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

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30th Aachen Colloquium 2021 • 04-06 October 2021

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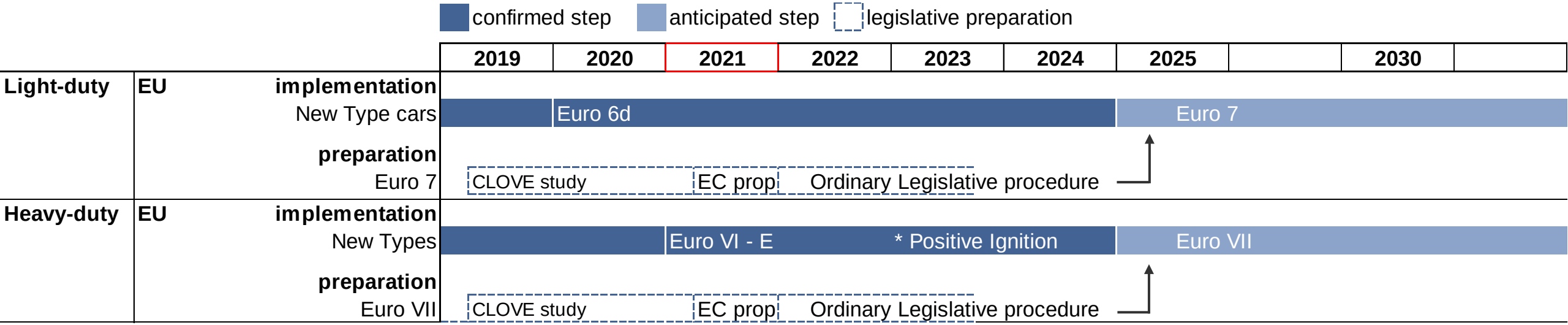
Content

- Introduction – Euro 7/VII process
- Heavy-duty Diesel – Ultra-low emissions demonstrator
- Summary and outlook

Emission legislation evolution expected towards Euro 7

- The AGVES expert working group met until end of April 2021
- CLOVE consortium
  - Presented scenarios for light- and heavy-duty vehicles
  - Will provide further input for the European Commission impact assessment
- The actual European Commission proposal is expected within 2021 followed by the ordinary legislative procedure with European Parliament and Council



HD demonstrator vehicle and project partners

- Base vehicle description
  - MB Actros 1845 LS 4x2
  - Euro VI C certified
  - Engine OM 471, 2nd generation
    - 12.8 liter, 6 cylinder in-line
    - High Pressure EGR
    - 450hp @ 1600rpm
- Project partners

FEV

IPA
INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION

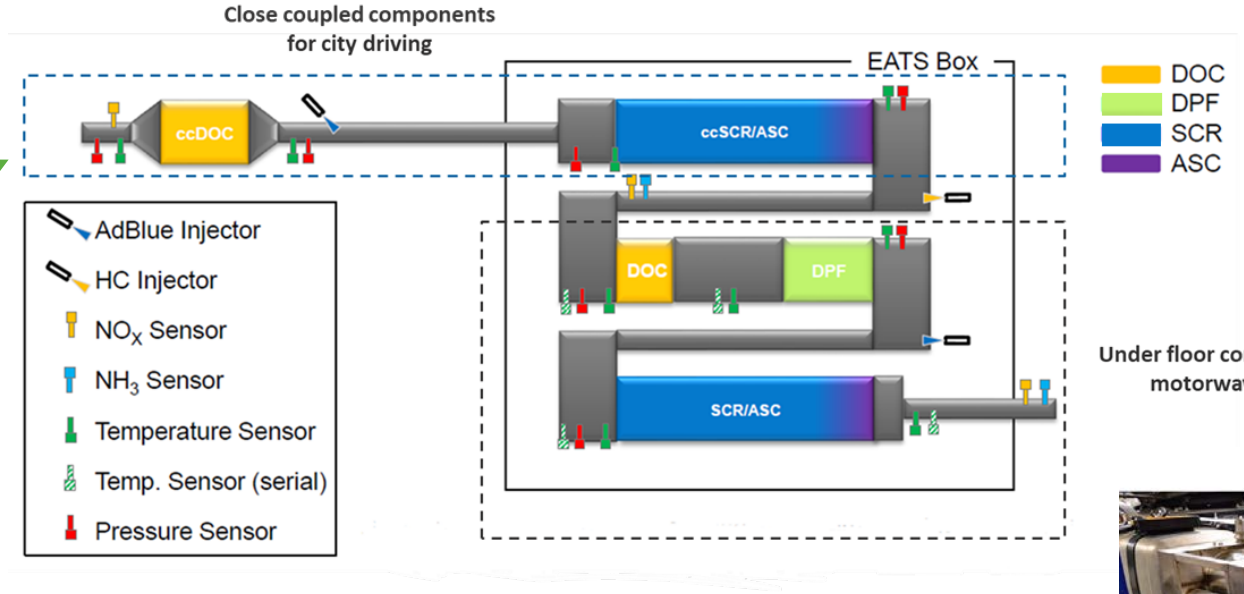
CORNING

Automotive Grade Urea Sector Group
cefic
sector group

HD demonstrator emission control system

- Catalysts and filter volumes from the AECC emissions control system installed on the truck
  - Combination of close-coupled and underfloor components
  - Components are hydrothermally aged targeting 500k km

Original system volumes:
DOC 11.4l
DPF 16.8l
SCR 28.4l



AECC HD demo
Volumes:
DOC: 7l + 7l
DPF: 16l
SCR: 25l + 25l

Under floor components for motorway driving

AECC HD demonstrator video can be seen at:
https://www.youtube.com/watch?v=MXBnhZMzISY

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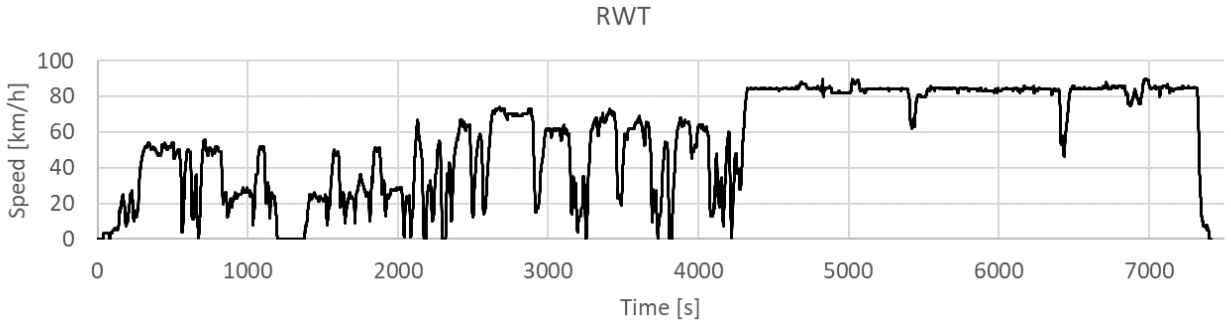
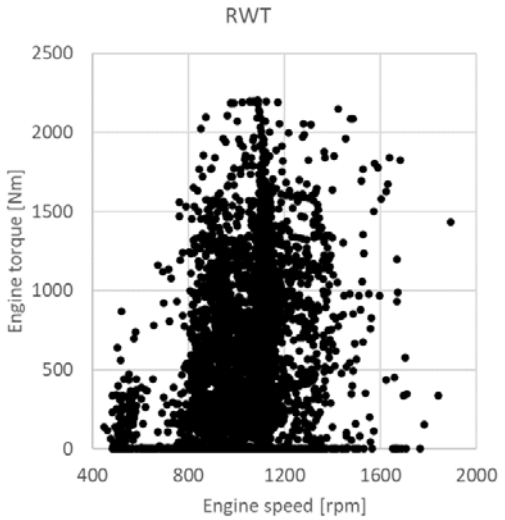
HD diesel demonstrator EC JRC campaign

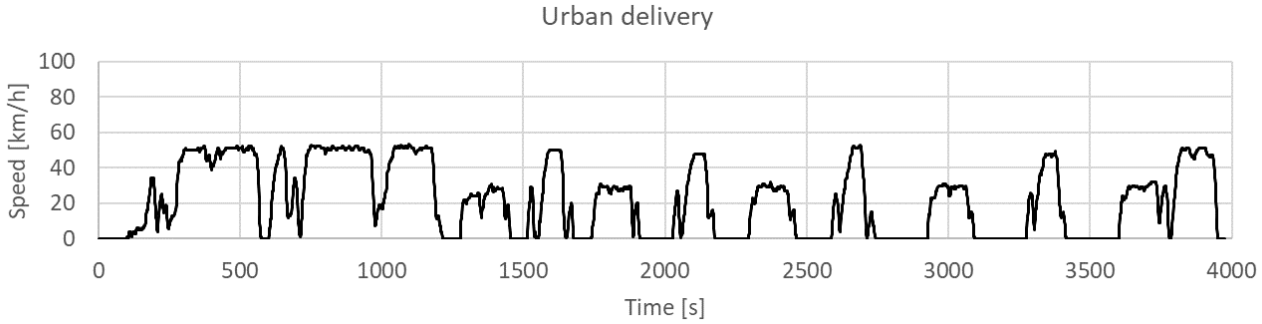
- Wide range of driving conditions including urban, rural and motorway operation as well as different ambient conditions
- Severe case conditions for cold start without ammonia stored on SCRs as well as with passively regenerated DPF
- Result shown today: NOx, SPN23, SPN10, NH_3 and N_2O
- Further analysis is being completed on other trip profiles

Challenging cycles for chassis dyno testing





- T_{amb}: -7 to 35 °C
- Payload: 10 %

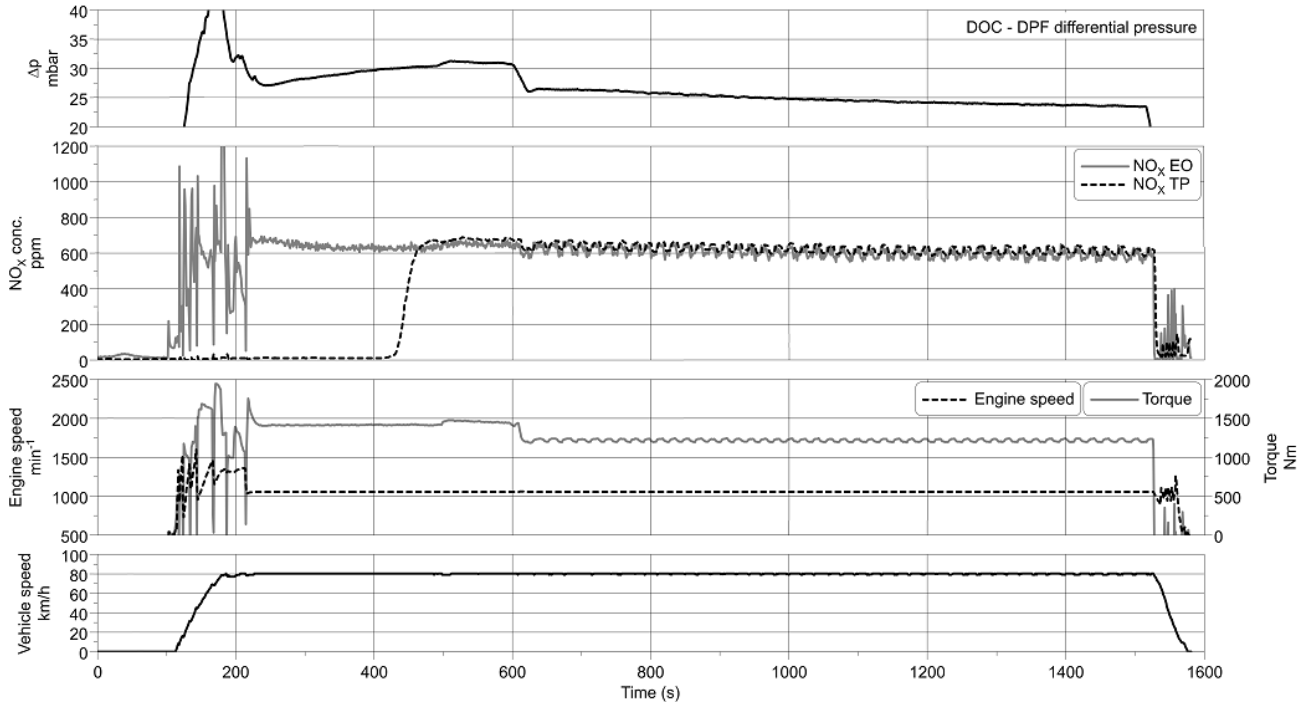


- T_{amb}: -7 °C
- Payload: 10 & 50 %

RWT – Real World Test

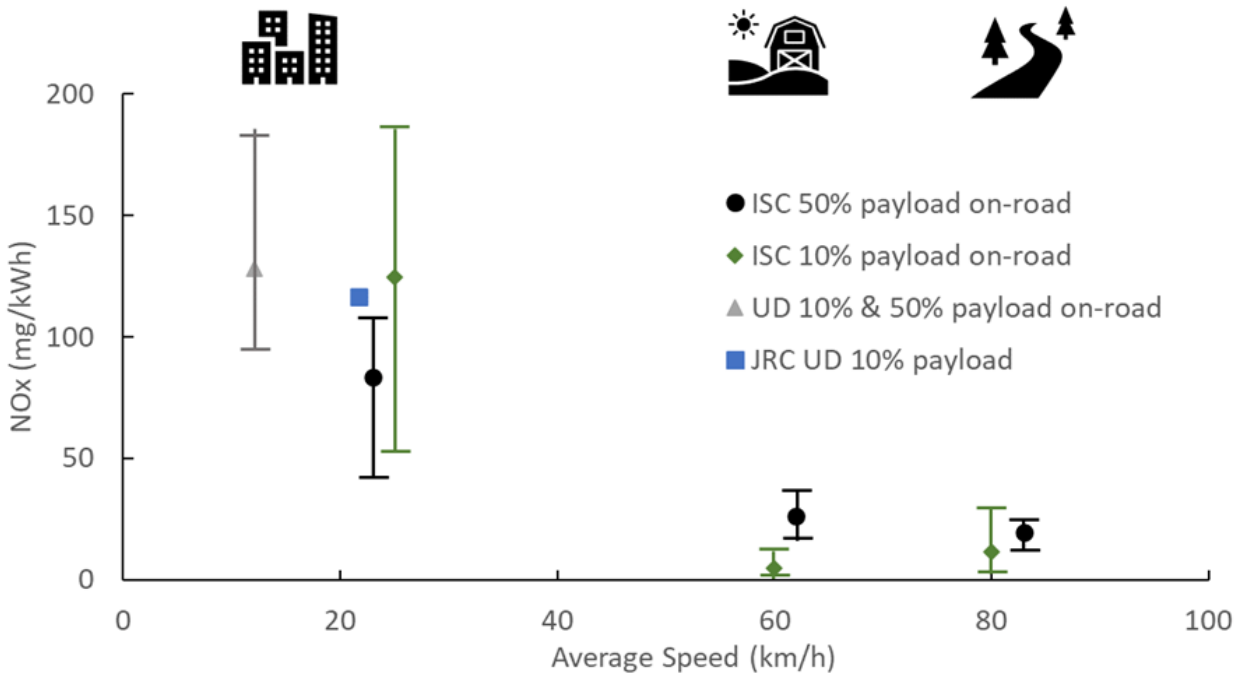
HD diesel demonstrator system preconditioning

- System preconditioning
  - DPF was passively regenerated, until pressure differential was below a defined threshold
  - SCR catalysts' ammonia storage was depleted until engine-out NOx equal to NOx at the tailpipe
- Ensure same starting conditions
- Investigate impact on gaseous and particulate emissions at severe cold-start conditions



HD diesel demonstrator initial results on road vs. chassis dyno

- On-road ultra-low NOx emissions over a broad range of operating conditions
  - ISC (N3 Euro VI-C route) and urban delivery[1] trips were conducted with 10 and 50% payloads
  - Tests covered a range of ambient temperatures from 4°C to 11°C
- Additional JRC chassis dyno test[2] result show good correlation between on-road and lab test



[1] Urban delivery (<35km/h) with 10 stops (~1 min), total trip duration is ~1 hour and work completed is about 14-16kWh

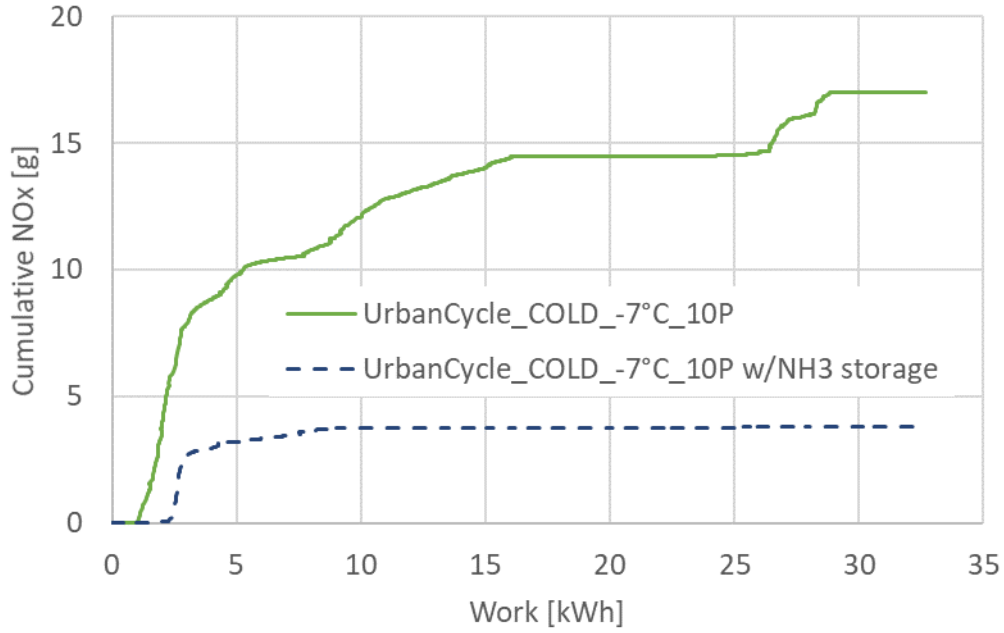
[2] Urban delivery completed at JRC contained several stops (~1, 2 & 3 min). JRC chassis dyno test result shown on this graph was conducted with ammonia stored in the SCRs

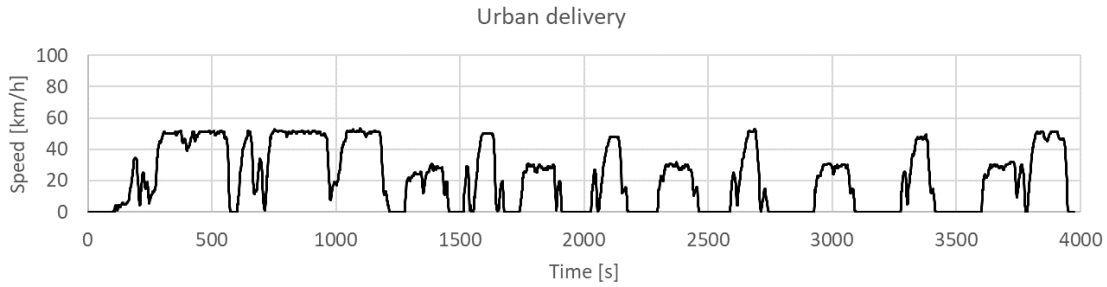
The results are reported as measured under the specified test routes and conditions

Content presented at 42nd International Vienna Motor Symposium with additional data from 1 test conducted at JRC

Effect of depleted ammonia storage on SCR

- A significant impact on cold-start NOx emissions has been identified when SCR ammonia storage is depleted
- Resulting cumulative emissions are higher when the system has been preconditioned [1,2]
- AdBlue® dosing strategy and ammonia storage must be well managed, in combination with robust thermal management

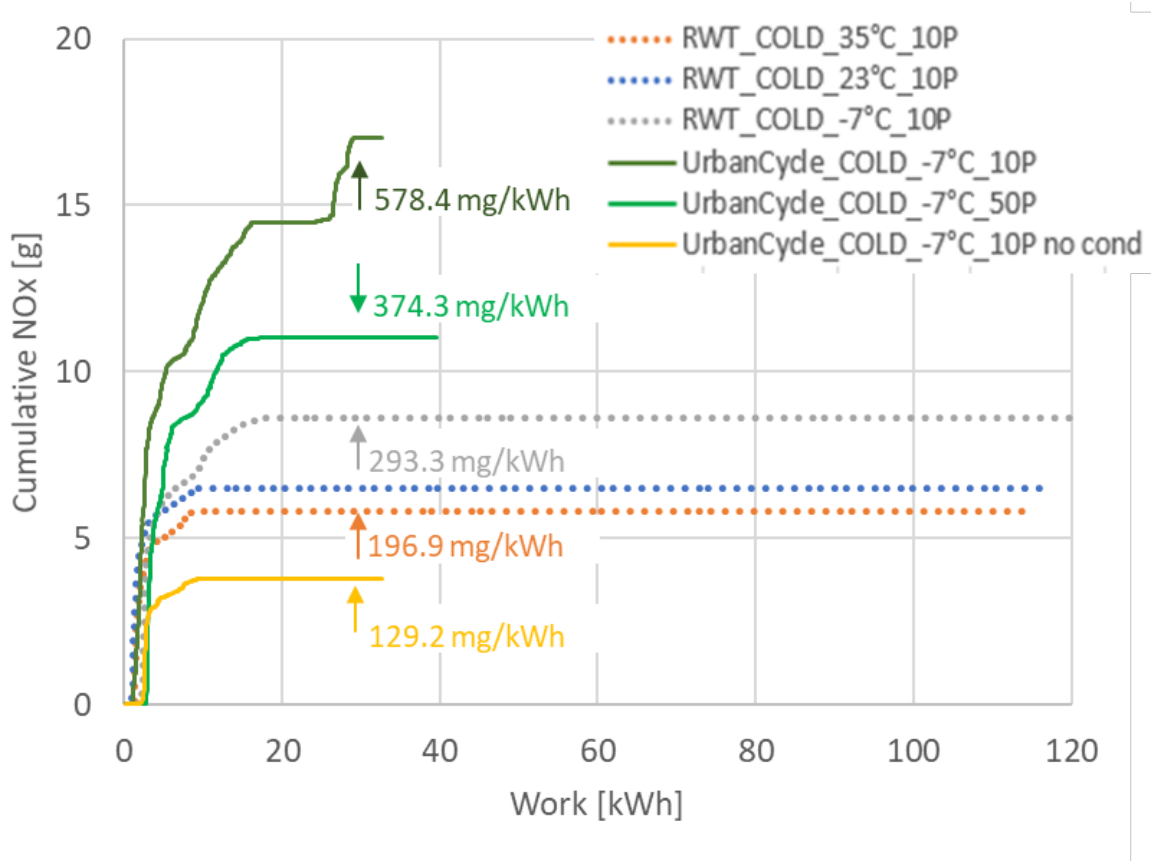




[1] Urban delivery tests were conducted with 10 % payload
[3] The results are reported as measured by the laboratory FTIR under the specified test routes and conditions

Majority of NOx emissions produced during cold-start phase

- Results[1,2,3] confirm low gaseous and emissions in a broad range of driving conditions
- Regardless of the test cycle, majority of NOx emissions (up to 99%) are produced during the cold-start phase
- Effect of temperature, payload, driving cycle and SCR ammonia loading can be studied



RWT – Real World Test

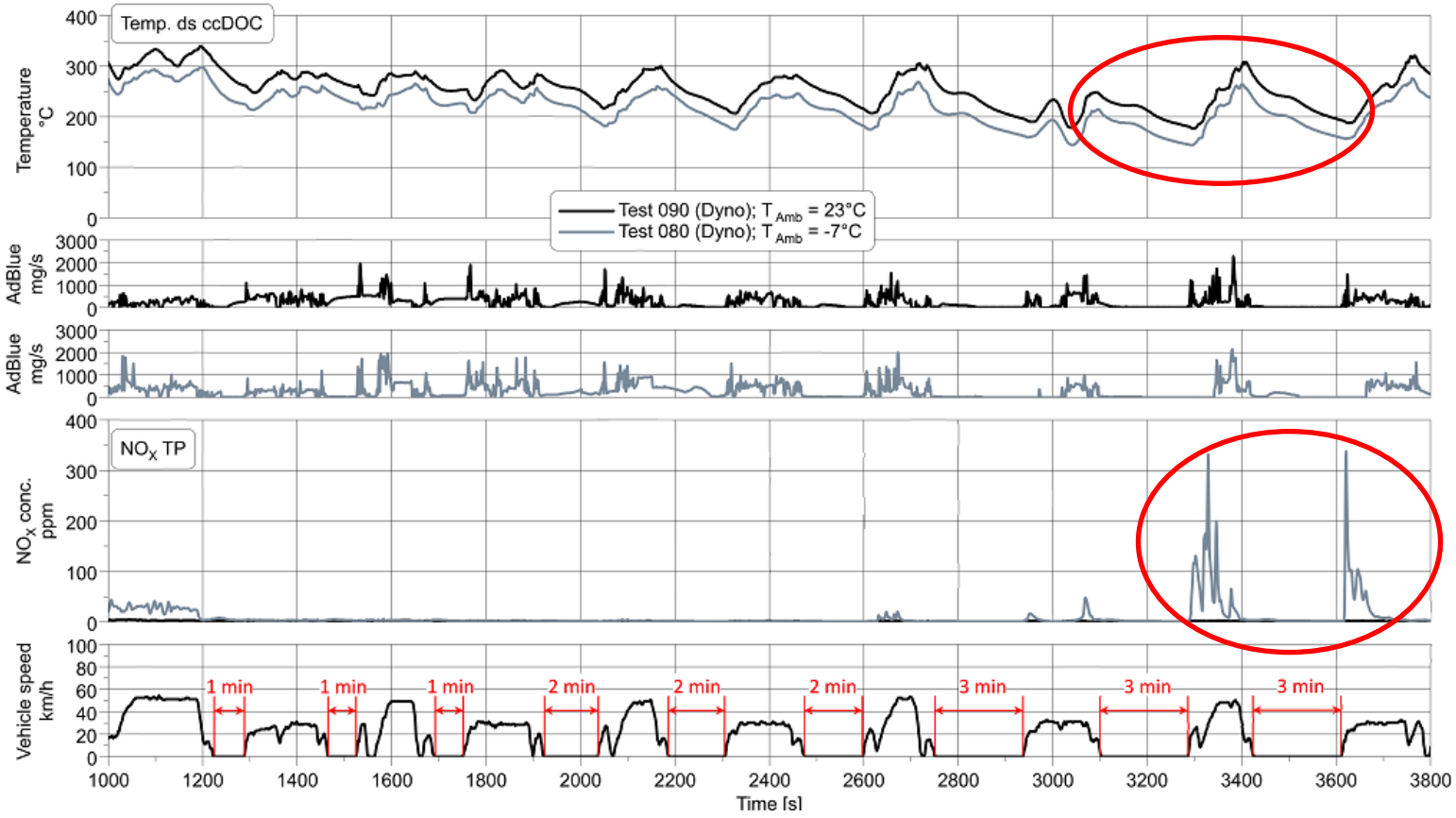
[1] The results are reported as measured by the laboratory FTIR under the specified test routes and conditions

[2] Tests were conducted with empty SCRs' ammonia storage and passively regenerated DPF unless indicated otherwise

[3] WHTC metric is used to make results comparable

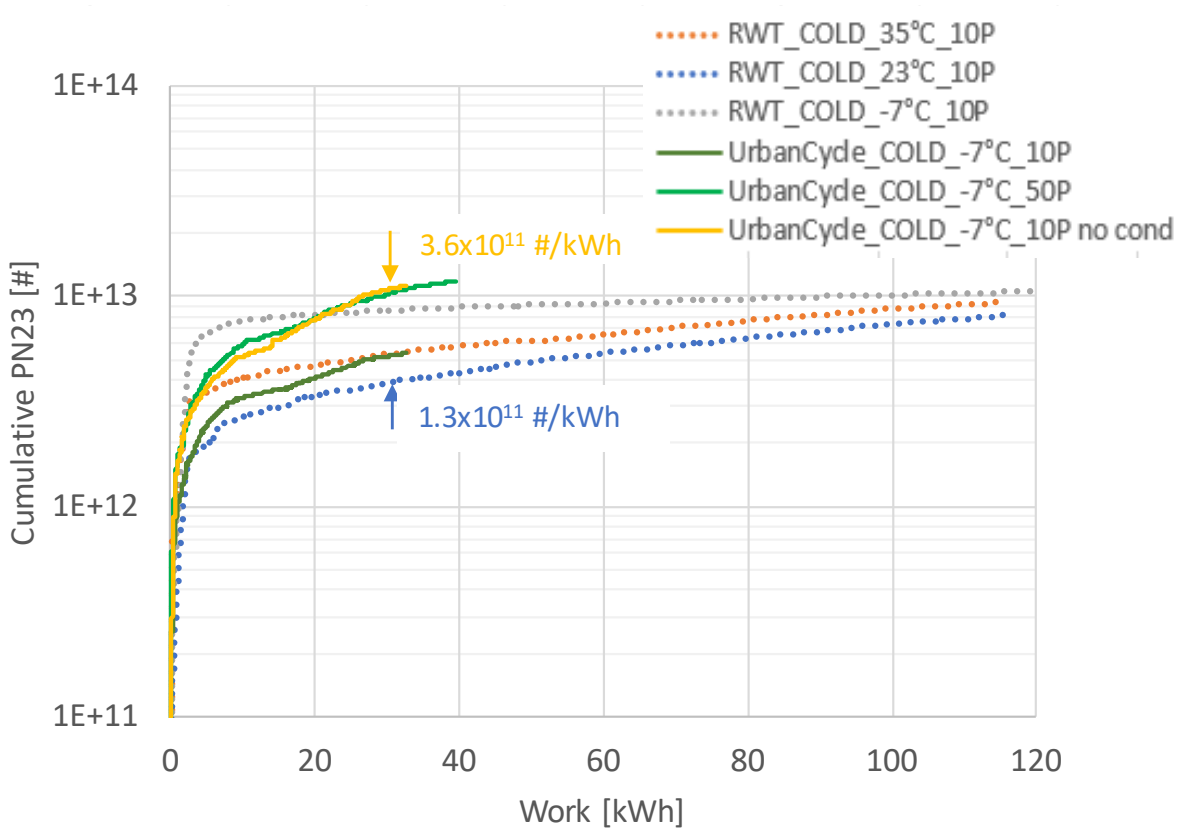
Low ambient temperature and idle conditions effect on DeNOx

- Specific cycles were investigated for urban delivery with stops of duration 1, 2 and 3 minutes
- Length and frequency of stops will have an impact on DeNOx performance
- The effect is significant when driving at cold ambient conditions (-7°C)



PN23 emissions are impacted by temperature and payload

- Results[1,2,3] confirm low particulate emissions can be achieved in broad range of driving conditions
- Most PN23 emissions are produced within the cold-start of the trip
- Tests have shown impact of temperature and payload
- Tests are not covering all possible critical conditions for PN



RWT – Real World Test

[1] The results are reported as measured by the laboratory AVL Particle Counter under the specified test routes and conditions

[2] Tests were conducted with empty SCRs' ammonia storage and passively regenerated DPF unless indicated otherwise

[3] WHTC metric is used to make results comparable

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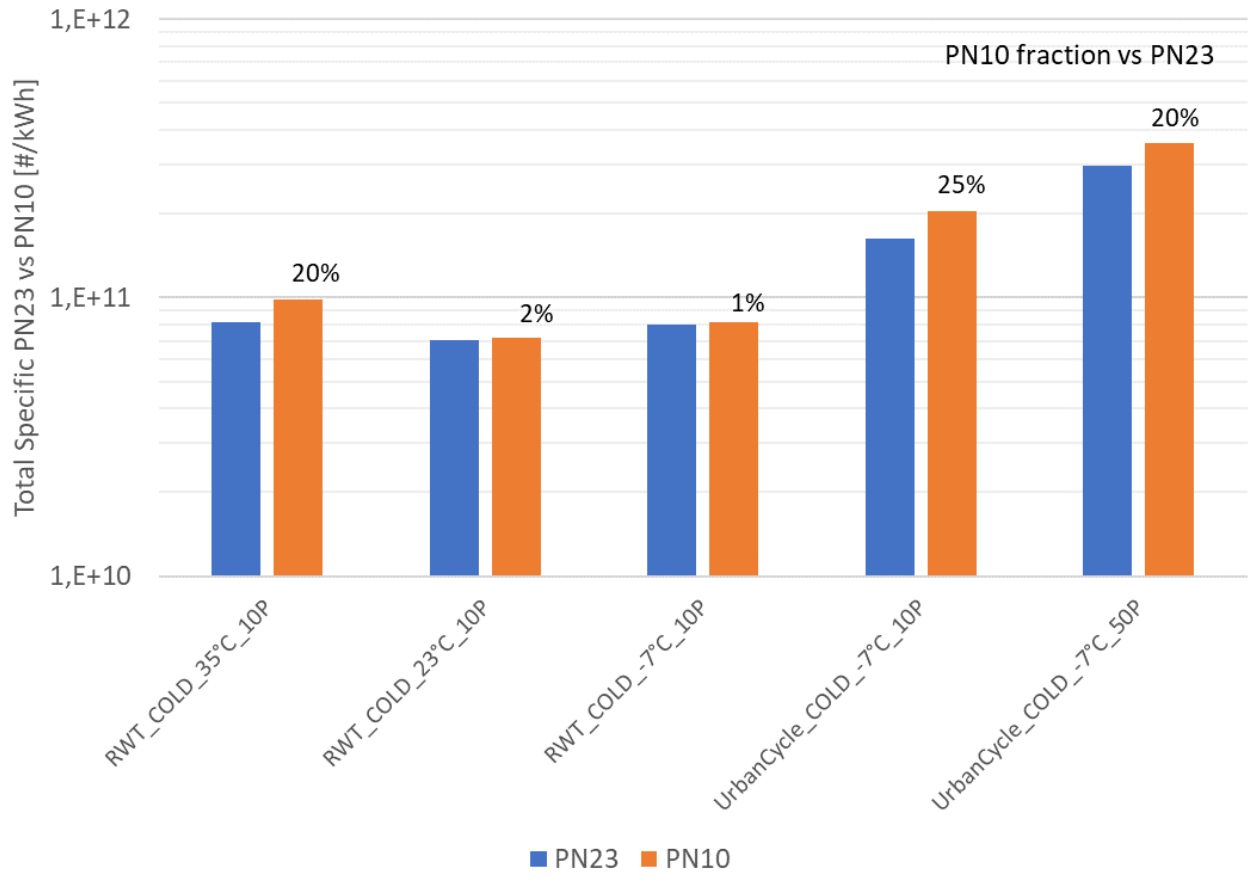
PN10 fraction in line with available literature

- PN10 measurement was conducted during the chassis dyno testing[1,2,4]
- Results show PN10 fraction varies from 1 to 25% vs PN23 which is in line with available literature[3]
- Tests are not covering all possible critical conditions for PN



RWT – Real World Test

[1] The results are reported as measured by the laboratory Particle number counter TSI 3772 used to measure PN10 under the specified test routes and conditions

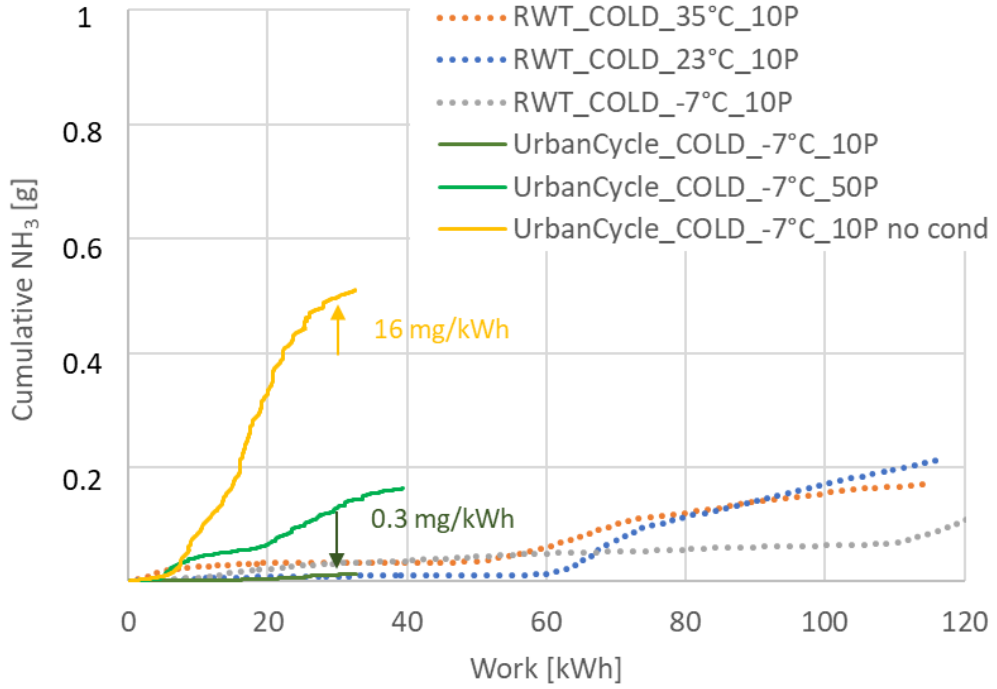
[2] Tests were conducted with empty SCRs' ammonia storage and passively regenerated DPF unless indicated otherwise

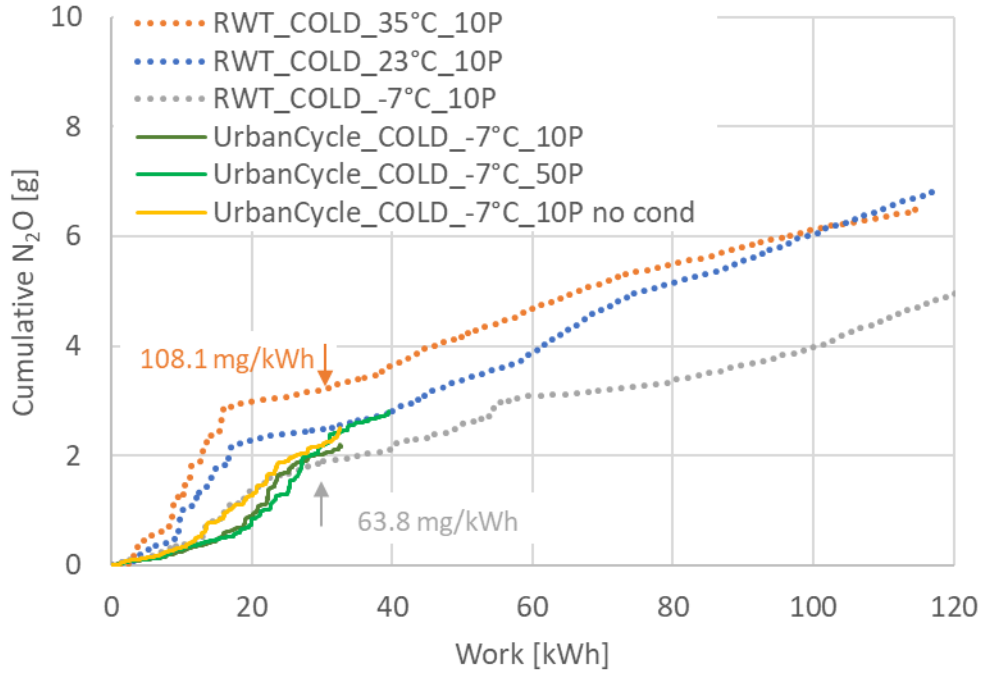
[3] Giechaskiel et al. Environmental Research 197, June 2021, 111068

[4] PN10 results of the Urban non-conditioned cycle at -7°C are not included due to possible artifact measurement issue

Non-regulated pollutant emissions are well controlled

- Chassis dyno test results[1] confirmed good control of NH_3 and relatively low N_2O





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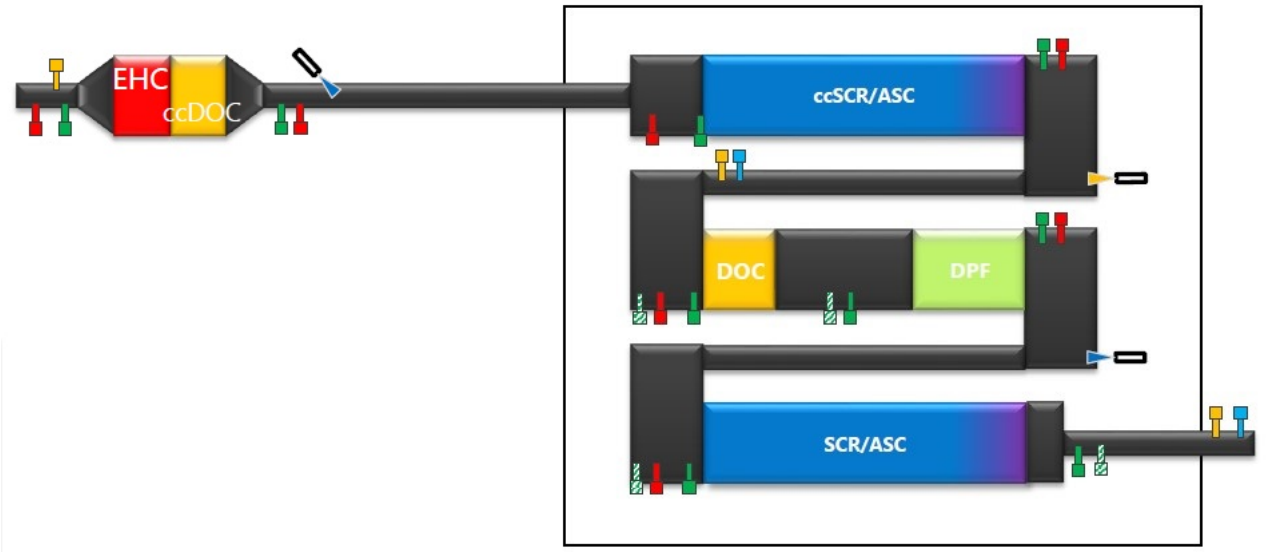
[3] WHTC metric is used to make results comparable

Summary

- Ultra-low gaseous and particulate emissions are technically feasible in a broad range of driving conditions thanks to the close-coupled catalysts and heating measures implemented on the truck
- The innovative emissions control system layout integrates proven emission reduction technology in a commercially feasible manner
- Results show low non-regulated emissions can also be achieved

Outlook

- 2021 follow-up activities for HD diesel
  - A different AdBlue® dosing strategy will be tested to investigate the impact on PN
  - Implementation of electrically heated catalyst to reduce the remaining initial cold-start emissions
  - Testing of renewable fuels with drop-in capabilities to investigate Well-to-Wheel CO_2 reductions



THANK YOU !

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