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

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Keynote
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AECC
ASSOCIATION FOR EMISSIONS CONTROL BY CATALYST

Content

- Euro 7 process and proposal
- AECC demonstrator vehicle data
  - Light-duty diesel
  - Light-duty gasoline
  - Heavy-duty diesel
- Summary and outlook

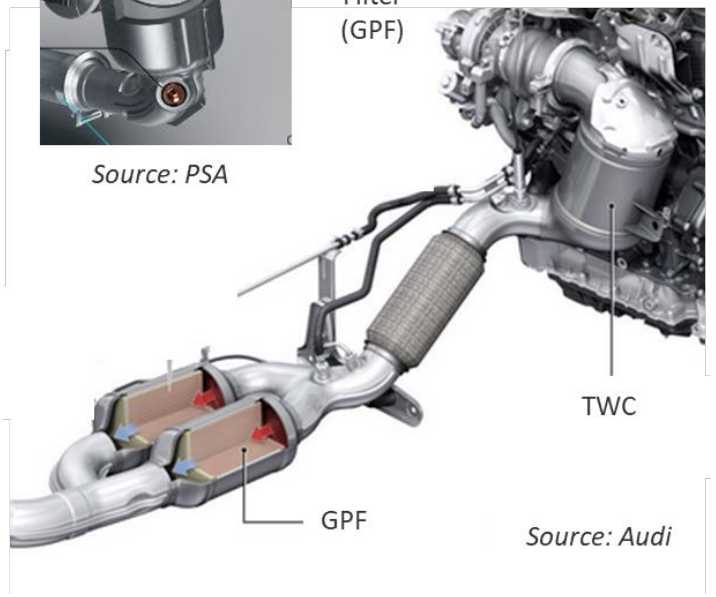
Emission control system evolution towards Euro 6d/VI-D

- LD Gasoline – introduction of Gasoline Particulate Filter
- LD Diesel – combination of deNOx technologies
- HD diesel – compact designs

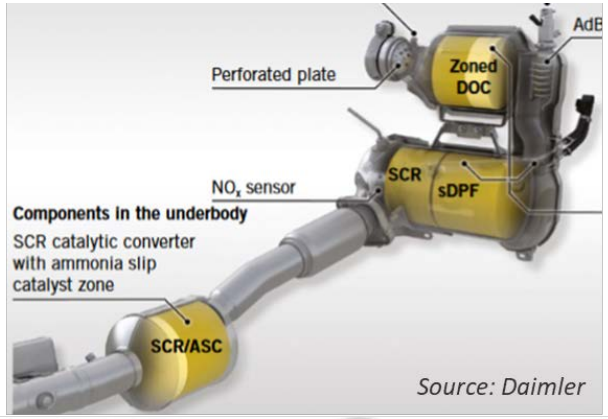
TWC

Gasoline Particulate Filter (GPF)

Source: PSA

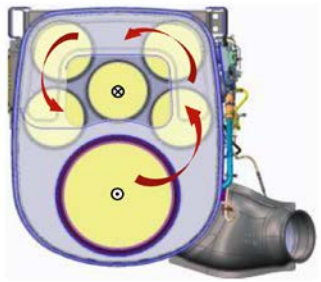


Source: Audi

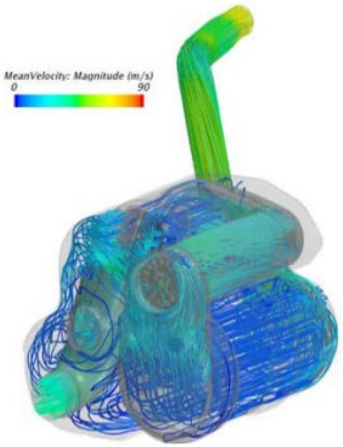


Source: Daimler

Source: VW



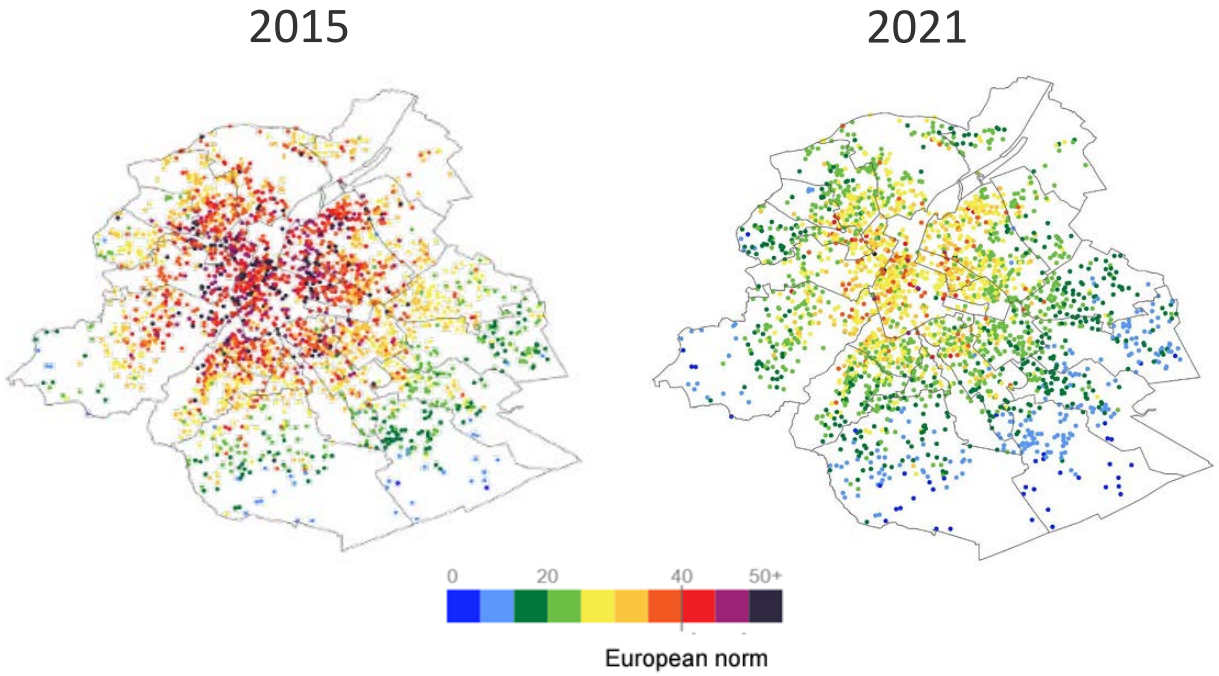
Source: DAF



Source: Daimler

Euro 6d/VI-D contributed to air quality improvements

- Example for NO_2 in Brussels
- Further improvements expected
  - New WHO guidelines from September 2021
  - Proposal for revised EU Ambient Air Quality Directive published on 26 October 2022
- Euro 7 to contribute with enhanced emission control technologies



Source: CurieuzenAir report air quality in Brussels, 2022

Euro 7 within the European Green Deal

- **Zero pollution action plan** for air, water and soil in 2021
- Address **industrial pollution** from large industrial installations in 2021
- **Chemicals strategy for sustainability** in summer 2020
- **Revision of Air Quality standards**

- Strategy for Sustainable and smart mobility
- Revise the CO2 emissions performance legislation for light duty vehicles by June 2021
- Extend EU's Emissions Trading to the maritime sector, and to reduce the free allowances for airlines by June 2021
- Support public charging points: 1 million by 2025
- Boost the production and supply of sustainable alternative fuels for the different transport modes
- Review the Alternative Fuels Infrastructure Directive and the TEN-T Regulation in 2021
- More stringent air pollutant emissions standards for combustion-engine vehicles (EURO 7)

Euro 7 process

- The AGVES expert working group met until end of April 2021
- CLOVE consortium studies finished within 2021
  - Scenarios presented for light- and heavy-duty vehicles
  - Further input for the European Commission impact assessment
- The European Commission
  - Finished the Euro 7 impact assessment on 26 January 2022
  - Published the Euro 7 proposal for cars, vans, trucks and buses on 9 November 2022
- Nex steps
  - The ordinary legislative process by European Parliament and Council
  - Development of implementing and delegated legislation by the European Commission involving the AGVES expert working group

Euro 7 impact assessment policy options

	PO1 Low Zero-pollution ambition	PO2a Medium Zero-pollution ambition	PO2b High Zero-pollution ambition	PO3a PO2a + Medium digital ambition
Simplification	Included	Included	Included	Included
Limits	Euro 6/VI	Medium ambition	High ambition	Medium ambition
Boundaries	Low ambition	Medium ambition	High ambition	Medium ambition
Durability	Low increase	Medium increase	Full increase	Medium increase
LD brake emissions	-	Brake pads	Brake filters	Brake pads
On-Board Monitoring	-	-	-	NOx, NH_3, PM

Boundaries of RDE test conditions for cars & vans

Parameter	Current RDE boundaries	Low Ambition Normal	Low Ambition Extended	Medium Ambition Normal	Medium Ambition Extended	High Ambition Normal	High Ambition Extended
Limit multiplier			4		2		3
Ambient temperature [°C]	Moderate: 0 – 30°C | Extended: -7 – 0°C & 30 – 35°C	-7°C to 35°C	-10°C to 45°C	-7°C to 35°C	-10°C to 45°C	-7°C to 35°C	-10°C to 45°C
Max. speed	145 km/h	145 km/h	160 km/h	145 km/h	160 km/h	160 km/h	Above 160 km/h
Aggressiveness	Speed-based calculated maximum limits	As in RDE	Outside RDE	Restriction to the average power at cold start	Higher average power at cold start	Restriction to the average power at cold start	Higher average power at cold start
Max. altitude	Moderate: 0 – 700m | Extended: 700 – 1300m	1300 m	1600 m	1300 m	1800 m	1600 m	2200 m
Trip composition/ distance	33% urban, 33% rural, 33% highway at least 16 km each	Any trip more than 10 km	-	Any	-	Any	-
Towing/aerodynamic modifications	Not included	Not allowed	Allowed within OEM limits and specs	Not allowed	Allowed within OEM weight limits and specs	Not allowed	Allowed within OEM weight limits and specs
Minimum mileage	15,000 km	10,000 km	-	10,000 km	Between 3,000 and 10,000 km	3,000 km	Between 300 and 3,000 km

Limit scenarios for cars & vans

Evaluated emission limits Lower Option	Cars	Small vans	Large vans
NO_x	60	75	82
PM	4.5	4.5	4.5
PN (#/km)	6×10^{11}	6×10^{11}	6×10^{11}
CO	500	630	740
THC	100	130	160
NMHC	68	90	108
THC+NOx	20	20	20
Evaporative	2 g/test	2 g/test	2 g/test

Evaluated emission limits Medium Option	Cars and vans	Large vans if underpowered
NO_x	30	45
PM	2	2
$PN_{>10nm}$ (#/km)	1×10^{11}	$1x10^{11}$
CO	400	600
NMOG	45	45
NH_3	10	10
N_2O+CH4	45	55
HCHO	5	10
Evaporative	0,5 g/test+ORVR	0,7 g/test+ORVR
Brake emissions	7	7
Battery Durability in 5/8 years	80/70%	80/70%

Evaluated emission limits Stricter Option	Cars and vans	Large vans if underpowered
NO_x	20	30
PM	2	2
$PN_{>10nm}$ (#/km)	1×10^{11}	1×10^{11}
CO	400	600
NMOG	25	25
NH_3	10	10
N_2O+CH4	20	25
HCHO	5	10
Evaporative	0.3 g/worst diurnal test + ORVR	0.5 g/worst diurnal test + ORVR
Brake emissions	5	5
Battery Durability in 5/8 years	90/80%	90/80%

Boundaries of RDE test conditions for trucks & buses

Parameter	Current boundaries	Low Ambition Normal	Low Ambition Extended	Medium Ambition Normal	Medium Ambition Extended	High Ambition Normal	High Ambition Extended
Limit multiplier			3		2		2
Ambient temperature [°C]	-7°C to 35°C	-7°C to 35°C	-10°C to 45°C	-7°C to 35°C	-10°C to 45°C	-7°C to 35°C	-10°C to 45°C
Minimum trip duration	More than 4 WHTC	More than 4 WHTC	Between 3 and 4 WHTC	Any (for MAW evaluation 4× WHTC)	-	Any (for MAW evaluation 4× WHTC)	-
Evaluation (MAW)	1x WHTC window	1x WHTC window		1x WHTC window	-	1x WHTC window	
Engine loading	Only work windows > 10% valid	All		All	-	All	
Payload		Higher than or equal to 10%	Less than 10%	Higher than or equal to 10%	Less than 10%	Any	-
Maximum altitude (m)	1600	Up to 1300	From 1300 to 1600	Up to 1600	From 1600 to 1800	Up to 1600	From 1600 to 2200
Minimum mileage	15,000 km	10.000 km	-	5 000 km for <16t TPMLM 10 000 km for > 16t TPMLM	Between 3 000 km and 5 000 km for <16t TPMLM Between 3 000 km and 10 000 km for > 16t TPMLM	3 000 km for <16t TPMLM 6 000 km for > 16t TPMLM	Between 300 km and 3 000 km for <16t TPMLM 6 000 km for > 16t TPMLM

Limit scenarios for trucks & buses

Evaluated Emission Limits HDV (mg/kWh) Low Ambition Option	Positive ignition vehicles
NOx	460
PM	10
PN (#/kWh)	$6{,}0 \times 10^{11}$
CO	4000
THC	660
NMHC	160
NH_3 (ppm)	10

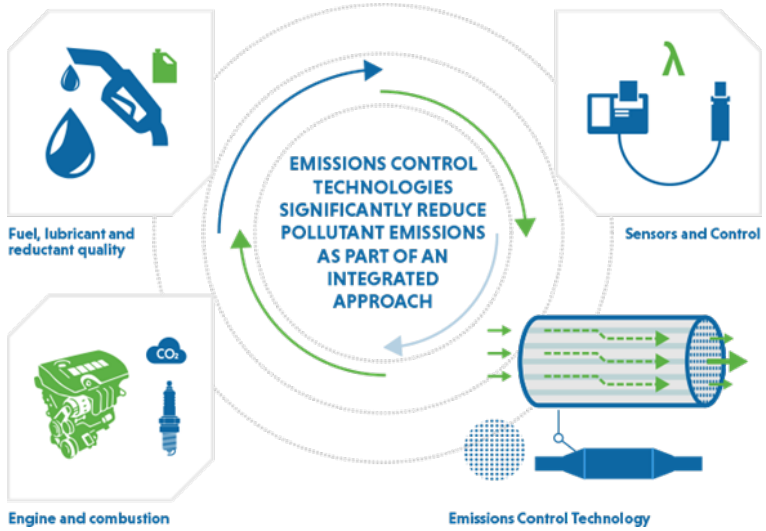
Evaluated limits HDV (mg/kWh) Medium Ambition	Cold emissions	Hot emissions
NO_x	350	90
PM	12	8
$PN_{>10nm}$ (#/km)	$5{\times}10^{11}$	$1{\times}10^{11}$
CO	3500	200
NMOG	200	50
NH_3	65	65
N_2O+CH4	660	410
HCHO	30	30
Brake emissions	Review	Review
Battery Durability	Review	Review

Evaluated limits HDV (mg/kWh) High Ambition	Cold emissions	Hot emissions
NO_x	175	90
PM	12	8
$PN_{>10nm}$ (#/km)	$5{\times}10^{11}$	$1{\times}10^{11}$
CO	1500	200
NMOG	150	50
NH_3	65	65
N_2O+CH4	660	410
HCHO	30	30
Brake emissions	Review	Review
Battery Durability	Review	Review

+ Optional idle limit of 5g/h NOx if engine does not shut off in 5 min when parked

AECC demo data supports Euro 7 and ‘Fit for 55’

- Three demonstration vehicle programmes have been completed showing how emission control technologies achieve ultra-low pollutant emissions
- These demonstrators have been tested with drop-in sustainable renewable fuels and substantial reduction in CO_2 emissions have been achieved in an objective Well-to-Wheel assessment



IPA IAV Concawe

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Automotive Grade Urea Sector Group

IPA FEV CORNING cefic sector group NESTE aramco

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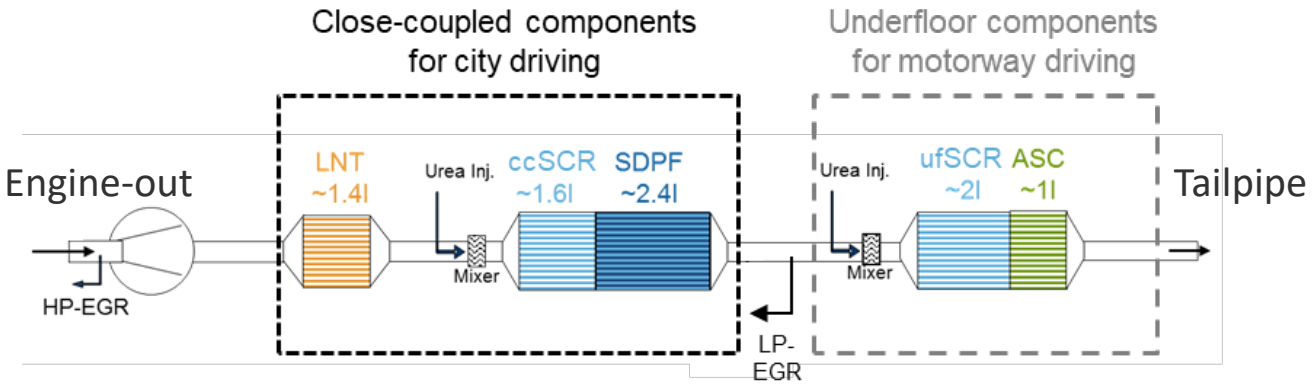
LD diesel demonstrator concept and results

- Objective is to demonstrate ultra-low NOx emissions over wide range of driving conditions on various fuels

- Emission control system based on combination of available components LNT + dual-SCR supported by 48V mild-hybrid system



Note: hydrothermal aged components used targeting 160k km

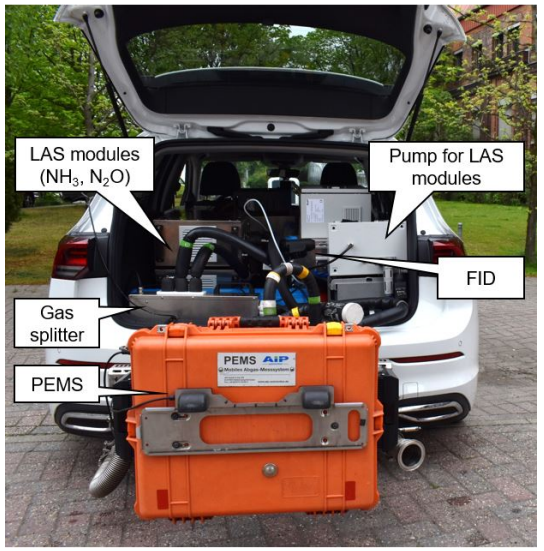
J. Demuynck, et al.; "Integrated Diesel System Achieving Ultra-Low Urban and Motorway NOx Emissions on the Road", 40th Vienna Motor Symposium, 2019
https://www.aecc.eu/wp-content/uploads/2020/07/190516-AECC-IAV-IPA-Integrated-Diesel-System-achieving-Ultra-Low-NOx-on-the-road-Vienna-Symposium.pdf
Joint MTZ publication with Bosch, Vitesco, FEV and IAV https://www.aecc.eu/wp-content/uploads/2020/09/200901-modern-diesel-MTZ.pdf
Videos of instantaneous conversion performance available at www.youtube.com/channel/UCbPS9op5ztLqrv6zlMH_IcQ

Engine load: 11% Vehicle speed: 0 km/h

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

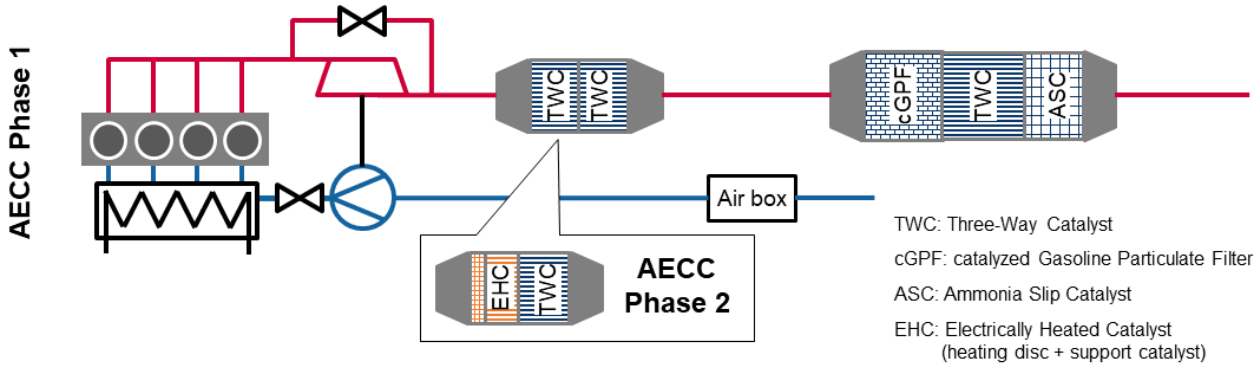
LD gasoline demonstrator concept

- Base vehicle
  - C-segment vehicle
  - 1.5l engine with 4 cylinders
  - Variable valve train and cylinder deactivation
  - 48V mild-hybrid (belt-driven, P0 configuration)
  - Euro 6d type-approval baseline: cc cGPF + uf TWC
- Instrumentation
  - Chassis dyno: 3x standard sampling points, 2x FTIR and tailpipe PN10
  - Road: prototype PEMS to measure CO_2, NOx, CO, THC, PN10, NH_3 and N_2O



LD gasoline demonstrator concept

- AECC emission control system
  - Phase 1: cc TWC, uf cGPF+TWC+ASC
  - Phase 2: cc EHC|TWC, uf cGPF+TWC+ASC
  - Bench aged components targeting 160k km



J. Demuynck, et al.; "Ultra-low Emissions of a 48V Mild-Hybrid Gasoline Vehicle with Advanced Emission Control Technologies", 15th International Conference on Engines and Vehicles, 2021
J. Demuynck, et al.; "Zero-Impact Emissions from a Gasoline Car with Advanced Emission Controls and E-Fuels" 43rd International Vienna Motor Symposium, 2022

Ignition

Engine load: *0* %

Vehicle speed: *0* km/h

500

0

NOx

2 ppm

30 s or 150 m to near-zero emissions

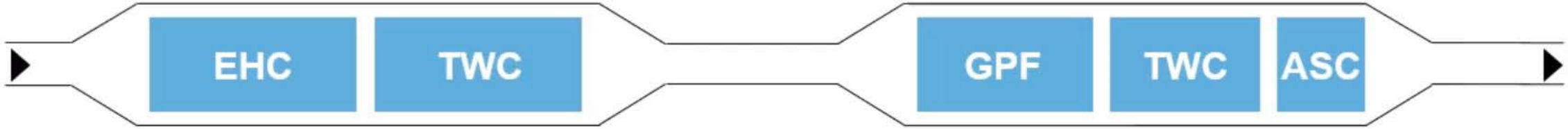
500

0

NOx

0 ppm

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



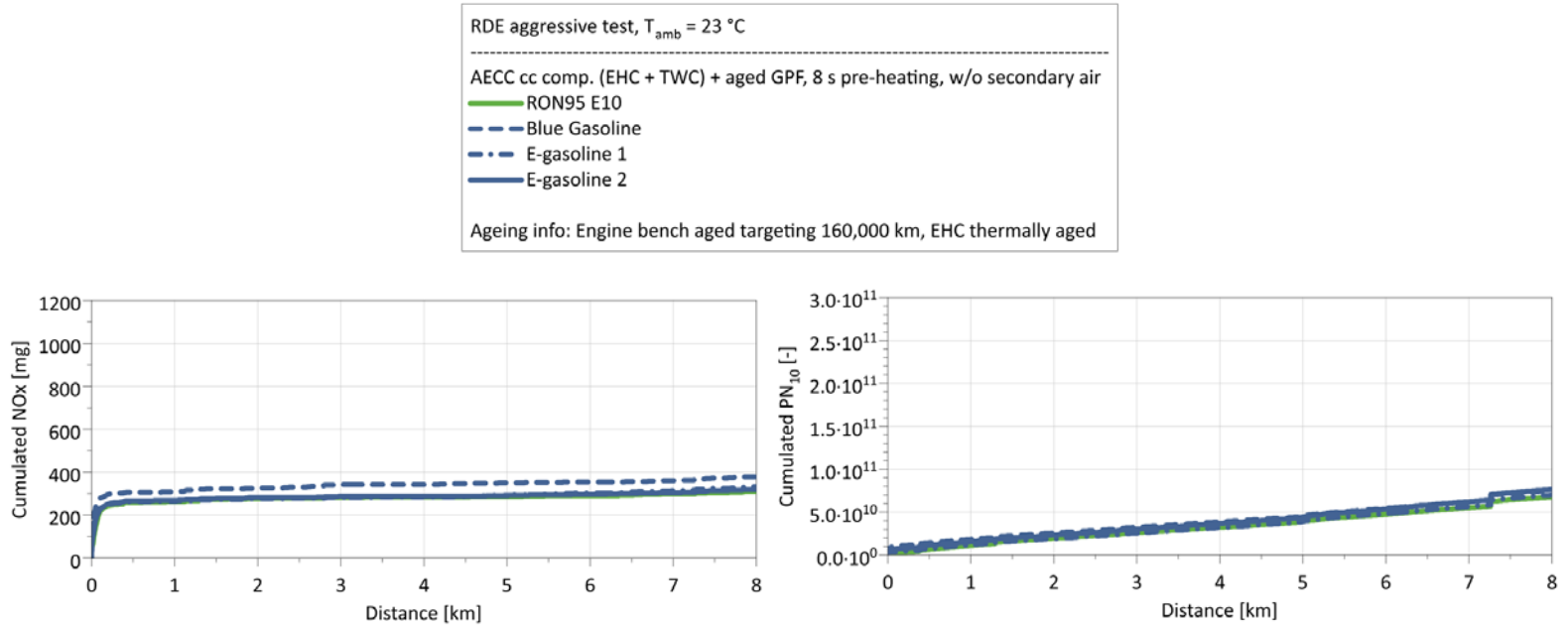
Engine catalyst heating

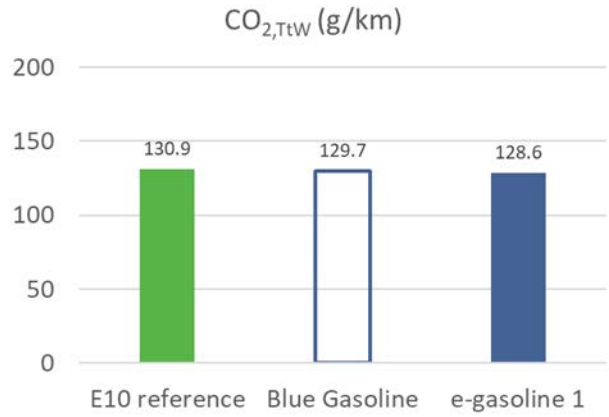
EHC heating

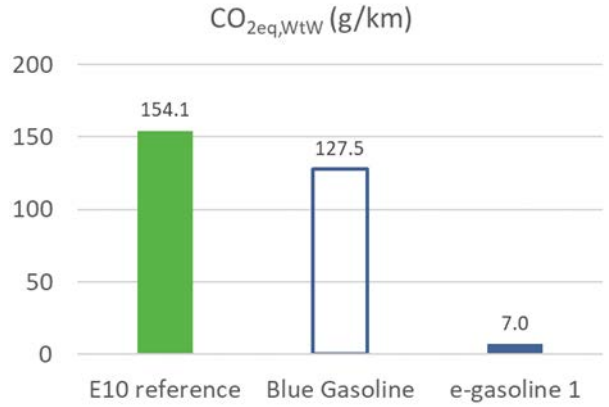
Closed-loop lambda control

LD gasoline demonstrator with sustainable renewable fuels

- Ultra-low pollutant emissions confirmed on Blue Gasoline and e-gasolines
- Well-to-Wheel CO2 compared to E10 reference
  - Blue Gasoline example of significant reduction possible today
  - E-gasoline has the potential to nearly eliminate WtW CO_2 emissions





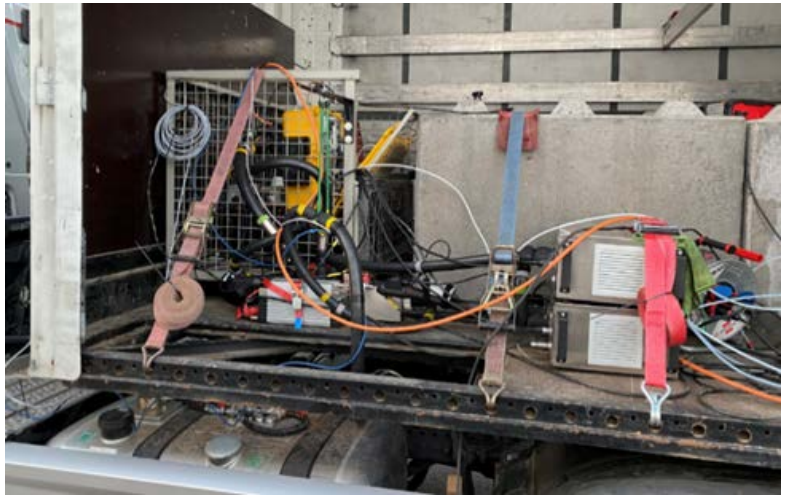


J. Demuynck, et al.; "Advanced Emission Controls and E-fuels on a Gasoline Car for Zero-Impact Emissions" SAE paper 2022-01-1014, SAE PFL conference, 2022

HD diesel demonstrator concept

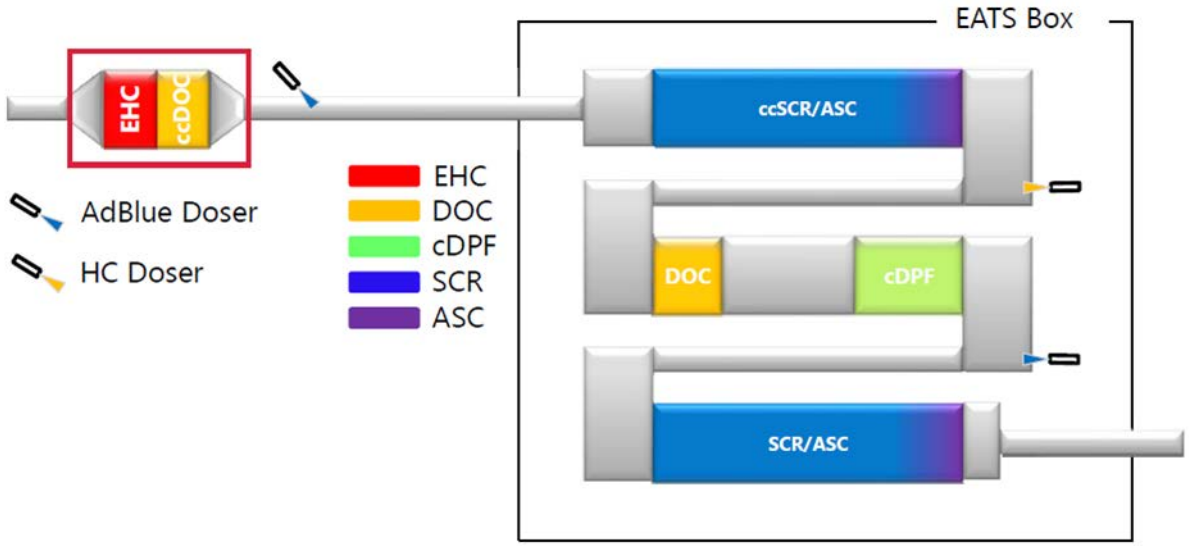
- Base vehicle description
  - MB Actros 1845 LS 4x2
  - Engine OM 471
    - Euro VI C certified
    - 12.8 litres, 6 cylinder in-line
    - High Pressure EGR

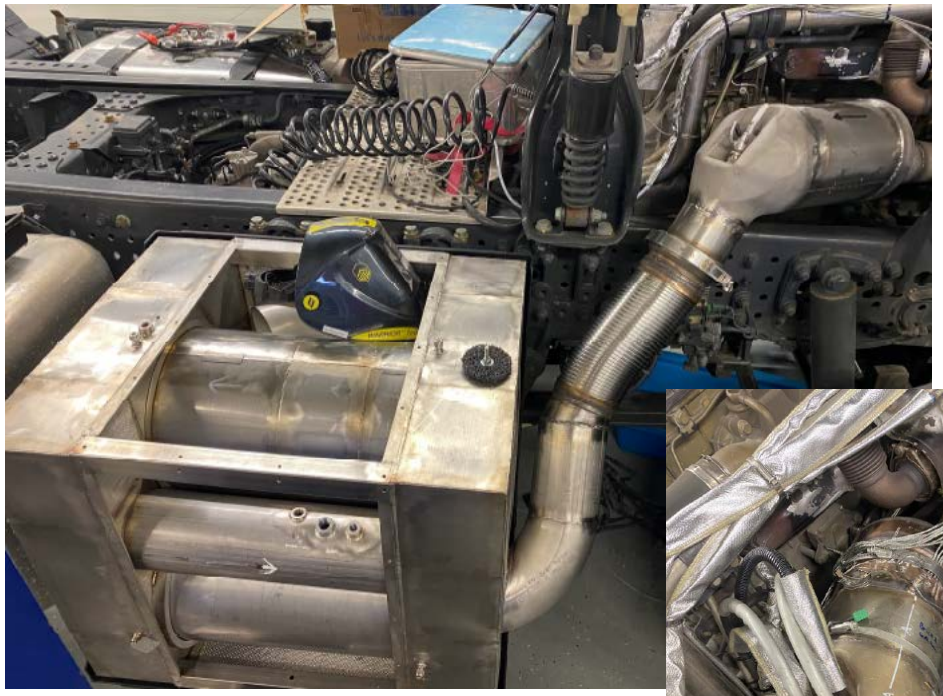
- Instrumented with prototype PEMS to measure CO_2, NOx, CO, PN10, NH_3 and N_2O

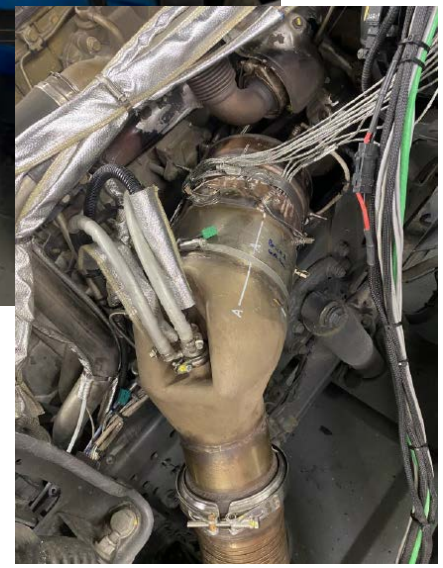


HD diesel demonstrator concept

- 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







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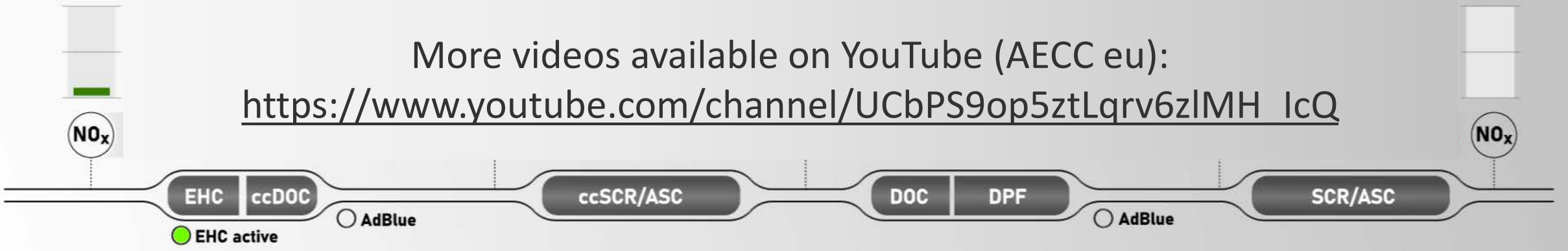
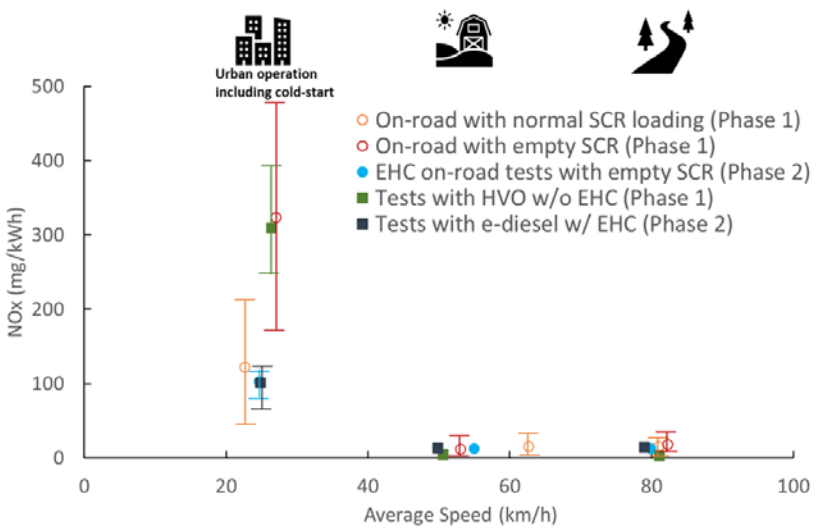
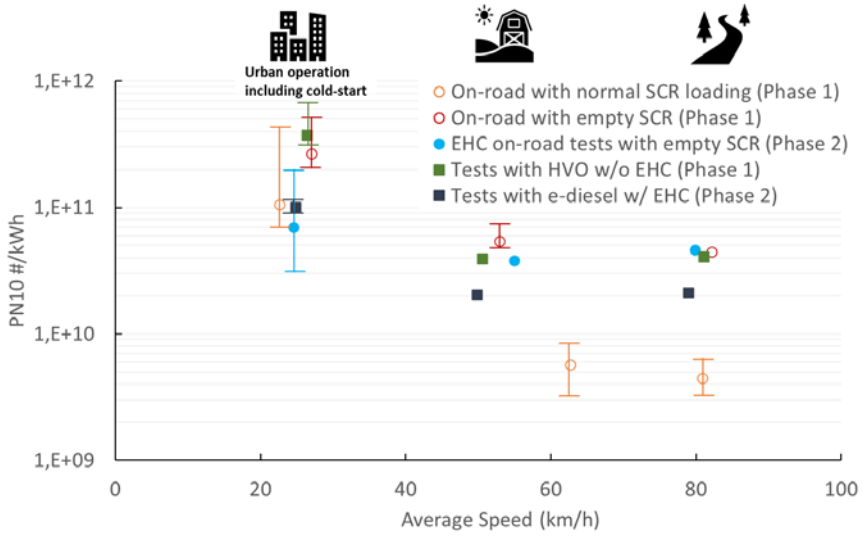
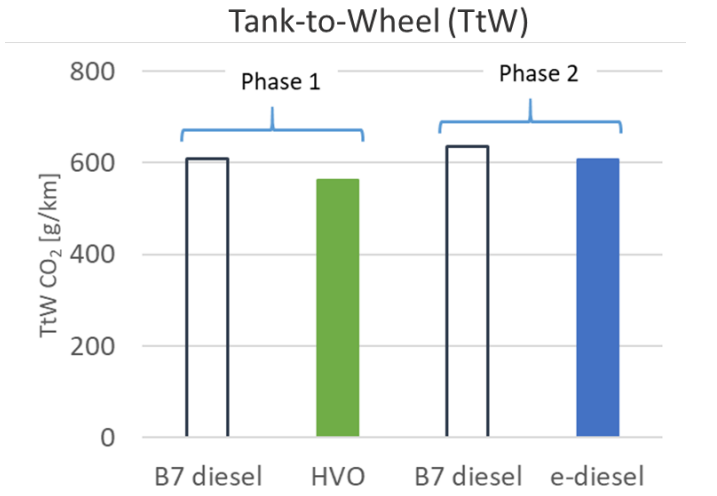


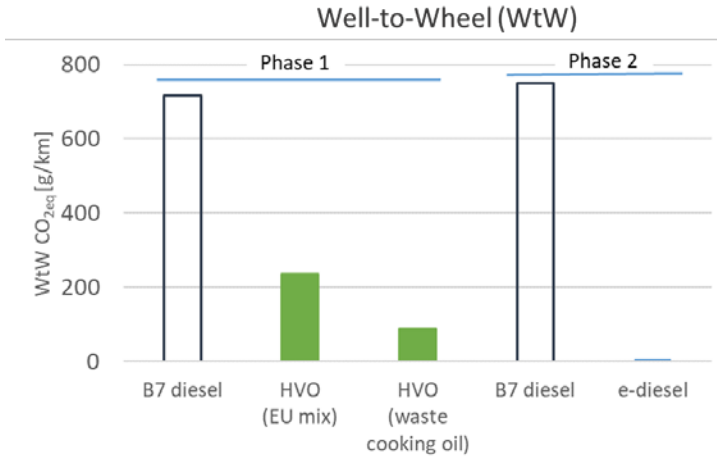
HD diesel demonstrator with sustainable renewable fuels

- Ultra-low pollutant emissions confirmed on HVO and e-diesel
- HVO already offers today up to 90% WtW CO_2 reduction
- 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

Summary and outlook

- AECC demonstrator vehicle project data shows
  - Significant reduction of initial cold-start peak compared to already low Euro 6/VI level
  - Near-zero emissions after initial cold-start including under low load/speed driving
  - Maintaining ultra-low pollutant emissions with sustainable renewable fuels which significantly reduce Well-to-Wheel CO_2 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 next steps
  - Development of ambitious Euro 7 standards in EU
  - Other regions of the world to move towards Euro 7 ambition in combination with uptake of sustainable renewable fuels for CO_2 reduction

THANK YOU !

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