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

Pablo Mendoza Villafuerte, Joachim Demuynck, Dirk Bosteels

AECC AISBL

Patrick Recker, Thomas Wilkes, Lynzi Robb

FEV Europe GmbH



# Content

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



# Euro 7/VII process

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- 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 triologue negotiations with European Parliament and Council



# Euro 7/VII process

- CLOVE scenarios for heavy-duty vehicles
  - Testing conditions
  - 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 <sup>(1)</sup>
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 <sup>(3)</sup> N3 > 16t: 1,200k km	N2, N3<16t, M3: 700k km <sup>(3)</sup> N3 > 16t: 1,200k km

100 Percentile Limit	NOx	SPN <sub>10</sub>	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	SPN <sub>10</sub>	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 <sub>10</sub>	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 and project partners

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

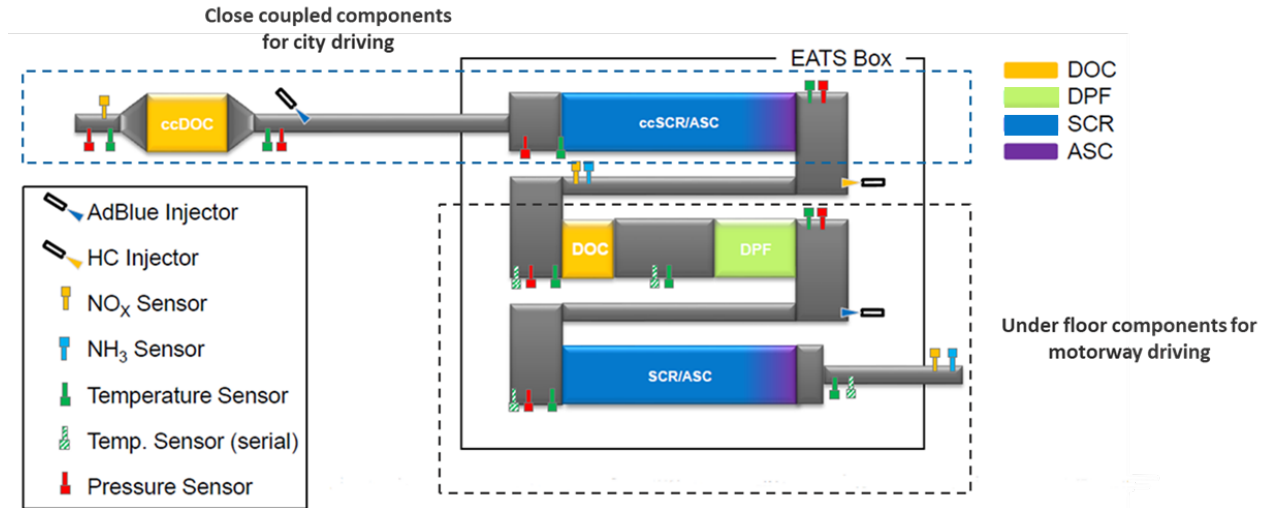


Automotive Grade  
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# HD demonstrator vehicle concept: emissions control technologies

- 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



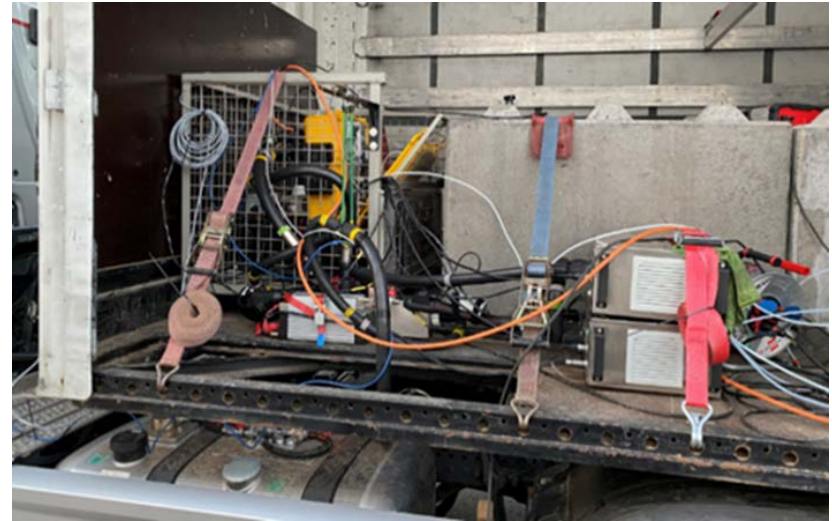
AECC HD demonstrator video can be seen at:  
<https://www.youtube.com/watch?v=MXBnhZMzISY>

DOC: Diesel Oxidation Catalyst  
SCR: Selective Catalytic Reduction  
DPF: Diesel Particulate Filter  
ASC: Ammonia Slip Catalyst

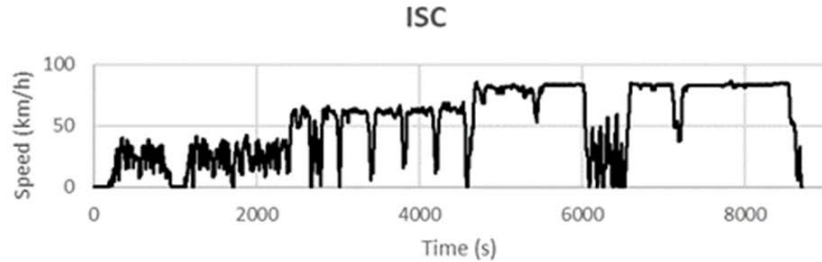
# HD demonstrator vehicle PEMS campaign

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- On-road test campaign to measure gaseous and particulate emissions a broad range of driving conditions
- Investigate urban delivery trips varying the duration of the stops (1, 2 and 3-min in idle)
- Cover a wide range of driving conditions including urban, rural and motorway operation



# Challenging cycles for on-road testing



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



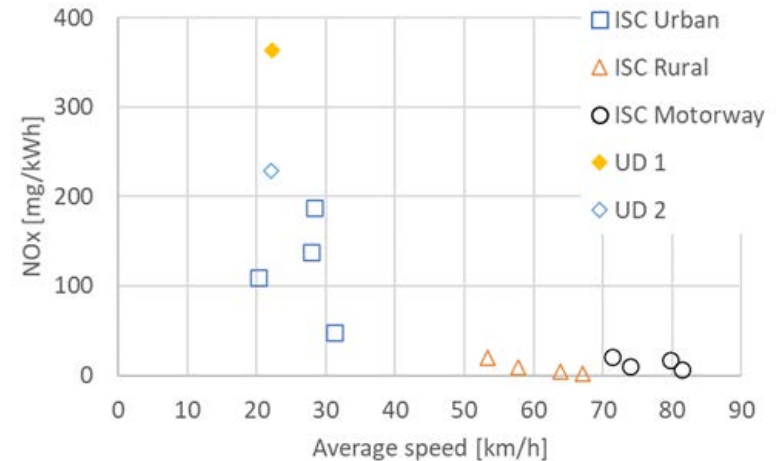
- $T_{amb}$ : 8 to 10 °C
- Payload: 10 %





# Ultra-low NOx achieved in urban operation

- Integrated system including close-coupled catalysts and heating measures ensure quick heat up of the emission control system
- Ultra-low NOx emissions are feasible over a broad range of operating conditions<sup>1,2,3</sup>



<sup>1</sup> Urban delivery (<50 km/h) with stops (varying from 1-3 min duration), total trip duration is ~1 hour and work completed is about 23-25 kWh

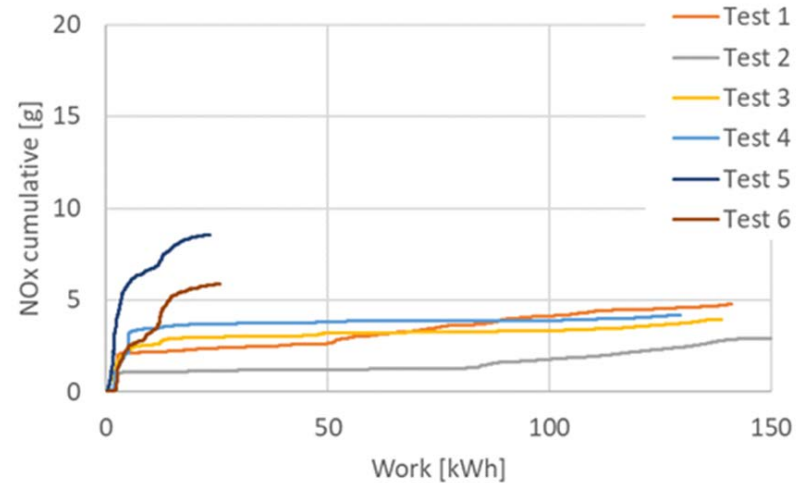
<sup>2</sup> ISC N3 Euro VI route

<sup>3</sup> The results are reported as measured under the specified test routes and conditions and cover a range of ambient temperatures from 4-10 °C



# Cold start NOx emissions remaining challenge

- NOx results<sup>1,2,3</sup> show that cold-start remains the main emission event
- The close-coupled catalysts result in a shortened heat-up time of the system
- Emissions are well controlled once the system is warm



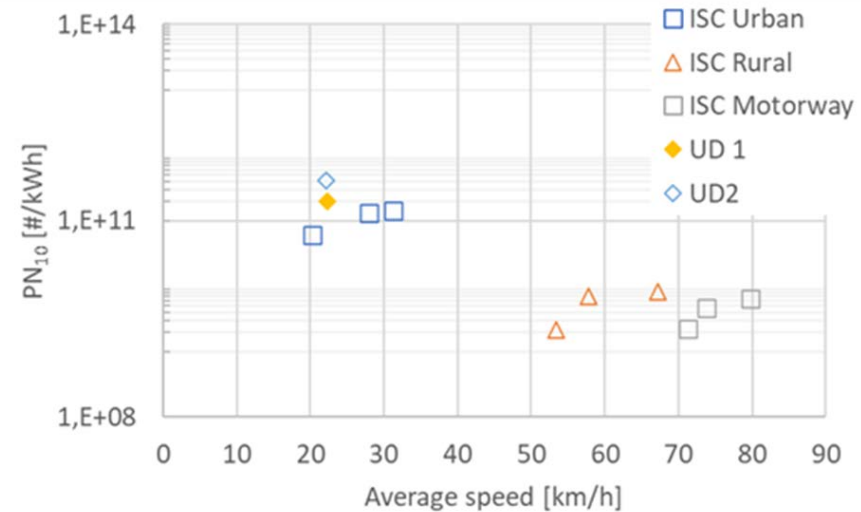
<sup>1</sup> Urban delivery (<50 km/h) with stops (varying from 1-3 min duration), total trip duration is ~1 hour and work completed is about 23-25 kWh

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# PN10 emissions are impacted by temperature and payload

- Low PN10 achieved within broad range of driving conditions
- Most PN10 emissions are produced within the cold-start of the trip
- Tests are not covering all possible critical conditions for PN



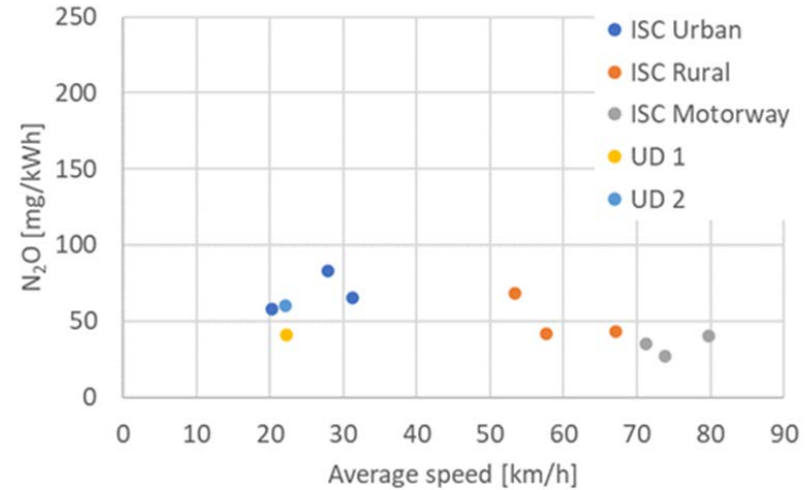
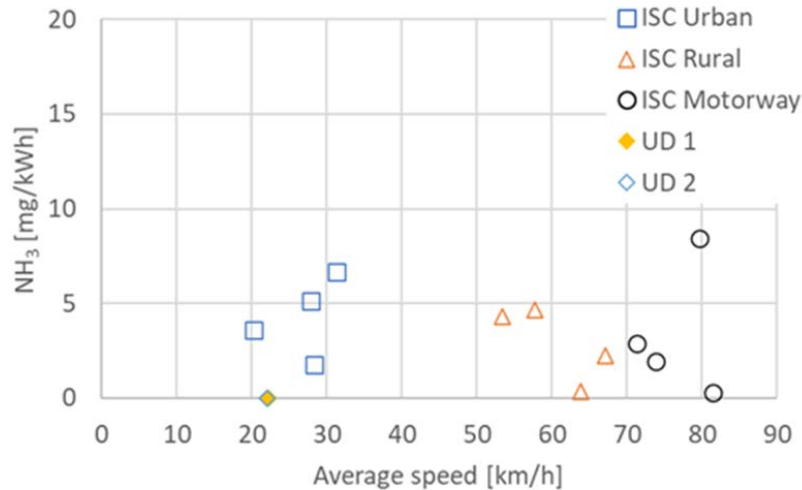
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# Low N<sub>2</sub>O and NH<sub>3</sub> emissions within broad range of operation

- Low N<sub>2</sub>O during high NO<sub>x</sub> conversion operation
- Near-zero NH<sub>3</sub> emissions in a broad range of operating conditions



# Summary and outlook

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- Ultra-low NOx 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 be achieved
- AECC continues to demonstrate technologies are available today to effectively control emissions from ICEs under real-world operation
- 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<sub>2</sub> emissions



# Thank you

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Pablo Mendoza Villafuerte


AECC AISBL

Bd. Auguste Reyers80, 1030 Brussels

+3227068164

[Pablo.Mendoza-Villafuerte@aecc.eu](mailto:Pablo.Mendoza-Villafuerte@aecc.eu)

 @AECC\_eu

 AECC (Association for Emissions Control by Catalyst)

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