US Tier 2 Bin 2 Diesel Research Progress

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Light Duty Diesel technology will continue to improve and meet long term emissions and fuel economy demands

- Tier 2 Bin 2 requires major advances in Diesel engine NMOG and NOx control. These challenges are driving innovation

- Highly Pre-mixed Cool Combustion (HPCC) enabled by air system technology can achieve 85-90% NOx reduction relative to Euro4
  - NMOG, transient combustion noise, robustness and durability issues are being targeted in an integrated approach

- The optimum balance between engine and aftertreatment technology is being investigated to maximise fuel economy

- Low NOx combustion technology will be fundamental to global Diesel product strategies and CO_2 reduction

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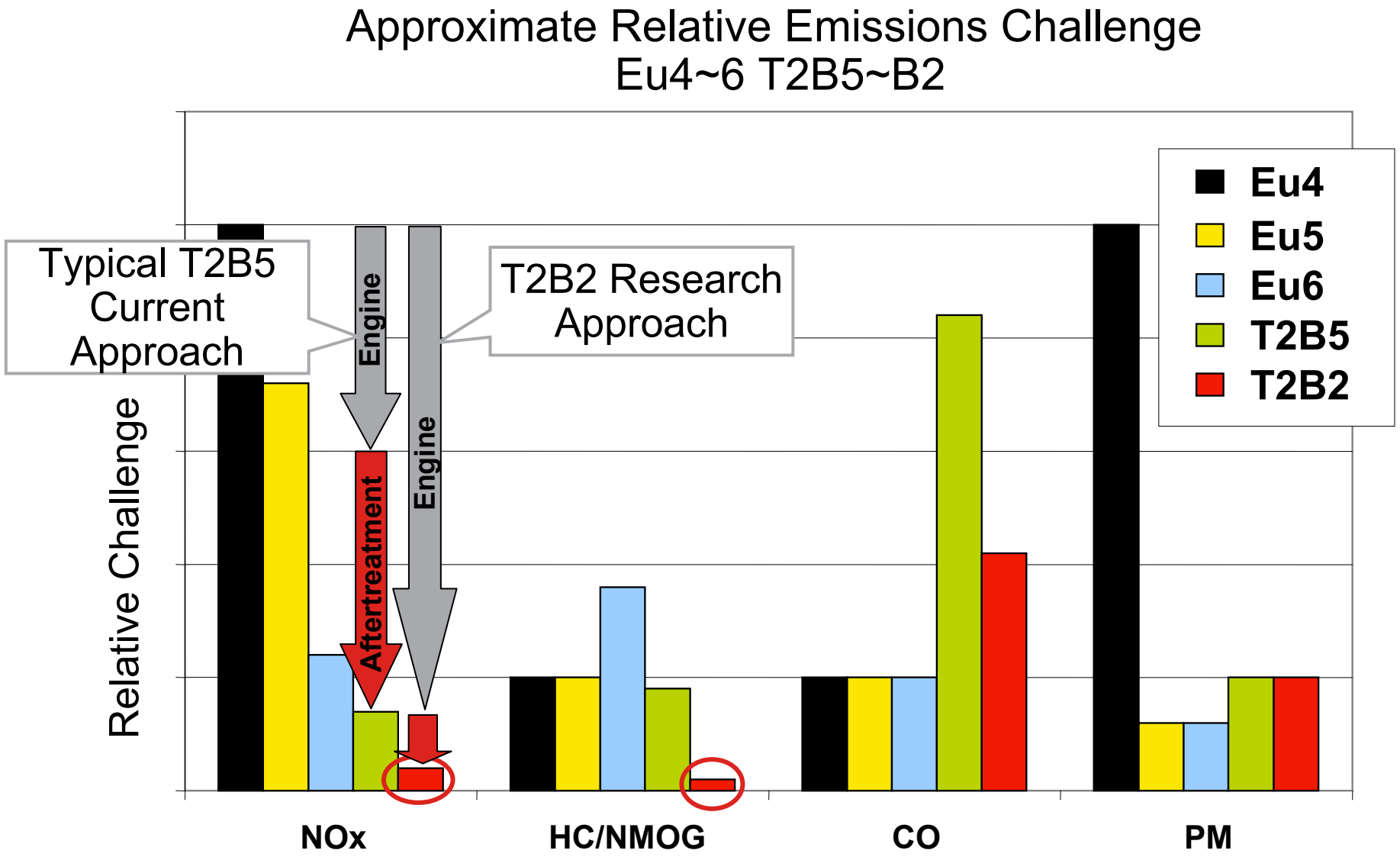
Tier 2 Bin 2 is a major challenge for Diesel and must be achieved with improved economy and realistic cost



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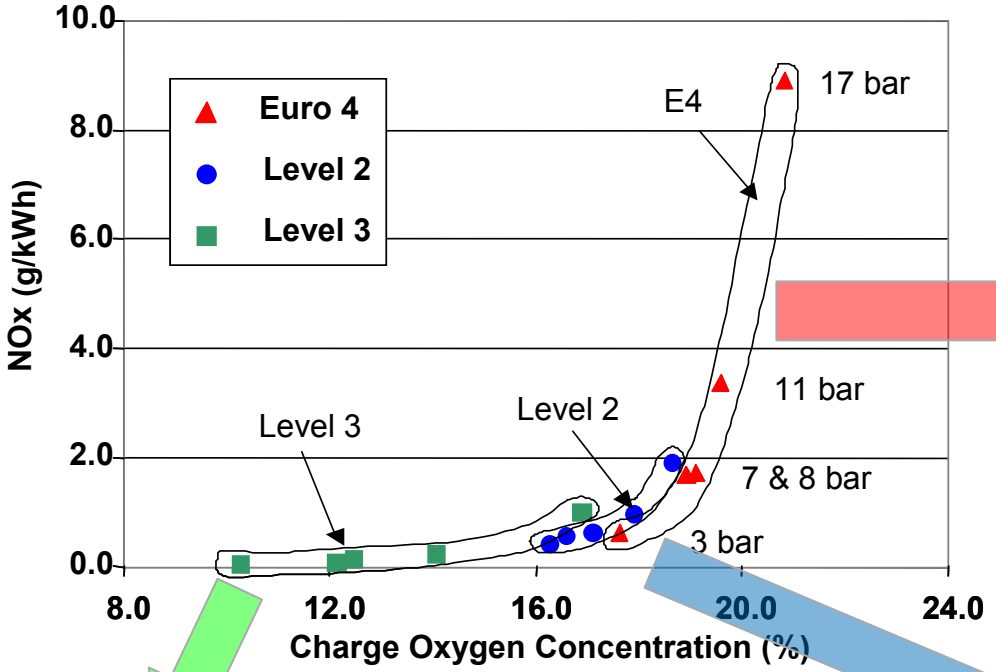
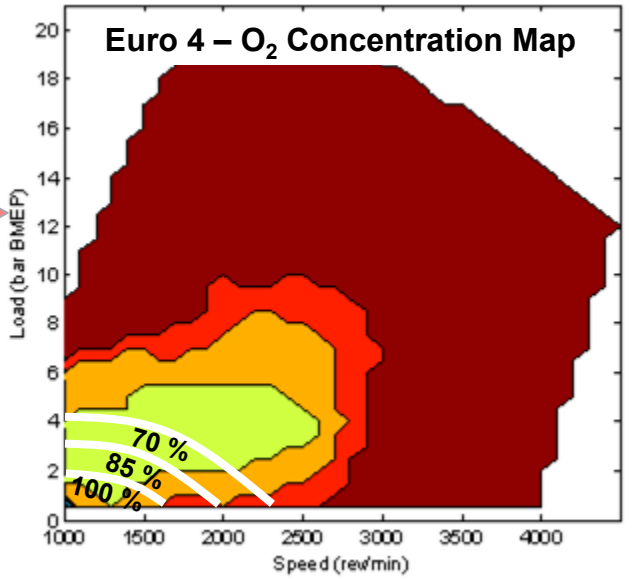
Roadmap of technologies to promote lower emissions while enhancing performance and drivability

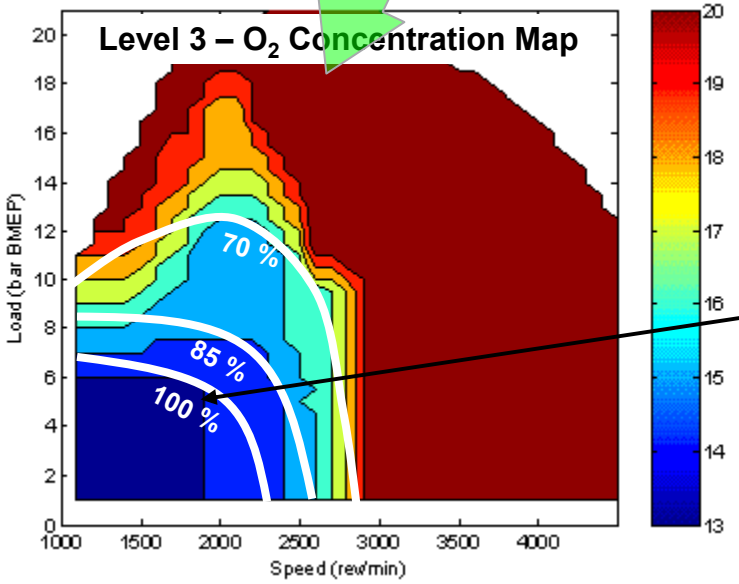
ACTION = Advanced Combustion Technology for Improved engine-Out NOx

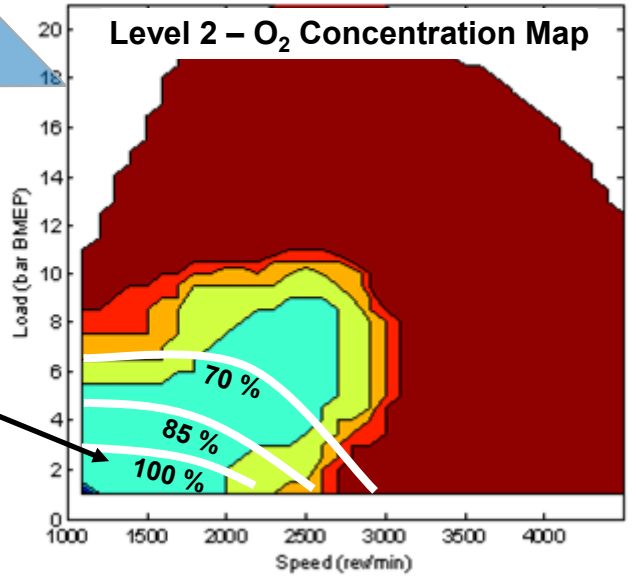
	LEVEL 2/2+	LEVEL 3	LEVEL 4
AIR/EGR SYSTEM	• Variable swirl • Advanced EGR • EGR bypass	• Advanced turbo concepts • Low Pressure EGR	• Assisted boosting • Variable valve actuation?
COMBUSTION SYSTEM	• 16-16.5 CR • 1600-1800 bar FIE	• 15.5-16 CR • >1800 bar FIE	• Variable nozzle? • >2000 bar FIE
CONTROL SYSTEM	• Lambda sensor • EGR temperature control	• Combustion control (CPEMS) • Virtual sensors	• Model based control (WAVE®RT)
CAPABILITY	• Euro 5 PC • Euro 6 PC • T2 Bin 8 FTP LDV	• T2 Bin 5 LDV	• Bin5 LDT4

Highly Pre-mixed Cool Combustion (HPCC)





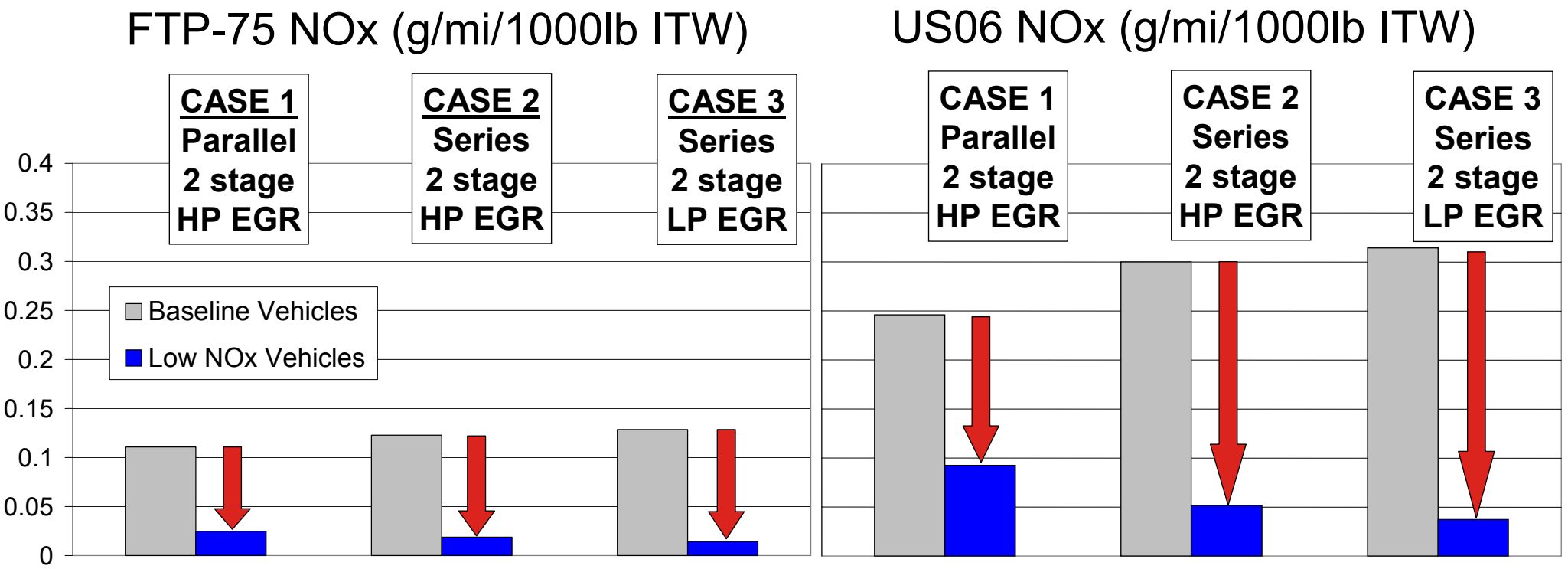




Numbers indicate percentage of fuel injected before start of combustion of the main injection

REFERENCE
SAE 2006-01-1145

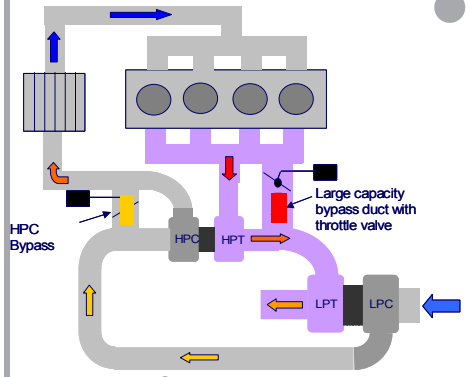
ACTION Level 3 technology enables lower NOx and improved fuel economy



- 80-90% NOx reduction with 3-5% fuel economy gain is possible
- Low pressure EGR solution offers advantage over US06 drive cycle

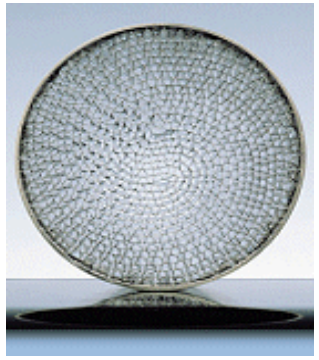
Key T2B2 challenges are being targeted by technology integration

Boost/EGR



- High efficiency air and EGR system
  - Low pumping losses
  - Enhanced performance & drivability

Aftertreatment



- HC control:
  - Fast light-off
  - HC conversion
- NOx control:
  - Low temp conversion
  - Low NOx DPF regen.

NOx

FUEL CONSUMPTION

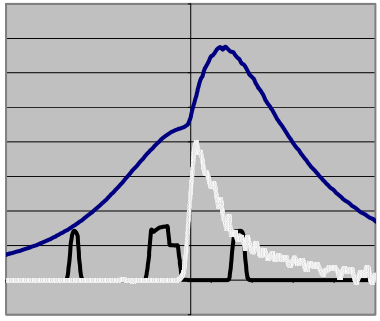
COMBUSTION NOISE

NMOG CHALLENGE

ROBUSTNESS & OBD

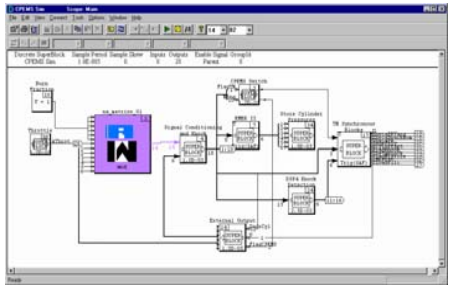
FUEL SENSITIVITY

Combustion



- HPCC combustion system
  - Low soot and good efficiency at low lambda
  - Enhanced performance

Control Strategy



- Advanced air path control
- CPEMS closed loop combustion control

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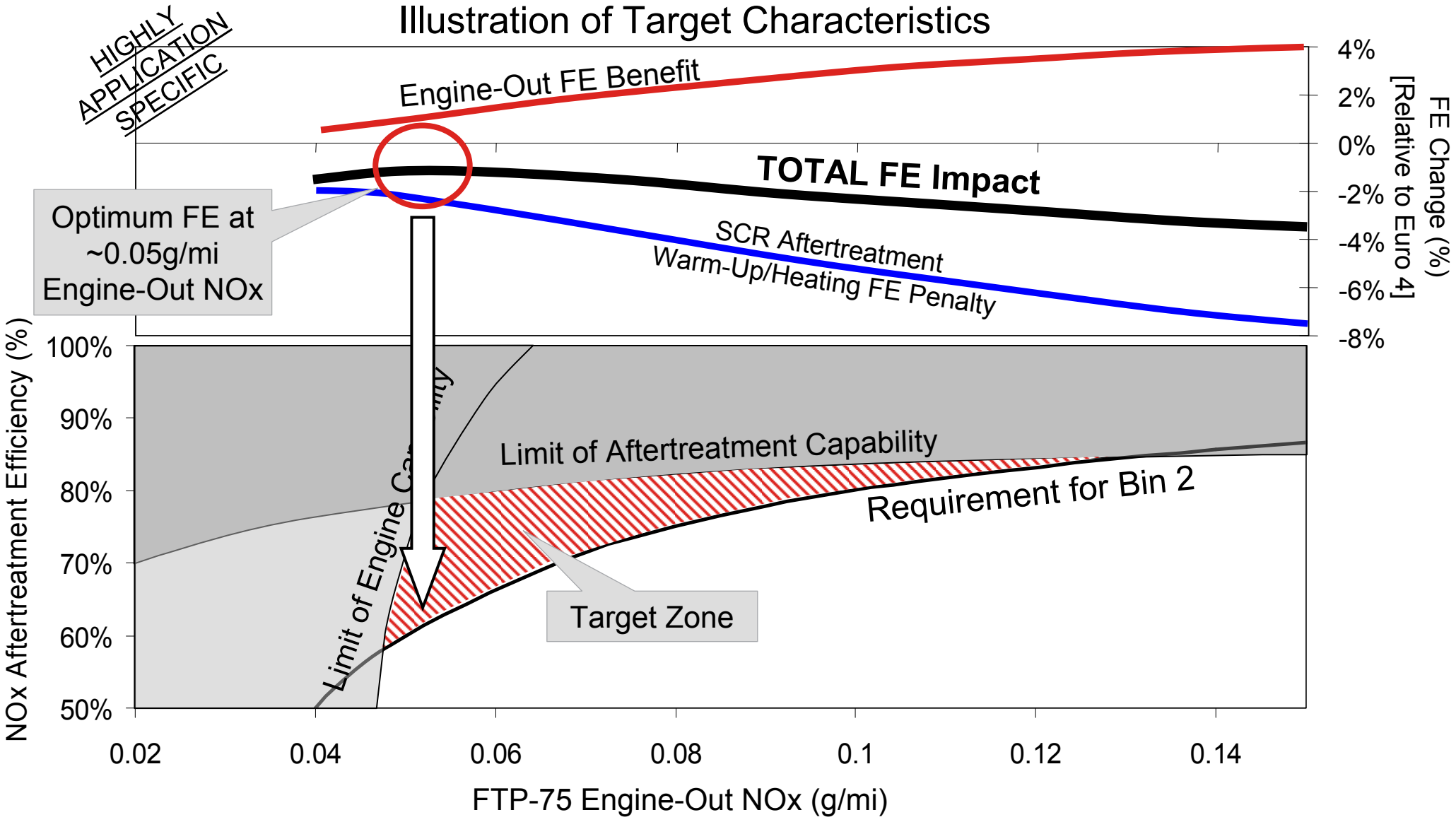
- Low NOx combustion technology will be fundamental to global Diesel product strategies and CO_2 reduction

Research is now examining the optimum engine and aftertreatment balance for best fuel economy at T2B2



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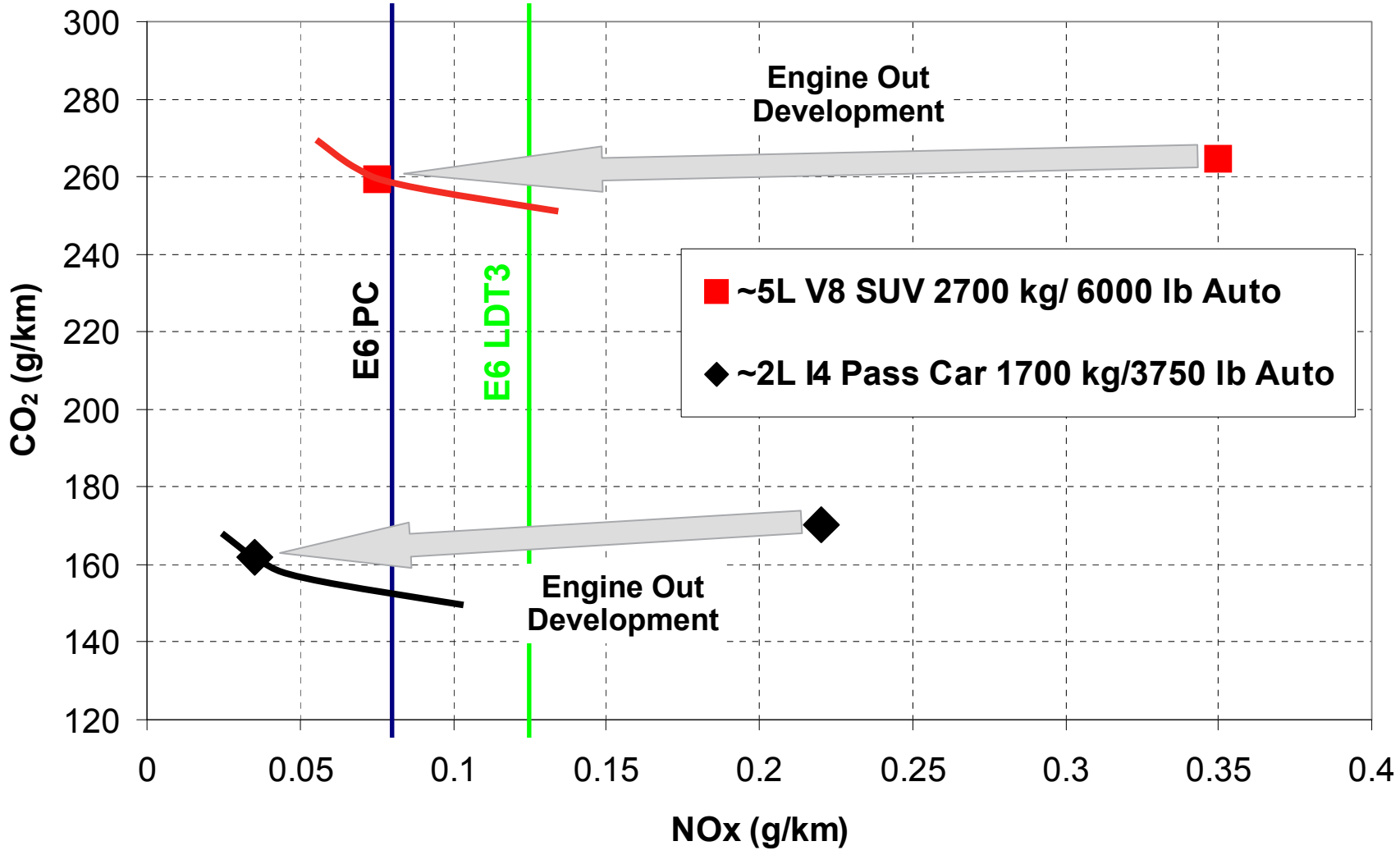
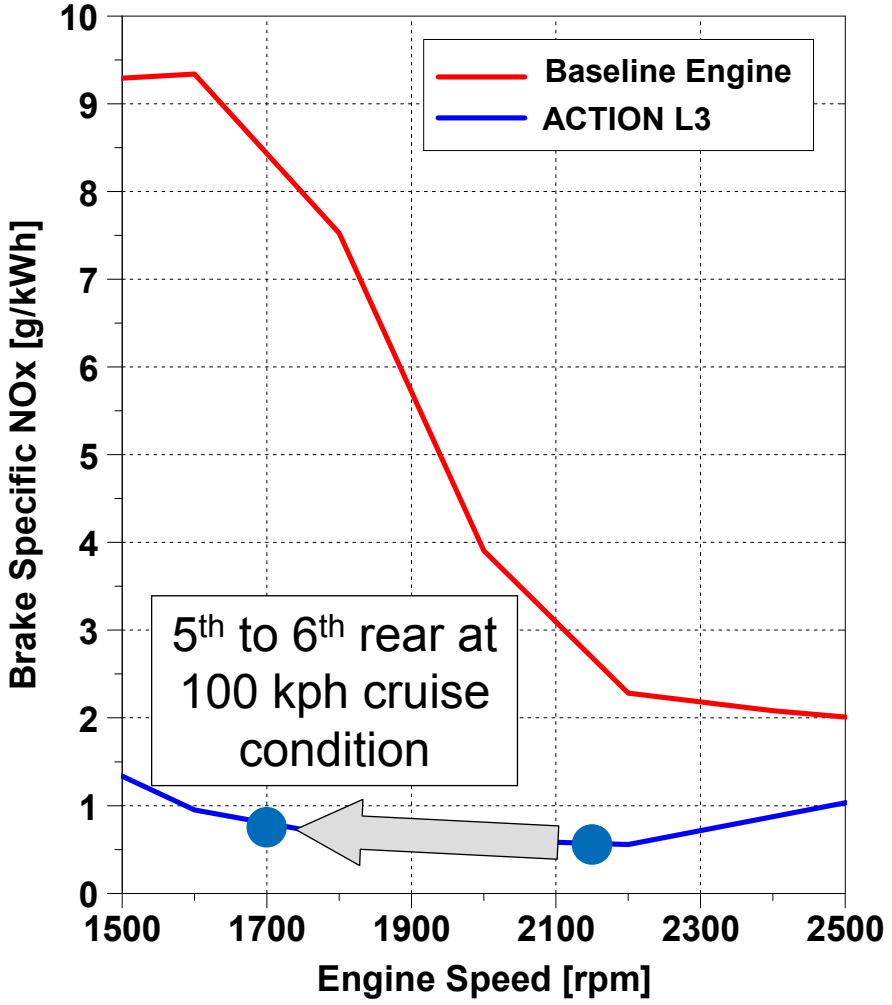
Engine out NOx control will be fundamental to global Diesel product strategies and CO_2 reduction

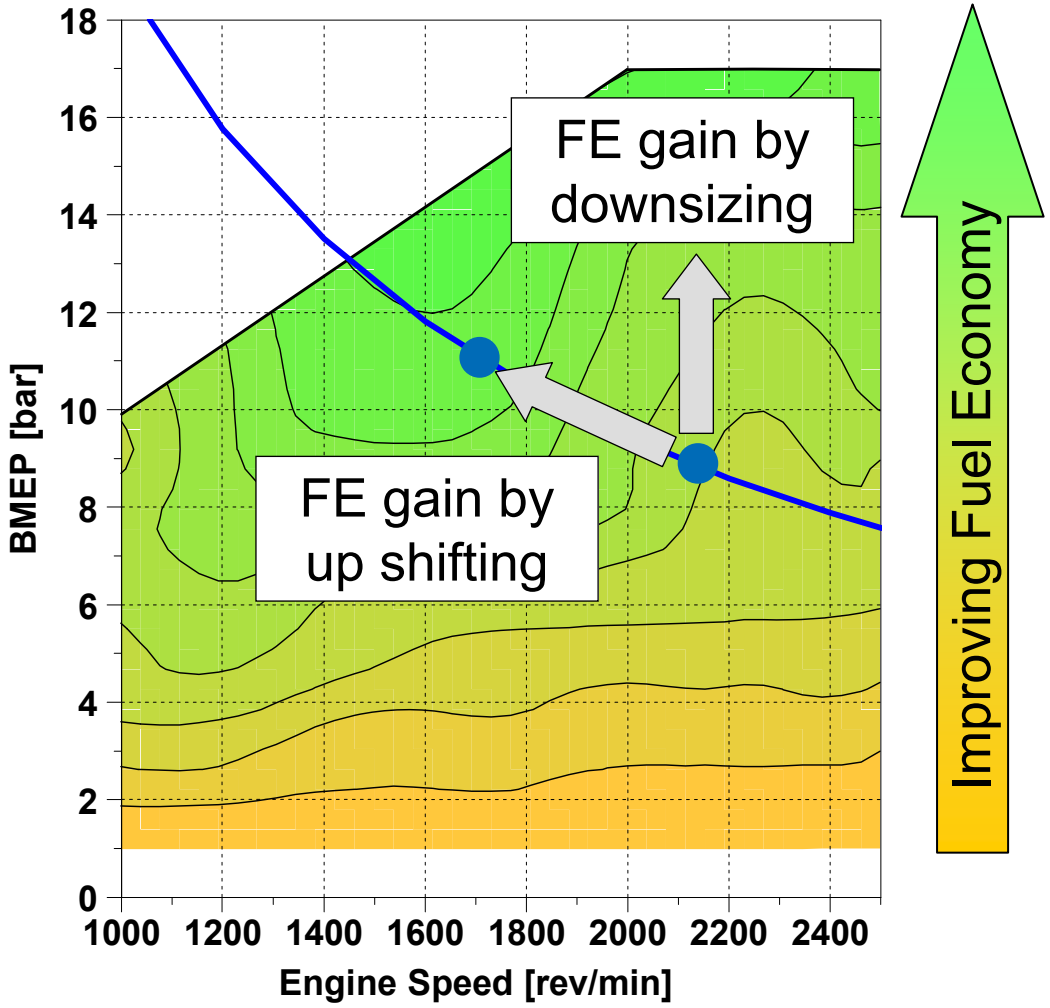


Low NOx technology will enable fuel economy gains through reduced operating speed or engine downsizing

Brake Specific NOx Comparison - Constant Power Condition of 30kW



ACTION Level 3 Engine Brake Specific CO2



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