Advanced Diesel Common Rail Injection System for Future Emission Legislation

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Common Rail System Engineering for PC Diesel Systems
Robert Bosch GmbH

Outlook

- Drivers and Challenges for PC and LDT - Diesel
- Overall System Requirements for Advanced Common Rail
- BOSCH 4th Gen Common Rail Injection Systems
- Potential Evaluation of 4th Gen Common Rail Systems

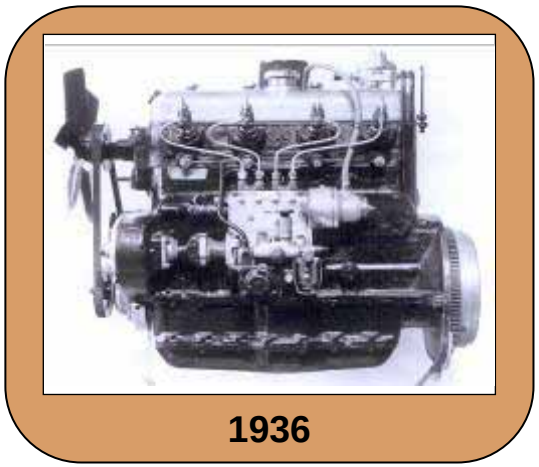
Diesel Progress - PC

Drivers

- High Specific Powe
- Fun to Drive
- Fuel Consumption

Challenges

- Emission Limits
- Noise
- System Costs
- FIE Lifetime



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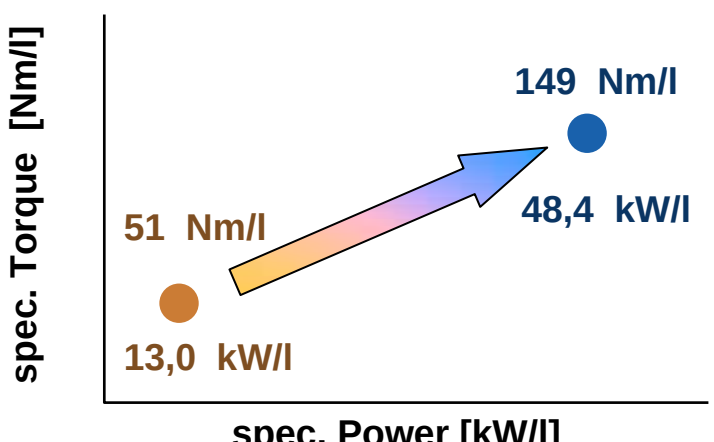
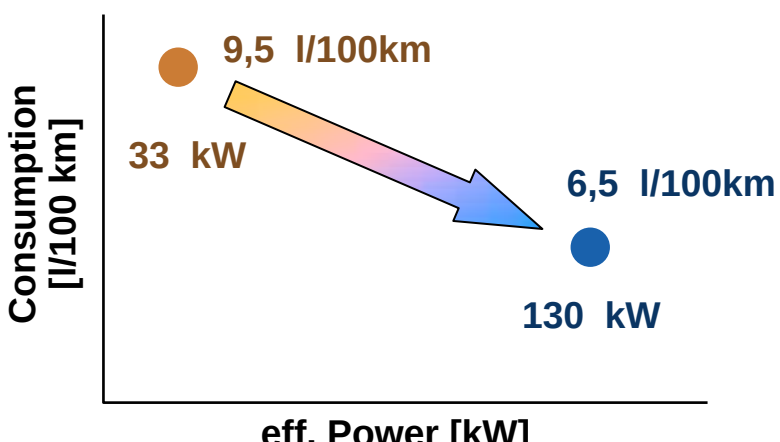
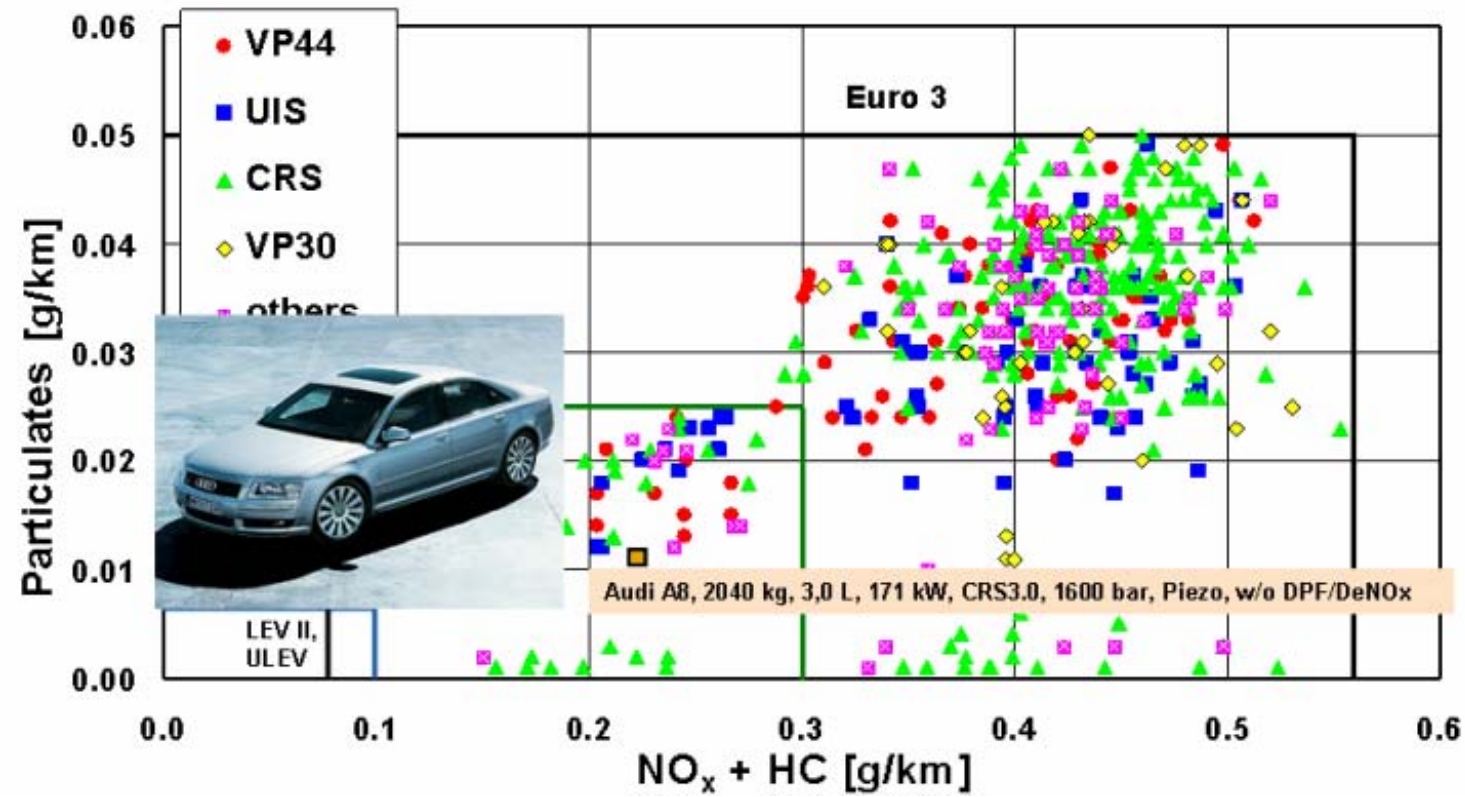




Approval Data for PC - Diesel at least Euro 3



source: KBA Germany

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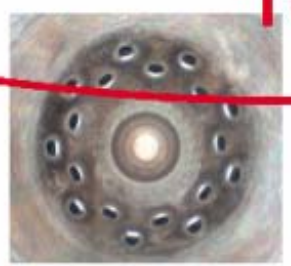
Advanced Common Rail Systems

- Variable Nozzle Injector
- Pressure Amplification
- Sophisticated Closed Loop Control

Today's Focus



Air System

- Super Charging
- LP/HP - EGR

Combustion Process

- Bowl Design, Compression Ratio ...
- Combustion Signal Control
- Optimized Nozzle Technology

EGT

- DPF
- DPF+NSC
- System Control

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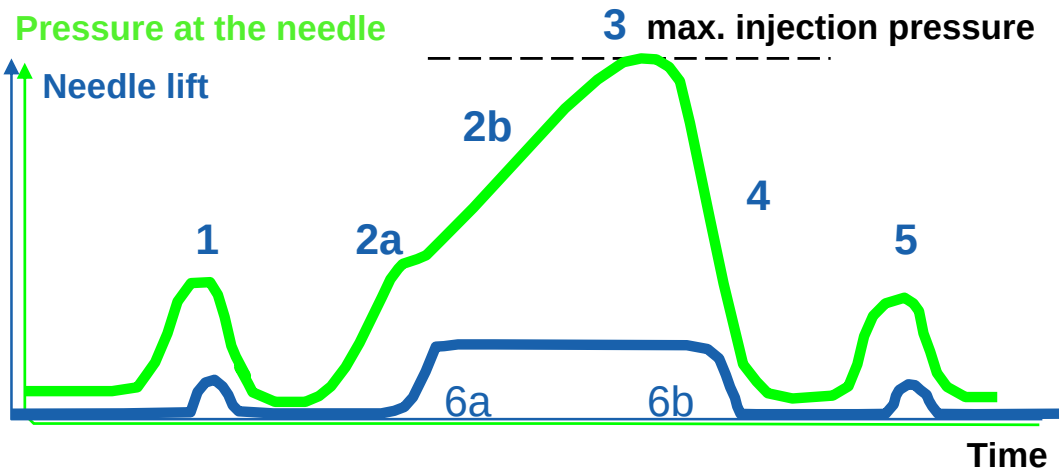
FIE Requirements Evaluation

Sensitivity analysis of important injection parameters for the engine performance



Feature:

1 **Pilot injection (number, time gap, quantity, tolerance)**

2 **Opening pressure, influence of pressure ramp, gradient**

3 **Max. injection pressure, influence of small nozzle holes**

4 **Pressure gradient during closing**

5 **Post injection (near, late, influence of pressure level)**

6 **Opening and closing speed of the needle**

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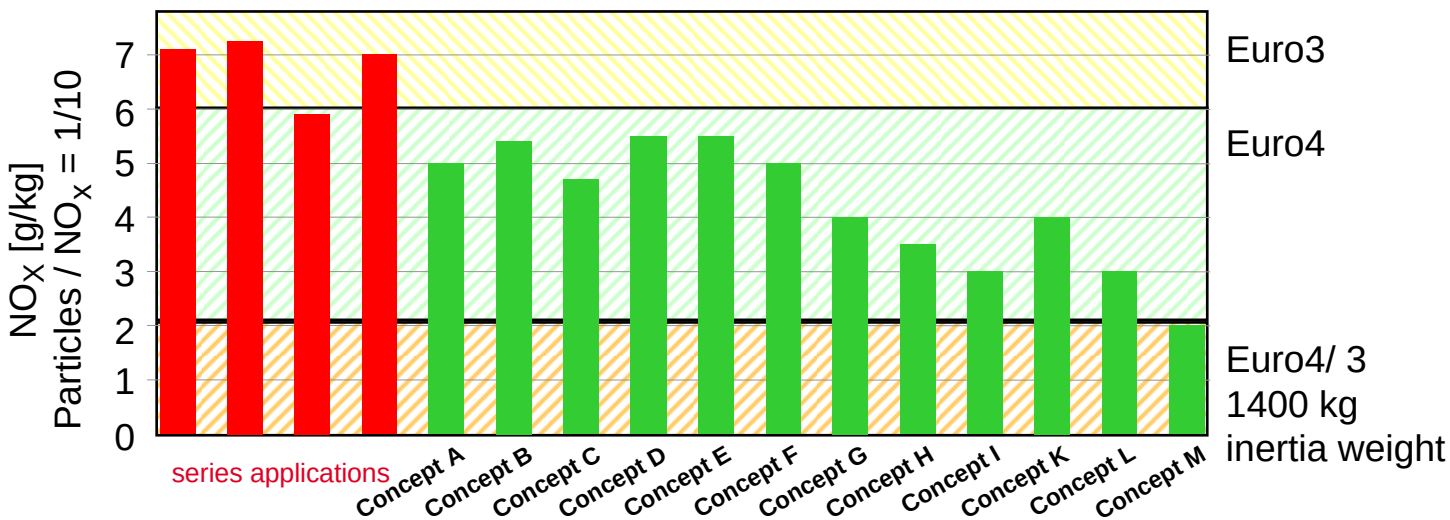
Potential Analysis for PC an LD-Combustion Process and FIE

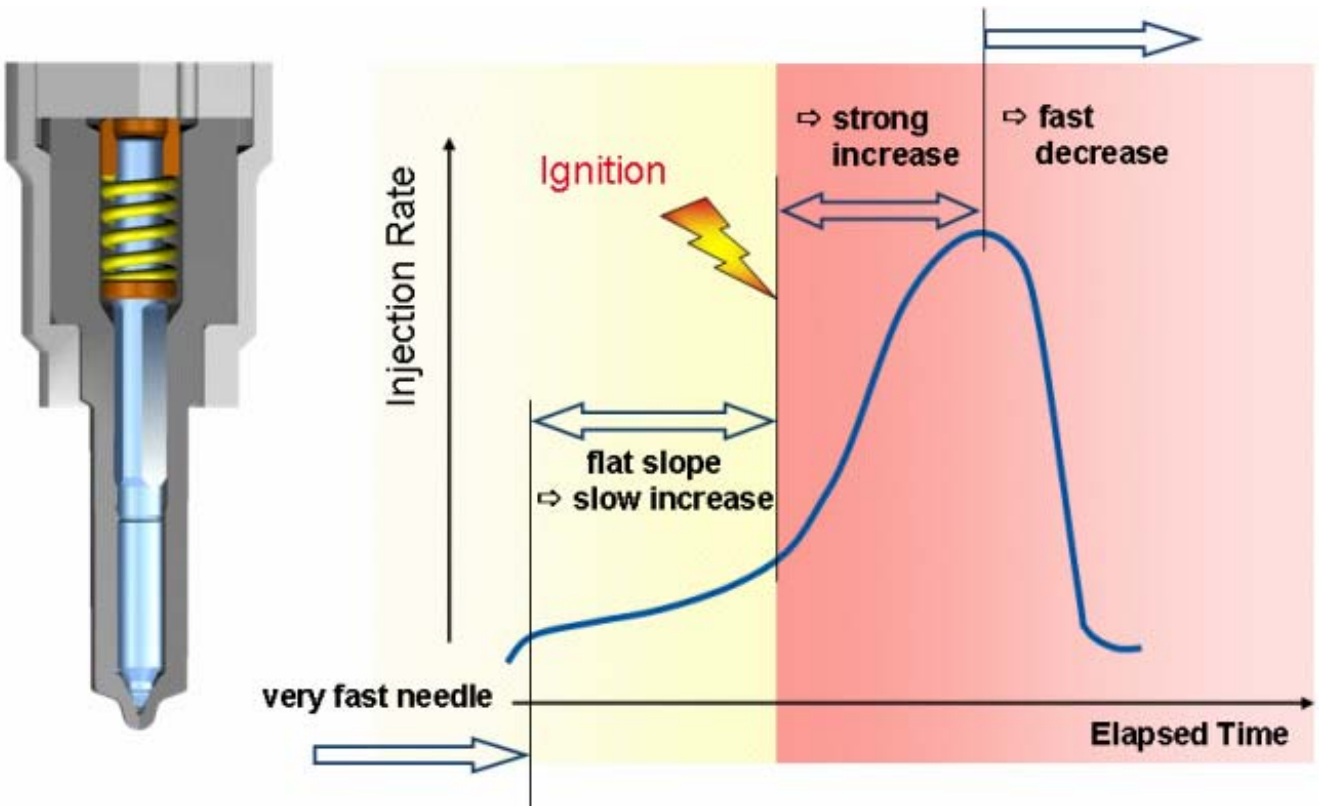
n = 2000/min,
BMEP = 6,5 bar



- fast needle opening velocity
  but: injection rate ↓ during ignition delay
- injection rate ↑ after start of combustion

→ „vario“ nozzle
→ rate shaping

“Optimal” Shape for PC Engines



CRS System Requirements for **PC** - Summary

⇨ full flexible timing of multiple injection events

⇨ full flexible choise of injection pressure in the engine map

⇨ small precise and stable in

still valid and well - known from series Common Rail technology, gaining goals on noise, power, Euro4 - emission and maintaining EGT

CRS System Requirements for **PC** - Summary

good spray formation	very fast needle opening @ start of injection
low Noise and NOx - formation	limited quantity during ignition delay, but
high spray momentum ⇨ increase EGR - acceptance	max. allowed injection rate to increase local air ratio
	strong increase of injection rate after start of combustion
	high maximum of main injection rate
seperate injection and burning phase	strong rate decrease and fast needle @ end of injection

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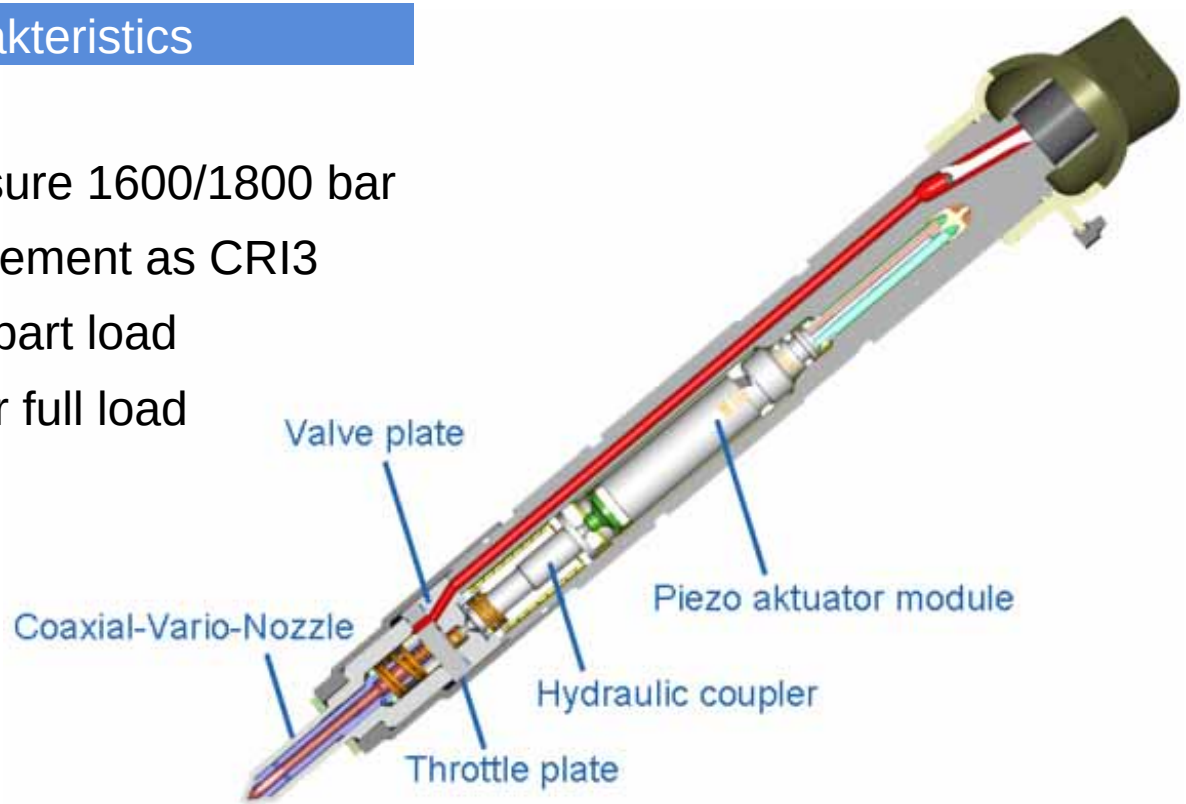
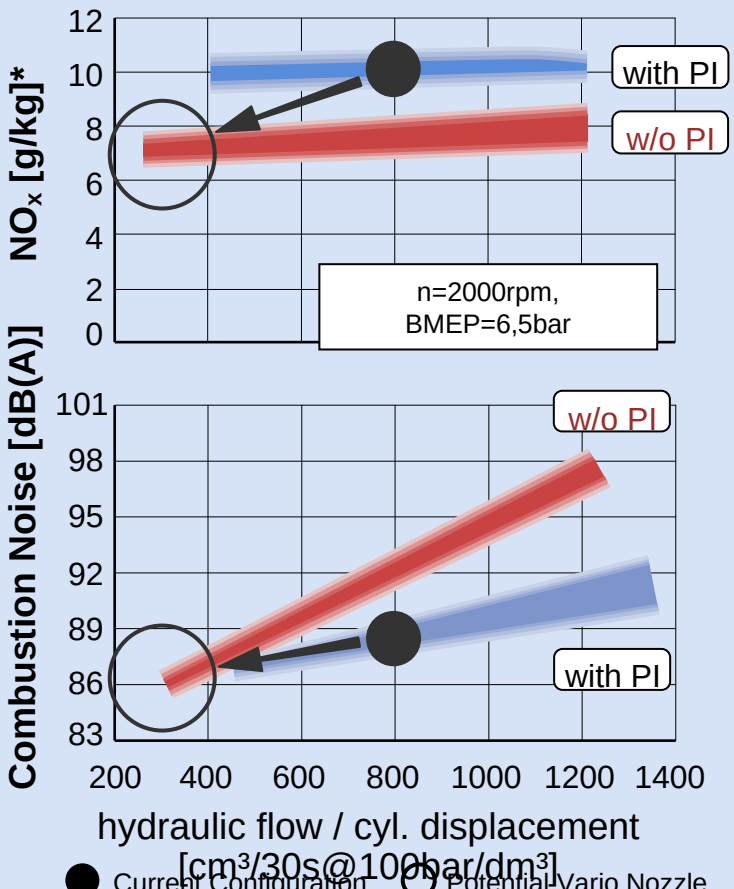
Piezo-Injector with Coaxial-Vario-Nozzle CRI4-PV

Injector -Charakteristics

- Basis: CRI3
- Systempressure 1600/1800 bar
- Space requirement as CRI3
- One row for part load
- Both rows for full load



Vario Nozzle Strategies



Avoidance of PI

(except for cold engine and idle)

⇒ Emission reduction

Reduction of Q_{HYD}

⇒ Noise reduction

Indepentantly switchable 2nd row of spray holes

⇒ appropriate power output

Advanced Common Rail Systems for PC

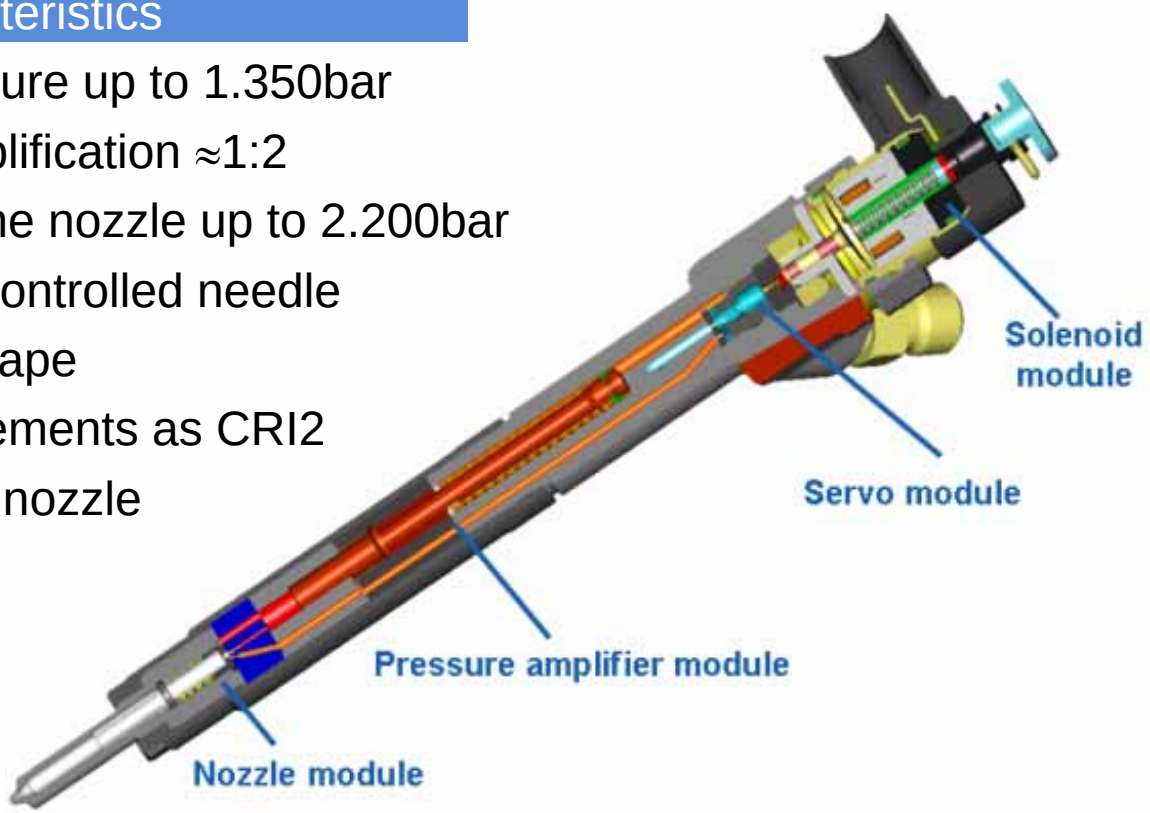
CRS 4 - Hydraulically Amplified Diesel Injection System

- Functions
  - ⇨ Rail Pressure up to 1350 bar
  - ⇨ HAD - Injector with hydraulic pressure amplification
  - ⇨ sophisticated closed loop fuel metering control
  - ⇨ innovative, delivery controlled high pressure pump platform
- Advantages
  - ⇨ small Q_{hyd} and passive rate shaping to pull down raw emissions and noise @ part load
  - ⇨ max pressure > 2200 bar @ spray hole to reach high power and reduce raw emissions @ full load (US 06, e.g. LD in EU)

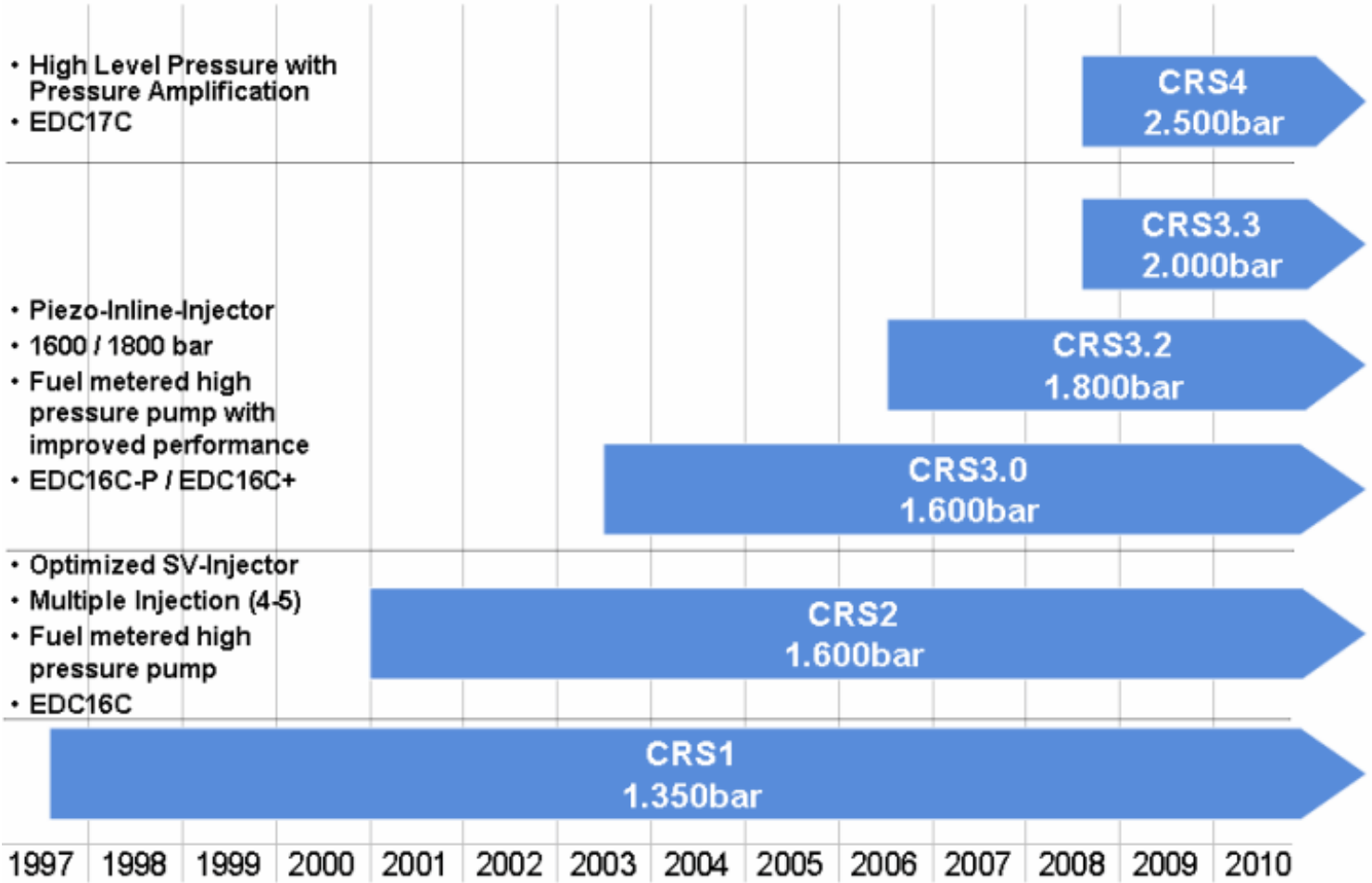
Hydraulically Amplified Diesel Injector (HADI)

Injector-Characteristics

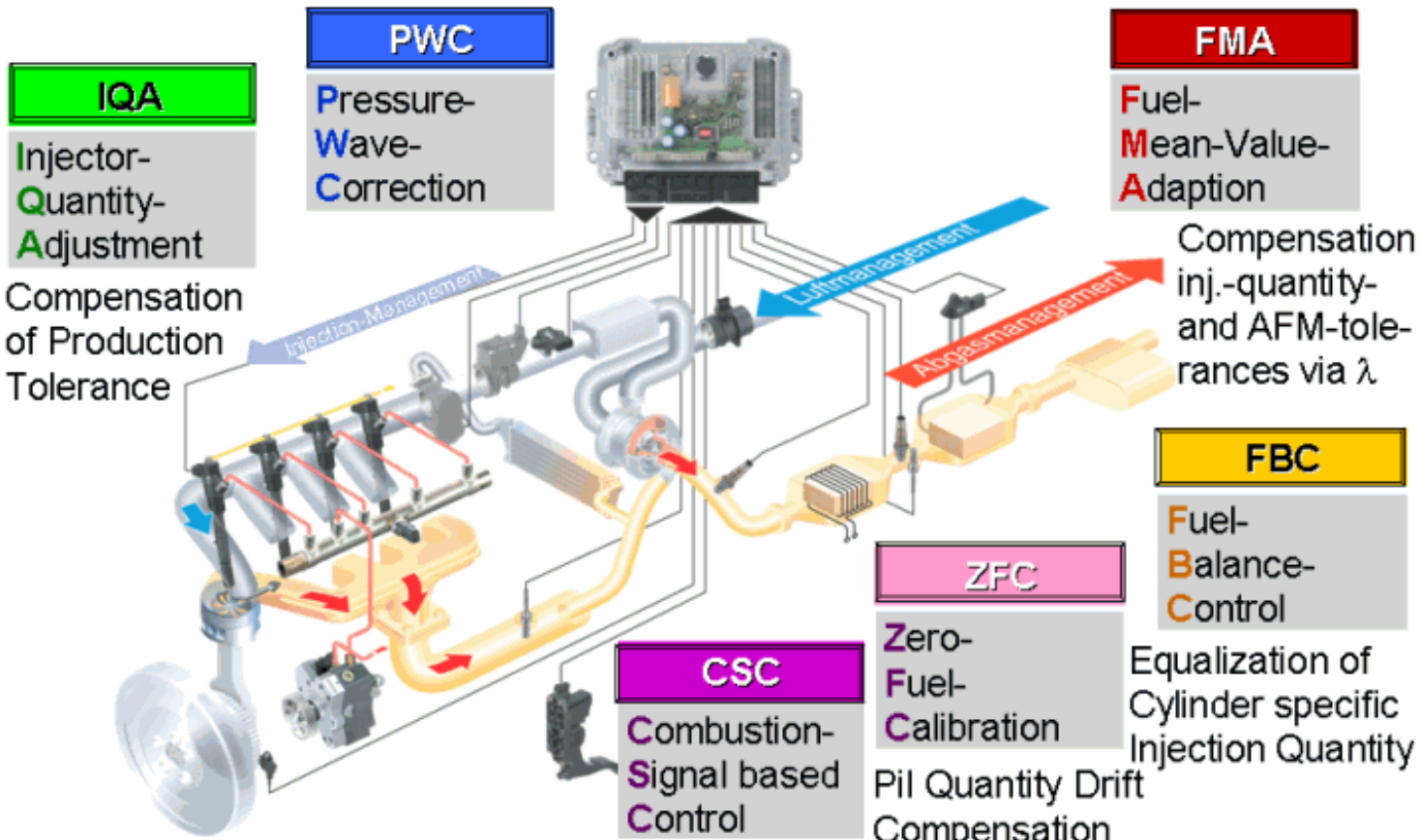
- System pressure up to 1.350bar
- Pressure amplification ≈1:2
- Pressure at the nozzle up to 2.200bar
- Pressure/lift controlled needle
- Ramp rate shape
- Space requirements as CRI2
- Conventional nozzle



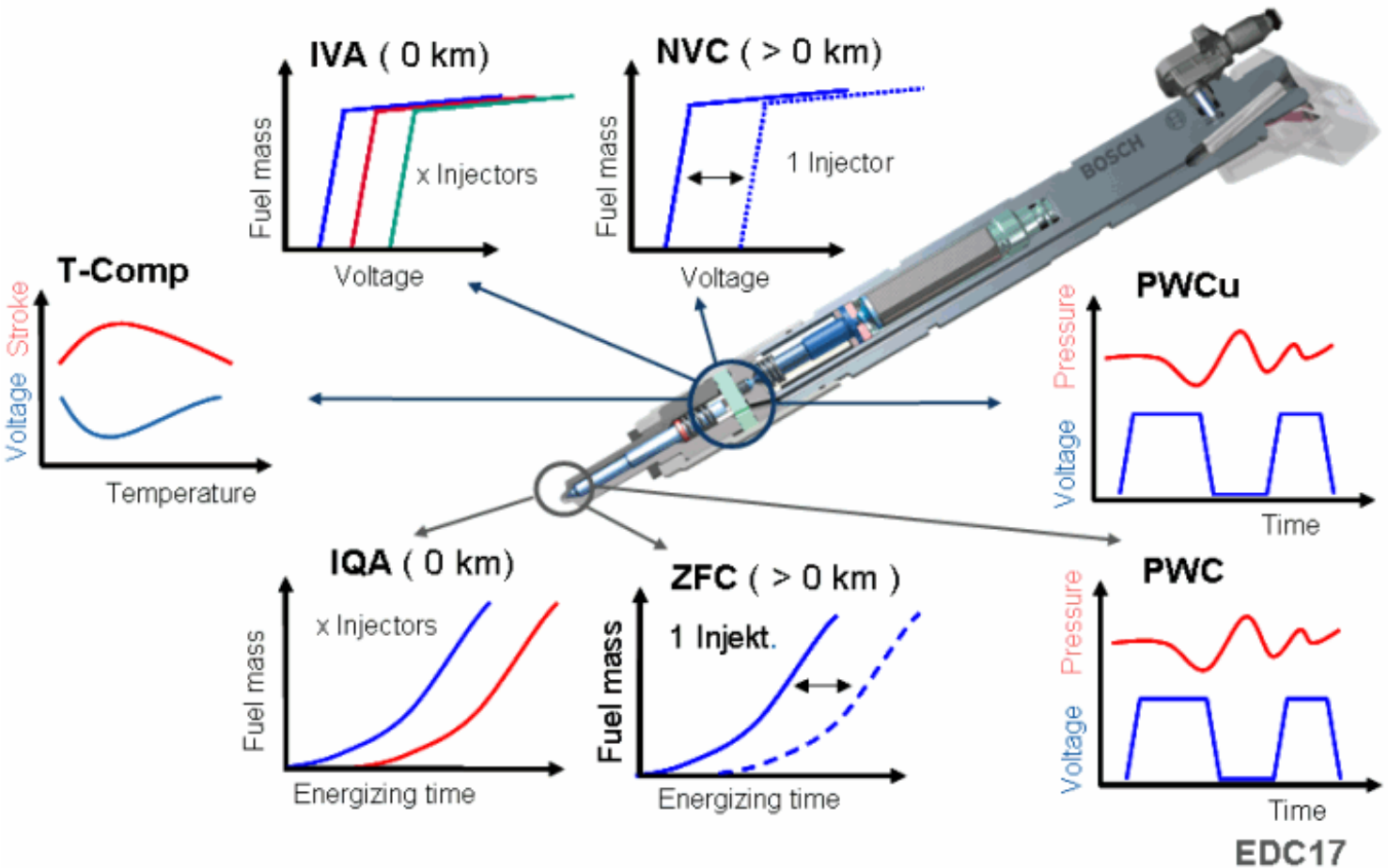
CRS - Roadmap Pkw und Light Duty < 6t



Advanced Control Functions



Advanced Control Functions



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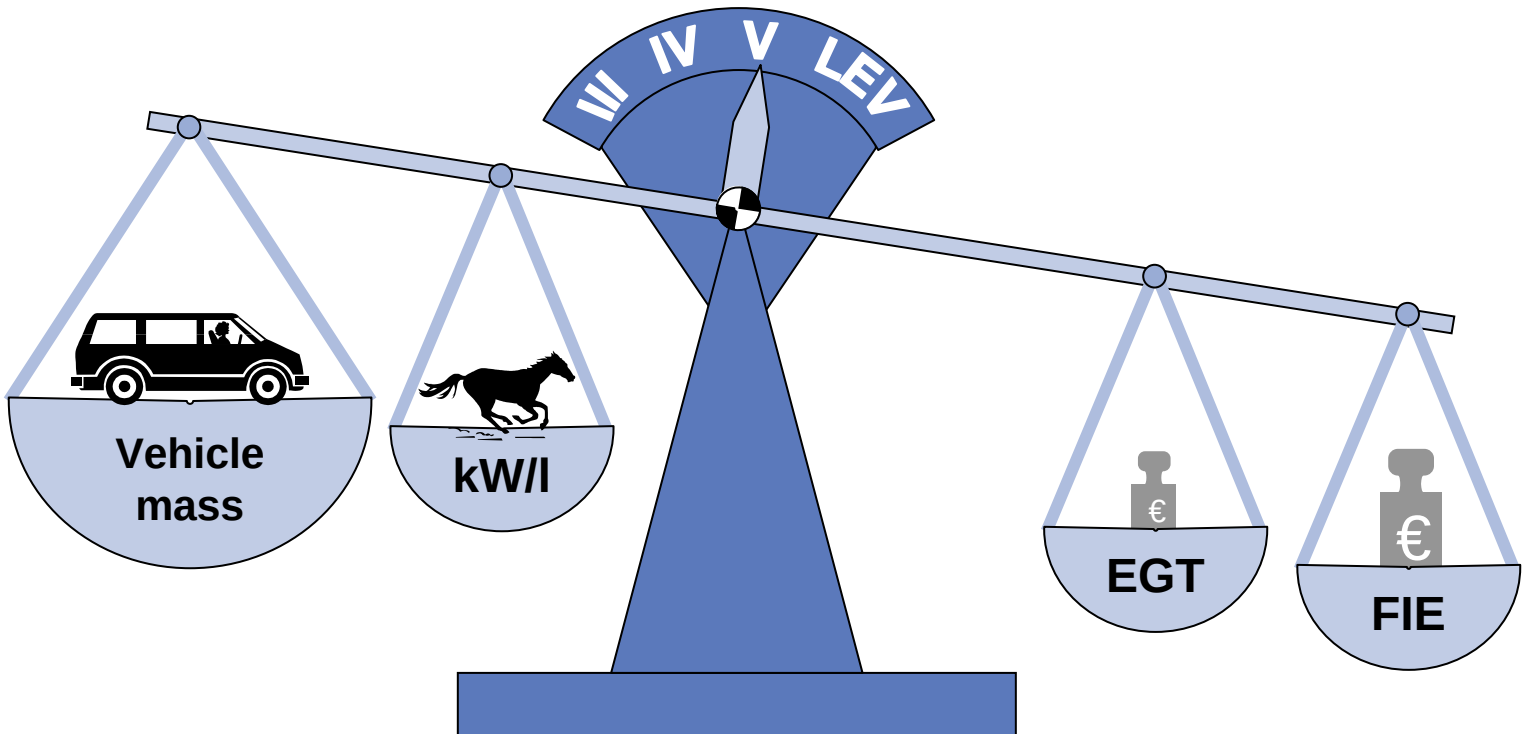
Diesel System Optimization



EGT=exhaust gas treatment FIE= fuel injection equipment

Diesel Challenges - Emission Legislation PC

Europe

- next step in legislation: Euro 5
- NEFZ - cycle *

Scenario 1:

- PM = 0,01 g/km
- NOx = 0,2 g/km
- CO/HC = 1,0/0,05 g/km

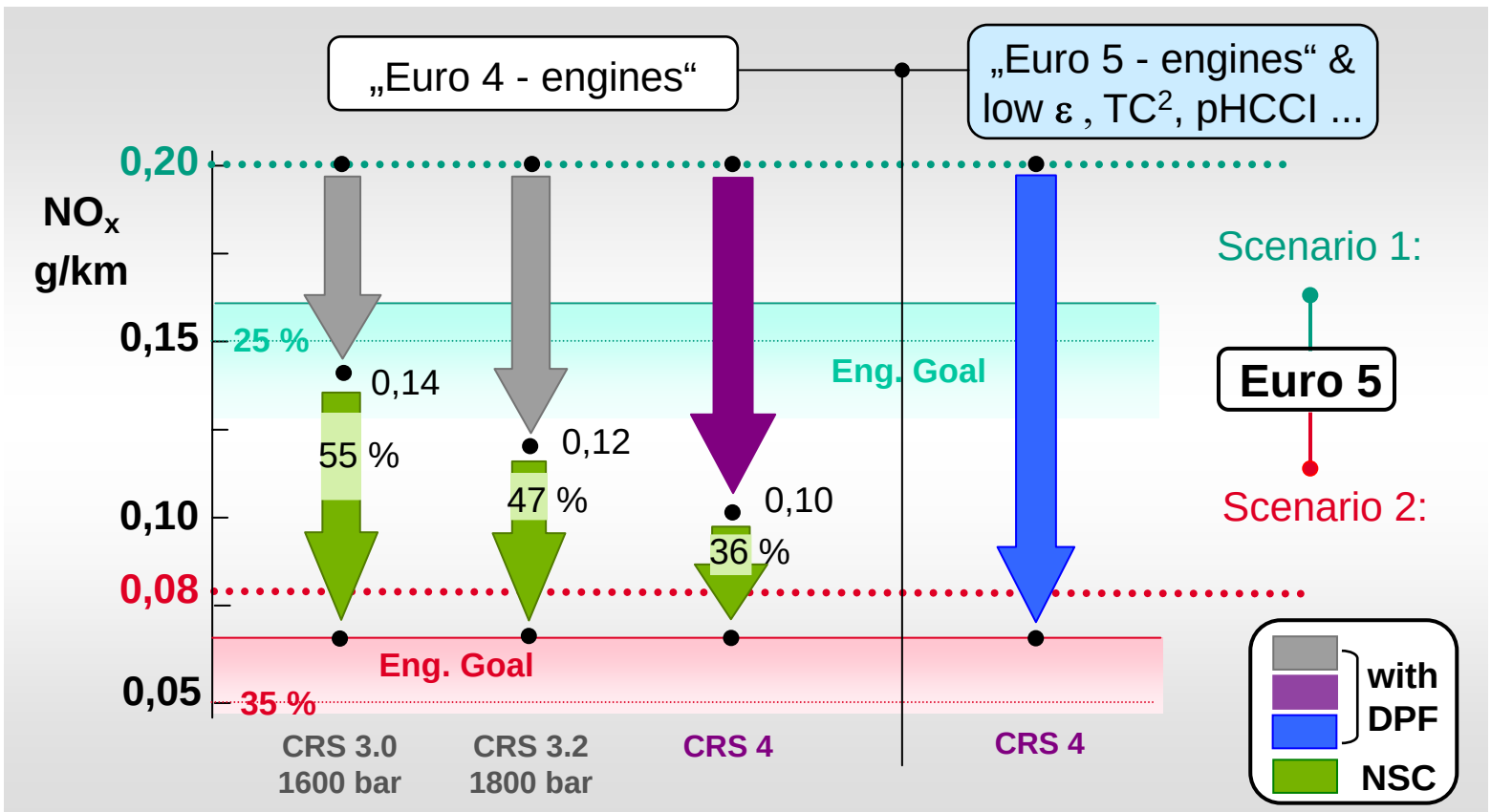
Scenario 2:

- PM = 0,0025 g/km**
- NOx = 0,08 g/km**
- CO/HC = 1,0/0,05 g/km

* no high load test under discussion

** UBA - Requirement 06.2003

Euro 5 Estimation, Vehicle Inertia Mass: 1400 kg,
out of best single cylinder results with series and prototype



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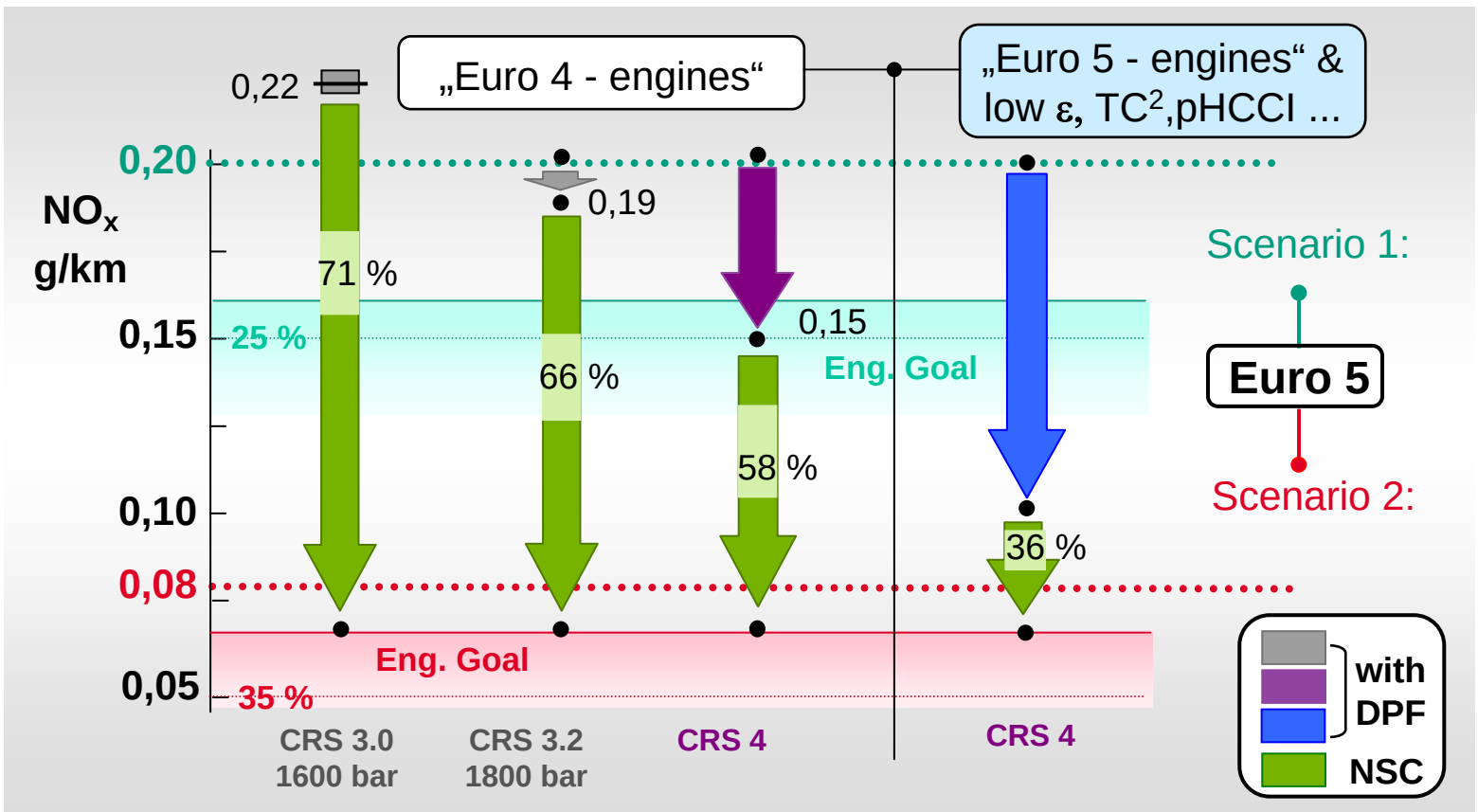
Euro 5 Estimation, Vehicle Inertia Mass: 1800 kg,
out of best single cylinder results with series and prototype



Summary PC

- Additonal EGT - effort scales with CRS - performance, vehicle weight and desired power output
- Facing a weak Euro 5 - scenario (NOx = 0,2 g/km) it‘s most likely to fulfill the limits w/o DeNOx - measures, also with „Euro 4 - engines“
- Facing a severe Euro 5 - scenario (NOx = 0,08 g/km) and „Euro 4 - engines“ a DeNOx - measure seems to be mandatory. The DeNOx - effort can significantly be reduced using high tech CR - systems
- First results out of advanced „Euro 5 - engine“ - technology combined with engine measures (e.g. pHCCI, TC^2) and CRS4 - FIE shows tremendeous improvement in NOx - reduction

Conclusion

- The biggest challenge for future Diesel technology are the continiously strengthenend emission targets
- Key factors like power output, vehicle weight and the engine itself scaling the effort on exhaust gas treatment side
- 4th Gen Common Rail Injection Systems combinded with modern Diesel engines provide lowest raw emissions and fuel consumption values.

Thank you for your attention.

BOSCH