



Potential for Reduction in NRMM Real-World CO₂ and NOx Emissions

Dirk Bosteels • 16th Int. ECT Conference • 7-8 October 2025

AECC is now the Association for Emissions Control and Climate

Expanding the scope

Components and systems

Full and Associate
member companies

- Air quality and **Climate** requirements
 - Mobile and **Stationary** emissions sources
 - Sustainable **components and systems**
-
- Catalysts
 - Filters
 - Adsorbers
 - Fuel cells
 - Electrolysers
 - System integration

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



H₂ production and utilisation

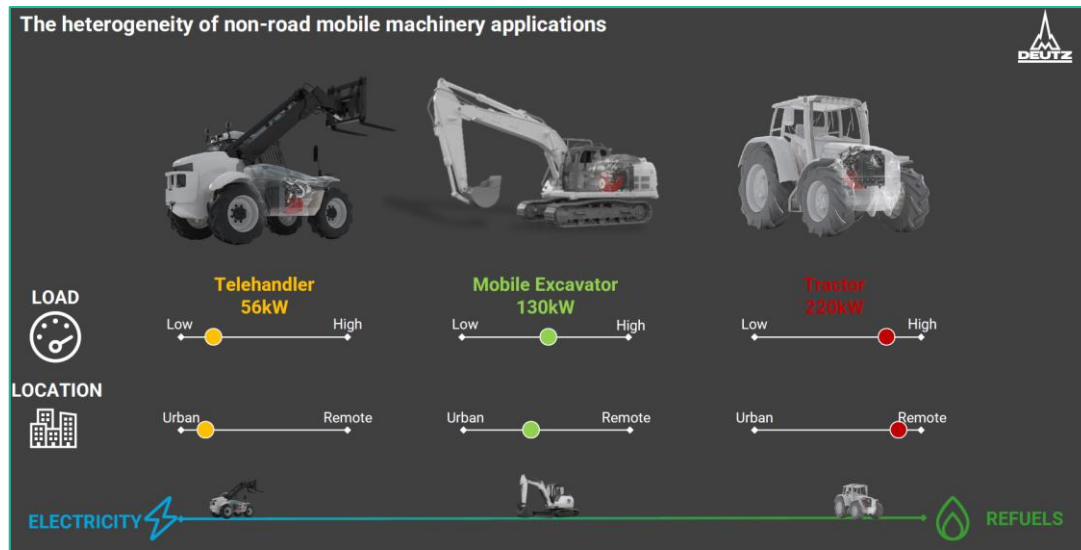


Life cycle assessment and circular economy

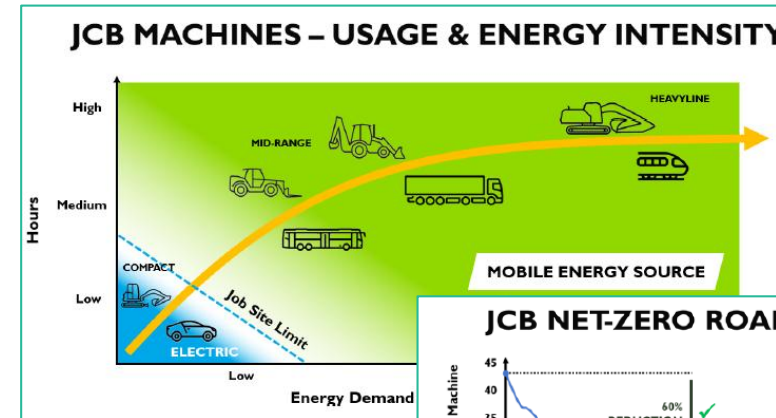


All powertrain technologies needed towards net-zero CO₂

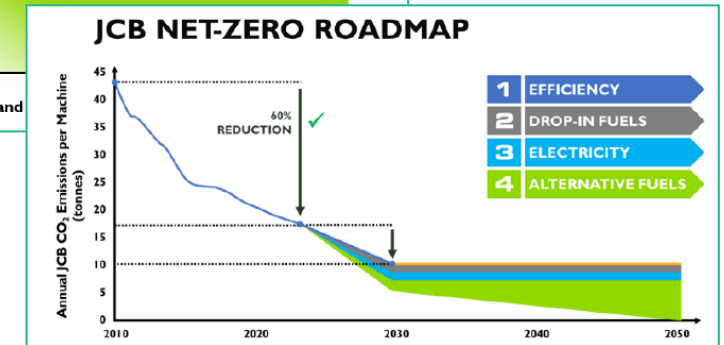
- Internal Combustion Engine (ICE) remains key for the NRMM use cases
- Different sustainable renewable fuels are investigated to reduce the carbon footprint



Deutz, Baden-Baden, 2024

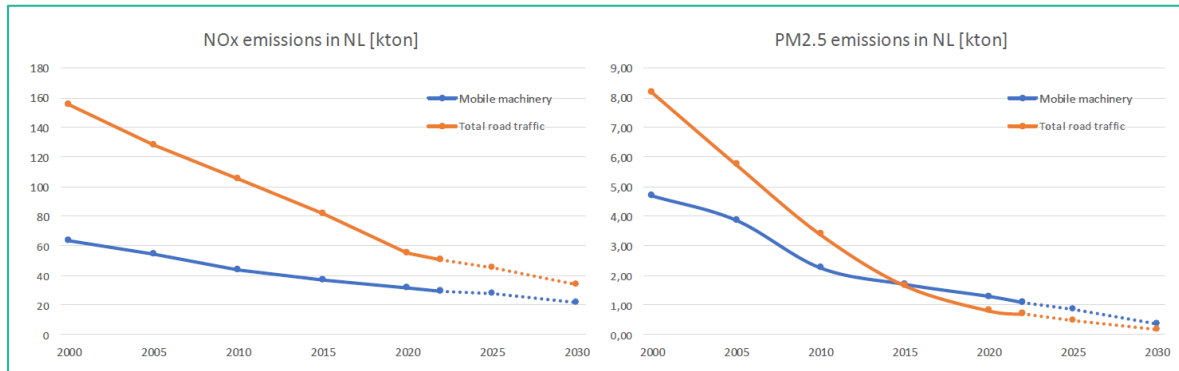


JCB, EA NRMM, 2024

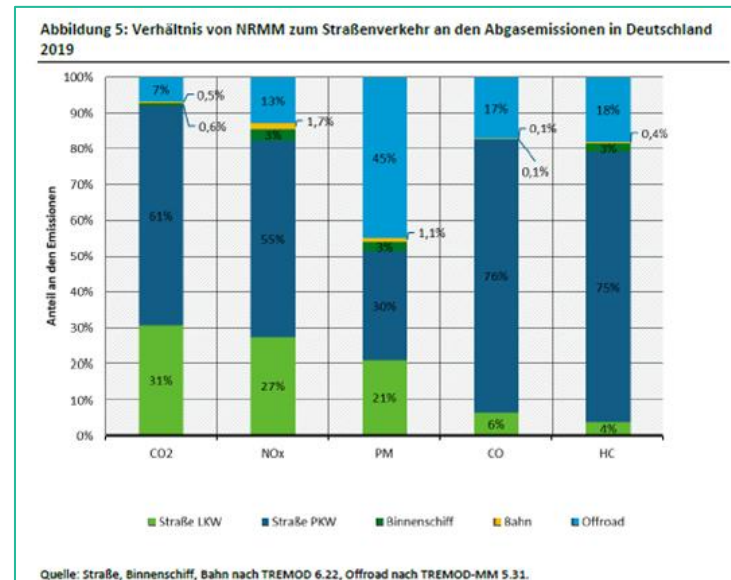


Increasing contribution of NRMM to air quality impact

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



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

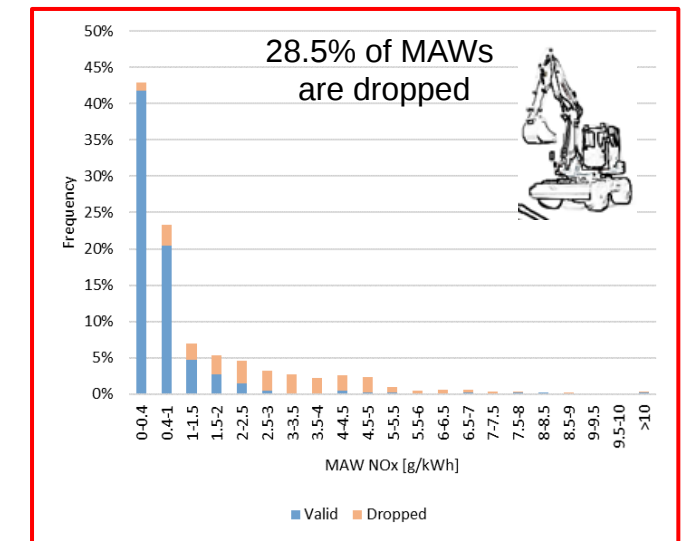
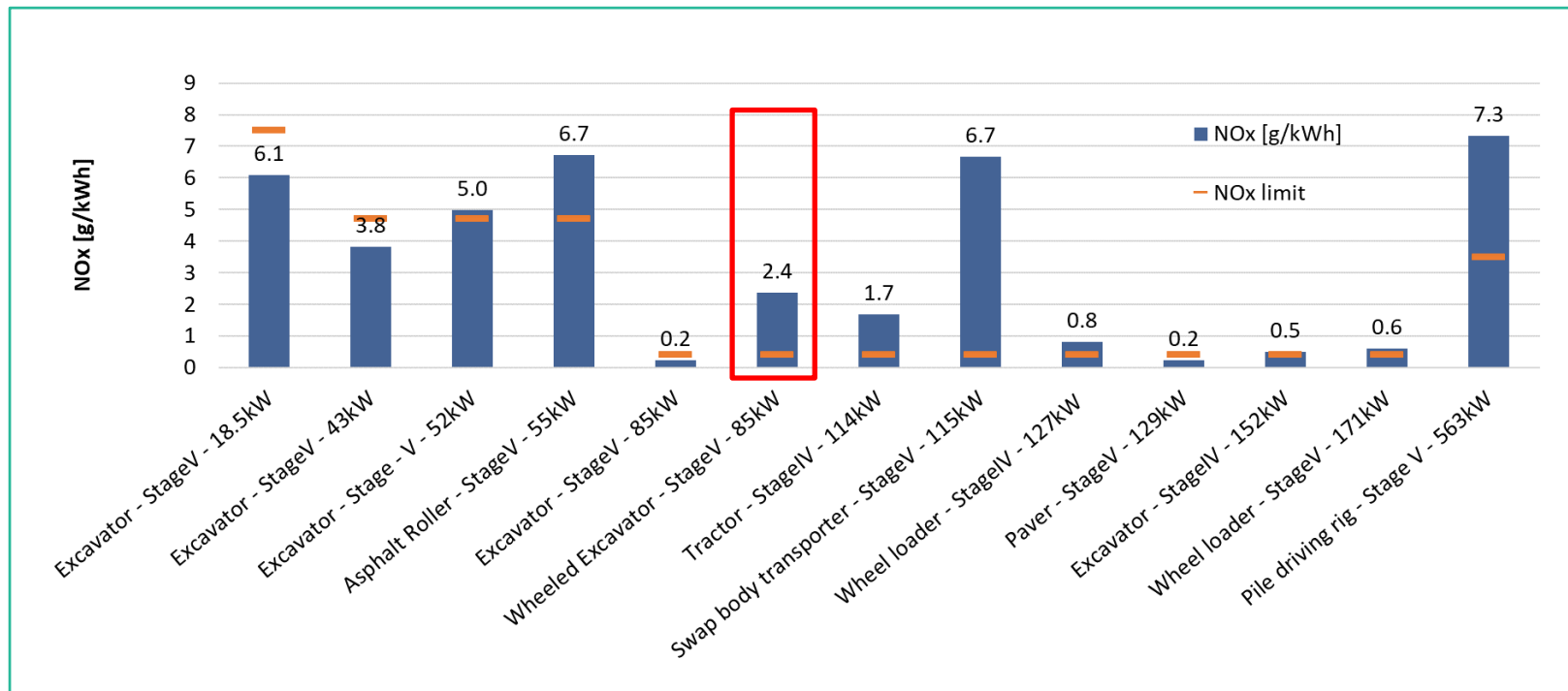


Evolution of EU NRMM Stage V legislation is expected

- EU 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 will review Stage V in 2025 based on PEMS monitoring data
 - US CARB [Tier 5 proposal](#) for MY2029+, US EPA announcement from 2024 tbc
 - 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

A large variation is observed in real-world NOx emissions

- Depending on the use case and applicable limit
- NRMM regulation does not consider a substantial share of the real working conditions

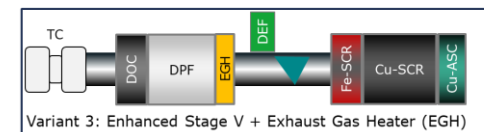
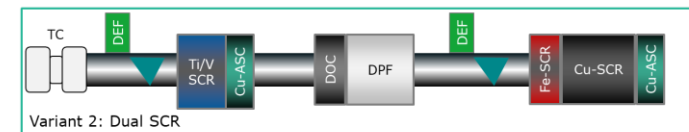
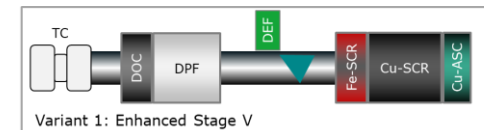
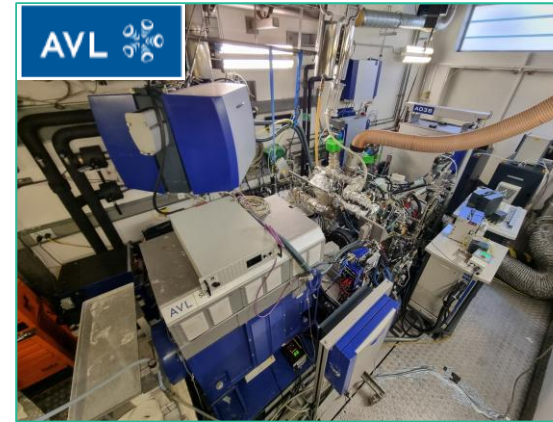


MAW: Moving Average Window

R. Vermeulen, et al.; *"Real-World NOx emissions of Stage V NRMM"*, Transport and Air Pollution Conference, 2023

AECC NRMM demonstrator project set-up

- NRMM engine
 - Base characteristics
 - 4l class, ~ 100 kW rated power
 - Cooled HP-EGR & intake throttle
 - ~ 4 g/kWh engine-out NO_x
 - EGR and thermal management recalibrated at low-load
- 3 emission control systems
 - Tested in modular approach
 - Hydrothermally aged

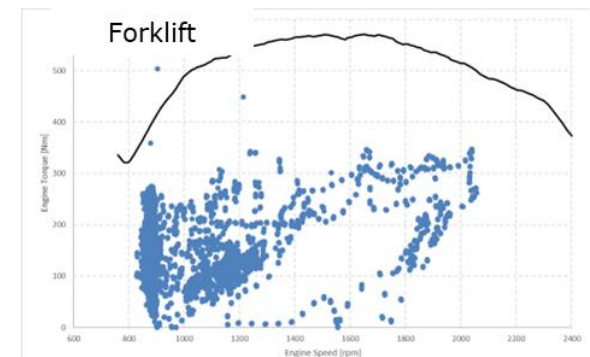
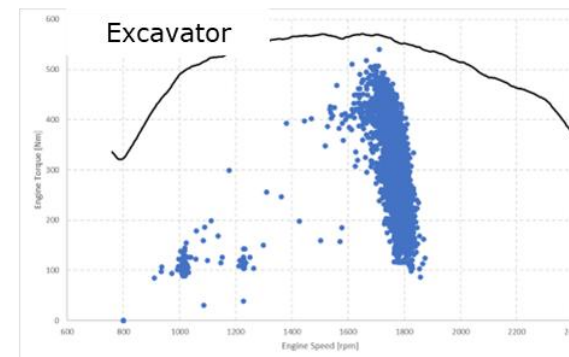
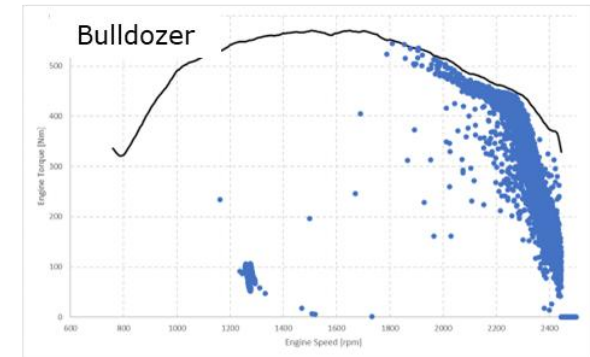
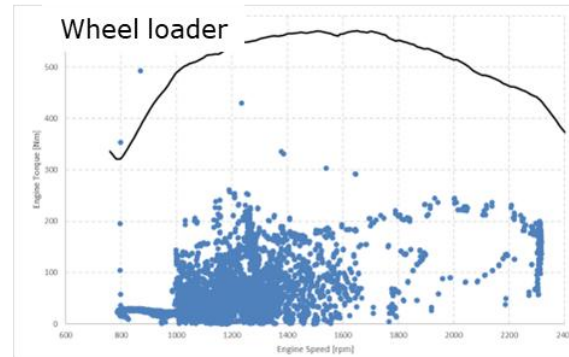
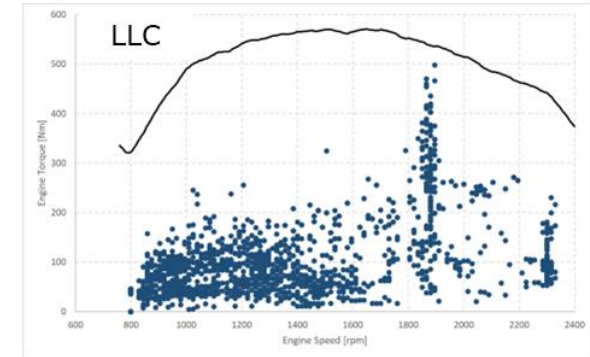
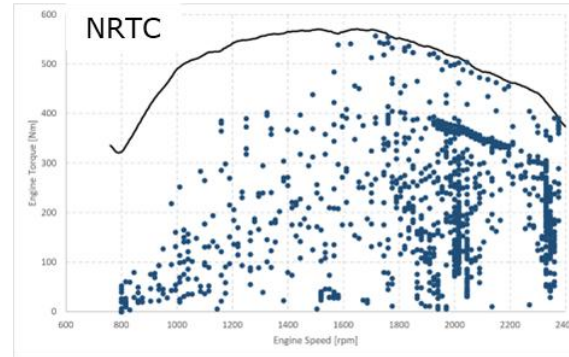
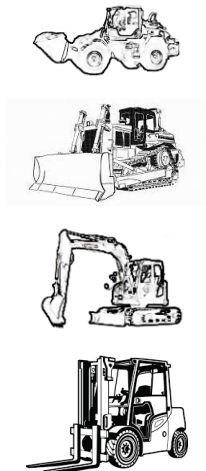


TC: Turbocharger
EGH: Exhaust Gas Heater
SCR: Selective Catalytic Reduction
ASC: Ammonia Slip Catalyst
DOC: Diesel Oxidation Catalyst
DPF: Diesel Particulate Filter

J. Demuyne, et al.; *"Demonstration of Potential for Reduction in NRMM Real-World Emissions"*, SAE HD Symposium, Gothenburg, 2025

Testing of wide variation in NRMM applications

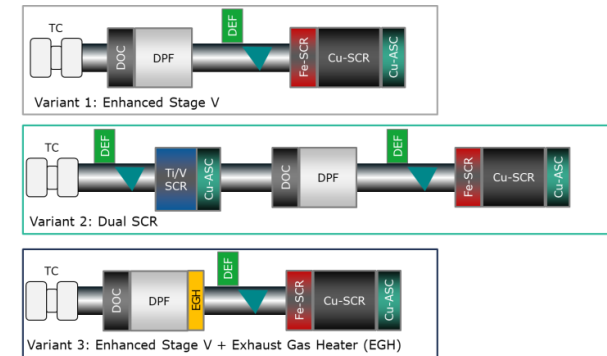
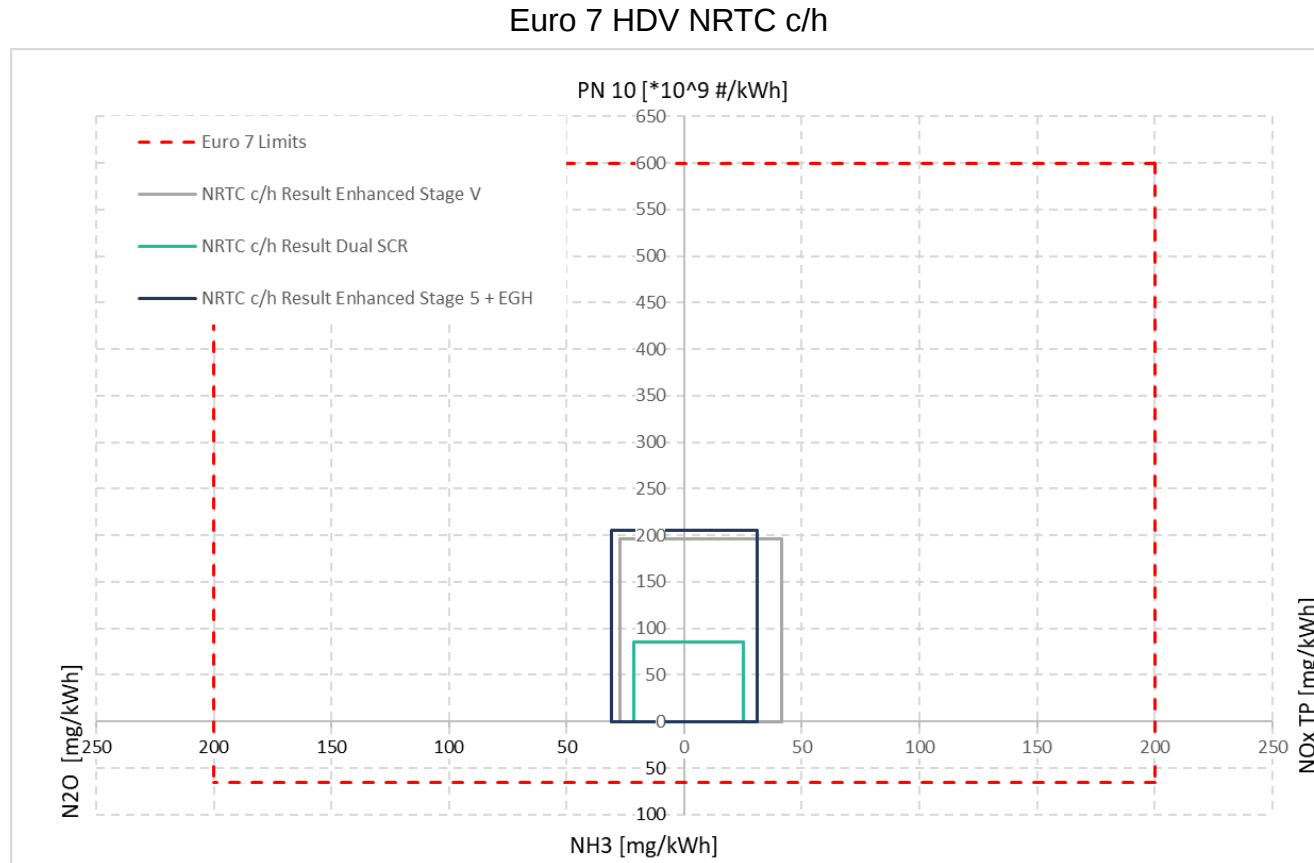
- Type approval cycles
 - NRTC cold and hot
 - RMC
 - LLC
- In-use application cycles
 - Wheel loader
 - Bulldozer
 - Excavator
 - Forklift



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

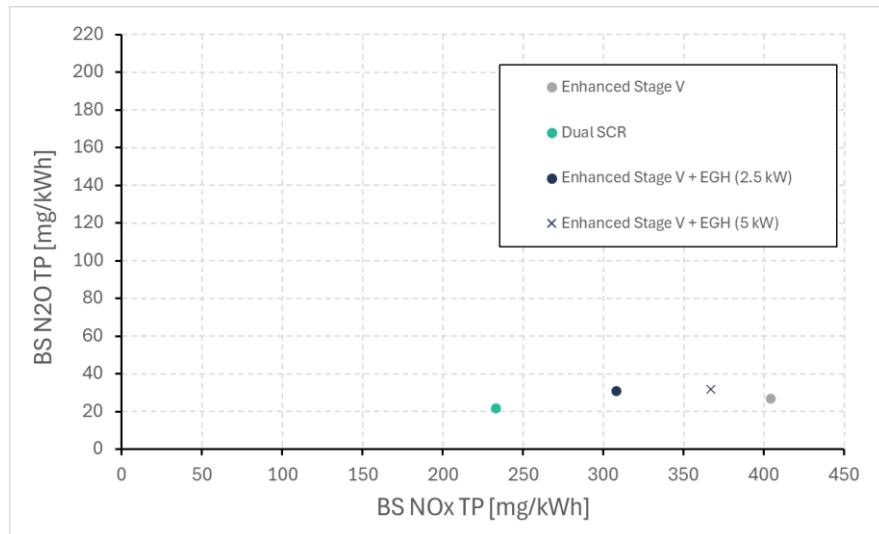
- Small differences between variants on NRTC after cold-hot weighing



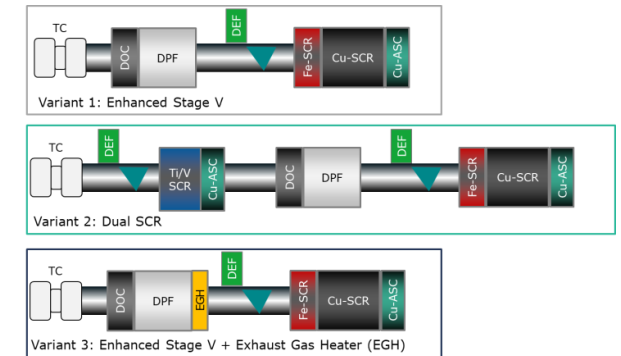
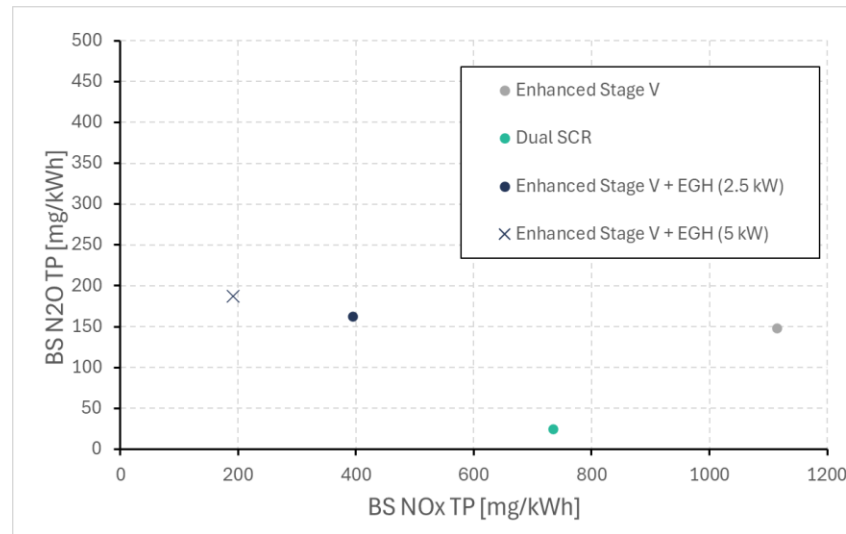
All 3 variants significantly reduce low-load/cold-start emissions

- Dual SCR configuration shows the lowest NO_x level on NRTC cold
- EGH shows the lowest NO_x level on LLC cold

NRTC cold

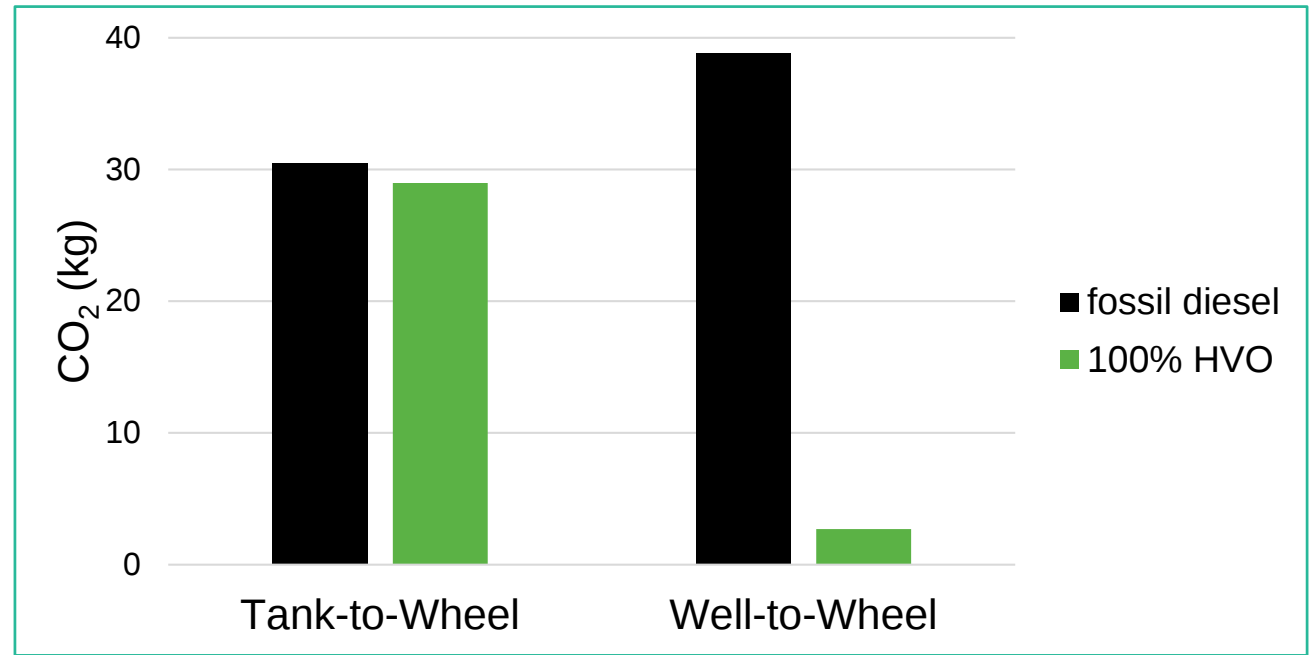


LLC cold



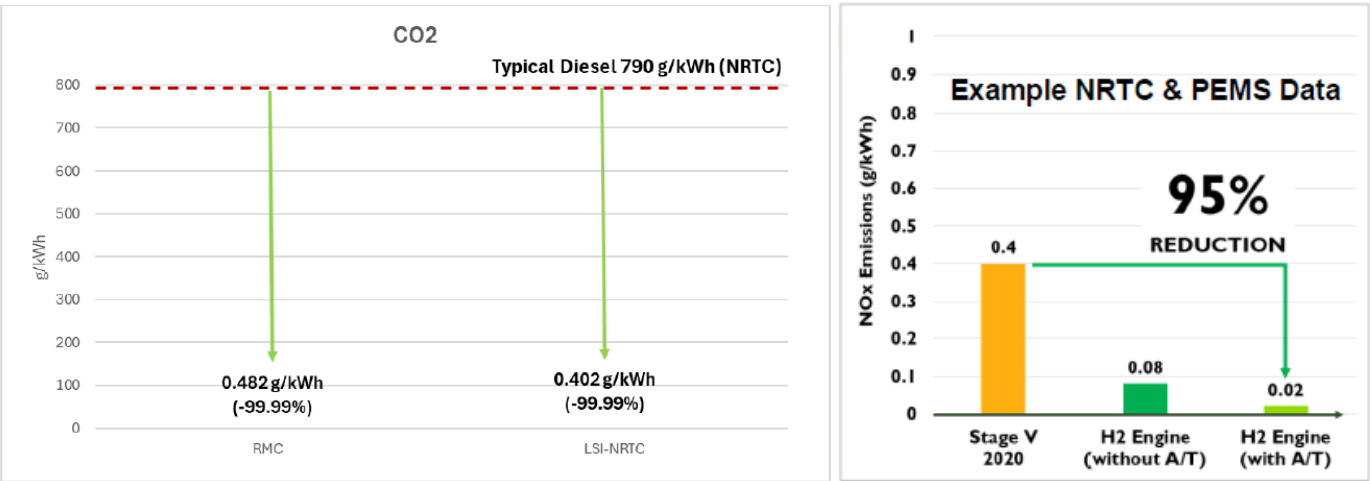
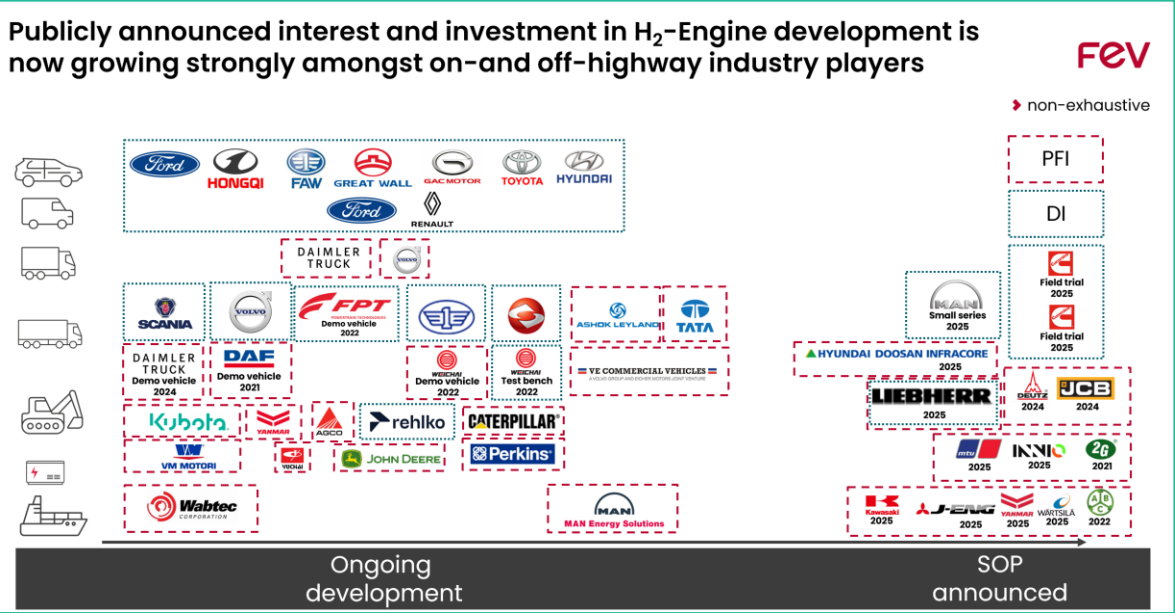
Well-to-Wheel CO₂ emissions nearly eliminated on CO₂-neutral fuels

- Exemplary WtW calculation for NRTC hot of simulation study
 - Fossil diesel
 - 100% HVO from Used Cooking Oil (UCO)
- Demonstrator results have also been validated on 100% HVO



H₂ ICE is a future-proof powertrain

- All OEMs work on it
- JCB obtained first type-approval under article 35 of Stage V



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 CO₂-neutral fuels including HVO, e-diesel and H₂, the Internal Combustion Engine is a future-proof NRMM powertrain option

THANK YOU!

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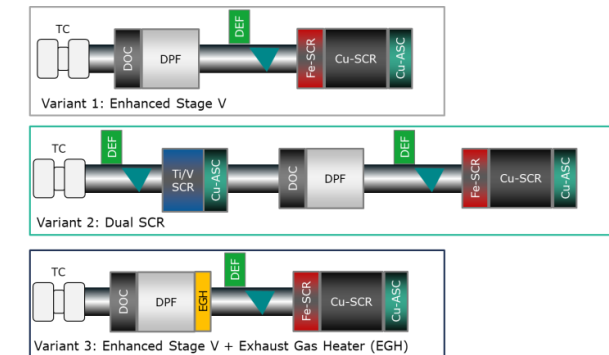
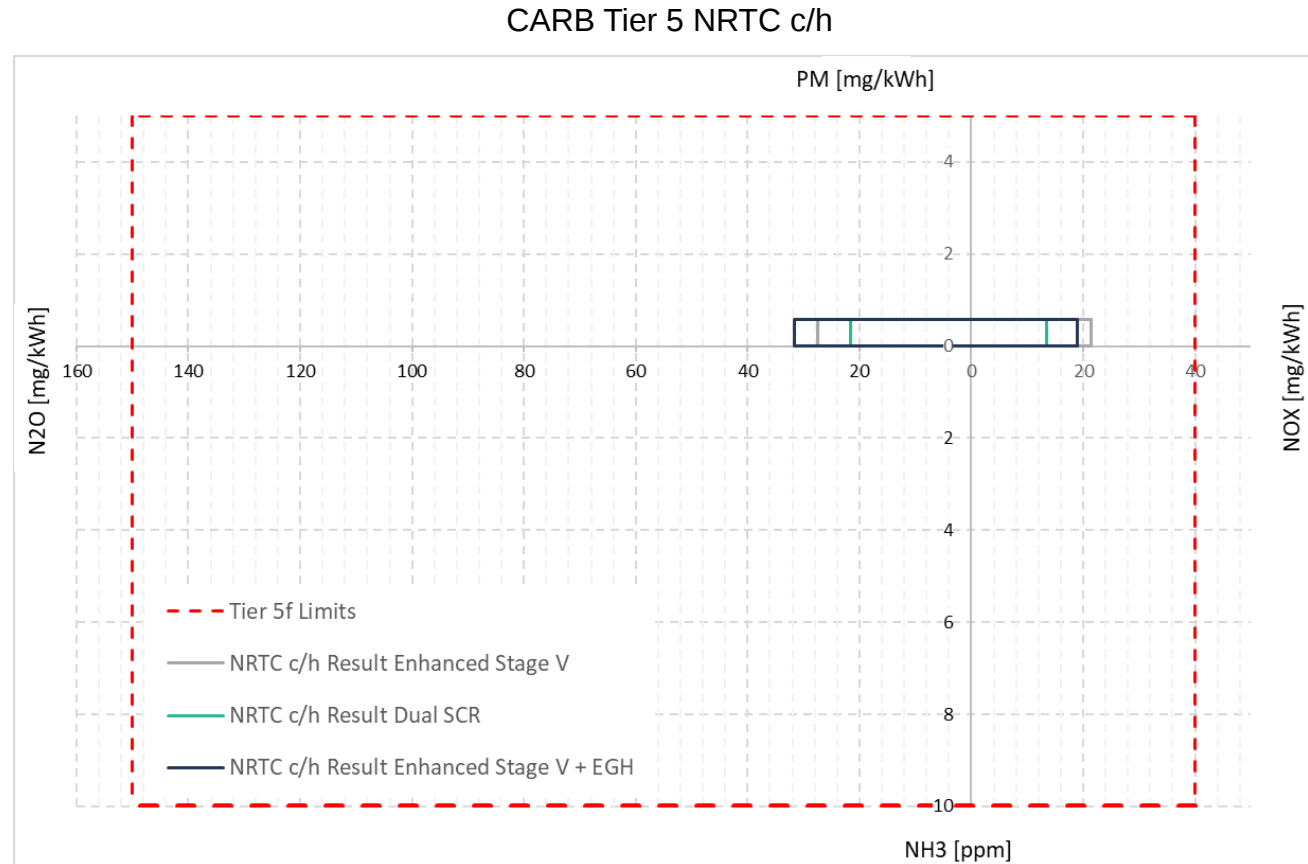
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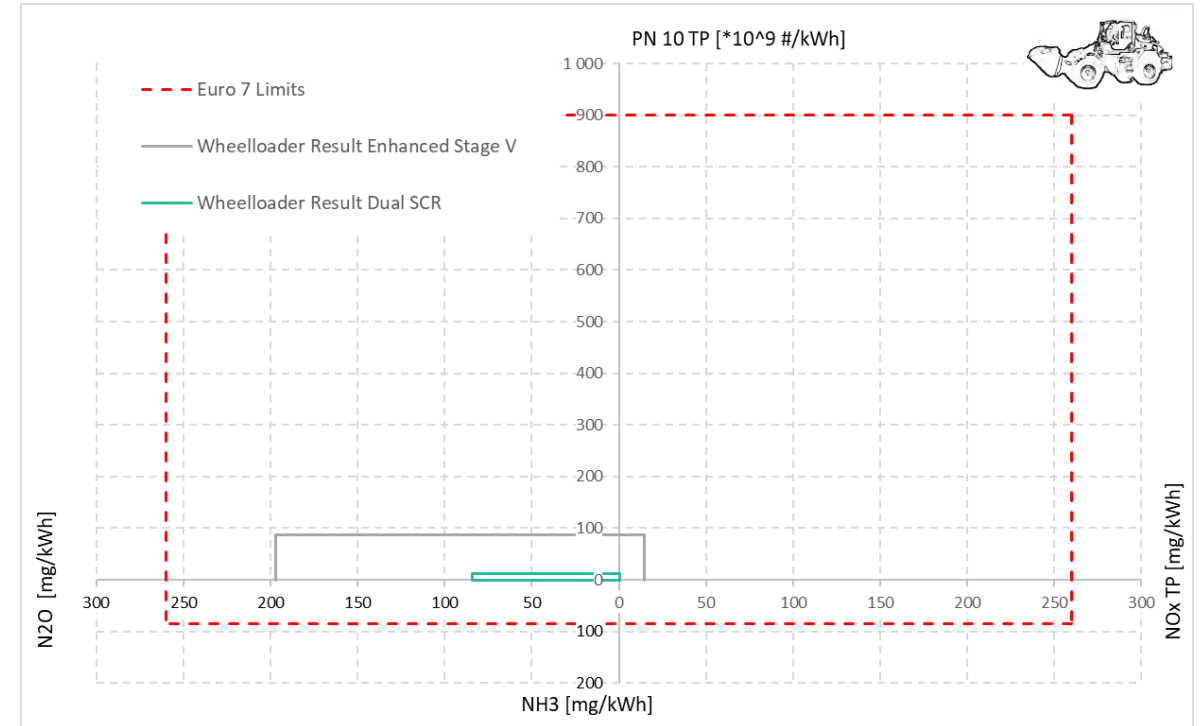
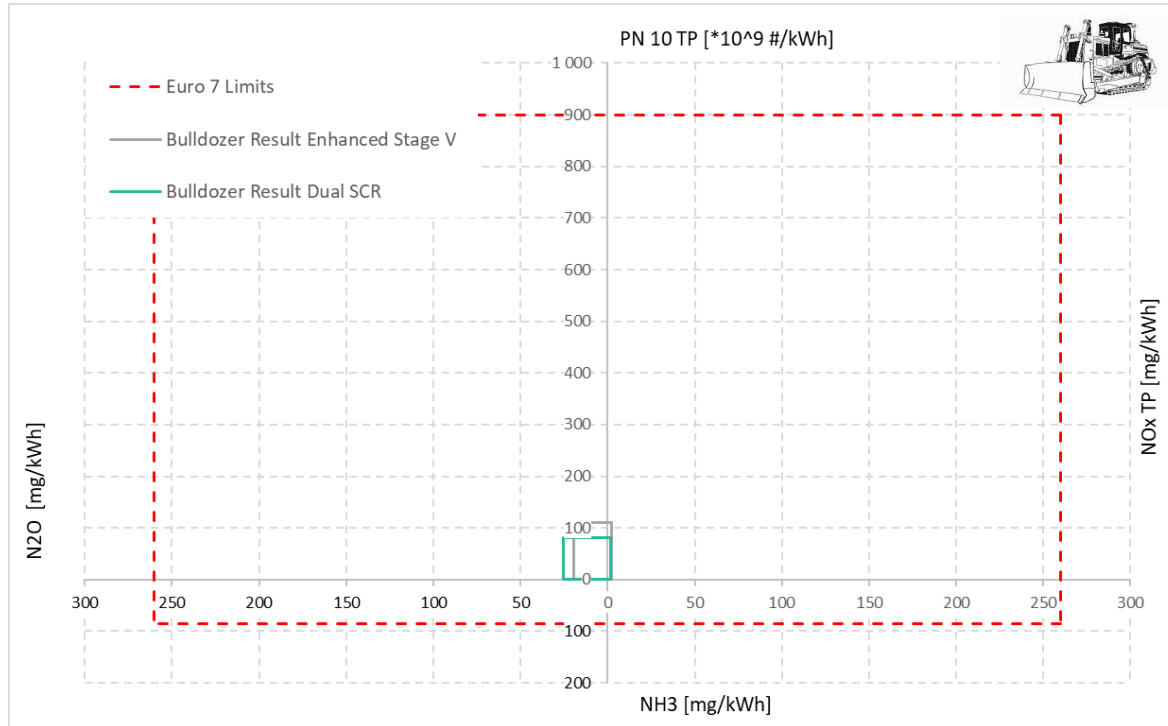
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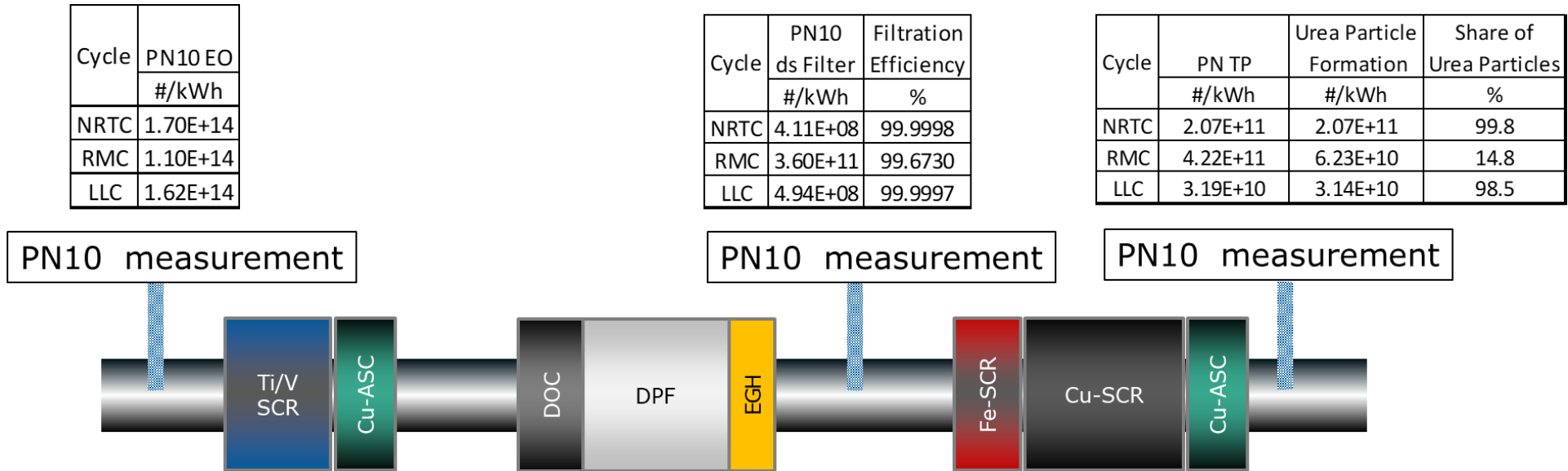
Consistent low emissions on in-use cycles

- 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)



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 born particles



NOx vs. CO₂ emissions - demonstrator

- Largest difference on LLC test

