Ultra-Low PN Emissions of a Close-Coupled Emission Control System on a Heavy-duty Truck Application

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AECC
ASSOCIATION FOR EMISSIONS CONTROL BY CATALYST

Association for Emissions Control by Catalyst (AECC AISBL)

AECC members : European Emissions Control companies

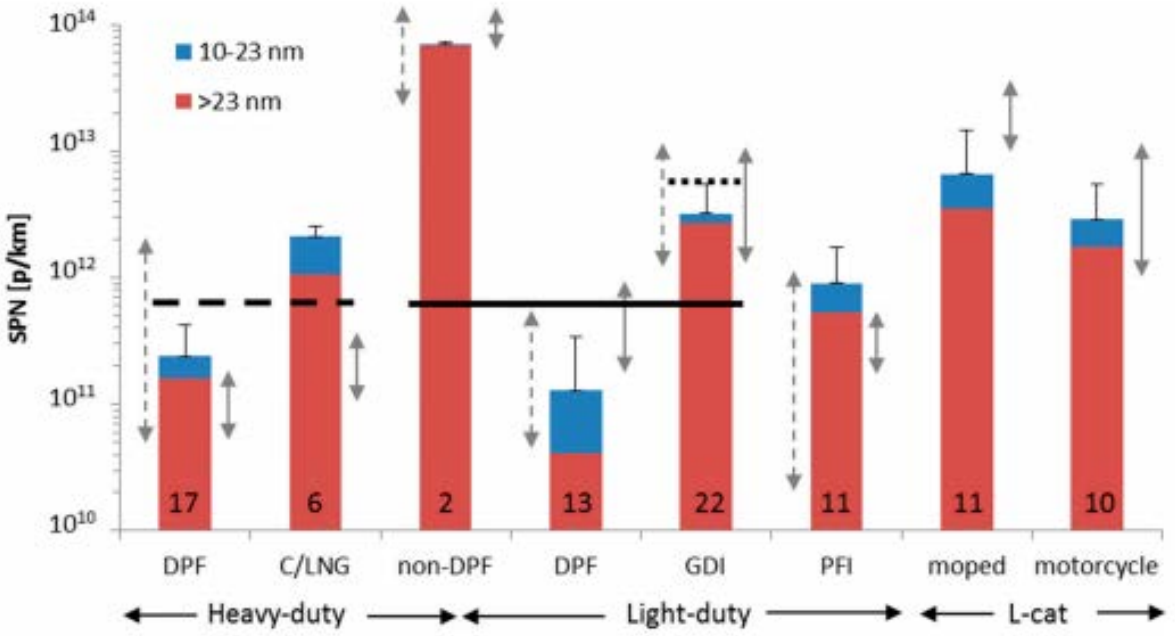
- Exhaust emissions control technologies for original equipment, retrofit and aftermarket for all new cars, commercial vehicles, motorcycles, and non-road mobile machinery
  - AECC is listed as # 78711786419-61 in EU Transparency Register and has consultative status with the UN Economic and Social Council (ECOSOC)

Content

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

Pollutant emissions significantly reduced towards Euro VI

- Diesel PN23 emissions for Euro VI vehicles
- Reference data of relationship between PN23 vs. PN10 on Euro VI applications



Source: "Solid Particle Number Emission Factors of Euro VI Heavy-Duty Vehicles on the Road and in the Laboratory", B. Giechaskiel, et al.; Int. J. Environ. Res. Public Health 2018

Euro 7/VII process

- The AGVES expert working group met until end of April 2021
- CLOVE consortium studies expected to finish by Q2/2021
  - Scenarios presented for light- and heavy-duty vehicles
  - Will provide further input for the European Commission impact assessment
- The European Commission proposal is expected within 2021
  followed by trialogue negotiations with European Parliament and Council

Euro 7/VII process

- CLOVE scenarios for heavy-duty vehicles
  - Testing conditions
    - Extract of table
  - Emission limits for normal conditions for HD diesel assessment
    - Combination of cold-start budget with Moving Average Window (MAW) values for 90th and 100th percentile
    - For 300/700k km, further deterioration factors for 700/1200k km are being evaluated by CLOVE

Parameter	EURO 7 Normal conditions	EURO 7 Extended conditions
Amb. temperature [°C]	-7°C to 35°C	-10 to +45 C (1)
Cold start	Test evaluation from engine start on; no weighting of cold start	Test evaluation from engine start on; no weighting of cold start
Windows	90% (with lower limit) + 100% (with higher limit)	As normal but Limits x 2 to cover all conditions
Payload	0%-100%	0%-100%
Max. altitude [m]	1600 m	2200m
Minimum km before testing	3.000 km	all
Durability [km]	N2, N3<16t, M3: 700k km (3) N3 > 16t: 1,200k km	N2, N3<16t, M3: 700k km (3) N3 > 16t: 1,200k km

100 Percentile Limit	NOx	SPN_{10}	PM	CO	NMOG	NH3	N2O*	CH4*
HD 2 (opt. +cc SCR diesel)	350	5.0E+11	12	3500	200	65	160	100
HD 3 (as HD2+pre-heat)	175	5.0E+11	12	1500	75	65	160	85

90 Percentile Limit	NOx	SPN10	PM	CO	NMOG	NH3	N2O*	CH4*
HD 2 (opt. +cc SCR diesel)	90	1.0E+11	8	200	50	65	60	50
HD 3 (as HD2+pre-heat)	90	1.0E+11	8	200	50	65	60	50

„Budget“ ≤ 3 x WHTC work	NOx	SPN_{10}	PM	CO	NMOG	NH3	N2O*	CH4*
HD 2 (opt. +cc SCR diesel)	150	2.0E+11	10	1250	75	65	140	30
HD 3 (as HD2+pre-heat)	100	2.0E+11	10	600	50	65	140	30

HD demonstrator vehicle

- 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

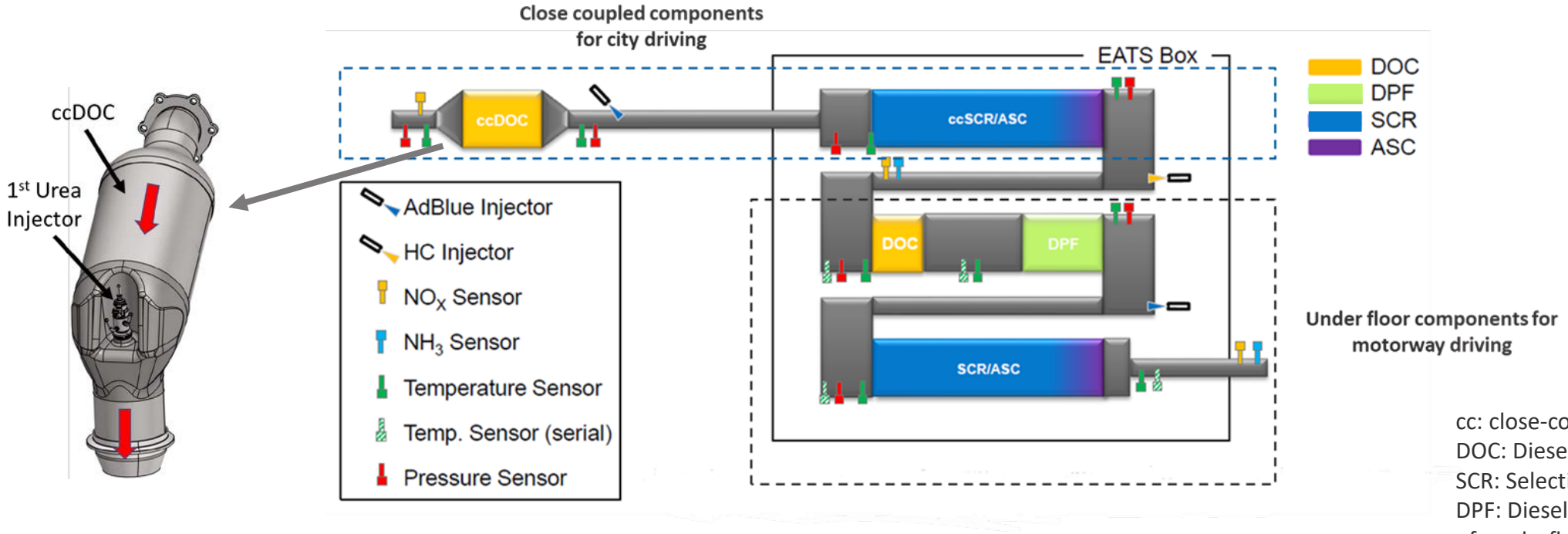
CORNING

Automotive Grade Urea Sector Group

cefic sector group

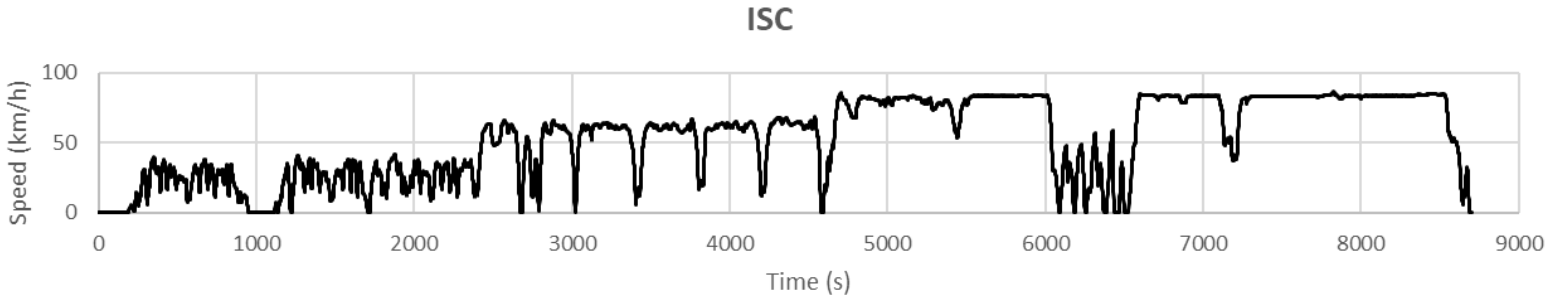
Demonstrator concept: emissions control technologies

- ccDOC + ccSCR/ASC + DOC + cDPF + ufSCR/ASC
  - Better integration of proven emission reduction technology in a commercially feasible manner
  - Hydrothermal aged components targeting 500k km

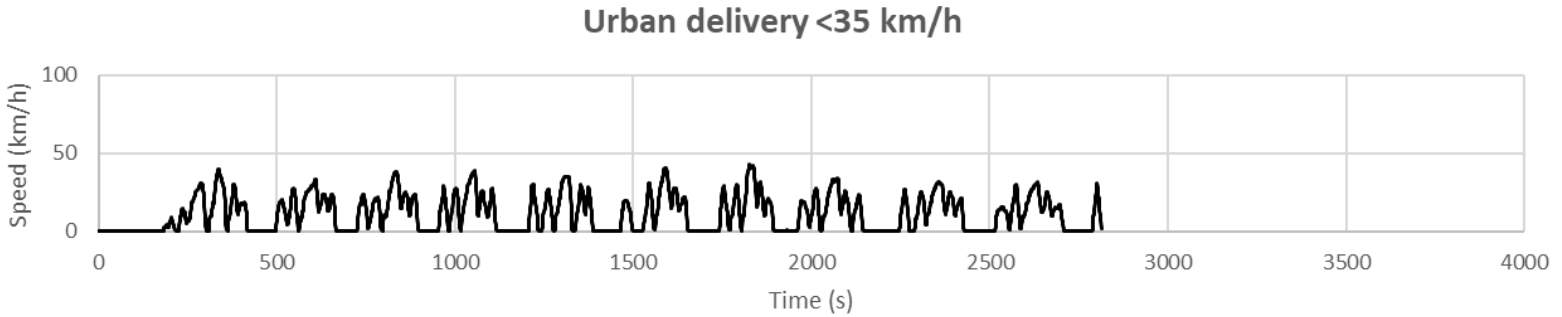


cc: close-coupled
DOC: Diesel Oxidation Catalyst
SCR: Selective Catalytic Reduction
DPF: Diesel Particulate Filter
uf: underfloor
ASC: Ammonia Slip Catalyst

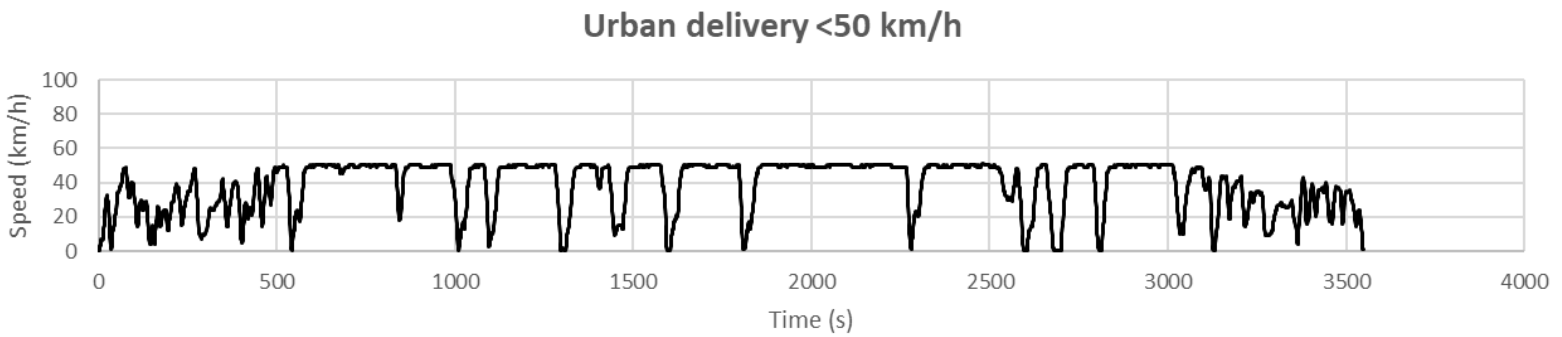
Trip profiles for on-road testing



- T_{amb}: 1 to 16 °C
- Payload: 10 & 50 %



- T_{amb}: 4 to 13.5 °C
- Payload: 10 & 50 %



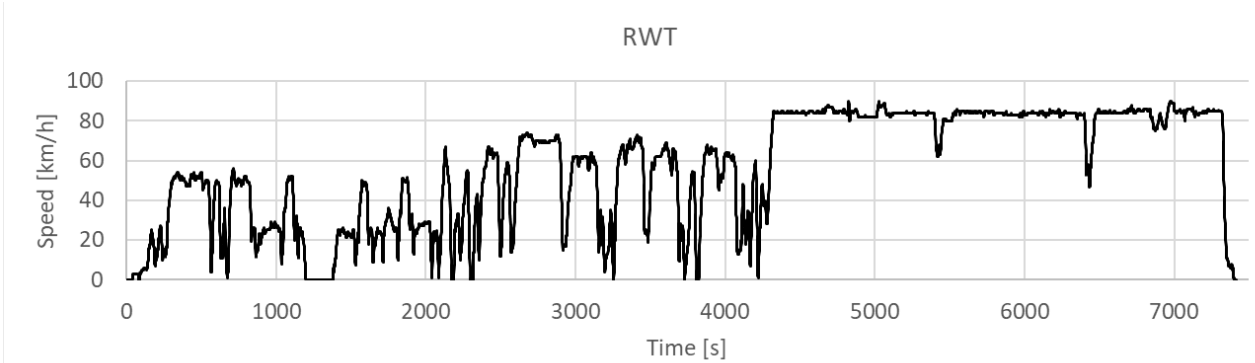
- T_{amb}: 4 to 8 °C
- Payload: 10 & 50 %

Content as presented on the 42nd International Vienna Motor Symposium

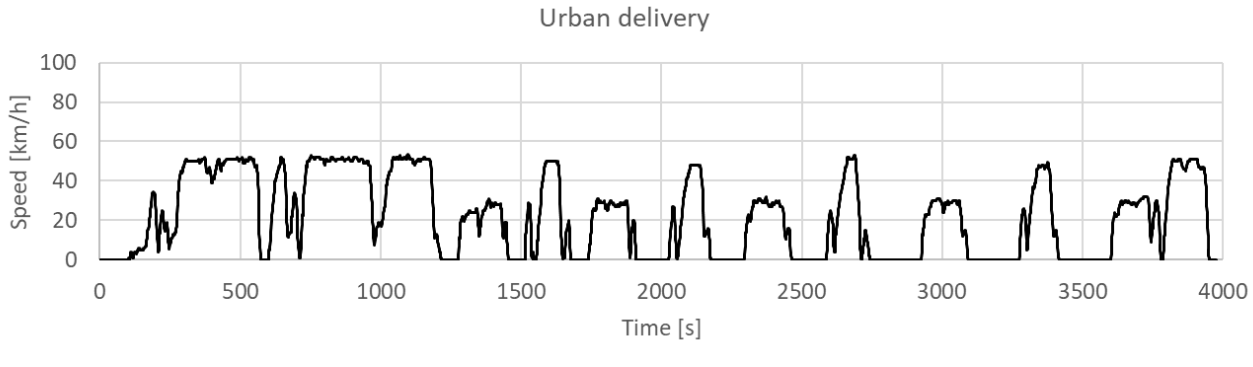
HD diesel demonstrator EC JRC campaign

- Dedicated testing campaign to measure gaseous and particulate emissions under cold (-7°C) and hot (35°C) ambient conditions
- Investigate severe case conditions for cold start without urea stored on the SCRs as well as with passively regenerated DPF
- Cover a wide range of driving conditions including urban, rural and motorway operation
- Results presented today cover the impact seen on SPN23, further analysis is being conducted on SPN10 results

Challenging cycles for chassis dyno testing



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

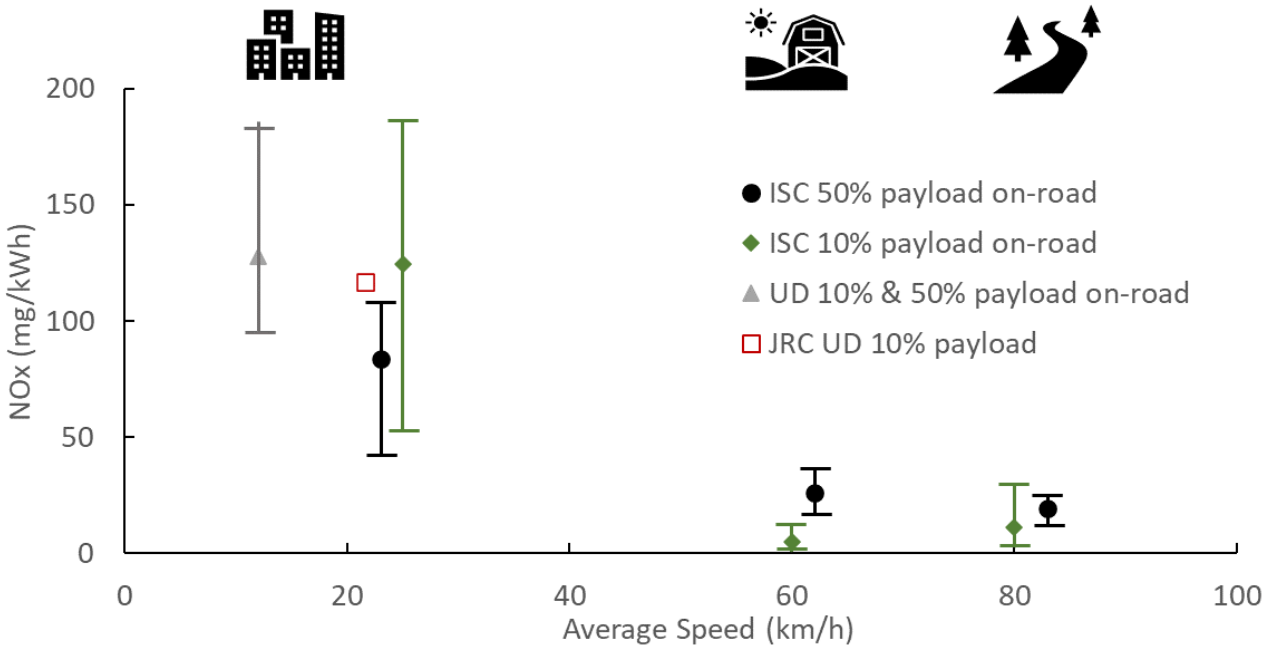


- T_{amb}: -7 °C
- Payload: 10 & 50 %

[1] RWT – Real World Test

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% payload
  - Tests covered a range of ambient temperatures from 4°C to 11°C
- Additional JRC chassis dyno test[2,3] 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. Results are binned by speed representing urban, rural and motorway operation
[2] Urban delivery completed at JRC contained several stops (~1, 2 & 3 min)
[3] JRC chassis dyno test result shown on this graph was conducted with urea storage in the SCRs

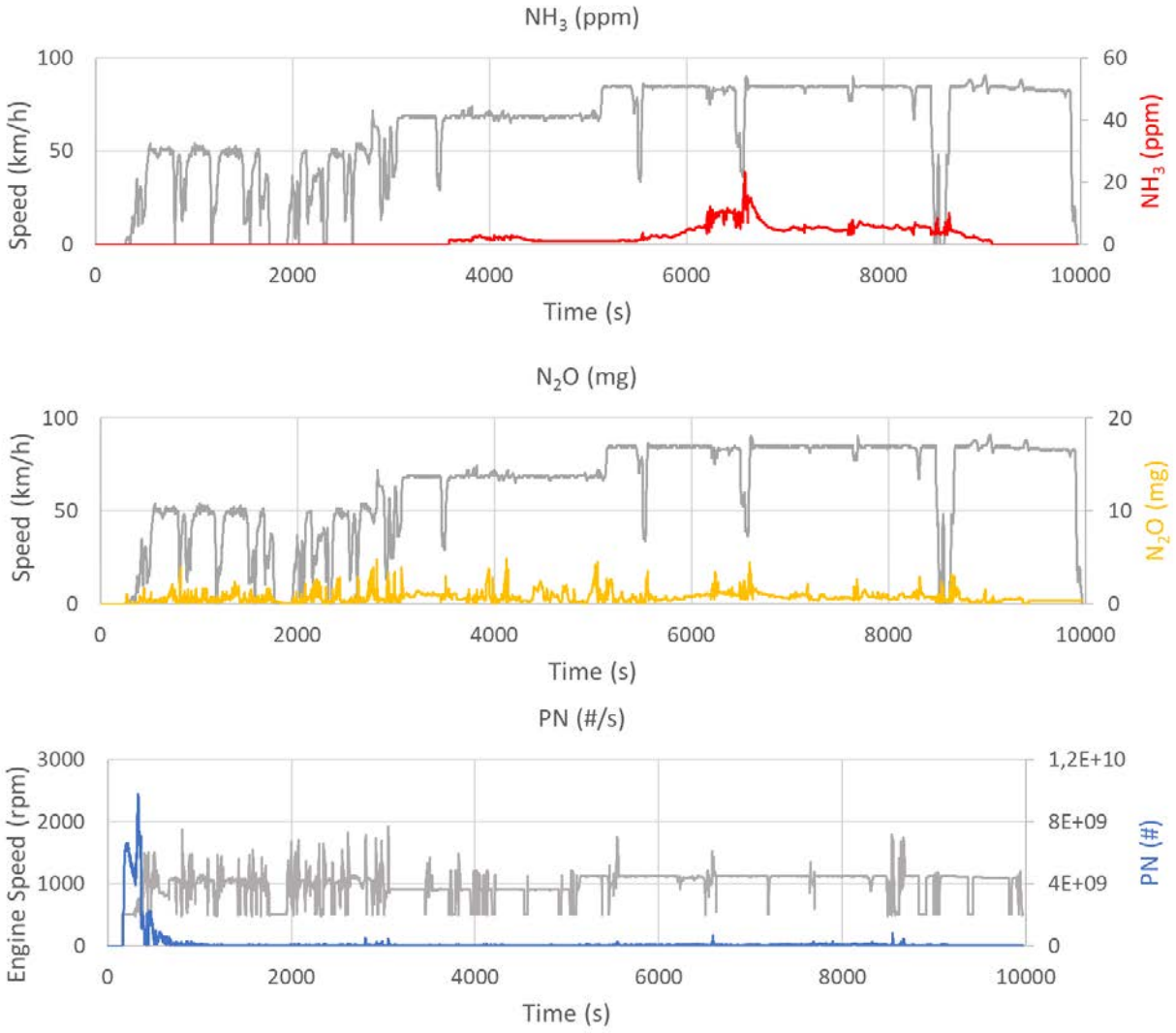
The results are reported as measured under the specified test routes and conditions

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

On-road non regulated emissions initial findings

- Preliminary results[1,3] show good control on NH_3, N_2O and PN10 during on-road testing
- Challenges expected towards combination of boundary conditions

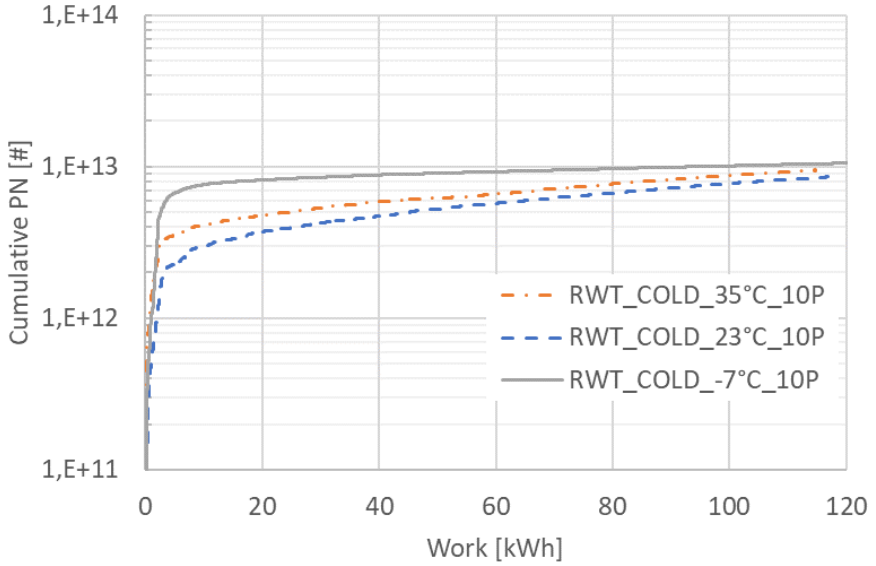
	NH_3	N_2O	PN_{10}
	(mg/kWh)	(mg/kWh)	(#/kWh)
Urban[2]	0,0	58,2	6,1E+10
Rural[2]	2,6	68,5	2,4E+09
Motorway[2]	13,0	35,2	2,3E+09
Total trip	6,9	45,3	3,1E+10



[1] ISC test performed with 10% payload and conducted at 10°C on-road
[2] Results are binned by speed representing urban, rural and motorway operation
[3] The results are reported as measured under the specified test routes and conditions
Content as presented on the 42nd International Vienna Motor Symposium

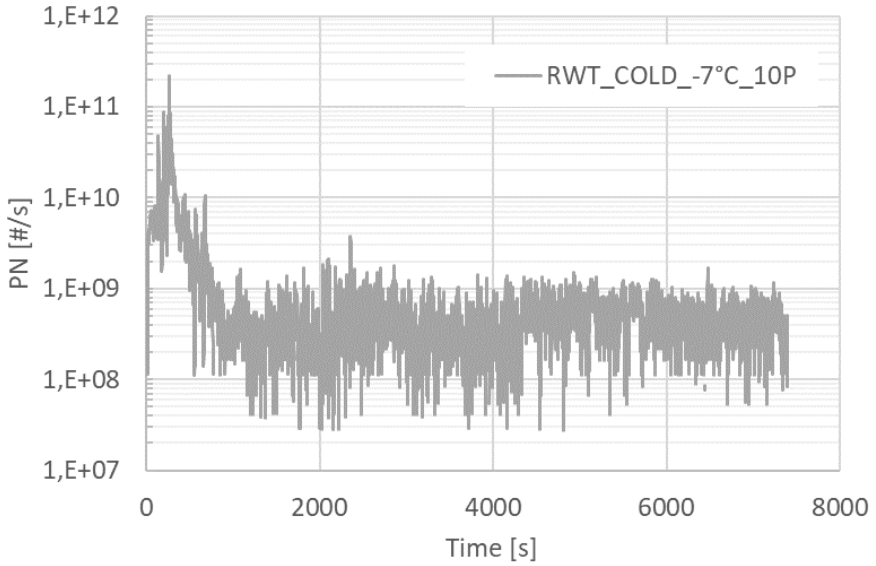
HD diesel demonstrator EC JRC campaign

- Temperature effect was investigated at -7, 23 & 35°C within a Real World Test (RWT) cycle containing urban, rural and motorway shares of operation[1]



	PN23 #/kWh @ 1xWHTC
RWT COLD -7°C	2,90E+11
RWT COLD 23°C	1,43E+11
RWT COLD 35°C	1,81E+11

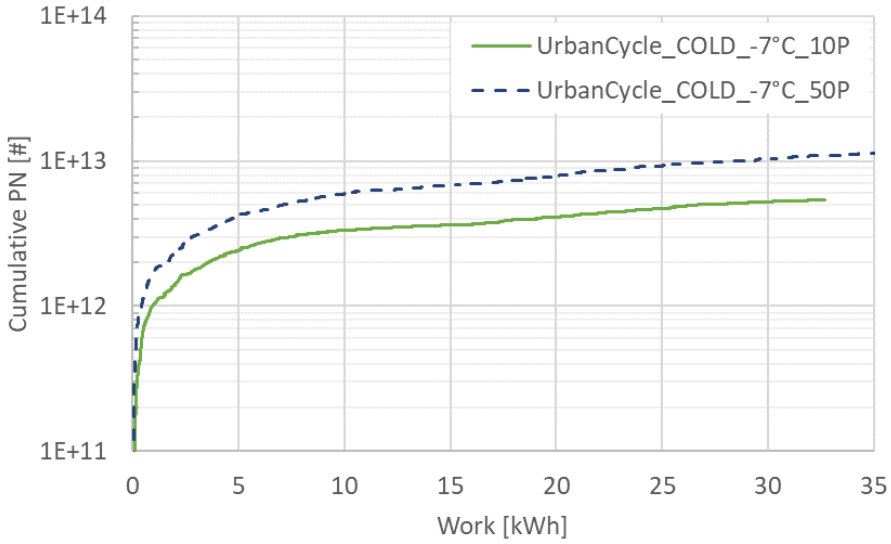
* Considering ref WHTC work 29,4kWh & all tests perfomed with 10% payload

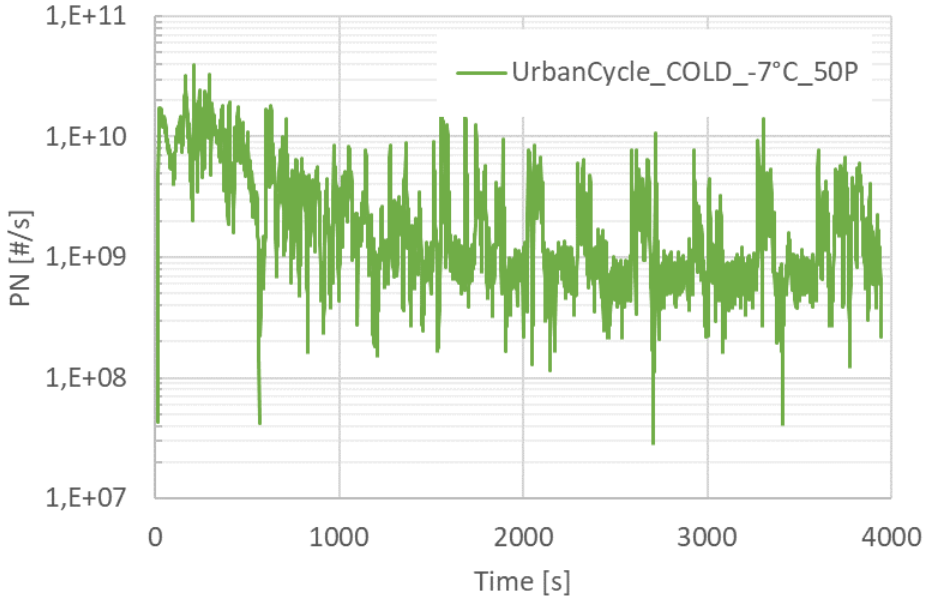


[1]Tests were conducted with empty urea storage SCR and passively regenerated DPF unless indicated otherwise, all PN 23 data as measured in the CVS by the laboratory AVL particle counter
[2]WHTC metric is used to make results comparable

HD diesel demonstrator EC JRC campaign

- Specific cycles were investigated for urban delivery with a number of stops with 1, 2 & 3 min duration[1] and different payloads
- Result show payload impact the PN23 emissions between 10% and 50% payload





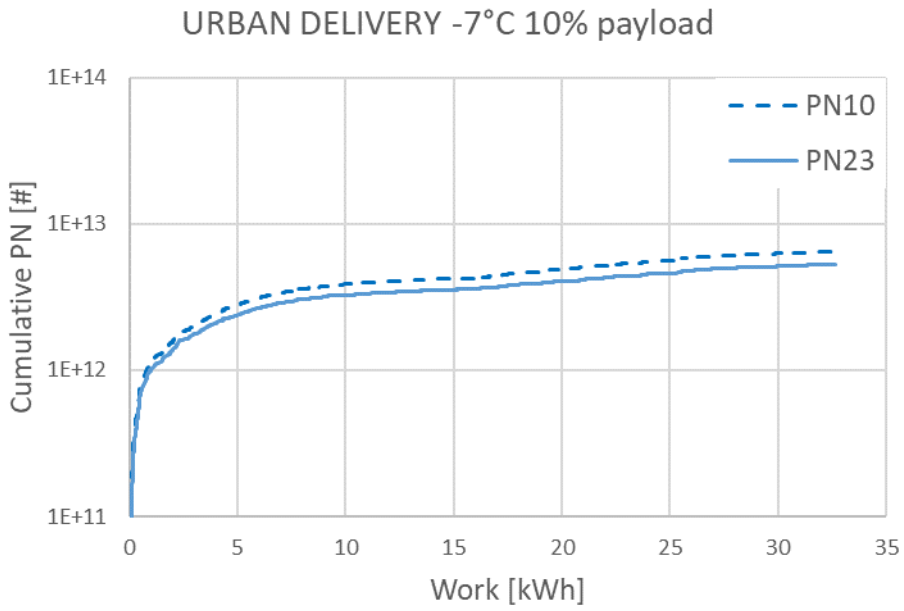
	PN23 #/kWh @ 1xWHTC
URBAN COLD -7°C 10P	1,76E+11
URBAN COLD -7°C 50P	3,43E+11

* Considering ref WHTC work 29,4kWh

[1]Tests were conducted with empty urea storage SCR and passively regenerated DPF unless indicated otherwise, all PN 23 data as measured in the CVS by the laboratory AVL particle counter
[2]WHTC metric is used to make results comparable

HD diesel demonstrator EC JRC campaign

- PN 10[1,2] fraction is being analysed by JRC
- Preliminary result show PN10 fraction is relatively small but impact the specific particulate results (~20%)



	PN23 #/kWh @ 1xWHTC
URBAN COLD -7°C 10P PN10	2,12E+11
URBAN COLD -7°C 10P PN23	1,73E+11

* Considering ref WHTC work 29,4kWh

[1] Tests were conducted with empty urea storage SCR and passively regenerated DPF unless indicated otherwise, all PN 23 data as measured in the CVS by the laboratory AVL particle counter
[2] PN 10 was measured also with AVL particle counter
[3] WHTC metric is used to make results comparable

Summary

- Motivation of the AECC HD demo vehicle is to reduce remaining NOx and particulate emissions mainly within urban operation, as seen on Euro VI vehicles
- The innovative emissions control system layout integrates proven emission reduction technology in a commercially feasible manner
- On particulates, chassis dyno test results confirm the good performance of the emission control system and the impacts of several parameters are being studied
- Results show low non-regulated emissions can be achieved
- AECC continues to demonstrate technologies are available today to effectively control emissions from ICEs under real-world operation

Outlook

- Further evaluation of other boundary conditions (i.e. 100% payload, other preconditioning status) and PN10 impact needs to be understood and test further
- AECC HD demo vehicle project objective is to further reduce NOx and particulate emissions mainly observed in urban operation on Euro VI vehicles
- Follow-up activities will investigate EHC to further reduce initial cold-start emissions
- Validate ultra-low pollutant emissions on sustainable renewable fuels for low CO_2 emissions

THANK YOU !

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