Emission Control for Future Heavy Duty Trucks and Buses

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Executive Summary

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- Regulation Updates | Implications
- Advanced Filter Design | Component Level Readiness
- Future Ready EATS | System Level Readiness

Regulation Updates | Implications

Next Wave of Regulations | Euro7 HD proposal*

GHG / Pollutant Limits

- CO_2 15% - 55%↓
- Detect & Count sub 23 nm PN
- PN > 70%↓
- NO_x 56%↓ CO 51%↓
- N_2O, HCHO will be regulated

Testing Methodology

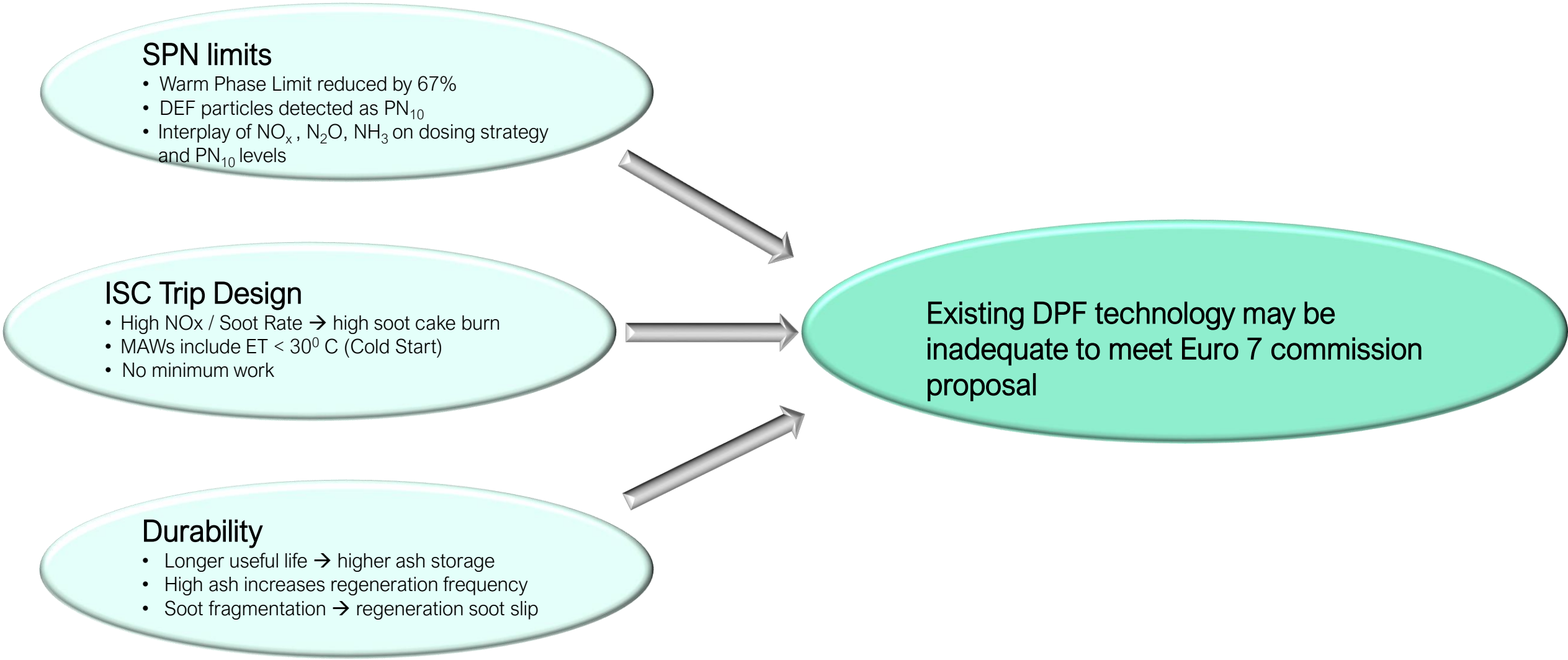
- Primary mode of evaluation is On-Road Testing
- Calculation of emissions to include low power, temperature MAWs
- No conformity factors
- Test conditions cover higher altitudes, all payloads

Durability Requirements

- No relaxation for aged catalyst
- Very high clean filter PN FE
- Longer vehicle useful life

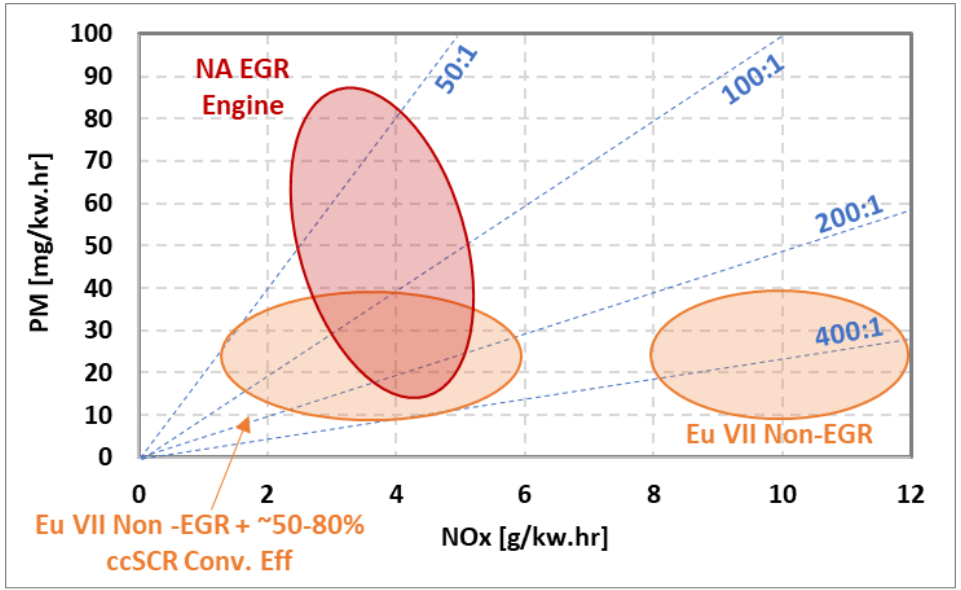
* The European Commission proposal is still being debated and awaiting approval from European Parliament

Euro 7 HD Proposal | Risks from SPN perspective



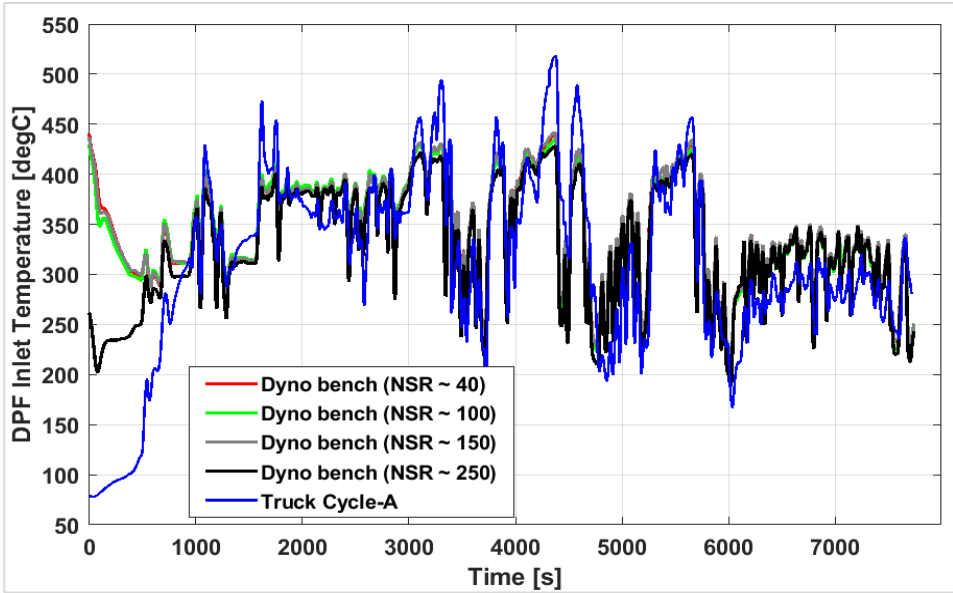
Advanced Filter Design | Component Level Readiness

Challenge Cycle to evaluate DPF filtration performance



- Comparison of NO_x – Soot Ratio [NSR] across a wide spectrum of engine technologies used worldwide.
- NO_x – Soot Ratio [NSR] varied in the range of 50:1 [NA EGR engine] to 400:1 [non-EGR engine]

- Conversion of an actual on-road truck duty cycle into an engine test bed cycle to understand scope of operation
- For the operating region identified, cycles with varying NSR values developed keeping similar DPF inlet temperature profiles



Reference : SAE paper # 2023 – 01 – 0386

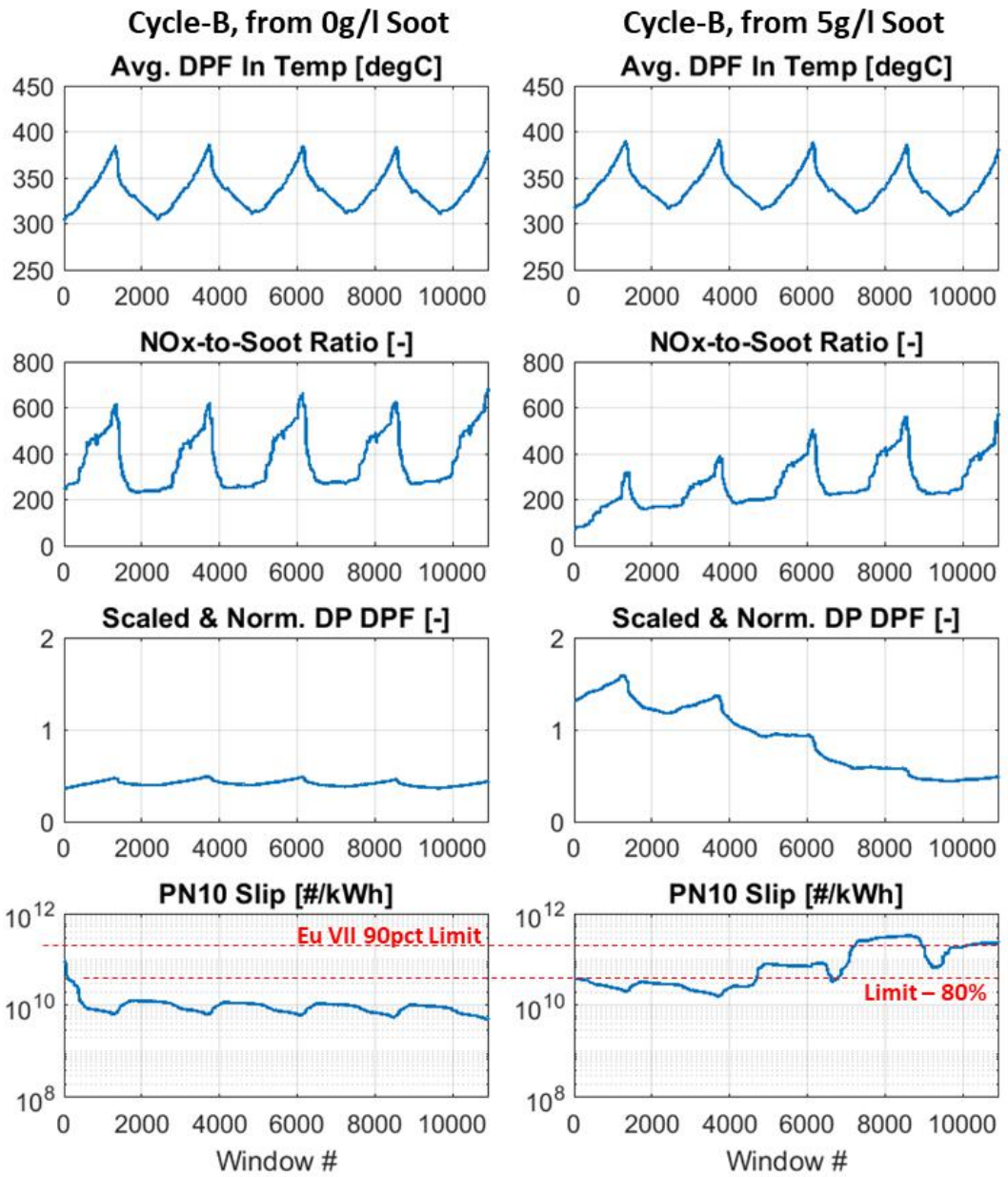
Impact of starting soot load

Testing Methodology

- Starting soot loads of 0 & 5g/l investigated
- High NSR cycle [NSR_{cc}~225] run back-to-back until the PN_{10} slip hit a maximum
- Work based window analysis performed

Key Observation

- PN10 slip starting from a soot loaded condition exceeded proposed Euro 7 limit.
- Occurred at 2.5-3g/l soot load or ~50% regen eff. non uniform soot burn in DPF



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Peak PN slip across DPF technologies

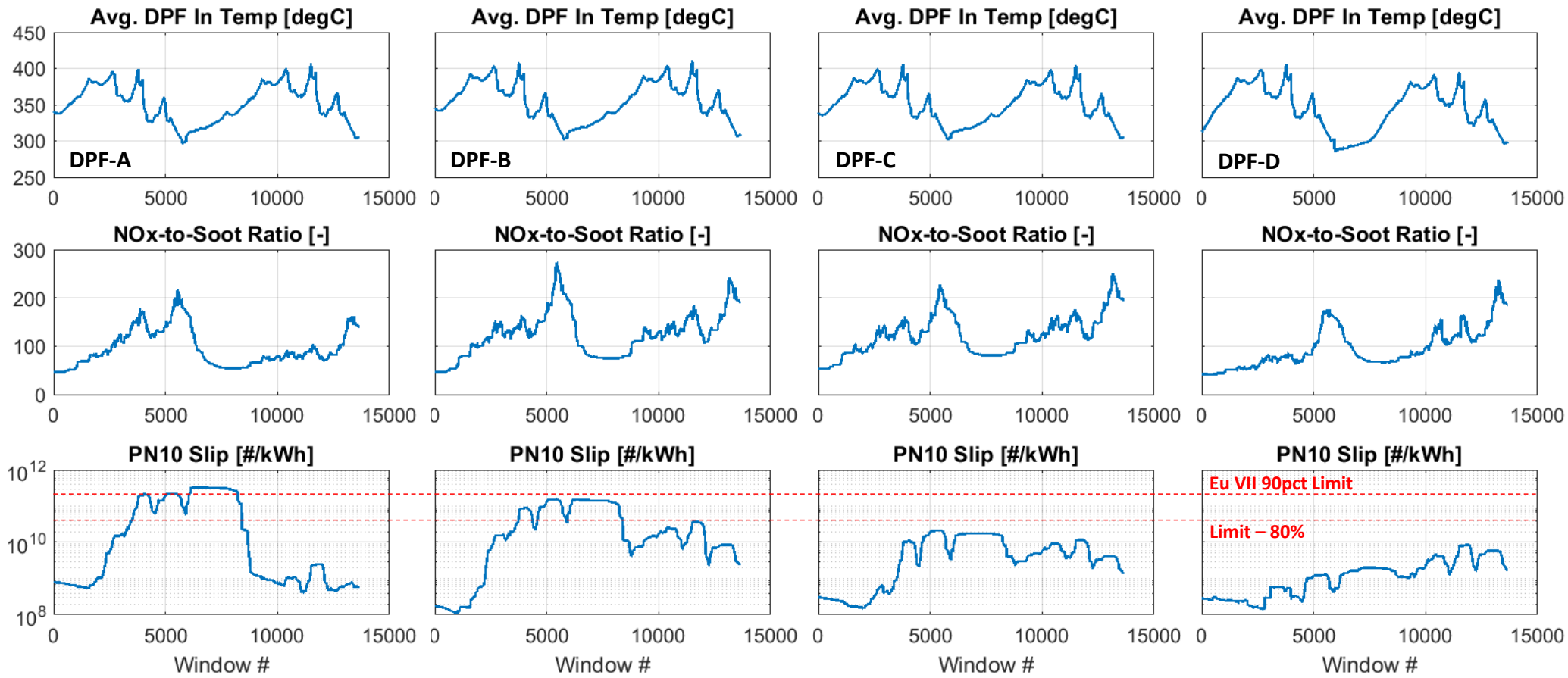
Existing DPF

Advanced DPF concepts

DPF in temp profile was repeatable

NSR_i was floating between ~40-250

Peak PN_{10} slip seen when scaled PD drops to minimum



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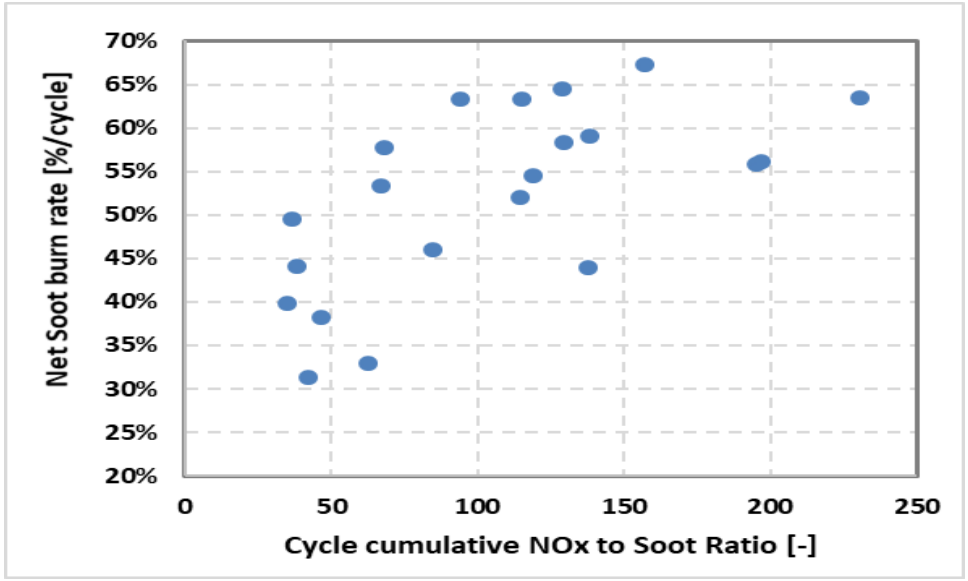
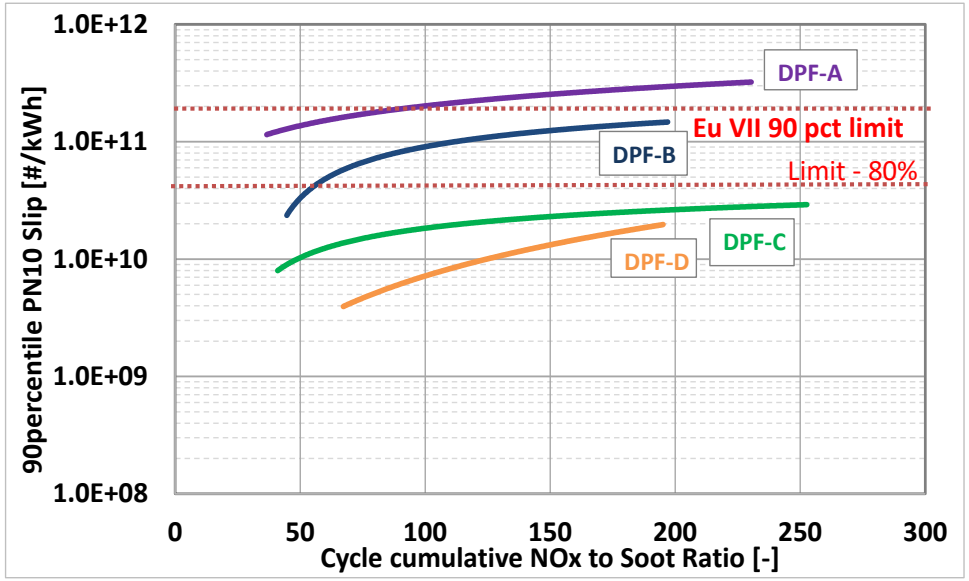
Advanced DPF technologies exhibit high filtration

- DPFs tested using Cycle-A over NSR_{cc} ~40 to ~250
- ~1.5x increase in burn rates for a ~6x increase in NSR_{cc}



- DPF technologies available to meet HD Euro 7 PN_{10} under aggressive operation
- PN_{10} slip increased ~6x with NSR_{cc} & leveled out >150 NSR_{cc}



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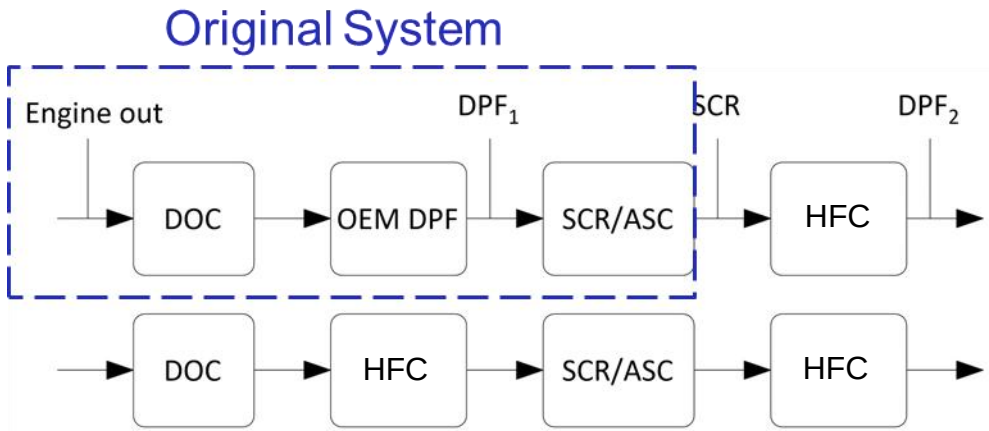
Future Ready EATS | System Level Readiness

HD Vehicle Emissions Study | Vehicle | EATS

Manufacturer	Scania
Rated Power	350 kW
Rated Speed	1700 rpm
Engine Volume	12.8 L
No. of Cylinders	6

OEM EATS – DOC + DPF + SCR/ASC

Two system configurations tested

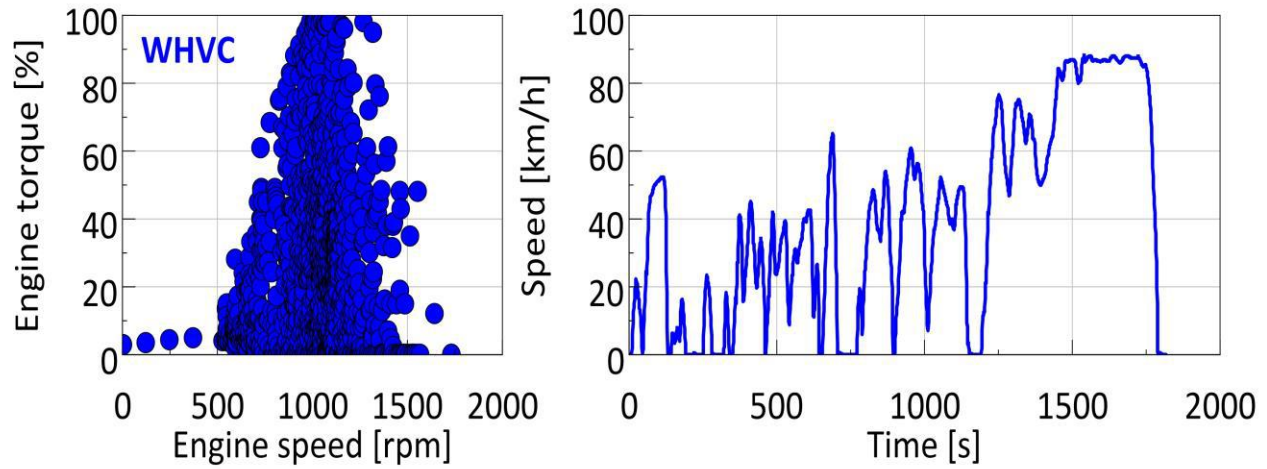


Reference : https://doi.org/10.3390/ atmos13101682

HD Vehicle Emissions Study | Test Cycles

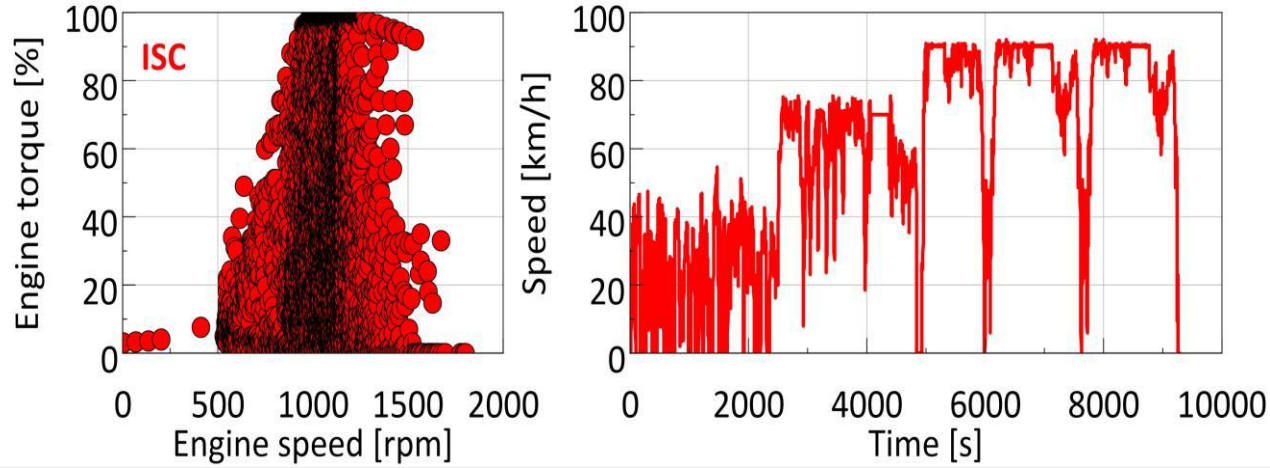
World Harmonized Vehicle Cycle (Short Trip)

- ❑ WHVC is the chassis dyno surrogate of the WHTC engine testing cycle
- ❑ WHVC cold and hot cycle emissions weighted as 14% and 86% respectively to get the final value



ISC – In Service Conformity (Long Trip)

- ❑ ISC developed by JRC European Commission to test heavy duty vehicle emissions
- ❑ ISC is split into urban (21.7%), rural (26.4%), motorway (46.5%).
- ❑ MAW methodology used to evaluate overall emissions



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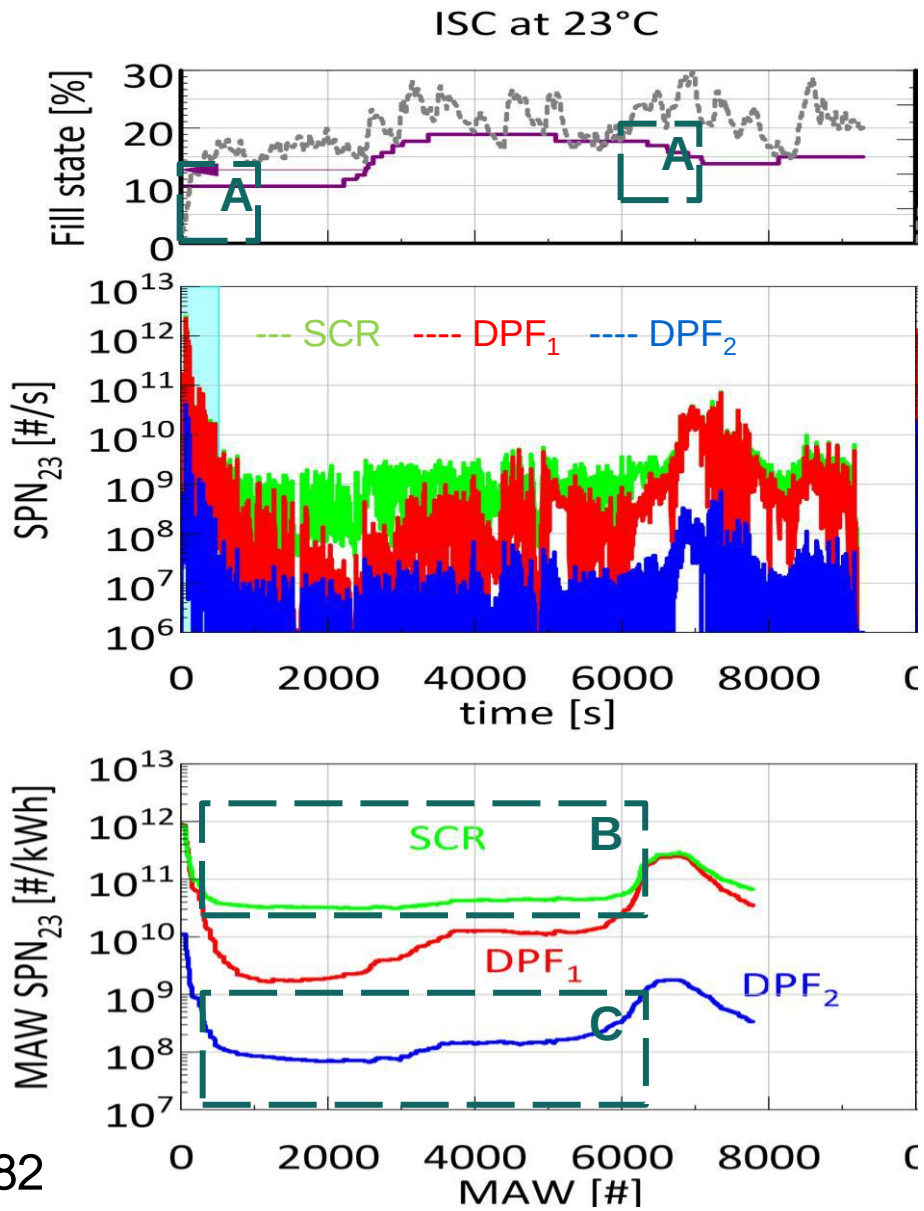
HD Vehicle Emissions Study | ISC Second by Second Data

Key Observations :

A. Two mechanisms for SPN emissions post primary DPF
   - ❑ DPF in clean state – not enough soot cake formed
   - ❑ Passive Regeneration – soot slip through partially burnt soot cake layer

B. SCR dosing in warm phase causes spike in SPN count due to non-volatile DEF particles

C. Use of secondary DPF can reduce the SPN count by more than two orders of magnitude



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HD Vehicle Emissions Study | ISC Cumulative Results

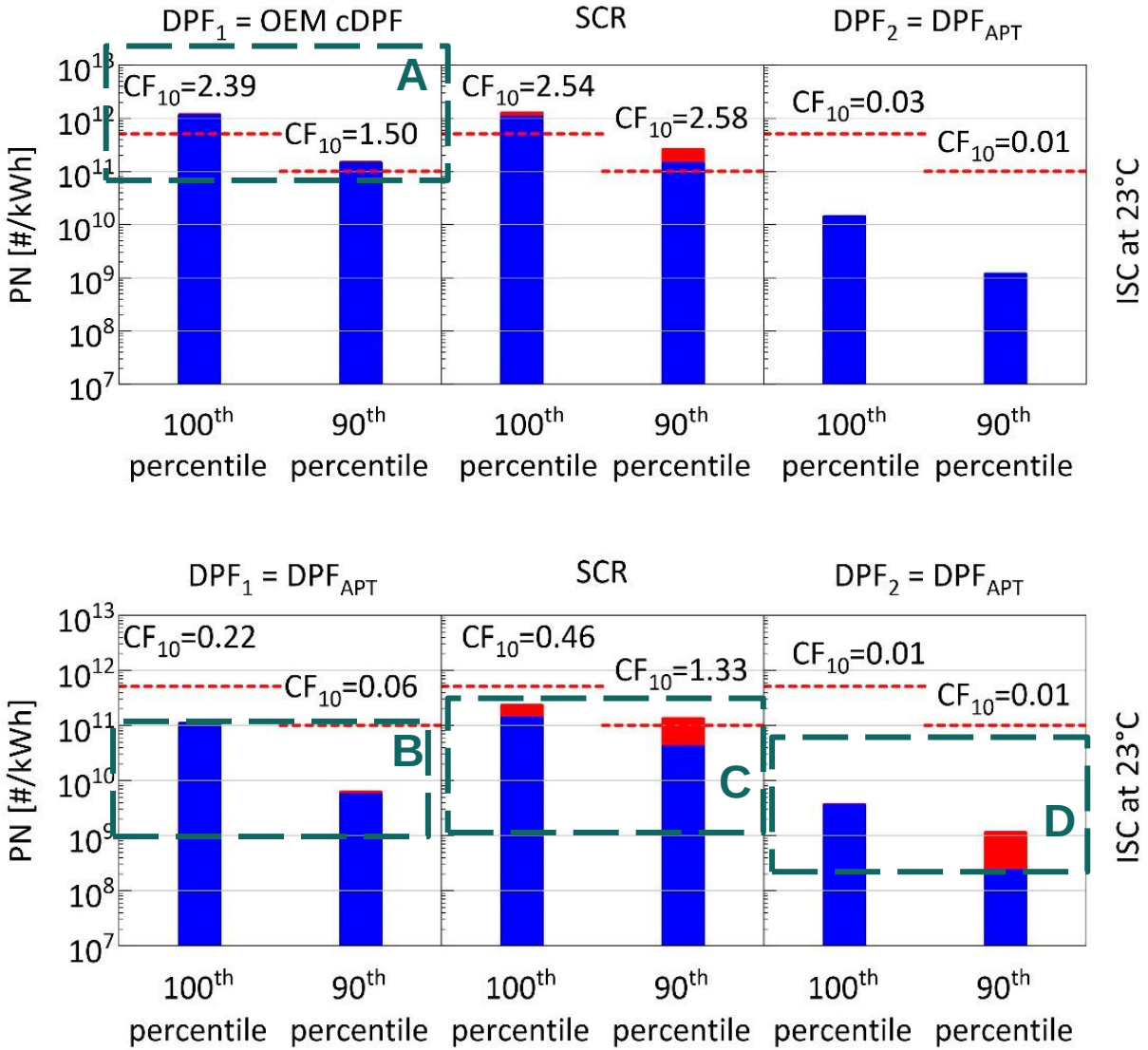
Key Observations :

A. Existing BS6 level technology for DPF is not enough to meet the proposed Euro 7 level emission targets.

B. High filtration DPF reduces the SPN levels by more than one order of magnitude.

C. Urea particles generated in the warm phase of ISC increase the SPN levels beyond the limit.

D. A dedicated secondary DPF downstream of SCR reduces the SPN levels by more than two orders of magnitude



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Key Takeaways

- Euro 7 commission proposal will require a step change in the system configuration layout

- Ultra high efficiency filters will be required to limit soot slip during passive regeneration conditions

- Non-volatile urea nanoparticles contribute significantly to the PN_{10} count. If not controlled by the dosing strategy, a secondary DPF downstream of SCR may be required to capture them

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