Enabling Upcoming Euro 7 Standards by Advanced Emission Controls with Low CO_2 Emissions

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Keynote
FEV Diesel Powertrains 3.0 conference • 29-30 June 2021

Content

- Introduction
  - European Commission work programme 2021
  - Euro 7/VII process
  - AECC work on sustainable ICE
- Heavy-duty diesel
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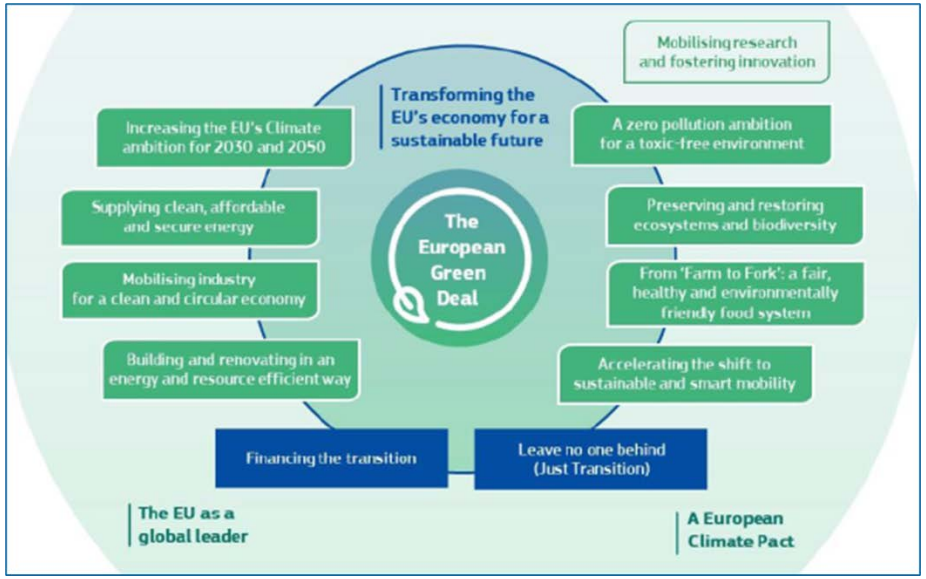
Commission work programme 2021

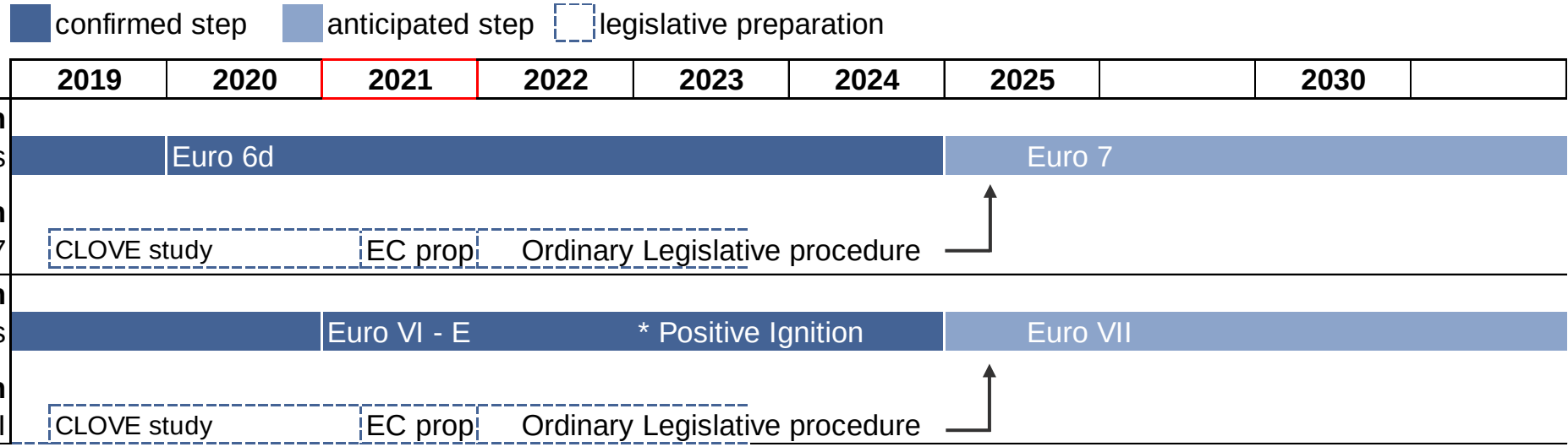
Transport related activities linked to European Green Deal Communication

- 'Fit for 55' package - to achieve 55% CO_2 reduction compared to 1990 (expected 14 July 2021)
  - Amendment to Renewable Energy Directive to implement the ambition of the new 2030 climate target
  - Revision of the Energy Tax Directive
  - Revision of the Regulation setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles
  - Revision of the Directive on deployment of alternative fuels infrastructure
- Sustainable and Smart Mobility Strategy (SSMS)
  - Development of Euro 7 emission standards for cars, vans, lorries and buses (in Q4 2021)



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 ordinary decision process by European Parliament and Council



Euro 7/VII process

- CLOVE scenarios for light-duty vehicles
  - Testing conditions
    - Extract of table
    - Any condition for several parameters for which boundary condition was defined in Euro 6d RDE
    - Possible power restrictions for first two kilometres for normal conditions are being evaluated by CLOVE
  - Emission limits for normal conditions
    - For 160k km, further deterioration factors for 240k km are being evaluated by CLOVE

Parameter	EURO 7 Normal Conditions of use	EURO 7 Extended Conditions of use
Emission Limit Form	A budget up to 16 km and a constant value in mg/km or #/km above 16 km	3 times the limit of normal conditions
Ambient temperature [°C]	-7 to 35°C	-10 to +45°C
Max. altitude [m]	1600 m	2200 m
Towing/aerodynamic modifications	Not included	Allowed
Age/Mileage of Vehicle [km]	Up to 240k km or 15 years (1)	Up to 240k km or 15 years (1)
Minimum mileage before testing	3000 km	Any condition

Pollutant	CO	NMOG	NO_x	PM	PN_{10}	NH_3	CH_4(*)	N_2O(*)	HCHO
Unit	mg/km	mg/km	mg/km	mg/km	#/km	mg/km	mg/km	mg/km	mg/km
Scenario 1									
Cars with and Vans	400	45	30	2	1×10^{11}	10	20	20	5
Scenario 2									
Cars and Vans	400	25	20	2	1×10^{11}	10	10	10	5

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 300k/700k km, further deterioration factors for 700k/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

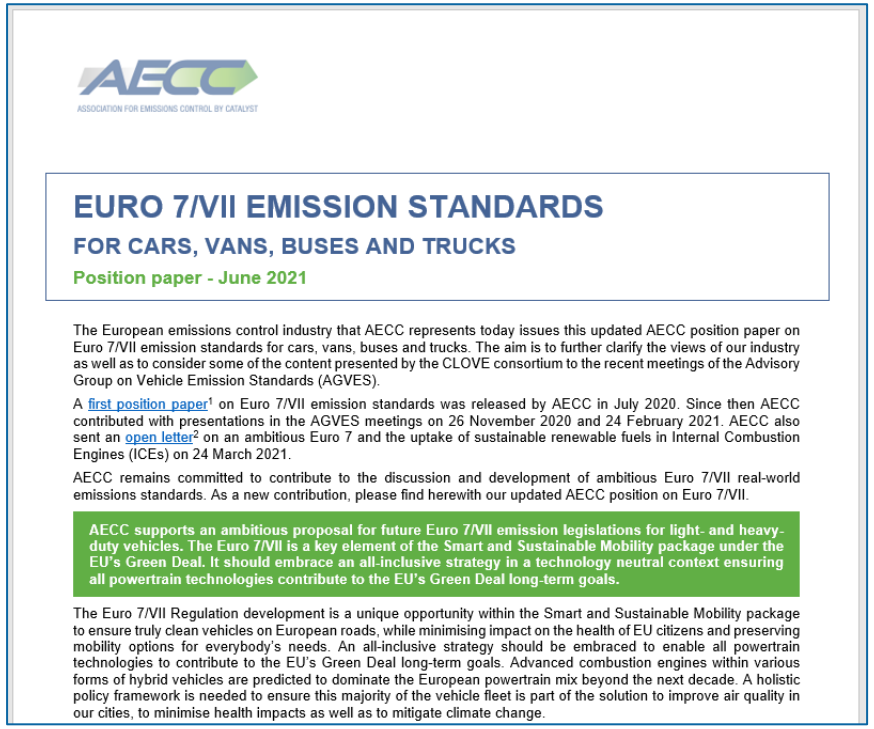
90 Percentile Limit	NOx	SPN10	PM	CO	NMOG	NH3	N2O*	CH4*
HD 2 (opt. +cc SCR diesel)	90	1.0E+11	8	200	50	65	60	50
HD 3 (as HD2+pre-heat)	90	1.0E+11	8	200	50	65	60	50

„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

AECC
ASSOCIATION FOR EMISSIONS CONTROL BY CATALYST

AECC work on sustainable ICE for the future

- Demonstrate that technologies are available today to effectively control emissions from ICE under real-world operation towards near zero-impact on air quality
  - Updated position paper on Euro 7/VII available
  - Technical note based on test programme data to follow
- Promote the enhanced usage of sustainable renewable fuels to deliver on the EU Green Deal and accelerate the CO_2 reductions in the transition to climate-neutrality in 2050
  - LCA data shows the ICE with renewable fuel can achieve net-zero GHG emissions
  - Drop-in fuel capabilities allow to use existing infrastructure
  - Immediate reduction in CO_2 emissions from the legacy vehicle fleet as well as from new vehicles
  - Testing with sustainable renewable fuels included in AECC demonstration programmes



AECC
ASSOCIATION FOR EMISSIONS CONTROL BY CATALYST

EURO 7/VII EMISSION STANDARDS

FOR CARS, VANS, BUSES AND TRUCKS

Position paper - June 2021

The European emissions control industry that AECC represents today issues this updated AECC position paper on Euro 7/VII emission standards for cars, vans, buses and trucks. The aim is to further clarify the views of our industry as well as to consider some of the content presented by the CLOVE consortium to the recent meetings of the Advisory Group on Vehicle Emission Standards (AGVES).

A first position paper[1] on Euro 7/VII emission standards was released by AECC in July 2020. Since then AECC contributed with presentations in the AGVES meetings on 26 November 2020 and 24 February 2021. AECC also sent an open letter[2] on an ambitious Euro 7 and the uptake of sustainable renewable fuels in Internal Combustion Engines (ICEs) on 24 March 2021.

AECC remains committed to contribute to the discussion and development of ambitious Euro 7/VII real-world emissions standards. As a new contribution, please find herewith our updated AECC position on Euro 7/VII.

AECC supports an ambitious proposal for future Euro 7/VII emission legislations for light- and heavy-duty vehicles. The Euro 7/VII is a key element of the Smart and Sustainable Mobility package under the EU's Green Deal. It should embrace an all-inclusive strategy in a technology neutral context ensuring all powertrain technologies contribute to the EU's Green Deal long-term goals.

The Euro 7/VII Regulation development is a unique opportunity within the Smart and Sustainable Mobility package to ensure truly clean vehicles on European roads, while minimising impact on the health of EU citizens and preserving mobility options for everybody's needs. An all-inclusive strategy should be embraced to enable all powertrain technologies to contribute to the EU's Green Deal long-term goals. Advanced combustion engines within various forms of hybrid vehicles are predicted to dominate the European powertrain mix beyond the next decade. A holistic policy framework is needed to ensure this majority of the vehicle fleet is part of the solution to improve air quality in our cities, to minimise health impacts as well as to mitigate climate change.

HD demonstrator vehicle and project partners

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

IPA
INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION

CORNING

Automotive Grade Urea Sector Group
cefic
sector group

AECC
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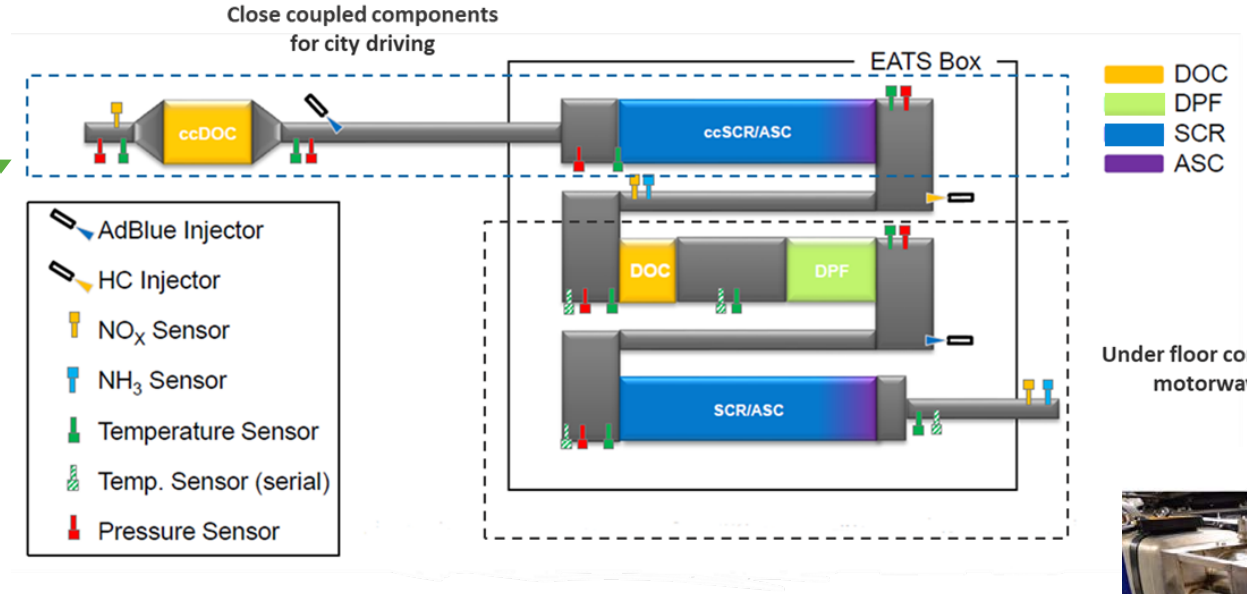
FEV

IPA
INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION

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



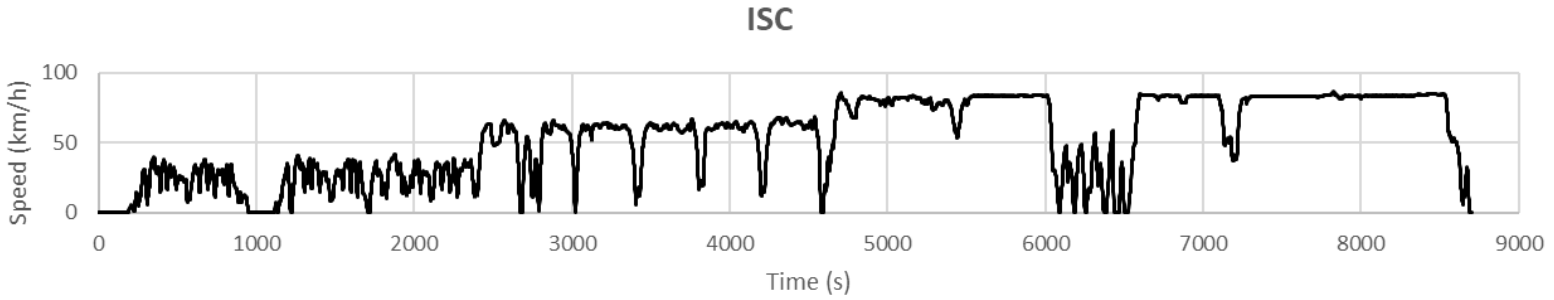
AECC HD demo
Volumes:
DOC: 7l + 7l
DPF: 16l
SCR: 25l + 25l

Under floor components for motorway driving

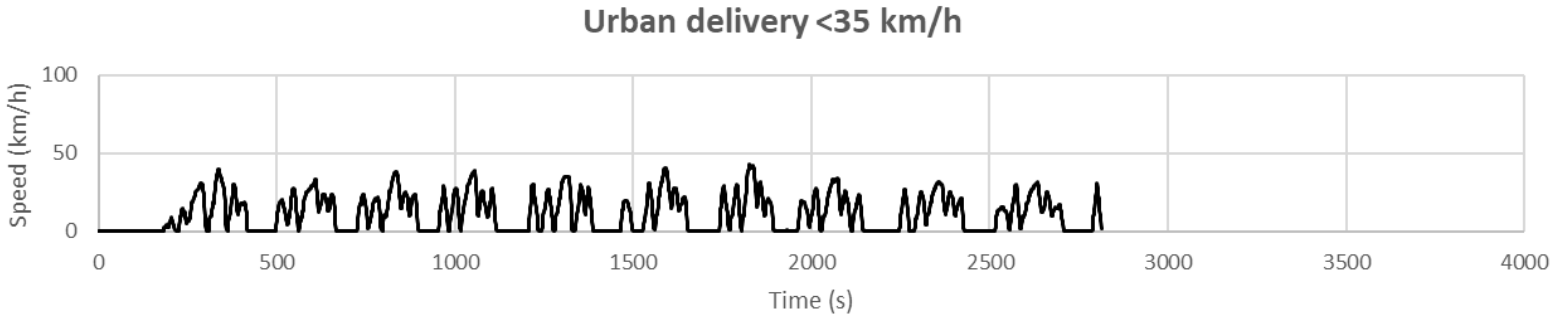
AECC HD demonstrator video can be seen at:
https://www.youtube.com/watch?v=MXBnhZMzISY

ASSOCIATION FOR EMISSIONS CONTROL BY CATALYST

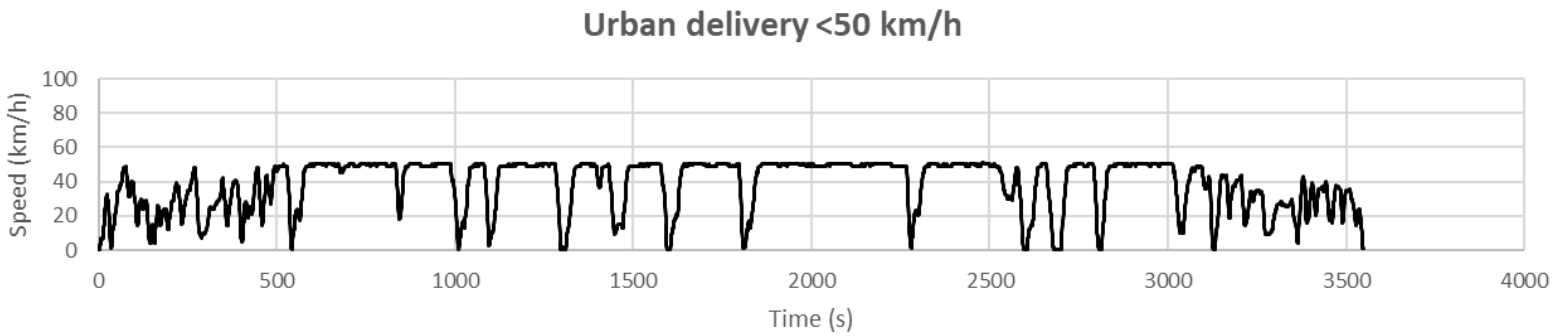
Trip profiles for on-road testing



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



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



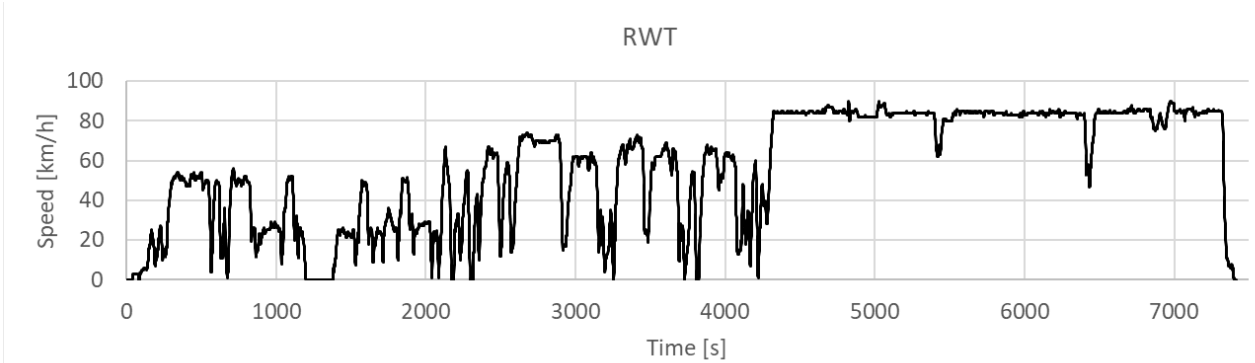
- T_{amb}: 4 to 8 °C
- Payload: 10 & 50 %

Presented at 42nd International Vienna Motor Symposium

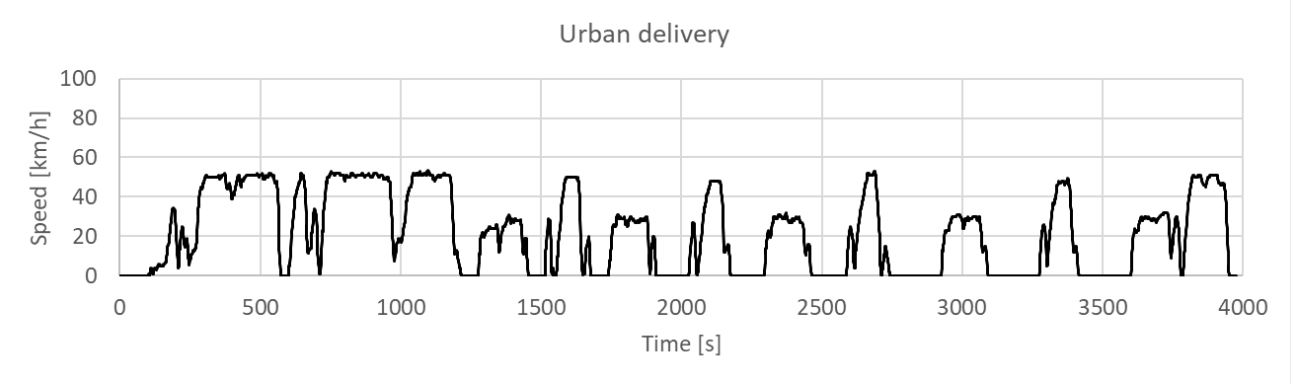
HD diesel demonstrator EC JRC campaign

- 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 ammonia stored on SCRs as well as with passively regenerated DPF
- Cover a wide range of driving conditions including urban, rural and motorway operation
- Preliminary results shown today contain emissions of NOx, SPN23, NH_3 and N_2O
- Further analysis is being completed on other trip profiles and pollutants including PN10

Challenging cycles for chassis dyno testing



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

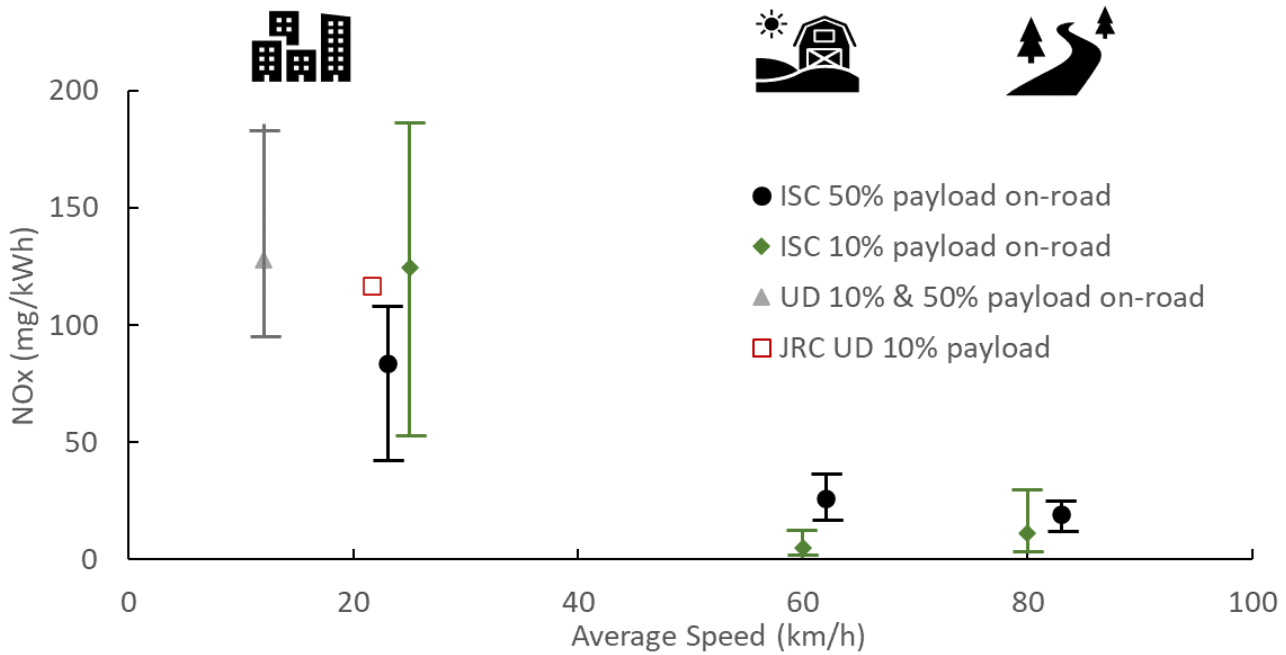


- T_{amb}: -7 °C
- Payload: 10 & 50 %

[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% 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

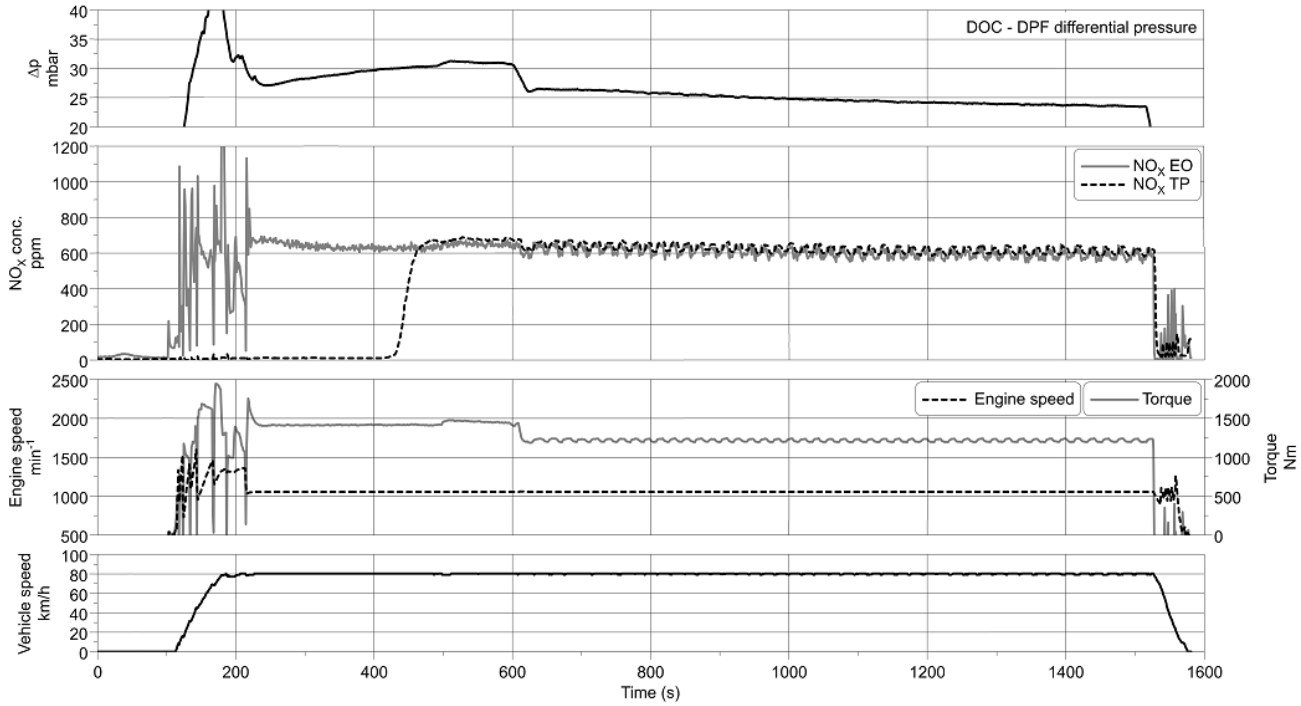
[2] Urban delivery completed at JRC contained several stops (~1, 2 & 3 min). JRC chassis dyno test result shown on this graph was conducted with urea storage in the SCRs

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

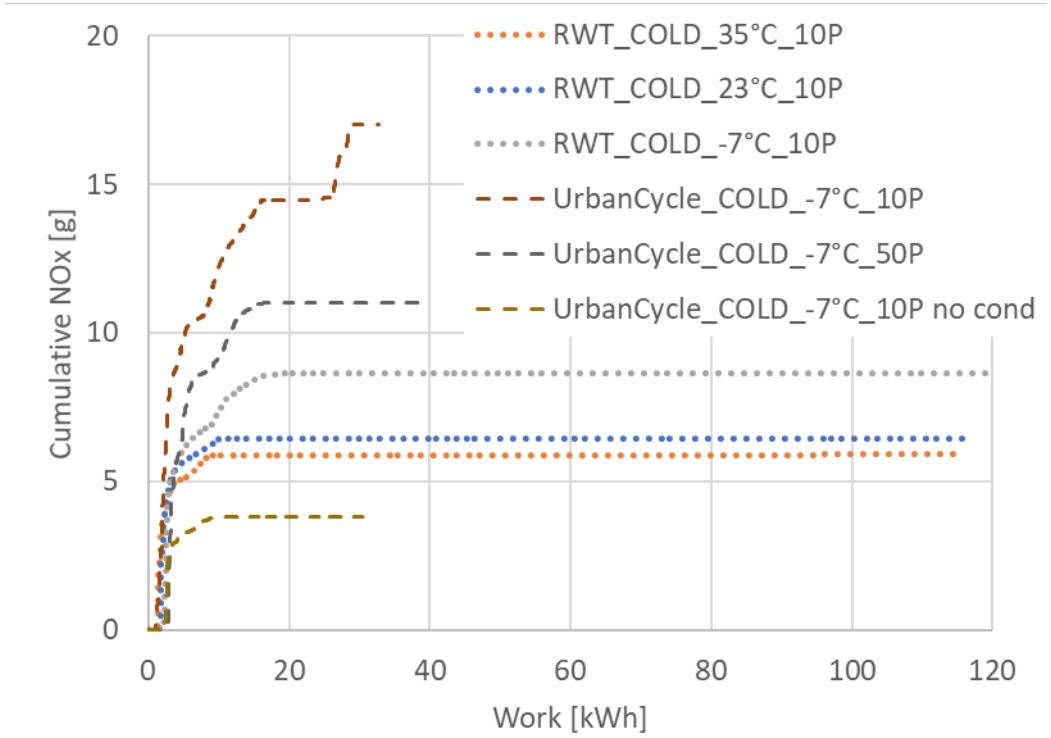
HD diesel demonstrator system preconditioning

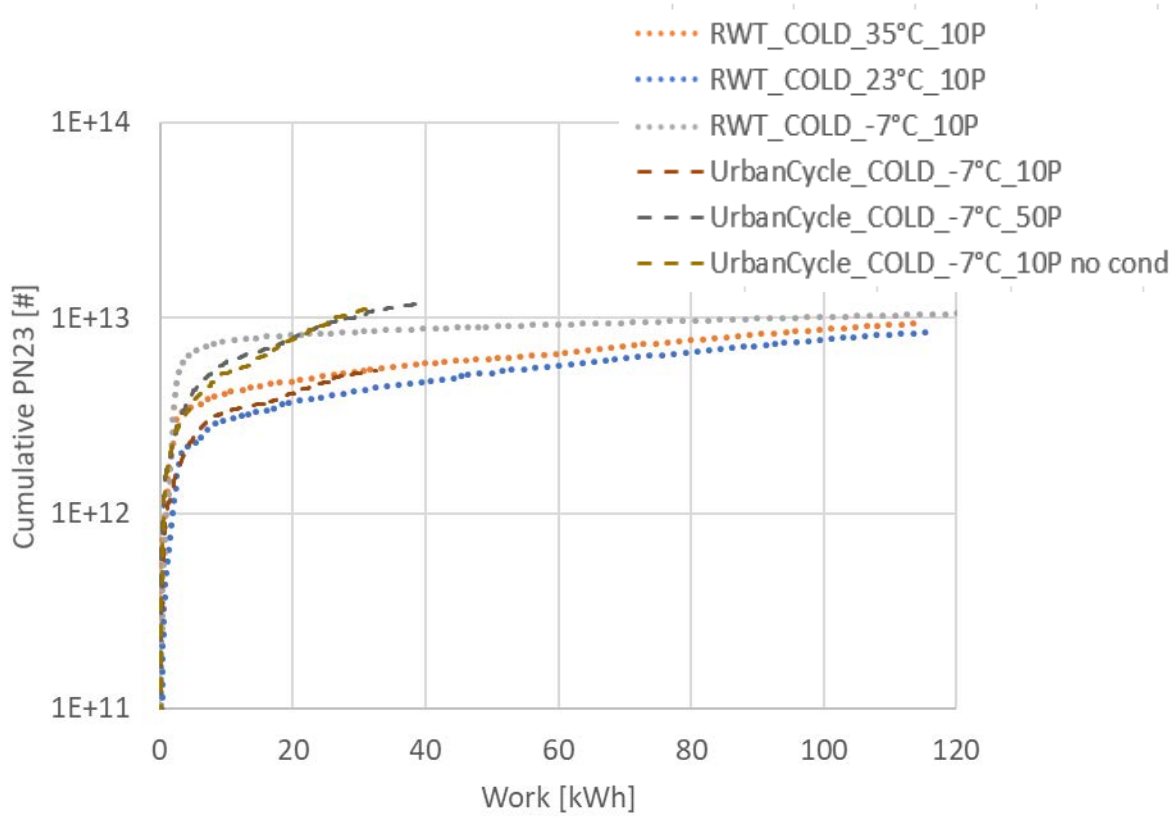
- System preconditioning
  - DPF was also passively regenerated, until pressure differential was below a defined threshold
  - SCR catalysts' ammonia storage was depleted prior to some of the tests conducted at the chassis dyno (until NOx EO = NOx TP)
- Ensure same starting conditions every time
- Investigate impact on gaseous and pollutant emissions at severe cold-start conditions



HD diesel demonstrator EC JRC campaign

- Results confirm low gaseous and particulate emission within broad range of driving conditions
- 99% of NOx emissions are produced within the cold start of the trip

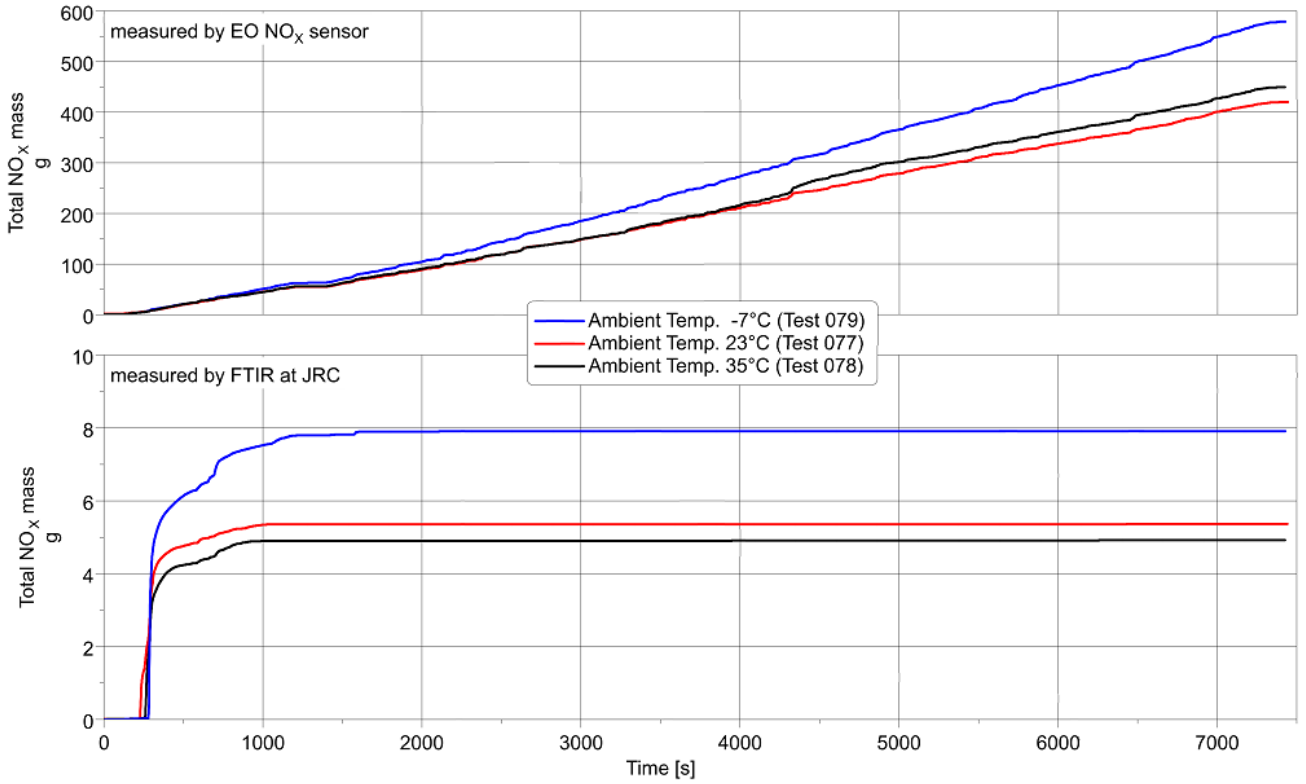




RWT – Real World Test
The results are reported as measured under the specified test routes and conditions

HD diesel demonstrator EC JRC campaign

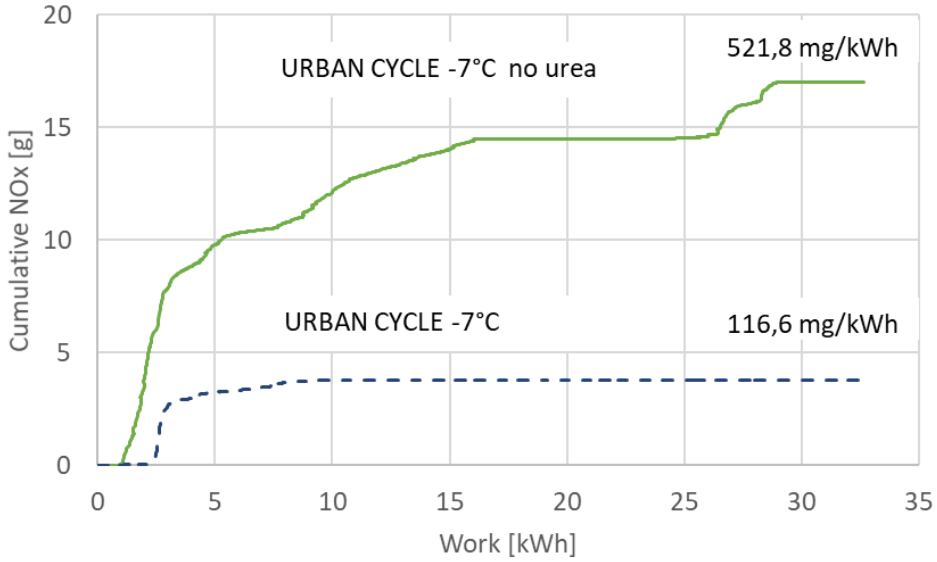
- Temperature effect was investigated at -7, 23 & 35°C within an RWT[1,2] trip containing urban, rural and motorway shares of operation
- Depending on the cold ambient conditions the NOx conversion efficiency of the system varies from 89 - 92% during cold-start

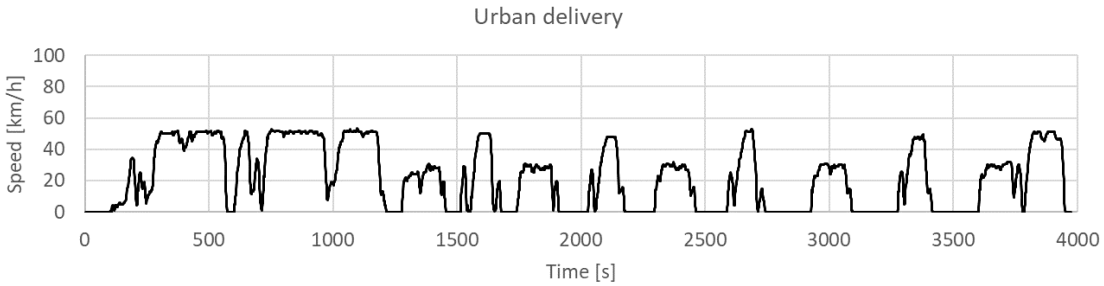


[1] All RWT conducted with 10% payload
[2] The results are reported as measured under the specified test routes and conditions

HD diesel demonstrator EC JRC campaign

- A significant impact on cold start NOx emissions has been identified when SCR ammonia storage is depleted
- Resulting cumulative emissions are around 4.5 times higher when the system has been preconditioned, highest emission concentration during the first part of the trip

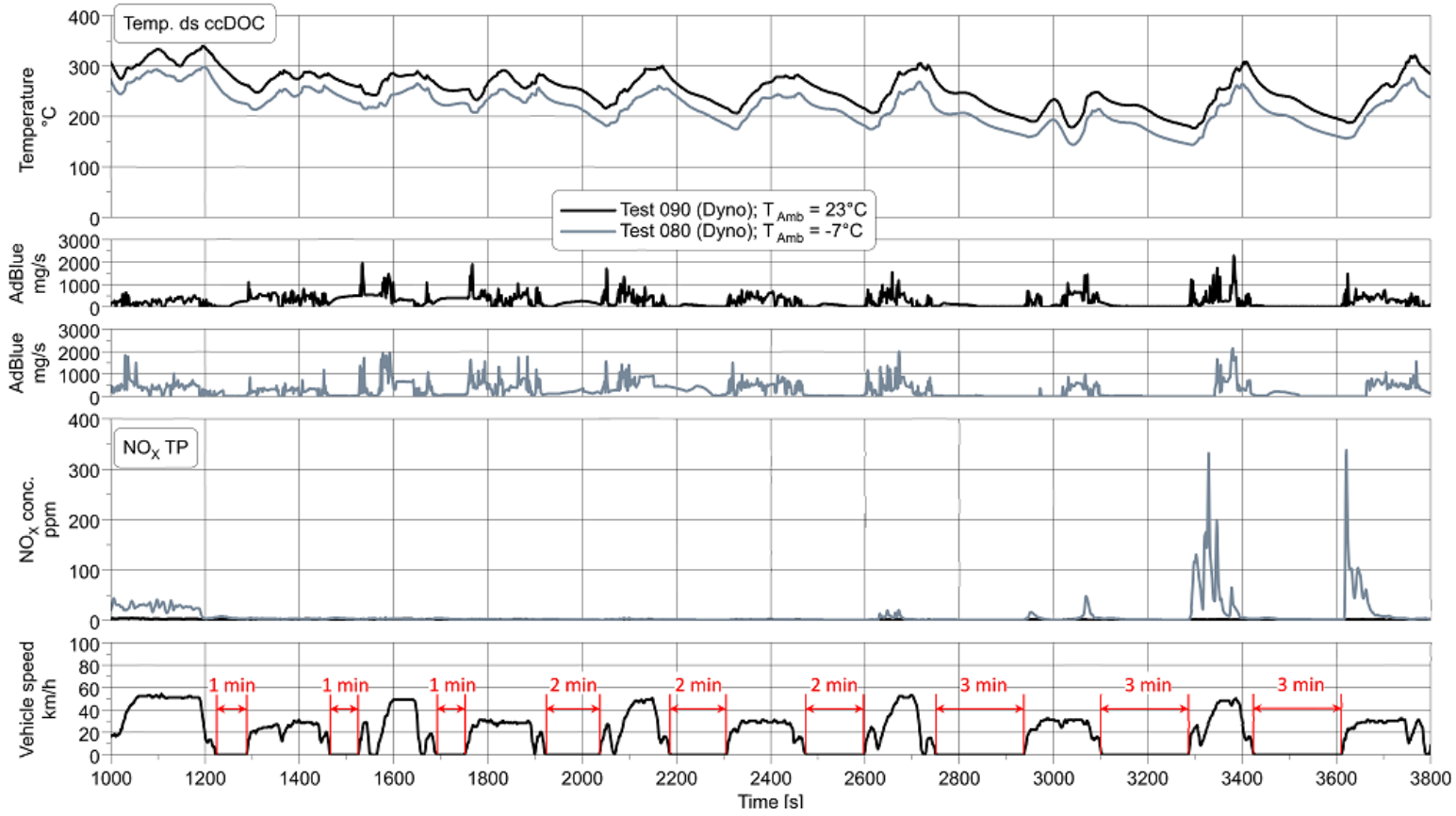




[1] WHVC tests were conducted with 50 % payload
[2] Urban delivery tests were conducted with 10 % payload
[3] The results are reported as measured under the specified test routes and conditions

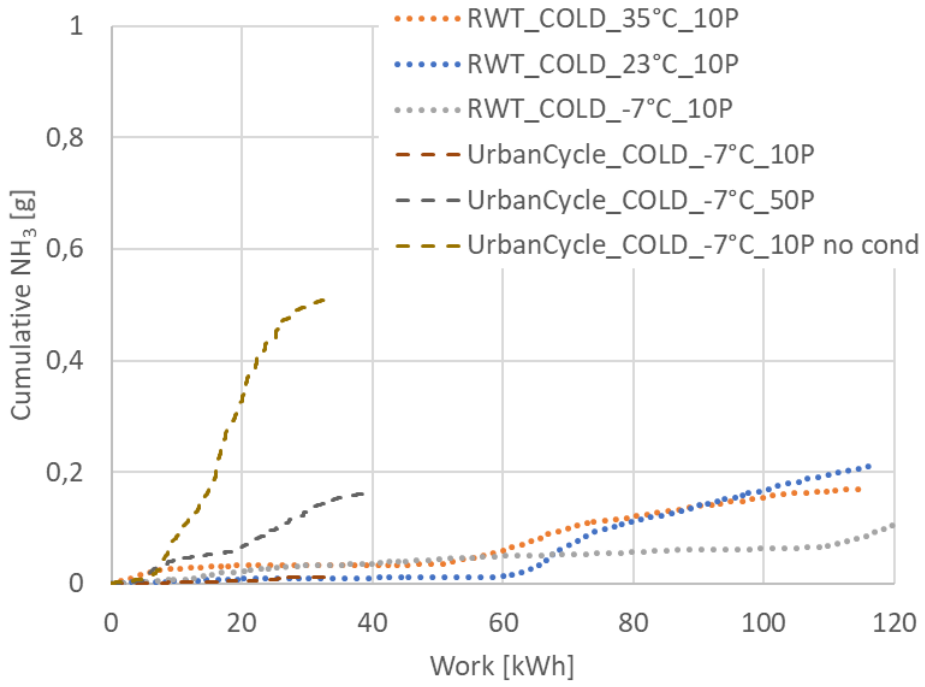
HD diesel demonstrator EC JRC campaign

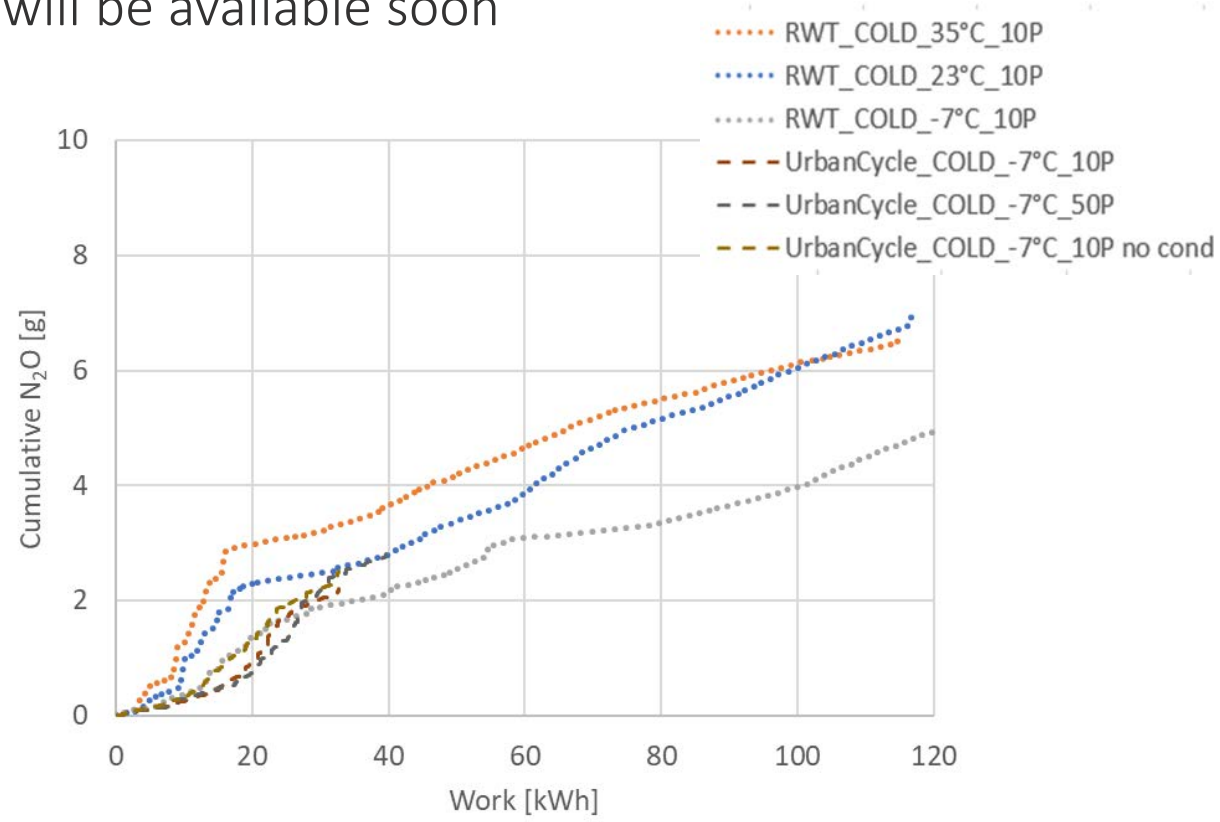
- Specific cycles were investigated for urban delivery with stops of duration 1, 2 and 3 minutes
- Length and frequency of stops will impact the emission control system performance, as well as the operation in-between
- The effect is even greater when driving at cold ambient conditions (-7°C)



HD diesel demonstrator EC JRC campaign

- Chassis dyno test confirmed good control of NH_3 and relatively low N_2O
- PN10 emissions are still being analysed, results will be available soon

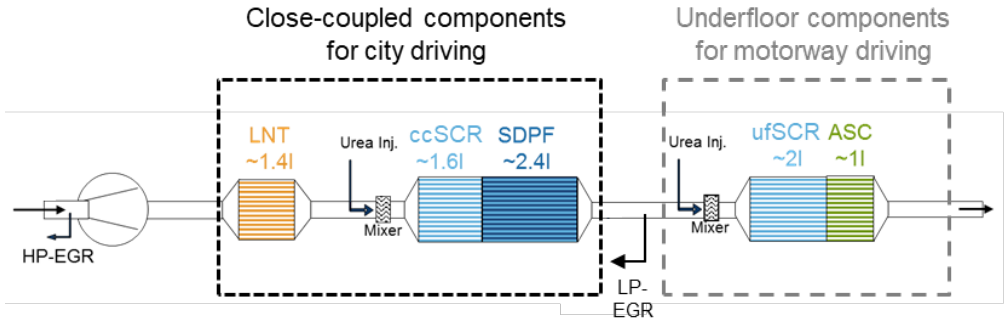




[1] The results are reported as measured under the specified test routes and conditions

Ultra-low emissions diesel demonstrator

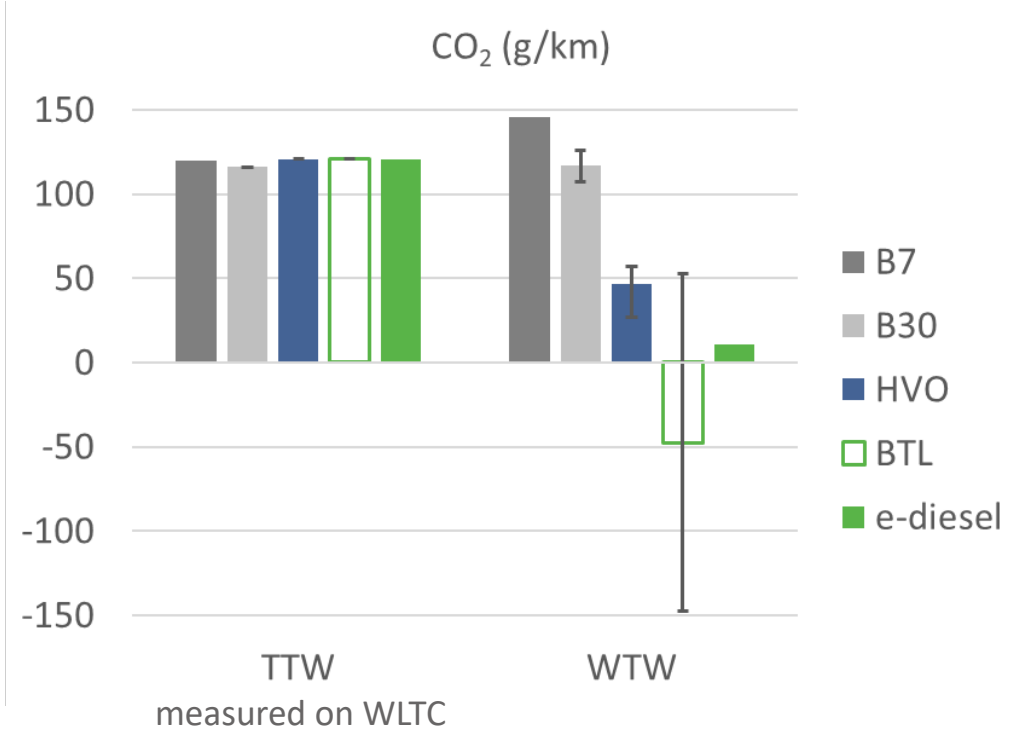
- Objective
  - Demonstrate ultra-low NOx emissions over wide range of driving conditions
  - Tests on sustainable renewable fuels
    - Investigate low Well-to-Wheel CO_2 emissions
      - Paraffinic fuels (HVO, BTL, e-diesel)
      - FAME based (B30)
    - Validate pollutant emissions achieved on market fuel
- Demonstrator concept
  - Emission control system with combination of Lean NOx Trap and dual-Selective Catalytic Reduction
  - 48V mild-hybrid system



1) *J. Demuynck, et al.; "Integrated Diesel System Achieving Ultra-Low Urban and Motorway NOx Emissions on the Road", 40th Vienna Motor Symposium, 2019*
https://www.aecc.eu/wp-content/uploads/2019/04/190516-AECC-IAV-IPA-Integrated-Diesel-System-achieving-Ultra-Low-NOx-on-the-road-Vienna-Symposium.pdf
2) Joint MTZ publication with Bosch, Vitesco, FEV and IAV https://www.aecc.eu/wp-content/uploads/2020/09/200901-modern-diesel-MTZ.pdf
3) Videos of instantaneous conversion performance available at www.youtube.com/channel/UCbPS9op5ztLqrv6zlMH_IcQ

Well-to-Wheel calculations to investigate CO_2 impact

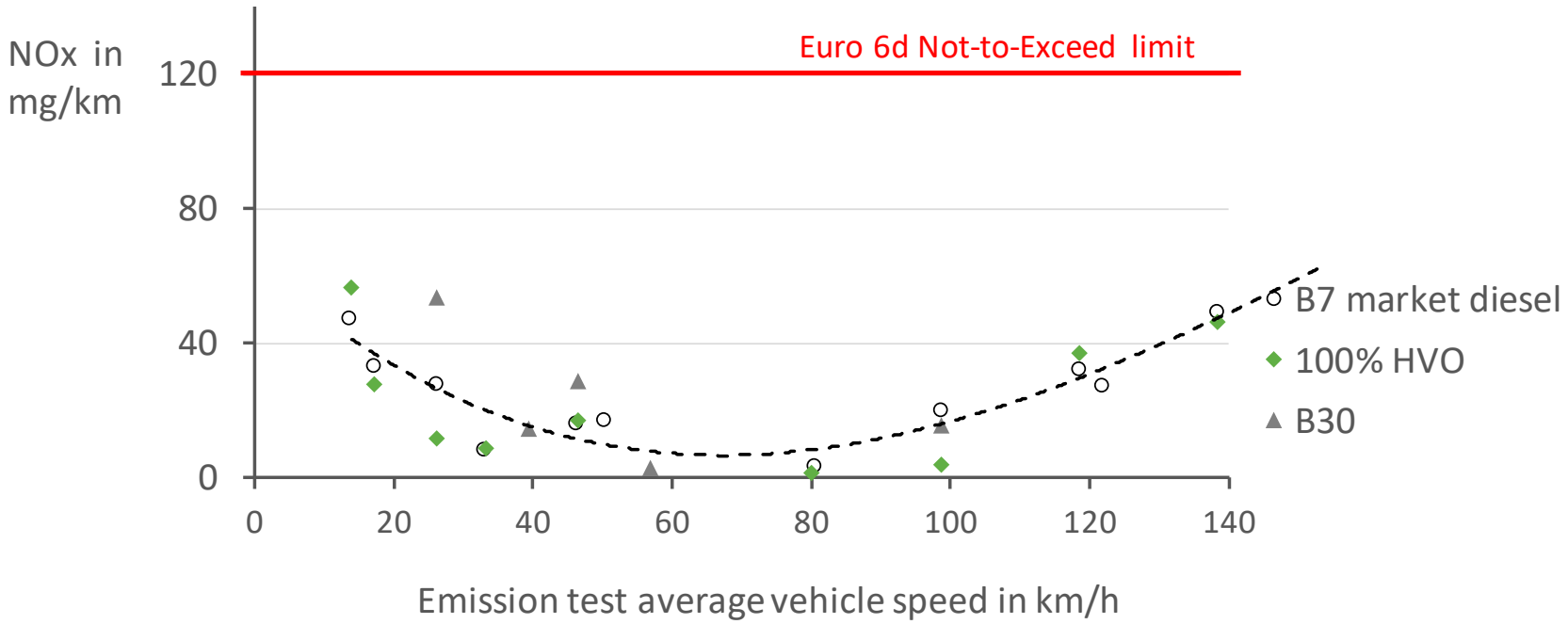
- Tank-to-Wheel (tailpipe) measurements show similar results for the different fuels
- Significant Well-to-Wheel reduction versus B7 depending on production pathway
  - B30: -14 to -26%
  - HVO: -60 to -82%
  - BTL: -64% to -200%
  - E-fuel: -93%



Advanced emission controls and renewable fuels for low pollutants and lifecycle CO_2 emissions, Sustainable Internal Combustion Engine Virtual 'Live', February 2021
https://www.aecc.eu/wp-content/uploads/2021/02/210204-AECC-presentation-sustainable-ICE-conference-final.pdf

Low pollutant emissions confirmed for low carbon fuels

- Reference tests on B7 market diesel (7% fatty-acid-methyl-ester content)
- Tests on renewable fuels without modification to vehicle hardware or software
  - 100% HVO (Hydrotreated Vegetable Oil)
  - B30 diesel



Advanced emission controls and renewable fuels for low pollutants and lifecycle CO_2 emissions, Sustainable Internal Combustion Engine Virtual 'Live', February 2021
https://www.aecc.eu/wp-content/uploads/2021/02/210204-AECC-presentation-sustainable-ICE-conference-final.pdf

Summary and outlook

- AECC heavy-duty demonstrator vehicle project objective is to further reduce NOx and particulate emissions mainly observed in urban operation on Euro VI vehicles
  - Results show regulated and non-regulated emissions can be well controlled
  - Higher emissions are still found towards the boundary conditions of normal operation i.e. cold ambient conditions, long stops during urban operation
  - Follow-up activities will investigate EHC to further reduce initial cold-start emissions and validate ultra-low pollutant emissions on sustainable renewable fuels for low CO_2 emissions
- AECC light-duty diesel demonstrator showed significant WtW CO_2 reductions are possible with the use of sustainable renewable fuels while maintaining the ultra-low pollutant emissions
- AECC will continue to demonstrate that technologies are available today to effectively control emissions from ICE under real-world operation towards near zero-impact on air quality
- AECC looks forward to the Euro 7/VII proposal and Impact Assessment from the EU Commission

THANK YOU !

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