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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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

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. Thirteen vehicles were tested on road using Portable Emissions Measurement System (PEMS). In addition were eight of these 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. One vehicle of EEV standard was tested.

For chassis dynamometer tests there are no legal requirements for HD vehicles but the WHTC engine test emission limits are in this investigation used as “fictive” pass/fail criteria for vehicles of emission standard Euro VI. 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.

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.

In addition has aspects of alternative fuels and technologies, temperatures and loads been taken into consideration.

The vehicles are denoted A – M in this report.

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

Table 1 Vehicle selection

Vehicle	Emission standard	Fuel	After treatment	Model year	Vehicle category	Mileage (km)	Power (kW)	Gross vehicle mass (kg)	NOx CF
A	EEV	CNG	TWC	2010	M3	258 600	230	18000	n.a
B	Euro VI	Diesel	DOC, SCR, DPF, ASC	2013	N3	28 100	350	27000	0,9
C	Euro VI	Diesel	DOC, SCR, DPF, ASC	2014	N3	27 200	250	21000	0,2
D	Euro VI	Diesel	DOC, SCR, DPF	2014	N2	30 000	130	11990	3
E	Euro VI	Diesel	DOC, SCR, DPF	2014	N2	28 900	160	11990	0,3
F	Euro VI	Diesel	DOC, SCR, DPF	2014	N3	116 000	550	32 000	0,5*
G	Euro VI	Diesel (HVO)	DOC, SCR, DPF	2014	M3	37 200	140	5500	0,6
H	Euro VI	Diesel	DOC, SCR, DPF	2013	N3	547 000	430	18000	0,6
I	Euro VI	CNG	TWC	2014	M3	9 600	230	30000	0,8
J	Euro VI	Diesel	SCRT	2014	N3	18 900	240	28000	0,9
K	Euro VI	Diesel	DOC, SCR, DPF	2014	N1	42 000	130	3500	0,8
L	Euro VI	CNG	TWC	2015	N2	42 200	100	7000	0,8
M	Euro VI	Diesel	DOC, SCR, DPF	2015	N3		190	16000	0,05

Vehicle A

In year 2012, a M3 CNG bus, model year 2010 and emission standard EEV, was tested for exhaust emissions and fuel consumption. In 2014/2015 the same bus was retested in order to verify the emission performance over time. (Δ mileage ~ 170 000 km) The testing was performed on chassis dynamometer (CD) with PEMS.

Between the testing occasions, the CO emissions have increased more than 100% and exceed the limit in all test cycles. The emissions of THC have, in the WHVC cycles, increased significantly but in the FIGE test cycle however, the THC level has not increased and is still below the EEV limit. The NOx emissions have increased by more than 600% and the vehicle exceeds the NOx emission limit by more than 300%. The PM levels showed a small decrease between the two testing occasions and the EEV PM Emission limit was not exceeded. Very high levels of ammonia were measured.

Vehicle B

In 2014, this N3, diesel vehicle of model year 2013 and emission standard Euro VI, was tested on chassis dynamometer and with PEMS. In 2015, the vehicle was retested only on the road, using the same test route as in 2014 as well as a shorter test route. (Δ mileage ~ 21 000 km)
The test results shows no aging effects. Tests in a shorter test route resulted higher all event NOx emissions.

Vehicle C was a N3 diesel vehicle of model year 2014 and emission standard Euro VI, was tested on chassis dynamometer and with PEMS. All tests resulted in emissions of CO, PM and PN well below the Euro VI emission limit. No emissions of THC were detected in any test. The NOx emissions measured during the tests were very low in all warm start tests. The cold start however generated a little higher NOx emissions. The ammonia emissions measured were low.

Vehicle D was a N2 diesel vehicle of model year 2014 and emission standard Euro VI, was tested on chassis dynamometer and with PEMS. All tests resulted in emissions of CO, PM and PN well below the Euro VI emission limit. No emissions of THC were detected in any test. The NOx emissions measured during the tests were rather high and the vehicle did not pass the Euro VI emission limit. The ammonia emissions measured were low.
The PEMS tests all started with a cold engine but with slightly different start temperatures. For this vehicle and for these tests, a start temperature difference of 5℃ resulted in an approximate 20 % difference of the conformity factor.

Vehicle E was a N2 diesel truck of emission standard Euro VI and model year 2014, was tested on chassis dynamometer and with PEMS. All tests resulted in emissions of CO and PM well below the Euro VI emission limit. No emissions of THC were detected in any test. The NO_X emissions measured during the tests were very low in all warm start tests. The cold start generated a little higher NO_X emissions but the weighted NO_X result was below the limit. The ammonia emissions measured were low. The emissions of PN where above the Euro VI limit in the cold start test and also in the weighted WHVC result.

Vehicle F was a N3 diesel truck of emission standard Euro VI and model year 2014, which was tested for exhaust emissions and fuel consumption. Testing was performed in the vehicle's normal, every-day test route, with PEMS. The vehicle was tested with and without load (24 400 – 80 000 kg) Emissions of THC, CO and PM were below the detection limits for the used instrument. The NOx emissions were passing the Euro VI emission limit with a conformity factor of 0.54 (work based) and 0.82 (CO2 based). Fuel consumption increased with 2.6 litres with an extra load of 55 000 kg.

Vehicle G was a small bus of category M3 and model year 2014 which was tested on road as well as on chassis dynamometer. The vehicle was of euro standard VI, equipped with a EGR, DOC, DPF and SCR and the fuel used during the tests was hydrogenated vegetable oil diesel (HVO) sold under the commercial name SweaX HVO 100 Bio which is 100 % renewable. (For further specifications, see Appendix 2, HVO fuel specifications).

Emissions of CO, THC, PM and PN are well below the Euro VI legislative limits for all test results. Only NOx emitted during the cold start tests were above the Euro VI limit of 0.46 g/kWh. However, the PEMS result analysis show a clear pass with respect to ISC criteria, NOx conformity factor included.

Vehicle H was a N3 diesel tractor trailer of emission standard Euro VI and model year 2013, which was tested on chassis dynamometer and with PEMS. The emission levels of CO, THC, NH_3, PM and PN all meet the regulatory Euro VI WHTC limitations. However, NO_X emissions from the cold start tests, and consequently the weighted WHVC results, on chassis dynamometer reach beyond the 0.46 g/kWh limit. Remaining tests meet the legal requirement on NO_X. All established conformity factors from the ISC evaluation, for both work and CO_2 based windows, passed the criteria below 1.5 value.

Vehicle I was a CNG fuelled M3 bus of model year 2014 and emission standard Euro VI which was tested for exhaust emissions and fuel consumption using PEMS. All calculated conformity factors in the ISC evaluation meet the legislative criteria.

Vehicle J was a N3 diesel crane vehicle of model year 2014 and emission standard Euro VI has been tested for exhaust emissions and fuel consumption with PEMS. The same vehicle went through emission tests in 2014, both on chassis dynamometer and using PEMS. (Δ mileage ~ 11 400 km) Emission results from both 2014 and 2015 are presented and compared in this report in order to evaluate any changes over time in vehicle emission performance. Calculated NO_X conformity factors in the ISC evaluation meet the legislative criteria. PM conformity factors show large variation between the tests. Measured brake specific emissions are below the Euro VI WHTC regulatory limitations. Generally, no significant vehicle ageing effect on emissions was observed.

Vehicle K was a small Euro VI van of vehicle category N1 and model year 2014 which was tested for exhaust emissions and fuel consumption using CD and PEMS. Emissions of CO, THC, PM and PN were below the Euro VI legislative limits for all test results. However, measured NOx indicated elevated emission levels in comparison to the WHTC Euro VI limit of 0,46 g/kWh. The ISC analysis indicate a clear pass with respect to NOx conformity factors. Ammonia slip levels were far below legislative limits.

Vehicle L was a CNG fuelled Euro VI truck of category N2 and model year 2015, which was tested for exhaust emissions and fuel consumption using CD and PEMS. The vehicle was equipped with a three-way-catalyst. The ISC analysis indicate a clear pass with respect to conformity factors for gaseous emissions. The all event results for emissions of CO, THC/CH_4/NMHC, PM and PN were below the Euro VI legislative limits for all test results. The NOx emission results are slightly higher than the limit. Ammonia slip levels were below legislative limits during the WHVC cycle but are slightly higher than most well-functioning diesel vehicles.

Vehicle M was a diesel fuelled Euro VI truck of category N3 and model year 2015, which was tested for exhaust emissions and fuel consumption using PEMS. The ISC analysis indicate a clear pass with respect to conformity factors for gaseous emissions. The all event results for emissions of CO, THC and NOx are below the Euro VI legislative limits.

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 EU-PEMS 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 2015 is presented in this report.

Test program

Thirteen vehicles have been tested on road with PEMS. In addition, nine 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 – M 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 and EEV. The 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**
EEV • European Transient Cycle (ETC)	3.0	0.40	0.65	2.0	0.02		
Euro VI • Worldwide Harmonized Transient Cycle (WHTC)	4	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.

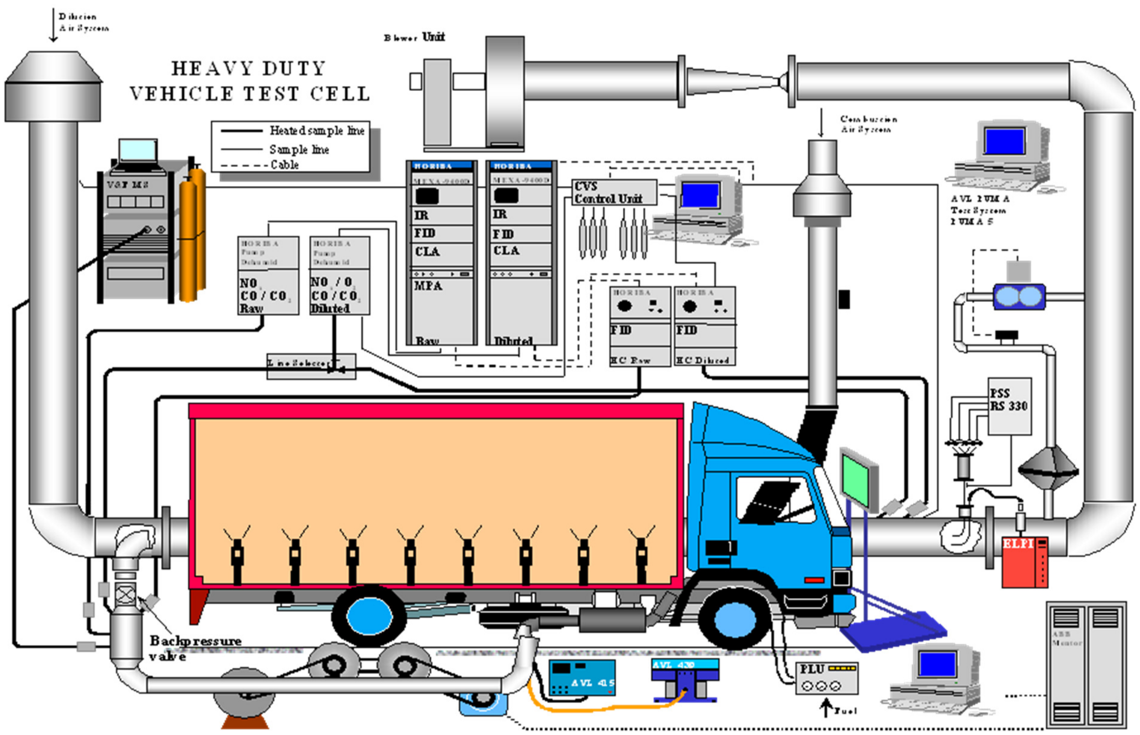


Figure 1 A schematic description of the test cell.

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.

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

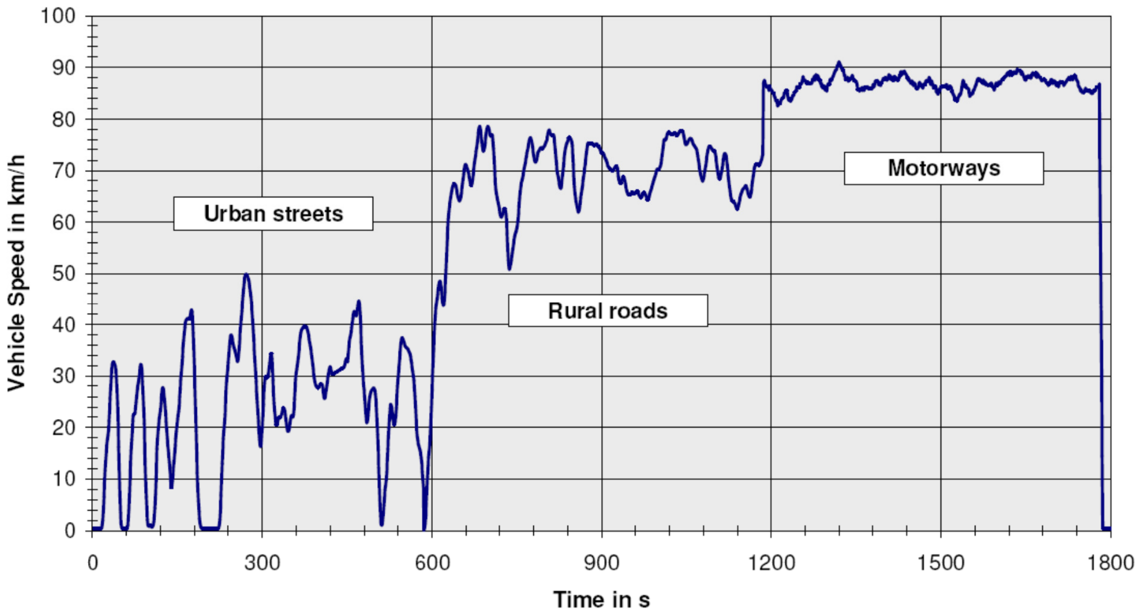


Figure 2 The FIGE driving cycle

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.

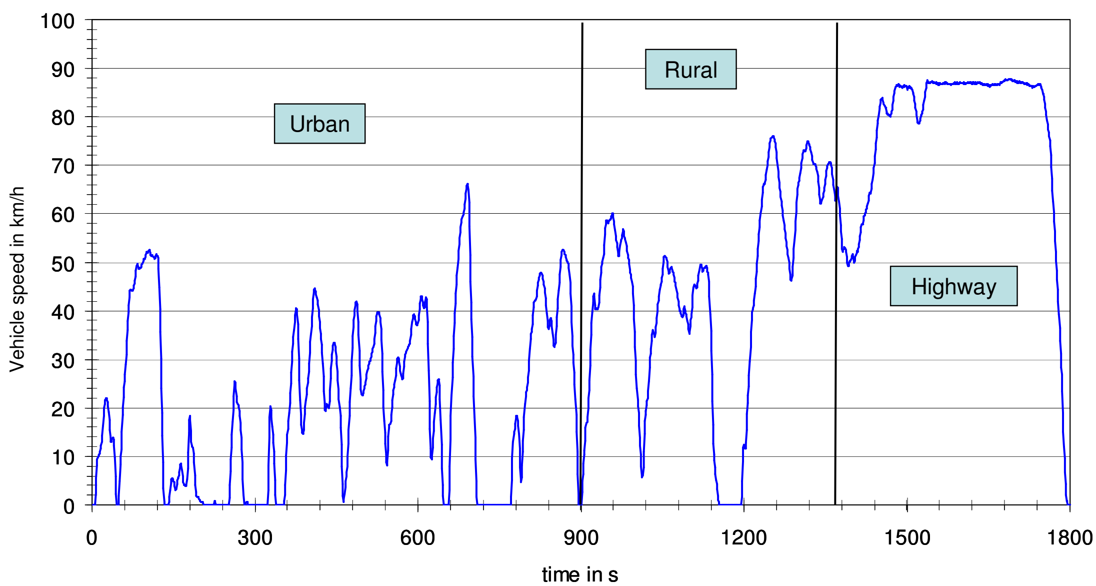


Figure 3 The WHVC test cycle

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℃ to 43℃
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): The actual DR will be displayed with the	Adjustable from 2 – 10 and from 10 – 20 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℃
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℃
Storage temperature	-40 to +70℃
Ambient rel. humidity	Corr. max. humidity of 95% at 25℃
Dimensions	appr. 19"*430*540 mm (w*h*d*)
Weight	appr. 45 kg
Warm-up time at 20℃ 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.

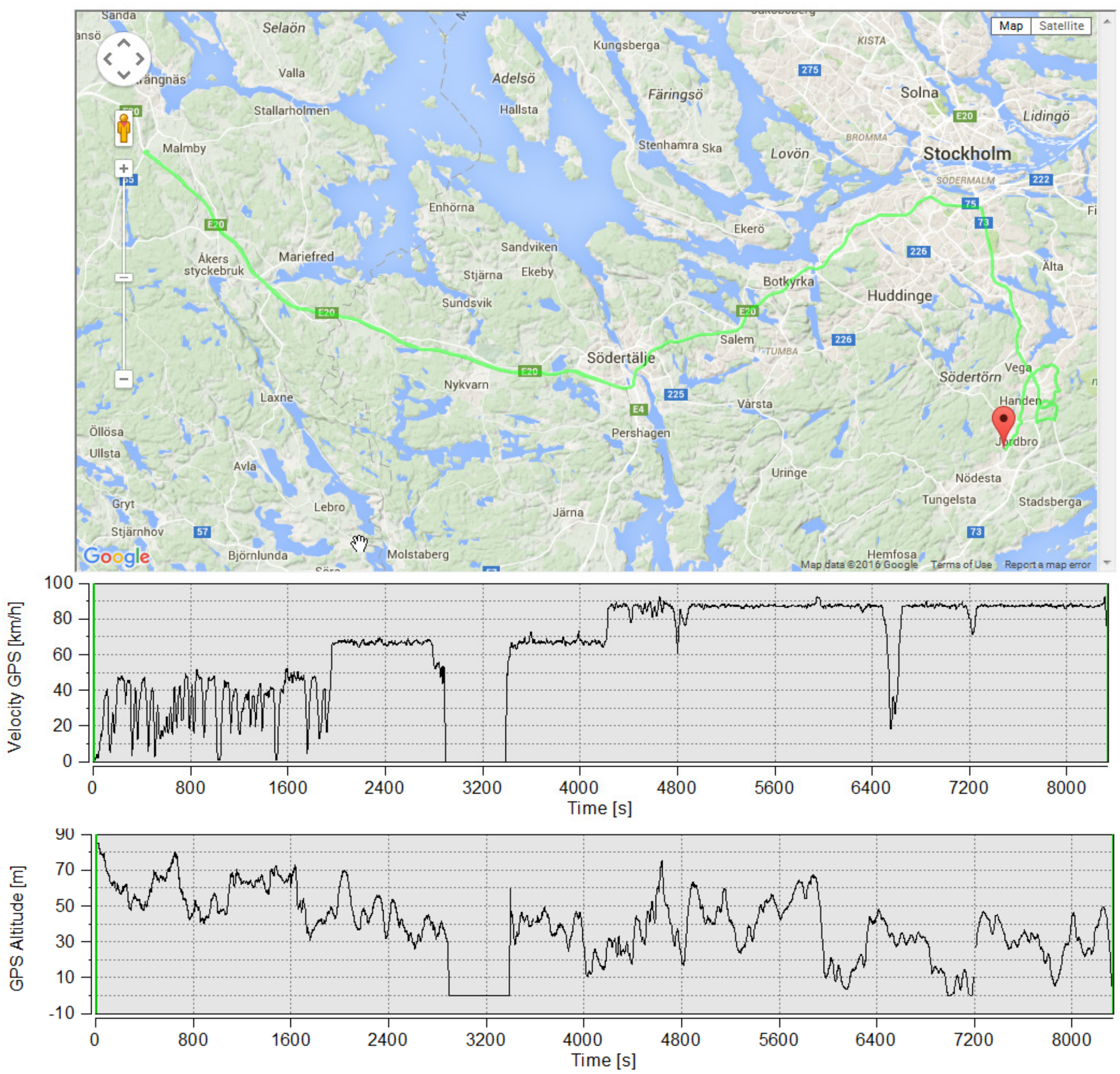


Figure 4 Characteristics of the Euro VI N3 route

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.

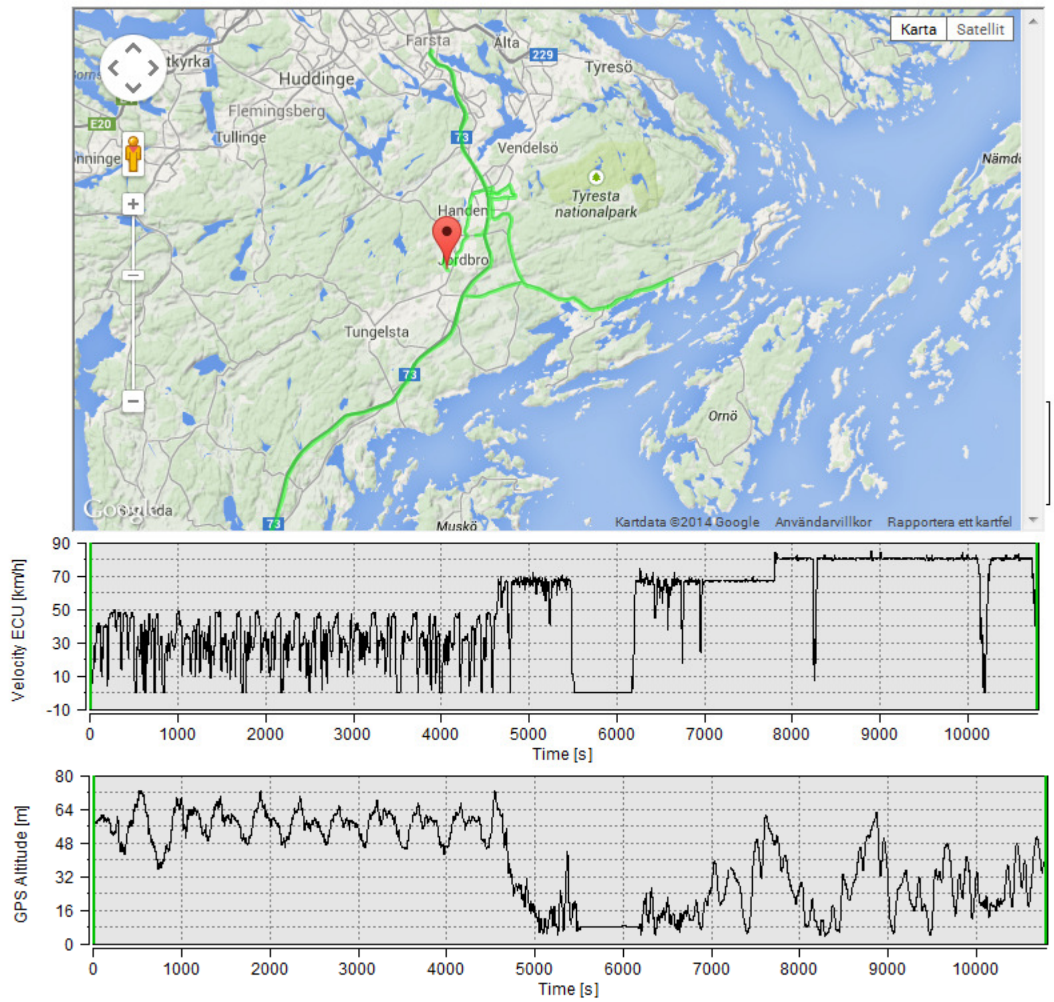


Figure 5 Characteristics of the Euro VI route for N1, N2, M1, M2 and M3 vehicles

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.

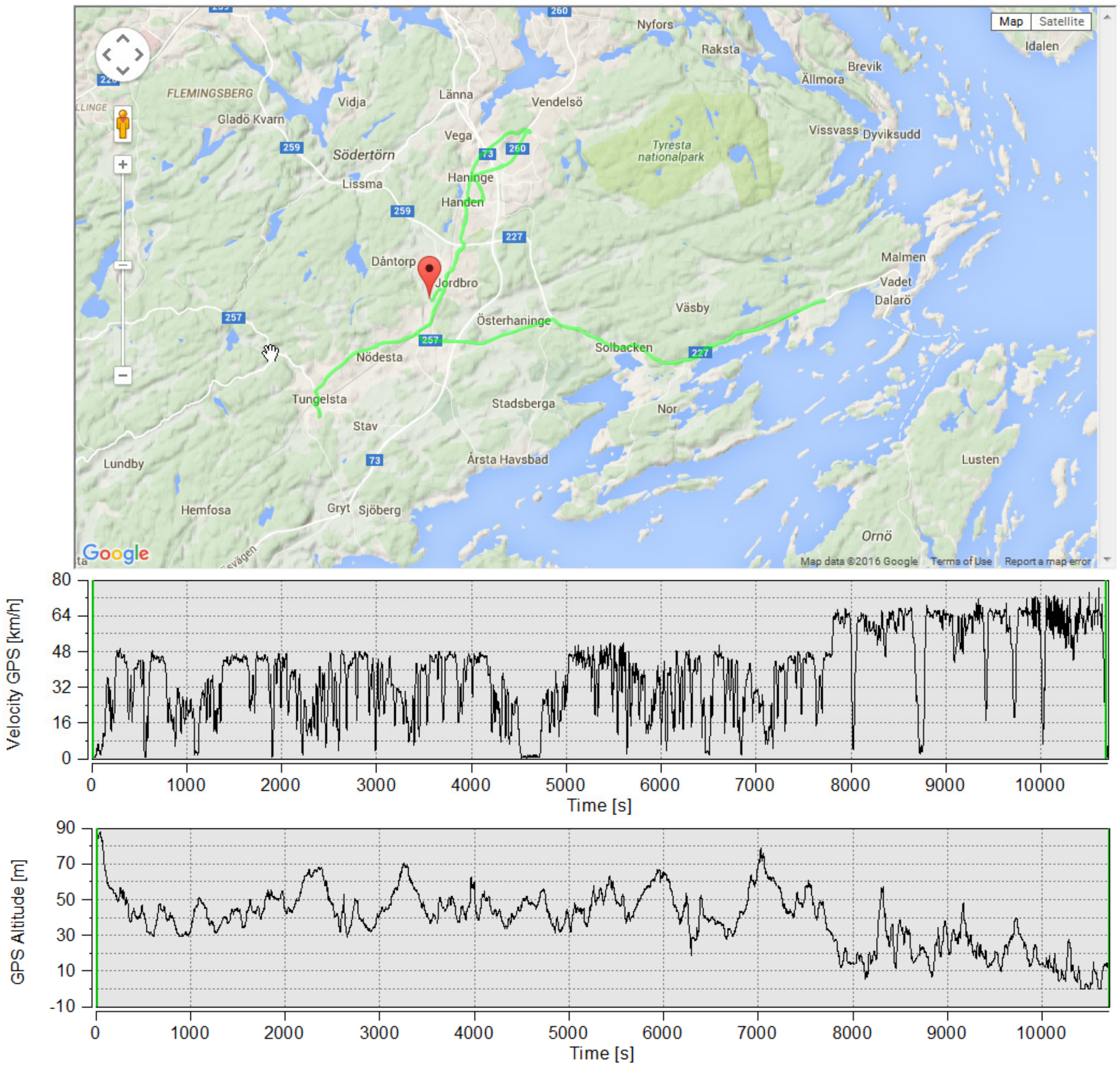


Figure 6 Characteristics of the Euro VI route for M2 and M3 vehicles of class I, II, or Class A

PEMS Pilot route (Euro V)

The PEMS Pilot route was developed during the PEMS Pilot study and does not fulfil any Euro VI requirements. It has historically been used extensively at AVL MTC and in 2015 one vehicle was tested in the route (Vehicle A).

The route has the following main data:

- Approximate trip duration: 5 000 seconds
- Average trip distance: 77 km
- Average speed: 55 km/h (of course dependent on traffic situation)
- Trip composition:
    - Urban driving: 43%
    - Rural driving: 17%
    - Highway driving: 40%
    - Idle: 7%

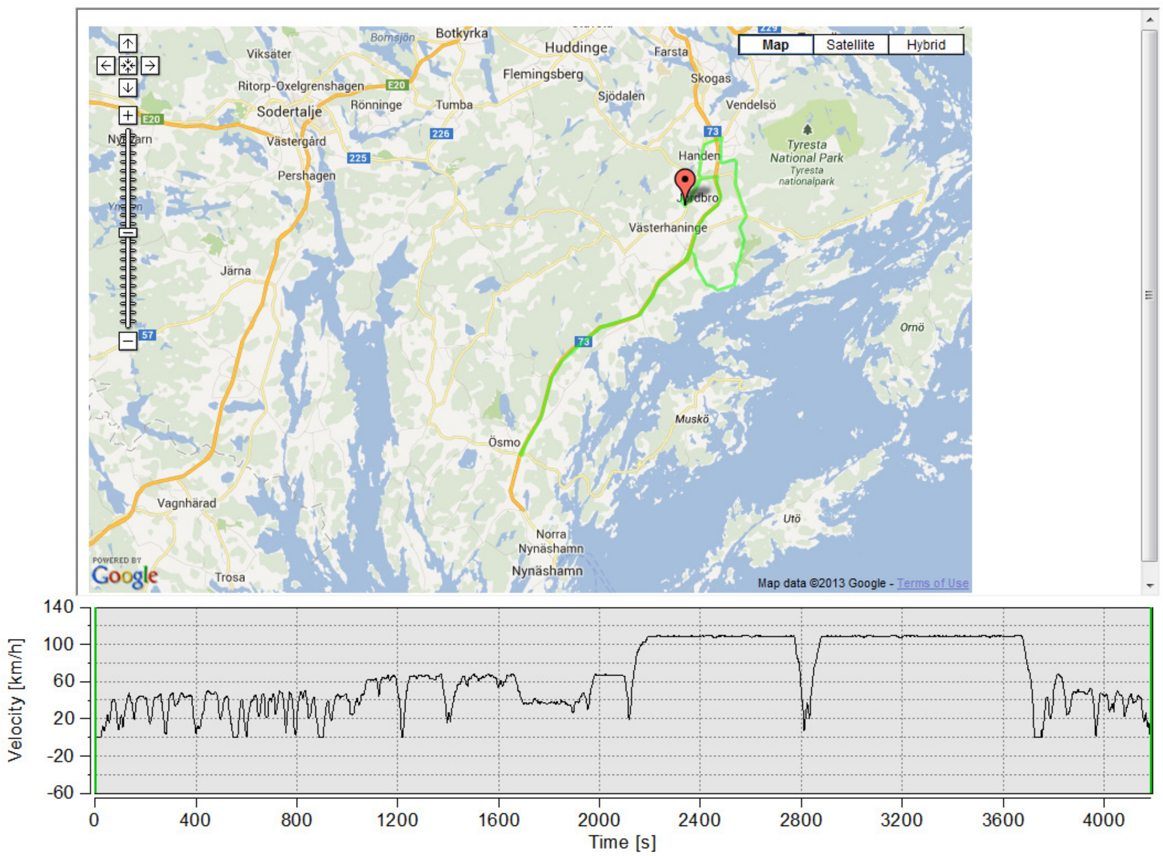


Figure 7 Characteristics of the PEMS Pilot route

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.

3 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 (vehicle G) was fuelled with hydrogenated vegetable oil diesel (HVO) sold under the commercial name SweaX HVO 100 Bio which is 100 % renewable. (For further specifications, see Appendix 2, HVO fuel specifications)

Vehicle A

In year 2012, a CNG bus of model year 2010 and environmental standard EEV, was tested for exhaust emissions and fuel consumption. In late 2014, approximately 2 years after the first test occasion (Δ mileage ~ 170 000 km), the same bus has been retested in order to verify the emission performance over time. The testing was performed on a chassis dynamometer (CD) and on Swedish roads using a portable emissions measurement system (PEMS).

In 2012, the vehicle did fulfil the EEV emission limits for CO, but in 2014, the CO emissions have increased more than 100% and exceed the limit in all test cycles. The emissions of THC have, in the WHVC cycles, increased significantly between the years 2012 and 2014. In the FIGE test cycle (~ETC=certification test cycle) however, the THC level has not increased and is below the EEV limit. In 2014, the NOx emissions have increased by more than 600% compared to 2012 and the vehicle exceeds the NOx emission limit by more than 300%. The EEV PM Emission limit have not been exceeded. The PM levels has decreased between the two testing occasions. During the testing in 2014, high levels of ammonia were measured.

Presentation of vehicle:

Model year:	2010
Vehicle category:	M3
Vehicle type:	Bus
Mileage:	258 580 km
Engine:	SI, 6-cylinder
Displacement:	~13 litres
Fuel:	CNG
Power:	~230 kW
Exhaust after treatment:	Three-way catalytic converter
Transmission:	automatic
Gross Vehicle Mass (GVM):	18000 kg
Mass in running order:	12102 kg
Maximum payload:	5898 kg
Emission standard:	EEV

Test program

The on-road testing was performed on the 7th and 8th of November 2014 and the ambient temperature varied between 1°C and 4°C. Tests on the chassis dynamometer were performed on the 16th and 19th of December 2014.

The vehicle was previously tested in 2012, and in order to make a proper comparison of emission performance, the same payload was used at both test occasions. The Euro V Pilot route was used in 2014 as well as in 2012 but instead of the “real-life” bus route (bus line 835) used in 2012, a Euro VI route for M3 vehicles of class I, II, or Class A, was performed.

Table 7 Test program (2014).

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	2	13802	(~1700)
WHVC	2	2	13802	(~1700)
PEMS Euro VI M3 route		2		1400
PEMS Euro V Pilot route		2		1400

Inertia is simulated inertia by the chassis dynamometer. The vehicle payload is reproduced by loading the vehicle with concrete blocks and water tubs during on-road tests.
The vehicle payload, during the on-road tests using PEMS, made 25 % of the maximum payload. The simulated vehicle payload during the tests on the chassis dynamometer made 30% of the maximum payload.

Emission test results

The results from the testing in 2012 and 2014 respectively are presented in Figure 8 to Figure 18. The results from 2012 are presented as average values only whereas the results from 2014 are presented as average values with standard deviation in those cases where the test cycle was repeated.

The CO emissions (Figure 8 and Figure 9) varied between the different test cycles. In 2012, the vehicle did fulfil the EEV emission limits for CO, but in 2014, the CO emissions have increased more than 100% and exceed the limit in all test cycles.

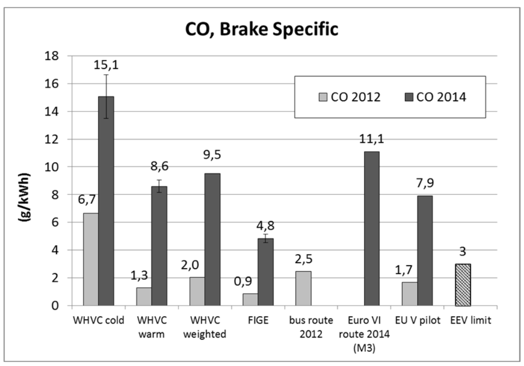


Figure 8 Brake specific CO emissions.

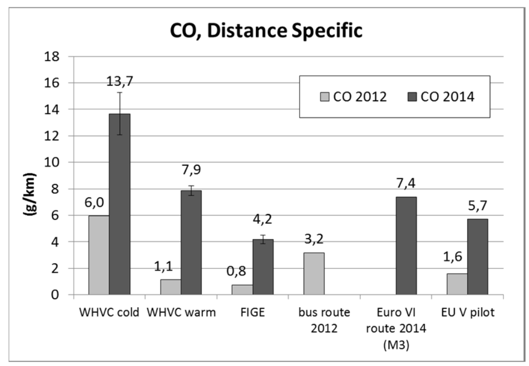
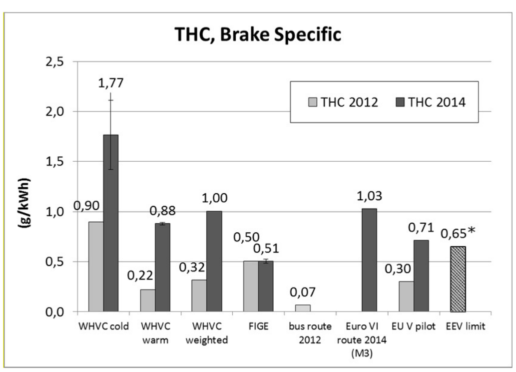


Figure 9 Distance specific CO emissions.

In the EEV emission standard for CNG engines, there are separate limits for methane and Non Methane Hydrocarbons [NMHC]. In this study only the total hydrocarbon emissions (THC) were measured. Since the tested vehicle was a CNG fuelled vehicle, the methane emissions were expected to dominate the total hydrocarbons. The certification cycle is the ETC cycle which is simulated in the FIGE test cycle. Figure 10 shows that the emissions of THC have, in the WHVC cycles, increased significantly between the years 2012 and 2014. In the FIGE test cycle however, the THC level has not increased and are below the EEV limit (for methane).



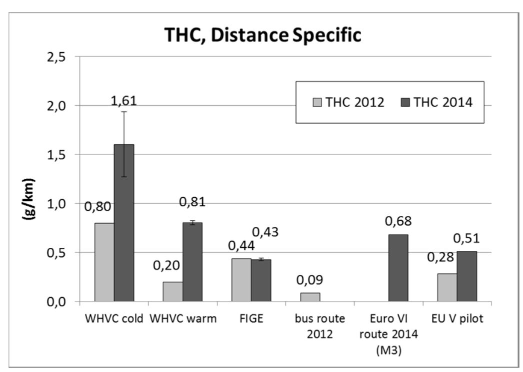


Figure 10 Brake specific THC emissions.
*emission limit for methane

Figure 11 Distance specific THC emissions.

In 2012, the NO_x emissions (Figure 12 and Figure 13) measured during the tests on chassis dynamometer were below the EEV emission limit (2 g/kWh). In 2014, the NOx emissions had increased considerably and the vehicle exceeds the NOx emission limit by more than 300%.

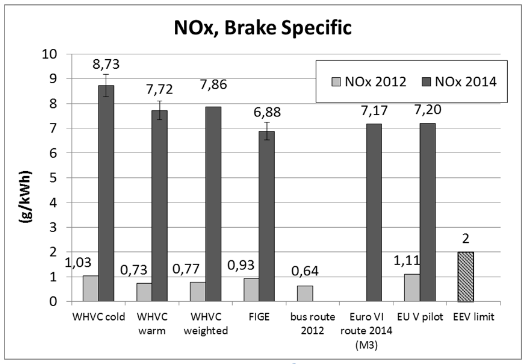


Figure 12 Brake specific NOx emissions.

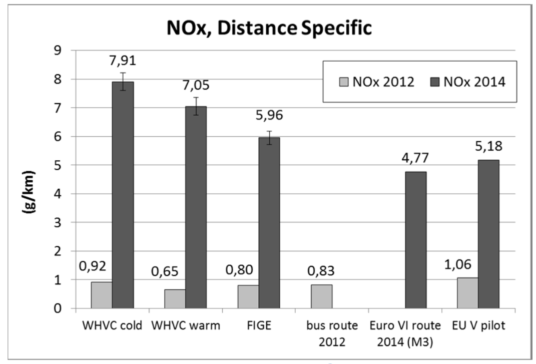


Figure 13 Distance specific NOx emissions.

The EEV PM Emission limit was not exceeded in any test (Figure 35). The PM levels has decreased significantly between the two testing occasions. In 2012, the PN level was measured with ELPI and can therefore not be compared with the results of 2014, measured with an APC.

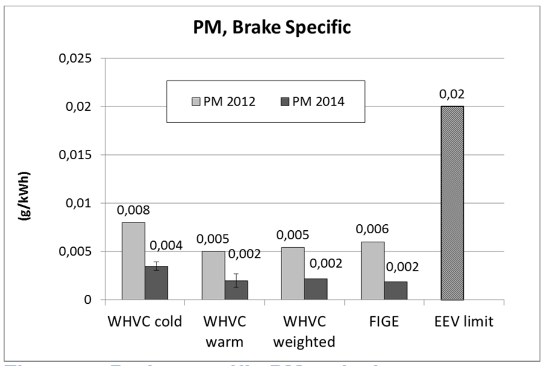


Figure 14 Brake specific PM emissions.

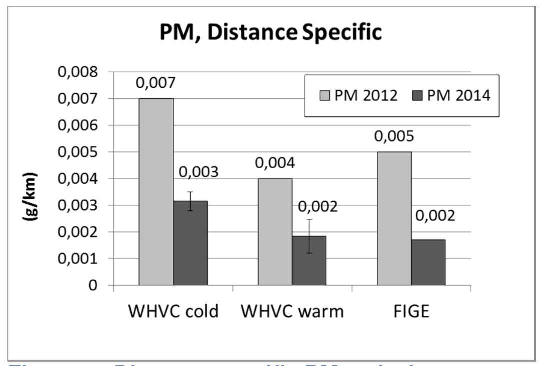


Figure 15 Distance specific PM emissions.

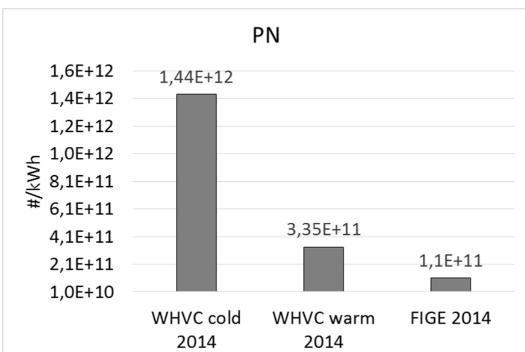


Figure 16 Brake specific PN emissions.

Figure 17 and Figure 18 presents the CO_2 emissions.

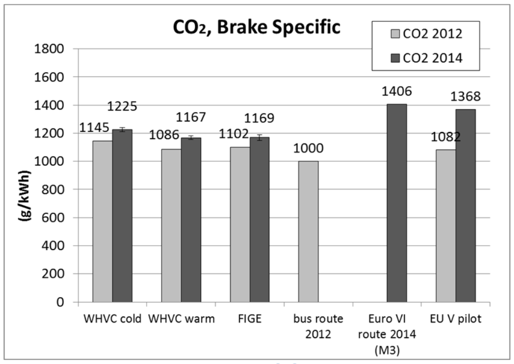


Figure 17 Brake specific CO_2 emissions.

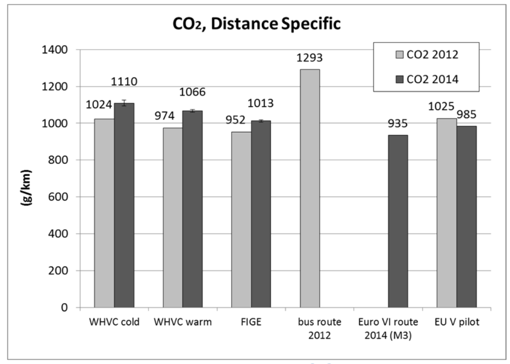


Figure 18 Distance specific CO2 emissions

Measurements of ammonia were performed and the levels were very high (Figure 19). It has previously been documented that in a vehicle with a positive ignited engine and a three-way catalyst, ammonia may form as a secondary pollutant during the NOx reduction process in the three-way catalyst. For example have similar results been measured by VTT, Finland.

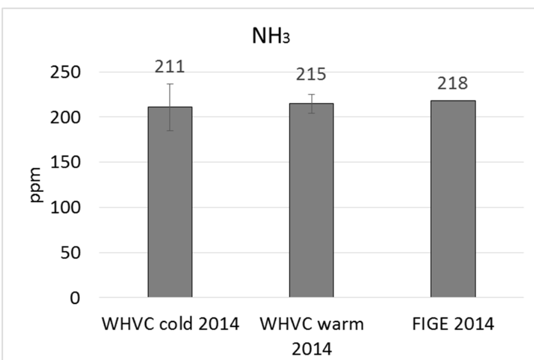


Figure 19 Emissions of ammonia (average ppm level)

Conclusions

In 2012, the vehicle did fulfil the EEV emission limits for CO, but in 2014, the CO emissions have increased more than 100% and exceed the limit in all test cycles. The emissions of THC have, in the WHVC cycles, increased significantly between the years 2012 and 2014. In the FIGE test cycle (~ETC=certification test cycle) however, the THC level has not increased and is below the EEV limit. In 2014, the NOx emissions have increased by more than 600% compared to 2012 and the vehicle exceeds the NOx emission limit by more than 300%. The EEV PM Emission limit have not been exceeded. The PM levels has decreased between the two testing occasions.

No malfunction was indicated by the OBD system.

Vehicle B.

A N3 diesel tractor trailer of emission standard Euro VI and model year 2013, was tested for exhaust emissions and fuel consumption. In 2014, the same vehicle was tested on a chassis dynamometer and on Swedish roads using a portable emissions measurement system (PEMS). In 2015, the vehicle was retested only on the road (Δ mileage ~ 21 000 km), using the same test route as in 2014 as well as a shorter test route. This report presents the emission performance from the PEMS testing, in 2014 compared to in 2015.

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 has been established.
No emissions of CO and THC were detected in any test. The NOx emissions measured during the tests were low. No aging effects can be seen. Tests in a shorter test route resulted higher all event NOx emissions.

Presentation of vehicle:

Model year:	2013
Vehicle category:	N3
Vehicle type:	Tractor trailer
Mileage:	28 131 km
Engine:	CI, 6-cylinder
Displacement:	~13 litres
Fuel:	Diesel
Power:	~350 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF, ASC
Transmission:	automatic
Gross Vehicle Mass:	27 000 kg
Mass in running order:	9 575 kg
Trailer weight:	9 840 kg
Emission standard:	Euro VI

Test program

The testing was performed between the 12th and 17th of March 2015.

Table 8 Test program.

Test	Cold start	Hot start	Vehicle Payload [kg]
PEMS Euro VI N3 route (long)	1	-	10 000
PEMS Euro VI N3 route (short)	2	-	

The vehicle payload, during the on-road tests using PEMS, made ~50% of the maximum EU payload (40 ton). 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℃ are excluded. In the “all event result” are cold start emissions included.

In addition, a test was performed where the vehicle cool down phase was monitored with regards to the exhaust gas temperature, engine coolant temperature and the engine oil temperature. The measurements started with a fully warmed up vehicle whose engine between the measurements was shut off. Every half hour the engine was restarted and a new measurement was performed until the temperatures begun to stabilize.

DRAFT

Ambient conditions

Test 1, long route (2015-03-12):

- Trip average RH: 47 %
- Trip average ambient temperature: 8℃

Test 2, short route (2015-03-13):

- Trip average RH: 77 %
- Trip average ambient temperature: 4℃

Test 3, short route (2015-03-17):

- Trip average RH: 43 %
- Trip average ambient temperature: 11℃

Emission test results

The ISC test results from the PEMS tests are presented in Figure 20. No emissions of CO and THC were detected in any PEMS test. The emissions of NOx were low, passing the conformity factor limit in all tests. The aging of the vehicle has not influenced the NOx emissions.

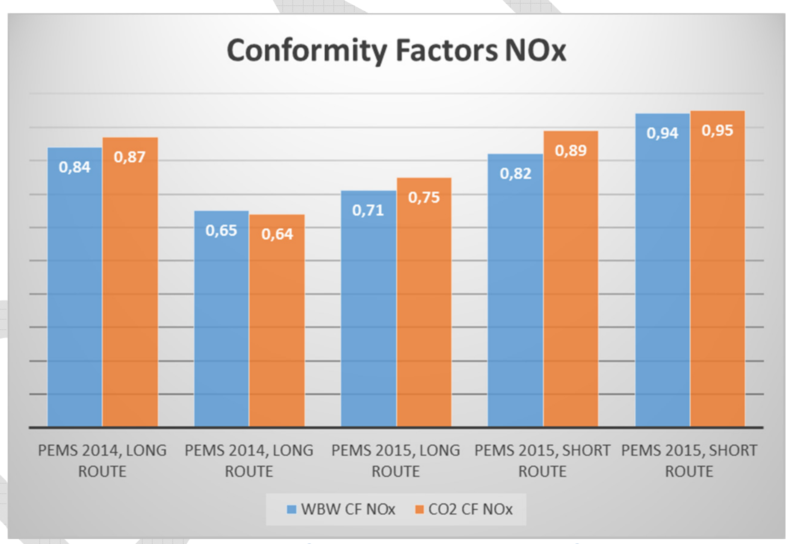


Figure 20 Conformity Factors for NOx

The results presented in Figure 21 to Figure 27 were recorded over the whole PEMS route (all events). In cases where the test-cycles/routes were repeated the results are presented as average values with standard deviation.

No emissions of CO and HC were detected in any test.

Low NOx emissions were detected. The aging of the vehicle has not influenced the NOx emissions significantly. The shorter PEMS test route generates higher NOx results since the influence of the cold start is larger.

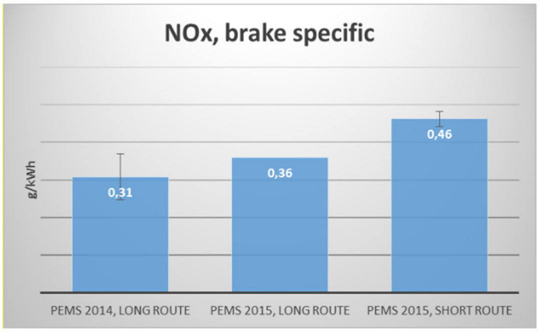


Figure 21 Brake specific NOx emissions.

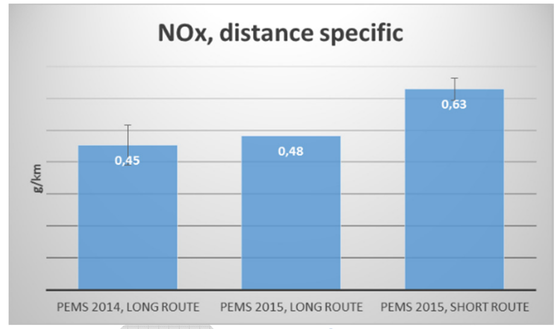


Figure 22 Distance specific NOx emissions.

The CO_2 emissions and fuel consumption followed the same trend (Figure 23, Figure 24, Figure 25 and Figure 26).

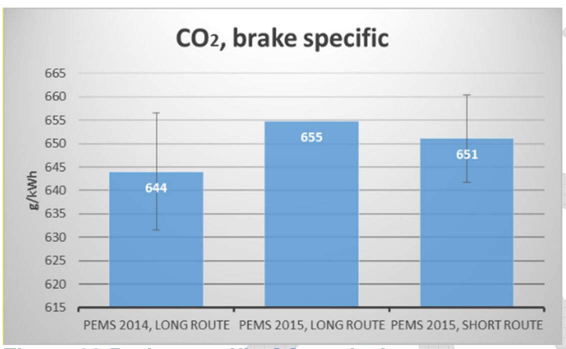


Figure 23 Brake specific CO_2 emissions.

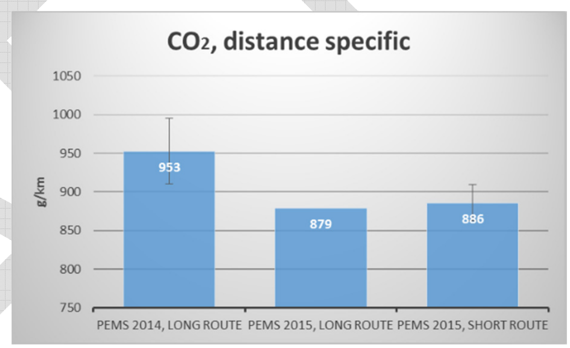


Figure 24 Distance specific CO_2 emissions.

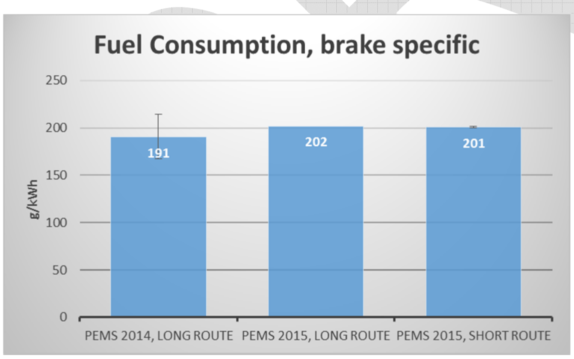


Figure 25 Brake specific fuel consumption.

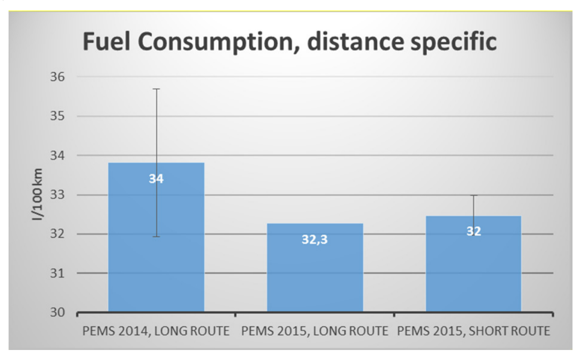


Figure 26 Distance specific fuel consumption

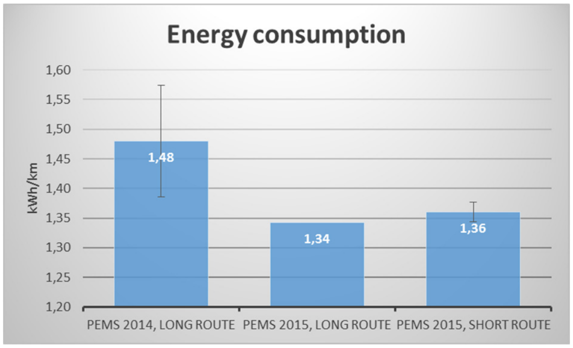


Figure 27 Energy consumption.

The exhaust gas temperature, which was measured at tailpipe, decreased relatively fast during the first hour after engine shut off, where after it continued to drop, but in a slower pace. The engine coolant temperature reached 70°C after approximately 1 hour.

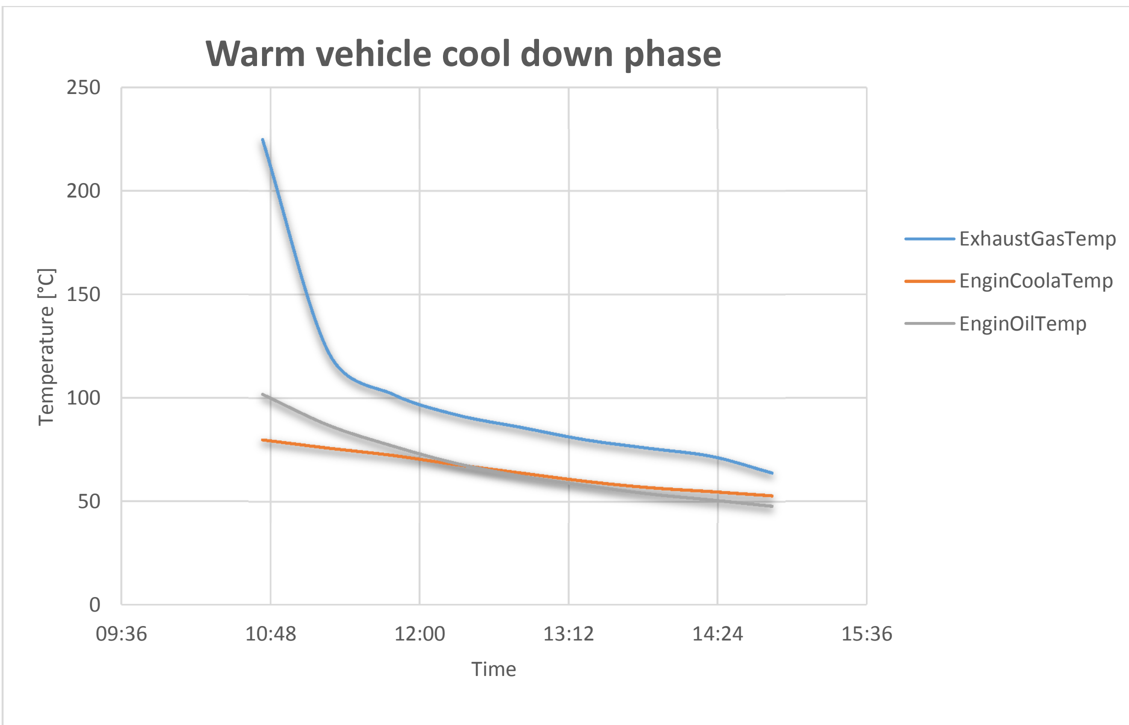


Figure 28 Cool down phase of warm vehicle

Conclusions

No emissions of CO and THC were detected in any test. The NOx emissions measured during the tests were very low. No aging effects can be seen. The shorter test route gives higher all event NOx emissions.

No malfunction was indicated by the OBD system.

Vehicle C

A N3 diesel rigid truck of emission standard Euro VI and model year 2014, has been tested for exhaust emissions and fuel consumption. The tests were performed on a chassis dynamometer and on Swedish roads using a portable emissions measurement system (PEMS).

All tests resulted in emissions of CO, PM and PN well below the Euro VI emission limit. No emissions of THC were detected in any test. The NOx emissions measured during the tests were very low in all warm start tests. The cold start however generated a little higher NOx emissions. The ammonia emissions measured were low.

Presentation of vehicle:

Model year:	2014
Vehicle category:	N3
Vehicle type:	Rigid truck
Mileage:	27 200 km
Engine:	CI, 6-cylinder
Displacement:	~11 litres
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:	11 205 kg
Maximum payload:	9 795 kg
Emission standard:	Euro VI

Test program

The on-road testing was performed between the 17^{th} and 19^{th} of February 2015. Tests on the chassis dynamometer were performed between the 24^{th} and 27^{th} of February 2015.

Table 9 Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	2	16 200	(~4 800)
WHVC	2	2	16 200	(~4 800)
PEMS Euro VI N3 route	-	3		5 000

Inertia is the inertia simulated by the chassis dynamometer. The vehicle payload is reproduced by loading the vehicle with large concrete blocks during on-road tests.

The vehicle payload, during the on-road tests using PEMS, made 51% of the maximum payload. The simulated vehicle payload during the tests on the chassis dynamometer made 49% of the maximum payload.

Ambient conditions

Warm test 1 (2015-02-17):

- Trip average RH: 53 %
- Trip average ambient temperature: 6 °C

Warm test 2 (2015-02-18):

- Trip average RH: 57 %
- Trip average ambient temperature: 11 °C

Warm test 3 (2015-02-19):

- Trip average RH: 64 %
- Trip average ambient temperature: 12 °C

Emission test results

The ISC test results from the PEMS tests are presented in Figure 29. No emissions of CO and THC were detected in any PEMS test. The emissions of NOx were low, passing the conformity factor limit in all tests.

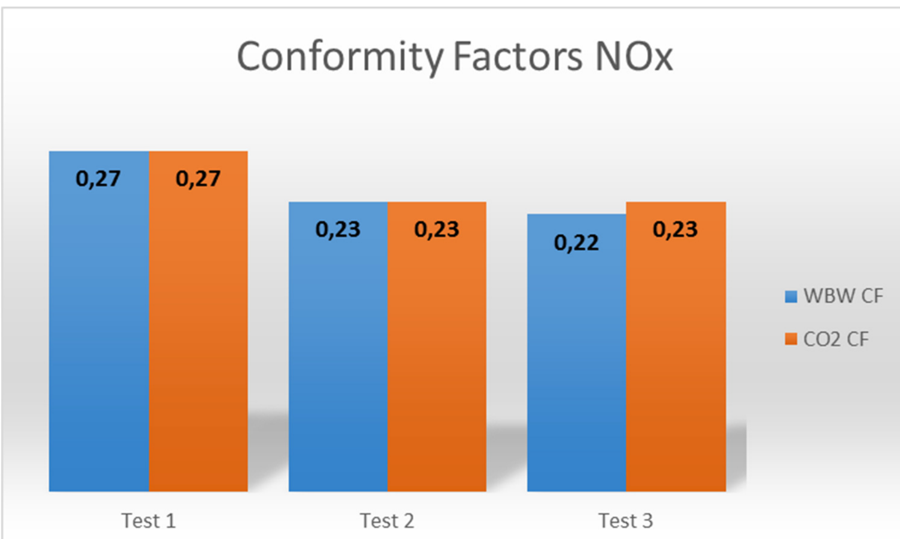


Figure 29 Conformity Factors NOx

The results presented in Figure 30 to Figure 43 were recorded over the whole PEMS route (all events) or test cycle. The weighted emissions are calculated as 86% of the warm test result added to 14% of the cold start test result. In cases where the test-cycles/routes were repeated the results are presented as average values with standard deviation.

All tests resulted in CO emissions (Figure 30 and Figure 31) well below the Euro VI emission limit (4 g/kWh).

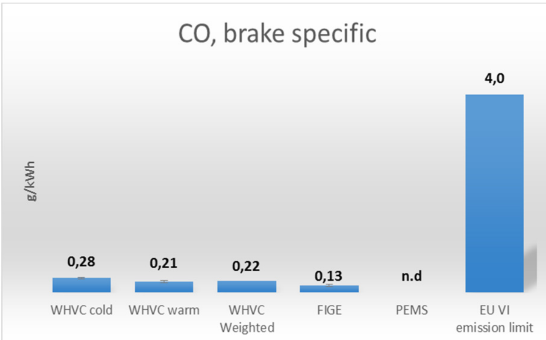


Figure 30 Brake specific CO emissions.

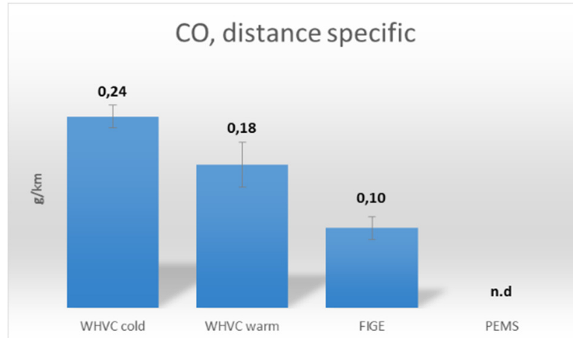


Figure 31 Distance specific CO emissions.

No emissions of THC were detected in any test.

The NOx emissions measured during the tests on the chassis dynamometer were in the WHVC cycles low (Figure 32 and Figure 33). The cold start tests generated higher NOx emissions but the weighted WHVC result was well below the Euro VI emission limit (0.46 g/kWh). Also the “all events” results from the PEMS testing showed low NOx emissions.

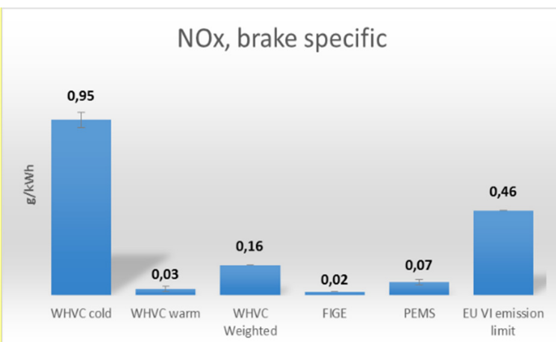


Figure 32 Brake specific NOx emissions.

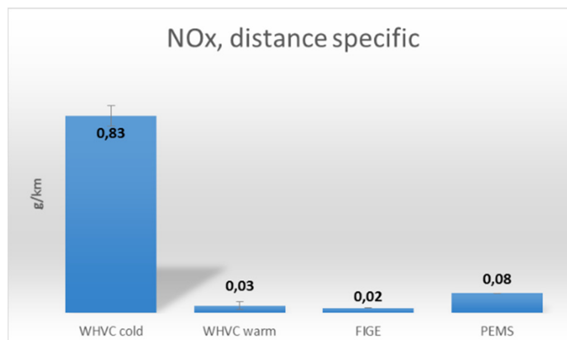


Figure 33 Distance specific NOx emissions.

The ammonia emissions measured were low (Figure 34).

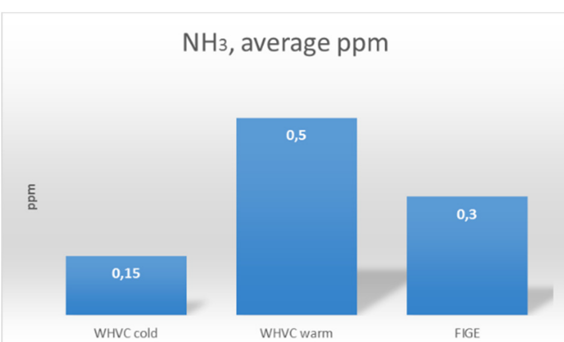


Figure 34 Emissions of ammonia

The PM level of the test vehicle was low and below the Euro VI limit in all tests (Figure 35). Also the PN levels were below the Euro VI applicable PN limit in all tests (Figure 37).

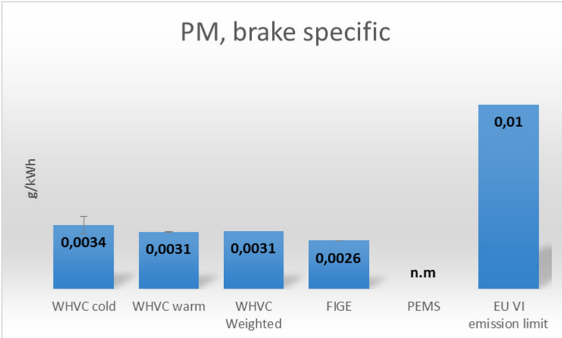


Figure 35 Brake specific PM emissions.

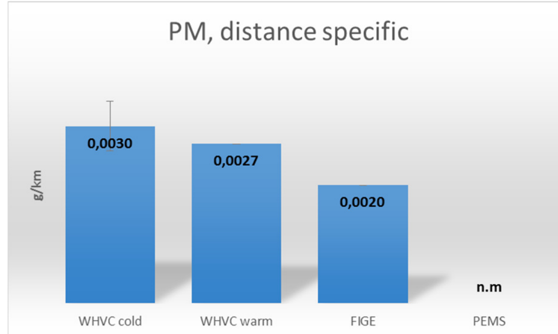


Figure 36 Distance specific PM emissions.

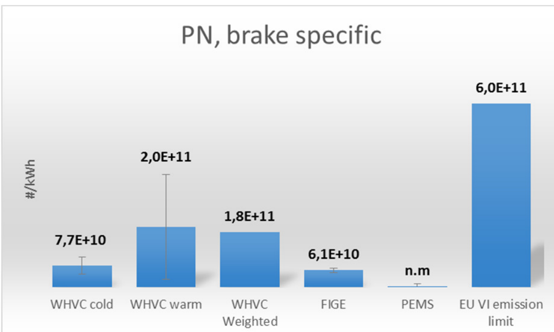


Figure 37 Brake specific PN emissions.

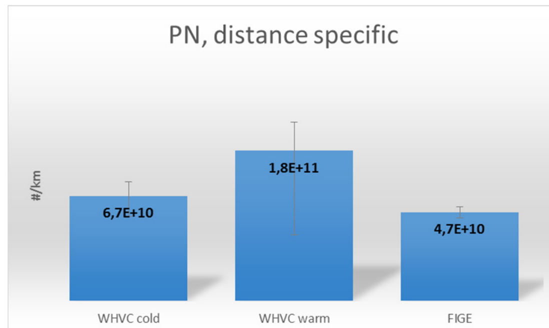


Figure 38 Distance specific PN emissions

The CO_2 emissions and fuel consumption followed the same trend (Figure 39, Figure 40, and Figure 41, Figure 42).

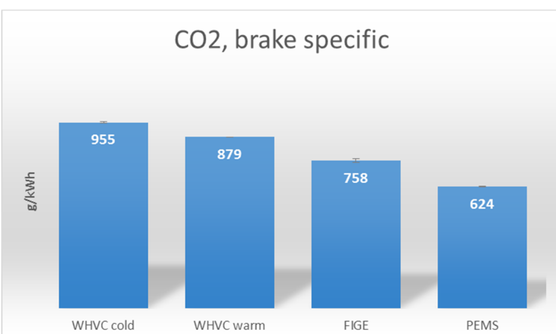


Figure 39 Brake specific CO_2 emissions.

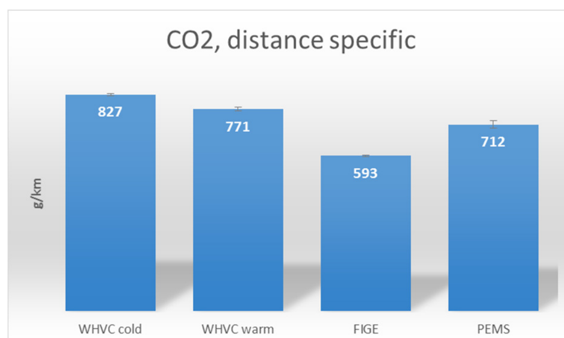


Figure 40 Distance specific CO_2 emissions.

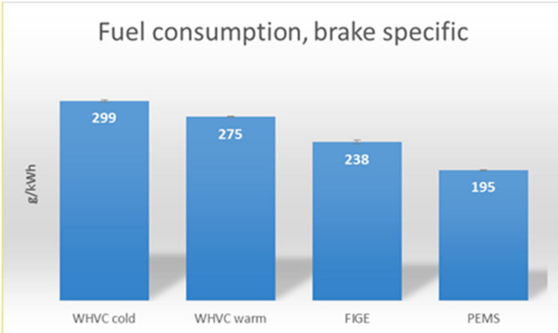


Figure 41 Brake specific fuel consumption.

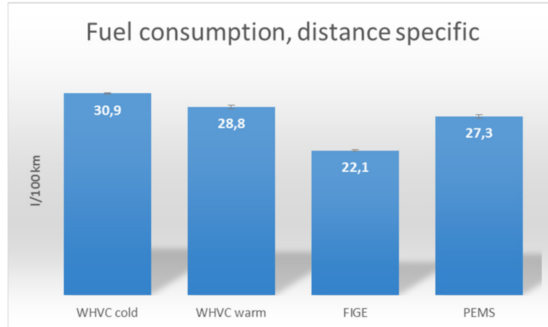


Figure 42 Distance specific fuel consumption

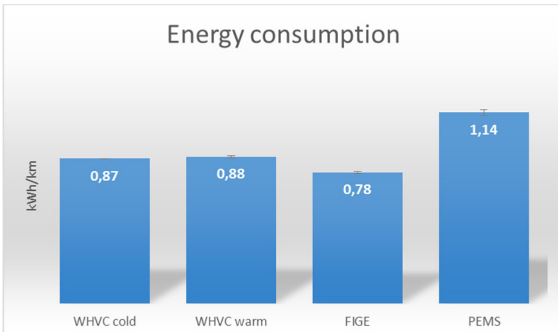


Figure 43 Energy consumption.

Conclusions

All tests resulted in emissions of CO, PM and PN well below the Euro VI emission limit. No emissions of THC were detected in any test. The NOx emissions measured during the tests were very low in all warm start tests. The cold start however generated a little higher NOx emissions. The ammonia emissions measured were low.

No malfunction was indicated by the OBD system.

Vehicle D

A flatbed truck of vehicle class N2 and emission standard Euro VI, has been tested for exhaust emissions and fuel consumption. Testing was performed on a chassis dynamometer and on Swedish roads using a portable emissions measurement system (PEMS).

All tests resulted in emissions of CO, PM and PN well below the Euro VI emission limit. No emissions of THC were detected in any test. The NOx emissions measured during the tests were rather high and the vehicle did not pass the Euro VI emission limit. The ammonia emissions measured were low.
The PEMS tests all started with a cold engine but with slightly different start temperatures. For this vehicle and for these tests, a start temperature difference of 5℃ resulted in an approximate 20 % difference of the conformity factor.

Presentation of vehicle:

Model year:	2014
Vehicle category:	N2
Vehicle type:	Flatbed truck
Mileage:	30 700 km
Engine:	CI, 4-cylinder
Displacement:	~5 litres
Fuel:	Diesel
Power:	~130 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF
Transmission:	automatic
Gross Vehicle Mass	11 990 kg
Mass in running order:	5 565 kg
Maximum payload:	6 425 kg
Emission standard:	Euro VI

Test program

The on-road testing was performed between the 20th and 26th of March 2015. All PEMS tests started with a cold engine and are evaluated according to the regulation. Tests on the chassis dynamometer were performed between the 27th of March and 1 of April 2015.

Table 10 Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	8 800	(~3 235)
WHVC	1	2	8 800	(~3 235)
PEMS Euro VI N3 route	5	-		3 500

Inertia is the inertia simulated by the chassis dynamometer. The vehicle payload is reproduced by loading the vehicle with large concrete blocks during on-road tests.

The vehicle payload, during the on-road tests using PEMS, made 54% of the maximum payload. The simulated vehicle payload during the tests on the chassis dynamometer made 50% of the maximum payload.

Ambient conditions

Test 1 (2015-03-19):

- Trip average RH: 53 %
- Trip average ambient temperature: 6°C
- Coolant temperature at test start: 6°C

Test 2 (2015-03-22):

- Trip average RH: 71 %
- Trip average ambient temperature: 7°C
- Coolant temperature at test start: 1°C

Test 3 (2015-03-23):

- Trip average RH: 35 %
- Trip average ambient temperature: 13°C
- Coolant temperature at test start: 5°C

Test 4 (2015-03-24):

- Trip average RH: 46 %
- Trip average ambient temperature: 4°C
- Coolant temperature at test start: 1°C

Test 5 (2015-03-25):

- Trip average RH: 70 %
- Trip average ambient temperature: 4°C
- Coolant temperature at test start: 1°C

Emission test results

The ISC test results from the PEMS tests are presented in Figure 44 and Figure 45. No emissions of CO and THC were detected in any PEMS test. The emissions of NOx where rather high, not passing the conformity factor limit in any test. The particulate emissions where low. It can also be seen that the temperature of the engine coolant in the beginning of the test is reflected on the conformity factor for NOx. For these tests, a start temperature difference of 5°C gives an approximate 20 % difference of the conformity factor.

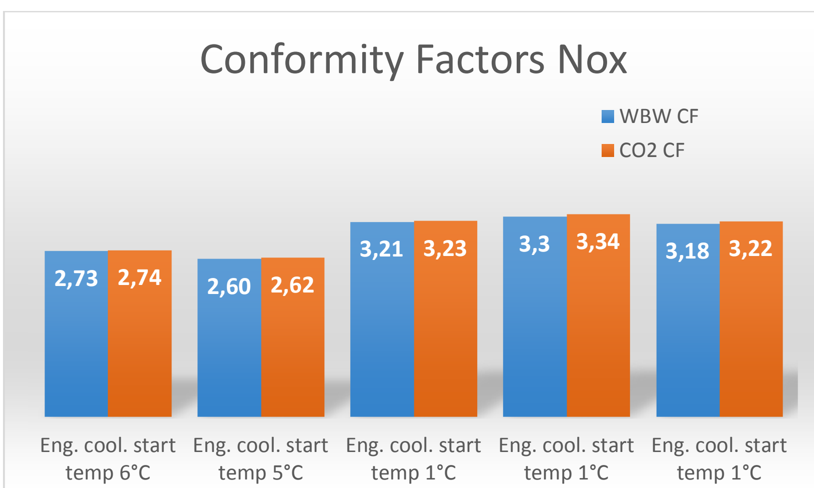


Figure 44 Conformity Factors NOx

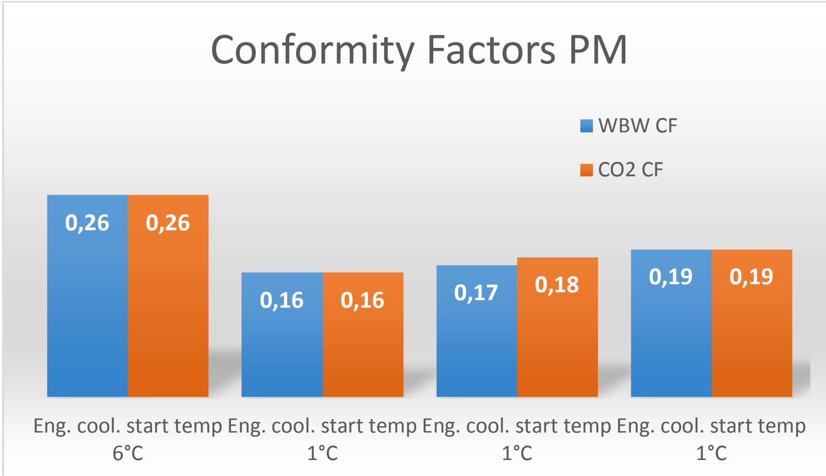


Figure 45 Conformity Factors PM

All tests were started with a cold engine. Figure 46 and Figure 47 shows how the different variants of data exclusions influences the work based windows conformity factors for this vehicle. The left bar shows the conformity factors when evaluated as prescribed in the regulation where the windows with the 10 % highest emissions are excluded as well as emissions emitted when the average window power is less than 20 % and before the engine coolant has reached 70℃.

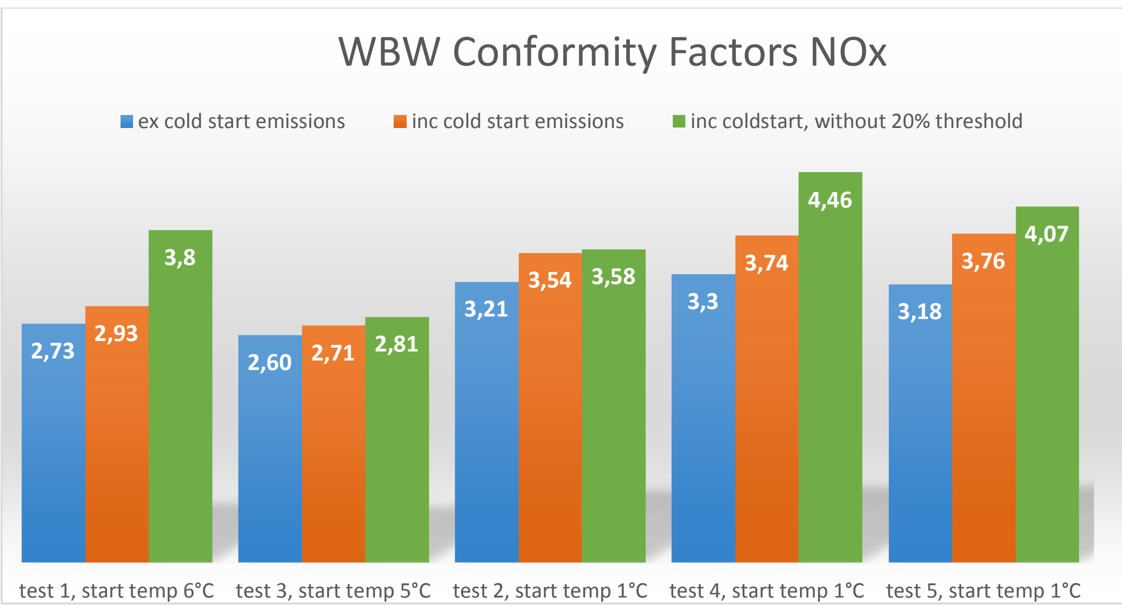


Figure 46 Conformity Factors NOx, influence of exclusions

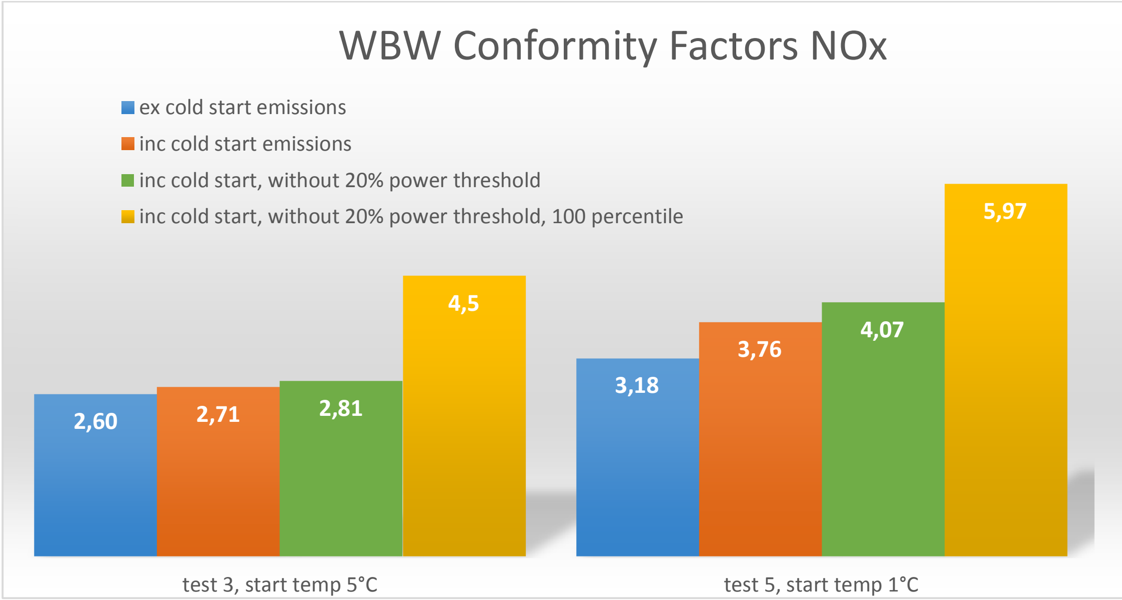


Figure 47 Conformity Factors NOx, influence of exclusions

The results presented in Figure 48 to Figure 62 were recorded over the whole PEMS route (all events) or test cycle. The weighted emissions are calculated as 86% of the warm test result added to 14% of the cold start test result. In cases where the test-cycles/routes were repeated the results are presented as average values with standard deviation.

All tests resulted in CO emissions (Figure 48 and Figure 49) well below the Euro VI emission limit (4 g/kWh).

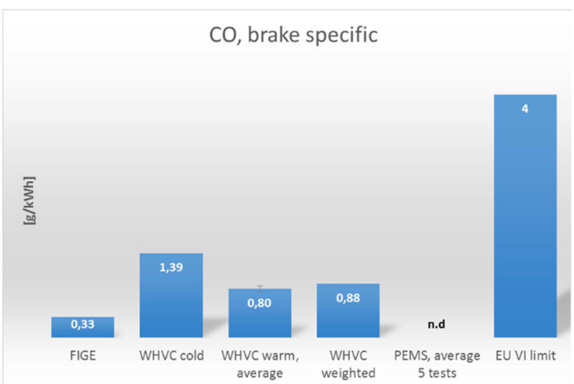


Figure 48 Brake specific CO emissions.

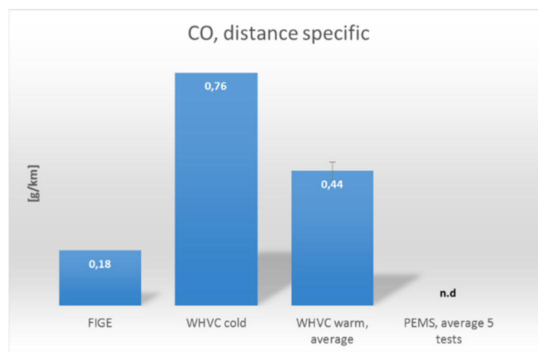


Figure 49 Distance specific CO emissions.

No emissions of THC were detected in any test.

The NOx emissions measured during the tests on the chassis dynamometer were in all cycles higher than the Euro VI emission limit (Figure 50 and Figure 51). Also the “all events” results from the PEMS testing showed high NOx emissions. In Figure 52 it can be seen that the exhaust gas temperature is too low for the SCR system to work during the entire urban and rural part of the cycle.

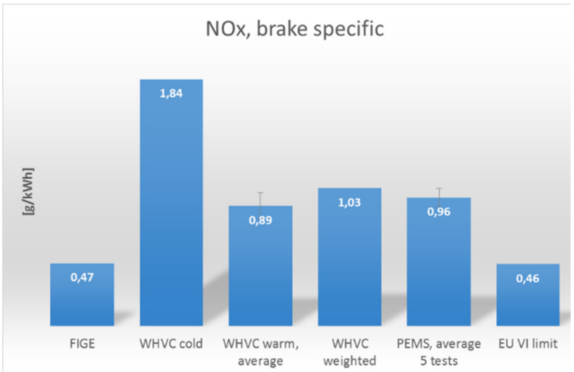


Figure 50 Brake specific NOx emissions.

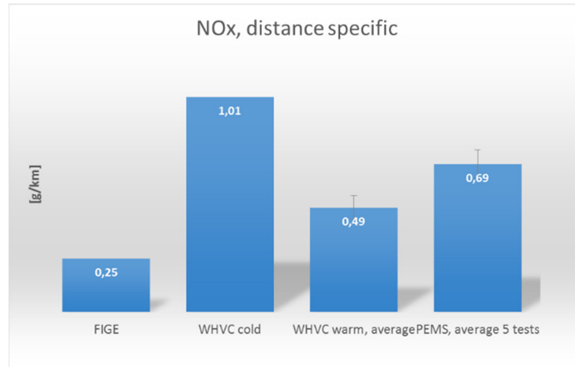


Figure 51 Distance specific NOx emissions.

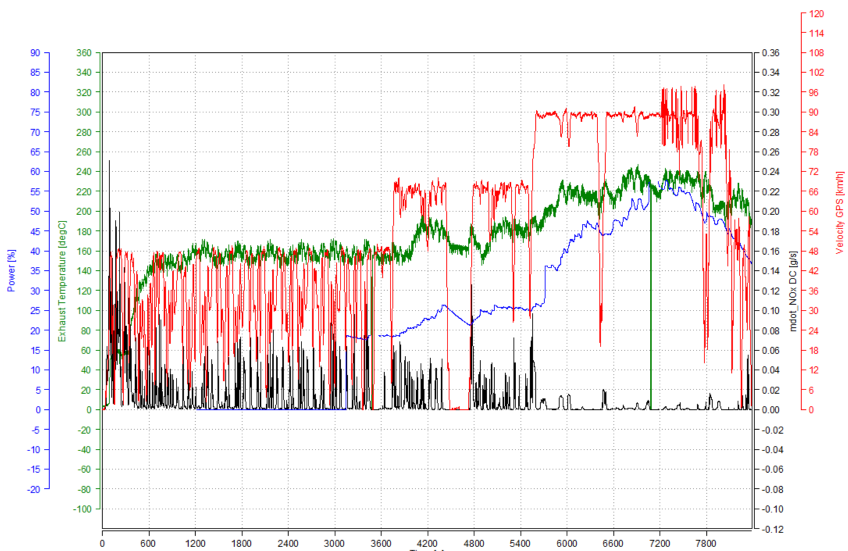


Figure 52

The ammonia emissions measured were low (Figure 34).

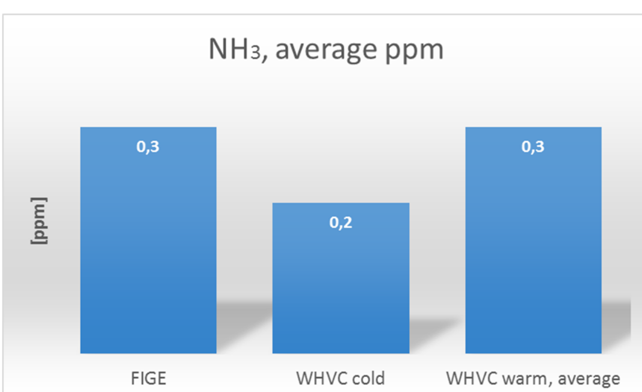


Figure 53 Emissions of ammonia

The PM level of the test vehicle was low and below the Euro VI limit in all tests (Figure 54). Also the PN levels were below the Euro VI applicable PN limit in all tests (Figure 56).

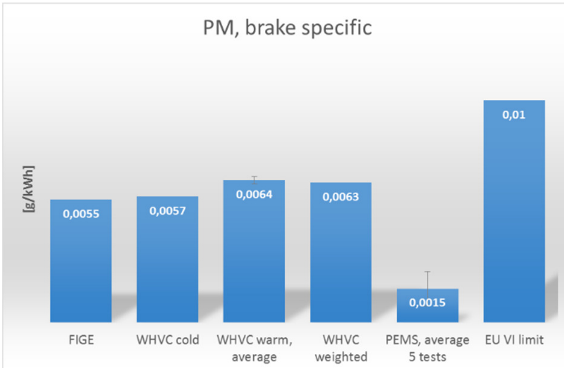


Figure 54 Brake specific PM emissions.

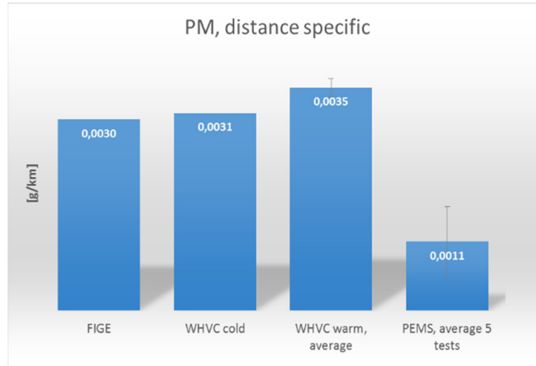


Figure 55 Distance specific PM emissions.

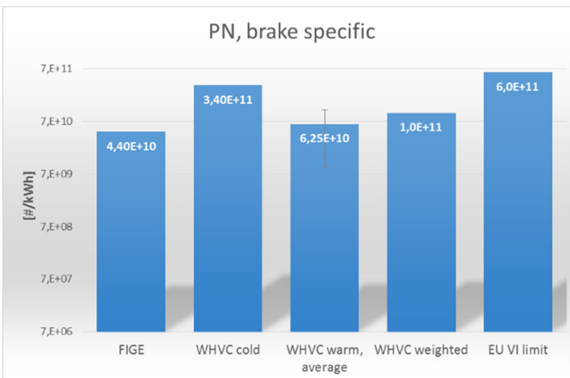


Figure 56 Brake specific PN emissions.

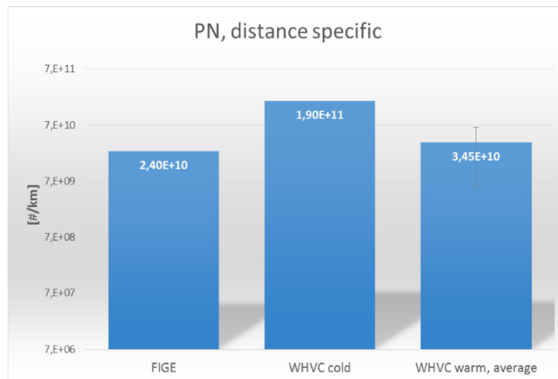


Figure 57 Distance specific PN emissions

The CO_2 emissions and fuel consumption followed the same trend (Figure 58, Figure 59 and Figure 60, Figure 61).

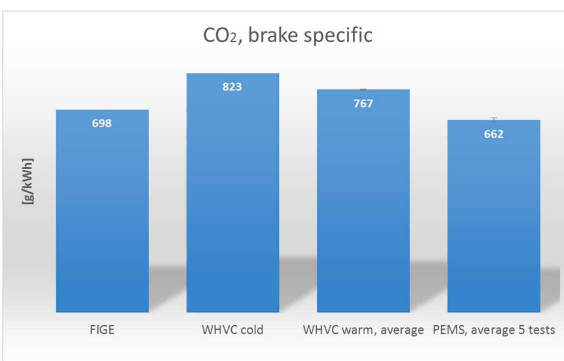


Figure 58 Brake specific CO_2 emissions.

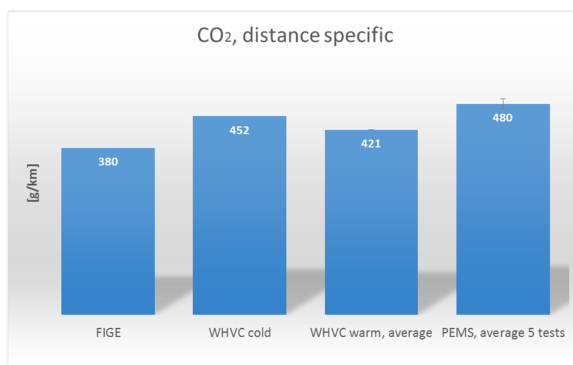


Figure 59 Distance specific CO_2 emissions.

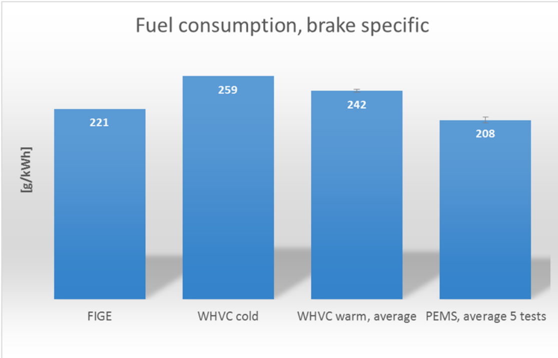


Figure 60 Brake specific fuel consumption.

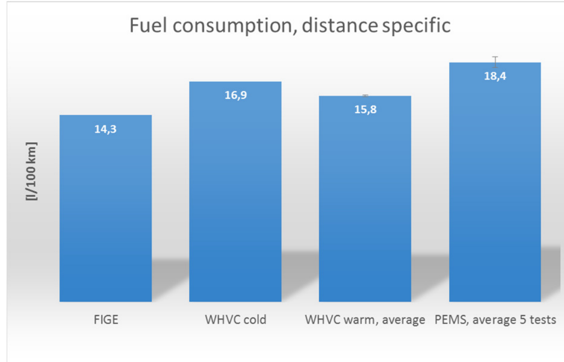


Figure 61 Distance specific fuel consumption

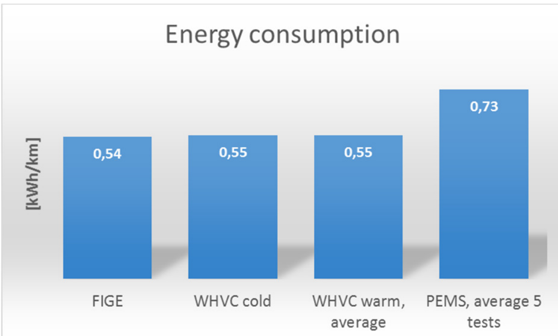


Figure 62 Energy consumption.

Conclusions

All tests resulted in emissions of CO, PM and PN well below the Euro VI emission limit. No emissions of THC were detected in any test. The NOx emissions measured during the tests were rather high and the vehicle did not pass the Euro VI emission limit. The ammonia emissions measured were low.

The PEMS tests all started with a cold engine but with slightly different start temperatures. For this vehicle and for these tests, a start temperature difference of 5℃ resulted in an approximate 20 % difference of the conformity factor.

No malfunction was indicated by the OBD system.

Vehicle E

A N2 rigid diesel truck of emission standard Euro VI and model year 2014, has been tested for exhaust emissions and fuel consumption. Testing was performed on a chassis dynamometer and on Swedish roads using PEMS.

All tests resulted in emissions of CO and PM well below the Euro VI emission limit. No emissions of THC were detected in any test. The NO_X emissions measured during the tests were very low in all warm start tests. The cold start generated a little higher NO_X emissions but the weighted NO_X result was below the limit. The ammonia emissions measured were low. The emissions of PN where above the Euro VI limit in the cold start test and also in the weighted WHVC result.

Presentation of vehicle:

Model year:	2014
Vehicle category:	N2
Vehicle type:	Rigid truck
Mileage:	28 849 km
Engine:	CI, 4-cylinder
Displacement:	~5 litres
Fuel:	Diesel
Power:	~160 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF
Transmission:	automatic
Gross Vehicle Mass	11 990 kg
Mass in running order:	7 280 kg
Maximum payload:	4 710 kg
Emission standard:	Euro VI

Test program

The on-road testing was performed between the 17th and 19th of February 2015. Tests on the chassis dynamometer were performed between the 24th and 27th of February 2015.

Table 11 Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	9 506	(~2 226)
WHVC	1	3	9 506	(~2 226)
PEMS Euro VI N2 route	3	-	-	2 355

Inertia is the inertia simulated by the chassis dynamometer. The vehicle payload is reproduced by loading the vehicle with large concrete blocks during on-road tests.

The vehicle payload, during the on-road tests using PEMS, made 50% of the maximum payload. The simulated vehicle payload during the tests on the chassis dynamometer made 47% of the maximum payload.

Ambient conditions

Test 1 (2015-02-17):

- Trip average RH: 34 %
- Trip average ambient temperature: 11°C
- Coolant temperature at test start: 5°C

Test 2 (2015-02-18):

- Trip average RH: 38 %
- Trip average ambient temperature: 11°C
- Coolant temperature at test start: 7°C

Test 3 (2015-02-19):

- Trip average RH: 48 %
- Trip average ambient temperature: 13°C
- Coolant temperature at test start: 6°C

Emission test results

The ISC test results from the PEMS tests are presented in Figure 63 and Figure 64.
No emissions of CO and THC were detected in any PEMS test. The emissions of NO_X were low, passing the conformity factor limit in all tests. PM conformity factors show similar results.

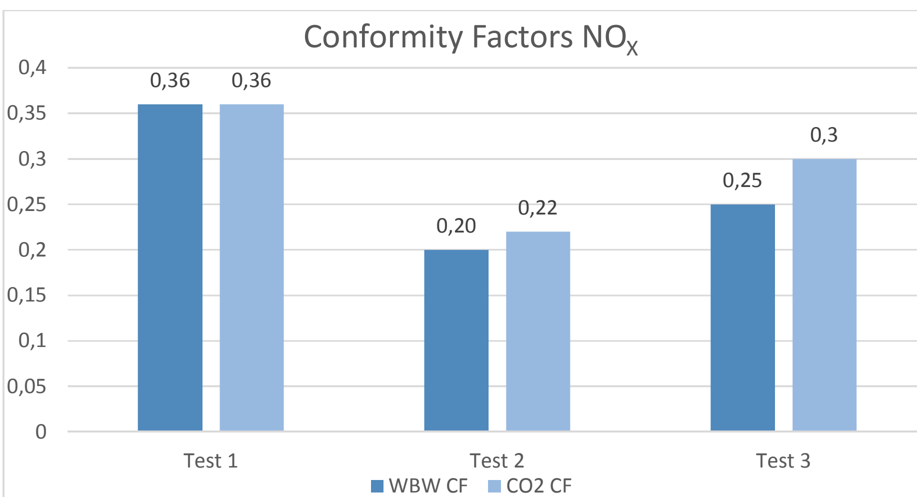


Figure 63. Conformity Factors NOx

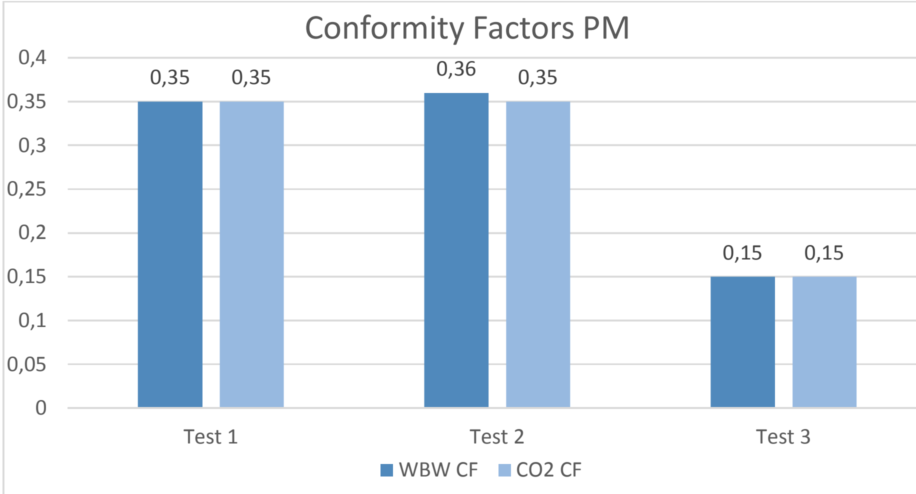


Figure 64. Conformity Factors PM

The results presented in Figure 65Figure 30 to Figure 78Figure 43 were recorded over the whole PEMS route (all events) or test cycle. The weighted emissions are calculated as 86% of the warm test result added to 14% of the cold start test result. In cases where the test-cycles/routes were repeated the results are presented as average values with standard deviation error bars.

All tests resulted in CO emissions (Figure 65 and Figure 66) well below the Euro VI emission limit (4 g/kWh).

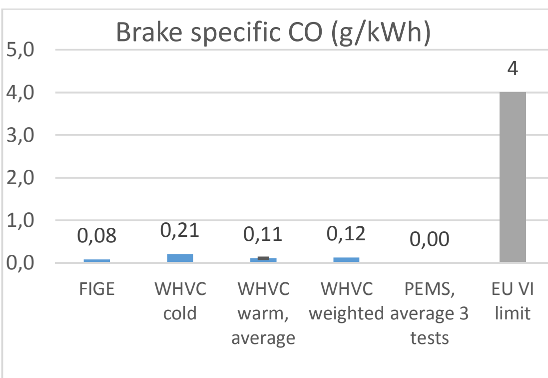


Figure 65. Brake specific CO emissions.

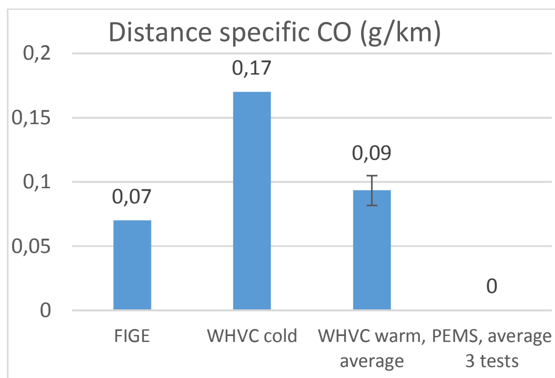


Figure 66. Distance specific CO emissions

No emissions of THC were detected in any test.

The NO_X emissions (Figure 67 and Figure 68) measured during the tests on the chassis dynamometer were low for the warm starts (FIGE and WHVC) but relatively high in the WHVC with cold start. However, the weighted WHVC result was well below the Euro VI emission limit (0.46 g/kWh). The “all events” results from the PEMS testing was below the limit for NOx.

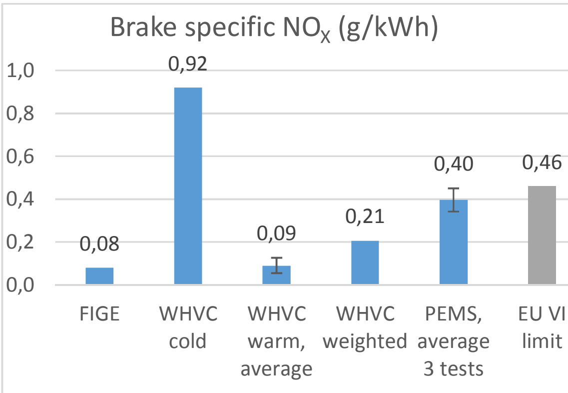


Figure 67. Brake specific NOx emissions.

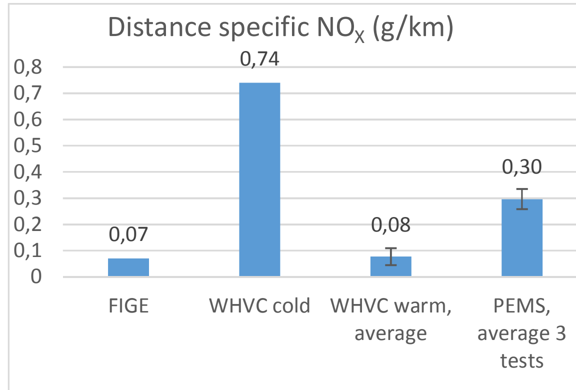


Figure 68 Distance specific NOx emissions.

The ammonia emissions measured were low (Figure 69).

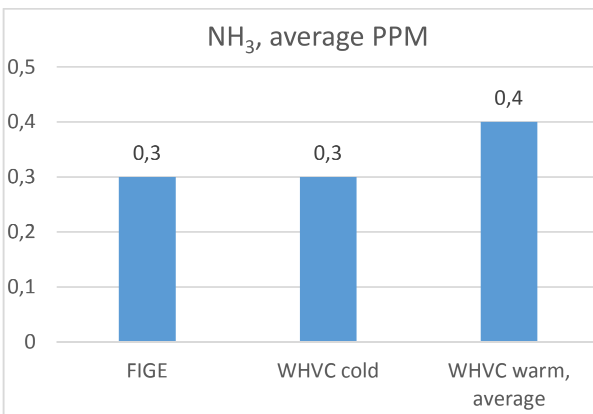


Figure 69. Emissions of ammonia in ppm

The PM level of the test vehicle was low and below the Euro VI limit in all tests (Figure 70). The weighted WHVC PN emissions exceeded the Euro VI limit due to high PN emissions in the cold start (Figure 72).

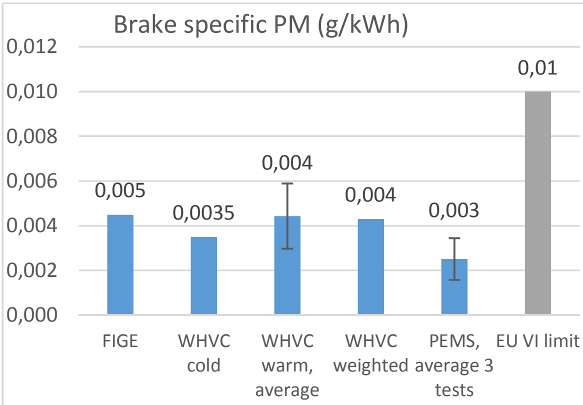


Figure 70. Brake specific PM emissions.

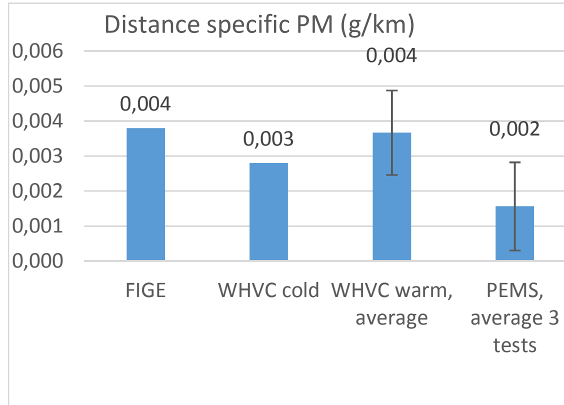


Figure 71. Distance specific PM emissions.

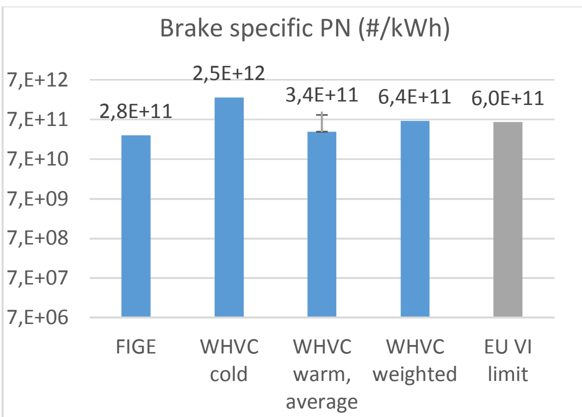


Figure 72. Brake specific PN emissions.

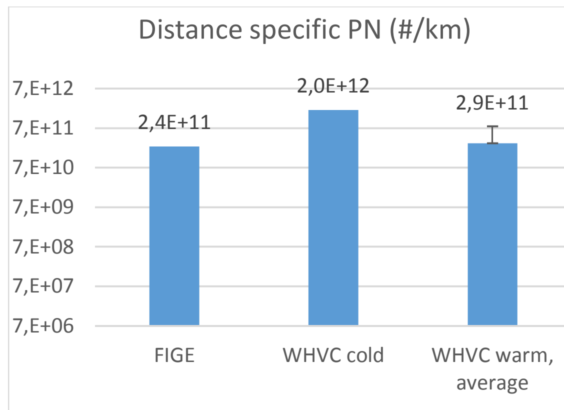


Figure 73. Distance specific PN emissions.

The CO_2 emissions and fuel consumption followed the same trend (Figure 74, Figure 75 and Figure 76, Figure 77).

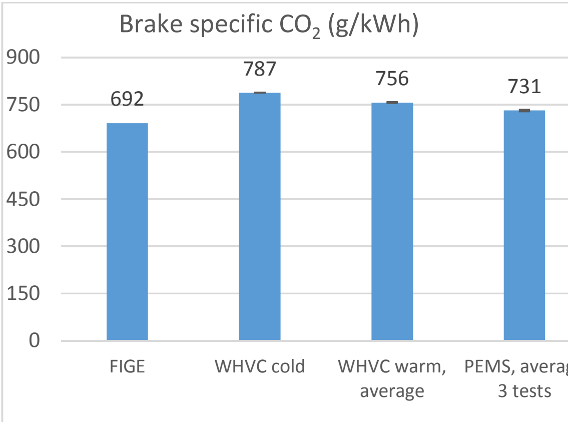


Figure 74. Brake specific CO_2 emissions.

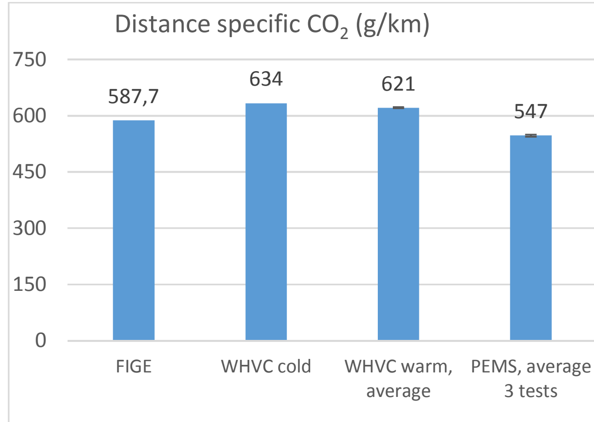


Figure 75. Distance specific CO_2 emissions.

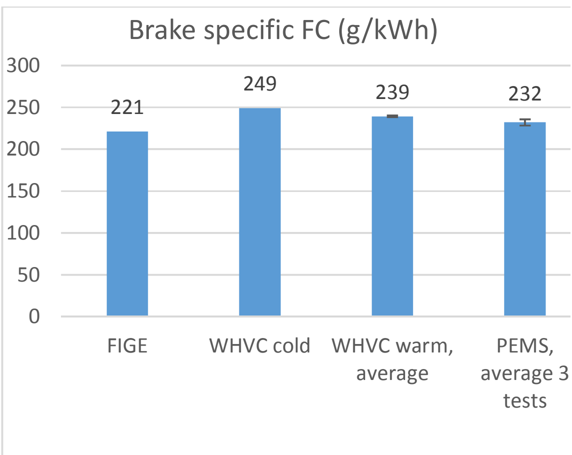


Figure 76. Brake specific fuel consumption.

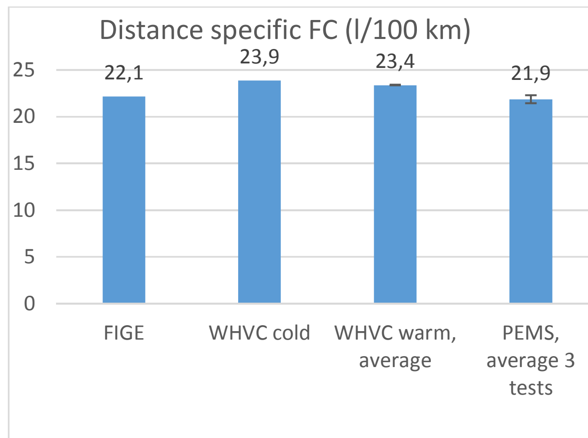


Figure 77 Distance specific fuel consumption

Finally, Figure 78 shows the energy consumption over the tests stated in kWh/km.

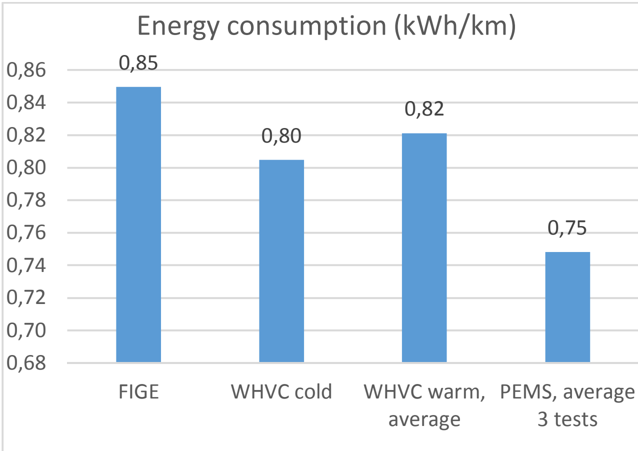


Figure 78. Energy consumption.

Conclusions

The in service conformity evaluated resulted in conformity factors well below the 1,5 max limit for NO_X and PM emissions.

All tests resulted in emissions of CO and PM well below the Euro VI emission limit. No emissions of THC were detected in any test. The NO_X emissions measured during the tests were very low in all warm start tests. The cold start generated a little higher NO_X emissions but the weighted result was below the limit. The ammonia emissions measured were low. The emissions of PN where above the Euro VI limit in the cold start test and also in the weighted WHVC result.

No malfunction was indicated by the OBD system.

Vehicle F

A N3 diesel truck of emission standard Euro VI and 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 test route used was the every-day route of the vehicle and therefore not according to Euro VI requirements. The vehicle was tested with and without load (24 400 – 80 000 kg)

Emissions of THC, CO and PM 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 0.54 (work based) and 0.82 (CO_2 based). Fuel consumption increased with 2.6 litres with an extra load of 55 000 kg.

Presentation of vehicle:

Model year:	2014
Vehicle category:	N3
Vehicle type:	Heavy duty truck
Mileage:	116000 km
Engine:	CI, 8-cylinder
Displacement:	~16 litres
Fuel:	Diesel
Power:	~550 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF
Transmission:	automatic
Gross Vehicle Mass (GVM):	32 000 kg
Mass in running order:	14 100 kg
Trailer weight:	10 300 kg
Maximum payload:	55 000 kg
Test weight:	24 400 – 80 000 kg
Emission standard:	Euro VI

Test Program

The on-road testing was performed between the 19th and 20th of April 2015 at an average temperature and humidity of 13 °C and RH 58 % respectively. The vehicle was tested during a normal working day in its' ordinary test route. Thus, the driving pattern and load does not fulfil the requirements of a Euro VI test route. Presented results originates from the total test route, Figure 79 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.

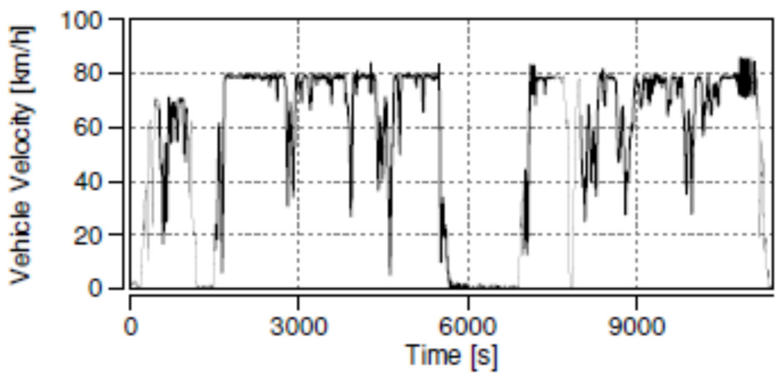


Figure 79 Test trip driving pattern.

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 %

Emission test results

The test results from the on-road driving measurements are presented in Figure 80 to Figure 82. No emissions of CO or HC were detected in the hot start tests i.e. < 0.01 g/kWh. During the complete test cycle the confirmatory factors varies from 0.2 to 0.82 CO and NO_x respectively (maximum allowed value, 1.5)

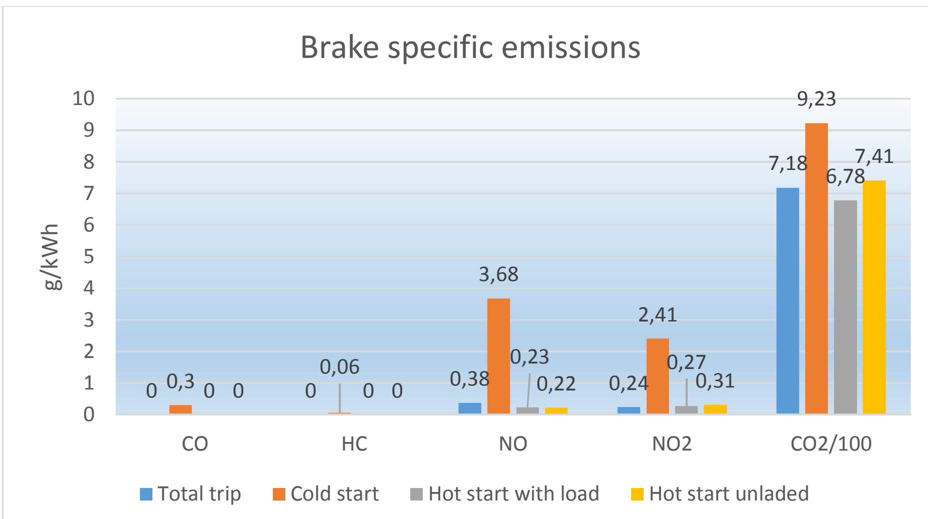


Figure 80 Brake specific emissions for the complete test and sub trips.

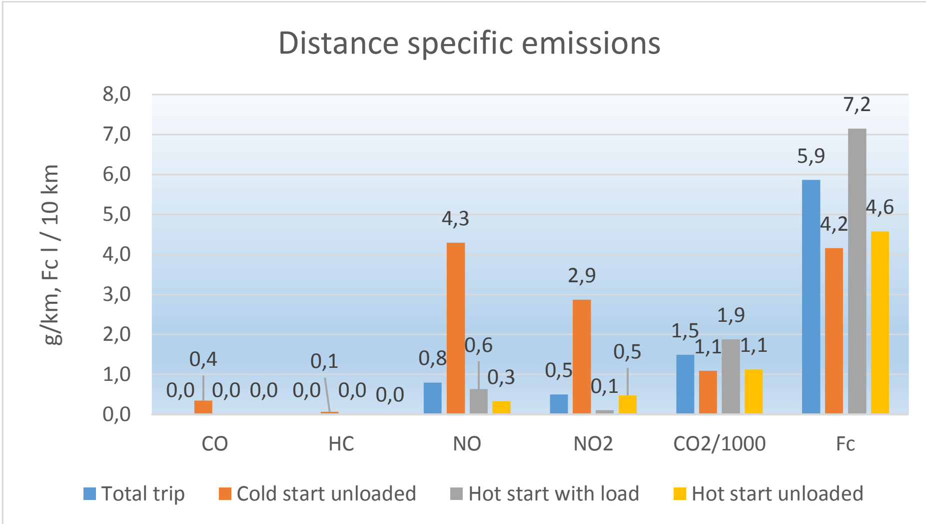


Figure 81 Distance specific emissions for the complete test and sub trips.

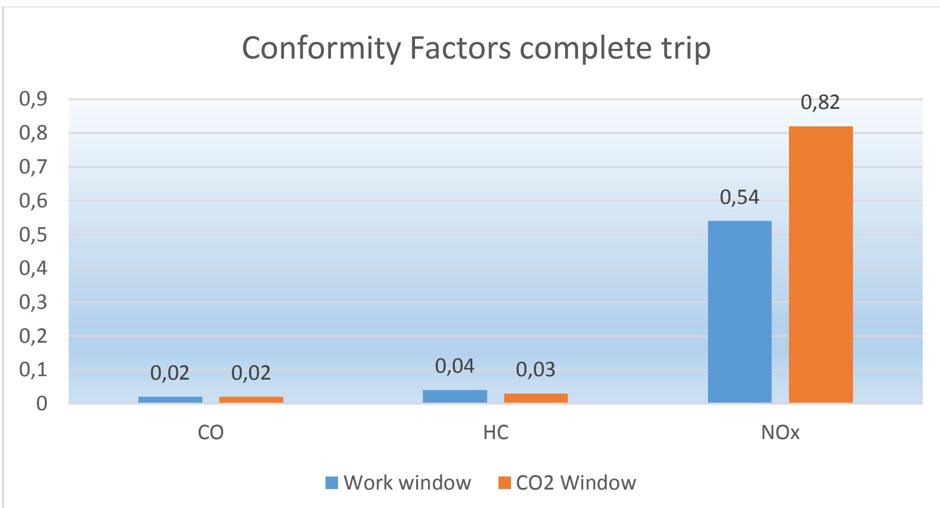


Figure 82 Conformity factors.

Conclusions

The NO_x emissions during the cold start phase were 6.1 g/kWh due to low SCR catalyst temperature. When the exhaust after treatment system were fully warmed up the NO_x emission levels varies from 0.3 to 0.5 g/kWh.

When comparing the fuel consumption it can be noted that 55 000 kg extra weight increases the consumption with 2.6 litres / 10 km.

Vehicle G

Vehicle G was a small bus of category M3 which was tested on road as well as on chassis dynamometer. The vehicle was of euro standard VI, equipped with a EGR, DOC, DPF and SCR and the fuel used during the tests was hydrogenated vegetable oil diesel (HVO) sold under the commercial name SweaX HVO 100 Bio which is 100 % renewable. (For further specifications, see Appendix 2, HVO fuel specifications).

Emissions of CO, THC, PM and PN are well below the Euro VI legislative limits for all test results. In fact, CO levels for all tests apart from the cold start WHVC were below detection limit. Only emitted NOx from the cold start tests exceed the Euro VI limit of 0.46 g/kWh. However, the PEMS result analysis show a clear pass with respect to ISC criteria, NOx conformity factor included.

Presentation of vehicle:

Model year:	2014
Vehicle category:	M3
Vehicle type:	Bus
Mileage:	37 167 km
Engine:	Daimler AG OM642, CI, 6-cylinder
Displacement:	~3 litres
Fuel:	Diesel/HVO
Power:	~140 kW
Exhaust after treatment:	EGR, DOC, DPF and SCR
Transmission:	Automatic
Gross Vehicle Mass	5 500 kg
Mass in running order:	3 850 kg
Maximum payload:	1 650 kg
Emission standard:	Euro VI

Test program

All on-road tests were started with a cold engine and carried out on the 3st and 5th of June 2015. PEMS results were evaluated according to EU regulation. Tests on the chassis dynamometer were performed between the 26th and 28th of May 2015.

Table 12 Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	3500	0
WHVC	2	2	3500	0
PEMS Euro VI M3 route	2	-	-	≈1000

Inertia is the inertia simulated by the chassis dynamometer. During PEMS is the vehicle payload reproduced by loading the vehicle with concrete blocks or water containers.

The vehicle payload during the on-road tests using PEMS was 60% of the maximum payload. Due to limitations of the chassis dynamometer, where the tests on the chassis dynamometer carried out without added vehicle payload.

Ambient conditions

Test 1 (2015-06-03):

- Trip average RH: 75 %
- Trip average ambient temperature: 14 ℃
- Coolant temperature at test start: 12℃

Test 2 (2015-06-05):

- Trip average RH: 40 %
- Trip average ambient temperature: 19 ℃
- Coolant temperature at test start: 13 ℃

Emission test results

The ISC evaluation results for the two PEMS tests are presented in Figure 83. NOx conformity factors are significant but the vehicle pass the ISC criteria (1.5) calculating both work- and CO_2 mass based windows respectively. Calculated conformity factors for CO and THC are insignificantly small (<0.1).

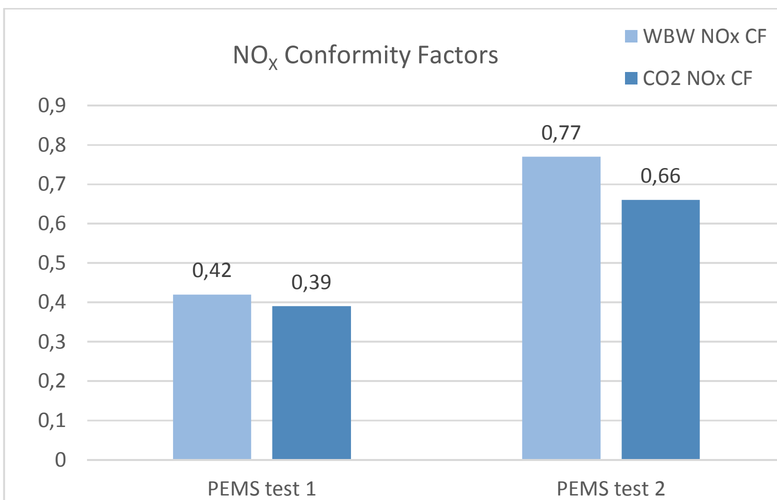


Figure 83. NOX Conformity factors for the PEMS tests using the Work based windows (WBW) and CO2 mass based windows, respectively.

Results presented below include PEMS tests when considering the complete route (all events) as well as the chassis dynamometer cycle tests. 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 to 14% of the average cold start test result.

All tests apart from WHVC cold start results indicate CO emissions below the detection limit, as can be seen in Figure 84 and Figure 85. Detected CO emitted is far below the Euro VI limit of 4 g/kWh.

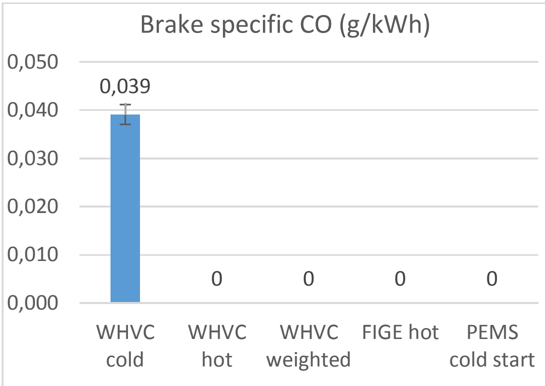


Figure 84 Avg. brake specific CO emissions (g/kWh)

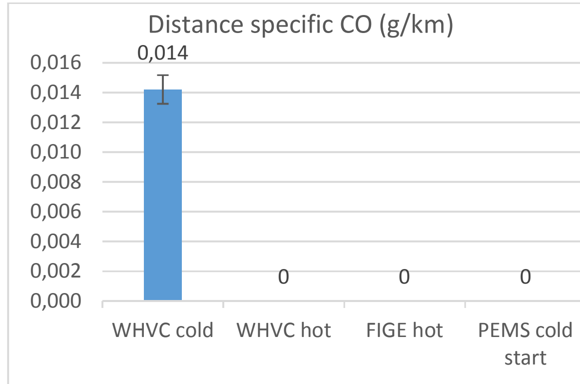


Figure 85 Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure 86 and Figure 87. Emitted THC levels are much lower than the WHTC Euro VI limit of 0.16 g/kWh.

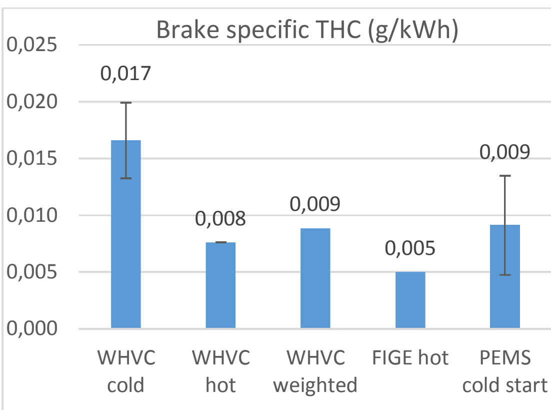


Figure 86 Avg. brake specific THC emissions (g/kWh)

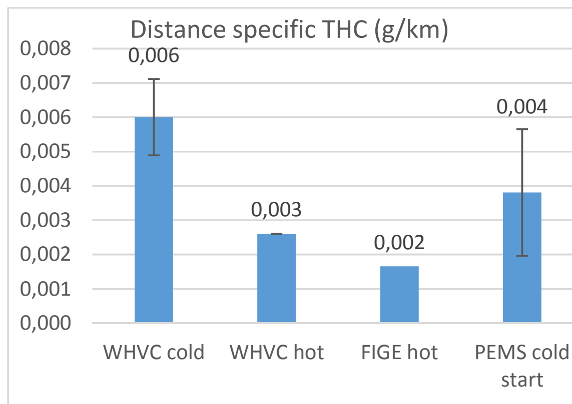


Figure 87 Avg. distance specific THC emissions (g/km)

Measured NO_X emissions from the chassis dynamometer and PEMS tests are shown in Figure 88 and Figure 89. As can be seen emission of NO_X is more problematic and cold start tests for both WHVC and PEMS exceed the set Euro VI limit. The weighted WHVC NO_X emission, however, is below the limit.

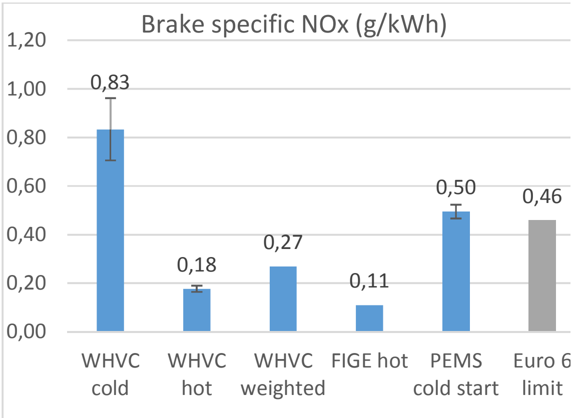


Figure 88 Avg. brake specific NOX emissions (g/kWh)

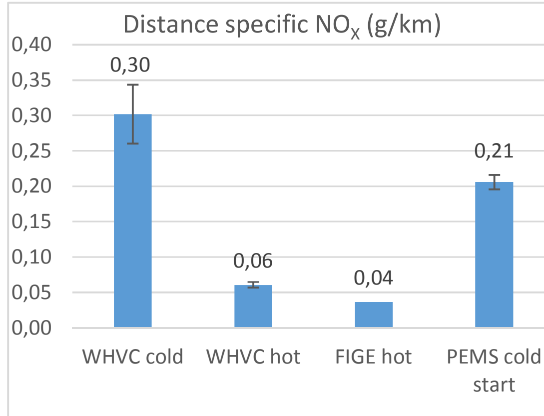


Figure 89 Avg. distance specific NOX emissions (g/km)

Gravimetrically measured PM results for the chassis dynamometer tests are presented in Figure 90 and Figure 91. PM levels are below the Euro VI limit by a good margin. The slightly higher PM levels for the FIGE cycle is a result of the extended highway phase for that cycle.

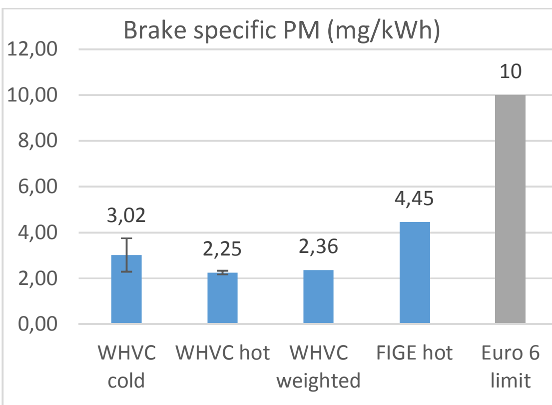


Figure 90 Avg. brake specific PM (mg/kWh)

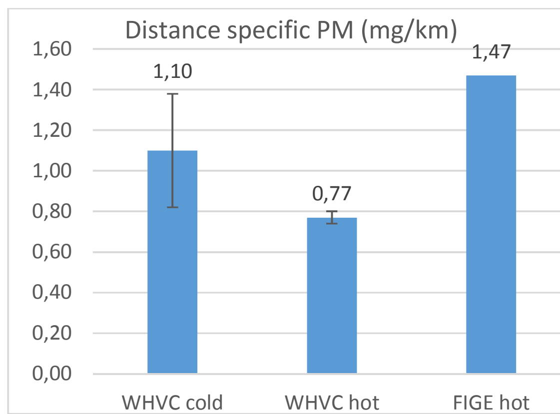


Figure 91 Avg. distance specific PM (mg/km)

Emitted number of particles results for the chassis dynamometer tests are presented in Figure 92 and Figure 93. All numbers measured are lower than the Euro VI 6.0×10^{11} particle number limit.

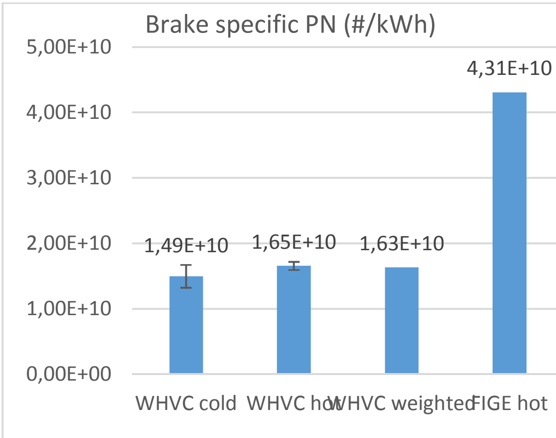


Figure 92 Avg. brake specific PN (#/kWh)

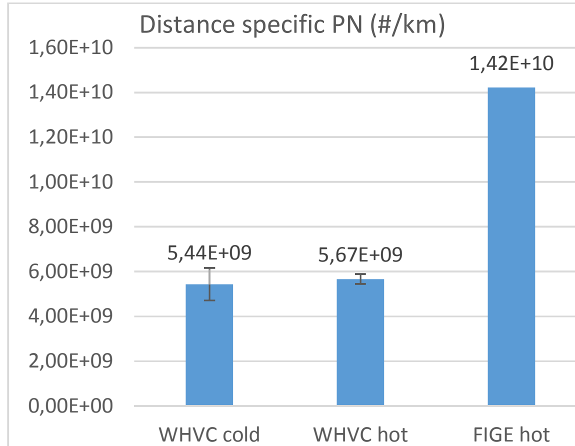


Figure 93 Avg. distance specific PN (#/km)

There is an elevated number of emitted particles during the FIGE cycle due to the longer highway driving phase compared to WHVC. CO_2 and fuel consumption results are shown in Figure 94 to Figure 97. It is apparent that both CO_2 emissions and FC follow a similar trend. The slightly lower CO_2 emissions and FC for the FIGE test is the outcome of the extended highway phase where the engine is in optimal operation.

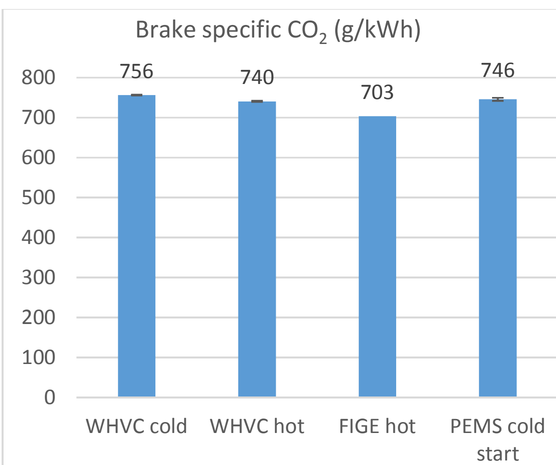


Figure 94 Avg. brake specific CO2 emissions (g/kWh)

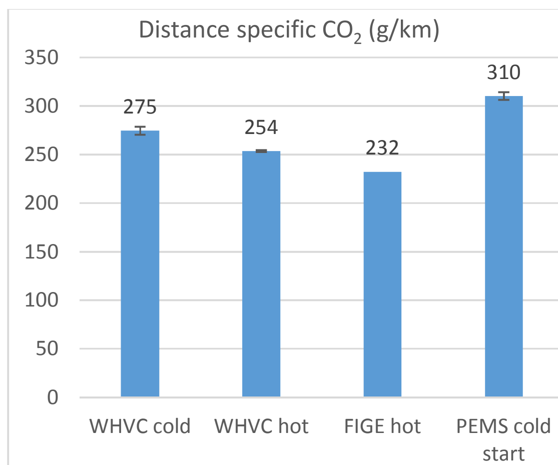


Figure 95 Avg. distance specific CO2 emissions (g/km)

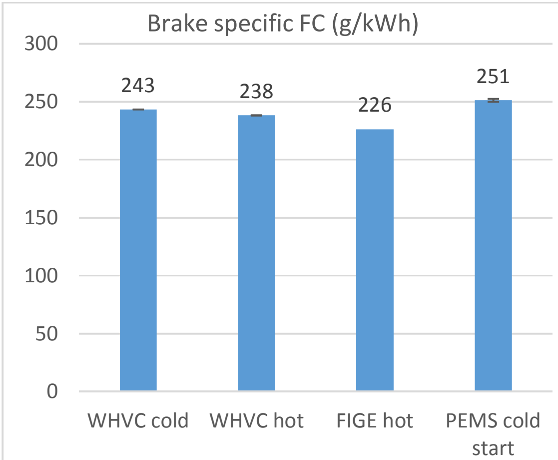


Figure 96 Avg. brake specific FC (g/kWh)

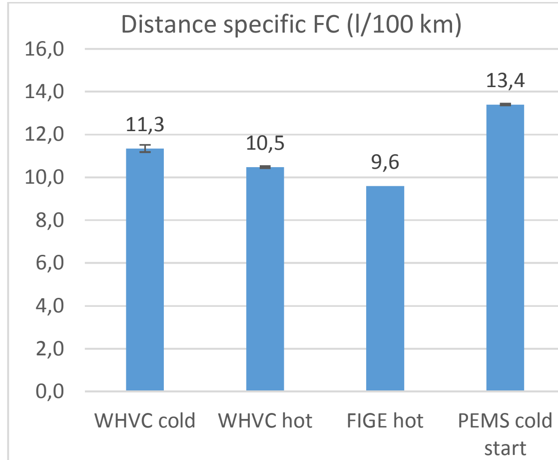


Figure 97 Avg. distance specific FC (l/100 km)

Figure 98 illustrate the energy consumption stated in kWh per km. The higher average energy consumption for the PEMS tests is a result of added vehicle payload and driving conditions real traffic.

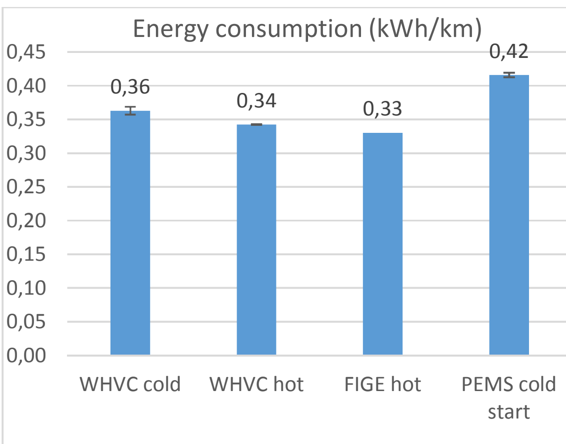


Figure 98 Average energy consumption (kWh/km)

Conclusion

It can be concluded that the measured levels of emitted CO, THC, PM and PN are safely below the Euro VI limit requirements. NO_X emissions calculated from the cold start tests on chassis dynamometer and the PEMS ("all events") tests exceed the WHTC Euro VI limit of 0.46 g/kWh by 80 % and 9 % on average and respectively. However, the weighted WHVC and hot start tests NO_X emissions were below the limit. ISC evaluation results indicated very small THC and CO conformity factors while NO_X conformity factors were significant but passing the criteria, for both work- and CO_2 mass based windows.

There were no malfunctions indicated from the OBD system.

Vehicle H

A N3 diesel tractor trailer of emission standard Euro VI and model year 2013, was 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

.

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 from the cold start tests, and consequently the weighted WHVC results, on chassis dynamometer reach beyond the 0.46 g/kWh limit. Remaining tests meet the legal requirement on NO_X. 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:	2013
Vehicle category:	N3
Vehicle type:	Tractor trailer
Mileage:	546 963 km
Engine:	DC16 102 580, CI, 8-cylinder
Displacement:	~16 liters
Fuel:	Diesel
Power:	~430 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF
Transmission:	Automatic
Gross Vehicle Mass	18 000 kg
Mass in running order (vehicle):	8 280 kg
Mass in running order (trailer):	7 000 kg
Maximum payload:	42 720 kg
Emission standard:	Euro VI

Test program

The testing was performed between the 4th and 12th of June 2015.

Table 13. Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	20 354	(≈12 100)
WHVC	2	4	20 354	(≈12 100)
PEMS Euro VI N3 route (long)	2	-	-	21 500

The inertia specified in Table 13 correspond to the chassis dynamometer inertia setting, which is produced by using a combination of flywheels of varying mass.

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℃ are excluded. However, in the “all events result”, emissions released during cold start are included.

Ambient conditions

Test 1 (2015-06-11):

- Trip average RH: 38 %
- Trip average ambient temperature: 20℃

Test 2 (2015-06-12):

- Trip average RH: 34 %
- Trip average ambient temperature: 24℃

Emission test results

PM sampling was not carried out for the initial PEMS trip, but was successfully measured for the second trip.

The ISC NO_X and PM results for both PEMS tests are presented in Figure 99 and Figure 100 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 but are lower for the second PEMS trip. Calculated PM conformity factors for the second PEMS test also meet the legislative criteria.

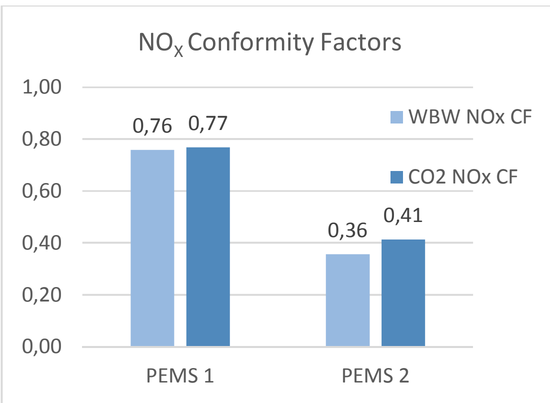


Figure 99. Work and CO2 based NOx conformity factors for both PEMS tests.

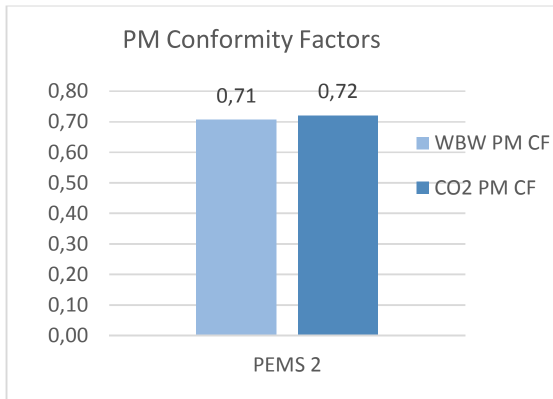


Figure 100. Work and CO2 based PM conformity factors for the second PEMS test.

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 101 and Figure 102, are below the Euro VI limit of 4 g/kWh. No CO was detected during the PEMS tests.

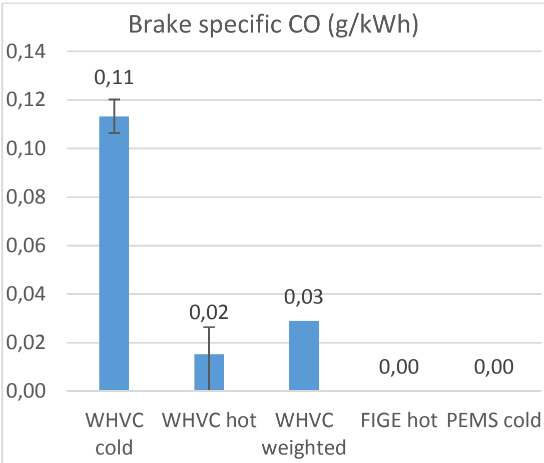


Figure 101. Avg. brake specific CO emissions (g/kWh)

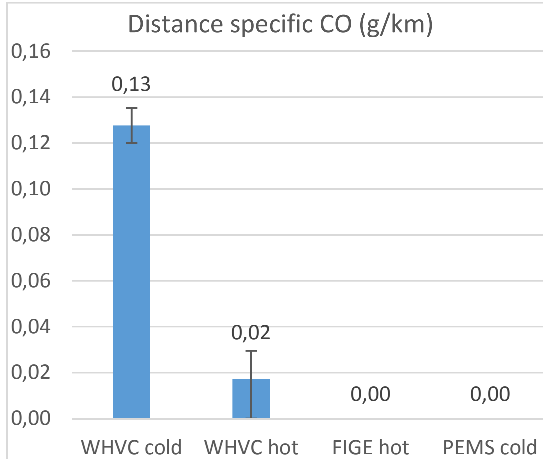


Figure 102. Avg. distance specific CO emissions (g/km)

Average THC emissions are presented in Figure 103 and Figure 104. Emitted THC is way below the Euro VI legislative limit of 0.16 g/kWh. There were no THC emissions detected during the PEMS trips.

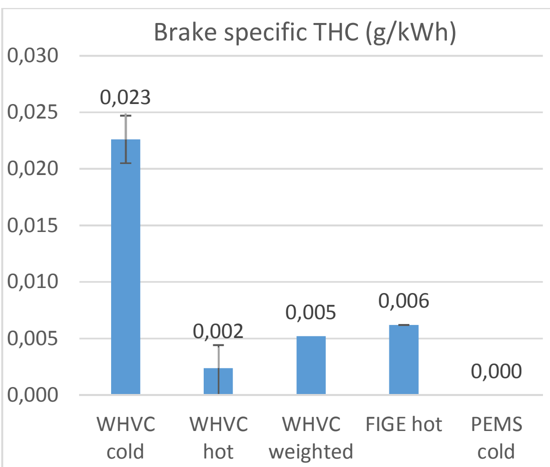


Figure 103. Avg. brake specific THC emissions (g/kWh)

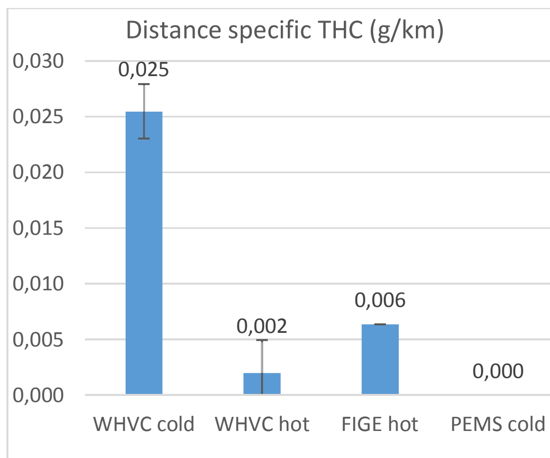


Figure 104. Avg. distance specific THC emissions (g/km)

Figure 105 and Figure 106 show the measured NO_X emissions from the chassis dynamometer and PEMS tests. Results indicate very high emissions of NO_X for the WHVC cold start and thus the weighted average, which exceed the Euro VI limit. Average NO_X emitted for PEMS, FIGE and the WHVC hot start remain under the limit, although the corresponding max value for the latter surpass the limit.

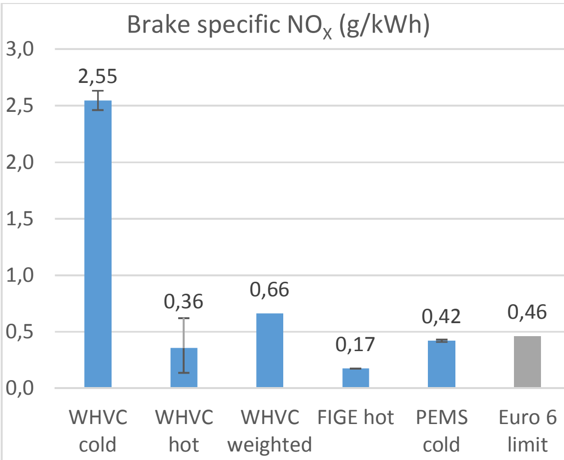


Figure 105. Avg. brake specific NOX emissions (g/kWh)

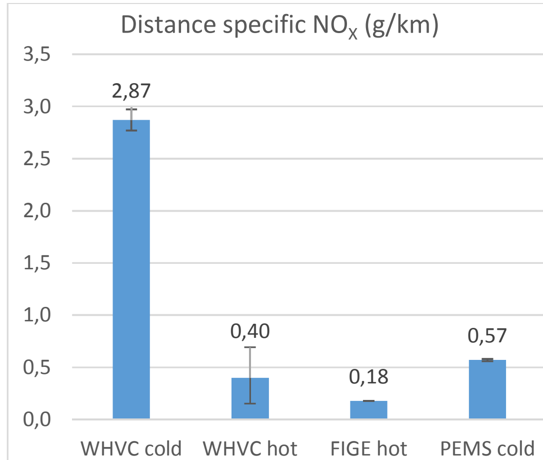


Figure 106. Avg. distance specific NOX emissions (g/km)

Gravimetrically measured PM results are presented in Figure 107 and Figure 108. As stated previously, PEMS PM measurement was carried out only during the second trip. Particle emissions are within the same ranges for the different tests, and safely under the legislative limits.

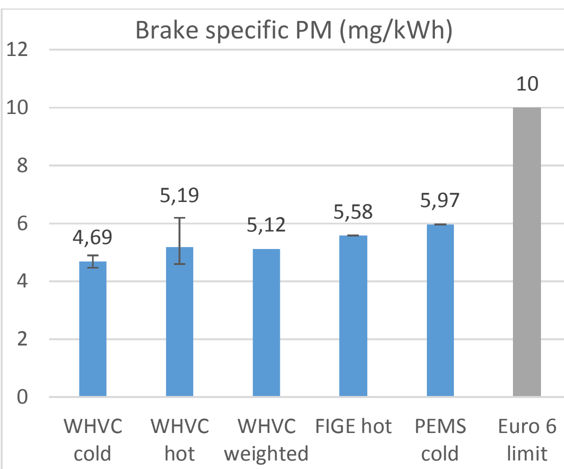


Figure 107. Avg. brake specific PM emissions (mg/kWh)

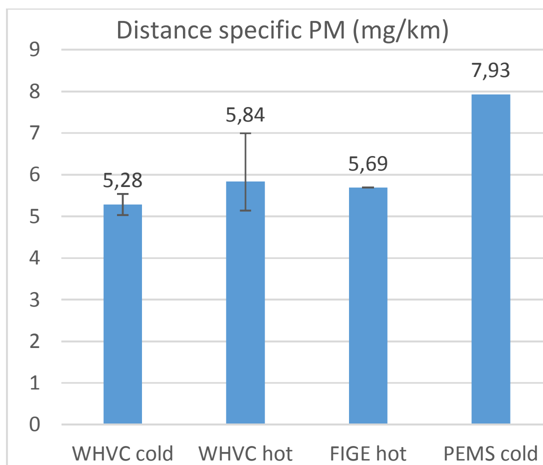


Figure 108. Avg. dist. specific PM emissions (mg/km)

Particle number emissions were only measured over the chassis dynamometer tests and are presented in Figure 109 and Figure 110. All results are lower than the Euro VI particle number limit. The number of emitted particles are higher for WHVC cold start tests.

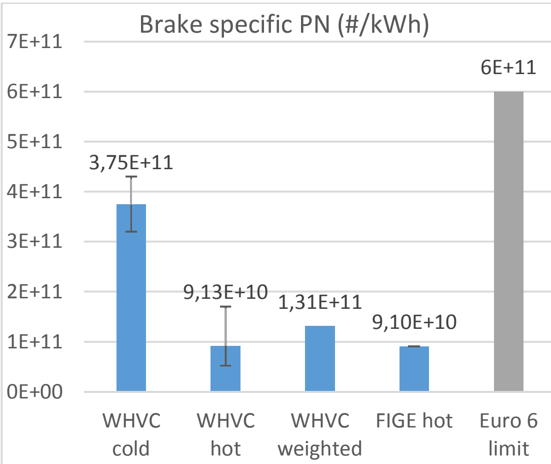


Figure 109. Avg. brake specific PN emissions (#/kWh)

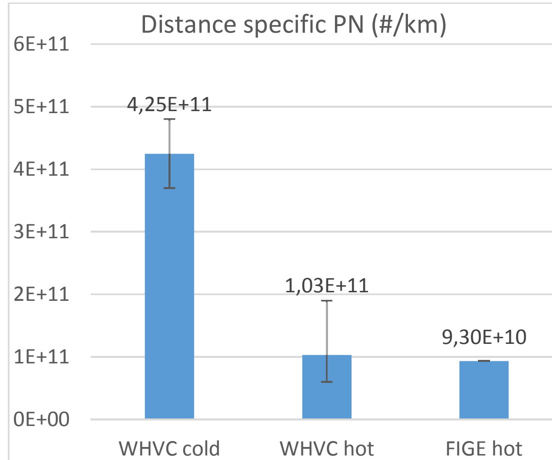


Figure 110. Avg. distance specific PN emissions (#/km)

CO_2 emissions and calculated fuel consumption results follow the same pattern and are presented in Figure 111 to Figure 114. The lower results for the FIGE and PEMS tests is the outcome of an extended motorway phase (FIGE) and higher payload (PEMS) which allow the engine to run at ideal operation
.

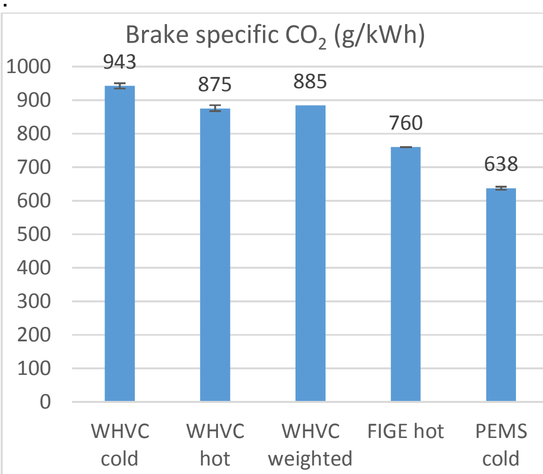


Figure 111. Avg. brake specific CO2 emissions (g/kWh)

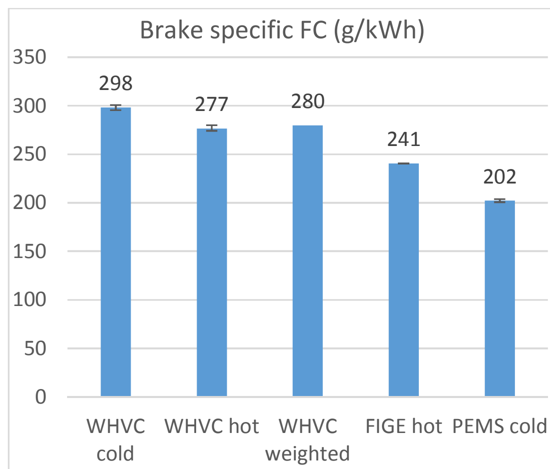


Figure 112. Avg. brake specific FC (g/kWh)

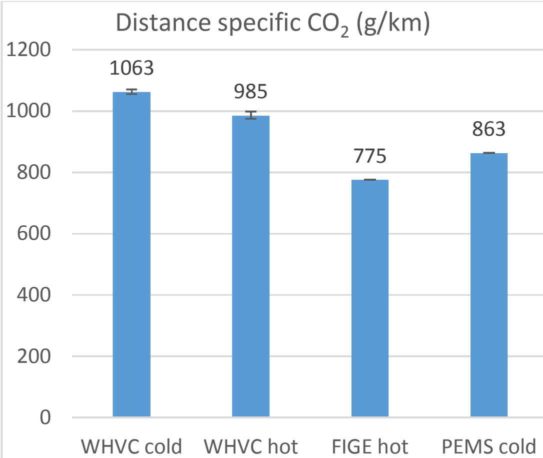


Figure 113. Avg. distance specific CO2 emissions (g/km)

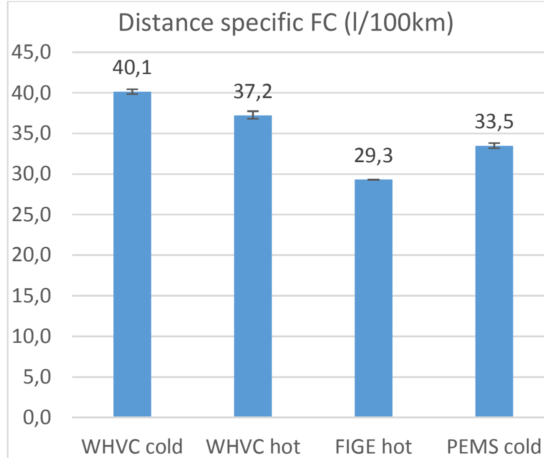


Figure 114. Avg. distance specific FC (l/100km)

Calculated energy consumptions for the test series, specified in kWh per km, are presented in Figure 115. 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 116 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.

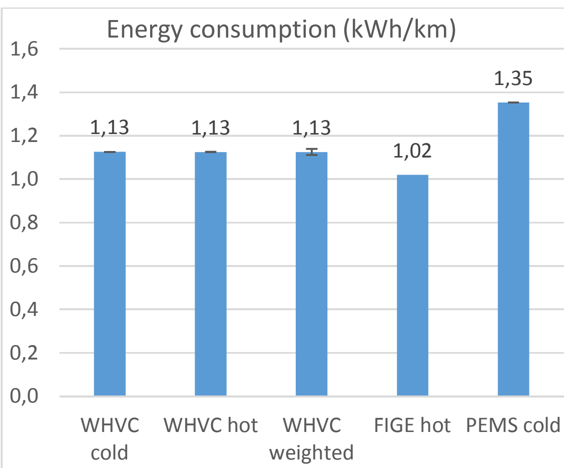


Figure 115. Avg. energy consumption (kWh/km)

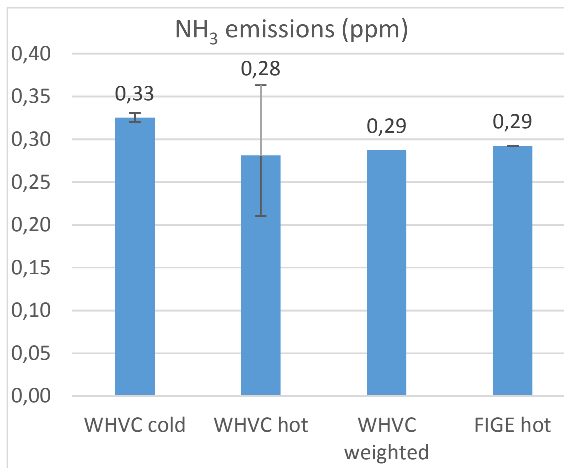


Figure 116. Avg. NH3 emissions over chassis dynamometer tests (ppm)

Conclusions

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

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 from the cold start, and consequently the weighted WHVC, tests on chassis dynamometer reach beyond the 0.46 g/kWh limit. All other tests meet the NO_X regulatory limit.

No malfunction was indicated by the OBD system.

Vehicle I

A CNG fuelled M3 bus of model year 2014 and emission standard Euro VI was tested for exhaust emissions and fuel consumption. Two on-road measurement tests were carried out using a portable emissions measurement system (PEMS) mounted on board.

All calculated conformity factors in the ISC evaluation meet the legislative criteria, for both work and CO_2 based windows. Measured brake specific emissions are well below the Euro VI WHTC regulatory limitations.

Presentation of vehicle:

Model year:	2014
Vehicle category:	M3
Vehicle type:	Bus
Mileage:	9 584 km
Engine:	E 2876 LUH (LOH07), 6-cyl
Displacement:	~12 litres
Fuel:	CNG
Power:	~230 kW
Exhaust after treatment:	TWC
Transmission:	Automatic
Gross Vehicle Mass	30 000 kg
Mass in running order (vehicle):	18 266 kg
Maximum payload:	11 734 kg
Emission standard:	Euro VI

Test program

PEMS tests were performed on the 30th of June and 1st of July 2015.

Table 14. Test program.

Test	Cold start	Hot start	Vehicle Payload [kg]
PEMS Euro VI M3 route [1]	-	2	6000

[1] For M3 of vehicle class I, II or A

Vehicle payload for the test series mark 50 % of the maximum permissible payload. Both PEMS trips were started after warming up the engine, thus no cold start effects on emissions were recorded. During the rural driving phase of the second measurement trip an analyser connection failure occurred which led to the rejection of measurement data from the final part of the test. Thus, the second PEMS test does not meet the Euro 6 trip requirement of operational shares between urban and rural driving. The shares of operation for the second trip was 79 % urban driving and 21 % rural driving.

Ambient conditions

Test 1 (2015-06-30):

- Trip average RH: 61 %
- Trip average ambient temperature: 23 °C

Test 2 (2015-07-01):

- Trip average RH: 34 %
- Trip average ambient temperature: 21 °C

Emission test results

Methane (CH_4) is not individually measured during the PEMS tests and has to be estimated from test data. Since methane is the main component of CNG, it should be the predominant component in the THC emissions. Other investigations suggest that methane constitute more than 90 % or even surpass 95 % of THC emissions. In this report methane emissions are approximated by 97 % of THC.

The in service conformity emission testing results are presented in Figure 117. Non-methane hydrocarbons (NMHC) conformity factors are very small (< 0,1) and excluded from the presentation. All calculated conformity factors pass the ISC criteria, which has a maximum limit value of 1,5 for gaseous components. Furthermore it can be gathered that all conformity factor values for the first PEMS trip are higher compared to the second trip.

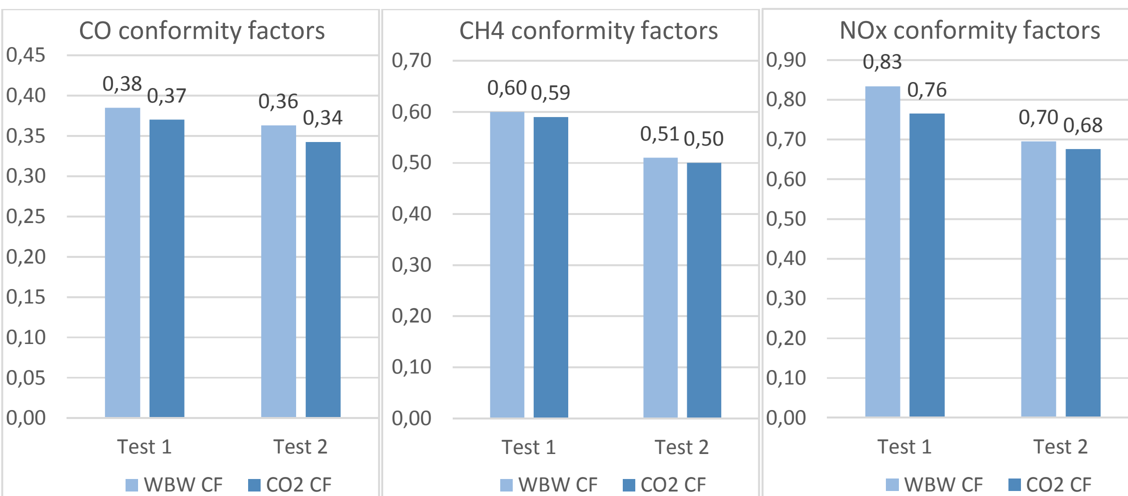


Figure 117. Work and CO2 based conformity factors for CO, CH4 and NOx from PEMS trip 1 and 2.

Vehicle emissions and fuel consumption results during the complete PEMS trips are summarized in both brake specific and distance specific units. Additionally, energy consumption is calculated and presented. Measurements are averaged over the tests and shown with corresponding error bar representing maximum and minimum values.

Calculated brake specific gaseous emissions are shown in Figure 118. The bars with dashed outline illustrate the Euro 6 regulatory emissions limits for each component respectively. Note that the limit for CO, 4 g/kWh, surpasses the graphs' axis maximum bound. None of the legislative emission limits are exceeded and only minor variations in emission levels can be seen between the two tests.

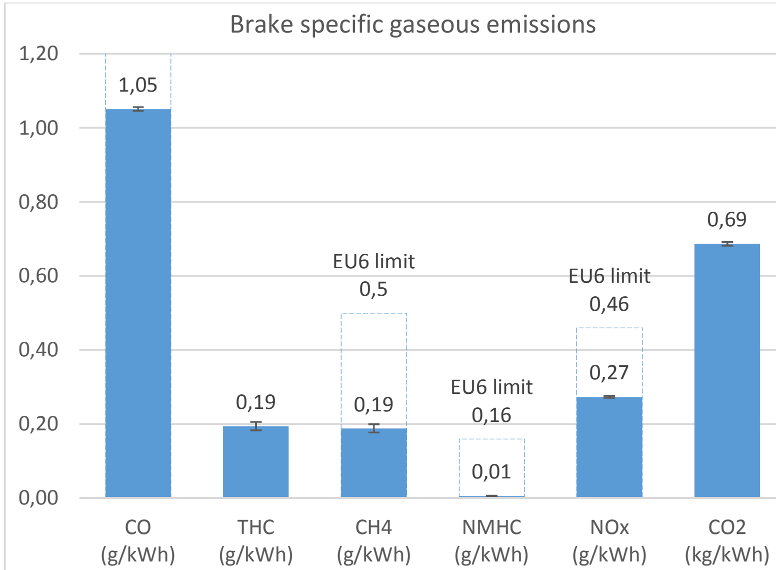


Figure 118. Avg. brake specific gaseous emissions.

Figure 119 presents the distance specific emission results. The error bars indicate a greater difference in measured maximum and minimum, compared to the brake specific emission graph. This is a consequence of the test interrupt during the second trip which truncated the rural driving share of operation and in turn resulted in a reduced trip distance.

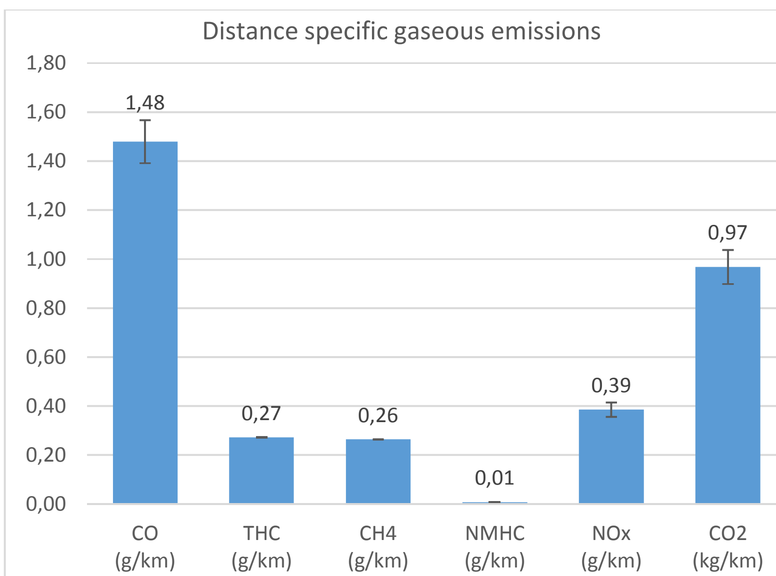


Figure 119. Avg. distance specific gaseous emissions.

Figure 120 shows the fuel consumption, specified in both brake and distance specific units, and the energy consumption. Observe that the energy consumption value is read from the secondary axis to the right in the graph.

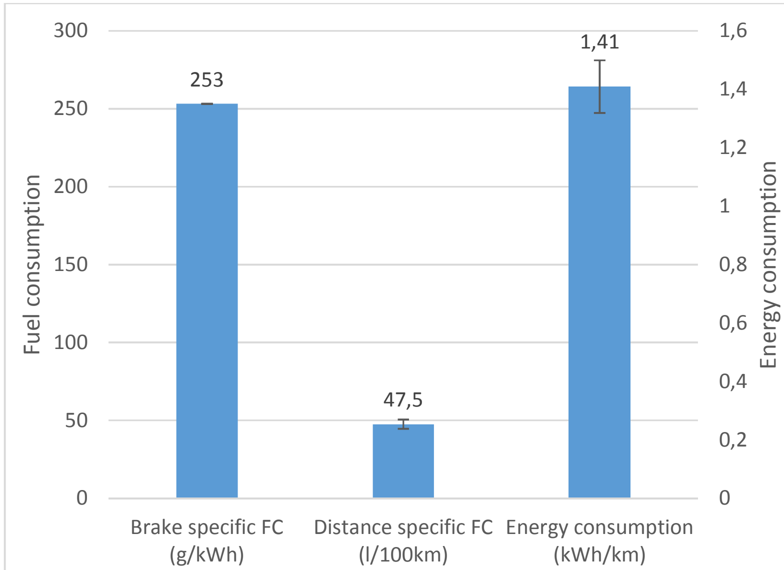


Figure 120. Avg. brake and distance specific fuel consumption and energy consumption.

Conclusions

All conformity factors pass the in service conformity criteria. The lower conformity factors for the second trip is most likely a consequence of the truncated rural phase. During rural driving, emissions are generally higher which means that measurements during the second trip gave a lesser number of averaging windows with high cumulative emissions. Following that the 90^{th} percentile of the measured cumulative emission over all windows is used in the evaluation, a possible explanation to the lower conformity factors arises.

Average brake specific emissions for the full PEMS trip duration are well below the Euro VI WHTC regulatory limits and with minor variations between tests. Larger variations could be observed for the distance specific emissions, explained by the shorter rural phase of the second trip. Same tendency could be seen for the energy consumption.

No malfunction was indicated by the OBD system.

Vehicle J

A N3 diesel crane vehicle of model year 2014 and emission standard Euro VI has been tested for exhaust emissions and fuel consumption. The same vehicle went through emission tests in 2014, both on chassis dynamometer and on road using a portable emission measurement system (PEMS). In 2015 the vehicle was retested by performing two on-road measurement tests using a PEMS mounted on board (Δ mileage ~ 11 400 km). Emission results from both 2014 and 2015 are presented and compared in this report in order to evaluate any changes over time in vehicle emission performance.

WHTC engine test emission limits are used in this investigation as fictive pass/fail criteria, 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 results analysis.

Calculated NO_X conformity factors in the ISC evaluation meet the legislative criteria, for both work and CO_2 based windows. PM conformity factors show large variation between tests, indicating erratic particle emissions. Measured brake specific emissions meet the Euro VI WHTC regulatory limitations. Generally, no significant vehicle ageing effect on emissions can be observed.

Presentation of vehicle:

Model year:	2014
Vehicle category:	N3
Vehicle type:	Crane
Mileage:	18 890 km
Engine:	CI, 6-cyl
Displacement:	~11 litres
Fuel:	Diesel
Power:	~240 kW
Exhaust after treatment:	SCRT®
Transmission:	Automatic
Gross Vehicle Mass (GVM)*:	28 000 kg
Mass in running order (vehicle):	14 043 kg
Maximum payload:	13 957 kg
Emission standard:	Euro VI

Test program

PEMS tests were performed on the 25th and 26st of August 2015.

Table 15. Test program.

Test	Cold start	Hot start	Vehicle Payload [kg]
PEMS Euro VI N3 route	2	-	6700

Vehicle payload for the test series reach 48 % of the maximum permissible payload. Both tests were initiated while the engine was still cold but the evaluation of conformity factors was carried out according to the legislation, where emission data before the engine has reached 70℃ is excluded. However, cold start emission data is included in the "all event result".

The PEMS trips carried out in 2015 are significantly shorter in distance compared to the ones in 2014, and must be taken into account when evaluating the results.

Ambient conditions

Test 1 (2015-08-25):

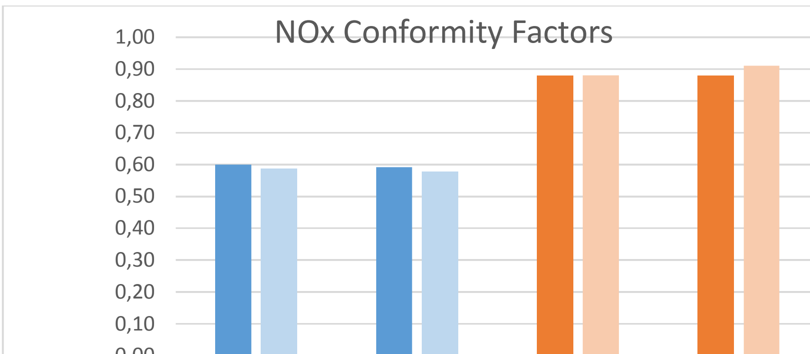
- Trip average RH: 46 %
- Trip average ambient temperature: 27°C

Test 2 (2015-08-26):

- Trip average RH: 69 %
- Trip average ambient temperature: 18°C

Emission test results

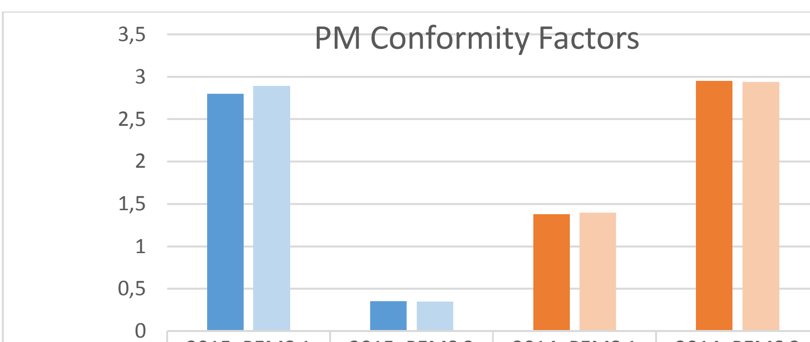
NO_X conformity factors are presented in Figure 121, for each PEMS test carried out in 2015 and 2014 respectively. All NO_X conformity factors pass the ISC criteria, which has a maximum regulatory limit value of 1,5. Furthermore it can be gathered that conformity factor values from PEMS tests in 2014 are higher compared to tests in 2015.



	2015, PEMS 1	2015, PEMS 2	2014, PEMS 1	2014, PEMS 2
WBW NOx CF	0,60	0,59	0,88	0,88
CO2 NOx CF	0,59	0,58	0,88	0,91

Figure 121. Work and CO2 based conformity factors for NOx.

PM in service conformity test results are shown in Figure 122 for all PEMS trips. Just as in 2014, major differences can be seen between the conformity factors for each test pair. No PM limit for in service conformity emission testing has yet been established but there appears to be elevated PM emissions from the test vehicle.



	2015, PEMS 1	2015, PEMS 2	2014, PEMS 1	2014, PEMS 2
WBW PM CF	2,7984	0,35468	1,38	2,95
CO2 PM CF	2,8951	0,35013	1,40	2,94

Figure 122. Work and CO2 based conformity factors for PM.

Vehicle emissions and fuel consumption results during the complete PEMS trips are summarized in both brake specific and distance specific units. Additionally, energy consumption is calculated and presented. Measurements are averaged over the tests and shown with corresponding error bar representing maximum and minimum values.

Brake specific emissions are shown in Figure 123. The gray bars illustrate the Euro 6 regulatory emissions limits for each component respectively (CO limit left out). Note the units specified within parenthesis and that the value of PM emitted is multiplied by ten. Vehicle ageing over the last year show no significant effects on the emissions. All components remain close to the same levels or within the test-to-test variations, when comparing the measurements from 2014 and 2015. Just as in previous year, large test-to-test variations and average values reaching the Euro 6 limit can be observed for PM emissions.

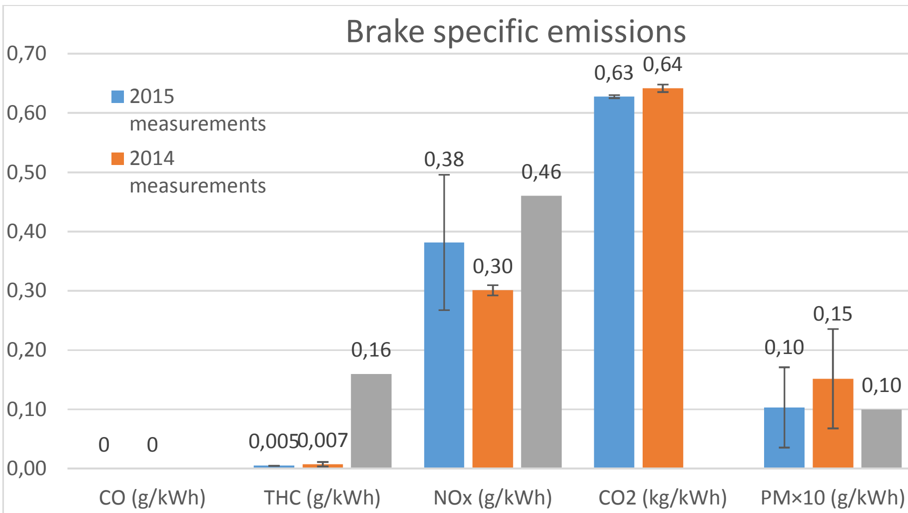


Figure 123. Avg. brake specific emissions.

Figure 119 represents the distance specific emission results.

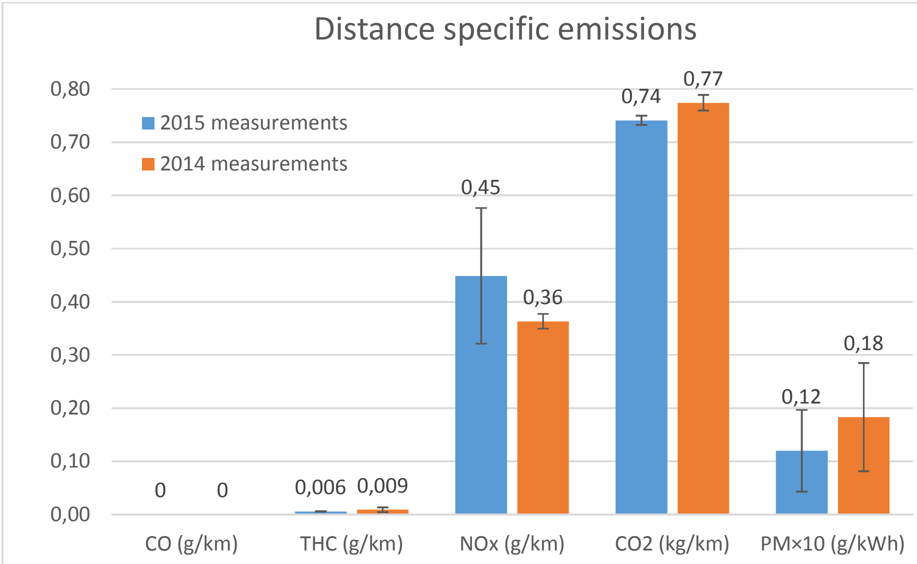


Figure 124. Avg. distance specific emissions.

Figure 125 shows the fuel consumption, specified in both brake and distance specific units, and the energy consumption. Observe that measured values of brake specific fuel consumption has been divided by ten. The results from new measurements correspond very well with tests carried out in 2014.

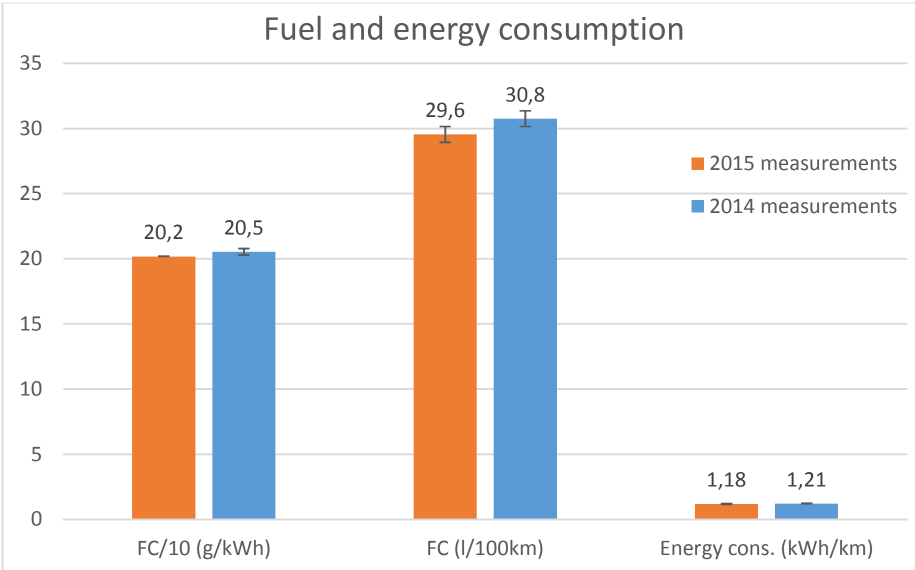


Figure 125. Avg. brake and distance specific fuel consumption and energy consumption.

Conclusions

NO_X conformity factors evaluated in 2015 pass the in service conformity criteria while having slightly lower values compared to last year's testing. PM conformity factors show large differences between tests just as in last 2014, which suggests irregular particle emissions.

Average brake specific emissions for the full PEMS trip duration correspond with test results from 2014. All regulated emissions meet the Euro VI WHTC limits. The slightly higher average NO_X in tests from 2015 may be the result of a shorter driven distance, thus cold start effects will be more substantial. Similar trends could be seen on distance specific emissions.

It can be concluded that ageing of the vehicle has no significant effect on emission performance.

No malfunction was indicated by the OBD system.

Vehicle K

A Euro VI van of vehicle category N1 has been tested for exhaust emissions and fuel consumption. A series of tests were carried out on both chassis dynamometer and on Swedish roads using a portable emissions measurement system (PEMS).

There are no emission regulations for 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.

Emissions of CO, THC, PM and PN are well below the Euro VI legislative limits for all test results. However, measured NOx indicated elevated emission levels in comparison to the WHTC Euro VI limit of 0,46 g/kWh. The ISC analysis indicate a clear pass with respect to NOx conformity factors. Ammonia slip levels were far below legislative limits.

Presentation of vehicle:

Model year:	2014
Vehicle category:	N1
Vehicle type:	Light truck
Mileage:	42 010 km
Engine:	F1C, CI
Displacement:	~3 litres
Fuel:	Diesel
Power:	~130 kW
Exhaust after treatment:	EGR, DOC, DPF and SCR
Transmission:	Manual
Gross Vehicle Mass:	3 500 kg
Mass in running order:	2 745 kg
Maximum payload:	755 kg
Emission standard:	Euro VI

Test program

On-road tests were carried out on the 21st and 22nd of October 2015. PEMS results were evaluated according to EU regulation. Tests on the chassis dynamometer were performed between the 12th and 15th of October 2015. The complete vehicle test program is presented in Table 16.

Table 16 Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	1	2745	0
WHVC	2	2	2745	0
PEMS Euro VI N1 route	1	1	-	≈250

Inertia is the inertia simulated by the chassis dynamometer. The vehicle payload is reproduced by loading the vehicle with weights during on-road tests.

The vehicle payload during the on-road tests using PEMS was around 33% of the maximum payload. The tests on the chassis dynamometer were carried out without added vehicle payload.
PM was only measured during the second PEMS trip.

Ambient conditions

Test 1 (2015-10-21):

- Trip average RH: 72 %
- Trip average ambient temperature: 12°C
- Coolant temperature at test start: 20°C

Test 2 (2015-10-22):

- Trip average RH: 75 %
- Trip average ambient temperature: 19°C
- Coolant temperature at test start: 60°C

Emission test results

When evaluating the PEMS test results, ECU data is required to calculate engine work over the trip. Some problems were encountered when attempting to record the ECU actual friction torque (%). This was resolved by setting a constant friction torque value of 12 % which is an estimated average from a similar previously tested vehicle.

The ISC evaluation results for the two PEMS tests are presented in Figure 126. NOx conformity factors are significant but the vehicle pass the ISC criteria (1,5) calculating both work- and CO2 mass based windows respectively. Calculated conformity factors for CO and THC are insignificantly small (<0,1).

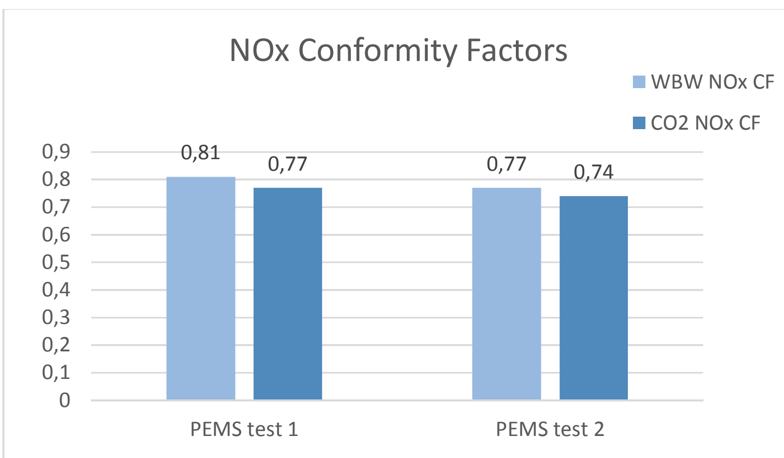


Figure 126. NOX Conformity factors for the PEMS tests using work based windows (WBW) and CO2 mass based windows, respectively.

Results presented below include PEMS tests when considering the complete route (all events) as well as the chassis dynamometer cycle tests. 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 to 14% of the average cold start test result.

CO emissions are presented in Figure 127 and Figure 128. Detected CO is far below the Euro VI limit of 4 g/kWh.

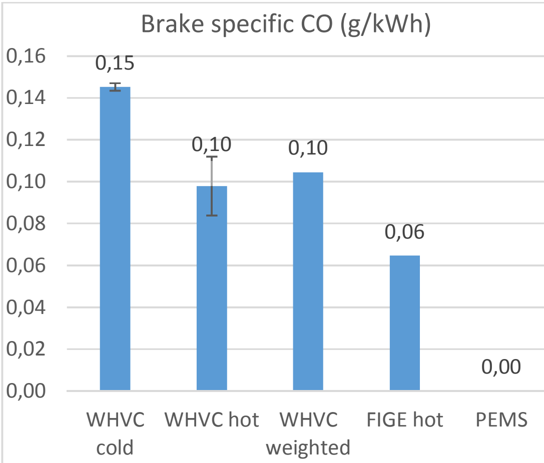


Figure 127. Avg. brake specific CO emissions (g/kWh)

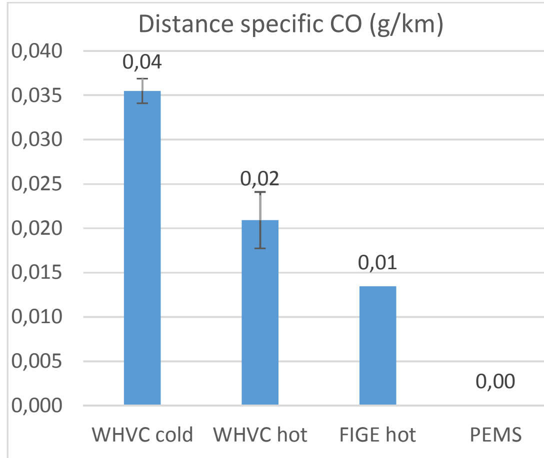


Figure 128. Avg. distance specific CO emissions (g/km)

Average THC emissions are shown in Figure 129 and Figure 130. Emitted THC levels are lower than the WHTC Euro VI limit of 0,16 g/kWh.

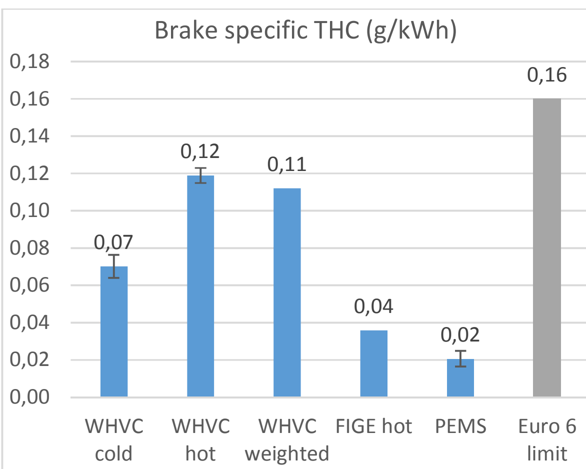


Figure 129. Avg. brake specific THC emissions (g/kWh)

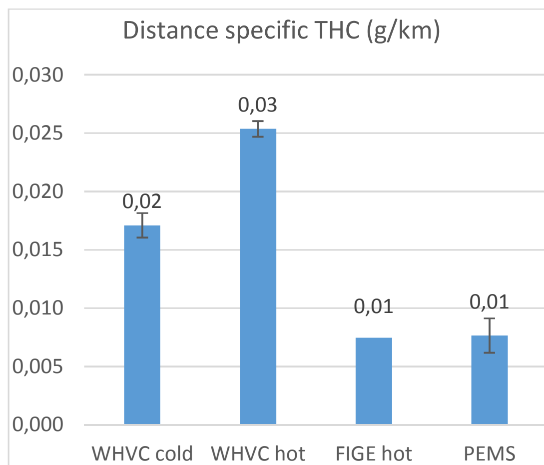


Figure 130. Avg. distance specific THC emissions (g/km)

Measured NOX emissions from the chassis dynamometer and PEMS tests are shown in Figure 131 and Figure 132. As can be seen the vehicle emission of NO_X is problematic and all average test values are high in comparison to the WHTC Euro VI limit.

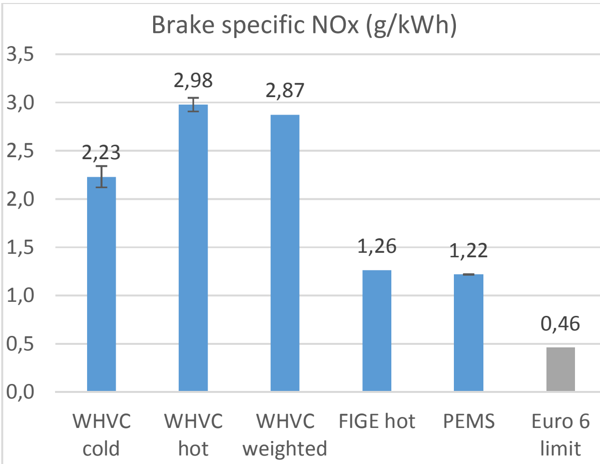


Figure 131. Avg. brake specific NOx emissions (g/kWh)

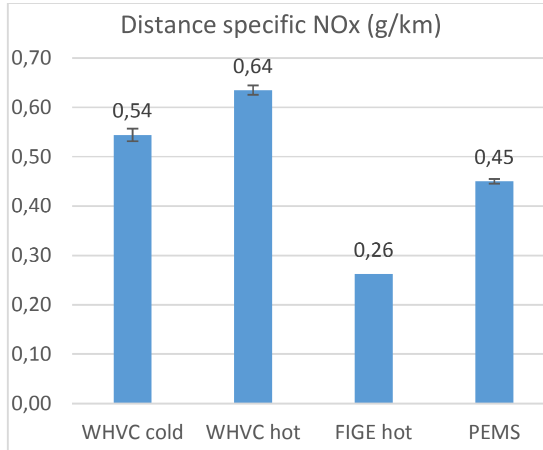


Figure 132. Avg. distance specific NOx emissions (g/km)

Gravimetrically measured PM results are presented Figure 133 in and Figure 134. PM levels are below the Euro VI limit by a good margin. The higher PM levels for the PEMS trip is most likely related to the realistic driving conditions but could also be a one-time deviation.

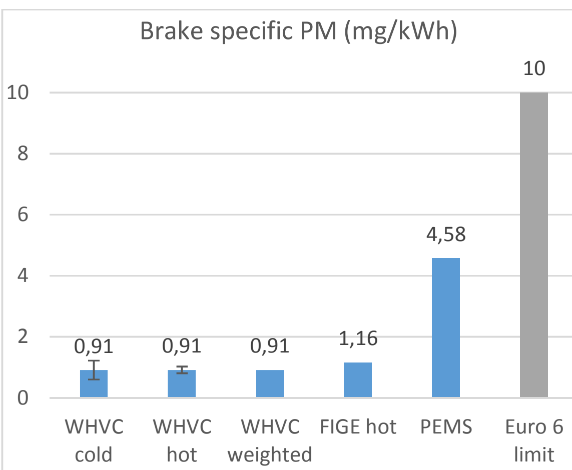


Figure 133. Avg. brake specific PM emissions (g/kWh)

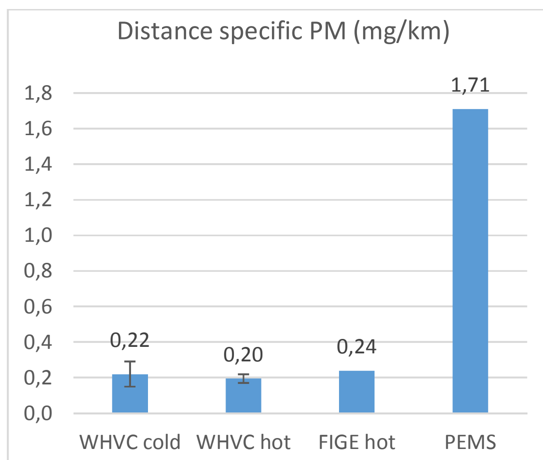


Figure 134. Avg. distance specific PM emissions (g/km)

Emitted number of particles results for the chassis dynamometer tests are presented in Figure 135 and Figure 136. All numbers measured are extremely low and far below the Euro VI 6E11 particle number limit

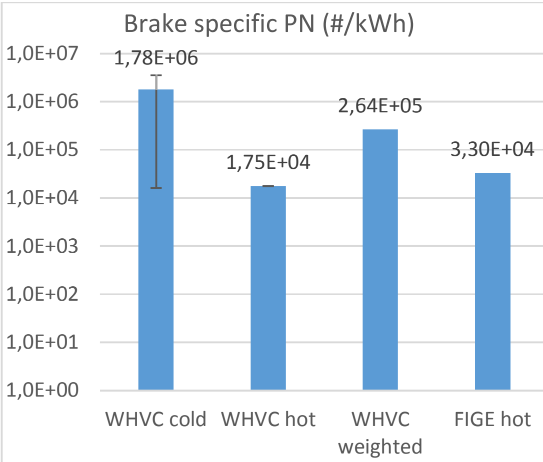


Figure 135. Avg. brake specific PN emissions (#/kWh)

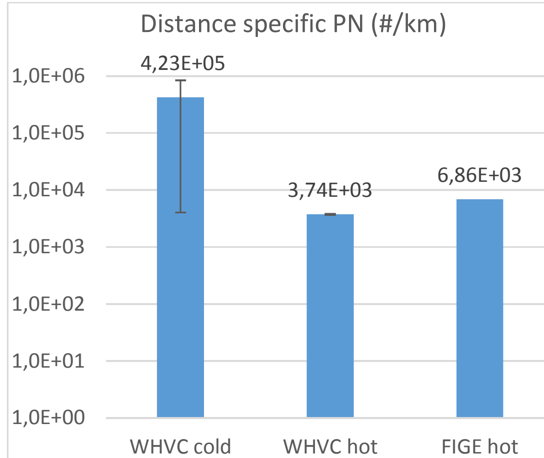


Figure 136. Avg. distance specific PN emissions (#/km)

CO_2 and fuel consumption results are shown in Figure 137 to Figure 140. It is apparent that both CO_2 emissions and FC follow a similar trend.

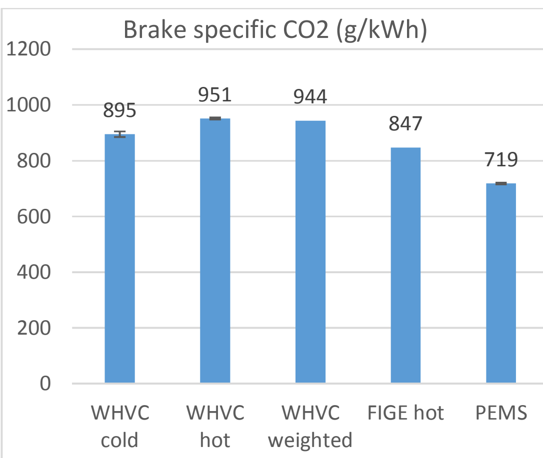


Figure 137. Avg. brake specific CO2 emissions (g/kWh)

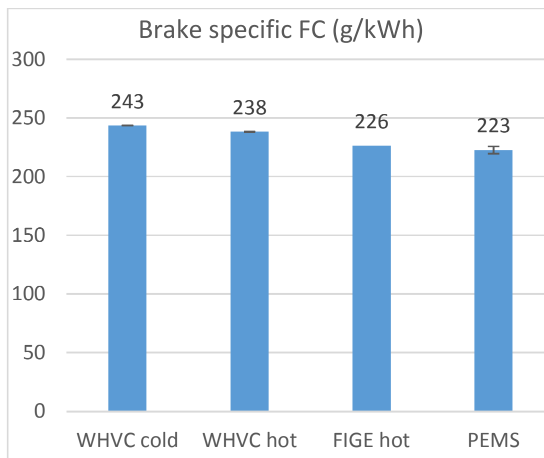


Figure 138. Avg. brake specific FC (g/kWh)

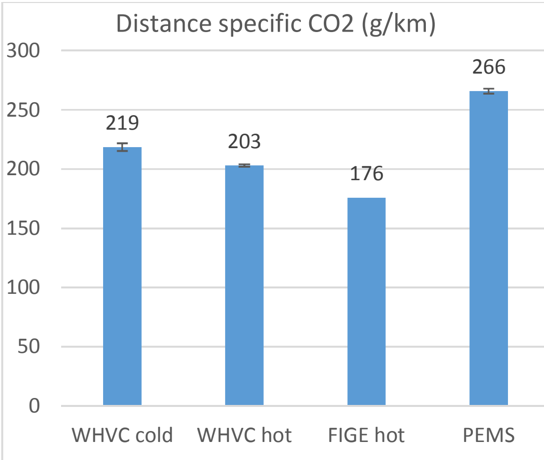


Figure 139. Avg. distance specific CO2 emissions (g/km')

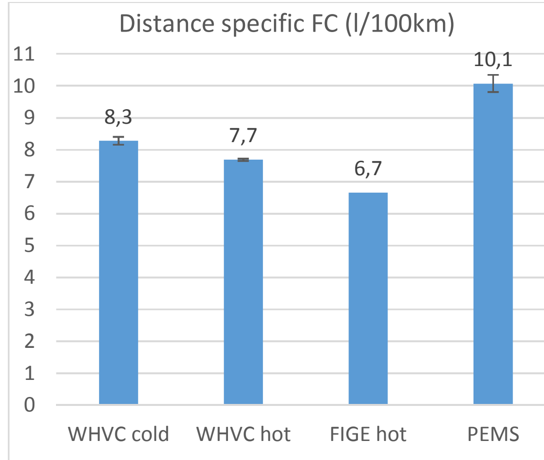


Figure 140. Avg. distance specific FC (l/100km)

Figure 141 illustrate the energy consumption stated in kWh per km. The higher average energy consumption for the PEMS tests is a result of added vehicle payload and driving conditions in real traffic. Figure 142 show the measured NH3 emissions during chassis dynamometer tests, which are far below the 10 ppm limit.

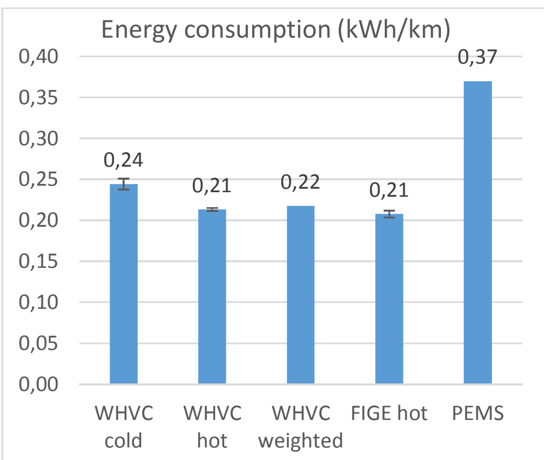


Figure 141. Avg. energy consumption (kWh/km)

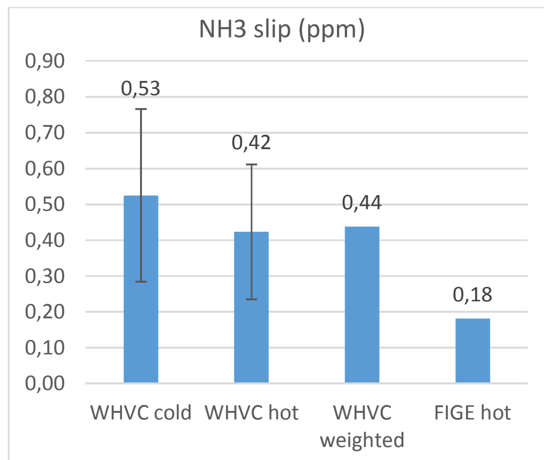


Figure 142. Avg. ammonia slip (ppm)

Conclusion

It can be concluded that the measured levels of emitted CO, THC, PM and PN are safely below the Euro VI limit requirements. However, NO_X emissions calculated from tests on chassis dynamometer and PEMS (“all events”) show indications of elevated levels and reach past the WHTC Euro VI limit of 0,46 g/kWh. Average ammonia slip levels were below the limit of 10 ppm.
ISC evaluation results indicated very small THC and CO conformity factors while NO_X conformity factors were significant but passing the criteria, for both work- and CO_2 mass based windows.

There were no malfunctions indicated from the OBD system.

Vehicle L

A CNG fuelled garbage truck of emission standard Euro VI and vehicle category N2, was tested for exhaust emissions and fuel consumption. A series of tests were carried out on both chassis dynamometer and on Swedish roads using a portable emissions measurement system (PEMS).

The ISC analysis indicate a clear pass with respect to conformity factors for gaseous emissions. The all event results for emissions of CO, THC, PM and PN are below the Euro VI legislative limits for all test results. The NOx emission results are slightly higher than the limit. Ammonia slip levels were below legislative limits during the WHVC cycle.

Presentation of vehicle:

Model year:	2015
Vehicle category:	N2
Vehicle type:	Garbage truck
Mileage:	42 152 km
Engine:	SI, stoichiometric combustion
Displacement:	~3 litres
Fuel:	CNG
Power:	~100 kW
Exhaust after treatment:	TWC
Transmission:	Manual
Gross Vehicle Mass (GVM)*:	7 000 kg
Mass in running order:	3 930 kg
Maximum payload:	3 070 kg
Emission standard:	Euro VI

Test program

On-road tests were carried out on the 26st and 27nd of November 2015. PEMS results were evaluated according to EU regulation. Tests on the chassis dynamometer were performed between the 1st and 2nd of December 2015. The complete vehicle test program is presented in Table 16.

Table 17 Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
FIGE	-	2	5664	~1730
WHVC	2	3	5664	~1730
PEMS Euro VI N1 route	2	-	-	1550

Inertia is the inertia simulated by the chassis dynamometer. The vehicle payload is reproduced by loading the vehicle with weights during on-road tests.

The vehicle payload during the on-road tests using PEMS was around 50% of the maximum payload. The simulated vehicle payload during the tests on the chassis dynamometer made 56% of the maximum payload.

Ambient conditions

Test 1 (2015-11-26):

- Trip average RH: 82 %
- Trip average ambient temperature: 5°C
- Coolant temperature at test start: 20°C

Test 2 (2015-11-27):

- Trip average RH: 75 %
- Trip average ambient temperature: 9℃
- Coolant temperature at test start: 20℃

Emission test results

Methane (CH_4) is not individually measured during the PEMS tests and has to be estimated from test data. Since methane is the main component of CNG, it should be the predominant component in the THC emissions. Papers suggest that methane constitute more than 90 % (Nylund et al. 2004) or even surpass 95 % (Lyford-Pike 2003) of THC emissions. In this report methane emissions are approximated by 97 % of THC.

The ISC evaluation results for the two PEMS tests are presented in Figure 143 to Figure 145. All calculated conformity factors pass the ISC criteria, which has a maximum limit value of 1,5 for gaseous components calculating both work- and CO_2 mass based windows respectively. Non-methane hydrocarbons (NMHC) conformity factors are very small (< 0,1).

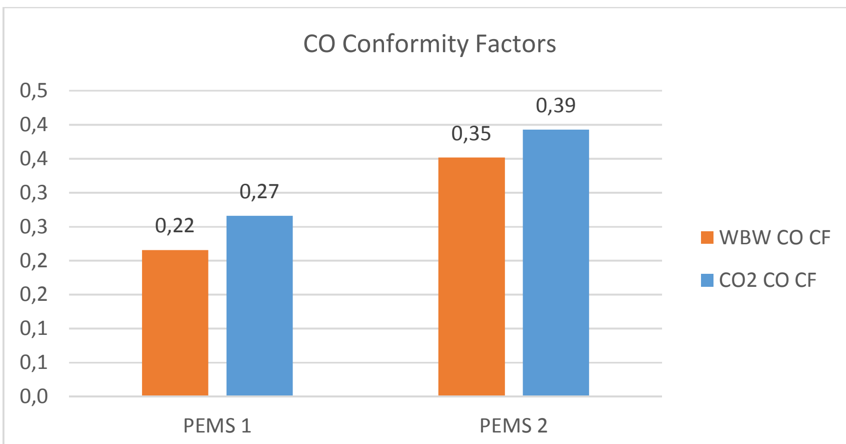


Figure 143 CO Conformity factors for the PEMS tests using work based windows (WBW) and CO2 mass based windows, respectively.

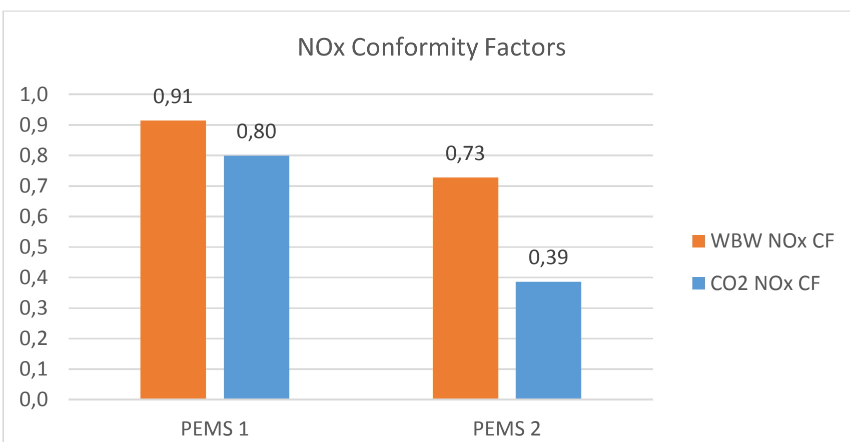


Figure 144. NOX Conformity factors for the PEMS tests using work based windows (WBW) and CO2 mass based windows, respectively.

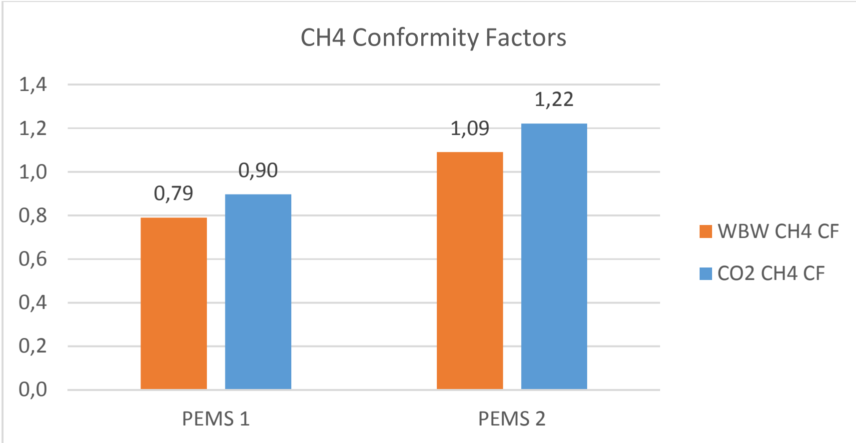


Figure 145 CH4 Conformity factors for the PEMS tests using work based windows (WBW) and CO2 mass based windows, respectively.

Results presented below include PEMS tests when considering the complete route (all events) as well as the chassis dynamometer cycle tests. 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 to 14% of the average cold start test result.
CO emissions are presented in Figure 146 and Figure 147. Detected CO is far below the Euro VI limit of 4 g/kWh.

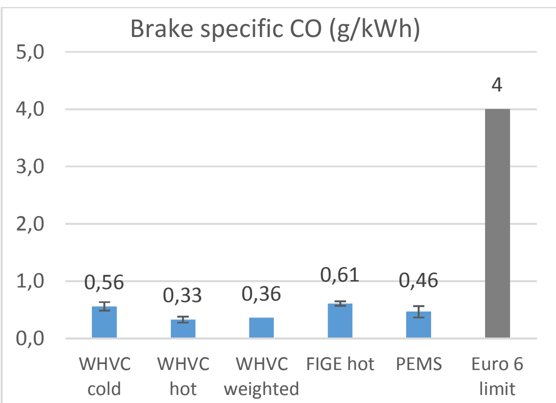


Figure 146. Avg. brake specific CO emissions (g/kWh)

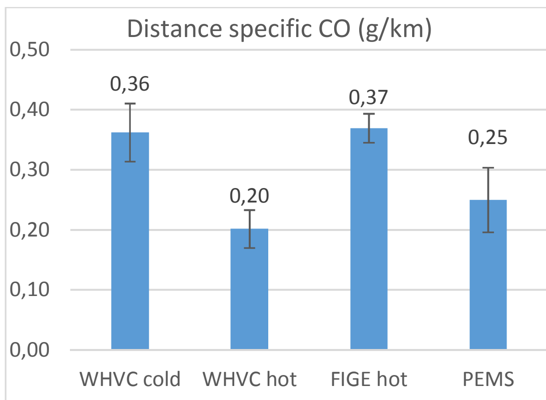


Figure 147. Avg. distance specific CO emissions (g/km)

Average THC emissions are shown in Figure 148 and Figure 149. Emitted CH_4 levels are lower than the Euro VI limit for gas engines in the WHTC (0,5 g/kWh).

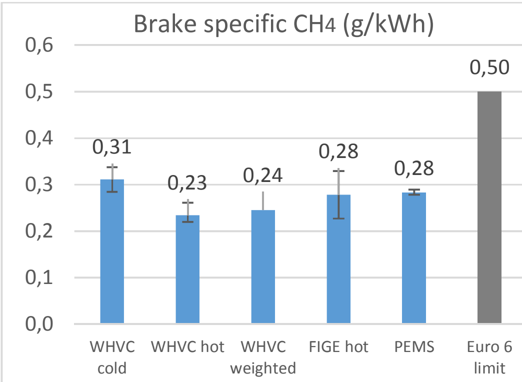


Figure 148. Avg. brake specific THC emissions (g/kWh)

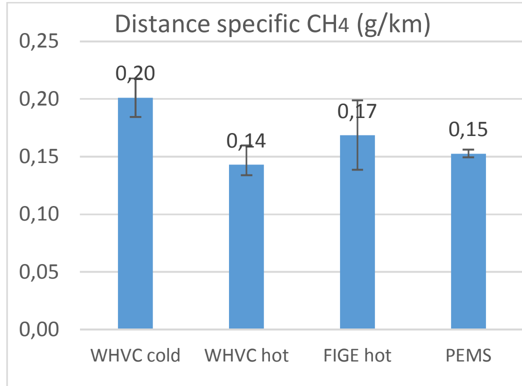


Figure 149. Avg. distance specific THC emissions (g/km)

Measured NOX emissions from the chassis dynamometer and PEMS tests are shown in Figure 150 and Figure 151. The weighted WHVC NOx result is higher than the Euro VI limit for engines in the WHTC.

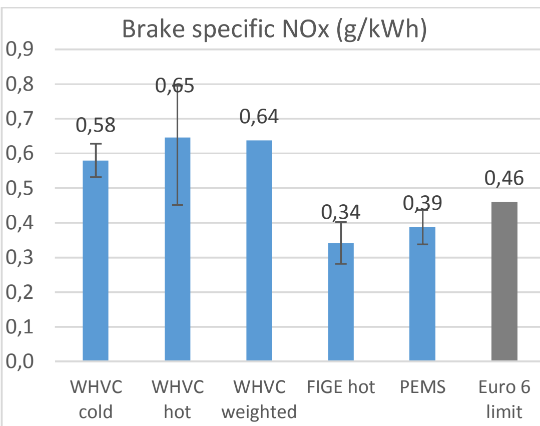


Figure 150. Avg. brake specific NOx emissions (g/kWh)

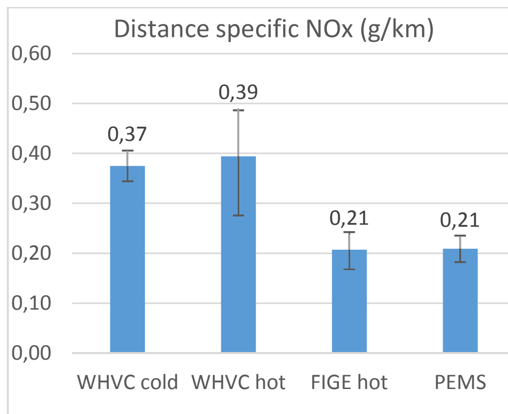


Figure 151. Avg. distance specific NOx emissions (g/km)

Gravimetrically measured PM results are presented Figure 152 in and Figure 153. PM levels are below the Euro VI limit.

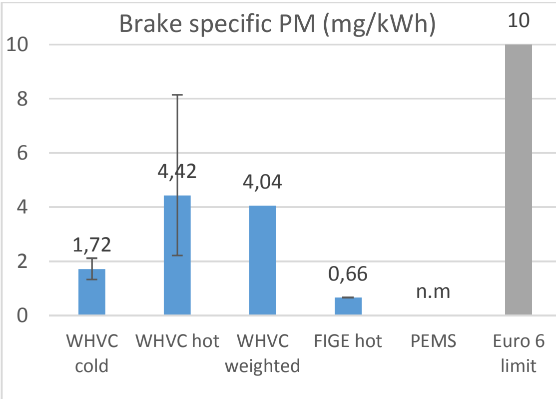


Figure 152. Avg. brake specific PM emissions (g/kWh)

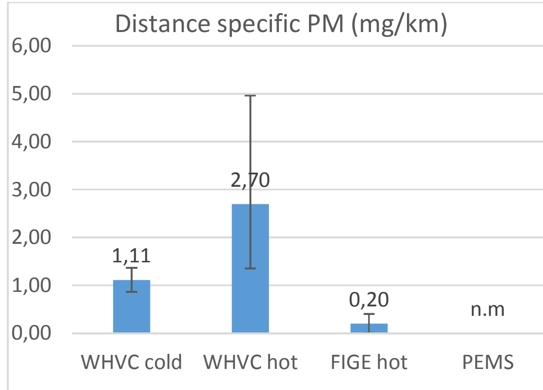


Figure 153. Avg. distance specific PM emissions (g/km)

Emitted number of particles results for the chassis dynamometer tests are presented in Figure 154 and Figure 155. The weighted WHVC PN result is lower than the Euro VI limit for engines in the WHTC ($6.0*10^{11}$)

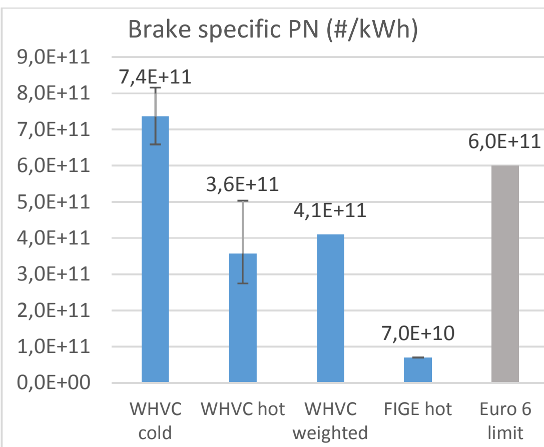


Figure 154. Avg. brake specific PN emissions (#/kWh)

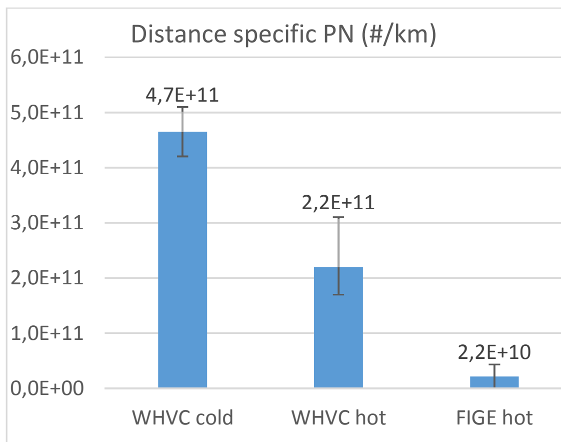


Figure 155. Avg. distance specific PN emissions (#/km)

CO_2 and fuel consumption results are shown in Figure 156 to Figure 159. It is apparent that both CO_2 emissions and FC follow a similar trend.

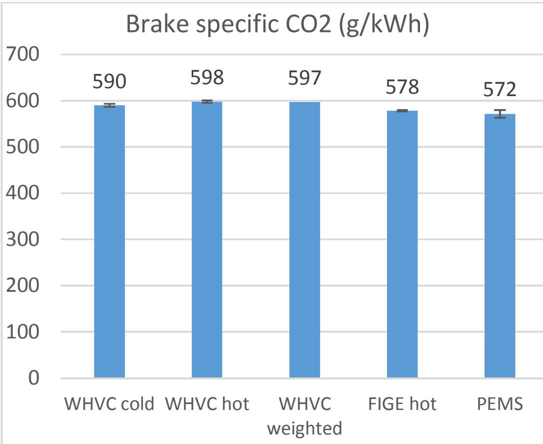


Figure 156. Avg. brake specific CO2 emissions (g/kWh)

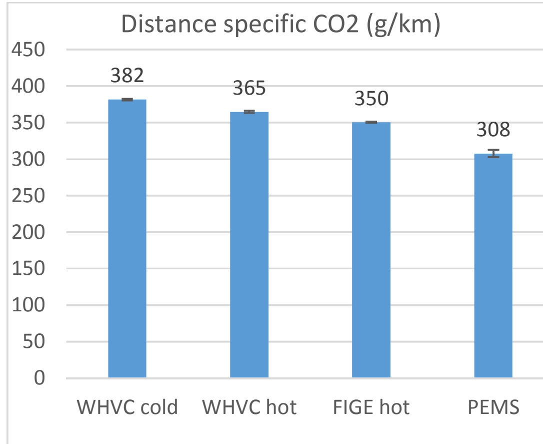


Figure 158. Avg. distance specific CO2 emissions (g/km)

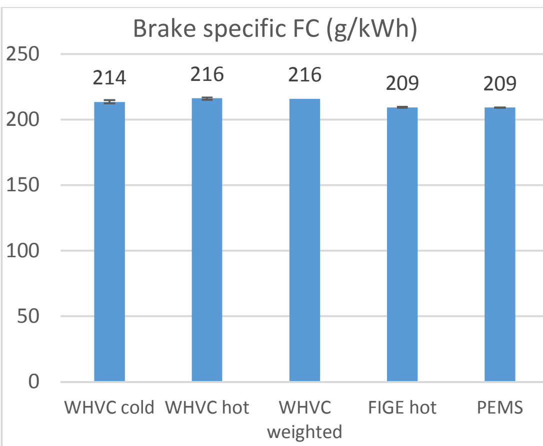


Figure 157. Avg. brake specific FC (g/kWh)

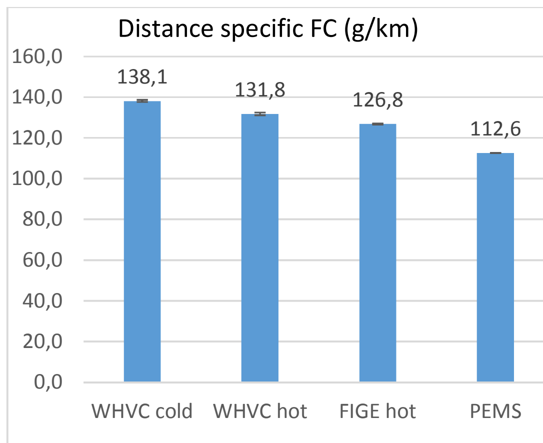


Figure 159. Avg. distance specific FC (l/100km)

Figure 160 illustrate the energy consumption stated in kWh per km. Figure 161 show the measured NH3 emissions during chassis dynamometer tests, which are below the 10 ppm limit in the WHVC cycle but the result from the FIGE cycle show that 10 ppm limit may be a problem for CNG vehicles with a three-way-catalyst.

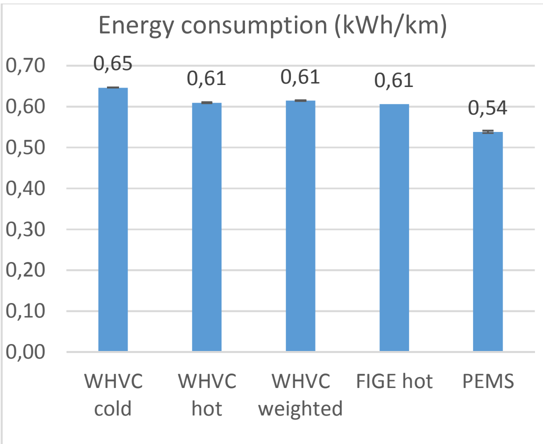


Figure 160. Avg. energy consumption (kWh/km)

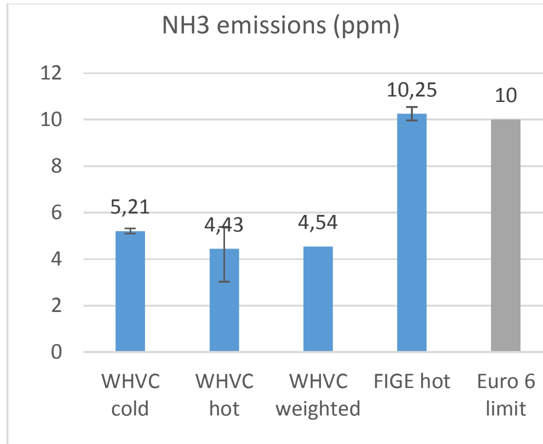


Figure 161. Avg. ammonia slip (ppm)

Conclusion

The in ISC evaluation resulted in conformity factors below the 1,5 max limit for all gaseous emissions for both work- and CO_2 mass based windows. However, NO_X emissions calculated from tests on chassis dynamometer and PEMS as “all events” show indications of elevated levels and reach past the WHTC Euro VI limit of 0,46 g/kWh. Average ammonia slip levels during the WHVC-cycle were below the limit of 10 ppm.

There were no malfunctions indicated from the OBD system.

Vehicle M

Vehicle M was a diesel fuelled Euro VI truck of category N3, which was tested for exhaust emissions and fuel consumption. Tests were carried out on Swedish roads using a portable emissions measurement system (PEMS).

The ISC analysis indicate a clear pass with respect to conformity factors for gaseous emissions. The all event results for emissions of CO, THC and NOx are below the Euro VI legislative limits.

Presentation of vehicle:

Model year:	2015
Vehicle category:	N3
Vehicle type:	Delivery truck
Mileage:	42 100 km
Engine:	CI, 6 cylinders
Displacement:	~7 litres
Fuel:	Diesel
Power:	~190 kW
Exhaust after treatment:	EGR, DOC, SCR, DPF
Transmission:	Automatic
Gross Vehicle Mass (GVM):	16 000 kg
Mass in running order:	8 250 kg
Maximum payload:	7 750 kg
Emission standard:	Euro VI

Test program

On-road tests were carried out on the 13th and 14th of January 2016. PEMS results were evaluated according to EU regulation. The complete vehicle test program is presented in Table 16.

Table 18 Test program.

Test	Cold start	Hot start	Inertia [kg]	Vehicle Payload [kg]
PEMS Euro VI N3 route	2	-	-	4000

The vehicle payload is reproduced by loading the vehicle with weights during on-road tests.
The vehicle payload during the on-road tests using PEMS was around 52% of the maximum payload.

Ambient conditions

Test 1 (2016-01-13):

- Trip average RH: 76 %
- Trip average ambient temperature: -4°C
- Coolant temperature at test start: 20°C

Test 2 (2016-01-14):

- Trip average RH: 68 %
- Trip average ambient temperature: -10°C
- Coolant temperature at test start: 20°C

The temperature during the second test was approximately -10℃ which is colder than allowed according to the legislation.

Emission test results

The ISC evaluation results for the two PEMS tests are presented in Figure 162 to Figure 163. During the first test the DPE regenerated and the test is not valid. Despite the low ambient temperature during the second test, all calculated conformity factors pass the ISC criteria, which has a maximum limit value of 1,5 for gaseous components calculating both work- and CO_2 mass based windows respectively.

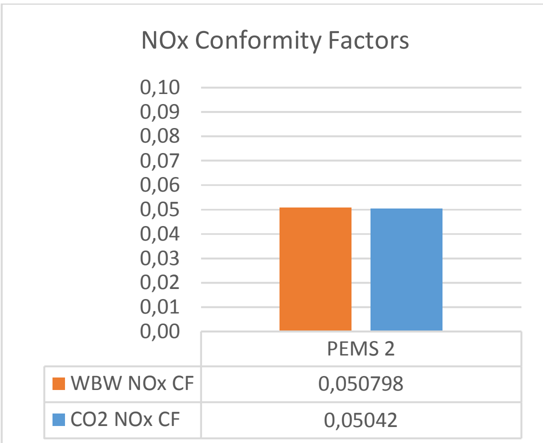


Figure 162. NOX Conformity factors for the normal PEMS test using work based windows (WBW) and CO2 mass based windows, respectively.

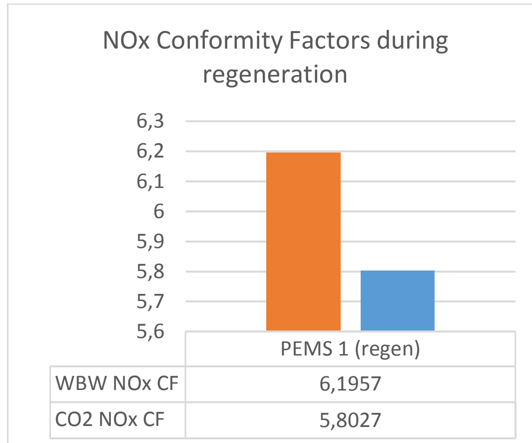


Figure 163 NOx Conformity factors for the PEMS test when DPF regeneration occurred, using work based windows (WBW) and CO2 mass based windows, respectively.

Results presented below (Figure 164 to Figure 170) are PEMS tests when considering the complete route (all events).

No emissions of CO were detected and very low emissions of THC. Clearly more emissions of CO and NOx can be seen in the test where the DPF regenerated, but during the normal test were all emissions very low.

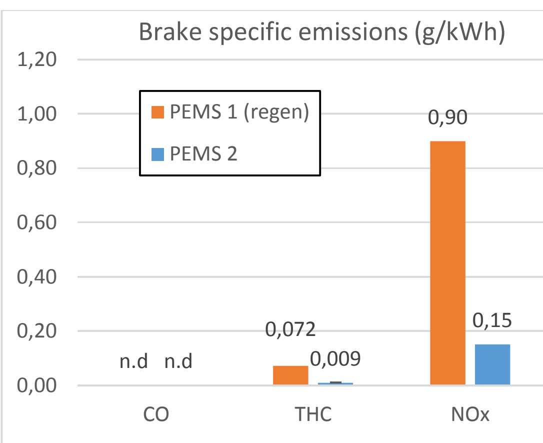


Figure 164. Brake specific emissions (g/kWh)

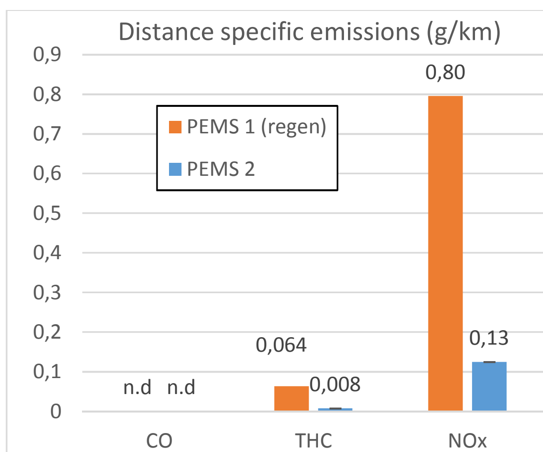


Figure 165. Distance specific emissions (g/km

CO_2 and fuel consumption results are shown in Figure 166 to Figure 169. It is apparent that both CO_2 emissions and FC follow a similar trend.

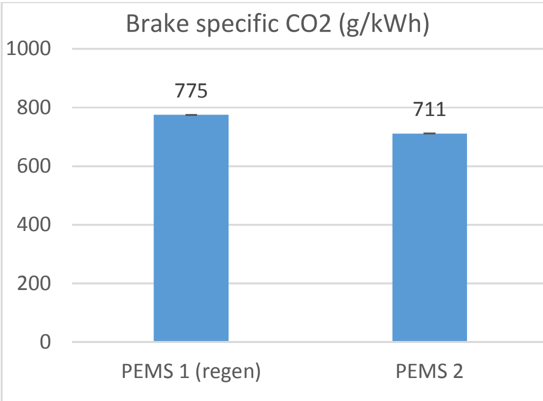


Figure 166. Avg. brake specific CO2 emissions (g/kWh)

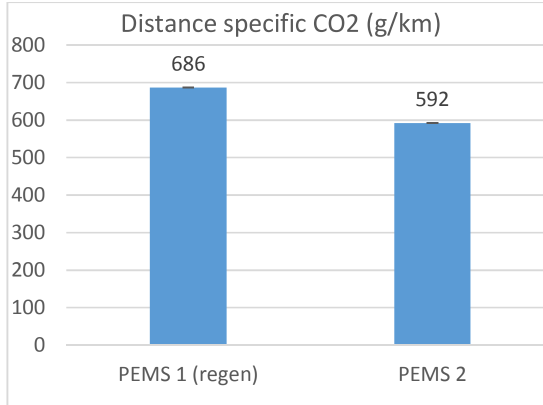


Figure 168. Avg. distance specific CO2 emissions (g/km)

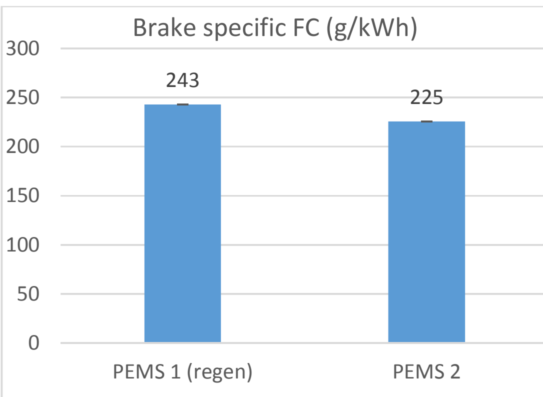


Figure 167. Avg. brake specific FC (g/kWh)

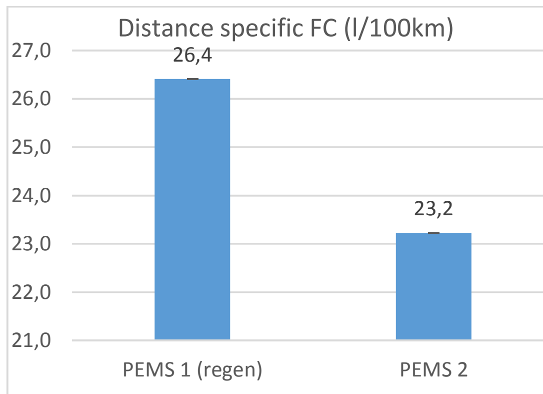


Figure 169. Avg. distance specific FC (l/100km)

Figure 170 illustrate the energy consumption stated in kWh per km.

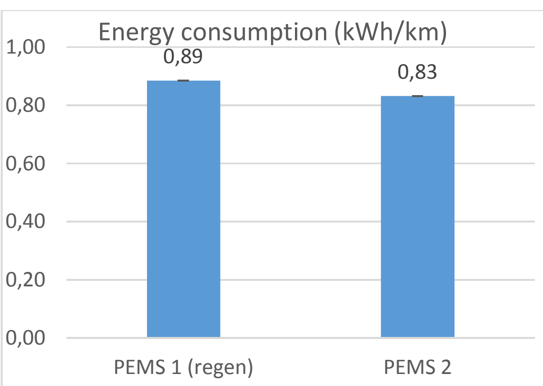


Figure 170. Avg. energy consumption (kWh/km)

Conclusion

The ISC evaluation resulted in conformity factors below the 1,5 max limit for all gaseous emissions for both work- and CO_2 mass based windows.

Summary of NOx and PM results on road

The overall impression from the eleven tested vehicles is that the exhaust after treatment devices are working adequate in order to meet the Euro VI standards. However, as can be seen from Figure 172, results from smaller vehicles, class N2, indicates some difficulties to reach the limit values. As a comparison data from 2014 testing are presented in Figure 173.

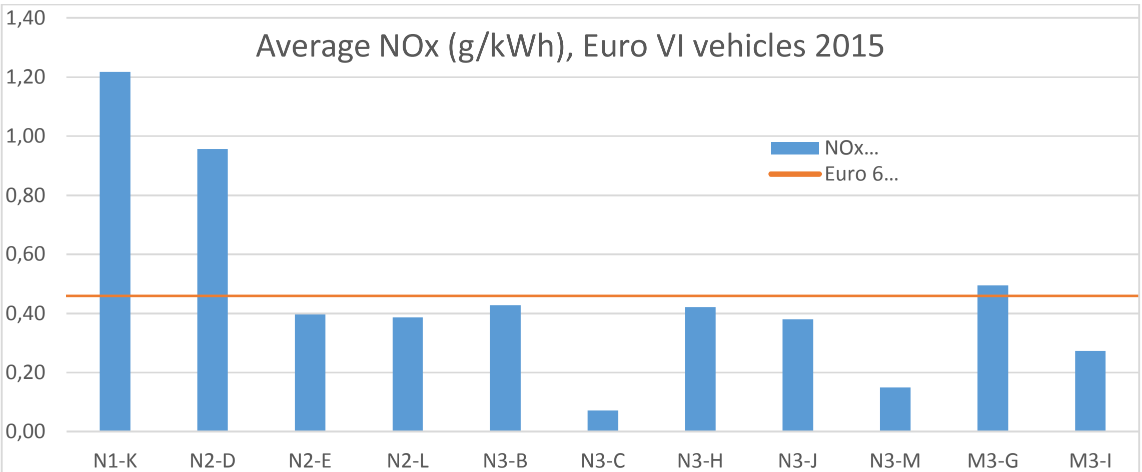


Figure 172. Average NOx emission and Euro VI limit, 2015 data.

Vehicle K was a small Euro VI van of vehicle category N1 and model year 2014. Emissions of CO, THC, PM and PN were below the Euro VI legislative limits. Measured NOx indicated elevated emission levels in comparison to the Euro VI limit of 0,46 g/kWh.
Vehicle D was a N2 vehicle of model year 2014 and emission standard Euro VI. All tests resulted in emissions of CO, and PM where well below the Euro VI emission limit. No emissions of THC were detected in any test. The NOx emissions measured during the tests were rather high and the vehicle did not pass the Euro VI emission limit. Vehicle G was a small bus of category M3 and model year 2014. The vehicle was of euro standard VI, equipped with an EGR, DOC, DPF and SCR.

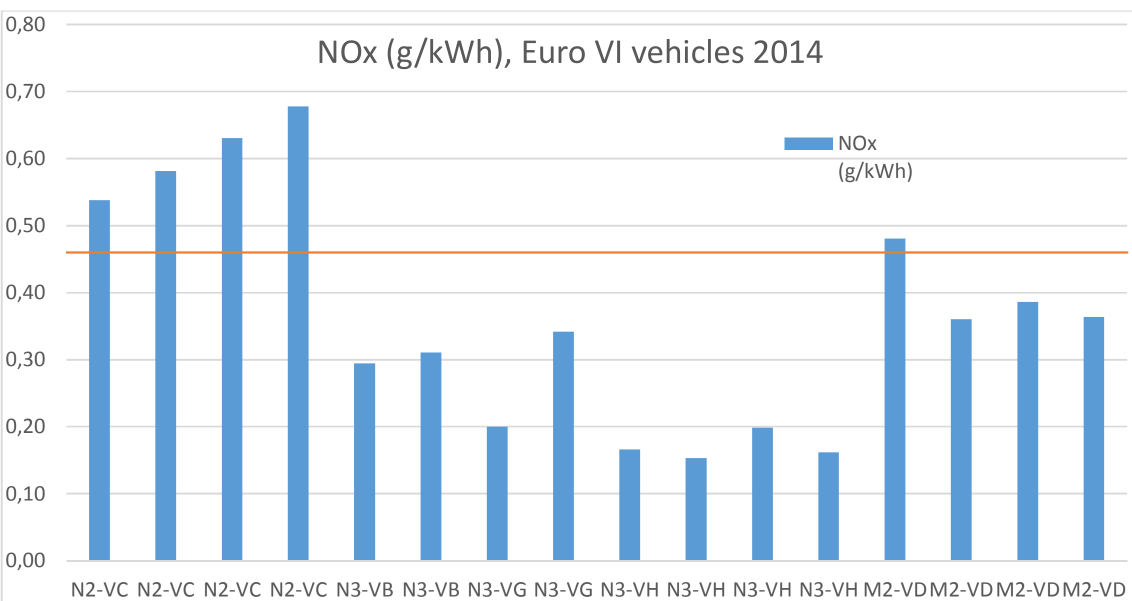


Figure173. Average NOx emissions and Euro VI limit, 2014 data.

Vehicle C in the 2014 study was a small distribution truck. The vehicle was of euro standard VI equipped with EGR, DOC, SCR and DPF. Emissions of THC, CO and PM were below the EU VI emission limits

Vehicle D in the 2014 study was a small bus which was tested on road as well as on chassis dynamometer. The vehicle was of euro standard VI, equipped with a SCR system and a DPF. Emissions of THC, CO and PM were below the EUVI emission limits The "all events" results from the PEMS testing showed lower NOx emissions, passing the applicable Euro VI emission limit. In one road test the vehicle failed the EUVI ISC conformity factor limits for NOx emissions.

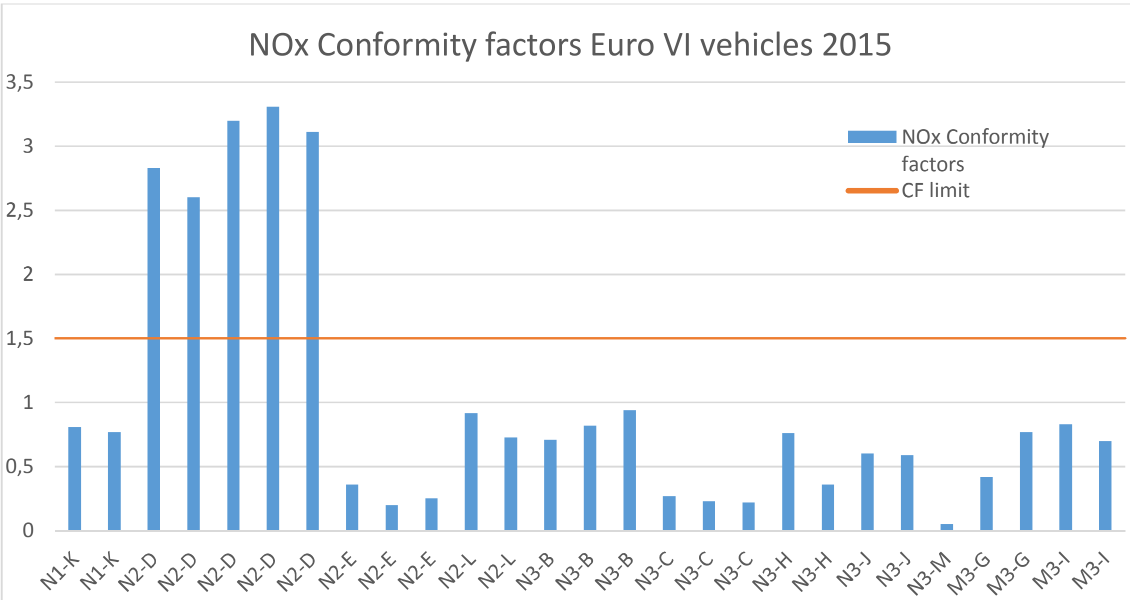


Figure 171

PM results from both 2015 as well as 2014 testing are presented in Figure 174 and 175 respectively. High emissions of particulate matter was measured from two vehicles.

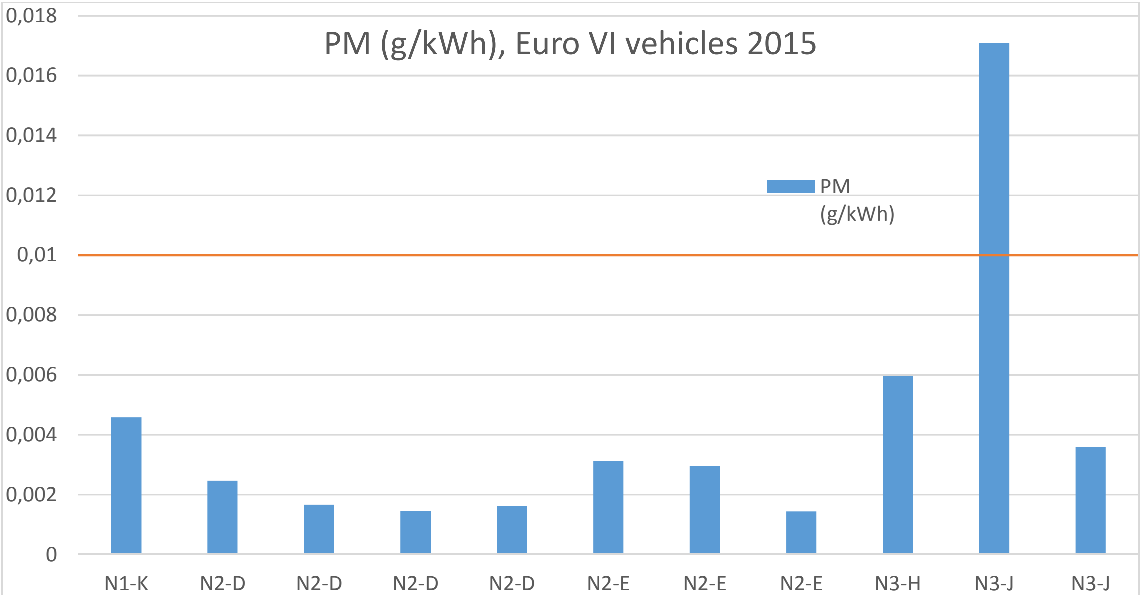


Figure 1724. PM emissions from 2015 testing

Vehicle J (denoted VB in the 2014 report) was a N3 diesel crane vehicle of model year 2014 and emission standard Euro VI equipped with a SCRT® filter. The same vehicle went through emission tests in 2014, both on chassis dynamometer and using PEMS. (Δ mileage ~ 11 400 km). During 2014 testing emissions of CO were below the EUVI emission limit on both chassis dynamometer and on the road. Emissions of NOx measured on chassis dynamometer exceeded the WHTC engine test emission limit. The results from the PEMS testing and the FIGE test cycle showed more moderate NOx emissions passing the applicable Euro VI emission limit. The vehicle passed the EUVI ISC conformity factor limits for all gaseous emissions. PM emissions were high and the WHTC engine test limit was exceeded in all CD tests. No PEMS IUC conformity factor limit for PM was established but the PM level could be considered high also in the road tests.

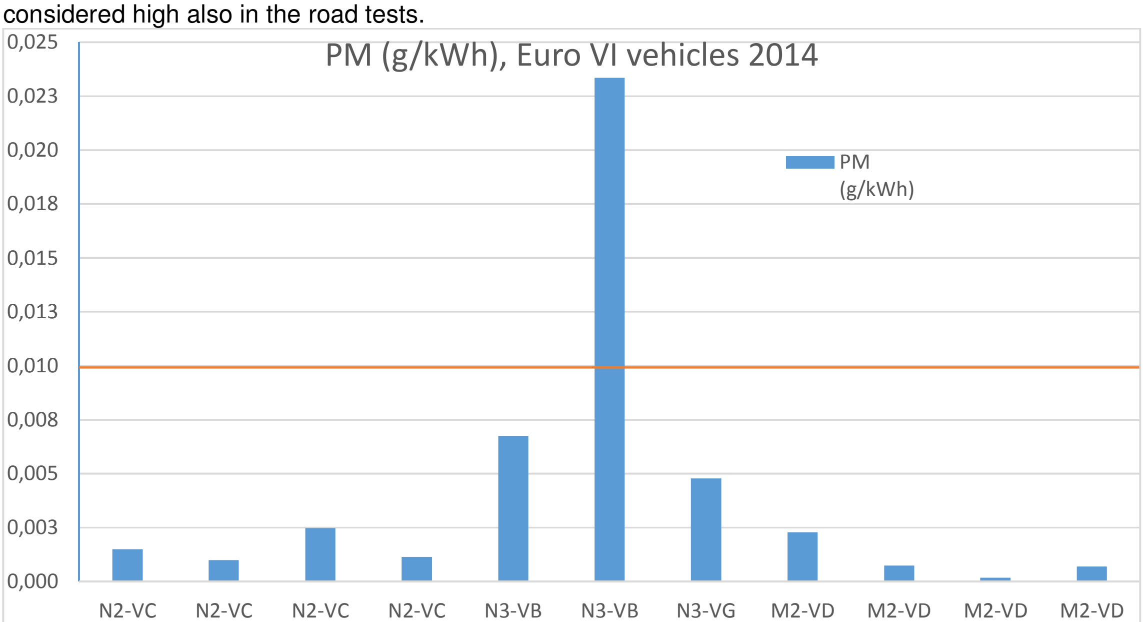


Figure 175. M emissions from 2015 testing

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

Ottmar Degrell

Director Ottmar Degrell

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

TÜV HESSEN - QUALITY

AUTOMOTIVE

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, 29th, 2013 and references the release of the software, and the results of the tests performed .

Certificate No.:	2013-06-03-AM-Z.02
Annexes:	Annex 1 – PEMS Software
Issued:	June, 3rd 2013
Valid until:	June, 3rd 2015

TÜV Technische Überwachung Hessen GmbH · 57000 · Automotive

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Appendix 2, HVO fuel specifications

SweaX HVO 100 Bio

April 2013

SweaX HVO 100 Bio uppfyller minst Klass A i den tekniska specifikationen CEN/TS 15940:2012 och Drivmedelslag (2011:319) Syntetiska dieselbräns-len i miljöklass 1. SweaX HVO 100 Bio är till 100% förnybar och baserad antingen på slaktavfall eller på raps/rybs.

Produkten uppfyller minst kraven för hållbarhet som definierade i lag (2010:598) om hållbarhetskriterier för biodrivmedel och flytande biobränslen samt EUROPAPARLAMENTETS OCH RÅDETS DIREKTIV 2009/28/EG av den 23 april 2009 om främjande av användningen av energi från förnybara energikällor och om ändring och ett senare upphävande av direktiven 2001/77/EG och 2003/30/EG.

Swea Energi har från energimyndigheten erhållit ett så kallat hållbarhetsbesked. Detta innebär att den av

Swea Energi hanterade volymen SweaX HVO 100 Bio är garanterat hållbara enligt lagen om hållbarhetskriterier för biodrivmedel. Kraven innebär t.ex. spårbarhet i leverantörskedjan och en garanterad minsta växthusgasminskning.

Genomsnittlig växthusgasminskning jämfört med om fossil diesel hade använts är för 2012 91%, fram till och med 2012-12-10. Växthusgasminskningen kan komma att variera över tid beroende på ingående råvara. Användande av slaktavfall ger den högsta växthusgasminskningen och raps/rybs en något lägre.

Produkten är klassificerad som H304 "Kan vara dödligt vid förtäring om det kommer ner i luft-vägarna" enligt CLP-förordningen (EU-förordning 1272/2008). Dvs. produkten är mindre farlig än den produkt som den ersätter, diesel.

TYPDATA	CEN/TS 15940:2012 – Class A	Swea Energi SweaX HVO 100 Bio
Tändvillighet, cetanindex	>70	76
Densitet, 15°C, kg/m^3	>765	780
Flampunkt, °C	>55	>65
Viskositet, 40°C, cSt	2<x<4,5	2,9
Destillation,		
Begynnelsekokpunkt vid °C	>180	>180
95% destillerat vid °C	<360	<330
Smörjförmåga, µm/60°C	<460	<400
FAME halt, % (V/V)	<7	0
Aromathalt, % (m/m)	<1	0,1
Svavelhalt, mg/kg	<5	<1
Kokstal, mikrometoden, % (m/m)	<0,3	<0,01
Askhalt, vikt %	<0,01	<0,001
Vattenhalt, mg/kg	<200	<100
Totalhalt föroreningar, mg/kg	<24	<15
Korrosiv inverkan på koppar, 3h vid 50°C	1b	1a
Oxidationsstabilitet, g/m^3	<25	12
Grumlingstemperatur, °C		<-15
Filtrerbarhet i kyla, °C		<-15
Total förnybar andel		100