Technologies for Meeting Future Heavy-Duty Diesel Emission Standards

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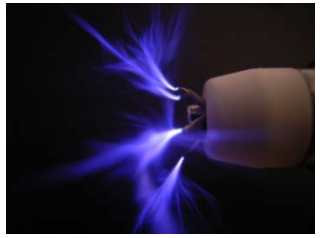
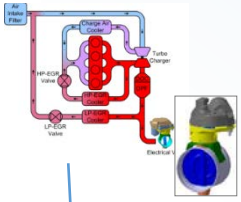
MECA Technologies Control Criteria and GHG Emission

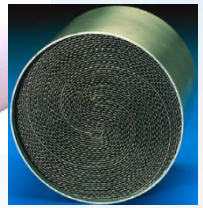
Fuel Combustion Controls



Air Handling

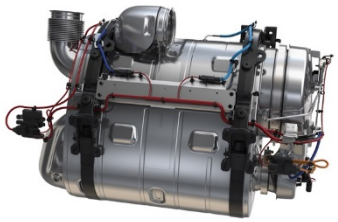


Filters & Substrates

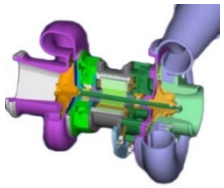


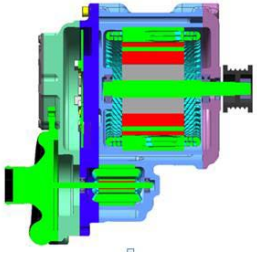
Evaporative Controls

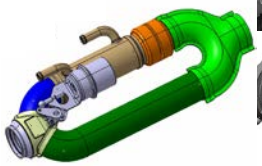
Exhaust System Integration

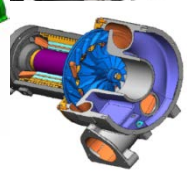


Powertrain Electrification

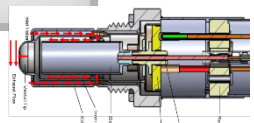








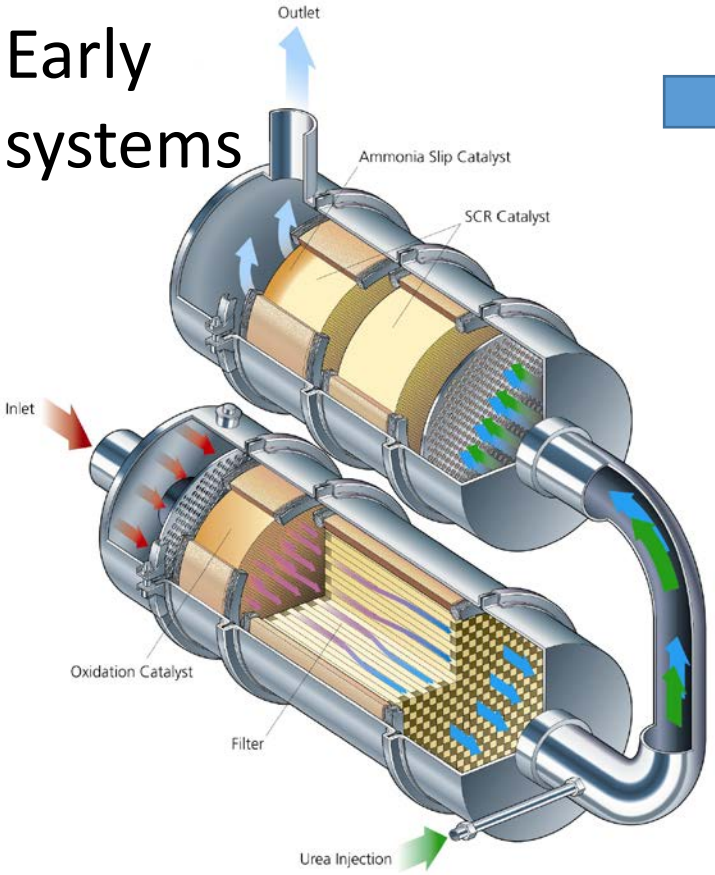
Waste Heat Recovery



OBD Sensors

Evolution of NOx Control Technology

Early systems



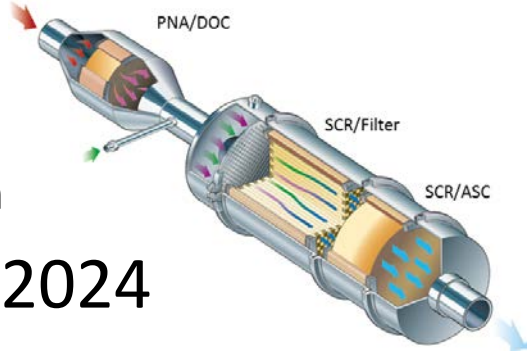
Repackaged

2010

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

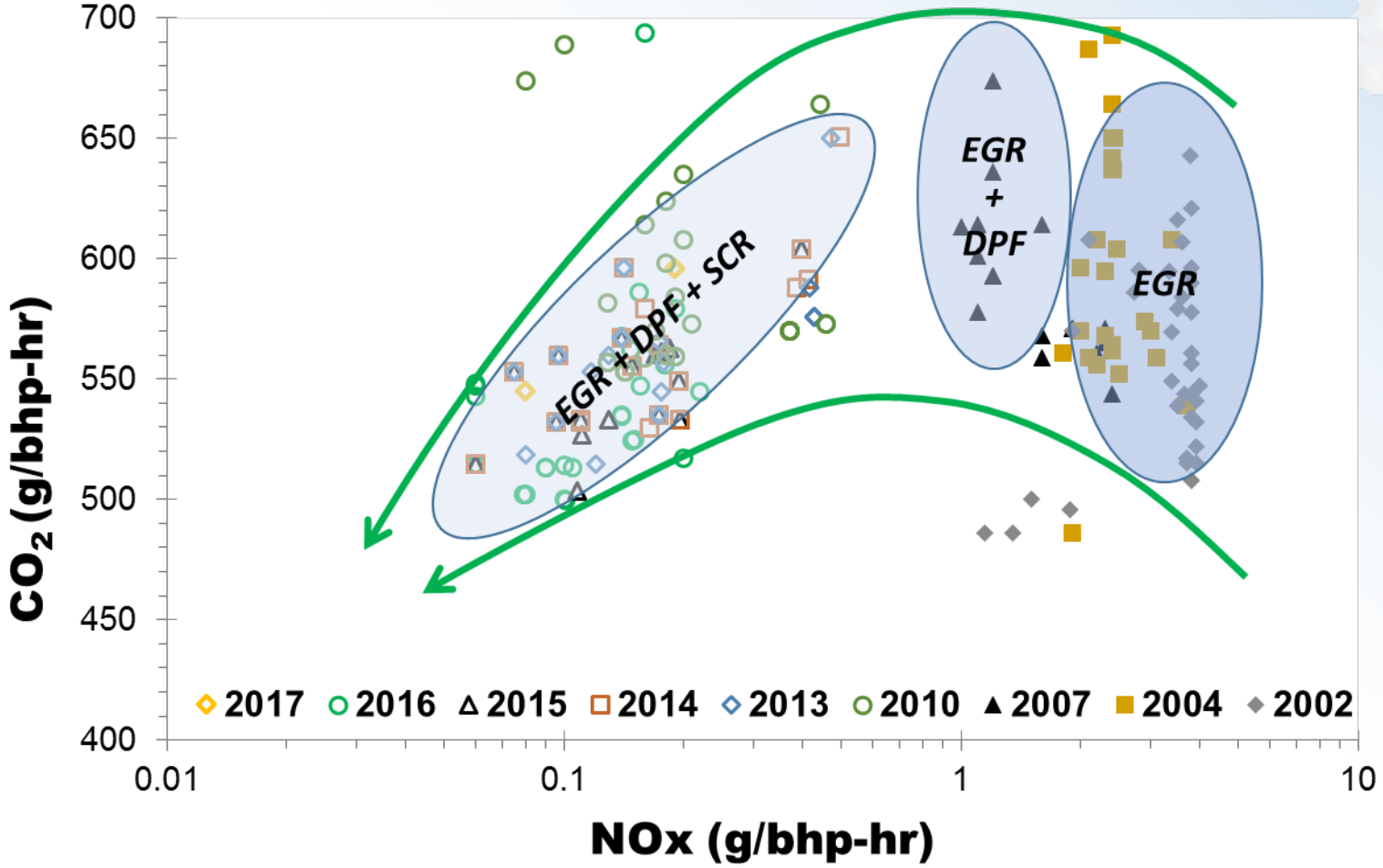
2016

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



2024

Simultaneous CO_2 and NOx Reductions Achievable



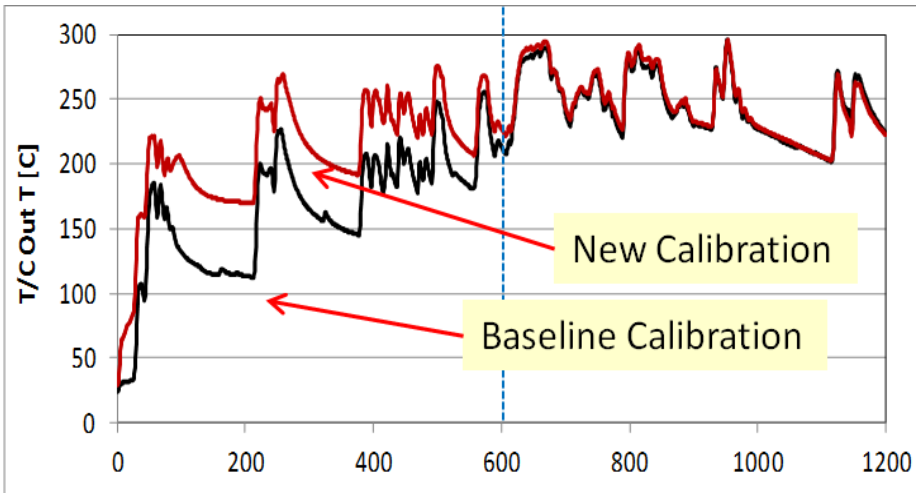
- Aligned regulations are allowing optimization of criteria and GHG technology
- Some 2016 and 2017 engine families are already certified below 0.1 g/bhp-hr, three at 0.06 g/bhp-hr NOx.

ARB HD Low NOx Program Objectives

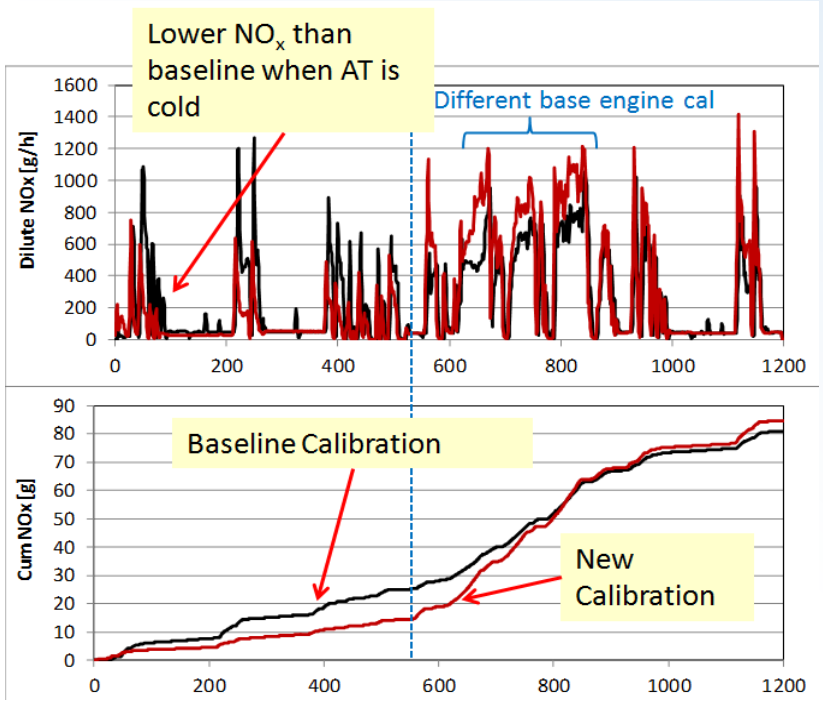
- Program started in 2013 at SwRI, directed and funded by ARB and MECA with focus on diesel and CNG engines
- MECA provided emission control strategies and funding for technology screening and full system engine aging
- Objective is to demonstrate 90% reduction below current HD NO_X standards
  - 0.02 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 on Advanced Diesel Engine

- Volvo 2014 diesel engine with cooled EGR, DPF and SCR stock engine achieved 0.14 g/bhp NOx and 2017 GHG standards via turbo compounded waste heat recovery.
- Cold start engine calibration modified to reduce cold start NOx and fast heat-up of catalyst.
- During hot operation return to original calibration to maintain fuel economy and GHG



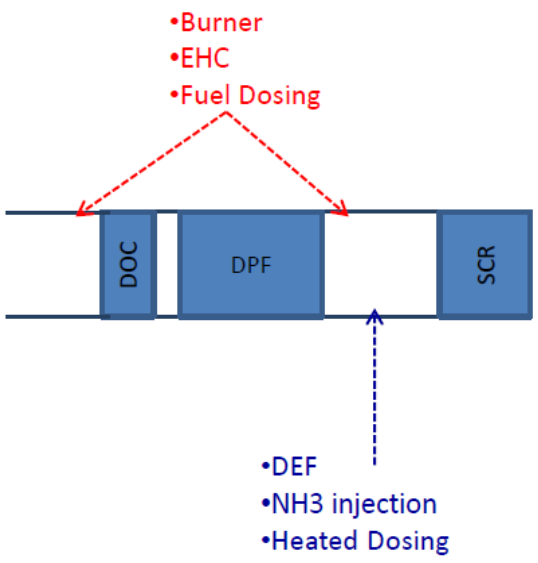
Increased Temperatures



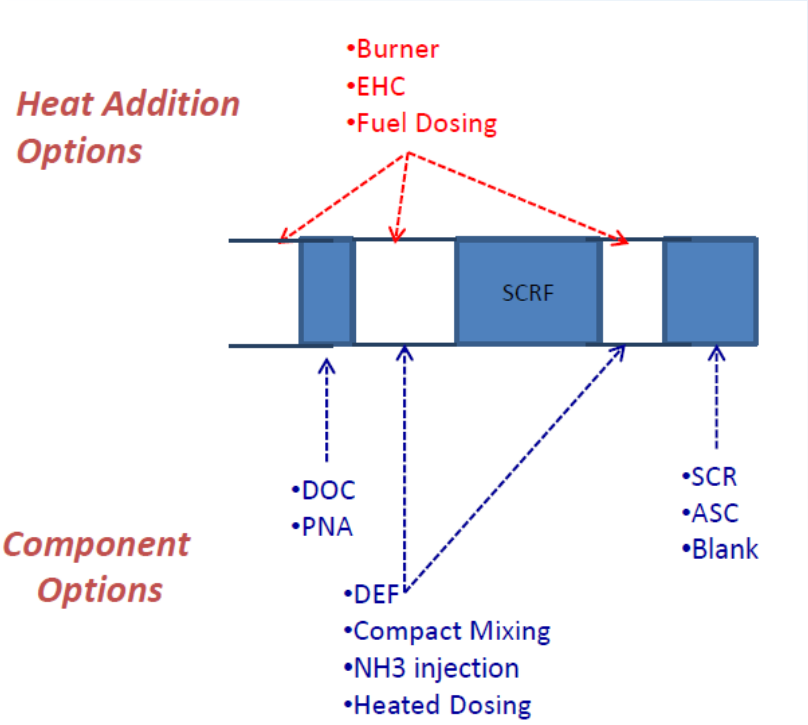
Decreased Engine Out NO_X

Diesel Aftertreatment Technology Options

Traditional Approach

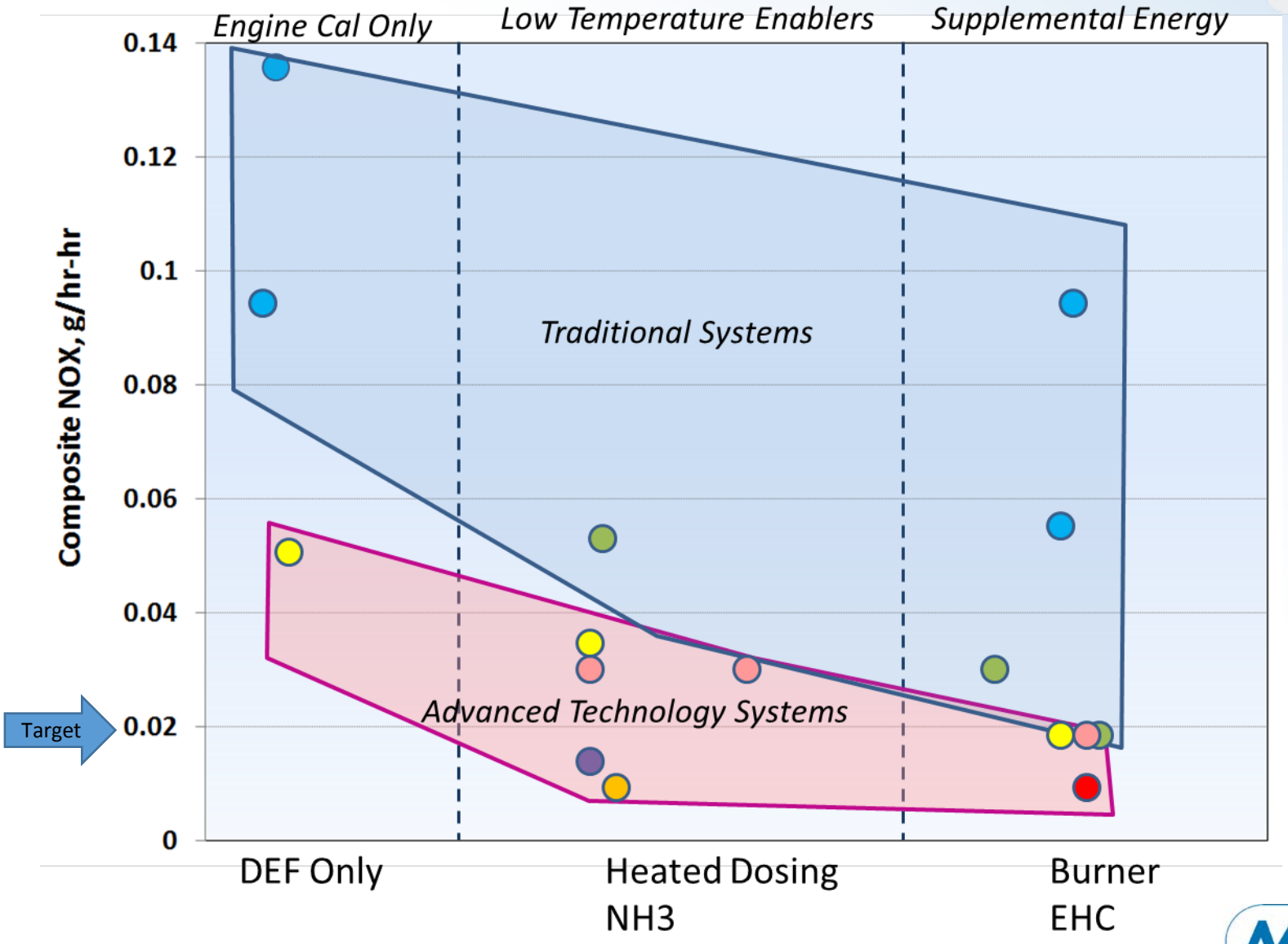


Advanced Approach



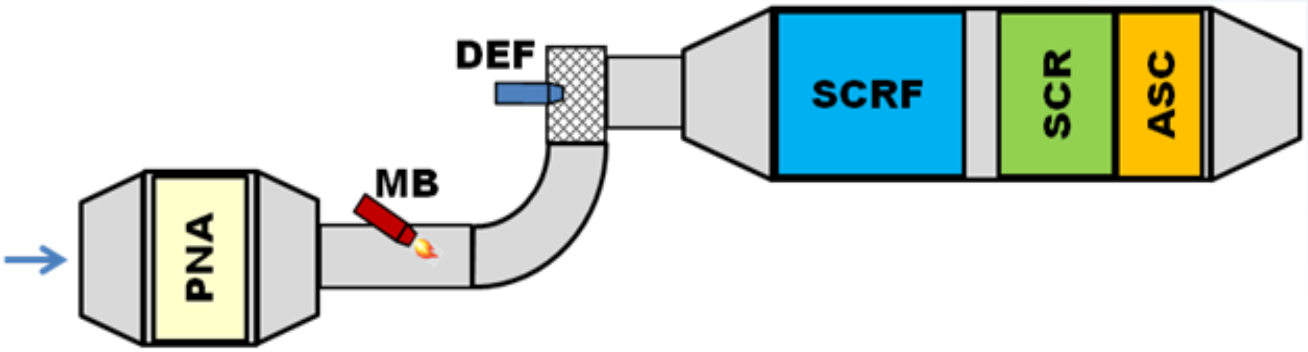
Examined 33 out of 500 possible configurations of component and heat addition options

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



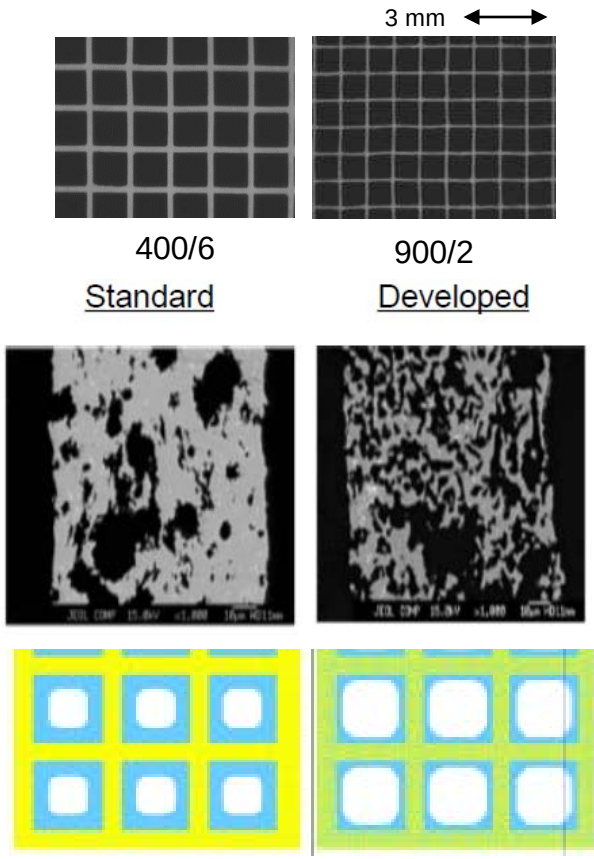
Final Low NO_X Configuration

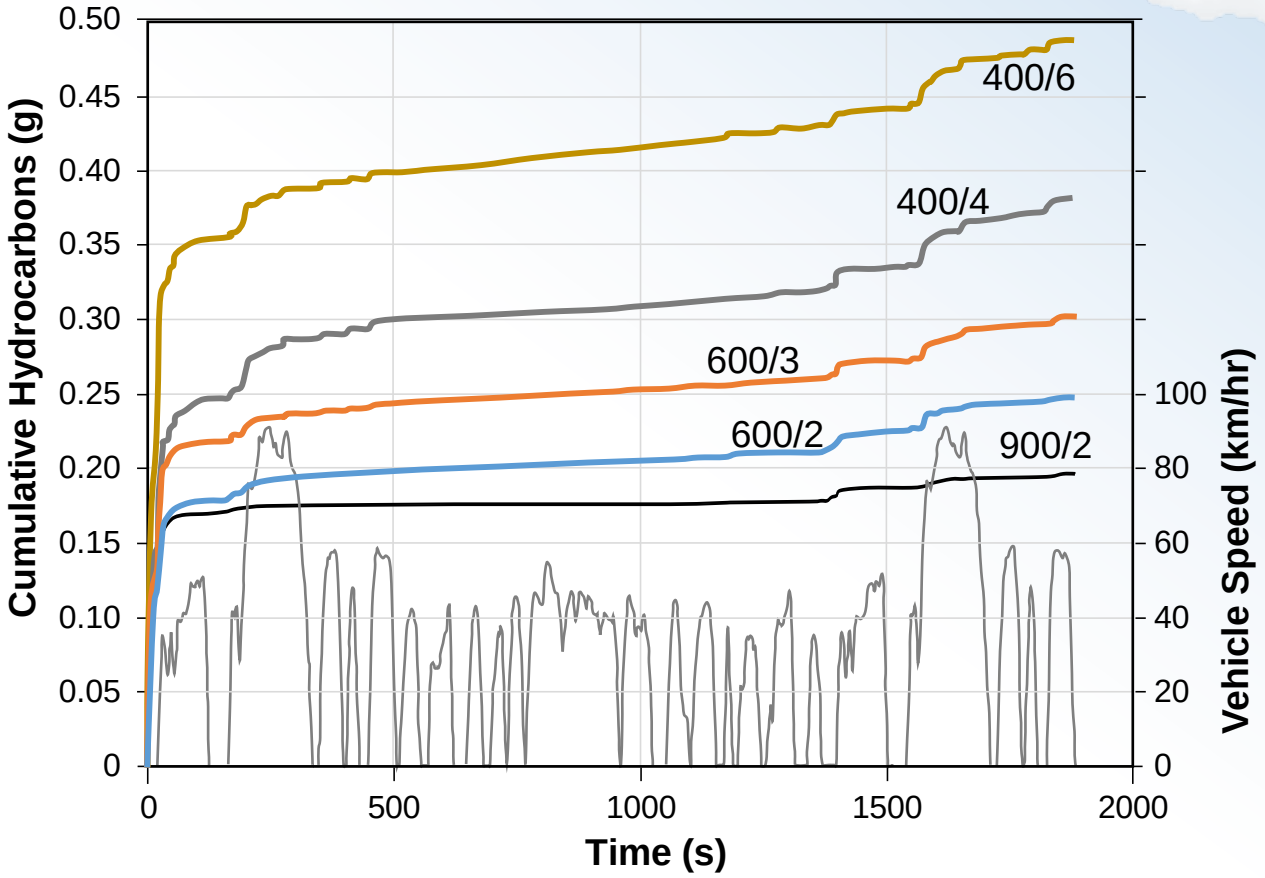
- Final system selection considered performance, cost and complexity feedback from technical advisory committee including suppliers and engine manufacturers.
- Particular waste heat recovery cooled the exhaust and required burner for auxiliary heat
- Future testing will include 2017 engine without waste heat recovery



NO_X Levels with Development Aged Parts, g/hp-hr				
	Cold-FTP	**Hot-FTP**	**Composite**	**RMC-SET**
Engine-Out	2.8	3.0	**3.0**	**2.1**
Tailpipe	0.06	0.008	**0.012**	**0.015**

Next Generation Substrates Reduce Backpressure and Fuel Consumption

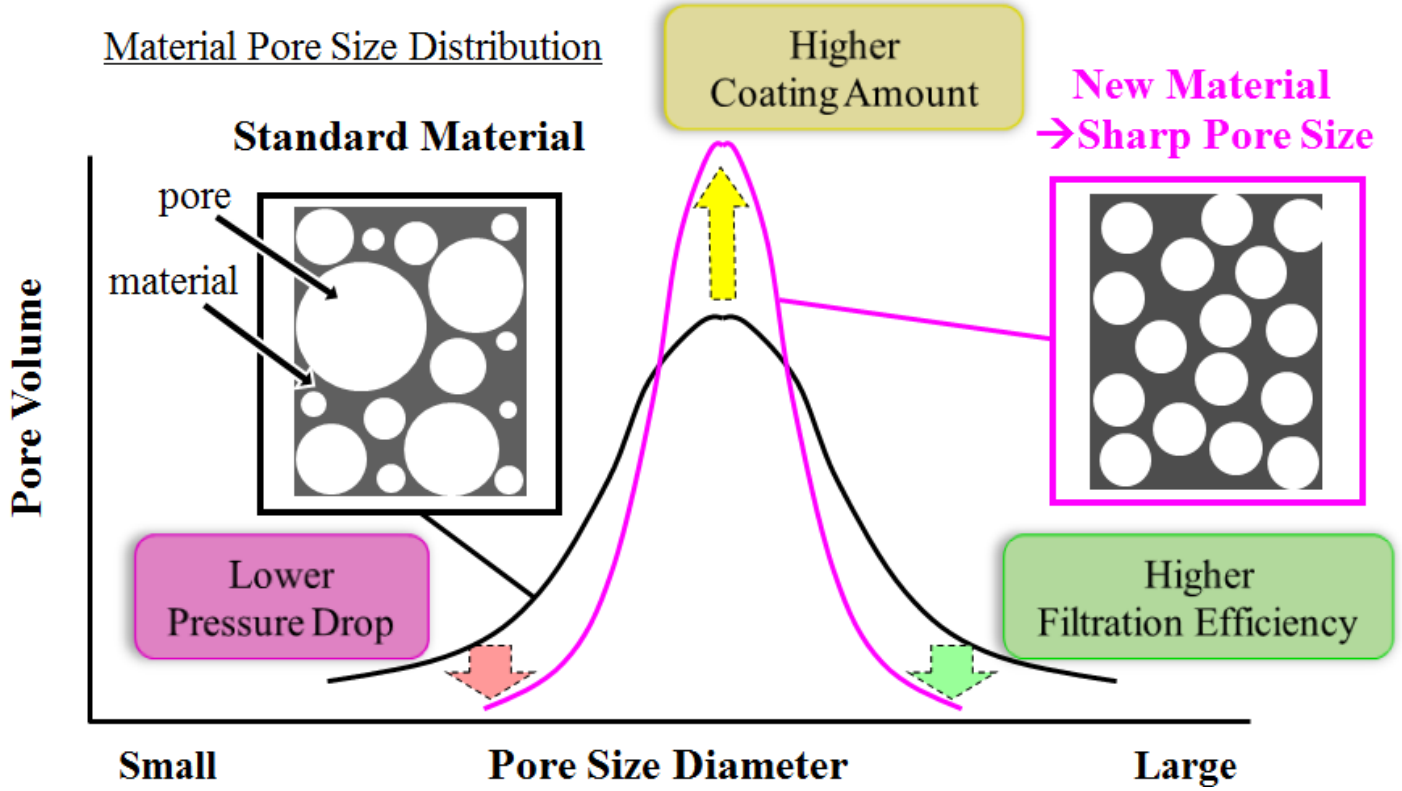




- Higher cell density and geometric surface area for better conversion
- Reduced back pressure with thinner, porous walls
- Higher catalyst loading in porous substrates

SAE 2015-01-1009

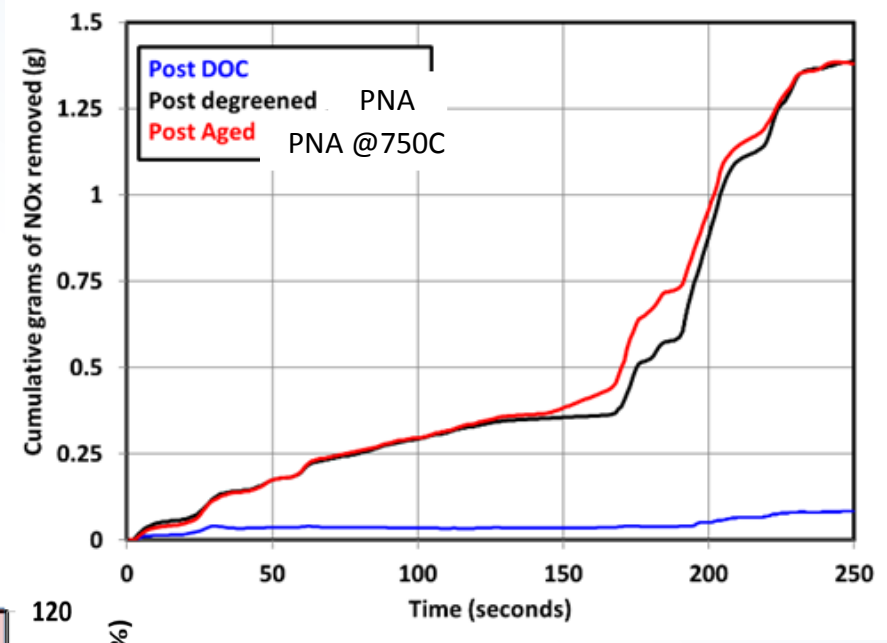
New Substrates for SCR Coated Filters

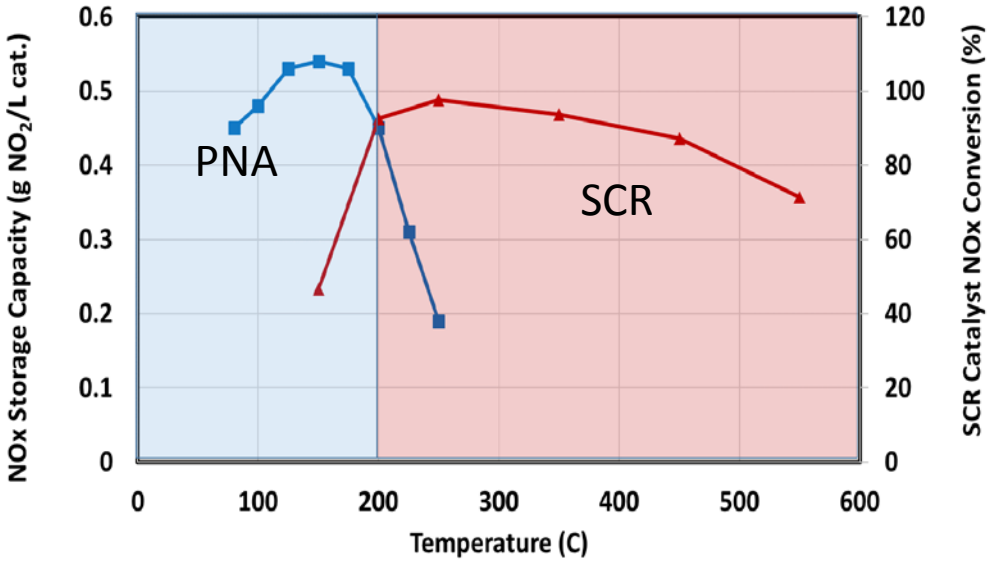


- High porosity (~65%) allows for higher catalyst loading at reduced pressure drop
- Sharper pore size distribution to optimize filtration and catalyst coating
  - Decrease small pores for lower pressure drop
  - Decrease large pores for better filtration
- Substrates can be downsized by 50% in volume

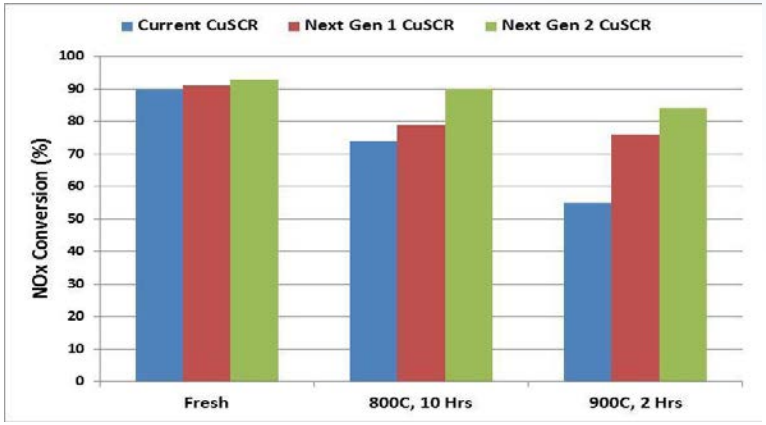
PNA Catalyst Development focused on Low Temperatures

- 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 desorption and SCR conversion window





Low Temperature NOx Conversion (200°C)



Next Steps

- Stage 2 – Vocational Low Load NO_X Demonstration on same engine and exhaust control technology from Stage 1 (mid-2018)
  - Develop Low Load duty cycle profiles from vehicle data
  - Develop low load calibrations/approaches for the Stage 1 engine

- Stage 3 – Low NO_X Development and Demonstration on a non-turbocompound engine (end of 2018)
  - Engine platform more representative of mainstream approach to GHG regulations
  - Combination of both regulatory and low-load cycles