

# Potential for Reduction in NRMM Real-World Emissions

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# AECC is the Association for Emissions Control and Climate

Scope

- Air quality and Climate requirements
- Mobile and Stationary emissions sources
- Sustainable components and systems

Components and systems

- Catalysts
- Filters
- Adsorbers
- System integration
- Fuel cells
- Electrolysers

Full and Associate  
member companies

**EMITEC**  
TECHNOLOGIES

**JM** Johnson  
Matthey

**NGK**

**umicore**

**Albonair**

**BASF**  
We create chemistry

**GORE**  
Creative Technologies  
Worldwide

EU Transparency Register #78711786419-61, consultative status with the UN Economic and Social Council (ECOSOC)

# NRMM is a key activity among the AECC policy focus areas

## On-road vehicles



## Non-Road Mobile Machinery



## Industrial and Stationary



## H<sub>2</sub> production and utilisation



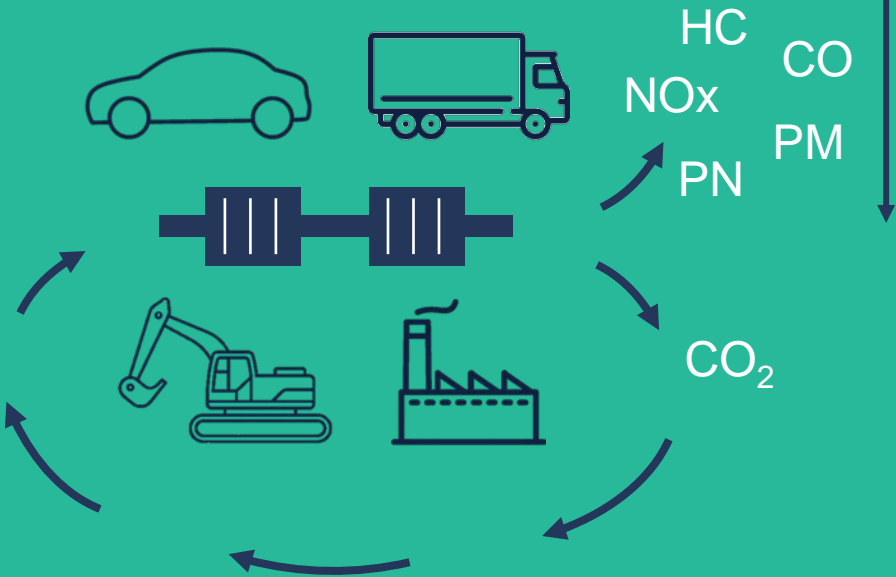
## Life cycle assessment and circular economy



# AECC works in partnership with EU policymakers on 2050 targets

**Zero-impact  
pollutant  
emissions**

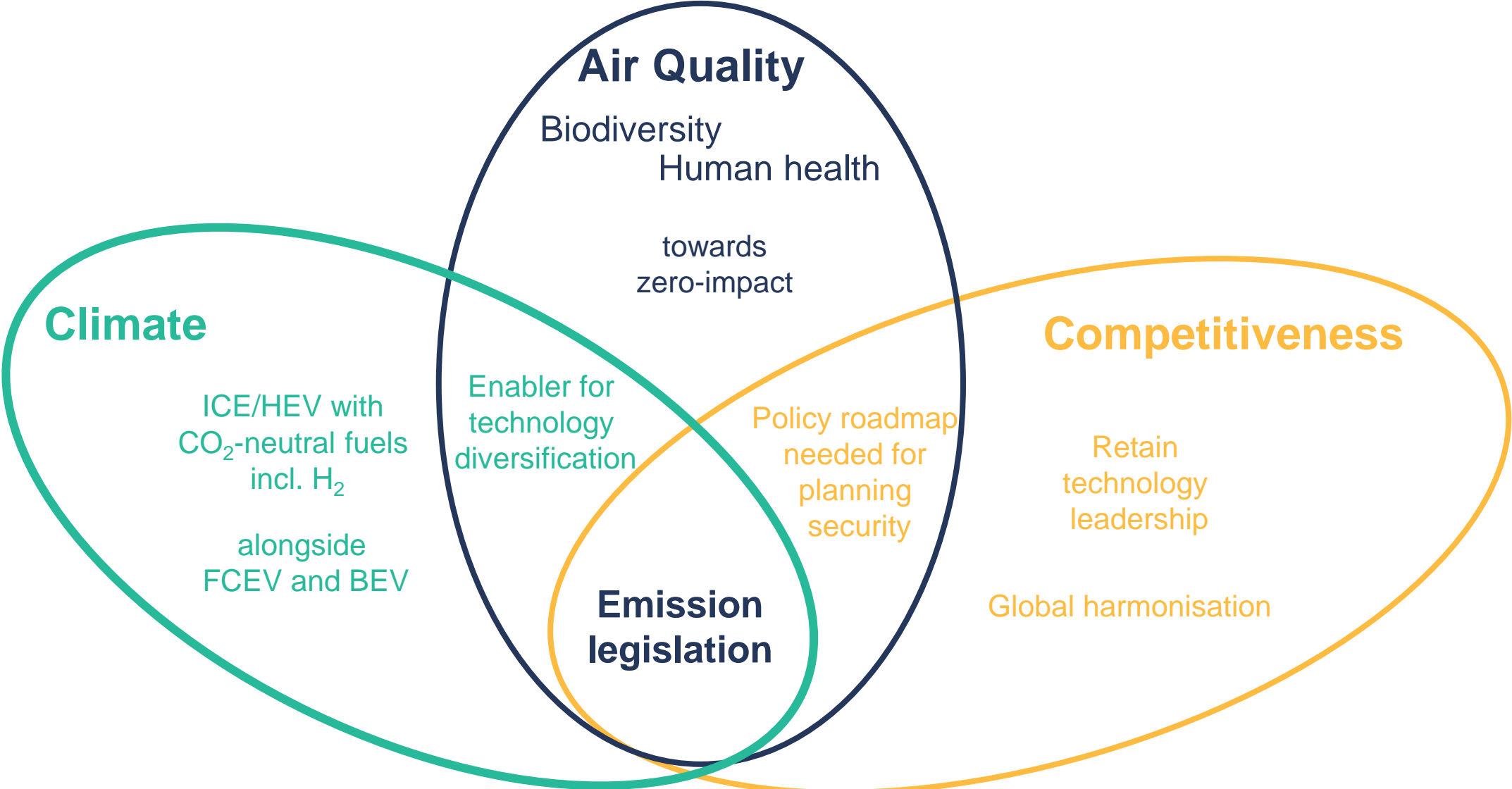
**Net-zero  
Greenhouse  
gas emissions**



AECC member emission control systems ensure there's **no measurable negative impact** of these pollutants on the **environment or on public health**

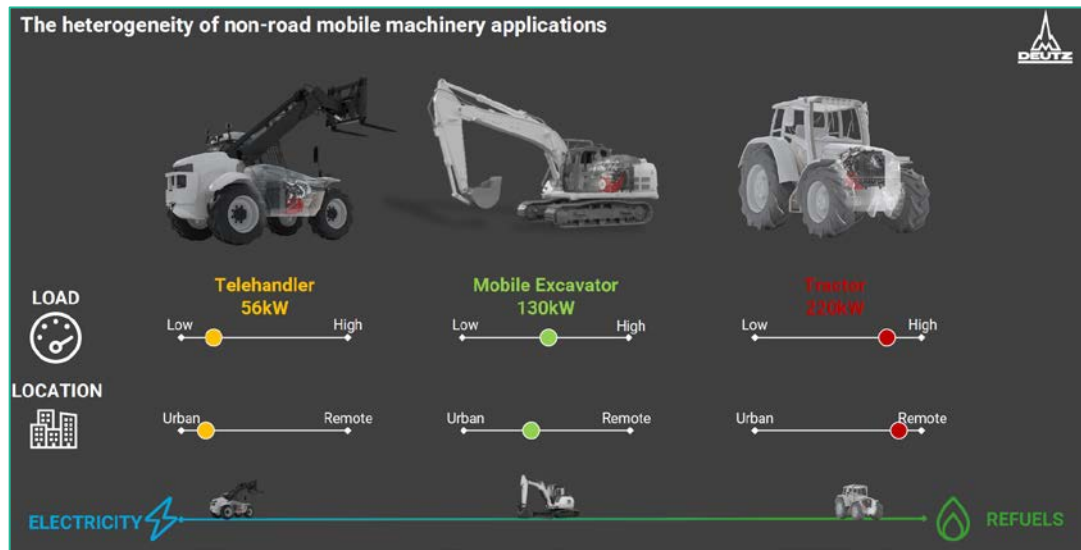
AECC member emission control systems are compatible with **CO<sub>2</sub>-neutral fuels** for a closed carbon cycle

# Key pillars for NRMM compatibility with 2050 targets

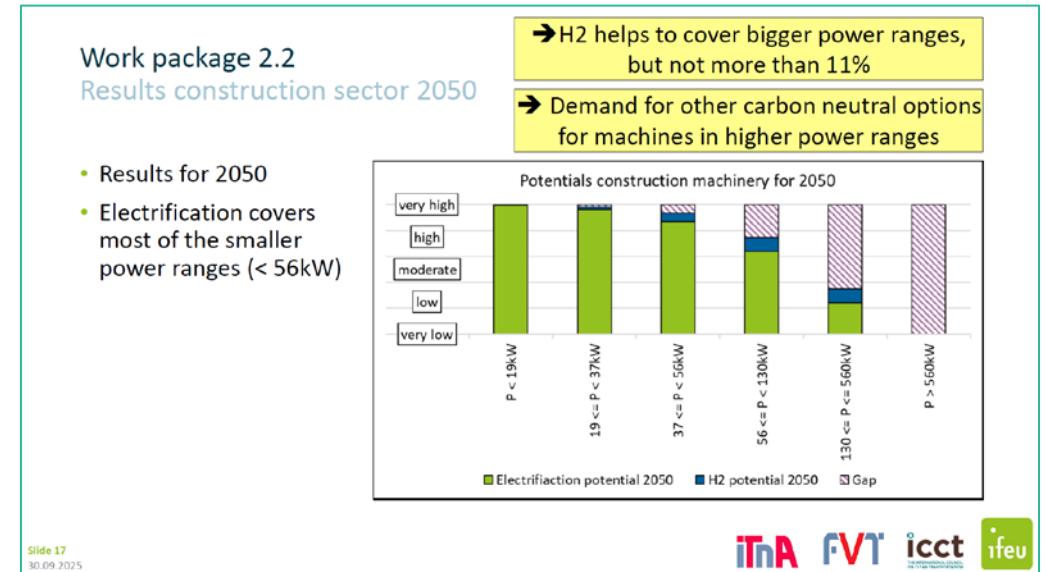


# All powertrain technologies needed towards net-zero CO<sub>2</sub>

- Internal Combustion Engine (ICE) remains key for the NRMM use cases
- Different sustainable renewable fuels are investigated to reduce the carbon footprint



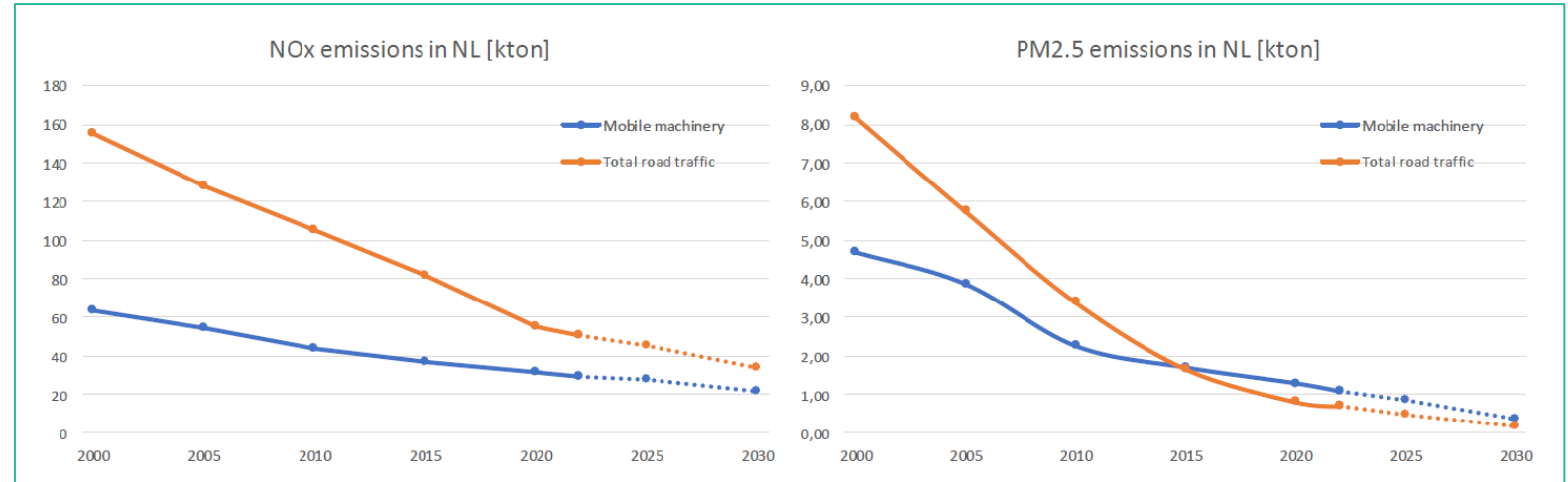
Deutz, Baden-Baden, 2024



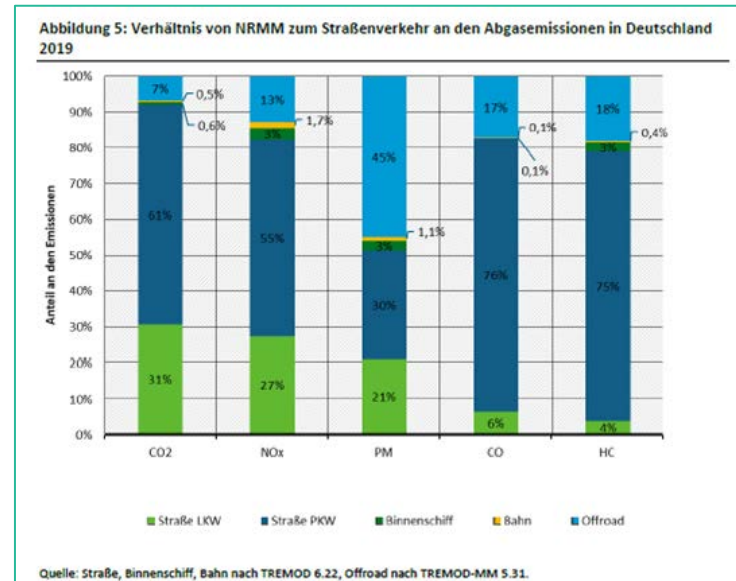
eNRMM consortium study on behalf of UBA and BMUV, 2025

# Increasing contribution of NRMM to air quality impact

- In the Netherlands, [GRPE presentation, 2023](#)



- In Germany, [UBA report, 2023](#)



# Evolution of NRMM Stage V legislation is expected

- NRMM legislation is several steps behind on-road HDV legislation
  - PEMS monitoring instead of In-Service Conformity (ISC) and Real-Driving Emissions (RDE)
  - More data exclusions
  - Higher limits than Euro 7
- Ongoing initiatives
  - European Commission is reviewing Stage V based on PEMS monitoring data, report expected Q1 2026
  - US CARB [Tier 5 proposal](#) for MY2029+
  - China expected to propose next step for NRMM in mid-2026
  - Informal discussions at UNECE GRPE about UN Regulation No. 96 and GTR No. 11

# NRMM demonstrator project set-up

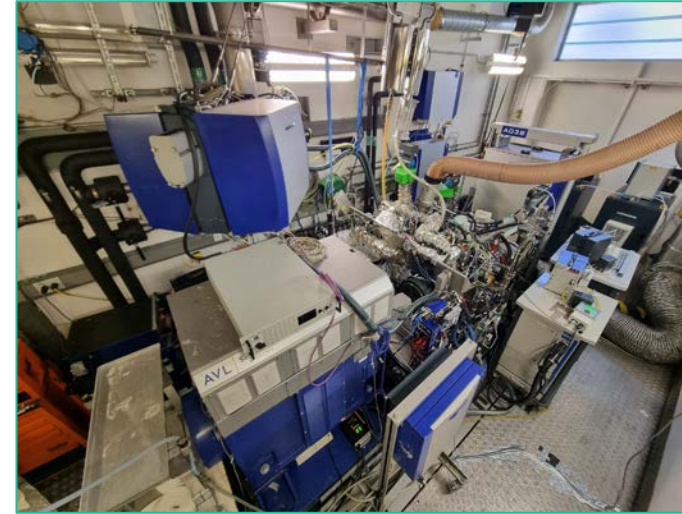
- Project partners



- NRMM engine

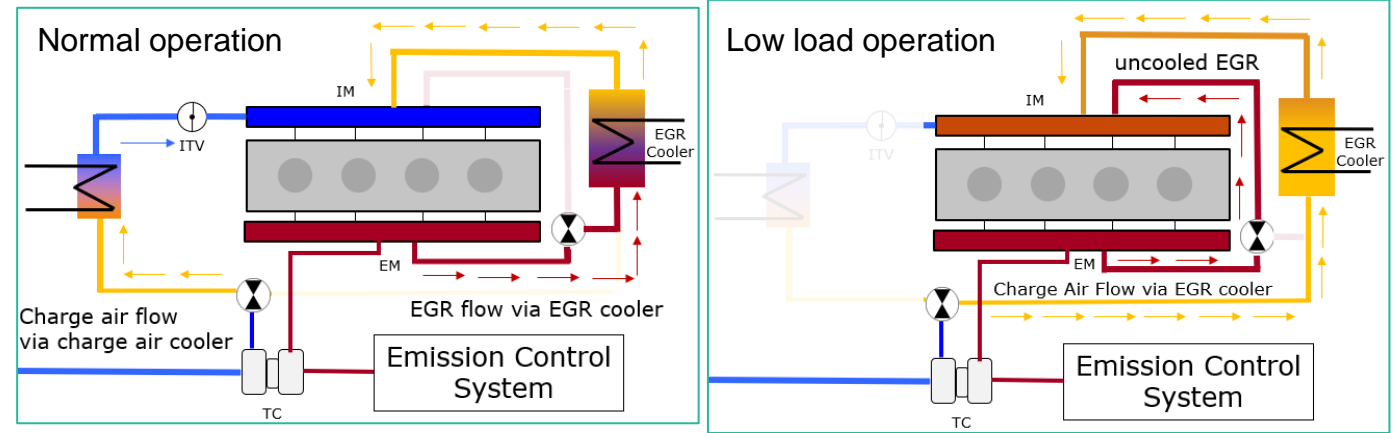
- Base characteristics

- 4l class, ~ 100 kW rated power
- Cooled HP-EGR & intake throttle
- ~ 4 g/kWh engine-out NOx



- Project modifications at low-load operation

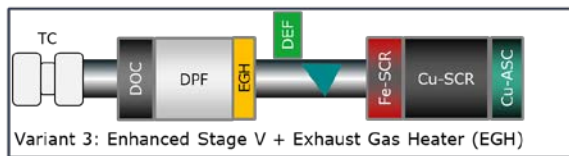
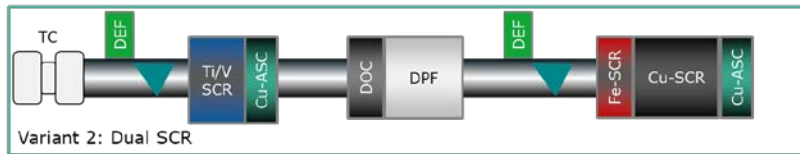
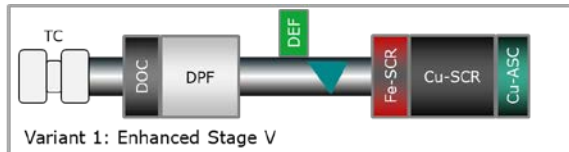
- Uncooled EGR & charge air heating
- EGR recalibration



TC: Turbocharger  
 ITV: Intake Throttle Valve  
 IM Intake Manifold  
 EM: Exhaust Manifold  
 EGR: Exhaust Gas Recirculation

# NRMM demonstrator project set-up

- 3 emission control system configurations
  - Modular approach
  - Hydrothermal ageing in oven







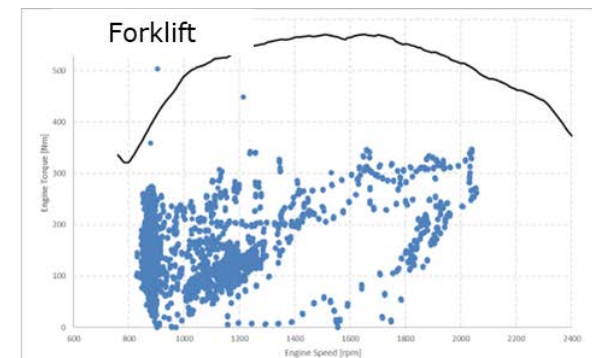
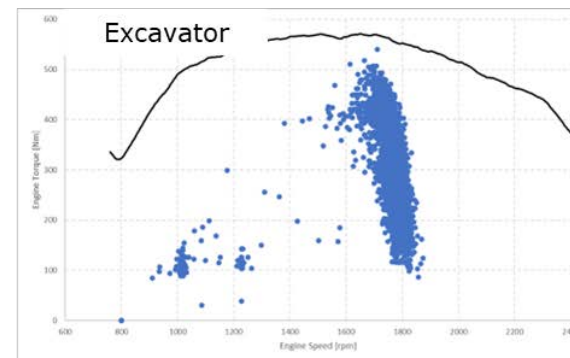
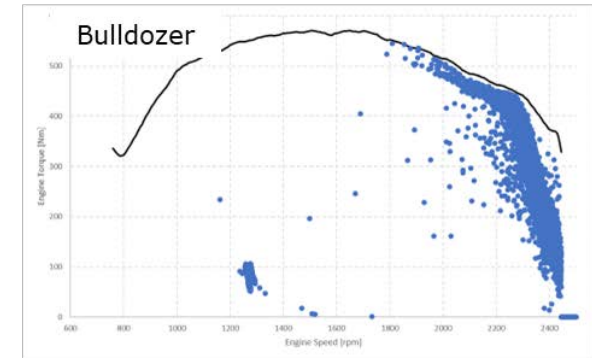
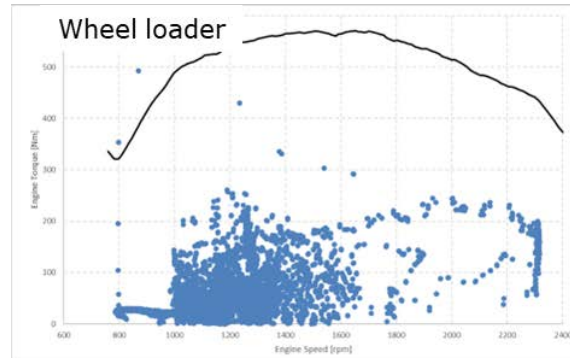
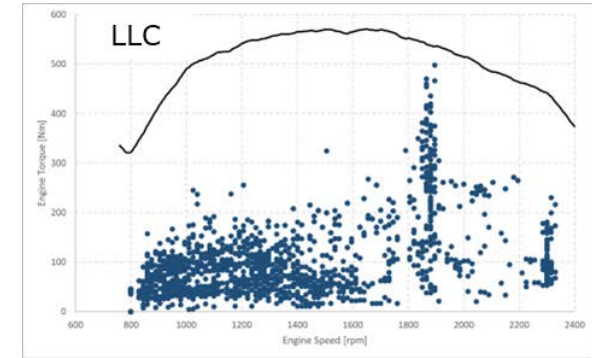
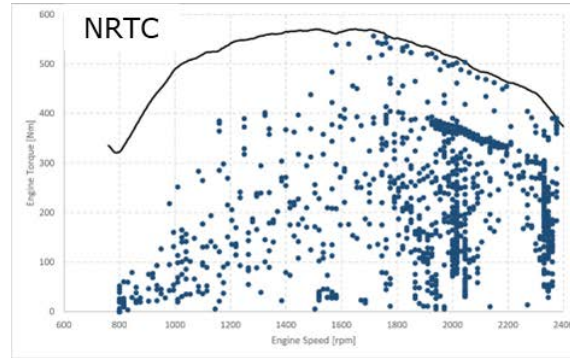
TC: Turbocharger  
EGH: Exhaust Gas Heater  
SCR: Selective Catalytic Reduction  
ASC: Ammonia Slip Catalyst  
DOC: Diesel Oxidation Catalyst  
DPF: Diesel Particulate Filter

- Complementary simulation study

*J. Demuyck, et al.; "Potential for Reduction in NRMM Real-World Emissions", SAE WCX, Paper 2025-01-8489, 2025*

# Testing of wide variation in NRMM applications

- Type approval cycles
  - NRTC cold and hot
  - RMC
  - LLC
- In-use application cycles
  - Wheel loader 
  - Bulldozer 
  - Excavator 
  - Forklift 

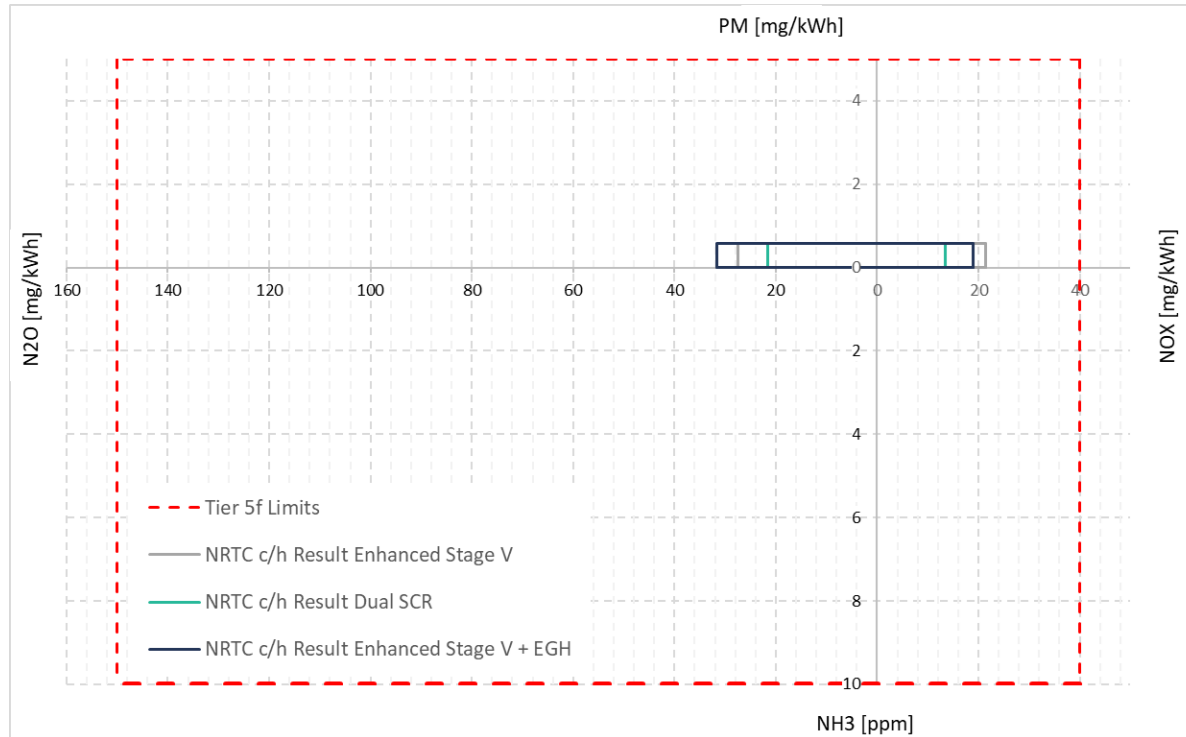


NRTC: Non-Road Transient Cycle  
RMC: Ramped Mode Cycle  
LLC: Low-load Cycle

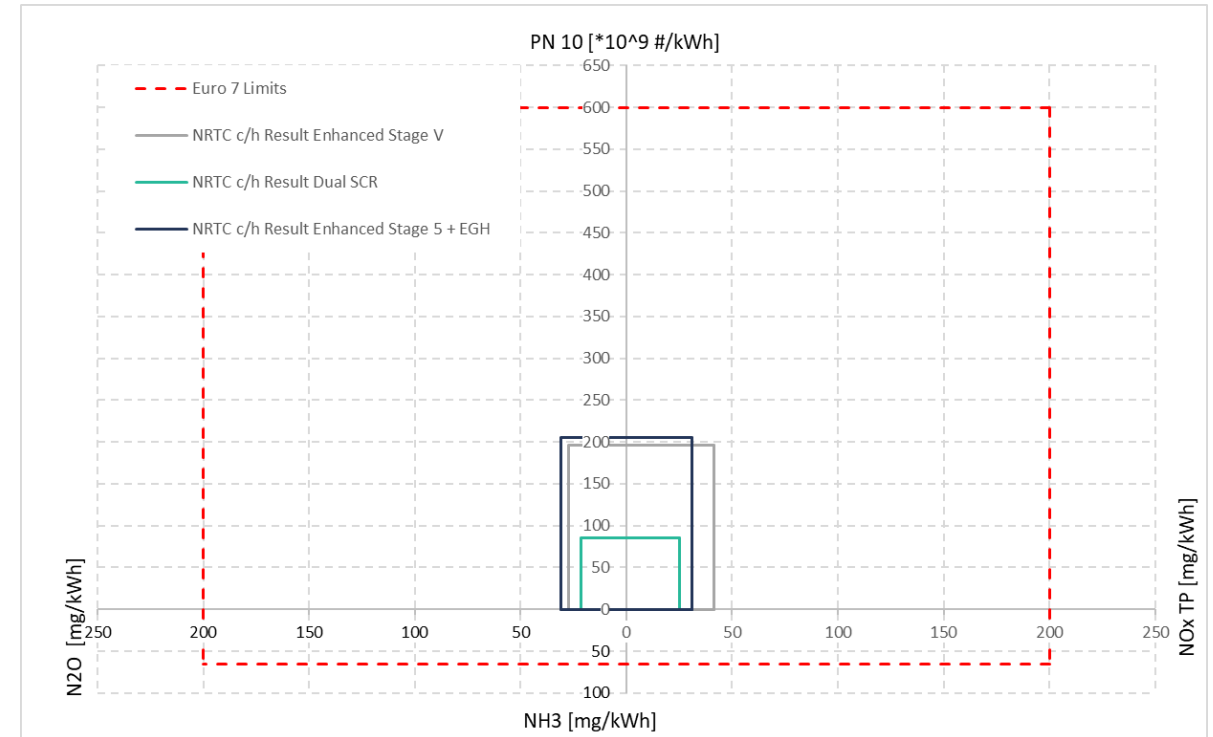
# All 3 variants within CARB Tier 5 and Euro 7 on NRTC

- Small differences between variants on NRTC after cold-hot weighing

CARB Tier 5 NRTC c/h

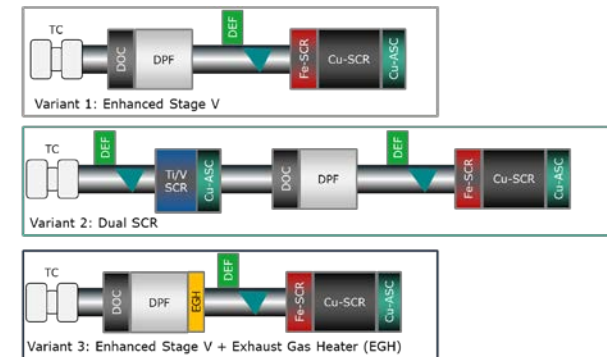
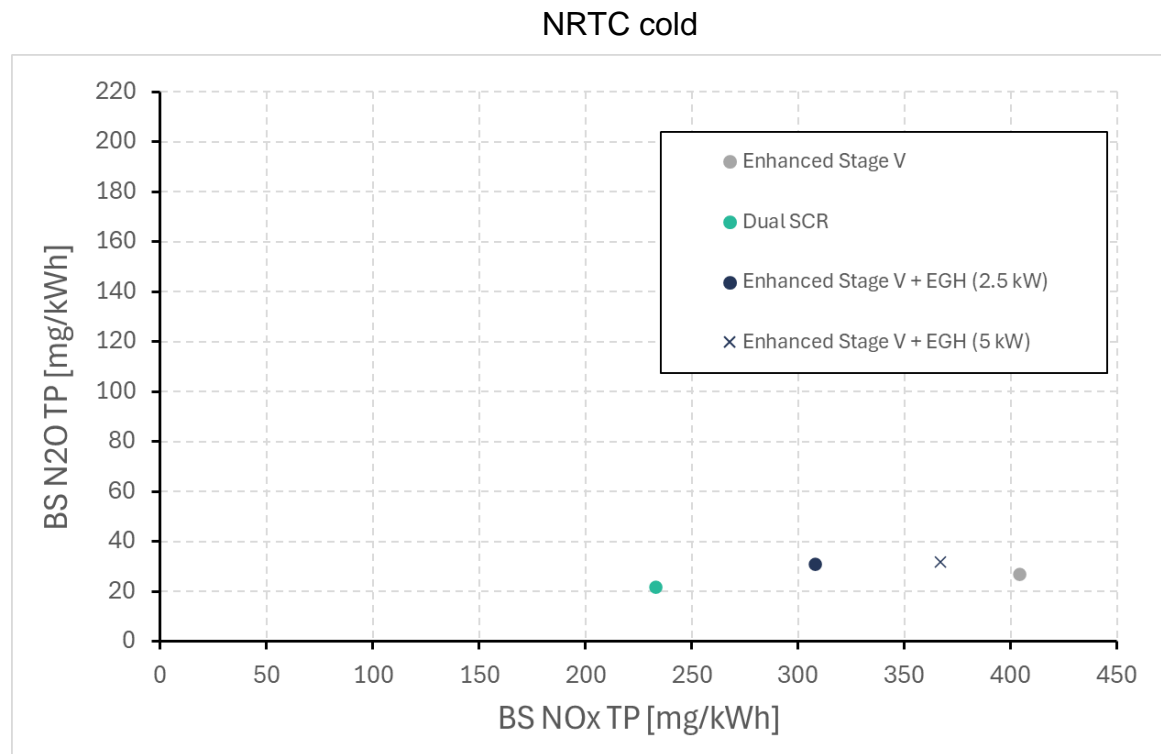


Euro 7 HDV NRTC c/h



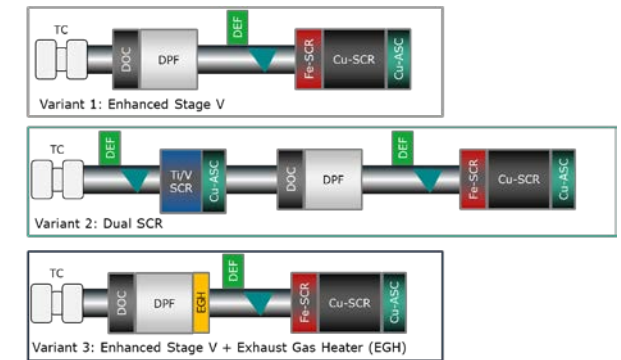
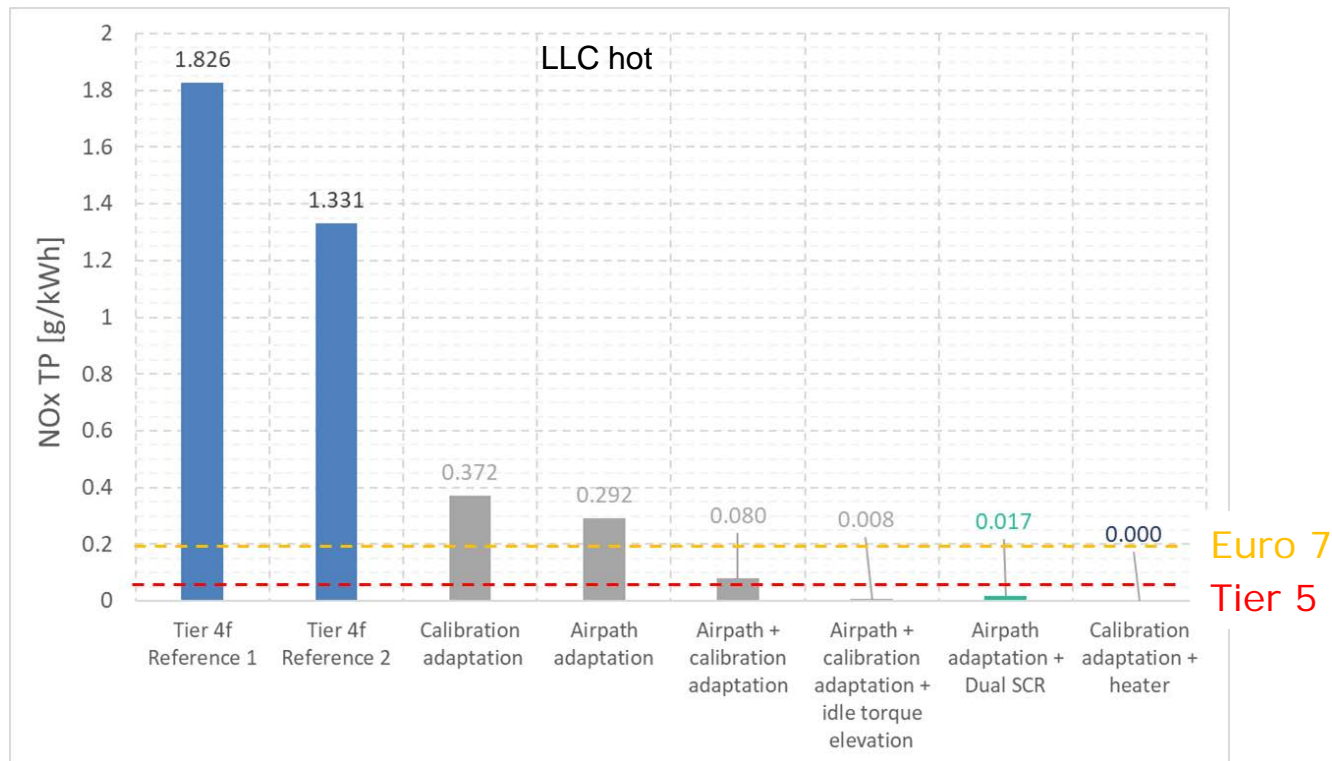
# All 3 variants within CARB Tier 5 and Euro 7 on NRTC

- Differences between variants mainly seen on NRTC cold
  - Dual SCR configuration shows the lowest NOx level



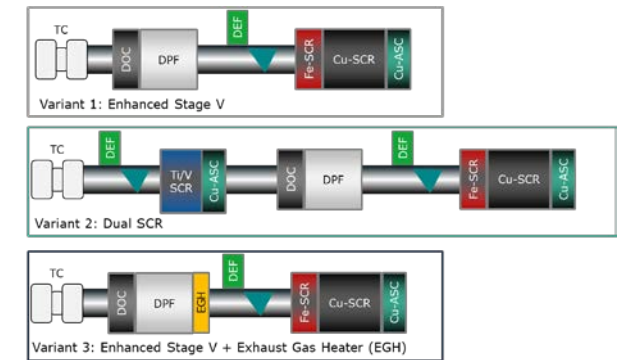
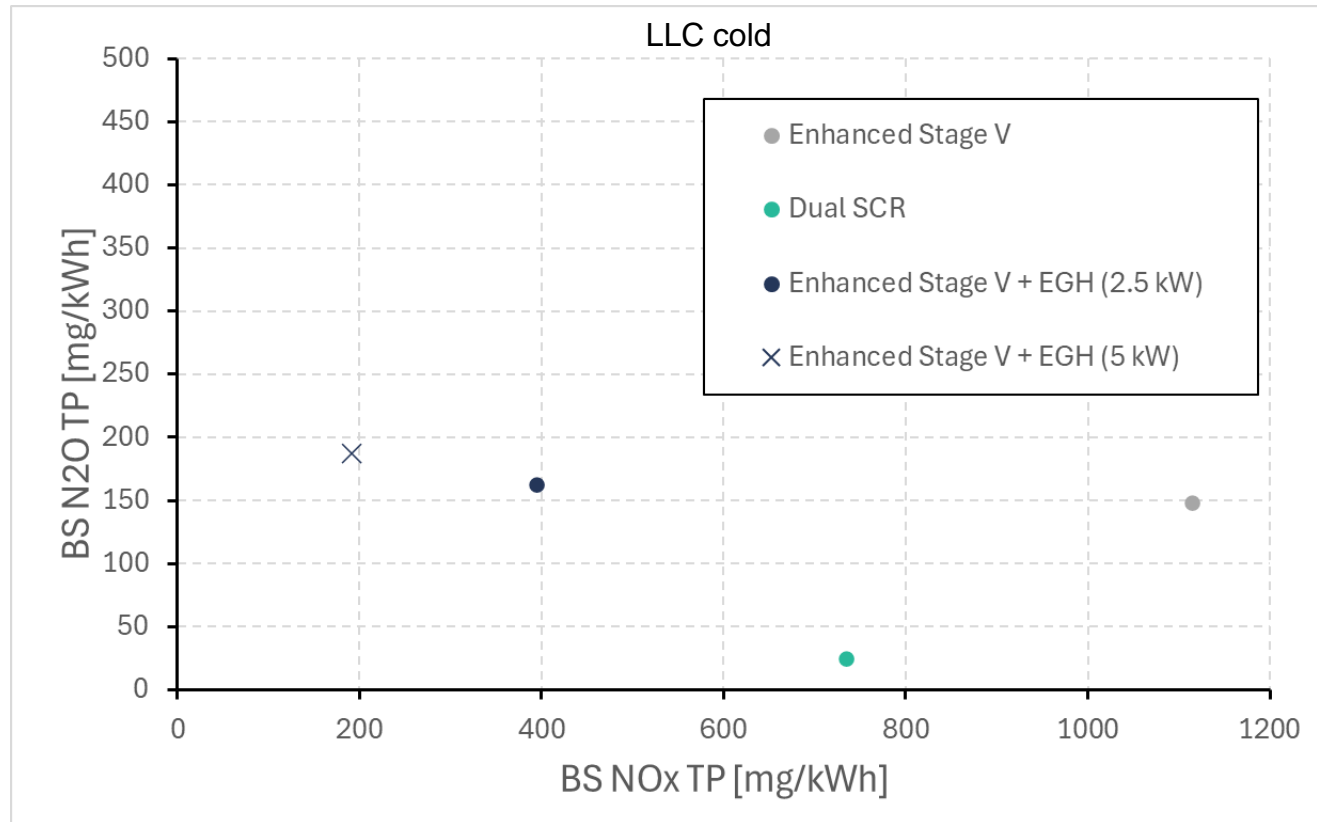
# All 3 variants significantly improve emissions at low load

- Data on LLC hot is compared to SwRI [data](#) of Tier 4 engines
- Variant 2 and 3 meet the Tier 5 NOx limit on LLC hot
- For variant 1, the idle load needs to be increased from 44 to 66 Nm



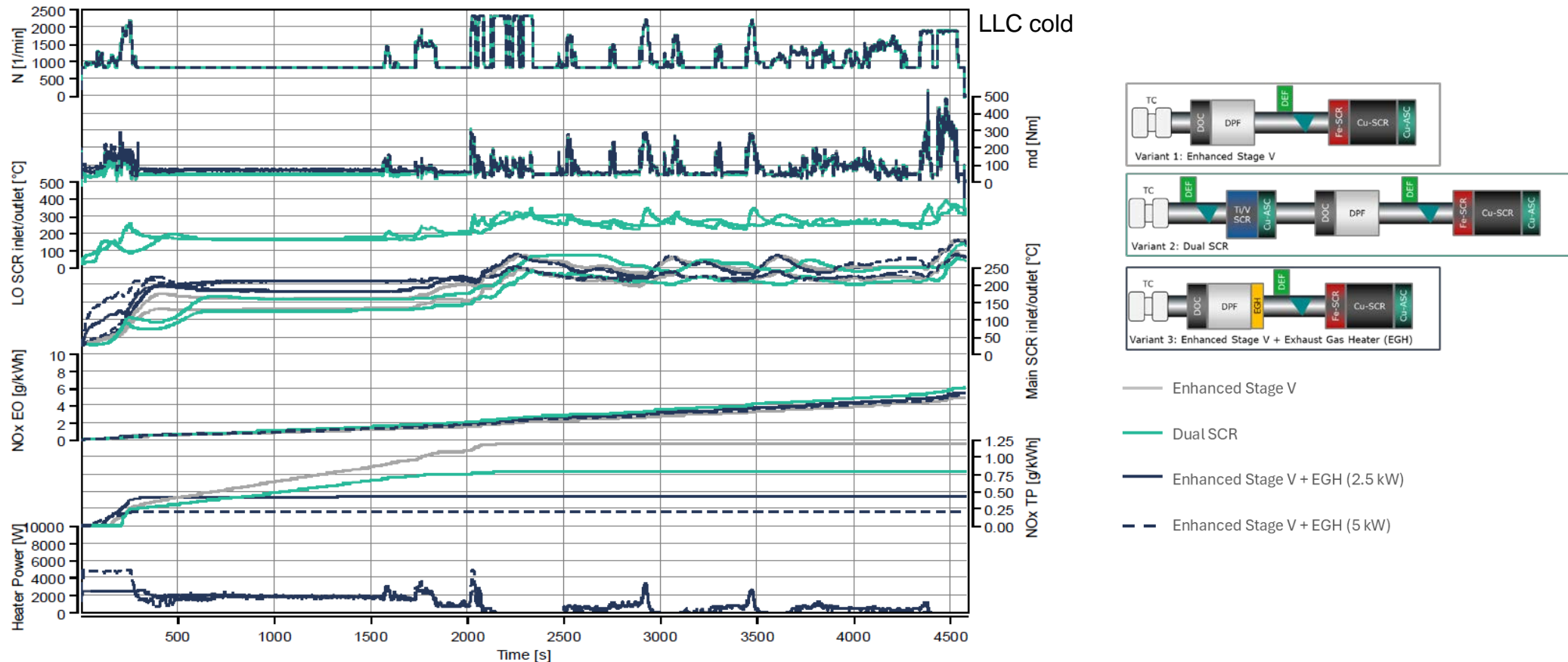
# All 3 variants significantly improve emissions at low load

- Engine heating measures are insufficient for Variant 1 and 2 on LLC cold
- NOx below 200 mg/kWh is observed for Variant 3 with 5 kW EGH heating power



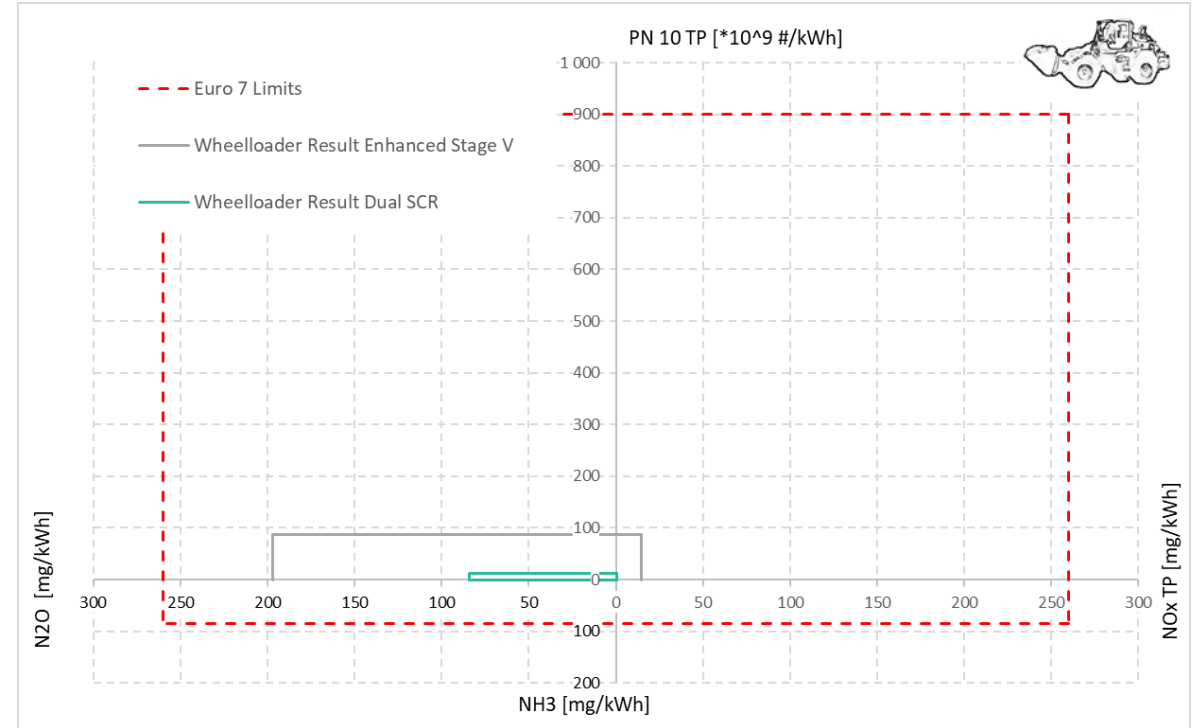
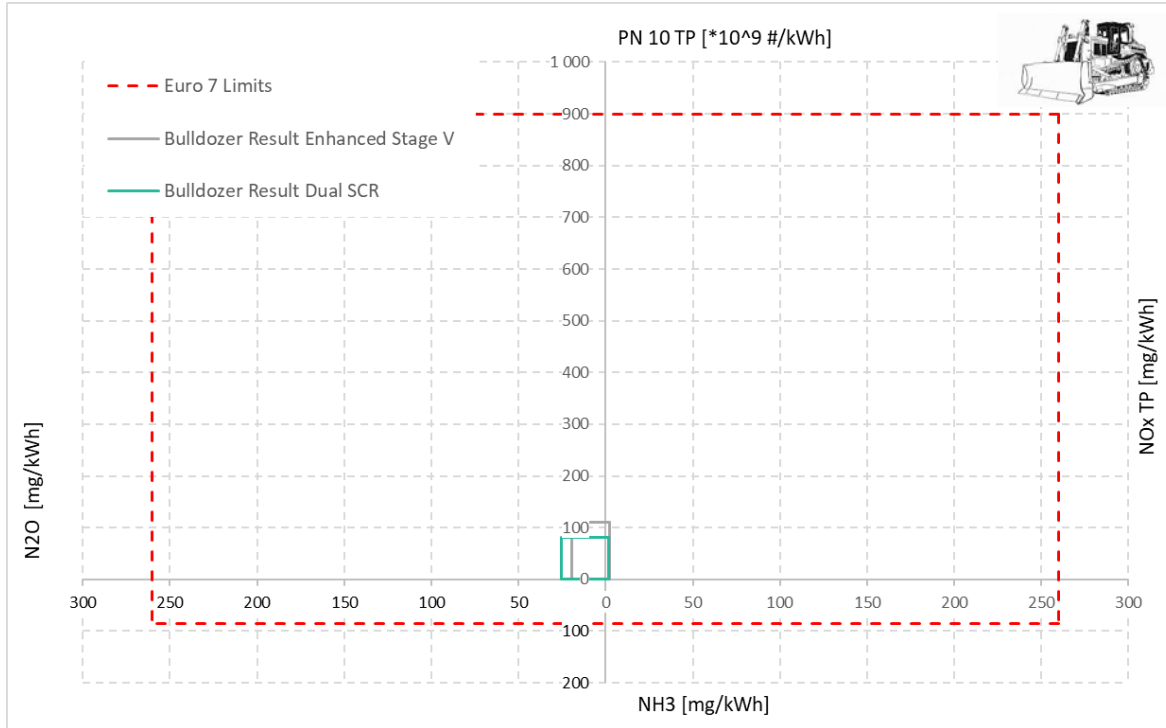
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# Consistent low emissions on in-use cycles

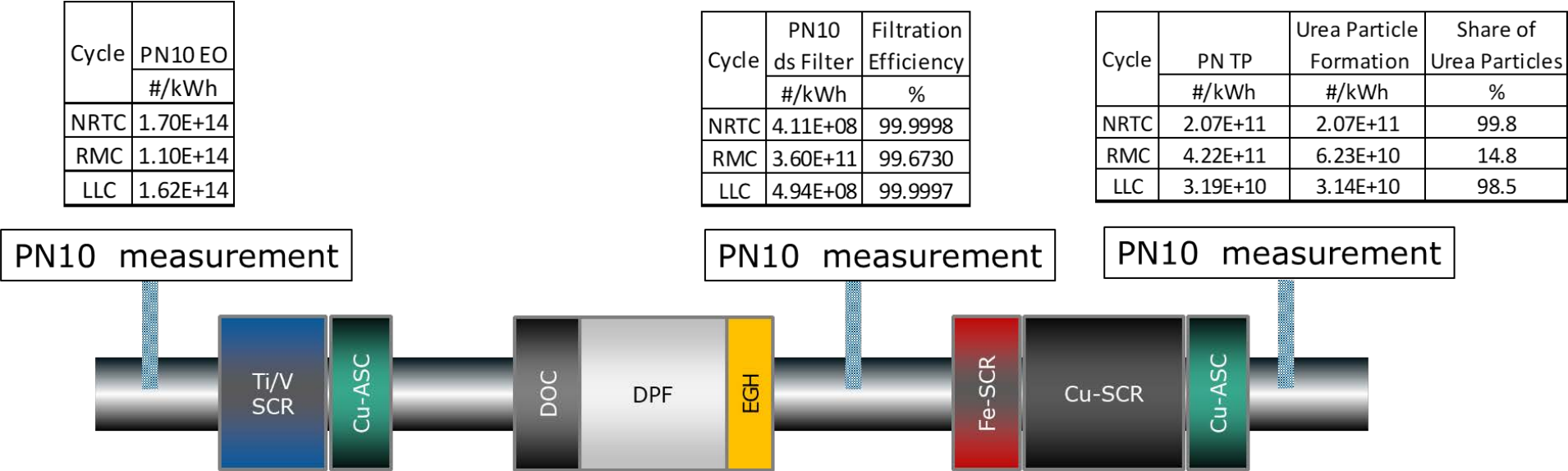
- All Variants generally meet Euro 7 ISC limits on in-use cycles
- No significant differences are observed over medium- to high-load profile (e.g. bulldozer)
- Variant 2 shows benefit over low-load profile (e.g. wheel loader)



\* Variant 3 not measured given same results as variant 1 on these hot start in-use cycles

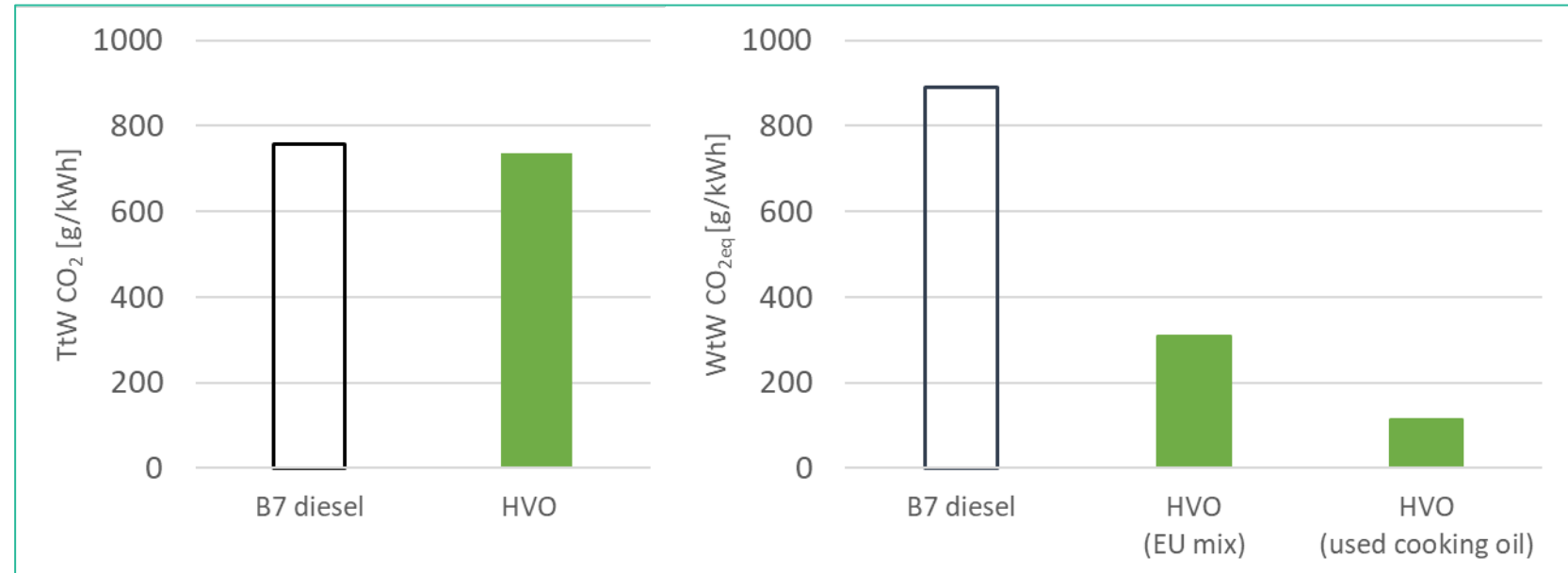
# PN emissions are within Euro 7 on all tests

- PN reduction over DPF from  $10^{14}$  #/kWh engine-out emissions
  - To  $10^8$  #/kWh on NRTC and LLC
  - To  $10^{11}$  #/kWh on RMC, due to passive soot oxidation at high load
- Tailpipe PN10 emissions on NRTC and LLC reach  $10^{10-11}$  #/kWh due to urea-borne particles



# Well-to-Wheel CO<sub>2</sub> emissions nearly eliminated on CO<sub>2</sub>-neutral fuels

- Demonstrator results have also been validated on 100% HVO
- WtW calculation for NRTC hot, based on [JEC methodology](#)
  - Fossil diesel
  - 100% HVO from
    - EU mix
    - Used Cooking Oil (UCO)



# Conclusions

- Emission control technologies are available to achieve **low NRMM pollutant emissions**
- **Single-dosing SCR** system can already address some shortcomings of Stage V regulation
- **Dual-dosing SCR** and **Exhaust Gas Heater** are available with further benefits to cover the varying needs of wide range of NRMM applications
  - Depending on OEM engine concept and engine-out NOx emission level
  - Alternating operating conditions
  - Continuous low-load operation
  - Initial cold-start
- Together with operation on **CO<sub>2</sub>-neutral fuels** including HVO, e-diesel and H<sub>2</sub>; the Internal Combustion Engine is a future-proof NRMM powertrain option

# THANK YOU!

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