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Advancing Emission Control through Hybrid Catalyst Technologies

Presented by:
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On behalf of
BASF Environmental Catalysts & Metals Solutions

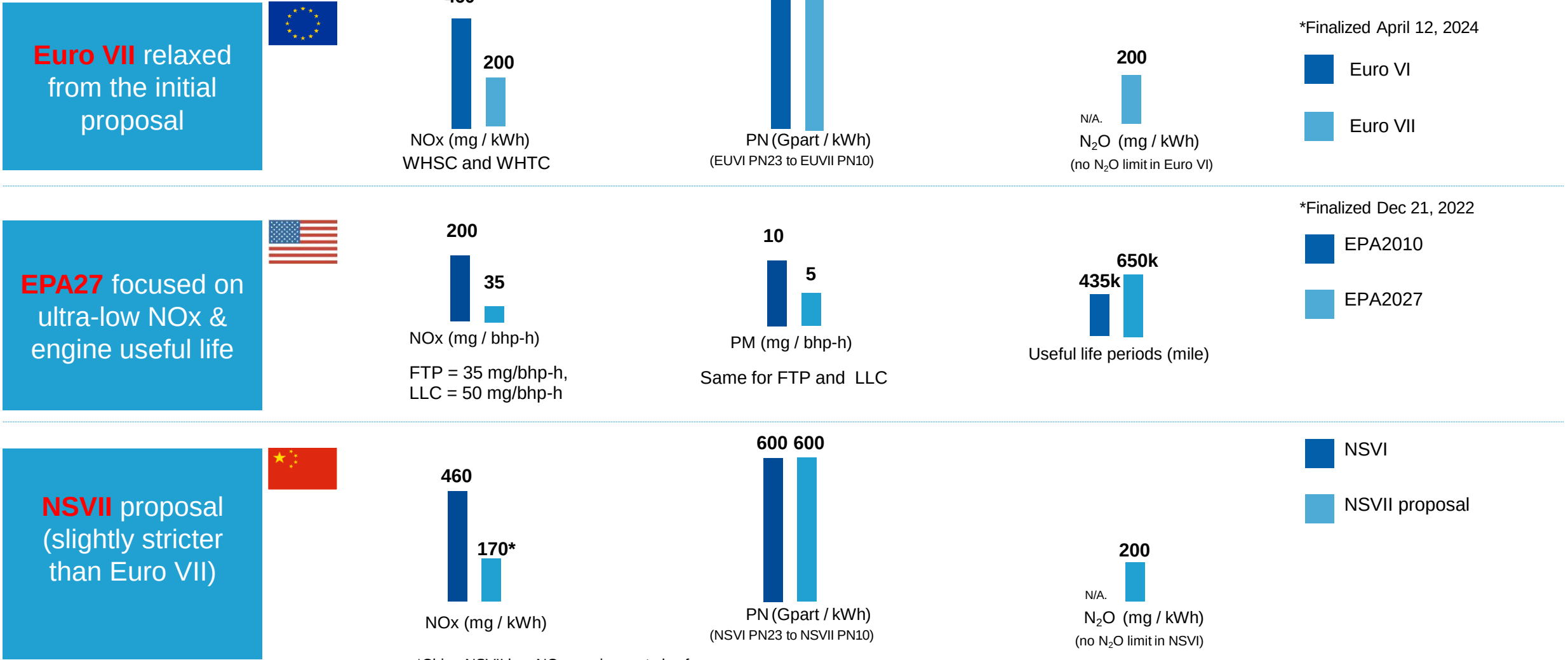
ECT 2025

Background

- BASF-ECMS is Committed to addressing the global challenge of reducing air pollution from internal combustion engines.
- We have been engaged in continuously developing New technology and formulations to improve Catalyst performance, robustness, life expectancy at the same time reducing the overall cost of ownership.
- This endeavor has been multi faceted and has led to integration of DOC functionality on CSF (DOCoF), SCR functionality on CSF (SCRoF), Advanced coating technologies that enhance PN filtration till PN10.
- This current design stands out from conventional SCR catalysts which require a DOC to generate de-sulfation exotherms.
- This new technology is capable of generating exotherm on its own.
- Uniquely so, this Technology is developed with CuZ SCR (Copper-zeolite Selective Catalytic Reduction) that offers significant reduction in sizing and wider operating range.

BASF is gearing up for the automotive growth in India and for the upcoming On road & Off road Emission Legislations.

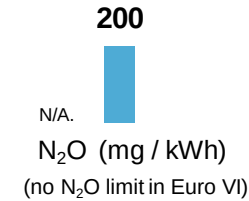
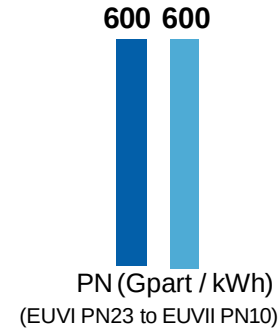
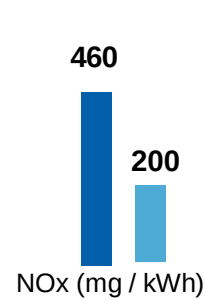
Future On-Road Emissions Limits



Status: April 2025

Outlook for Euro VII

Euro VII relaxed
from the initial
proposal



*Finalized April 12, 2024



What's Adopted:

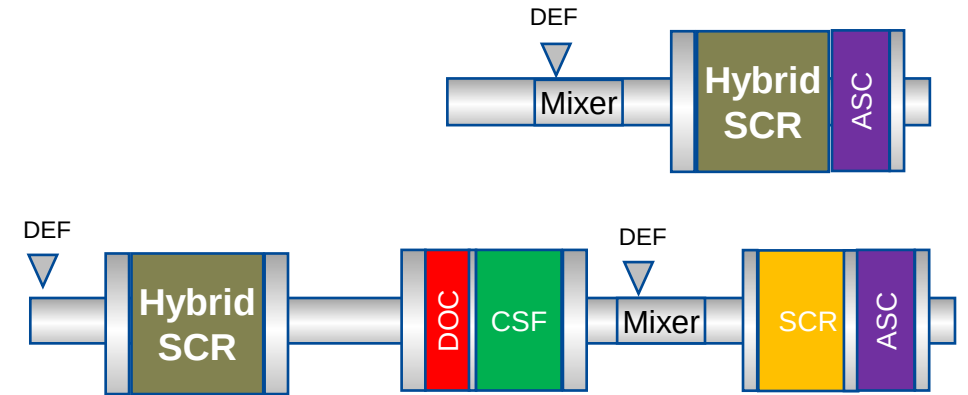
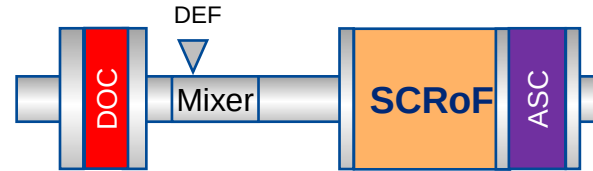
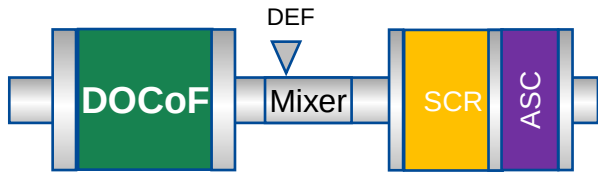
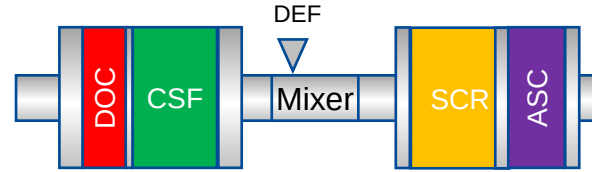
- As per EU & ACEA – More Realistic
- Neutral to fuel type & Technology.
- Closely Linked to CO₂ 2030 targets and climate neutrality.
- On-board emission monitor for NO_x, PM & NH₃ for HD vehicles.

What's Left Out:

- PN Limit relaxed by 200% compared to recommendations .
- The durability period is much relaxed compared to CARB (1.3 mi kms for Class 8 Vehicles by 2031)

- General trend :
 - ▶ Initial EUVII proposal is mainly RDE based – other proposals are focusing on EUVI type of procedures.
 - ▶ Introduction timeline 48 months (new type approvals) / 60 months (new vehicles) after adoption of all parts of the legislation.

Conventional vs Hybrid System Integration



■ DOCoF

- ▶ Conversion of CO & HC (including slip)
- ▶ Soot removal
- ▶ L/O injected fuel for active filter regeneration
- ▶ NO → NO₂ (soot combustion & “fast” SCR reaction.)

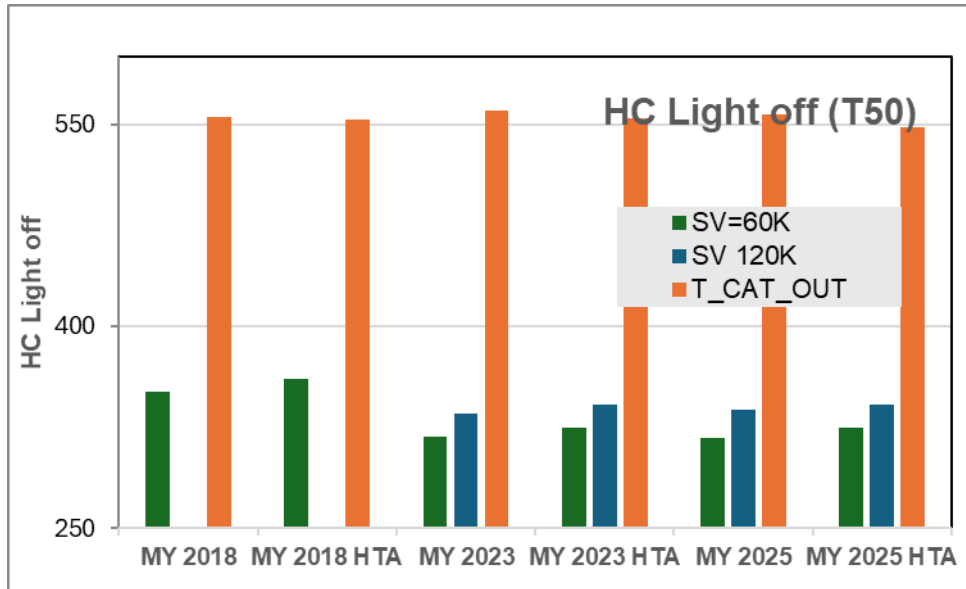
■ SCRoF

- ▶ Conversion of NO_x
- ▶ Soot removal
- ▶ Active filter regeneration

■ Hybrid CuZ SCR

- ▶ Smaller packaging for ccSCR functionality.
- ▶ Lower dependency on uF SCR performance.
- ▶ Broad operation window for optimizing Fuel Consumption.

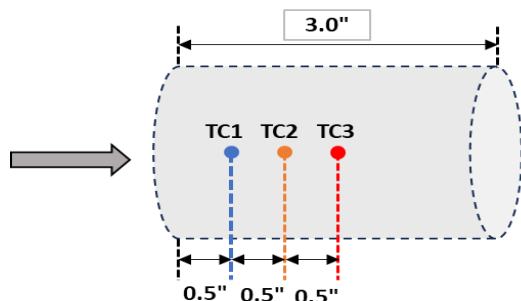
DOC Functionality Validation for Fuel burn



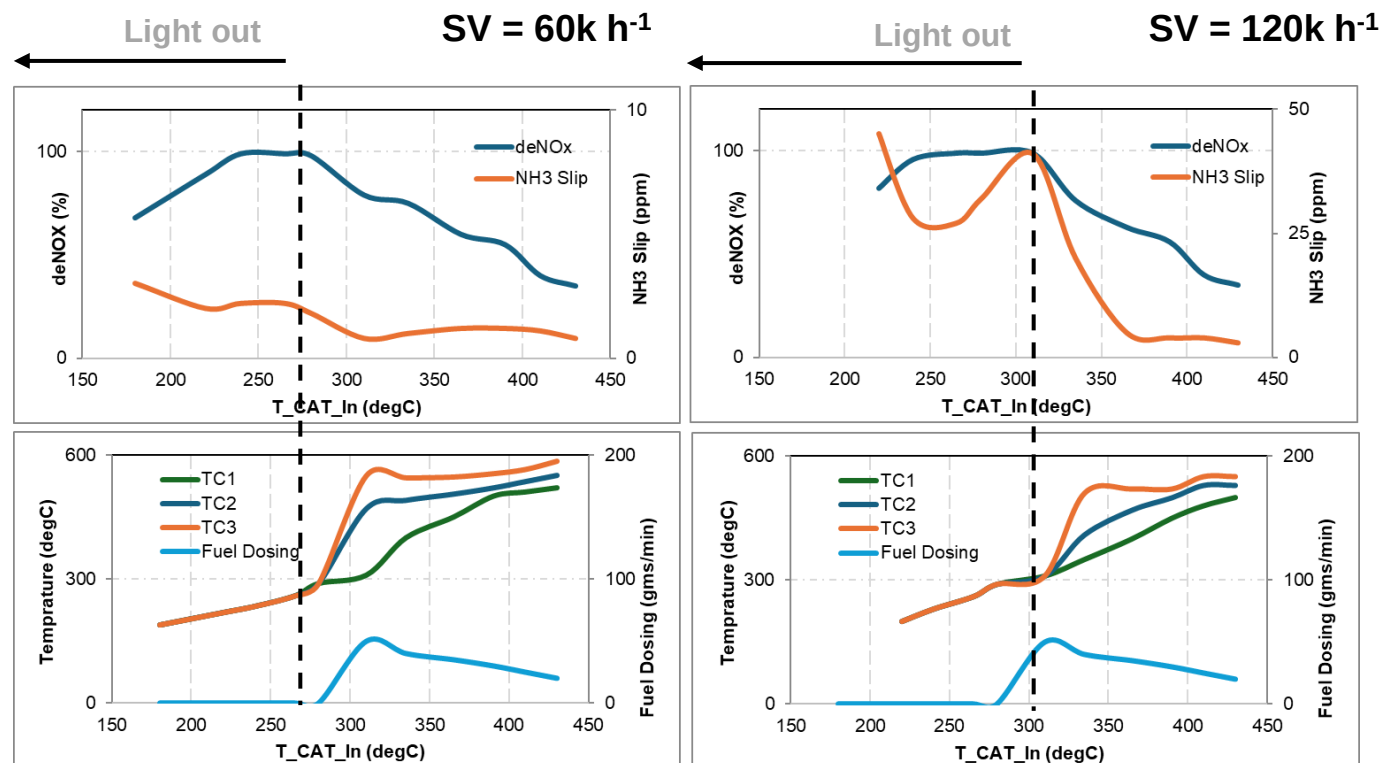
- The Unique design of this Catalyst technology enables furl burn to be carried out.
- As demonstrated in the graph, it can light off to reach upto 550 degC and disulfate itself periodically.
- **With Technology improvements in MY 2023/25 Hybrid catalysts**
 - ▶ HC Light off temperature could be lowed upto ~30 °C at low and High SV) than earlier ones.
 - ▶ The deterioration in HC Light off temperature post HTA aging / Engine ageing is also lower compared to earlier designs.

Essentially this catalyst can regenerate itself for reaching ideal temperatures for carrying out deSOX

SCR performance during HC oxidation (MY 2025) at SV = 60 and 120k h⁻¹



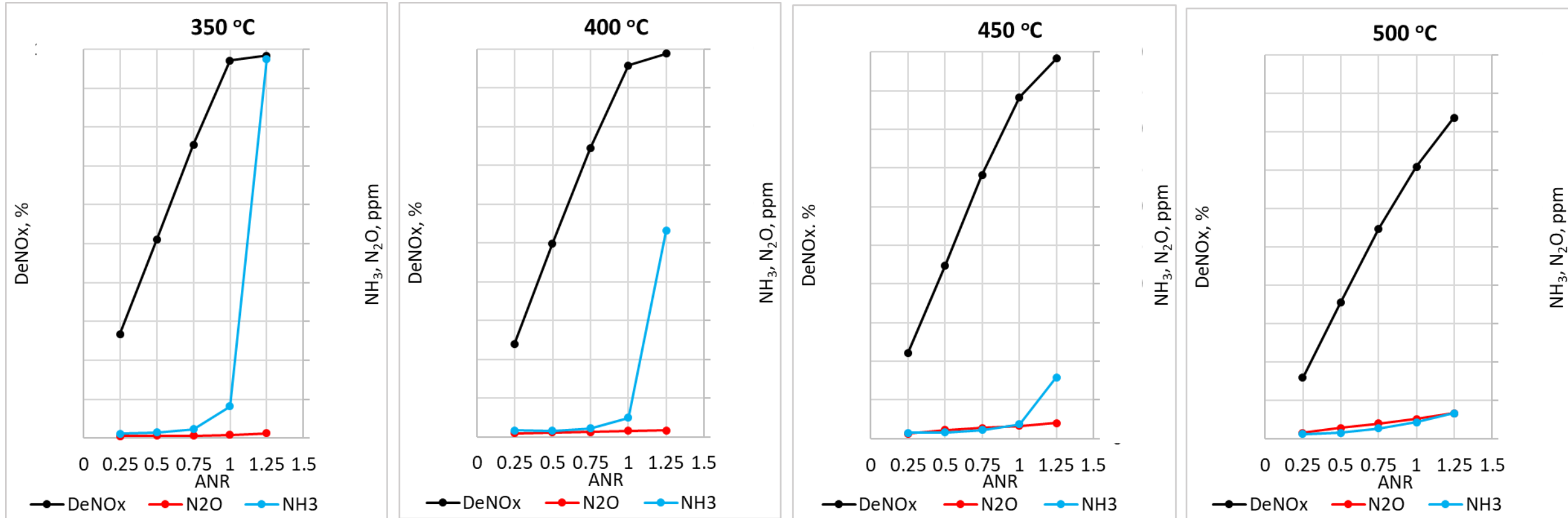
- HC oxidation tests started with $T_{in} = 430^{\circ}\text{C}$ and gradually decreasing to 180°C
- Catalyst front zone lower temperatures (TC₁-3) result in decreased NH₃ oxidation and increased NO_x conversion.
- Injected fuel amount does not seem to affect NO_x conversion.



No hydrocarbon injection below light-out temperature

De-greened Performance (MY 2025)

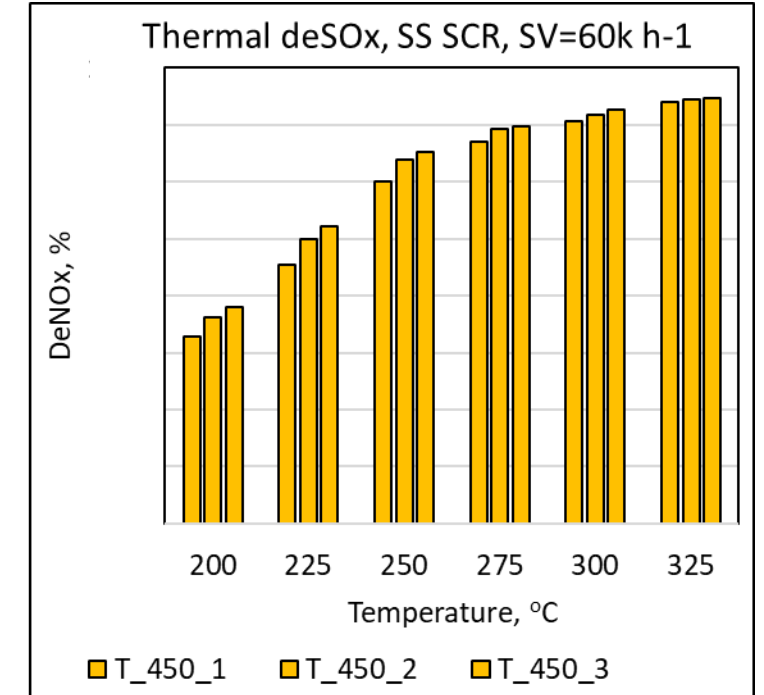
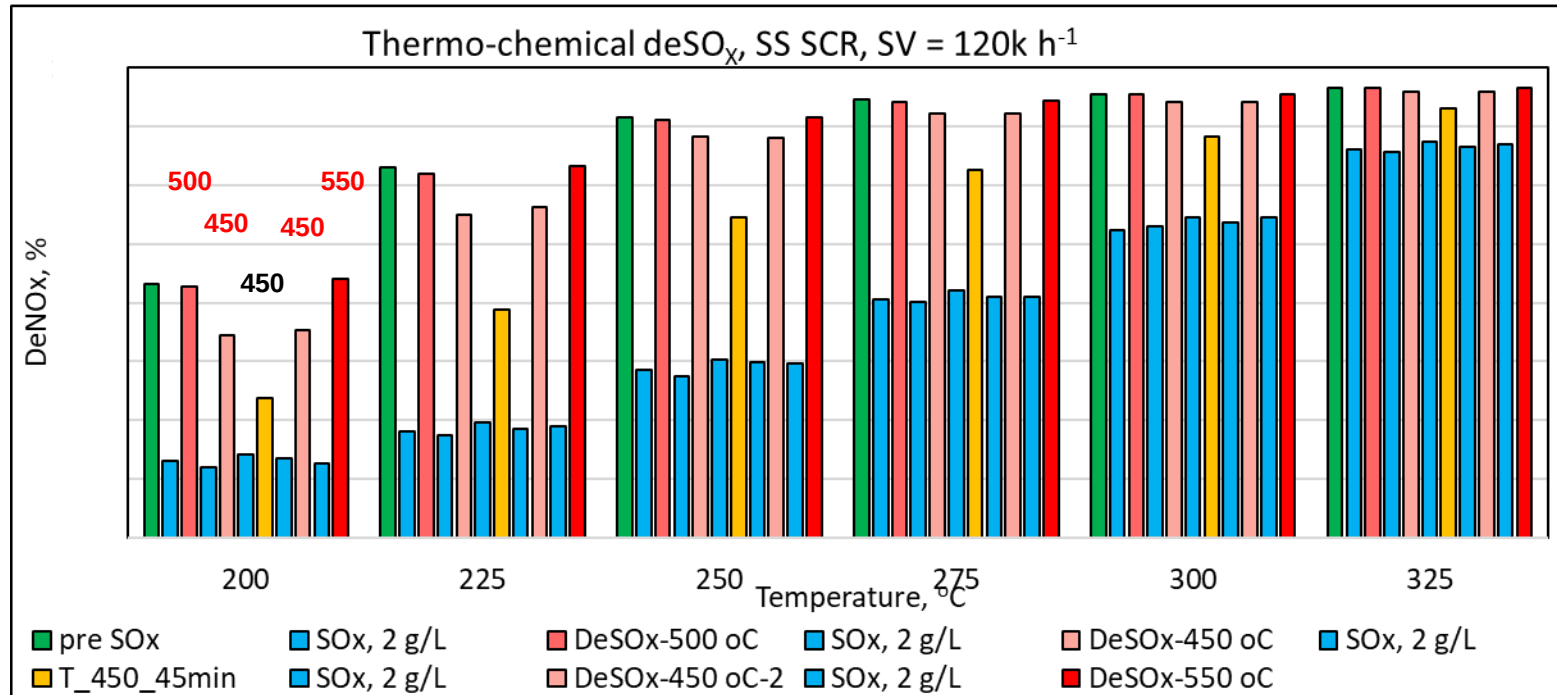
SS test: SV = 120k h⁻¹



- The de-greened MY 2025 Catalyst could demonstrate adequate conversion efficiency at 450 °C at ANR1.0 .
- With onset of NH₃ Oxidation beyond 450 °C with additional urea injection the NOx conversion targets can be met.

SOx-DeSOx Validation for MY 2025 Catalyst

- Sulfation with 150 ppm S fuel: sulfur exposure per cycle = 2 g/L (T = 325 °C)



DeSOx: T_{in} = 375 °C, T_{out}_Target = 550, 500 or 450 °C (15min at target T)

T_{in} = 450 °C, 3 x 15min

No HC Injection

- MY 2025 Catalyst fully regenerates at 550 and 500 °C after 15min HC injection
- Thermo-chemical deSOx at 450 °C is much more effective than thermal deSOx

Summarizing...

- This Catalyst Technology can cater to various on road and off road applications.
- This unique design gives opportunity to optimize the engine calibration for better fuel economy and CO₂ targets.
- ECMS is carrying out extensive development and validation of this Catalyst technology at various global locations on customer specific projects.
- This Technology is completely customizable to meet size, performance and cost targets.



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