Measurement of Emissions from Four Diesel Fuelled Passenger Cars Meeting Euro 4 Emission Standards

MTC 5505

Hua Lu Karlsson

AVL MTC AB
2005/10

INFORMATION FOR THE LIBRARY

Publisher	Project	Published
AVL MTC AB Box 223 S-136 23 Haninge Sweden Tel: +46 8 500 656 00 Fax: +46 8 500 283 28	8050505	2005/10
	Client Vi Bilägare	
	Author Hua Lu Karlsson e-mail:hua.lu_karlsson@avlmtc.com	

REPORT No

MTC5505

ISSN
1103-0240

ISRN
ASB-MTC-R-05/4--SE

Title and subtitles of the report	Language
Measurement of Emissions from Four Diesel Fuelled Passenger Cars Meeting Euro 4 Emission Standards	English
	No of pages 39

Abstract

Four diesel passenger vehicles approved according to Euro 4 emission standards were tested in this project. Two of the vehicles are equipped with DPF. The vehicles were tested using the NEDC test cycle at 22°C and -7°C and the Artemis test cycle at 22°C. CO, HC, NO_x, NO_2, PM, particle number emissions and fuel consumption were measured. The PM and particle number emissions were measured according to the PMP protocol.

The fuel consumption and CO_2 emissions of all 4 vehicles are in good agreement with the declared values. Except SKODA for PM emissions, all the regulated emissions are below the regulated limits.

The vehicles with DPF have significantly lower PM and particle number emissions comparing to the non-DPF vehicles. During regeneration the DPF vehicle has much higher PM and particle number emissions than the non-regeneration test. The regeneration also leads to increasing in CO, HC and NO_x emissions and fuel consumption.

Generally the NEDC tests have higher HC and CO emissions and lower NO_x emissions than the Artemis test. The fuel consumption follows such a sequence: AU > NEDC > AH > AEU.

Comparing to the 22°C NEDC test, the -7°C NEDC tests lead to increasing in regulated emissions (both gaseous and PM) and fuel consumption. However the low test temperature has no significant impacts upon the particle number emissions.

In both 22°C and -7°C NEDC tests, most emissions (HC, CO, NO_x, CO_2 and particle number) emit during the cold start urban driving phase, but the highest NO_2/ NO_x ratio occurs in the extra urban driving phase.

Suggestion of keywords
Diesel, Euro 4 passenger car, PMP protocol, diesel particulate trap, NEDC, Artemis, -7ºC NEDC.

Title of series
Rapport – AVL MTC AB

Measurement of Emissions from Four Diesel Fuelled Passenger Cars Meeting Euro 4 Emission Standards

for

Vi Bilägare

Hua Lu Karlsson

October, 2005

Table of contents

AVL MTC

AVL MTC Motortestcenter AB
P.O. Box 223
SE-136 23 Haninge
Sweden

Visiting Address: Armaturvägen 1

Phone: +46 8 500 656 00
Fax: +46 8 500 283 28
e-mail: info@avlmtc.com
Web: http://www.avl.com/mtc

1. INTRODUCTION

The share of diesels in the new passenger car market in Western Europe has reached an all-time high. The continuous increase of the diesel share has been driven by their superior fuel economy and the corresponding reductions in greenhouse gas emissions, as well as by the good performance of advanced diesel cars. Even thought Sweden has the second lowest penetration in Europe of light duty diesel vehicles on the market, still we see a clear tendency of increasing in diesel car sales. Increased usage of diesels has resulted in particulate matter (PM) emissions. The Euro 5 diesel emission standards with PM emissions less than 5 mg/km, proposed in 2005, will make it necessary to fit all new diesel cars with particulate filters (DPF). In the meantime, car manufacturers increasingly introduce particulate filters on a voluntary basis. Some countries have already used national incentives to promote the DPF diesel cars. Sweden will probably during next year (2006) introduce tax incentive to promote diesel cars with PM emissions less than 5mg/km.

As requested by the magazine Vi Bilägare and Swedish Road Administration, four Euro 4 diesel passenger vehicles have been tested at AVL MTC AB. The vehicles are CITROËN C4 1,6 HDI, OPEL Astra 1,7 CDTI, PEUGEOT 407 ST 2,0 Hdi SW and SKODA Octavia 1,9 TDi Aut. Among them PEUGEOT and CITROËN are equipped with catalysed diesel particulates filter (DPF). The test methods and results are presented in this report.

A Mercedes A 180 CDI was also meant to be tested in this project, but this task could not be fulfilled because of technical problem with the vehicle (impossible to disconnect ESP, also with telephone support from the vehicle manufacturer).

2 EXPERIMENTAL

2.1 Fuel and vehicle

Swedish commercial MK1 diesel fuel of the same batch was used in the tests of all the vehicles. The specifications of the tested vehicles are presented in Table 1.

Table 1: Vehicle specifications.

	CITROËN C4 1,6 HDI	OPEL Astra 1,7 CDTI	PEUGEOT 407 ST 2,0 Hdi SW	SKODA Octavia 1,9 TDi Aut
Model year	2005	2005	2005	2005
Odometer (km)	40855	43120	38033	42842
Inertia mass (kg)	1360	1360	1700	1474
Maximum load (kg)	400	550	515	500
Injection system	Common rail	Common rail	Common rail	Pump spay
Power (kW@rpm)	80@4000	74@4400	100@4000	77@4000
Torque (Nm@rpm)	240@1750	240@2300	320@2000	250@1900
Gears	M5	M5	M6	A6
Emission control	DPF, Oxi. Cat.	Oxi. Cat.	DPF, Oxi. Cat.	Oxi. Cat.
Declared mixed driving fuel consumption (l/100km)	4,7	5,0	6,0	5,8
Declared CO_2 emissions (g/km)	125	135	159	157

2.2 Driving cycles and Euro 4 diesel emission standard

A set of different driving cycles were used in the study. The driving cycles represent cold engine start (as NEDC) and warm engine start, different speeds and transient behaviours (as Artemis cycle).

NEDC and Euro 4 diesel emission standard

The legislative NEDC cycle (New European Driving Cycle, Figure 1) is the current test cycle for emission certification of light duty vehicles. The first 780 s includes four identical cycles, representing the Urban Driving Cycle (UDC). This part may be further divided into two parts of 390 s each (C_1+2 as UDC1 and C_3+4 as UDC2) in order to compare vehicle emissions from a cold engine and exhaust system with those from the engine and exhaust system at a proper operating temperature. The period from 780 s to the cycle end at 1180 s represents the higher speed part of the cycle, the Extra Urban Driving Cycle (EUDC).

Prior to each NEDC test, the vehicle was preconditioned by driving 3 EUDC cycles, and then the vehicle was soaked for 6 h to 24 h at 20 to 30°C or at -7°C.

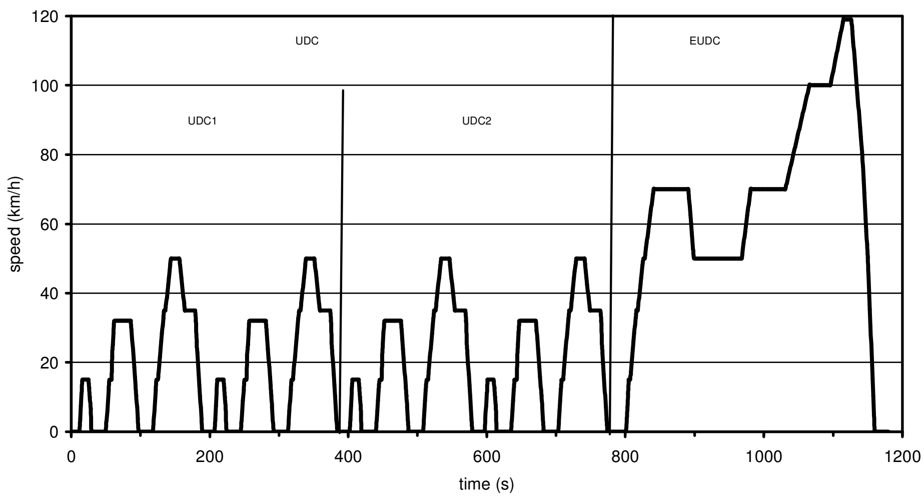


Figure 1: The NEDC driving cycle.

The Euro 4 emission standard applies to the NEDC test at 22°C. The Euro 4 diesel emission standard is illustrated in the table below:

Table 2: Euro 4 Emission regulation for diesel vehicles with weight less than 3500 kg.

Standard	CO	NO_x	$HC+NO_x$	PM
Unit (g/km)	0,5	0,25	0,30	0,025

Artemis Cycles

Artemis driving cycles (Figures 2-4) were used in this study. Artemis was originally designed by INRETS (Institut national de recherche sur le transports et leur securite, France) as Real World Cycles and has been used in the European Artemis project (Assessment and Reliability of Transport Emission Models and Inventory). The cycles describe various current driving patterns encountered frequently in Europe as they were built from a database of real-world driving conditions for a set of 80 cars from different European countries. The three cycles used are referred as Artemis Urban (AU), Artemis Extra Urban (AEU), and Artemis Highway (AH).

The cycles are all warm engine cycles, i.e. not including cold start, and contain a preconditioning part of different lengths for the respective cycles (73 s for AU, 102 s for AEU, and 177 s for AH as marked by the line in the figures). For the AH cycle there is also a post-conditioning part of the cycle from 912 s and onwards. All results presented and discussed in the following report only concern the valid part of the cycle.

Since the Artemis cycles are all warm engine cycles, a common procedure was defined in order to enable as good as possible repeatability between tests. The procedure presented in Table 3 was used. According to the procedure, a number of EUDC was driven depending on the time elapsed between tests.

Table 3: Vehicle conditioning procedure for warm start Artemis test.

Minutes elapsed between two tests	Number of EUDC
0-15	0
15-30	1
30-60	2
>60	3

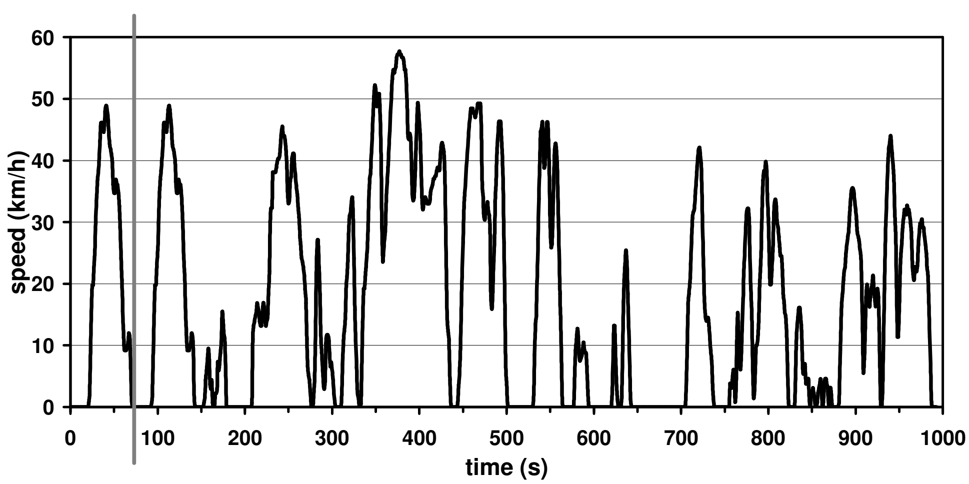


Figure 2: The Artemis Urban driving cycle with the valid part of the driving cycle from 73 to 993 s.

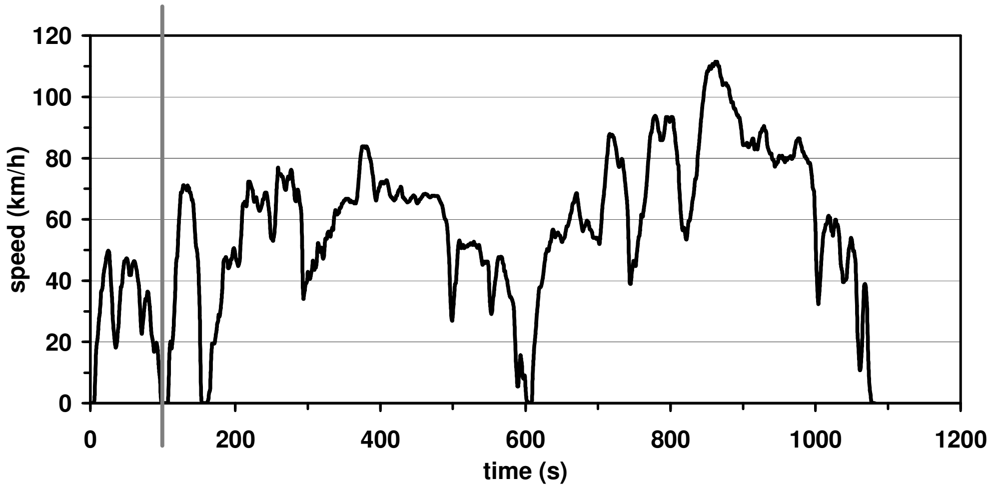


Figure 3: The Artemis Extra Urban driving cycle with the valid part of the driving cycle from 102 to 1082 s.

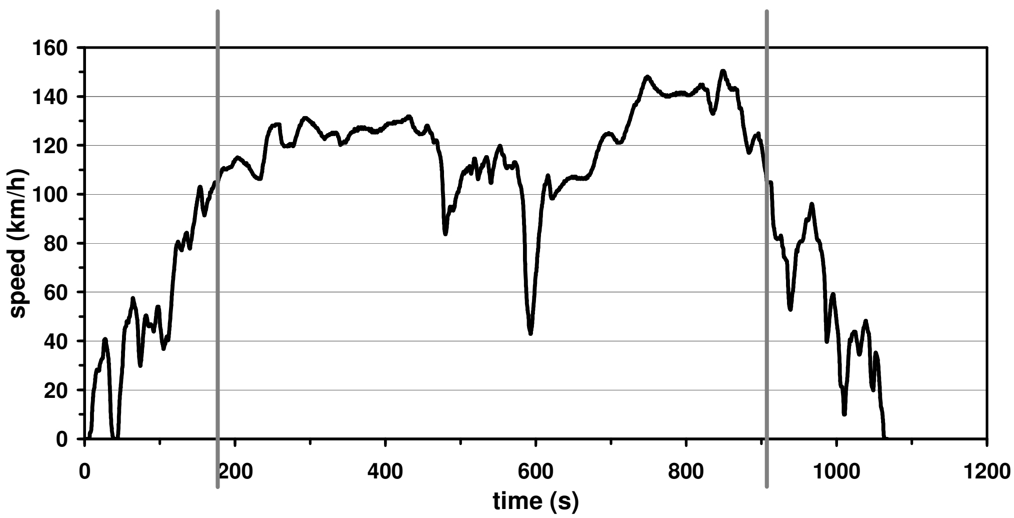


Figure 4: The Artemis highway driving cycle with the valid part of the driving cycle from 177 to 912 s.

2.3 Test programme

The test program is presented in Table 4. In this table also the test names used in the report are given. Two Artemis highway tests were performed for CITROËN, since a regeneration[1] of the DPF occurred during the first Artemis highway test.

[1] Regeneration of DPF means oxidation of solid particulates trapped in the filter into gaseous products. The regeneration process cleans the trap almost completely, lowers the pressure drop to a level comparable with that of a new filter.

Table 4: Test programme.

Driving cycle	CITROËN	PEUGEOT	OPEL	SKODA
NEDC at 22°C	CNE22	PNE22	ONE22	SNE22
Artemis urban at 22°C	CAU22	PAU22	OAU22	SAU22
Artemis extra urban at 22°C	CAEU22*	PAEU22	OAEU22	SAEU22
Artemis highway at 22°C	CAH22	PAH22	OAH22	SAH22
NEDC at -7°C	CNE-7	PNE-7	ONE-7	SNE-7
Artemis highway at 22°C	CAH22-2			

* Regeneration of the DPF occurred during this Artemis highway test.

2.4 Chassis dynamometer

The cars were tested on an electric Clayton DC500 500 mm double roller chassis dynamometer at two test cell temperatures, ambient temperature (20 - 30°C) and cold temperature (-7°C), according to the test programme in Table 4. The dynamometer settings were applied for each vehicle according to the regulation and the vehicle type approval data provided by manufactures.

2.5 CVS-tunnel

A Constant Volume Sampler (CVS) (Horiba, CVS-9300T) was used in the study. The CVS tunnel has a total length of 3150 mm with an inner diameter of 250 mm and is connected to the tailpipe via a 5 m long section of 110 mm diameter insulated stainless steel transfer tube. The transfer tube is connected to the tailpipe with a 30 cm section of flexible stainless steel tubing. At a distance of 30 cm from the tailpipe, cleaned and HEPA filtered test cell air is introduced to the transfer tube into the exhaust stream. The CVS tunnel flow rate is controlled by use of a 9 m^3/min critical venturi.

2.6 Regulated emissions measurements

The regulated gaseous emissions were measured according to the test procedures corresponding to the regulation (70/220/EEC including later amendments). A Horiba Mexa 9000 series (9400D) instrument was used for CO, HC, NO, NO_x, and CO_2 analysis. The measurement principles for the different components are given in Table 5 below. The regulated NEDC test bag sampling was performed using a set of 3 bags for exhausts, and 3 bags for dilution air sampling; whereas for Artemis single bag system for both exhausts and dilution air sampling was used.

The particulate mass (PM) measurement procedure was performed in accordance with the PMP-protocol (measurement positions are indicated in Figure 5 below). The filters were 47 mm diameter TX40 filters (PTFE bonded glass fibre filters; PALL) mounted in a filter holder meeting the standards for the US2007 regulation [Andersson]. The filters were weighed with a balance (Satorius) with a resolution of 0.1 µg.

Table 5: Measurement principles.

Emission component	**Measurement principle**
Total hydrocarbons (THC)	HFID (heated flame ionization detector, 190°C)
Carbon monoxide (CO)	NDIR (Non-dispersive infrared analyzer)
Nitrogen oxides (NO, NO_x)	CLA (Chemiluminescence)
Carbon dioxide (CO_2)	NDIR (Non-dispersive infrared analyzer)
Fuel consumption (FC)	Carbon balance of HC, CO and CO_2
Particulate emissions (PM)	Gravimetric

2.7 PMP system and particle number measurements

The instrumental set-up for particulate mass and particle number measurement was designed according to the PMP-protocol [PMP]. Both PM (measurement of mass emissions according to gravimetric method) and particle number (PMP system) sampling were performed from the CVS-tunnel as shown in Figure 5 below.

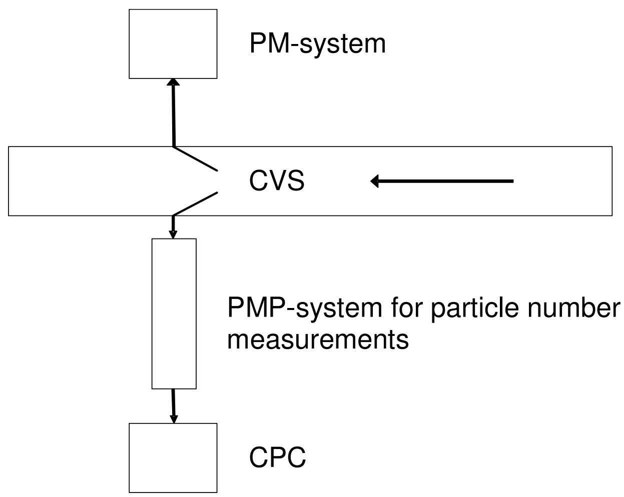


Figure 5: Schematic for the measurements of particulate number and mass.

The PMP-system according to the PMP-protocol is presented in Figure 6 below. The system is designed to measure aerosol particles from which volatile material is removed from the particulate phase by heating the aerosol. In brief the system may be described as: a sampling probe inside the CVS-tunnel, a unit to remove coarse particles (PCF), a dilution unit (PND1) to provide dilution factors (DF) in the range 1-1000, the evaporation tube (ET) to heat the aerosol, a second dilution stage (PND2) to provide DF 1-30, and an instrument (PNC) to measure the particle number concentration [PMP].

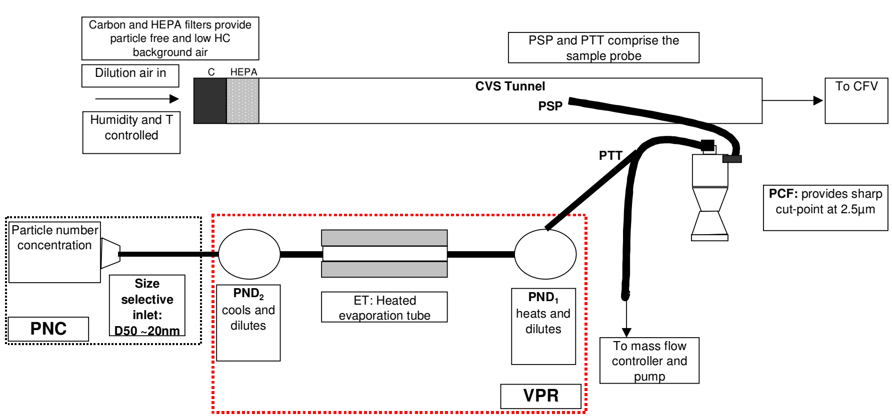


Figure 6: Schematic of the PMP-system used [PMP].

In this project the PMP-system used a stainless-steel inlet sample probe with the tip in a counter-flow position in the CVS-tunnel. The dimensions of the probe were i.d. 12 mm with a total length of 30 cm, of which 20 cm was positioned inside the CVS-tunnel. A Dekati SAC-65 cyclone (PCF) was connected to the sample probe.

The primary diluter (PND1) used an ejector dilutor (Dekati, DI-1000) for the tests of PEUGEOT and CITROËN and a rotating disc dilutor (Matter Engineering AG, MD19) for the OPEL and SKODA. This was chosen due to the significantly higher particle number emissions from non DPF vehicles than the DPF vehicles. The ejector dilutor provided a DF of 8.2 and rotating disc of 1493. Both diluters were operated at 150°C.

The ET consisted of electrically heated stainless steel tubing of i.d. 6.1 mm. The ET was connected to a second section of tubing, the cooler, cooled by pressurised air flowing through an outer jacket. The cooler was used in order to reduce thermoforetic losses of particles. The temperature of the ET was set at 350°C that rendered a section of 80 cm with temperatures at 300 - 400°C. The ET meets the design criteria in the PMP-protocol.

For the particle number measurements a TSI3010 CPC with an adjusted lower particle cut-off diameter was used. The cut-off diameter was set at 23 nm by adjusting the temperature difference between the vapour chamber and the condenser tube to 9°C in accordance with TSI instructions (Oliver Bischof / TSI, private communication). The measurement range of the CPC is 0-10000 particles/cm^3 and the time resolution used was 1 Hz.

3. RESULTS AND DISCUSSION

All the test results are enclosed in Appendix 1-4. The Online particle emissions are illustrated in Appendix 5. The CO, HC, NO_x, NO_2, NO_2/NO_x ratio, CO_2, PM, particle number emissions and fuel consumptions (FC) from the NEDC and the Artemis tests at 22°C are presented in Figures 7-15. In able to have fair comparisons among the vehicles and the test cycles, only the results of AH2 test (without regeneration) of CITROËN are presented in the figures. It is worth to point out that the Euro 4 limits and declared CO_2, fuel consumption indicated in the figures are only applicable to NEDC test at 22°C (marked as NEDC+22).

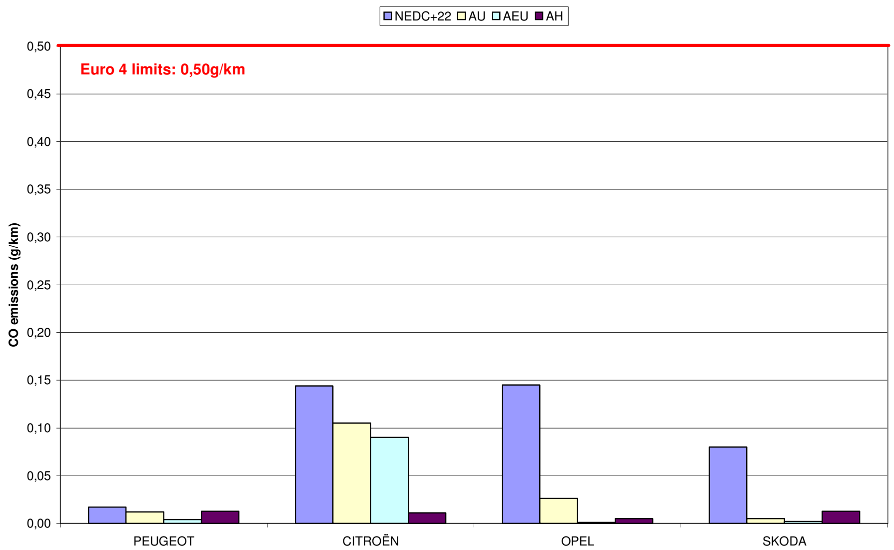


Figure 7: CO emissions from NEDC tests and Artemis tests at 22°C.

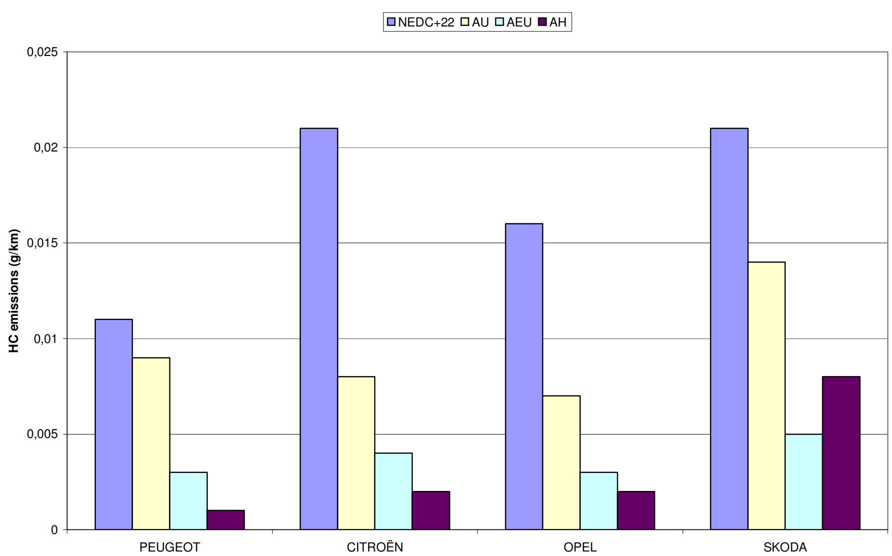


Figure 8: HC emissions from NEDC tests and Artemis tests at 22°C.

Figure 7 clearly shows that the CO emissions of NEDC tests from all four vehicles are well below the Euro 4 limits. The NEDC tests have higher HC and CO emissions than the Artemis tests. This can be explained by the NEDC cold start effects. The cold start effects are further illustrated in the NEDC results in different phases later on.

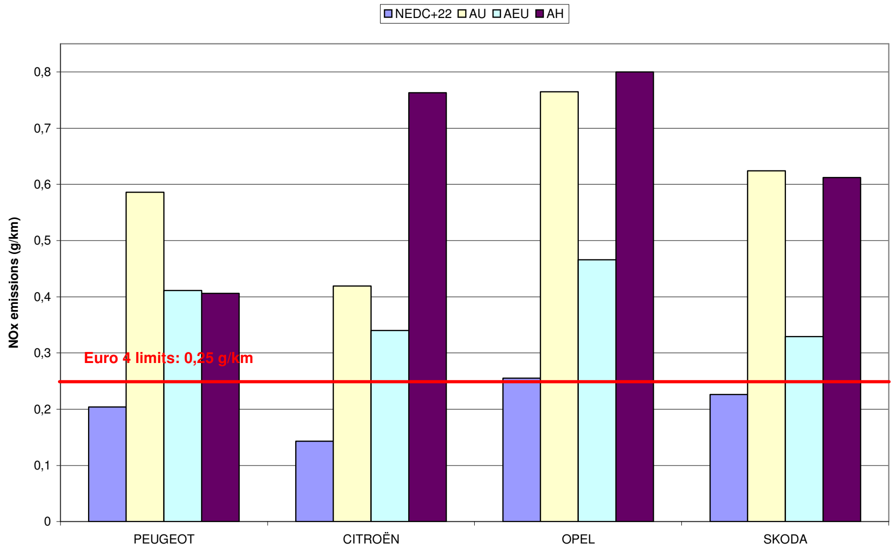


Figure 9: NO_x emissions from NEDC tests and Artemis tests at 22°C.

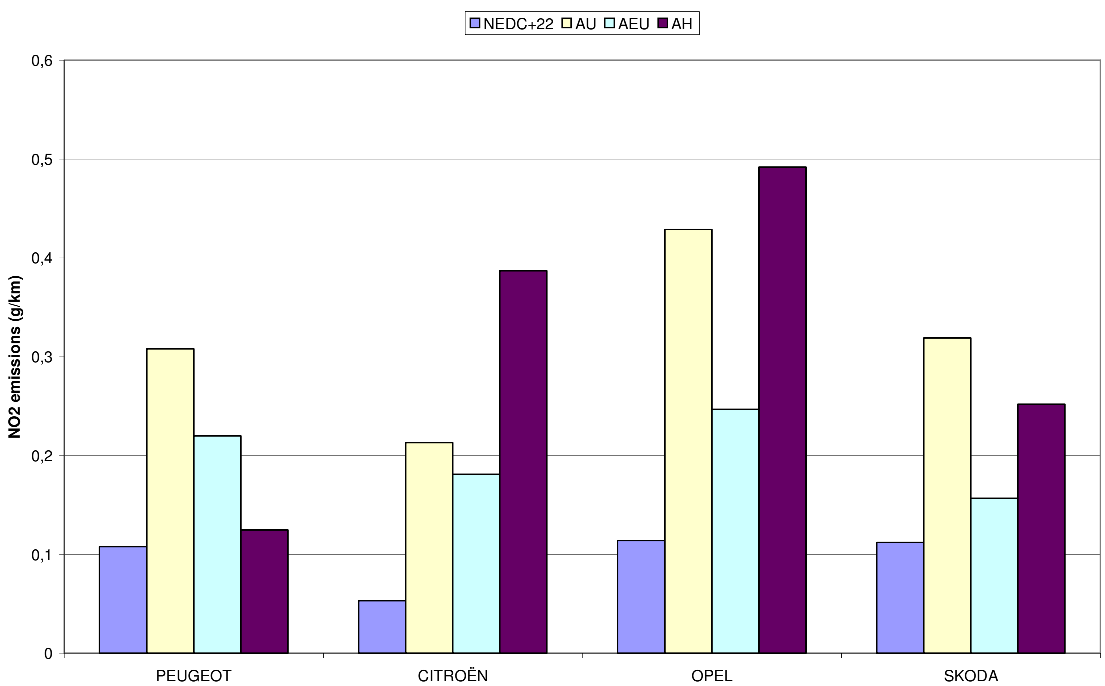


Figure 10: NO_2 emissions from NEDC tests and Artemis tests at 22°C.

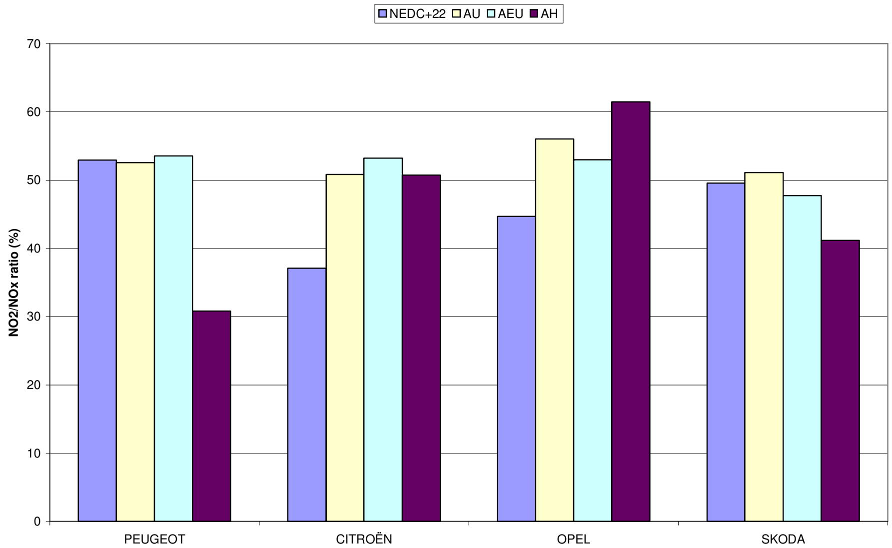


Figure 11: NO_2/ NO_x ratio from NEDC tests and Artemis tests at 22°C.

Figure 9 clearly shows that the NO_x emissions of NEDC tests from all four vehicles are within the Euro 4 limits. The Artemis tests have higher NO_x and NO_2 emissions than the NEDC tests as illustrated in Figure 9 and 10. From Figure 11 it is observed that the NO_2/NO_x ratio depends upon the driving cycle and the vehicle type; it is in the range 30-60%. There is no conclusive difference in NO_2 emissions or NO_2/NO_x ratio between the vehicles with DPF and the vehicles without DPF.

It is known that NO_2 is present in the native diesel exhaust in small quantities (5-15%), but its concentration can be increased by using oxidation catalyst. The oxidation of NO to NO_2 is an equilibrium process. NO conversion rate is controlled by the reaction kinetics at low temperatures and by thermodynamic constrains at high temperatures [DieselNet]]. The highest NO conversion occurs at medium temperature of about 250 to 350°C, the NO_2 fraction can be increased to 70-80% of total NOx with the use of a sufficiently large and active catalyst. For diesel with DPF it is important to maintain certain NO_2/NO_x ratio, since NO_2 can oxidize diesel particulate at higher rate than oxygen [Allansson], and thus increase soot oxidation and decrease the DPF regeneration temperature.

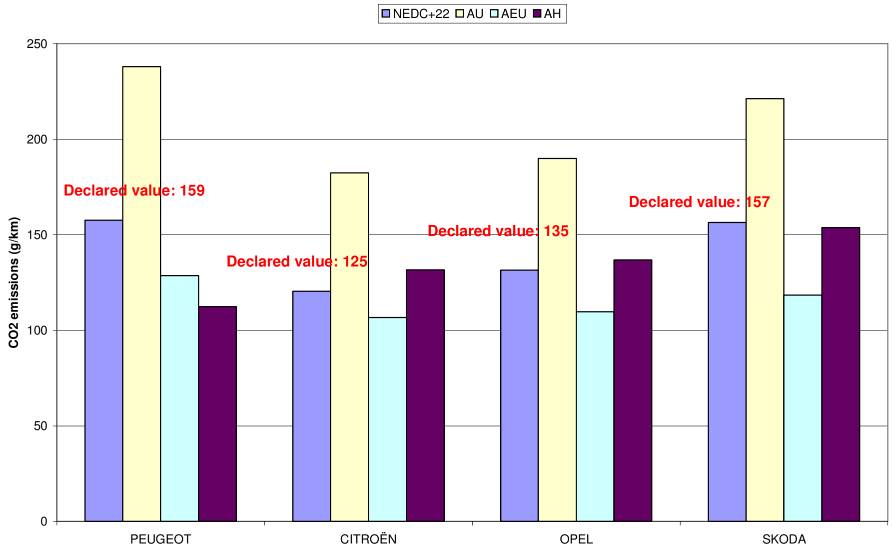


Figure 12: CO_2 emissions from NEDC tests and Artemis tests at 22°C.

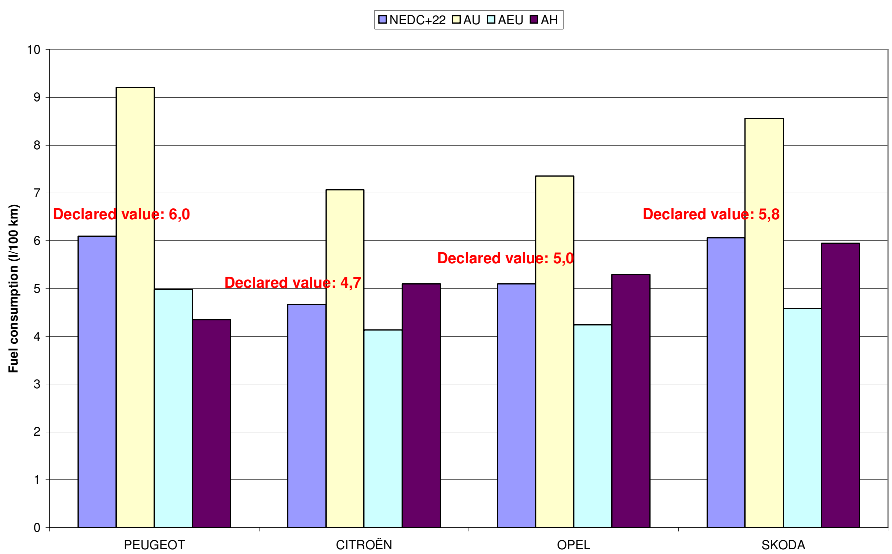


Figure 13: Fuel consumption from NEDC tests and Artemis tests at 22°C.

Figures clearly show the fuel consumption and CO_2 emissions of the NEDC tests match very well with the declared values of the type of vehicle. For all the vehicles the Artemis urban tests have the highest fuel consumptions among the test cycles. The fuel consumption generally has such a sequence: AU > NEDC > AH > AEU. The exception is observed in the PEUGEOT AH tests, it has lower fuel consumption than the AEU test.

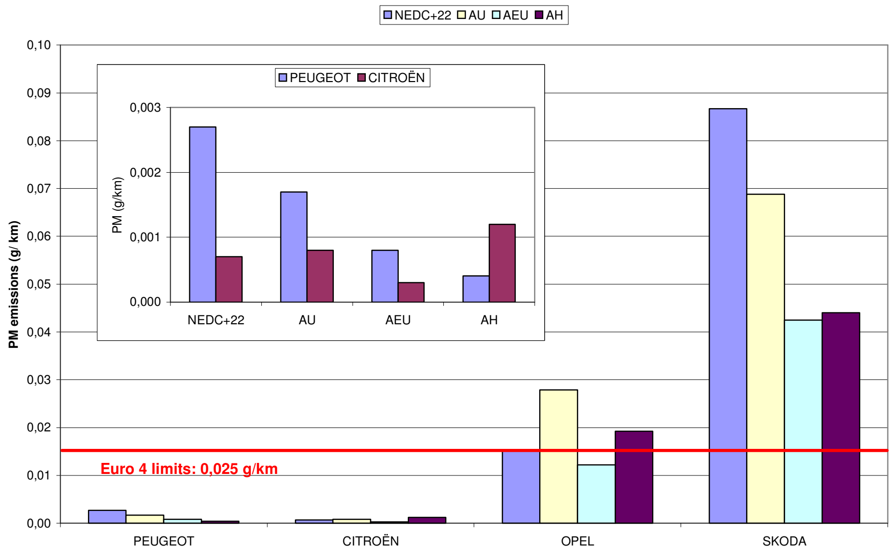


Figure 14: PM emissions from NEDC tests and Artemis tests at 22°C.

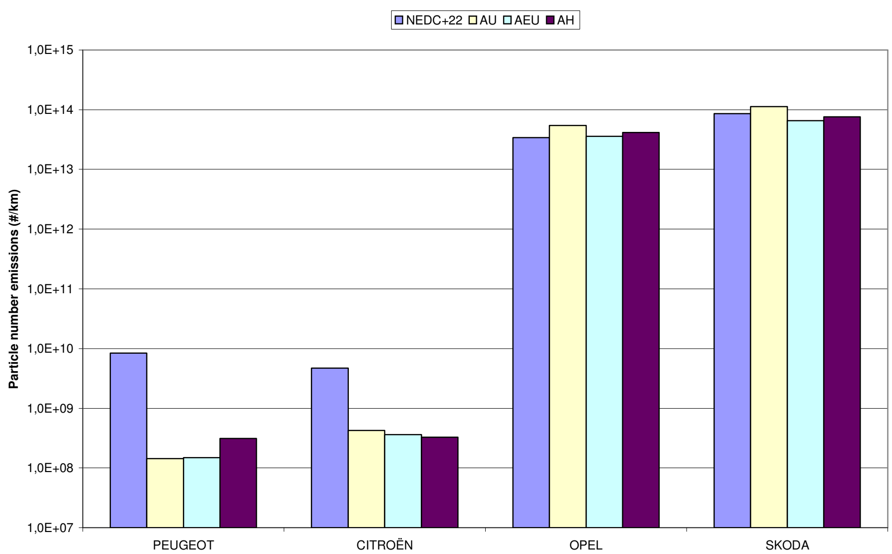


Figure 15: Particle number emissions from NEDC tests and Artemis tests at 22°C.

We note that the PM emissions from SKODA (0,0867 g/km) is higher than the limited value (0,025g/km), the other vehicle PM emissions are below the regulated limits. Clearly the PM and particle number emissions from the DPF equipped vehicles are significantly lower than the non DPF equipped vehicles. The PM emissions follow the sequence: SKODA > OPEL > > PEUGEOT > CITROËN (except AH for CITROËN). The particle number emission from

DPF equipped vehicles are in the range 10^8-10^{10} /km and non DPF equipped vehicles are in the range 10^{13}-10^{14} /km. This is in good agreement with previous studies of diesel vehicles [Karlsson]. For every driving cycle the emissions follow the sequence: SKODA > OPEL > > PEUGEOT, CITROËN.

As we mentioned above 2 AH tests were performed for CITROËN, the first one with regeneration of the DPF during the test. The online particle number measurement (Appendix 5) indicates that the regeneration lasted more than 500 s. In Table 6 and Figure 16 the emissions from the two tests are summarised. Comparing the two AH tests, the AH test with regeneration has significantly higher CO, HC, NO_x, CO_2, PM and particle number emissions than the AH test without regeneration. During the regeneration process extra fuel was injected to facilitate the process, thus caused higher CO, HC, NO_x and CO_2 emissions. The higher PM and particle number emissions are caused by the higher fuel/air ratio and are also originated from the soot oxidation. Interestingly the AH test without regeneration has lower NO_x but higher NO_2 emissions than the AH test with DPF regeneration. This could be due to that the NO_2 in the AH-regeneration test was used as oxidant for the DPF regeneration.

Table 6: Emissions from two AH tests of CITROËN.

g/km	CO	HC	NOx	NO2	NO2/Nox	CO2 (kg/km)	PM	Particle number (#/km)
CAH regeneration	0,45	0,01	0,85	0,33	0,38	0,173	0,0054	1,39E+11
CAH non-regeneration	0,01	0,00	0,76	0,39	0,51	0,132	0,0012	3,28E+08

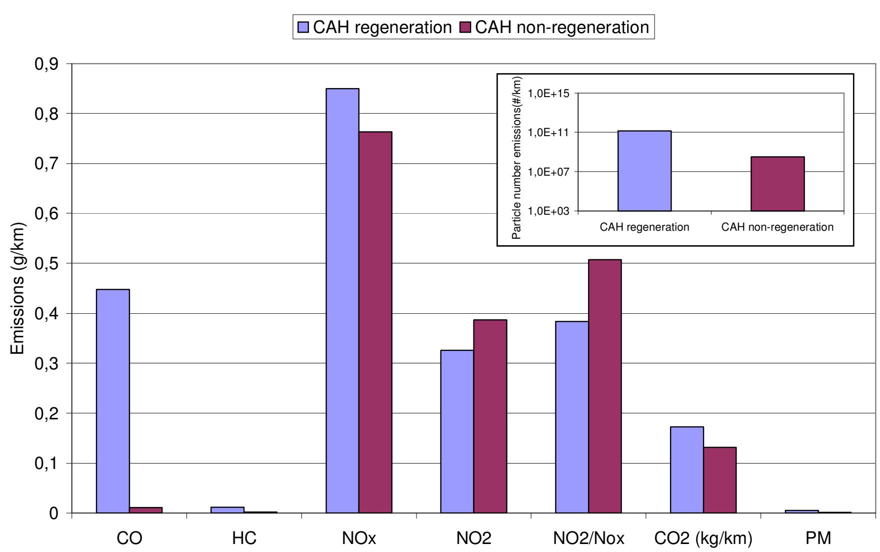


Figure 16: Particle number emissions from 2 AH tests of CITROËN at 22°C

In Figures 17-24, the NEDC tests at 22°C and -7°C are displayed. The cold climate effects upon emissions are clear; the -7°C NEDC tests have higher HC, CO, NO_x, NO_2, CO_2 (FC) and PM emissions than 22°C. Exception is observed for SKODA, the -7°C NEDC has lower HC, CO and PM emissions than the 22°C tests. This could be due to a decreased EGR rate during the -7°C test.

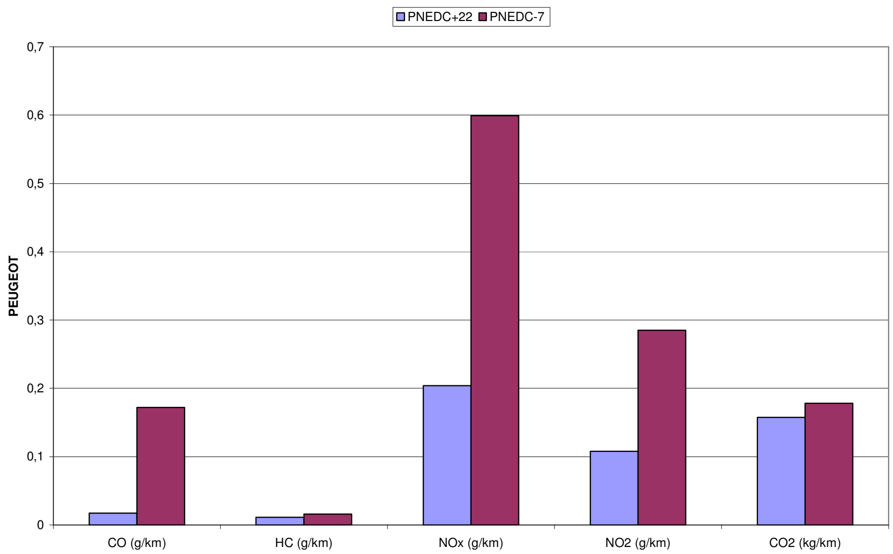


Figure 17: PEUGEOT NEDC tests at 22°C and -7°C.

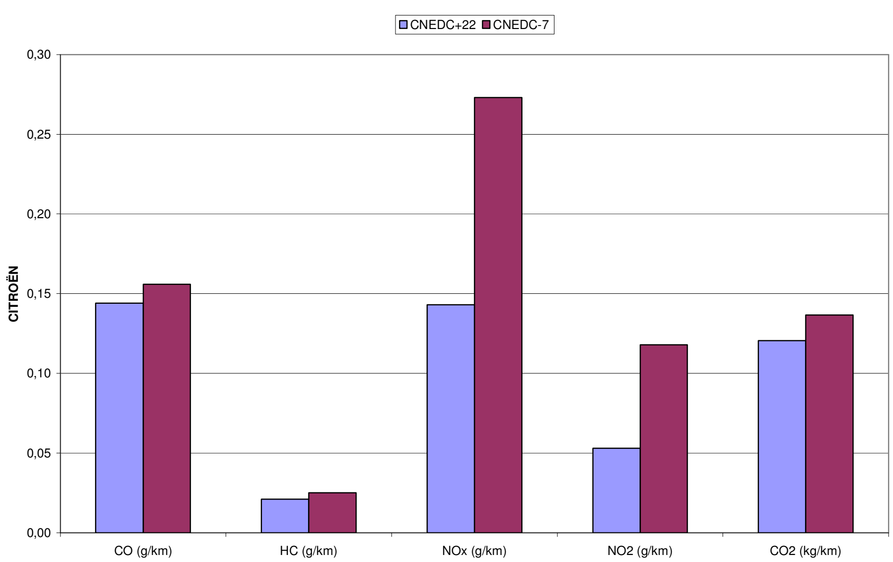


Figure 18: CITROËN NEDC tests at 22°C and -7°C.

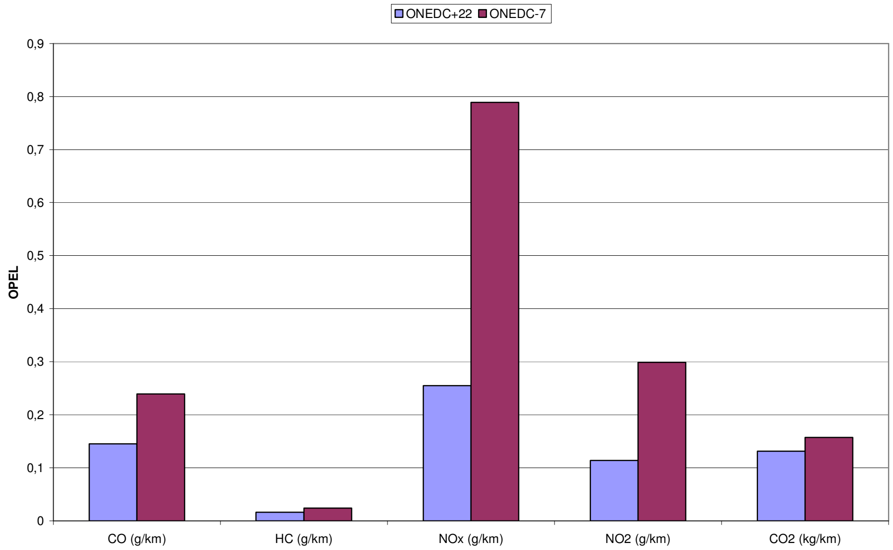


Figure 19: OPEL NEDC tests at 22°C and -7°C.

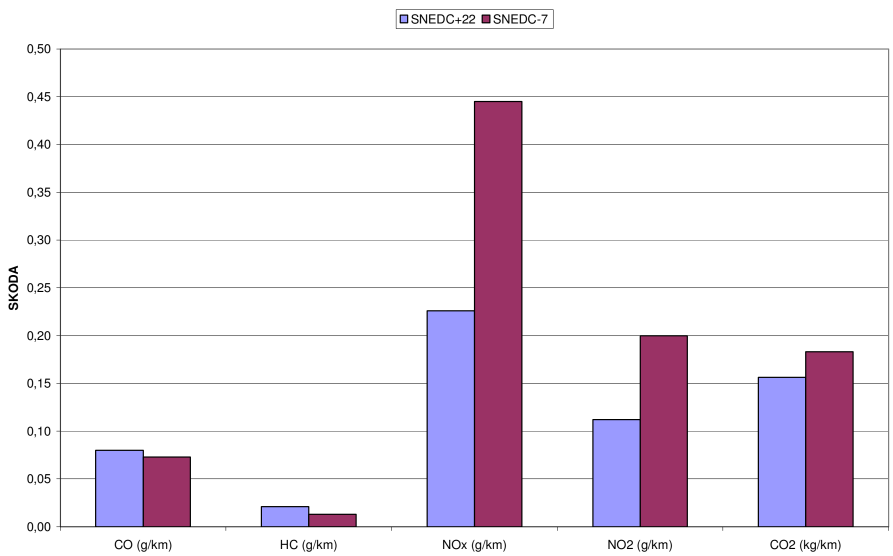


Figure 20: SKODA NEDC tests at 22°C and -7°C.

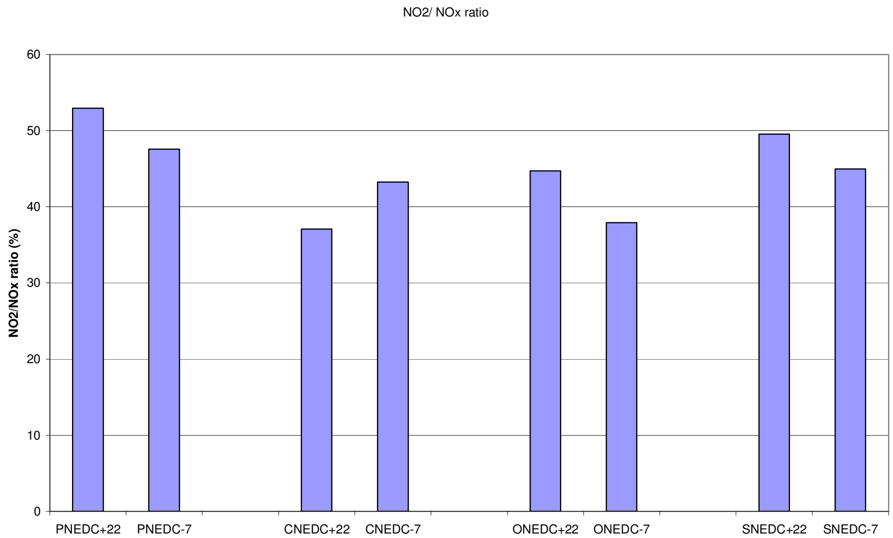


Figure 21: NO_2/ NO_x ratios in NEDC tests at 22°C and -7°C.

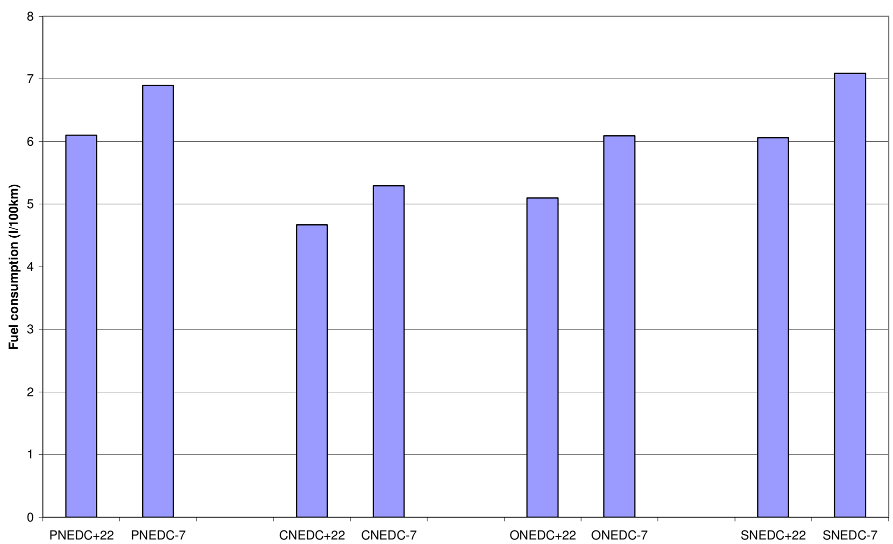


Figure 22: Fuel consumption in NEDC tests at 22°C and -7°C.

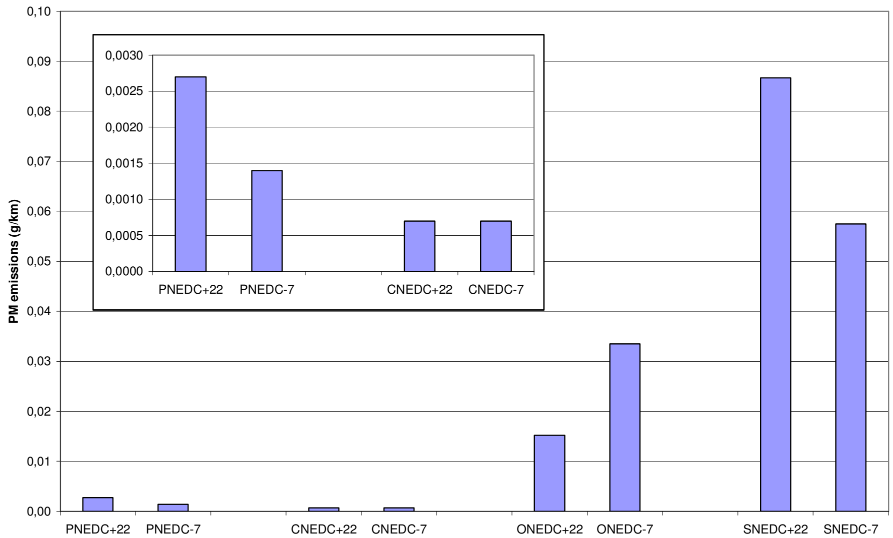


Figure 23: PM emissions in NEDC tests at 22°C and -7°C.

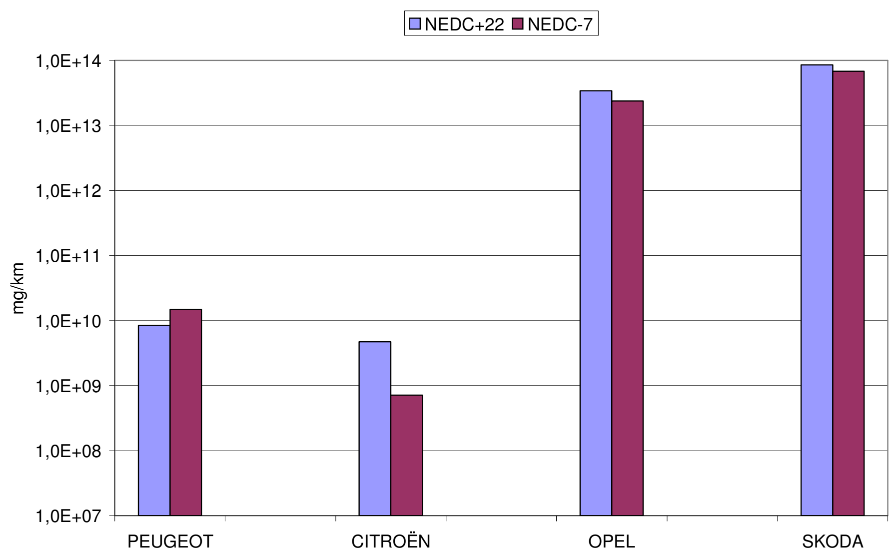


Figure 24: Particle number emissions in NEDC tests at 22°C and -7°C.

The particle number emissions are mostly in a similar range in the 22°C and in the -7°C tests. We note that the CITROËN -7°C test has significantly lower particle number emissions than the 22°C test. It is worth to point that the CITROËN -7°C test was performed directly after the AH test with DPF regeneration. The test history of the vehicle (i.e. DPF loading) could contribute to the low particle number emission in the test. Except PEUGEOT all the other three vehicles has somewhat lower particle number emissions in the -7°C test than the 22°C test.

In order to illustrate the emissions at different phase of the NEDC tests, the emissions from UDC1 (cold start urban driving), UDC 2 (warm engine urban driving) and EUDC (extra urban driving) are presented in Figures 25-32. The CO, HC, NO_x, CO_2 (fuel consumptions) and particles number emissions follow the sequence: UDC1 > UDC > EUDC, i.e. the most emissions are from the cold start phase of the test cycle. However for CITROËN and PEUGEOT 22°C tests the highest NO_x emissions occurred at EUDC phase. For SKODA the highest particle number emissions were observed at UDC2 phase.

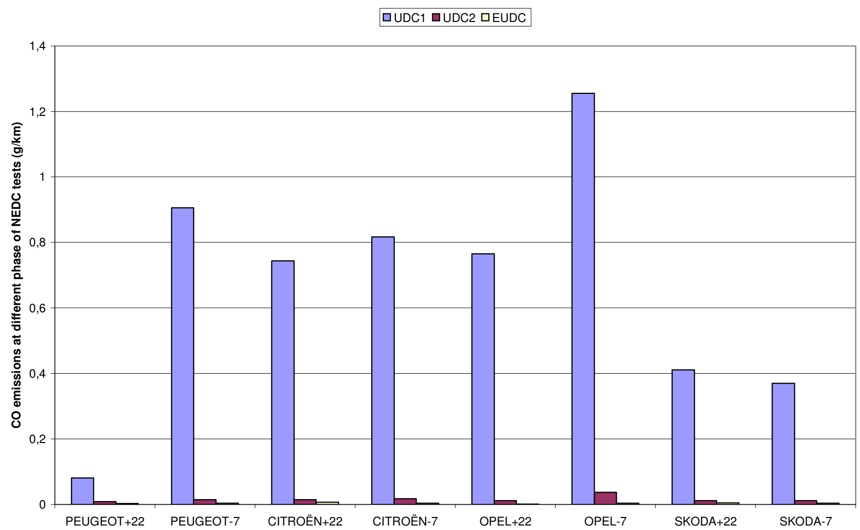


Figure 25: CO emissions from different phases of NEDC tests at 22°C and -7°C.

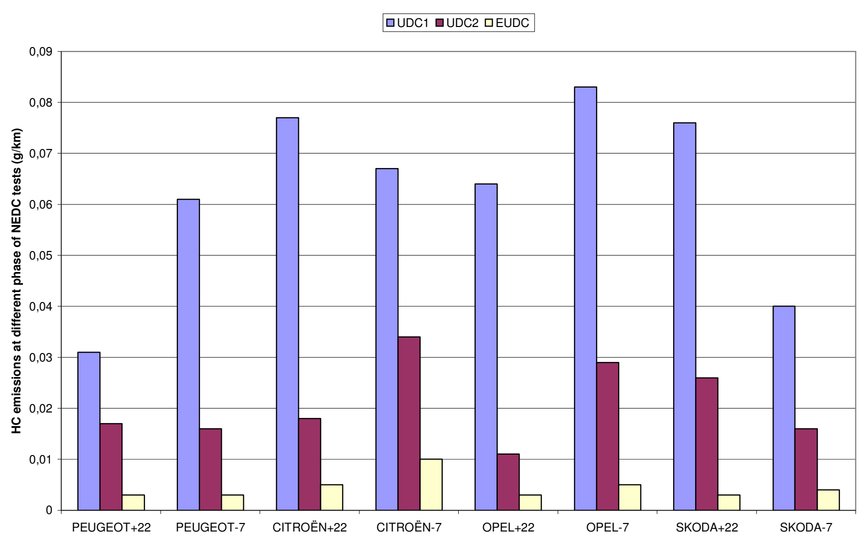


Figure 26: HC emissions from different phases of NEDC tests at 22°C and -7°C.

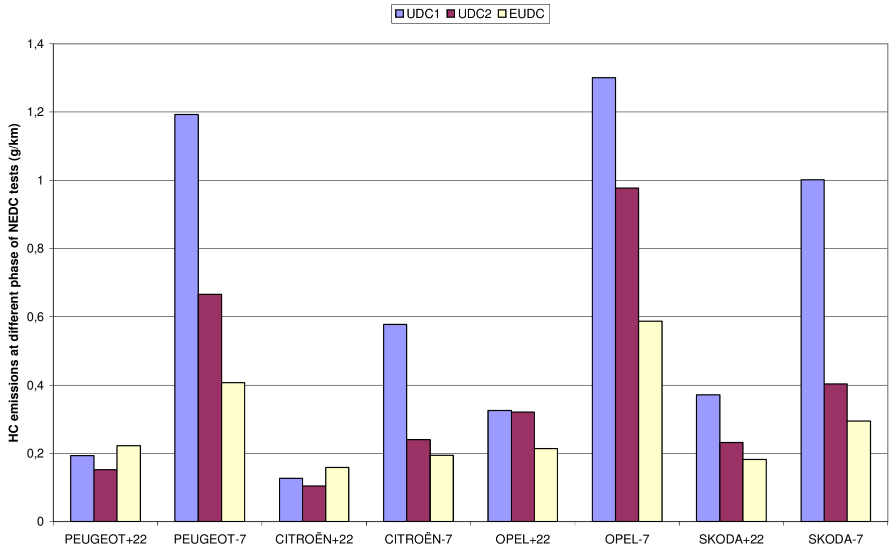


Figure 27: NO_x emissions from different phases of NEDC tests at 22°C and -7°C.

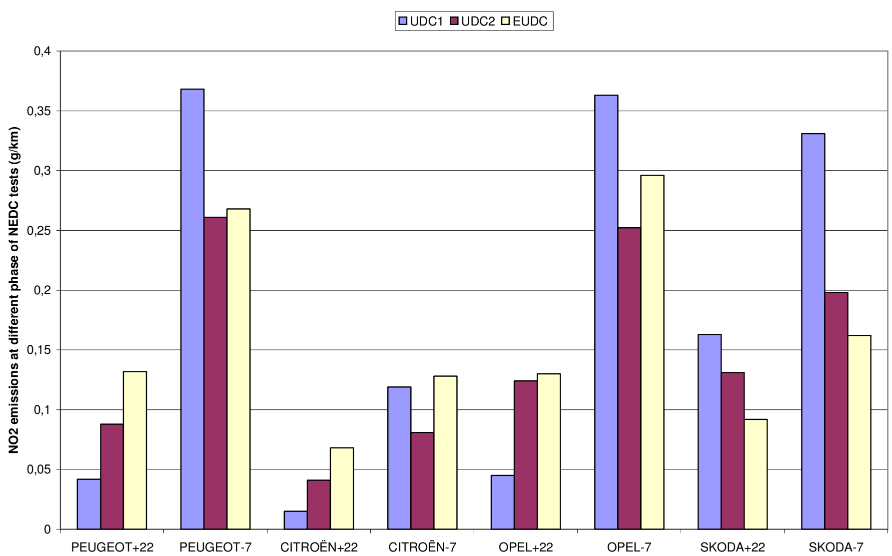


Figure 28: NO_2 emissions from different phases of NEDC tests at 22°C and -7°C.

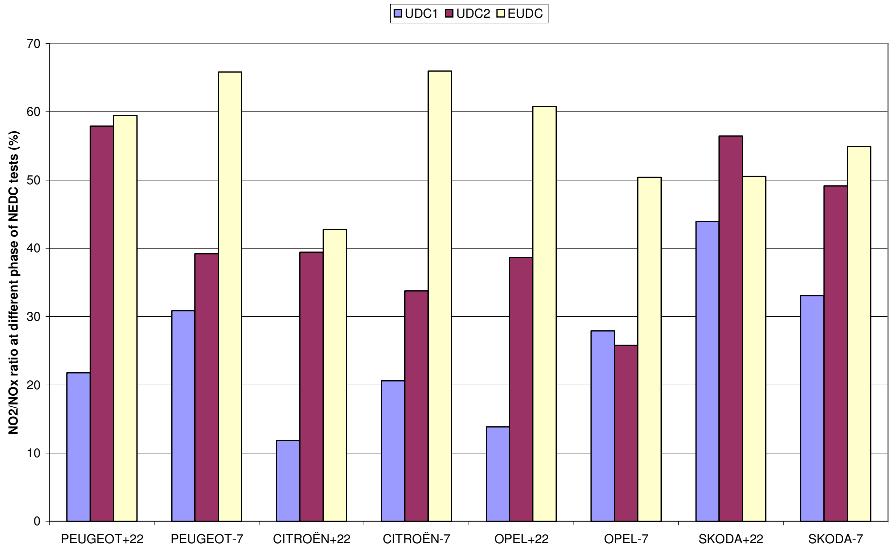


Figure 29: NO_2/ NO_x ratio from different phases of NEDC tests at 22°C and -7°C.

Figure 28 shows the NO_2 emissions depend upon the vehicle and test cycles. For example SKODA has highest NO_2 emissions in the UDC1 phase whereas CITROËN in the EUDC phase. Generally the NO_2/ NO_x ratio follows the sequence: EUDC > UDC2 > UDC1 (Figure 29).

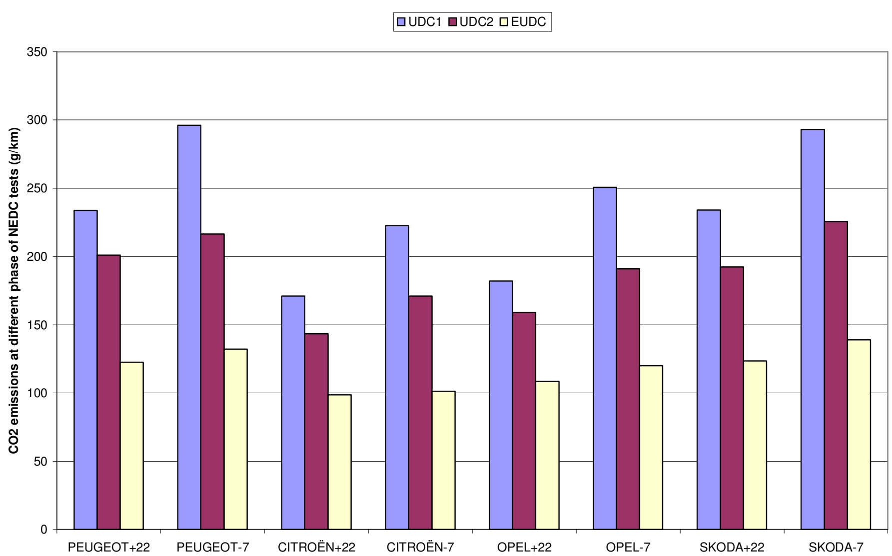


Figure 30: CO_2 emissions from different phases of NEDC tests at 22°C and -7°C.

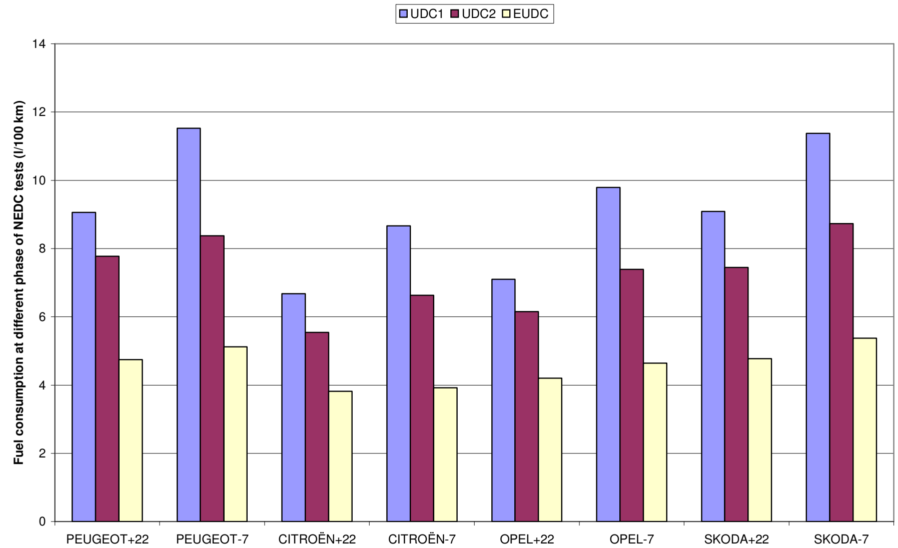


Figure 31: Fuel consumption from different phases of NEDC tests at 22°C and -7°C.

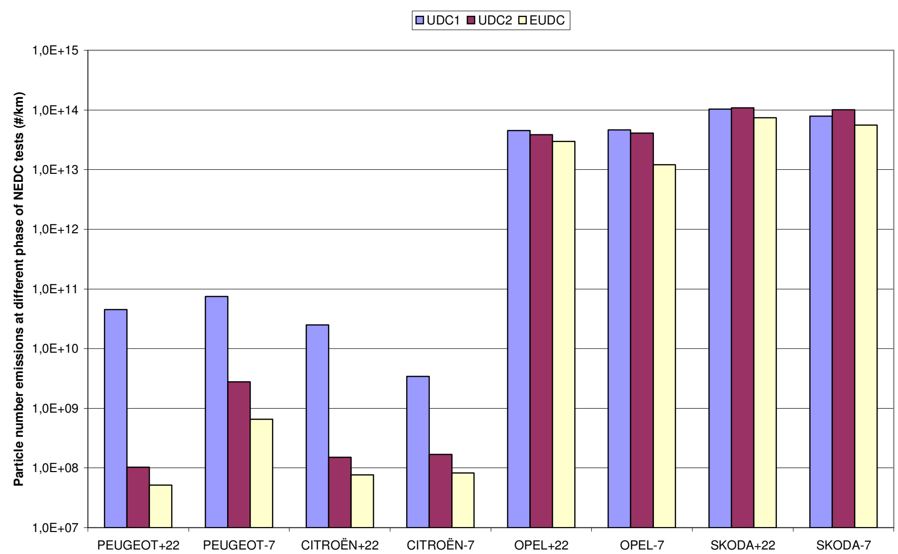


Figure 32: Particle number emissions from different phases of NEDC tests at 22°C and -7°C.

4. SUMMARY

Four diesel passenger vehicles approved according to Euro 4 emission standards were tested in this project. Two of the vehicles are equipped with DPF. The vehicles were tested using the NEDC test cycle at 22°C and -7°C and the Artemis test cycle at 22°C. CO, HC, NO_x, NO_2, PM, particle number emissions and fuel consumption were measured. The PM and particle number emissions were measured according to the PMP protocol.

The fuel consumption and CO_2 emissions of all 4 vehicles are in good agreement with the declared values. Except SKODA for PM emissions, all the regulated emissions are below the regulated limits.

The vehicles with DPF have significantly lower PM and particle number emissions comparing to the non-DPF vehicles. During regeneration the DPF vehicle has much higher PM and particle number emissions than the non-regeneration test. The regeneration also leads to increasing in CO, HC and NO_x emissions and fuel consumption.

Generally the NEDC tests have higher HC and CO emissions and lower NO_x emissions than the Artemis test. The fuel consumption follows such a sequence: AU > NEDC > AH > AEU.

Comparing to the 22°C NEDC test, the -7°C NEDC tests lead to increasing in regulated emissions (both gaseous and PM) and fuel consumption. However the low test temperature has no significant impacts upon the particle number emissions.

In both 22°C and -7°C NEDC tests, most emissions (HC, CO, NO_x, CO_2 and particle number) emit during the cold start UDC1 phase, but the highest NO_2/ NO_x ratio occurs in the EUDC phase.

5. SVENSK SAMMANFATTNING

Fyra Euro 4 diesel personbilar, två med och två utan partikelfilter, har provats med avseende på emissioner av reglerade emissioner och partikelantal. Partikelmassa och partikelantal mättes enligt PMP protokollet.

Proven genomfördes som enkeltest i NEDC och i Artemiskörcyklerna vid provcellstemperaturer 22°C. Prov med NEDC genomfördes även vid - 7°C.

Bilarna med partikelfilter visade betydligt lägre partikelmassa och partikelantal än bilarna utan filter. Vid regeneration av partikelfilter observeras hög partikelmassa och antal partiklar samt höga emissioner av CO, HC, NO_x och CO_2.

Till följd av kallstarteffekt visade Artemis (start med varm motor) vanligtvis lägre HC och CO emissioner men högre NO_x jämfört med NEDC (start med kall motor). Kallstarten vid NEDC associeras med högre emissioner av de flesta avgaskomponenterna både vid prov körda vid 22°C och vid -7°C i fasen UDC1. Vid -7°C visades dock högre NO_2/ NO_x i fasen EUDC.

Prov körda vid -7°C visade högre emissioner jämfört med prov körda vid 22°C med undantaget för partikelantal vilket visade emissioner i samma storleksordning som för proven körda vid 22°C.

5. REFERENCES

[Andersson]. Andersson J.D., Clark, D.P. and Watson, J.A., UK Particulate Measurement Programme (PMP): A Near US 2007 Approach to Heavy Duty Diesel Particulate Measurements-Comparision with the Standar European Method. SAE 2004-01-1990.

[Allansson]. Allansson, R, et al, SAE 2002-01-0428.

[DieselNet]. WWW.dieselnet.com, Diesel Filter Regeneration, 2004.

[Karlsson]. Karlsson H., de Serves C, Report of Emission Performance of Euro 4 Passenger Cars, AECC Report, 2005.

[PMP]. GRPE_PMP 13-3 document of June 1, 2004.

APPENDIX 1a: Emissions from PEUGEOT NEDC and Artemis tests

g/km	PNEDC+22	PNEDC-7	PAU	PAEU	PAH
CO	0,02	0,17	0,01	0,00	0,01
HC	0,01	0,02	0,01	0,00	0,00
NOx	0,20	0,60	0,59	0,41	0,41
NO	0,10	0,31	0,28	0,19	0,28
NO2	0,11	0,29	0,31	0,22	0,13
CO2	157,60	177,90	238,00	128,60	112,30
FC	6,10	6,89	9,21	4,98	4,35
PM	0,0027	0,0014	0,0017	0,0008	0,0004
Particle number (#/km)	8,38E+09	1,47E+10	1,43E+08	1,50E+08	3,13E+08

APPENDIX 1b: Phase separated emissions, PEUGEOT NEDC tests

g/km	PNEDC22(UDC1)	PNEDC22(UDC2)	PNEDC22(EUDC)	PNEDC+22
CO	0,08	0,01	0,00	0,02
HC	0,03	0,02	0,00	0,01
NOx	0,19	0,15	0,22	0,20
NO	0,15	0,06	0,09	0,10
NO2	0,04	0,09	0,13	0,11
CO2	233,90	200,90	122,60	157,60
FC	9,06	7,78	4,74	6,10
PM				0,0027
Particle number (#/km)	4,51E+10	1,04E+08	5,19E+07	8,38E+09
g/km	PNEDC-7(UDC1)	PNEDC-7(UDC2)	PNEDC-7(EUDC)	PNEDC-7
CO	0,91	0,01	0,00	0,17
HC	0,06	0,02	0,00	0,02
NOx	1,19	0,67	0,41	0,60
NO	0,83	0,41	0,14	0,31
NO2	0,37	0,26	0,27	0,29
CO2	296,30	216,40	132,30	177,90
FC	11,53	8,38	5,12	6,89
PM				0,0014
Particle number (#/km)	7,46E+10	2,76E+09	6,60E+08	1,47E+10

APPENDIX 2a: Emissions from CITROËN NEDC and Artemis tests

g/km	CNEDC+22	CNEDC-7	CAU	CAEU	CAH	CAH-2
CO	0,14	0,16	0,11	0,09	0,45	0,01
HC	0,02	0,03	0,01	0,00	0,01	0,00
NOx	0,14	0,27	0,42	0,34	0,85	0,76
NO	0,09	0,16	0,21	0,16	0,52	0,38
NO2	0,05	0,12	0,21	0,18	0,33	0,39
CO2	120,40	136,50	182,40	106,70	173,10	131,70
FC	4,67	5,29	7,07	4,13	6,72	5,10
PM	0,0007	0,0007	0,0008	0,0003	0,0054	0,0012
Particle number (#/km)	4,70E+09	7,17E+08	4,25E+08	3,62E+08	1,39E+11	3,28E+08

APPENDIX 2b: Phase separated emissions, CITROËN NEDC tests

g/km	CNEDC22(UDC1)	CNEDC22(UDC2)	CNEDC22(EUDC)	CNEDC+22
CO	0,74	0,01	0,01	0,14
HC	0,08	0,02	0,01	0,02
NOx	0,13	0,10	0,16	0,14
NO	0,11	0,06	0,09	0,09
NO2	0,02	0,04	0,07	0,05
CO2	171,10	143,30	98,70	120,40
FC	6,68	5,55	3,82	4,67
PM				0,0007
Particle number (#/km)	2,50E+10	1,51E+08	7,66E+07	4,70E+09
g/km	CNEDC-7(UDC1)	CNEDC-7(UDC2)	CNEDC-7(EUDC)	CNEDC-7
CO	0,82	0,02	0,00	0,16
HC	0,07	0,03	0,01	0,03
NOx	0,58	0,24	0,19	0,27
NO	0,46	0,16	0,07	0,16
NO2	0,12	0,08	0,13	0,12
CO2	222,60	171,10	101,30	136,50
FC	8,67	6,63	3,92	5,29
PM				0,0007
Particle number (#/km)	3,44E+09	1,68E+08	8,25E+07	7,17E+08

APPENDIX 3a: Emissions from OPEL NEDC and Artemis tests

g/km	ONEDC+22	ONEDC-7	OAU	OAEU	OAH
CO	0,15	0,24	0,03	0,00	0,01
HC	0,02	0,02	0,01	0,00	0,00
NOx	0,26	0,79	0,77	0,47	0,80
NO	0,14	0,49	0,34	0,22	0,31
NO2	0,11	0,30	0,43	0,25	0,49
CO2	131,40	157,00	189,90	109,70	136,80
FC	5,10	6,09	7,35	4,24	5,29
PM	0,0152	0,0335	0,0279	0,0122	0,0192
Particle number (#/km)	3,40E+13	2,38E+13	5,46E+13	3,59E+13	4,16E+13

APPENDIX 3b: Phase separated emissions, OPEL NEDC tests

g/km	ONEDC22(UDC1)	ONEDC22(UDC2)	ONEDC22(EUDC)	ONEDC+22
CO	0,77	0,01	0,00	0,15
HC	0,06	0,01	0,00	0,02
NOx	0,33	0,32	0,21	0,26
NO	0,28	0,20	0,08	0,14
NO2	0,05	0,12	0,13	0,11
CO2	182,00	159,00	108,50	131,40
FC	7,10	6,15	4,20	5,10
PM				0,0152
Particle number (#/km)	4,48E+13	3,84E+13	2,96E+13	3,40E+13
g/km	ONEDC-7(UDC1)	ONEDC-7(UDC2)	ONEDC-7(EUDC)	ONEDC-7
CO	1,26	0,04	0,00	0,24
HC	0,08	0,03	0,01	0,02
NOx	1,30	0,98	0,59	0,79
NO	0,94	0,73	0,29	0,49
NO2	0,36	0,25	0,30	0,30
CO2	250,80	190,90	120,00	157,00
FC	9,79	7,39	4,64	6,09
PM				0,0335
Particle number (#/km)	4,63E+13	4,11E+13	1,22E+13	2,38E+13

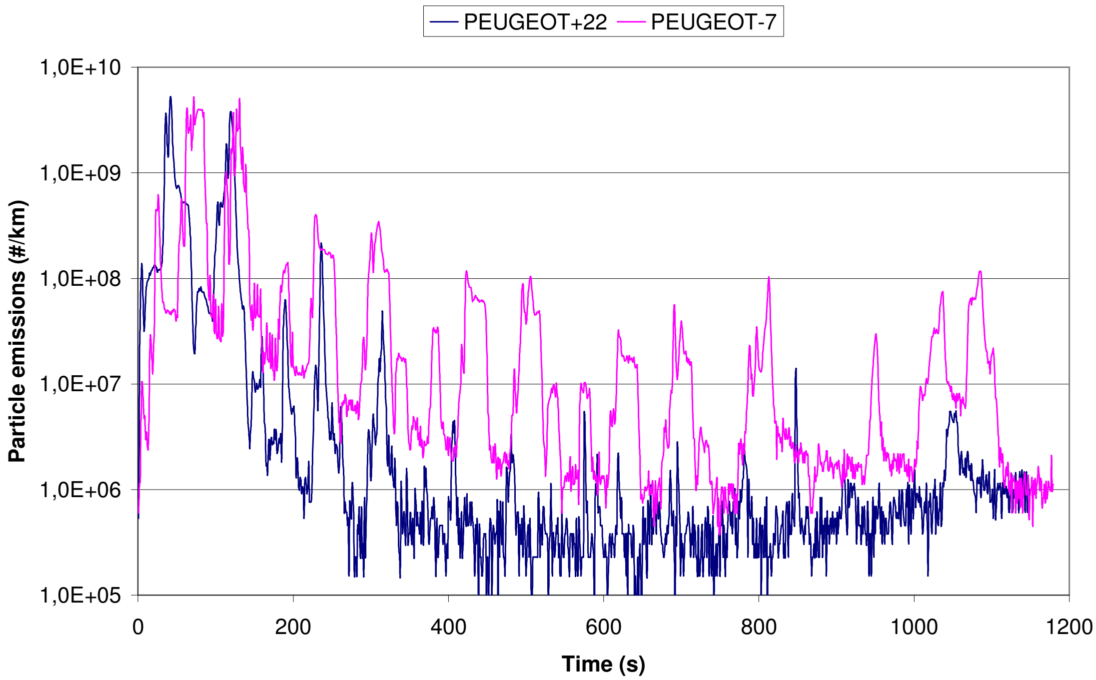
APPENDIX 4a: Emissions from SKODA NEDC and Artemis tests

g/km	SNEDC+22	SNEDC-7	SAU	SAEU	SAH
CO	0,08	0,07	0,01	0,00	0,01
HC	0,02	0,01	0,01	0,01	0,01
NOx	0,23	0,45	0,62	0,33	0,61
NO	0,11	0,25	0,31	0,17	0,36
NO2	0,11	0,20	0,32	0,16	0,25
CO2	156,40	183,10	221,20	118,50	153,70
FC	6,06	7,09	8,56	4,59	5,95
PM	0,0867	0,0575	0,0688	0,0425	0,044
Particle number (#/km)	8,57E+13	6,80E+13	1,13E+14	6,56E+13	7,59E+13

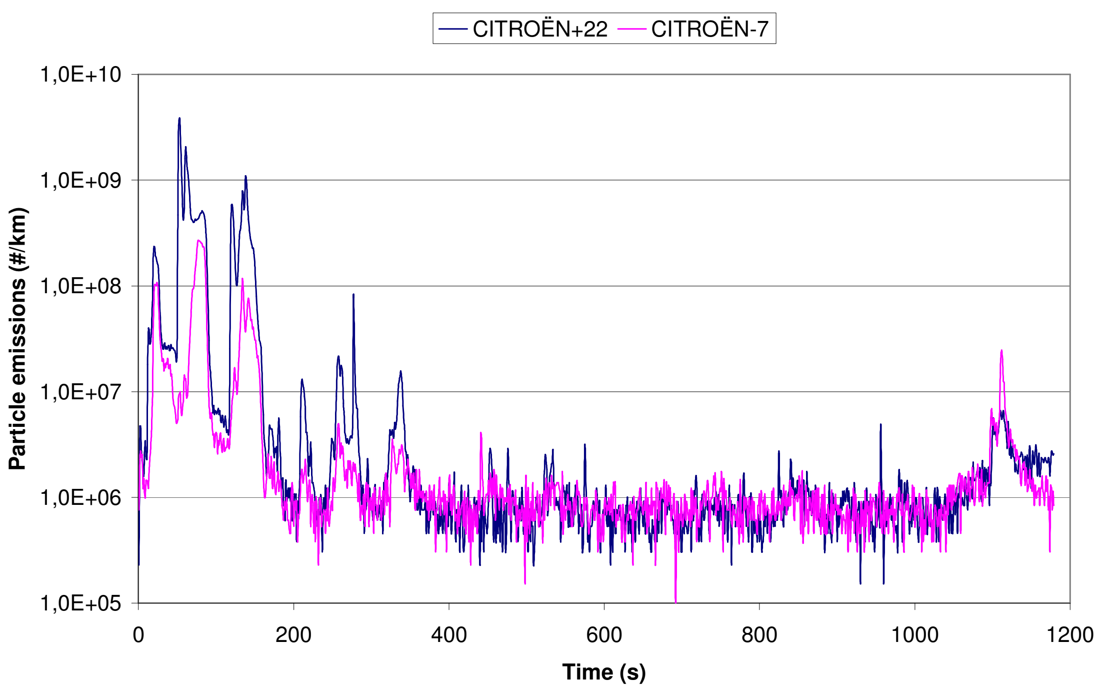
APPENDIX 4b: Phase separated emissions, SKODA NEDC tests

g/km	SNEDC22(UDC1)	SNEDC22(UDC2)	SNEDC22(EUDC)	SNEDC+22
CO	0,41	0,01	0,01	0,08
HC	0,08	0,03	0,00	0,02
NOx	0,37	0,23	0,18	0,23
NO	0,21	0,10	0,09	0,11
NO2	0,16	0,13	0,09	0,11
CO2	234,10	192,30	123,40	156,40
FC	9,09	7,44	4,78	6,06
PM				0,0867
Particle number (#/km)	1,04E+14	1,09E+14	7,38E+13	8,57E+13
g/km	SNEDC-7(UDC1)	SNEDC-7(UDC2)	SNEDC-7(EUDC)	SNEDC-7
CO	0,37	0,01	0,00	0,07
HC	0,04	0,02	0,00	0,01
NOx	1,00	0,40	0,30	0,45
NO	0,67	0,21	0,13	0,25
NO2	0,33	0,20	0,16	0,20
CO2	293,20	225,70	138,90	183,10
FC	11,37	8,73	5,38	7,09
PM				0,0575
Particle number (#/km)	7,90E+13	1,00E+14	5,54E+13	6,80E+13

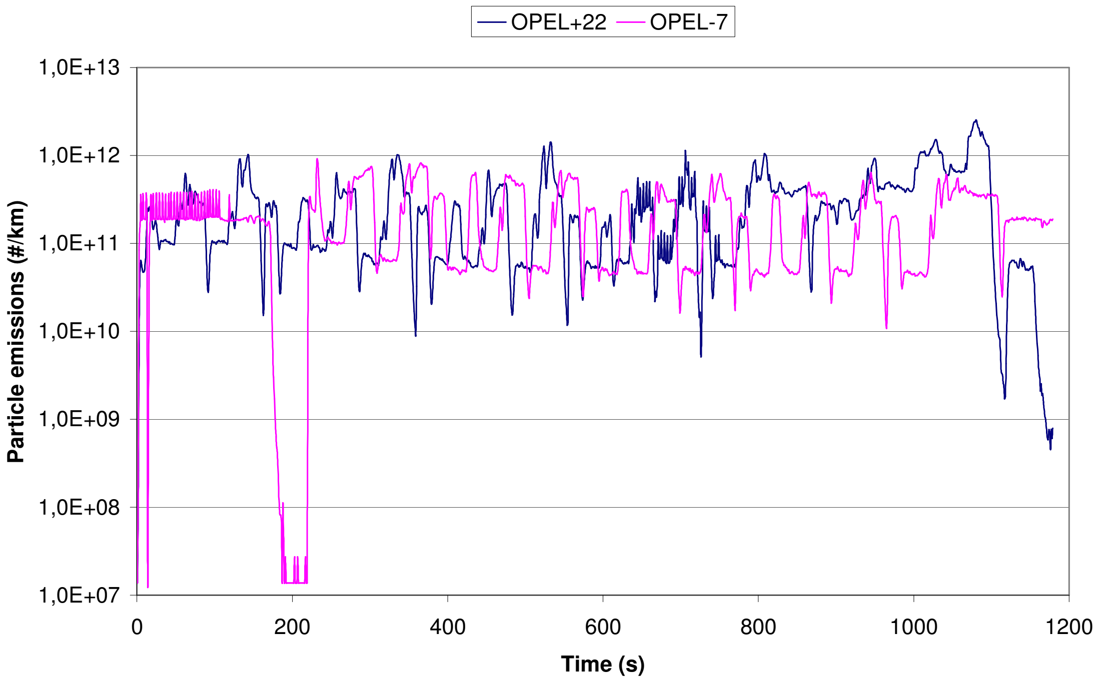
APPENDIX 5: Online particle number emissions



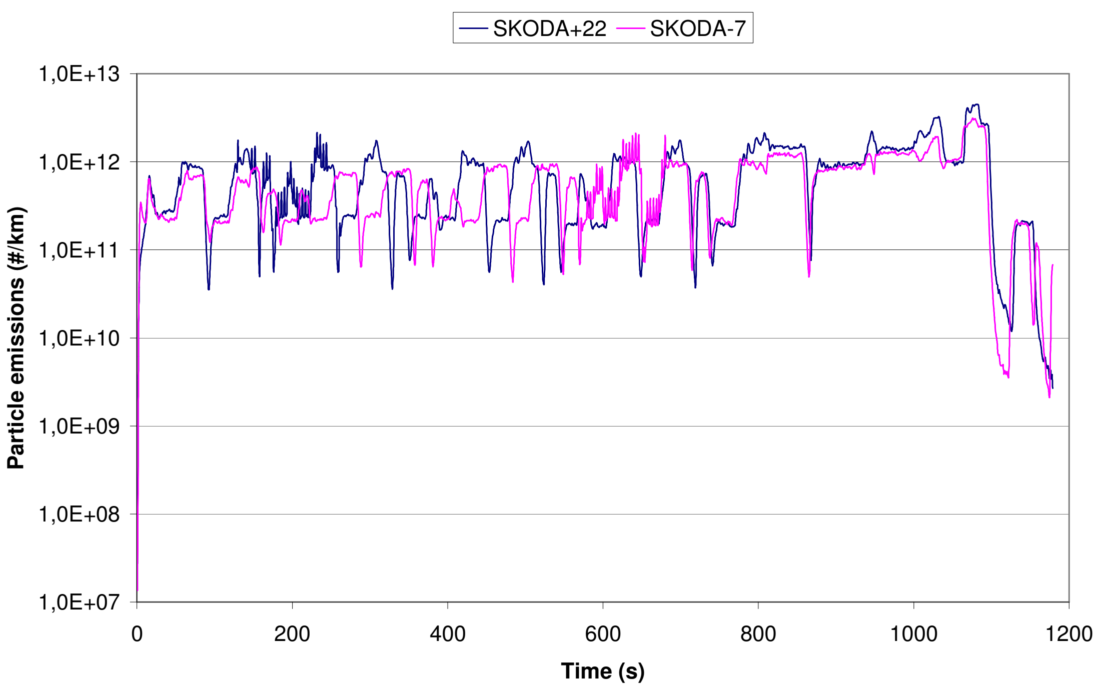
PEUGEOT online particle number emissions from NEDC tests at 22°C and -7°C.



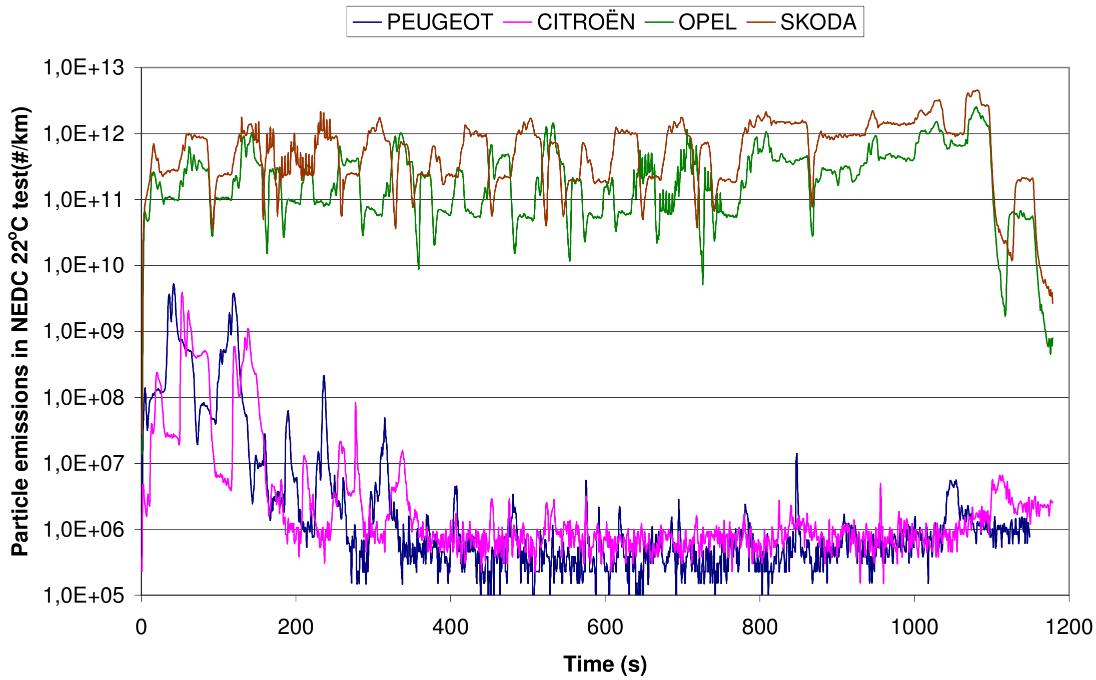
CITROËN online particle number emissions from NEDC tests at 22°C and -7°C.



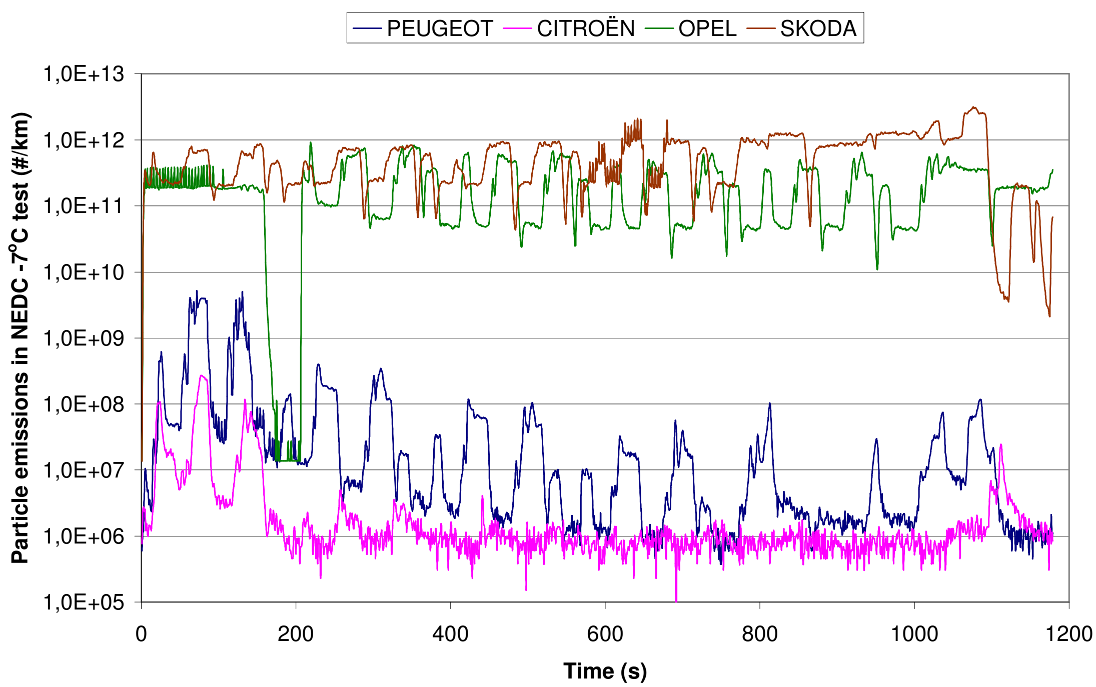
OPEL online particle number emissions from NEDC tests at 22°C and -7°C.



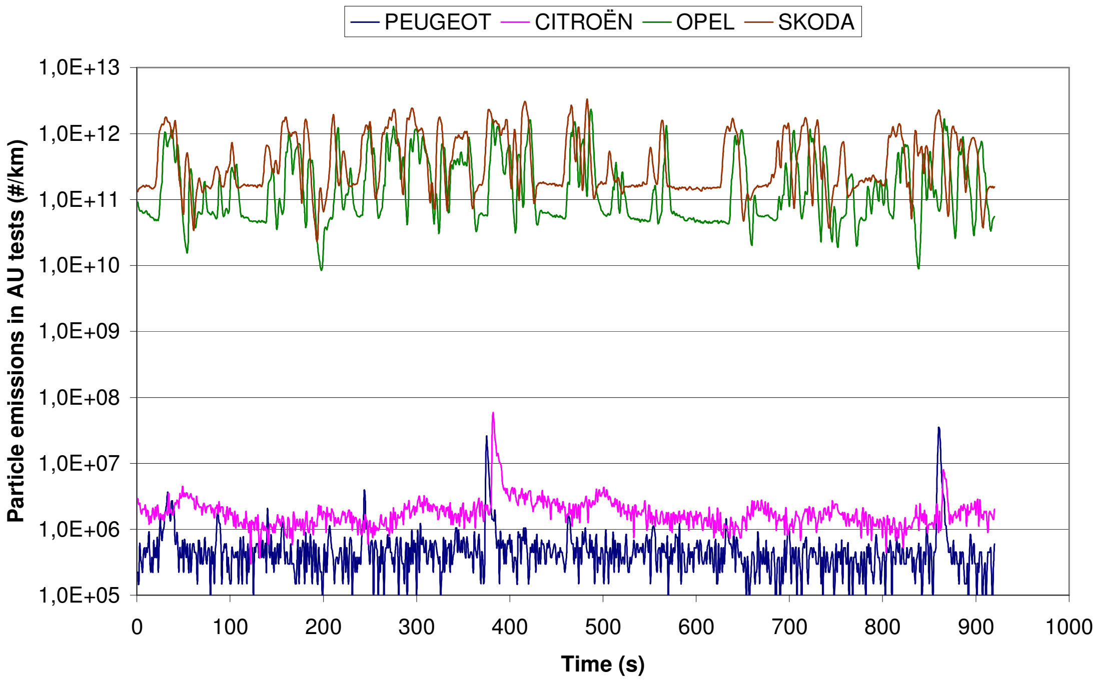
SKODA online particle number emissions from NEDC tests at 22°C and -7°C.



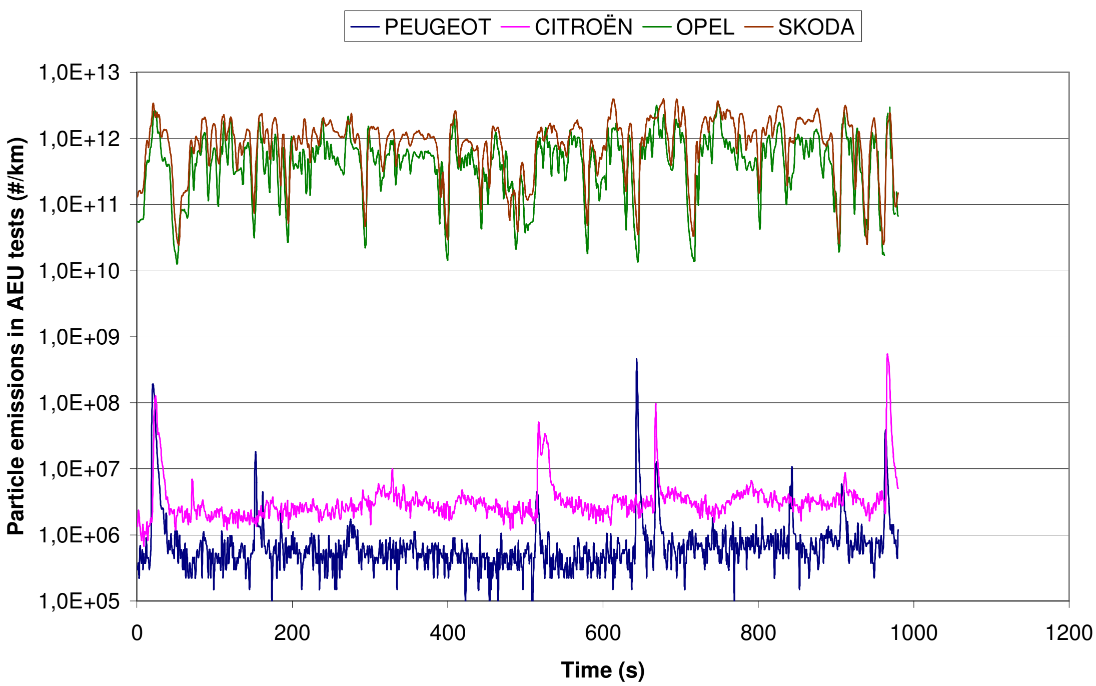
Online particle number emissions from NEDC tests at 22°C.



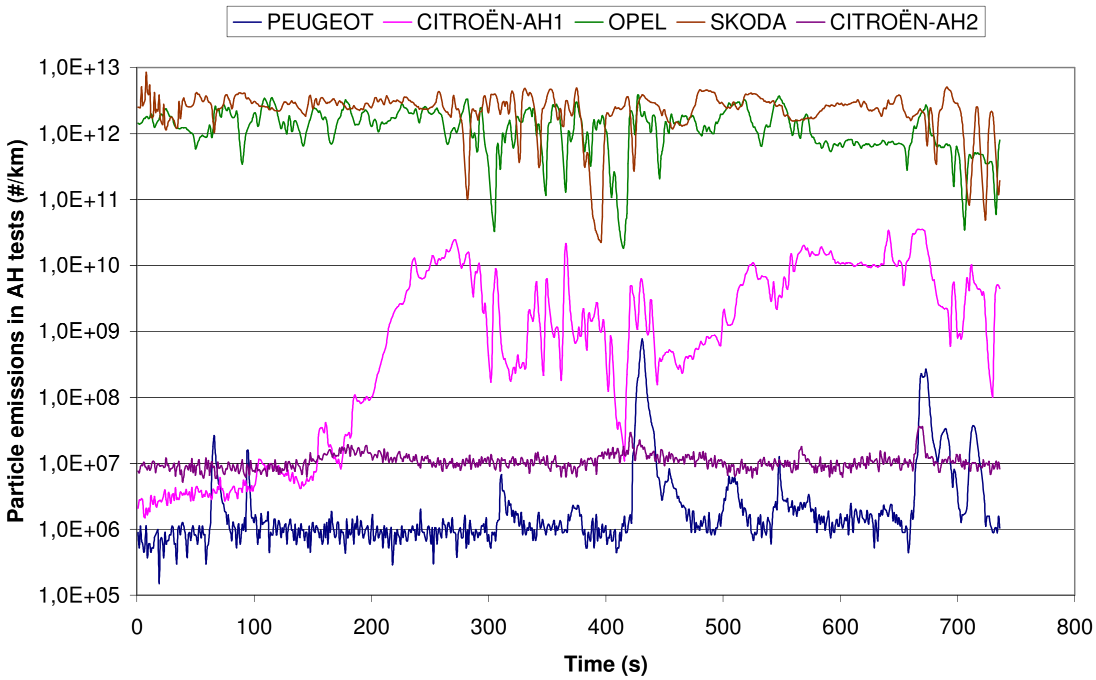
Online particle number emissions from NEDC tests at -7°C.



Online particle number emissions from AU tests.



Online particle number emissions from AEU tests.



Online particle number emissions from AH tests.