Institute of Transport Economics
Norwegian Centre for Transport Research

Summary

Emission from vehicles with Euro 6/VI technology. Results from the measurement program in EMIROAD 2015

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This report presents findings from the measurement program EMIROAD (EMIssions from ROAD transport vehicles), which is a cooperation of TØI and the Norwegian Public Roads Administration. The program focuses on exhaust emissions from modern passenger cars and heavy duty vehicles.

In the EMIROAD measurement program vehicles are tested in the laboratory by applying test-cycles which represent real traffic, and conditions that to most possible extent correspond to the actual use of the vehicle. For example, the program investigates "local emission factors" which include nitrogen oxides (NO_x) and particulate matter (PM). Furthermore, the emission of greenhouse gases (CO_2 in particular) is investigated.

The new results widely confirm earlier findings, which showed that heavy duty vehicles with Euro VI-engines have low emissions of NO_x in real traffic situations, while diesel-fueled Euro 6-passenger cars have high emissions compared to the emission limits in the emission legislation. This report also presents remarkable results for modern gasoline-fueled personal cars with direct-injection technology, exhibiting high emissions of NO_x in the laboratory tests.

Low values for local emission factors of city buses

The emission limits for vehicles are regulated in the EU-directives. For cars, the Euro-classes "Euro 1-6" are defined, where Euro 6 is the strictest. For the engines of heavy duty vehicles, the Euro-classes are defined in "Euro I-VI", where Euro VI is the strictest. Historically, the Euro-classes were sharpened about every 5th year. These regulations also apply to the Norwegian market. The EMIROAD-project focuses on documenting how much the real-world emissions will be reduced during the ongoing shift from Euro 5 to Euro 6 for passenger cars, and from Euro V to Euro VI for heavy duty vehicles.

For the measurements presented in this report, emissions from 5 city buses with Euro VI-diesel engines were recorded. One of the buses had a hybrid drivetrain. The buses were driven in an emission laboratory with simulated driving cycles that correspond to real-world use patterns for city-buses. All measurements for the buses were carried out at about 23 °C.

As shown in earlier measurements (Hagman & Amundsen 2013a; Hagman & Amundsen 2013b; Weber et al. 2015; Hagman et al. 2015), the current measurements show low emissions of NO_x and PM from the buses with Euro VI-engines, when compared to typical values for city-buses with Euro V-engines. The average values for the emission factors are shown as numbers and scaled clouds in Figure S 1.

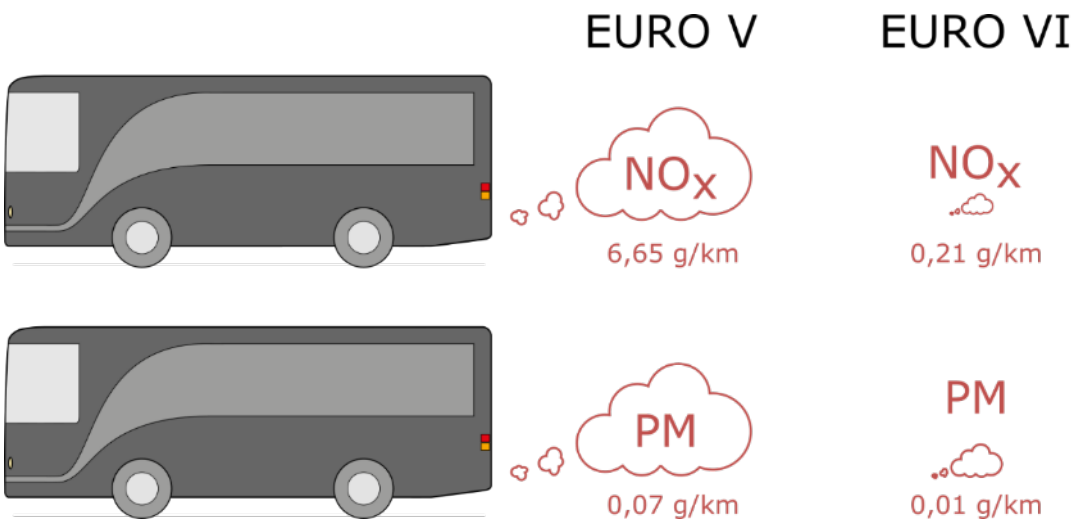

Figure S 1: Average emission values for NO_x and particulate matter (PM), measured in g/km. The measurements were conducted at around +23 °C for 11 buses with Euro VI-diesel engines, driving the Braunschweig city-cycle. The results are compared to typical values for city-buses with Euro V-diesel engines. The size of the clouds for the Euro VI-average are scaled in relation to the emission factor from the Euro V-class.

Cars

This report presents emission measurements for 4 new passenger cars: 2 models from 2 different manufacturers, with diesel- and gasoline engines, respectively. The emission measurements were conducted at +23 °C and -7 °C.

Warm-start of the engine

While emissions of PM are low for diesel-fueled cars in tests with warm-start of the engine, are emissions of NO_x high, especially in cold conditions (-7 °C). The gasoline-fueled cars with gasoline direct injection (GDI) technology show low values for all emission factors, however, surprisingly high values for NO_x are observed. Since only a few GDI-cars have been tested yet, it is too early to conclude on the emission characteristics of the technology. The measurement program will however follow the future developments of GDI vehicles.

The measurements continue to display a big difference between the CO_2-emission that is stated in the type-approval cycle (NEDC) and the emission that occurs in more realistic driving cycles – especially in cold conditions (see Figure S 2).

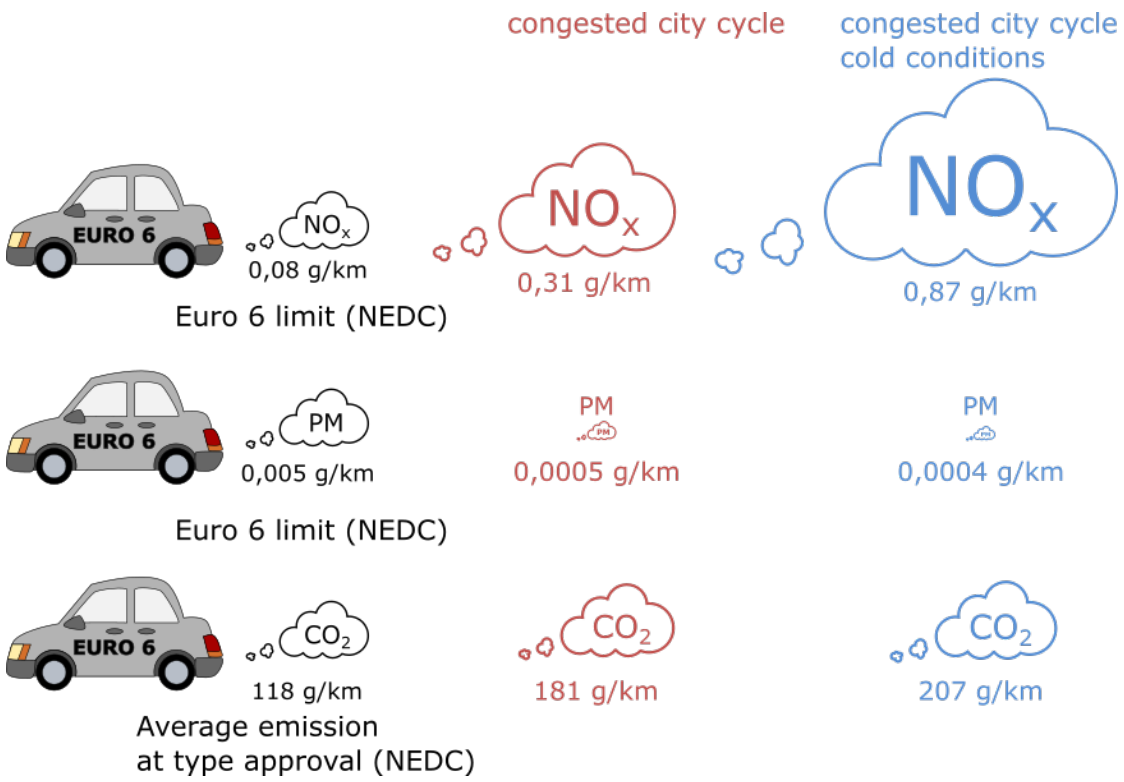

Figure S 2: Comparison of the limit values for NO_x and PM, and the average CO_2 emission that are reported in the Euro 6-type approval (black clouds) to the respective average emission measured in more realistic congested city cycles for the 7 Euro 6-approved diesel cars tested to far. The red- and blue clouds represent the average of results from measurements at 23 °C and -7 °C, respectively. The size of the colored clouds is scaled relatively to the NEDC-values.

Cold-start of the engine

In this round of measurements, also emissions during cold-starts of the engine were investigated. Also here, the diesel-fueled cars showed low values for all local emission factors – with the exception of NO_x. During cold-starts in cold conditions (-7 °C), NO_x-emissions were measured to be up to 18 times as high as the limit value in the type-approval directive.

The two gasoline-fueled cars with GDI-technology had low emission values for cold-starts at 23 °C. At lower temperatures, however, high emissions of PM, PN (particulate number), NO_x, CO (carbon monoxide) and THC (hydrocarbons) were observed. Especially the emission of PM and PN were high, with emission values up to 8.6 and 4.1 times as high as the limit value in the type-approval directive, respectively. These measurements present the findings for only 2 cars. It is therefore too early to conclude over drawbacks of the GDI-technology. However, the measurement program will follow the future developments. The EU commission is aware of the problem, and from 2017 the limit value for PN-emission of cars with GDI-technology will be revised.

Nearly all of the PM-emissions during cold-starts occur during the first kilometers of the driving cycle. This is shown in Figure S 3, where the measurement results for PM in the NEDC driving cycle are divided into 3 categories. It is obvious that the first 2 km produce the largest part of the emission. As soon as the engine and the emission after-treatment systems have warmed up, the emissions are low (after about 2 km).

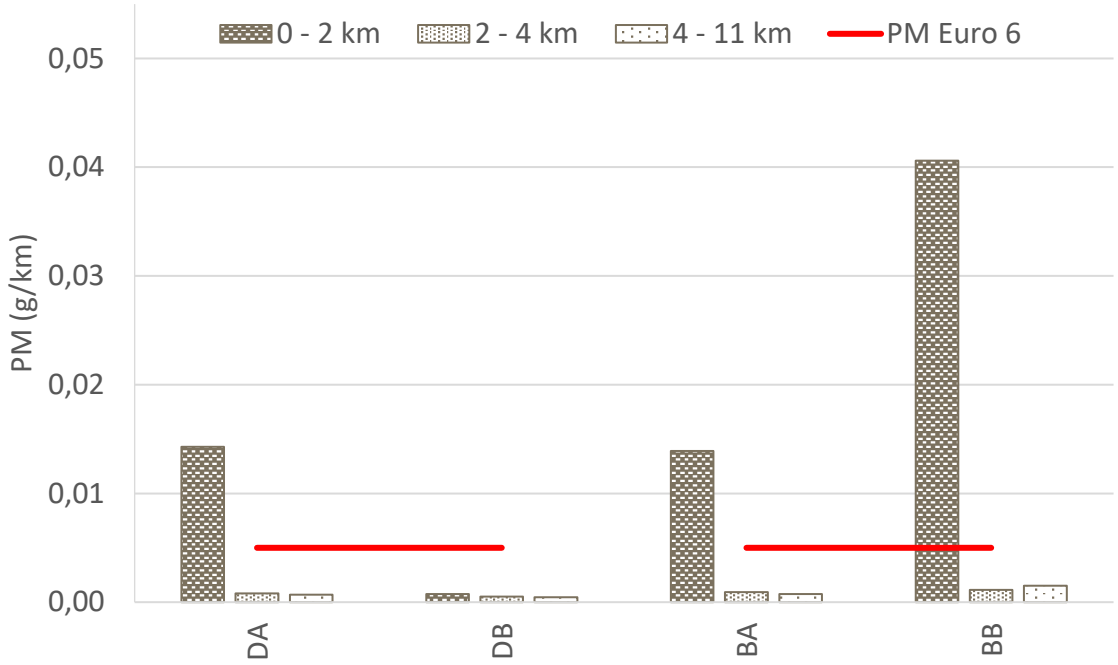

Figure S 3: PM-emission in g/km for the tested diesel-fueled cars (DA, DB) and gasoline fueled cars (BA, BB) after cold-start of the engine in the NEDC-cycle at -7 °C. The pillars show the emission for the first 2 km, 2 to 4 km and 4 to 11 km, respectively. The red line marks the limit value in the type-approval.

Follow-up of the "Diesel-scandal"

After it became public in autumn 2015 that Volkswagen cheated in the type-approval tests, by employing an illegal software ("defeat device") that manipulates emissions in some of their engine control software versions, several countries started detailed measurement programs to investigate if also other manufacturers broke the laws. The measurements of several institutions show that many manufacturers choose exhaust after-treatment strategies that satisfy the emission limits in the type-approval cycle, but fail in real traffic and daily use of the vehicle. Certain brands chose to stop the after-treatment when the outside temperature lies below the temperature band that is defined in the type-approval test. Their justification bases on the reasoning that the after-treatment has to be paused or reduced in order to protect the engine – which the regulation allows in extreme conditions, e.g. during startup or in order to prevent overheating, however is not allowed in the everyday use of the vehicle. Figure S 4 shows that Volkswagens cars with "defeat device" perform quite similar as the cars of other manufacturers, when looking at the NO_x-emission in real traffic.

These findings call for a thorough definition of "normal use" in the type-approval directive, and whether it could be possible to introduce not-to-exceed-values that should not be exceeded in any driving condition.

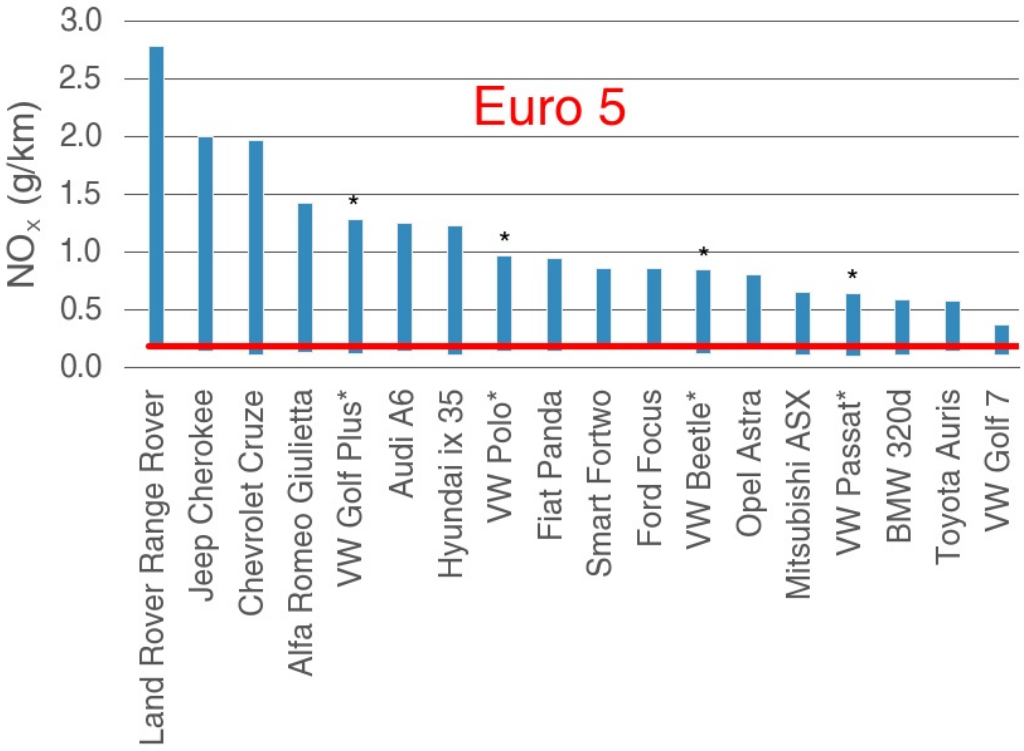

Figure S 4: Overview over results of laboratory- and road measurements of Euro 5-cars, conducted by German Kraftfahrt Bundesamt (KBA). The vehicles are sorted by the highest emission of NO_x. The lower end of each pillar shows the result of a measurement in the type-approval cycle (NEDC) in the laboratory, whereas the higher end is measured in a cycle that is more representative for real traffic. The cars marked with '' are Volkswagen cars with a "defeat device". The red line marks the limit value in the type-approval. Data from KBA (BMVI 2016).*

International study of light- and heavy duty vehicles

In an upcoming report, IEAs (International Energy Agency) collaboration program for the introduction of advanced motor fuels (Advanced Motor Fuels Implementing Agreement) examined different combinations of vehicles and fuels, with special focus on energy efficiency and emission of CO_2, NO_x and PM. EMIROAD contributed to the study by financing one of the tests. The study concludes that it is more the type-approval class than the type of fuel that determines the amount of local emissions of NO_x and PM. Regarding greenhouse gasses, the report clearly states that gas engines fueled by natural gas from fossil sources do not result in savings of CO_2-emission in a well-to-wheel (WTW) perspective. Some types of regenerative fuels (e.g. biogas from organic waste, renewable diesel from used cooking oil) are found to have a big potential to reduce CO_2-emissions.

Electric vehicles are the most energy efficient and give the largest savings in WTW CO_2-emissions, given that the electric power is produced from renewable sources.

Emission measurements for diesel-fueled heaters – preliminary results

In this measurement period, the possibility of measuring exhaust gasses of diesel-fueled heaters for cars was examined. This type of warmers can be found in many new cars that are sold in the Norwegian market. The preliminary results hint at clean combustion, only

during startup and shutdown are there noteworthy emissions of hydrocarbons. The emission of NO_x seems to be low compared to the NO_x-emission of diesel cars in city traffic.