TEST REPORT

Swedish In-Service Testing Programme 2010
on Emissions From Heavy-Duty Vehicles

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Content

Summary

AVL MTC AB has on the commission of The Swedish Transport Agency carried out The Swedish In-Service Testing Programme on Emissions from Heavy-Duty Vehicles. Seven vehicles have been tested on road in accordance with the PEMS protocol which include urban, suburban, and highway driving. In addition two of these vehicles have also been tested on chassis dynamometer according to the ESC (European Stationary Cycle) and the Fige (chassis dynamometer version of ETC – European Transient Cycle). Two of the vehicles have been tested twice, one during both summer and winter conditions and one after service of the exhaust gas recirculation (EGR) system. The selection of the vehicles was based on Euro IV and V standard.

The scope of the investigation was, beside in use compliance, to generate emission factors from commercial vehicles during a normal working day and representative driving. In addition aspects of retrofit system, alternative fuels, driving pattern and loads were taken into consideration.

The vehicles are denoted A – G in this report.

The vehicle A study was designed to compare emission levels from a Euro IV truck driven both on diesel as well as fatty acid methyl ester (FAME). The truck was tested during summer and winter conditions. It was found that the emission of nitrogen oxides (NOx) increased when using FAME compared to diesel.

Vehicle B was a dual fuel, i.e. compressed natural gas (CNG) and diesel, converted garbage truck. The truck was tested both in dual fuel mode as well as diesel mode. The vehicle was certified according to Euro V standard in diesel mode. It was found that the emissions of hydrocarbons increased more than 4000 times in dual fuel mode compared to diesel mode.

Vehicle C was a distribution truck and the vehicle was tested both on chassis dynamometer and on road. Due to high emission levels of NOx the vehicle was retested after service of the EGR system. The measure on the EGR system reduced the NOx emission by a factor of two.

Vehicle D was a Euro IV environmentally enhanced vehicle (EEV) bus driven on CNG. Low emission and fuel consumption were measured.

Vehicle E was a Euro V EEV bus driven on ethanol. The vehicle was tested both on chassis dynamometer and on road. Relatively low emissions of all regulated components were detected.

Vehicle F was a Euro V bus driven on Diesel. The vehicle was used as a reference to vehicle D and E.

Vehicle G was a long distance Euro V truck driven on di methyl ether (DME). High emissions of carbon monoxide and oxides of nitrogen were measured during urban driving conditions.

Introduction

Sweden has been considered as for runner related to emission legislations and emission testing especially for light duty vehicles among European countries. The first emission legislation, the ECE R15, was introduced in 1971. However, decision makers did not feel comfortable with the European emission legislation and therefore Sweden introduced US federal requirements in 1975. Later, when Sweden became member of the European Union, the European regulation laid down as directive 70/220/EEC with later amendments was introduced. Together with the requirements at type approval for LDV´s, Sweden introduced Conformity of Production (COP) and In-use compliance testing (IUC) at a very early stage. In-use compliance testing of light duty vehicles in normal operation and owned by private persons has been carried out by AVL MTC/MTC for more than 20 years. During the years more than 900 passenger cars and light duty trucks have been subjected to in-use compliance testing.

The development of emission requirements for diesel fuelled engines to be used in heavy-duty vehicles has not been as progressive as the ones for LDV´s. Emission requirements for type approval were introduced in Sweden by directive 88/77/EEC, but the regulation is only dealing with the engine itself and not the vehicle. Therefore, IUC testing has been a difficult task.

Historically, the responsible party for administration and implementation of emission requirements in Sweden has been the Swedish Environmental Protection Agency (SEPA) but gradually the responsibility has been transferred to the Swedish Road Administration (SRA). Since 2009 The Swedish Transport Agency (STA) has the full responsibility for emissions from the transportation sector.

The emission laboratory operated by AVL MTC comprises several test cells with various capabilities and performance. One test cell is dedicated to test heavy duty vehicles on a chassis dynamometer, several other test cells are dedicated to test diesel engines to be used in heavy duty vehicles. In-use compliance testing of heavy duty engines/vehicles started as a research and development program in year 2000. The first phase of the program tried to establish correlation between vehicle testing and engine testing under stationary test conditions later also a significant number of tests was carried out under transient conditions. Later, correlation between chassis dynamometer tests and real life on-board measurement was investigated. Since year 2000 approximately 100 heavy duty engines/vehicles have been tested, and several hundreds of tests have been carried out. The results have been published in cases of public financing of projects. Based on experiences gained from testing, the focus for IUC tests of heavy duty vehicles has gradually shifted towards on-board measurement. However, testing of heavy duty vehicles by the use of a chassis dynamometer is still open as an alternative.

The Swedish Transport Agency has commissioned AVL MTC by a long term contract from year 2009 to perform in-service testing on heavy-duty vehicles operating on Swedish roads. This type of testing has for a long time been performed on light duty vehicles, not only in Sweden but also for example in Germany, the Netherlands and

Great Britain. The intention is to include heavy duty vehicles in this procedure from Euro VI.

The manufacturer has a responsibility that the type approved engine/vehicle does not exceed the emission limits stated in the type approval during a specified period of time or driving distance.

Since the type approval for heavy duty vehicles is related to the engine, and based on tests performed in engine test bench, it is not uncomplicated to verify emission performance for vehicles in use. Earlier studies have included dismounting the engine from the vehicle, but since the engines and associated exhaust emission control systems get more and more complicated and more electronic controlled devices are used, this is an unreasonable procedure – not at least from cost and time perspectives. The development of in-use testing for heavy duty vehicles have therefore been towards methods that are more practically accomplished.

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 year 2006 where manufacturer of engines/vehicles, manufacturer of instrument, approval authorities and technical services was invited to participate. The activity is called EU-PEMS project (Portable Emission Measurement System). Several meetings have been organized by JRC and interested parties have been invited to share experiences. A common way to calculate and present results from measurement have been introduced by JRC and a standardized test protocol has been established, the PEMS-protocol.

Sweden, represented by STA, is strongly promoting the activities of JRC and the EU-PEMS project. In 2006, STA initiated a national project based on the EU-PEMS project including on-road measurement of heavy duty vehicles in normal operation, as well as comparative testing on chassis dynamometer. The result from national activities carried out 2010 is presented in this report.

Test program

Seven vehicles have been tested on road by a portable exhaust measurement system. In addition, two of these vehicles have also been tested on chassis dynamometer. The aim of the study was not to pinpoint specific manufacturer thus, the vehicles in this report will be denoted A – G.

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.

Measuring methods – gaseous emissions

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 steady state tests, the raw exhaust gases are sampled for further gaseous analysis before the dilution in the tunnel occurs. 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 directive 2005/55/EEC and also the U.S. Federal Register in terms of sampling probes and heated lines etc.

Table 1: *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)
Fuel consumption (FC)	Carbon balance of HC, CO and CO_2

Measuring methods – particle emissions

The particulate emissions were measured gravimetrically by the use of glass fibre filters. The diluted exhausts were sampled on the filters according to standard procedures. Two filters were used, mounted in series.

1 ESC (European Stationary Cycle)
2 Fige (chassis dynamometer version of ETC – European Transient Cycle)

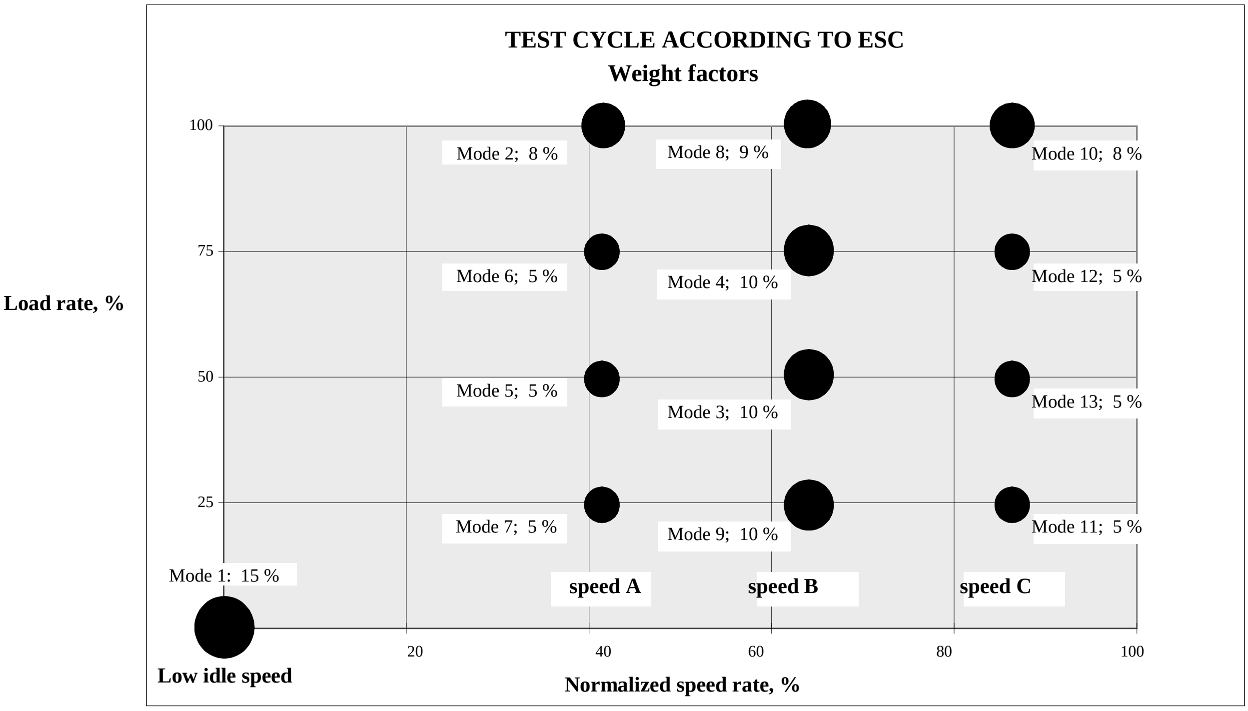

Figure 1: The ESC steady state test cycle.

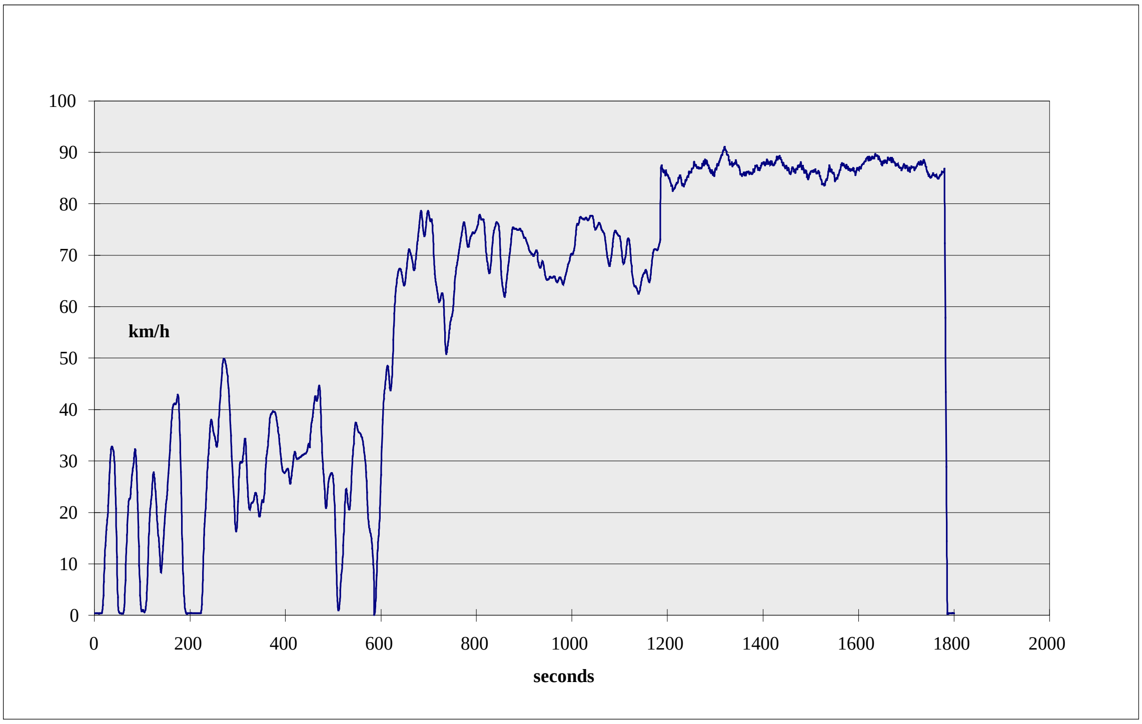

***Figure 2**: The Fige test cycle – chassis dynamometer version of the ETC cycle.*
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On-road measurement

The Semtech-DS is developed by Sensors for testing all classes of light as well as heavy duty vehicles under real-world operating conditions. The instrument is an on-board emissions analyzer and enables tailpipe emissions to be measured and recorded simultaneously while the vehicle is in operation.

The following measurement subsystems are included in the Semtech-DS 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.

The instrument is operated in combination with an electronic vehicle exhaust flow meter, Semtech E_xFM. The Semtech-DS 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. A 4” flow meter was used, which is suitable for the engine size of the tested vehicles. In addition to the Semtech instrument an AVL 483 Micro Soot Sensor was used to measure the soot emissions. The AVL 483 Micro Soot Sensor works on a photoacoustic principle (PASS) and the cell design chosen (called the "resonant measuring cell") allows a detection limit of ≤10 μg/m³, (typically ~ 5 μg/m³).

The instrument is operated in combination with an electronic vehicle exhaust flow meter, Semtech E_xFM. The Semtech-DS 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. A 4" flow meter was used, which is suitable for the engine size of the tested vehicles. The program for emission calculation was supplied by JRC.

Selection of test vehicles

The selection of the vehicle type for testing was based on Euro IV or V technology. The selection was done in cooperation with The Swedish Transport Agency. 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.

Vehicle A

The vehicle type chosen was a distribution truck equipped with a SCR system.

The vehicle was tested on roads during driving conditions and loads representing a normal working day with a cargo load of 2450 kg.

The first three tests were carried out with commercially available Environmental class 1 diesel (Mk1) and the following three tests with a FAME fuel from recycled cooking oil. The vehicle was served in accordance to the manufacturer specification. The vehicle was tested at an average ambient temperature of 20 ^{o}C.

Test route description:
Start at Armaturvägen in Jordbro, Haninge (AVL MTC) – through Handens centrum – Årsta Havsbad – Ösmo – Armaturvägen (end).

Table 2. Total test route data, PEMS test route.

Trip duration (s)	4493 - 4644
Trip distance (km)	75.5 – 75,7
Average speed (km/h)	59 – 61
Average altitude (m)	30,5

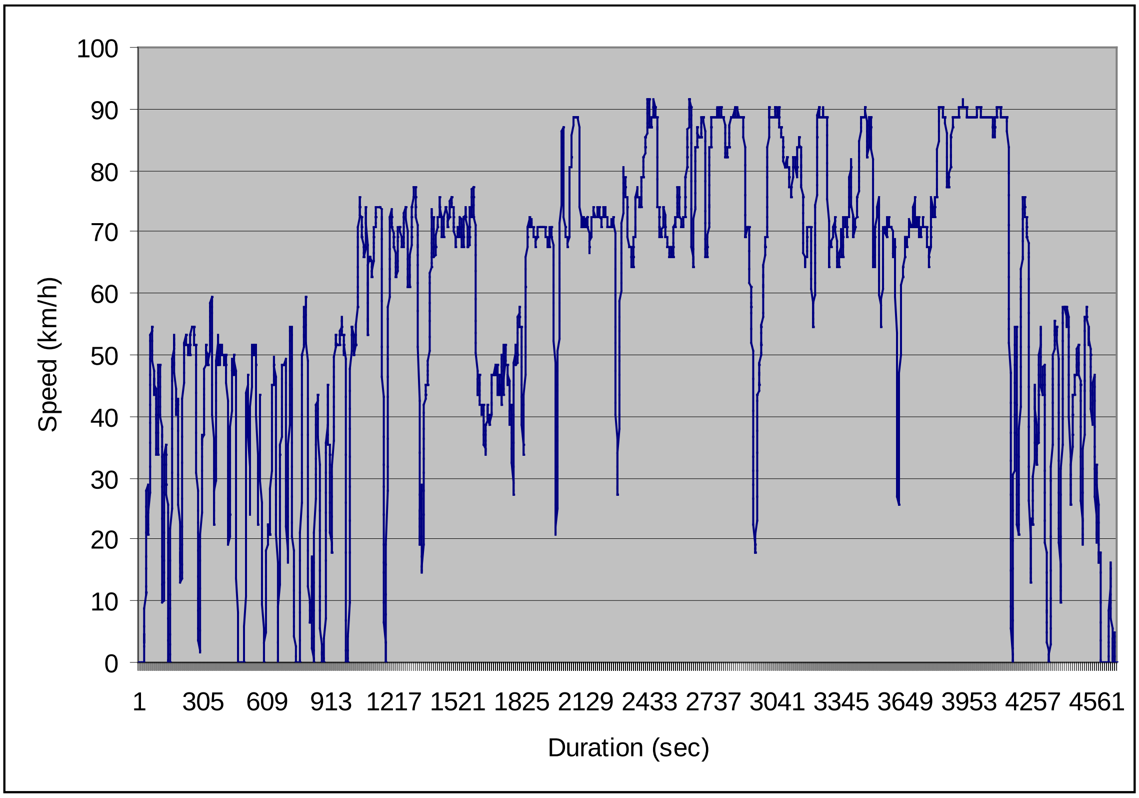


Figure 3: *The PEMS test route*

Presentation of vehicle:
Table 3. Vehicle data.

Year model	2008
Mileage, km	26 900
Date of registration	May 2008
Approximately power, kW	100
Test weight, kg	8 200
Emission standard	Euro IV

Test results

From Figure 4 – 5 some general conclusions can be made. The CO emissions increases with the FAME fuel with in average, 30 % during the total trip. The emissions of NOx are increasing with, in average, 12 % when using the FAME fuel. Emissions of HC and soot seem to be low from the FAME fuelled vehicle. However, this is due to the portable emission measurement system. Heated sampling line and detectors are developed for diesel and gasoline fuelled vehicles where the stated temperature is set to 190 ^{o}C. The higher boiling point of HC originating from FAME, requires system temperatures of 250 °C. Thus, condensation of HC in the sampling system will reduce the yield of measured volatile components.

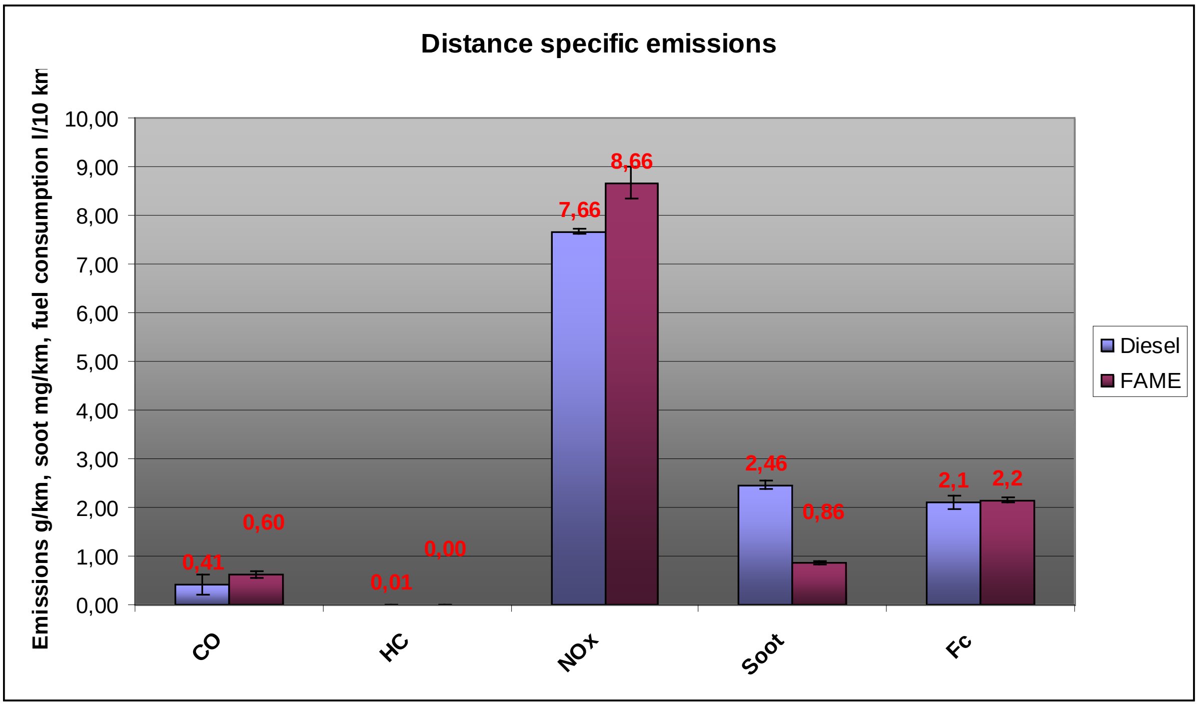


Figure 4. Distance specific mass emission.

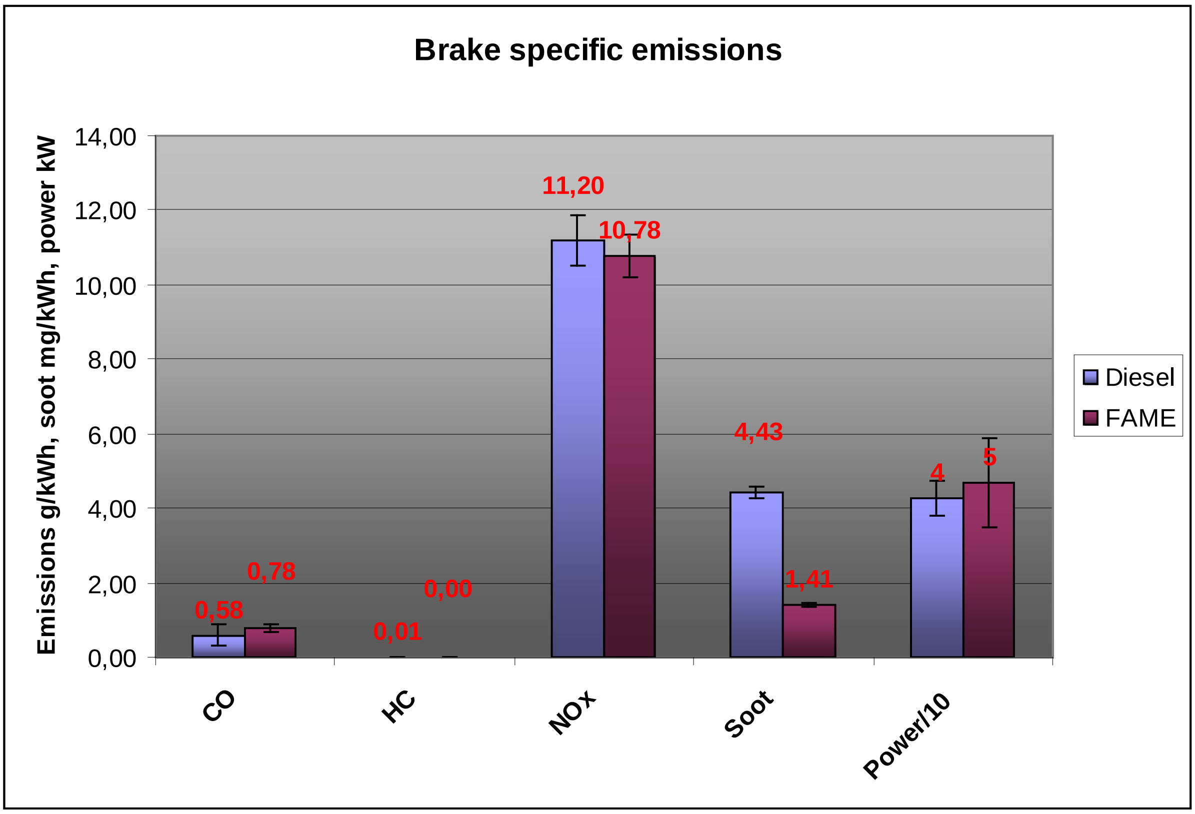


Figure 5. Brake specific emission.

The emissions of NOx are high for both tested fuels. This may be due to a poor functioning SCR system since the exhaust temperature during a major part of the test was high enough for SCR catalyst light off. No mil light indicated exhaust after treatment failure.

Results from winter testing

The ambient temperature was -4°C when the vehicle was tested. The first test was started with a cold engine. The ECU signal for the engine coolant temperature was logged throughout the test. In Figure 6 and Figure 7 the temperature difference during the first 1000 seconds and during the whole test, respectively, can be studied. The maximum temperature is reached after approximately 1500 seconds. In the same diagrams the NOx mass emissions can be studied. In case of a functioning SCR system the emissions would show a different kind of behaviour. The NOx emissions would be high until engine operation temperature is reached and would thereafter show a decreasing trend. In these diagrams the NOx emissions shows an increase with a higher engine temperature which is the opposite from expected.

The SCR is not functioning as expected which can be due to either malfunctioning or that the ambient temperature is too low for the system to work properly.

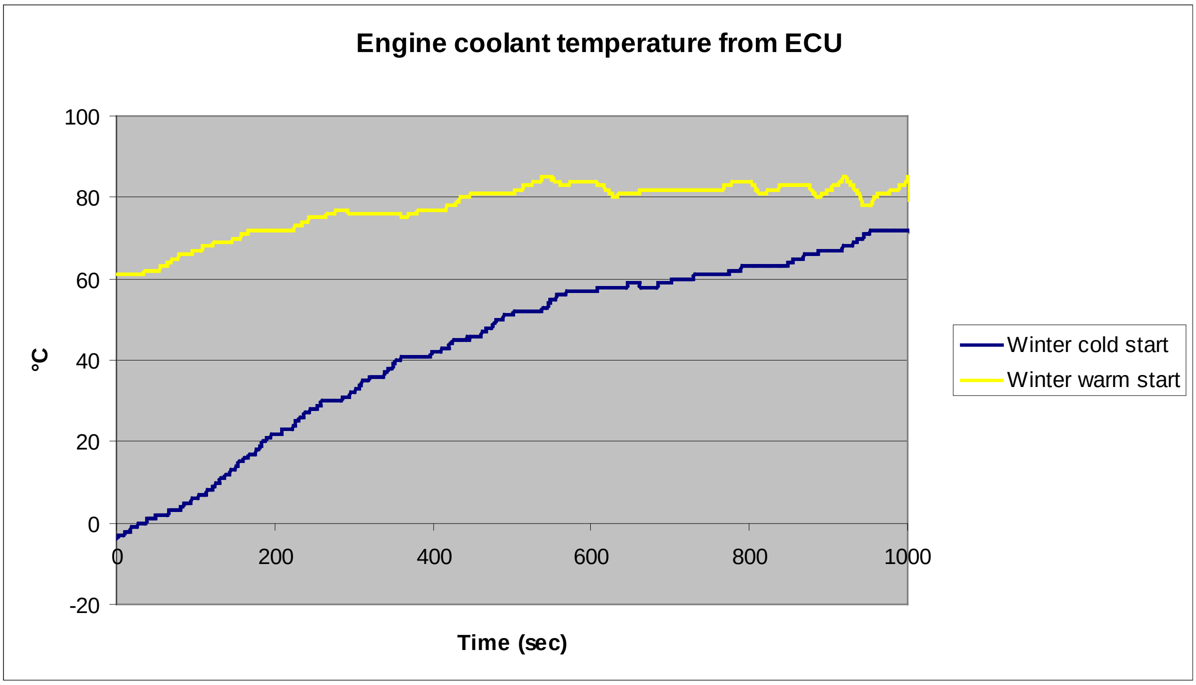


Figure 6: Comparison of engine coolant temperature during the first 1000 seconds.

The temperature curve from the cold start and warm start test can be compared in Figure 6. The engine coolant temperature is regulated in the proposal for Euro VI, where it should be equal to or exceed 70°C.

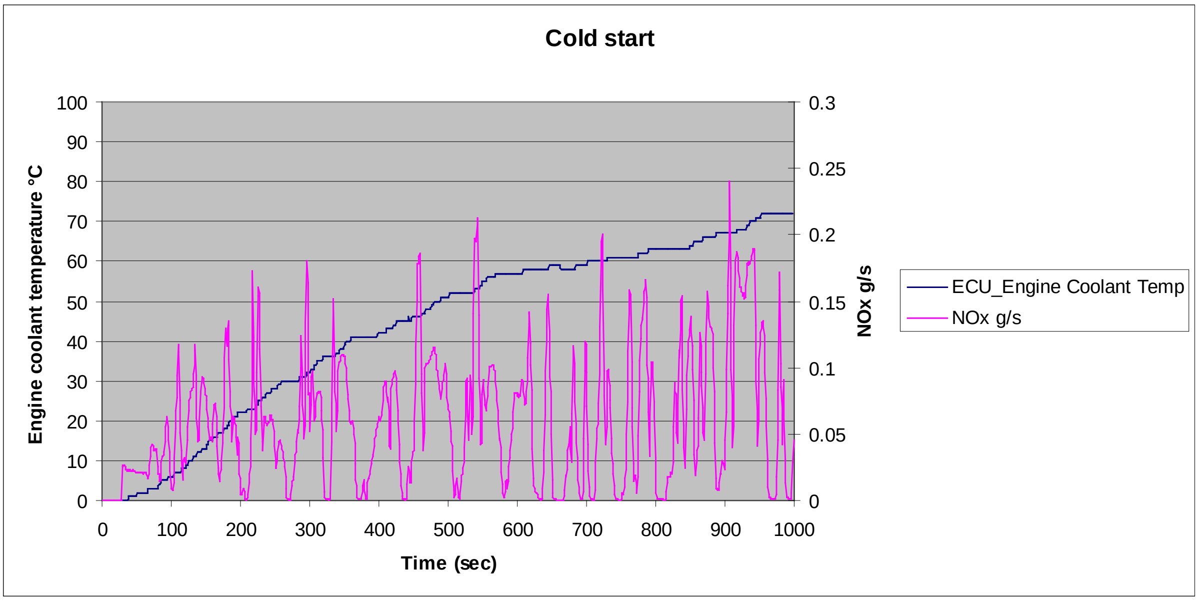


Figure 7: Engine coolant temperature (from ECU) and NOx mass emissions during the first 1000 seconds in the cold start test.

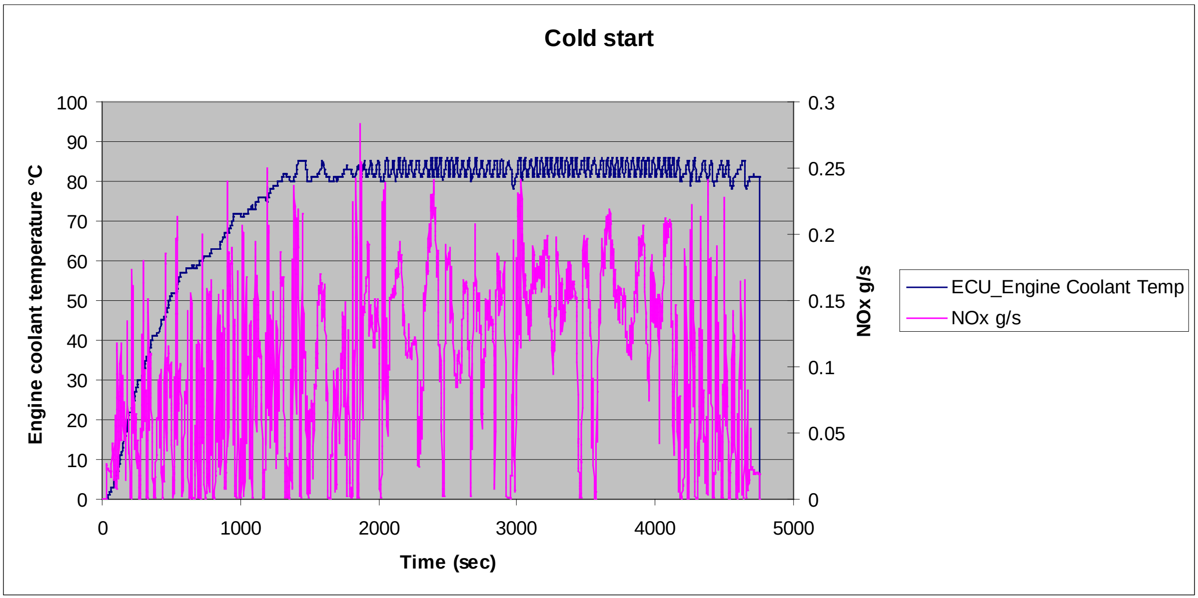


Figure 8: Engine coolant temperature (from ECU) and NOx mass emissions in the cold start test.

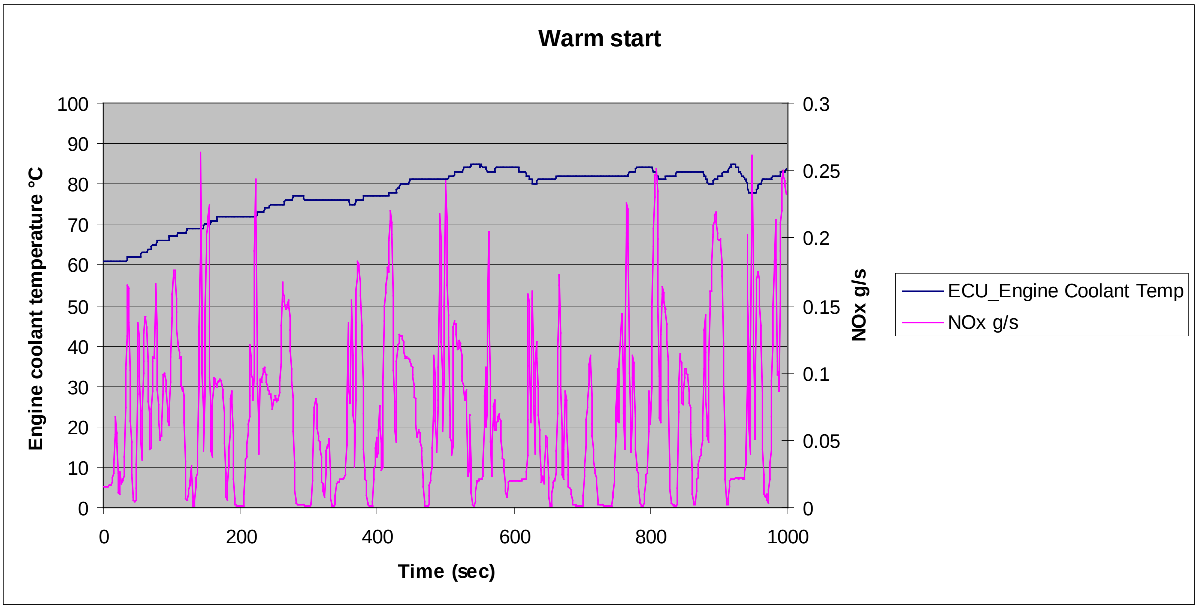


Figure 9: Engine coolant temperature (from ECU) and NOx mass emissions during the first 1000 seconds in the warm start test.

The maximum engine coolant temperature is reached after approximately 600 seconds. The NOx emissions are stable during the whole test.

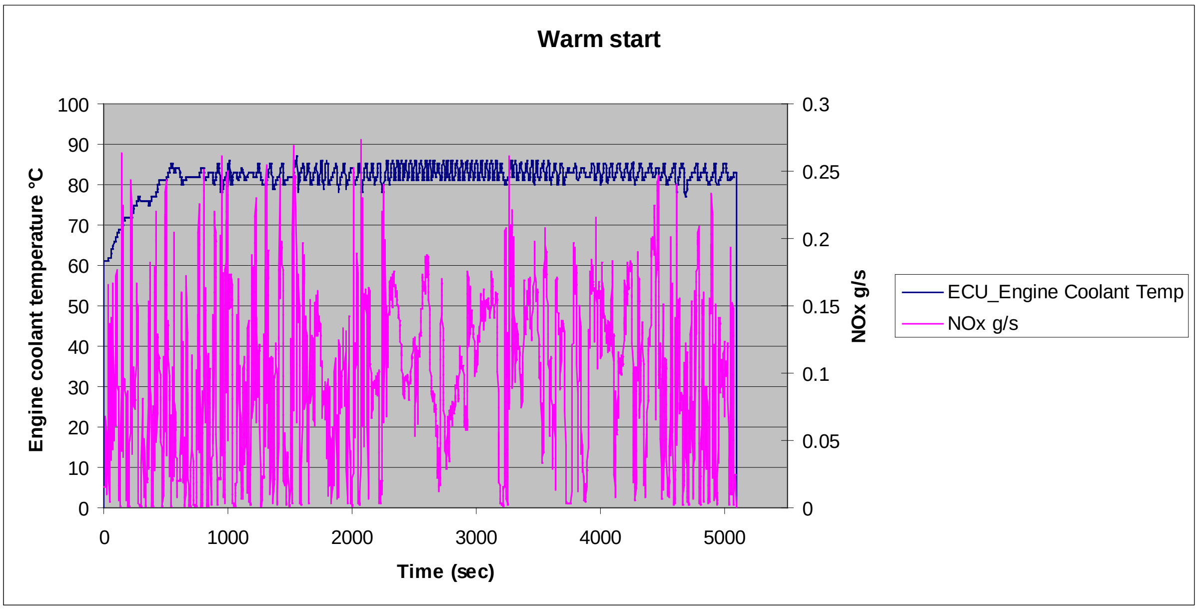


Figure 10: Engine coolant temperature (from ECU) and NOx mass emissions in the warm start test.

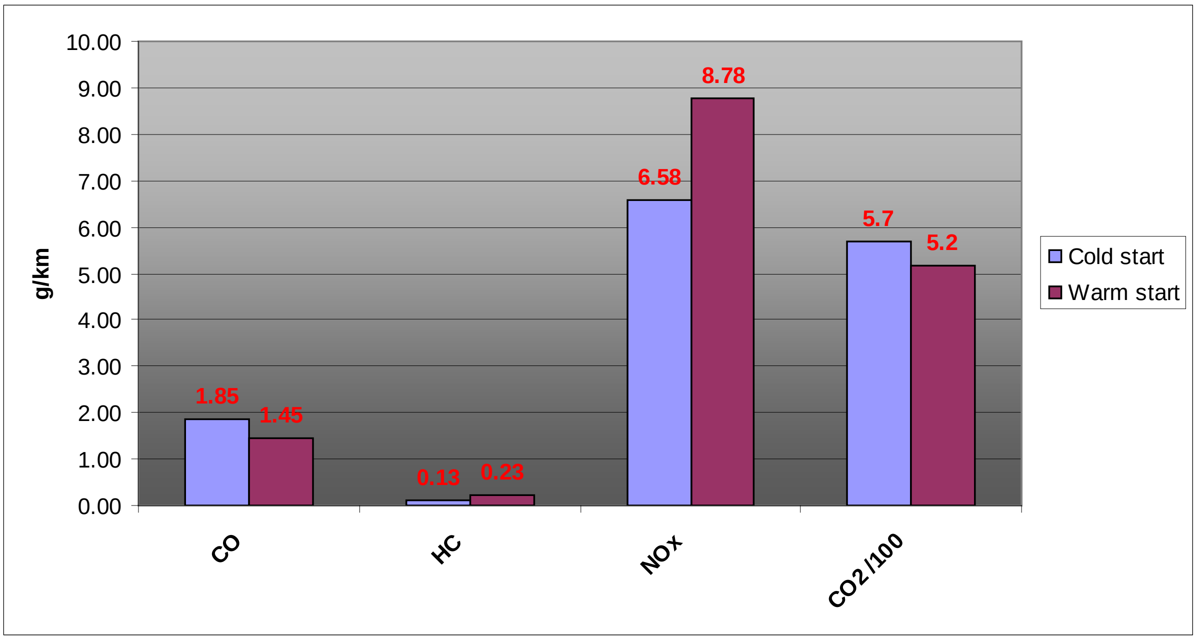


Figure 11: Exhaust emissions in g/km during the first 1000 seconds of the driving route (urban and suburban driving). Comparison between cold and warm start.

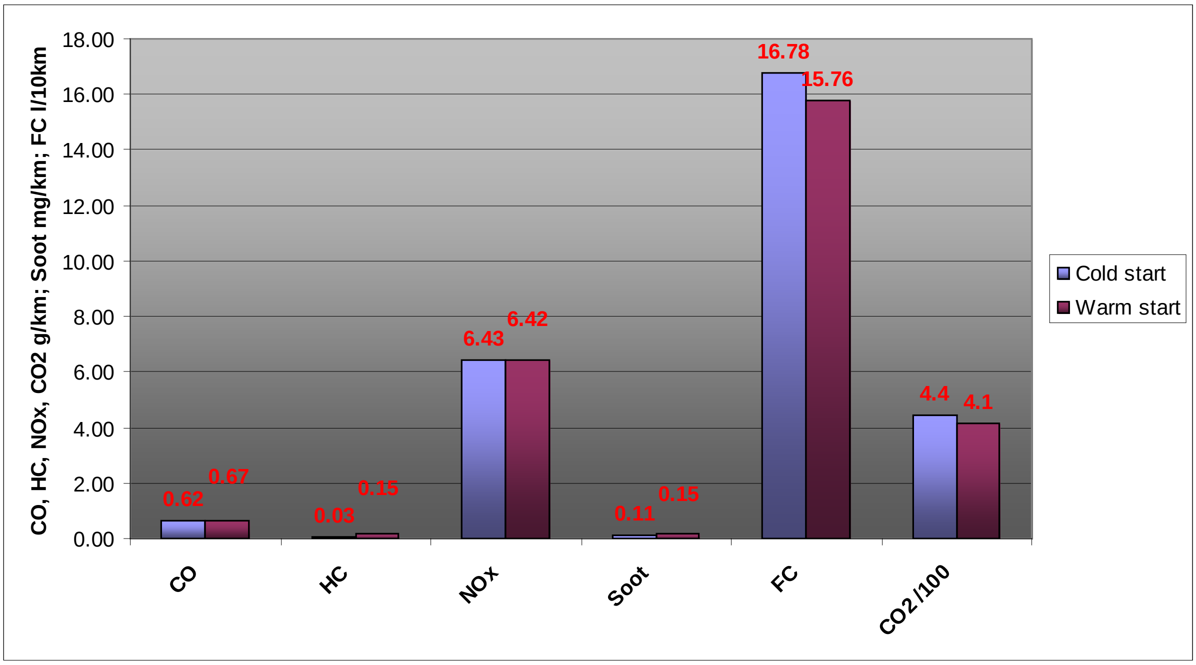


Figure 12: Exhaust emissions in g/km during the complete test route (urban, suburban and motorway driving). Comparison between cold and warm start.

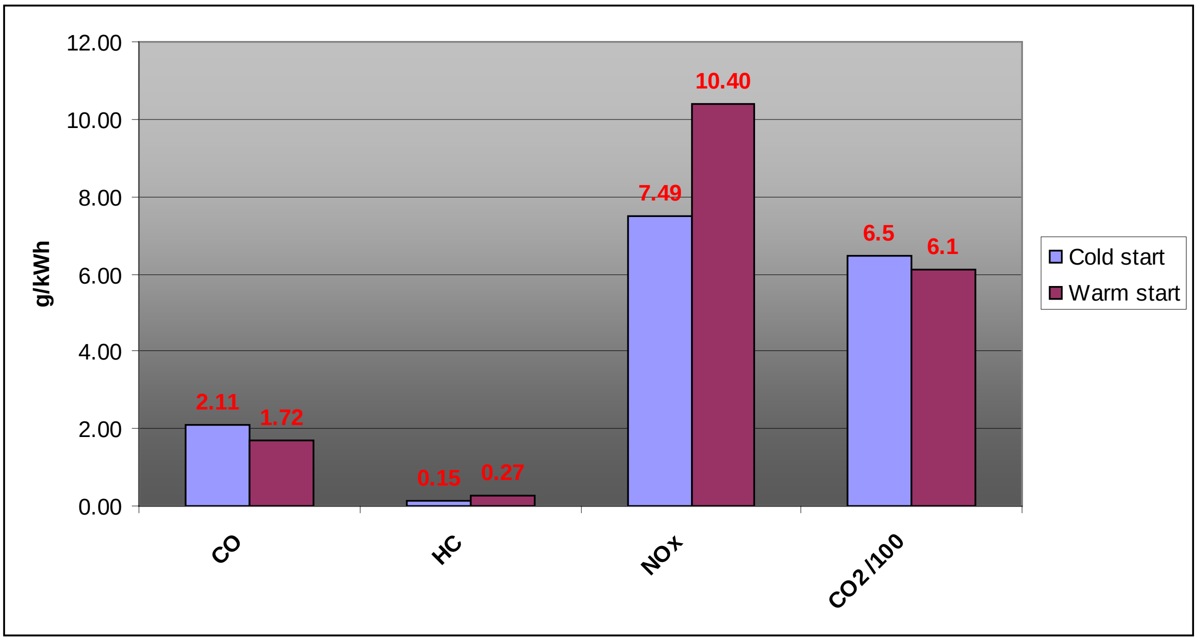


Figure 13: Exhaust emissions in g/kWh during the first 1000 seconds of the driving route (urban and suburban driving). Comparison between cold and warm start.

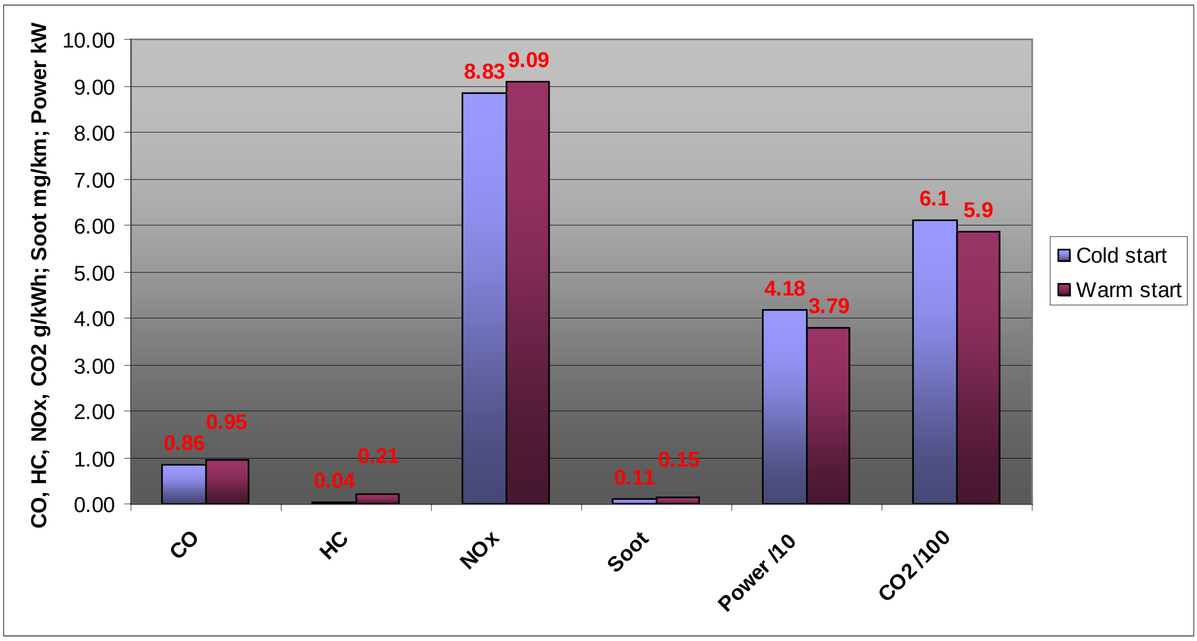


Figure 14: Exhaust emissions in g/kWh during the complete test route (urban, suburban and motorway driving). Comparison between cold and warm start.

In Figure 11-12 and 13-14 the mass emissions are presented in g/km and g/kWh, respectively. The NOx emissions are far above the certification limit for this vehicle (3.5 g/kWh). (In the certification test the vehicle is however tested in a controlled environment and according to a specific driving cycle.) The NOx emissions are lower in the cold start test which is explained by the lower engine temperature.

Comparison between summer and winter testing

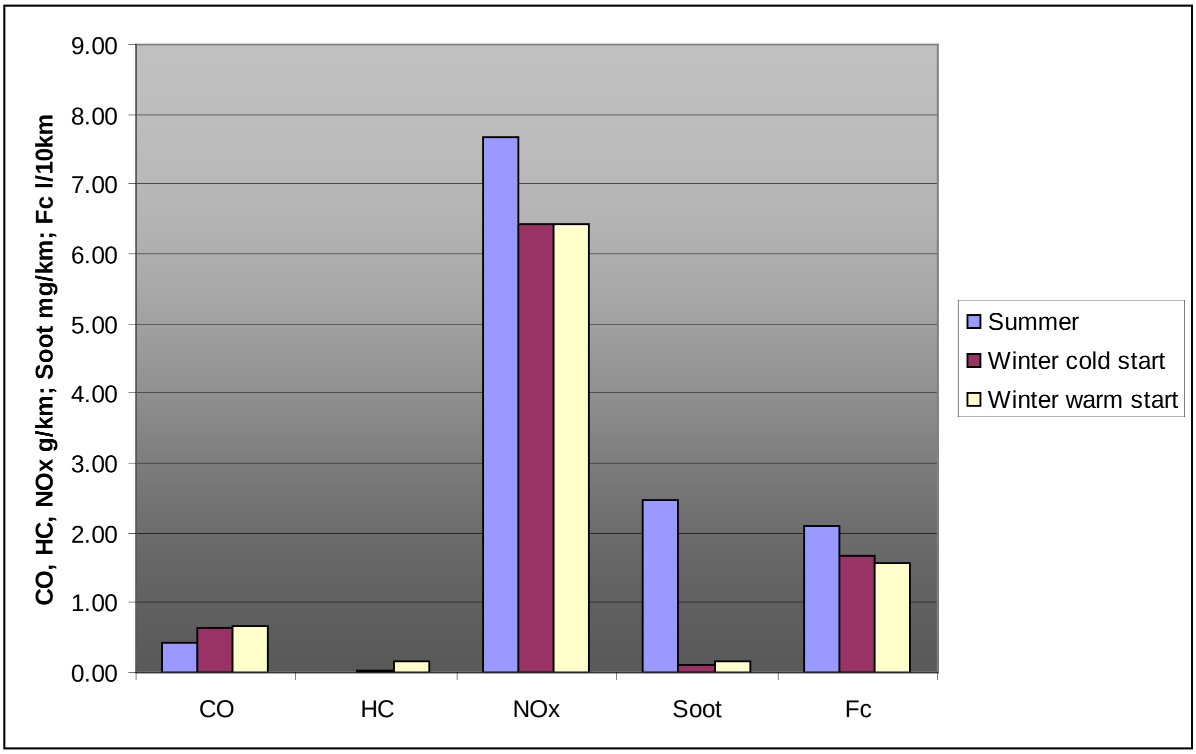


Figure 15: Exhaust emissions in g/km during the complete test route (urban and suburban driving). Comparison between cold and warm start.

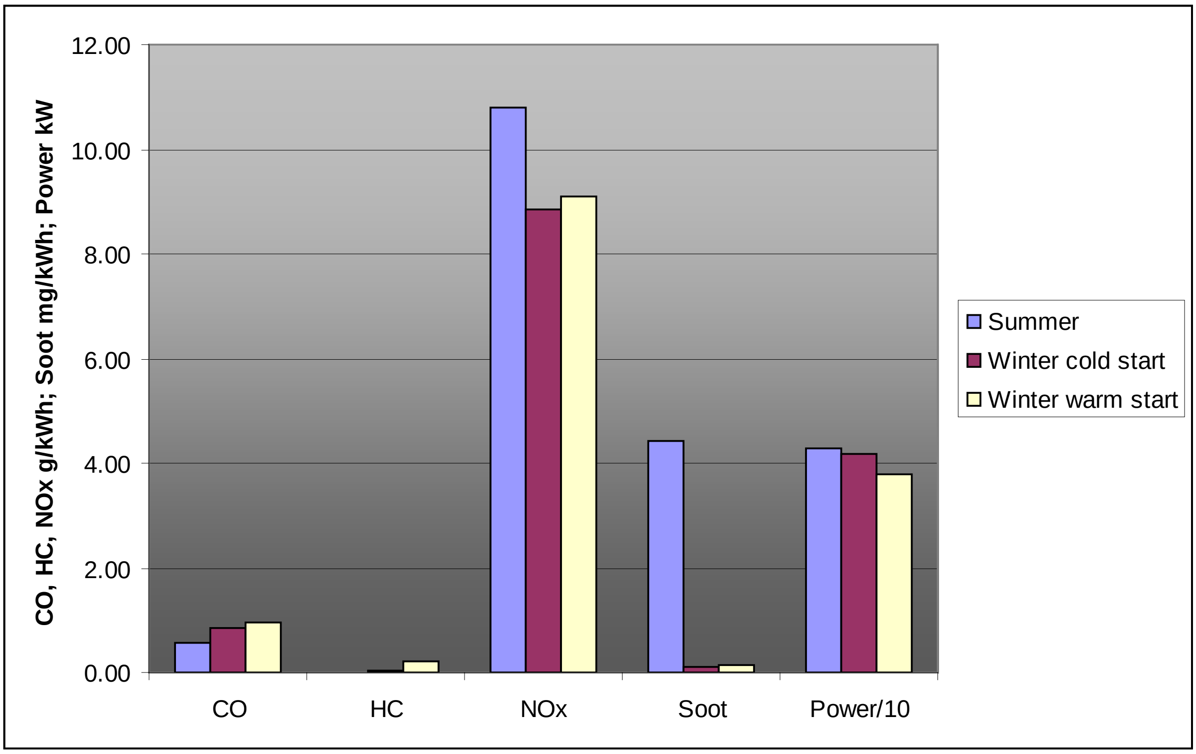


Figure 16: Exhaust emissions in g/kWh during the first 1000 seconds of the driving route (urban and suburban driving). Comparison between cold and warm start.

The NOx emissions were very high already at the summer testing. The SCR system is probably not working correctly, although there was no fault signal (MIL).

If the SCR system had worked properly, the NOx emissions should have been low at summer testing. In the winter testing there would have been higher emissions due to low exhaust temperatures, and the highest NOx emissions should have been achieved at the cold start test.

Vehicle B.

Vehicle B was a dual fuel converted garbage truck. The truck was tested both in dual fuel mode as well as diesel mode.

Test route description:
Below are the test routes presented divided into dual fuel and diesel driving, Figure 17 - 18 and table 4.

Table 4. Total test route data, PEMS test route.

	Dual fuel mode	Diesel mode
Trip duration (s)	1050	900
Trip distance (km)	6.0	10
Average speed (km/h)	20	40
Average altitude (m)	15	43

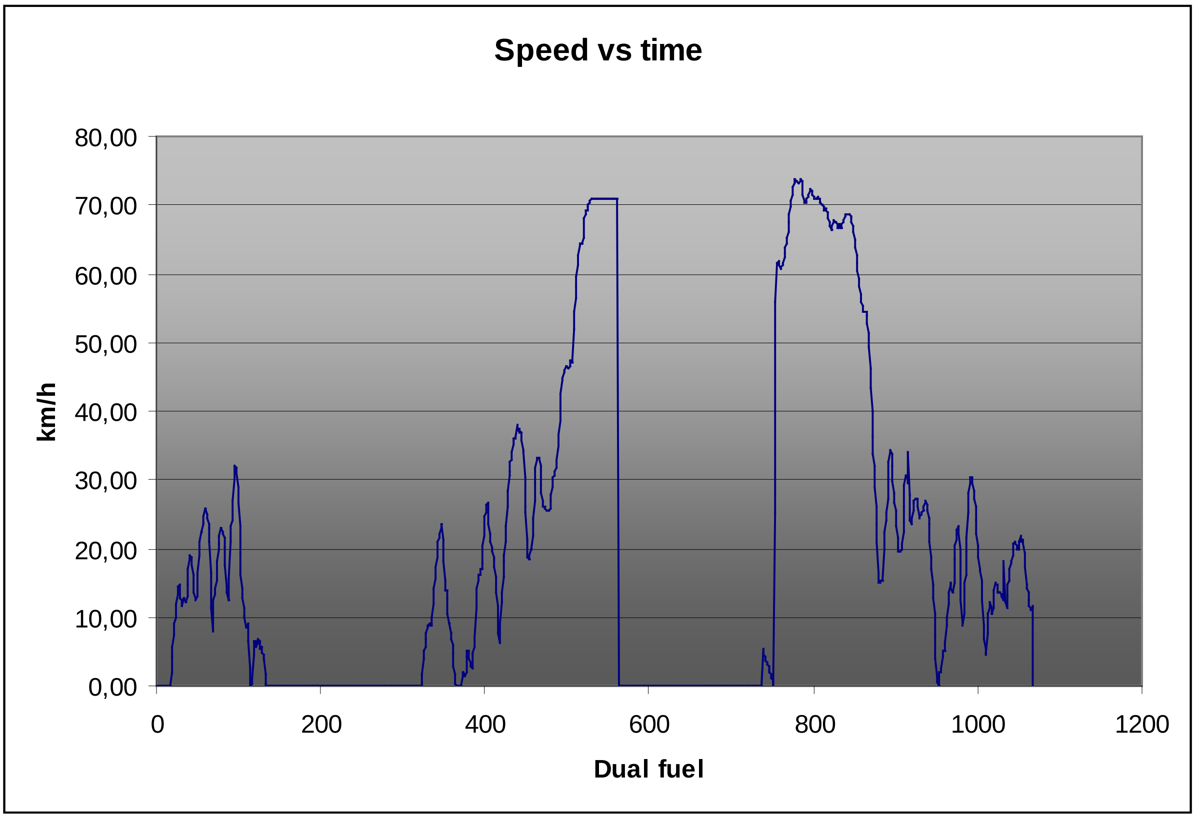


Figure 17: *The PEMS test route, dual fuel.*

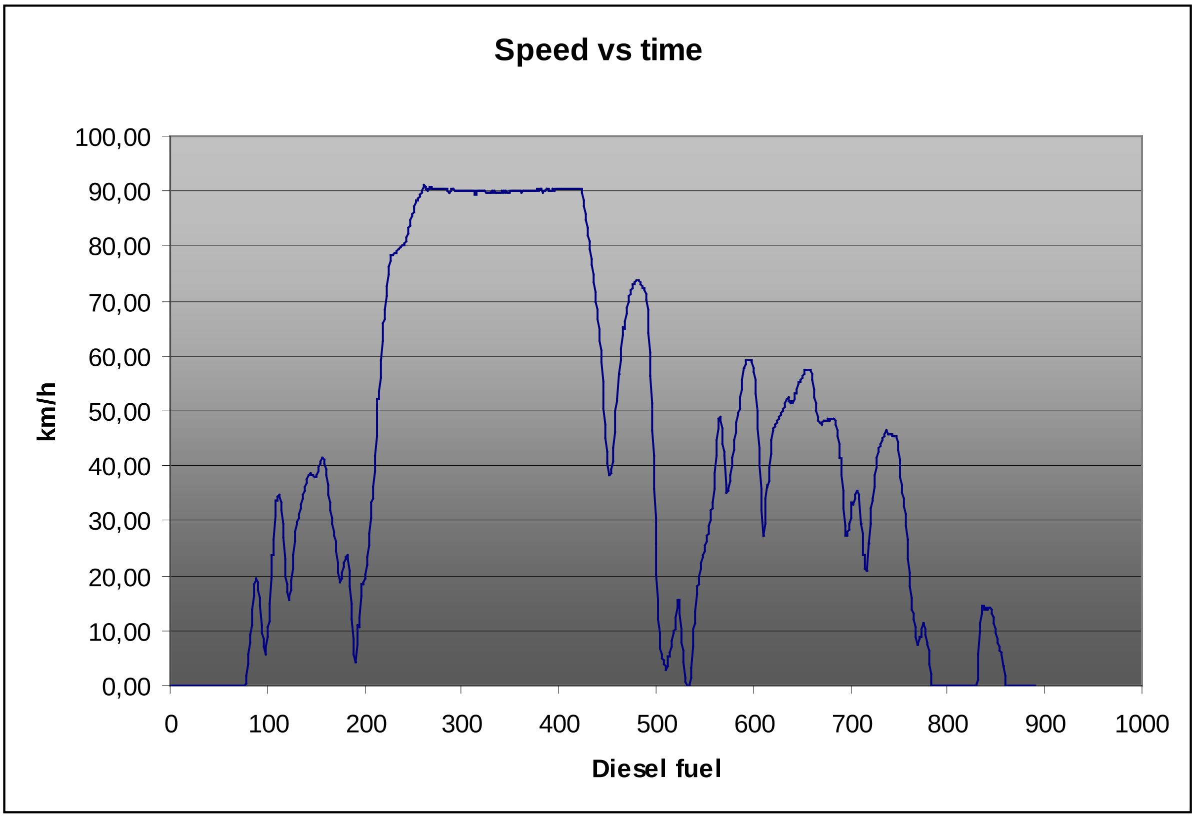


Figure 18: *The PEMS test route, diesel.*

Selection of test vehicle
The vehicle type chosen was a diesel / CNG fuelled garbage truck equipped with a SCR system. The vehicle was certified as a diesel vehicle according to the Euro V standard.

The dual fuel system was not developed by the vehicle manufacturer. A separate electronic control unit (ECU) is used for the natural gas fuel, providing a full closed loop feedback system that monitors existing variables alongside the diesel electronic control unit (ECU) and controls the gas injection based on the feedback from the various engine sensors. The sensors include boost pressure, lambda sensor signal, pedal deflection, coolant temperature, gas temperature and pressure, and many more inputs.
To be able to calculate emissions in g/kWh, it is necessary to connect the on-board measurement equipment to the ECU of the vehicle. This is however not uncomplicated and even if the connection works, the manufacturer has determined which parameters can be read. If, for instance, the engine effect is a hidden parameter, a lug curve is needed from the manufacturer to be able to get emissions in g/kWh. In this case, since the dual fuel ECU programming was not available, no reliable torque curve could be used thus, enabling calculation in g/kWh.

The vehicle has been tested during a normal working day at net weight with extra weight corresponding to approximately 1000 kg.

The tested vehicle has been supplied through kind cooperation with Ragn-Sells AB.

Table 5. Vehicle data.

Year model	2010
Mileage, km	22 500
Date of registration	2010-05-07
Approximately power, kW	180
Test weight, kg	9 100
Emission standard (diesel)	Euro V

Test results

From Figure 19 some conclusions can be made. When comparing the distance specific emissions (g/km) from the diesel and dual fuel driving mode all measured components were higher while driving with the dual fuel system. The difference in HC emission levels are in the order of 4000 times higher due to methane slip. However, during a large part of the test route the measuring range of the HC detector were exceeded thus implying even higher emissions of HC. This suggests that the dual fuel system and the vehicle exhaust after treatment system are not performing in accordance with the vehicle certification data.

No failure indication from the ECU or MIL light was noted.

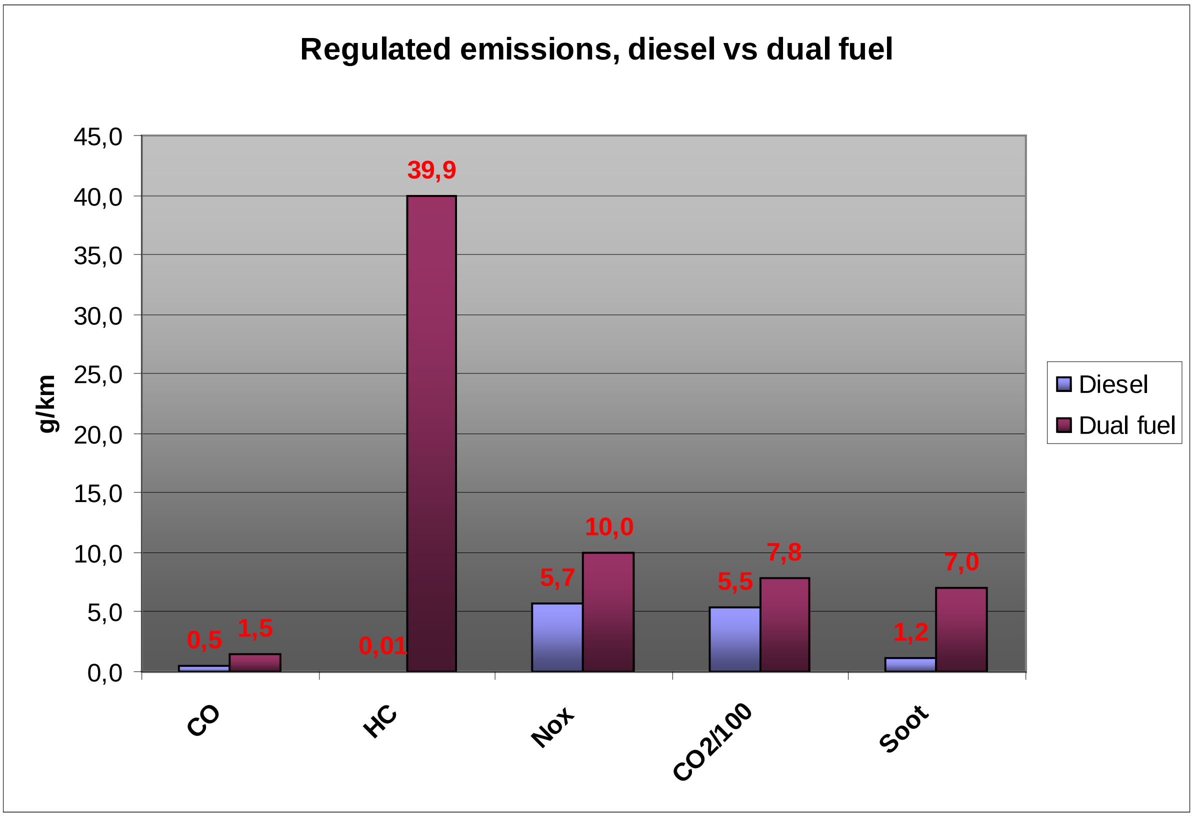


Figure 19. Distance specific mass emission.

Picture 1. Exhaust flow meter.

Vehicle C.

The vehicle type chosen was a diesel fuelled distribution truck equipped with an EGR and a particulate filter system fulfilling the requirement of Euro IV.

The vehicle has been tested both on chassis dynamometer according to ESC and Fige as well as on road with net weight with extra weight corresponding to 50 % of maximum pay load i.e. 2500 kg. Due to high NOx values the vehicle was retested after EGR service.

Test route description:
Start at Armaturvägen in Jordbro, Haninge (AVL MTC) – through Handens centrum – Årsta Havsbad – Ösmo – Armaturvägen (end).

Table 6. Total test route data, PEMS test route.

Trip duration (s)	4493 - 4644
Trip distance (km)	75.5 – 75,7
Average speed (km/h)	59 – 61
Average altitude (m)	30,5
Altitude range (m)	2,5-86,8

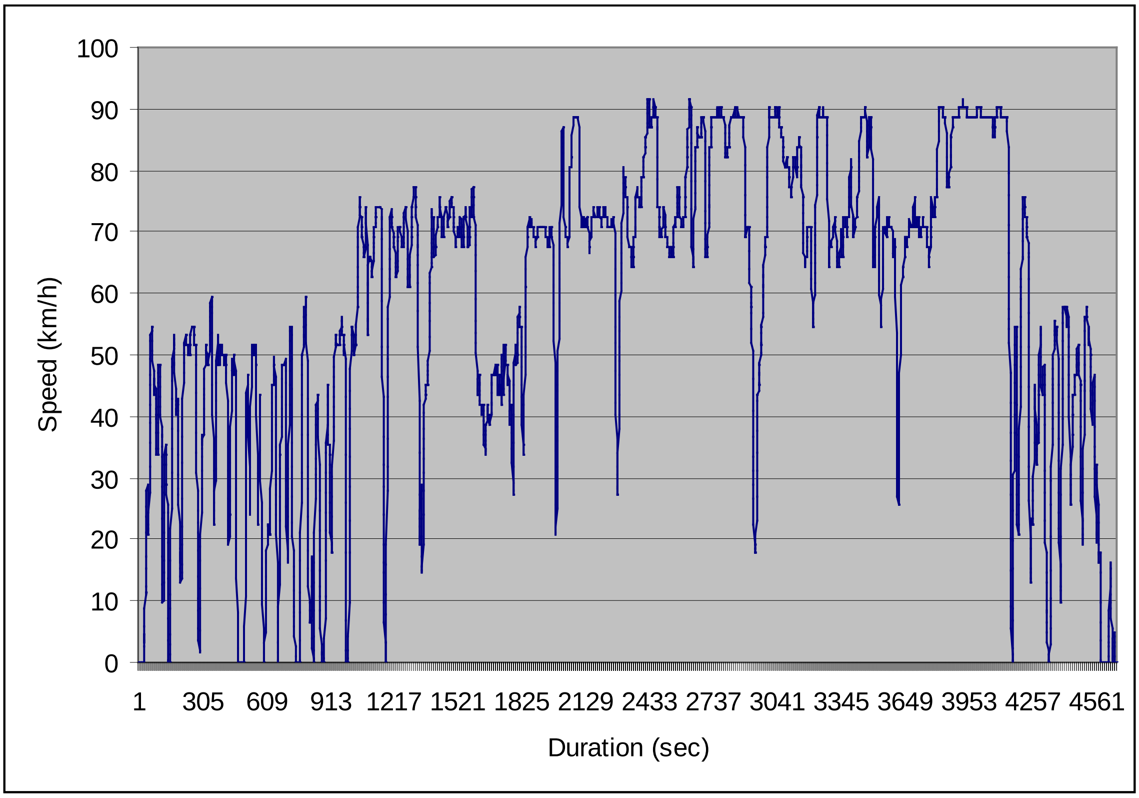


Figure 20: *The PEMS test route*

Presentation of vehicle:
Table 7. Vehicle data.

Year model	2008
Mileage, km	185 600
Date of registration	June 2008
Approximately power, kW	180
Test weight, kg	9 500
Emission standard	Euro IV

Test results

From Figure 21 – 22 some general conclusions can be made. When comparing the distance specific emissions (g/km) from on-road and Fige testing the difference in emission levels are 20 – 50 % except HC. The emission levels of HC are close to detection limit and may thus not be significant. Relatively high levels of NOx were detected.
The brake specific emissions from on-road and ESC are in the same order of magnitude except for average power. Comparing the ESC results it can be seen that CO and HC are below the emission standard, Table 7, while NOx and PM are

exceeding the limits. The NOx emission are more than a factor of two times higher compared to Euro IV standard suggesting that the vehicle exhaust after treatment system (EGR) are not performing in accordance with the certification data. However, it must be emphasized that the test procedure of ESC in engine test bench and vehicle testing on chassis dynamometer differs. No failure indication from the ECU or MIL light was noted.
The emission levels of soot were below the detection limit of the soot sensor system during the on-road testing.

After service of the EGR and pressure point valves carried out by the manufacturer the vehicle was retested (Pems 2, Fige 2 and ESC 2). The NOx emission decreased by a factor of two which clearly reveals the importance of a well functioning MIL.

Table 7. EU emission levels, IV.

CO (g/kWh)	**HC** (g/kWh)	**NOx** (g/kWh)	**PM** (g/kWh)
1.5	0.46	3.5	0.02

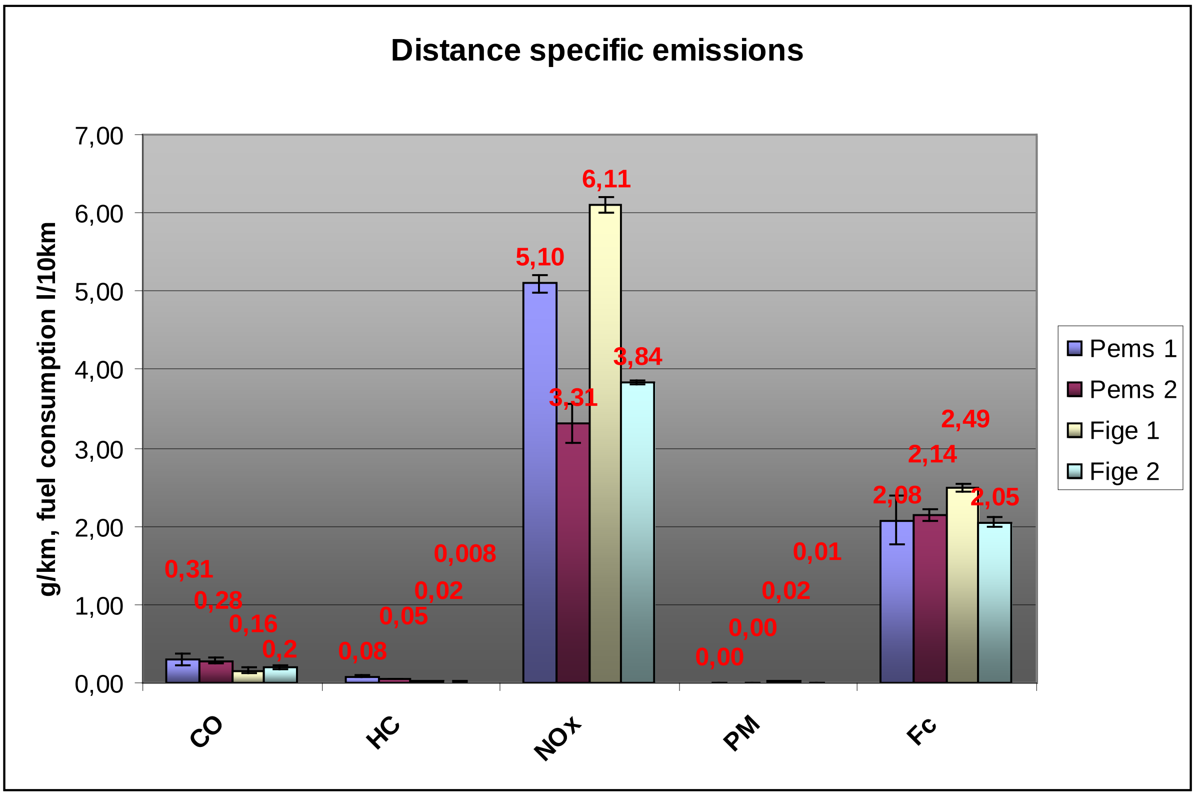


Figure 21. Distance specific mass emission.

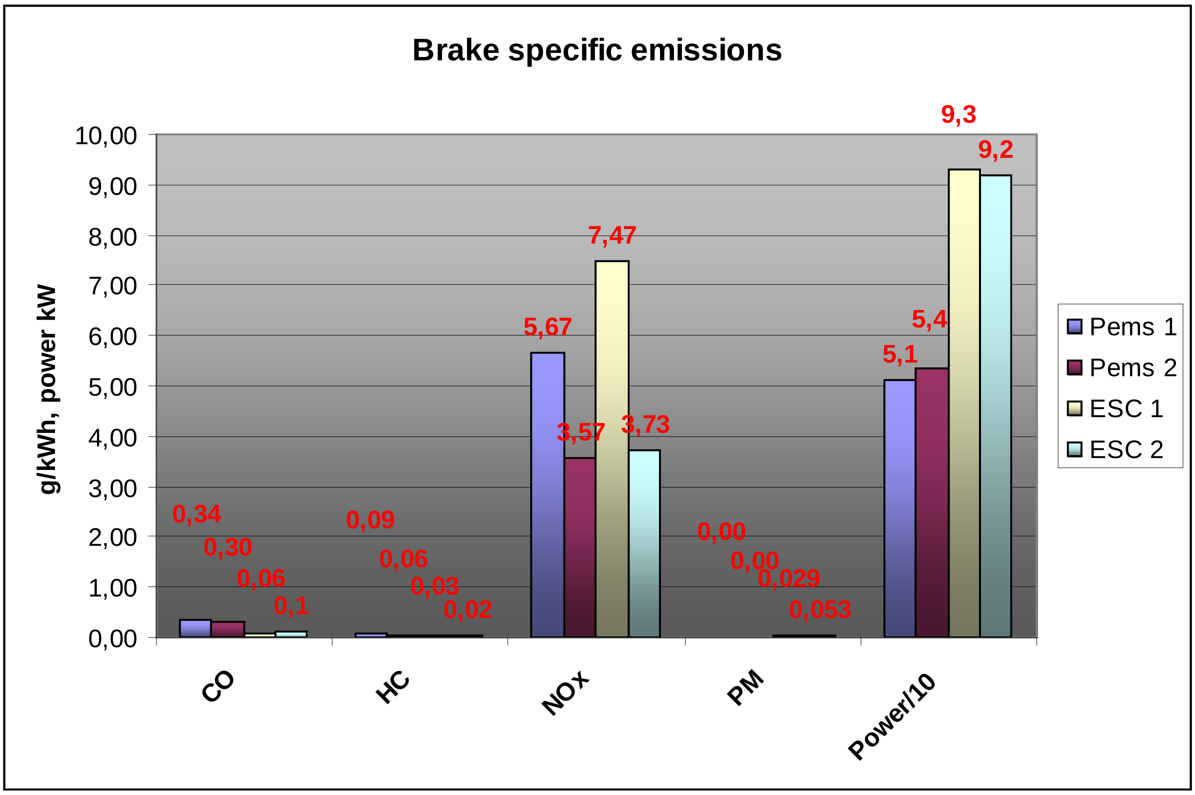


Figure 22. Brake specific emission.

Vehicle D

The vehicle type chosen was a CNG fuelled city bus equipped with a SCR system.

The tests were carried out with compressed natural gas (CNG) supplied by the vehicle fleet owner. The vehicle was tested at an average ambient temperature of 20^{o}C.

Test route description.
The selected test route for this vehicle was bus line 835 in Haninge, Sweden and three test runs were carried out.

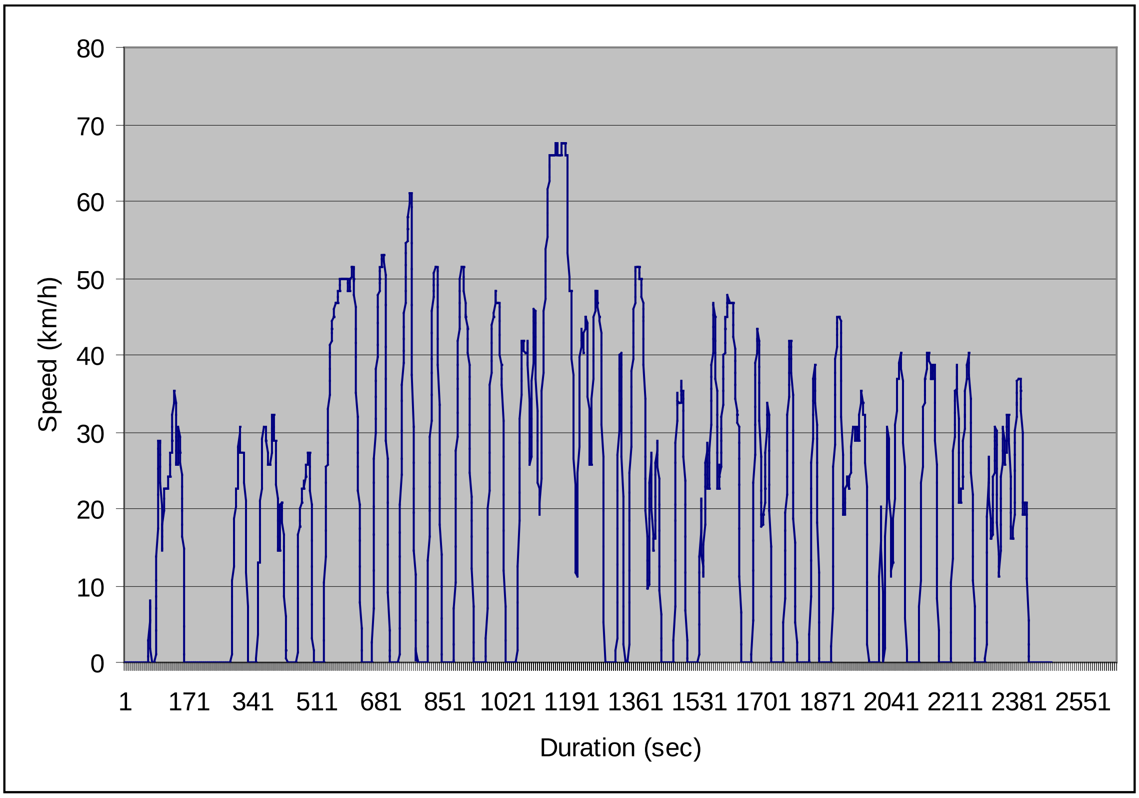


Figure 23: *The Buss line test route*

Table 8. Total test route data, Bus route 835.

Trip duration (s)	2133 - 2454
Trip distance (km)	13.5 – 13.7
Average speed (km/h)	19 – 23
Average altitude (m)	45 - 46
Altitude range (m)	27 - 70

Presentation of vehicle:

Table 9. Vehicle data.

Year model	2009
Mileage, km	51 000
Date of registration	February 2009
Approximately power, kW	230
Test weight, kg	15 840

Test results

From Figure 24 – 25 some general conclusions can be made. With regard to brake specific emission both t CO as well as NOx emissions is well below the limit values for Euro IV EEV i.e CO 3.0 g/kWh and NOx 2.0 g/kWh. Non methane hydrocarbons (NMHC) and particulate (PM) emissions has not been measured. To AVL experience measurement of PM with a soot sensor instrument on CNG fuelled vehicles will be below the detection limits. The fuel consumption is expressed as diesel equivalents. The low obtained emission values combined with no failure indication from the ECU or MIL light suggest that the vehicle is performing in accordance with the certification data.

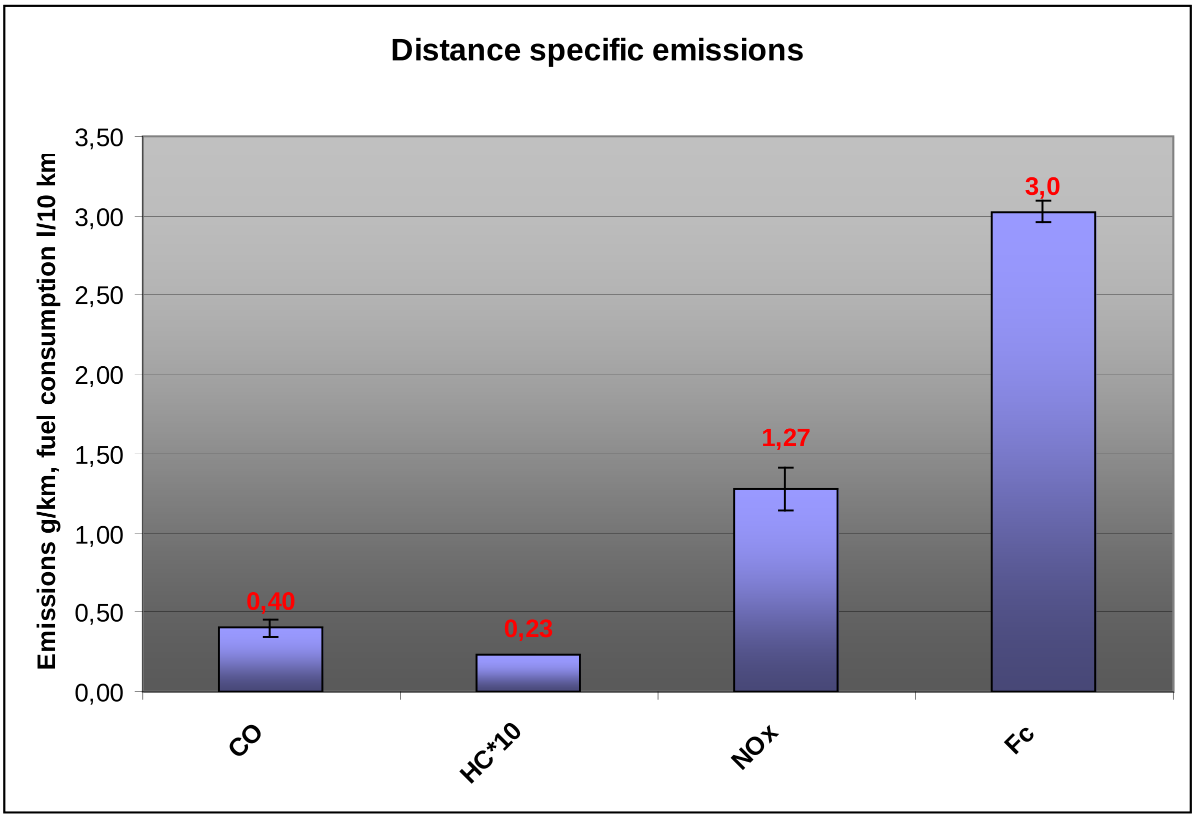


Figure 24. Distance specific mass emission.

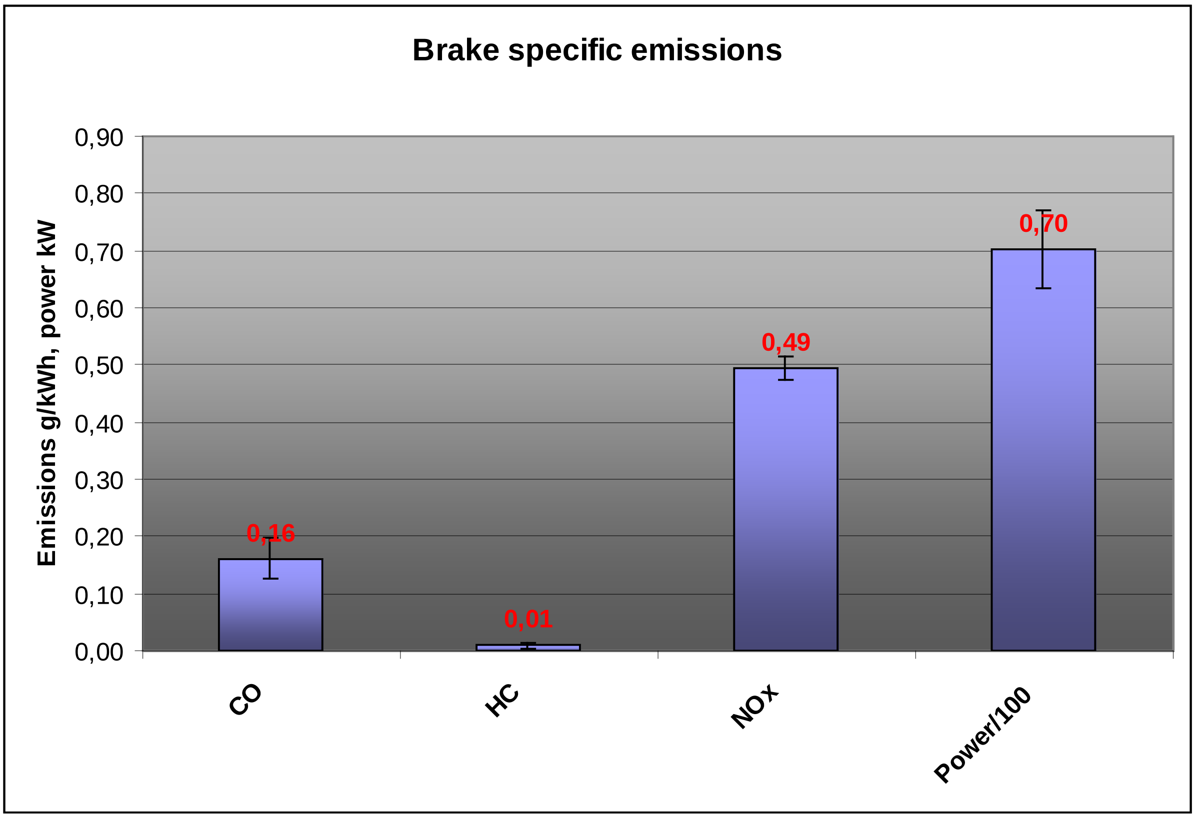


Figure 25. Brake specific emission.

Vehicle E

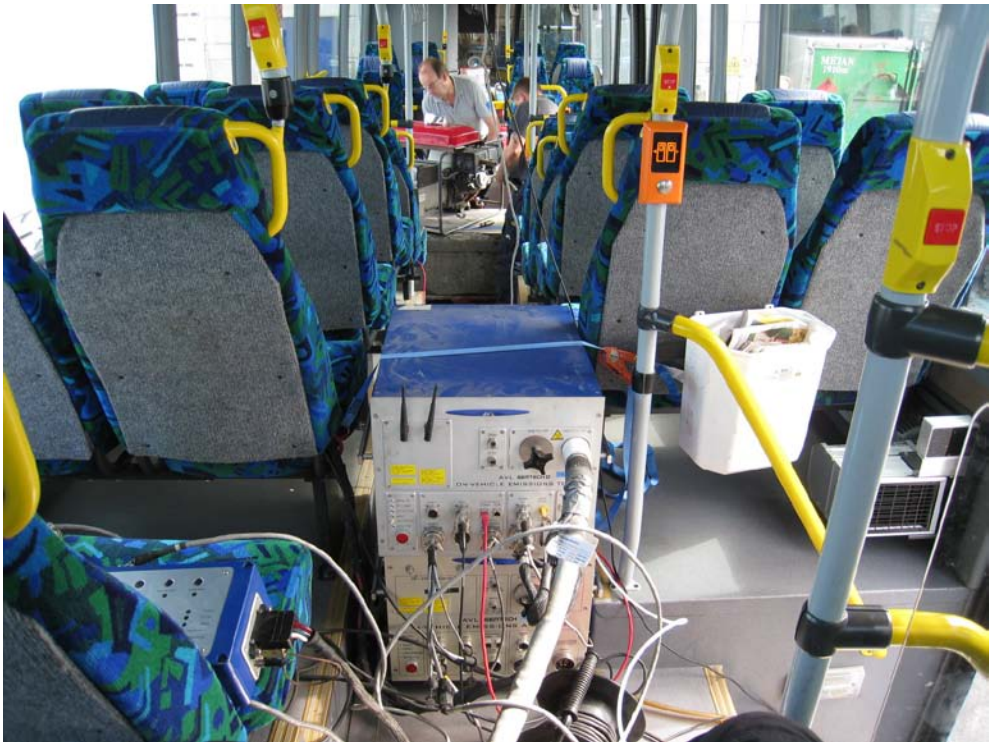
The vehicle type chosen was an ethanol fuelled city bus equipped with a SCR system fulfilling the requirement of Euro V EEV. Three test runs were carried out on the same test route as vehicle D.

The vehicle has been tested at net weight with extra weight corresponding to 25 passengers i.e. 1750 kg. The number of passenger was based on data from the bus owner.

The vehicle was served in accordance to the manufacturer specification. The vehicle was tested at an average ambient temperature of 20 ^{o}C.

Table 10. Vehicle data.

Year model	2008
Mileage, km	17 2400
Date of registration	October 2008
Approximately power, kW	200
Test weight, kg	13 900
Emission standard	Euro V



***Picture 2*.** Test equipment inside the vehicle**.**

Test results

From Figure 26 – 27 some general conclusions can be made. When comparing the distance specific emissions (g/km) from on-road and Fige testing higher levels of all measured components were detected. The differences may due to the driving pattern. The Fige cycle includes much tougher transient driving and, in addition, a highway part, thus giving a higher exhaust temperature compared to the bus route. This will affect the efficiency of the catalytic system.
The brake specific emissions from on-road and ESC are in the same order of magnitude except for CO were the bus route are eight times higher. Comparing the ESC results it can be seen that CO and PM are well below the emission standard, while NOx and HC are slightly exceeding the limits. However, it must be emphasized that the test procedure of ESC in engine test bench and vehicle testing on chassis dynamometer differs. The low obtained emission values combined with no failure

indication from the ECU or MIL light suggest that the vehicle and its exhaust after treatment system are performing in accordance with the certification data. The emission levels of soot were below the detection limit of the soot sensor system during the on-road testing.

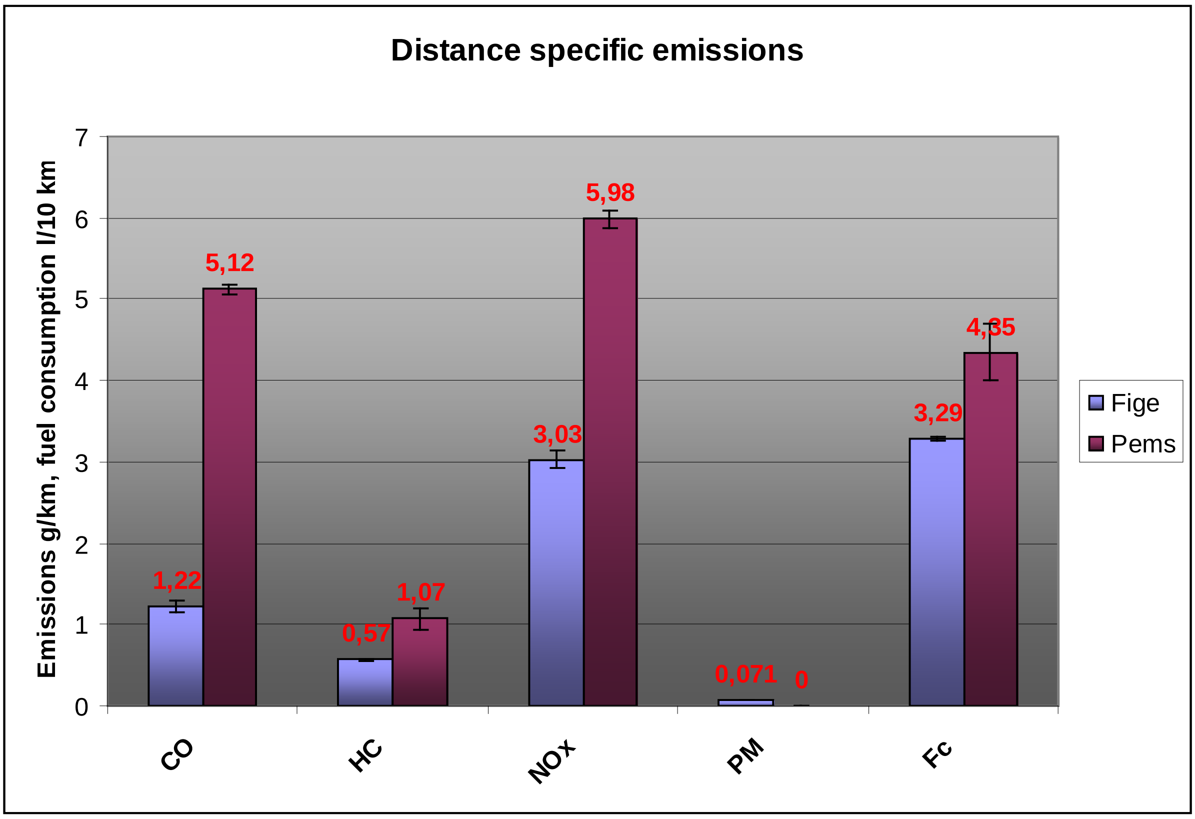


Figure 26. Distance specific mass emission.

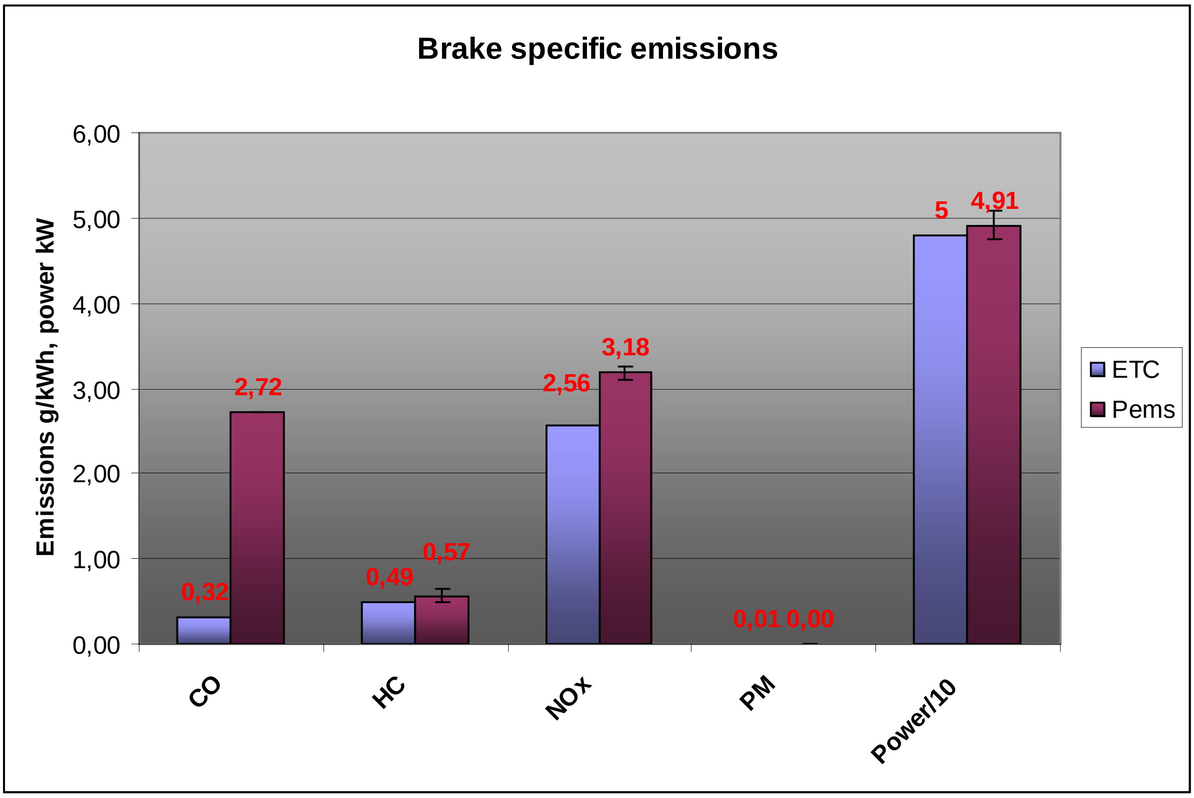


Figure 27. Brake specific emission.

Vehicle F

Vehicle F was a Euro V bus driven on Diesel. The vehicle was used as a reference to vehicle D and E.

To be able to get emissions in g/kWh it is necessary to connect the on-board measurement equipment to the ECU of the vehicle. This is however not uncomplicated. And even if the connection works, the manufacturer has determined which parameters can be read. If, for instance, the engine effect is a hidden parameter, a lug curve is needed from the manufacturer to be able to get emissions in g/kWh. In this case no connection to the ECU was possible, thus the results are only calculated as g/km.

The tests were carried out with Swedish environmental class 1 diesel fuel and the average ambient temperature was 25^{o}C.

Test route description.
The selected test route for this vehicle was bus line 835 in Haninge, Sweden and three test runs were carried out.

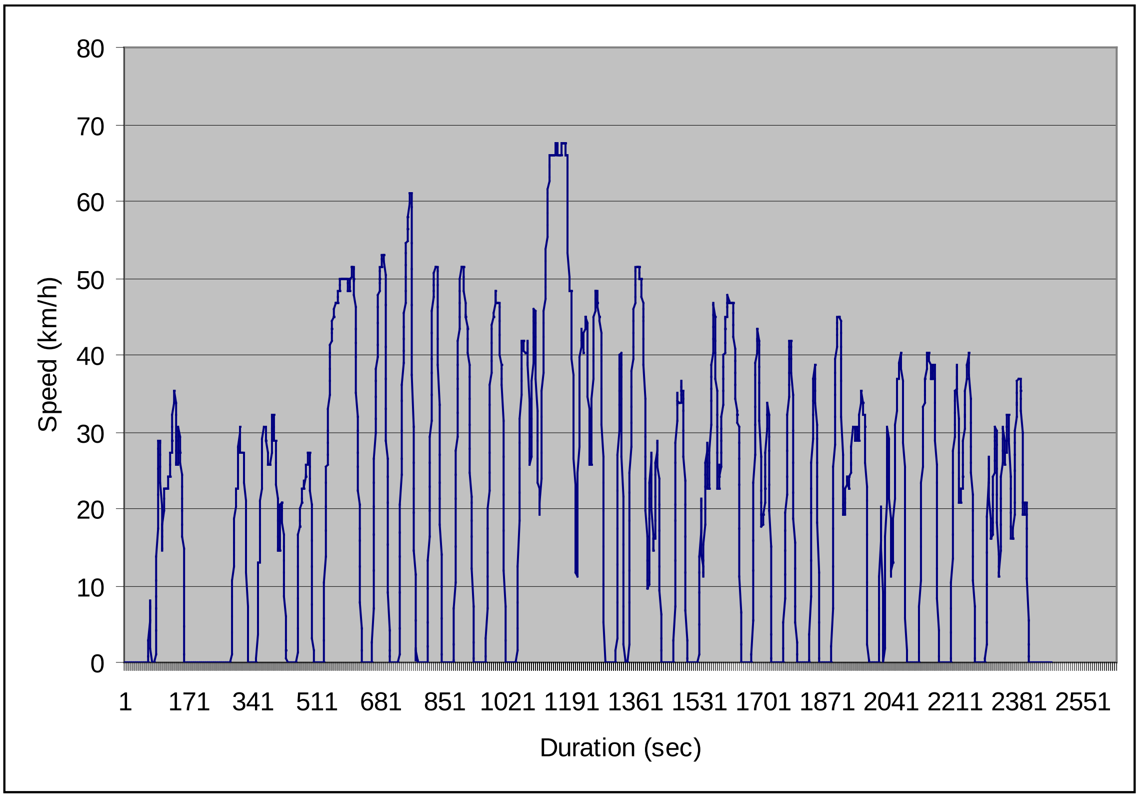


Figure 28: *The Buss line test route*

Table 11. Total test route data, Bus route 835.

Trip duration (s)	2133 - 2454
Trip distance (km)	13.5 – 13.7
Average speed (km/h)	19 – 23
Average altitude (m)	45 - 46
Altitude range (m)	27 - 70

Presentation of vehicle:

Table 12. Vehicle data.

Year model	2007
Mileage, km	310 000
Date of registration	September 2007
Approximately power, kW	200
Test weight, kg	13600

Test results

From Figure 29 some general conclusions can be made. With regard to distance specific emission both CO as well as HC emissions are below the values compared to the ethanol and CNG fuelled busses. The NOx are lower compared to the ethanol bus but 1.8 times higher compared to the CNG bus.
The low obtained emission values combined with no failure indication from the ECU or MIL light suggest that the vehicle is performing in accordance with the certification data.

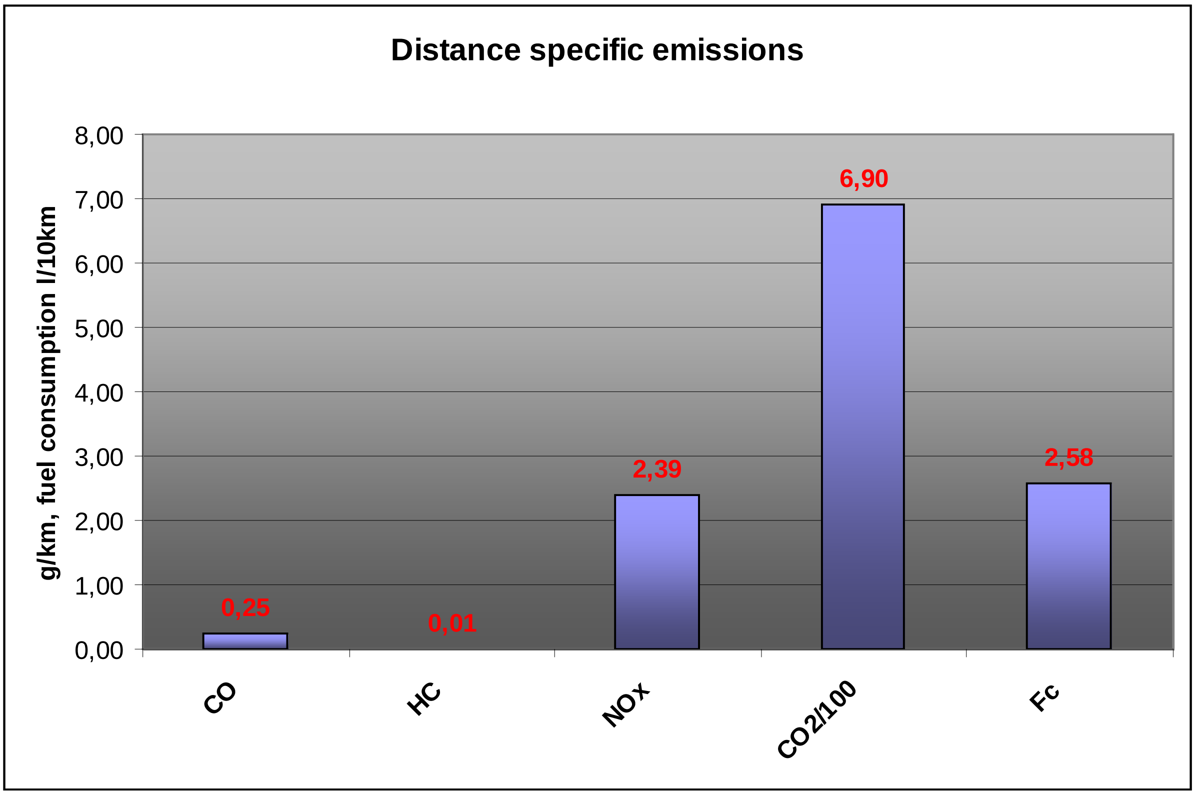


Figure 29. Distance specific emission.

Vehicle G.

Vehicle G was a long distance Euro V truck equipped with a SCR system. The vehicle is driven on DME. The DME truck uses a regular 13 litres engine which, after some modification of the tank system, injection system and engine management, functions perfectly together with the biofuel. The vehicle is running within a field test is carried out on a local basis i.e. returning to the same location for refuelling.

Table 13. Total test route data.

	Urban driving	Motorway driving	Urban without trailer
Trip duration (s)	1360	500	1000
Trip distance (km)	13.8	9.2	9.4
Average speed (km/h)	37	70	36
Average altitude (m)	13	80	12

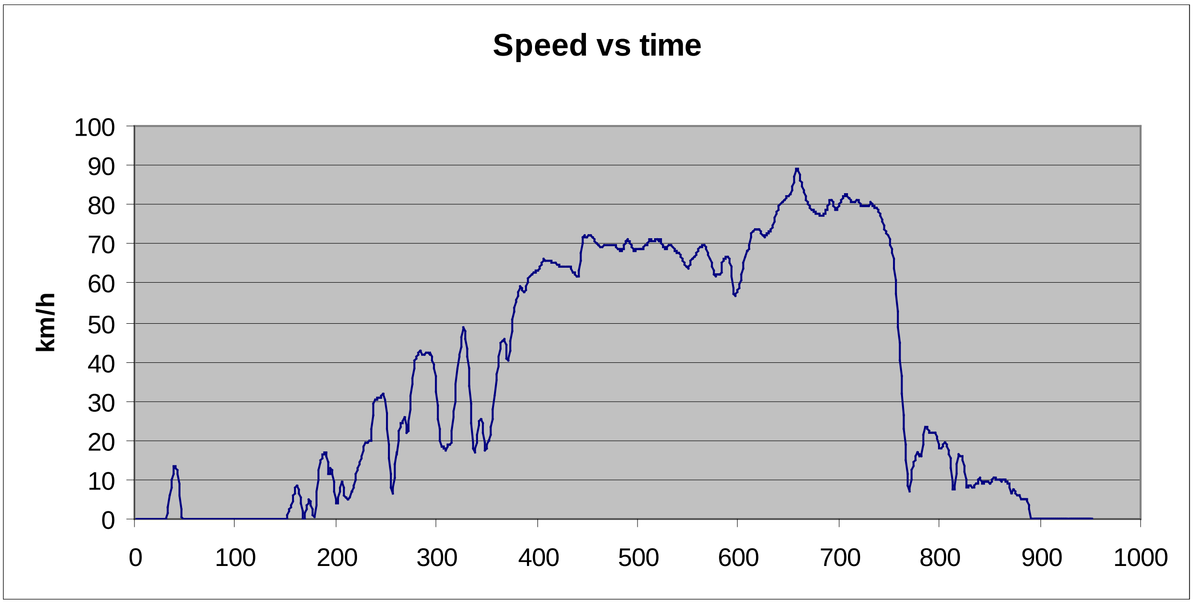


Figure 30: *Test route*

Table 14. Vehicle data.

Year model	2009
Mileage, km	11000
Date of registration	2009-09-04
Approximately power, kW	350
Test weight, kg	23 000 – 39 000
Emission standard	V

Test results

From Figure 31 – 32 can it be seen that increased emissions of carbon monoxide and oxides of nitrogen were detected during urban driving conditions with low load compared to high load and motorway driving. According to the manufacturer transient optimizing of the engine was still under development.

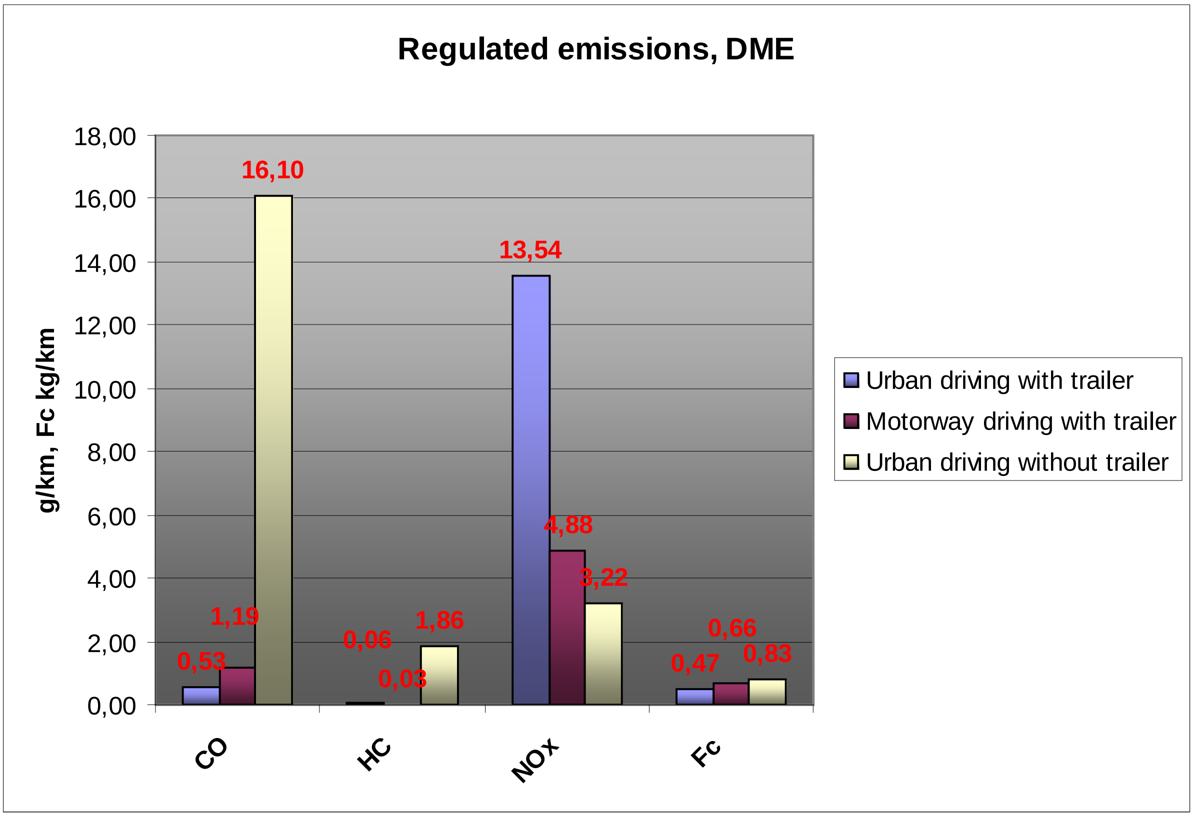


Figure 31. Distance specific emission.

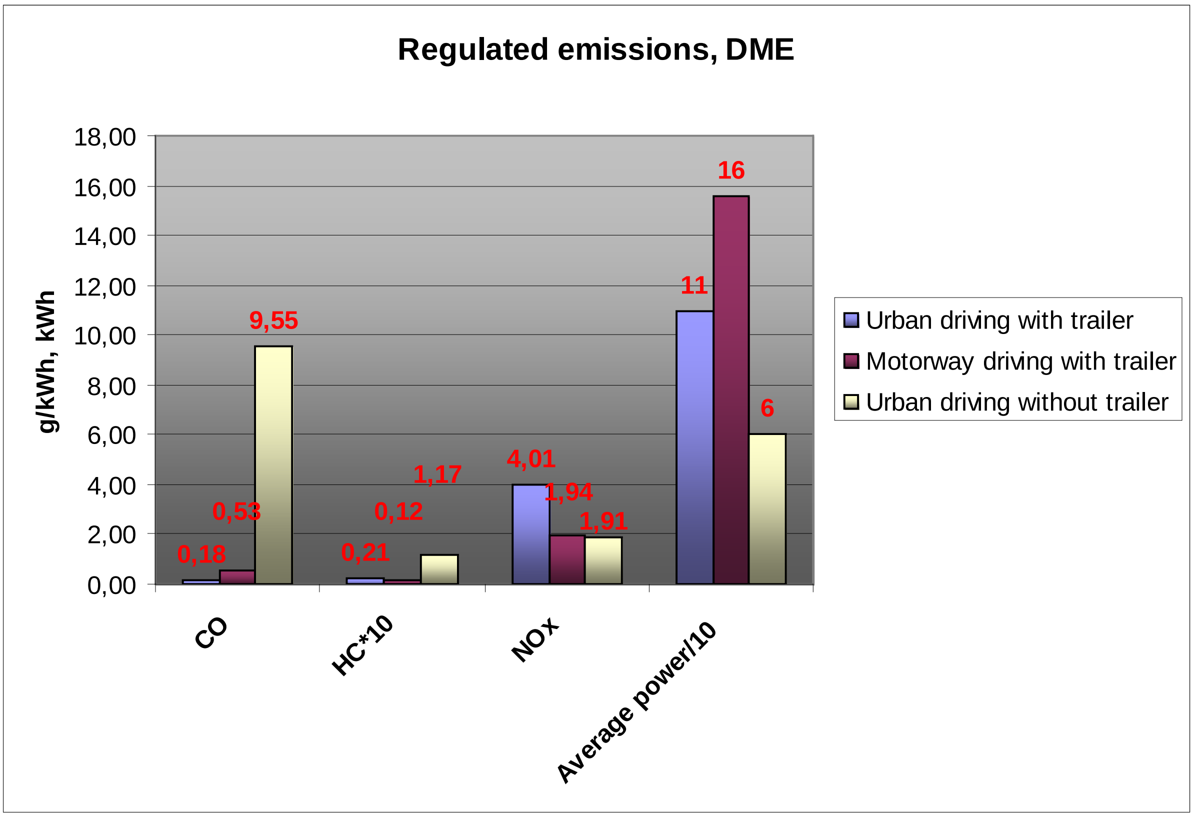


Figure 32. Brake specific emission.