TEST REPORT
TR-SITP-HDV-0009-00

Swedish In-Service Testing Programme 2009
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. Eight 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). The selection of the vehicles was based on Euro III, 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 – H in this report.

The vehicle A study was designed to compare emission levels from a Euro IIIbus pre- and after the installation of a retrofit exhaust after treatment device in order to verify if there exist any possibilities to reach Euro V levels from Euro III.

Vehicle B - C and were tested in order to compare emission levels of two identical vehicles driven by different fuels. The vehicle type chosen was an airport coach equipped with a SCR system. Two busses were tested one fuelled with diesel, and one with rapeseed methyl ester (RME).

Vehicle D type was a distribution truck and the vehicle was tested both on chassis dynamometer and on road.

Vehicle E was a truck for transportation of gravel and dirt. The vehicle was equipped with a SCR system and tested on road. The results are divided into five trips with different loads and average speeds

Vehicle F was a garbage truck chosen in order to determine if there exist any possibilities to programme the engine control unit (ECU) in order to reduce fuel consumption without increasing the emissions.

Vehicle G was a truck for transportation of construction waste. The vehicle was equipped with a SCR system fulfilling Euro V EEV and the scope of the investigation was to determine emission levels at different loads.

Vehicle H was a long distance truck. The vehicle was equipped with a EGR system fulfilling Euro V.

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 in the future also 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 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 meeting have been organized by JRC and interested parties have been invited to share experience. 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 2009, contract no TSA 2009:236, is now presented in this report.

Test program

Eight vehicles have been tested on road by a portable exhaust measurement system, two of them in different constellations i.e. exhaust after treatment devices and engine optimisation. 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 – H.

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)

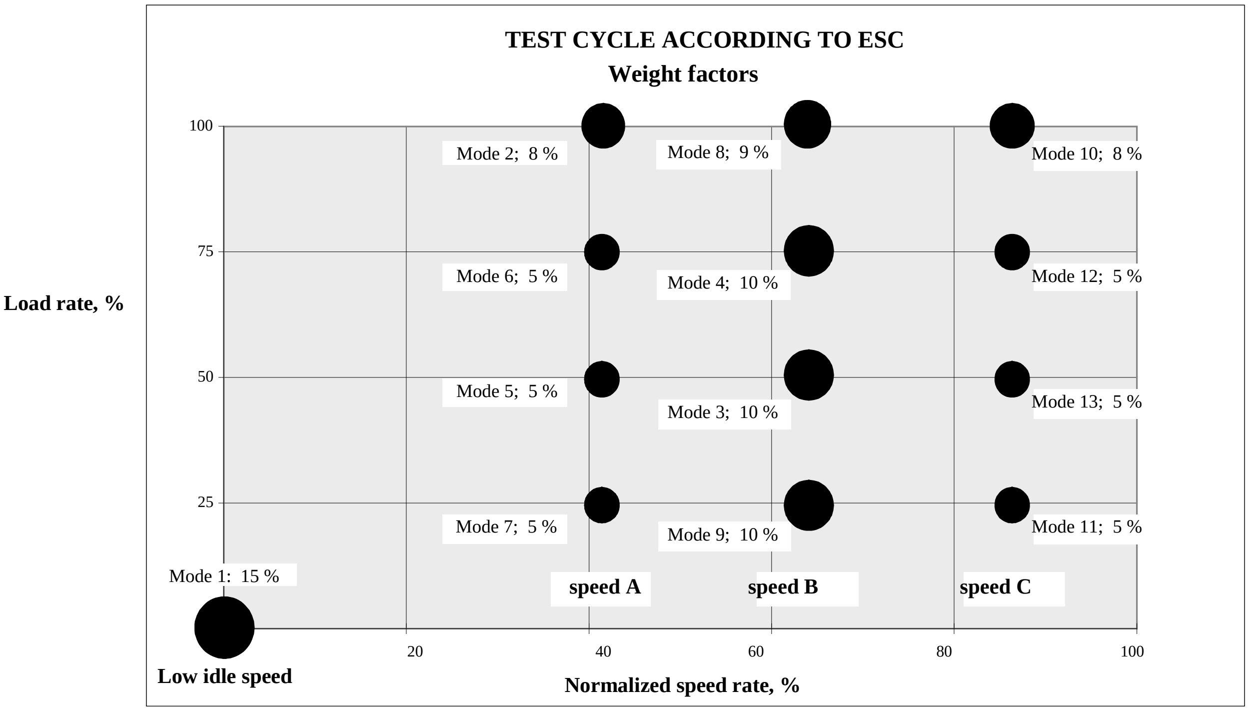

Figure 1: The ESC steady state test cycle.

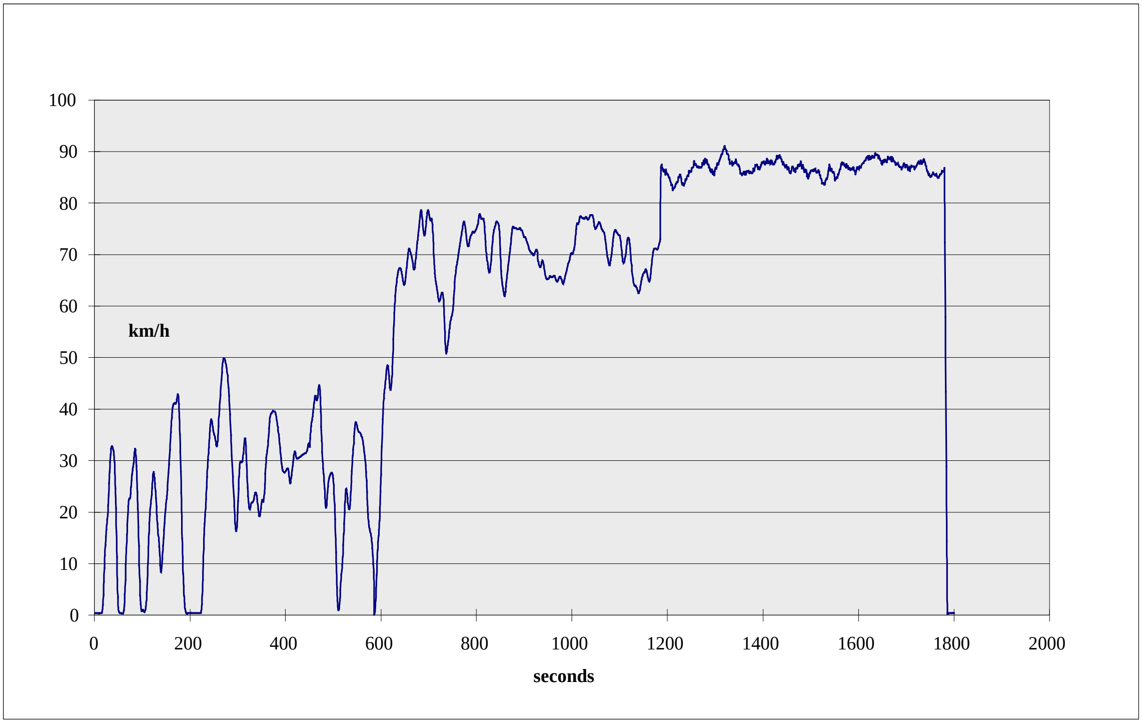

***Figure 2**:* The Fige test cycle – chassis dynamometer version of the ETC cycle**.**
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Test equipment

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 photo-acoustic 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 III, 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 aim of the vehicle A study was to compare emission levels from the bus pre- and after the installation of a retrofit exhaust after treatment device in order to verify if there exist any possibilities to reach Euro V levels from Euro III. The retrofit system consisted of urea injection and a particulate filter (SCRT). The bus was also tested after nine months i.e 53000 km mileage accumulation.

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

The vehicle was tested on roads during traffic situations normal to city busses. Extra load, 5775 kg, was used to simulate 82 passengers.

Commercially available Environmental class 1 diesel (Mk1) was used and the vehicle was served in accordance to the manufacturer specification. The vehicle was tested at an average ambient temperature of 20 ^{o}C and slight wet road surface during all test occasions.

AVL MTC did not have any control over the test vehicle during the nine months of mileage accumulation.

The tested vehicle has been supplied through kind cooperation with Göteborgs Spårvägar.

Test route description:
In Figure 3, below are the test route presented. The average speed was 20 km/h, the duration 23 min and the distance 7.8 km. At all three test occasions, measurements were carried out in triplicate.

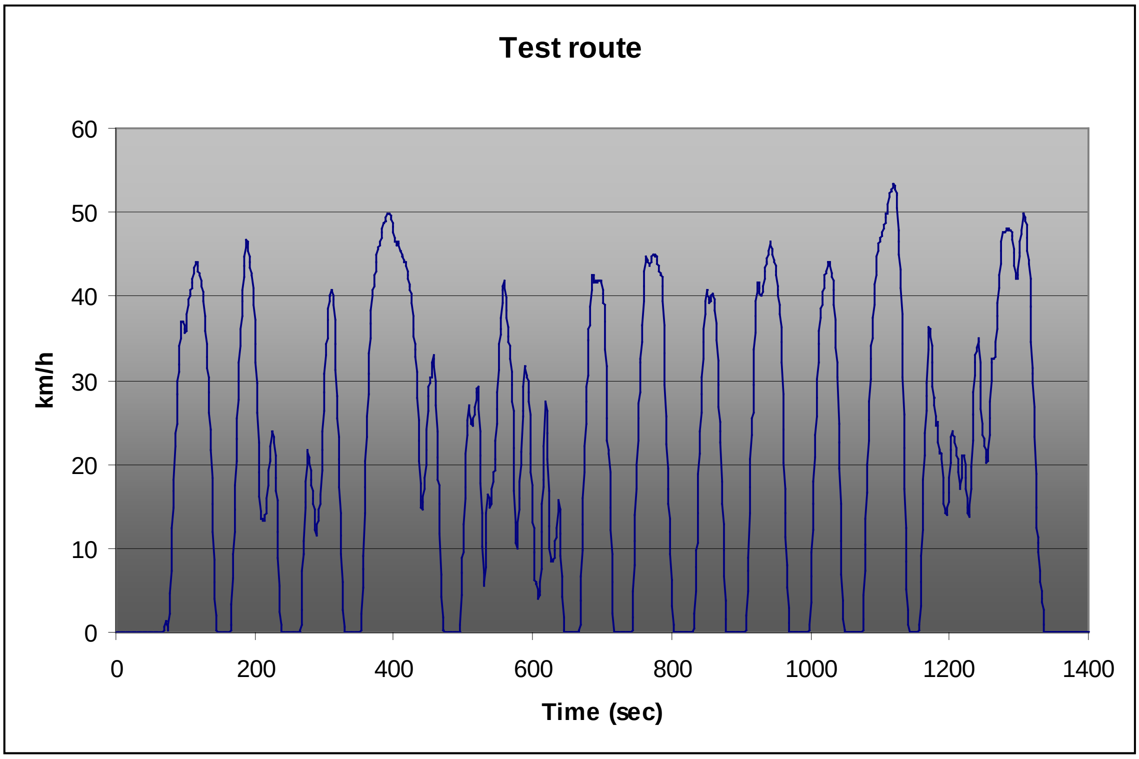

Figure 3. Driving pattern of the test route, Tagenevägen-Transportgatan, Hisingen.

Table 2. Vehicle data.

Model Year	2006
Odometer reading, km	192180 - 245280
Date of registration	2006-01-02
Approximately power, kW	250
Test weight, kg	27555

Test results

Obtained test results are presented in Figures 4 – 5 as mean value with standard deviation. From the data the following conclusions can be made.

The emissions of HC are low and close to detection limit for the test without SCRT and below detection limit for both HC and PM with SCRT.

The emission of CO was reduced by 95% and NO_x by 70% based on distance specific mass emission. An increase of 10% was noted for CO_2 when comparing the first two tests with and without the system.

After mileage accumulation the CO emission was increased with a factor of 3.8, however, still well below the Euro V value.

NO_x emissions were further reduced after mileage accumulation by 12 %.

When comparing CO_2 emissions prior installation of the system and after 9 months of driving, an increased emission of 5 % was measured.

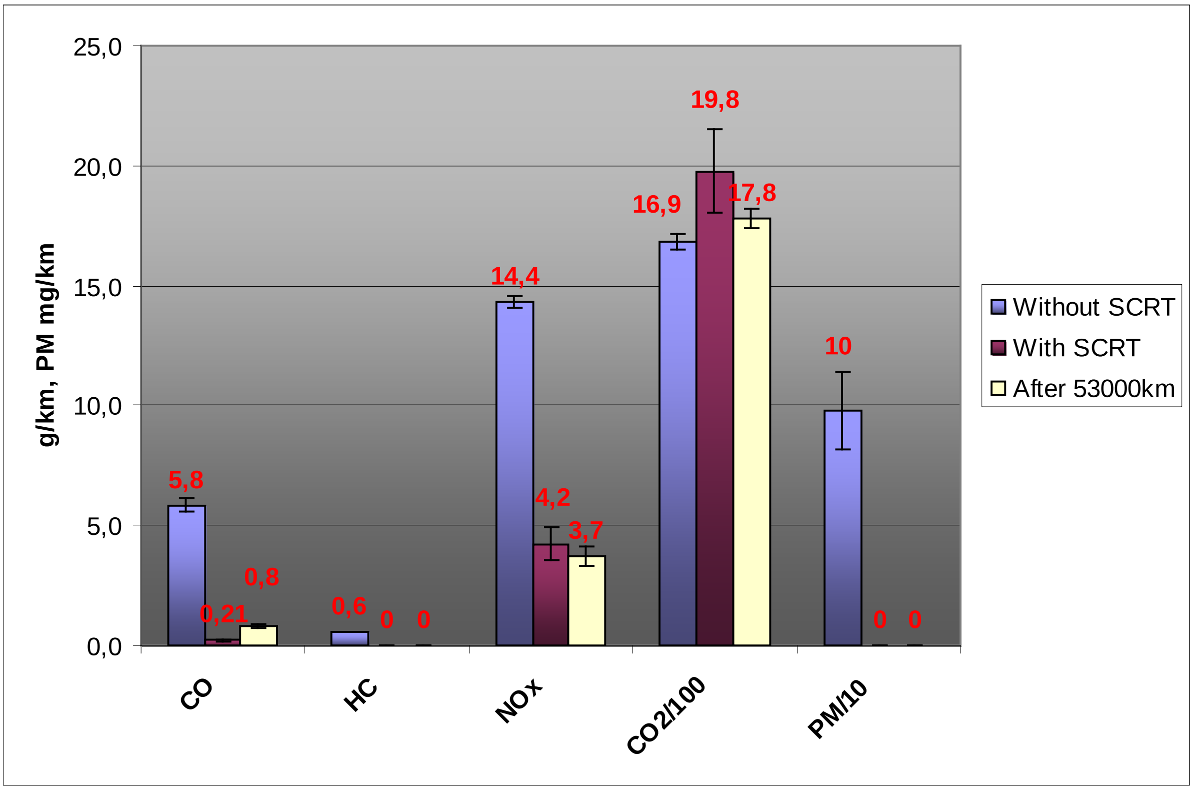

Figure 4. Distance specific mass emission.

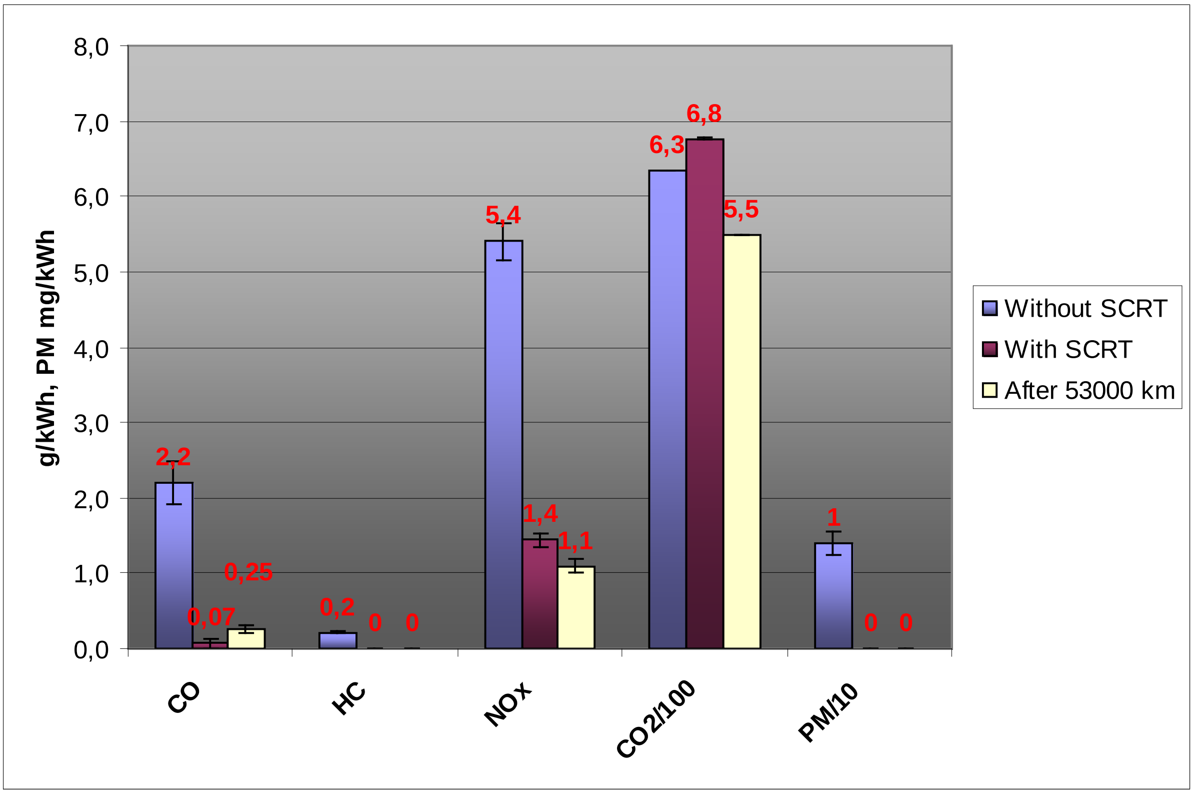

Figure 5. Brake specific emission.

When comparing the emission results in g/kWh with the legislative limits for engines used in heavy duty vehicles the first test i.e. without the system are slightly exceeding the Euro III limits for CO and NOx but well under the Euro V limits with the system. However, it must be emphasised that on-board measurement during transient driving of a vehicle and engine testing according to the European Steady State Cycle (ESC) are two complete different way of measuring exhausts. Further, during the ESC particles are being measured gravimetrically, while during on-board testing soot (approximately 80% of the particle mass) are being measured by means of a photo acoustic principle.

Table 3. Euro III and V limits.

g/kWh	Euro III, ESC	Euro V, ESC	Without SCRT	With SCRT, ESC	Mileage acc.
CO	2.1	1.5	2.2	0.06	0.25
HC	0.66	0.46	0.2	0	0
NOx	5.0	2.0	5.4	1.4	1.1
PM	0.1	0.02	0.014	0	0

Vehicle B and C.

The Aim of The selection of the test was to compare emission levels when two identical vehicles were driven on different fuels. The vehicle type chosen was a airport coach equipped with a SCR system. Two busses were tested one fuelled with diesel, and one with rapeseed methyl ester (RME).
The vehicles were tested on roads during driving conditions representing a normal working day with a load corresponding to 20 passengers i.e. 1500 kg.

Commercially available Environmental class 1 diesel (Mk1) and RME was used. The vehicles were served in accordance to the manufacturer specifications. Both vehicles were tested at an average ambient temperature of approximately 10 ^{o}C.

The tested vehicle has been supplied through kind cooperation with Flygbussarna Airport Coaches AB

Two test runs, were carried out for each vehicle. Test run one was the route from the central area of Stockholm to Bromma airport and test run two from the same site in central Stockholm to Arlanda airport. Measurements were carried out in both directions. Test run two is divided into total trip as well as only the motorway part.

Test route description:
Below are the test routes presented with data in Tables and a plot speed vs time in Figures. From Figure one and two it can be seen that the last seconds in the plot are missing due to parking in a garage, thus losing the GPS signal.

Table 4. City- Bromma – City, test route data.

Trip duration (s)	2240
Trip distance (km)	31
Average speed (km/h)	31

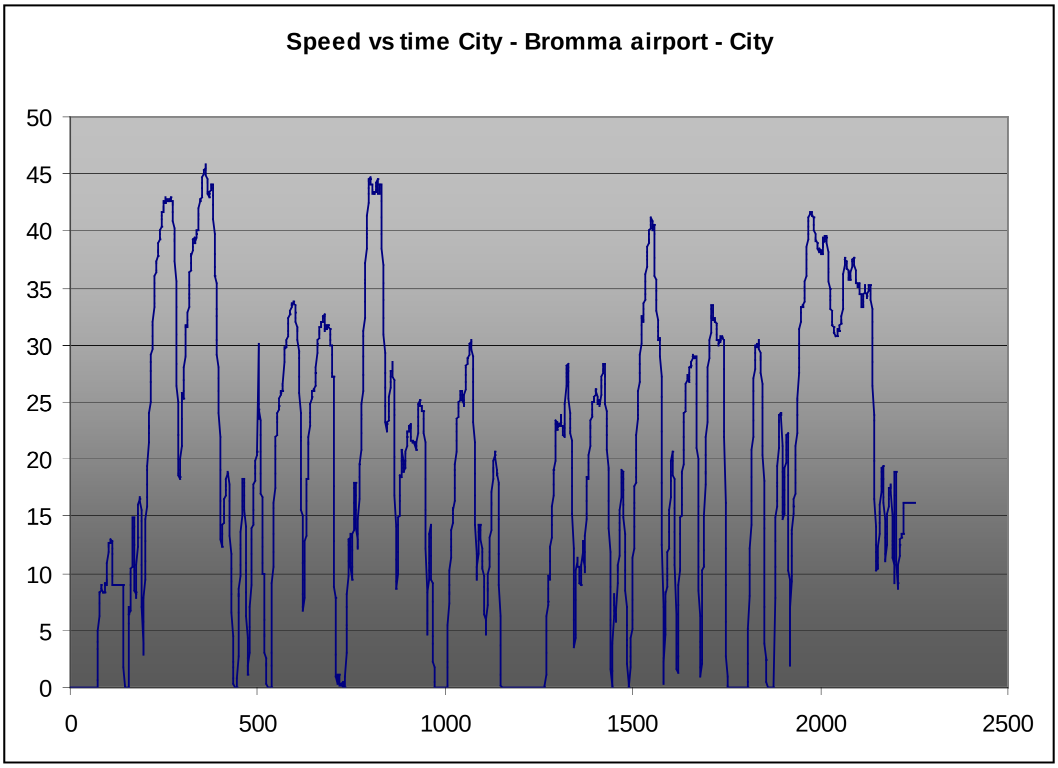

Figure 6. Speed vs. time, Bromma.

Table 5. City – Arlanda – City, test route data.

Trip duration (s)	6350
Trip distance (km)	86.2
Average speed (km/h)	49

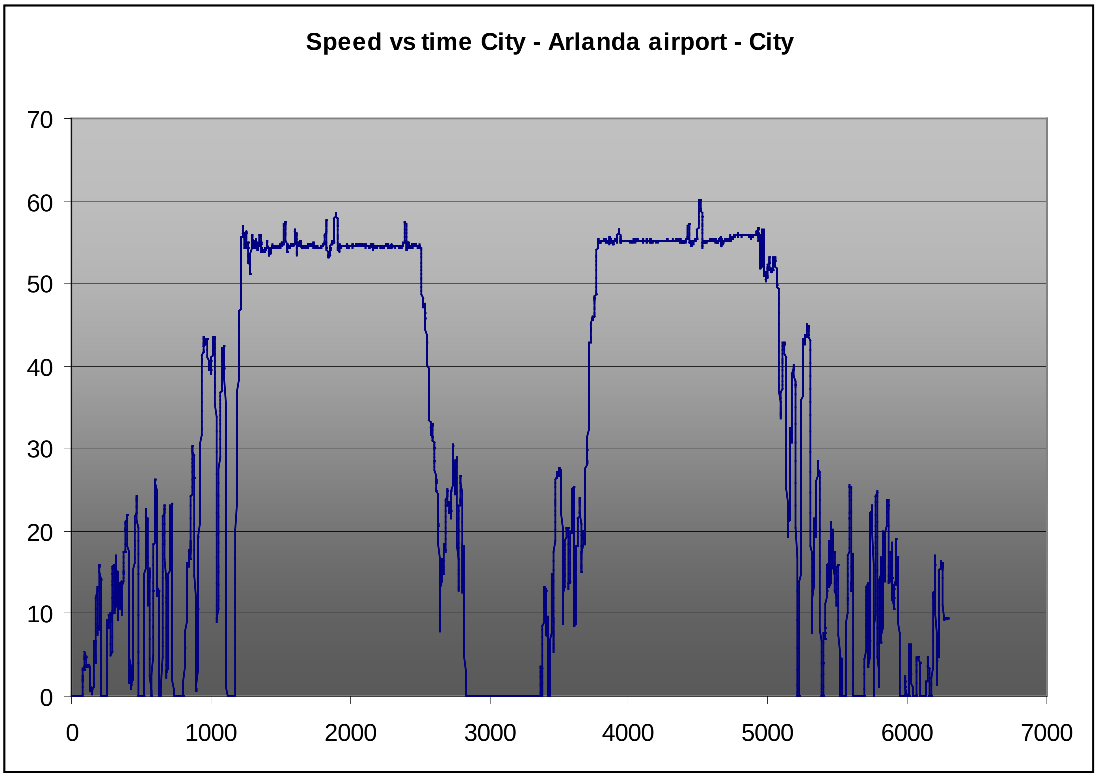

Figure 7. Speed vs. time, Arlanda.

Table 6. Motorway, test trip data.

Trip duration (s)	900
Trip distance (km)	22
Average speed (km/h)	89

Table 7. Vehicle data.

Year model	2008
Mileage, km	49800 (diesel), 50300 (RME)
Date of registration	December 2008
Approximately power, kW	250
Test weight, kg	17 400

Test results

From Figure 8 – 13 some general conclusions can be made. The CO emissions increases with the RME fuel with, in average, 20 % during urban and suburban driving while the CO emission are 15 % lower during motorway driving. The emissions of NOx are increasing with, in average, 42 % when using RME. Emissions of HC and soot are low from the RME 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 RME requires system temperatures of 250 ^{o}C. Thus, condensation of HC in the sampling system will reduce the yield of measured volatile components.

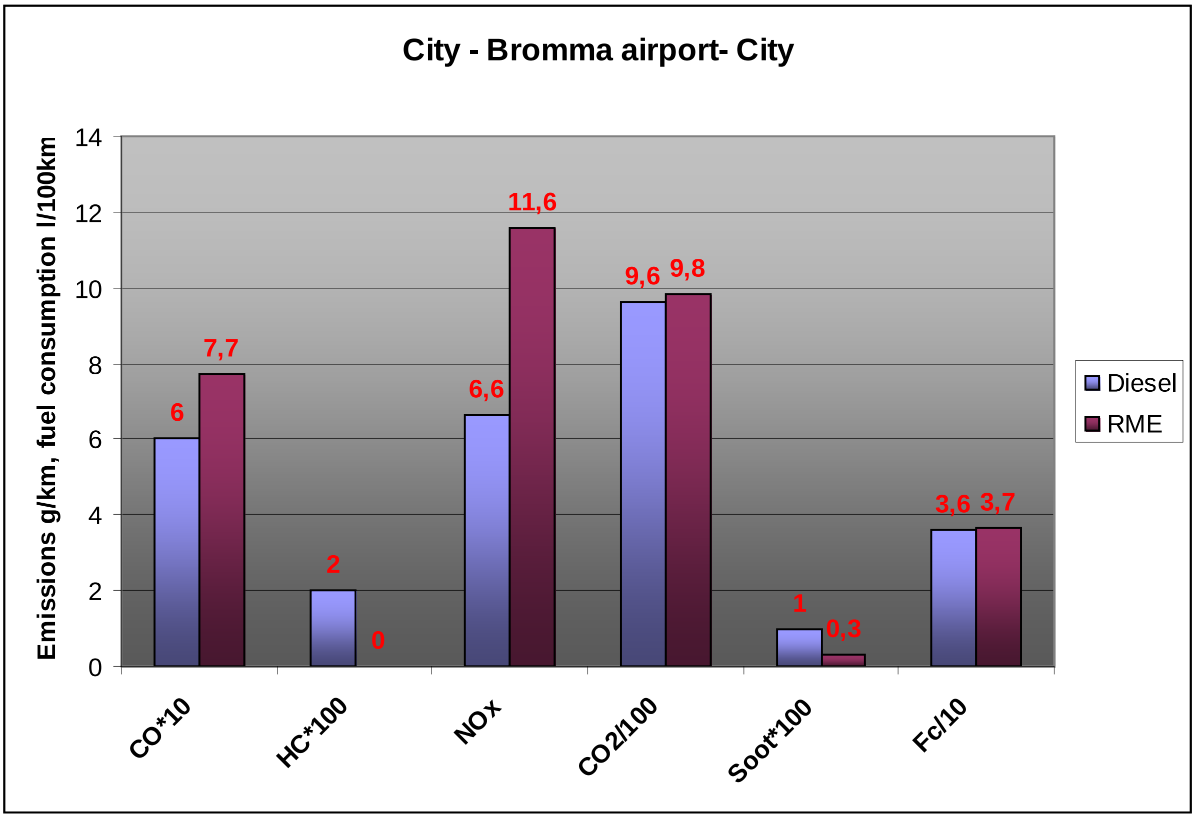

Figure 8: *Distance specific mass emissions.*

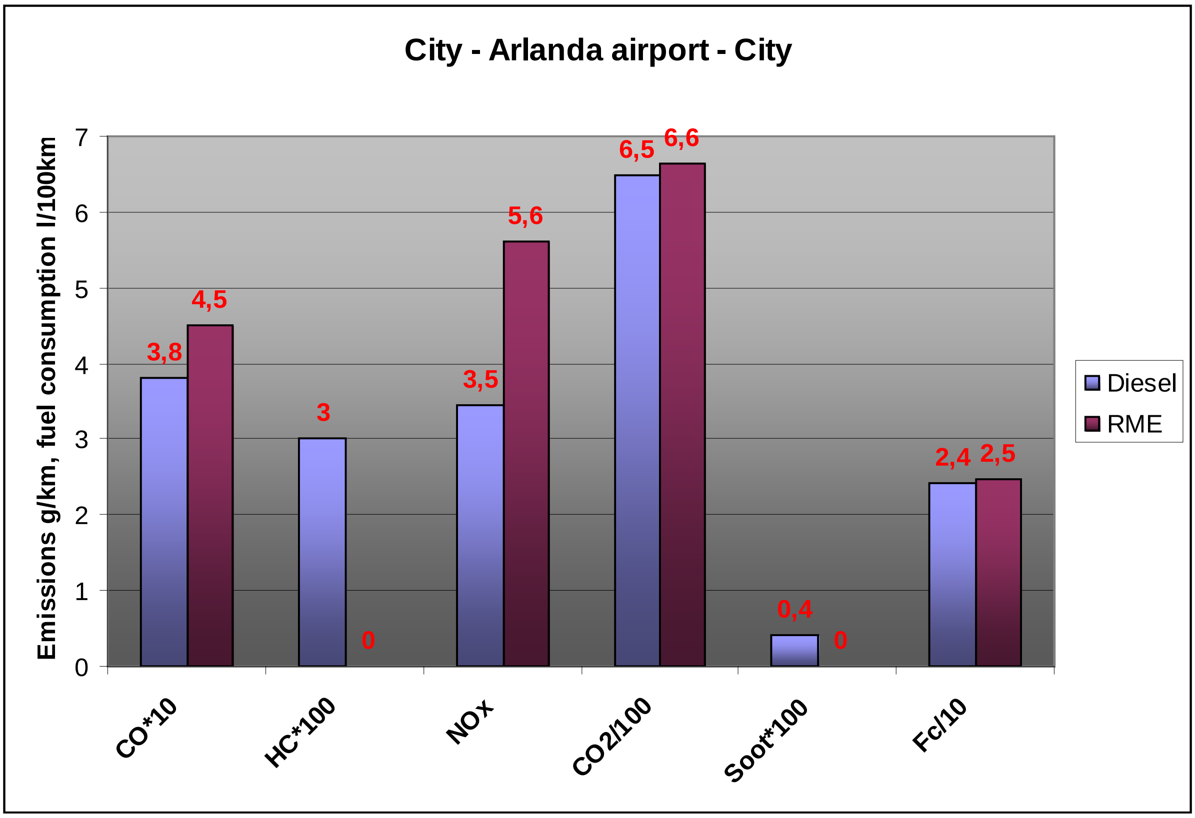

Figure 9: *Distance specific mass emissions.*

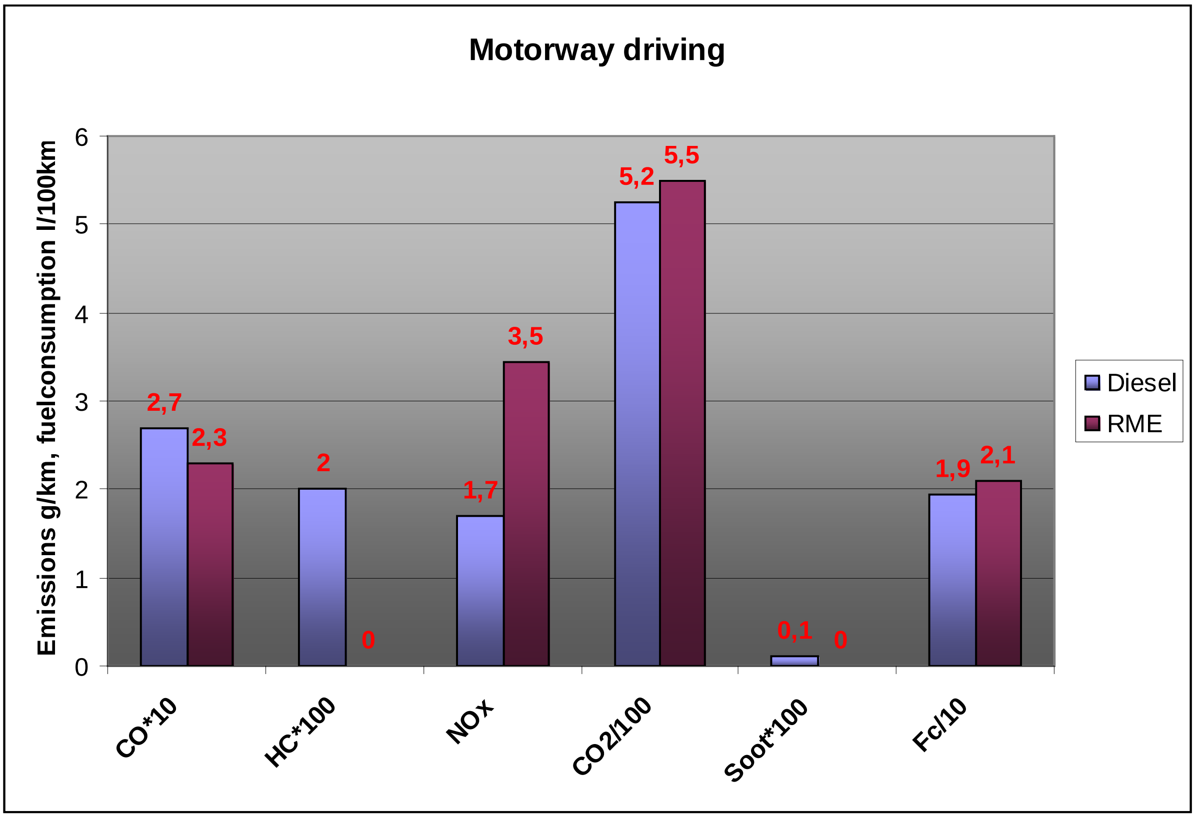

Figure 10: *Distance specific mass emissions.*

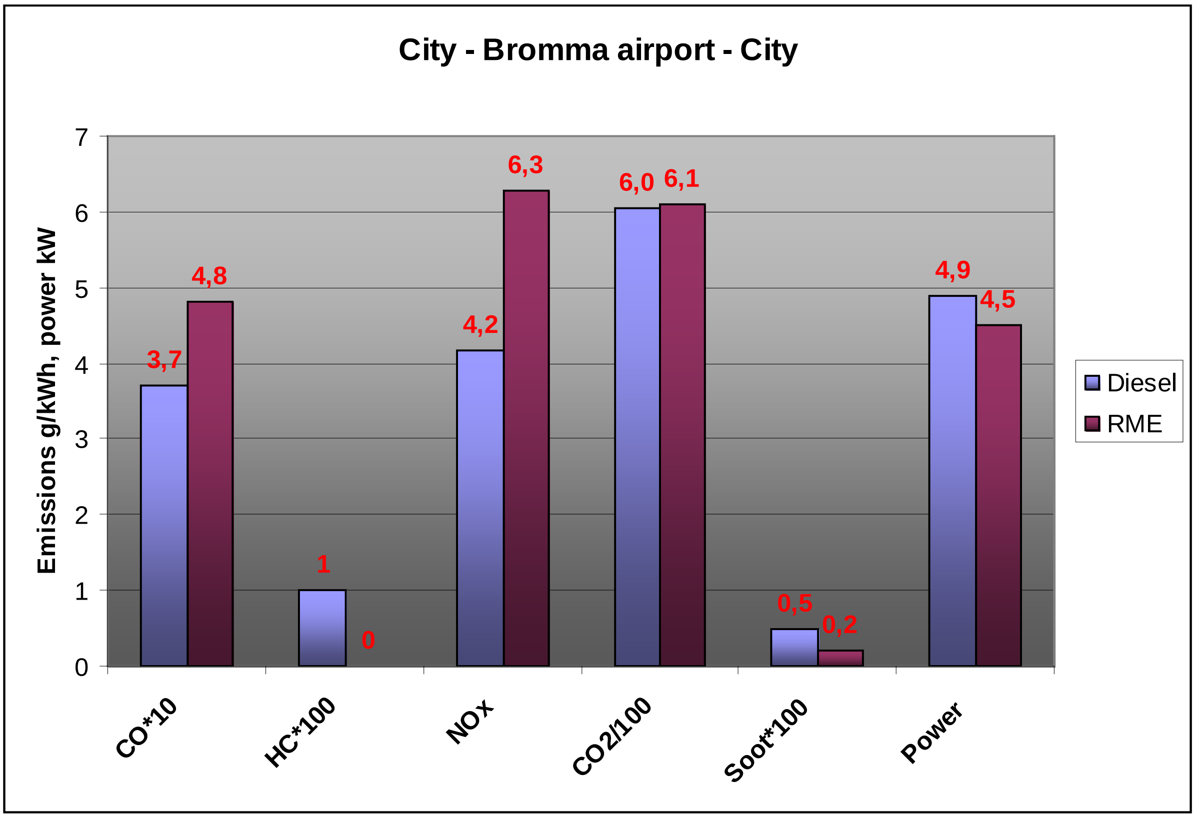

Figure 11: *Brake specific emissions. Power/10*

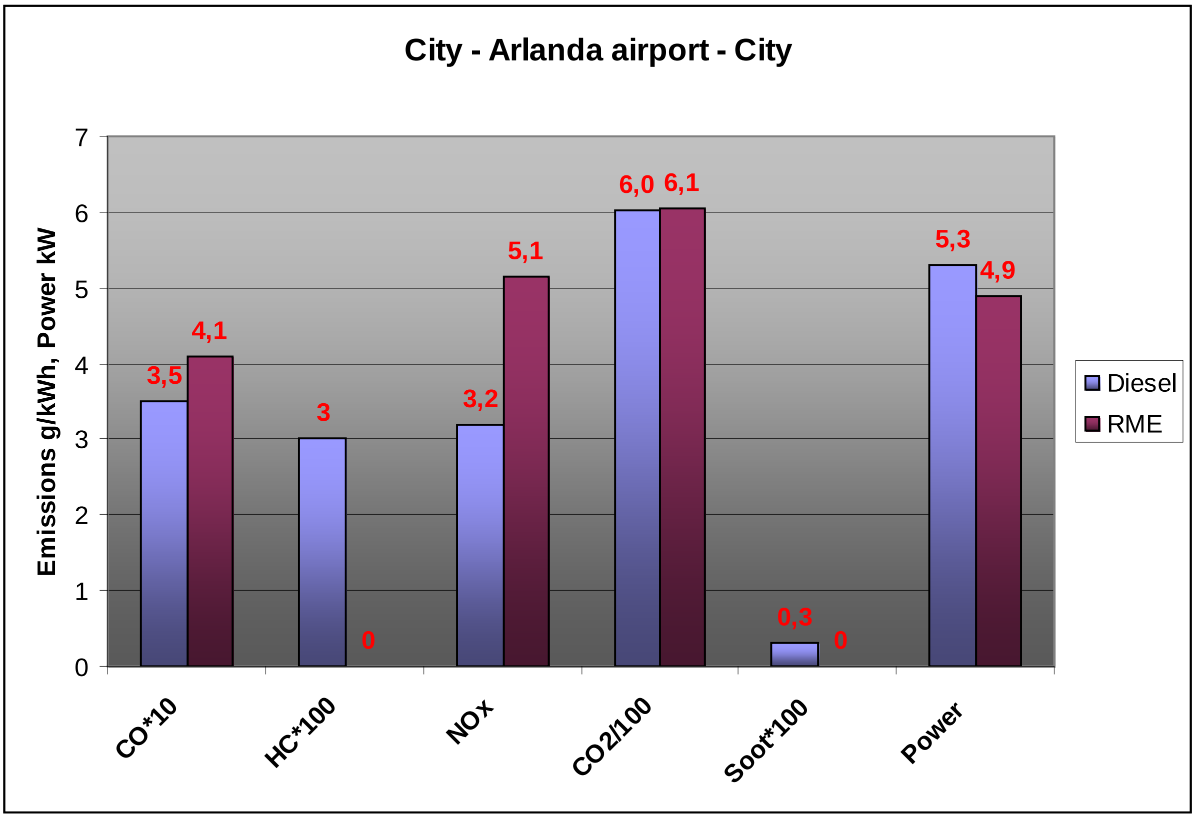

Figure 12: *Brake specific emissions. Power/10*

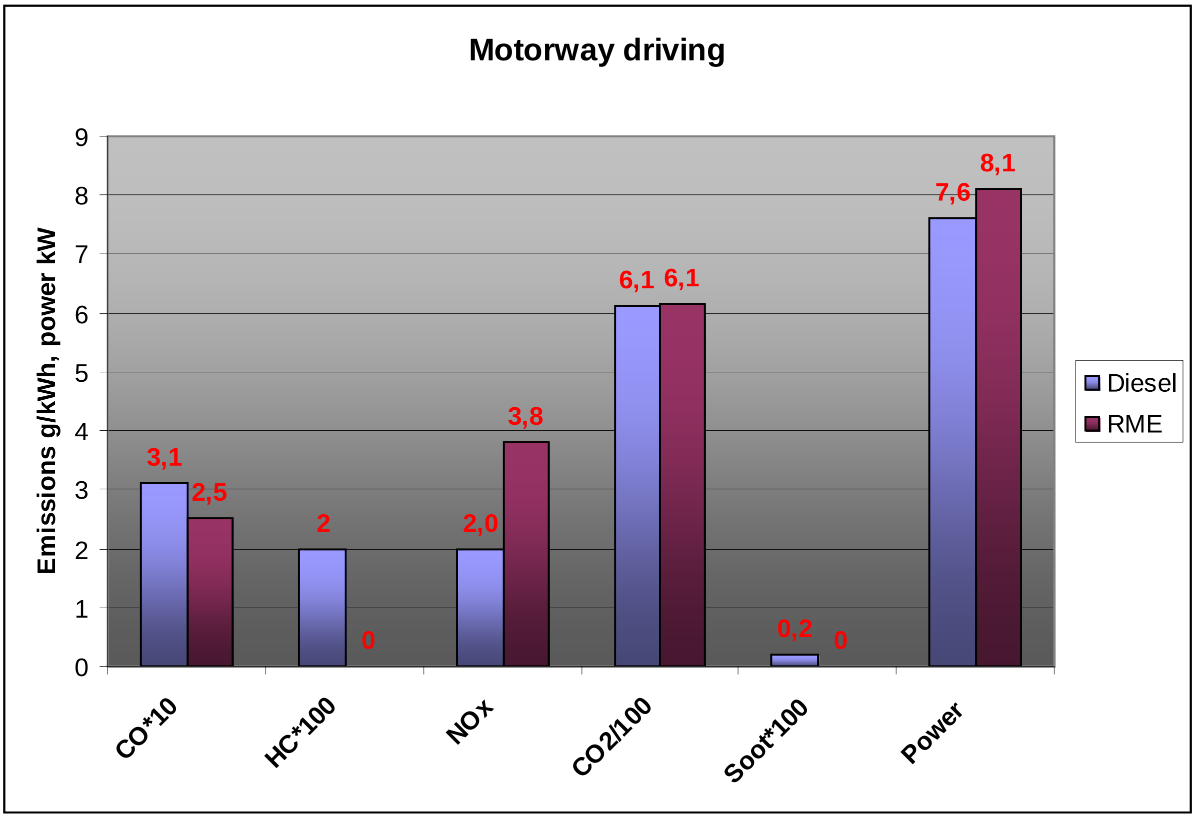

Figure 13: *Brake specific emissions. Power/10*

Vehicle D.

The vehicle type chosen was a distribution truck and the vehicle has been tested both on chassis dynamometer and on road.

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

Table 8. 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

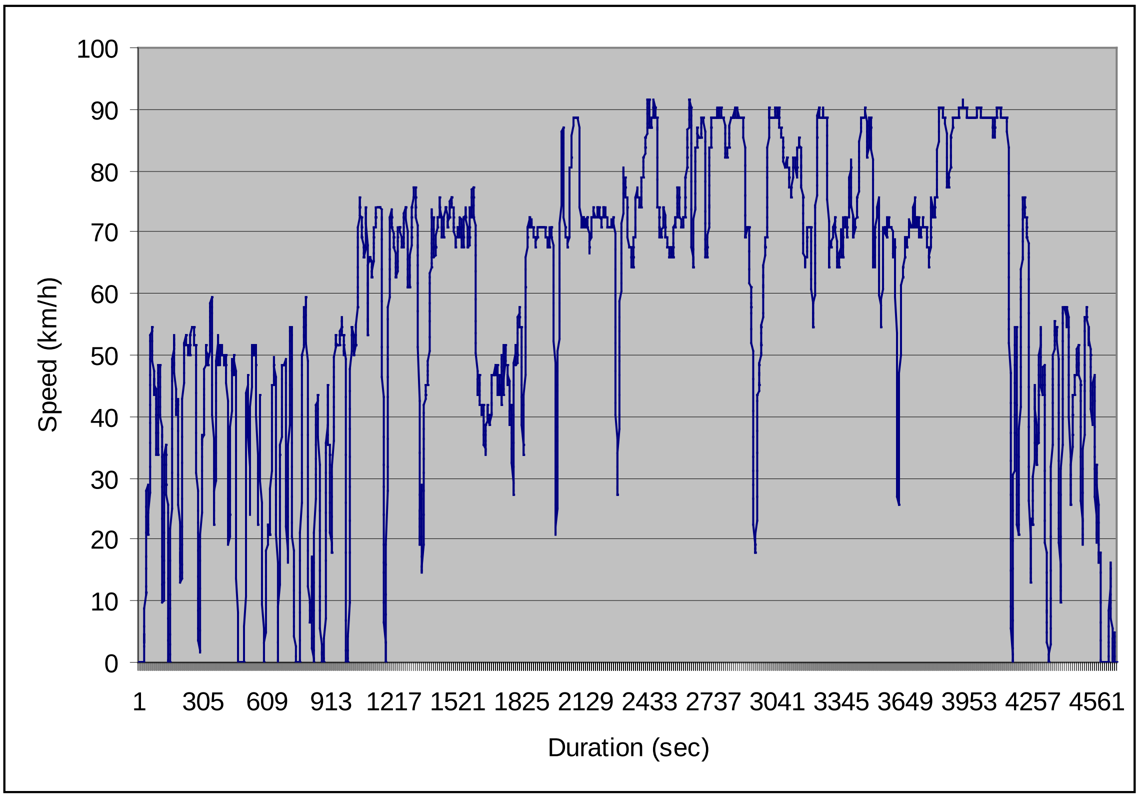

Figure 14: *The PEMS test route*

Presentation of test vehicle:
Table 9. Vehicle data.

Year model	2007
Mileage, km	38 500
Date of first registration	2007-12-27
Approximately power, kW	200
Test weight, kg	12 100
Exhaust after treatment	SCR

Test results

Obtained test results are presented in Figure 15 – 18. From the data some observations can be made. The emissions of HC from the chassis dynamometer testing and the soot measurement from the on-board testing are below the detection limit. It shall also be emphasised that HC from the on-board testing are close to the detection limit and may thus not be reliable. Further, the vehicle complies with the emissions standards.

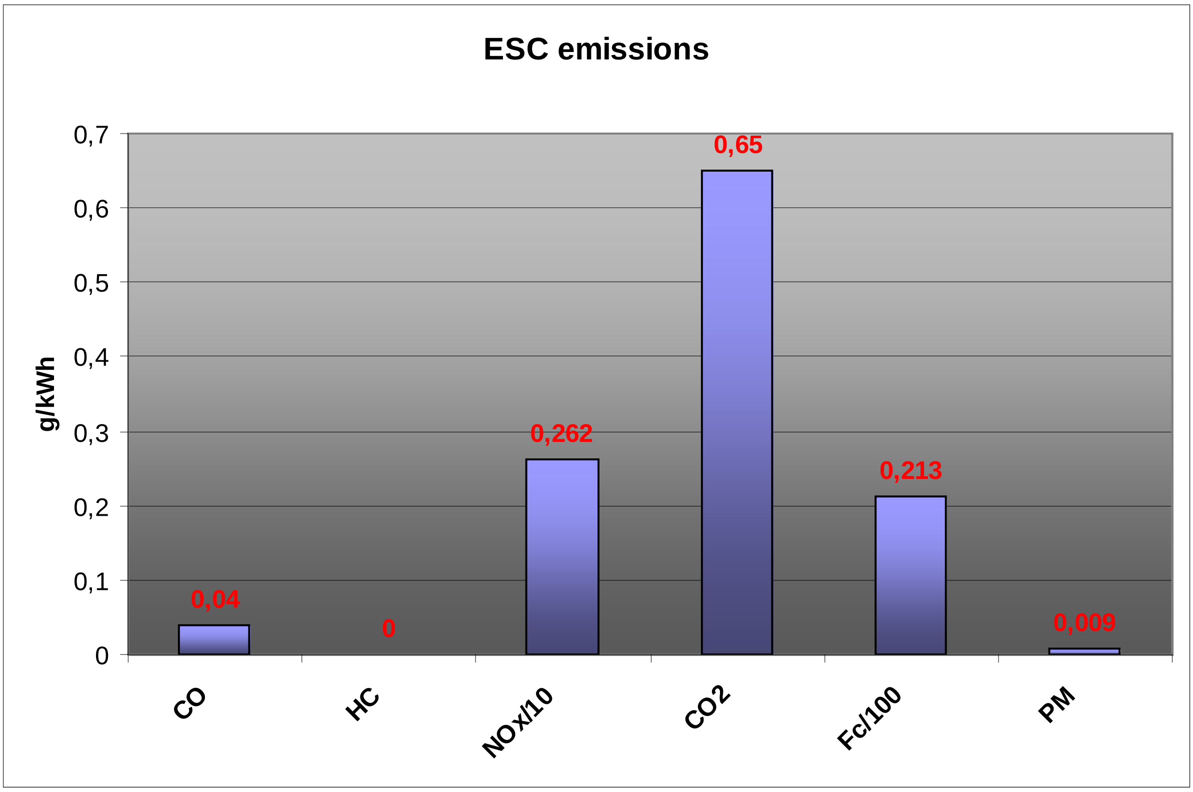

Figure 15: *Brake specific emissions ESC.*

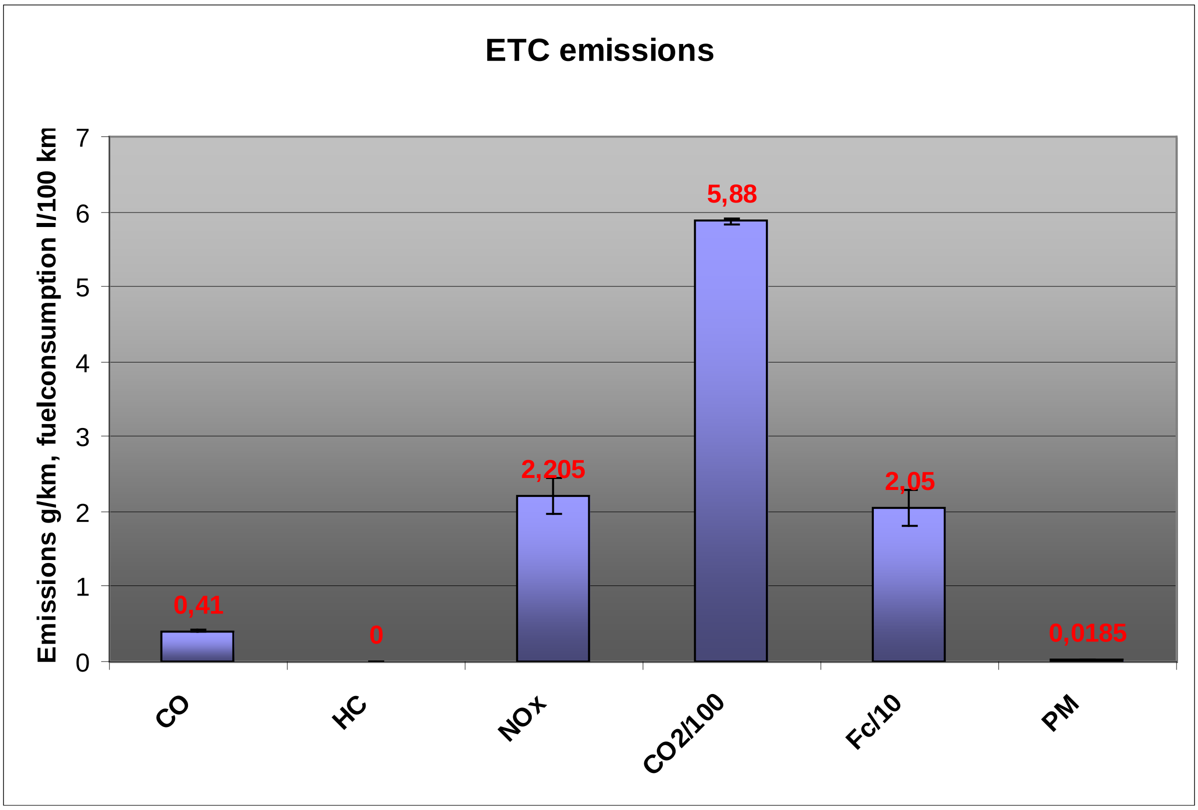

Figure 16: *Distance specific mass emissions, ETC.*

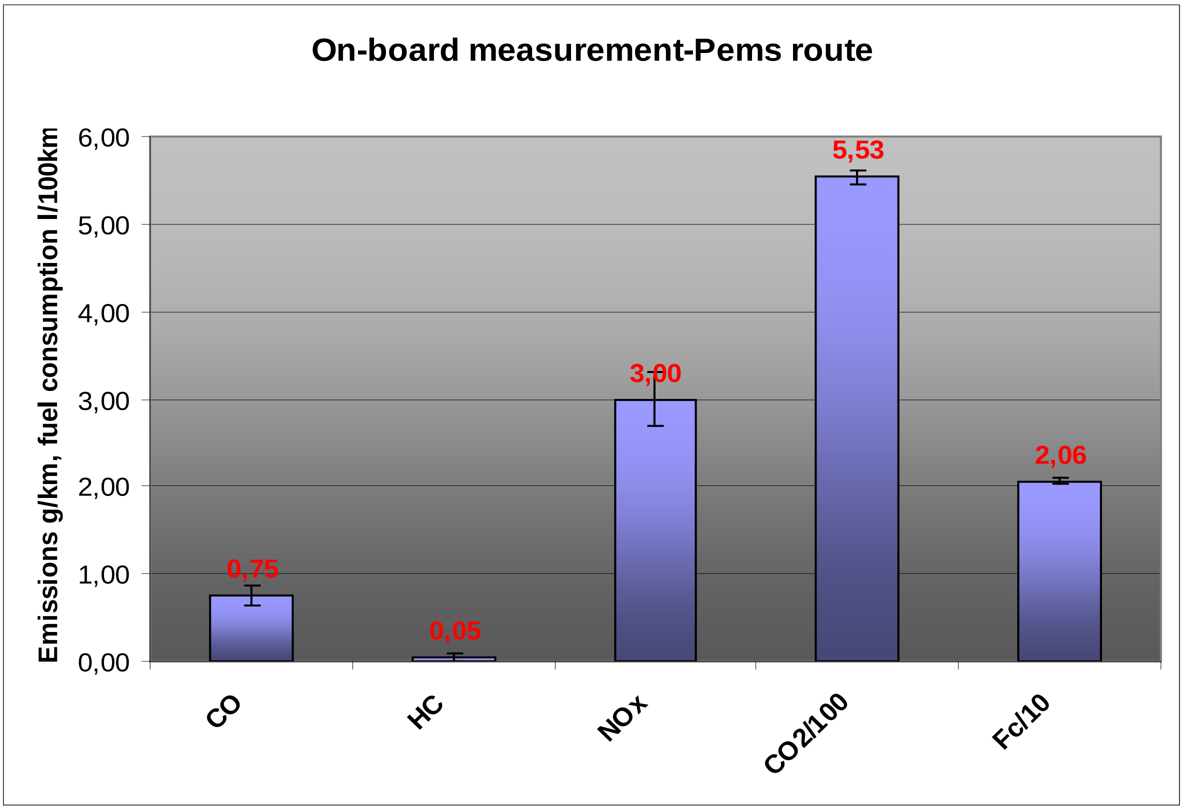

Figure 17: *Distance specific mass emissions, Pems route.*

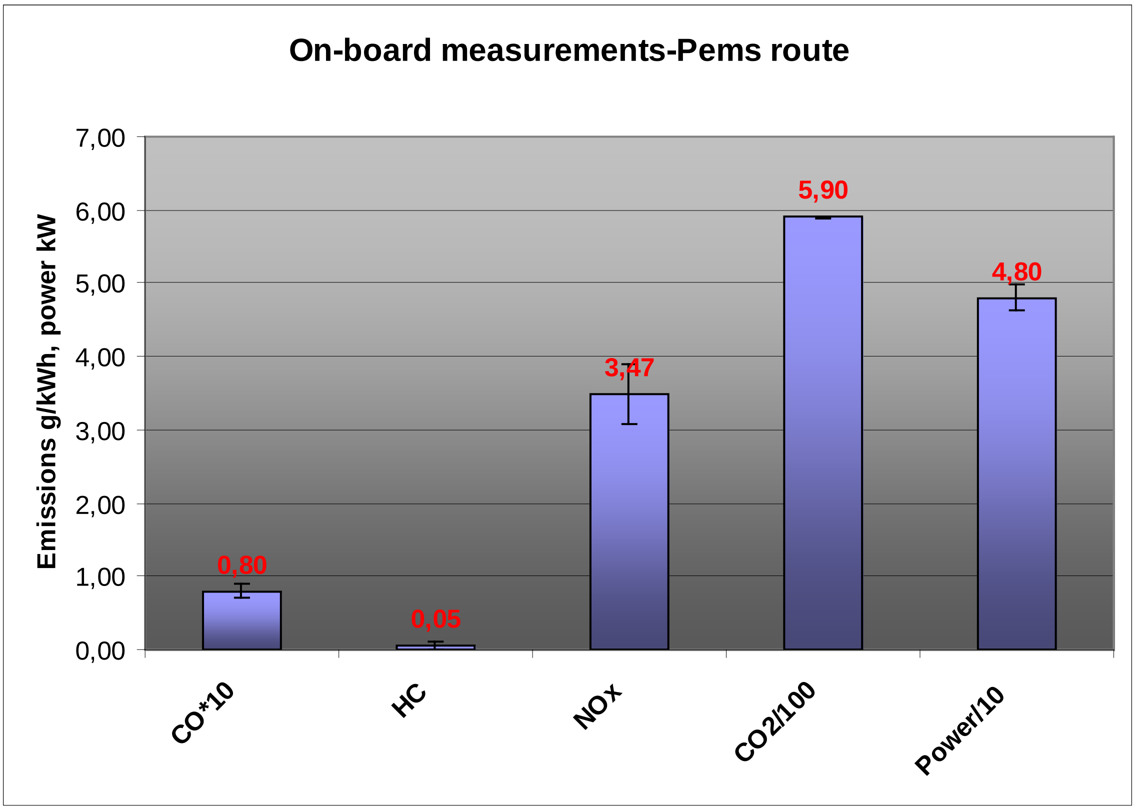

Figure 18: *Brake specific emissions, Pems route.*

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Vehicle E

The vehicle type chosen was a truck for transportation of gravel and dirt. The vehicle was equipped with a SCR system.

The vehicle was tested on roads during driving conditions and loads representing a normal working day.

Commercially available Environmental class 1 diesel (Mk1) was used and the vehicle was served in accordance to the manufacturer specification. The vehicle was tested at an average ambient temperature of -5 ^{o}C.

The tested vehicle has been supplied through kind cooperation with PG´s Maskin AB, Saltsjö-Boo.

Test route description:
Below are the test routes presented divided into five trips with different test weights and average speeds, Figure 19 - 23.

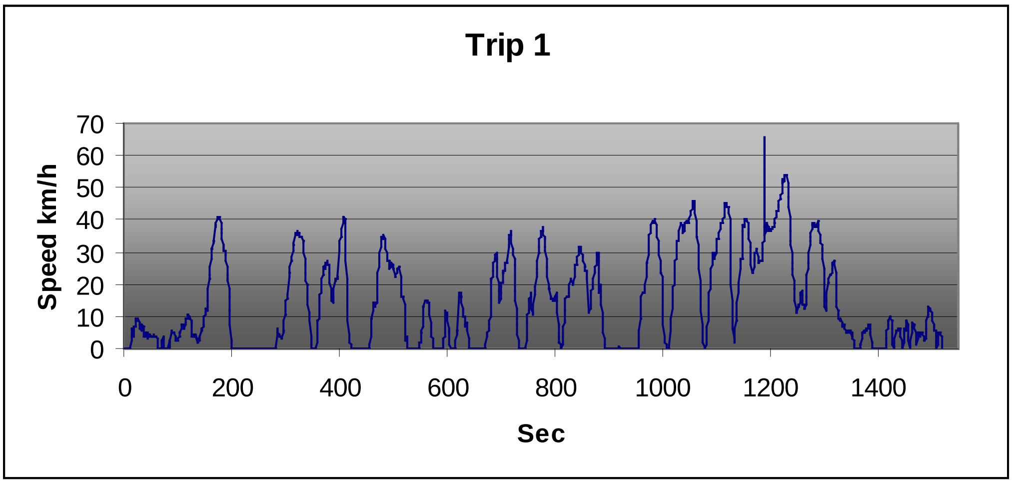

Figure 19. Driving pattern trip 1. Average speed 15 km/h and 12 tonnes test weight.

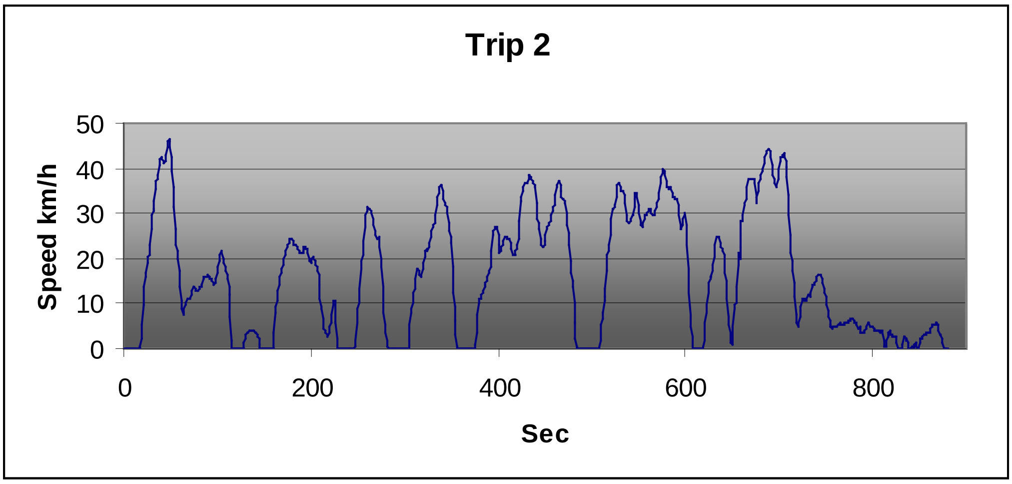

Figure 20. Driving pattern trip 2. Average speed 40 km/h and 12 tonnes test weight.

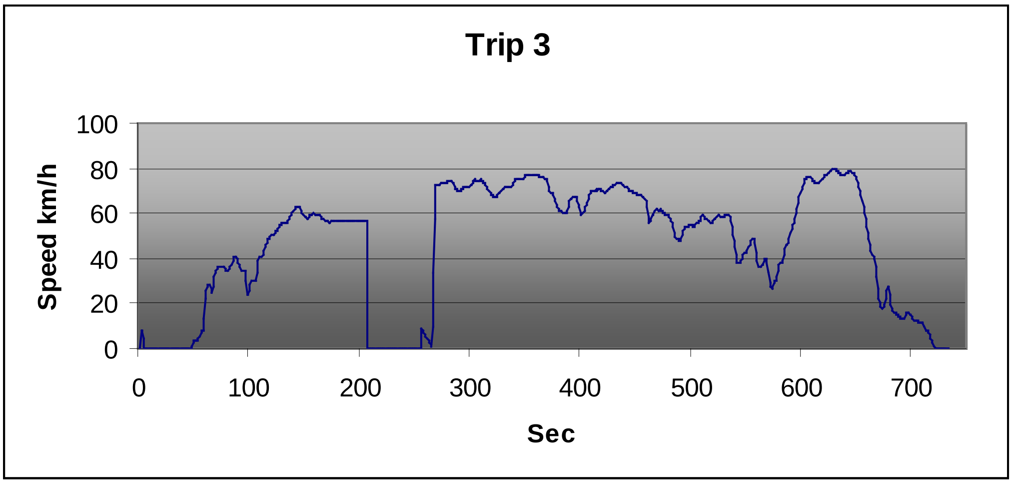

Figure 21. Driving pattern trip 3. Average speed 15 km/h and 16 tonnes test weight.

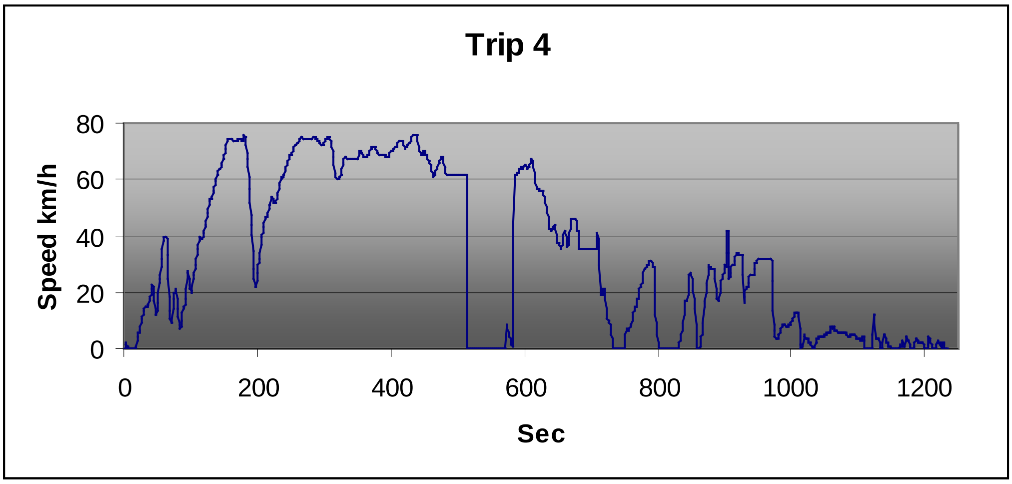

Figure 22. Driving pattern trip 4. Average speed 35 km/h and 12 tonnes test weight.

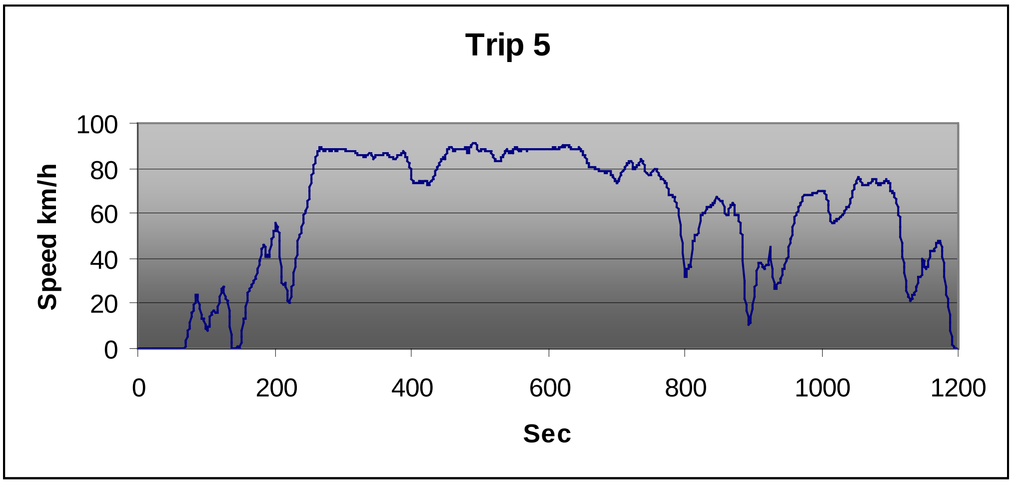

Figure 23. Driving pattern trip 5. Average speed 70 km/h and 25 tonnes test weight.

Presentation of vehicle:
Table 10. Vehicle data.

Year model	2008
Mileage, km	67 200
Date of registration	January 2008
Approximately power, kW	280
Test weight, kg	12 000 – 25 000

Test results

As can be seen from below presented figures high emissions of CO and NOx were detected while the HC emission are low and close to detection limit. High NOx levels may be du due to the weather conditions, sub zero degrees, where the EGR is not active. High fuel consumption during trip 1 is du to start/stop driving and idling while the increased consumption in trip 4 and 5 are due to the load

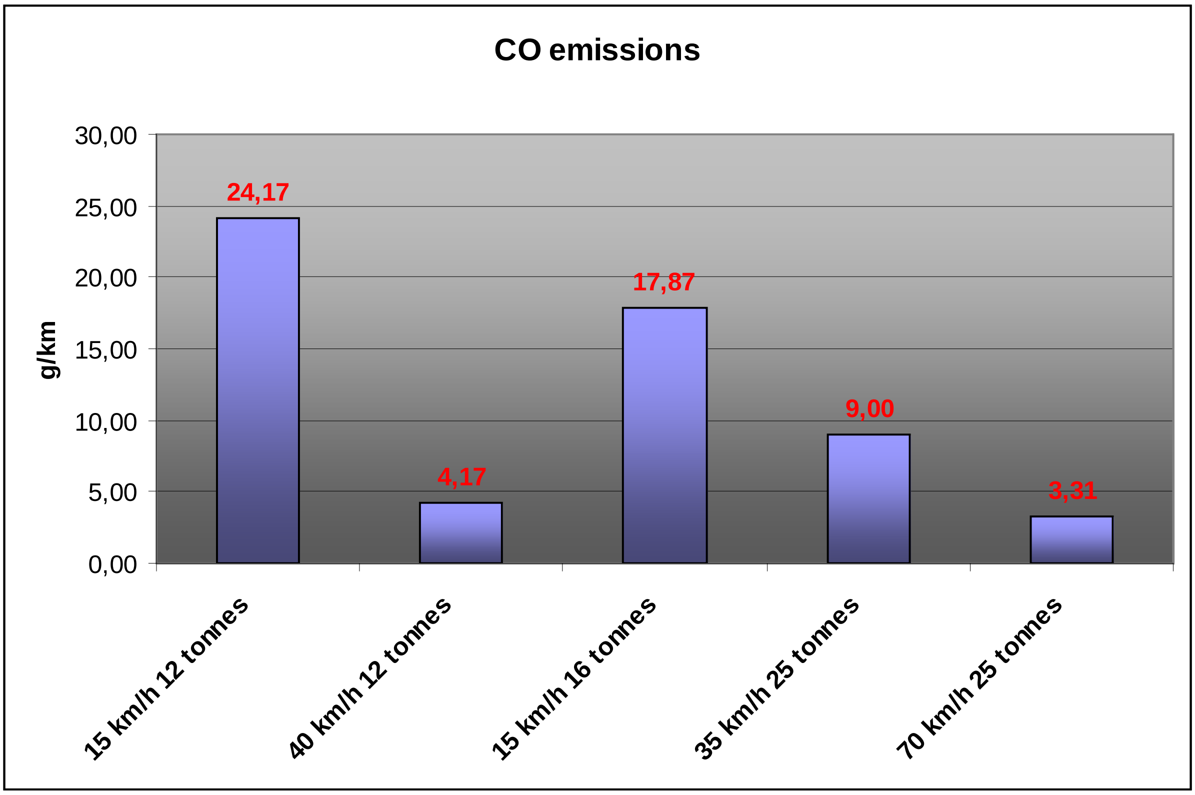

Figure 24. Distance specific CO emissions.

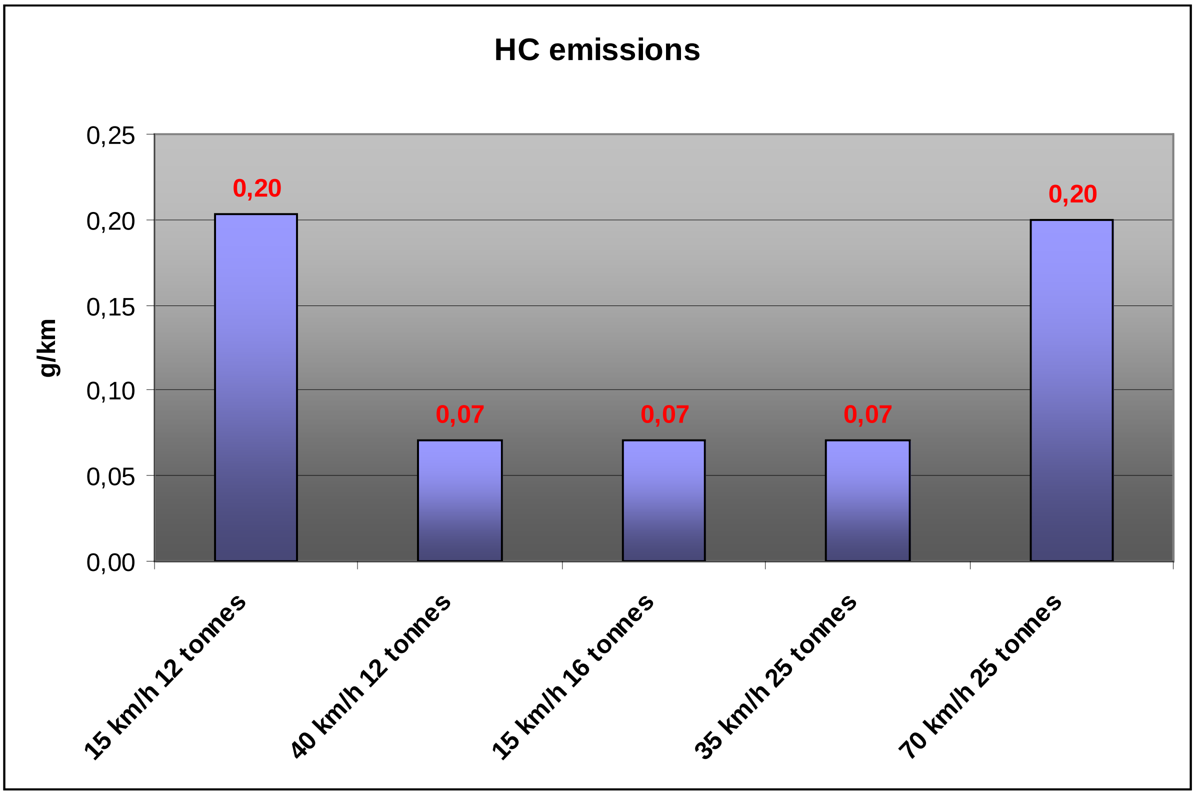

Figure 25. Distance specific HC emissions.

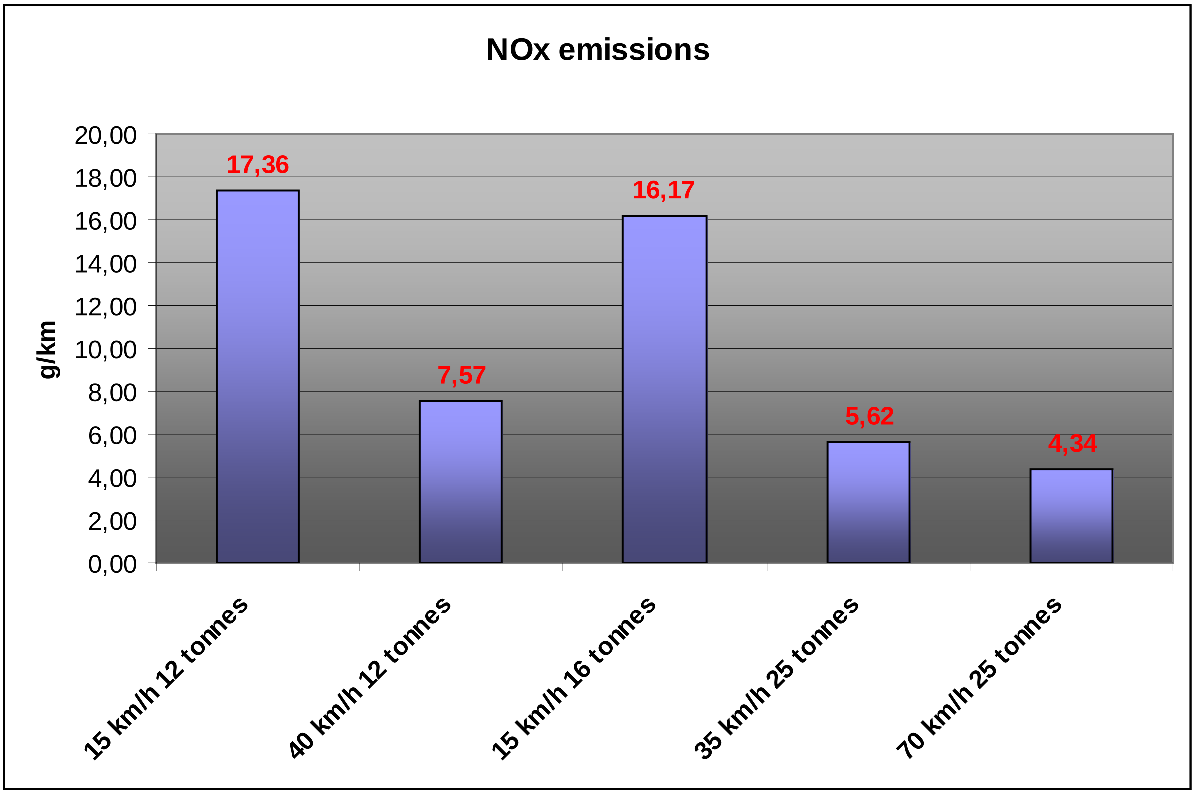

Figure 26. Distance specific NOx emissions.

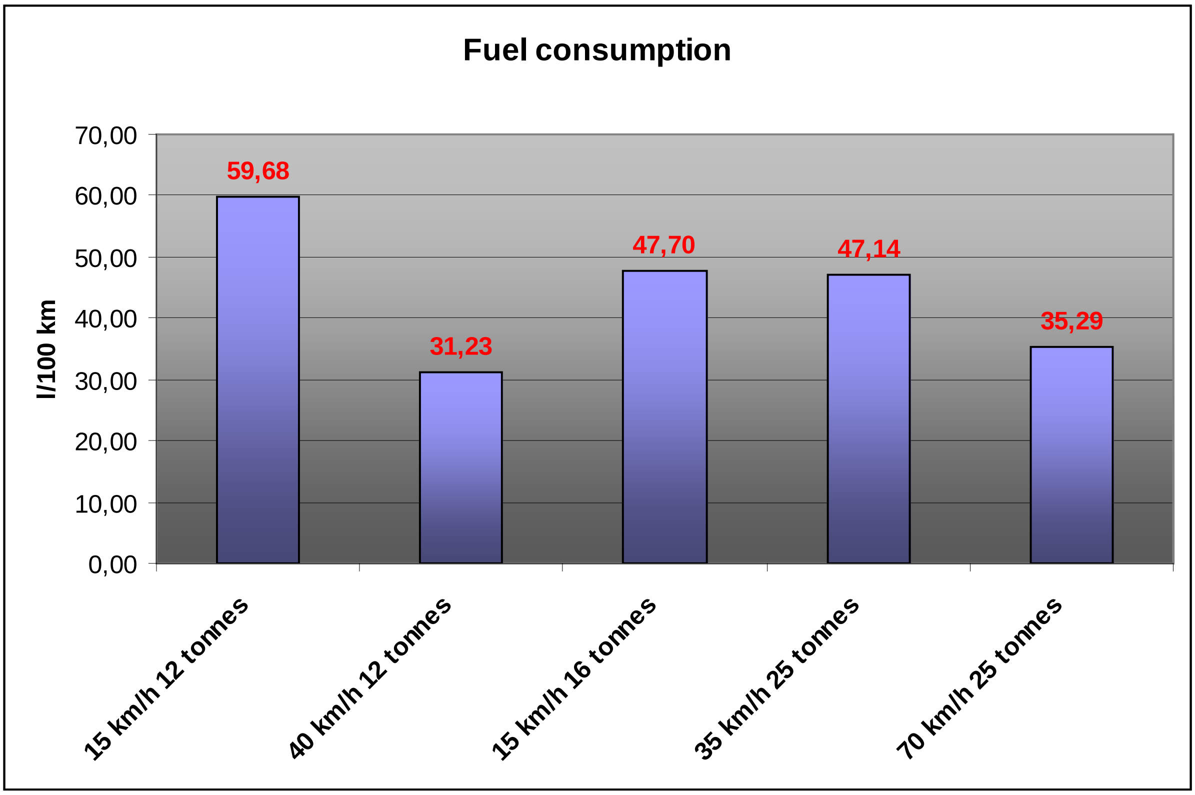

Figure 27. Fuel consumption.

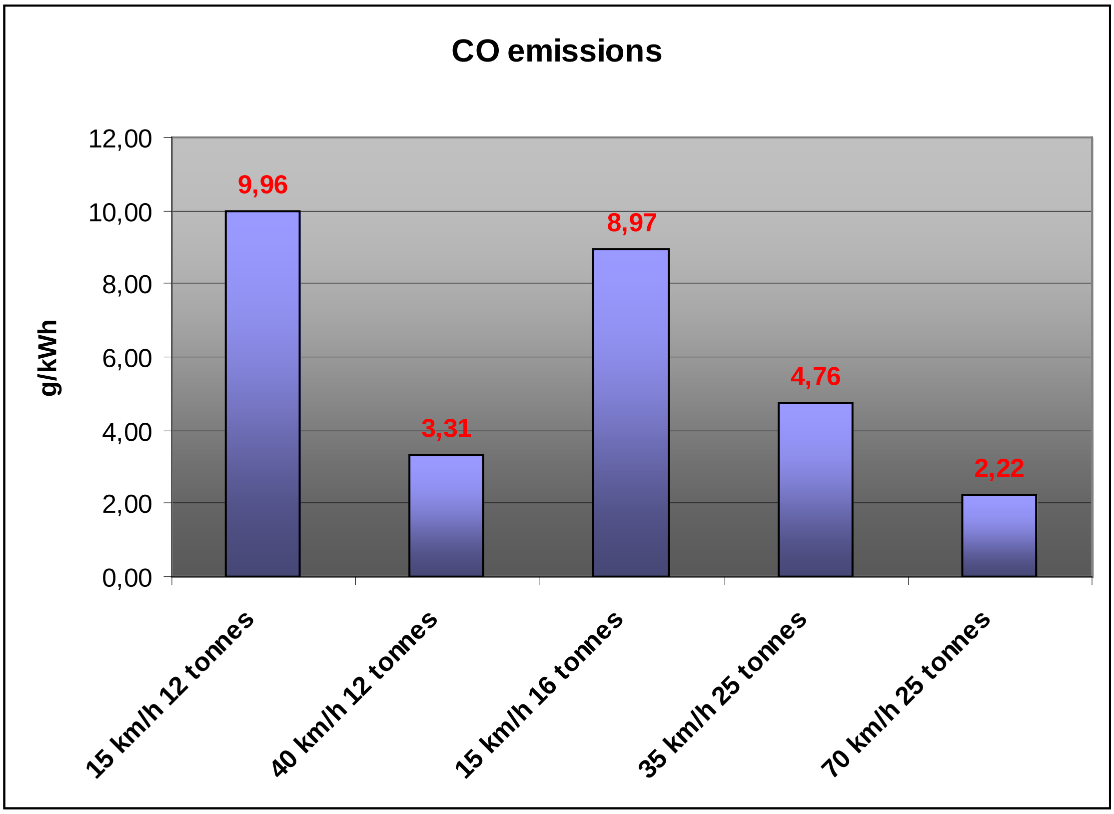

Figure 28. Brake specific CO emissions.

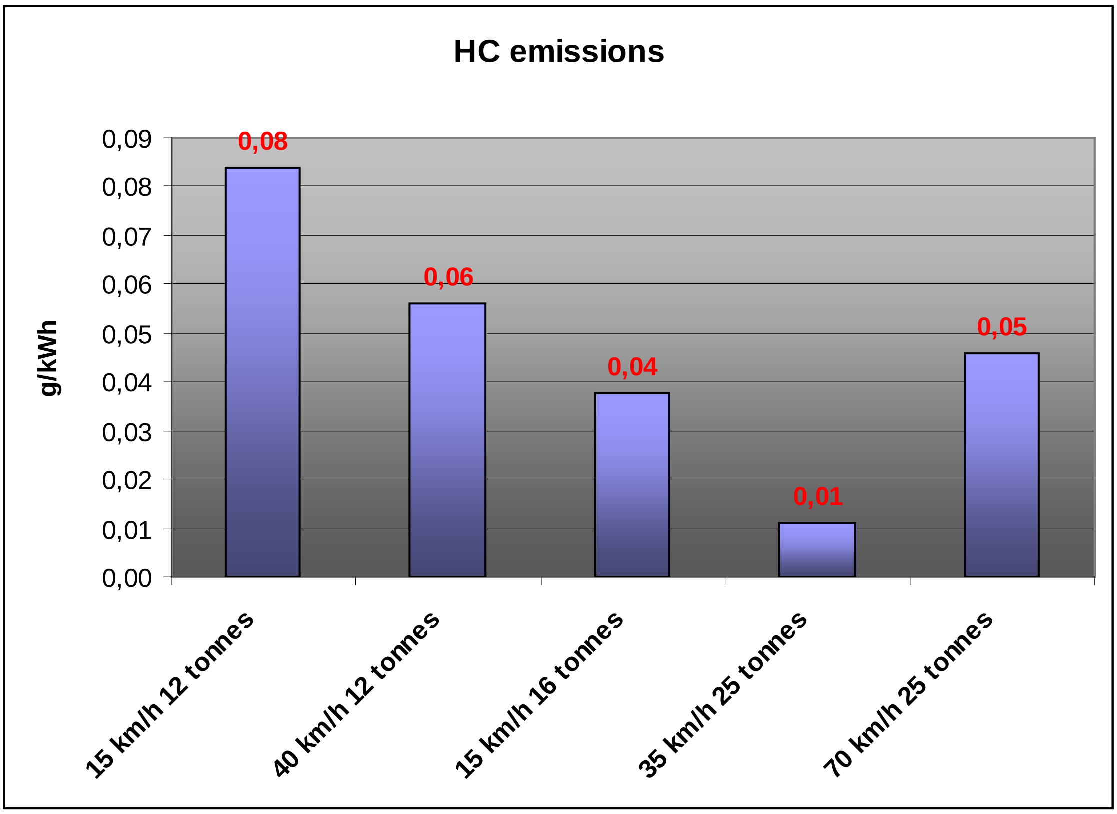

Figure 29. Brake specific HC emissions.

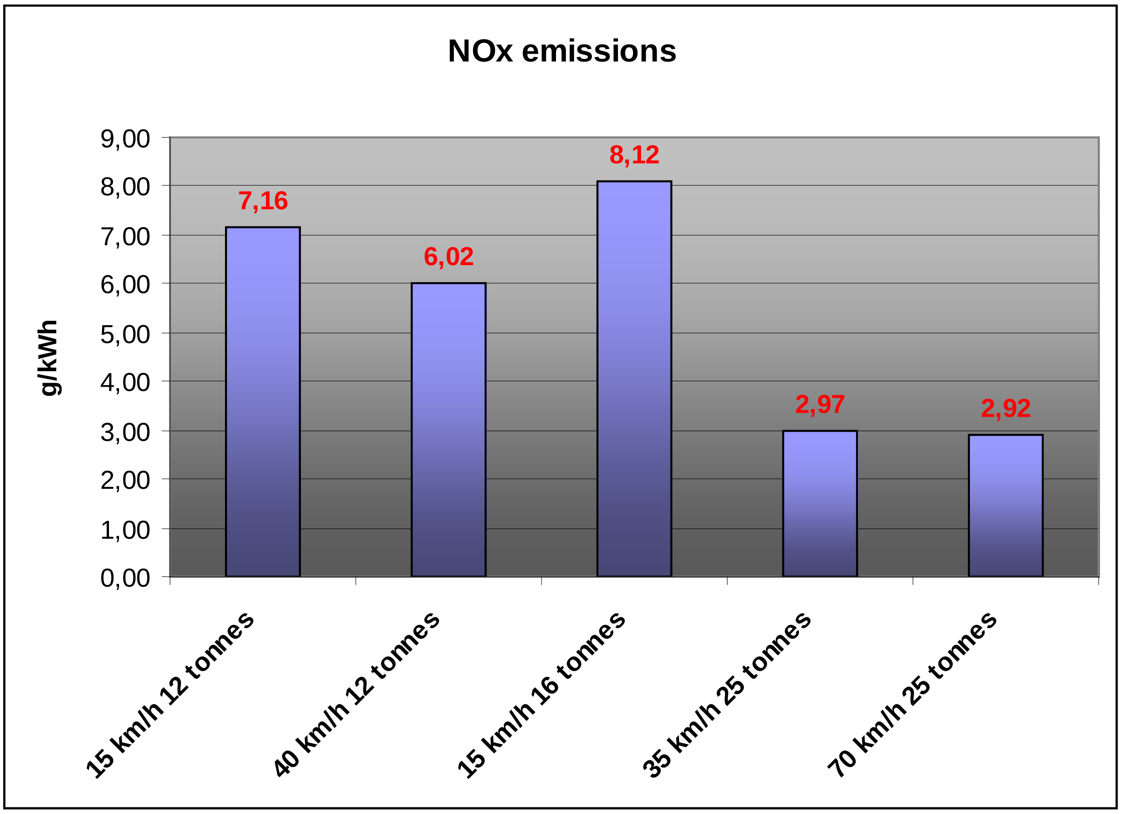

Figure 30. Brake specific NOx emissions.

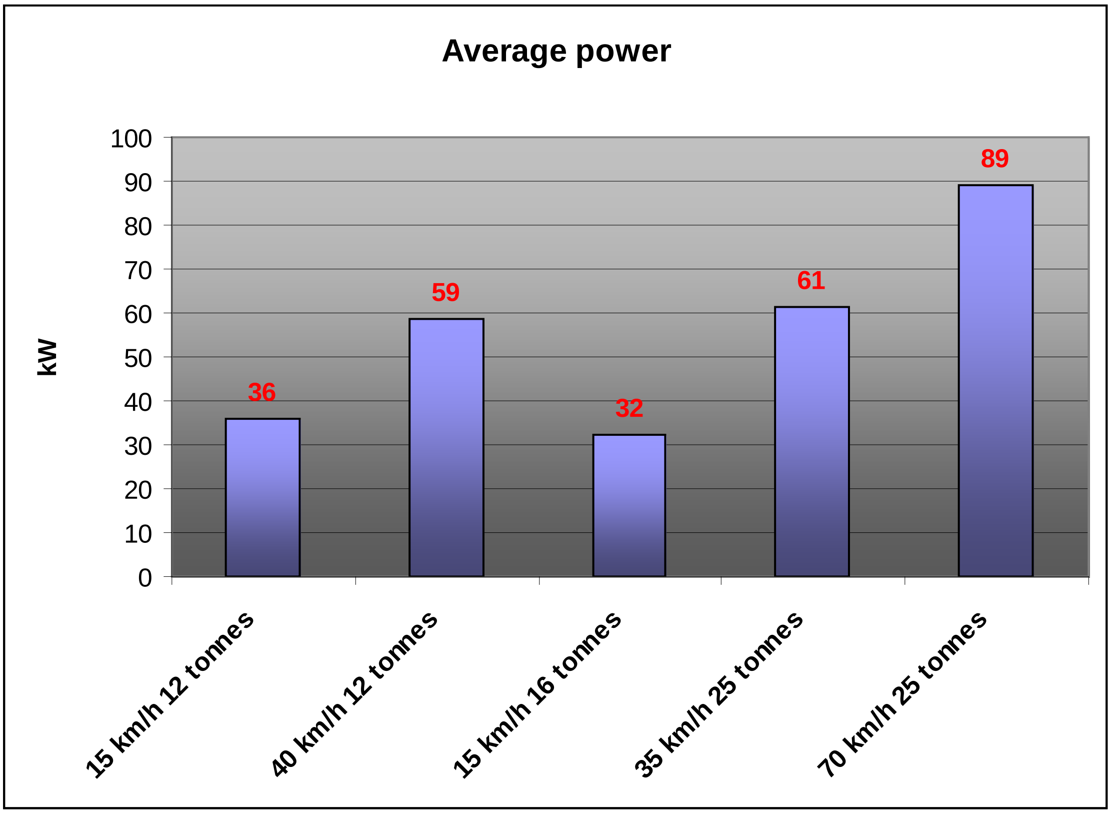

Figure 31. Average power.

Vehicle F

The scope of this investigation was to determine if there exist any possibilities to programme the engine control units (ECU) in order to reduce fuel consumption without increasing the emissions.
Vehicle manufacturers develop commercial vehicle engines and ECU as standard products. Similar engines are fitted into various types of HD vehicles. In order to reduce development and production costs, different engine options are not offered, though vehicle driving condition differs greatly. This is possible due to the optimisation of inner-city traffic demands (lower average speed, increased stopping and starting, etc.) which are not considered by vehicle manufacturers

According to the manufacturer of the system optimisation occurs by adapting the characteristics of the ECU (e.g. torque control, injection quantity, etc.). The optimised engine performance results in improved acceleration increased travelling at a constant speed and earlier gear change points.

The vehicle was a garbage truck tested with original ECU system and with an optimized system. Test was carried out both on cassis dynamometer as well as on road. The onboard measurement was divided into start/stop and motorway driving.

Table 11. Vehicle data.

Year model	2004
Mileage, km	139750
Date of first registration	October 2004
Approximately power, kW	200
Test weight, kg	14 000 – 18 500
Exhaust after treatment	-

Test results

As can be seen from the bar charts Figure 32 – 37 no difference can be seen for the regulated components and the fuel consumption while driving in accordance with the Fige test procedure. However, an increased emission of PM was detected when using the engine optimized system compared to the original system.
The ESC test results show no differences between the two systems with regard to al measured parameters.

When looking at the results from on road measurement during motorway driving and idling, the NOx emission was increased with the system while no differences in fuel consumption was measured. However, the results from start/stop driving, Figure 40, a fuel reduction of 25 % was measured at a cost of 25 % increased NOx emission.

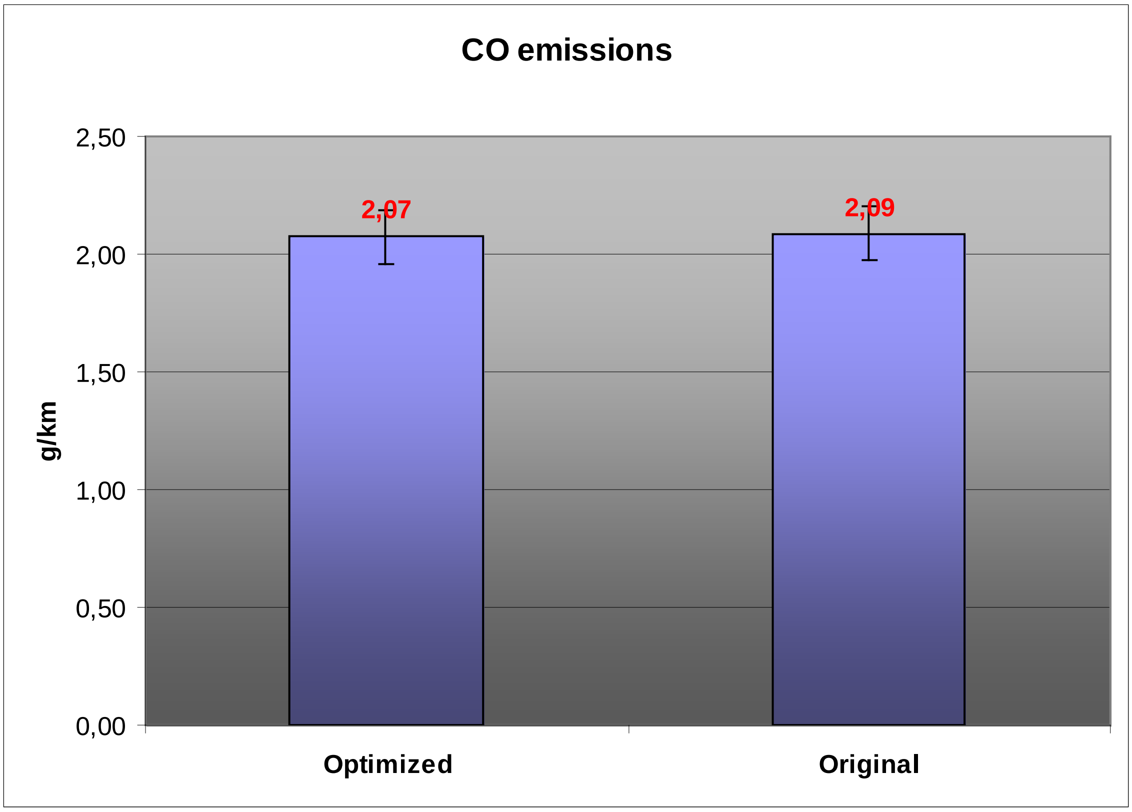

Figure 32. Distance specific CO emissions, FIGE test.

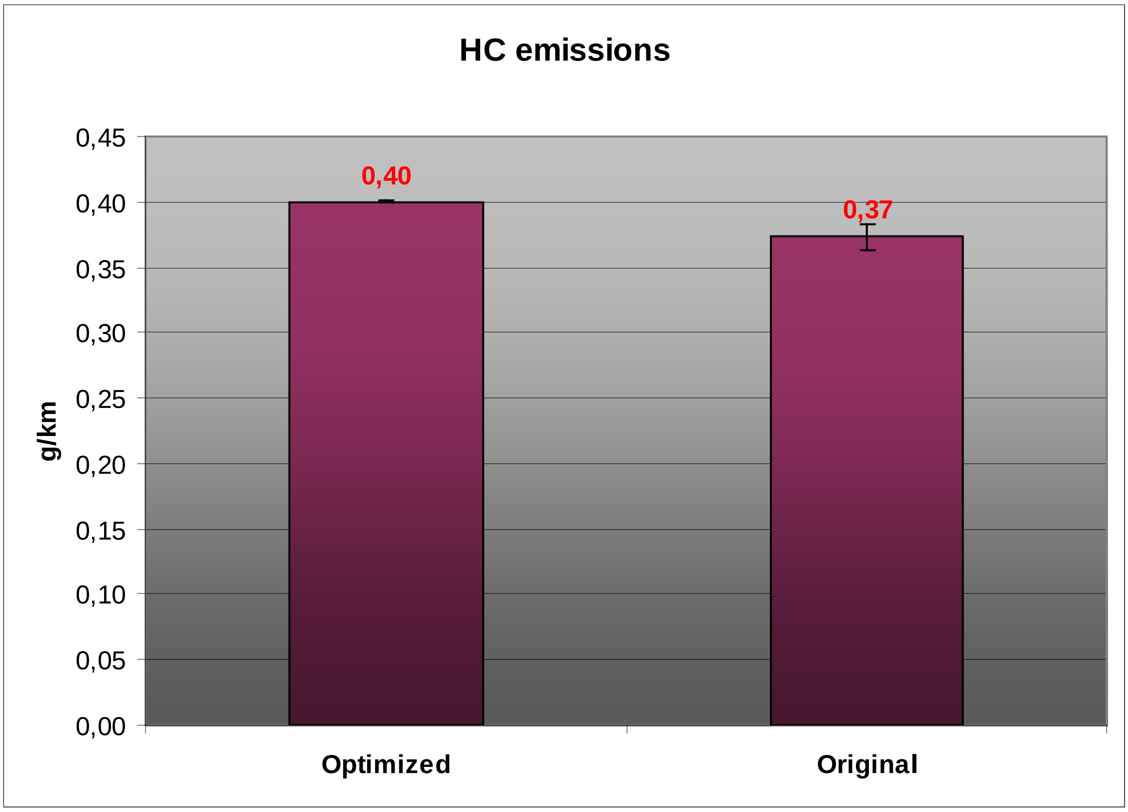

Figure 33. Distance specific HC emissions, FIGE test.

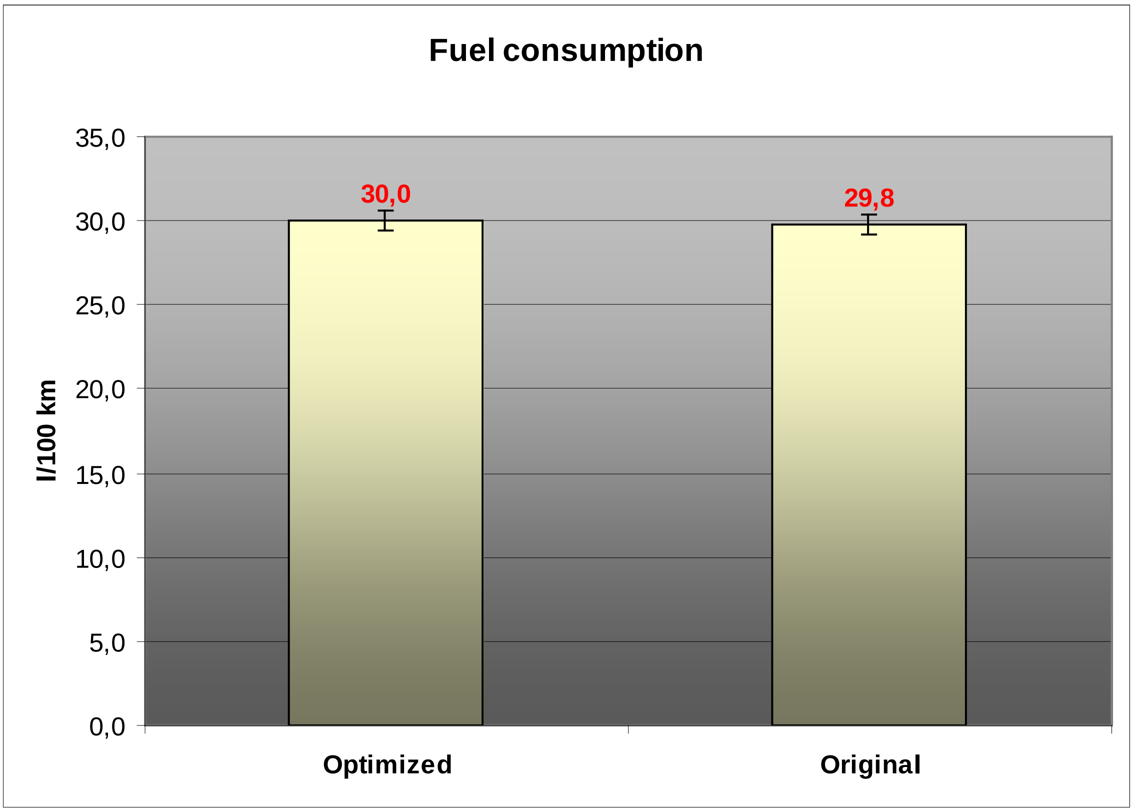

Figure 34. Distance specific fuel consumption, FIGE test.

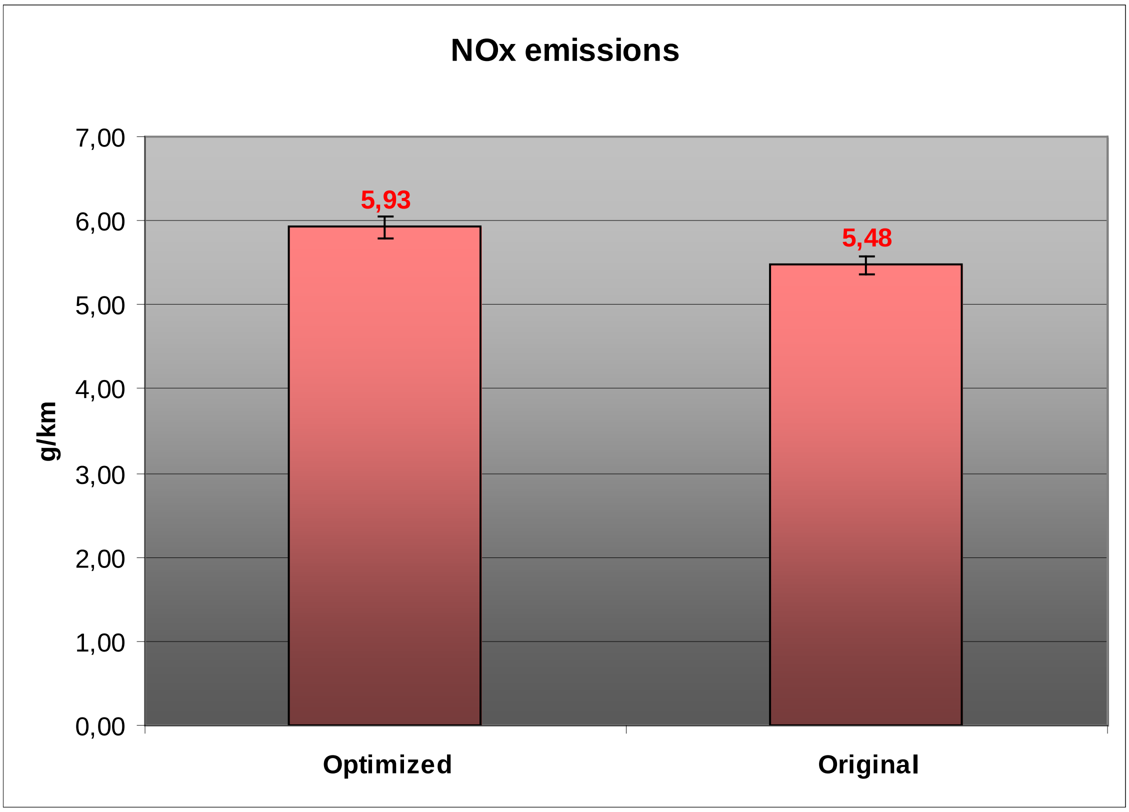

Figure 35. Distance specific NOx emissions, FIGE test.

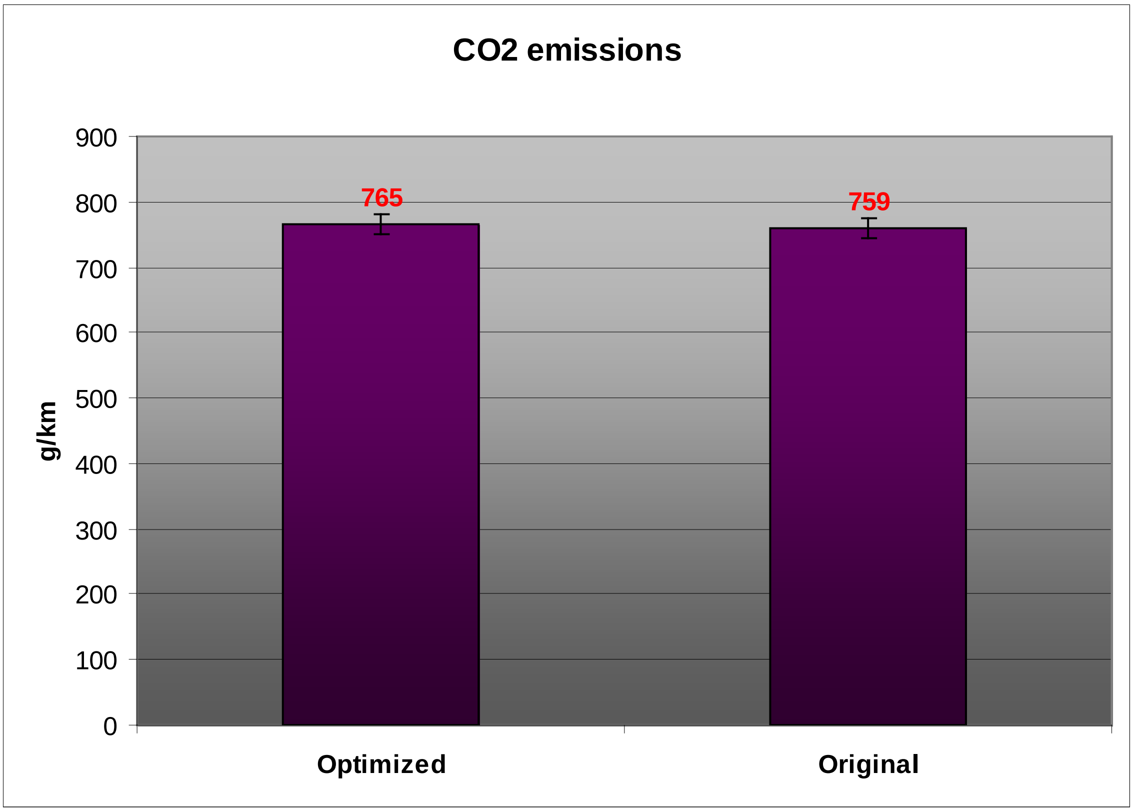

Figure 36. Distance specific CO_2 emissions, FIGE test.

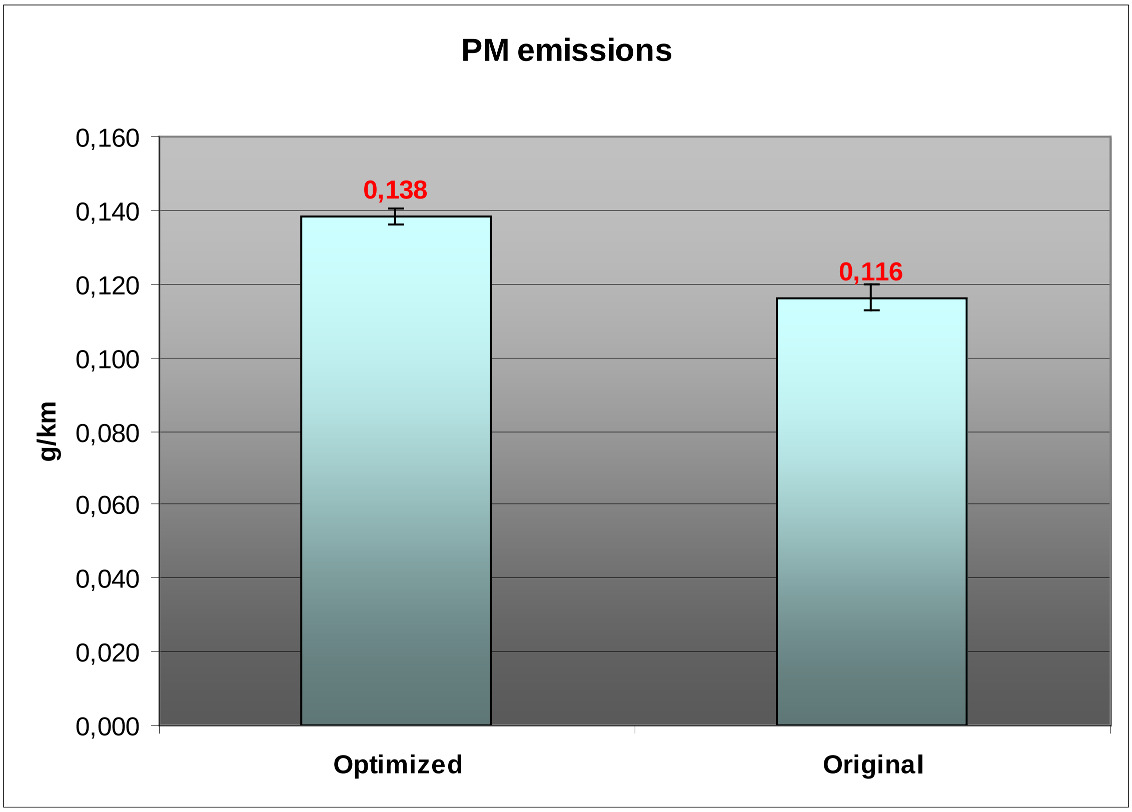

Figure 37. Distance specific PM emissions, FIGE test.

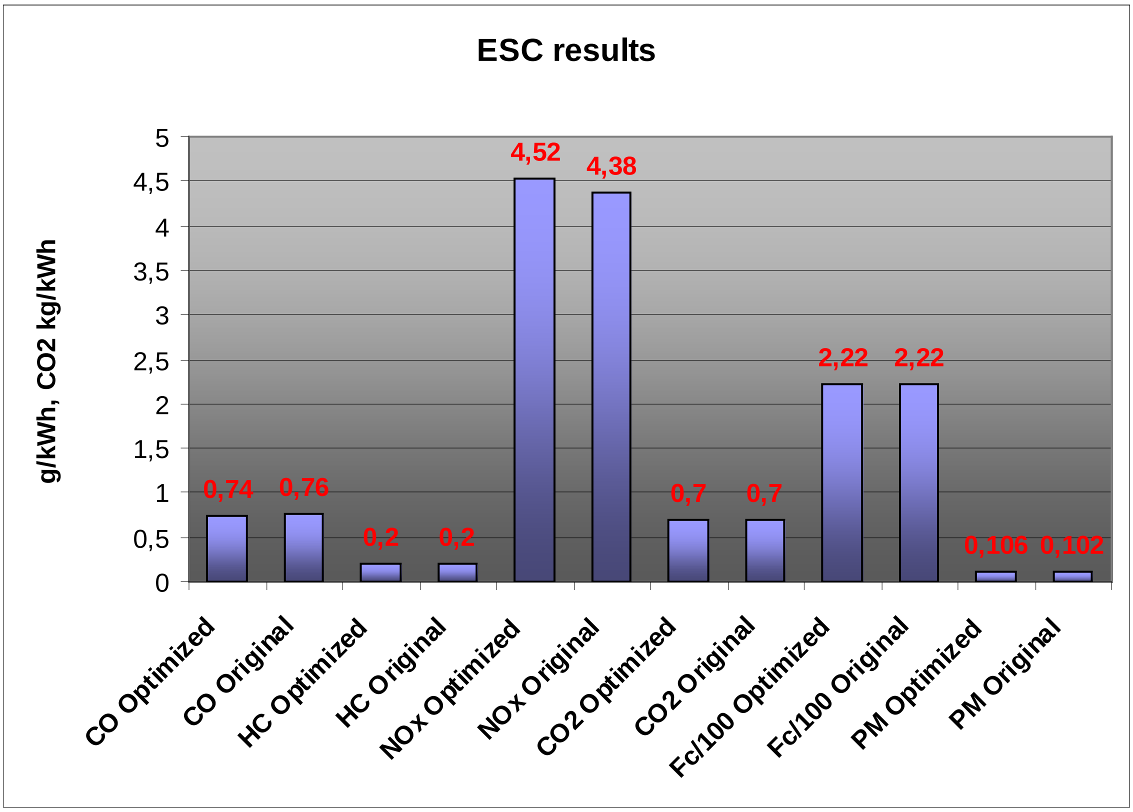

Figure 38. Brake specific ESC emissions.

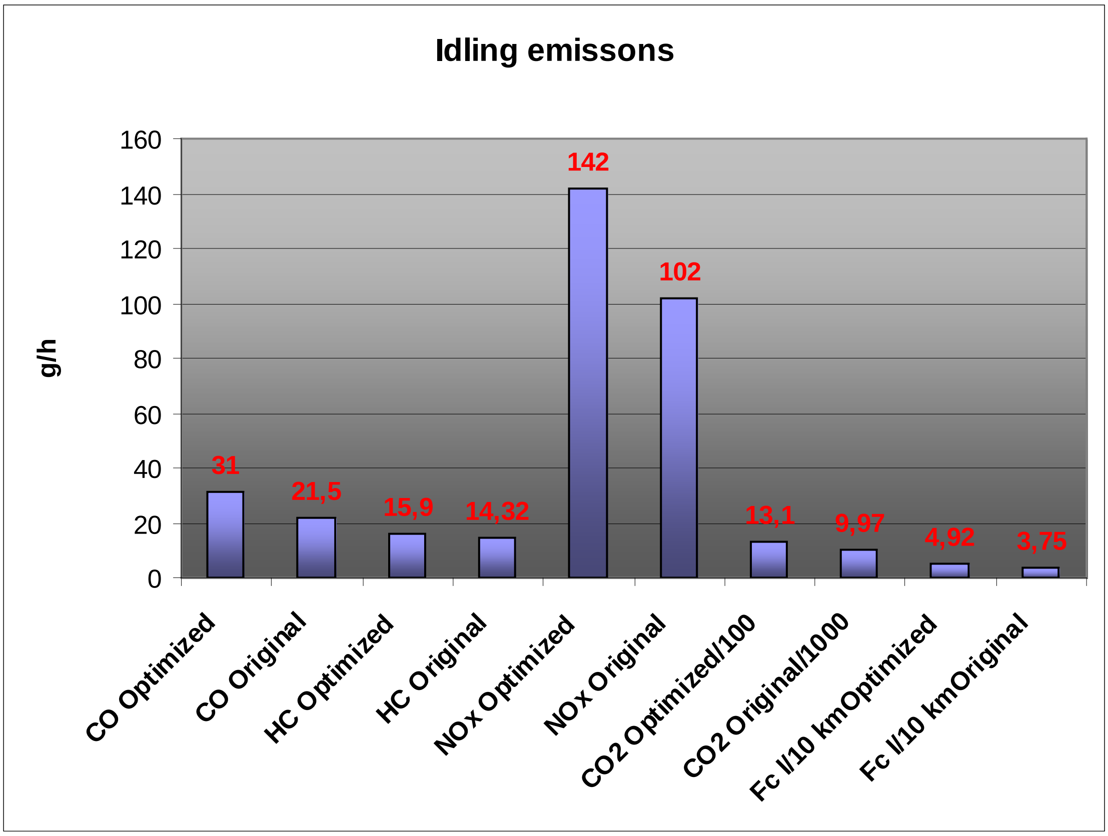

Figure 39. Distance specific idling emissions, Pems.

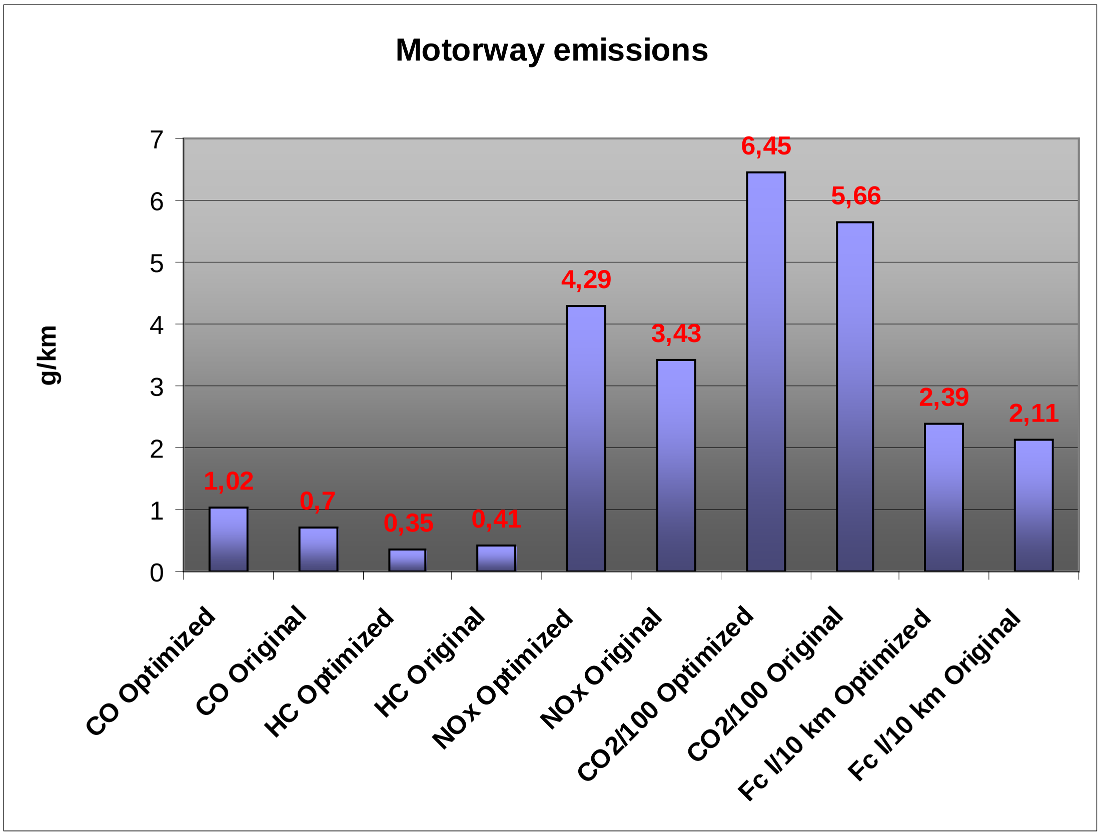

Figure 40. Distance specific motorway emissions, Pems.

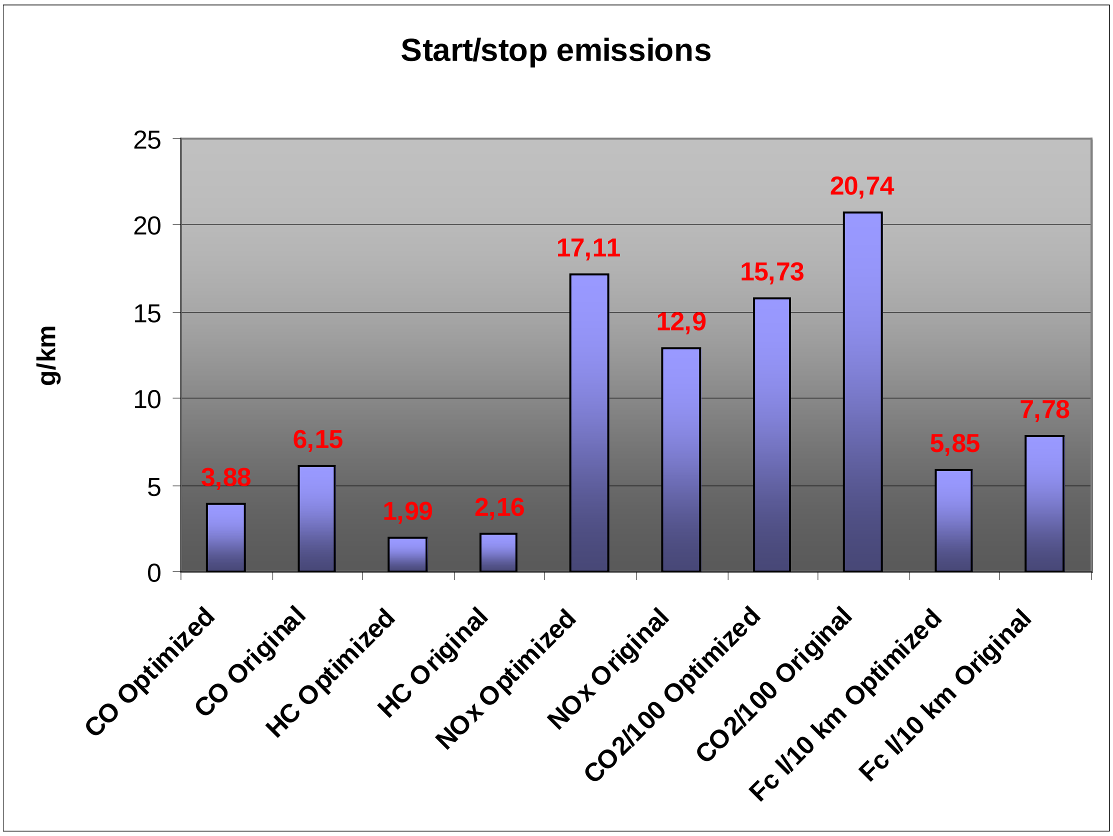

Figure 41. Distance specific start/stop emissions, Pems.

Vehicle G

The vehicle type chosen was a truck for transportation of construction waste. The vehicle was equipped with a SCR system fulfilling Euro V EEV and the scope of the investigation was to determine emission levels at different loads.

The vehicle was tested on roads during driving conditions and loads representing a normal working day.

Commercially available Environmental class 1 diesel (Mk1) was used and the vehicle was served in accordance to the manufacturer specification. The vehicle was tested at an average ambient temperature of 10 ^{o}C.

The tested vehicle has been supplied through kind cooperation with Sortera, Haninge

Test route description:
Below is the test routes presented divided into three trips with different loads, Figure 42 - 44.

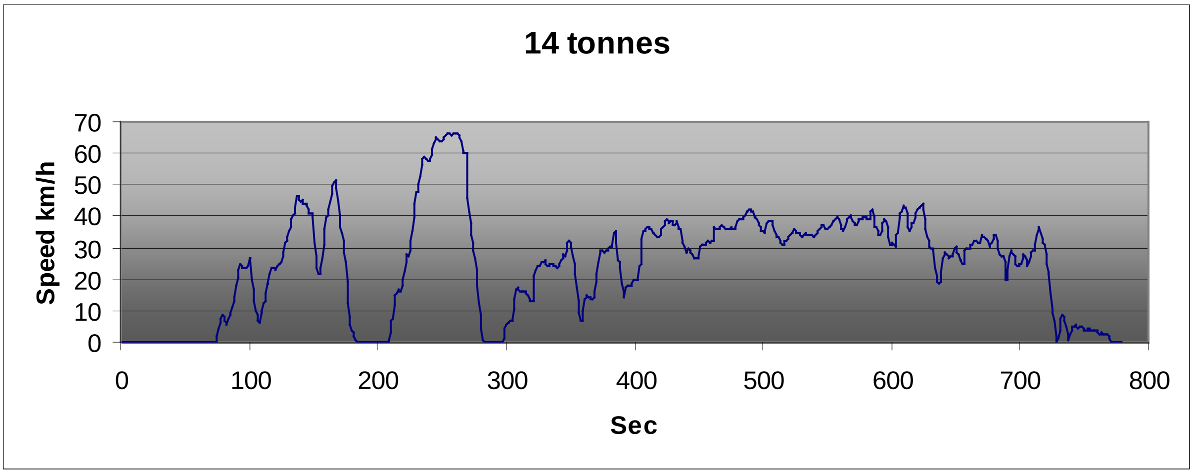

Figure 42. Driving pattern trip 1.

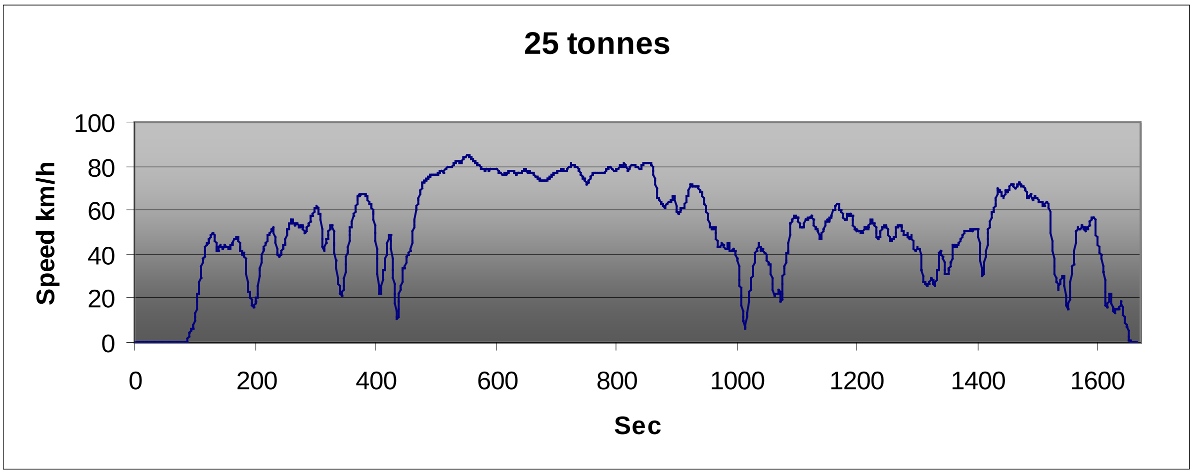

Figure 43. Driving pattern trip 2.

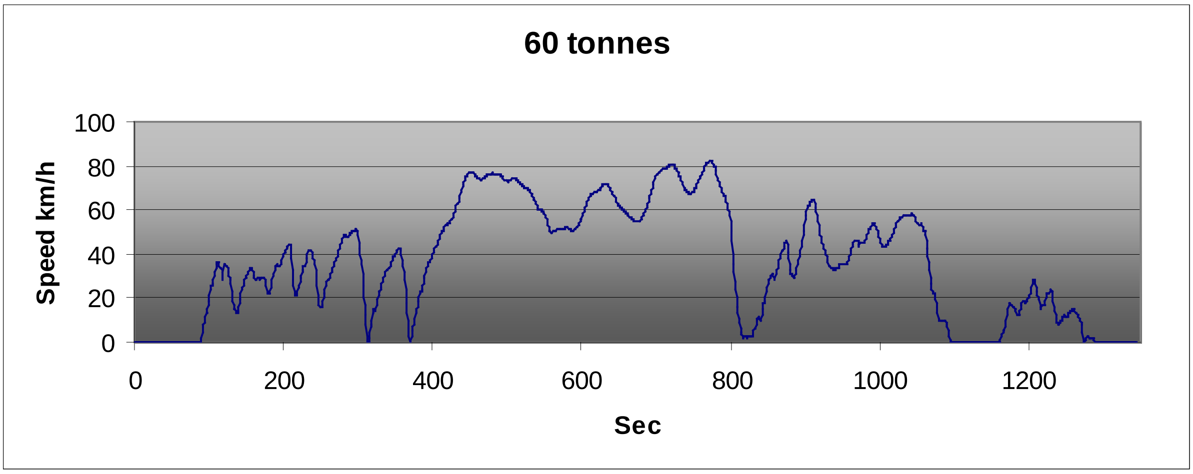

Figure 44. Driving pattern trip 3.

Table 12. Vehicle data.

Year model	2008
Mileage, km	67 200
Date of first registration	January 2008
Approximately power, kW	290
Test weight, kg	14 000 – 25 000
Exhaust after treatment	SCR

Test results

The results are presented in Figure 45 – 48 as distance specific emissions and in Figure 49 – 51 as brake specific emissions. From the results it can be seen that relatively low ambient temperature and average speed generate high emissions of NOx , three times over Euro V limit, probably due to catalyst temperature below light off. The HC emission is low and close to detection limit.

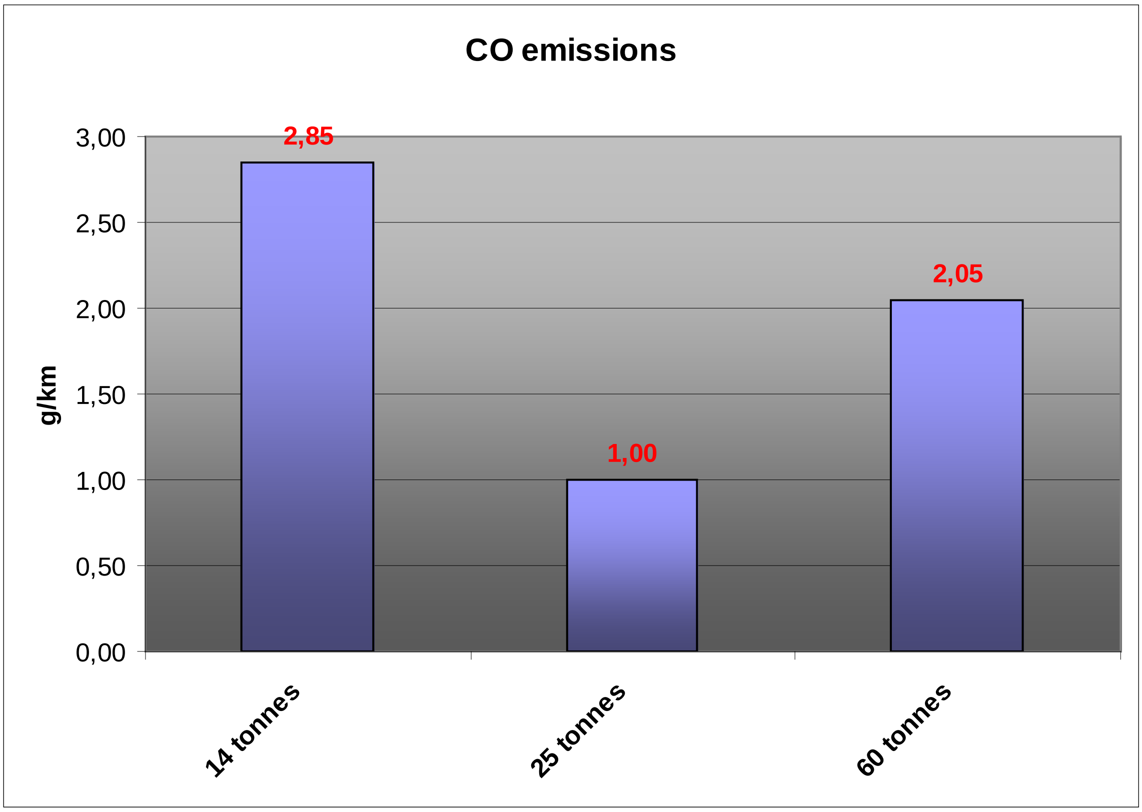

Figure 45. Distance specific CO emissions.

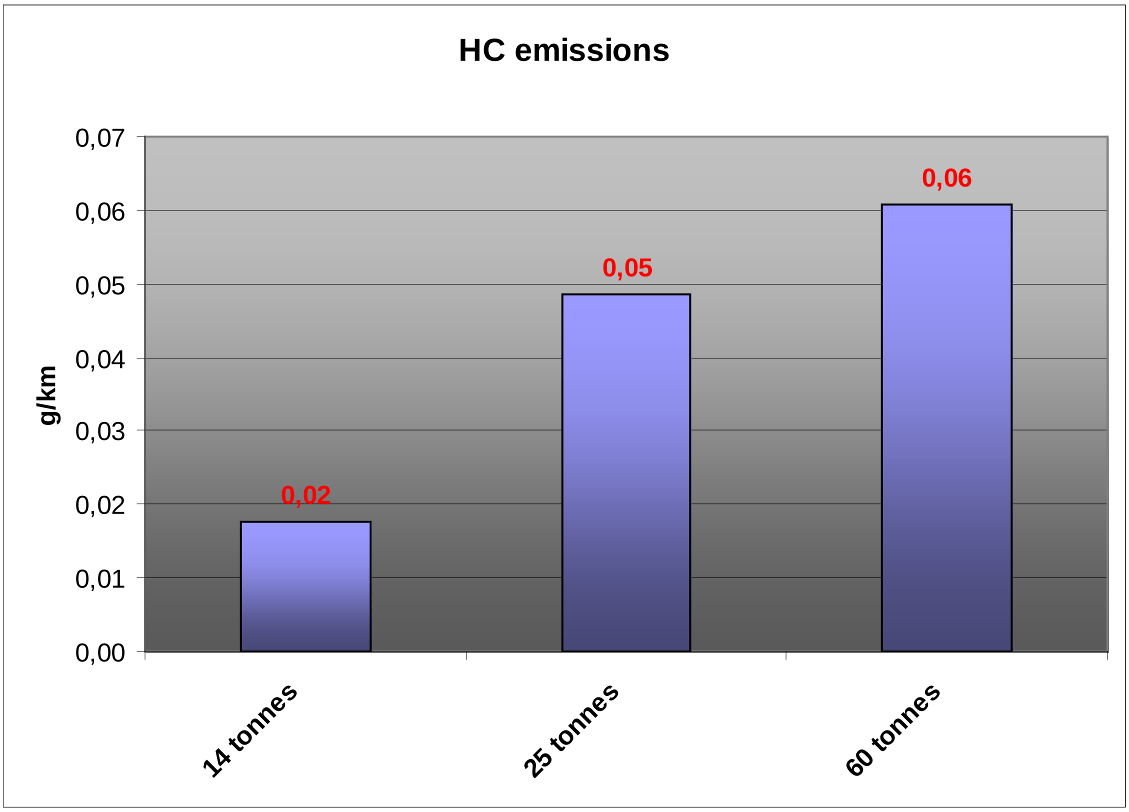

Figure 46. Distance specific HC emissions.

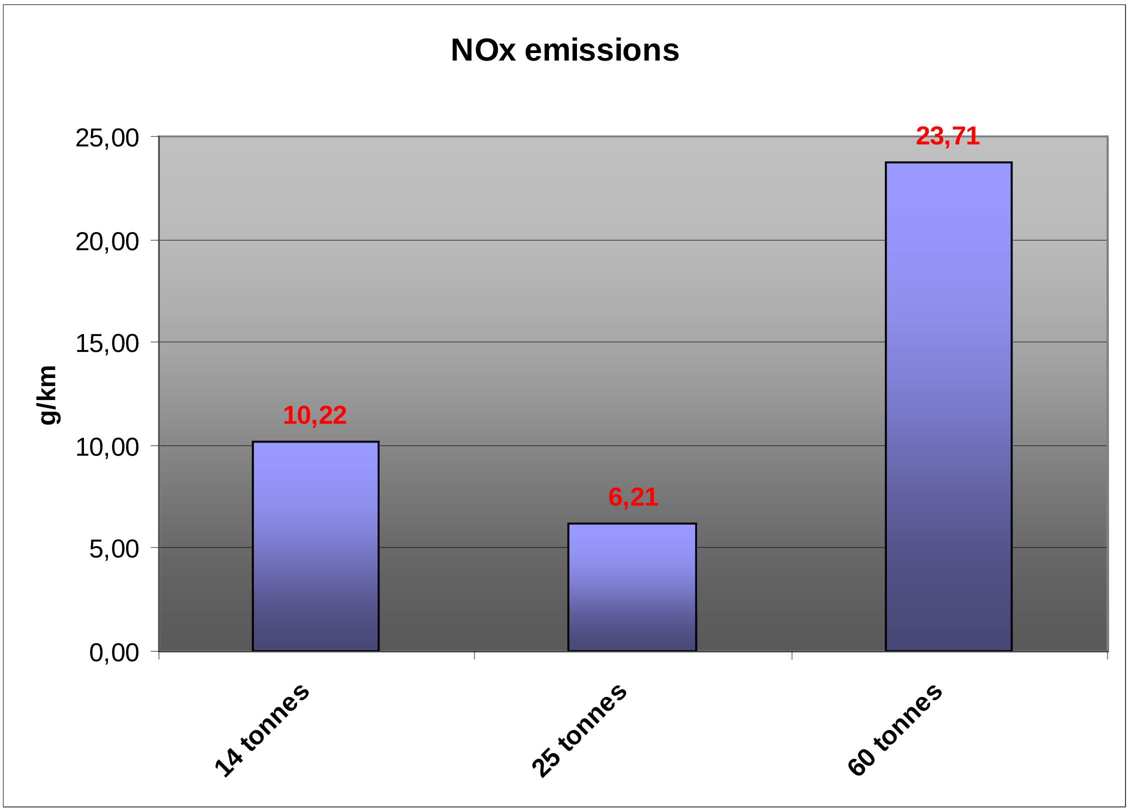

Figure 47. Distance specific NOx emissions.

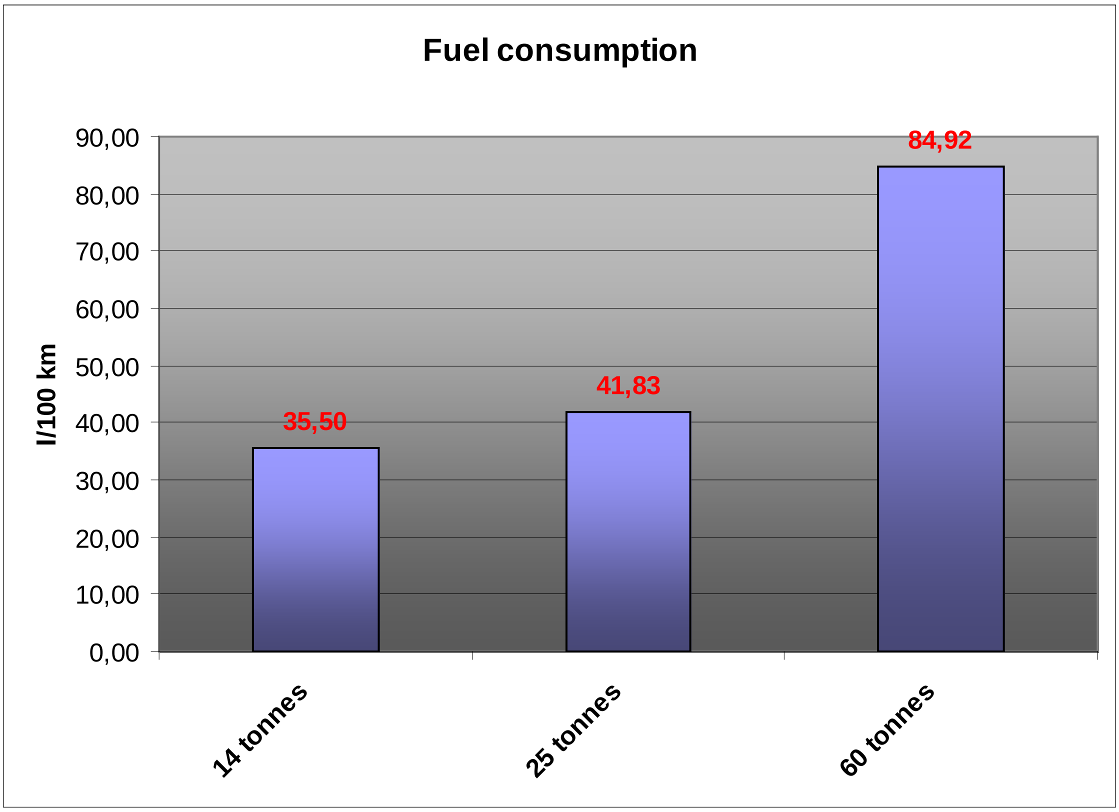

Figure 48. Distance specific fuel consumption.

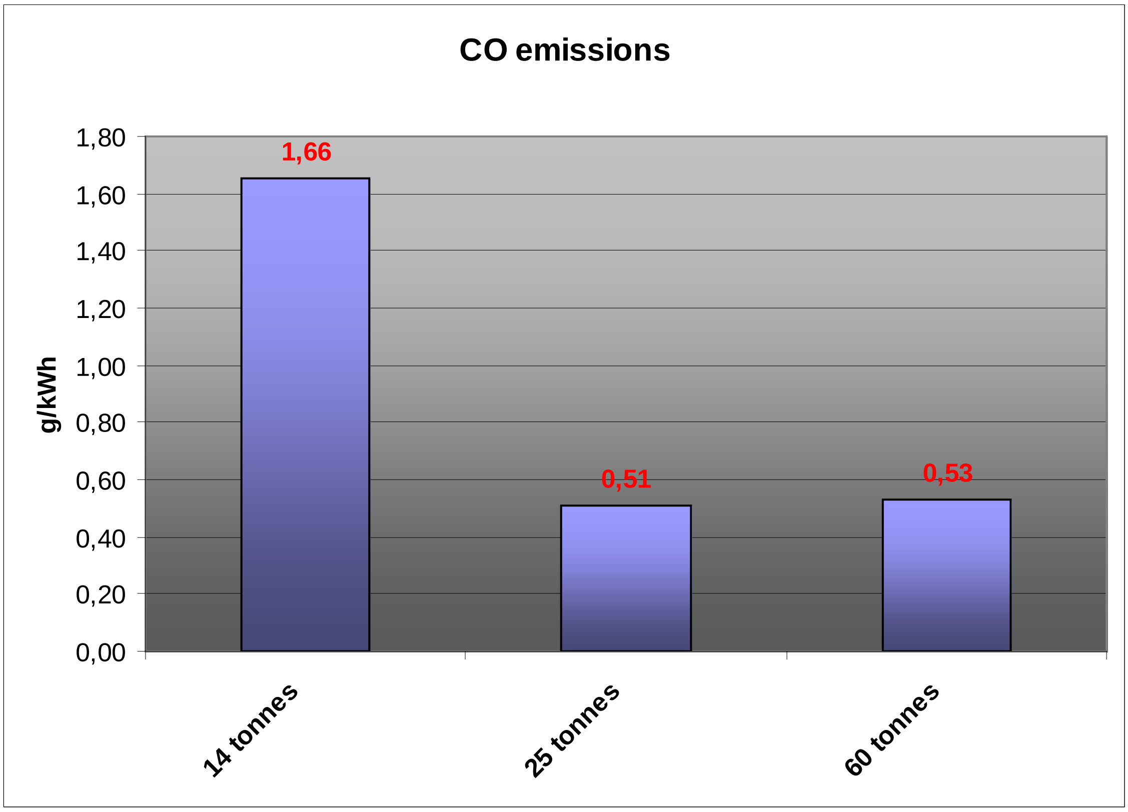

Figure 49. Brake specific CO emissions.

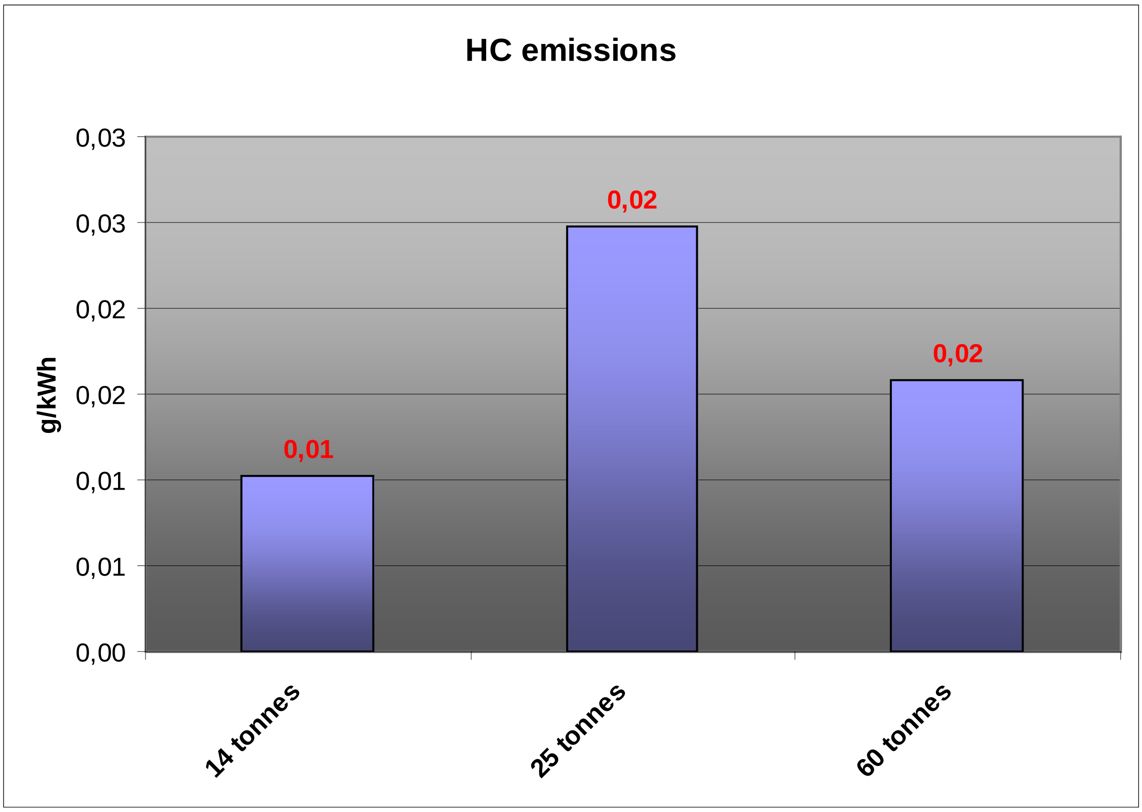

Figure 50. Brake specific HC emissions.

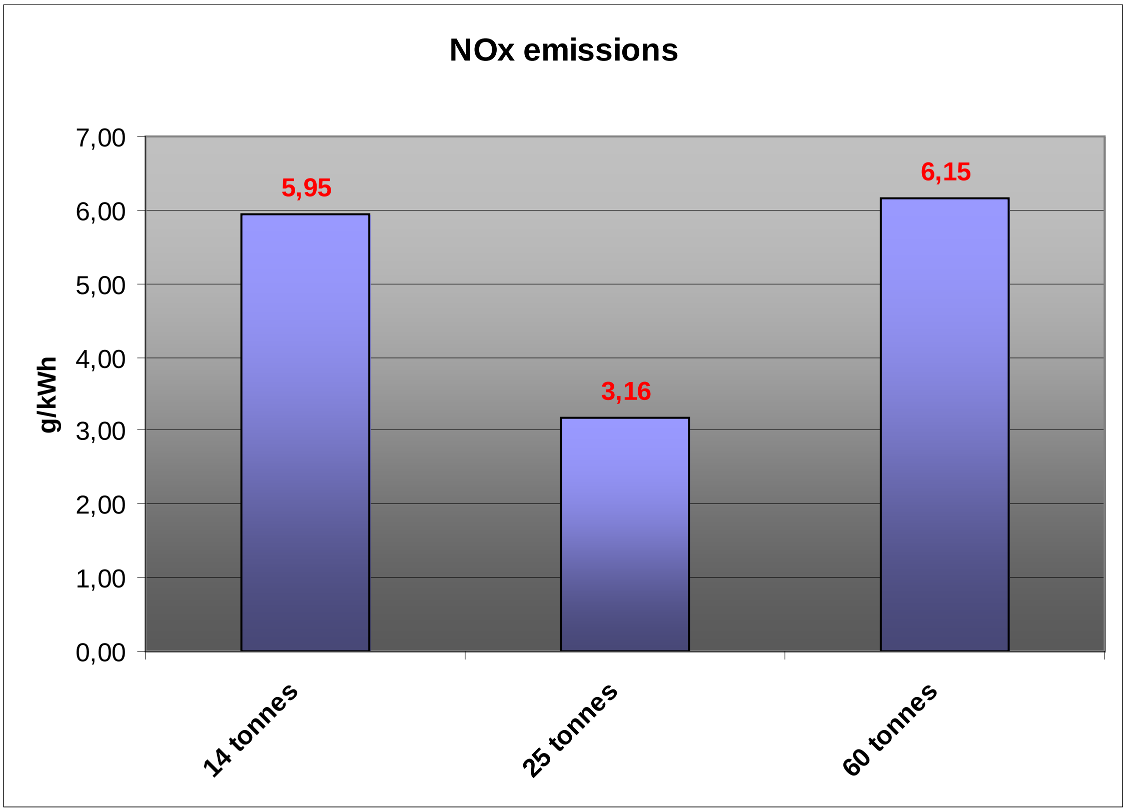

Figure 51. Brake specific NOx emissions.

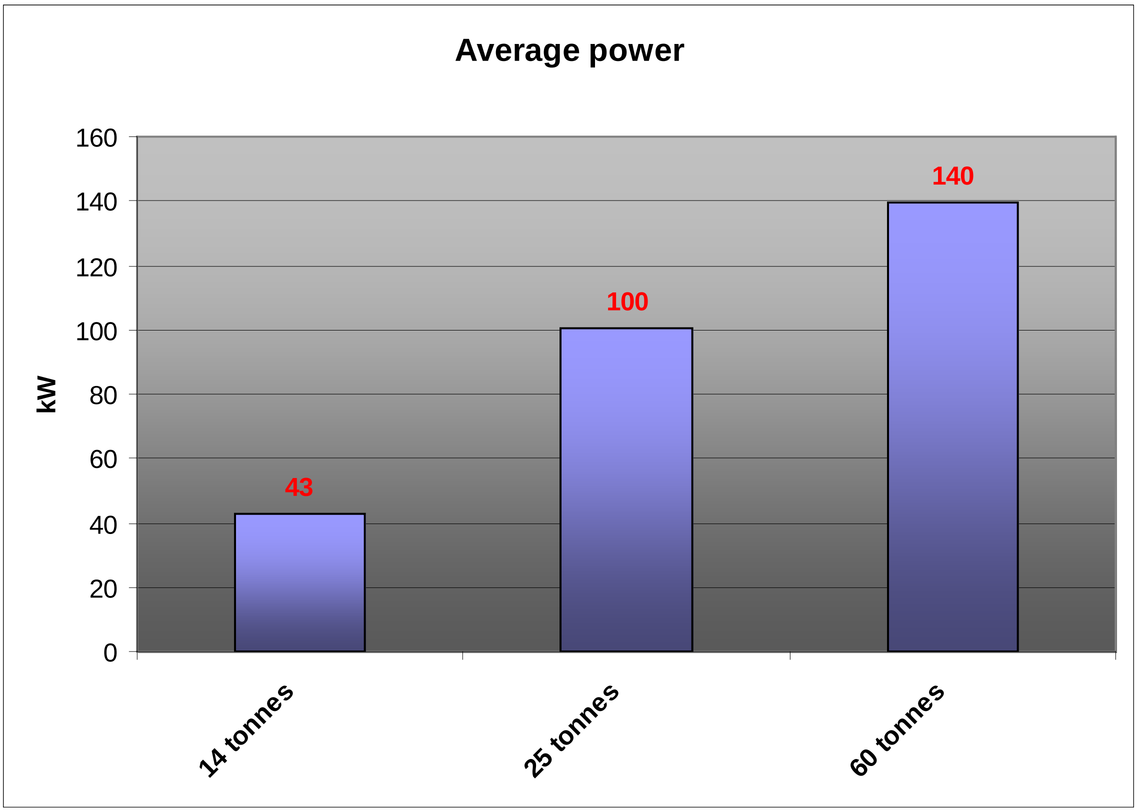

Figure 52. Average power.

Vehicle H

The vehicle type chosen was a long distance truck. The vehicle was equipped with a EGR system fulfilling Euro V.

Test was carried out both on cassis dynamometer as well as on road. The onboard measurement was in accordance with the previous described Pems route, Figure 53.

Commercially available Environmental class 1 diesel (Mk1) was used and the vehicle was served in accordance to the manufacturer specification. The vehicle was tested at an average ambient temperature of 15 ^{o}C.

Table 11. Vehicle data.

Year model	2009
Mileage, km	50000
Date of first registration	April 2009
Approximately power, kW	350
Test weight, kg	20 000
Exhaust after treatment	EGR

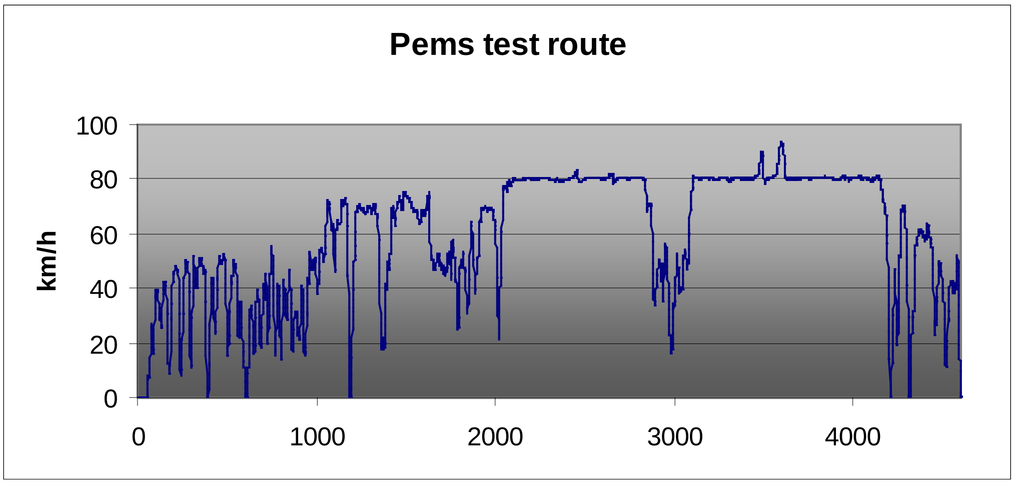

Figure 53. Test route.

Test results

In Figure 54 are the results from ESC and Pems (g/kWh) presented and in Figure 55 the results from Fige and Pems (g/km). The vehicle is well below the Euro V limits for all components with regard to chassis dynamometer test and have a good correlation with the on board measurement except NOx.

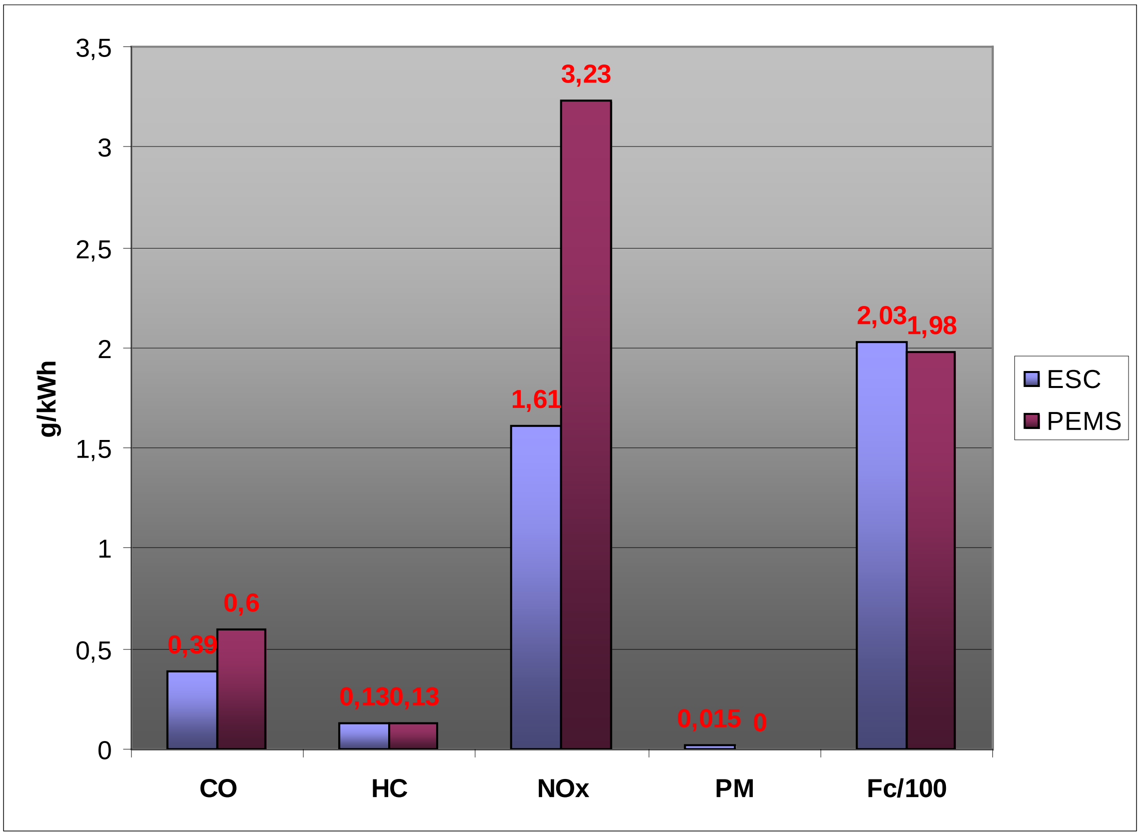

Figure 54. Brake specific emissions and fuel consumption, ESC and Pems.

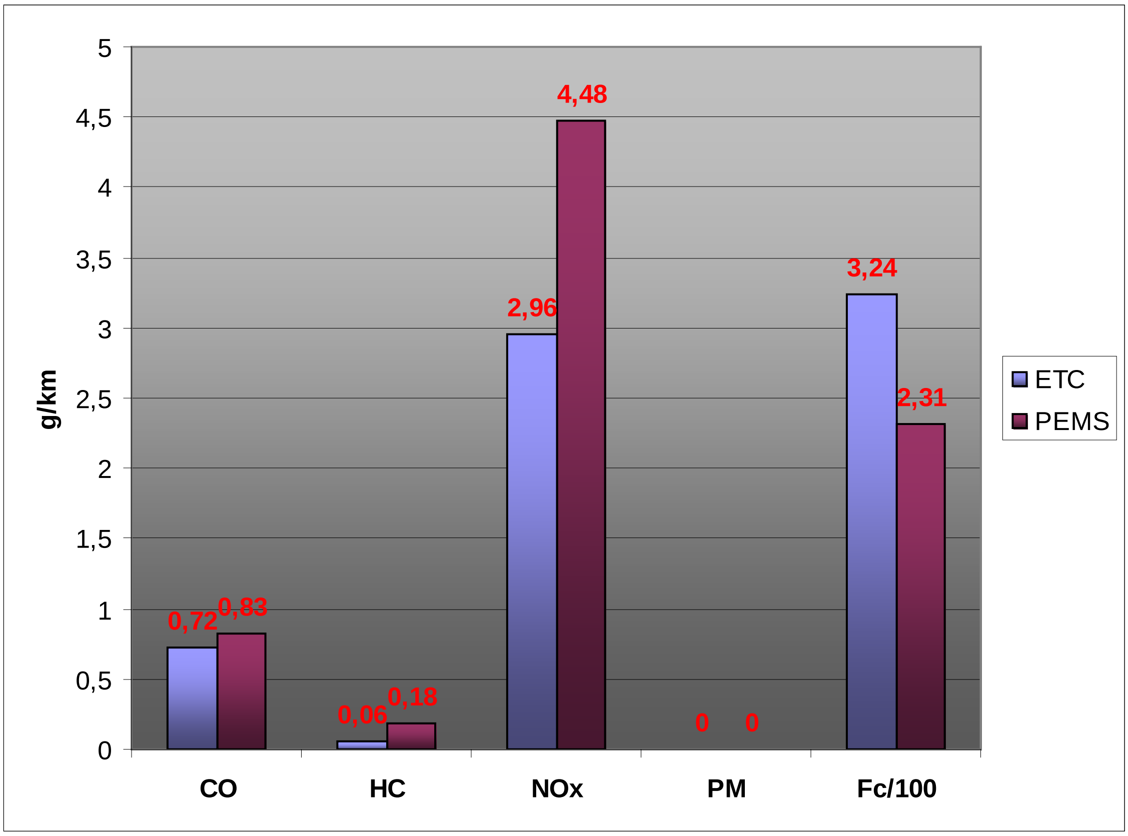

Figure 55. Distance specific emissions and fuel consumption, FIGE and Pems.