# Ultra-low pollutant and $CO_2$ emissions on demonstrator vehicles with advanced emission controls and sustainable renewable fuels

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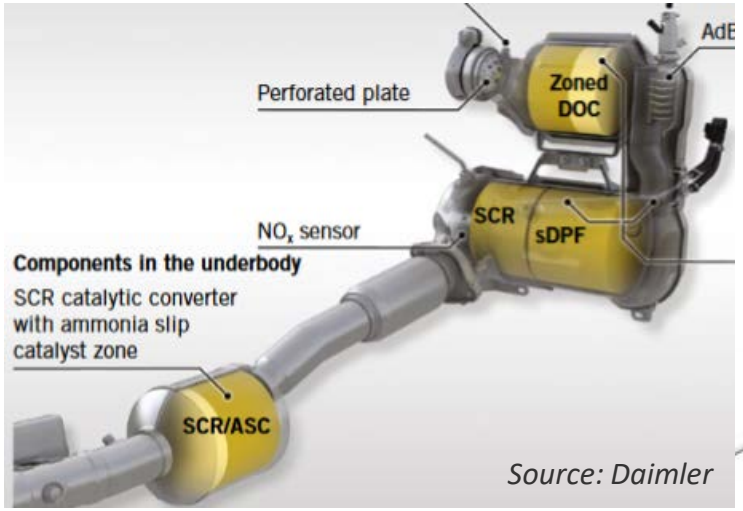
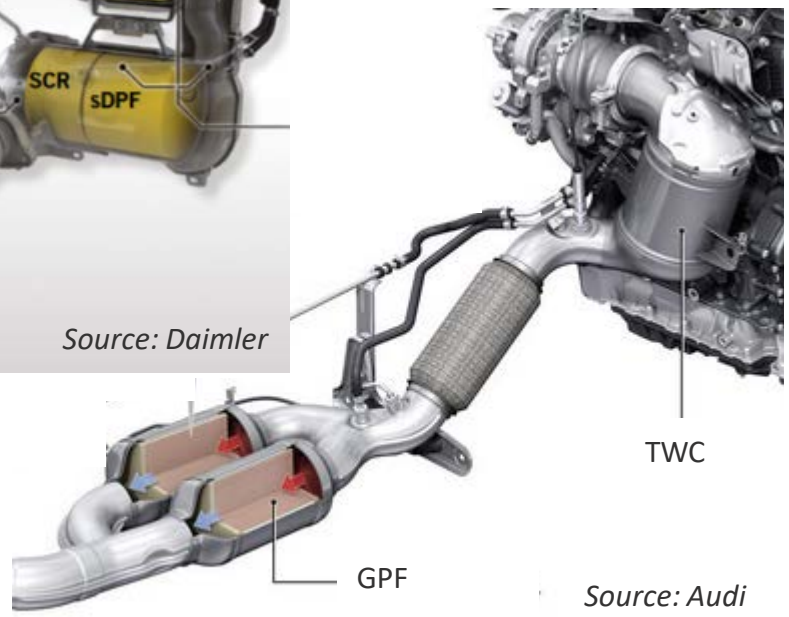
# Euro 6d/VI-D significantly reduced impact on air quality

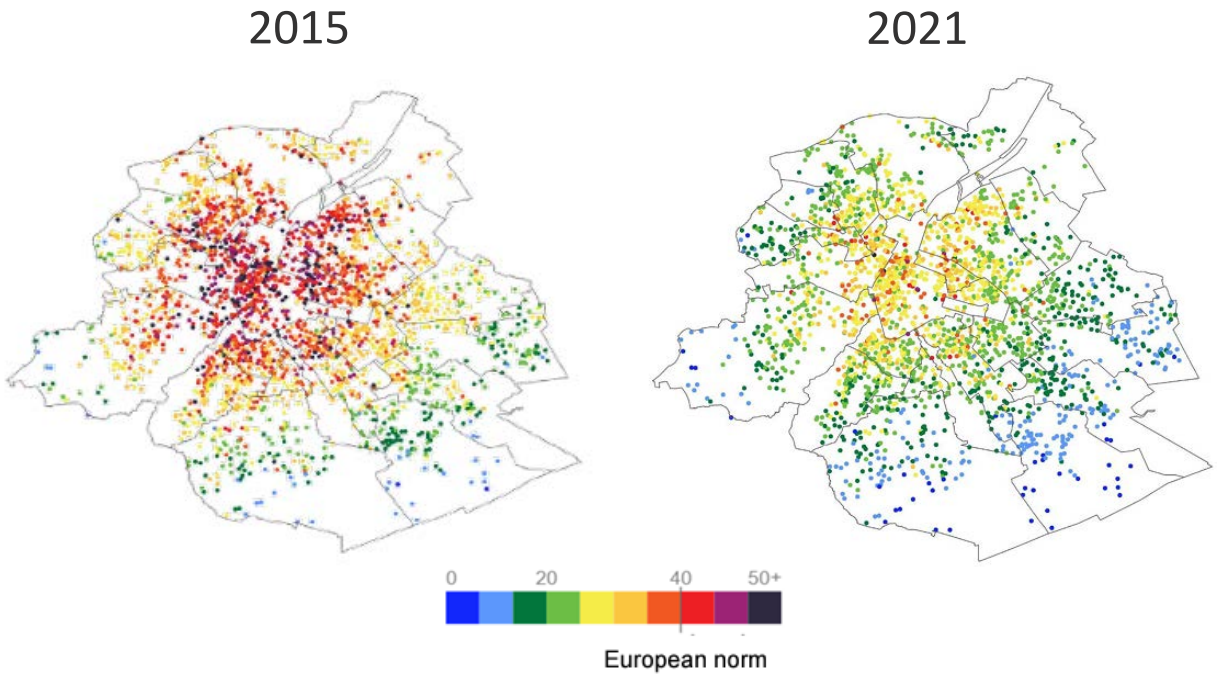
- Implementation of advanced emission control systems
- Several reports about improved air quality, for example $NO_2$ in Brussels
- Further emission legislation evolution expected towards Euro 7



*Source: Daimler*



*Source: Audi*



Source: CurieuzenAir report air quality in Brussels, 2022

# Reduction of ICE $CO_2$ emissions to mitigate climate change

- Increase in efficiency and level of electrification for new vehicles
- Wider usage of sustainable renewable fuels to reduce Well-to-Wheel and lifecycle emissions
  - Immediate reductions for the existing fleet in addition to new vehicles
  - Production is a reality, further investments depending on the policy framework
  - Usage for road transport is not fully recognised in ‘Fit for 55’ proposal under discussion

03.05.2021 | Image | #Powertrain systems

Source: Bosch (2021)

**Blue Gasoline with 20 percent lower $CO_2$ emissions**


BOSCH

**Synthetic diesel and gasoline**

Source: Aramco (2021)

Two 50 BPD fuel pilot plants

80% $CO_2$ abatement compared to fossil

REPSOL NEOM aramco

**Haru Oni pilot plant: wind power to e-fuel**

Source: Siemens Energy (2020)


SIEMENS energy PORSCHE

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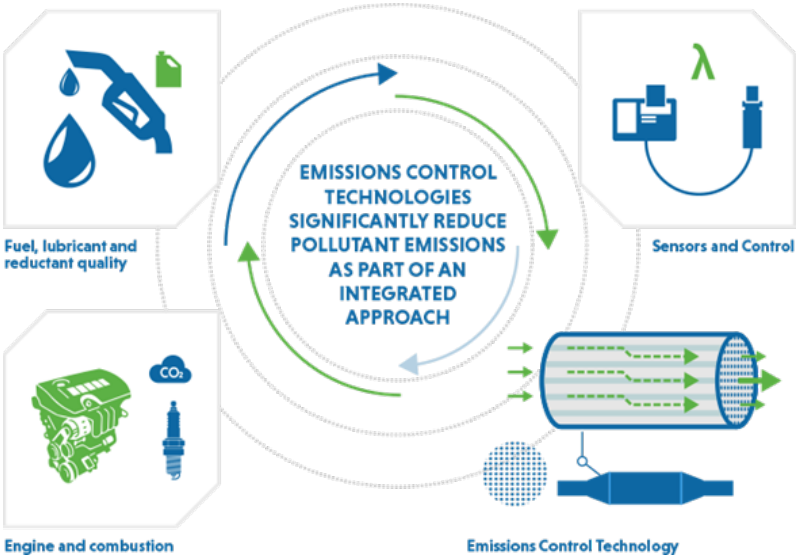
# AECC demonstrator vehicles

- Showing how emission control technologies achieve ultra-low pollutant emissions
- Tested with drop-in sustainable renewable fuels to look into substantial reduction in Well-to-Wheel $CO_2$ emissions





IPA IAV Concawe


IPA IAV DENSO BOSCH aramco


Automotive Grade Urea Sector Group

IPA FEV CORNING cefic sector group NESTE aramco

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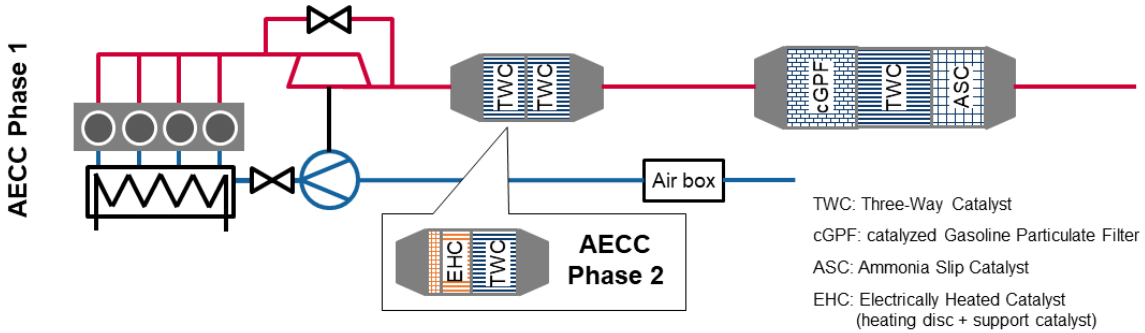
# LD gasoline demonstrator concept

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

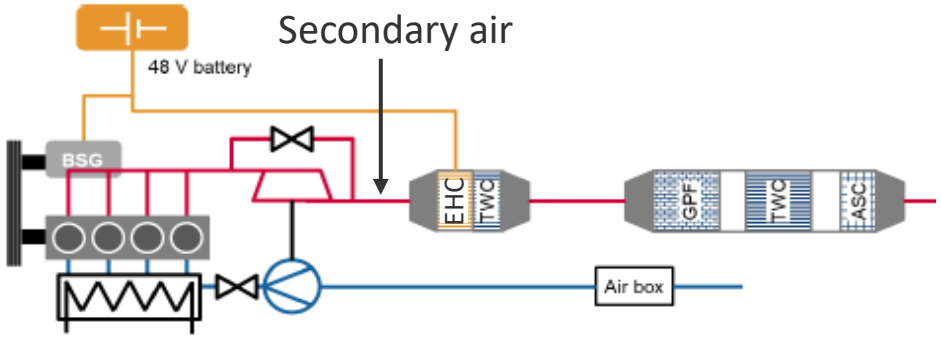


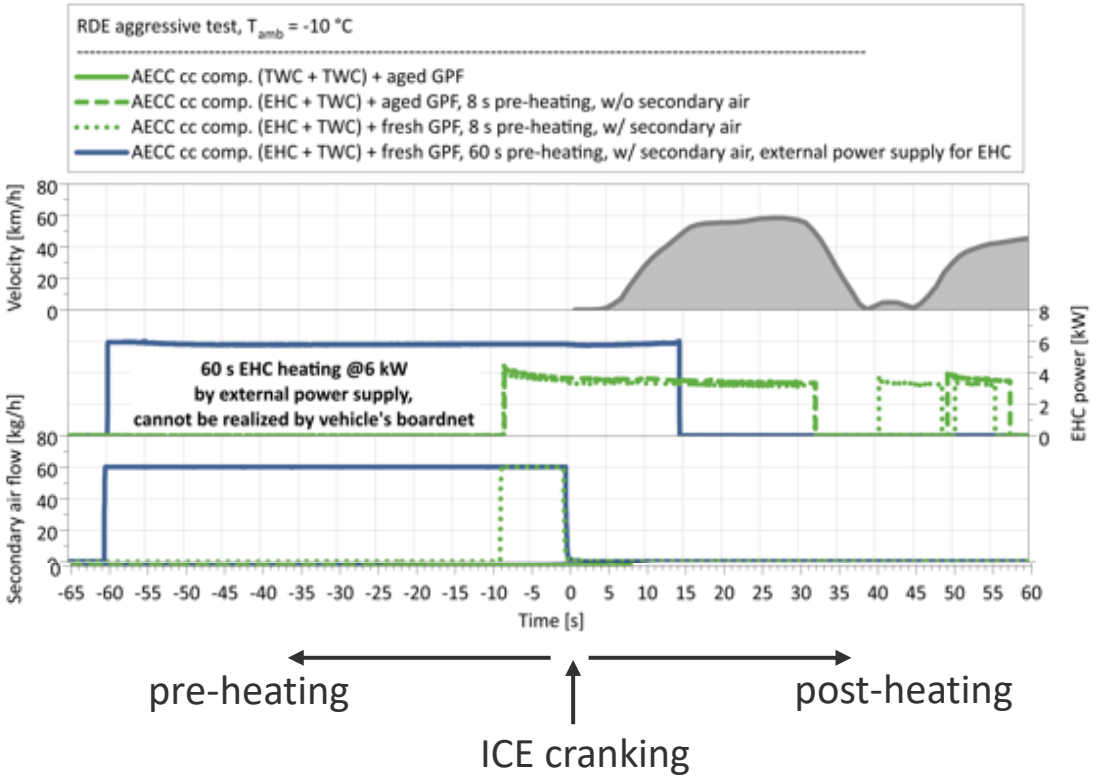
*J. Demuynck, et al.; "Ultra-low Emissions of a 48V Mild-Hybrid Gasoline Vehicle with Advanced Emission Control Technologies", 15th International Conference on Engines and Vehicles, 2021*

*J. Demuynck, et al.; "Zero-Impact Emissions from a Gasoline Car with Advanced Emission Controls and E-Fuels" 43rd International Vienna Motor Symposium, 2022*

# EHC control strategy

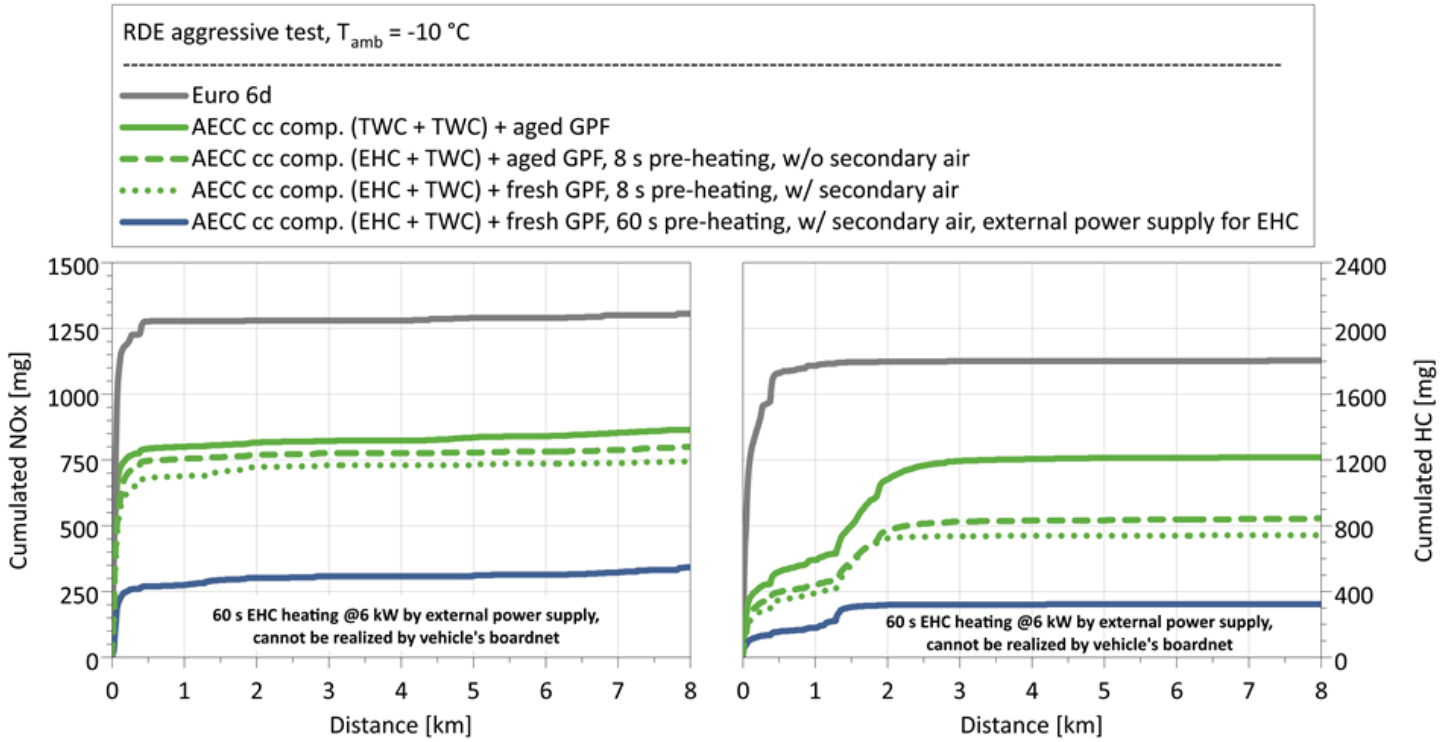
- Pre- and post-heating
  - 8 s pre-heating
  - 60 s pre-heating as outlook to advanced hybrids
- Secondary air in exhaust manifold to enhance heat transfer within catalyst during pre-heating phase in some tests



# Reduction of initial cold-start emissions with EHC

- 8s pre-heating: similar NOx emissions compared to project phase 1, some reduction for THC
- 60s pre-heating as outlook to advanced hybrid: significant reduction for NOx and THC



Ignition

Engine load: *0* %

Vehicle speed: *0* km/h

500

0

NOx

*2* ppm

30 s or 150 m to near-zero emissions

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

500

0

NOx

*0* ppm

EHC | TWC | GPF | TWC | ASC

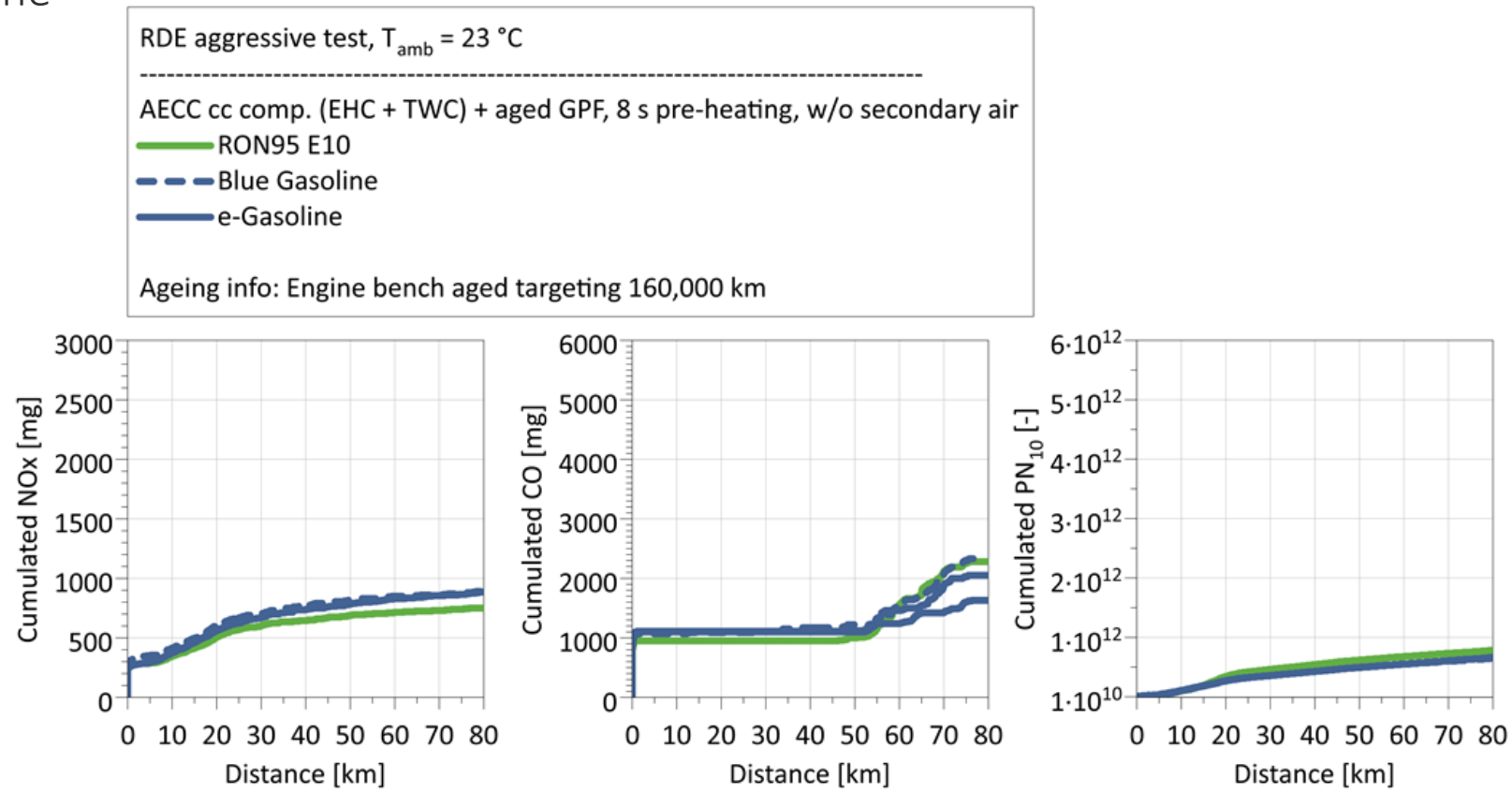
Engine catalyst heating

EHC heating

Closed-loop lambda control

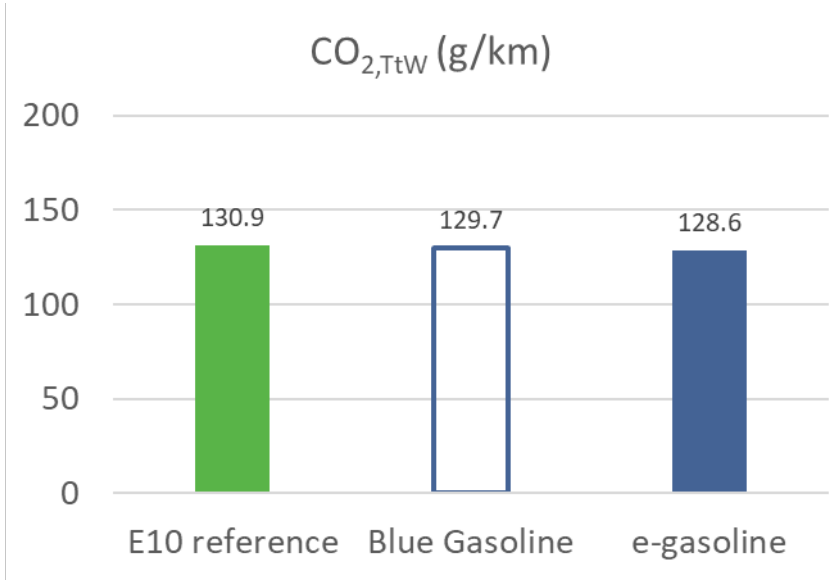
# Ultra-low emissions on sustainable renewable fuels

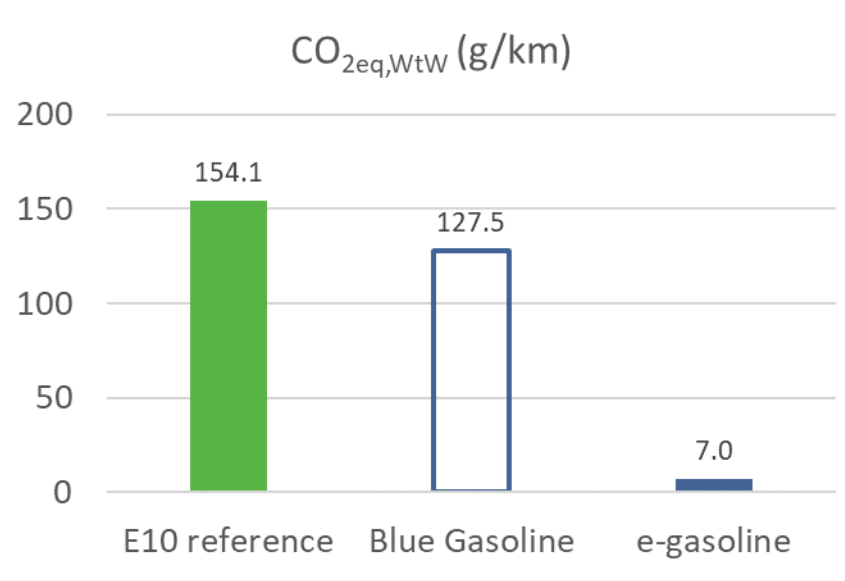
- Similar gaseous and particulate emissions
  - Blue Gasoline
  - e-gasoline



# Well-to-Wheel $CO_2$ emission reduction

- Similar tailpipe $CO_2$ emissions, but significant reductions in Well-to-Wheel $CO_2$ emissions
  - Blue Gasoline already offers today significant reduction of 17% (20% compared to E0)
  - E-gasoline has the potential to nearly eliminate Well-to-Wheel $CO_2$ emissions

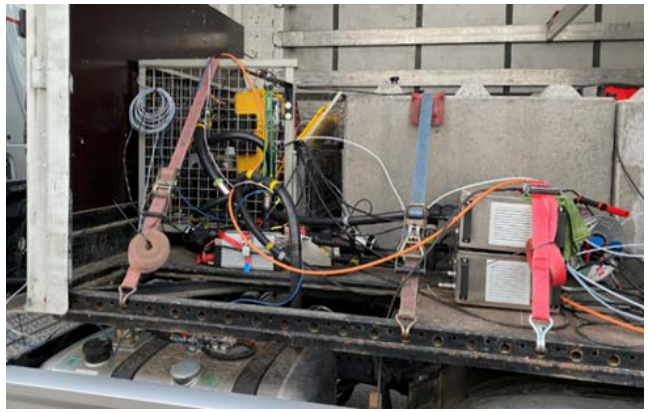


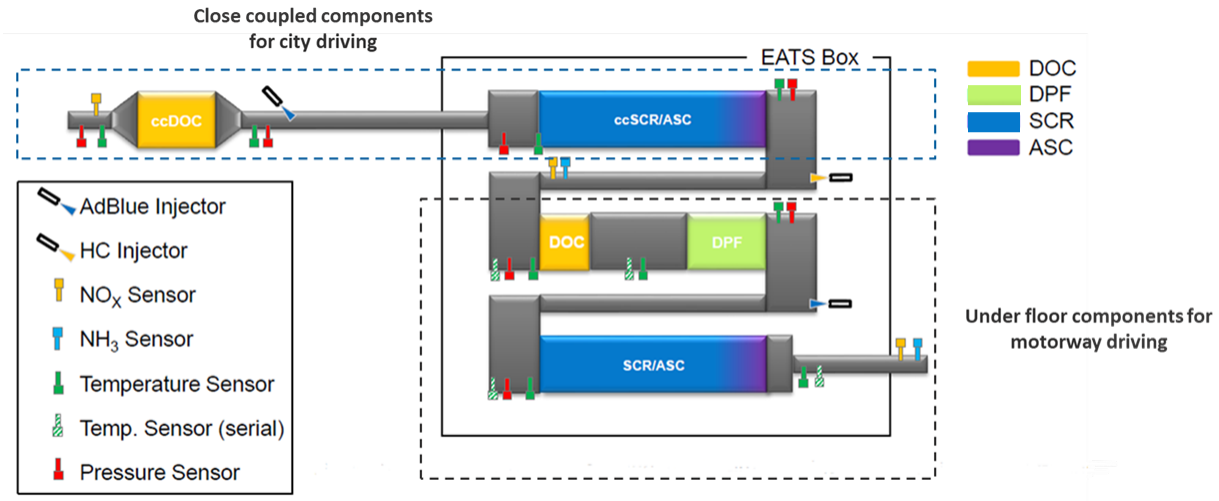




Calculated according to methodology of JEC WtW report v5

# HD 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
- AECC emissions control system
  - Phase 1: cc DOC, ccSCR/ASC+ uf DOC+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
- Instrumented with prototype PEMS to measure $CO_2$, NOx, CO, PN10, $NH_3$ and $N_2O$

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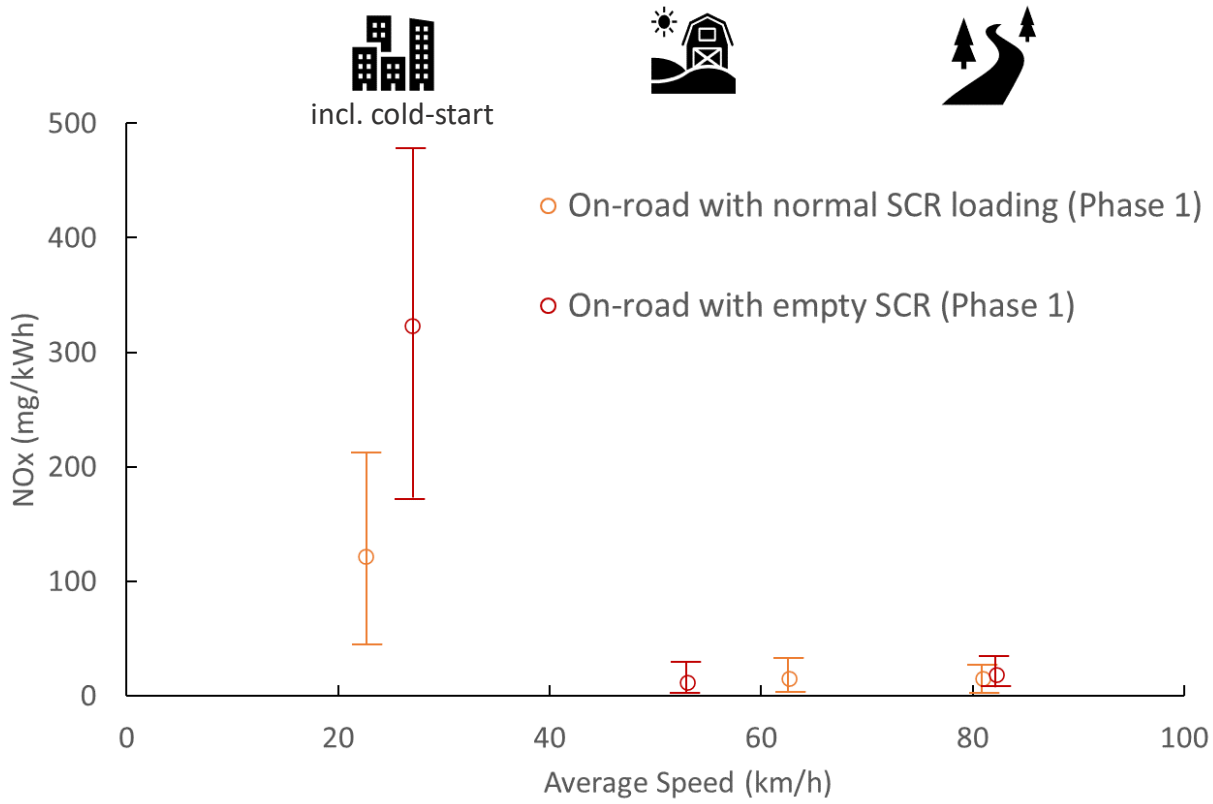
# HD diesel demonstrator overall phase 1 NOx results

- On-road and chassis dyno test campaigns confirm significant improvement for urban emissions including cold-start compared to Euro VI-D[1, 2, 3]
- Near-zero emissions under warm operation
- Impact of ammonia storage depletion procedure shows robust control is needed for AdBlue® dosing, ammonia storage and thermal management




[1] P. Mendoza Villafuerte, et al.; "Real-World Emissions of Euro VI Heavy-Duty Vehicles", SAE Technical paper, 2021-01-5074, 2021.
[2] 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,
[3] T. Selleri, et al.; "Measuring Emissions from a Demonstrator Heavy-Duty Diesel Vehicle under Real-World Conditions—Moving Forward to Euro VII", Catalysts 2022, 12(2), 184, 2022.

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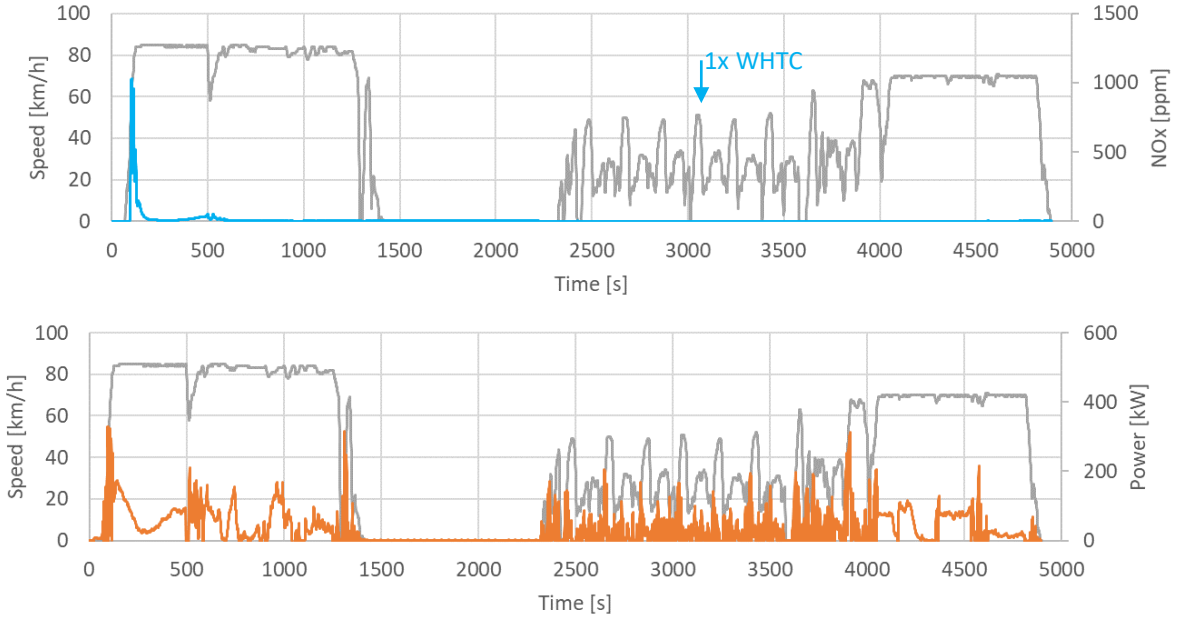
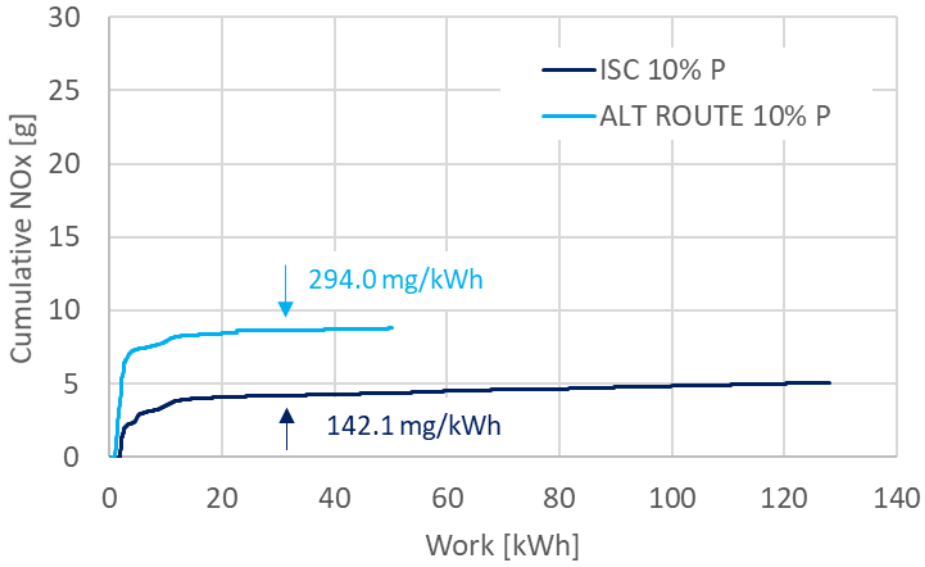
# Near-zero NOx emissions in idle and low power operation

- Alternative route starting from highway, including a long idle phase and then urban operation
- Results show low overall NOx emissions[1,2]
- Near zero NOx emissions in urban operation after a long idle period[3]

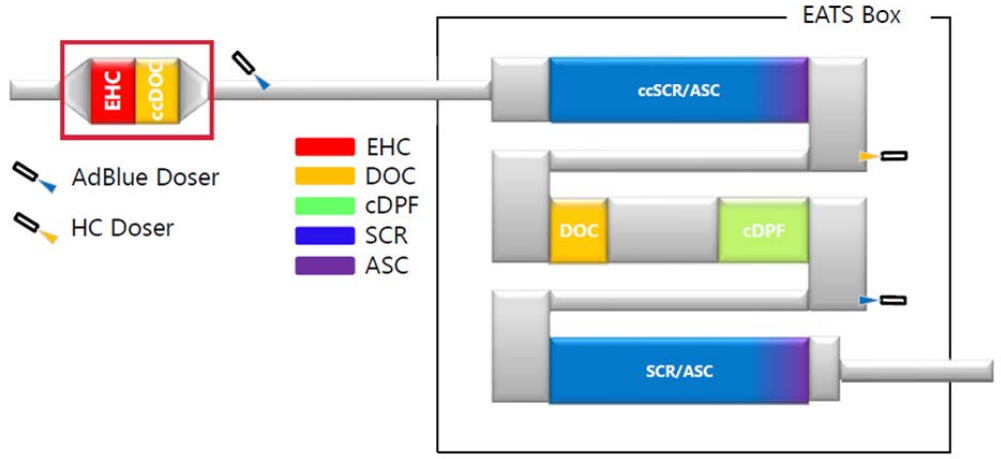


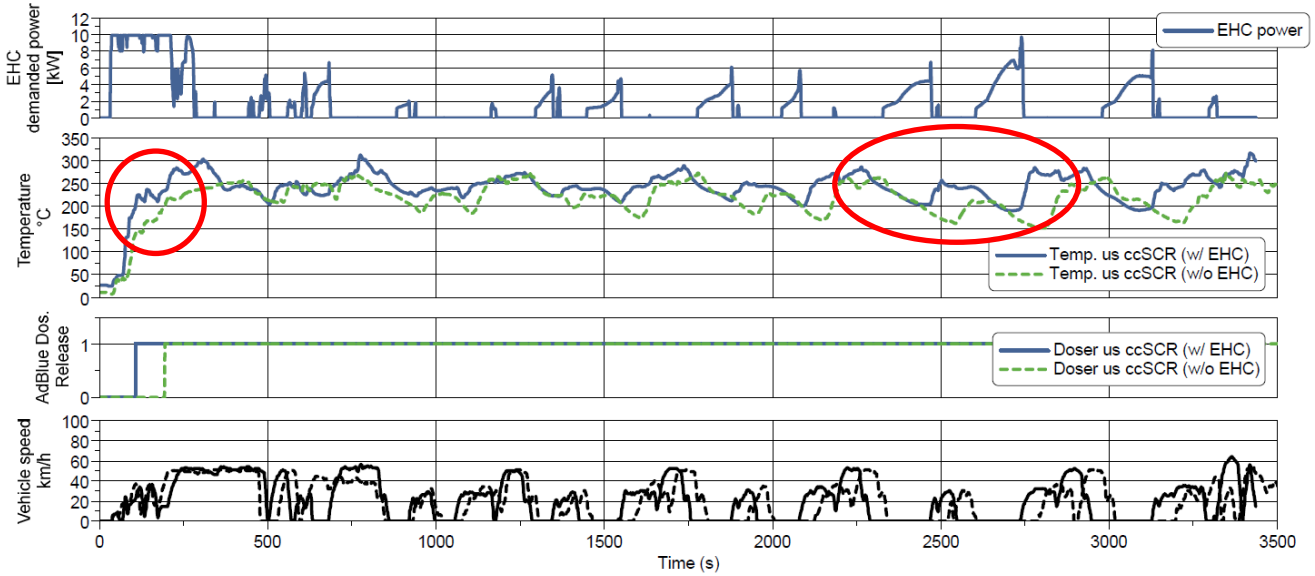




[1] The results are reported as measured
[2] Tests were conducted with empty SCRs' ammonia storage and passively regenerated DPF unless indicated otherwise. Alt Route 10% payload conducted at 24°C
[3] Average power (vs Max power) from 0-2350 s = 10%, from 1430-4898 s = 8%, from 1430-3640 s = 5%

# Phase 2 of the HD Diesel demonstrator project

- Implementation of electrically heated catalyst as part of the ccDOC to reduce the remaining initial cold-start emissions
- Operation strategy
  - AdBlue dosing starts when ccSCR reaches 200°C, EHC helps reducing the heat up time
  - System is kept at operating temp regardless of long stops
- As the vehicles is not a hybrid, the required power needed for the EHC was generated by a genset installed in the trailer



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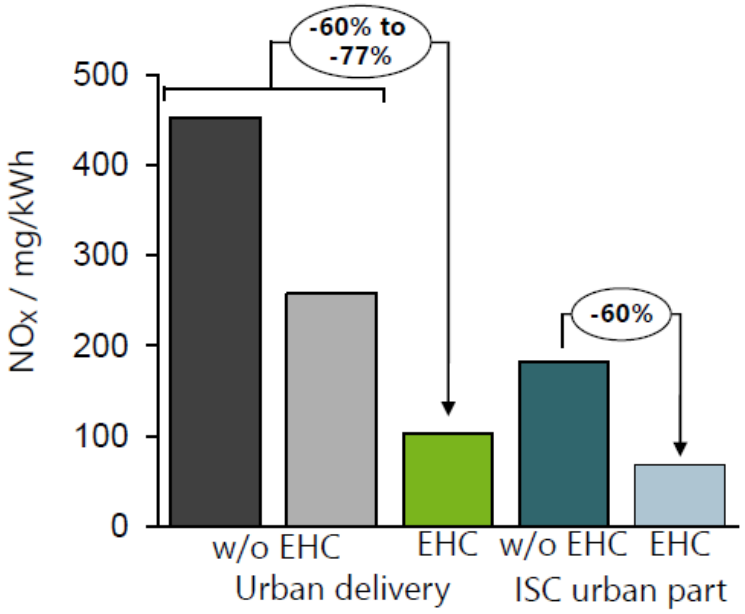
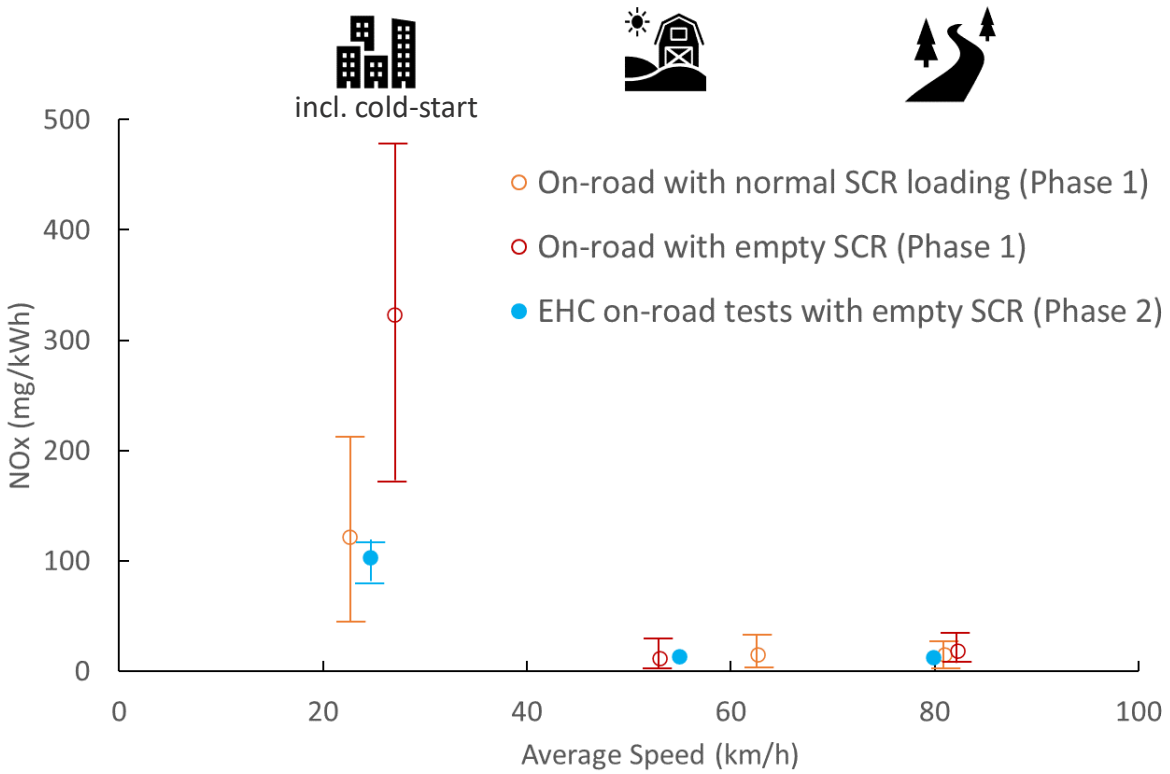
# Reduction of initial cold-start emissions with EHC

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

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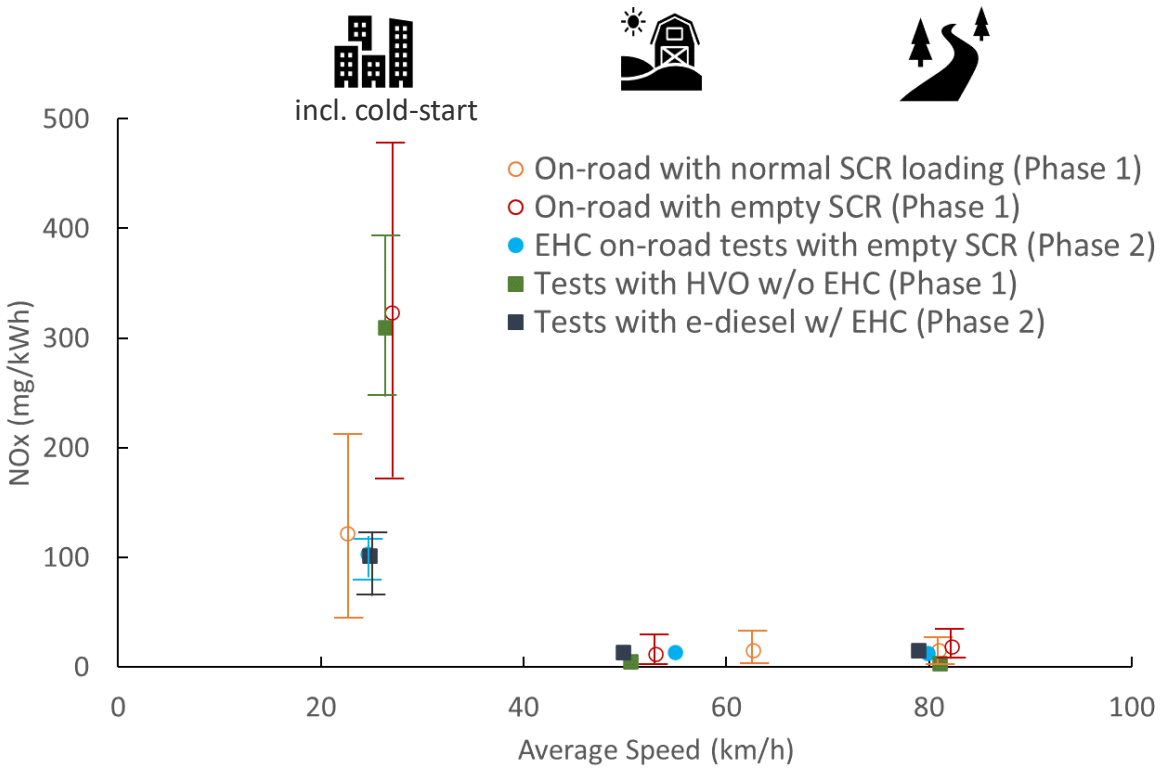
# Ultra-low emissions on sustainable renewable fuels

- Preliminary results
  - 100% HVO (within phase 1)
  - E-diesel (within phase 2)
- Further analysis will be published at SIA Powertrain and Energy conference in June 2022
  - Other pollutant emissions
  - Well-to-Wheel $CO_2$ emissions



# Summary and conclusions

- Advanced emission control systems implemented on light-duty and heavy-duty demonstrator vehicles
- Ultra-low pollutant emissions measured on market fuel
  - Significant reduction of initial cold-start peak
  - Near-zero emissions after initial cold-start peak
- Results validated on sustainable renewable fuels
  - Ultra-low pollutant emissions confirmed
  - Well-to-Wheel analysis shows significant $CO_2$ emissions reduction
- The internal combustion engine is part of the solution for meeting the EU Green Deal climate-neutral and zero-emission goals in 2050 along with electrification

# THANK YOU !

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