Diesel Passenger Car Technology for Low Emissions and CO_2 Compliance

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Ricardo plc

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Diesel engine technology will contribute to the fuel economy improvement of future US light duty vehicles

- Cost effective reduction of legislated emissions (including CO_2) is a major issue. NOx control must not be a limiting factor to the long term success of Diesel engines

- Promising ultra low NOx and NMHC emissions have been achieved through the integration of combustion, air and aftertreatment developments

- New Diesel technology offers extremely low NOx potential and good fuel economy if key issues regarding robustness, aging and OBD can be successfully resolved

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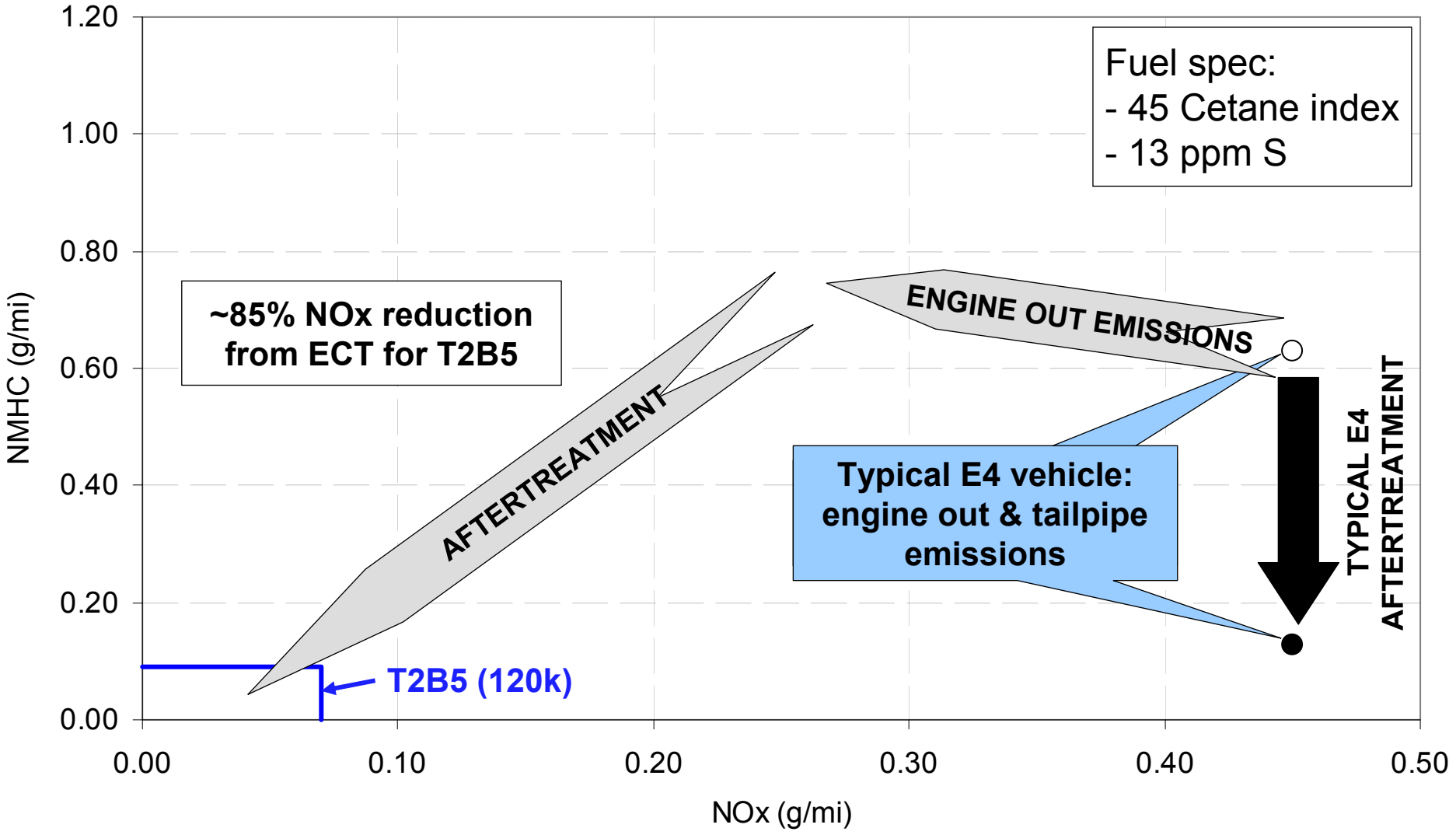
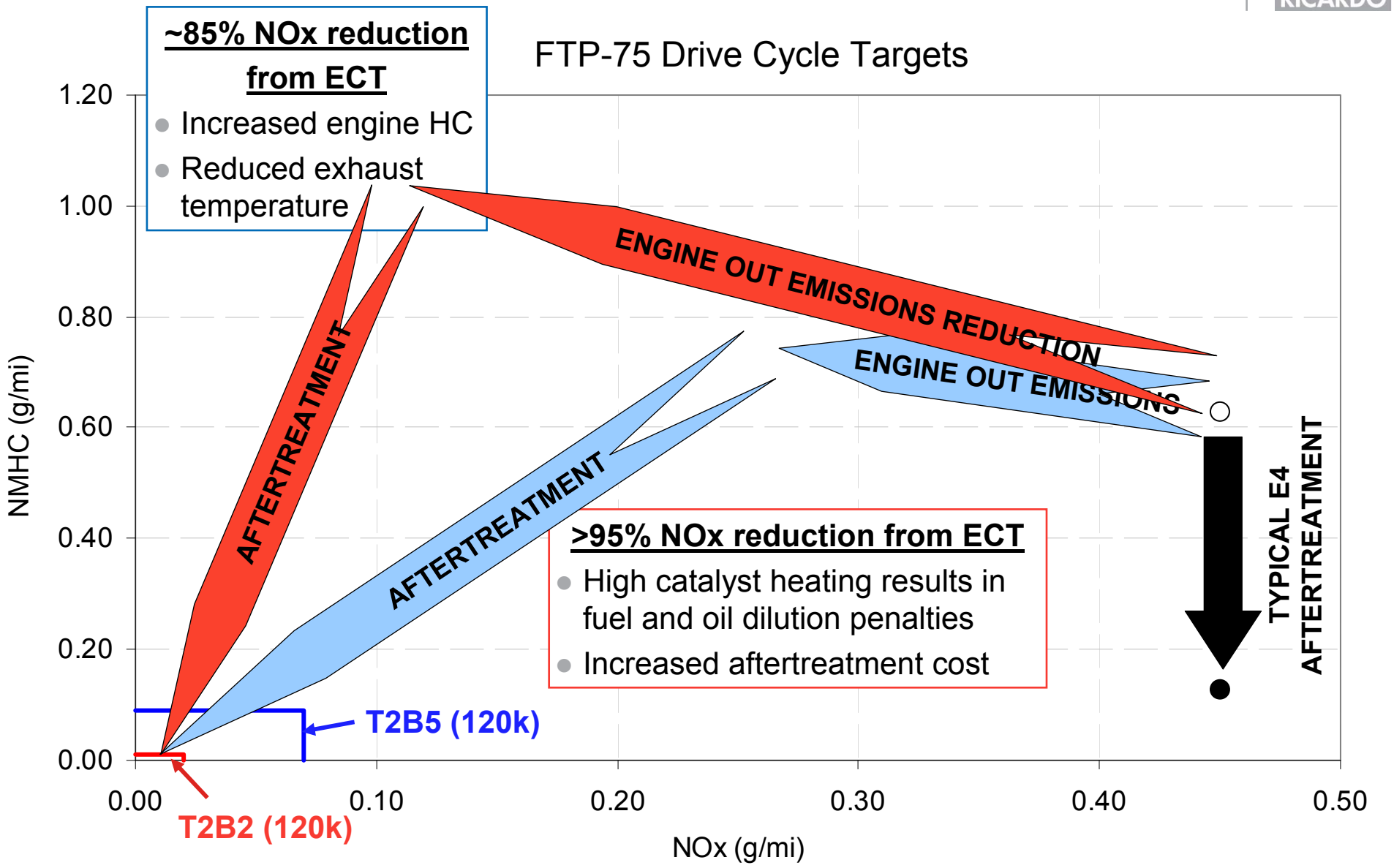
LEV2 Diesel challenge



SULEV Diesel challenge



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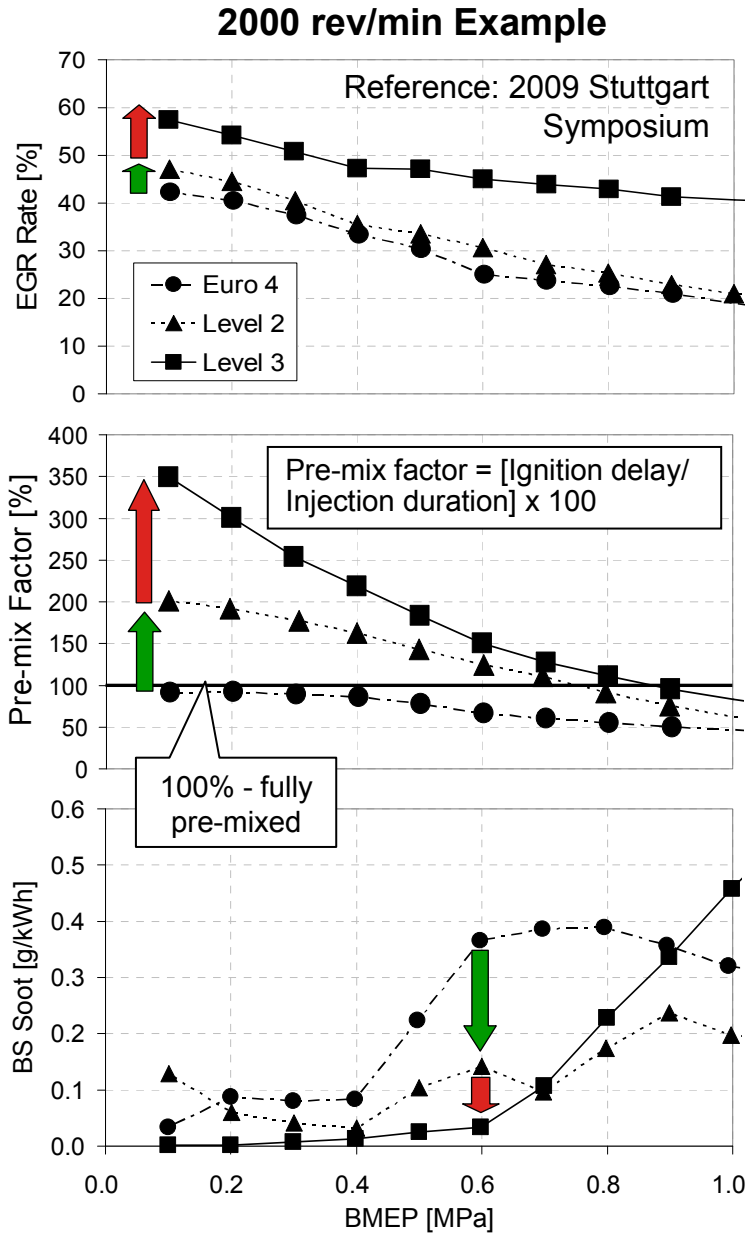
NZED: Integration of combustion, air and aftertreatment developments to target future emissions goals

- 3500 lb ITW Mid Size Passenger Car
- 6 speed conventional auto transmission
- 1.9 litre in line 4 cylinder DOHC 16v
- Production 1600 bar 2nd generation FIE
- New two-stage series-sequential turbocharging and hybrid EGR system
- Ricardo air/EGR path, combustion and aftertreatment control strategy
- New integrated aftertreatment system (LNT + DPF)

NZED
Near Zero Emissions Diesel

Benefits of air, EGR, combustion and control technology



NEW AIR, EGR & CONTROL TECHNOLOGY

HIGHLY PRE-MIXED COOL COMBUSTION

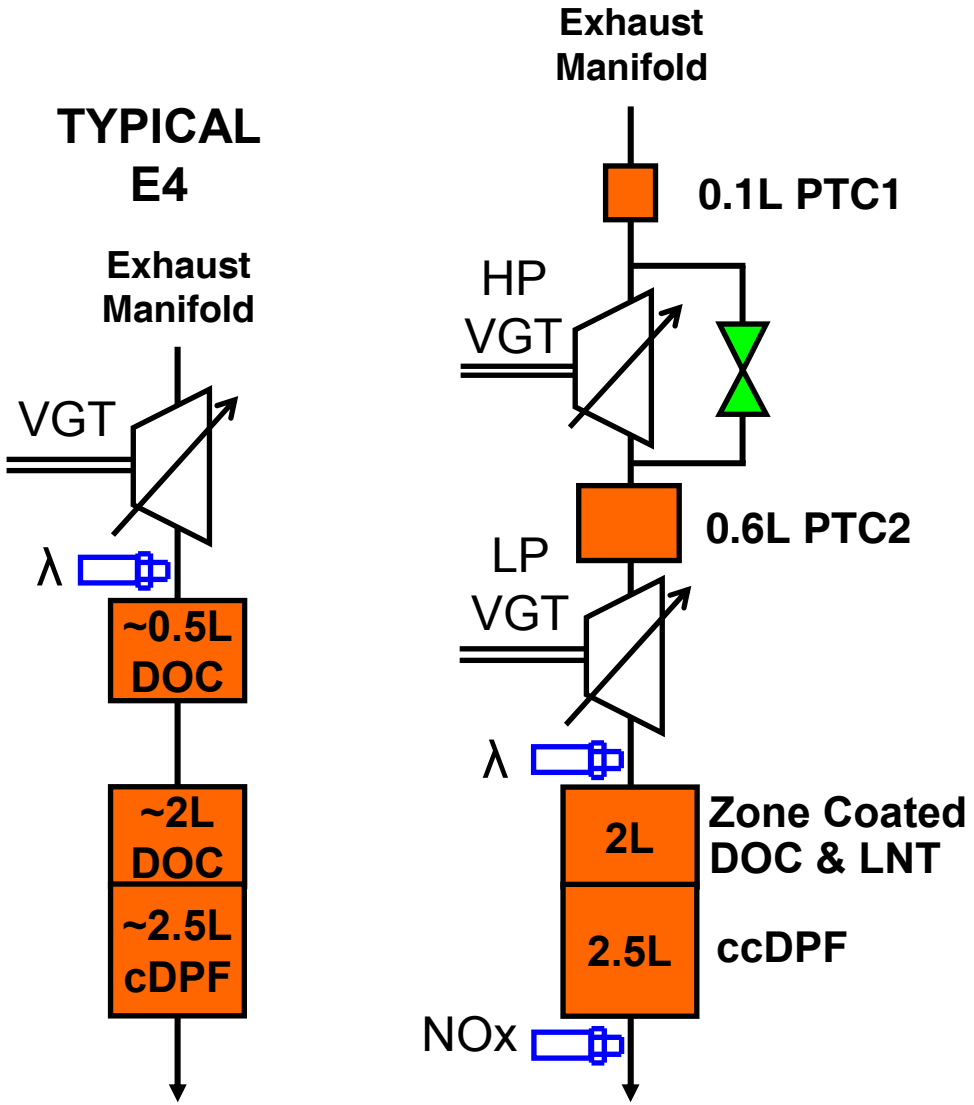
LOW CHARGE O_2 CONC.
LEAN COMBUSTION
OPTIMISED TIMING
AVOID MISFIRE
NO MODE SWITCHING
CONTROL INLET TEMP.

IMPROVED POWER, TORQUE AND TRANSIENT BOOST RESPONSE

ULTRA LOW NOx, LOW SOOT AND CO_2

ENABLE DOWNSPEEDING AND LOWER CO_2

The aftertreatment system has been integrated into the engine design to target SULEV NMHC compliance

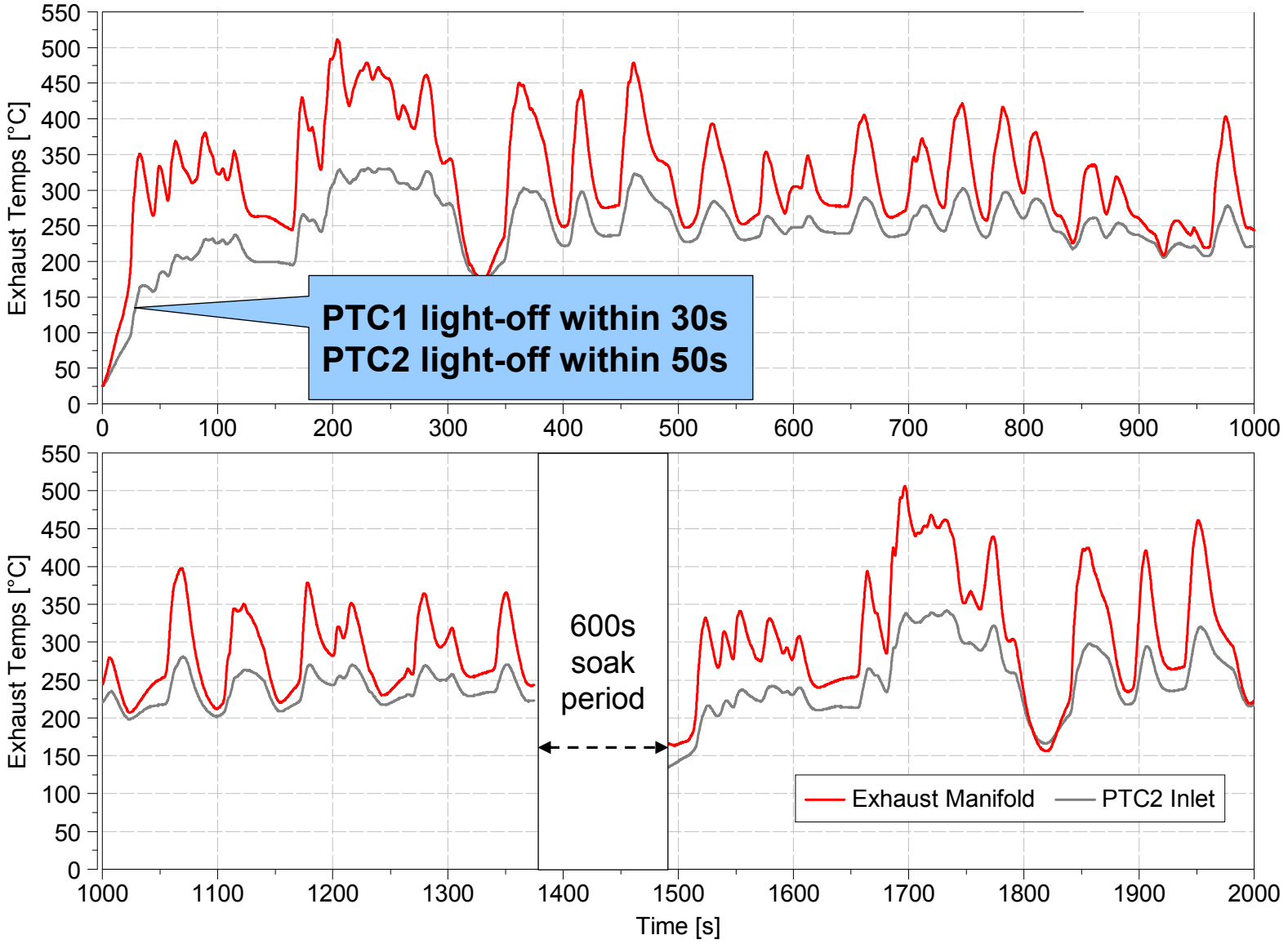


NZED AFTERTREATMENT SYSTEM

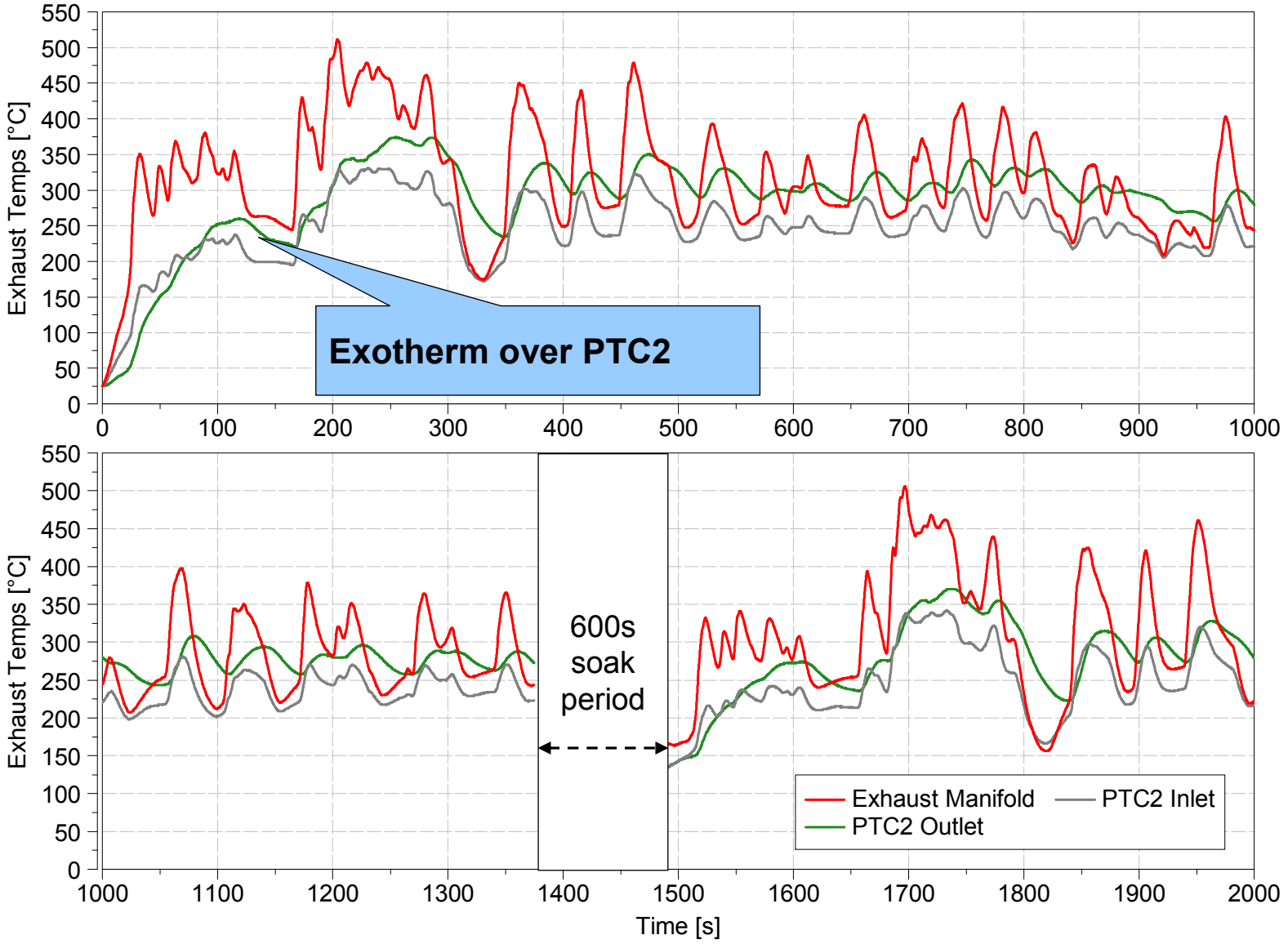
- Pre turbo catalysts for low NMOG
- Small LNT due to low absolute NOx mass reduction required
- All catalysts on hot side of engine
- Increase in PGM (E4 to T2B2)
  - Cost increase of $360 (based on PGM prices 22/7/09)

NZED
Near Zero Emissions Diesel

FTP-75 temperatures with no forced heating strategy



FTP-75 temperatures with no forced heating strategy



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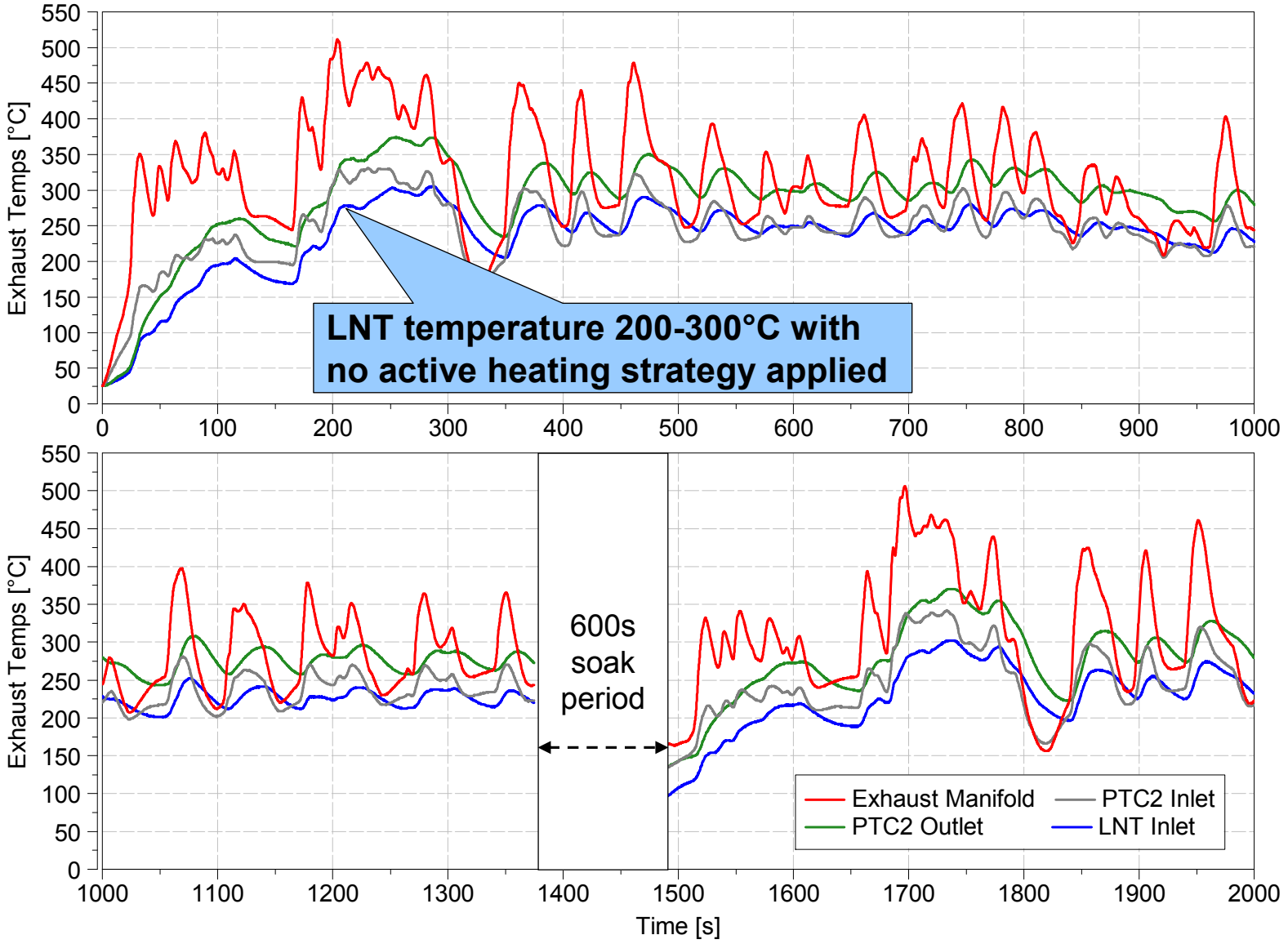
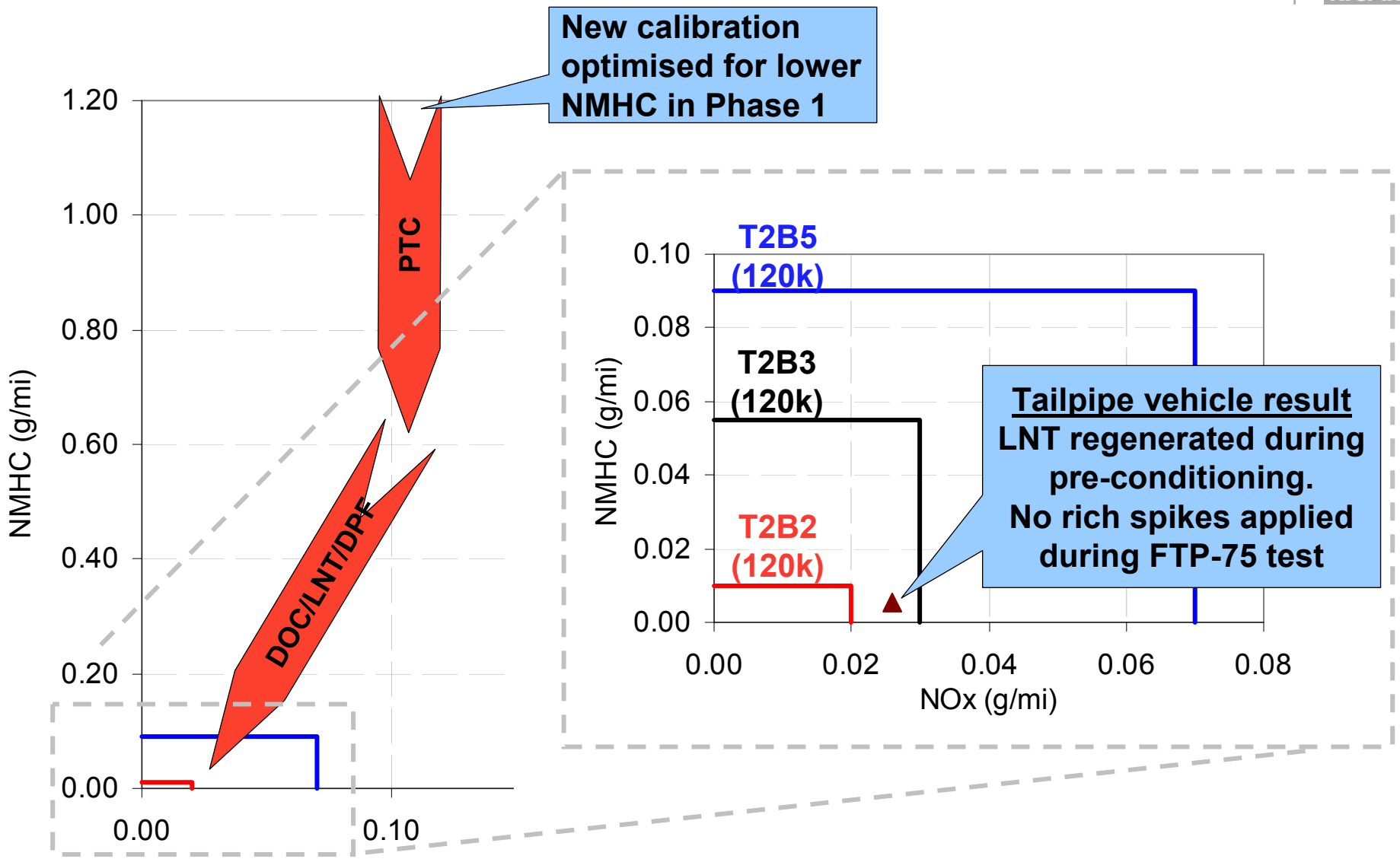
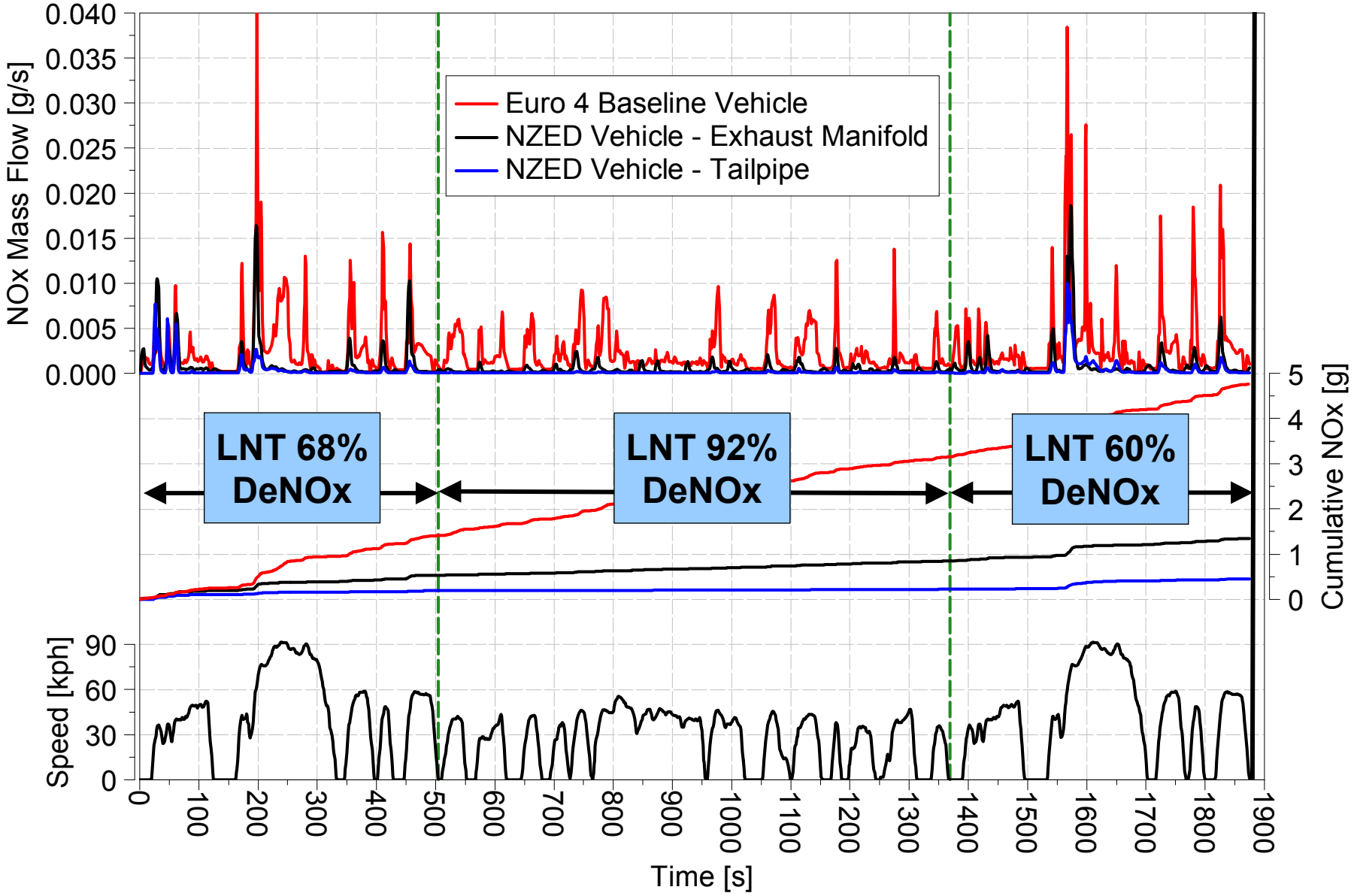


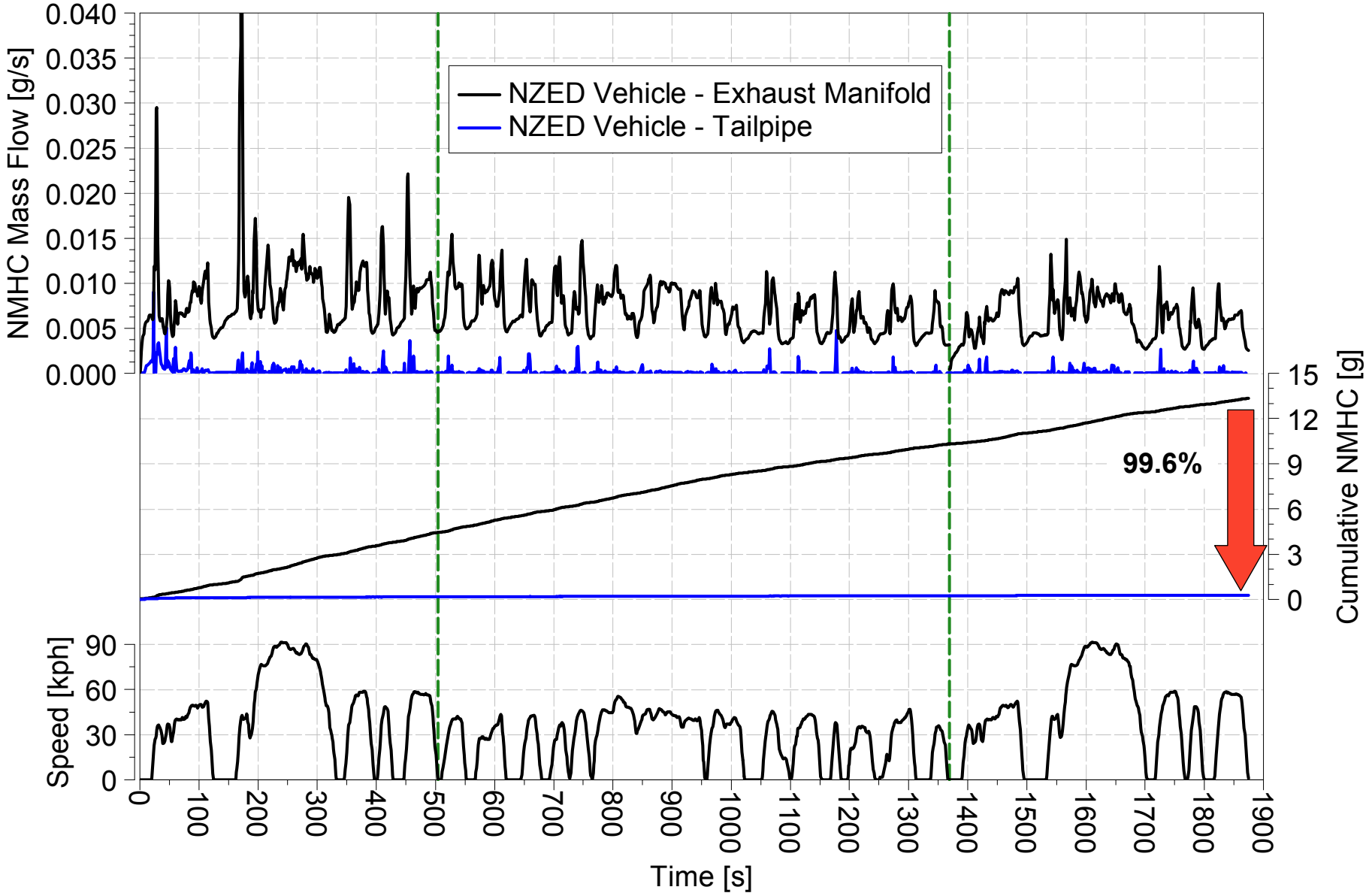
NZED FTP-75 Emissions Status



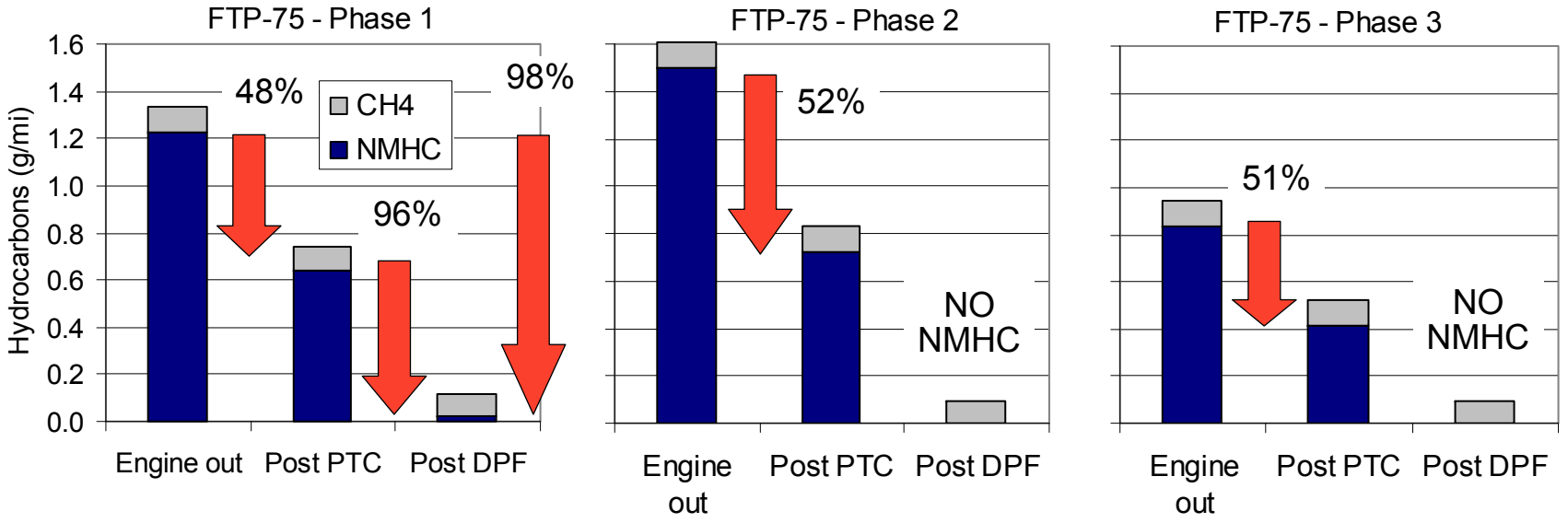
94% tailpipe NOx reduction overall relative to typical E4: 76% from engine and additional 76% from LNT

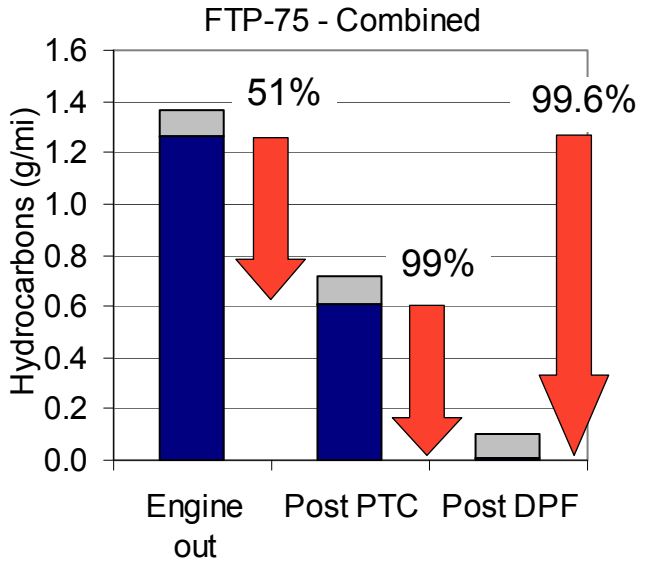


Exceptional aftertreatment performance is required to achieve SULEV levels of NMHC



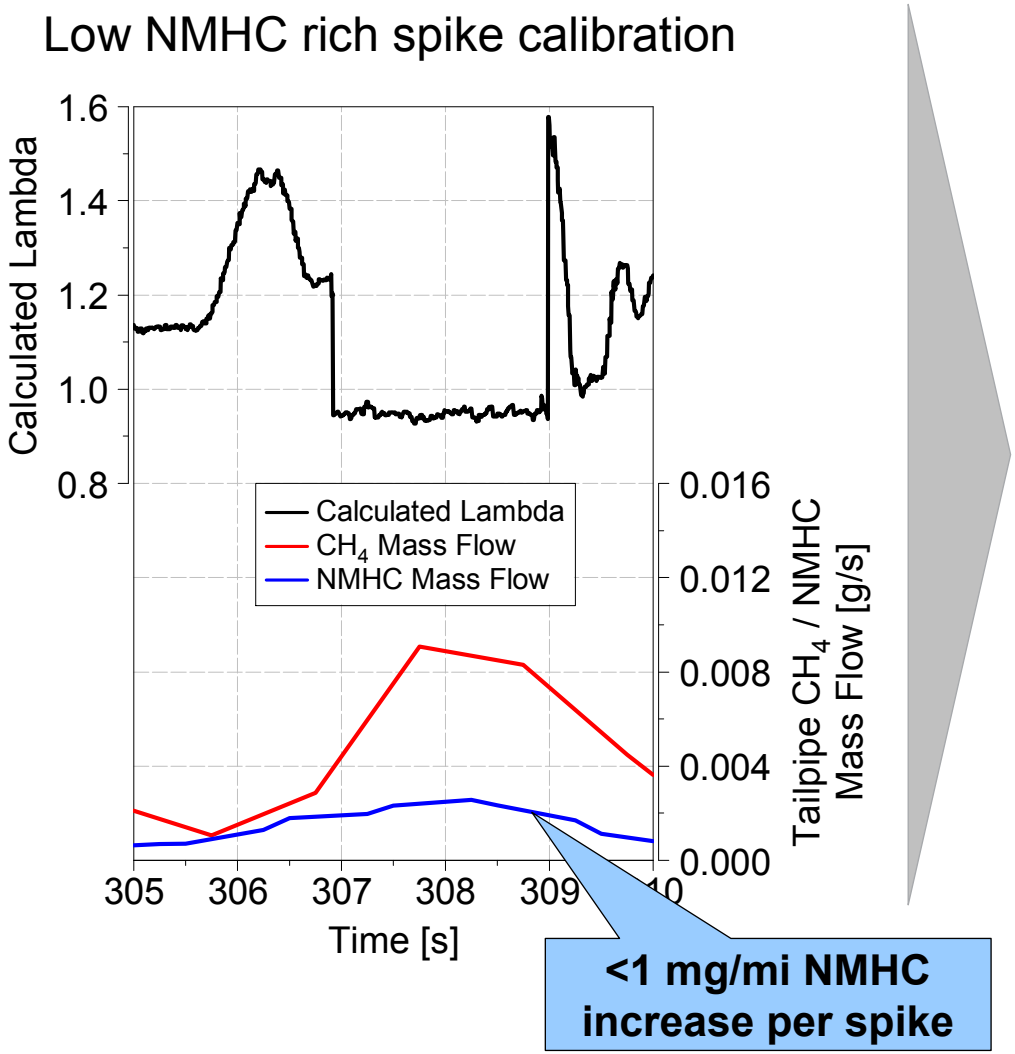
NZED emissions presents challenges for measurement system capability

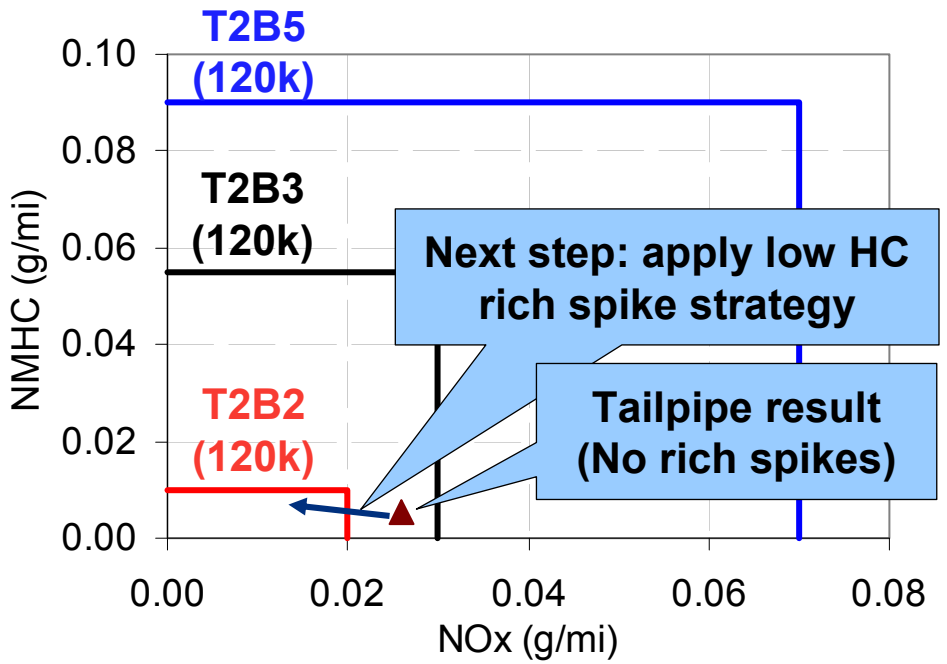




- Catalysts subject to 8h oven aging at 800°C
- PTC subject to 200h running test bed & vehicle
- LNT/DPF subject to 30h running in vehicle
- CVS dilution ratio reduced to improve accuracy
- 4-6 mg/mi tailpipe NMHC observed during repeat testing

Next step: application of rich spike to increase NOx conversion while minimising NMHC penalty





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Significant issues must be resolved for SULEV Diesel vehicles to become practical

Emissions Robustness

- New combustion system
- Catalyst durability development
- Combustion control R&D
- EGR system fouling research

OBD

- New control algorithms
- New and improved sensors

Low NOx DPF Regeneration

- O2 calibration optimisation
- Application of exhaust fuel injection and fuel reforming technology

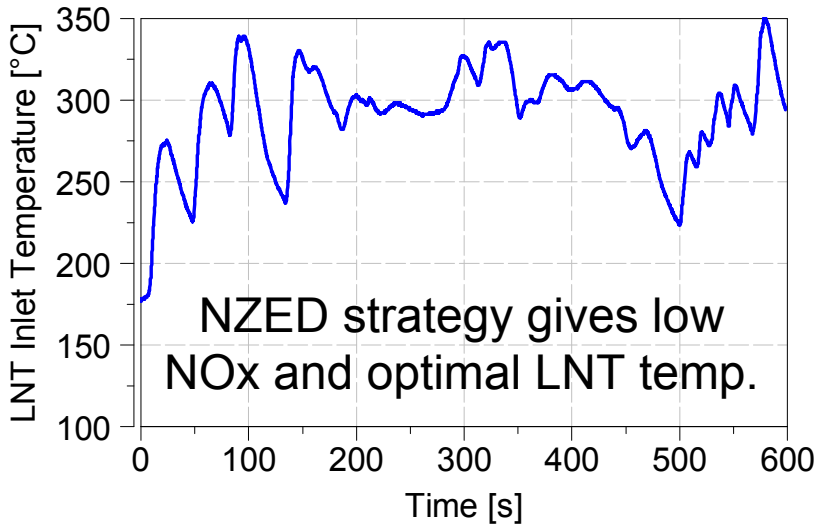
SULEV DIESEL?

Cost Reduction

- Integrated engine design
- Optmised catalysts with reduced PGM loading
- Decontent engine technology

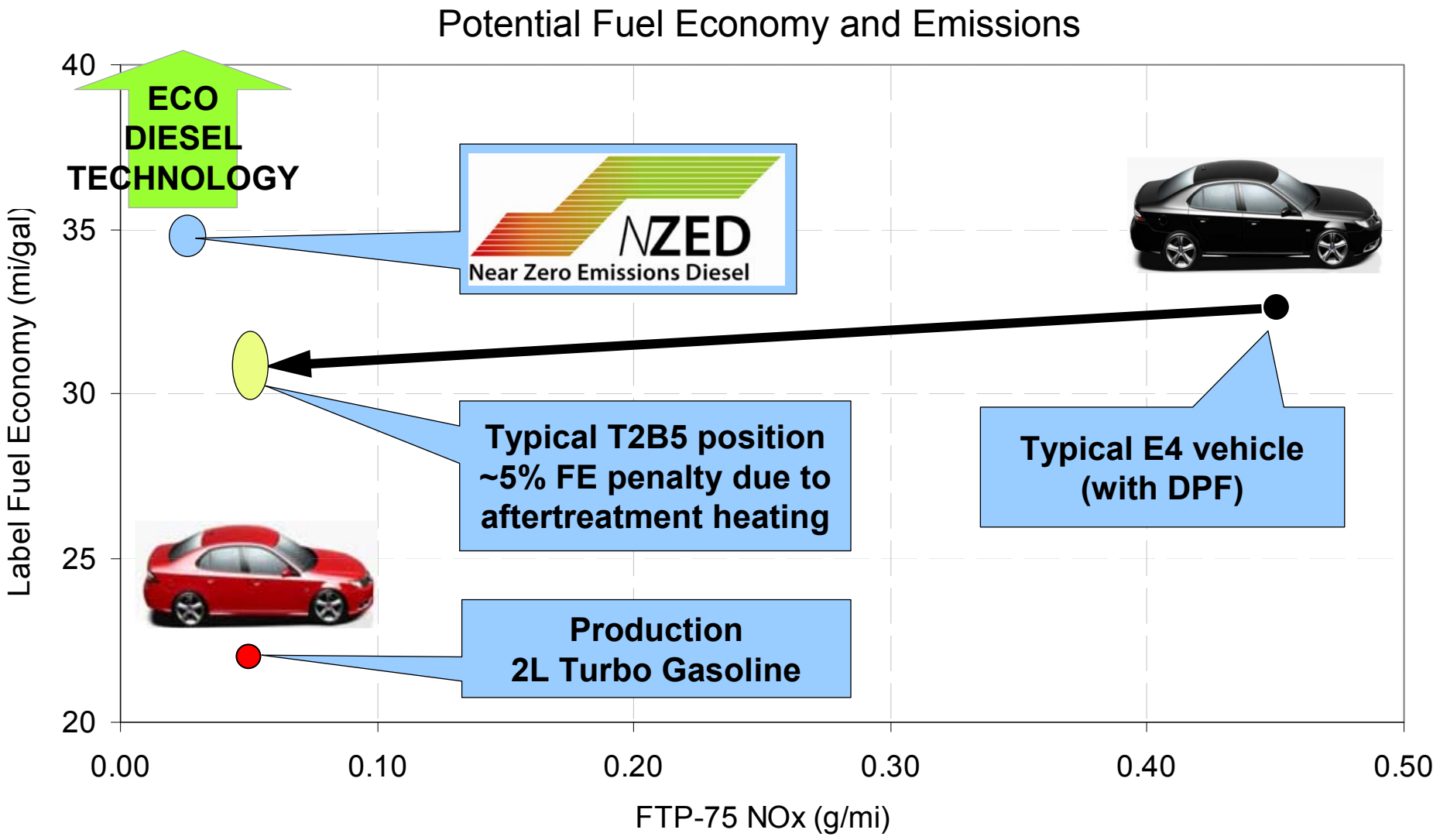
Ultra low NOx US06 threat

- Optimised aftertreatment strategy



Source:

The NZED approach offers fuel economy benefits by improving efficiency and reducing aftertreatment heating



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