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Potenziale von EU6-PKW mit SCR zur Erfüllung von RDE-Anforderungen

Potential for Euro 6 Passenger Cars with SCR to meet RDE Requirements

Abstract

The RDE (Real Driving Emissions) legislation will require highly efficient DeNO$_X$ systems in the complete operating range of the vehicle. Selective Catalytic Reduction (SCR) technology has proven its performance already in numerous passenger cars which are compliant with the current Euro 6 legislation. In the presented study, AECC and FEV investigated the RDE compliance potential of SCR-based solutions in on-road driving tests with Portable Emission Measurement System (PEMS) and demonstrated the specific challenges in comparison with NEDC and WLTC emissions tests on the chassis dynamometer.

The E-segment test vehicle with SCR-coated DPF (SDPF) was in the first step investigated with the available emission calibration, which was targeting Euro 6b emission limits. In the RDE test, the reduced EGR rate in higher engine load regions caused a significantly elevated level of NO$_X$ raw emissions. Even though the NO$_X$ conversion of the SDPF system was at the same time higher than 85 %, the NO$_X$ tailpipe emissions exceeded a conformity factor of 3. This characterizes the starting point of the calibration work using the existing aftertreatment system on the test vehicle. With dedicated re-calibration of both the EGR and the urea dosing strategy, a significant reduction of the NO$_X$ raw and tailpipe emissions was reached, so that in the finally conducted RDE-route NO$_X$ conformity factors between 1.1 and 1.6 have been achieved.

The reduction of the NO$_X$ raw emissions however caused an increase in the real-world fuel consumption between 1.3 and 2.7 %. Despite the lower NO$_X$ raw emission level, the AdBlue® consumption of approximately 2.5 l/1000 km reached a higher level than commonly known for current Euro 6b compliant vehicles.

Based on these measurement results with the test vehicle, a C-segment vehicle with an alternative EGR and aftertreatment system has been simulated over the same route. The combination of LNT and passive SDPF showed reduced NO$_X$ conversion efficiencies, especially during transient phases with increased engine loads. For the RDE compliant usage of such simplified aftertreatment systems without urea dosing it is therefore even more important, besides the improvement of the catalyst performance, to avoid high NO$_X$ raw emissions in highly dynamic operation, e.g. by optimized EGR and boosting systems as well as model-based NO$_X$ control.

Introduction and overview of state of the art

In most of the European Union Member States the limits for NO_2 which are defined in the Air Quality Directive are exceeded in densely populated metropolitan areas (Figure 1). Traffic related emissions are a major contributor to this. The Joint Research Center (JRC) of the European Commission has pointed out in [1] that in real driving especially the NO_X emissions of vehicles with Diesel engines exceed the limits which apply for homologation. Several other independent studies have basically confirmed these investigations, e.g. [2].

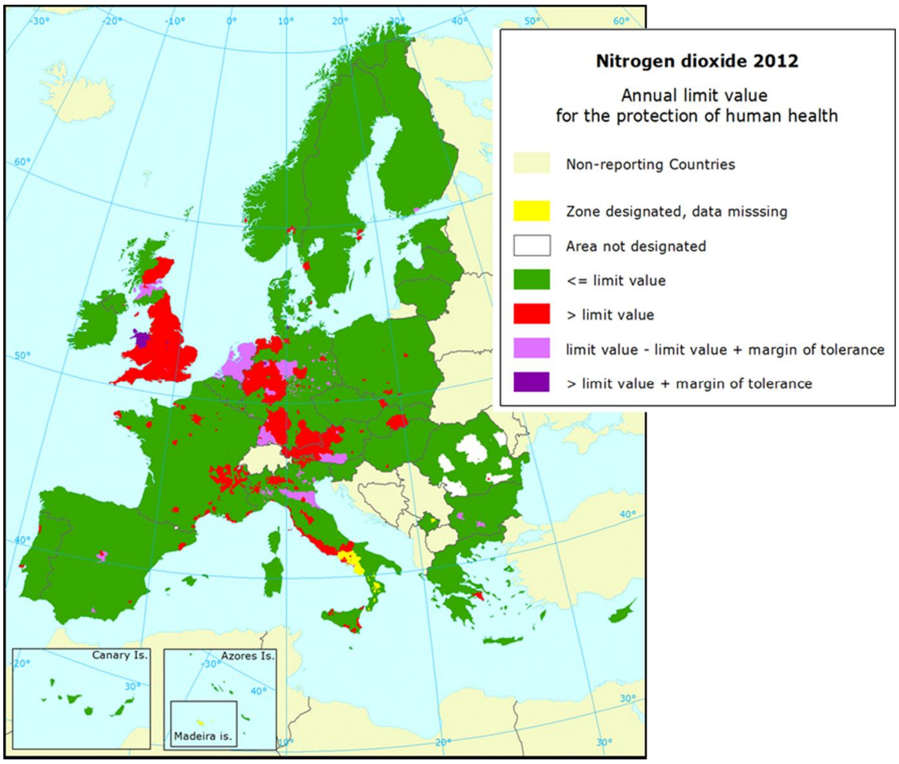

Figure 1: Areas in which the NO_2 limits according to the air quality directive are exceeded [3]

As a consequence, the European commission will, as foreseen by Regulation (EC) No 715/2007, require the validation of Real Driving Emissions (RDE) with Portable Emissions Measurement Systems (PEMS) from 2017/18 (the Euro 6c stage) onwards. As a first step NO_X emissions and particulate number (PN) will have to be checked. A conformity factor defined by emissions in the RDE test divided by emission limits on the homologation cycle will be introduced; thresholds or limits for this Conformity Factor (CF) have yet to be defined.

According to current assumptions city, extra-urban and motorway operation have to contribute to 1/3 of the overall RDE test distance respectively. Maximum RDE vehicle speed has not been finally defined yet, speeds of up to 160 km/h are discussed. The maximum duration of the RDE test shall not exceed 120 minutes [4].

RDE results will be evaluated with a relative weighting method, at the moment two alternative software solutions are considered. The EMROAD software developed by the EU's Joint Research Center (JRC), and the CLEAR software developed by the Technical University of Graz.

Especially the compliance with NO_X emission limits has to be considered as a challenge for Diesel passenger cars. On the one hand there is a general trade-off between low NO_X

emissions and low fuel consumption. On the other hand technologies for the reduction of NO_X emissions as e.g. air path technologies and aftertreatment technologies have to be optimised further to cover the complete engine operating range and highly transient driving profiles.

With the introduction of Euro 6 more and more Diesel passenger cars have been equipped with selective catalytic reduction converters (SCR). For the current homologation process which uses the New European Driving Cycle (NEDC) especially, good low temperature SCR catalyst efficiency is required. This is usually realized by NH_3 storage control and in some cases by the implementation of a rapid heat up mode to increase the exhaust temperature levels. Recently close coupled Diesel Particulate Filters with SCR coating (referred to as SDPF or SCRF) have been presented, SCR catalyst light-off is achieved earlier with such solutions [5].

For WLTP (the UN Worldwide harmonized Light vehicles Test Procedure) with its associated test cycle (WLTC) and RDE requirements the SCR system has to cover the complete temperature range and also be highly efficient under transient driving conditions and varying engine-out NO_X emission levels.

The main target for the study presented in this paper was to determine the tailpipe emissions of a Euro 6 passenger car equipped with SDPF under real driving emissions conditions. Chassis dyno NEDC and WLTC tests and on road RDE PEMS measurements were conducted. In a next step the engine air path / EGR set points and the SCR dosing calibration were adapted and optimised to reach a sufficiently low and robust conformity factor in the RDE test.

In the price sensitive small size sub-C passenger car segment Lean NO_X Traps (LNT) are often preferred instead of SCR $DeNO_X$ systems. Major advantages are the improved packaging and reduced costs as no SCR urea tank and dosing system are required. The major drawback of LNTs is that high NO_X storage efficiency can only be achieved in a more limited exhaust gas / catalyst temperature window in comparison to SCR. The question of whether LNT technology alone remains a suitable option for RDE requirements has yet to be answered. Especially for highly dynamic driving conditions the engine-out NO_X emissions can be significantly higher than measured in NEDC and WLTC tests as depicted in Figure 2 for a C-segment vehicle.

As an alternative aftertreatment technology scenario an LNT combined with passive SDPF (without AdBlue® dosing) was investigated in this study. While the active SDPF was investigated on an E-segment vehicle equipped with a ~2l displacement engine, the combined LNT/passive SDPF system was analysed for a C-segment vehicle with a 1.6l engine by simulation means. To achieve the passive SCR functionality, the NH_3, which is formed on the LNT during the rich LNT regeneration events, is stored in the passive SDPF. The SDPF then reduces the NO_X emissions remaining downstream LNT further. Similar systems have been presented in numerous publications e.g. [6].

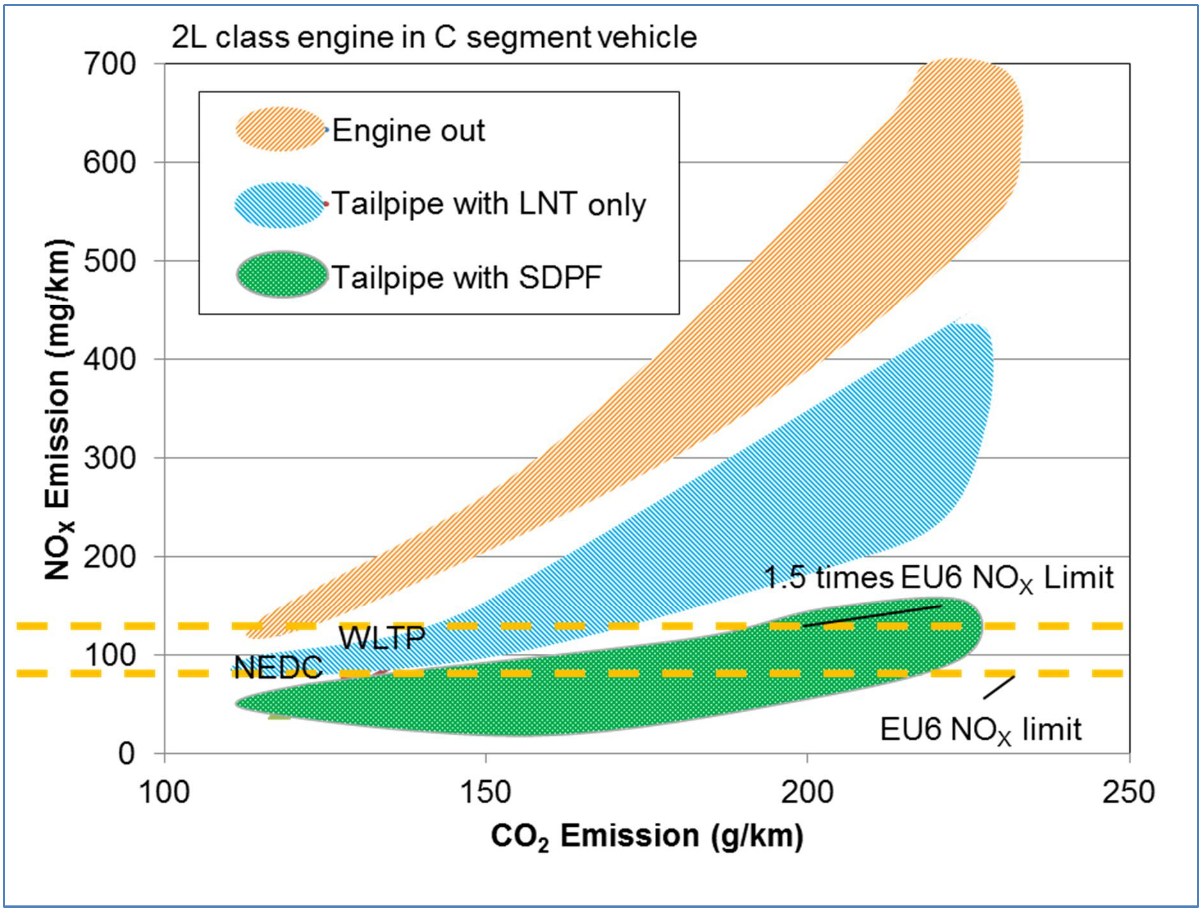

Figure 2: Exemplary increase of the NO_X emissions depending on the driving cycle

Boundary conditions for the investigations

The physical tests presented in this study were conducted with an E-segment vehicle in the 1810 kg inertia test weight category. The vehicle is equipped with a ~2l Diesel engine featuring cooled high-pressure EGR and an 8-speed automatic transmission. For the exhaust aftertreatment a close-coupled DOC, a DPF with SCR coating (SDPF) and a flow through SCR which is located directly downstream the SDPF are used. Due to packaging constraints the SDPF is not located immediately downstream of the DOC. The mixing length between urea injector and SDPF is longer than 1 m which is beneficial for NH_3 uniformity in the SDPF but not ideal for the SDPF catalyst heat-up. Figure 3 shows the relevant main dimensions and catalyst volumes.

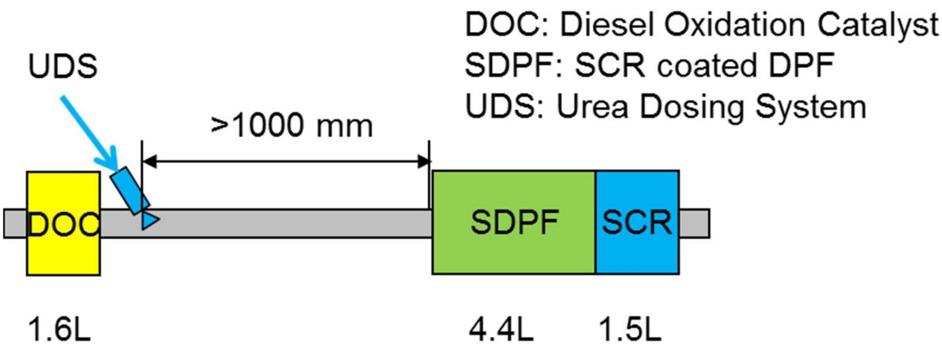

Figure 3: Main dimensions of the exhaust aftertreatment system on the test vehicle

The vehicle used complies with current Euro 6b legislation, hence achieves NO_X emissions below 80 mg/km safely on the NEDC. This limit is the same for Euro 6c.
To investigate if the above described Euro 6b hardware is also capable of achieving Euro 6c requirements including RDE, the vehicle was investigated on a chassis dynamometer in the WLTC and on-road in various real-world driving cycles with a PEMS. For the chassis dynamometer WLTC tests only the worst case highest vehicle weight category ”TM_H” was used, as the 2091 kg which applied for the tested vehicle resulted in highest engine-out NO_X emissions. For the on-road tests a SEMTECH® Ecostar PEMS was used. The equipment was installed in the interior of the car, the exhaust volume flow meter was installed on the extended tail pipe (Figure 4).

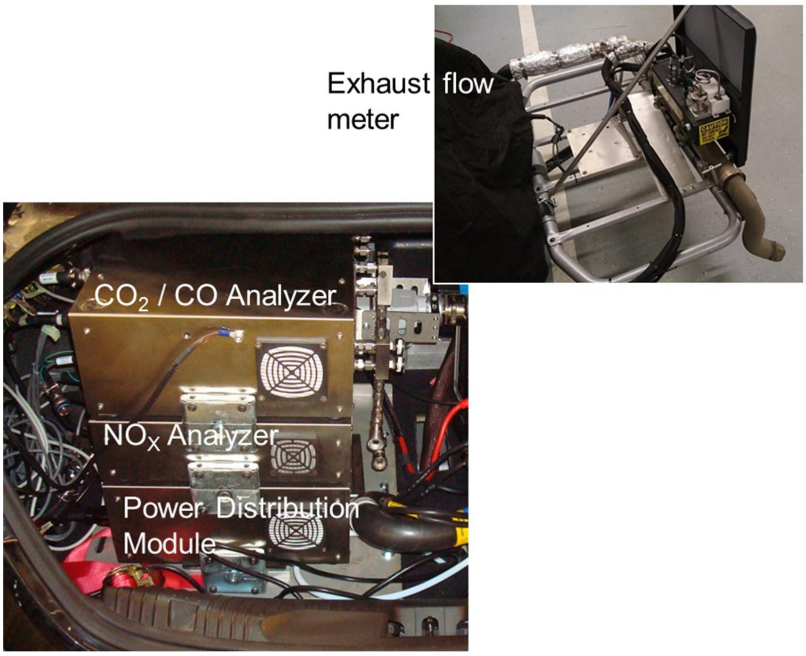

Figure 4: PEMS on the test vehicle

For the analysis and post-processing of the RDE test results both the EMROAD (version 5.80) and the CLEAR (version 1.8.6) software were used to determine the NO_X conformity factor.
Both programs use fundamentally different relative weight criteria. EMROAD uses a Moving Average Window approach and separates the obtained RDE results into a normal,

soft and aggressive range based on the WLTC CO_2 results for urban/city, extra-urban and motorway driving.
CLEAR uses the frequency distribution of effective engine power to classify the RDE results. Figure 5 shows the results from repeated tests of 2 vehicles, one using SCR, the other using only EGR for NOx control, when tested over 2 different RDE routes. As shown in Figure 5, for the same RDE route the weighted NO_X results can differ significantly depending on the software used.

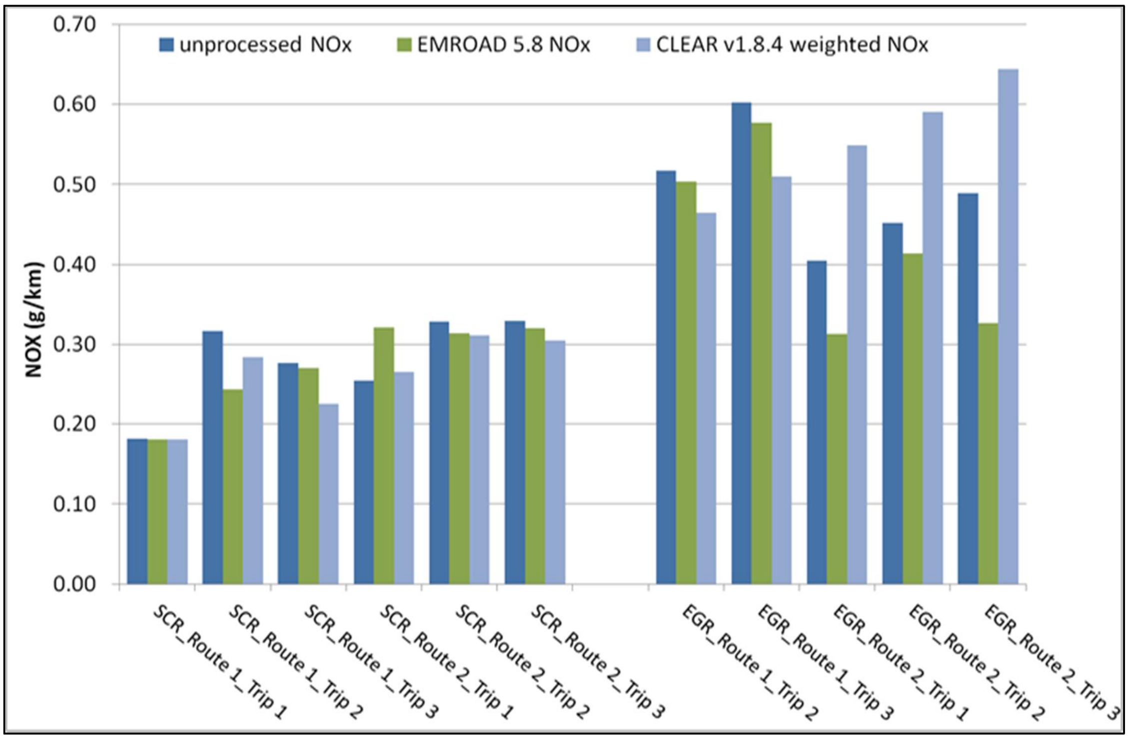

Figure 5: Comparison of the NO_X-emissions with different evaluation methods [7]

The EMROAD software was also used to check if the selected RDE test is in line with the proposed RDE boundary conditions as listed in Figure 6.

Parameter	Proposals (as at January 2015)
Ambient conditions	Moderate: 0°C < T < 30°C, h < 700 m
	Extended: - 7°C < T < 35 °C, 700 m < h < 1300m
Vehicle weight	Max 90% of the Gross Vehicle Weight
Trip definition	Urban → 0-60 km/h, Rural → 0-90 km/h, Motorway → 90-160 km/h
Trip sequence	Urban + Rural + Motorway
Trip sharing	1/3 Urban + 1/3 Rural + 1/3 Motorway
Maximum speed	up to 160 km/h during short time
Test duration	Max 120 min
Ambient humidity	No humidity correction of NO_x measurements
Cold start	Not included in emission evaluation, specific requirements are under discussion
Regeneration event	Not considered if it does not happen in 2 consecutive RDE testing on the same vehicle
Use of air conditioning, other auxiliary devices	The air conditioning system or other auxiliary devices shall be operated normally during the test
Traffic conditions	Daytime traffic conditions
Street condition	Only paved streets

Figure 6: Possible RDE boundary conditions

The first tests were conducted with the baseline calibration which was optimized for the NEDC; especially in the RDE test higher NO_X emissions were obtained.
The engineering vehicle used for this study was equipped with a calibratable, open engine control unit (ECU) which allowed the adaptation of both, the engine and the aftertreatment control.
Several optimization loops were carried out to assess the impact of adapted EGR and SCR strategies on the emissions results.

Experimental results

Initially the vehicle was tested with the Euro 6b baseline calibration on the NEDC. Road load settings for an inertia category of 1810 kg according to manufacturer specification resulted in Euro 6 compliant tailpipe NO_X emissions of 71 mg/km with a NO_X conversion rate of 58 % in the exhaust aftertreatment.
The WLTC tests were conducted with the highest inertia test weight category TM_H (in this case 2091 kg) and adapted coast down settings which correspond to higher road loads. This caused significantly higher NO_X and CO_2 emissions in comparison to the baseline NEDC results. With the Euro 6b baseline calibration 133 mg/km tailpipe NO_X were achieved with a NO_X conversion efficiency of 74%. Additionally the PEMS measurement equipment was installed during the WLTC tests, which resulted in an actual vehicle weight of approximately 2150 kg on the chassis dynamometer.
Figure 7 shows the NO_X emissions, conversion rates and exhaust temperatures in the WLTC.

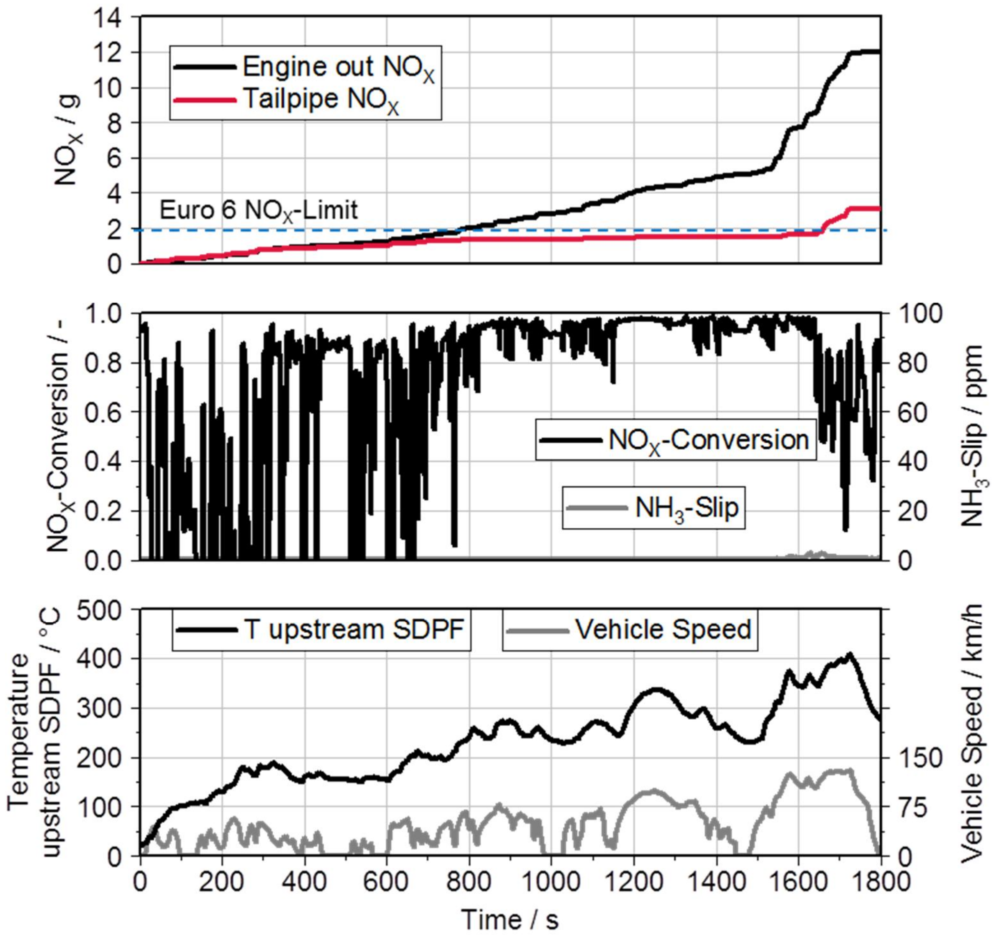

Figure 7: Results in WLTC with baseline calibration

Figure 8 depicts the cumulated NO_X engine-out and tailpipe emissions for WLTC and NEDC. Also NO_X conversion efficiencies and fuel consumption are shown for NEDC and WLTC in comparison. In WLTC with TM_H the NO_X raw emissions are in this case three times as high as in the NEDC with the lower test mass and driving resistance, whereas the fuel consumption increases by 12 %.

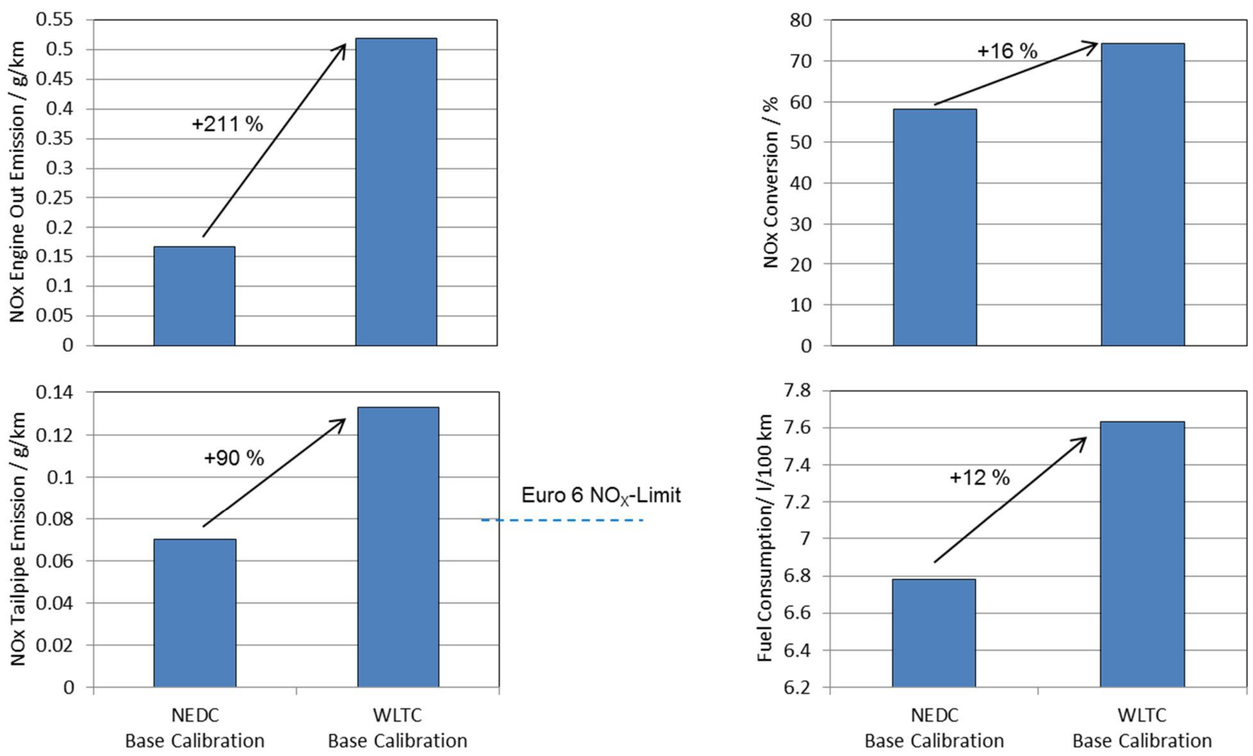

Figure 8: Comparison of the results in NEDC and WLTC with baseline calibration

For the on-road RDE tests a route in the Aachen area was defined. This route was supposed to be compliant with the requirements of city, extra-urban and motorway driving shares and should reach a duration of close to 120 minutes. Part of the route was also conducted in the more mountainous Eifel region to consider gradients and road elevations. The motorway share included also non speed limited legs to allow maximum vehicle speeds of up to 160 km/h.

During the first conducted RDE test the vehicle speed was significantly reduced on the motorway due to ongoing road works. Due to the low vehicle speeds the motorway driving portion was no longer in line with RDE requirements and therefore was classified as extra-urban driving. The post-processing with EMROAD confirmed that this particular first RDE test was non-compliant as the share of moving average windows in the motorway part was below the required 15 %. Figure 9 shows the EMROAD analysis of this test. As soon as the CO_2 emissions in the RDE tests exceed 50 % of the WLTC CO_2 value the moving average calculation of CO_2 and vehicle speed starts (upper part of Figure 9). These average values are then compared with the vehicle characteristic curves as obtained in the WLTC. An RDE road test is only valid if at least 50% of the respective city, extra-urban and motorway driving moving average windows can be considered as normal as defined by curves H1 and L1. Additionally at least 15 % of the moving average windows have to be classifiable as city, extra-urban or motorway driving respectively. The latter requirement was not fulfilled in the first RDE test as a motorway share of only 14 % was achieved due to the low vehicle speed after ~ 6200 seconds of on-road driving.

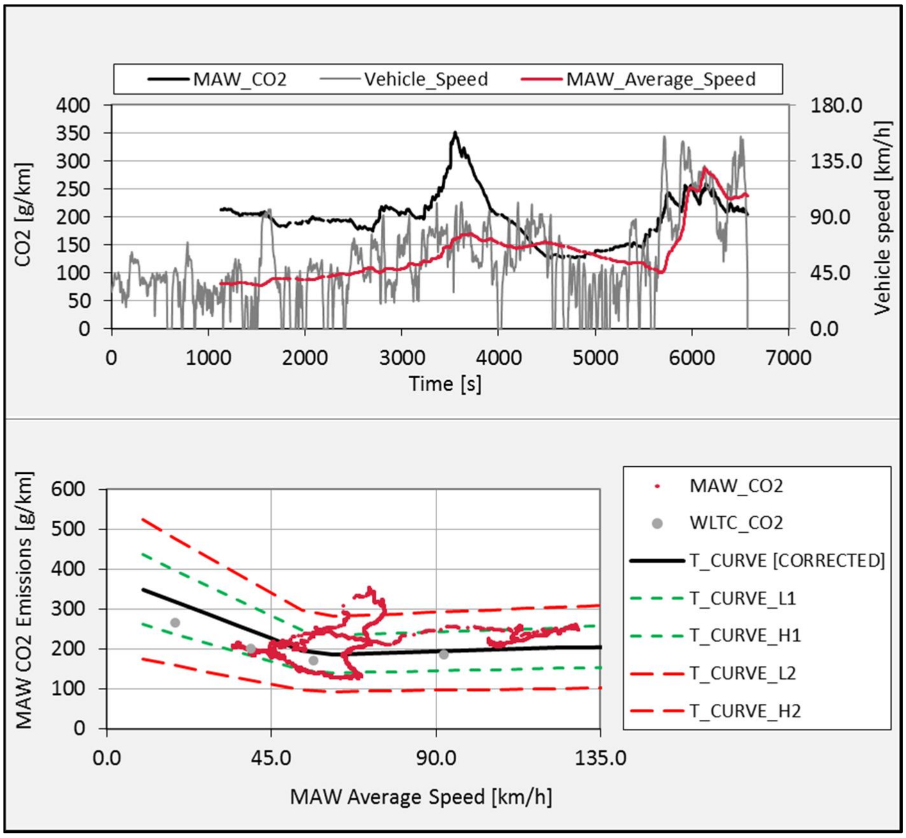

Figure 9: EMROAD analysis of the first RDE test

The route was re-arranged to avoid the motorway road works. The major specifications of the new RDE route are shown in Figure 10. For these tests ambient temperatures ranged from 0 to +7 °C which corresponds to the lower expected limit temperatures as summarized in Figure 6. The new RDE route covered a distance of 107 km.

This updated route complied with the EMROAD criteria for a valid RDE test. In addition to the EMROAD analysis the CLEAR software developed by TU Graz was used. This software considers a target frequency scale distribution range for engine power. The investigated RDE tests did not comply with this range and therefore were not valid according to CLEAR criteria. The one test which did comply with the CLEAR criteria was not valid according to EMROAD. For the following considerations the focus is therefore put on the EMROAD results.

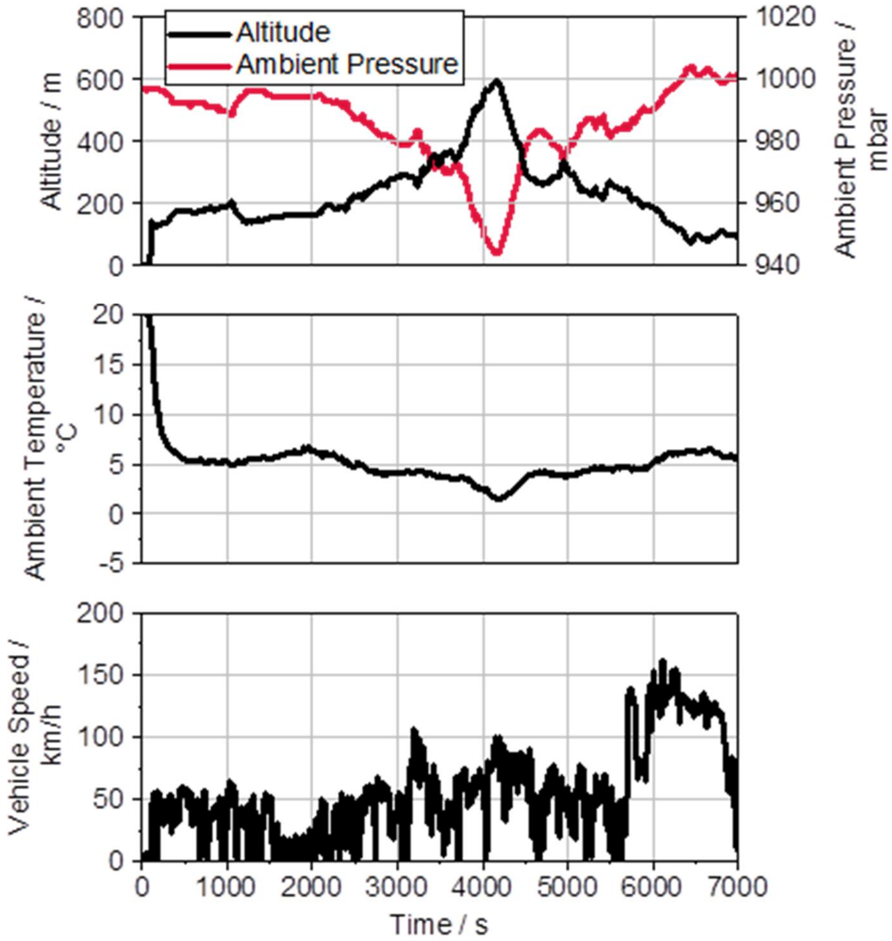

Figure 10: Boundary conditions of the RDE test with modified route

Using EMROAD, NO_X tailpipe emissions of 272 mg/km were achieved with the Euro 6b baseline calibration resulting in a conformity factor of 3.4. These relatively high NO_X emissions are mainly a result of reduced EGR set points due to low ambient temperatures and deactivated EGR at high engine loads. Figure 11 shows that especially in the last phase of the test the NO_X emissions increase significantly. The SCR dosing strategy had been optimized already before this test with increased dosing rates at SCR catalyst temperatures above 350 °C as well as an elevated set point for the NH_3 storage level of the SCR catalyst. Thus, NO_X conversion efficiencies of more than 80 % were achieved for the majority of the test after a short heat up phase. The temperature upstream of the SDPF usually ranged from 200 °C to 400 °C, but in phases of low engine loads temperatures below 200 °C were observed which are critical for SCR efficiency.

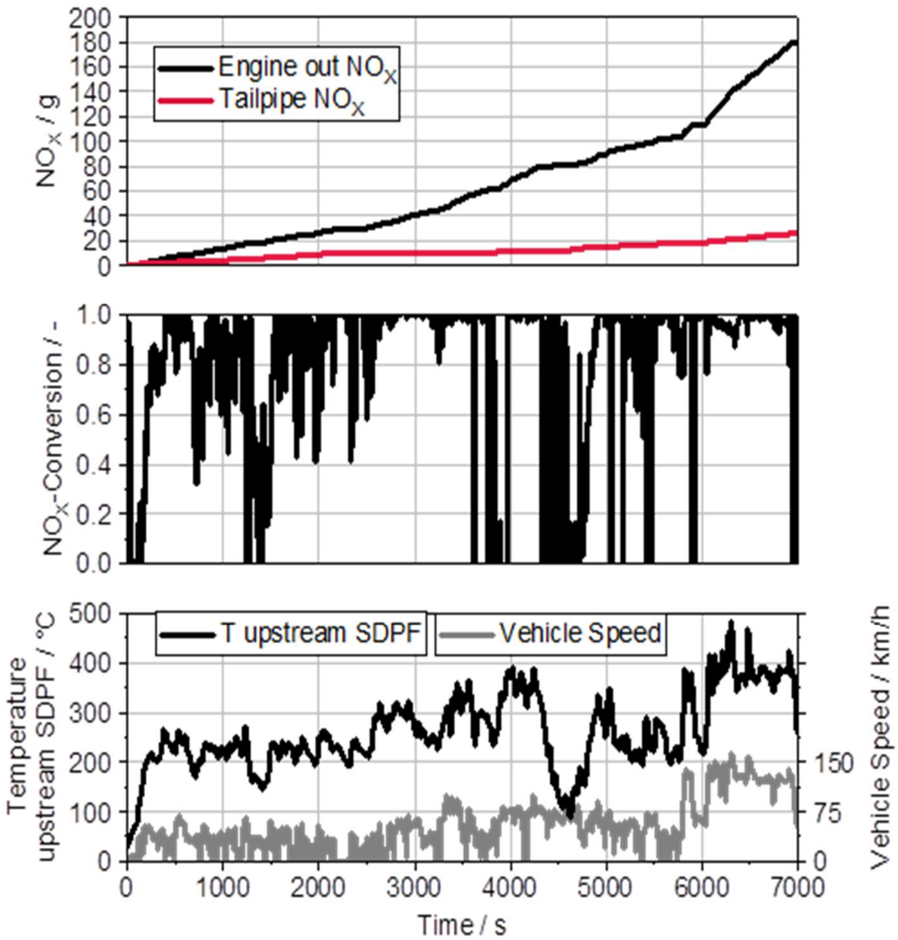

Figure 11: Results in RDE test with baseline calibration

The EGR strategy was adapted in the next step to achieve lowest possible NO_X emissions in the RDE test. The ambient temperature dependent correction of EGR set points was turned off and the EGR operating range was extended towards higher loads. This optimization was carried out as an iterative process as the extension of EGR did show a negative impact on general drivability especially for highly dynamic driving scenarios.
For high EGR rate set points the boost pressure build-up was delayed significantly causing slow transient response and high transient soot emissions. This had to be considered for the calibration adaptations as the EGR and boosting system of the investigated test vehicle had not been designed for to accommodate high EGR rates at high loads and engine speeds.
The adapted calibration was checked in a WLTC test, in which the NO_X Type Approval limits were fulfilled. A further decrease in engine-out emissions was achieved with 440 mg/km vs. 520 mg/km. The increased AdBlue® dosing rate of the adapted SCR dosing strategy resulted in a NO_X conversion efficiency increase from 74 % to 82 % (Figure 12).

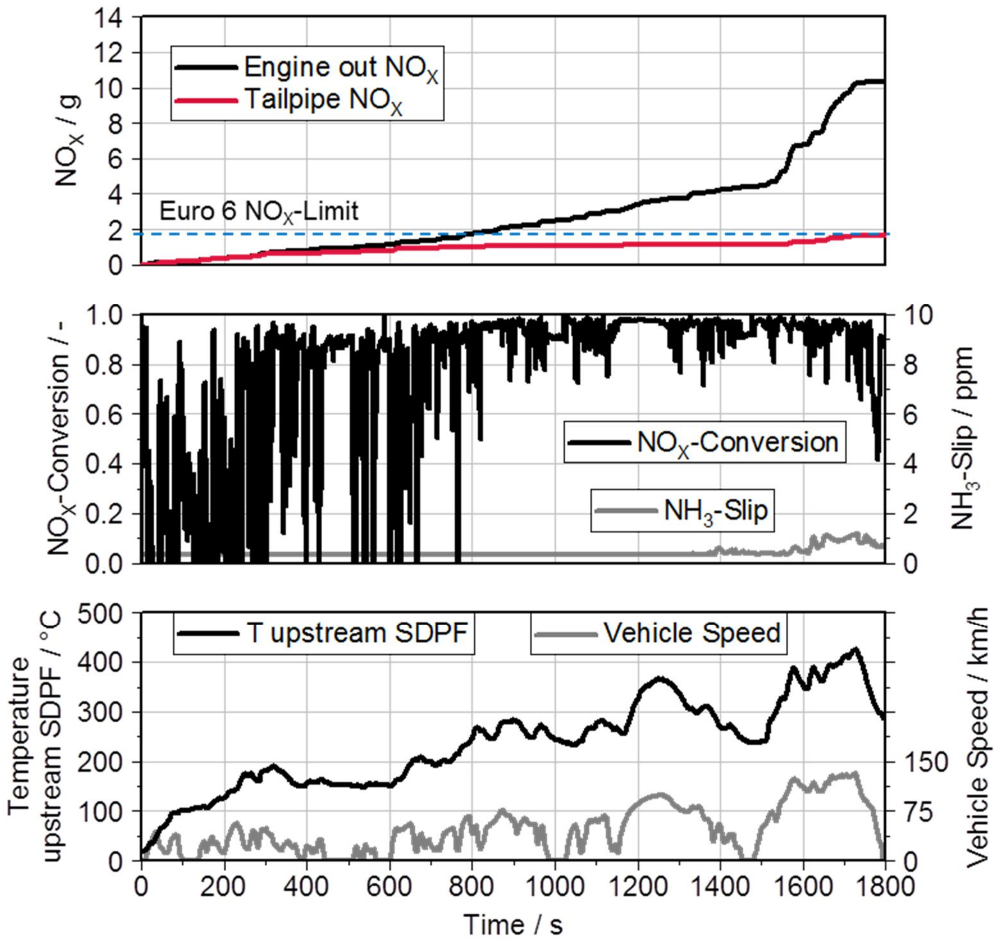

Figure 12: Results in WLTC with modified calibration

Several RDE tests were carried out with this adapted calibration. Some tests were deemed by EMROAD to be not valid as driving conditions affected the proportions classified as urban, rural and motorway driving or the severity of some sections. Two of the tests which are valid according to EMROAD criteria are discussed in the following. The EMROAD post-processing resulted in 88 mg/km for the first test, corresponding to a conformity factor of 1.1. The second test resulted in higher NO_X emissions of 126 mg/km and a conformity factor of 1.57. The EMROAD-processed CO_2 emissions on these tests were 229 and 232 g/km respectively, very little changed from the 226 g/km achieved with the baseline system.

In Figure 13 the ambient and dynamic conditions are compared for both tests with modified calibration which were conducted by the same driver. While the ambient temperature is only 2-3 K lower in the second test and the ambient pressure is almost exactly the same, significant differences can be observed in the actual vehicle speed profiles. This is a result of the "real world" operation of the vehicle. The driver is not following a pre-defined speed trace but has to consider and adapt to real world traffic conditions. The second test e.g. features higher average motorway speeds.

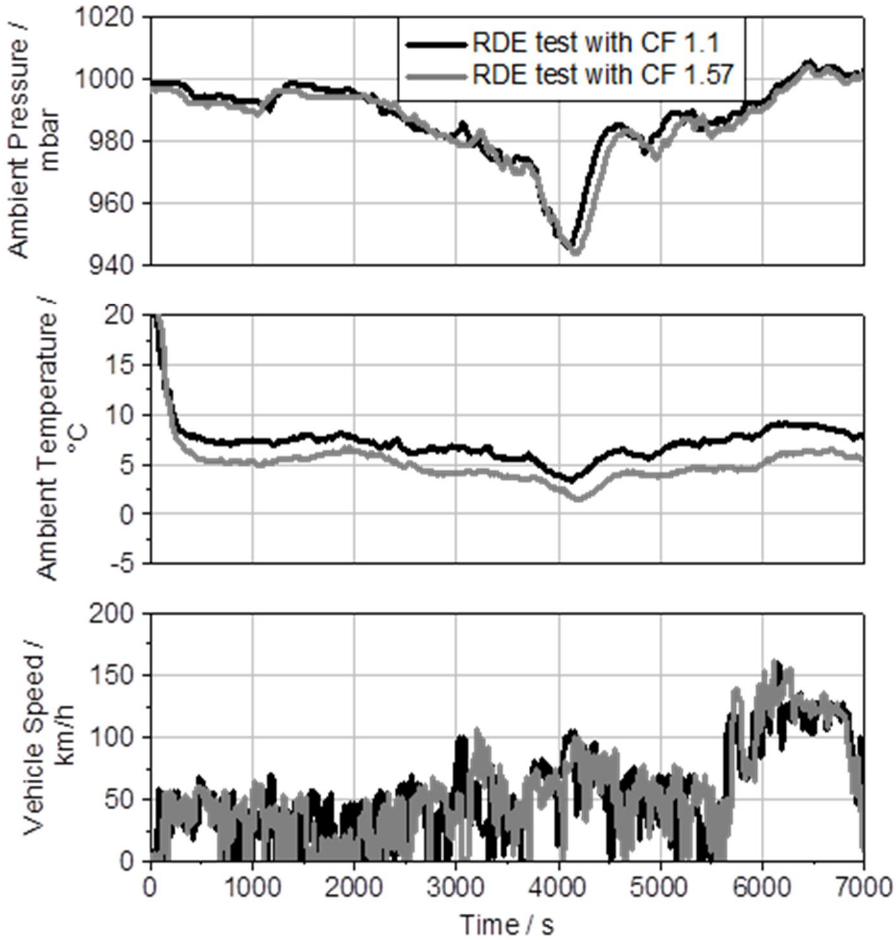

Figure 13: Comparison of the ambient and dynamic conditions of two exemplary RDE tests with modified calibration

Figure 14 summarizes the results of both RDE tests. Temperature upstream of the SDPF and NO_X conversion traces as well as NO_X raw emissions in the urban/city phase are comparable. The impact of slightly differing ambient temperatures seems to be negligible. Significantly different NO_X emissions are apparent in the extra-urban and motorway phases though.

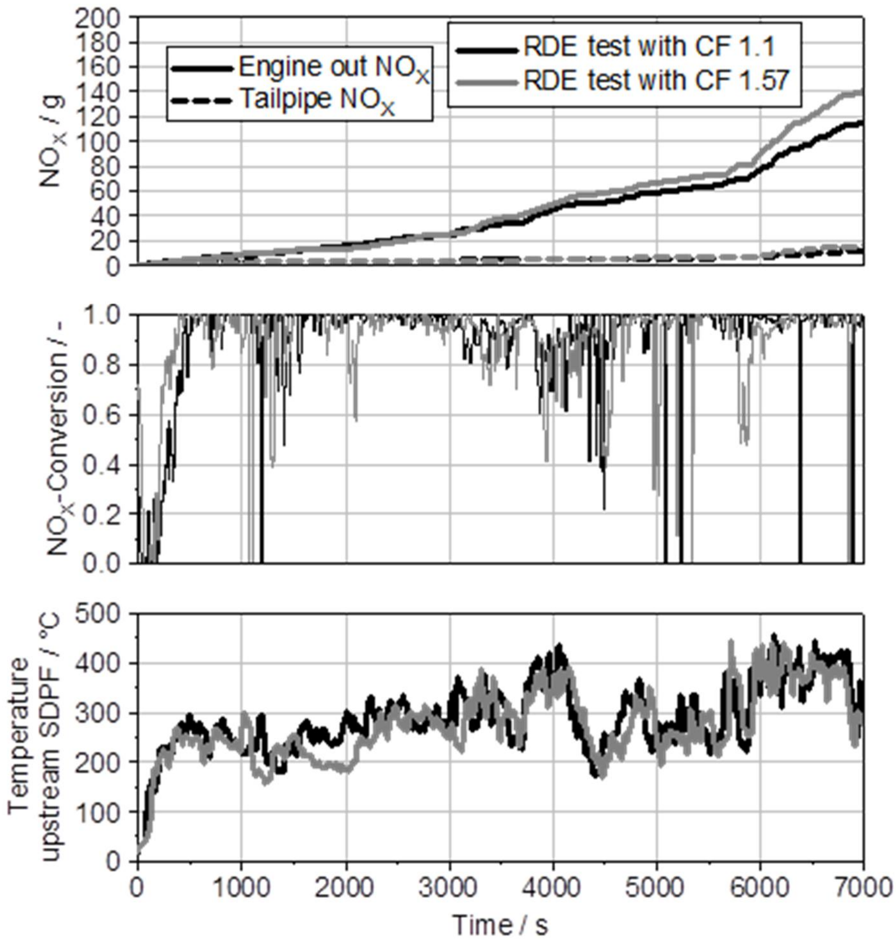

Figure 14: Results of the two exemplary RDE tests with modified calibration

A detailed, extracted view of the extra-urban / motorway phase is shown in Figure 15. A significantly more aggressive pedal usage is observed for the RDE test which resulted in a CF of 1.57. The maximum pedal positions correspond to peaks in NO_X raw emissions. This was due to the limited EGR-rates at high engine loads which the EGR and boosting system of the tested vehicle were laid out for.

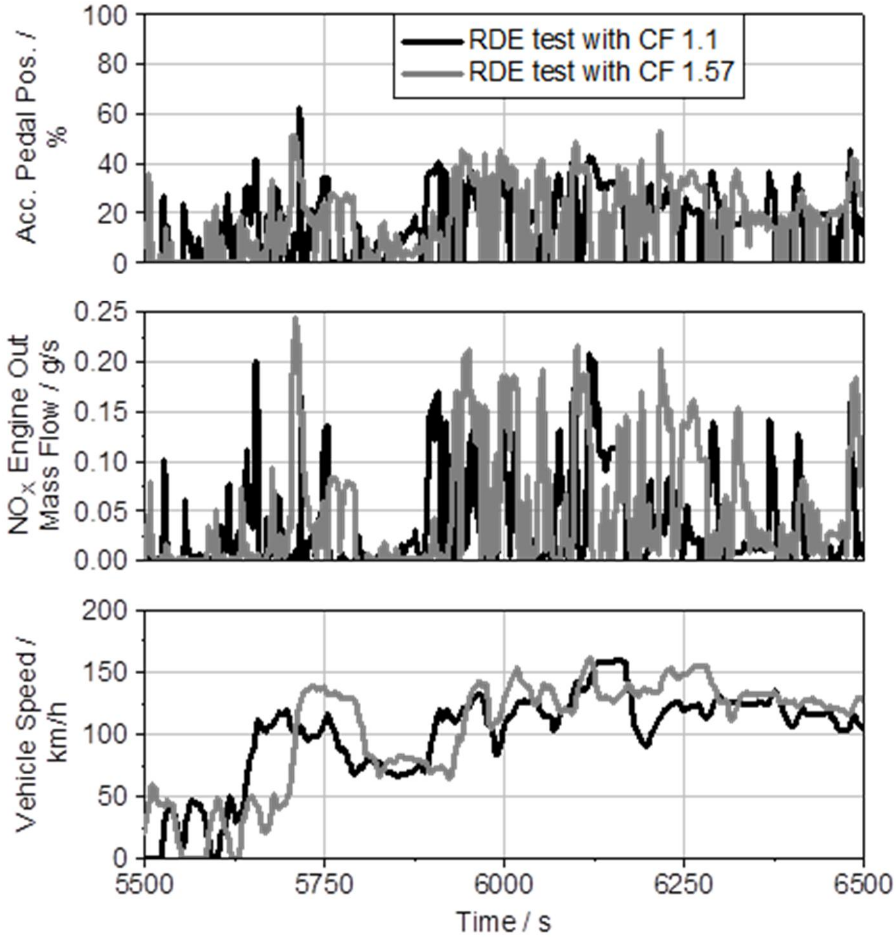

Figure 15: Detailed view of an extracted phase of both RDE tests with modified calibration

NO_X raw and tailpipe emissions are shown in Figure 16 for the three RDE tests (one with baseline calibration and the two mentioned above using the final modified calibration). The extended EGR operation leads to significantly lower NO_X emissions but the RDE NO_X level is still more than double the WLTC NO_X level. The post-processing with EMROAD results in this particular case in lower overall NO_X emissions compared to the unadjusted (only integrated) measurement value. But the differences of both RDE tests with adapted calibration are also apparent after EMROAD post-processing.

The post-processing with CLEAR results in more comparable NO_X emissions for both RDE tests with adapted calibration, but again it has to be mentioned that both tests did not meet the CLEAR requirements of a valid test.

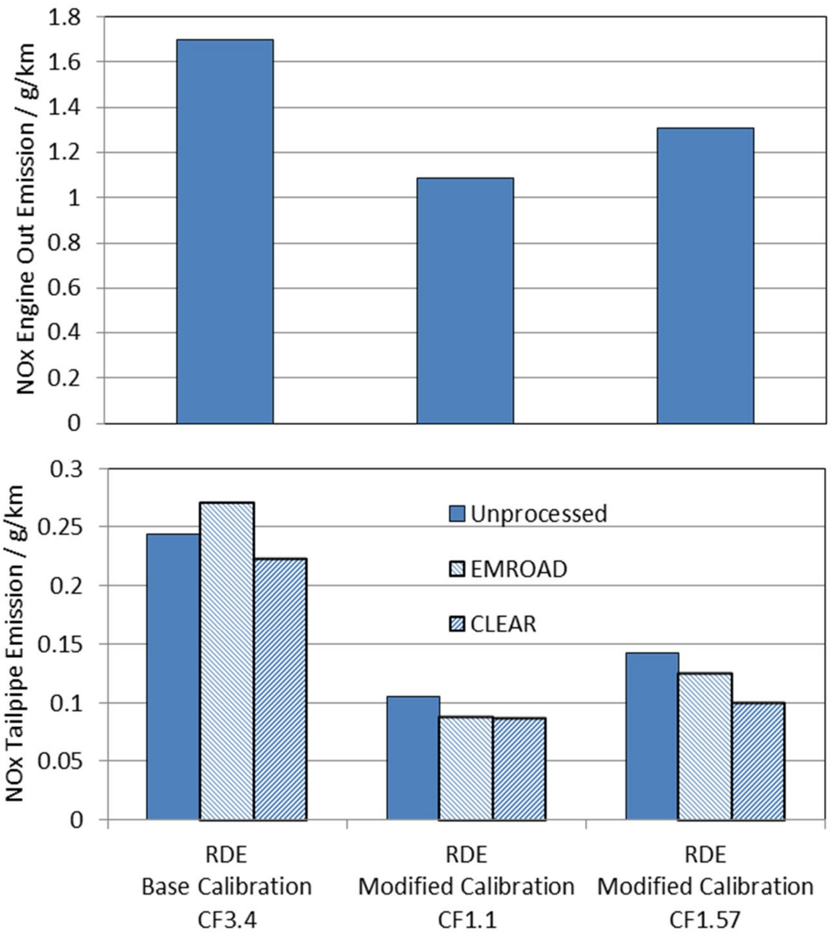

Figure 16: Comparison of the NO_X emissions in the RDE tests

Finally Figure 17 shows the impact of the different calibrations and real-world test conditions on CO_2 and AdBlue® consumption. The calibration changes had a negative impact on fuel consumption but a thorough comparison is not possible for RDE tests as ambient conditions and driving style differ between tests. For both tests with the adapted calibrations the fuel consumption is astonishingly similar in spite of the significantly different NO_X emissions. This confirms a trend which has been discussed in [8] already and which Figure 2 implies indirectly. For highly dynamic driving cycles short term high load requests cause high NO_X peaks while fuel consumption is hardly impacted. Urea consumption ranged from 2-2.5 l/1000 km due to the high engine-out NO_X emissions. For the baseline calibration, despite the lower NO_X-conversion, the AdBlue®-consumption was even higher due to the elevated NO_X raw emission level. Such values will definitely require a urea top-up by the customer as a typical tank size will not be sufficient to cover a normal service interval.

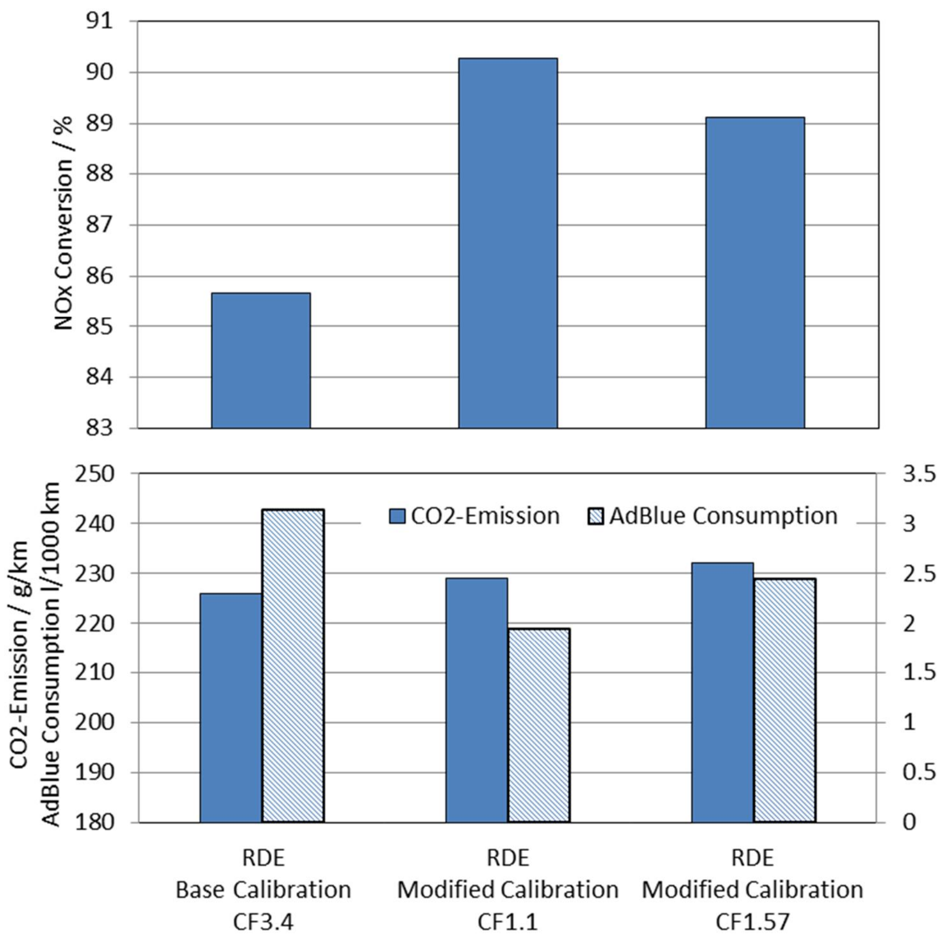

Figure 17: Comparison of CO_2-emission and AdBlue® consumption in the RDE tests

Simulations

Active SCR systems with AdBlue® dosing, as used in the vehicle presented in this study allow high NO_X conversion rates for a wide operating range. The additional components (e.g. urea injector, tank, pump) however cause significant extra costs, increase vehicle weight and require packaging space. Total cost of ownership is increased due to AdBlue® costs, and possible refills within an engine service interval might present challenges for customer acceptance.

Due to these challenges there is a need to investigate alternative $DeNO_X$ systems especially for smaller, more cost sensitive passenger car segments.

A combination of LNT and passive SDPF was investigated for a C-segment vehicle with a 1.6l Diesel engine and six-speed manual transmission with the help of integrated vehicle/powertrain/aftertreatment simulations.

As such a less complex aftertreatment system is not capable of achieving the same NO_X conversion efficiencies as an active SCR based system, an engine with cooled high pressure and low-pressure EGR was considered to reduce engine-out NO_X emissions especially for high engine loads.

The main dimensions of the simulated aftertreatment system are shown in Figure 18.

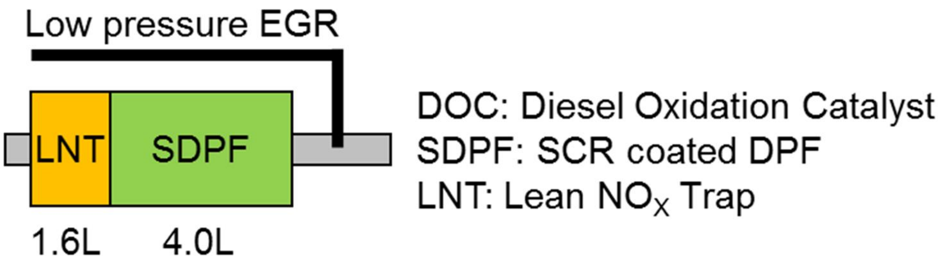

Figure 18: Main dimensions of the exhaust aftertreatment system in the simulation

The simulations were carried out with the SIMULINK® based "SimEx" software developed by FEV.

In a first step a simulation model was created for the physically tested E-segment vehicle which is discussed in the first part of this paper. The simulation model was validated with the engine speed, load and emissions traces obtained from the RDE tests. In a further step the simulation was modified to represent a C-segment vehicle, a relevant vehicle weight of 1832 kg was assumed for the RDE test simulation and the same underlying route was used.

Due to the lower vehicle weight and an optimized EGR-system the NO_X raw emissions are significantly lower at 512 mg/km (calculated with the exhaust mass flow including low-pressure EGR) compared to the tested vehicle used in the experimental part of the study. The simplified aftertreatment system without active SCR however only achieves significantly lower NO_X conversion efficiencies compared to the SDPF/SCR system with active urea dosage on the tested vehicle. The LNT has to achieve the major part of NO_X conversion and its performance is limited due to the relatively high exhaust temperatures and mass flows in the highly dynamic RDE test which limit the storage capability of the LNT. At the same time the opportunities for LNT purging/regeneration are limited as only few instances allow rich engine operation. As the rich engine operation is also required for NH_3 formation, the NO_X conversion efficiency contribution of the downstream passive SDPF is further reduced.

The $DeNO_X$ strategy which was used for the simulation runs considered various release conditions such as LNT storage level, LNT temperature and engine operating points. The fuel consumption penalty caused by the rich engine operation during LNT regeneration was in the range of 3 % compared to the same cycle with continuous lean engine operation. In the motorway part of the RDE test the temperature of the close-coupled LNT exceeds 400 °C which leads to very low NO_X storage and NH_3 formation capabilities as depicted in Figure 19.

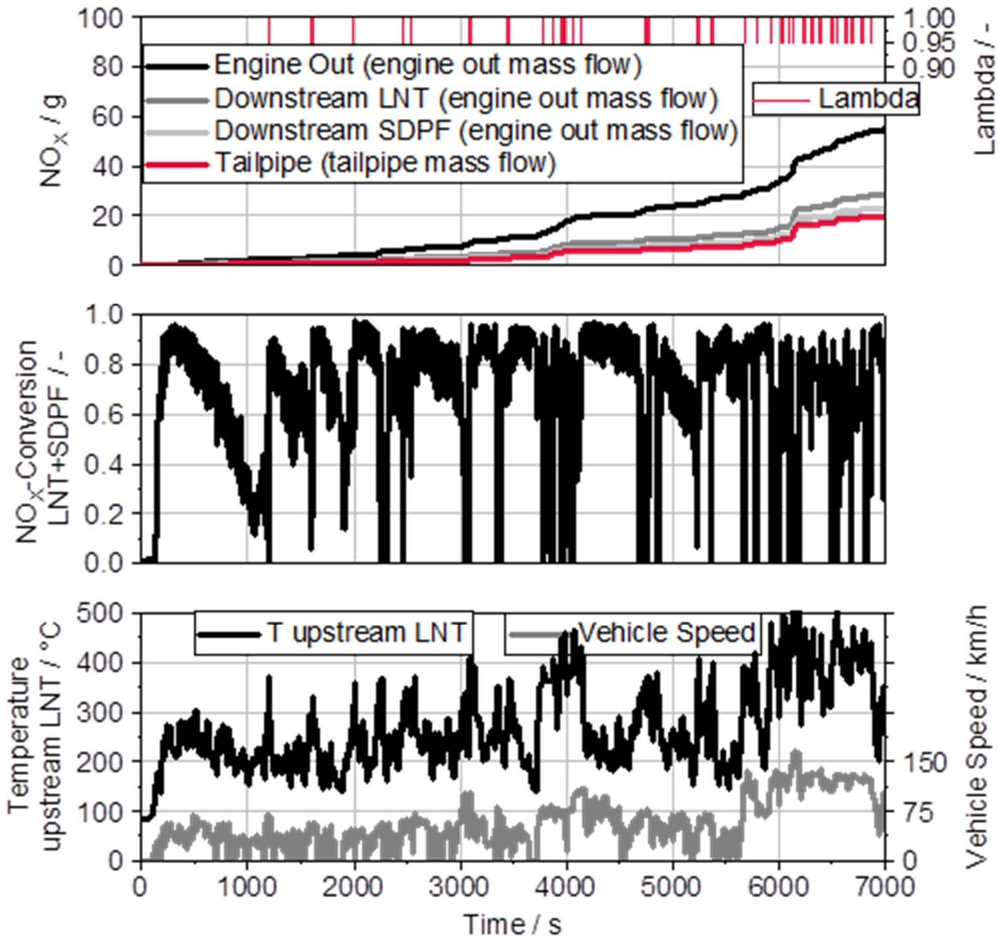

Figure 19: Simulated traces in the RDE test with LNT and passive SDPF

This results in a NO_X conversion efficiency of 58 % (considering the complete exhaust mass flow including low-pressure EGR), the passive SDPF contribution is 9 %. The corresponding NO_X conformity factor of 2.19 shows that such an LNT/passive SDPF system is only sufficient to meet RDE requirements if on the one hand catalyst technology is significantly improved towards high LNT efficiency at high temperatures and further measures to reduce engine-out NO_X emissions are taken. In addition to further optimized air path hardware with improved cooling performance also an effective NO_X control using actual engine-out NO_X as control parameter has to be considered. Such a control allows a significant reduction of transient NO_X peaks as e.g. described in [9].

Summary and Outlook

The vehicle investigations show that a vehicle representative of current Euro 6 hardware is capable of achieving very low NO_X emissions in real world driving conditions with limitations. Both the SCR and the EGR systems have to be specifically adapted. For the tested E-segment vehicle NO_X conformity factors between 1.10 and 1.56 were achieved with 1.3 to 2.7 % increase in real-driving CO_2. However the reduction of engine-out NO_X emission was limited. The extension of the EGR operating range was only possible to a certain extent as neither the boosting nor the EGR system were designed to run EGR at high engine loads. NO_X raw emissions exceeded 1000 mg/km in the RDE test, low NO_X conformity factors thus were only achievable with high SCR NO_X conversion rates of more than 90 %. Compared to current Euro 6b compliant vehicles, this results in higher AdBlue® consumption values in the range of 2-2.5 l/1000 km. Higher refill costs and the necessity of refills within a service interval are the consequence. The extended EGR operating area had a negative effect on drivability and this effect had to be balanced against emissions to achieve a satisfactory solution. Additionally an increase of the soot raw emissions has to be considered, such that shorter DPF regeneration intervals and a further increase of fuel consumption are expected.

Updated engine technologies to achieve lower engine-out emissions are therefore mandatory. Especially advanced air path technologies such as combined high pressure / low pressure EGR systems allow improved engine-out NO_X emissions for high loads and transient operation.

Such a combined EGR system was also investigated in the simulations carried out within the presented study. In the simulations a smaller vehicle with a more compact, less costly LNT+passive SDPF aftertreatment system was investigated. In spite of low engine-out NO_X emissions, a conformity factor of 2.19 was predicted, as especially high LNT temperatures during high load operation limited the NO_X conversion efficiency of the LNT+passive SDPF system. Compared to an identical vehicle with SDPF and AdBlue®-injection, the fuel consumption penalty was in the range of 3 %.

Valuable real world experiences related to the conduct and post-processing of RDE tests with PEMS were gained in the course of the presented study. Although conducted on the same public roads by the same driver different traffic conditions can cause significantly different emission results. Unexpected road conditions such as construction works can make an RDE test not meet the criteria of a valid RDE test.

Should the assumed boundary conditions for the conduction and post-processing of RDE tests be turned into definitive legal requirements, vehicle testing and homologation will be an even more challenging task than today, but the resulting improvement in emissions and their effect on ambient air quality should assist in maintaining the public acceptability of the Diesel engine.

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