Ultra-Low Emissions from a Truck with Close-Coupled Emission Control System and Active Thermal Management using e-Fuels

Dr P. Mendoza Villafuerte; Dr J. Demuynck; MSc MBA D. Bosteels
Association for Emissions Control by Catalyst (AECC aisbl), Brussels

Dipl.-Ing T. Wilkes; MSc V. Mueller; Dr P. Recker
FEV Europe GmbH, Aachen

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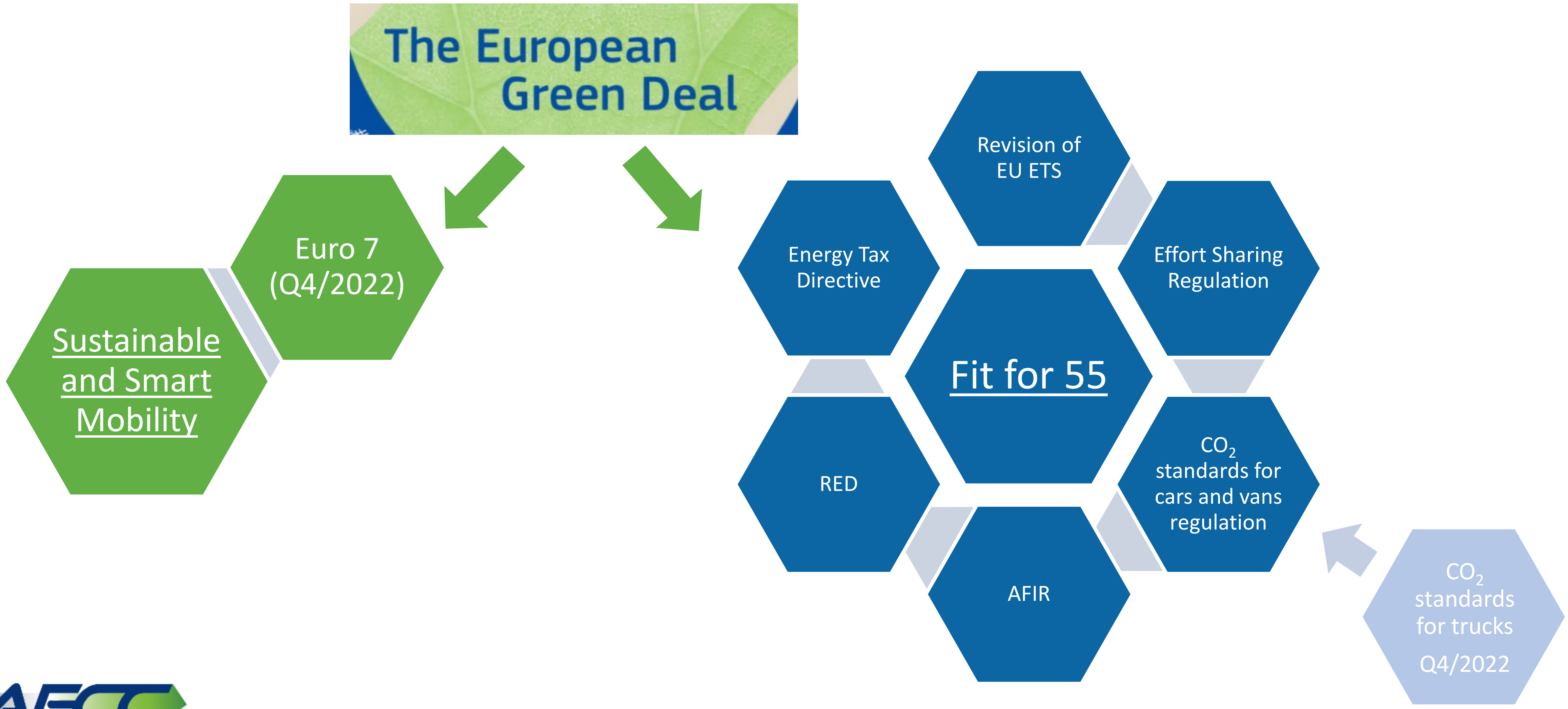
Content

- Euro 7 for heavy-duty vehicles
- AECC results of the heavy-duty demonstrator programme
- Summary

Euro 7 emission standards proposal in context



Euro 7 scenarios

- April 2021 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 700k km, further deterioration factors for 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
HC 2 (opt. CNG SI)	350	5.0E+11	12	6500	150	70	300	450

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
HC 2 (opt. CNG SI)	90	1.0E+11	8	300	50	70	35	300

HD diesel demonstrator vehicle and project partners

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

FEV

IPA INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION

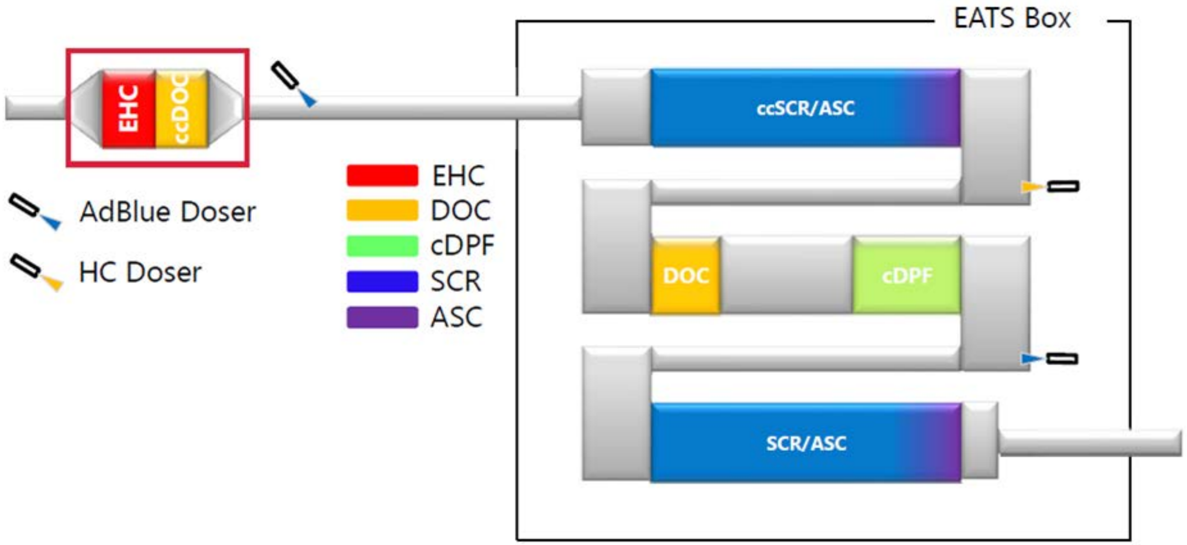
CORNING

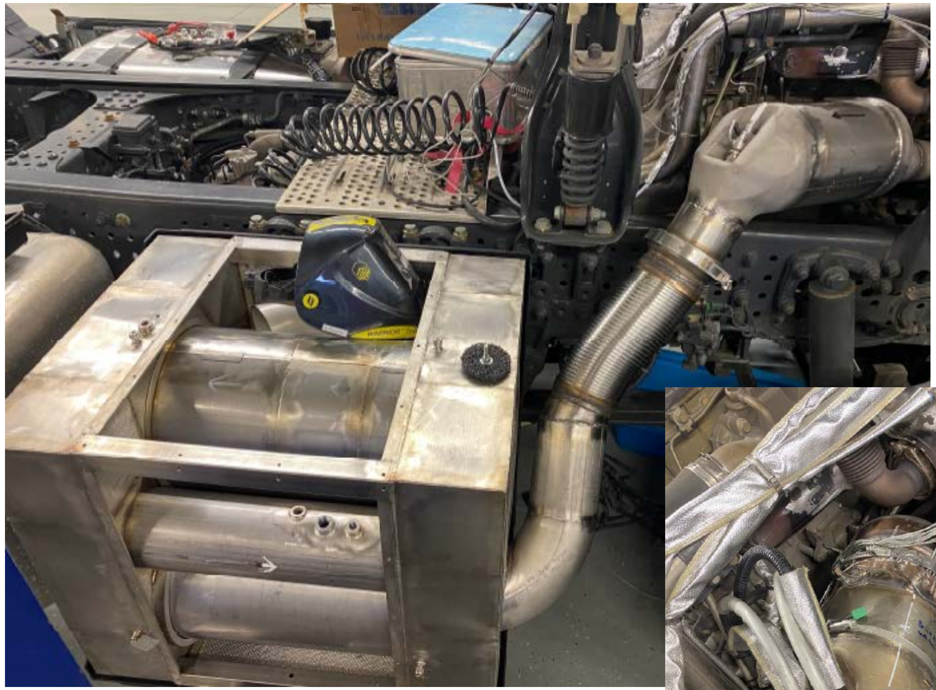
Automotive Grade Urea Sector Group

cefic sector group

HD diesel demonstrator concept

- AECC emissions control system
  - Phase 1: ccDOC, ccSCR/ASC+ ufDOC+cDPF+ SCR/ASC, twin AdBlue dosing and HC doser
  - Phase 2: additional EHC as part of the ccDOC
  - Components are hydrothermally aged targeting 500k km

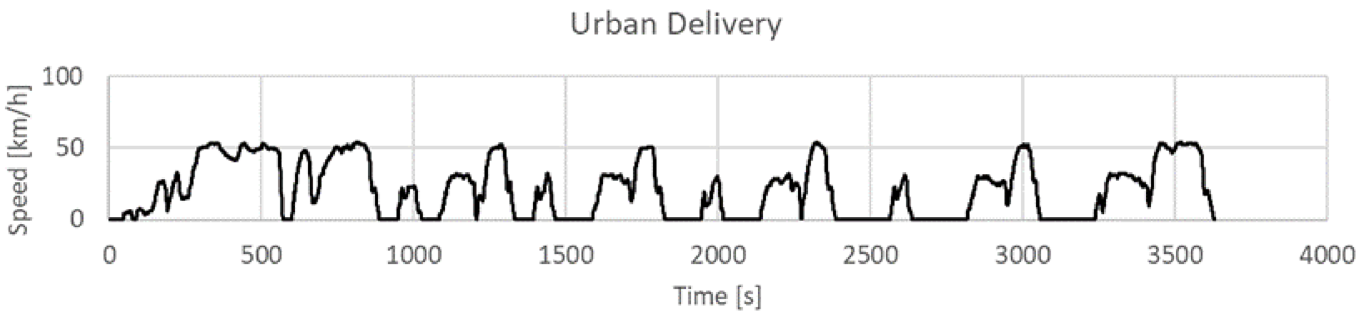




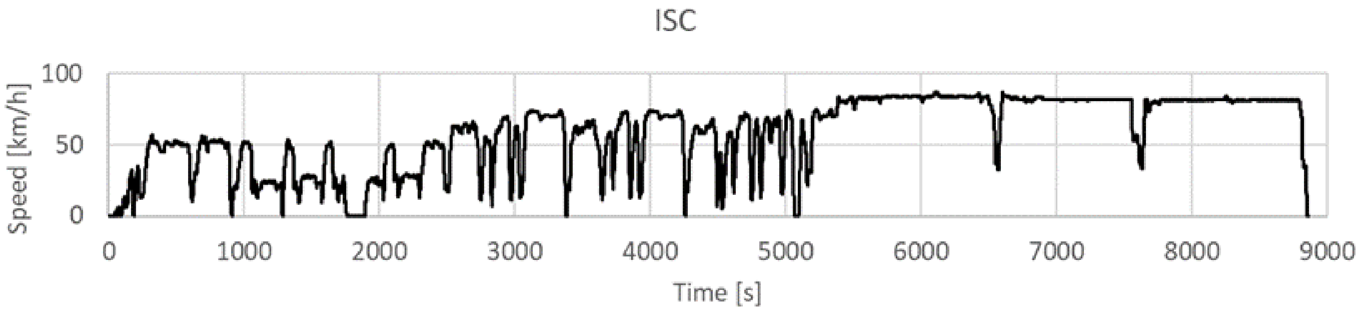
HD diesel demonstrator testing

- Overview of the on-road testing conditions (Phase 1 and 2)

  - Urban delivery route

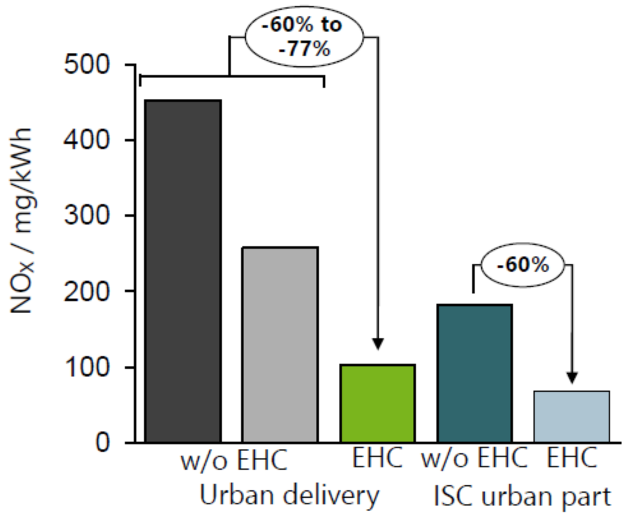
  

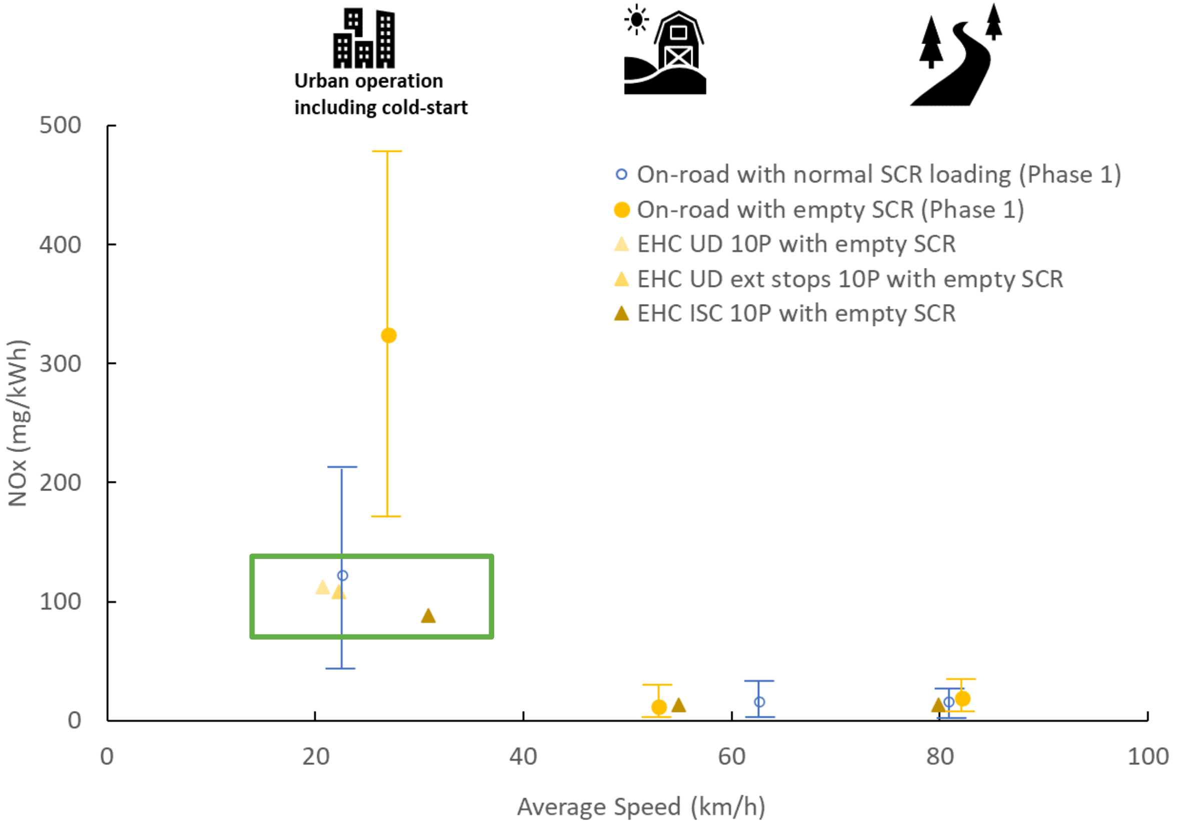
  - On-road in-service conformity route

Reduction of initial cold-start emissions with EHC

- NOx emissions are reduced by 60-77% with EHC compared to first project phase[1, 2]
  - Faster heat-up during initial cold-start
  - Maintaining temperature during low-load or start-stop driving

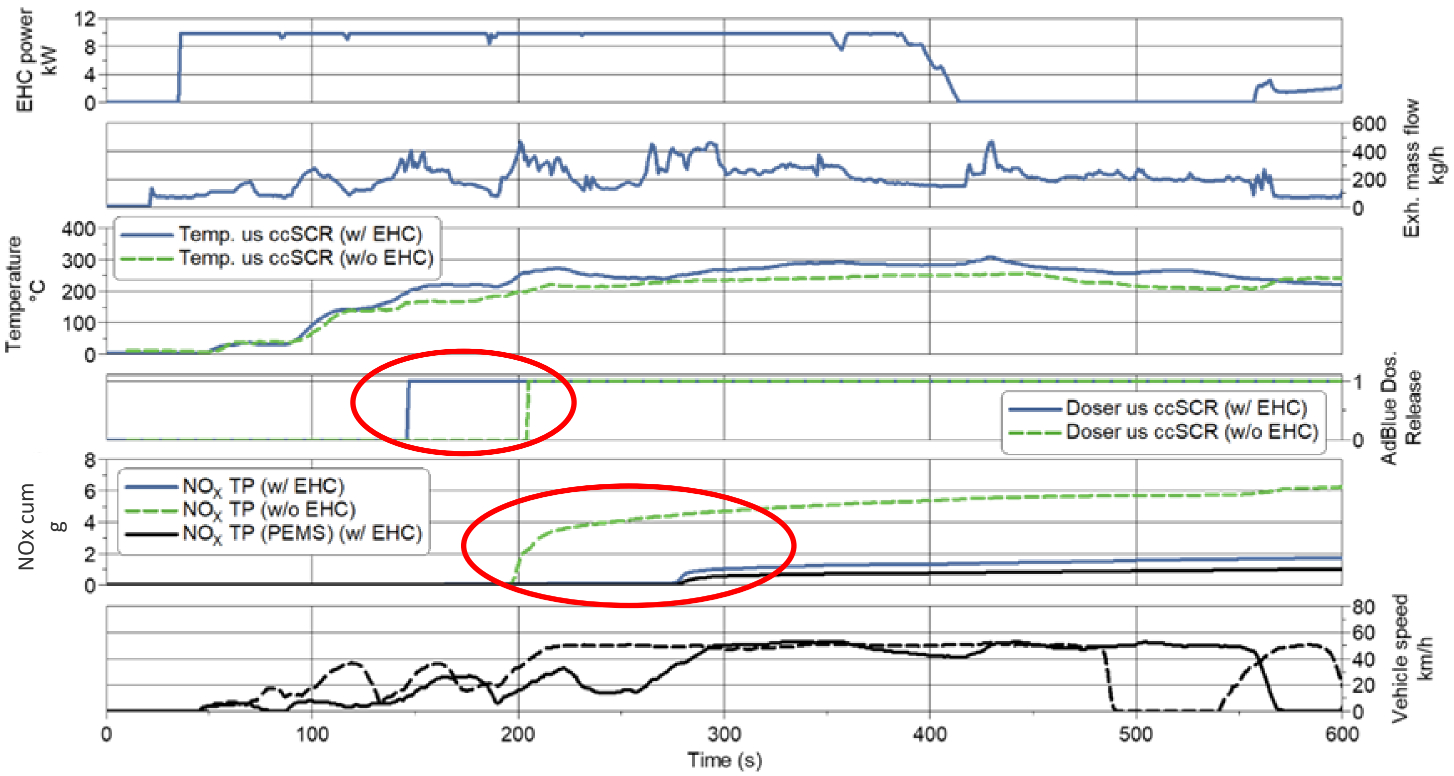




[1] P. Mendoza Villafuerte, et al.; "Demonstration of Extremely Low NOx Emissions with Partly Close-Coupled Emission Control on a Heavy-duty Truck Application", 42nd Vienna Motor Symposium 2021
[2] P. Mendoza Villafuerte, et al.; "Future-proof heavy-duty truck achieving ultra-low pollutant emissions with a close-coupled emission control system including active thermal management", Transportation Engineering, Volume 9, September 2022, 100125, 2022

Reduction of initial cold-start emissions with EHC

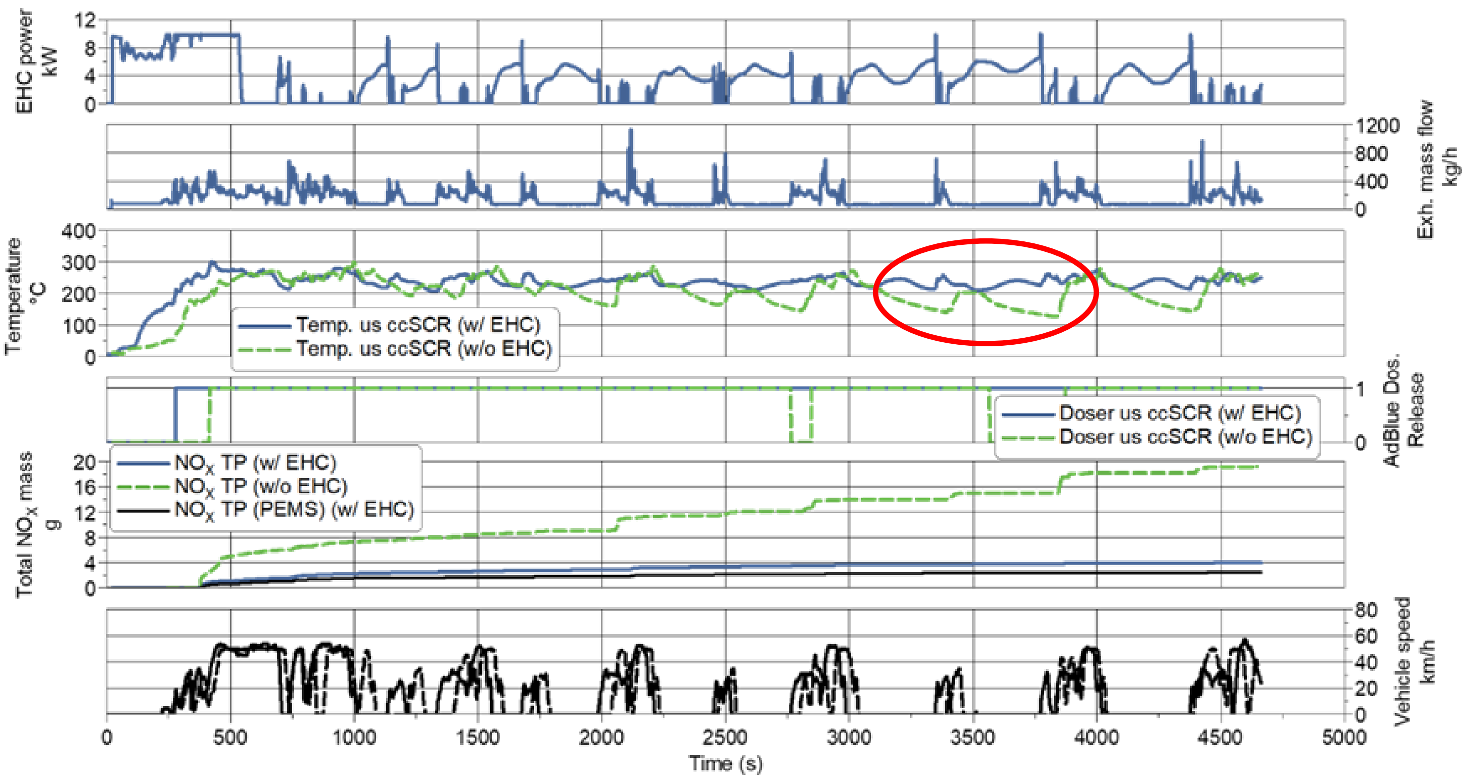
- Urban delivery trip[1,2] initial 600 s
- EHC control strategy and effect
  - AdBlue dosing release of ccSCR is advanced 60 s
  - Around 67% NOx emissions reductions in complete cycle
- CO_2 impact depends on EHC control strategy



[1] The results are reported as measured by NOx and temperature sensors instrumented in the exhaust system
[2] Tests were conducted with depleted SCRs' ammonia storage and passively regenerated DPF unless indicated otherwise, test conducted at 5°C, 10% PT

Near-zero emissions at longer idling stops with EHC

- Total urban delivery trip[1,2]
- EHC control strategy and effect
  - Keeps the ccSCR within the target temperature on a dedicated extended stops test (2, 4 and 6 min)
  - Around 67% NOx emissions reductions in complete cycle
- Emission slip during first acceleration is no longer present thanks to the use of the EHC



[1] The results are reported as measured by NOx and temperature sensors instrumented in the exhaust system
[2] Tests were conducted with depleted SCRs' ammonia storage and passively regenerated DPF unless indicated otherwise, test conducted at 7°C, 10% PT

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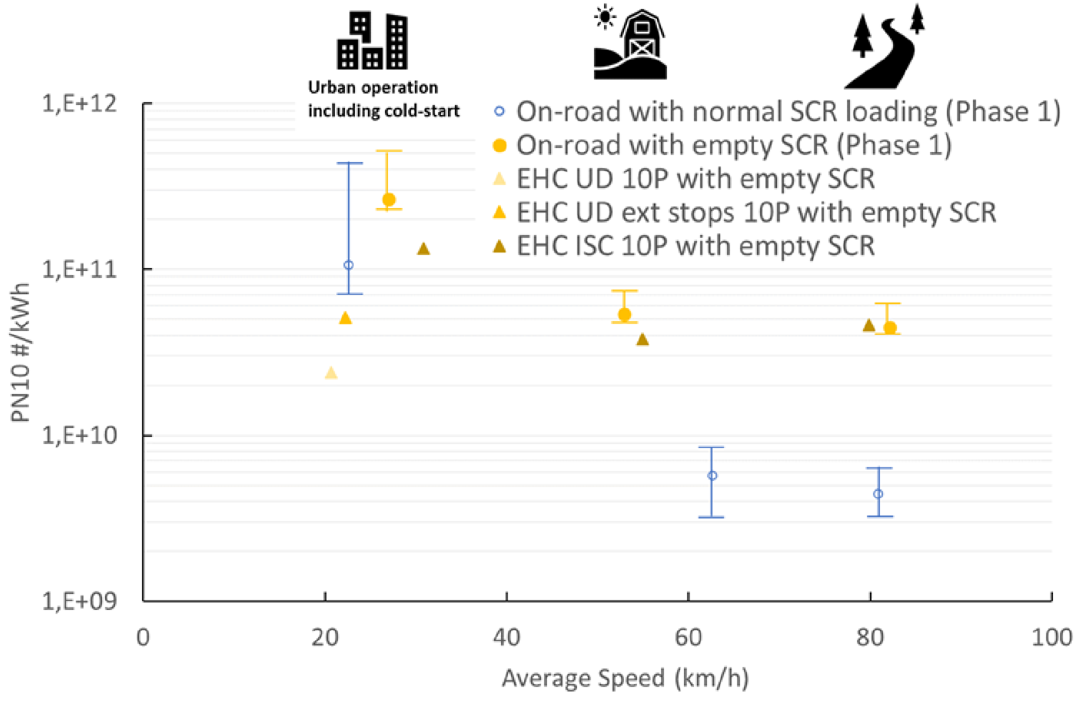
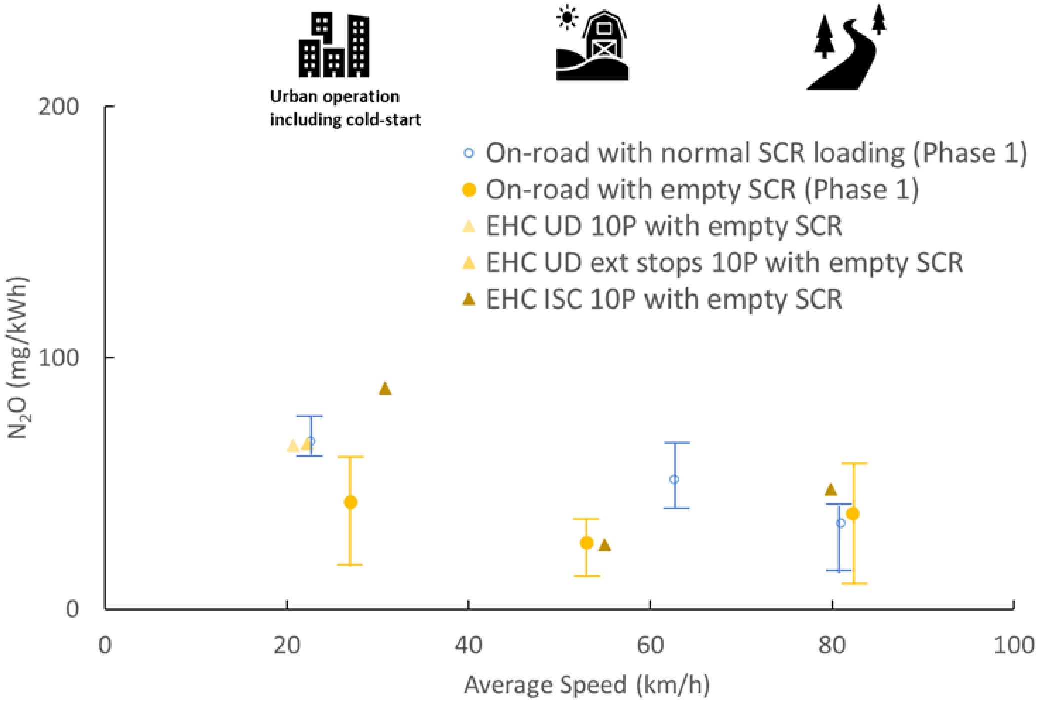
Good control of non-regulated emissions

- Low PN10[1,2] emissions are achieved overall, cold start particulates remain main emission event
- N_2O emissions are kept at low levels

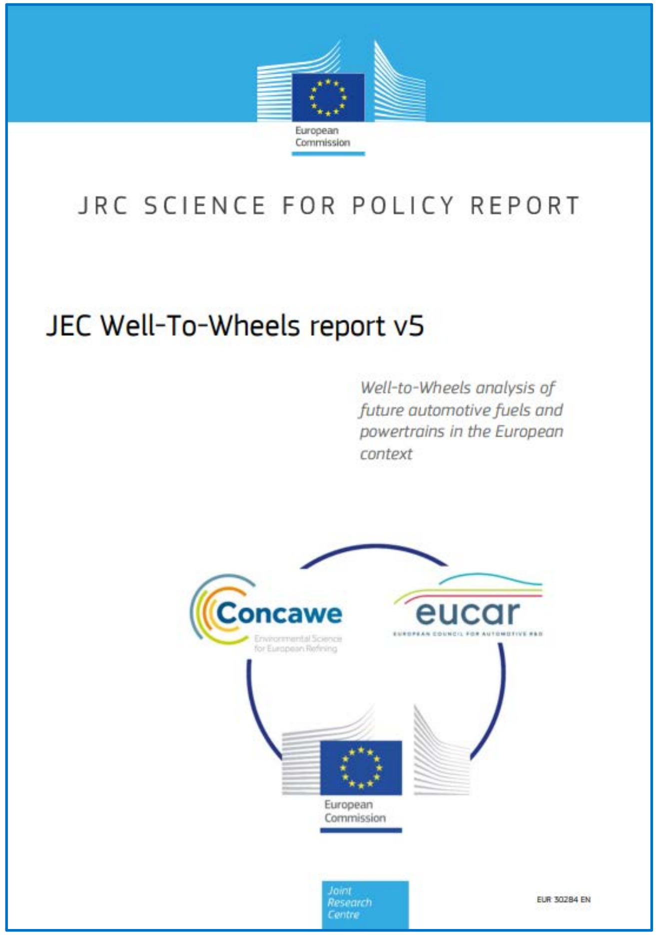




[1] The results are reported as measured by protype PN10 PEMS
[2] Tests were conducted with depleted SCRs' ammonia storage and passively regenerated DPF unless indicated otherwise

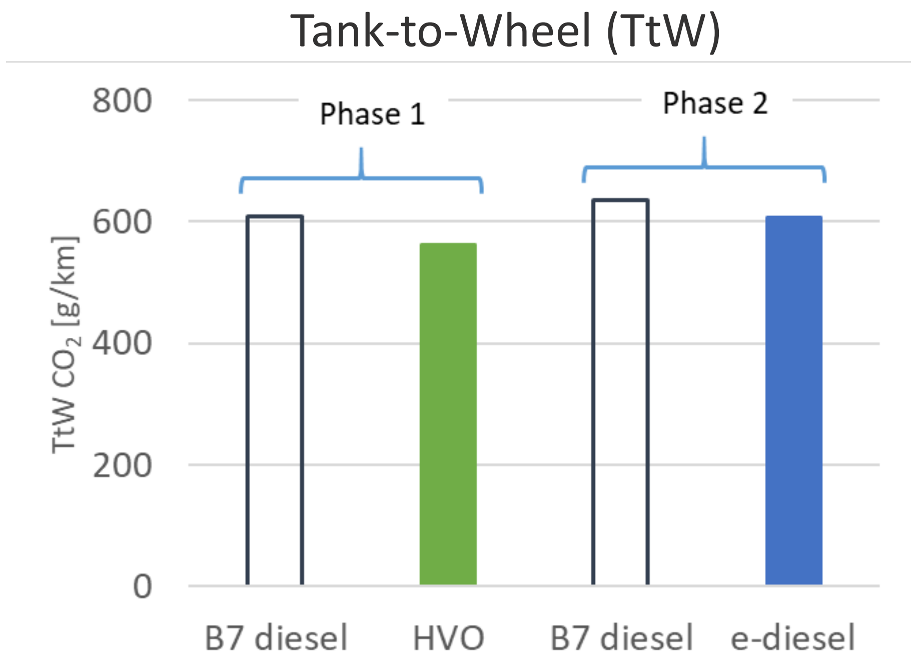
HD diesel demonstrator Well-to-Wheel CO_2 emissions

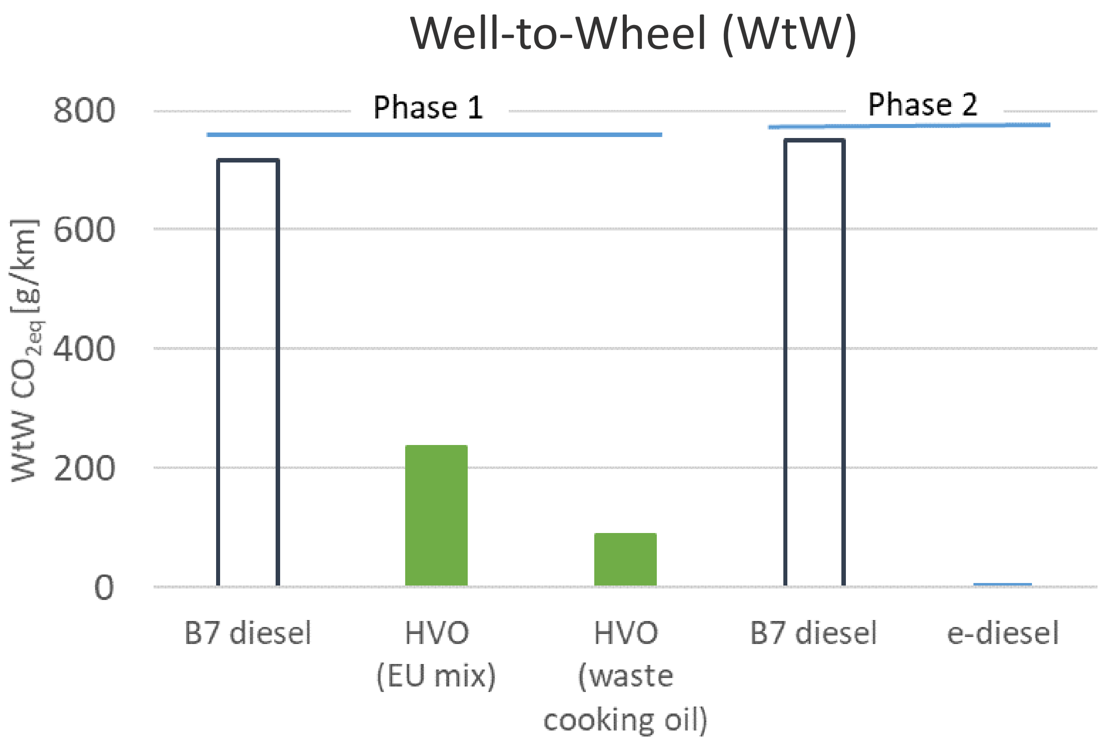
- JEC Well-To-Wheel report version 5 methodology has been used to calculate the WtW CO_2 emissions
  - Well-to-Tank (WtT) input data is coming from the JEC WtW report
  - Tank-to-Wheel input data is from the on-road testing performed and fuel properties provided by the fuel suppliers
- Following pathways are investigated
  - B7 market diesel
  - HVO
    - EU mix
    - Waste cooking oil
  - e-diesel



HD diesel demonstrator Well-to-Wheel CO_2 emissions

- HVO already offers today significant reduction of up to 90% WtW CO_2 reduction straight from the pump depending on the feedstock
- e-diesel has the potential to nearly eliminate WtW CO_2 emissions





D. Bosteels, et al.; "Combination of advanced emission control technologies and sustainable renewable fuels on a long-haul demonstrator truck", SIA Powertrain & Energy conference, 2022

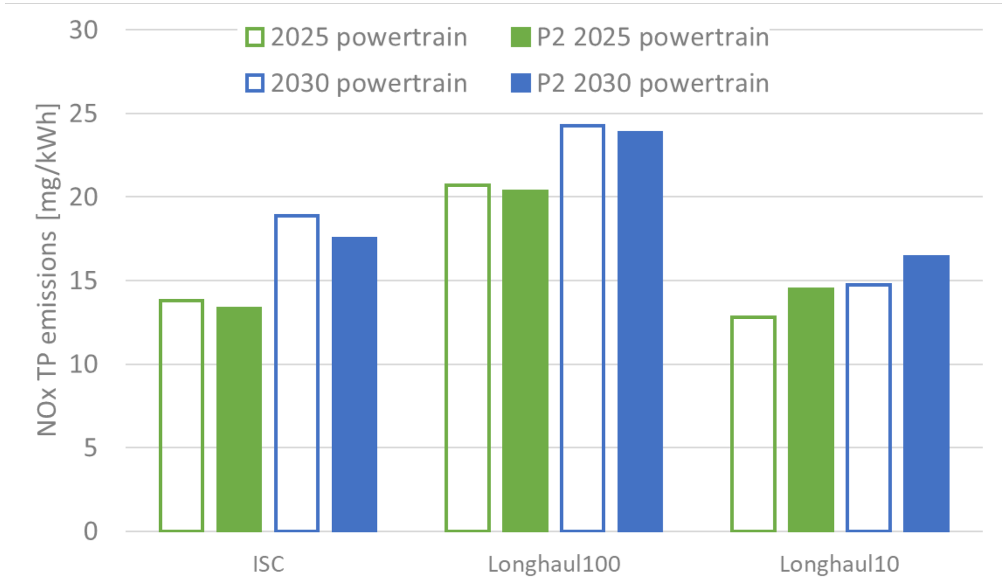
Additional simulations on NOx and CO_2 emissions

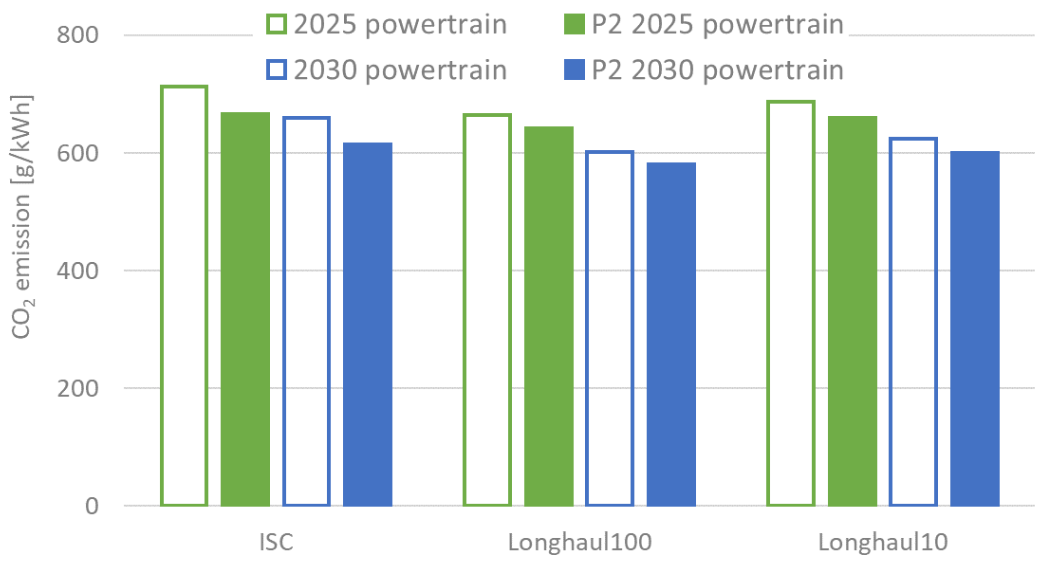
- Simulations conducted by FEV
  - Phase 2 emission control system
  - Model validated based on available measurement data
- Reference simulation for 2025 powertrain
  - In-Service Conformity test
  - VECTO long haul cycles
- Investigation of 2030 powertrain, focusing on following potential technologies (not exhaustive list of available technologies)
  - ICE with BTE of ~55%
  - P2 hybrid

	2025 powertrain	2025 P2 hybrid	2030 powertrain	2030 P2 hybrid
Low NOx mode (~2 g/kWh)	✓	✓	✓	✓
High efficiency mode (~5-8 g/kWh)	✓	✓	✓	✓
FEV 55% BTE engine			✓	✓
Increased peak firing pressure and compression ratio			✓	✓
Improve boosing system, friction layout and combustion system			✓	✓
Waste Heat Recovery			✓	✓
P2 hybrid system		✓		✓

Additional simulations about NOx and CO_2 emissions

- NOx tailpipe emissions remain between 15-25 mg/kWh
  - Despite up to 40% increase in engine-out NOx emissions, from 5 to 8 g/kWh
- Tailpipe CO_2 reduction potential of 11-14%
  - Further Well-to-Wheel reduction to come from running on a sustainable renewable fuel





More videos available on YouTube (AECC eu):
https://www.youtube.com/channel/UCbPS9op5ztLqrv6zlMH_IcQ

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
- Emission control technologies fully operating in combination with drop-in sustainable renewable fuels enable ultra-low pollutant emissions while contributing towards net-zero CO_2 emissions
- NOx-CO_2 simulations show 11-14% tailpipe CO_2 reduction can be expected with 2030 engine combustion technology improvements, additional WtW CO_2 reduction needed and to come from running on a sustainable renewable fuel

THANK YOU !