EURO 7/VII EMISSION STANDARDS

FOR CARS, VANS, BUSES AND TRUCKS

Technical note – November 2021

The European emissions control industry that AECC represents issues this technical note on Euro 7/VII emission standards for cars, vans, buses and trucks. This technical note complements the AECC position paper[1] that was released on 28 June 2021. This note considers some of the content presented by the CLOVE consortium (Consortium for ultra-Low Vehicle Emissions) to the meetings of the Advisory Group on Vehicle Emission Standards (AGVES). Specific comments on light- and heavy-duty vehicles emissions are given based on the latest AECC test programme data.

AECC supports an ambitious proposal for future Euro 7/VII emission legislations for light- and heavy-duty vehicles to further decrease road traffic pollutant emissions with advanced emission control systems. The Euro 7/VII is a key element of the Smart and Sustainable Mobility package under the EU's Green Deal. It should embrace an all-inclusive strategy in a technology neutral context ensuring all powertrain technologies contribute to the EU's Green Deal long-term goals.

To undertake all possible efforts to reduce harmful effects of vehicle pollutants on the health of European citizens and to improve European air quality, a next step in the on-road vehicles' emission legislation is surely needed. It will have a positive effect well beyond the next decade as the fleet renewal takes more than 10 years. AECC provides robust scientific data about the application of state-of-the-art emission control technologies to modern ICE powertrain systems.

As reported in various studies on Euro 6/VI emission factors, improvements have been achieved with previous legislative steps. For light-duty vehicles, the introduction of on-road testing with Portable Emissions Measurement Systems (PEMS) within the Real Driving Emissions procedures (RDE), as of Euro 6dTEMP and Euro 6d, has significantly reduced vehicle emissions. The testing framework however still has limitations to the coverage of possible vehicle operation, and is not fully guaranteeing low emissions in high impact areas for urban air quality. For heavy-duty vehicles, the introduction of PEMS testing in Euro VI also reduced emissions. However, this is so far limited to the emissions from an In-Service Conformity test that mimics the type-approval test conditions. A real-world operation test, similar to the light-duty RDE procedure is still to be introduced. Furthermore, several pollutants that are of concern today were not included in the past. Consequently, areas for further improvements do remain for both light- and heavy-duty vehicles.

AECC welcomes the CLOVE scenarios presented to AGVES until the meeting of 27 April 2021 include to some extent the three overarching principles suggested by AECC: further focus on real-world emissions, be fuel- and technology-neutral, and legislate according to a total system approach using a whole vehicle basis. This will enable to significantly further reduce emissions, including cold-start, compared to the current Euro 6d and VI-D vehicles.

AECC furthermore appreciates the overall technical assessment presented by the CLOVE consortium. But for PN, it is challenging to achieve the expected Euro 7/VII emission reduction performance, because extra changes with a similar effect as a reduction in the limit value (e.g. PN23 to PN10) require a higher improvement factor compared to gaseous emissions. For gaseous emissions, technology modifications may need to be required to overcome interdependencies of emission components, e.g. NOx and N_2O.

AECC remains committed to contribute to the discussion and development of ambitious Euro 7/VII real-world emissions standards and will keep this technical note up to date according to available data. Basic information about emissions control technologies to meet current and future European vehicle emissions legislation is furthermore available on the AECC website[2-3].

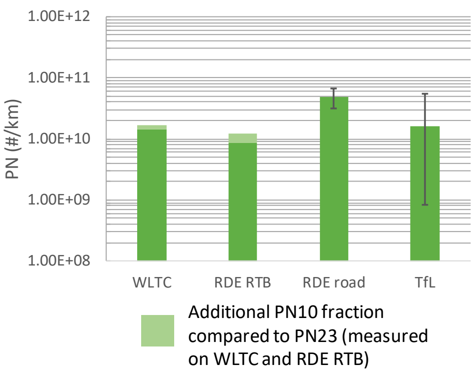
Light-duty vehicles

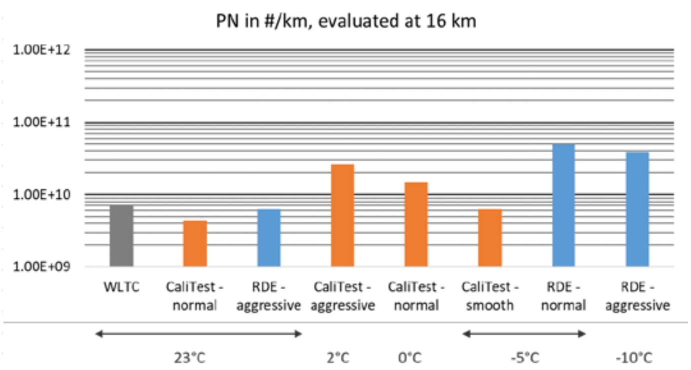
Data from two AECC light-duty test programmes on diesel and gasoline are analysed. Both programmes investigated ultra-low pollutant emissions over a wide range of driving conditions with a state-of-the-art emission control system. In the diesel programme[4], the original emission control system of a Euro 6b C-segment base vehicle with 1.5 litre engine and 48V mild-hybridisation was replaced by a combination of Lean NOx Trap (LNT) and dual Selective Catalytic Reduction (SCR). The gasoline programme[5] started from a Euro 6d C-segment base vehicle with 1.5 litre engine and 48V mild-hybridisation. The original emission control system was replaced by a system consisting of a close-coupled Three-Way Catalyst (TWC) in combination with an underfloor catalysed Gasoline Particulate Filter (cGPF), second TWC and Ammonia Slip Catalyst (ASC).

All results are reported as measured under the specified test routes and conditions. A combination of tests on the road and in the lab are performed to characterise the emissions performance. A variation of ambient temperature and driving dynamics is covered. More details about the test conditions are available in the different references listed.

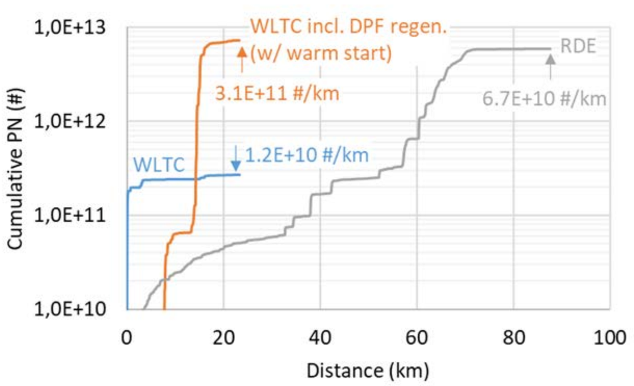
Particulate emissions

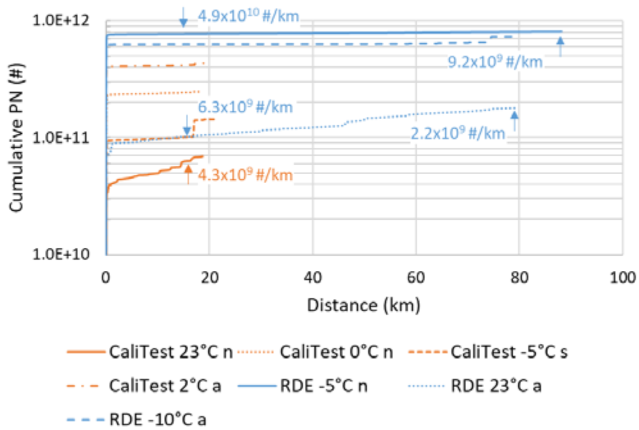
Aged parts were used in these programmes which supports the filtration due to accumulation of soot and ash. The PN data of the diesel (left, PN23 measured except for those tests were additional PN10 fraction is indicated) and gasoline (right, PN10 measured) vehicle vary between 10^9 and 10^{10} #/km.



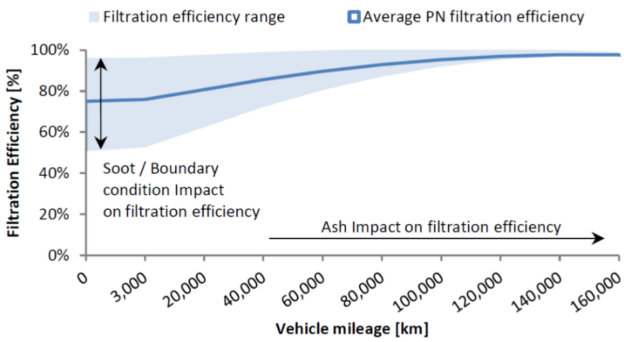


The overall PN report value is determined by emissions caused by single events, see the graphs of the cumulative emissions below. In case of the diesel vehicle (left), there was either an initial cold-start peak or emissions from periodic regeneration (1 active during WLTC and passive during motorway driving). In case of the gasoline vehicle (right), PN emissions are dominated by the initial cold-start peak. The absolute cold-start emissions varied between 6.8×10^{10} particles and 7.7×10^{11} particles. Near-zero PN emissions are observed during the rest of the test.





The variation in #/km over 2 orders of magnitude is impacted by a combination of effects, incl. ambient temperature, driving conditions, engine-out emissions and initial filter status. All diesel and gasoline tests were conducted with some amount of soot in the vehicle from on-road driving. No specific preconditioning was conducted to control the filter status in between tests. The order in which tests are conducted influences the results as well[6].



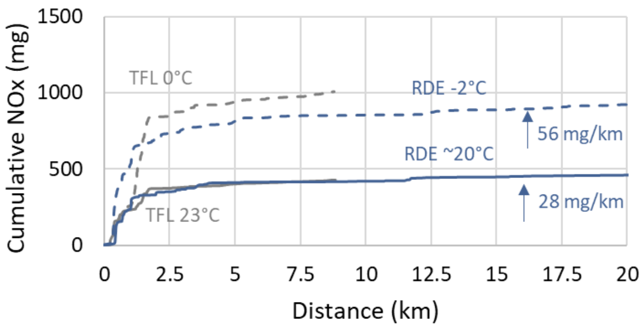
The CLOVE scenarios request a significantly higher improvement factor for PN compared to gaseous pollutants because extra changes with a similar effect as a reduction in the limit value (e.g. PN23 to PN10) require a higher improvement factor compared to gaseous emissions. Filter efficiency improves over the lifetime with ash layer build-up. Most data available is for a status of the filter after initial ash layer build-up. This is also the case for the AECC data analysed above. The CLOVE scenarios consider an initial degreening mileage of 3000 km for the definition of normal conditions. No degreening is considered for the extended conditions. This requires design modifications for the initial period of vehicle lifetime (1.25% for the 240k km durability requirement considered in the CLOVE scenarios), but with possible impact on emissions during the whole vehicle lifetime. Membrane/coating technologies are investigated, but were not at TRL level for inclusion in AECC test programmes.

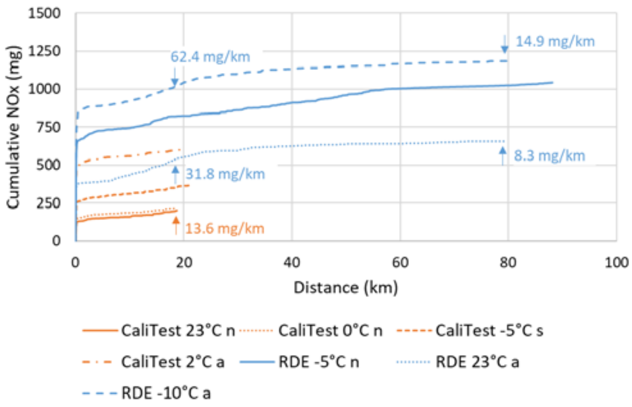
It will be investigated what the effect of a fresh GPF is on the PN data of the LD gasoline vehicle.

Gaseous emissions

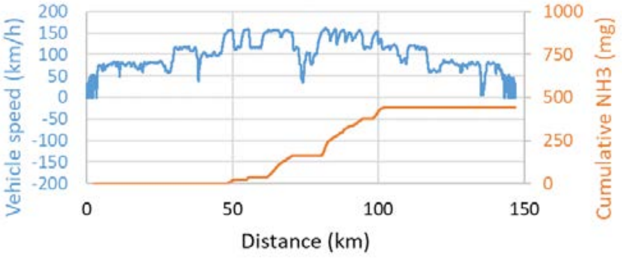
CLOVE elaborated its assessment for gaseous pollutants, NOx in particular, relying on e.g. active thermal management and proper system volumes to derive expected Euro 7 performances. The results presented here are with engine internal thermal management measures and some support from the 48V mild-hybrid system. Additional active thermal management measures are possible to further reduce initial cold-start emissions observed. This will be investigated for the gasoline vehicle through the implementation of an electrically heated catalyst.

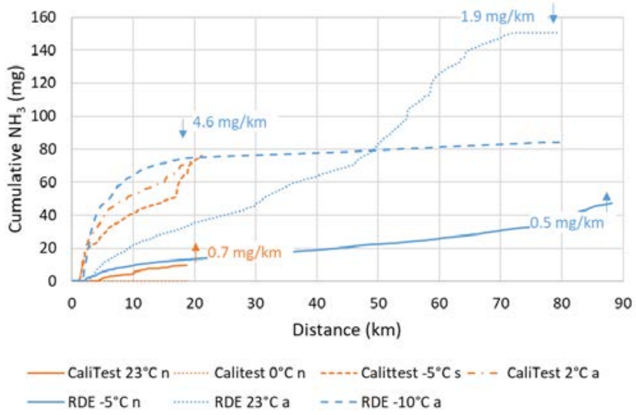
The NOx emissions of both the diesel (left) and gasoline (right) vehicle are dominated by the initial cold-start emissions. Near-zero emissions are measured for the rest of the test, independently from the ambient temperature or driving condition. The absolute initial cold-start emissions varied between 500 mg (at 23°C) and 1000 mg (at 0°C) for the diesel vehicle and 250-500 mg (at 23°C depending on driving style) and 1000 mg (at -10°C) for the gasoline vehicle. The report value in mg/km depends on the averaging distance, due to the initial cold-start impact. When evaluated over the current Euro 6 RDE minimum urban driving distance of 16 km, this corresponds with a variation between 28 mg/km to 56 mg/km for the diesel vehicle and 13.6 to 62.4 mg/km for the gasoline vehicle.



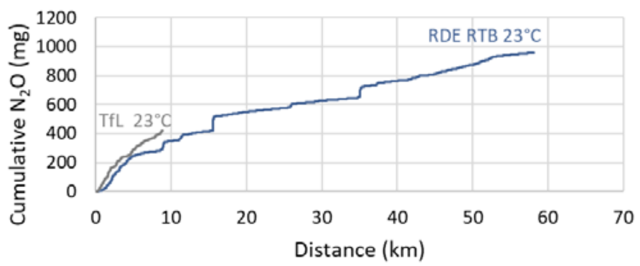


NH_3 emissions are well controlled for both vehicles. The most challenging condition tested for the diesel vehicle (left) is the control of NH_3 emissions under dynamic motorway driving conditions as there is no initial cold-start. A maximum of 500 mg was observed over a distance of 50 km, which corresponds to 10 mg/km. For the gasoline vehicle, the ASC is able to cover the very initial cold-start emissions within the first 2 kilometers. Absolute cold-start emissions within the current Euro 6 RDE minimum urban driving distance of 16 km vary between 10 and 80 mg.

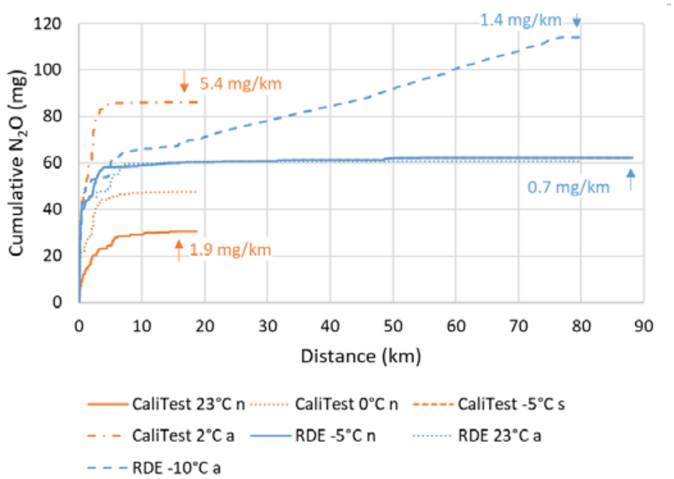




Absolute N_2O emissions from the diesel vehicle, shown here at the right, are up to 524 mg within the current Euro 6 RDE minimum urban driving distance of 16 km. Over the entire RDE test 17 mg/km are measured. It is a challenge to significantly reduce NOx while keeping low N_2O, technology modifications may need to be required to overcome interdependencies of emission components.



The gasoline vehicle shows N_2O emissions between 0.7 mg/km and 5.4 mg/km for the range of tests and evaluation distances. The emissions are dominated by an initial cold-start peak up to 86 mg, except in the test at -10°C with aggressive driving, where emissions continue during the rest of the test.



The CLOVE scenario mentions a possible classification of the maximum power developed for the first 2 kilometres as a boundary condition for the normal conditions. Further details of this approach are not yet known and might have a significant impact on required thermal management.

Heavy-duty vehicles

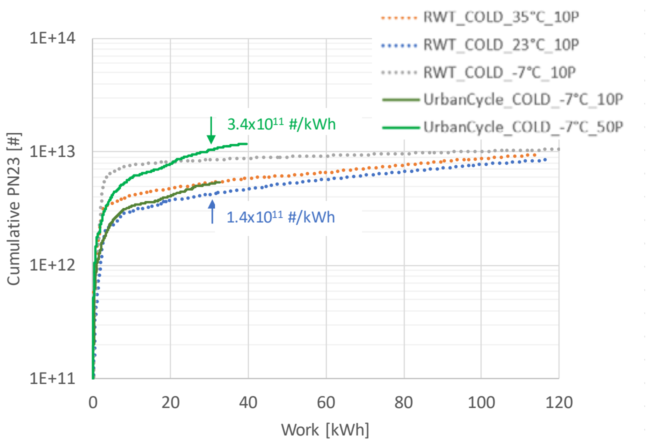
AECC welcomes the introduction of a framework that covers the wide range of missions that these vehicles conduct within the European Union. There is currently no real driving emissions framework for heavy-duty vehicles. This is required to guarantee low emissions in high impact areas for urban air quality. Normal as well as extended driving conditions shall be clearly specified within this framework. The duration of the trip will have a significant impact on the declared emissions.

The AECC heavy-duty demonstrator vehicle[7-8] is an N3 4x2 tractor equipped with a 12.8l engine with high pressure EGR and homologated to Euro VI-C. The rated power of the engine is 450hp. In this vehicle, the original emission control system was replaced by a system including close coupled DOC and SCR in addition to an underfloor DOC, catalysed DPF and a second SCR, both SCRs are equipped with ammonia slip catalysts.

More details of the conditions tested is available in the references listed. Vehicle testing was conducted on the road and in the lab to study the impact of external factors like payload, traffic or driving routes (including stop and go operation). Also the impact of the initial status of the emission control system has been investigated, including the initial ammonia storage in the SCR catalyst as well as a regenerated filter. Unless reported otherwise, the results shown are following a procedure to obtain a severe initial status of the emission control system without ammonia storage in the SCR and an empty filter. All results are reported as measured under the specified test routes and conditions.

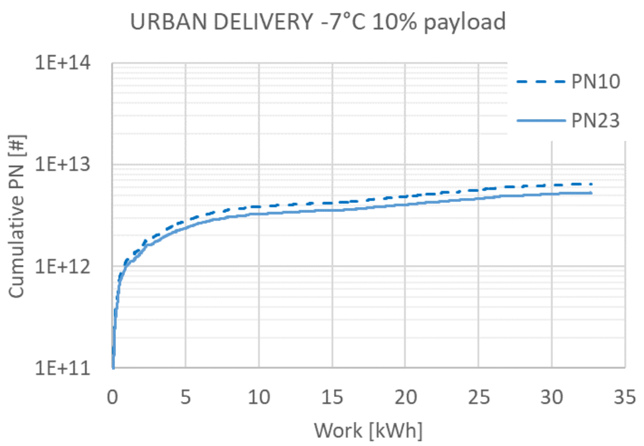
Particulate emissions

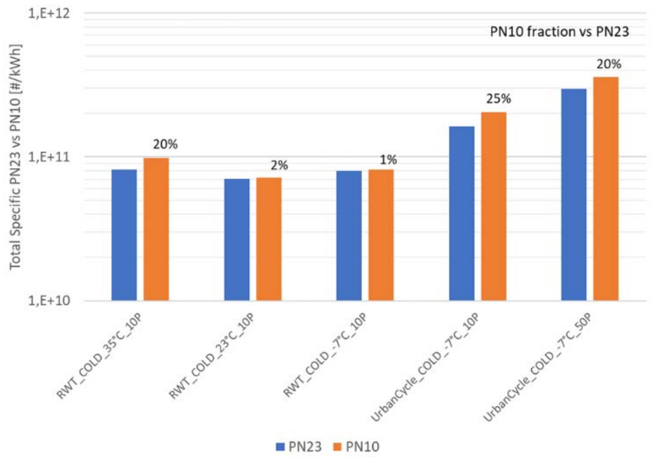
The PN23 and PN10 data obtained from the chassis dyno test campaign show the bulk of the PN emissions are produced during the beginning of the trip, and particularly during the initial cold-start phase. This can be attributed to the state of the filter at the beginning of the tests. Test PN23 results shown at the right have been conducted with passively regenerated filters under a broad range of driving conditions. There was no possibility to exactly determine the initial status of the soot cake in the filter.



The arrows indicate the specific emissions at 1x WHTC reference work for this application (29.7 kWh). The tests included represent two trip profiles, a real-world test (RWT) and an urban delivery trip. The RWT contains shares of urban, rural and motorway operation. The urban delivery has a maximum speed of 50 km/h and includes idling stops varying from 1-3 minutes duration.

Analysis of the PN10 fraction of an urban delivery test conducted with a passively regenerated filter shows there is no significant impact from PN23 to PN10 during cold-start, but it adds ~20% to total PN emissions on an urban delivery trip. The PN10 fraction varies between the different tests, as presented in the figure below, but in-line with available literature[9].





More PN data should be evaluated to judge emissions for combination of boundary conditions, including measurements of PN10. PN-slip during high-load operation in combination with pre-soot loading was for example not assessed.

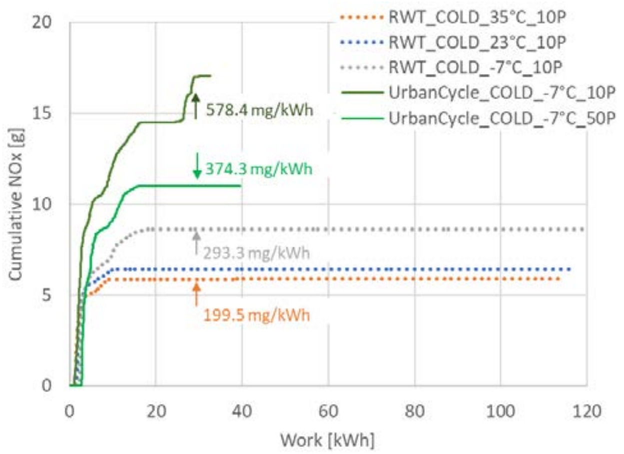
Gaseous emissions

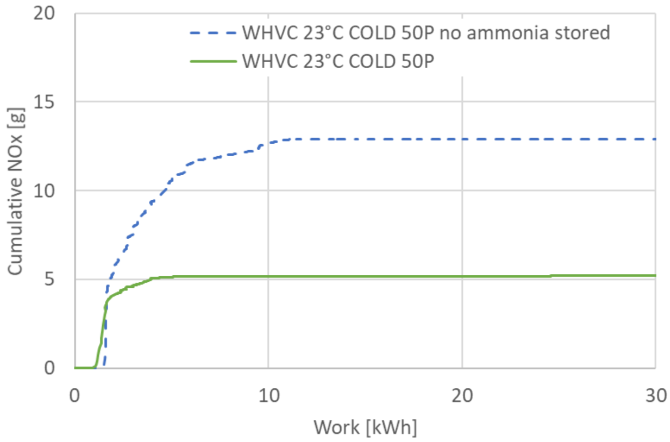
Ultra-low NOx emissions are observed under most driving conditions. However, from the results obtained during the chassis dyno testing, specific impact from trip profile, temperature, payload and empty urea stored in the SCR have been studied.

As can be seen on the figure on the left below, cold start emissions are influenced by the ambient temperature. An increase of ~30% can be observed for this specific vehicle when tested under cold ambient conditions down to -7 °C.

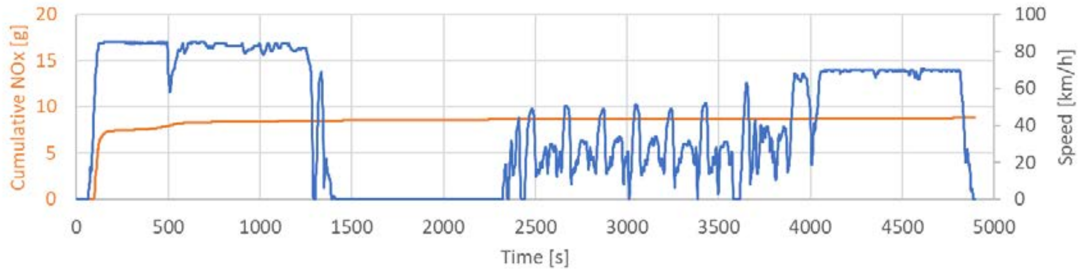
The effect of the trip profile between a RWT trip and an urban delivery trip tested under similar payload conditions shows an increase in the cumulated NOx emissions with a factor of ~2. The payload can also have an impact if the vehicle is nearly empty and driven in cold ambient conditions. The urban delivery trip driven at -7°C with 10% has an increase in total NOx emissions by ~30% compared to the test ran at 50% payload.

On the figure on the right, the effect of the initial ammonia storage in the system is illustrated. The status of the system before the test has a significant impact on the initial cold-start emissions. This is the case for all tests, and confirmed both on the road and on the chassis dyno. The range of urban NOx emissions including the initial cold-start is 42 - 209 mg/kWh with normal SCR loading and 168 – 522 mg/kWh with the severe situation of an empty SCR.

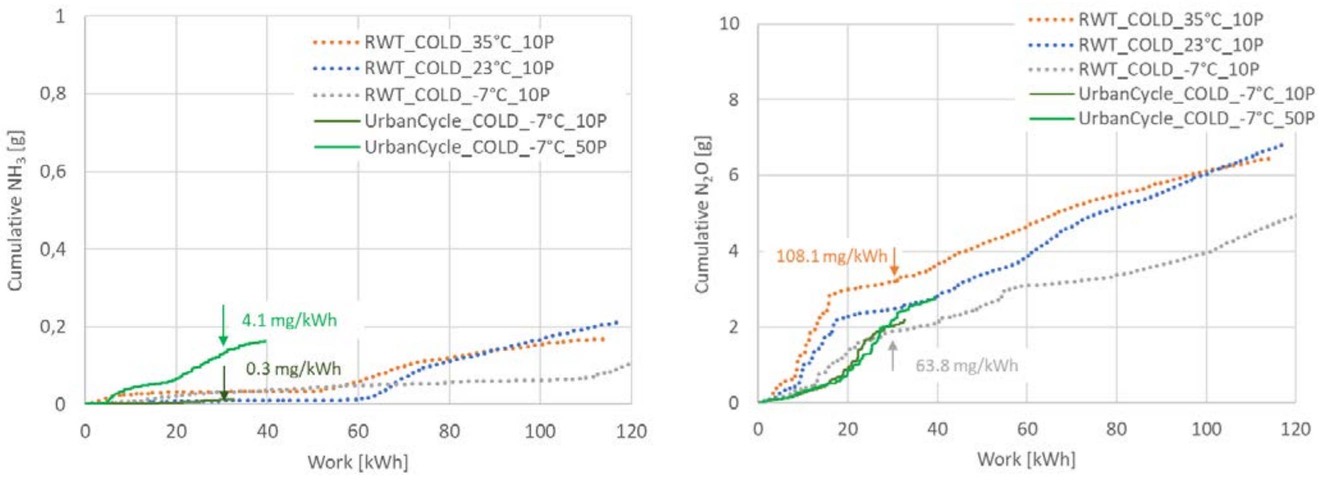




It is important to emphasize that the results show that most of the NOx emissions are produced during the initial cold-start of the trip. Once the system is warm, near-zero emissions are produced even during urban operation. An example is shown below. The graph shows an alternative route which begins when the vehicle is started from cold after spending the night in a service station in the middle of the motorway. After the initial cold-start NOx peak, the emission control system heats up and stays warm even after 15 min of idle operation before entering the urban environment (average power vs maximum power: from 0-2350 s = 10%, from 1430-4898 s = 8%, from 1430-3640 s = 5%). The overall work produced during this trip was 50kWh. The urban and rural operation following the idle shows hardly any NOx emissions are produced. This results in a value of 13.7 mg/kWh over the idle and urban operation (from 1430-3640 s).



Other gaseous emissions, namely ammonia (NH_3) and nitrous oxide (N_2O) measured from the system are shown below. During the tests conducted, the ammonia results have shown a robust slip control from the emissions control system. The results of the chassis dyno tests can be seen on the figure on the left below. N_2O emissions can be generated as a by-product of the chemical reactions within the SCR. It is also produced via unselective oxidation of unreacted NH_3 within the ASCs. As such, each of these mechanisms needs to be optimized to achieve the lowest tailpipe N_2O values. As it can be seen from the right figure below, N_2O emissions are produced throughout the trips.



Summary and outlook

AECC supports an ambitious proposal for future Euro 7/VII emission legislation to further decrease road traffic pollutant emissions with advanced emission control systems. Euro 7/VII should embrace an all-inclusive strategy in a technology neutral context ensuring all powertrain technologies contribute to the EU's Green Deal long-term goals. A swift adoption of Euro 7/VII is welcomed to enable the innovation in emission control technologies.

AECC welcomes the CLOVE scenarios presented to AGVES until the meeting of 27 April 2021 include to some extent the three overarching principles suggested by AECC: further focus on real-world emissions, be fuel- and technology-neutral, legislate according to a total system approach using a whole vehicle basis. This will enable to significantly further reduce emissions, including cold-start, compared to the current Euro 6d and VI-D vehicles.

AECC appreciates the overall technical assessment presented by the CLOVE consortium. But for PN, it is challenging to achieve the expected Euro 7/VII emission reduction performance, because extra changes with a similar effect as a reduction in the limit value (e.g. PN23 to PN10) require a higher improvement factor compared to gaseous emissions. For gaseous emissions, technology modifications may need to be required to overcome interdependencies of emission components, e.g. NOx and N_2O.

This note provided an overview of data from light-duty diesel and gasoline as well as heavy-duty diesel test programmes. A combination of tests on the road and in the lab are performed to characterise the emissions performance. A variation of ambient temperature, driving routes and driving dynamics is covered. All results are reported as measured under the specified test routes and conditions.

AECC remains committed to contribute to the discussion and development of ambitious Euro 7/VII real-world emissions standards and will keep this technical note up to date according to available data. Testing on the LD gasoline and HD diesel continues to look into further reduction of the initial cold-start emissions with active thermal management. On both vehicles an electrically heated catalyst will be implemented. On the LD gasoline vehicle, PN levels will be evaluated for a fresh filter. The work will also validate the pollutant emissions when operating the vehicles on sustainable renewable fuels to reduce CO_2 emissions.

References

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AECC is an international non-profit scientific association of European companies operating worldwide in the research, development, testing and manufacture of key technologies for emissions control. Their products are the ceramic substrates for catalysts and filters; catalysts (substrates with catalytic materials incorporated or coated); adsorbers; filter-based technologies to control engine particulate emissions; and speciality materials incorporated into the catalyst or filter. Members' technology is integrated in the exhaust emissions control systems of cars, commercial vehicles, buses, non-road mobile machinery and motorcycles in Europe. More information on AECC can be found at www.aecc.eu and www.dieselinformation.aecc.eu.

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