Demonstration of Extremely Low NOx Emissions with Partly Close-Coupled Emission Control on a Heavy-duty Truck Application

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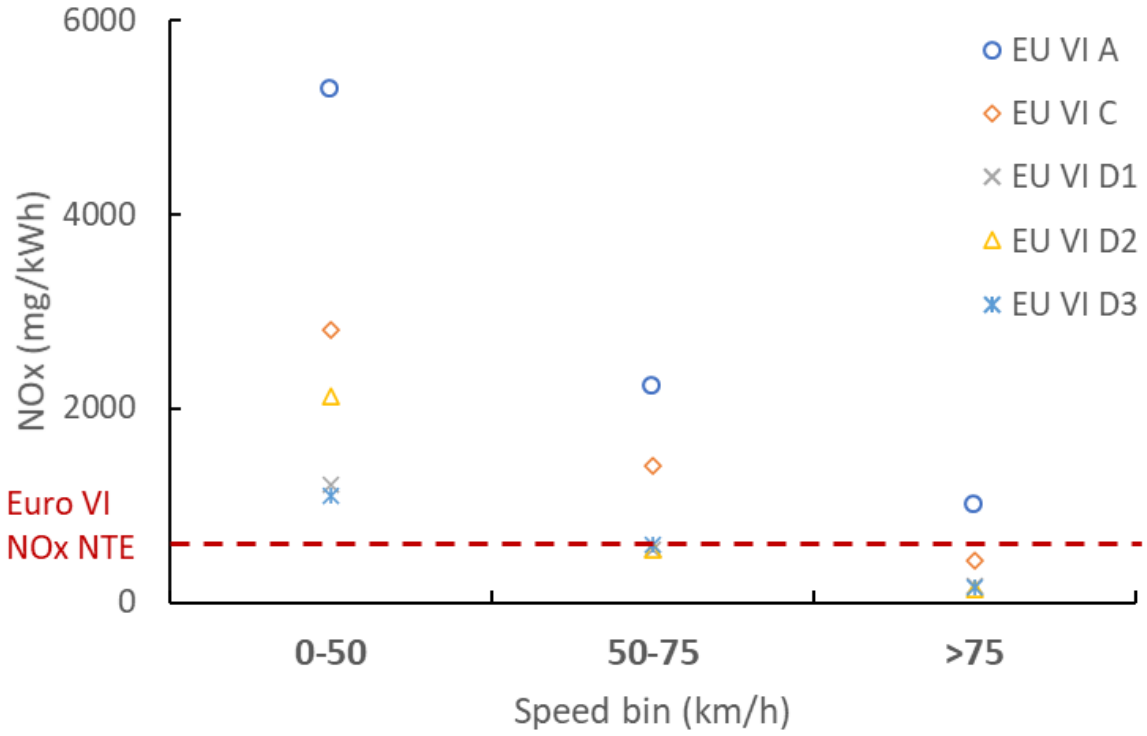
Motivation : Emissions from Euro VI vehicles

- Euro VI heavy-duty vehicles show low NOx emissions overall
- There are, however, remaining NOx emissions events, mainly within urban operation.



Examples of NOx emissions over different speed ranges for a Euro VI Step A N3 tipper, a Euro VI Step C N3 tractor, a Euro VI N2 Step D rigid distribution truck (D1), a Euro VI Step D N3 tractor tanker semi-trailer (D2) and a Euro VI Step D N3 tractor semi-trailer (D3) as presented by AECC at the AGVES meeting, July 2020.

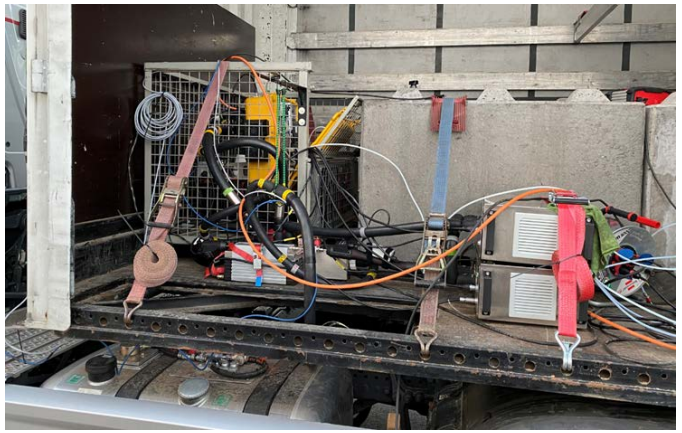
NTE – Not-to-exceed limit

Agenda

- Objective of the heavy-duty demonstrator vehicle project
- Demonstrator concept: emissions control technologies combined in integrated approach
- AECC HD diesel demo vehicle tailpipe emissions results
- Summary

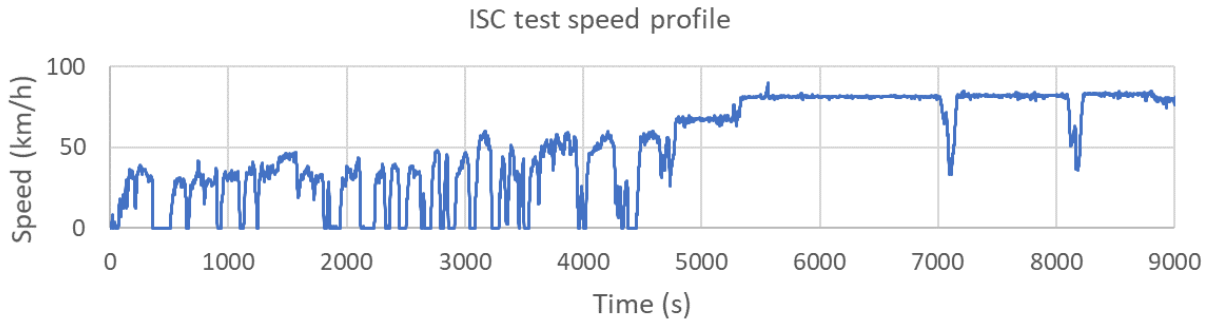
Objective: demonstrate ultra-low NOx emissions

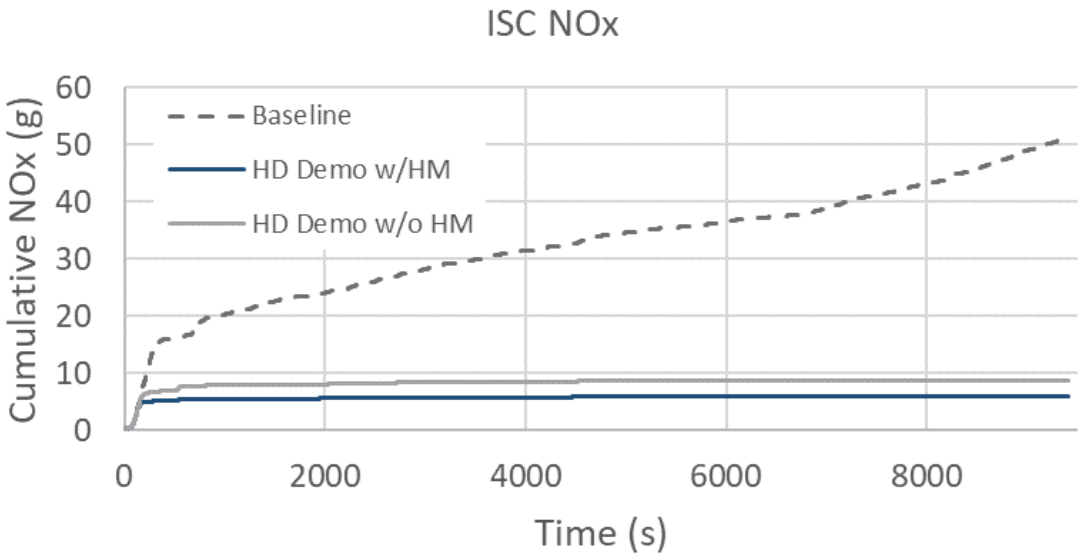
- In a broad range of driving conditions including cold start, urban and regional delivery
  - With minimum impact on CO_2
- Focus on on-road vehicle measurements
  - All calibration was performed on the road
  - PEMS testing has been used to verify and complement results
  - Both regulated and unregulated pollutants have been measured (N_2O, NH_3 and PN_{10}) during the PEMS campaign
- Vehicle: MB Actros, Euro VI C, 12.8 l, HP EGR, 450hp

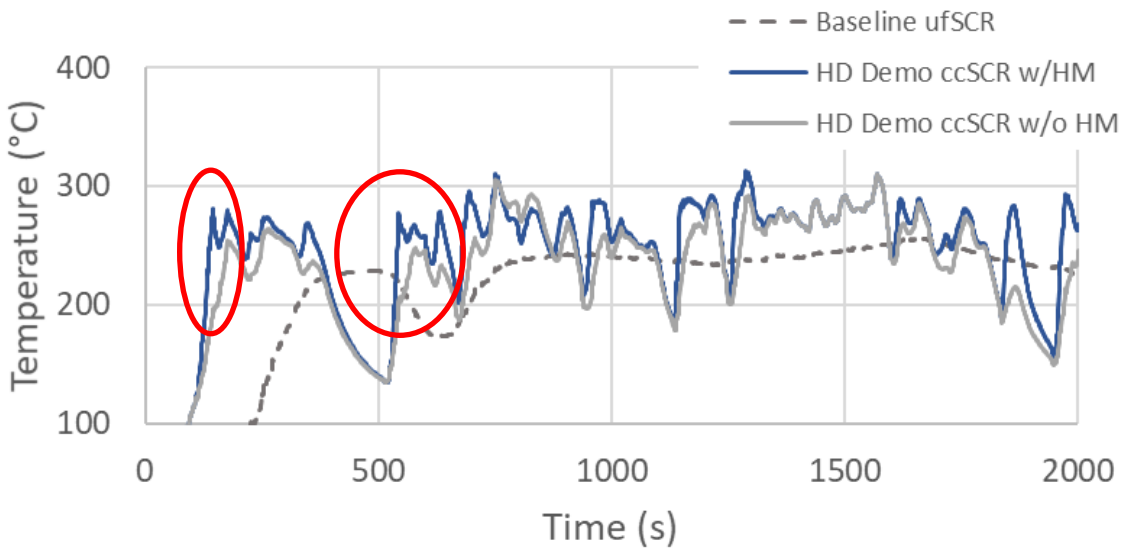


Concept phase simulation & technology assessment

- Simulation was conducted to investigate implementation of the new emissions control system layout with or without internal heating measures (HM)



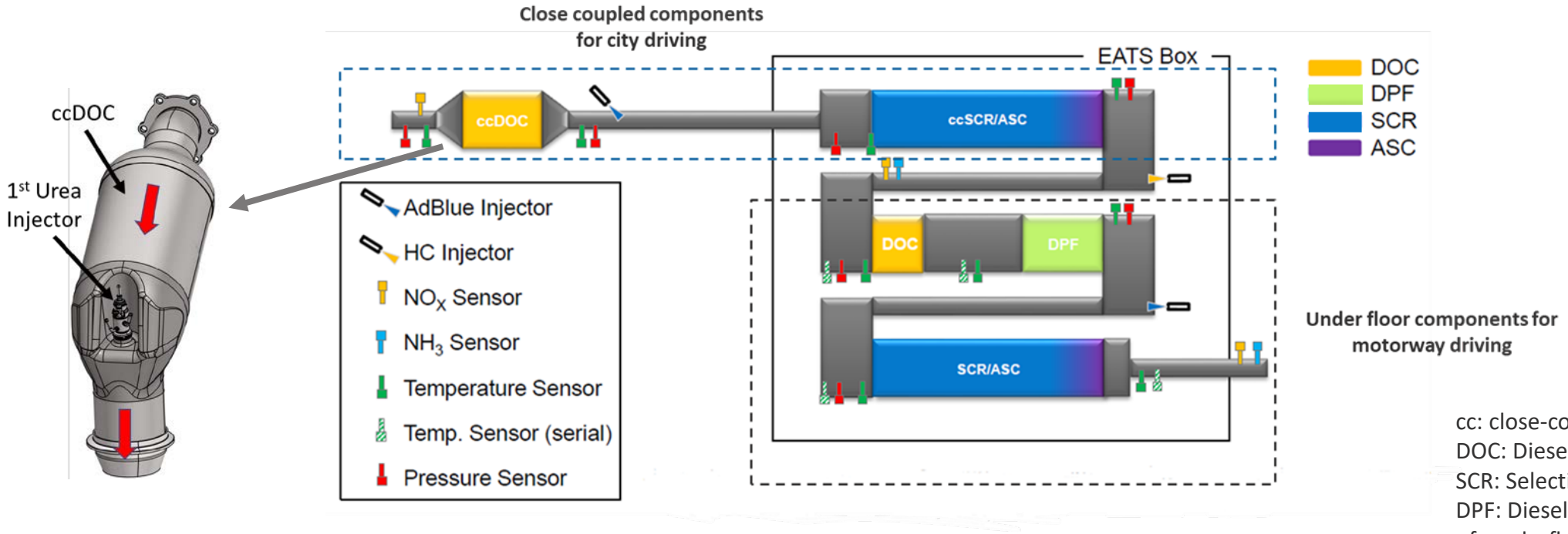




*Simulated performance for ISC route at ~20°C and 100% payload, HM – Heating Measures

Demonstrator concept: emissions control technologies

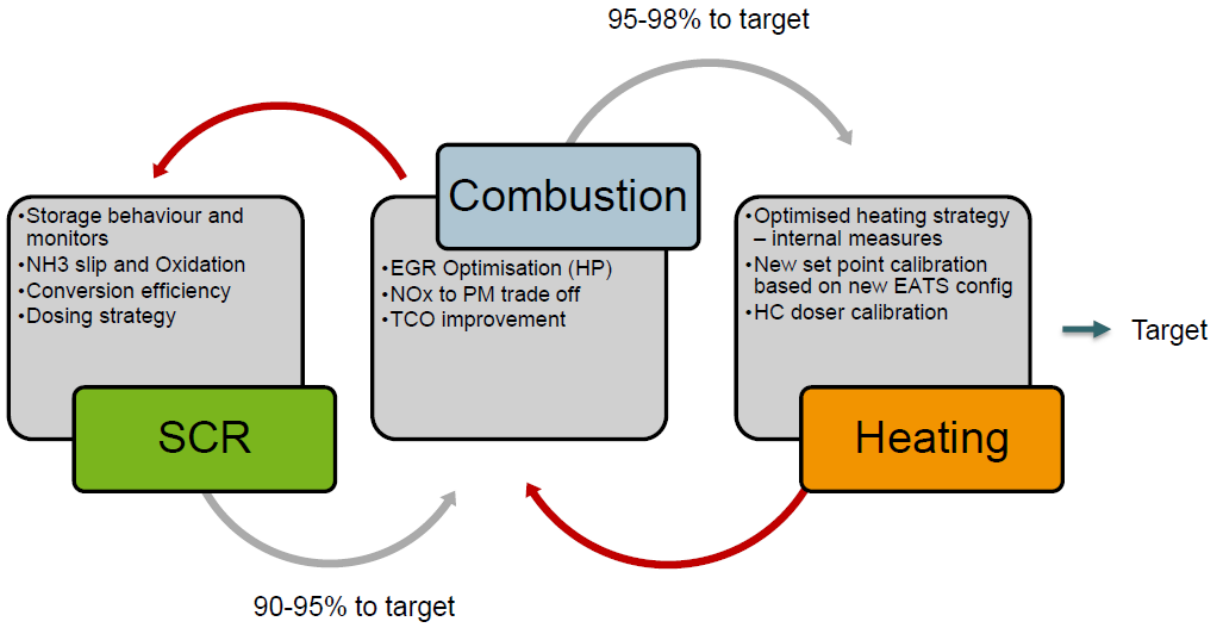
- ccDOC + ccSCR/ASC + DOC + cDPF + ufSCR/ASC
  - Better integration of proven emission reduction technology in a commercially feasible manner
  - Hydrothermal aged components targeting 500k km



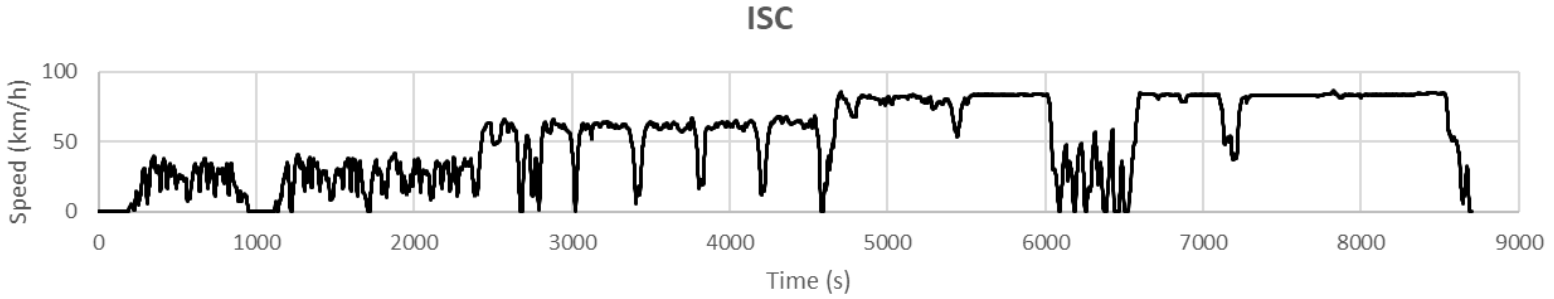
cc: close-coupled
DOC: Diesel Oxidation Catalyst
SCR: Selective Catalytic Reduction
DPF: Diesel Particulate Filter
uf: underfloor
ASC: Ammonia Slip Catalyst

Smart Integration of catalysts and engine operation

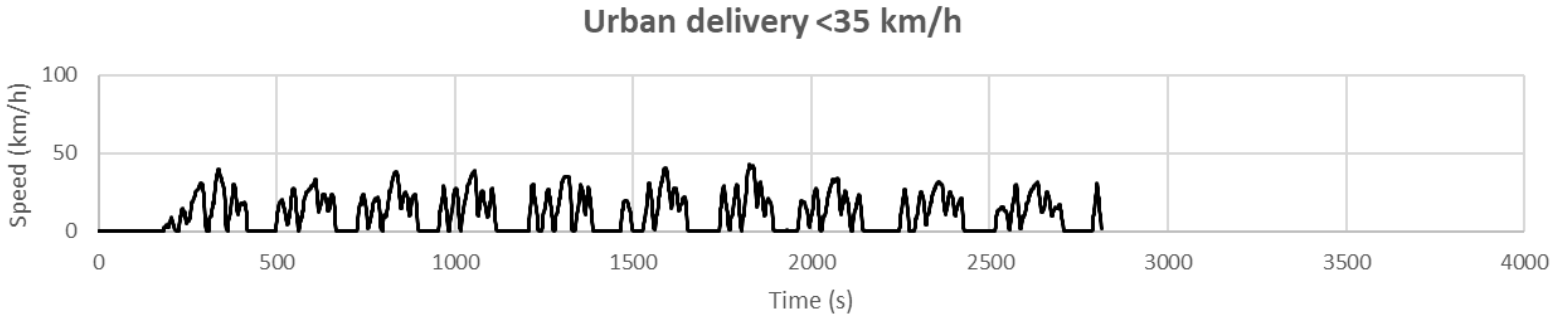
- Three calibration loops were conducted covering the SCR, combustion and heating measures
- During the calibration loops, data was obtained by NOx & NH_3 sensors installed in the system
- PEMS testing used to fine tune the calibration and to verify the regulated and non-regulated emissions results



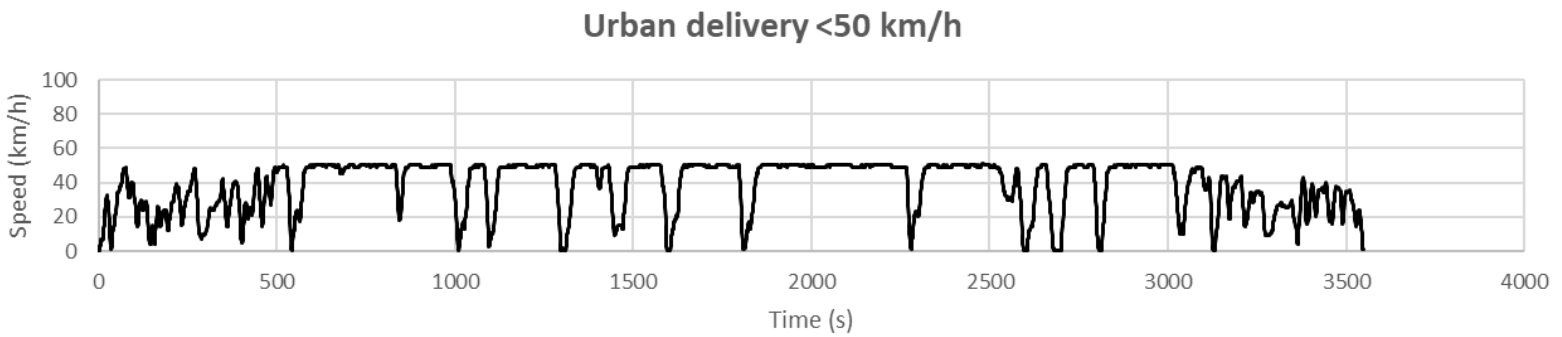
Challenging cycles have been applied for on-road testing



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



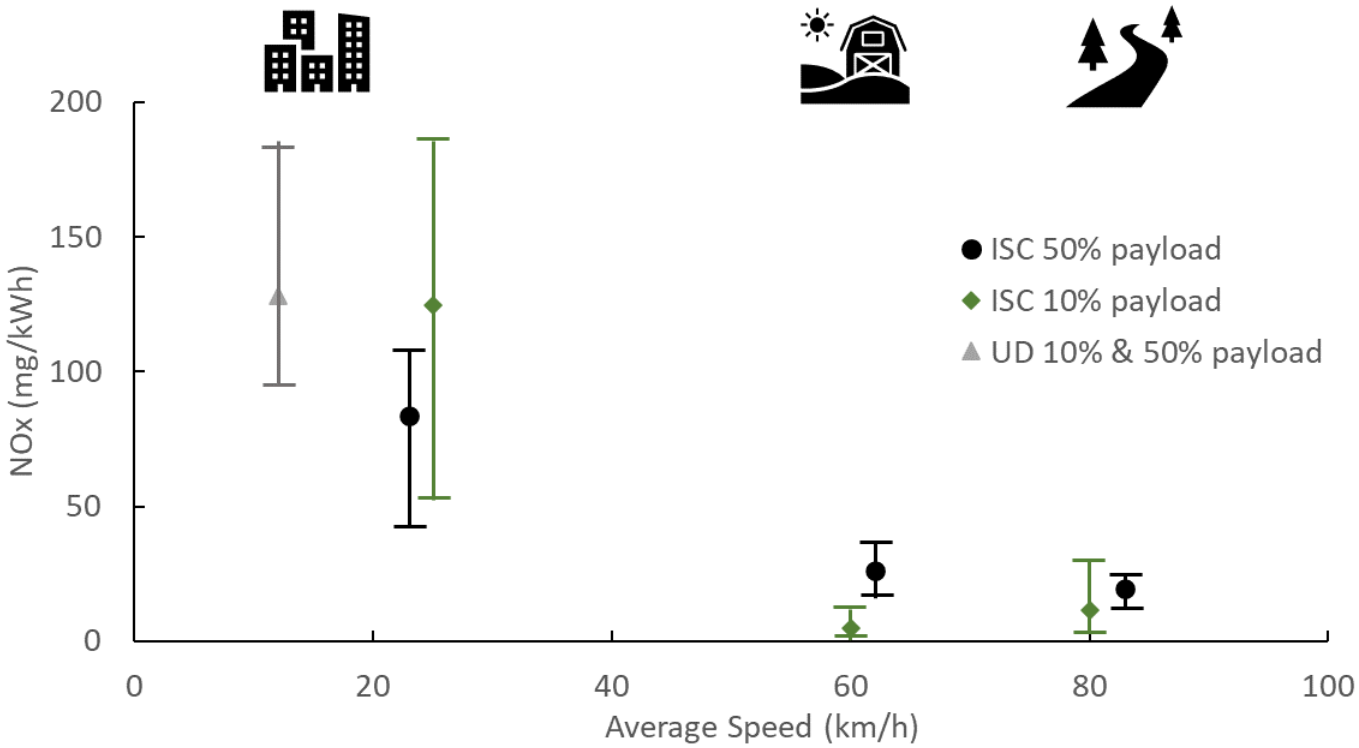
- T_{amb}: 4 to 13.5 °C
- Payload: 10 & 50 %



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

42 to 187 mg/kWh of NOx achieved in urban operation

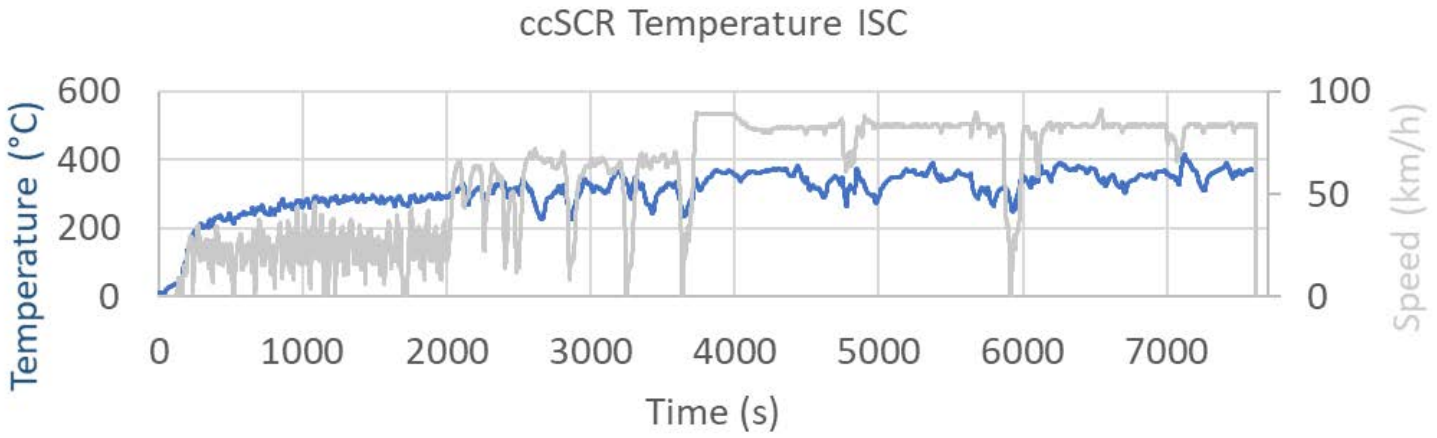
- Integrated system including close-coupled catalysts and heating measures ensure quick heat up of the emission control system
- Ultra-low NOx emissions are feasible over a broad range of operating conditions[1,2,3]

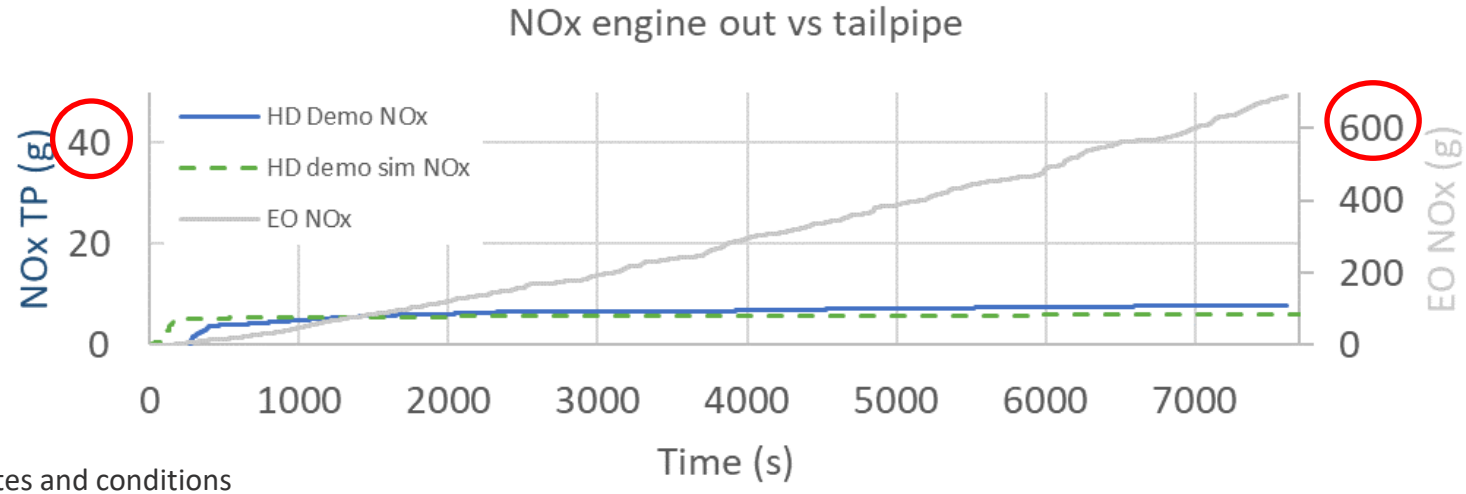


[1] Urban delivery (<35 km/h) with 10 stops (~1 min), total trip duration is ~1 hour and work completed is about 14-16 kWh
[2] ISC N3 Euro VI-c route
[3] The results are reported as measured under the specified test routes and conditions and cover a range of ambient temperatures from 4-11 °C

High DeNOx efficiency overall

- Initial simulation results confirmed with significant reduction of NOx during on-road testing[1,2]
  - Total engine out NOx = 690 g
  - Total tailpipe NOx = 7.9 g
- 98 % NOx reduction

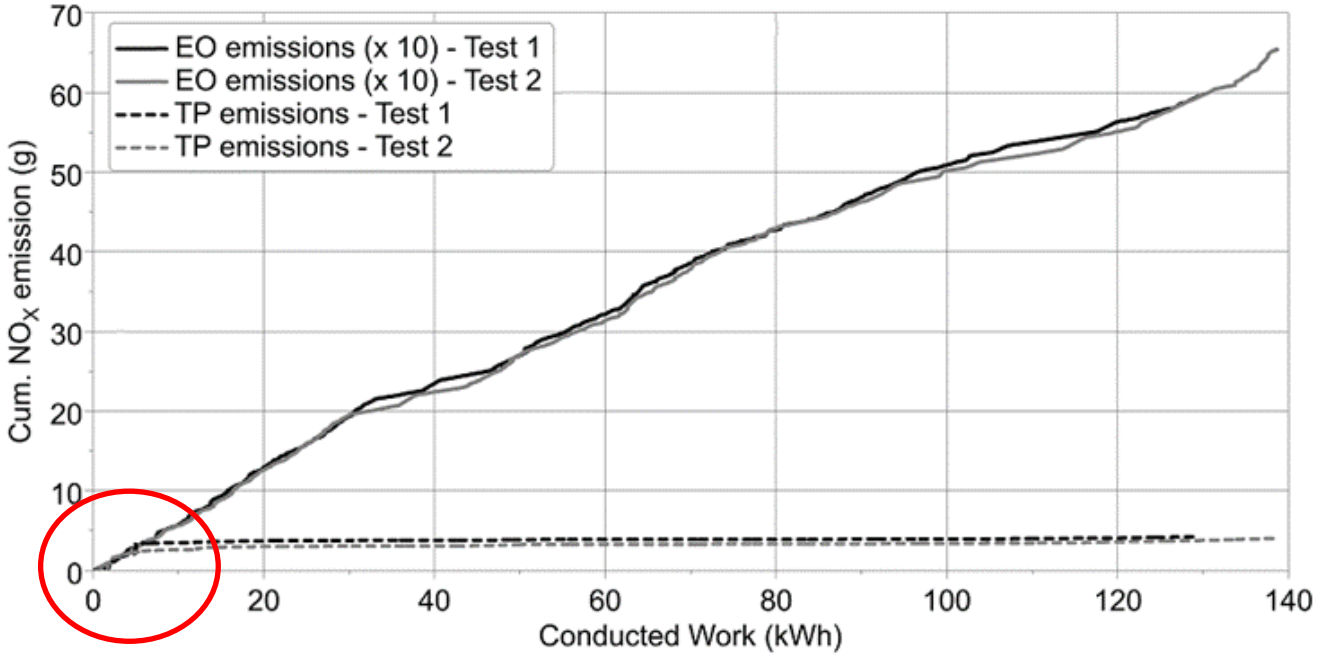




[1] ISC N3 Euro VI-c route, 10 °C ambient temperature, 50 % payload
[2] The results are reported as measured under the specified test routes and conditions

Cold start NOx emissions remaining challenge

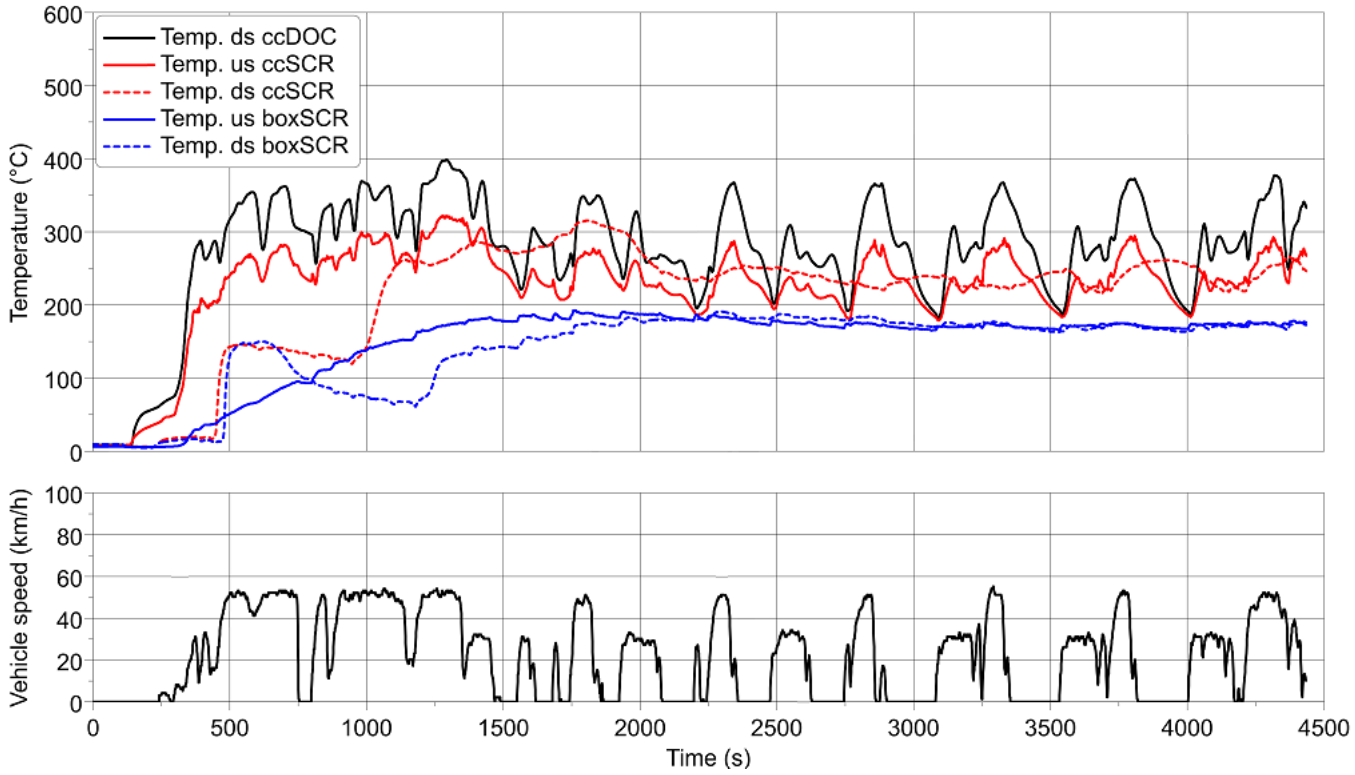
- NOx results[1,2] show that cold-start remains the main emission event
- The close-coupled catalysts result in a shortened heat-up time of the system
- Emissions are well controlled once the system is warm



[1] ISC tests performed with 10 % payload, Test 1 & 2 conducted at 8 °C and 10 °C respectively
[2] The results are reported as measured under the specified test routes and conditions

Beating the thermal challenge in urban operation

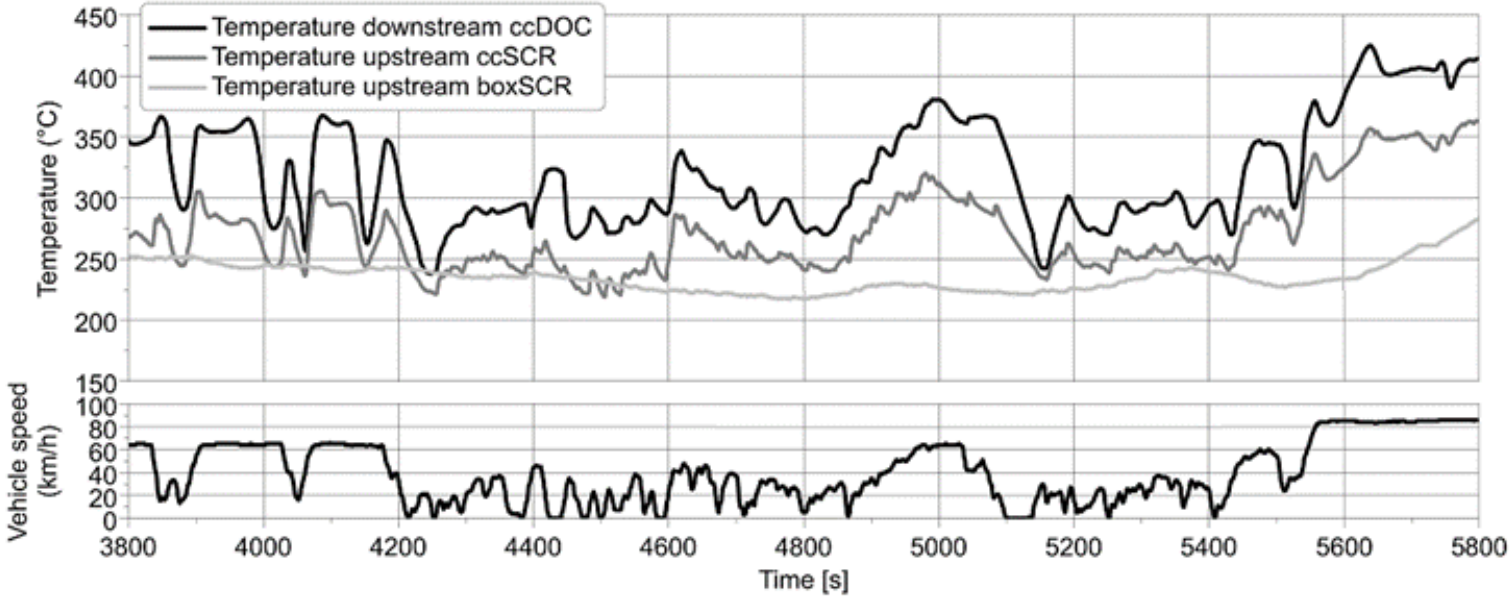
- Results[1,2] show the innovative system can hold its temperature through stop-go urban delivery operation
- The close-coupled catalysts and engine heating measures ensure a consistent thermal behavior



[1] Urban Delivery test performed with 10 % payload, at 10 °C. The trip combined short stops with duration between 1 to 3 minutes.
[2] The results are reported as measured under the specified test routes and conditions

Catalyst temperature is kept during heavy rural traffic

- The system demonstrates the ccSCR temperature is well kept during heavy traffic conditions within the rural driving[1,2]

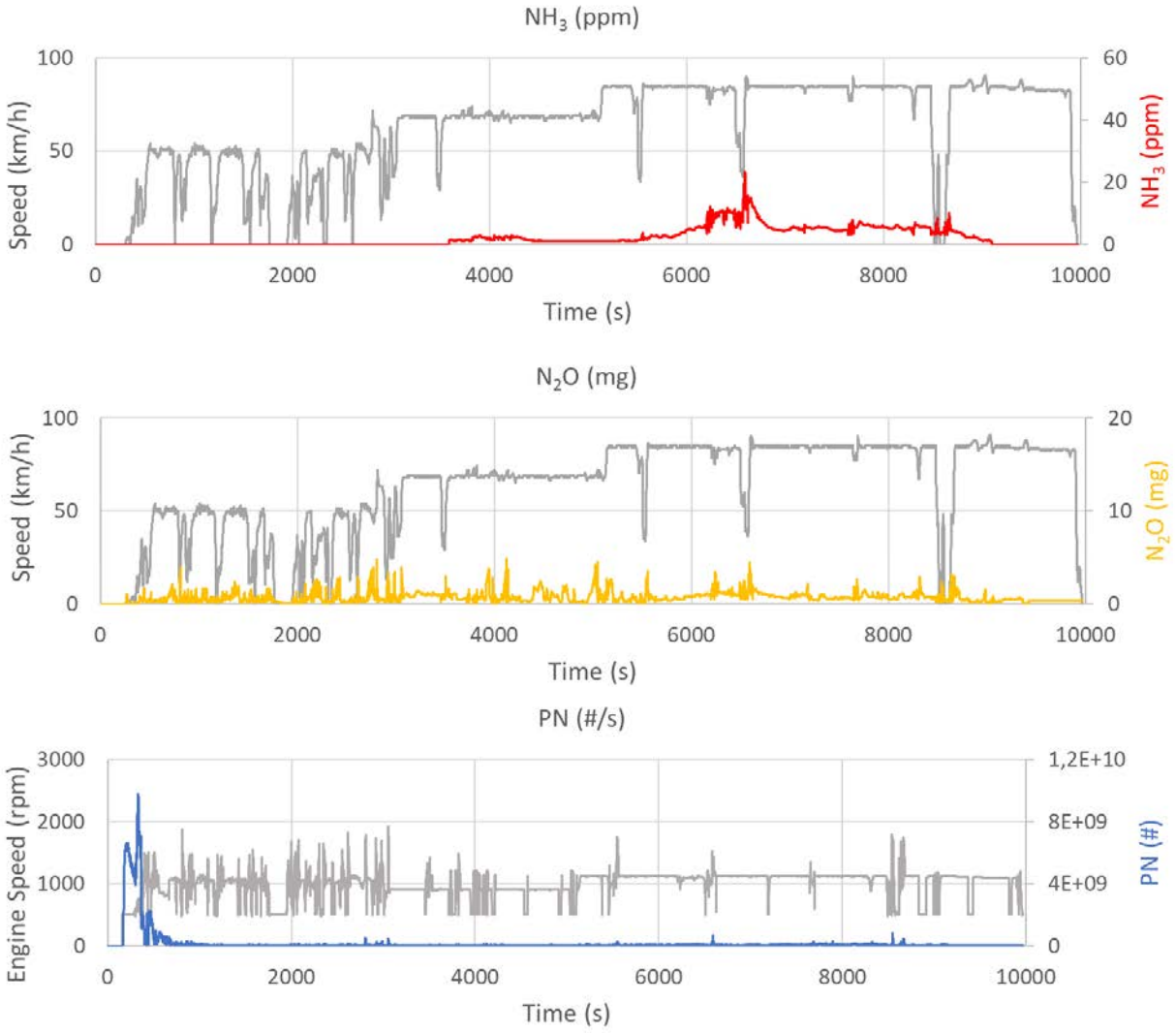


[1] ISC test performed with 10 % payload, at 8 °C. The figure represents 20 minutes peak time traffic during the rural section of the ISC with an average speed of 24 km/h
[2] The results are reported as measured under the specified test routes and conditions

Non regulated emissions are well controlled

- Preliminary results[1,2] show good control on NH_3, N_2O and PN_{10}
- Challenges are expected towards combination of boundary conditions to be tested further

	NH_3 (mg/kWh)	N_2O (mg/kWh)	PN_{10} (#/kWh)
Urban	0,0	58,2	6,1E+10
Rural	2,6	68,5	2,4E+09
Motorway	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
[2] The results are reported as measured under the specified test routes and conditions

Summary

- Motivation of this work was to control remaining NOx emission events mainly within urban operation seen on Euro VI vehicles
- Objectives and targets of the program on ultra low pollutant emissions and minimum CO2 impact have been met
- The innovative emissions control system layout integrates proven emission reduction technology in a commercially feasible manner
- 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
- Results show low non-regulated emissions can be achieved
- AECC will continue to demonstrate technologies are available today to effectively control emissions from ICE under real-world operation

THANK YOU !

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