

Ultra-Low NO_x Emissions with Close-Coupled Emission Control System on a Heavy-duty Truck Application

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Summary

Heavy-duty vehicles represent a significant portion of road transport and they need to operate in a clean and efficient manner. Further improvement of their emission control systems to achieve high conversion efficiency under wide operating conditions is needed.

The European Commission is developing legislative proposals for Euro 7 and VII emissions regulations for light- and heavy-duty vehicles. The new Euro VII regulation will likely focus on ensuring that the emissions from heavy-duty vehicles are minimized over extensive on-road operating conditions and in particular for urban driving and cold-start operation. These challenges are increased by the need to ensure low emissions of NH_3 and N_2O as well as low impact on CO_2 emissions.

This paper outlines the low pollutant emissions achieved by a heavy-duty diesel demonstrator vehicle. The vehicle is equipped with an innovative layout of state-of-the-art emission control technologies, combined with an advanced engine strategy on an existing Euro VI long-haul truck. The new emissions control system integrates a close-coupled DOC, a catalyzed DPF, dual-SCR system -one in a close-coupled position-, with twin AdBlue® dosing controlled by FEV developed software. Both SCR catalysts contain an ammonia slip catalyst.

The results show the innovative system layout allows ultra-low NO_x emissions and well controlled emissions of NH_3 and N_2O in very challenging conditions with low impact on CO_2 emissions. Pollutant emissions were evaluated over a broad range of operating conditions, including different payloads to show the emissions reduction potential.

1 Introduction

Heavy-duty vehicles represent the backbone of European economy in transportation. Millions of euros on tons of goods are moved across European highways using commercial vehicles, and most of these deliver also within the cities and towns. It is therefore essential for these vehicles to be clean and efficient. The Euro VI emission standards [1] for heavy-duty vehicles entered into force in January 2013. The type approval process for the engines of these vehicles includes two sets of emissions cycles: stationary engine operation using the World Harmonized Stationary Cycle (WHSC) and transient testing using the World Harmonized Transient Cycle (WHTC). Both cycles are conducted on an engine test bench and performed in a laboratory. The introduction of a Portable Emission Measurement System (PEMS) demonstration test at type approval, combined with on-road in-service conformity testing allows for comprehensive analysis of the emission performance of these vehicles while driving on public roads. The recent introduction of Euro VI step E [2], applicable for new vehicles registered from the beginning of 2021, ensures that for the first time, the cold-start emissions are included in the emissions analysis during on-road testing. In addition, a limit has been introduced for the solid particulate number (PN) measured with PEMS.

The Euro VI regulation applies the moving average window (MAW) data post processing as a method to compare the on-road emissions to the test bench type approval

WHTC test. When the emissions are calculated through this MAW method, the final result is confronted with the emission limits. The allowed variation is called “Conformity Factor (CF)” and it accounts for any variation linked to the measurement procedure or instrumentation uncertainty as well as the variation between different tests on-road.

The on-road tests prescribed by the regulation today have very strict requirements and as such do not fully cover all driving conditions trucks encounter frequently on the road. This includes heavy and static traffic or the transition from highway to urban operation. During these conditions, the exhaust emission control system will potentially cool down and lose conversion efficiency. This has been studied recently [3-6].

Euro VI vehicles have achieved a progression to lower emissions at urban operation. Latest research confirms an improvement can be seen from Euro VI A to D [7]. The Euro VI regulatory evolution has focused on increased representation of urban vehicle operation. Naturally, this has increased the need for technology innovation with improved emissions control at these conditions.

To develop legislation to achieve lower pollutant emissions in real-world driving conditions, the European Commission began the process of reviewing the emissions standards for cars, vans, trucks, and buses in 2019. The objective expressed by the European Commission is to ensure clean vehicles throughout their expected lifetime measured in real-world driving. The expected introduction of Euro 7/VII standards is intended to further reduce emissions significantly from heavy-duty vehicles with internal combustion engines to improve air quality on the roads and especially in cities.

A project was set up to investigate improvement potential in emission control over the full operational window of a truck. A combination of a newly designed emission control technology system layout and a NO_x emissions control system were implemented on a N3 heavy-duty vehicle. The objective was to achieve ultra-low levels of emissions over a wide range of driving conditions. An initial simulation study was conducted to determine the optimal emissions control technology sizing and layout to achieve lowest possible pollutant emissions. The system was calibrated for enhanced NO_x conversion finding an optimized AdBlue® dosing profile to achieve lowest emissions of NH₃ and N₂O. This paper analyses the results of a dedicated chassis dyno test, which complements on-road testing conducted with the vehicle before. This campaign was conducted at the Joint Research Centre of the European Commission in Ispra.

2 Project setup

2.1 Vehicle and powertrain characteristics

The heavy-duty vehicle used in the project is an N3 Daimler Actros 1845 LS 4x2 tractor equipped with a 12.8 l engine with high pressure EGR and homologated to Euro VI-C. The rated power of the engine is 335 kW at 1600 rpm and the type approval reference work [1] in the WHTC is 29.4 kWh.

2.2 Emission control system layout design

A simulation study was conducted using FEV's SimEx software. This study evaluated the impact of different layout combinations, catalyst volumes and materials based on project engineering targets. The simulation covered a variation of payload (50 % and 100 %) over established emissions cycles like the World Harmonised Vehicle cycle (WHVC) and In-Service Conformity route as well as urban and rural delivery routes. The engine behavior was simulated using FEV benchmark engine and emissions maps. Both normal operation mode and "heating" mode were used to assess the potential impact of heating modes on both CO₂ and NO_x raw engine and tailpipe emissions. The combined heating and low NO_x strategy were simulated at cold-start and the heat mode was left active until a desired gas temperature within the upstream SCR was reached. The AdBlue® dosing for the SCR system was predicted using base dosing control algorithms, and the pipework was modelled to determine heat loss between components.

The main conclusions from the simulation study were that the integration of the close-coupled components significantly improve the NO_x reduction efficiency in all investigated cycles and routes, especially within the cold-start and long idling phases.

2.3 Emission control technology system implemented

The design considered the OEM original system layout and packaging of the truck. Implementing the close coupled components within current packaging space available in the truck was challenging. Most of the components of the new emission control system were installed within a box equivalent to that of the baseline configuration.

As shown in Figure 1, a close-coupled Diesel Oxidation Catalyst (ccDOC) was fitted directly behind the turbine for fast CO and HC control and to allow optimal heat transfer into the emissions control system. The outlet cone of the DOC was modified to integrate an urea injector, allowing the use of the downpipe and compensator for optimal mixing of the injected AdBlue® before entering the close-coupled Selective Catalytic Reduction (ccSCR) catalyst. The ccSCR has a zone coated Ammonia Slip Catalyst (ASC) to ensure minimized secondary emissions creation. This close-coupled system was integrated with the purpose of improving the cold-start, low temperature and city driving emission performance.

Downstream of the close-coupled SCR system, the system layout resembles that of a conventional truck emission control system design, containing a DOC and catalysed Diesel Particulate Filter (DPF) with integrated Hydrocarbon (HC) doser for DPF regeneration support. Downstream of the DPF is a second urea injector and mixing pipe before the second SCR with an integrated ASC to minimize ammonia slip.

A novel twin dosing system was implemented to the demonstrator truck and controlled using FEV's in house developed twin dosing control software. The software controls both injection systems individually and coordinates the AdBlue® dosing. The system determines if the front or rear system should be used to optimize conversion efficiency. As an example, it determines, based on the colder temperatures of cold-start operation

that the conversion should be dominated by the first system. Further details on the system can be found in [8].

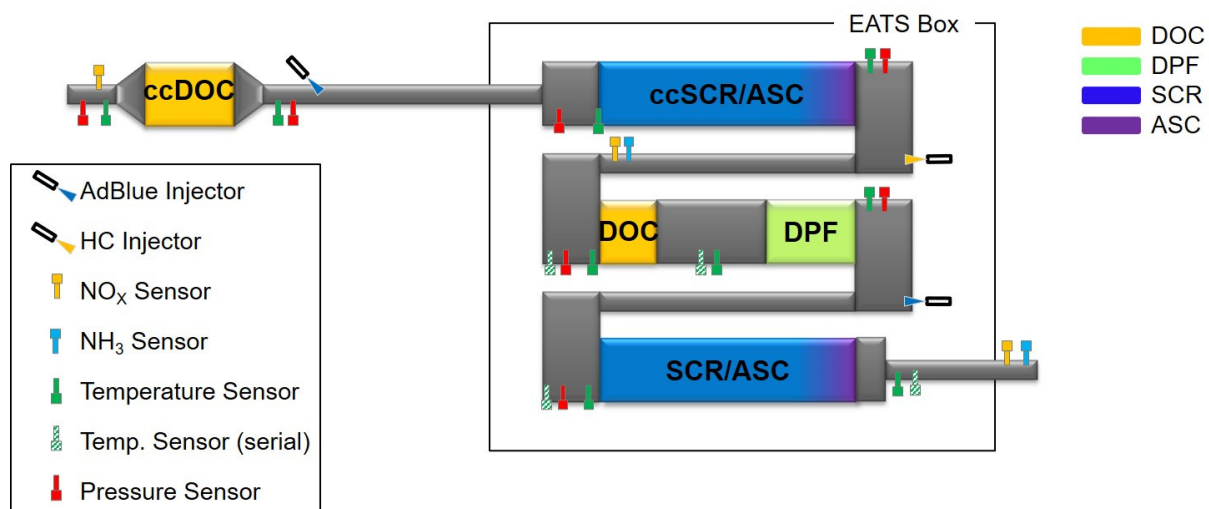


Fig. 1 Layout and instrumentation plan of the emission control system.

3 Chassis dynamometer experiments

To assess tailpipe emissions from the demonstrator vehicle, a chassis dynamometer measurement campaign was conducted at the European Commission Joint Research Centre (JRC) located in Ispra, Italy. The testing was conducted in the Vehicle Emission Laboratories (VELA).

The VELA 7 is the dedicated heavy-duty chassis dyno facility in the JRC. It is composed of a chassis dynamometer, a Constant Volume Sampler (CVS) with four critical flow venturi, and gas analyzer benches (AMA i60 for both the raw exhaust and the dilution tunnel and bags) [10].

N₂O and CH₄ measurement were carried out using Fourier-transform Infrared spectroscopy (FTIR) technique. For this scope, an FTIR instrument was connected to the raw exhaust at the vehicle tailpipe, using a heated sampling line (191 °C). The FTIR spectrometer was equipped with a multipath gas cell with 2 m of optical path, a downstream sampling pump and had the acquisition frequency of 1 Hz. Results obtained with the instrument were found in good agreement with the VELA results obtained following regulated measurement procedures.

For particulates, the laboratory is equipped with an AVL Particle Counter. This is a measurement device for counting particle numbers, which complies with the UNECE Regulations Nos 83 and 49 specifications. Exhaust gas is sampled from a CVS tunnel and diluted with HEPA filtered compressed air using the AVL Primary Diluter. Inside the evaporation tube the diluted exhaust gas is heated to a degree that causes the volatile emission components to vaporize, leaving behind nothing other than solid particles. After this, the exhaust gas is diluted once again using a porous tube diluter and fed into the Particle Number Counter (PNC).

In the PNC, butanol is condensed onto the particles inside the exhaust gas to enlarge them so that they become visually detectable by the optics of the device. The enlarged particles are then counted based on the scattered light pulses generated when the particles pass through the laser beam. This makes it possible to determine the number of particles per volume unit [11]. The vehicle and part of the instrumentation in the laboratory can be seen at Figure 2 below.



Fig. 2 Heavy-duty vehicle in the VELA 7 chassis dyno.

4 Driving conditions

The trips speed profiles ran on the dyno were chosen with the intention to cover a broad range of driving conditions and to complement previous on-road testing. The urban delivery as well as the real-world speed profiles correspond to on-road tests presented in previously reported results from this project [8, 9]. The ambient temperatures in which the chassis dyno tests have been conducted vary from -7°C to 35°C . The truck was loaded with 10 % and 50 % payload and 4 driving profiles were used during the campaign: World Harmonized Vehicle Cycle (WHVC), an urban delivery route as well as a Real-World Test (RWT), finally a steep route. The trips studied in this paper are the urban delivery as well as the real-world tests.

The urban delivery, and real-world tests speed/slope profiles are meant to replicate typical missions of the vehicle. Two of the routes are represented in Figure 3 below as an example of the broad driving conditions tested.

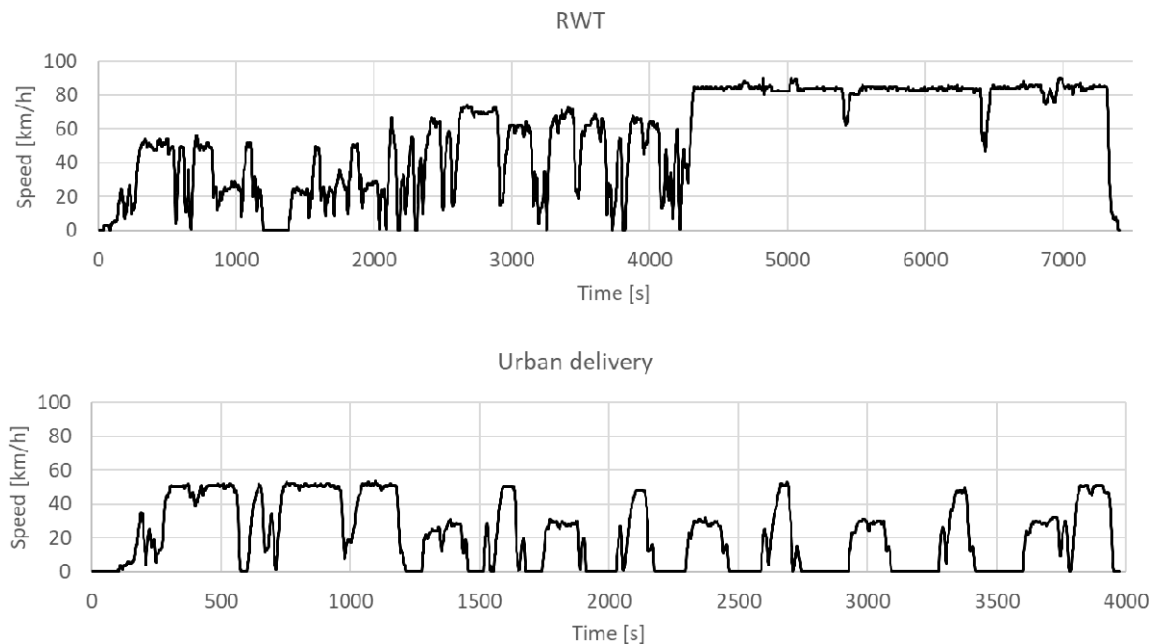


Fig. 3 Real-World Test (RWT) and urban delivery speed profiles.

The routes ensure a broad coverage of the engine operating map, this can be seen in Figure 4. The real-world test ensures a complete operation of the engine torque, including full load operation. The urban delivery route covers lower load operation compared to the real driving as it contains continuous 1, 2- and 3-minute stops where vehicle is kept idling.

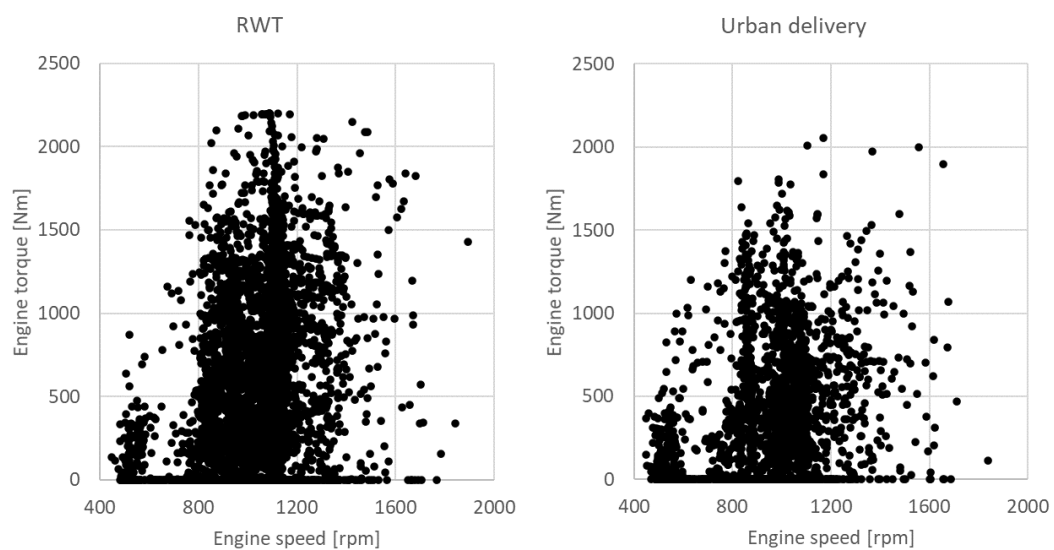


Fig. 4 Engine torque covered by different driving routes.

During the campaign, several tests were conducted with the vehicle preconditioned. Such preconditioning included running the vehicle at constant speed with high engine load to prepare the vehicle for the next day of testing, the details of the preconditioning are shown in Figure 5. This protocol was implemented to investigate severest condition for the emission control system. The preconditioning depletes both SCR's ammonia storage as well as passively regenerates the diesel particulate filter. Consequently, testing under cold ambient conditions would show the challenge for the system to perform efficiently in a short time after engine start. Furthermore, the preconditioning allows to test the vehicle in comparable starting conditions, and this is important to compare the test results.

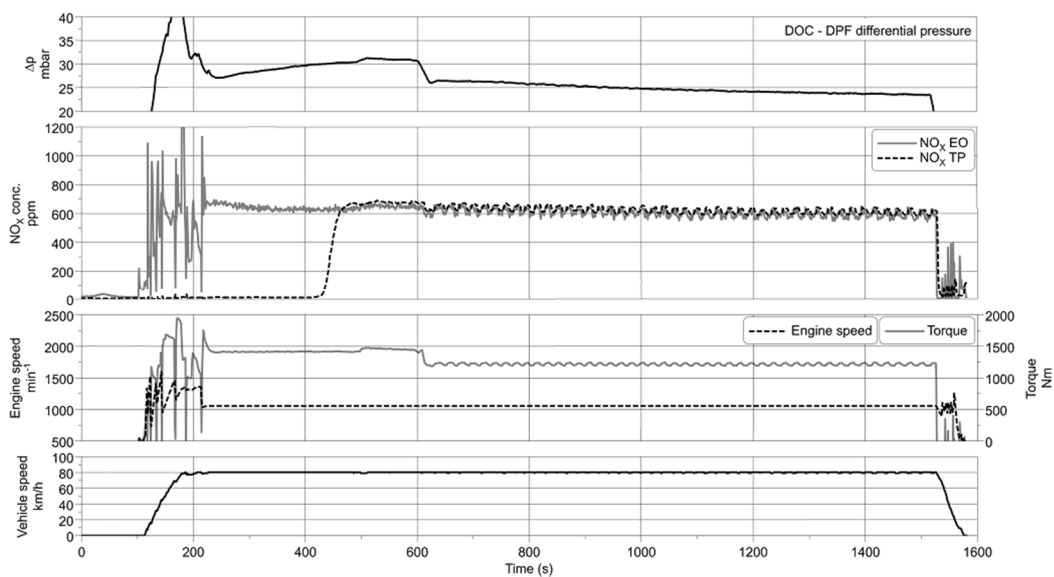


Fig. 5 Preconditioning protocol implemented to deplete ammonia storage in both SCRs and passively regenerate the DPF.

Some tests were conducted without such preconditioning and results will also be later discussed. These tests are comparable to the previous on-road tests as no specific preconditioning was applied there as well.

5 Results

The test evaluation shows the benefits achieved with this system. It must be noted that all results are reported as measured and do not consider any additional post processing or error margins at this point. All results relate to the preconditioned system as detailed in the previous section unless otherwise stated. The test conditions do not represent all critical driving situations but give a good illustration of severe conditions.

5.1 Previous results

Figure 6 shows NOx emission results obtained during in-service conformity (ISC) and urban delivery (UD) routes on the road as reported in a previous publication of this project [8]. Results show urban operation emissions between 48 and 187 mg/kWh. The results are presented using the average speed of the share of operation. The ISC tests were conducted at ambient temperatures between 8 °C and 11 °C and most started

with a cold engine. The testing at chassis dyno confirmed these urban NO_x emissions. For the sake of comparison, a test conducted at the chassis dyno was added in the same figure and is represented by the blue square. This is an urban delivery test without preconditioned SCR and conducted at -7 °C. The emissions results are within the range of emissions previously published from this project.

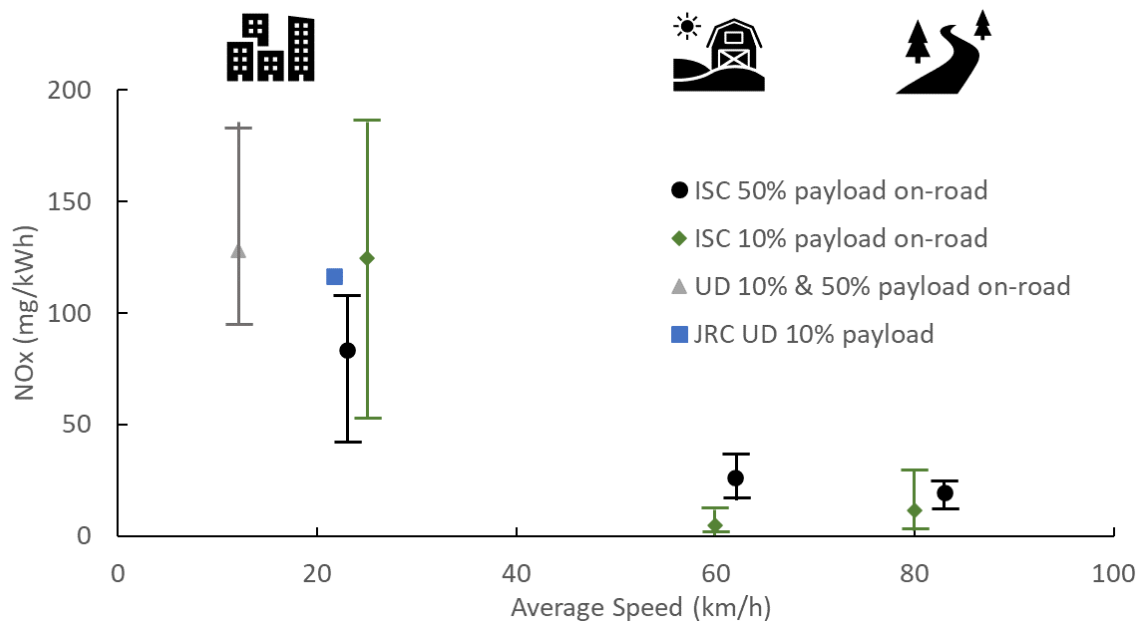


Fig. 6 NO_x emissions for ISC trips and urban delivery trips at 10 % and 50 % payload by share of operation as reported previously [8].

This test which replicates the route including speeds and slopes, was included to confirm the low emissions results seen during the on-road testing prior to the JRC campaign.

5.2 NO_x emissions

5.2.1 Effect of the preconditioning of the catalysts on NO_x emissions

As stated in the section 5.1, a preconditioning of the catalysts and filter was conducted before most of the tests reported in this paper. Figure 7 shows the effect of such preconditioning on the cumulative NO_x emissions of 2 urban delivery tests. These tests were conducted at -7 °C with 10 % payload. As it can be seen, the resulting cumulative emissions are around 4.5 times higher when the system has been preconditioned, and the highest concentration of emissions occurs during the first part of the trip, which includes the cold-start.

It is evident, that the depletion of the ammonia storage of the SCR system impacts in a significant manner the performance of the system during cold-start.

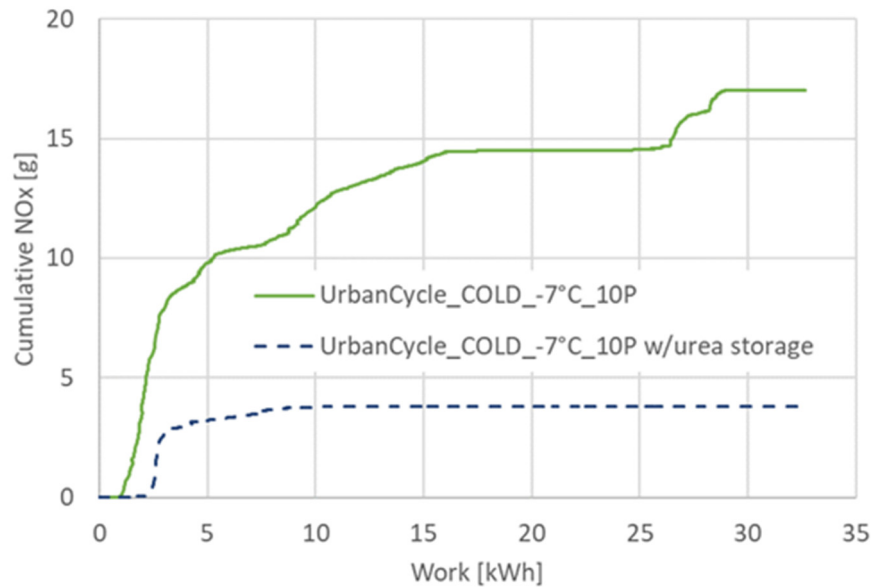


Fig. 7 Cumulative NOx emissions between a cycle with ammonia storage and one without ammonia stored in the SCR.

5.2.2 Overview of NOx emissions results

An overview of the cumulative NOx emissions obtained during the trips reported in this paper is shown in Figure 8. The cumulative emissions are a good way to understand how such an emission control system behaves regardless of the cycle.

As it can be seen, one of the tests reported has been conducted with ammonia stored on the SCRs (labeled as “no cond”). All other tests were conducted with the catalysts preconditioned.

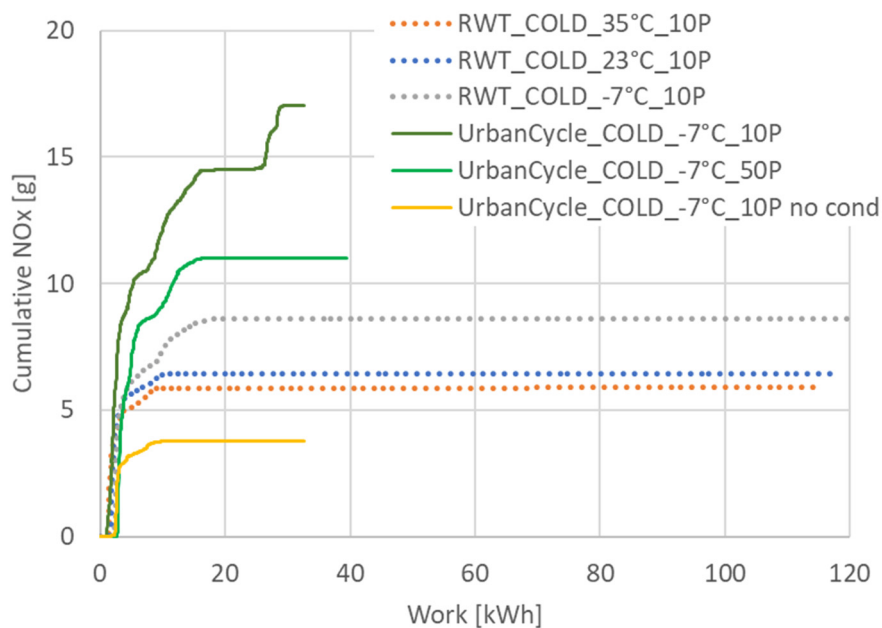


Fig. 8 Cumulative NOx emissions of tests conducted in the chassis dyno.

5.2.3 Ambient temperature effect on NOx emissions

Comparison between the cumulative emissions obtained from the RWT tests conducted at -7 °C, 23 °C and 35 °C all loaded with 10 % payload is shown below in Figure 9. Highest NOx emissions are emitted at -7 °C, in all three tests the NOx emissions are very low after ~15 kWh, this is about the half of the WHTC reference work for this application (reported in section 3.1). All three tests were conducted with pre-conditioned SCRs.

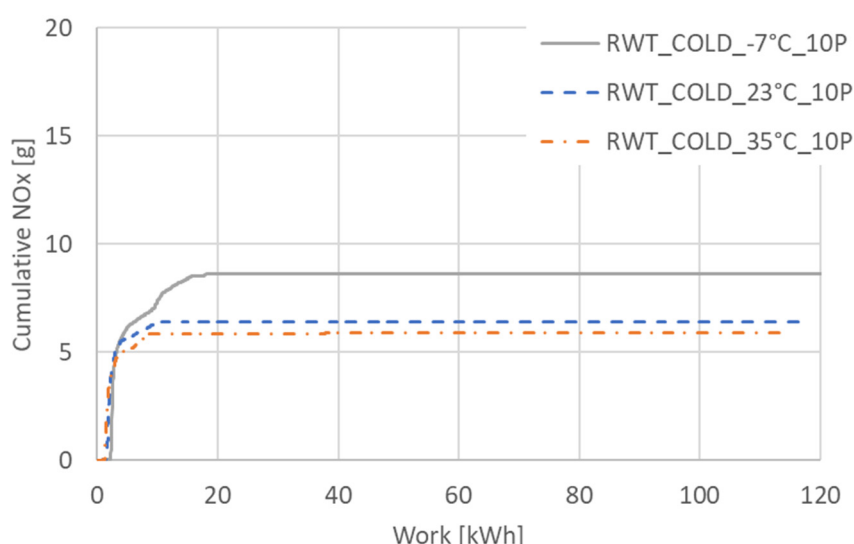


Fig. 9 Cumulative NOx emissions of three RWT test repetitions at different ambient conditions with 10 % payload.

While the cumulative NOx emissions during the two real-world tests conducted at ambient conditions above 0 °C show cumulative emissions of ~6 g NOx, the same test profile at -7 °C shows ~30 % increase on the cumulative emissions. The performance of the system within the first 1500 seconds during the cold-start varies depending on the ambient temperature. The NOx conversion efficiency is about 89 % at -7 °C and reaches 92 % at 35 °C. After 1500 seconds (~15 kWh), the NOx conversion efficiency is about 99.9 % for all cases.

5.2.4 Payload and urban delivery stop duration impact on NOx emissions

Figure 10 shows the impact of the payload in two tests running the same speed profile at the same temperature within the chassis dyno testing controlled conditions. The figure shows the urban delivery route conducted at -7 °C with 10 and 50 % payload. Both tests were conducted with preconditioned SCRs and therefore empty ammonia storage.

The highest payload reduces the emissions during the second part of the trip where the longest stops are located and where the combination of cold ambient conditions and low payload have the highest impact.

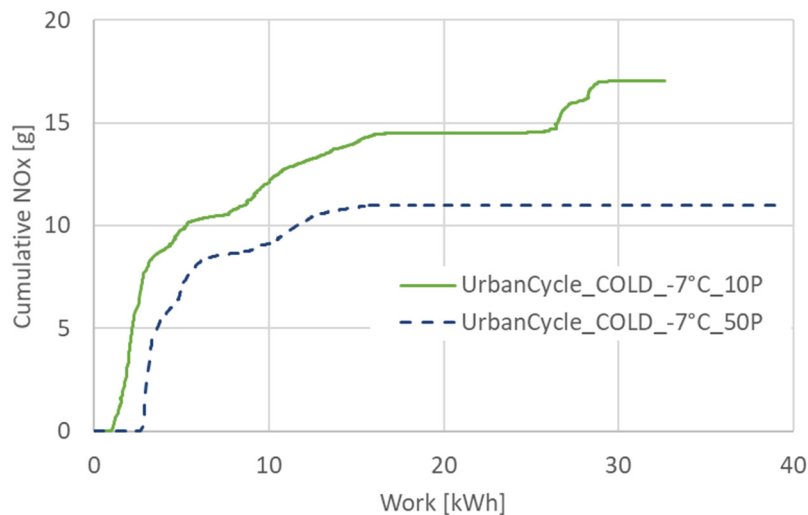


Fig. 10 Cumulative NOx emissions from two urban cycles ran with 10 % and 50 % payload at -7 °C.

Figure 11 below shows the comparison of the impact of the long stops (~3 minutes) on NOx emissions during two urban delivery chassis dyno tests. The tests were conducted with 10 % payload at -7 °C and 23 °C. Both tests had the SCRs preconditioned. These long stops are concentrated in the last part of the urban delivery test. The tailpipe NOx shows a slippage towards the end of the second three-minute stop and after the third stop. The loss of temperature delays the start of AdBlue® injection and causes significant NOx slippage.

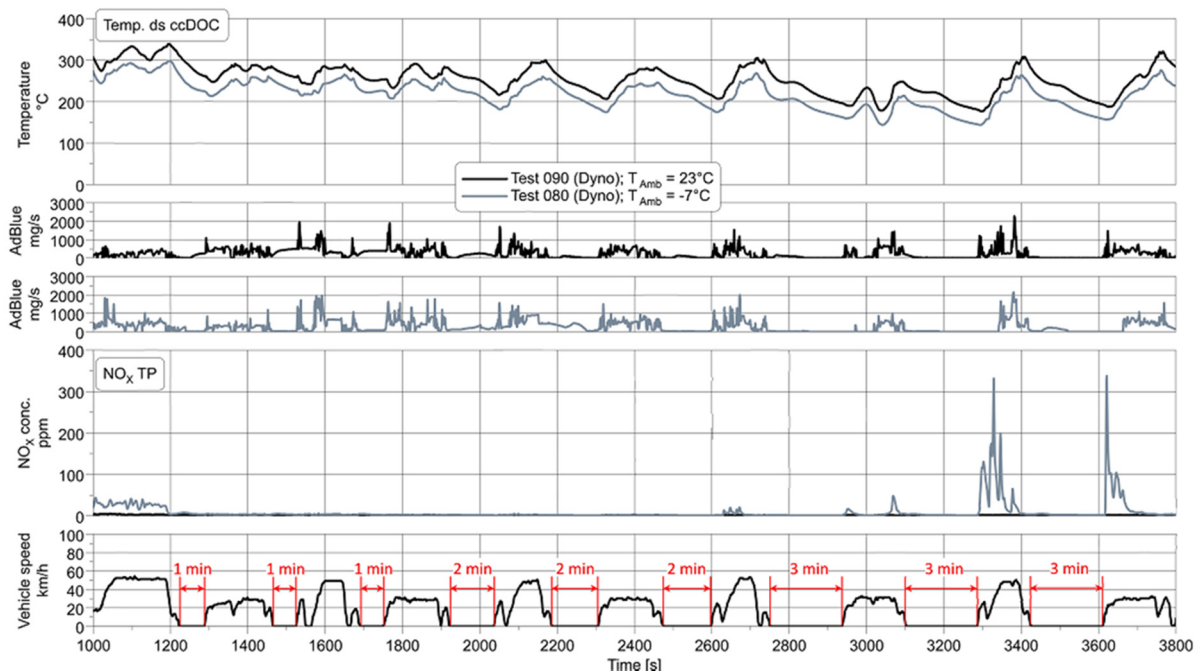


Fig. 11 Impact of stop duration and temperature on NOx emission and AdBlue® dosage.

5.3 Ammonia (NH₃) emissions

Figure 12 shows the ammonia emission results for the trips. Ammonia emissions can be generated by an overdose of AdBlue®. Current Euro VI emission standards include a 10-ppm average limit for NH₃ emissions over the WHTC cycle. During the tests conducted, the ammonia results have shown an excellent slip control from the emissions control system. Overall, the NH₃ emissions measured in every condition have been extremely low.

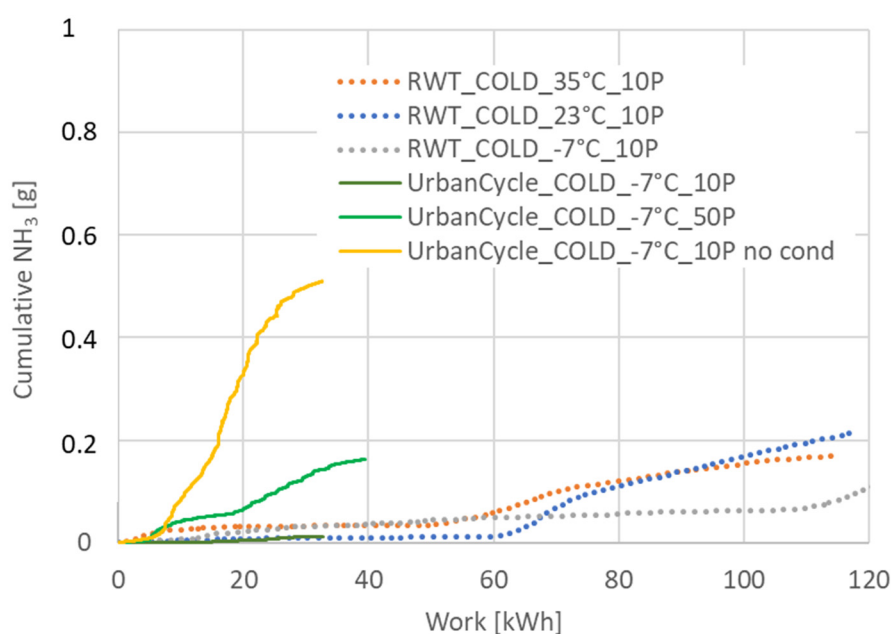


Fig. 12 Cumulative NH₃ emissions of tests conducted in the chassis dyno.

The system includes ammonia slip catalysts after each SCR; this allows to control ammonia slippage. Furthermore, the tests conducted with the pre-conditioned and therefore empty ammonia storage explaining the time needed to fill up the ammonia storage and the impact on NO_x pollutant emissions at cold start.

By positioning the catalysts in close couple position reaching operating temperature is much faster than a conventional under-floor system. The AdBlue® dosing in this system starts very early in the trip, once the system has reached regime temperature (over 200 °C), Adblue® dosing starts and the ccSCR converts NO_x.

5.4 Nitrous Oxide (N₂O) results

N₂O emissions can be produced via various complex mechanisms. N₂O can be formed over a DOC. Additionally, N₂O emissions can be generated as a by-product of the chemical reactions within the SCR. It is also produced via unselective oxidation of unreacted NH₃ within the ASCs. As such, each of these mechanisms needs to be optimized to achieve the lowest tailpipe N₂O values. N₂O emissions are currently neither regulated within the Euro VI standards nor as CO₂ equivalent as greenhouse gas emission [5, 16].

In the demonstrator vehicle, the goal was to generate N_2O emissions as low as possible and achieving lowest possible NO_x emissions. Figure 13 shows N_2O while being relatively well contained, it is produced throughout the trip duration.

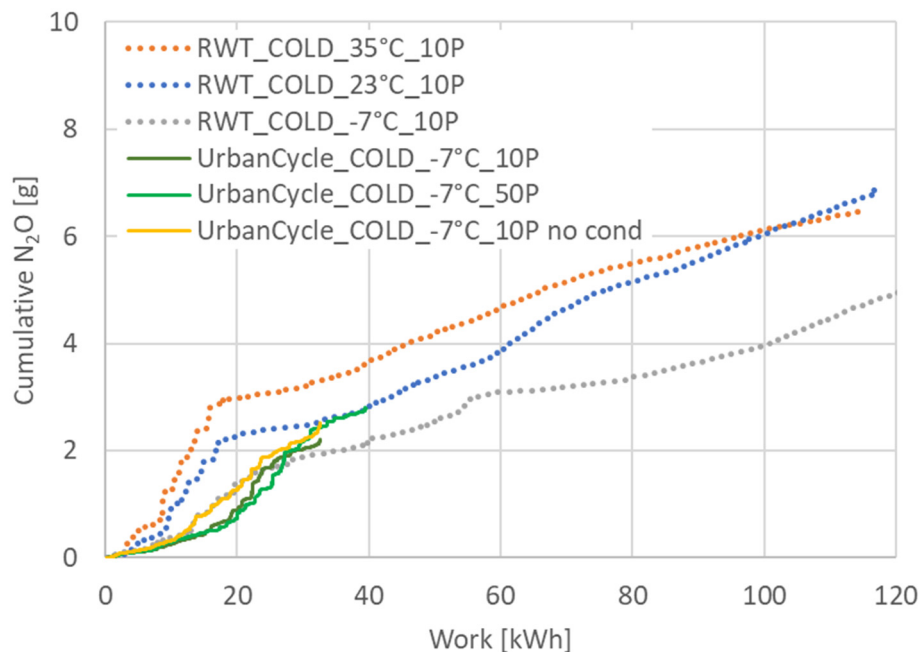


Fig. 13 Cumulative N_2O emissions of tests conducted in the chassis dyno.

5.5 Particulate emission results

The particulate number (PN23) results obtained during these tests are presented in Figure 14. The particulate emissions have been measured with the AVL Particulate Counter, this instrument has been described above and the particulates are reported as measured without considering any measurement uncertainty. Crankcase emissions have not been considered in the results.

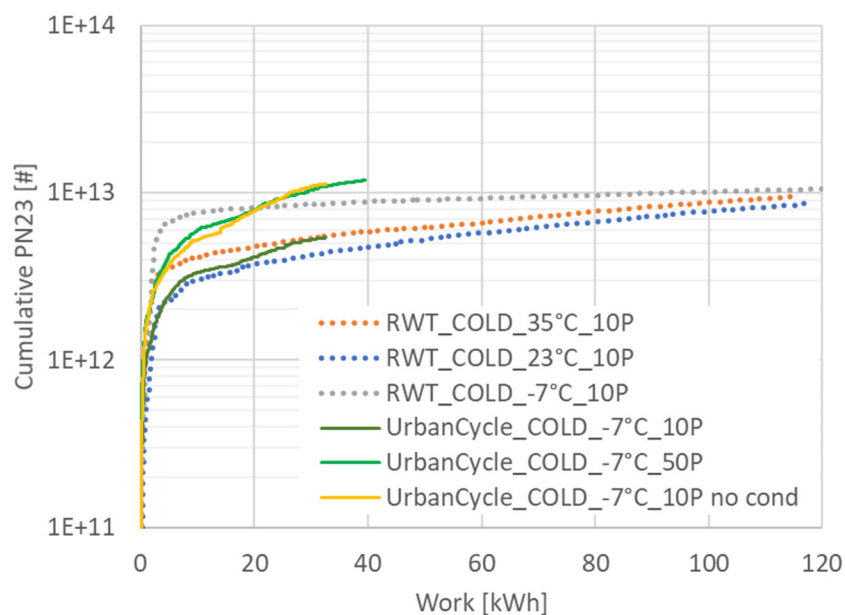


Fig. 14 Cumulative PN23 emissions of tests conducted in the chassis dyno.

The bulk of the PN emissions are produced during the beginning of the trip, and particularly during the cold-start phase. This can be attributed to the state of the filter at the beginning of the tests in combination with engine-out emissions and “blow-off” effect described below. The protocol described in section 5.1 was conducted to perform passive regeneration to the filter. In this case, the initial loading status of the filter was assumed to be almost empty or very low. The particulates generated might be attributed to the blow off from the cold pipes and combustion chambers at the initial start of the engine. After this initial emission peak the PN behavior is consistent with very low particulate emissions produced.

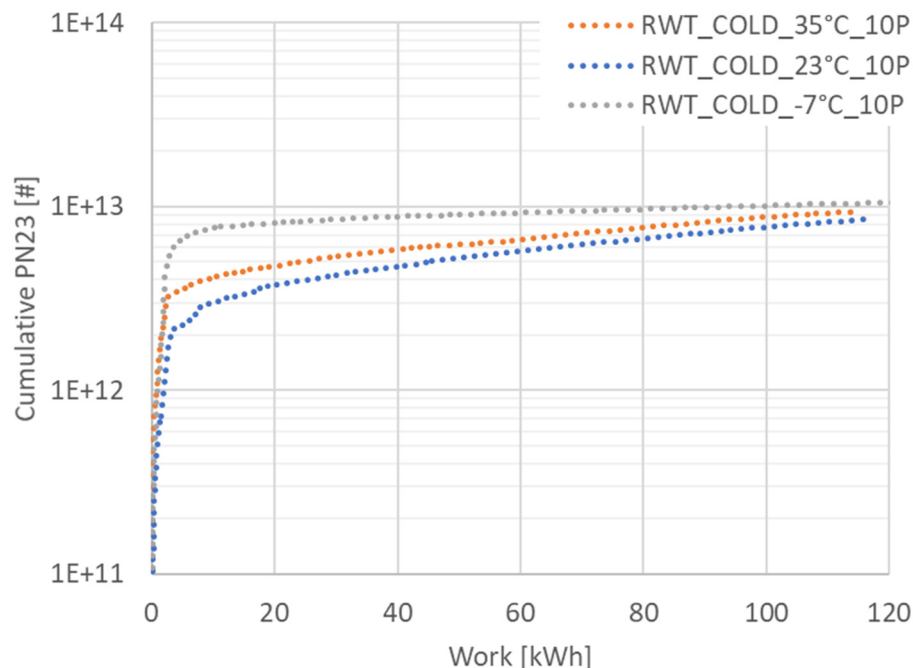


Fig. 15 Effect of temperature on cumulative PN23 emissions in three RWT tests.

The effect of the cold ambient conditions can be seen on Figure 15. Three RWT were conducted at -7 °C, 23 °C and 35 °C. While cumulative emissions reached a similar level at the end of the tests, a clear difference exists in the first cold-start part of the trip, where the initial status of the filter and engine out emissions have an impact on the particulates at this stage.

Particulate emissions are also impacted by payload as shown in figure 16. Two urban delivery tests were conducted at -7 °C with two payloads, 10 % and 50 %. The cumulative particulate emissions achieved in the test with 50% payload are about 50 % higher than those from the test conducted at 10 % payload and mainly produced in the first few seconds. This can be explained by the higher mass flow of emissions produced when the vehicle needs to move a heavier load. Tests conducted are not covering all possible critical conditions for PN.

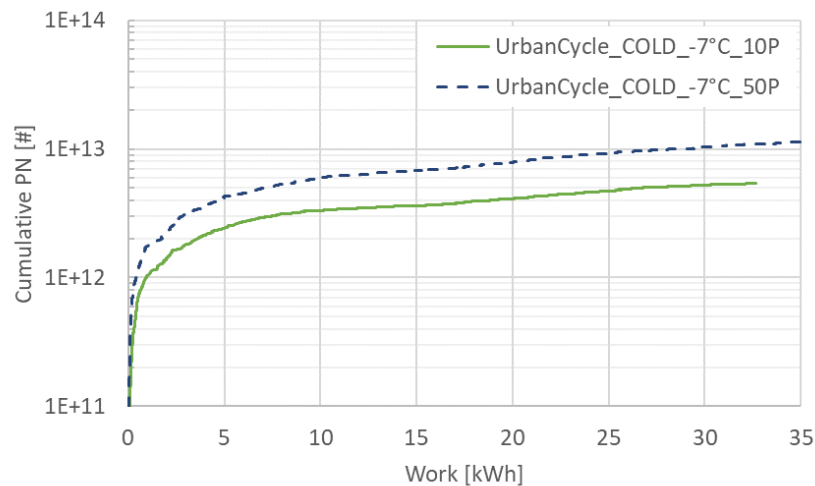


Fig. 16 Effect of payload on cumulative PN23 emissions in two urban delivery tests.

6 Summary

A state-of-the-art emissions control system has been implemented on an N3 heavy-duty vehicle where the combustion was adapted to reduce NO_x emissions as well as to use internal heating measures to allow a rapid heat up of the system. The system includes close coupled DOC and SCR catalysts and dual SCR with twin dosing. The proximity of the catalysts to the engine out emissions allows the system to reach 200 °C required for robust AdBlue® dosing conditions significantly quicker than any standard Euro VI emission control technologies currently in the market.

The results presented in this paper examine the tests conducted during a dedicated chassis dyno campaign where the main objectives were to measure gaseous and particulate emissions under cold (-7 °C) and hot (35 °C) ambient conditions, investigate severe case conditions for cold-start without ammonia stored on the SCRs, as well as with passively regenerated DPF and cover a wide range of driving conditions within the controlled environment of the laboratory.

The results confirm that remaining NO_x emissions are mainly generated during the cold-start operation. It also shows that a SCR with a depleted ammonia storage has a significant impact on cold-start emissions and that payload can impact the performance of the system when driving under urban operation containing several stops. It is also important to highlight that the length of the stops is critical for such a system and this should be carefully considered for the future.

Other currently non-regulated emissions were investigated. The ammonia emissions on this truck are very low in every tested condition, this shows the good integration of the ammonia dosage and application of slip catalyst after each SCR which is robustly preventing any slippage. N₂O emissions are formed along the trip during NO_x conversion of the system shown in this paper.

Finally, an initial analysis on the particulate emissions measured during this campaign has been discussed. Overall, low particulate emissions have been measured in every condition. The results indicate that temperature and payload will have an impact on these emissions.

7 Outlook

Heavy-duty vehicles need to achieve high gaseous and particulate pollutant emissions reductions combined with demanding CO₂ reduction targets in the following decade. Euro VI trucks currently on the road have shown that through the different regulatory steps, the urban operations have been enhanced [7], however some high emission event that remain can be addressed with smart integration of proven emission control technology, as presented in this project.

It is expected that light and medium commercial vehicles, as well as long haul trucks, will continue using internal combustion engines for a long time as energy storage and density of liquid fuels, like sustainable renewable diesel, are superior to batteries. Solutions are needed to continue improving the emission performance of these vehicles. On heavy-duty vehicles, the implementation of close-coupled catalysts significantly contributes to the reduction of high NO_x emissions in challenging conditions like cold-start and urban operations.

As it has been shown by the chassis dyno results, that even though cold-start emissions are significantly improved, this remains challenging for long haul trucks, and further technologies will be necessary to control the emissions during this phase. Some of these technologies are being studied, like the electric heated catalyst [13], fuel burners [14], amongst others.

Further testing is planned on the AECC heavy-duty demo vehicle to address additional challenging conditions for the emission control system achieving lowest emissions. Higher payloads will be tested on the roads including slopes. Further urban testing and the implementation of an electrically heated catalyst is foreseen for the next phase of the project.

As stated above, new pollutant emissions standards will be combined with ambitious CO₂ reduction targets. The European Union has preliminary agreed to an overall GHG reduction target for 2030 of at least 55% compared with 1990 levels. The current CO₂ reduction targets for the heavy-duty vehicles fleet sold from 2025 and 2030 onwards are -15 % and -30 % respectively, compared to the EU average in the reference period July 2019 to June 2020. These targets will be discussed again in 2022 and it is expected that some adjustments will be made to comply with the new European Union GHG objectives.

All available paths to reduce the carbon footprint of these vehicles will be needed and it is expected that the vehicle mix of the future will be more diverse than it is today, comprising hybrid and plug-in hybrid trucks, as well as fuel cell and fully electric vehicles [15].

The AECC heavy-duty demo vehicle will also be tested using 100 % renewable liquid fuels to show the compatibility of such fuels to reduce Well-to-Wheel (WtW) CO₂ emissions while achieving ultra-low pollutant emissions. Sustainable renewable liquid fuels, like e-fuels or carbon-neutral fuels, are particularly fit for purpose as they can use the same fueling infrastructure already in place and existing vehicle fleets allowing a swift implementation in the market.

8 Acknowledgements

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9 Abbreviations

ASC	Ammonia Slip Catalyst
cc	close coupled
CO	Carbon monoxide
CPC	Condensing Particulate Counter
CVS	Constant Volume Sampler
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
EFM	Exhaust Flow Meter
EGR	Exhaust Gas Recirculation
FTIR	Fourier-transform Infrared
HC	Hydrocarbons
ICE	Internal combustion engine
JRC	Joint Research Centre
MAW	Moving Average Window

NDIR	Non-dispersive Infrared
NO _x	Nitrogen oxides (refers to the sum of NO and NO ₂)
PEMS	Portable Emission Measurement System
SPN10	Particulate Number with diameter of 10 nm
SPN23	Particulate Number with diameter of 23 nm
PNC	Particle Number Counter
RWT	Real-World Test
SCR	Selective Catalytic Reduction
UNECE	United Nations Economic Commission for Europe
VELA	Vehicle Emission Laboratory
WHSC	World Harmonized Stationary Cycle
WHTC	World Harmonized Transient Cycle
WHVC	World Harmonized Vehicle Cycle

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