Technologies for Meeting Future Heavy-Duty Diesel Emission Standards

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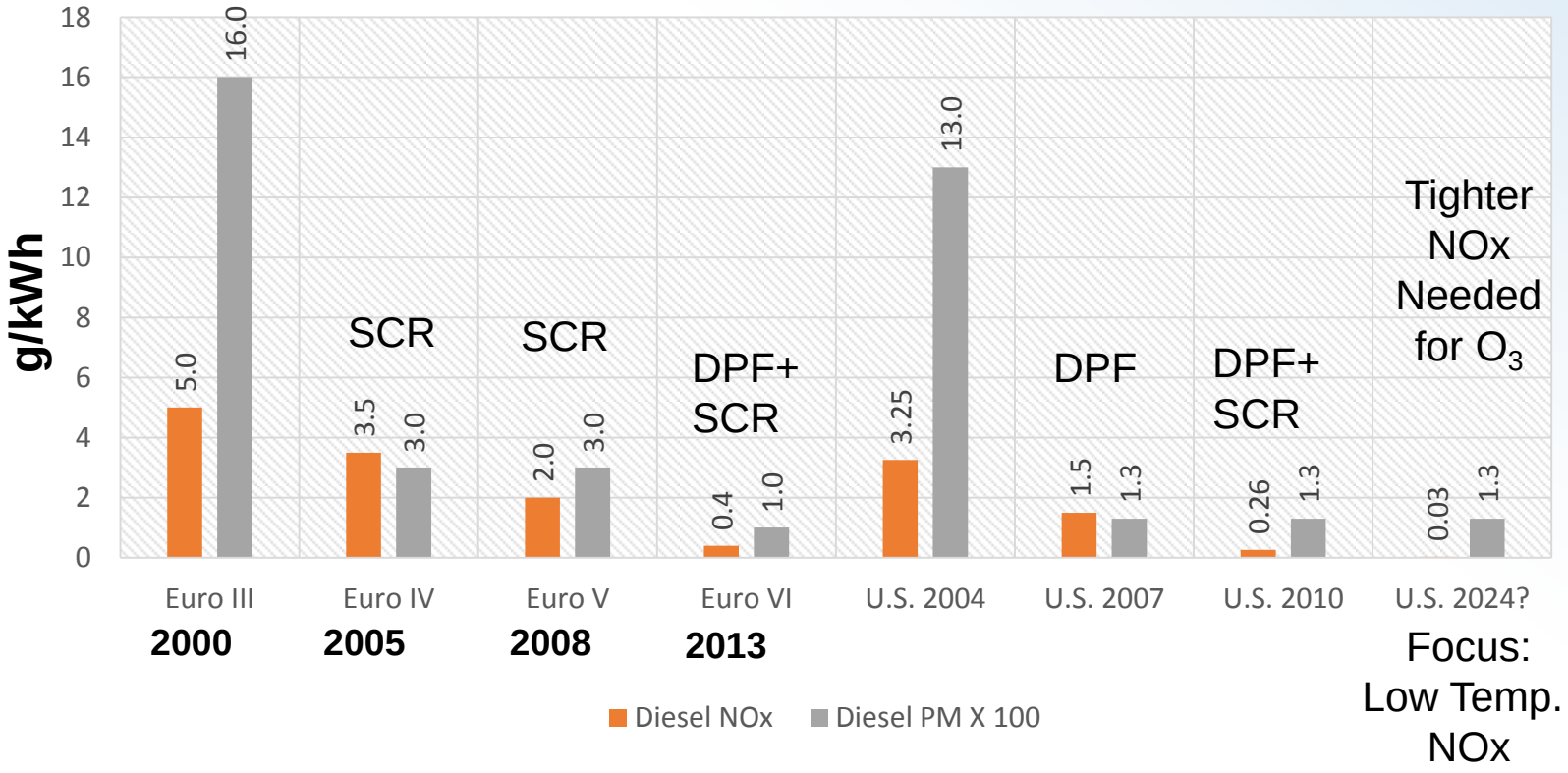
ECT 2017: Enabling Cleaner and Greener India, Progressing Towards BS VI Norms
New Delhi, India
November 2-3, 2017

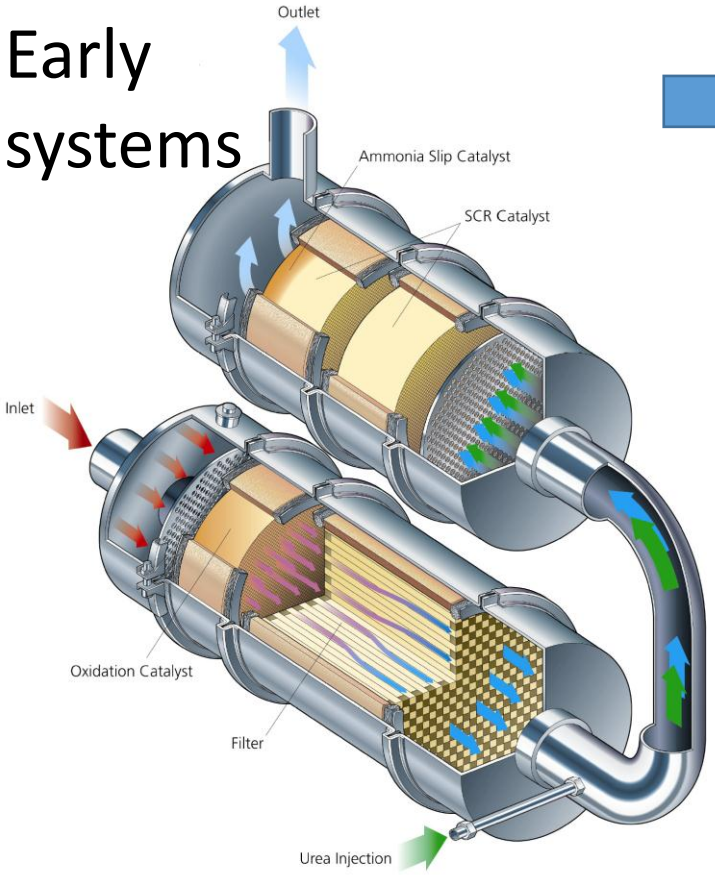
U.S. vs. Europe Heavy-Duty Engine Transient Cycle Emission Standards



Note: Euro VI NOx limit is 0.46 g/kWh on the WHTC
Euro VI includes 6.0 X 10^{11}/kWh particle number limit for diesels on WHTC

Evolution of NOx Control Technology

Early systems



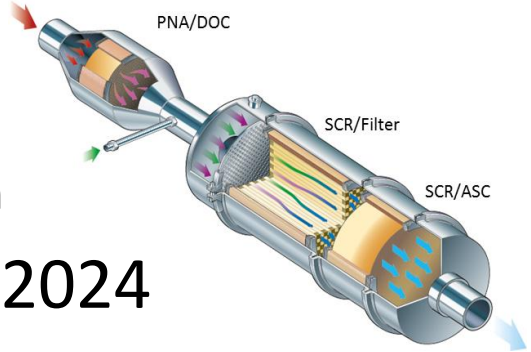
Repackaged

2010

A natural optimization has resulted in 2017 systems being 60% smaller, 40% lighter, and cheaper than 5 years ago.

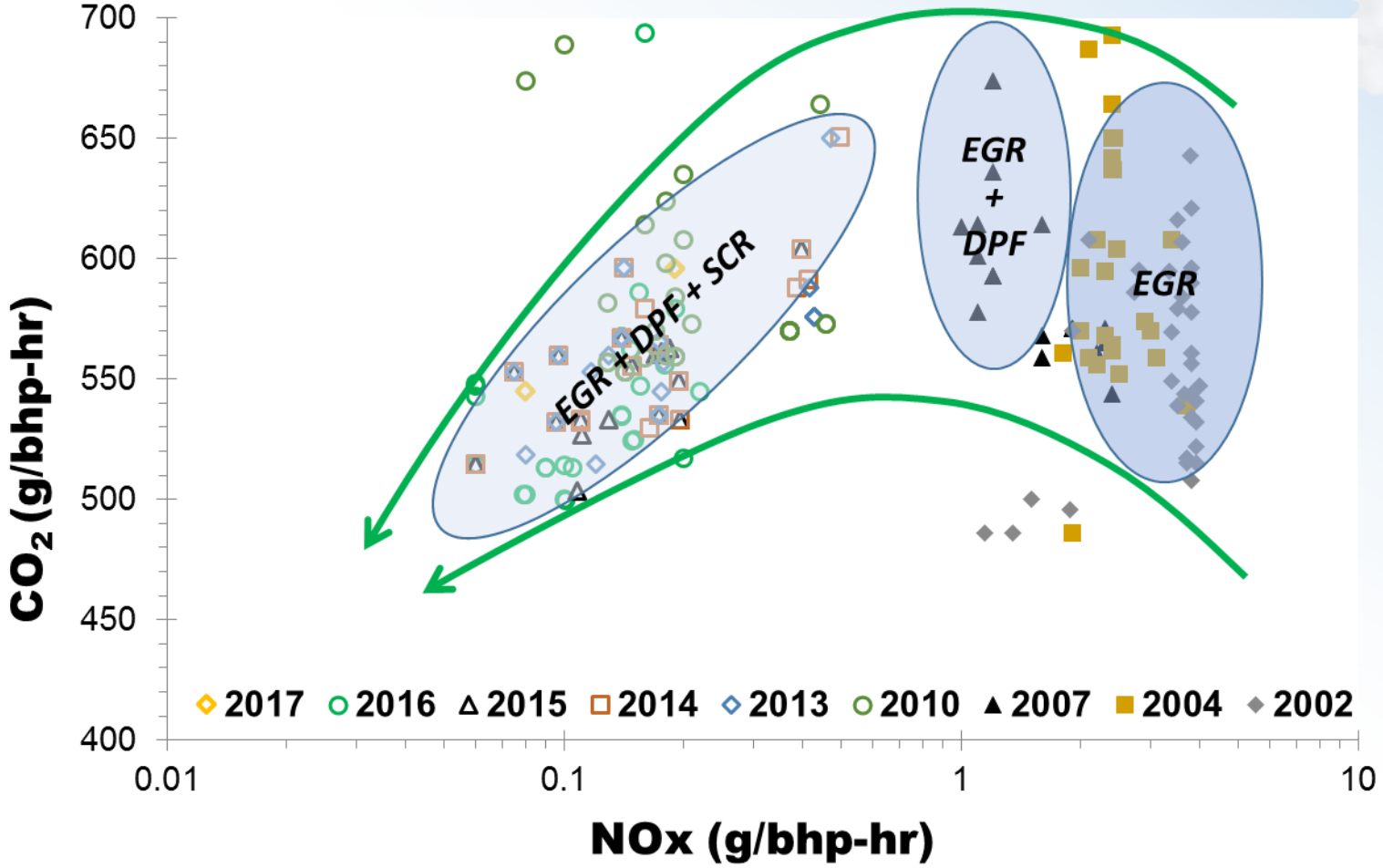
2016

Most of these improvements are already commercialized on light-duty vehicles in Europe.



2024

Simultaneous CO_2 and NOx Reductions Achievable



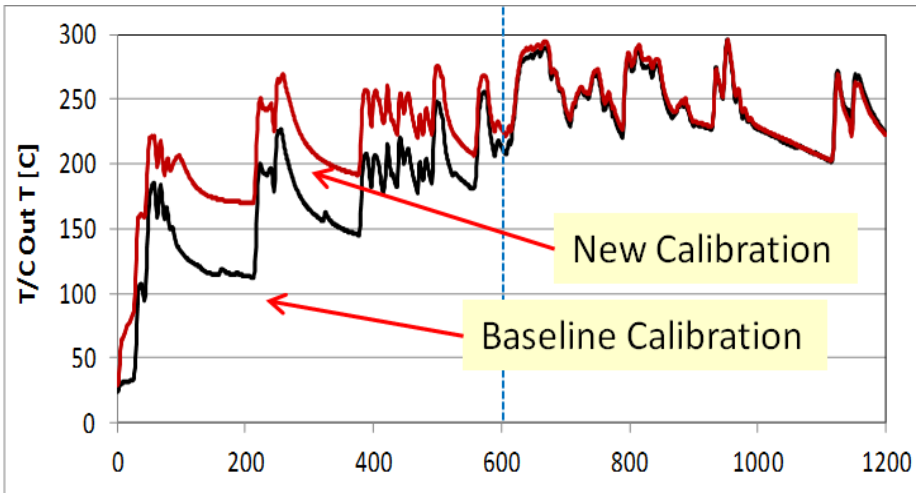
- Aligned regulations are allowing optimization of criteria and GHG technology
- Some 2016 and 2017 engine families are already certified below 0.1 g/bhp-hr, three at 0.06 g/bhp-hr NOx.

CARB and MECA Demonstrating HD Ultra Low NOx Technologies

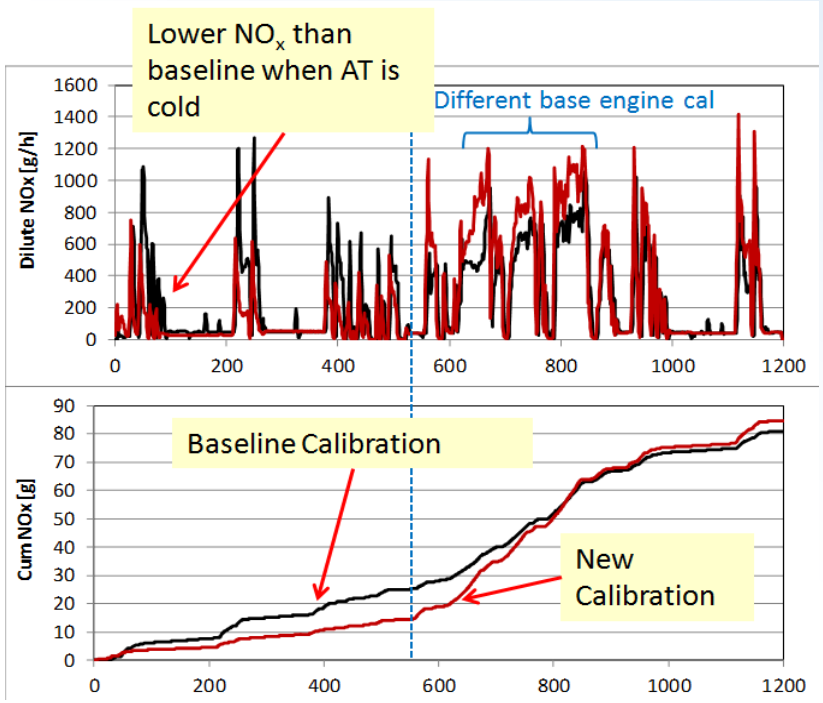
- Program started in 2013 at SwRI with focus on Volvo 2014 MD13TC diesel engine with turbocompounding and Cummins ISX12G CNG engine
- Objective is to demonstrate 90% reduction below current HD NO_X standards
  - 0.02 g/bhp-hr on certification and vocational cycles
- Fully aged, production ready technology
- Solution must be consistent with path toward meeting future GHG standards
  - CO_2, CH_4, N_2O

Calibration to Address Cold Start and Low Speed Operation

- Cold start engine calibration modified to reduce cold start engine out NOx and fast heat-up of catalyst.
- During hot operation return to original calibration to maintain fuel economy and GHG



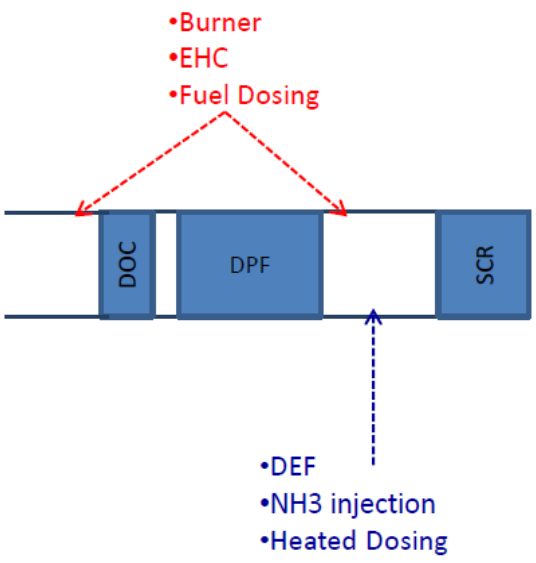
Increased Temperatures



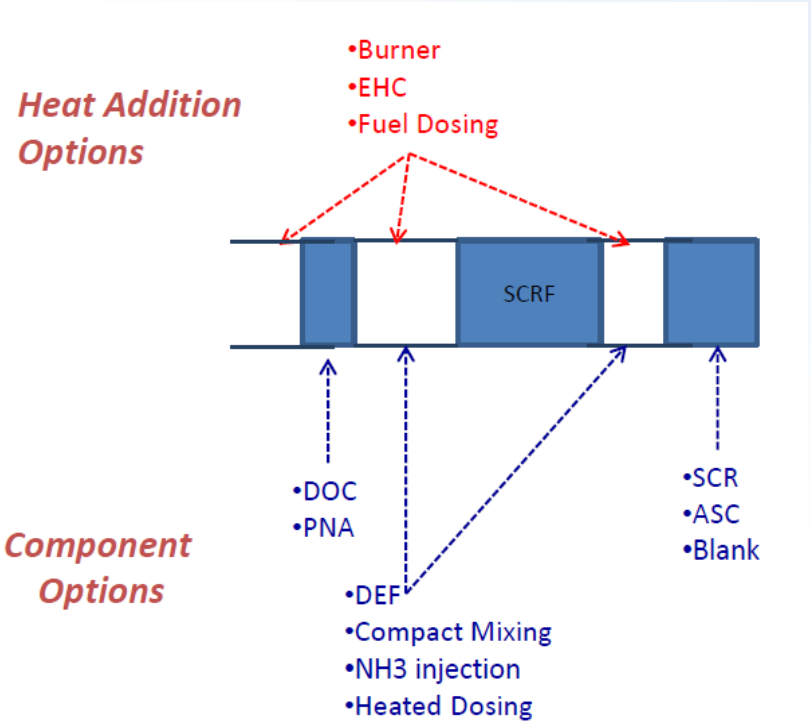
Decreased Engine Out NO_X

Diesel Aftertreatment Technology Options

Traditional Approach

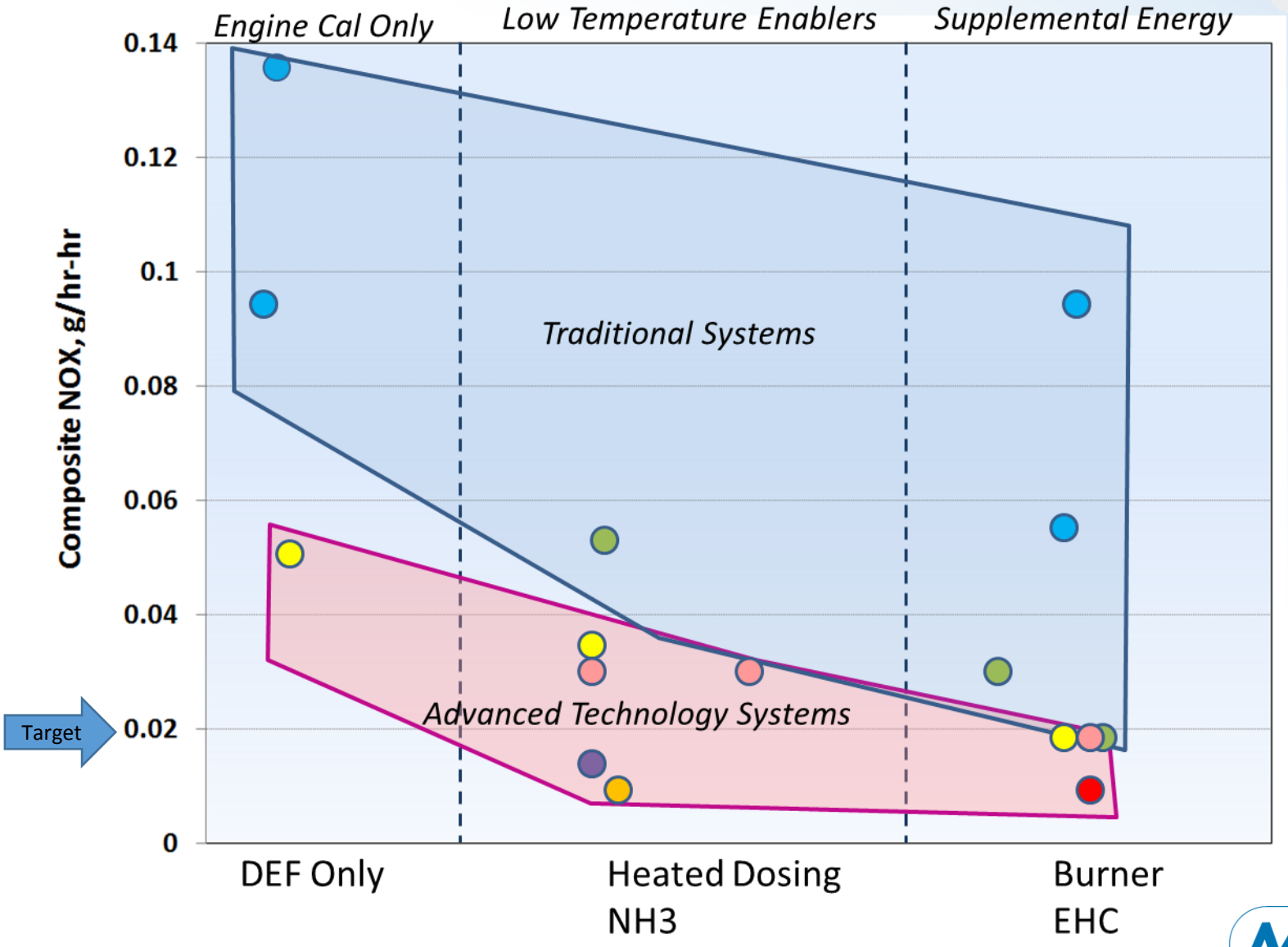


Advanced Approach

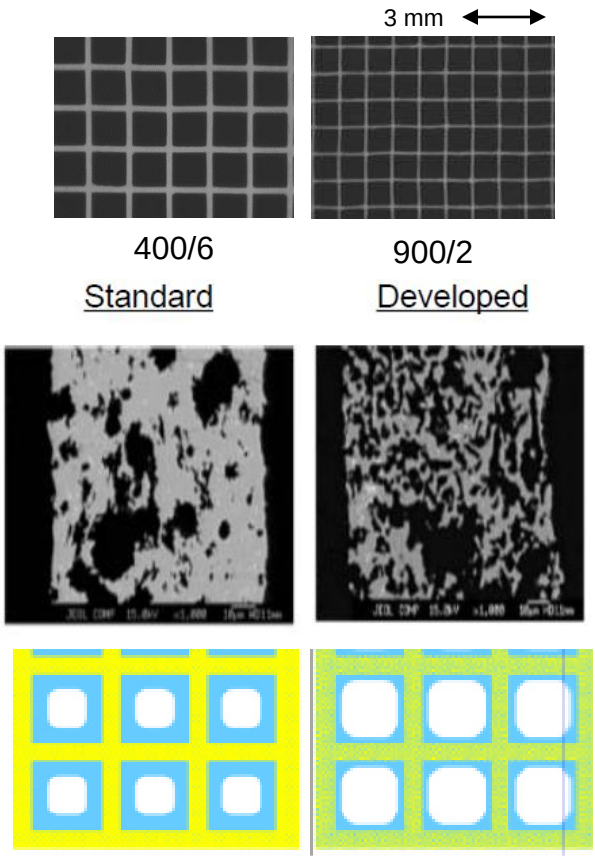


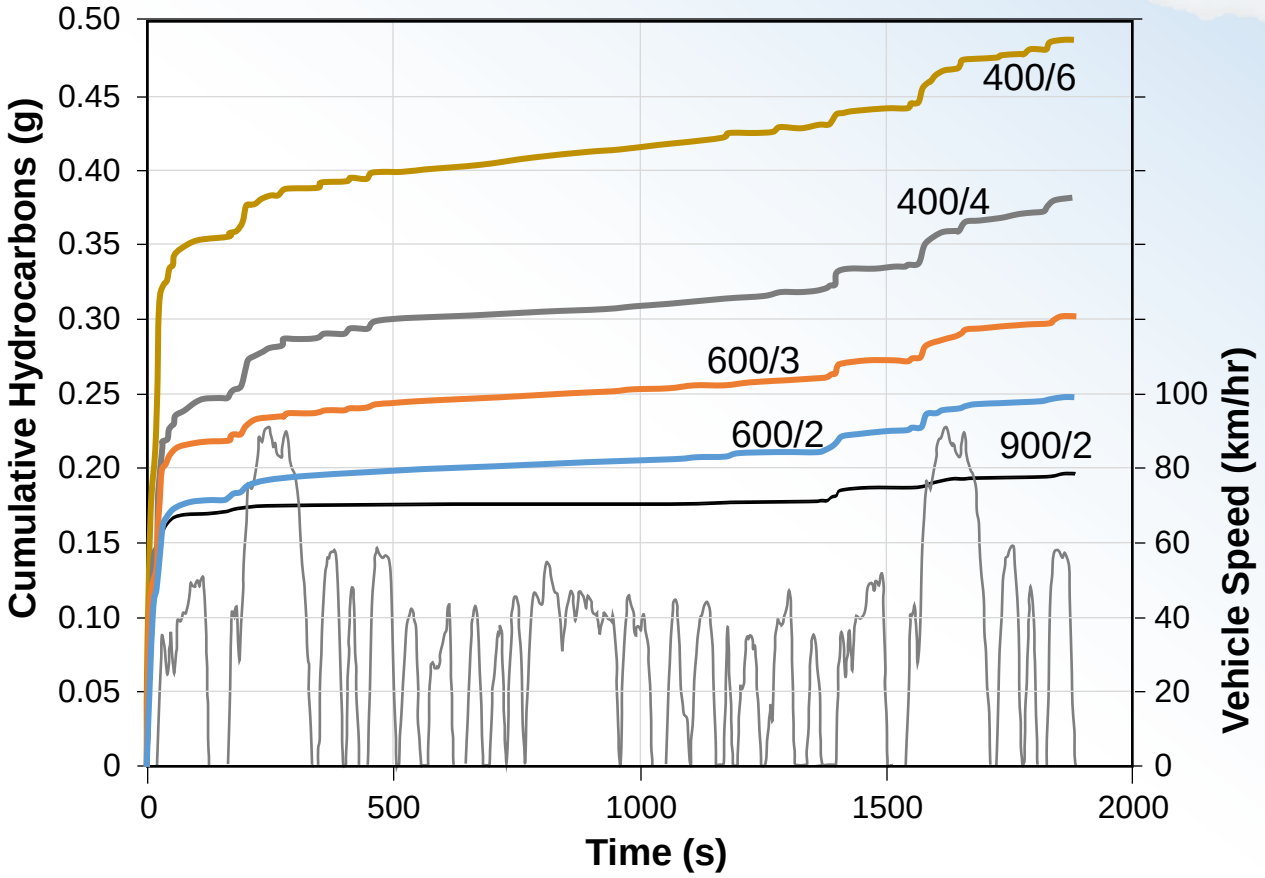
Examined 33 out of 500 possible configurations of component and heat addition options

Multiple potential pathways to achieve NO_X emissions below 0.02 g/bhp-hr



Next Generation Substrates Reduce Backpressure and Fuel Consumption

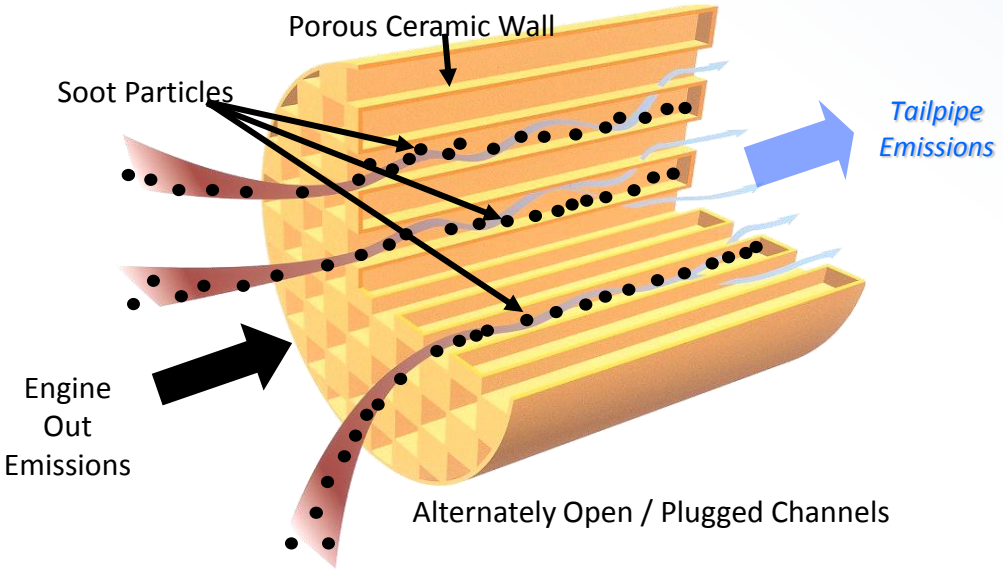


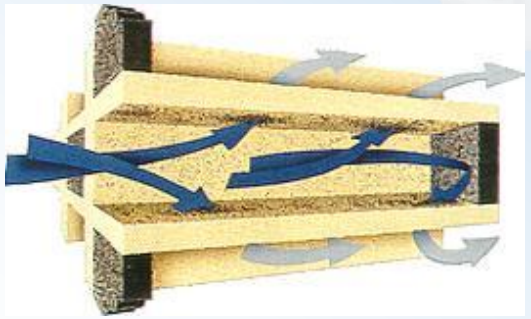


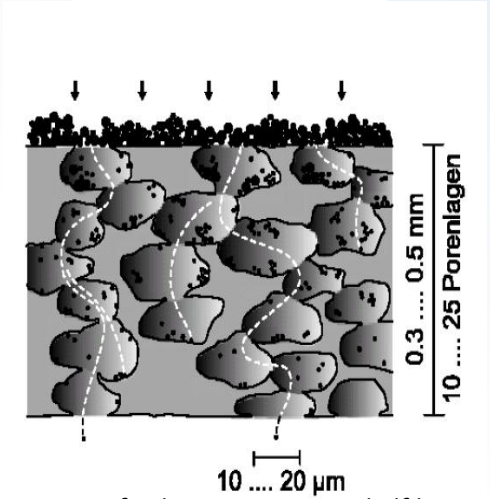
- Higher cell density and geometric surface area for better conversion
- Reduced back pressure with thinner, porous walls
- Higher catalyst loading in porous substrates

SAE 2015-01-1009

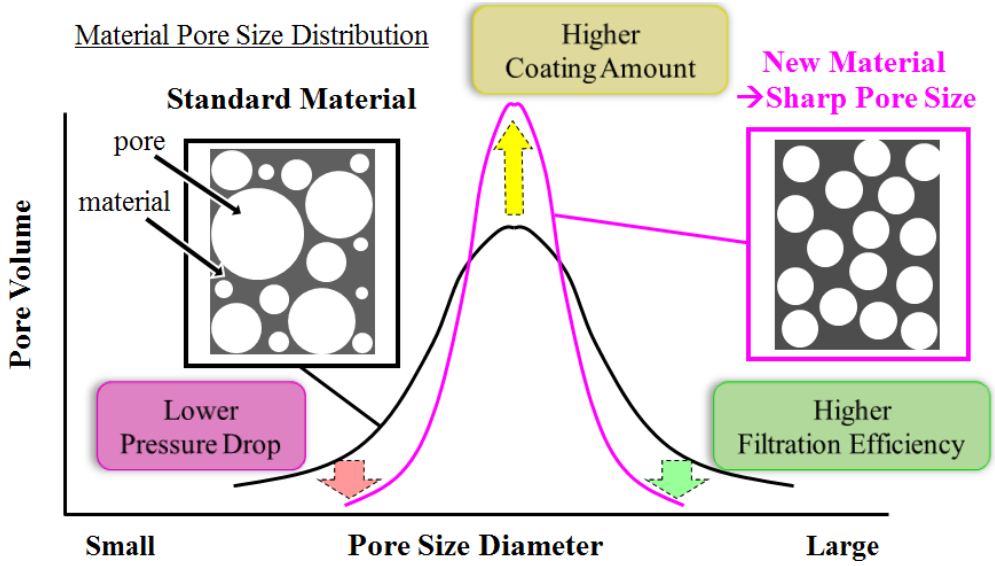
New Substrates for SCR Coated Filters





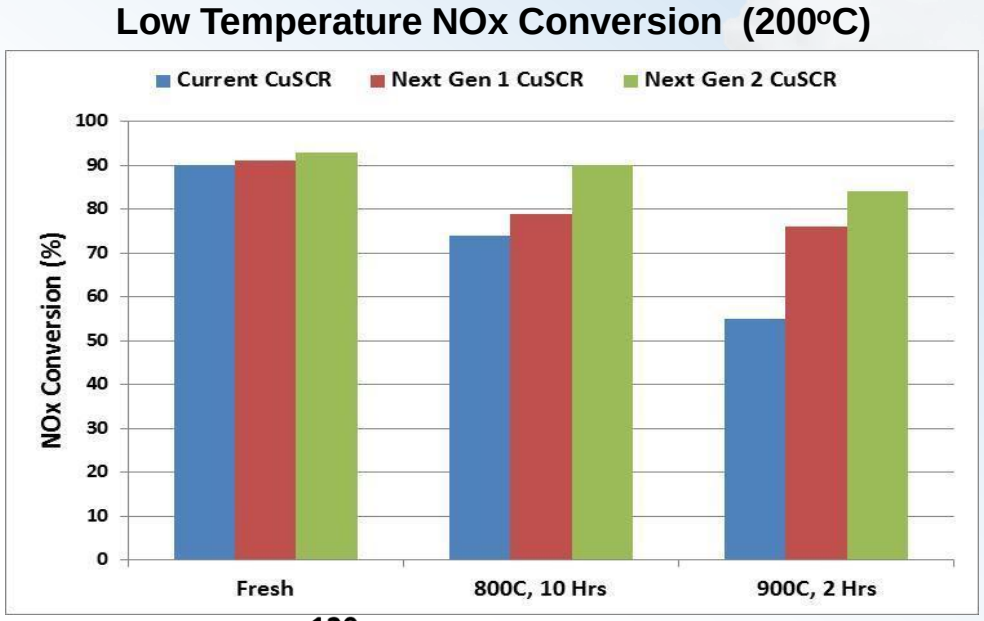


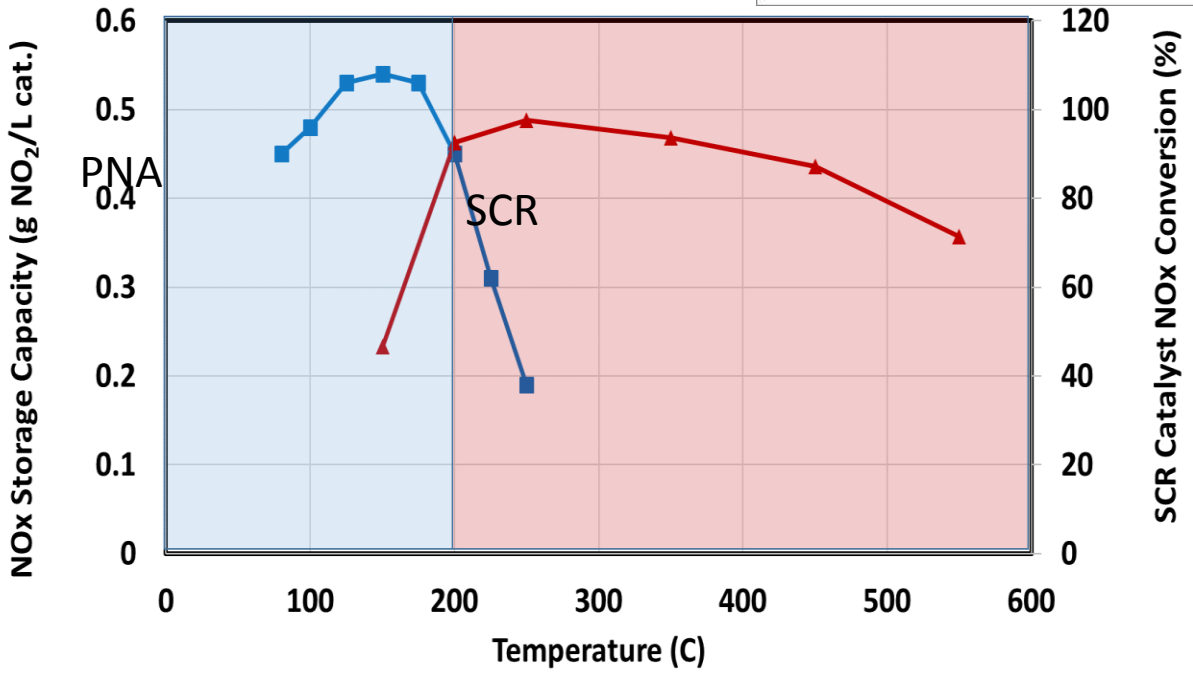
Source : Anforderungen an Partikelfiltersysteme für Dieselmotoren, A.Mayer, TTM



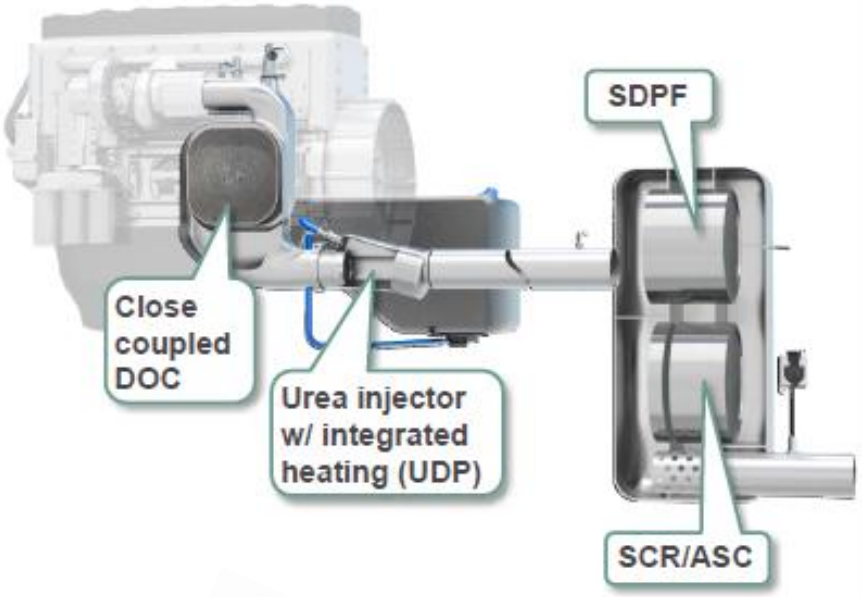
Catalyst Development focused on Low Temperatures

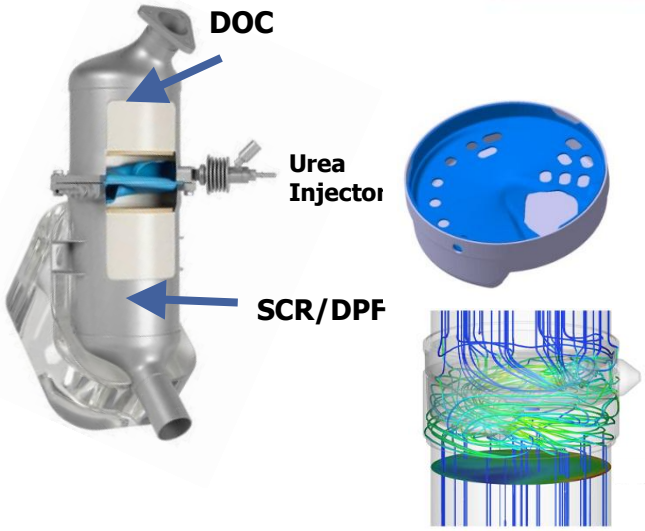
- Passive NOx Adsorbers (PNA) can replace traditional DOC and combine NOx trap, HC trap and DOC into single device
- Thermal durability and sulfur tolerance being improved
- Optimization of PNA NOx desorption and SCR conversion window

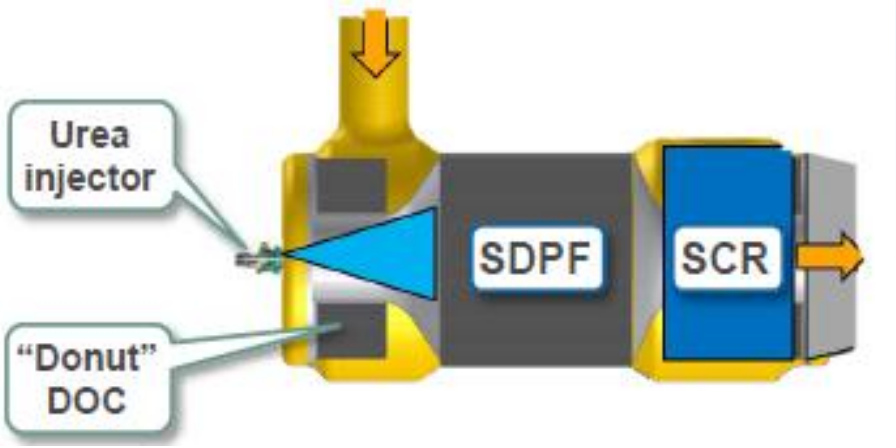




Improved Packaging Increases Low Temperature Performance

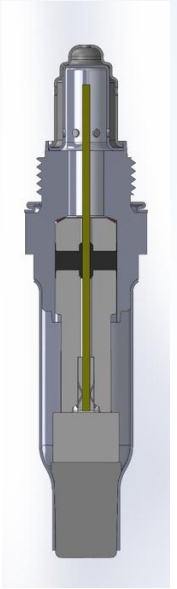






OBD Sensor Manufacturers Addressing Issues

- Particle mass and number sensor variability and accuracy improving near OBD threshold
- Gas sensor development continues with efforts to enable lower emission standards
- New sensor technologies for measuring SCR system functions



Summary

- Euro VI and U.S. 2010 emission control strategies have continued to evolve through innovation by OEMs and suppliers on engines, catalysts, substrates and packaging
- Next generation Low-NOx technologies are already being demonstrated on diesel passenger cars and nonroad engines in Europe
- Real world compliance requires careful calibration of engine for low temperature operation and urea dosing strategies.
- Sensor development is addressing future OBD needs
- Opportunity exists for significant reductions in the off-road diesel sector