Test report

Emission measurement on two passenger cars of M1 type diesel, Euro 5

2012-01-12
Report no. 127056

Ecotraffic

Innehållsförteckning

Project information (in Swedish)

Beställare	Trafikverket	**Beställningsnummer**	TRV2011/48682 A
Beställningsdatum	2011-11-01	**Slutdatum enligt beställning**	2012-12-31 [1]
Ansvarig hos beställare	Peter Smeds	**Projektnummer**	7056
Ansvarig hos Ecotraffic	Lars Eriksson	**Rapportering**	Svensk testrapport [2]
Avvikelser	Ja [3]	**Provningsplats**	TUV Nord - Essen
Rapport språkgranskad	Nej	**Rapport godkänd av**	Börje Gevert
Rapportnummer	127056	**Rapporteringsdatum**	2012-01-12
Författare	Lars Eriksson och Peter Ahlvik		

Rapporten och resultaten diskuterades på möte hos Trafikverket den 13 februari 2012. Deltagare Ecotraffic, Lars Eriksson och Peter Ahlvik. Trafikverket, Peter Smeds, Magnus Lindgren och Olle Hådell.

Abbreviations, acronyms and glossary

CVS	Constant Volume Sampler/Sampling, a dilution device used for dilution of engine/vehicle exhaust for emission measurements.
CH4	Methane
CO	Carbon monoxide
CO2	Carbon dioxide
EGR	Exhaust Gas Recirculation
FAME	Fatty Acid Methyl Esters
FC	Fuel Consumption
NEDC	New European Driving Cycle
NOX	Nitrogen oxides (NO + NO2)
NO	Nitrogen oxide
NO2	Nitrogen dioxide
PM	Particulate Matter
PMP	Particulate Measurement Programme (the EU programme for developing new measurement methods for particle mass and number)
PN	Particle number
RME	Rasped Methyl Ester

1. The assigment

Scope of work

Ecotraffic shall on behalf of Trafikverket carry out emission tests on two diesel fuelled passenger car of M1 type, Euro 5. Result shall be reported as modal results for exhaust components NMHC, CH_4, CO, CO_2, BF, NO_X, NO_2 and PN. Particle mass shall during UDC tests be collected on two filters – so it will be possible to see the effect of the cold start periods. In this study the first filter represented 25 % of the total driving cycle and the second filter represented the last 75 % of the driving cycle. Ecotraffic suggest that this is the most relevant way to investigate the effect of cold start. However, this is of course a compromise between different temperatures but for most of the exhaust component – there are modal results so it is possible to follow the whole driving cycle second by second.

Used driving cycles shall be:

- 2*UDC at + 22°C
- Artemis (hot)
- 2*UDC at – 7°C
- 2*UDC at – 15°C

The study shall be reported as a technical test report and the modal results shall be reported is such formatting so they can be used for calculation of emission factors.

Fuels

Diesel fuel (market) with 5 % RME (FAME), density 0.835 kg/l have been used for UDC tests at -7 and – 15 C. At UDC tests at + 20 C and during Artemis tests, reference fuels, were used (see attached analyze certificate)

Test sites

Tests at temperatures below 22°C have been carried out at RWTH in Aachen (test cell 3). All outer tests have been carried out at TUV NORD in Essen (test cell 1). All tests were performed during December 2011.

	Test Cell 1	**Test Cell 3 (climatised)**
Climatisation	20-30°C	-20°C - +35°C WEISS
Chassis Dynamometer	Schenck 500GS60	MAHA ECDM 48L 4x4
Control Unit	Siemens SIGAS 900	MAHA
CVS-Unit	SIEMENS SIGAS 623	MAHA-CVS
Analytical System for gaseous emissions (CO, CO2, THC, NMHC, NO, NOx)	SIEMENS	MAHA-AMA D1
Particle Collector	SIEMENS SIGAS 660	MAHA-PTS
Particle Balance for particle mass	SARTORIUS SE2-F	SARTORIUS SE2-F
Particle Counter	TSI	MAHA

Dynomometer settings

Identical values as in the type approval tests have been used

		A	**B**
F0	N	-28	-6
F1	[N/(km/h)]	0.094	-0.24
F2	$[N/(km/h)^2]$	0.0406	0.0309
Inertia	kg	1360	1590

Vehicles

Two diesel cars of euro 5 class have been used in this study. In this document, the cars are named A and B, se table below. Both cars were sold in Germany (German registration plate).

	B	**A**
Manufacture	X	Y
Model	X	Y
Chassi no	X	Y
Gear Box	M6	M6
Wheel/Tires	205/55R16 Winter	205/55R17 Winter
Engine deplacement	Ca 2 000 cm^3	Ca 1 600 cm3
Power	103 kW	85 kW
Odometer	5 550 km	8 818 km
Exhaust class	Euro 5	Euro 5
Year model	2010	2010

Type approval values

Deterioration factors are included in the values below.

Car A						
CO mg/km	**THC** mg/km	**NMHC** mg/km	**NOX** mg/km	**THC+NOX** mg/km	**PM** mg/km	**PN #/km**
249.5	-	-	170.9	192.7	0.16	0.02 E11
CO2 Urban g/km	**CO2** Extra Urban g/km	**CO2** Combined g/km	**FC** Urban liter/ 100 km	**FC** Extra Urban liter/100 km	**FC** Combined liter/100 km	
124	110	115	4.7	4.2	4.4	

Car B						
CO mg/km	**THC** mg/km	**NMHC** mg/km	**NOX** mg/km	**THC+NOX** mg/km	**PM** mg/km	**PN #/km**
196.5	-	-	94.1	125.3	0.32	0.04 E11
CO2 Urban g/km	**CO2** Extra Urban g/km	**CO2** Combined g/km	**FC** Urban liter/ 100 km	**FC** Extra Urban liter/100 km	**FC** Combined liter/100 km	
147	106	120	5.6	4.0	4.6	

Driving Cycles

See also chapter 3

2*UDC

In this study, the first part of European driving cycle (NEDC) is used. This part also known as UDC (Urban Driving Cycle) is a cycle that is commensurate with a typical run in a typical European town. The cycle consists of four identical parts with a total length of 13 minutes. Maximum speed is 50 km / h. The UDC was repeated 2 times, i.e. 8 repetitions, totaling 26 minutes. Before starting the vehicle should take the ambient temperature and the start will be preceded by 40 seconds idle

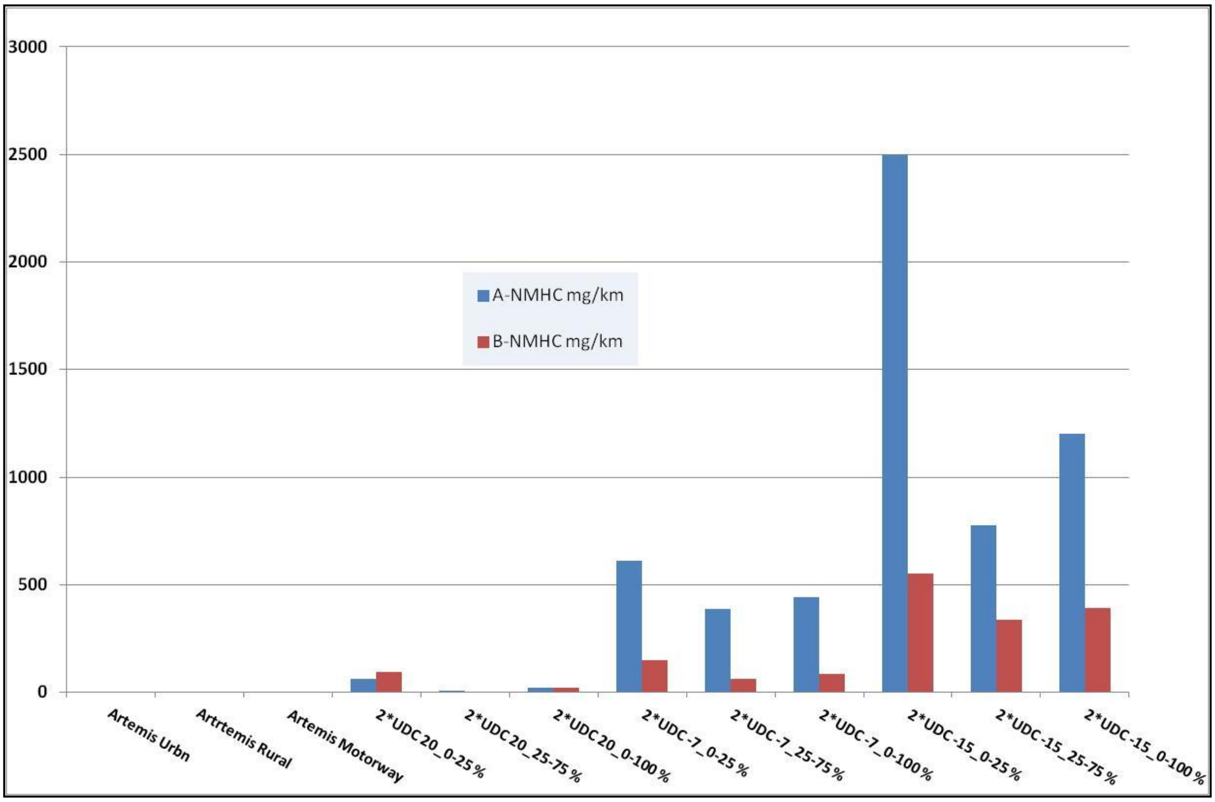
Artemis

Artemis is a driving cycle that is supposed to be more reality-like than the NEDC. Before Artemis started as the vehicle should be warmed it up. In practice this means that the catalyst has reached operating temperature already at the start. Compared to the UDC driving cycle - Artemis has higher load, faster acceleration and higher top speeds. The cycle consists of three parts, urban (about 15 minutes, 4.5 km), rural (about 18 min, 17 km) and highway (about 18 min, 29 km).

2. Results

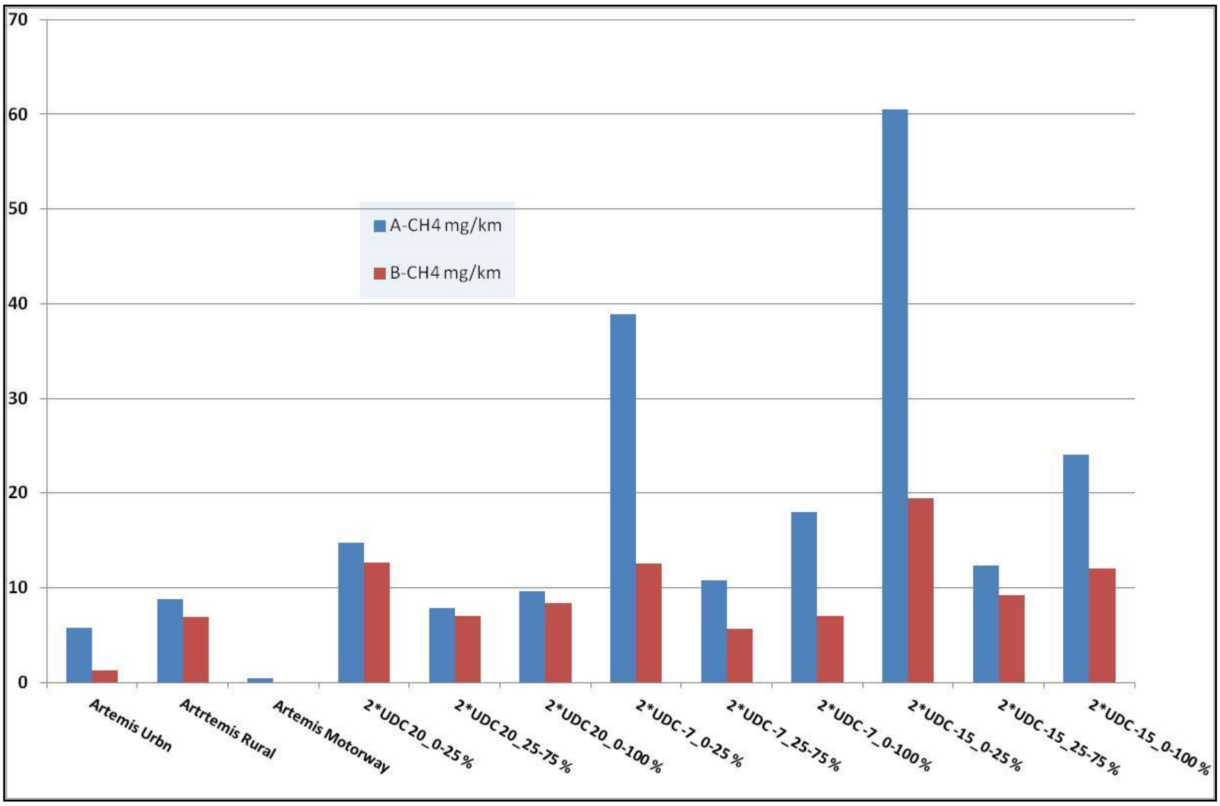
Below are measurements from the tests. For samples of 2 * UDC, the results have been divided into two parts and a total for the entire test. The first part represents 25% of the distance and the other part remaining 75%. The reason for this choice was that the results of PMP measurements showed that the particle number leveled off after about half the first UDC cycle. The first part of the measuring over a long period of time would lead to the effect of the cold start component was "diluted" by the successive lower levels. In addition to modal measurements were also performed measurements in which the gases were collected in bags for analysis. These bags are divided so that they follow the first bag represent the first 25%-one and the other remaining 75%. For Artemis reported according to the values divided into urban, rural and motorway

NMHC



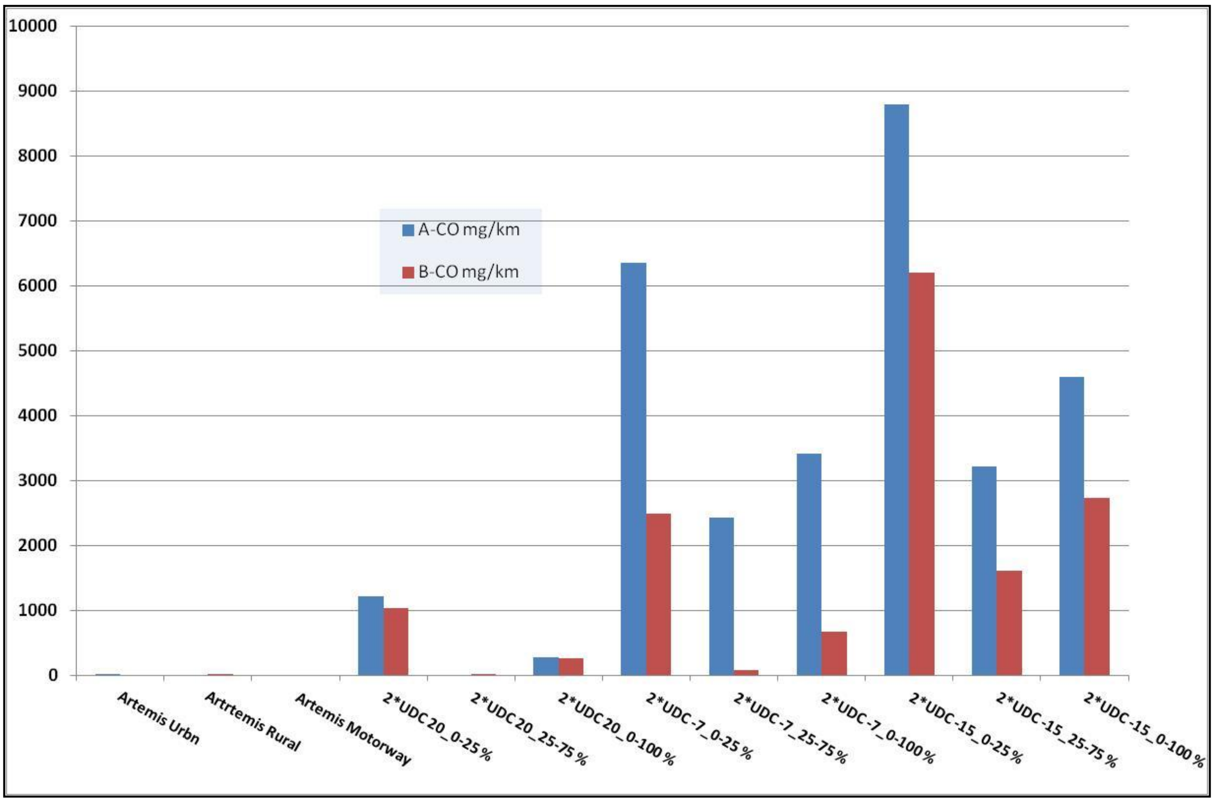
The HC levels are in all cases very low for warm vehicles (e.g. after catalyst has reached light off temperature). The time to light off is faster for car B compared with car A. At start at – 15^{O} C it showed an effect of the low temperature, resulting in relatively high HC emission during the first 25 % of the driving cycle.

CH_4



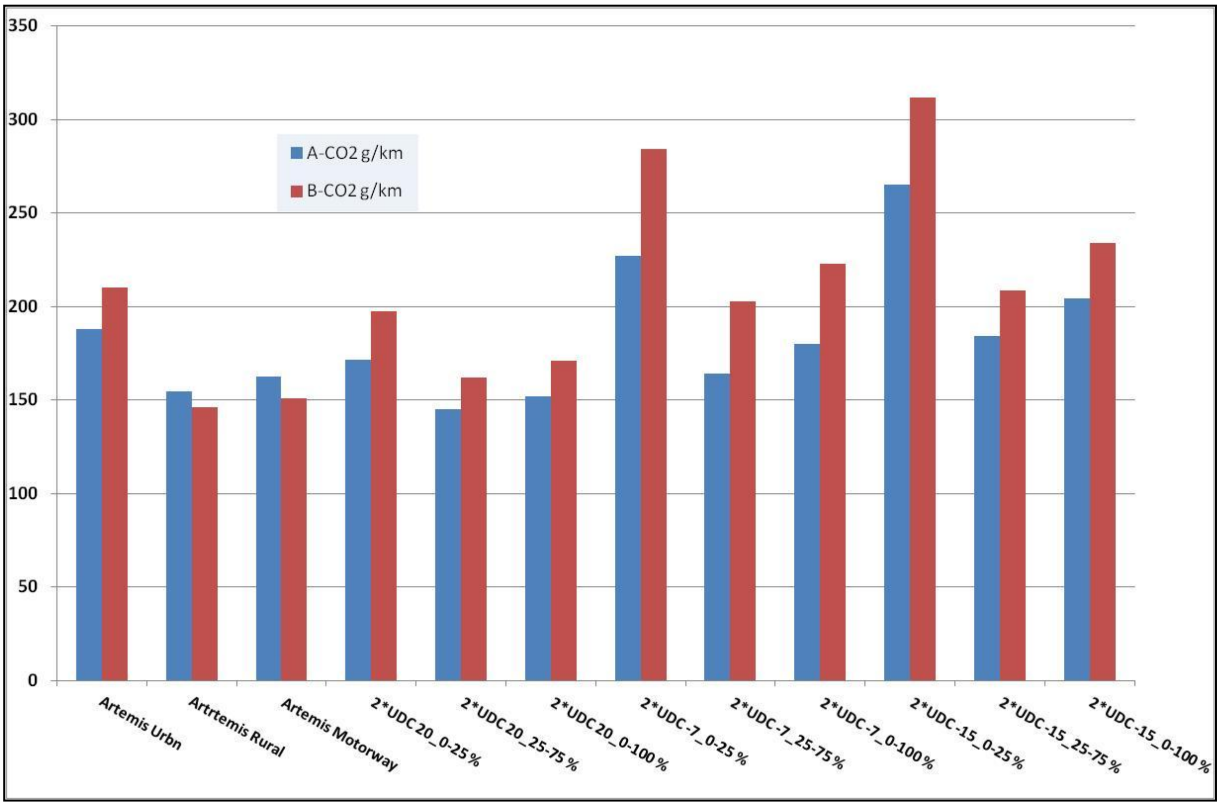
In general, the levels of CH_4 are very low. Methane is considered a relatively potent greenhouse gas, about 25 CO_2 equivalents, but otherwise as a harmless component. For car B is exceeded not 20 mg per km at some point. This is equivalent to the greenhouse contribution is less than 0.5 g CO_2 equivalents

CO



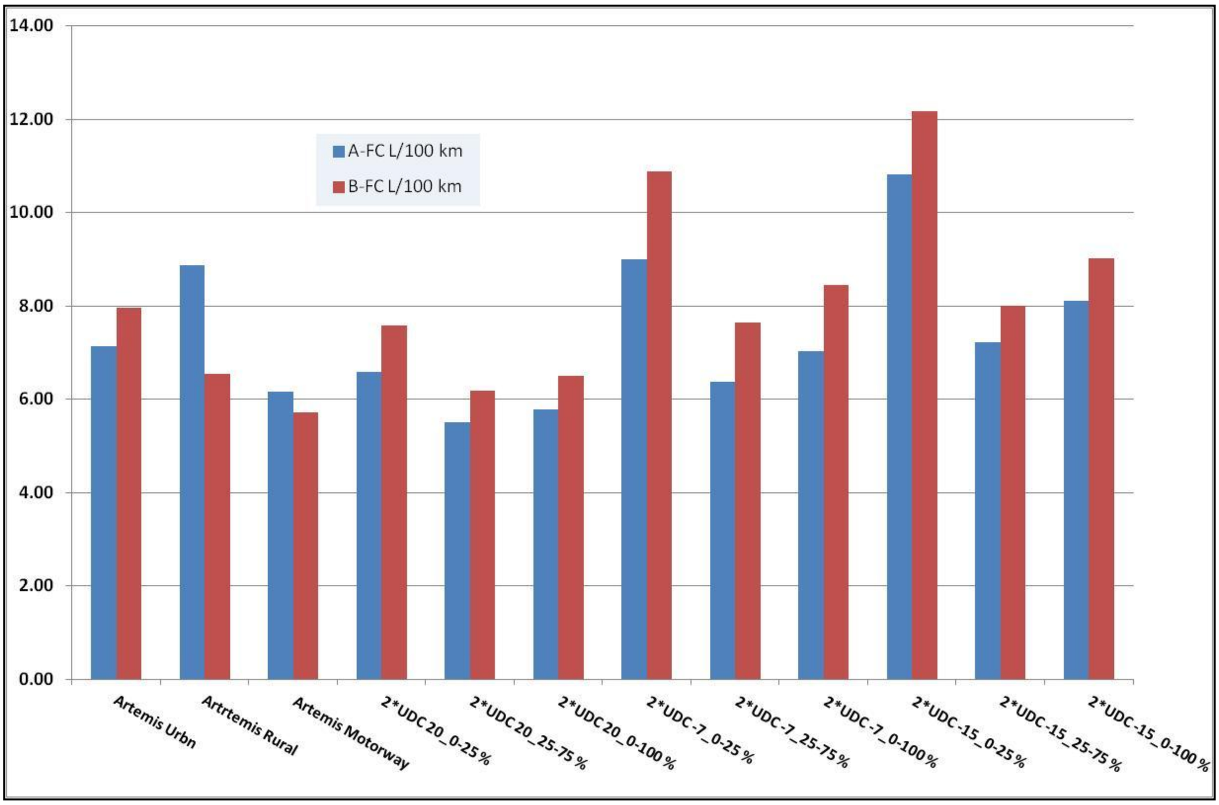
Generally, for all Artemis runs as the CO emissions are very low. This is expected since Artemis starts with warmed (and active catalyst) car. Cold-start effect is more pronounced the colder it becomes. In the tests at 20 ° C, time to light the catalyst in full within the 25% of the driving cycle. At -7 and - 15 ° C as catalyst do not have time to reach full CO oxidation in the first 25% of the driving cycle. Another general conclusion is that the Car A has higher CO emissions than car B

CO_2



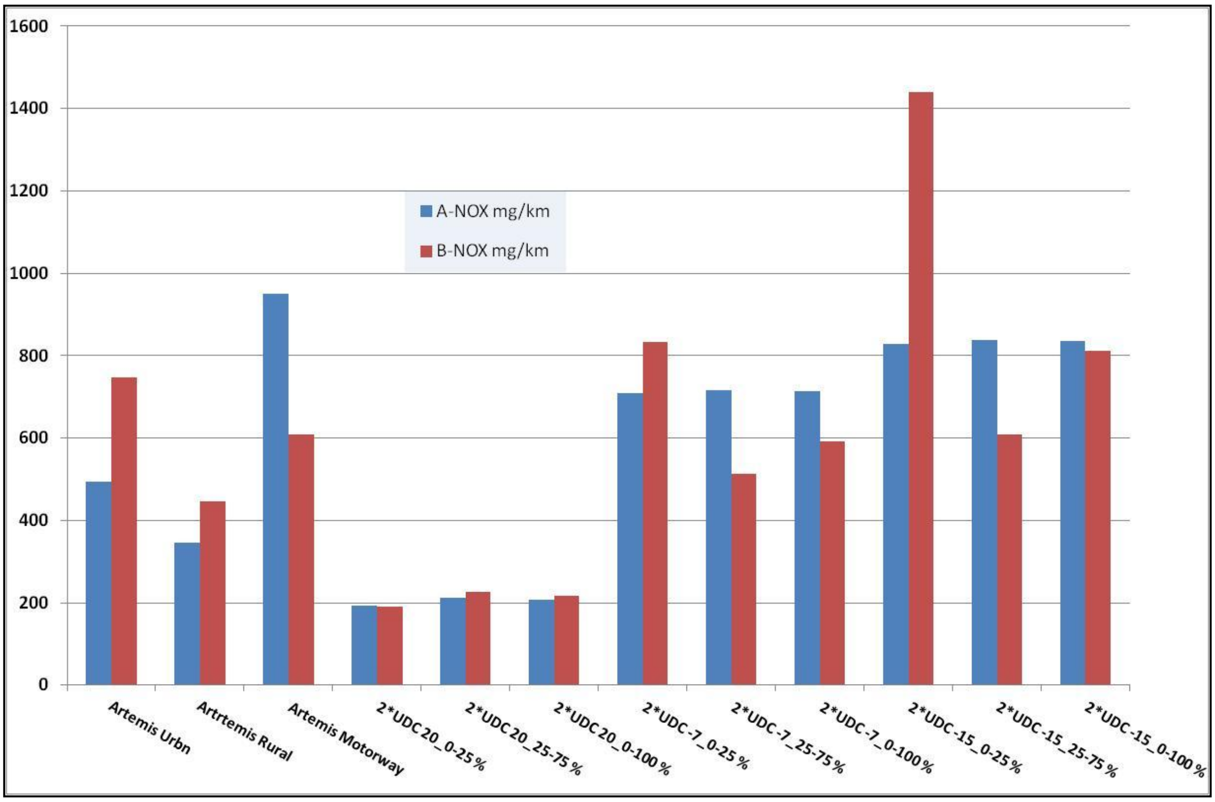
CO_2 emissions increase with decreasing temperature and decreases as the vehicle warms up by driving. The emissions were lower for car B than for car A at two of the three Artemis cycles, although car B is both heavier and more powerful engine power

Fuel consumption



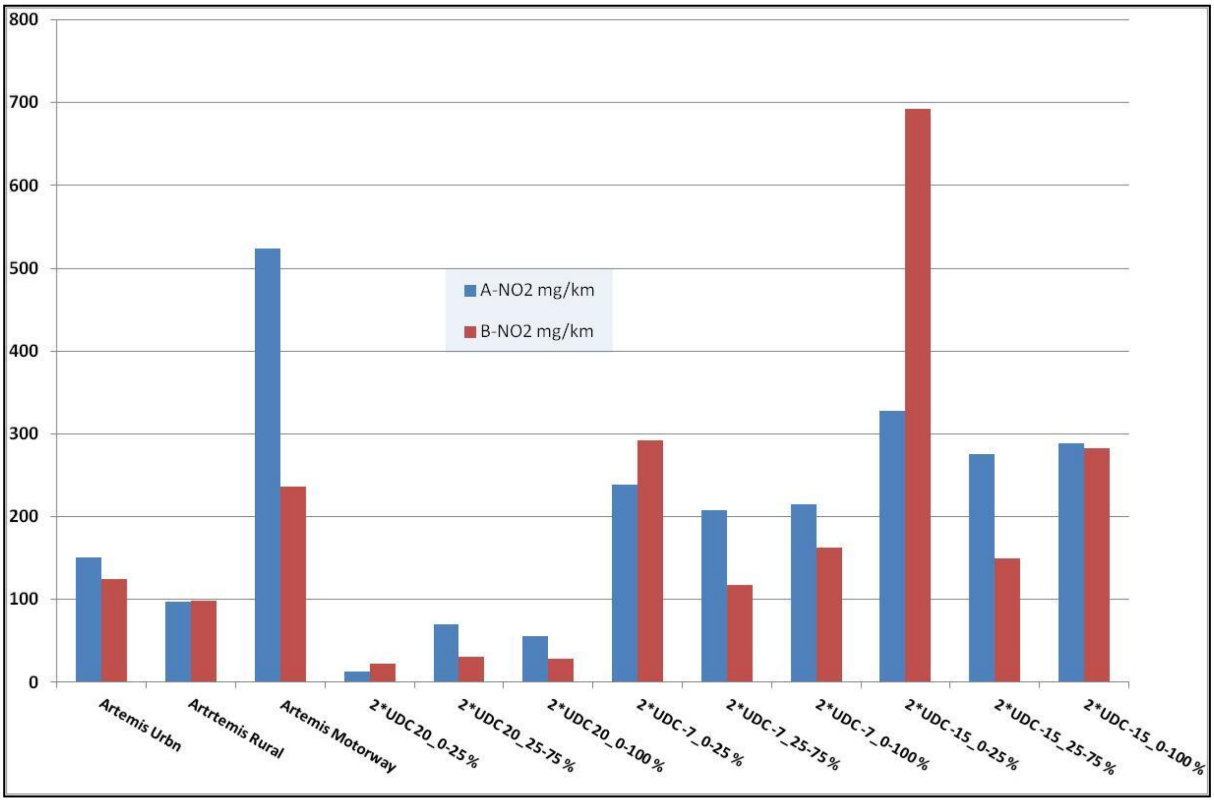
Fuel consumption can use the same reasoning as for CO_2. The contribution of CO_2 in the calculation of fuel consumption is quite dominant

NO_X



For car A increasing NO_X emissions are relatively high during Artemis Highway while car B did not show as clear trend. There is a clear temperature effect for both cars, NO_X emissions are generally much higher at -7 and -15 ° C compared at +22 ° C. The main reason for this may be that the exhaust recirculation (EGR) is connected later. Generally, lower temperatures gives lower NO_X, resulting in an adverse effect, but less than that of the EGR. Car A was no apparent cold-start effect (0-25% cf. 25-75%) of NO_X. For car B, NO_X emissions are higher during the first part of the cold cycles than the remainder.
A general conclusion may be that driving cycles and temperatures different from those used for certification (NEDC +22 ° C) gives significantly higher NO x emissions

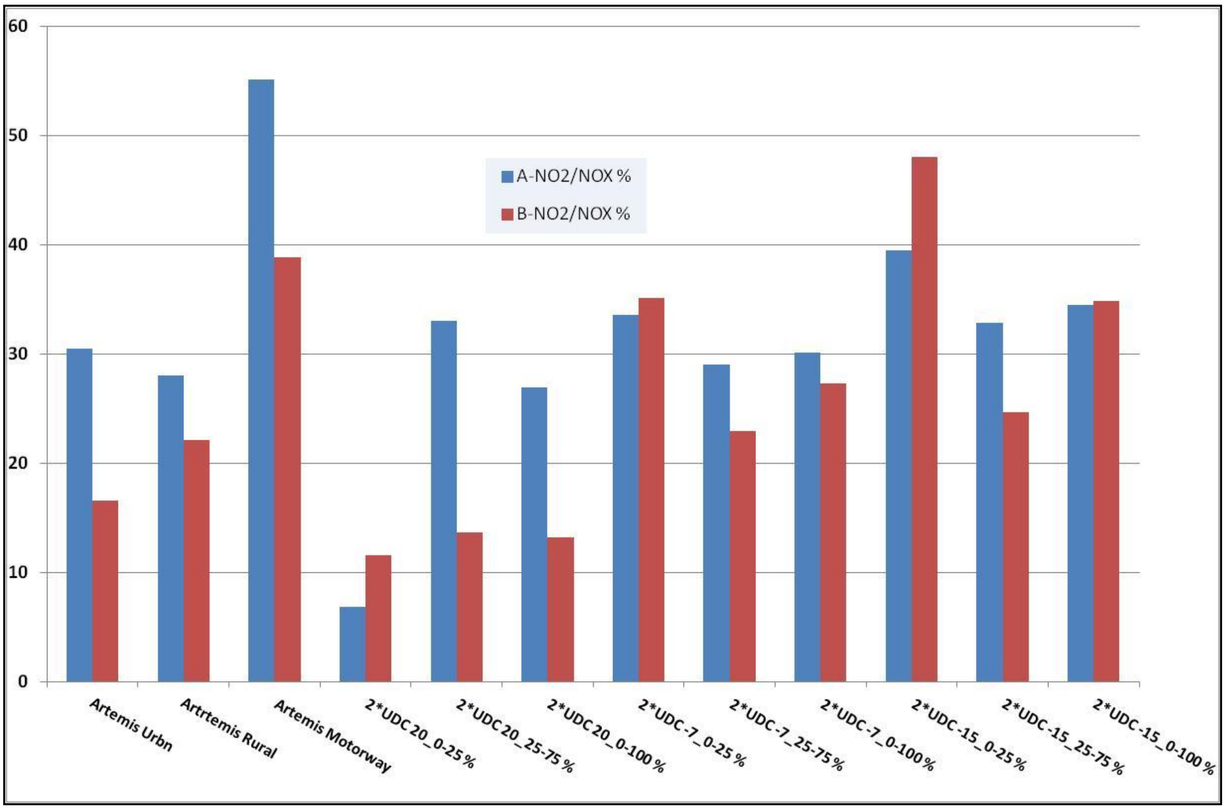
NO_2



See further discussion on next page - ratio NO_2/NO_X

.

Ratio NO_2/NO_X

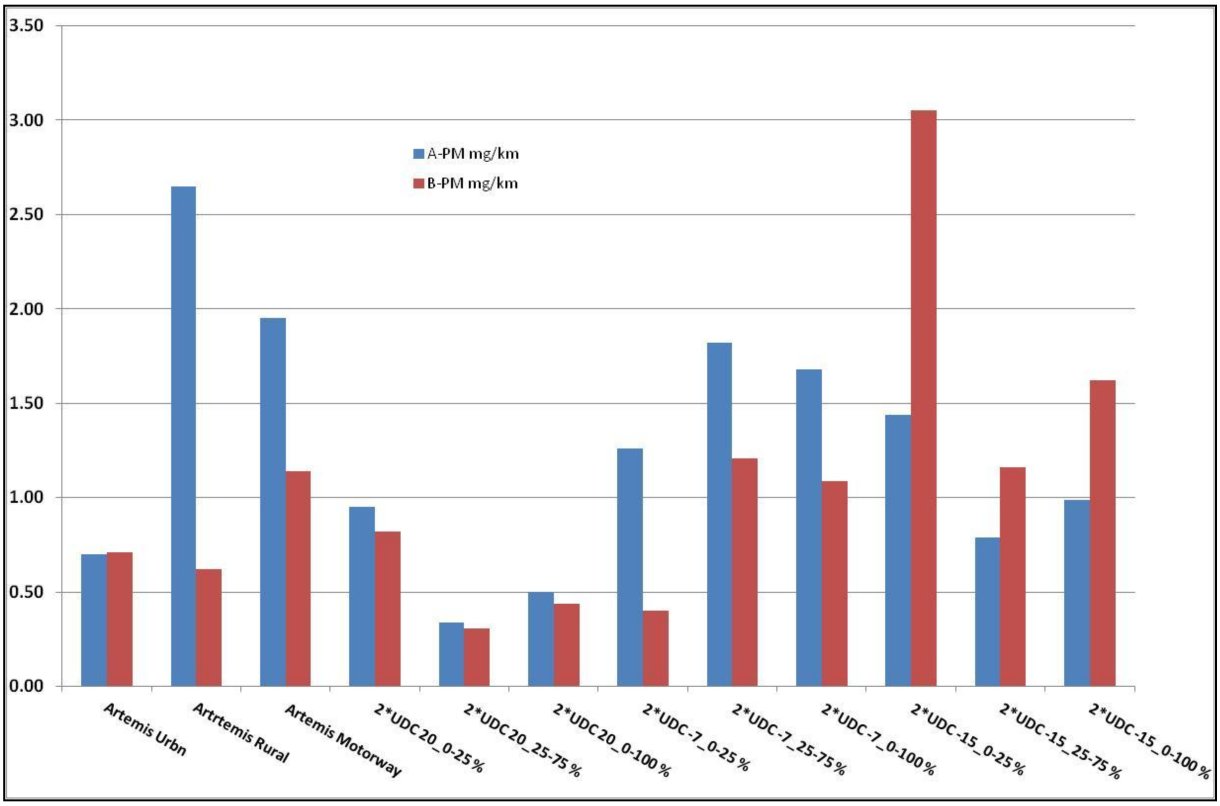


NO_X consist of NO and NO_2. When the EGR is not being used, NO_X from the engine, consist to more than 95% of NO. When EGR is used, the proportion of NO_2 increases. NO is oxidized with O_2 to form NO_2. How much and how fast that NO is oxidized to NO_2 depends on several factors, including exhaust gas temperature and type of catalyst. The oxidation decreases slightly with aging catalyst.

For car A NO_2 level seems to be around 30% except during Artemis Highway when the proportion is over 50%. For car B NO_2 also here increase at high load (Highway). Unlike car A is a greater cold-start effect with a higher proportion of NO_2 during the first part of cold start cycles compared to the last part. One explanation for this is that oxidation NO + O_2 to NO_2 has negative temperature dependence, i.e. lower temperature shifts the equilibrium to the right.

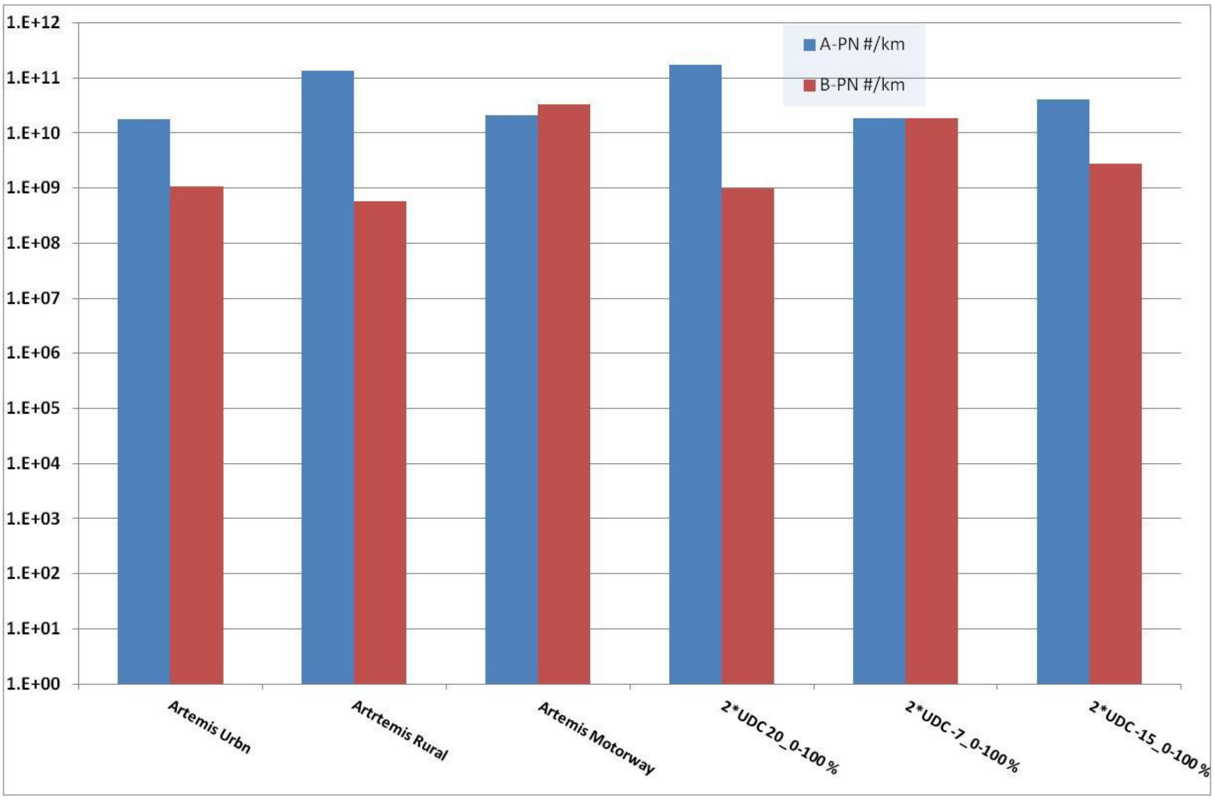
When driving at -7 and - 15 ° C, the modal signal for NO_2 was not recorded (but recorded as bag values). This is a deviation from the order. Our view is still that with the help of bag values and modal signals for the other tests in a more detailed analysis could explain the effects observed

Particle mass (PM)



PM was measured by collecting particles on filter paper. These are very low weights (in absolute terms). This allows the measurement uncertainty is relatively large, so large that it is difficult to draw relevant conclusions from filter weight. A general conclusion is that there are very low PM emissions from both vehicles

Particle number (PN)



Measurement of particles number according to the PMP is associated with many uncertainties. Both vehicles are equipped with particulate filter (DPF). When this type of filter is running and has a layer of soot in it so is the filtration rate is very high. It is however possible to draw the conclusion that the emissions of particle number is very low and that the filters work well. To draw conclusions other than it is associated with considerable uncertainty

Start/Stop

Both vehicles have the start / stop function and this was enabled during all runs. The only time the function was used (engine was shut off automatically) was for car B in the UDC tests at + 22^{O} C. In all other samples that did not shut the engine off at stop.

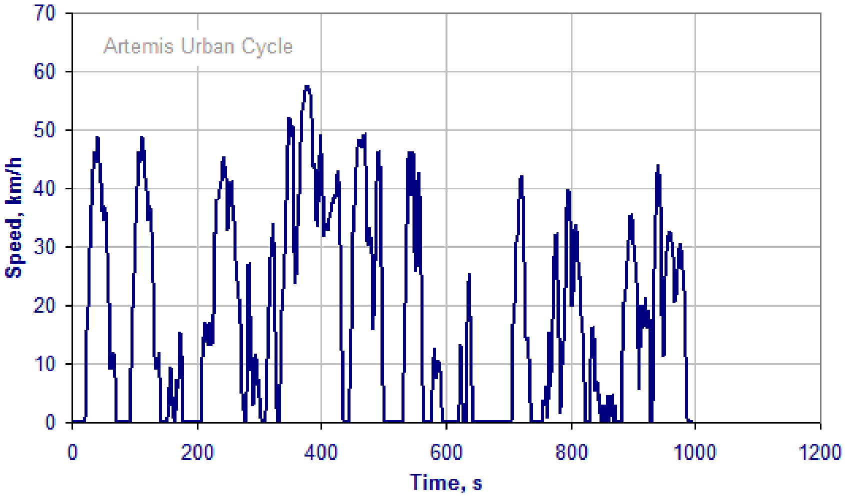
.

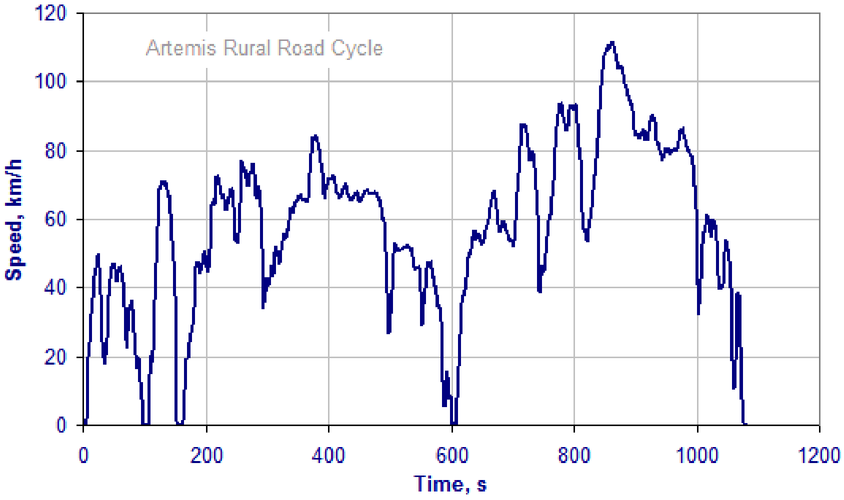
Results summary-table

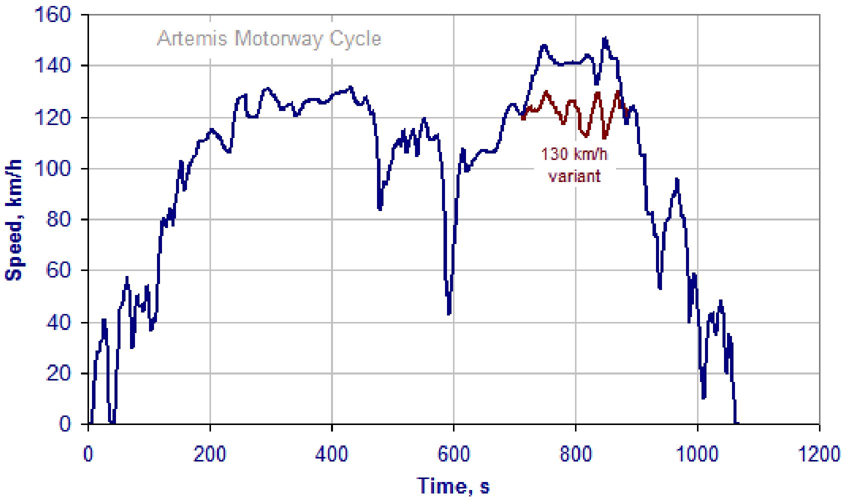
	THC	CH4	NMHC	NOX	NO2	NO2/NOX	CO	CO2	BF	PM	PN
	mg/km	mg/km	mg/km	mg/km	mg/km	%	mg/km	g/km	L/100 km	mg/km	#/km
Mini Atrtemis Urban	4.21	5.77	0.00	492.98	150.30	30.49	22.95	187.84	7.126	0.70	1.78E+10
Mini Atrtemis Rural	3.45	8.77	0.00	346.69	97.12	28.01	0.00	154.67	8.866	2.65	1.32E+11
Mini Artemis Motorway	0.20	0.44	0.00	950.91	524.07	55.11	0.00	162.27	6.154	1.95	2.08E+10
Mini 2*UDC 20_0-25 %	75.88	14.72	63.06	194.05	13.26	6.83	1222.64	171.43	6.578	0.95	
Min1 2*UDC 20_25-75 %	13.77	7.90	6.88	213.16	70.42	33.04	0.00	145.07	5.503	0.34	
Mini 2*UDC 20_0-100 %	29.28	9.60	20.92	208.38	56.19	26.97	280.46	151.65	5.772	0.50	1.74E+11
Mini 2*UDC -7_0-25 %	647.80	38.90	610.00	709.60	238.40	33.60	6361.00	226.95	8.999	1.26	
Mini 2*UDC -7_25-75 %	399.50	10.80	389.00	716.00	208.00	29.05	2430.00	164.23	6.376	1.82	
Mini 2*UDC -7_0-100 %	461.00	18.00	444.00	714.00	215.00	30.11	3408.00	179.84	7.028	1.68	1.89E+10
Mini 2*UDC -15_0-25 %	2256.00	60.50	2497.00	828.00	327.20	39.52	8793.00	265.23	10.811	1.44	
Mini 2*UDC -15_25-75 %	790.00	12.30	778.10	838.80	275.40	32.83	3218.00	183.95	7.211	0.79	
Mini 2*UDC -15_0-100 %	1225.00	24.00	1202.00	836.00	288.00	34.45	4594.00	203.99	8.099	0.99	4.08E+10
Passat Atrtemis Urban	5.95	1.28	4.84	746.60	124.04	16.61	0.00	209.89	7.961	0.71	1.06E+09
Passat Atrtemis Rural	9.87	6.92	3.84	445.44	98.74	22.17	6.17	145.80	6.531	0.62	5.78E+08
Passat Artemis Motorway	0.00	0.00	0.00	607.88	236.03	38.83	0.00	150.87	5.722	1.14	3.29E+10
Passat 2*UDC 20_0-25 %	103.46	12.61	92.48	191.34	22.13	11.57	1032.48	197.61	7.568	0.82	
Passat 2*UDC 20_25-75 %	0.00	7.00	0.00	225.76	30.92	13.70	0.64	161.74	6.173	0.31	
Passat 2*UDC 20_0-100 %	25.76	8.39	23.02	217.18	28.73	13.23	257.51	170.67	6.491	0.44	9.90E+08
Passat 2*UDC -7_0-25 %	159.50	12.60	147.20	832.90	292.30	35.09	2498.00	284.30	10.870	0.40	
Passat 2*UDC -7_25-75 %	69.60	5.70	64.00	513.70	118.00	22.97	77.90	202.80	7.650	1.21	
Passat 2*UDC -7_0-100 %	92.00	7.00	85.00	593.00	162.00	27.32	675.00	222.95	8.446	1.09	1.84E+10
Passat 2*UDC -15_0-25 %	571.00	19.50	552.00	1440.00	692.40	48.08	6203.00	311.50	12.164	3.05	
Passat 2*UDC -15_25-75 %	347.10	9.20	338.10	607.40	150.10	24.71	1613.00	208.70	7.996	1.16	
Passat 2*UDC -15_0-100 %	402.00	12.00	390.00	811.00	283.00	34.90	2737.00	233.89	9.017	1.62	2.72E+09

3. Driving cycles (graphs)

Artemis

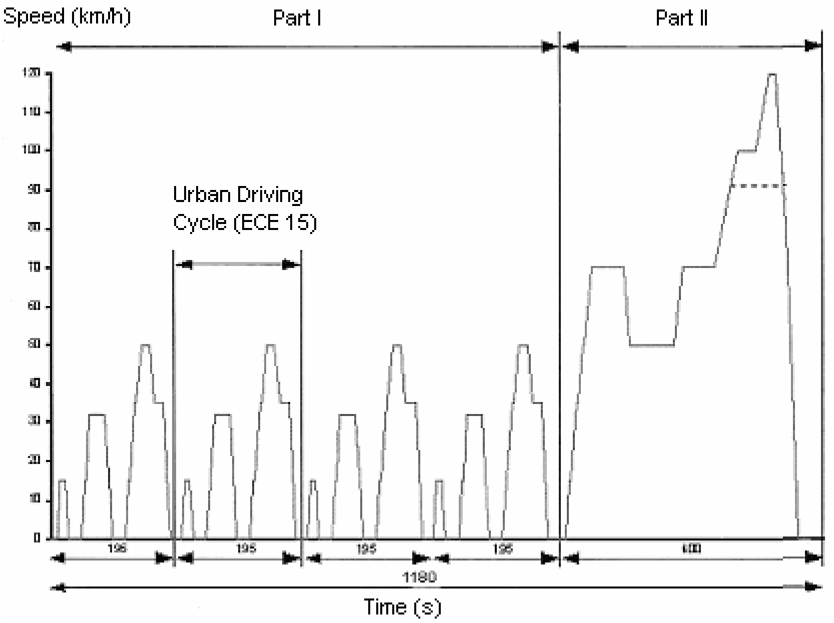






Source – Dieselnet

UDC



Source – GlobalNEST