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TNO report

TNO-060-DTM-2012-01193

Real-world NO_x emissions of Euro V and Euro VI heavy-duty vehicles

Date	11 April 2012
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Number of pages	10 (incl. appendices)
Number of appendices	0
Sponsor	Mr. H.L. Baarbé Ministry of Infrasctructure and the Environment Directorate-general for Environment and International Coordination P.O. Box 20901, 2500 EX DEN HAAG
Project name	In-service emission testing programme for heavy duty vehicles 2011
Project number	033.27092

Management samenvatting

In opdracht van het Ministerie van Infrastructuur en Milieu voert TNO Sustainable Transport and Logistics regelmatig metingen uit aan vrachtwagens om de prestaties en duurzaamheid op het gebied van schadelijke emissies te bepalen voor representatieve praktijksituaties.

Het meetprogramma van 2011 voorziet in nieuwe inzichten over de emissieprestatie van de aankomende Euro VI technologie die verplicht wordt vanaf 31 December 2013 voor zware bedrijfsvoertuigen. Samen met resultaten van eerdere meetprogramma's kunnen tevens conclusies worden getrokken over de emissies van de huidige generatie zware bedrijfsvoertuigen (Euro V, EEV).

De resultaten van testen met twee Euro VI vrachtwagens, een prototype en een productievoertuig, zijn een eerste indicatie dat de Euro VI technologie de potentie heeft om de schadelijke uitstoot significant te verminderen in vergelijking met de huidige Euro V vrachtwagens.

Hoewel de eerste resultaten veelbelovend zijn, beperkt deze eerste indicatie zich tot de geteste vrachtwagens en de gegeven technologie die de fabrikanten hebben gekozen voor de motorenfamilie geplaatst in hun range zware vrachtwagens. De emissieprestaties van nog niet verkrijgbare Euro VI distributievrachtwagens en bussen en vrachtwagens van andere fabrikanten zijn nog niet bekend. Ook de effecten van veroudering zijn onbekend. Voorts is de EU emissiewetgeving nog in ontwikkeling en zijn er nog aanpassingen nodig om lage emissies te garanderen onder alle relevante gebruikscondities. Het wordt daarom aanbevolen om de emissies en de veroudering te blijven monitoren en om de sterke kennispositie die Nederland heeft ten aanzien van de ontwikkeling van emissiewetgeving te handhaven.

Na een flink aantal Euro V en EEV voertuigen uitvoerig te hebben getest, kan geconcludeerd worden dat de emissies een gespreid beeld laten zien. Gemiddeld genomen, lijken de NO_x emissies van vrachtwagens van de tweede generatie Euro V bij lage snelheden wat te zijn gedaald ten opzichte van de eerste generatie. Het EEV en Euro V keurmerk geven echter geen garantie voor lage emissies omdat de resultaten per voertuig sterk kunnen verschillen en sommige voertuigen en voertuigentypes problemen hebben om in de praktijk een lage uitstoot te halen. Hierdoor ontstaat een behoefte aan een aanvullende methode om de praktijkemissies te beoordelen, los van de bestaande Euro V en EEV emissiewetgeving. Dit kan bijvoorbeeld vlooteigenaren ondersteunen bij een milieubewuste keuze voor de aanschaf van nieuwe voertuigen. TNO werkt op dit moment aan een dergelijke methode die eenvoudig en goedkoop inzicht zal geven in de praktijkemissies van voertuigen.

Management summary

Commissioned by the Ministry of Infrastructure and the Environment of the Netherlands, TNO Sustainable Transport and Logistics regularly performs measurements to determine the in-service performance and durability with respect to the pollutant emissions of heavy-duty vehicles under representative driving conditions.

The 2011 measurement programme yields new insights regarding the emission performance of the upcoming Euro VI technology for heavy-duty vehicles, mandatory as of 31 December 2013 and, together with the results from earlier performed programmes, leads to conclusions on the emission performance of past and present generations of heavy-duty vehicles (Euro V, EEV).

The test results of two heavy-duty vehicles with Euro VI technology, one prototype and one production vehicle, are a first indication that this Euro VI emission stage has a large potential to reduce pollutant emissions significantly compared to the current generation of Euro V heavy-duty vehicles.

This first indication is limited to vehicles of two manufacturers who have chosen a certain technology path for their mainstream engines mounted in long-haulage vehicles. The emission performance of other vehicles and of other brands and types of the Euro VI stage is still uncertain as they have not been tested yet. Also the durability has not been investigated. Furthermore, the EU emission legislation still needs further refinement to guarantee low pollutant emissions under all relevant circumstances. It is therefore recommended to continue monitoring the emission performance and durability of representative vehicles in service and to continue the knowledge position that supports the strong Netherlands role in the development of robust European emission legislation.

After having tested a large number of Euro V and EEV vehicles extensively it can be concluded that the emission performance of these vehicles is mixed. On average the NO_x emissions of the last generation of Euro V seem to have improved somewhat at low driving speeds, compared to the first generation Euro V. Still Euro V and also EEV does not guarantee low emissions because the results are scattered. Some individual vehicles and types of vehicles still proved to have problems to perform well under real-world driving conditions. Because of this a need exists for an additional method to judge the emission performance apart from the existing Euro V and EEV emission legislation. This could for instance assist fleet-owners with the choice for a clean vehicle. At the moment TNO develops a simple and cheap method to fulfill this need.

Background

Road Transport is of great economic importance for the Netherlands. With large ports on the North Sea and a dense network of roads, rail-, water- and airways the Netherlands logistic infrastructure serves as a gateway for the transport of goods and people from all over the world to the inner lands of Europe and vice versa. These activities and all local activities, all increased by economic growth, come with an environmental burden to the region, mainly for air quality. Already in the previous century the Ministry of the Environment recognized this situation and introduced amongst others national policies with the aim to effectively reduce pollutant emissions at the source.

In 1994 the Ministry started the SELA programme (Schone En Lawaai Arme voertuigen) to stimulate the introduction of clean and low-noise heavy-duty vehicles on the market. This programme required vehicles to comply with certain stringent national emission and noise requirements which were checked by TNO with dedicated test procedures.

In the meantime the EU emission type approval legislation [70/156/EC] developed its procedures and requirements, helped by insights of the national programmes. As a result, EU emission limits have become more stringent over time and the procedure recently improved by moving from an engine-based laboratory procedure to a procedure also including more real-world oriented requirements [2007/46/EC, 2011/595/EC]. All this resulted in enormous technological improvements made by the manufacturers to reduce the pollutant emissions and at the same time also improving the efficiency of the powertrain.

Today, the EU emission legislation is still under development and although it has advanced substantially over time, results of the in-service testing programme performed with the current generation of vehicles (Euro V) showed that the EU emission legislation still requires some further refinement to guarantee the so needed low-pollutant emissions at the source.

Aim and approach

The general aim of the Netherlands in-service testing programme for heavy-duty vehicles is to gain insight into trends in real-world emissions of generations of heavy-duty vehicles, under the usage conditions relevant for the Dutch situation.

The aims of the programme are:

- to assess the real-world emission performance with a focus on the NO_x and NO_2 emissions. In particular urban or low speed driving conditions are considered.
- to check the conformity of vehicles in service against the applicable requirements as laid down in the EU emission legislation [2011/582/EC].
- to collect information to establish emission factors for the (inter)national models which calculate pollutant emissions. In particular urban or low speed driving conditions and different payloads are of interest.
- to evaluate the in-service conformity procedure for the type of truck using latest Euro V and Euro VI emission technologies, and
- to extend the knowledge needed for the development of methods to effectively regulate real-world emissions in the EU.

For this investigation, TNO used a Portable Emission Measurement System (PEMS) for determination of the real-world truck emissions. PEMS is introduced in the Euro V and Euro VI heavy-duty emission legislation for determination of 'In-Service Conformity' [2011/582/EC] and as such is a widely accepted method to measure real-world emissions and determine the in-service emission performance.

PEMS measures the exhaust gas components NO_x, NO_2, CO_2, CO and HC. The measurements can take place driving the truck on the road in normal traffic. As such, PEMS yields estimates for real-world emissions performance of the investigated vehicle. PEMS does not yet include a validated method to measure PM (particulate matter).

This report

This report summarizes the findings of the Netherlands in-service testing programme for heavy Duty Vehicles performed in 2011. A separate report with detailed information regarding the method, the results and the conclusions will be published shortly.

Hereafter this report presents and discusses the results of the two tested vehicles that were equipped with the upcoming Euro VI technology and of the present generation of heavy duty vehicles (Euro V, EEV).

Results

Together with results from earlier test programmes the in-service emission test programme of 2011 yields insights in the emission performance of the recent technology and EU emission stages of heavy duty vehicles on the market. The available dataset, which includes results of all kinds of heavy-duty vehicles for different stages of emission legislation, allows different cross sections to be made to evaluate the progress of emission performance over the different stages to:

- conclude on the NO_x emission performance of heavy-duty vehicles up to and including Euro V and EEV. In particular two Euro V generations are compared and EEV vehicles are evaluated and to
- give a first indication of the NO_x emission performance of EURO VI long-haulage trucks.

The methodology of testing is extensively described in [Verbeek et al, 2010], [Vermeulen et al, 2010] and [2011/582/EC].

EU emission legislation

The table below gives the most important air quality problem related limit values over the recent and new EU legislative emission stages for heavy-duty engines and vehicles.

Table 1: overview of most important air quality problem related limit values for the ETC test cycle (up to Euro V and EEV) and the WHTC test cycle (Euro VI).

Stage Date of first registration	Euro III Oct. 2001	Euro IV Oct. 2006	Euro V 01 Oct. 2009	Euro V EEV 01 Oct. 2009	Euro VI 31 Dec. 2013
NO_x [g/kWh]	5,0	3,5	2,0	2,0	0,46
PM [g/kWh]	0,16	0,03	0,03	0,02	0,01

The Euro V emission legislation is more or less split in two major generations: This first generation of Euro V vehicles was introduced earlier than the official date of entry into force of the EU Euro V regulation because the German Maut incentivized Euro V. These vehicles entered the Dutch fleet as of 2005. For the vehicles registered before 2009 and after 2009 different legislative requirements apply. Also in 2007 a step is made in requirements. There are no differences in emission limits: the main differences can be found in OBD (On-Board Diagnostics) (stage II vs. stage I) and control measures for NO_x.

The EEV label, which spelled out stands for 'Enhanced Environmentally friendly Vehicle', in practice means a set of limits which are slightly stricter than the standard Euro V limits. The main difference between Euro V and Euro V EEV is the limit for particulate matter which is 0,02 g/kWh instead of 0,03 g/kWh.

The Euro VI emission regulation for heavy-duty vehicles [2011/595/EC] comes with stricter limits for the NO_x and PM emissions and introduces a limit for particle number emissions (PN). Furthermore, major improvements have been made with regard to the test procedure, introducing a more representative laboratory test cycle (WHTC) and new in-service conformity requirements which requires vehicles to be tested on the road with PEMS. Additional requirements which cover a wider range of real driving circumstances than the ones laid down for in-service conformity are still under development.

Euro V: NO_x emission performance is scattered, also for EEV. The latest generation Euro V long-haulage trucks seems to have improved.

The NO_x emissions of the first generation of Euro V heavy-duty vehicles which was introduced in advance of EU legislation and was stimulated by local policies, did not result in a reduction in the real-world emissions as expected by the step in emission limits, especially under urban, low speed driving conditions [Verbeek, 2010].

The second generation of Euro V long-haulage vehicles seems to have improved somewhat due to additional requirements in the EU legislation and possibly also

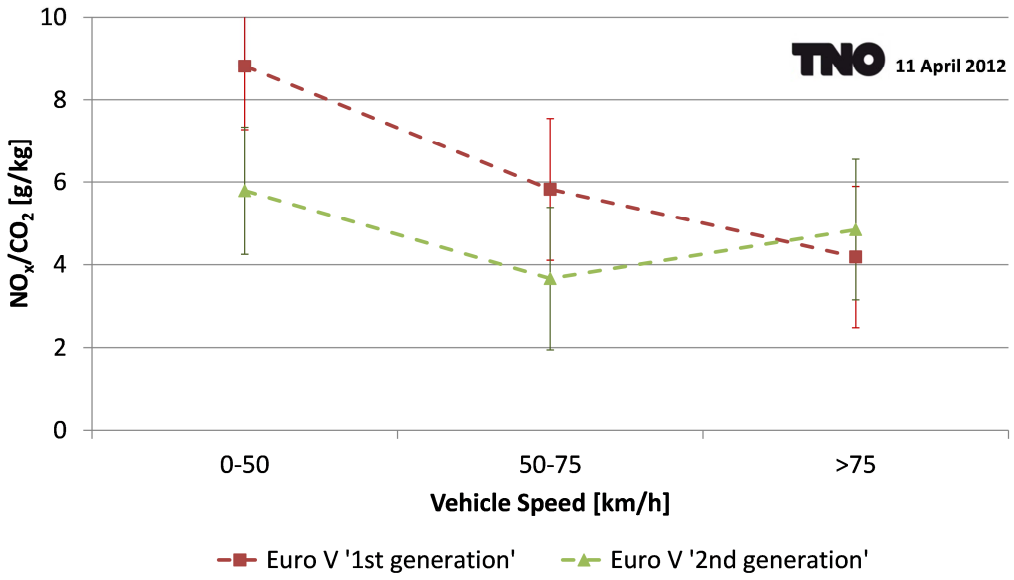
due to learning effects with regard to the SCR (Selective Catalytic Reduction) technology mainly used to reduce the NO_x emissions.

However, the emission performance of different Euro V vehicles is still scattered and shows different types of behaviour over the usage profile. Also the EEV vehicles, which are often claimed to be 'environmentally enhanced vehicles', scatter a lot, meaning that some good examples have been observed but also some bad examples. Therefore, the labels 'Euro V' and 'EEV' are no guarantee for low pollutant emissions.

The 2011 programme aimed to test vehicles of the 'second generation' and as such, after finalization of the programme together with the results of the earlier programme the emission performance of Euro V vehicles could be concluded. Also the two Euro V generations of vehicles could be compared to judge if the additional requirements for On-Board Diagnostics and NO_x control measures has led to an improvement of the NO_x emission performance. All these vehicles have been tested in the same way and the NO_x emissions have been related to the CO_2 emissions in order to make vehicles of different capacities comparable

Figure 1 below shows the average CO_2 specific NO_x emissions of the two generations of Euro V (all N3 trucks with SCR technology to reduce NO_x). Given the statistical analyses based on this data it is not likely that the groups behave differently for the high speed and the intermediate speed ranges. For the low speed range it seems more likely that the groups differ, with a somewhat lower NO_x emissions for the second generation of long-haulage Euro V vehicles.

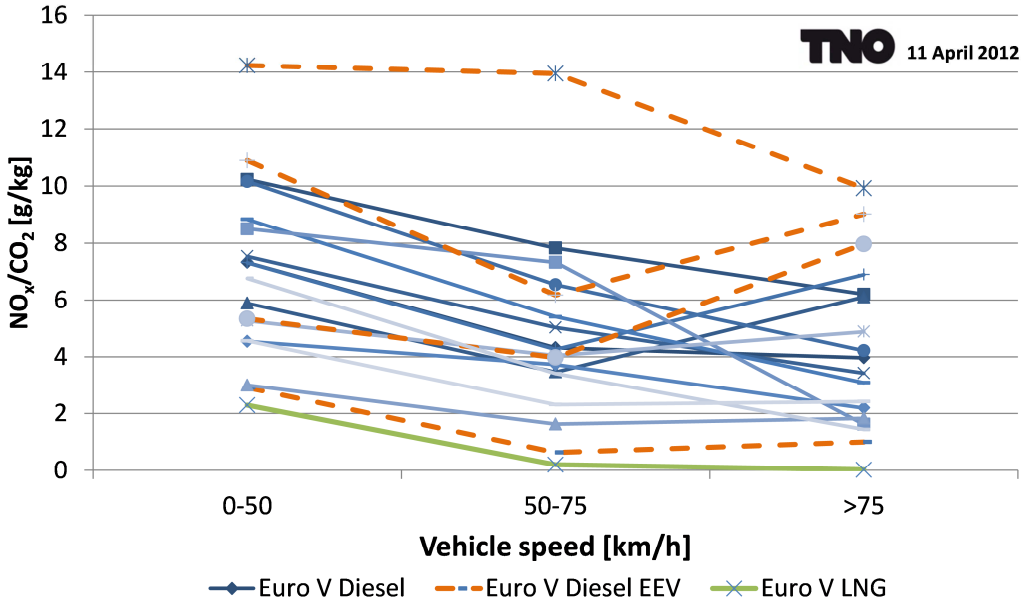
Figure 1: average CO_2 specific NO_x emission over three speed ranges for two Euro V legislative sub classes of long haulage vehicles equipped with SCR: 1) the 'first generation', as introduced before the mandatory date of entry into force of Euro V in 2009 and 2) the 'second generation' as introduced after the mandatory date of entry into force of Euro V in 2009. Error bars represent the student-T 95% confidence interval.



Another cross section of the dataset shows the NO_x emissions for individual Euro V and EEV vehicles on diesel and one on LNG (Liquid Natural Gas), see Figure 2.

The NO_x emission of individual Euro V and EEV vehicles scatters substantially from very high to very low CO_2 specific NO_x emissions. Also the emission behaviour is different: whereas most vehicles tend to emit more at low, urban driving speeds (0-50 km/h), some also have high NO_x emissions at typical motorway speeds (>75 km/h). One tested truck on LNG shows a very low NO_x emission.

Figure 2: another cross section of the data. Only Euro V vehicles are shown. Fuel type and Euro V vs. EEV are distinguished. The NO_x emissions for diesel Euro V and EEV vehicles are very scattered. The LNG vehicle shows low NO_x emissions.

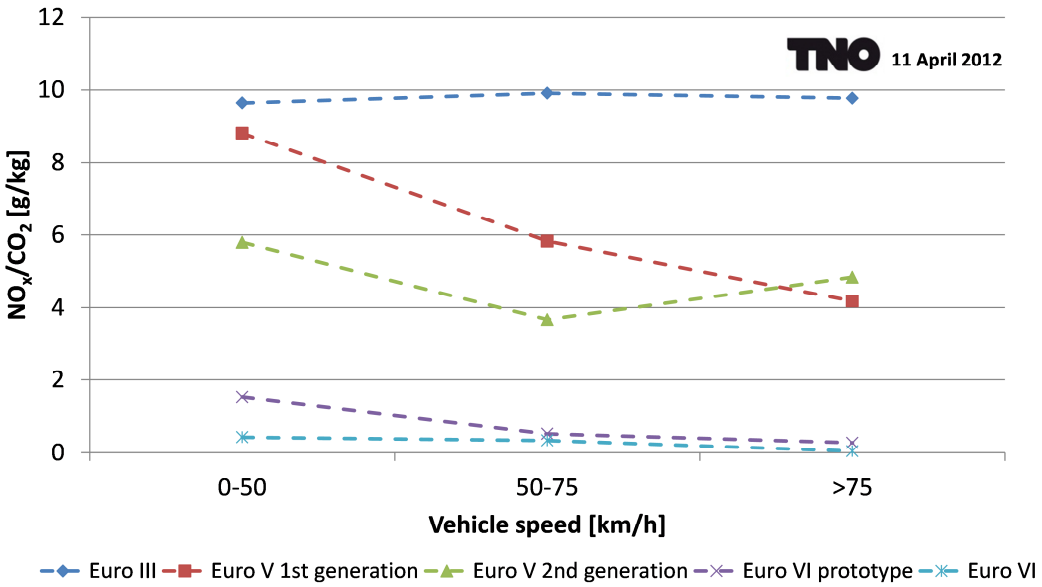


Euro VI: first indications show a good progress compared to Euro V

Two Euro VI long-haulage vehicles were tested with a portable emission measurement system on the road while driving a variety of trips with different payloads. One vehicle was a prototype and one was a production vehicle. The NO_x emissions of these vehicles can be compared with the emissions of earlier generations of heavy-duty long haulage vehicles, see Figure 3..

The two tested Euro VI vehicles clearly have a very low CO_2 specific NO_x emission compared to the preceding generation of Euro V vehicles.

Figure 3: trend of the real world CO_2 specific NO_x emissions as measured for different generations of N3 (long haulage) heavy-duty vehicles equipped with SCR (Selective Catalytic Reduction).



Conclusions and recommendations

The Euro V and EEV NO_x emission performance of heavy-duty vehicles varies per vehicle and thus does not guarantee low emissions in the real world for individual vehicles and vehicle types. Still a significant portion of the tested vehicles showed high NO_x emissions under certain relevant driving circumstances. Because of this a need exists for an additional method to judge the emission performance apart from the existing Euro V and EEV emission legislation. At the moment TNO develops a simple and cheap method to fulfill this need.

On average the second generation of Euro V long-haulage trucks seems to be somewhat better compared to the first generation Euro V trucks with regard to the NO_x emission at low, urban driving speeds. Some vehicles still performed poorly, however.

The two tested Euro VI long-haulage trucks showed significantly lower NO_x emissions compared to the preceding generation of Euro V trucks. This first indication is promising but it is recommended to monitor if this trend is similar for other brands and types of heavy-duty vehicles when they arrive on the market.

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Signature

Delft, 16 April 2012

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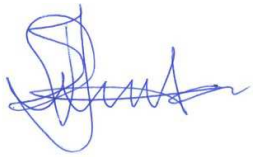

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