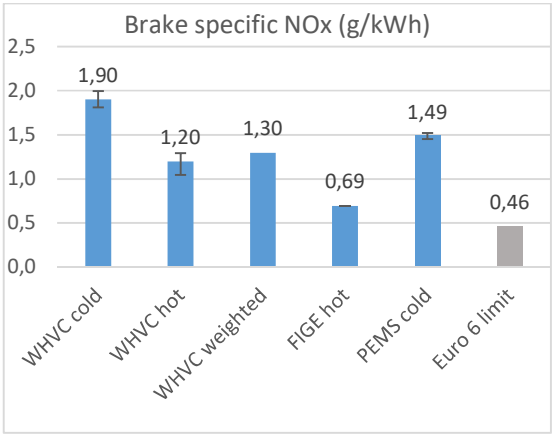


Figure 134. Avg. brake specific NO_X emissions (g/kWh)

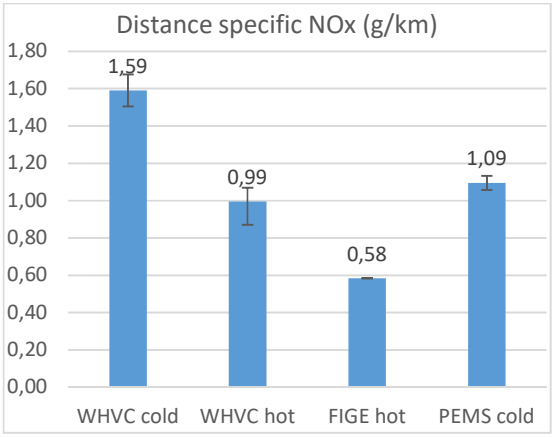


Figure 135. Avg. distance specific NO_X emissions (g/km)

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. Particle emissions are below the legislative limits.

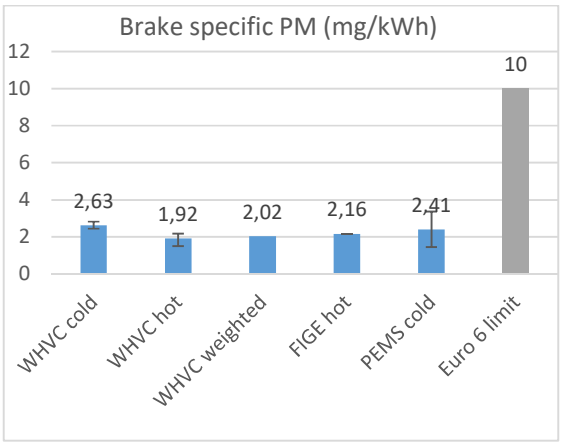


Figure 136. Avg. brake specific PM emissions (mg/kWh)

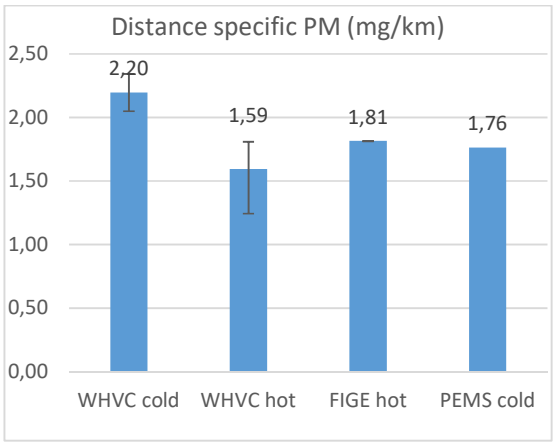


Figure 137. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. All results in the WHVC are lower than the Euro VI particle number limit.

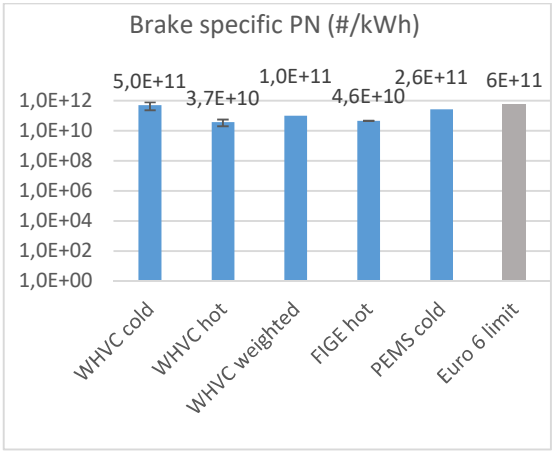


Figure 138. Avg. brake specific PN emissions (#/kWh)

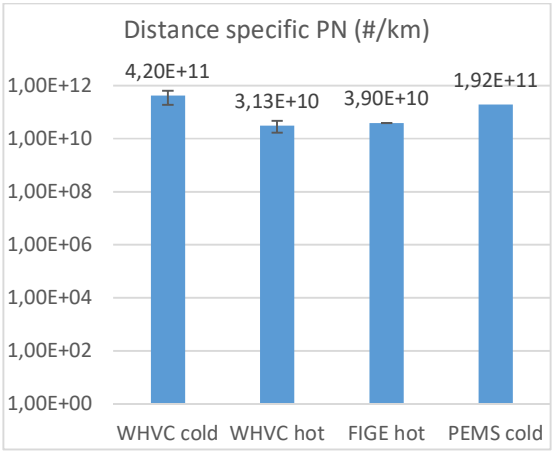


Figure 139. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to Figure A15.

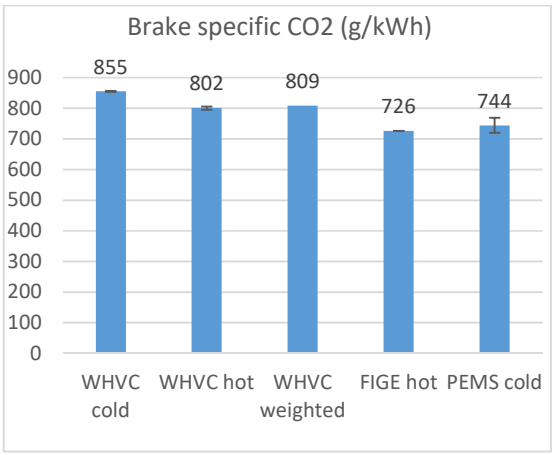


Figure 140. Avg. brake specific CO_2 emissions (g/kWh)

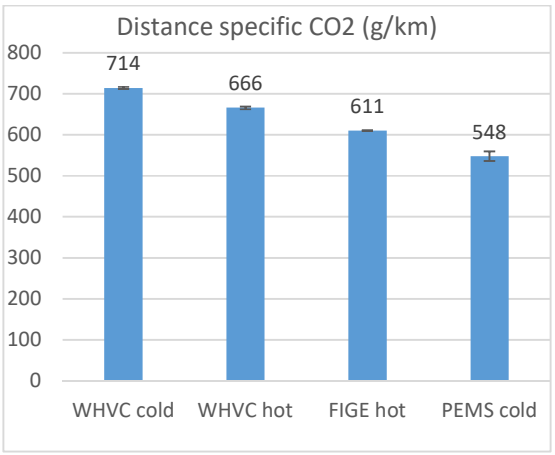


Figure 141. Avg. distance specific CO_2 emissions (g/km)

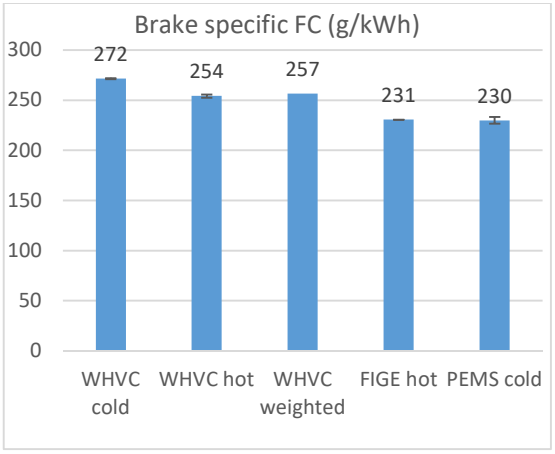


Figure M15. Avg. brake specific FC (g/kWh)

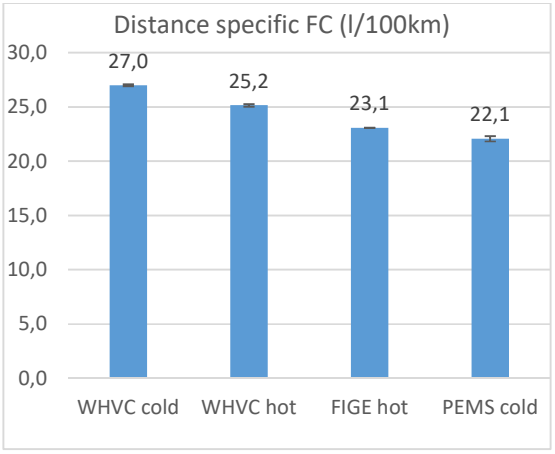


Figure M16. Avg. distance specific FC (l/100km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure A16.

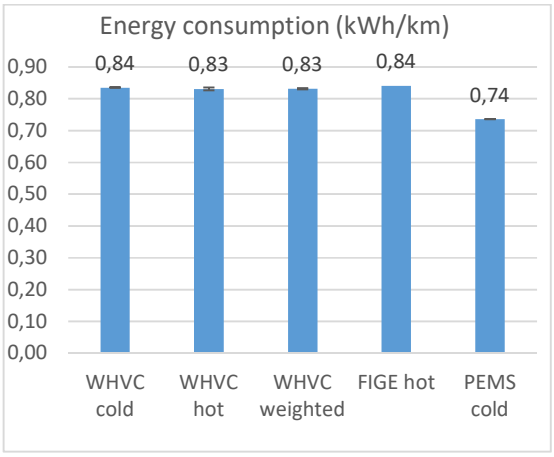


Figure 142. Avg. energy consumption (kWh/km)

Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are below the Euro VI regulatory limit of 10 ppm.

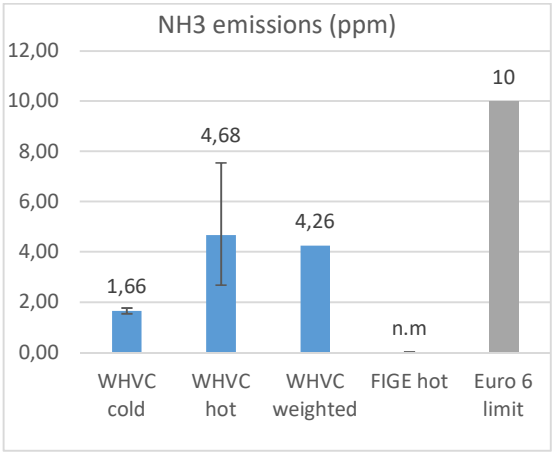


Figure 143. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

The established NOx conformity factors from the ISC evaluation, for both work and CO_2 based windows, were rather high and the vehicle did not pass the Euro VI emission limit of 1.5. The particulate emissions where low, meeting the legislative criteria.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions measured during all tests were above the Euro VI limit for engine tests. The ammonia emissions measured were rather low.
No fault codes were indicated by the OBD system.

Vehicle N

Vehicle

Model year:	2014
Vehicle category:	N3
Vehicle type:	Garbage truck
Mileage:	58 000 km
Engine:	5-cylinder
Displacement:	9 300 cm^3
Fuel:	Diesel
Power:	~ 200 kW
Exhaust after treatment:	DOC, DPF, SCR
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	18 600 kg
Mass in running order (vehicle):	12 000 kg
Maximum payload:	6 000 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 26th of October and 3d of November 2016.

Table 4. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	14 026	(≈2 100)
WHVC	2	3	14 026	(≈2 100)
PEMS Euro VI N3 route	2	-	-	2 100

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 843 N
- A1: 59 N/(km/h)
- A2: 1.85 $N/(km/h)^2$

The simulated vehicle payload during the tests on the chassis dynamometer made 34% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 34 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors were performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the "all events result", emissions released during cold start are included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-10-26):

- Trip average RH: 82 %
- Trip average ambient temperature: 6°C

Test 2 (2016-11-03):

- Trip average RH: 72 %
- Trip average ambient temperature: 2 °C

On Board Diagnostics (OBD)

No fault codes were indicated by the OBD system.

Emission test results

The ISC NOX and PM results for both PEMS tests are presented in Figure A1 and Figure A1 respectively. CO and THC conformity factors are insignificantly small. The emissions of NOx low, passing the conformity factor limit in both tests. Also the particulate emissions where low meeting the legislative criteria.

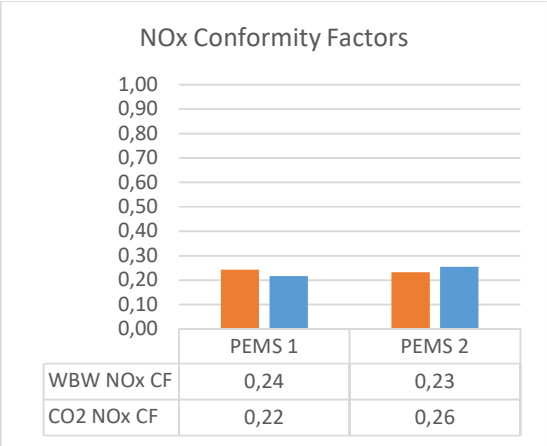


Figure 144. Work and CO2 based NOx conformity factors for the PEMS tests.

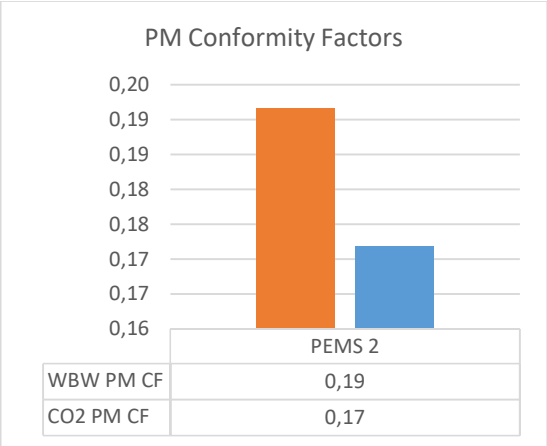


Figure 145. Work and CO2 based PM conformity factors for the second PEMS test.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are far below the Euro VI limit of 4 g/kWh in all tests.

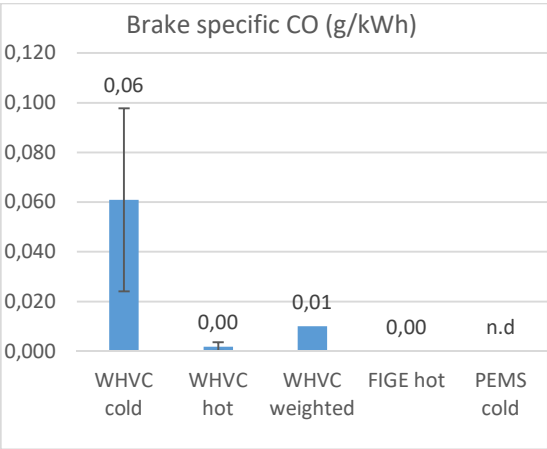


Figure 146. Avg. brake specific CO emissions (g/kWh)

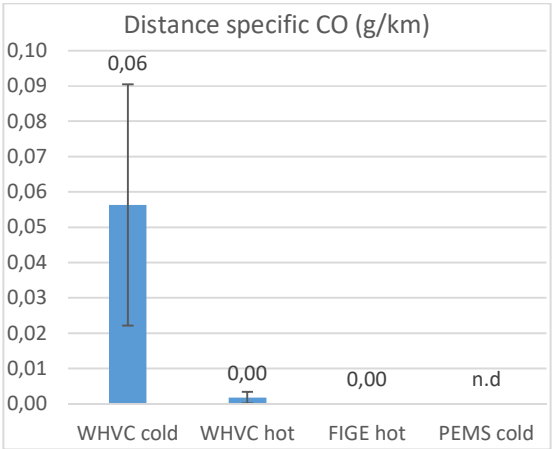


Figure 147. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure A4 and Figure A5. Emitted THC is below the Euro VI legislative limit of 0.16 g/kWh.

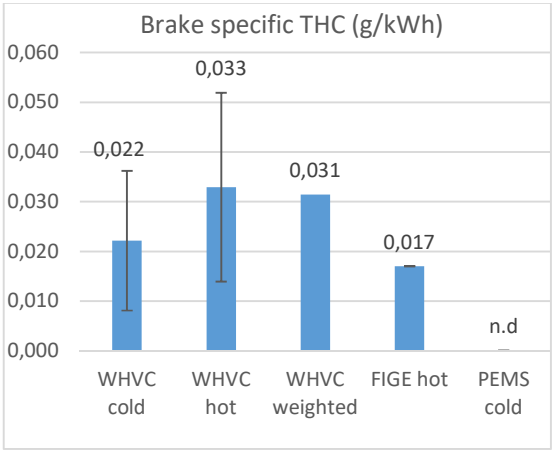


Figure 148. Avg. brake specific THC emissions (g/kWh)

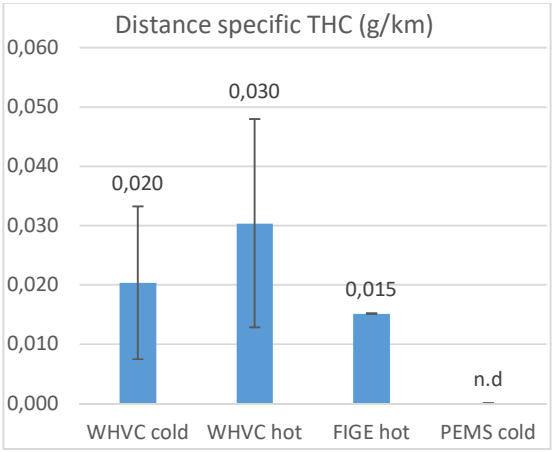


Figure 149. Avg. distance specific THC emissions (g/km)

Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS tests. Results indicate raised emissions of NO_X for the WHVC cold start however, the weighted average, is below the Euro VI limit.

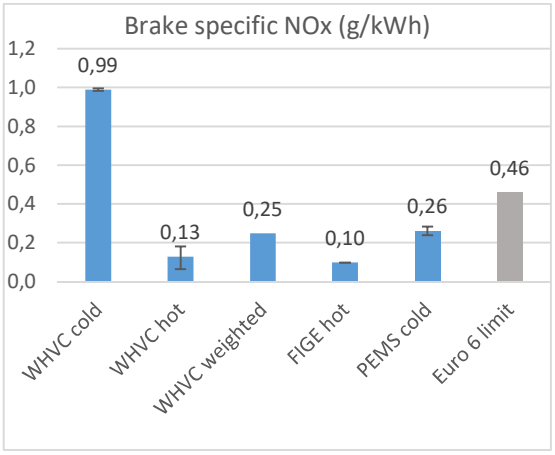


Figure 150. Avg. brake specific NO_X emissions (g/kWh)

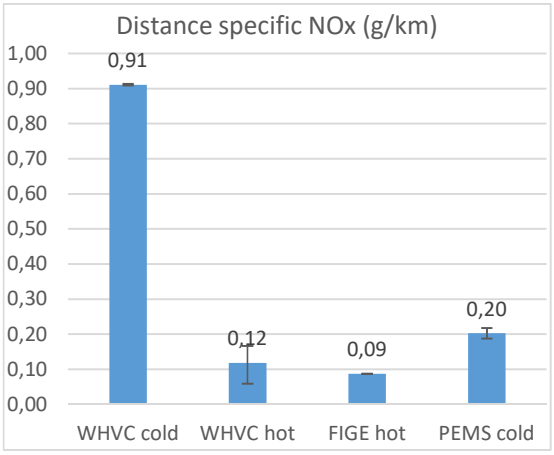


Figure 151. Avg. distance specific NO_X emissions (g/km

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. Particle emissions are below the legislative limits.

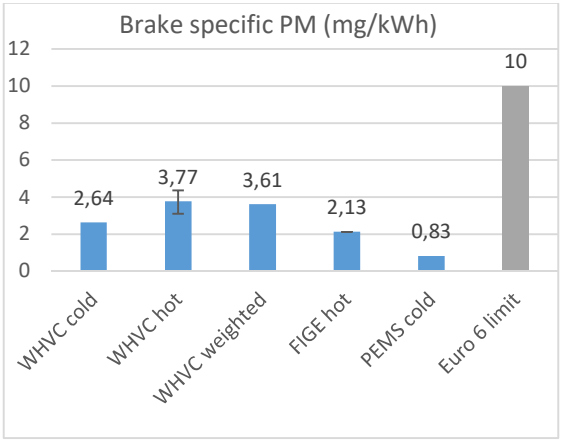


Figure 152. Avg. brake specific PM emissions (mg/kWh)

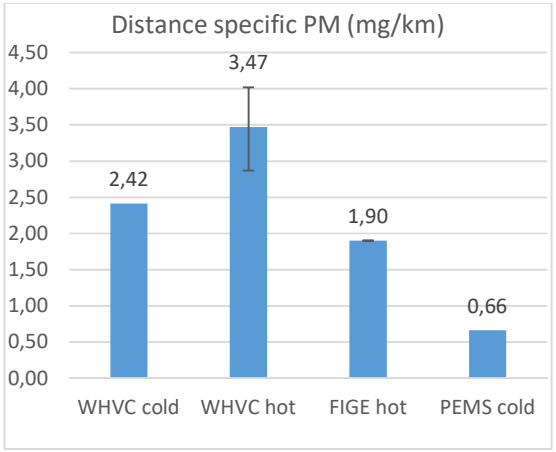


Figure 153. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. All results are lower than the Euro VI particle number limit. The number of emitted particles are higher for WHVC cold start tests.

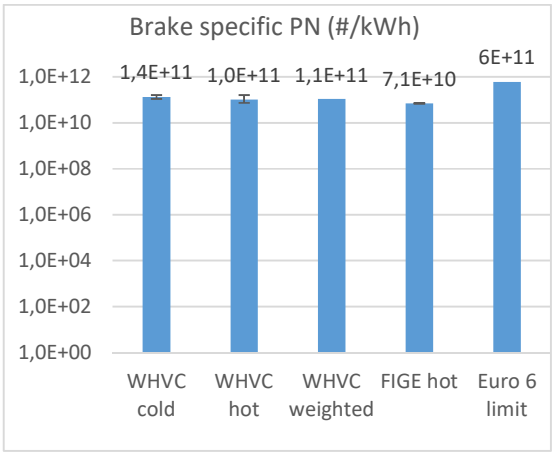


Figure 154. Avg. brake specific PN emissions (#/kWh)

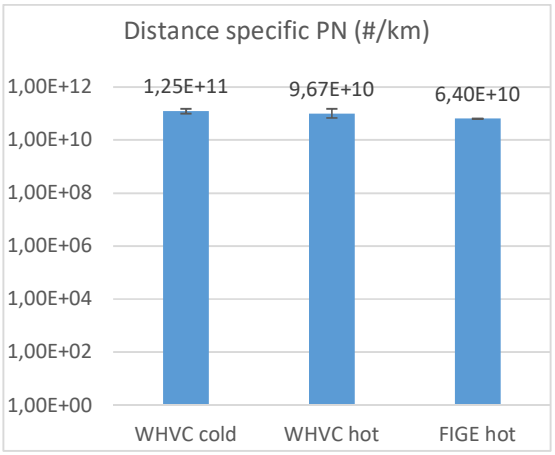


Figure 155. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to Figure A15.

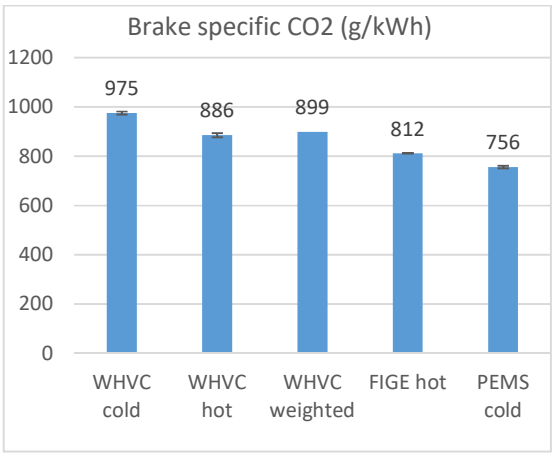


Figure 156. Avg. brake specific CO_2 emissions (g/kWh)

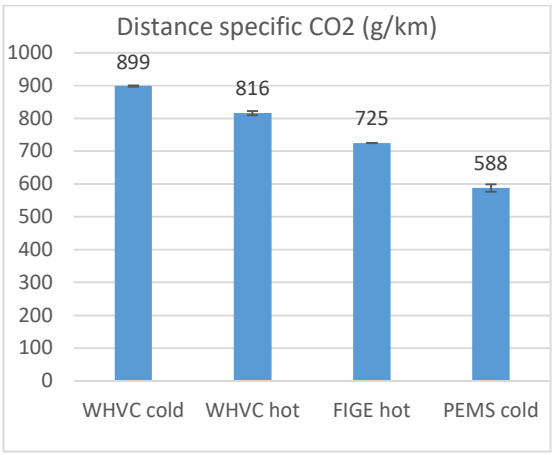


Figure 158. Avg. distance specific CO_2 emissions (g/km)

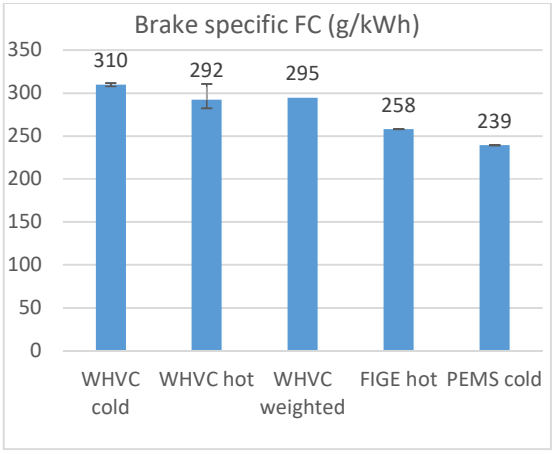


Figure 157. Avg. brake specific FC (g/kWh)

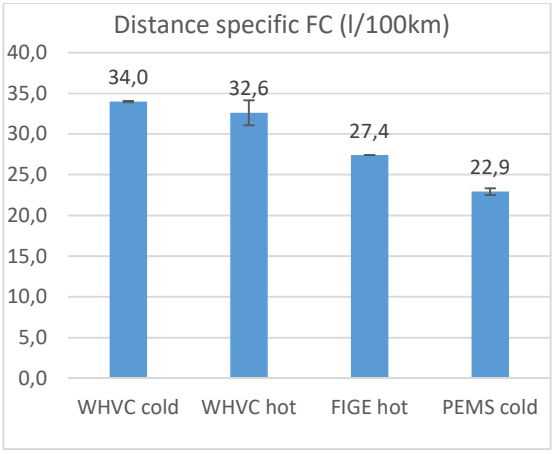


Figure 159. Avg. distance specific FC (l/100km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure A16.

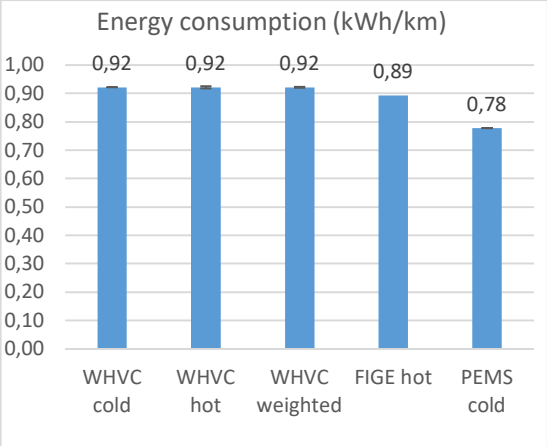


Figure 160. Avg. energy consumption (kWh/km)

Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are below the Euro VI regulatory limit of 10 ppm.

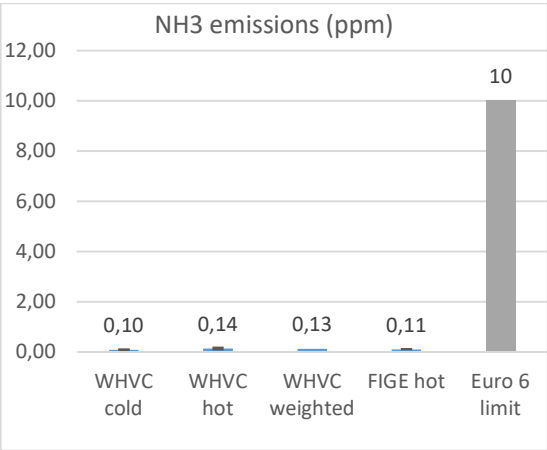


Figure 161. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions were a little high in the WHVC cold start, however very low in all warm start tests resulting in a weighted average below the Euro VI limit. The ammonia emissions measured were low.
No fault codes were indicated by the OBD system.

Vehicle O

Vehicle

Model year:	2013
Vehicle category:	N3
Vehicle type:	Tractor trailer
Mileage:	140 000 km
Engine:	6-cylinder
Displacement:	12 800 cm^3
Fuel:	Diesel
Power:	~ 350 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF, ASC
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	27 000 kg
Mass in running order:	9 600 kg
Maximum trailer weight:	60 000 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed on the 16th and 17th of November in 2016.

Table 5. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
PEMS Euro VI N3 route	2	-	-	20 000

All tests where started with a cold engine but the evaluation of conformity factors has been performed according to the legislation where emissions emitted before the engine has reached 70°C are excluded. In the “all event result” are cold start emissions included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-11-16):

- Trip average RH: 87 %
- Trip average ambient temperature: 5 °C

Test 2 (2016-11-17):

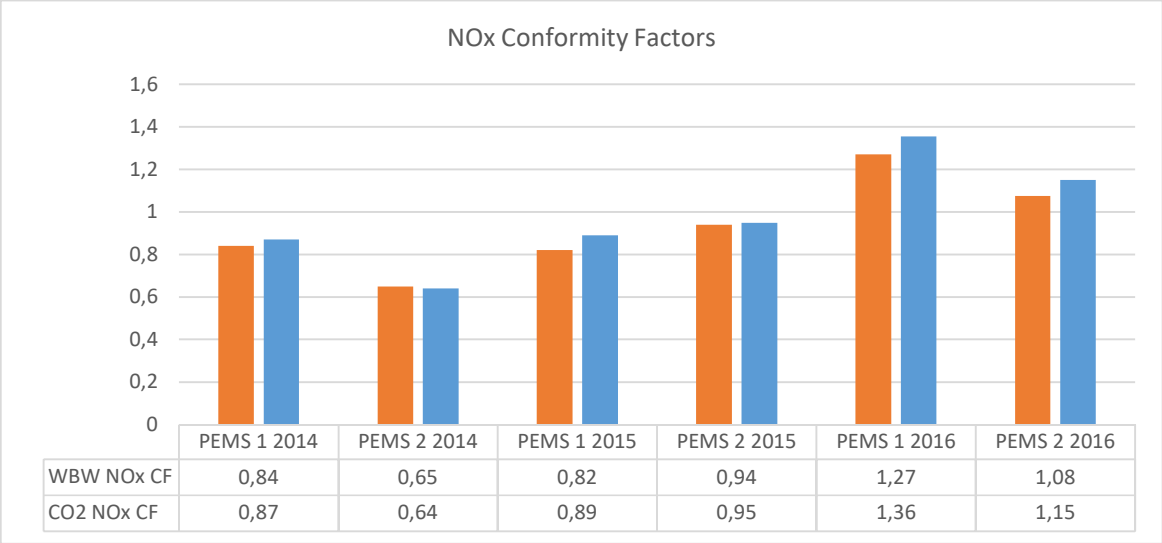
- Trip average RH: 84 %
- Trip average ambient temperature: 5 °C

On Board Diagnostics (OBD)

No diagnostic trouble codes from the OBD system.

Emission test results

CO and THC conformity factors are insignificantly small. The ISC NO_X results for PEMS tests are presented in Figure A1. NO_X conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows in 2016 as well as in 2015 but have increased over the past year.



	PEMS 1 2014	PEMS 2 2014	PEMS 1 2015	PEMS 2 2015	PEMS 1 2016	PEMS 2 2016
WBW NOx CF	0,84	0,65	0,82	0,94	1,27	1,08
CO2 NOx CF	0,87	0,64	0,89	0,95	1,36	1,15

Figure 162. Work and CO2 based NOx conformity factors for the PEMS tests in 2014, 2015 and in 2016.

PM was not measured in 2015, but is low and meet the legislative criteria in 2016 (Figure A1).

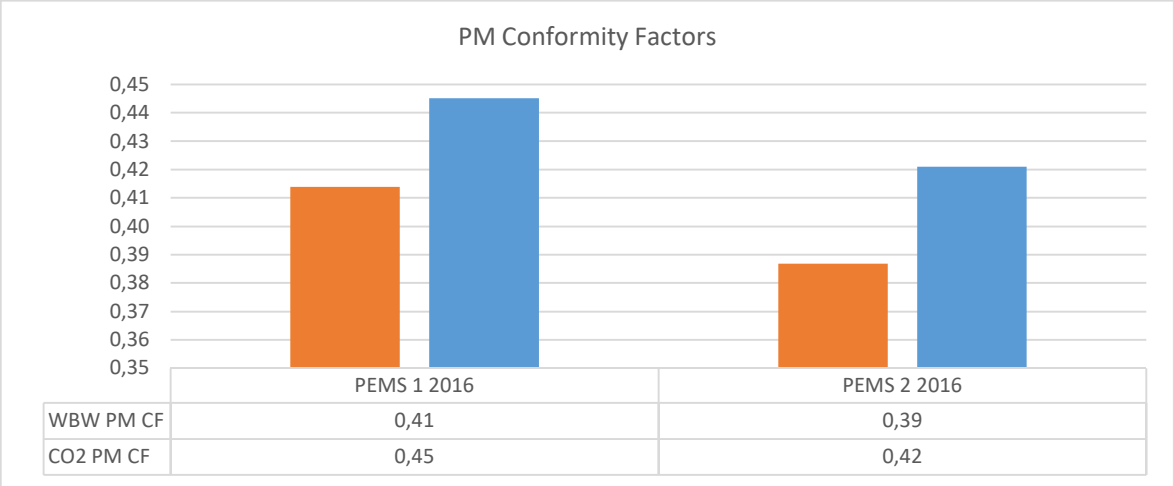


Figure 163. Work and CO2 based PM conformity factors in 2016.

PEMS tests when considering the complete route (all events) are summarized in both brake specific and distance specific units.
Both CO and THC emissions were either insignificantly small or not detected during the PEMS tests.
Figure A6 and Figure A7 show the measured NO_X emissions PEMS tests. Emissions of NOx have increased each year.

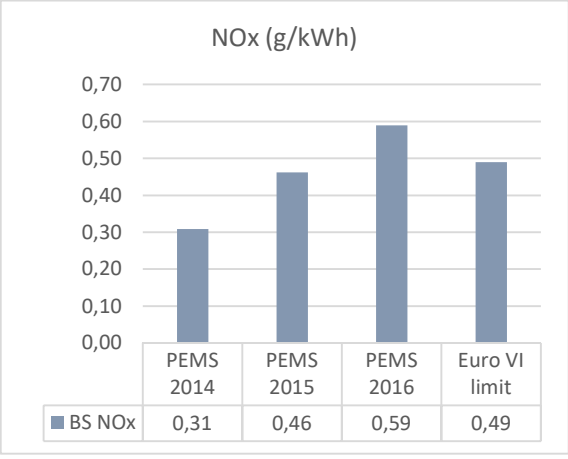


Figure 164. Avg. brake specific NO_X emissions (g/kWh)

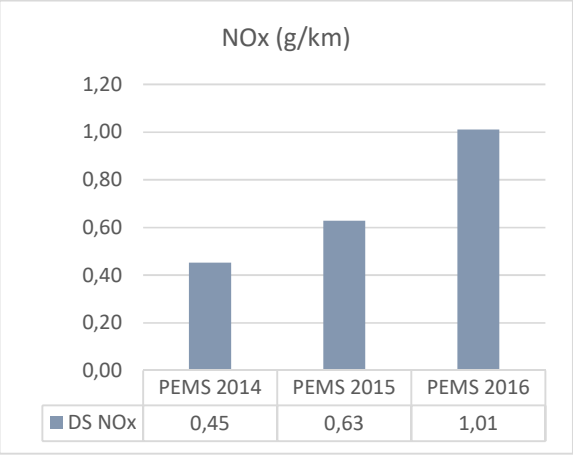


Figure 165. Avg. distance specific NO_X emissions (g/

Particle Matter (PM) measured in 2016 is presented in Figure 166. All results are lower than the Euro VI limit (10 mg/kWh).

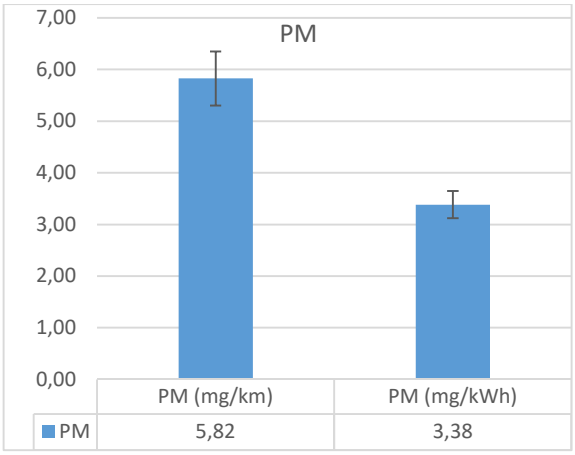


Figure 166 Avg. PM emissions

Conclusions

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value. Emissions of NOx have increased over the past year. Emissions of PM were low.

No malfunction was indicated by the OBD system.

Vehicle P

Vehicle

Model year:	2014
Vehicle category:	N2
Vehicle type:	Delivery truck
Mileage:	68 000 km
Engine:	6-cylinder
Displacement:	7 700 cm^3
Fuel:	Diesel
Power:	180 kW
Exhaust after treatment:	DOC, DPF, SCR
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	12 000 kg
Mass in running order (vehicle):	7 600 kg
Maximum payload:	4 400 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test information

The testing was performed between the 30th of November and 8th of December 2016.

Table 6. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	10 184	(≈2 600)
WHVC	2	3	10 184	(≈2 600)
PEMS Euro VI N3 route	2	-	-	2 500

The inertia specified in Table B 1 correspond to the chassis dynamometer inertia setting. Settings for the chassis dynamometer are specified below:

Road load (Polynomial coefficients):

- A0: 843 N
- A1: 59 N/(km/h)
- A2: 1.85 $N/(km/h)^2$

The simulated vehicle payload during the tests on the chassis dynamometer made 59% of the maximum payload.

Vehicle payload during the on-road tests using PEMS was 57 % of the maximum payload. Both PEMS trips were started with a cold engine but the evaluation of conformity factors was performed according to the legislation where all emissions before the engine coolant has reached 70°C are excluded. However, in the "all events result", emissions released during cold start are included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Results and discussion

Ambient conditions during PEMS testing

Test 1 (2016-11-30):

- Trip average RH: 61 %
- Trip average ambient temperature: 2°C

Test 2 (2016-12-01):

- Trip average RH: 63 %
- Trip average ambient temperature: -1°C

On Board Diagnostics (OBD)

No fault codes were indicated by the OBD system.

Emission test results

The ISC NOX, CO and THC results for both PEMS tests are presented in Figure A1 to Figure 169. The emissions of NOx where rather high, not passing the conformity factor limit in any test.

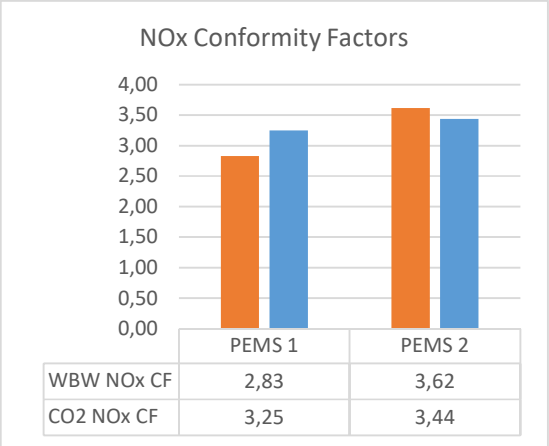


Figure 167. Work and CO2 based NOx conformity factors for the PEMS tests.

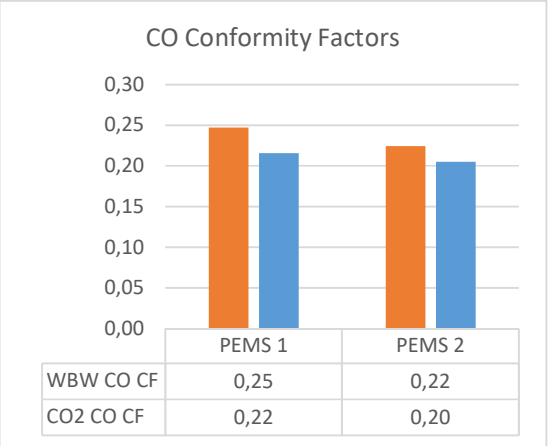


Figure 168. Work and CO2 based CO conformity factors for the PEMS tests.

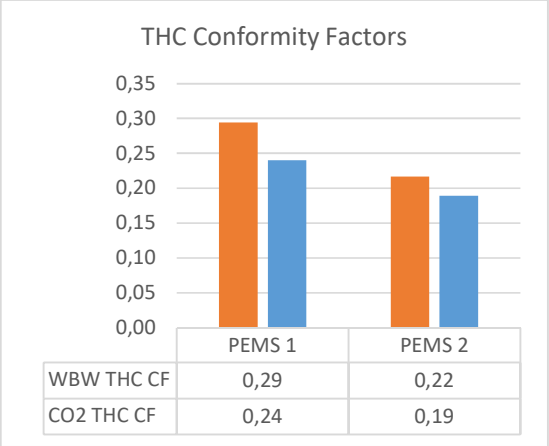


Figure 169 Work and CO2 based THC conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) as well as the chassis dynamometer tests are summarized in both brake specific and distance specific units. Emission levels are averaged for repeated tests and shown with corresponding measured minimum and maximum value. The weighted WHVC emissions are calculated by 86% of the average hot test result and 14% of the average cold start test result.

Measured CO emissions, shown in Figure A2 and Figure A3, are far below the Euro VI limit of 4 g/kWh in all tests.

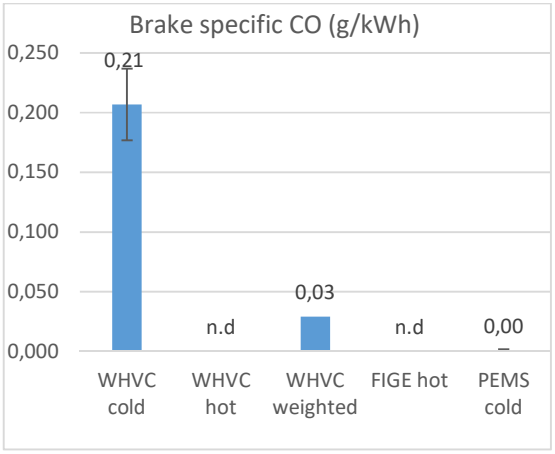


Figure 170. Avg. brake specific CO emissions (g/kWh)

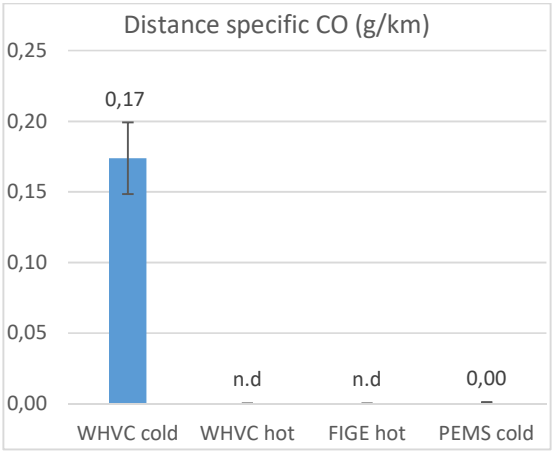


Figure 171. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure A4 and Figure A5. Emitted THC is below the Euro VI legislative limit of 0.16 g/kWh.

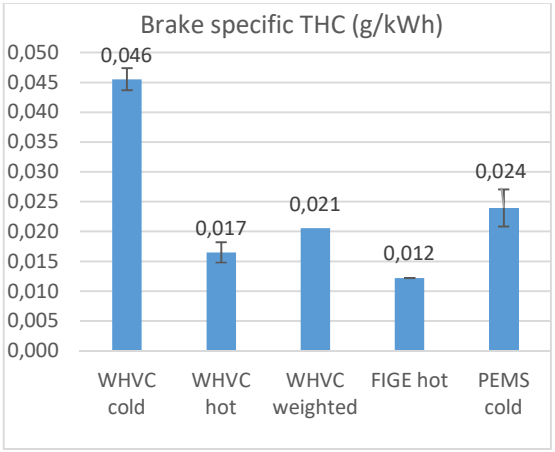


Figure 172. Avg. brake specific THC emissions (g/kWh)

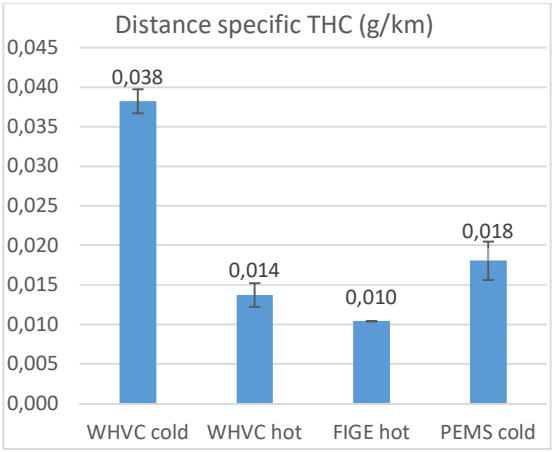


Figure 173. Avg. distance specific THC emissions (g/km)

The NOx emissions measured during the tests on the chassis dynamometer were in all cycles higher than the Euro VI emission limit. Also the “all events” results from the PEMS testing showed high NOx emissions. Figure A6 and Figure A7 show the measured NO_X emissions from the chassis dynamometer and PEMS tests.

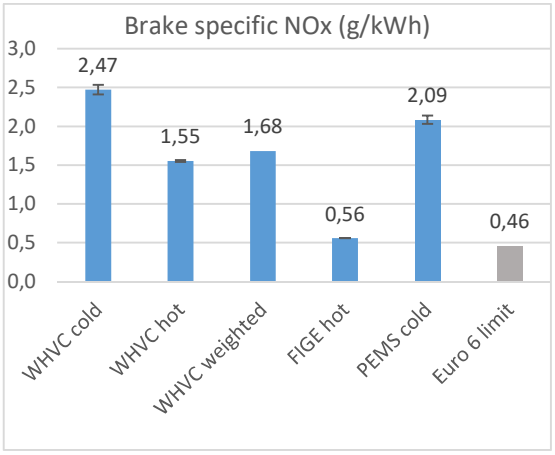


Figure 174. Avg. brake specific NO_X emissions (g/kWh)

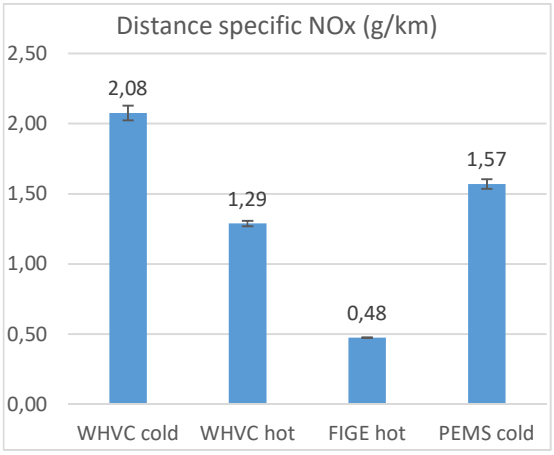


Figure 175. Avg. distance specific NO_X emissions (g/km)

Gravimetrically measured PM results are presented in Figure A8 and Figure A9. Particle emissions are below the legislative limits.

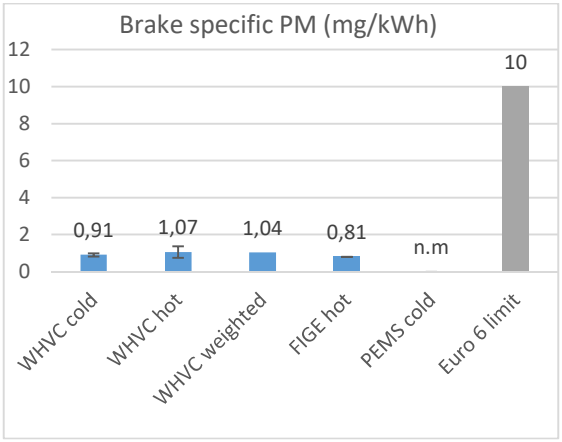


Figure 176. Avg. brake specific PM emissions (mg/kWh)

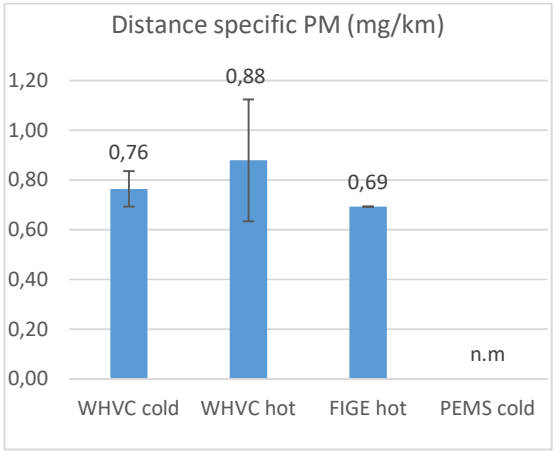


Figure 177. Avg. dist. specific PM emissions (mg/km)

Particle number emissions are presented in Figure A10 and Figure A11. All results in the WHVC are lower than the Euro VI particle number limit.

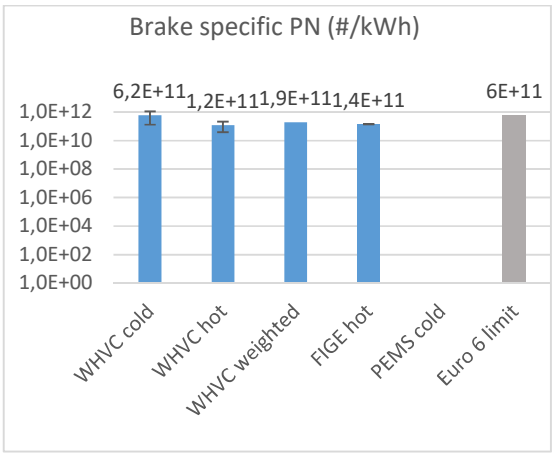


Figure 178. Avg. brake specific PN emissions (#/kWh)

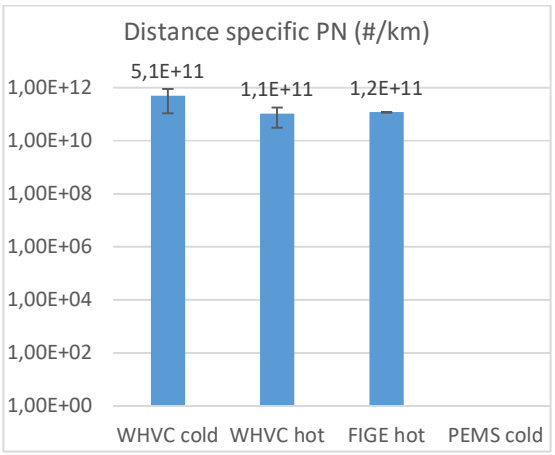


Figure 179. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure A12 to P17.

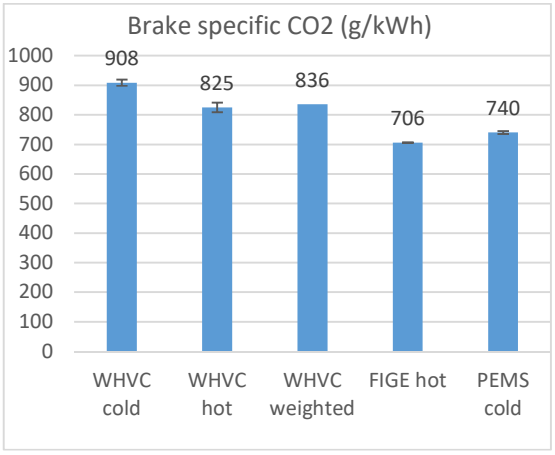


Figure 180. Avg. brake specific CO_2 emissions (g/kWh)

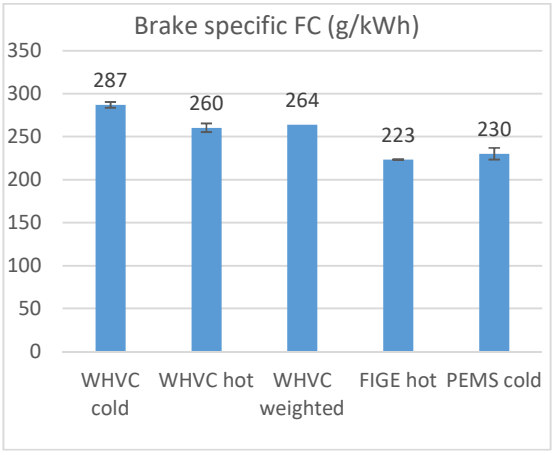


Figure 181. Avg. brake specific FC (g/kWh)

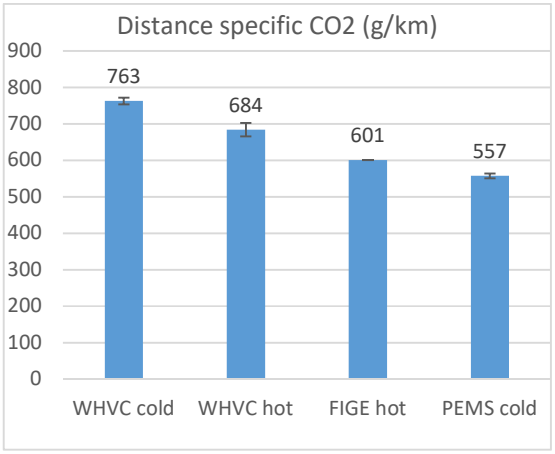


Figure 182. Avg. distance specific CO_2 emissions (g/km)

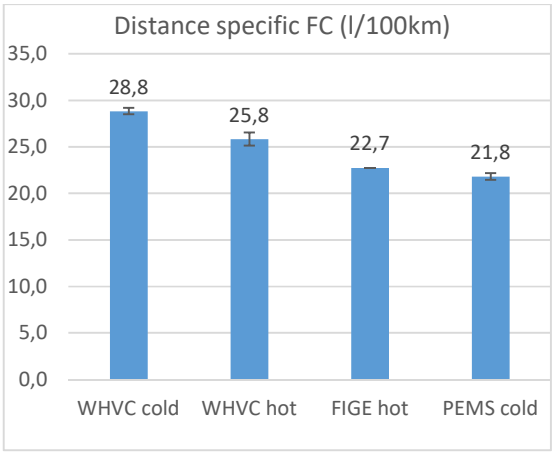


Figure 183. Avg. distance specific FC (l/100km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in P18.

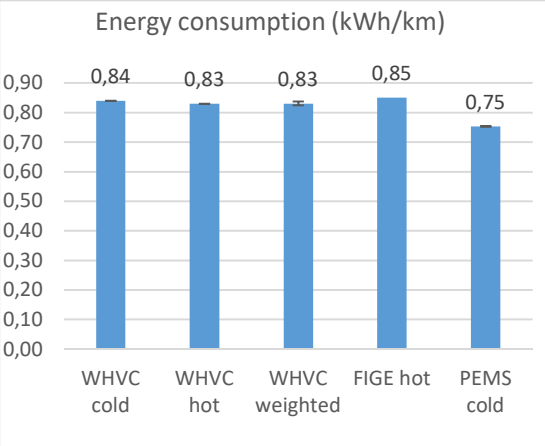


Figure 184. Avg. energy consumption (kWh/km)

Figure A17 indicate the measured NH_3 ppm levels over the chassis dynamometer tests. Demonstrated values are below the Euro VI regulatory limit of 10 ppm.

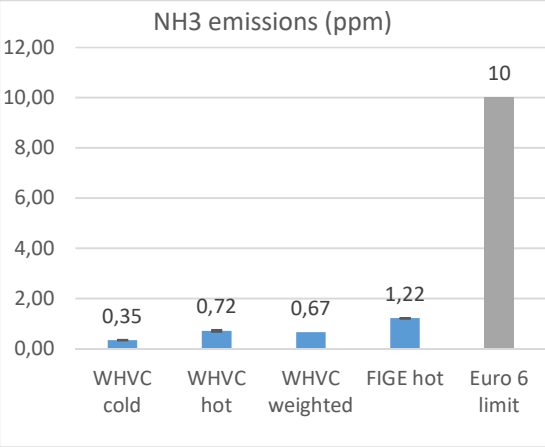


Figure 185. Avg. NH_3 emissions over chassis dynamometer tests (ppm)

Conclusions

The established NOx conformity factors from the ISC evaluation, for both work and CO_2 based windows, were rather high and the vehicle did not pass the Euro VI emission limit of 1.5. The particulate emissions where low, meeting the legislative criteria.
All tests resulted in emissions of CO, THC, PM and PN well below the Euro VI emission limit. The NOx emissions measured during all tests were above the Euro VI limit for engine tests. The ammonia emissions measured were low.
No fault codes were indicated by the OBD system.

Vehicle Q

A delivery truck Euro VI, model year 2015, has been tested for exhaust emissions and fuel consumption. The vehicle was tested on Swedish roads using a portable emissions measurement system (PEMS).
The PEMS test results are presented as “all events” as well as the pass/fail criteria for In Service Conformity (ISC) where conformity factors limit for gaseous emissions and PM have been established.
All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

Presentation of vehicle:

Model year:	2015
Vehicle category:	N3
Vehicle type:	Delivery truck
Mileage:	53 000 km
Engine:	6-cylinder
Displacement:	7 700 cm^3
Fuel:	Diesel
Power:	~ 200 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	16 000 kg
Mass in running order:	8 100 kg
Maximum payload:	7 900 kg
Emission standard:	Euro VI

(* = *technically permissible maximum laden mass of the vehicle and trailer)*

Test program

The testing was performed on the 16th and 20th of December in 2016.

Ambient temperature for the PEMS tests varied between 3 °C and 5 °C. The relative humidity varied between 83 % and 86 %.

No diagnostic trouble codes from the OBD system.

Table Q1. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
PEMS Euro VI N3 route	2	-	-	4 100

The vehicle payload, during the on-road tests using PEMS, made 52% of the maximum payload. All tests where started with a cold engine but the evaluation of conformity factors has been performed according to the legislation where emissions emitted before the engine has reached 70°C are excluded. In the "all event result" are cold start emissions included.

The vehicle was fuelled with commercially available Environmental class 1 diesel (Mk1) during all tests.

Emission test results

The ISC NO_X results for PEMS tests are presented in Figure Q1. CO and THC conformity factors are insignificantly small. NO_X conformity factors pass the ISC criteria (below 1.5) for both work- and CO_2 mass based windows.

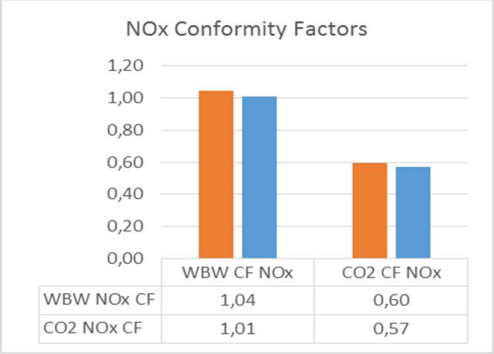


Figure Q1. Work and CO2 based NOx conformity factors for the PEMS tests.

PEMS tests when considering the complete route (all events) are summarized in both brake specific and distance specific units.

Measured emissions, shown in Figure Q2 and Figure Q3, are all below the Euro VI emission limits.

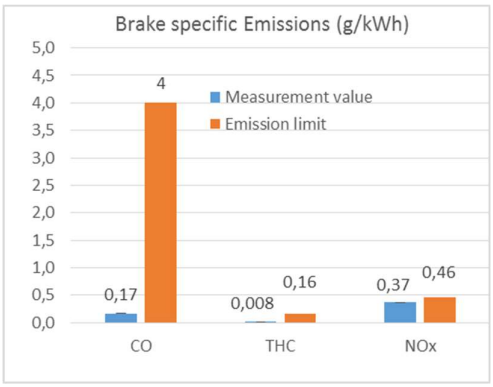


Figure Q2. Avg. brake specific emissions (g/kWh)

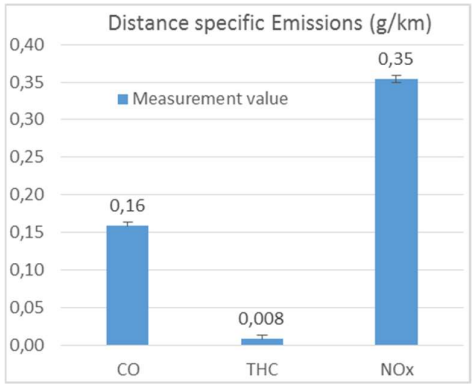


Figure Q3. Avg. distance specific emissions (g/km)

CO_2 emissions and calculated fuel consumption results are presented in Figure Q4 and Figure Q5.

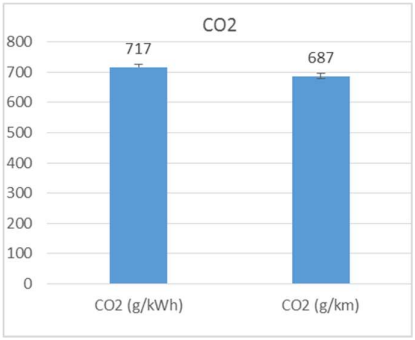


Figure Q4. Avg. CO_2 emissions

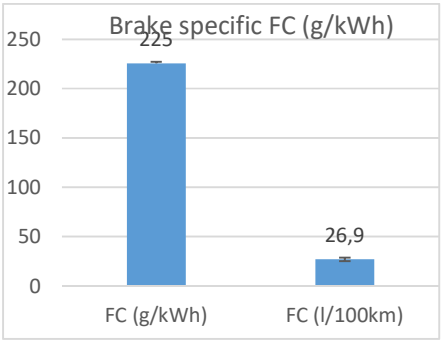


Figure Q5. Avg. fuel consumption

Calculated energy consumption, specified in kWh per km, are presented in Figure Q6.

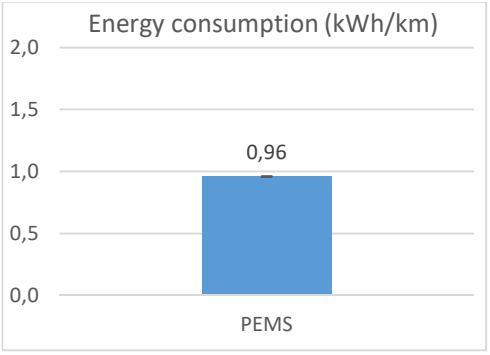


Figure Q6. Avg. energy consumption (kWh/km)

Conclusion

All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value. No malfunction was indicated by the OBD system.

Summary of NOx results on road

The overall impression from the tested vehicles is that most of the exhaust after treatment devices are working adequate in order to meet the Euro VI standards. However, as can be seen from Figure 186, results from some of the smaller vehicles and buses, class N2 and M3, indicates some difficulties to reach the limit values. As a comparison data from 2015 testing are presented in Figure 187

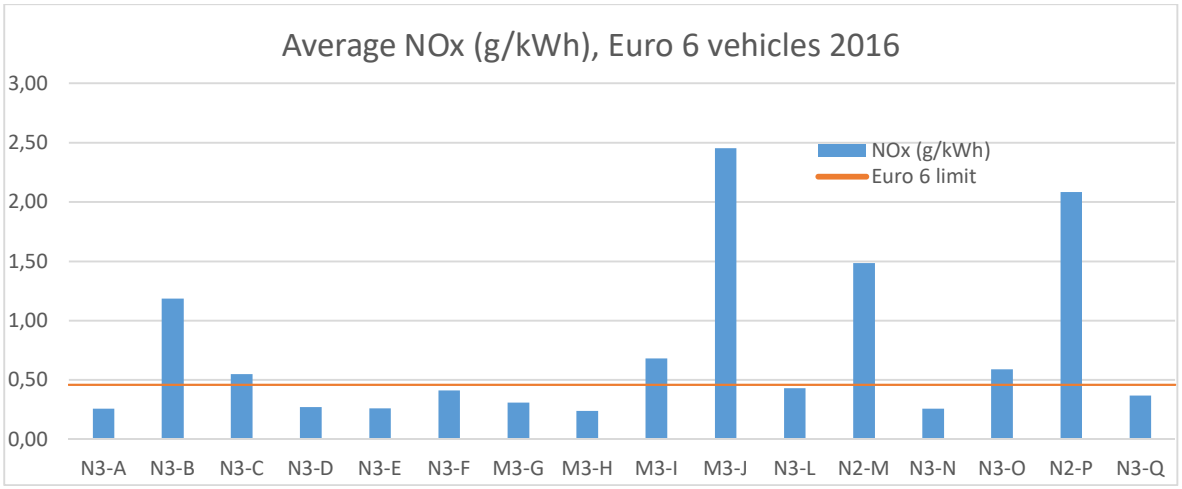


Figure 186 Average NOx emission and Euro VI limit, 2016 data

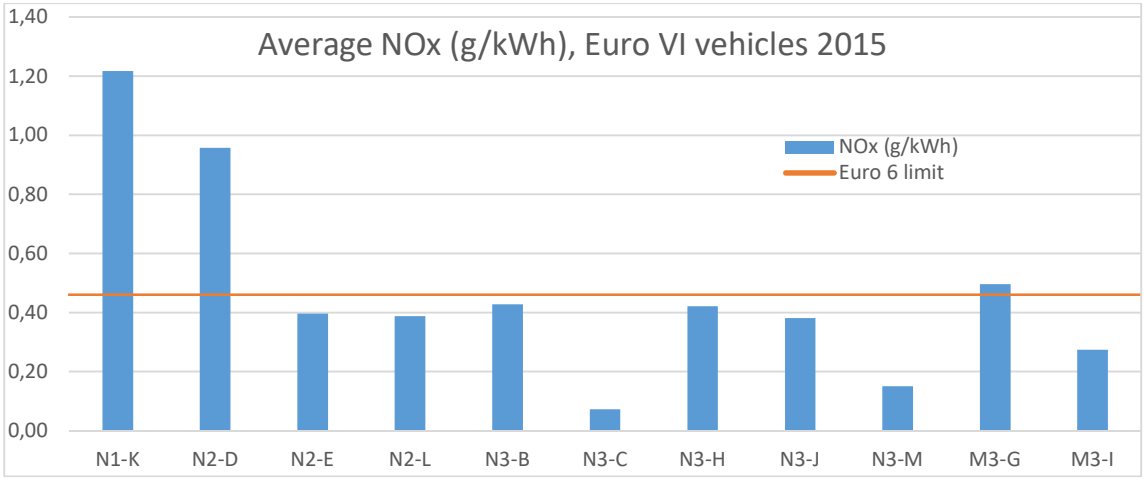


Figure 187 Average NOx emission and Euro VI limit, 2015 data.

Regarding Conformity Factors, it is clear that it is the N2 vehicles that are having problems with emissions of NOx, Figure R3 and R4.

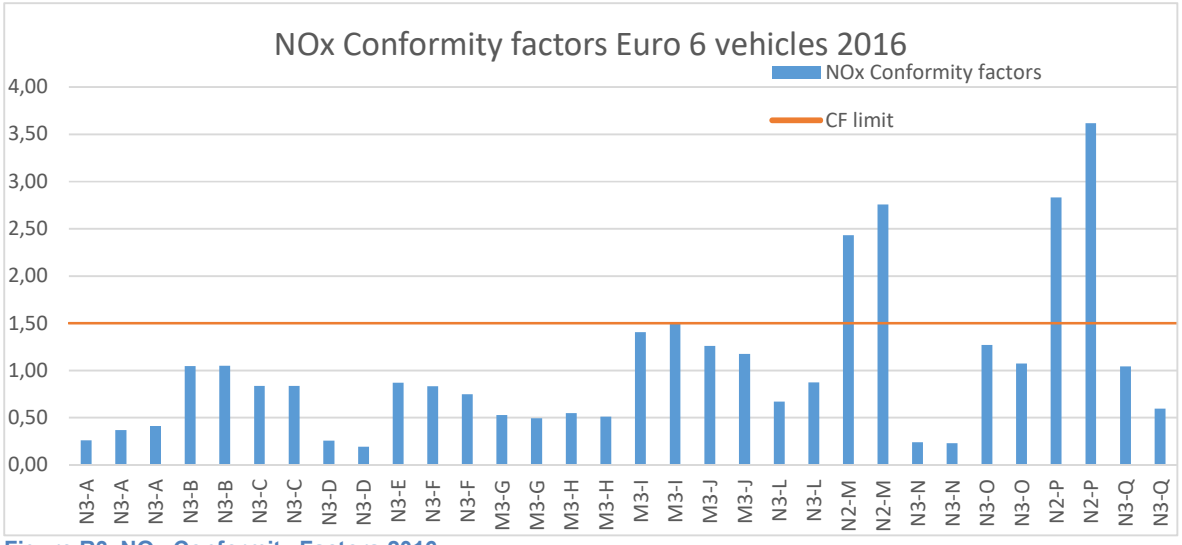


Figure R3. NOx Conformity Factors 2016

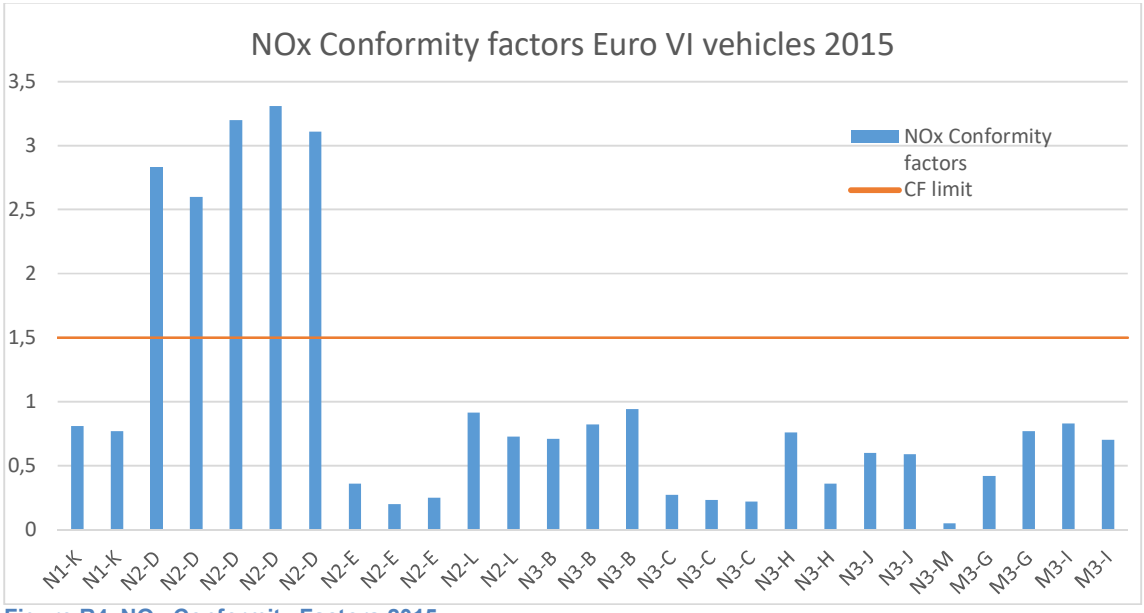


Figure R4. NOx Conformity Factors 2015

Appendix 1, PEMS system approval

TÜV HESSEN - QUALITY

AUTOMOTIVE

CERTIFICATE

AVL M.O.V.E SYSTEM GAS PEMS 493

Hard- and Software Release May 2013

The TÜV®-tested PEMS system meets the requirements

of the regulation

(EU) No. 582/2011 Annex II
and (EU) No. 64/2012/EC

The Certificate is based on the test reports TÜH TB 2013 – S9.00 and TÜH TB 2013 - S10.00 dated May, 29th, 2013 and references the release of the hard- and software, and the results of the tests performed .

Certificate No.:	2013-06-03-AM-Z.01
Annexes:	Annex 1 – PEMS System
Issued:	June, 3rd 2013
Valid until:	June, 3rd 2015

TÜV HESSEN

Director Ottmar Degreif

TÜV Technische Überwachung Hessen GmbH
Automotive, Werner-von-Siemens-Straße 35, D-64319 Pfungstadt

CERTIFICATE

AVL Concerto PEMS, Version 4.5

Software Release May 2013

The TÜV®-tested PEMS data evaluation software meets the requirements

of the regulation

(EU) No. 582/2011 Annex II and (EU) No. 64/2012

The Certificate is based on the test report TÜH TB 2013 - S10.00 dated May, 28th, 2013 and references the release of the software, and the results of the tests performed .

Certificate No.:	2013-06-00-AM-Z.02
Annexes:	Annex 1 – PEMS Software
Issued:	June, 3rd 2013
Valid until:	June, 3rd 2015

Director Ottmar Degroll

TÜV Technische Überwachung Hessen GmbH
Automotive, Werner-von-Siemens-Straße 15, D-64319 Pfungstadt