

Enabling Upcoming Euro 7 Standards by Advanced Emission Controls with Low CO₂ Emissions

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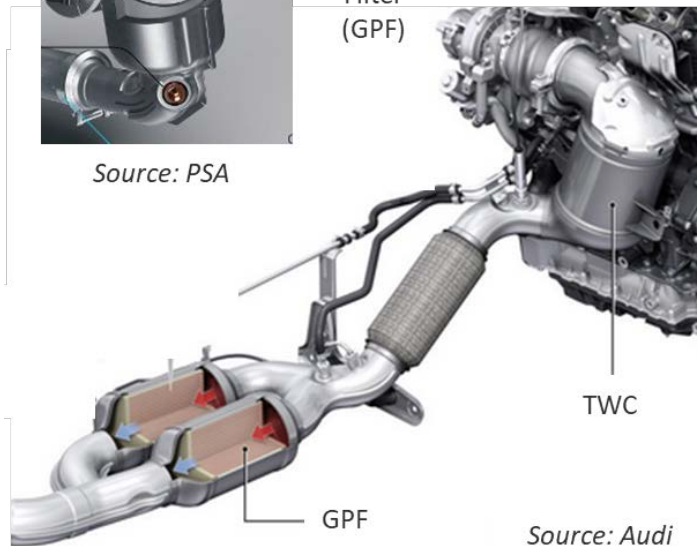
Emission control system evolution towards Euro 6d/VI-D

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



TWC
Gasoline
Particulate
Filter
(GPF)

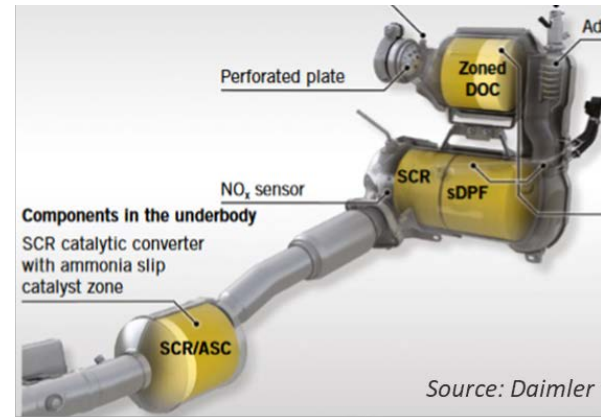
Source: PSA



TWC

GPF

Source: Audi

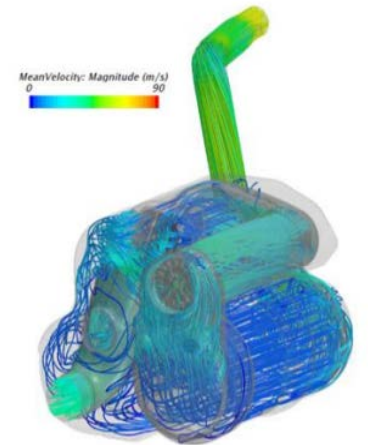


Components in the underbody
SCR catalytic converter
with ammonia slip
catalyst zone

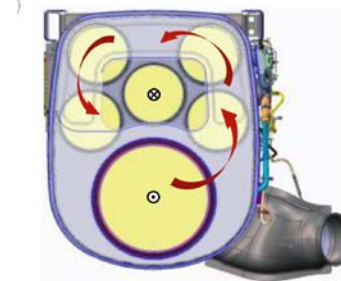
Source: Daimler



Source: VW



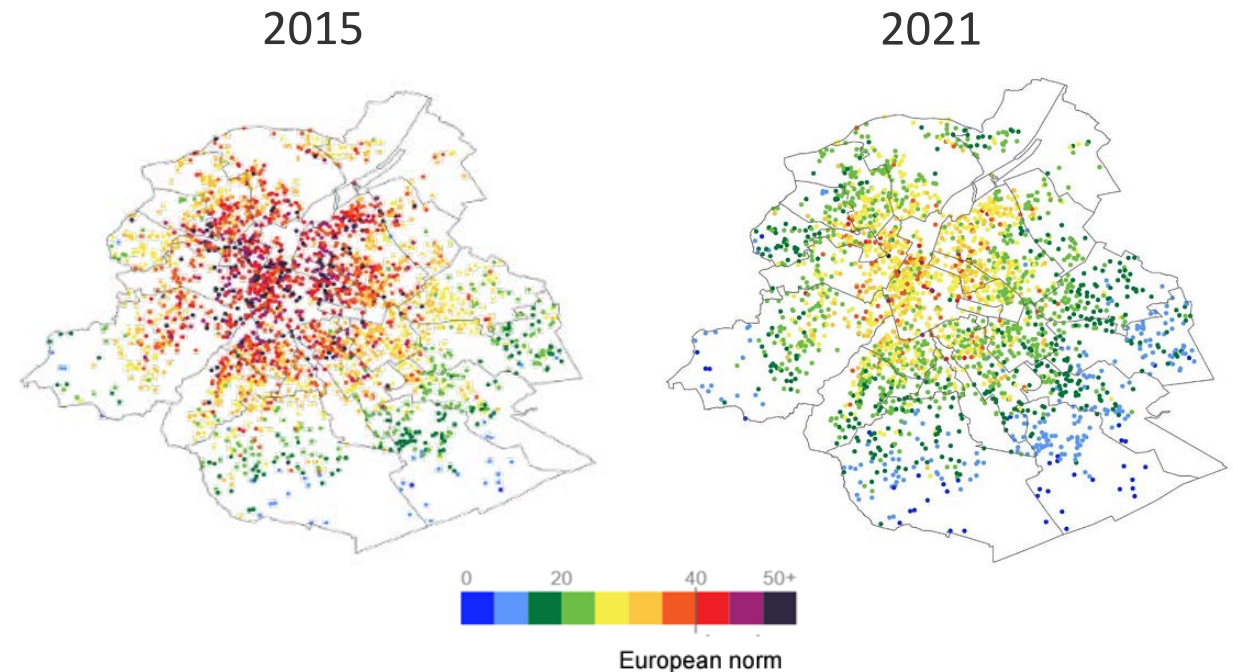
Source: Daimler



Source: DAF

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

- Example for NO₂ 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



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	-	-	-	NO _x , NH ₃ , PM

Presented by EC DG-GROW during AECC-IPA Euro 7 Technical Seminar, 28 September Brussels, <https://www.aecc.eu/wp-content/uploads/2022/09/AECC-Euro-7-workshop-Dilara-final.pdf>

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+NO _x	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	1×10 ¹¹
CO	400	600
NMOG	45	45
NH ₃	10	10
N ₂ O+CH ₄	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 ₂ O+CH ₄	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

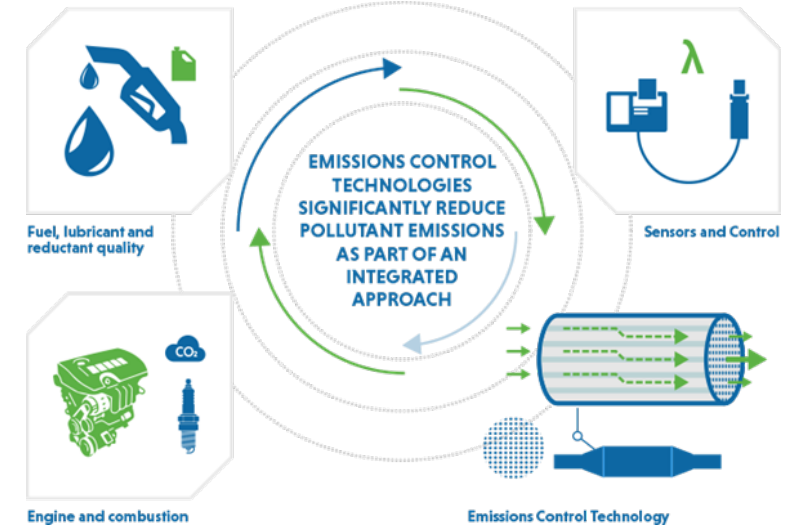
Evaluated Emission Limits HDV (mg/kWh) Low Ambition Option	Positive ignition vehicles
NO _x	460
PM	10
PN (#/kWh)	$6,0 \times 10^{11}$
CO	4000
THC	660
NMHC	160
NH ₃ (ppm)	10

Evaluated limits HDV (mg/kWh) Medium Ambition	Cold emissions	Hot emissions	Evaluated limits HDV (mg/kWh) High Ambition	Cold emissions	Hot emissions
NO _x	350	90	NO _x	175	90
PM	12	8	PM	12	8
PN _{>10nm} (#/km)	5×10^{11}	1×10^{11}	PN _{>10nm} (#/km)	5×10^{11}	1×10^{11}
CO	3500	200	CO	1500	200
NMOG	200	50	NMOG	150	50
NH ₃	65	65	NH ₃	65	65
N ₂ O+CH ₄	660	410	N ₂ O+CH ₄	660	410
HCHO	30	30	HCHO	30	30
Brake emissions	Review	Review	Brake emissions	Review	Review
Battery Durability	Review	Review	Battery Durability	Review	Review

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

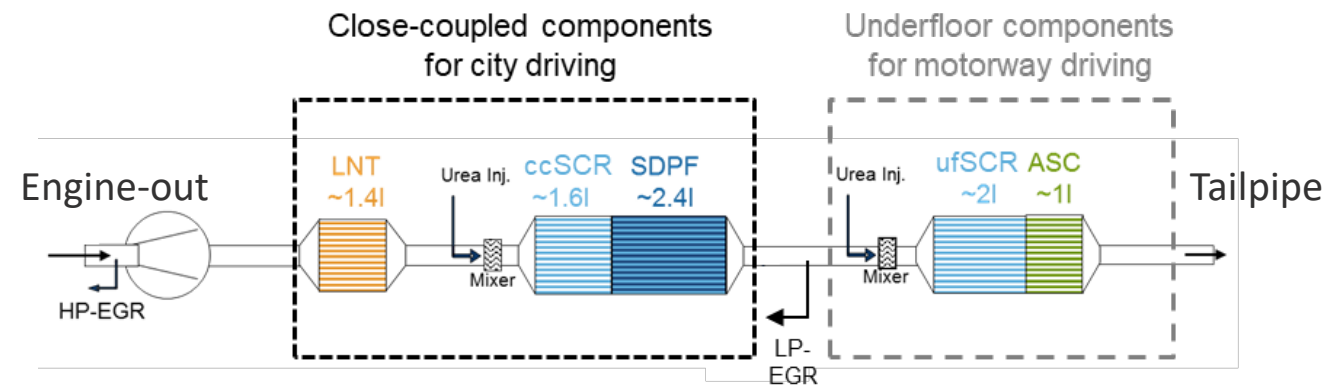
AECC demo data supports Euro 7 and 'Fit for 55'

- 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 CO₂ emissions have been achieved in an objective Well-to-Wheel assessment



LD diesel demonstrator concept and results

- Objective is to demonstrate ultra-low NO_x 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 NO_x 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/UCbPS9op5ztLqrv6zIMH_IcQ



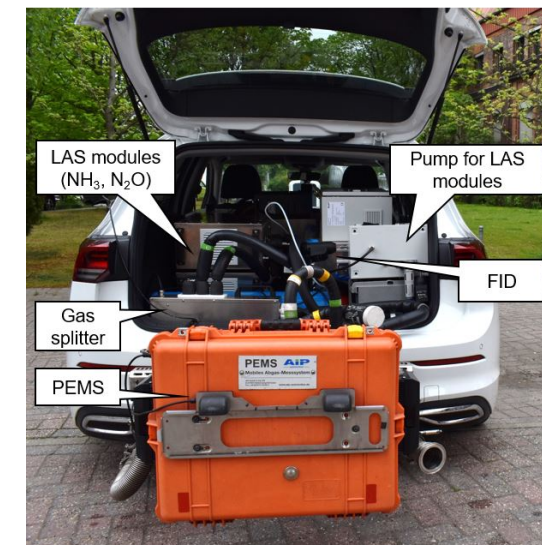
Engine load: 11% Vehicle speed: 0 km/h

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



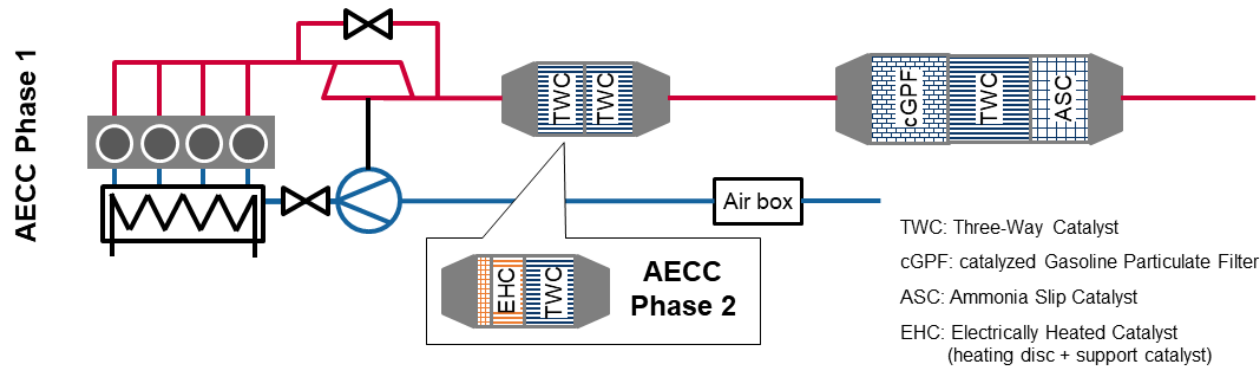
LD gasoline demonstrator concept

- 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 CO₂, NO_x, CO, THC, PN10, NH₃ and N₂O



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%

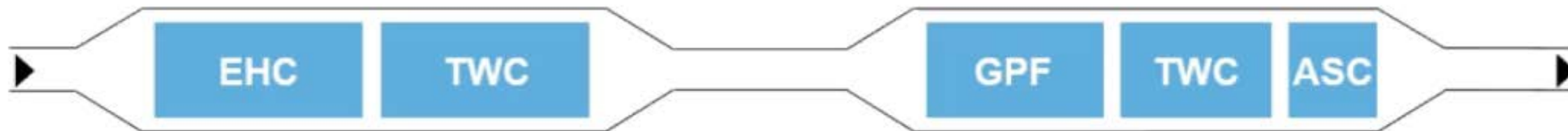
Vehicle speed: 0 km/h



30 s or 150 m to near-zero emissions



More videos available on YouTube (AECC eu): https://www.youtube.com/channel/UCbPS9op5ztLqrv6zIMH_IcQ



Engine catalyst heating



EHC heating

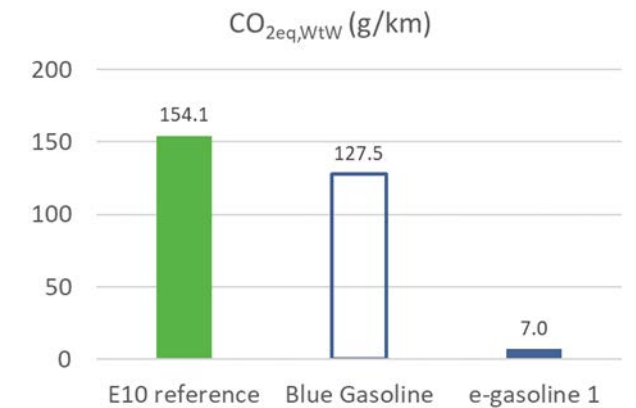
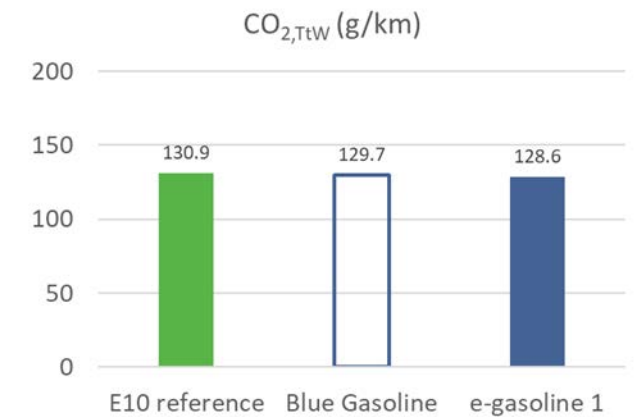
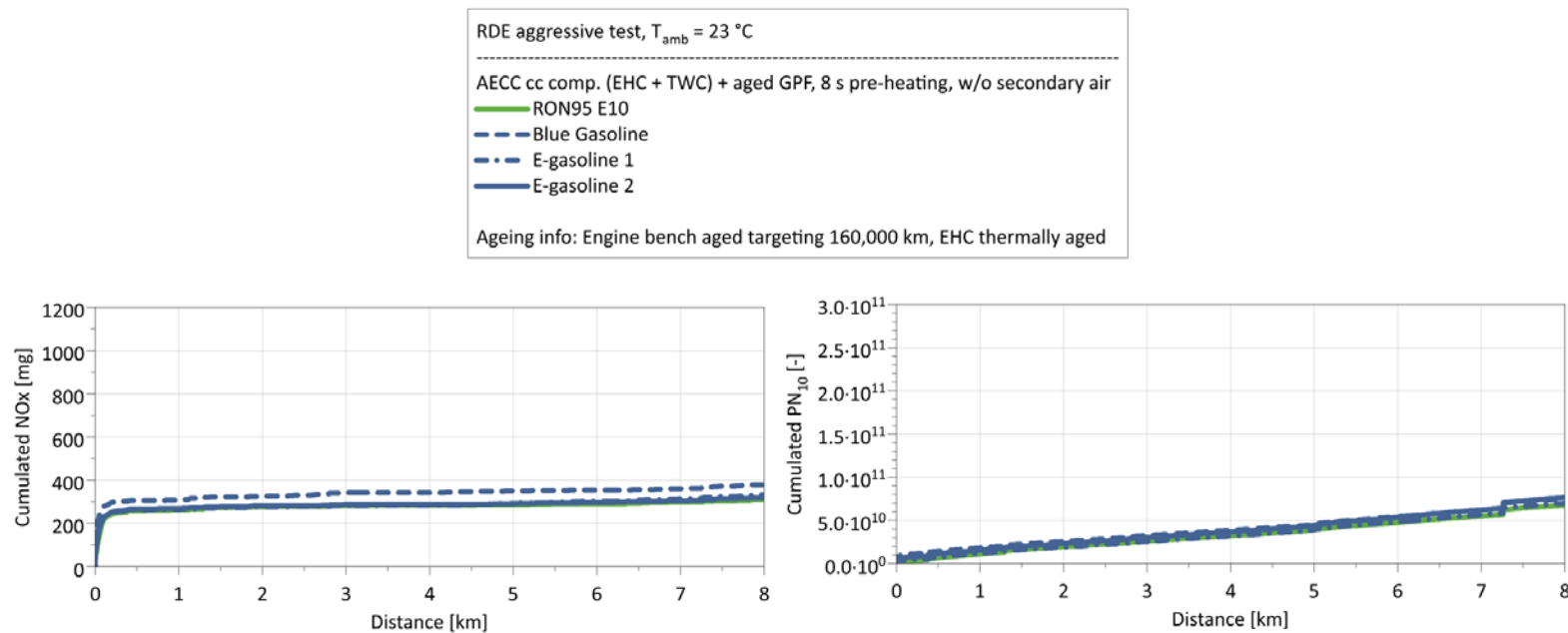


Closed-loop lambda control

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 CO₂ emissions

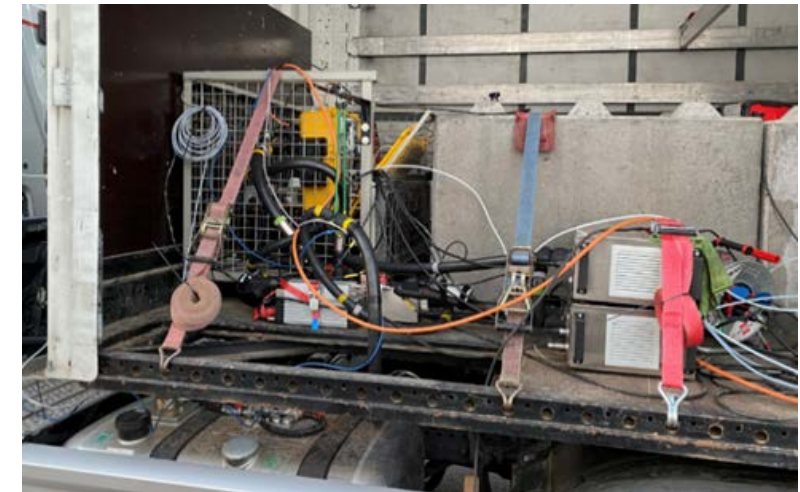


J. Demuyne, et al.; [“Advanced Emission Controls and E-fuels on a Gasoline Car for Zero-Impact Emissions”](#) SAE paper 2022-01-1014, SAE PFL conference, 2022

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

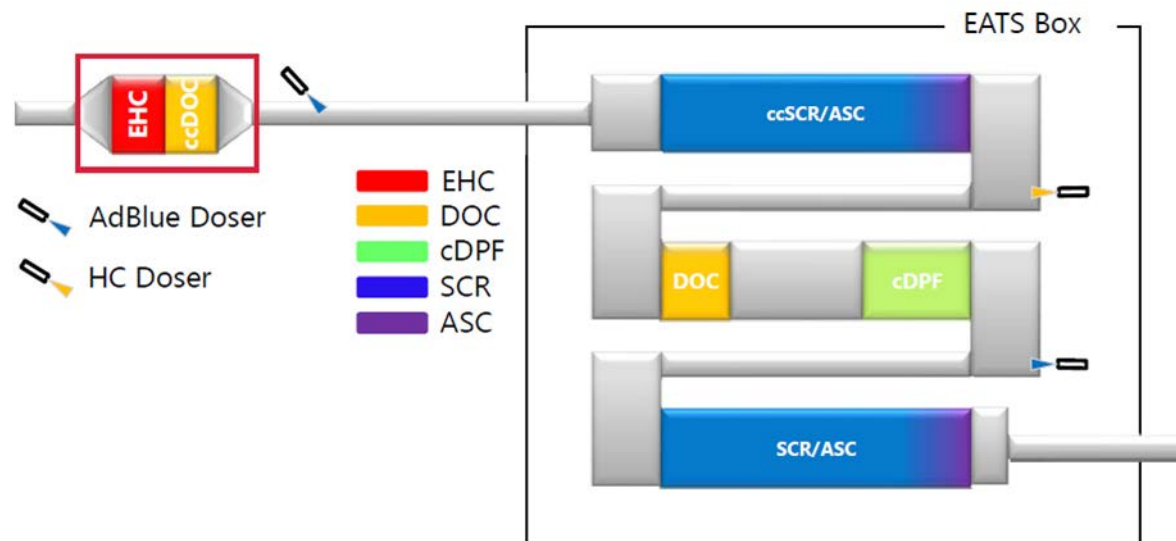
- Instrumented with prototype PEMS to measure CO₂, NO_x, CO, PN10, NH₃ and N₂O



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





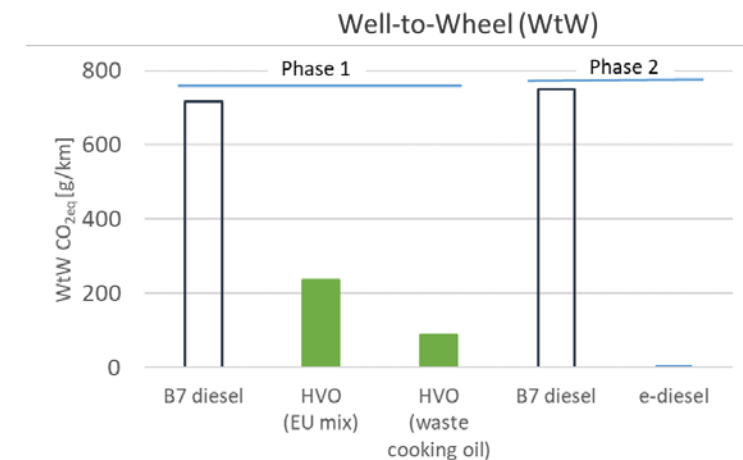
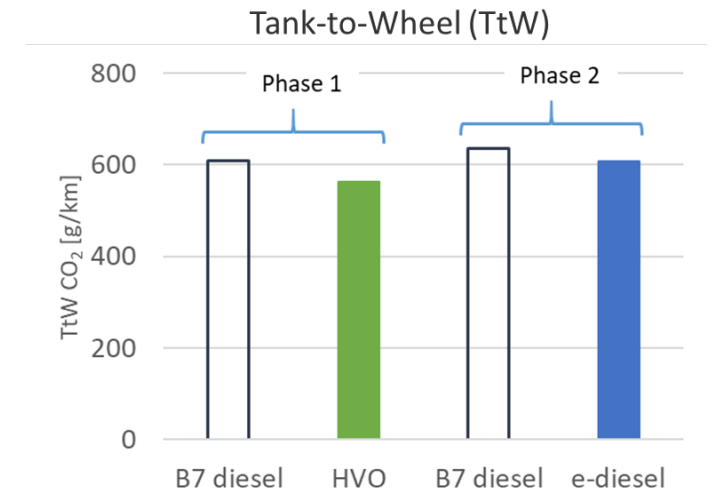
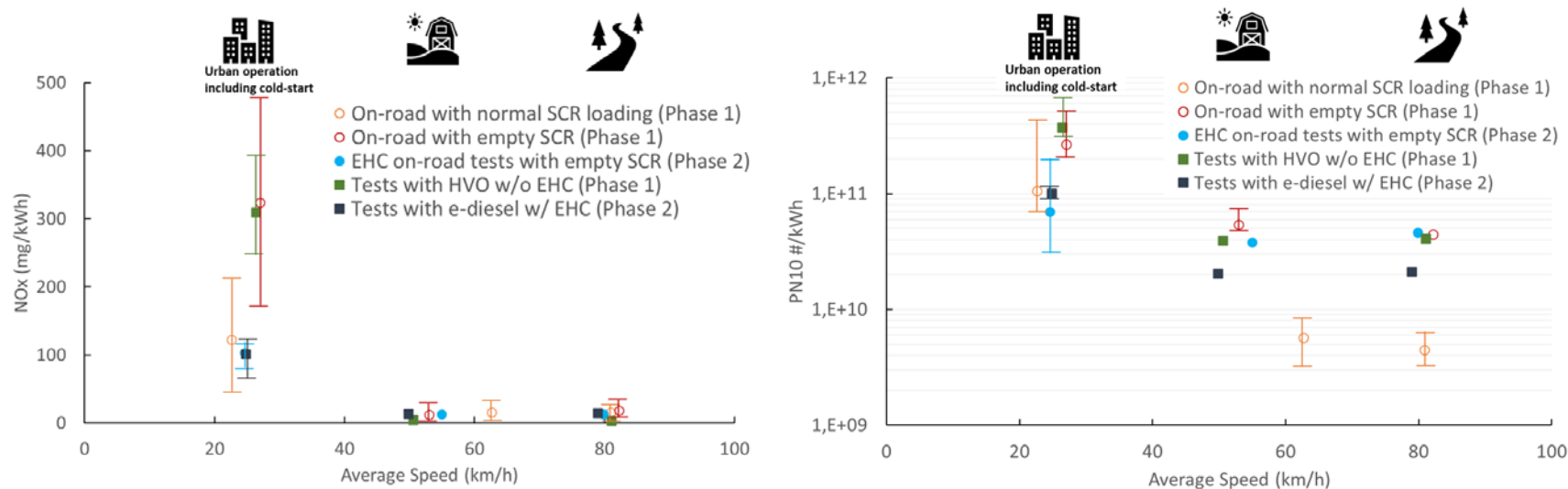
More videos available on YouTube (AECC eu):

https://www.youtube.com/channel/UCbPS9op5ztLqrv6zIMH_IcQ



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 CO₂ reduction
- E-diesel has the potential to nearly eliminate WtW CO₂ 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 CO₂ 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 CO₂ reduction

THANK YOU !



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[AECC \(Association for Emissions Control by Catalyst\)](#)



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