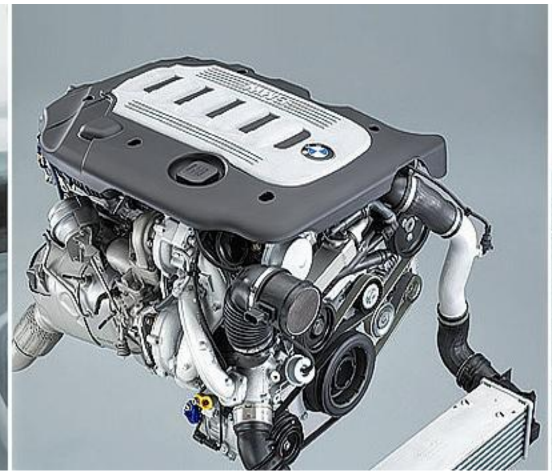
BMW Diesel.

13th DEER Conference, 13-16th August 2007 Detroit



The BMW Approach to Tier2 Bin5

Wolfgang Mattes

BMW Group

BMW Diesel.
Contents.

- Challenges in the US market
- Tier2 Bin5 Concept
  → Internal Engine Measures
  → Aftertreatment: SCR System
  → OBD
- Summary

BMW Diesel.
Challenges in the US-Market.

- **Stringent emission legislation**
  → limits and test-procedures
- **High requirements to OBD**
  → new engine control functions
- **Intensified climatic edge conditions**
  → altitude up to 4000 m
- **Customer expectations**
  → noise, vibrations, harshness
- **Various fuel quality with large dispersions**
  → combustion noise, driveability

→ New technologies are necessary
→ Robust, sustainable solutions are required

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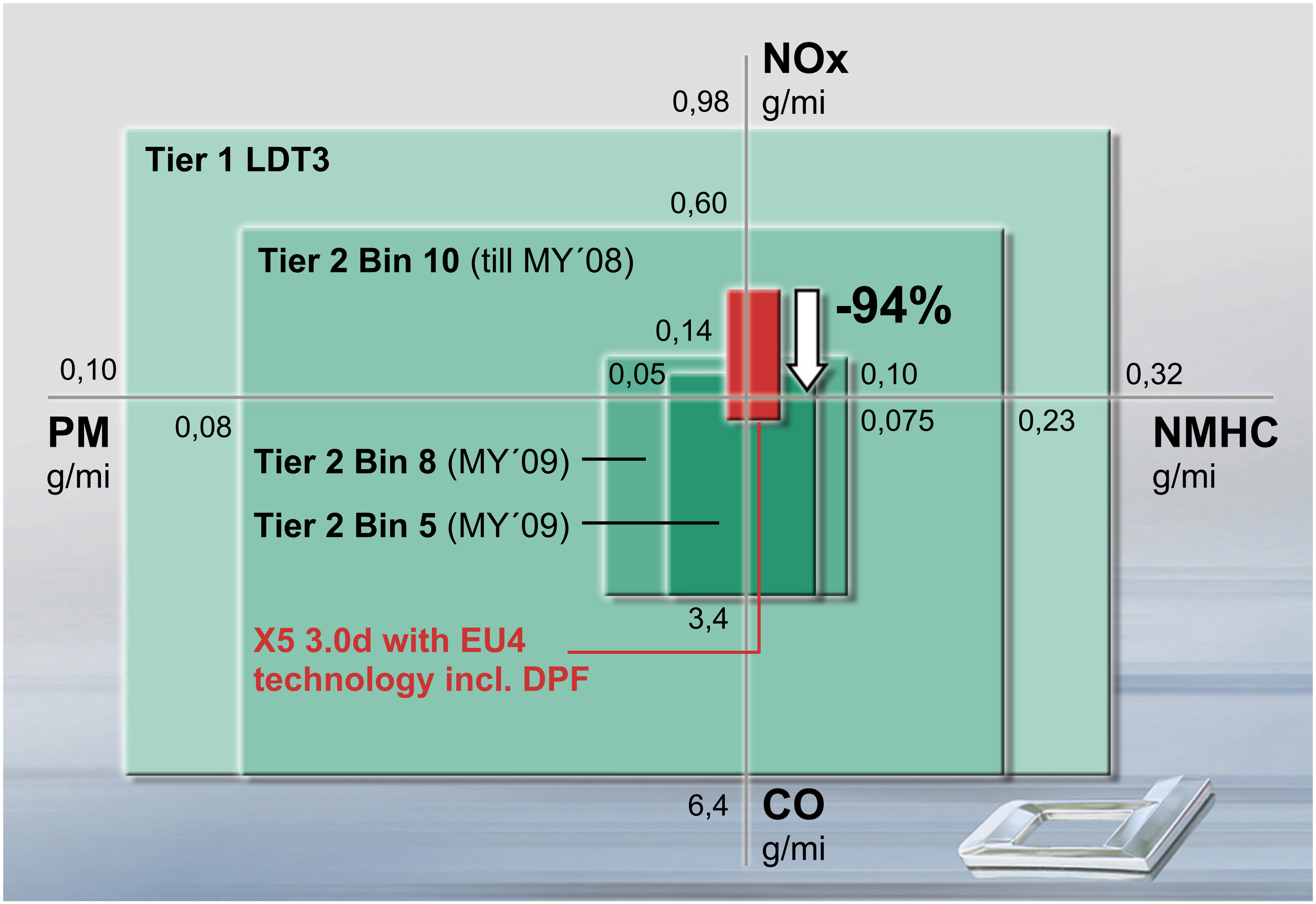
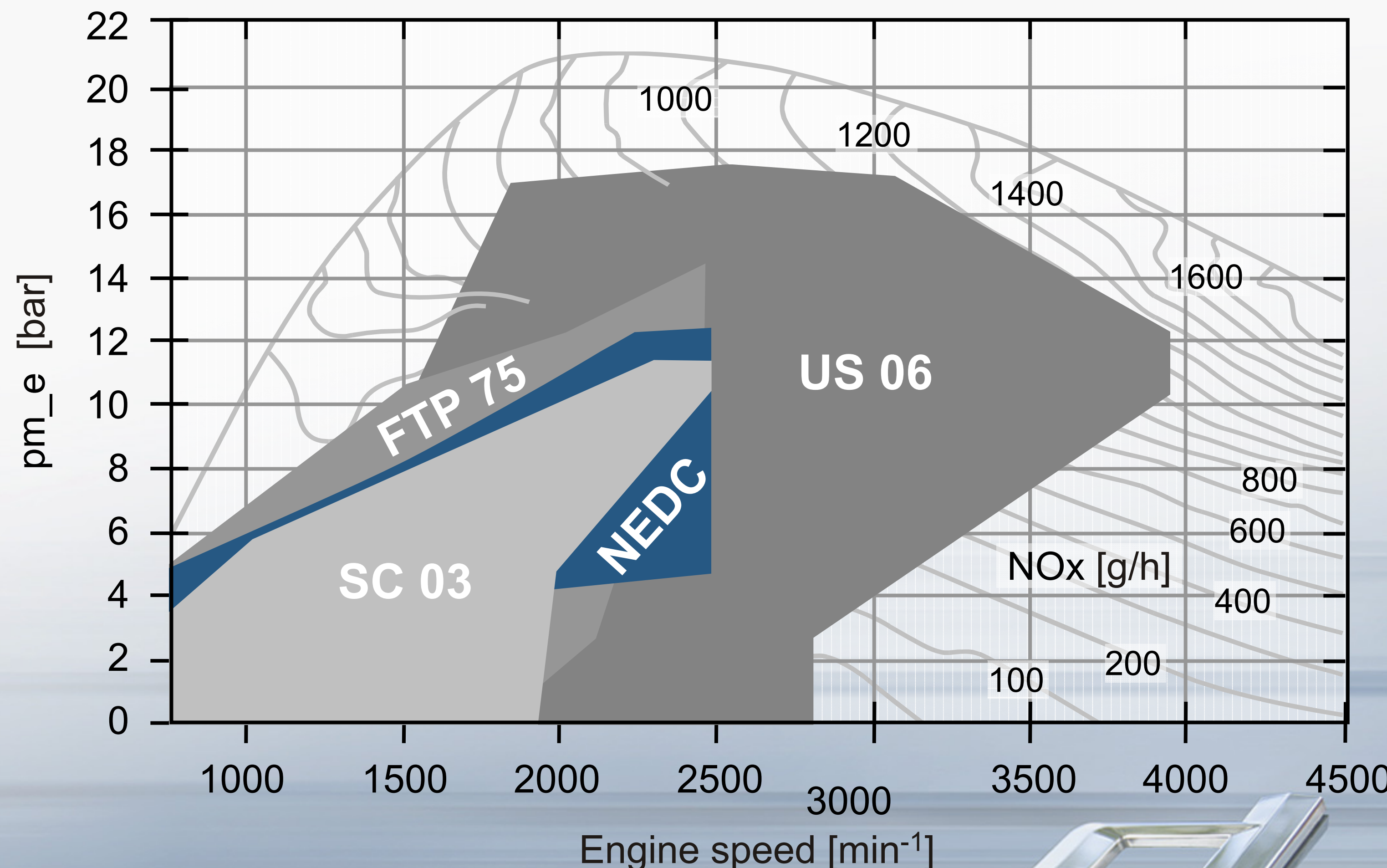
BMW Diesel.
NOx Challenge BIN 5.



BMW Diesel.
Test cycles.



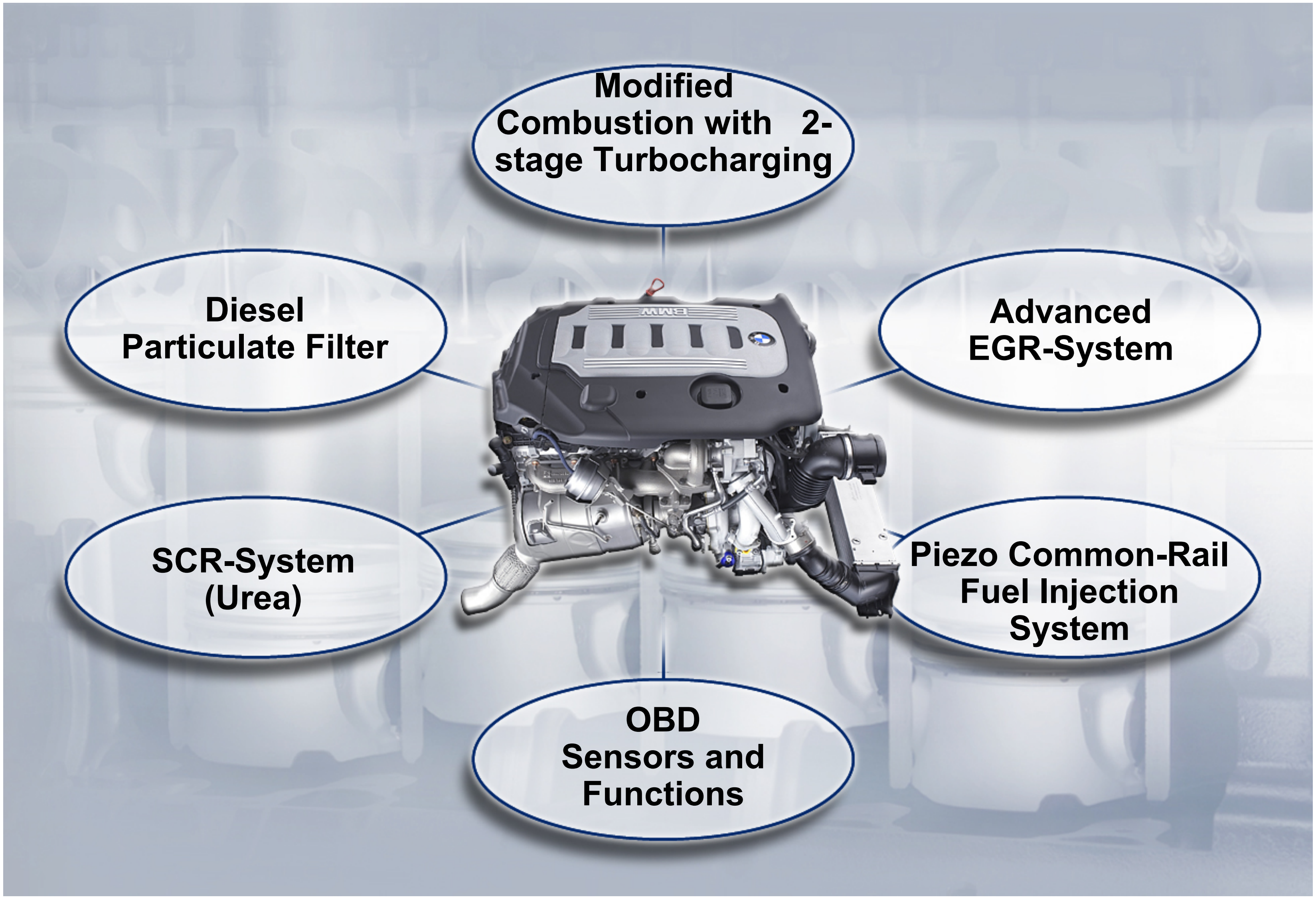
BMW Diesel.
Targets for BMW US Diesel.

- **BMW typical fun to drive**
- **Fulfill 50 state legislations (→ Tier2 Bin5)**
- **BMW Diesel Strengths:**
  - **Low fuel-consumption**

    → 20-30% below comparable petrol cars
    → cost saving, sometimes supported by low fuel costs
    → high cruising range
  - **Fun to drive, outstanding torque characteristics**

    → relaxed cruising
    → torque on demand
    → good NVH due to low engine speed

BMW Diesel.
TIER2 BIN5 Concept.



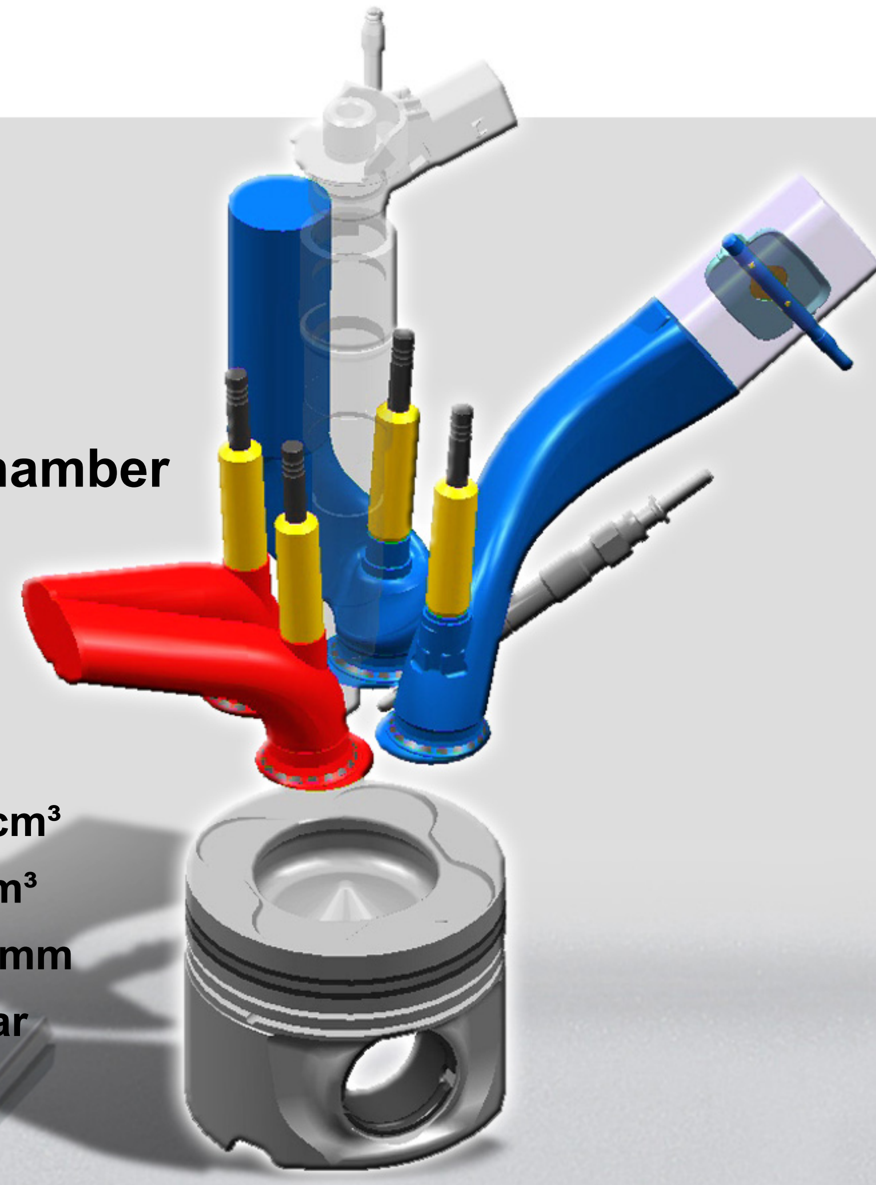
BMW Diesel.
Combustion.

→ Central injector position

→ 4 valves per cylinder

→ Symetrical combustion chamber

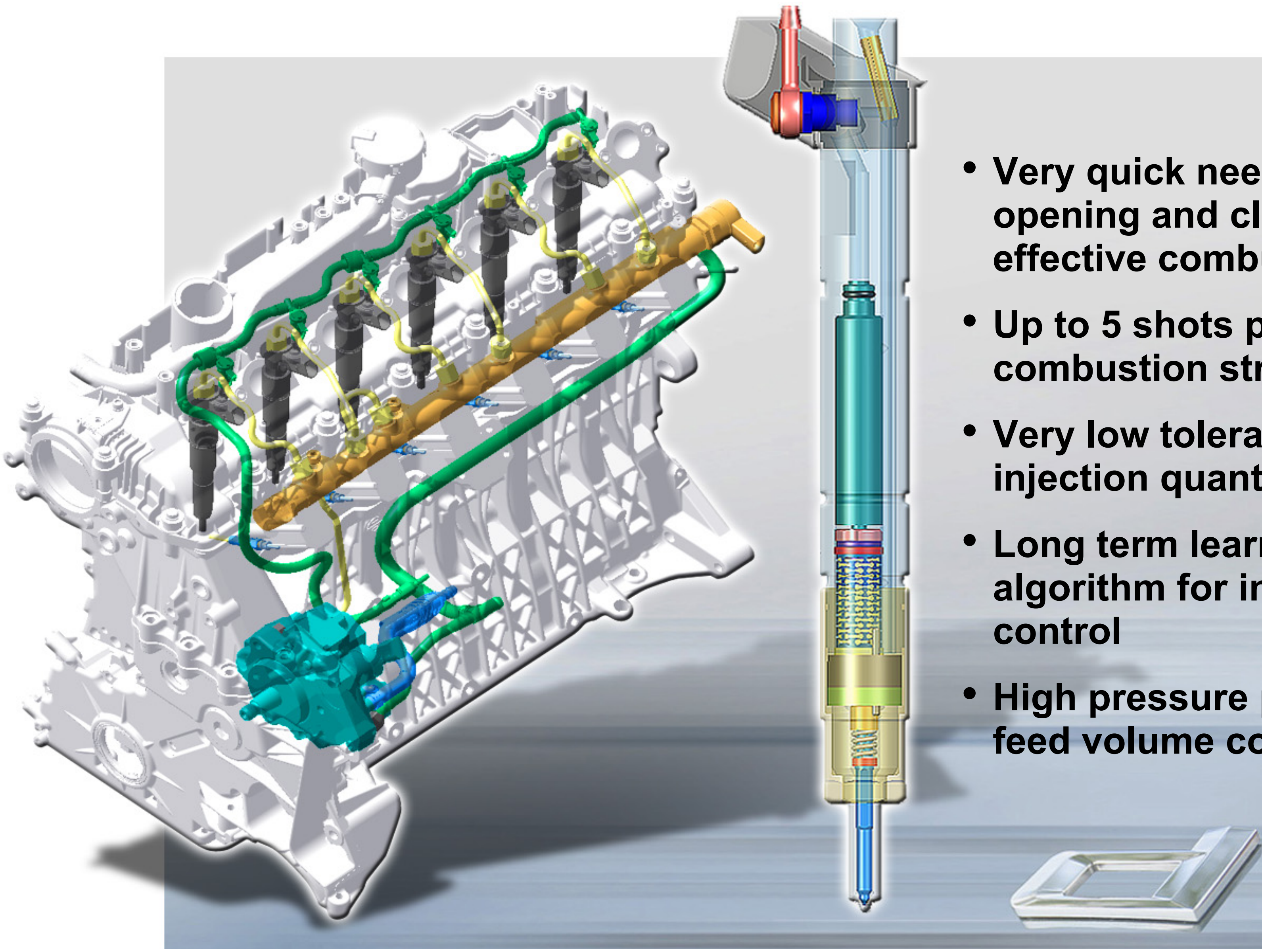
→ Variable air control



Inline 6.	
Displacement	**2992 cm^3**
Single Cylinder Displ.	**499 cm^3**
Bore / Stroke	**84/90 mm**
Max. Combustion Pressure	**180 bar**

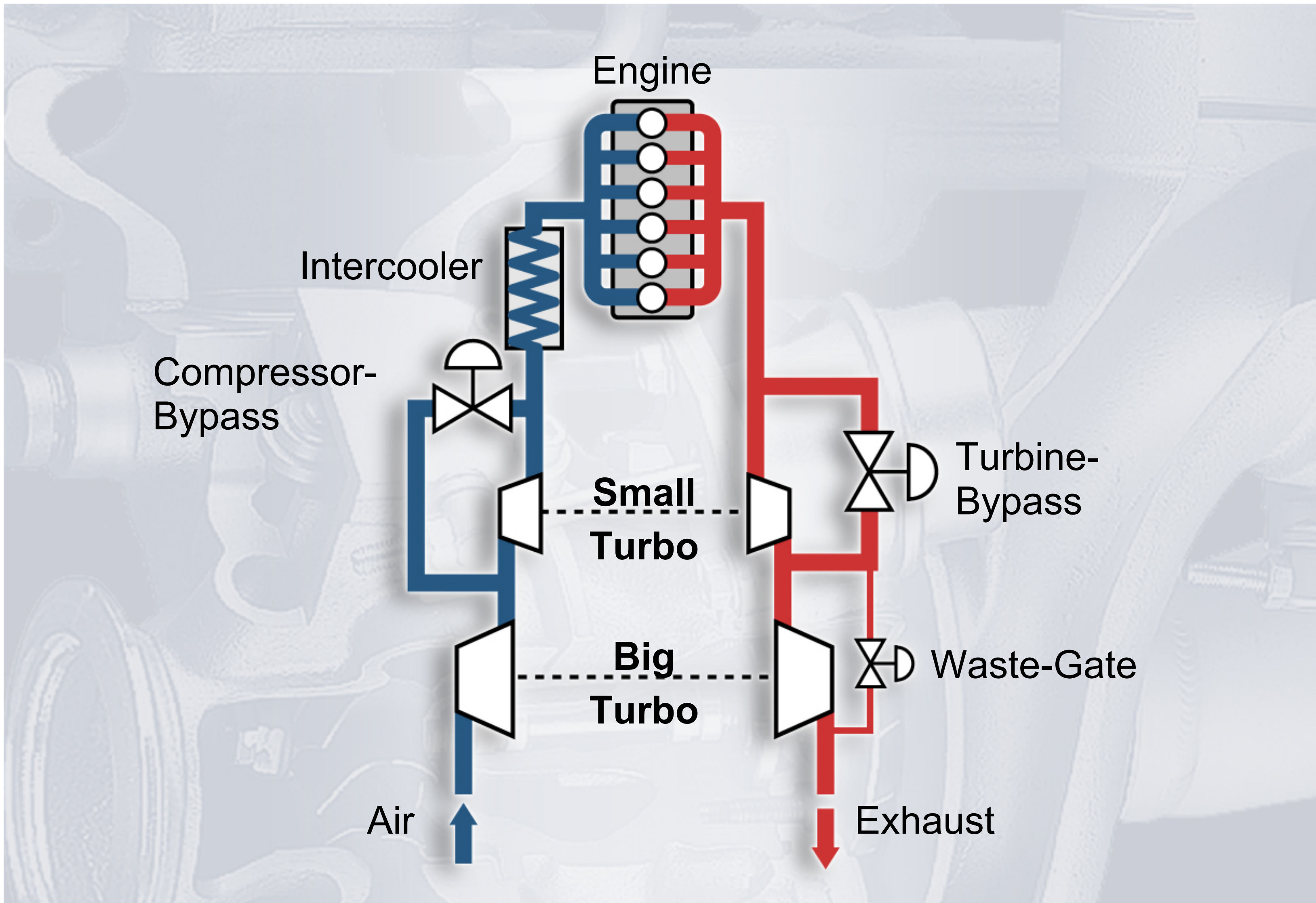
BMW Diesel.

Piezo Common-Rail System.

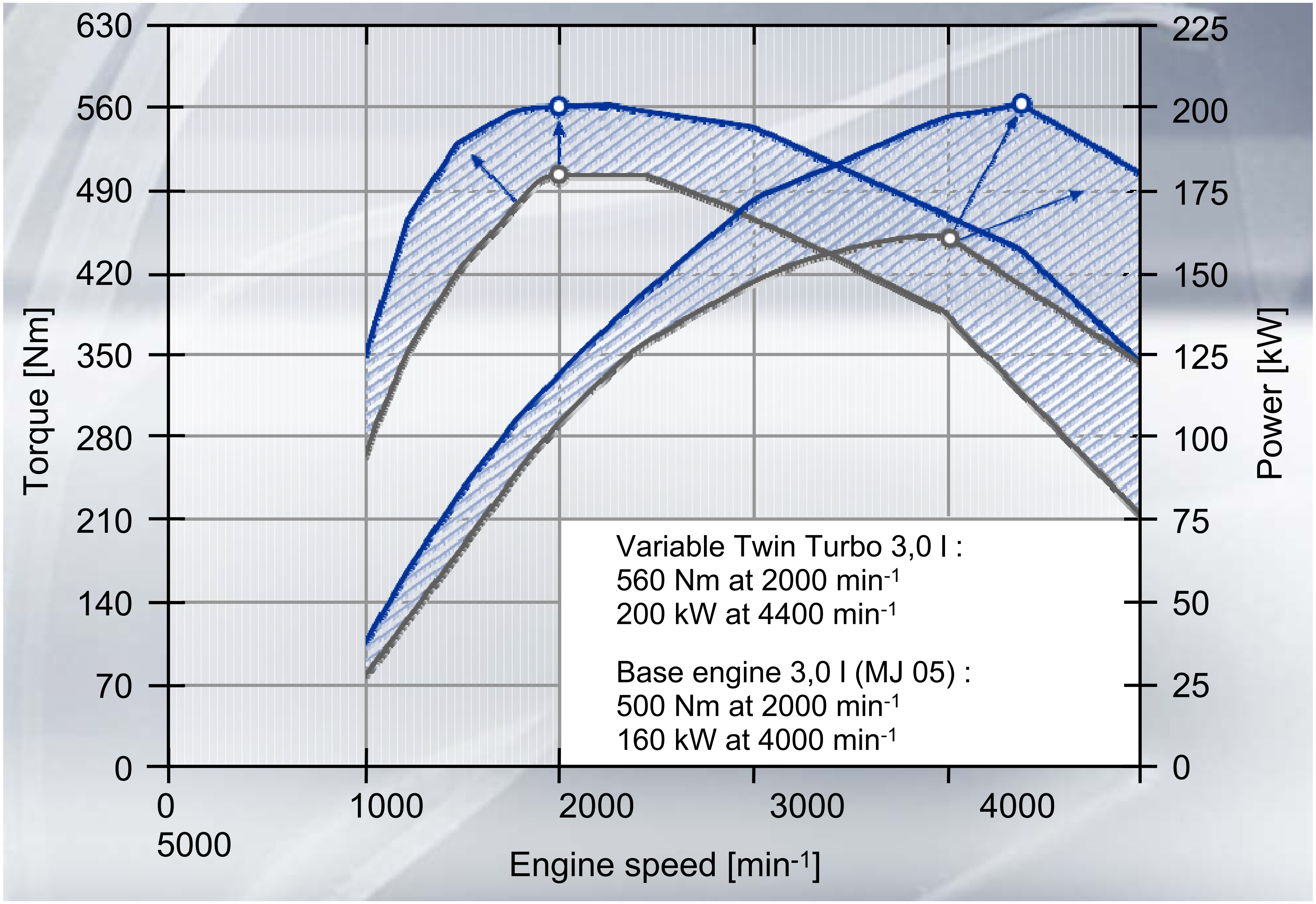


- Very quick needle opening and closing for effective combustion
- Up to 5 shots per combustion stroke
- Very low tolerances of injection quantities
- Long term learn-algorithm for injection control
- High pressure pump with feed volume control

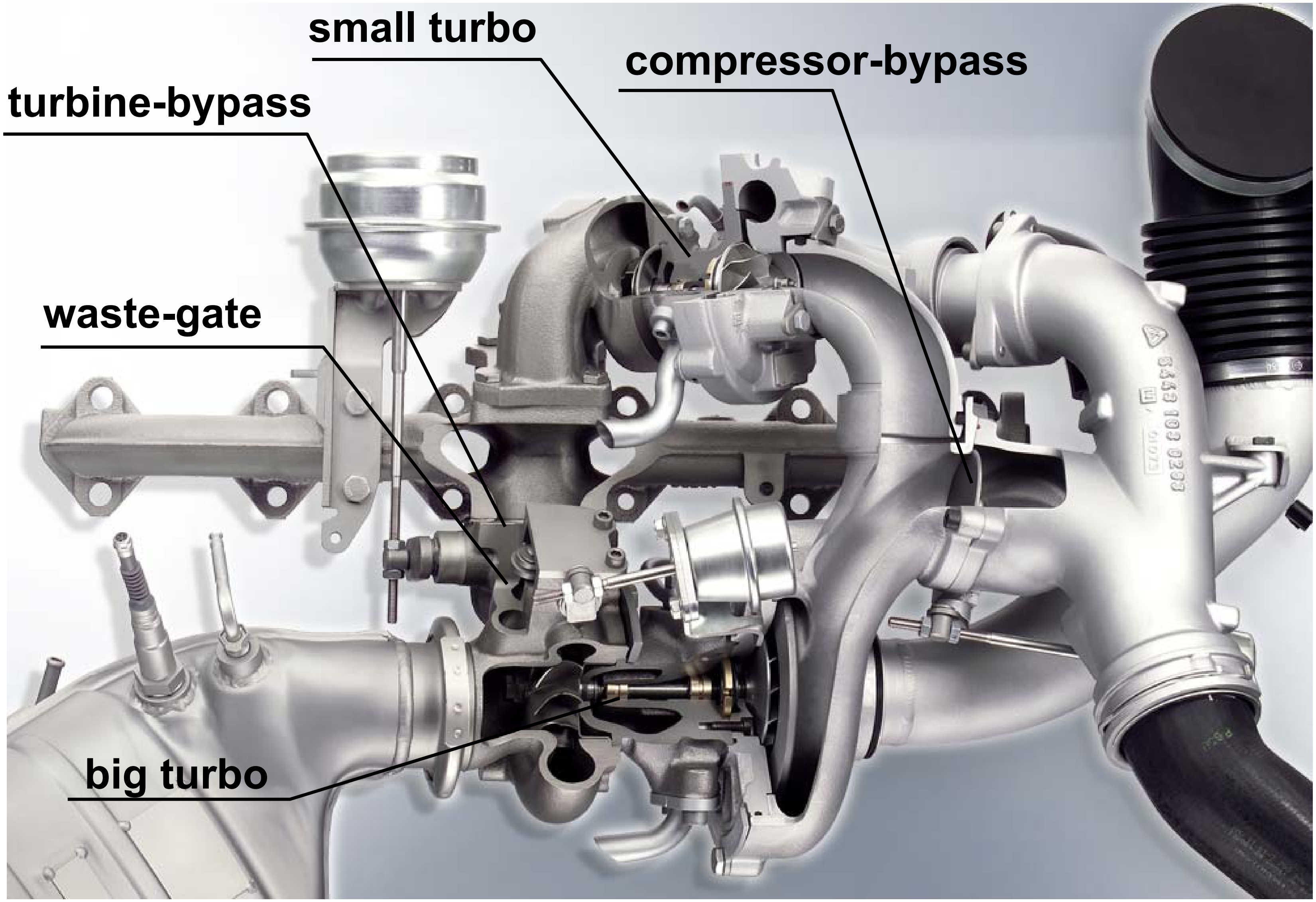
BMW Diesel.
2-Stage Turbocharger (Variable Twin Turbo).



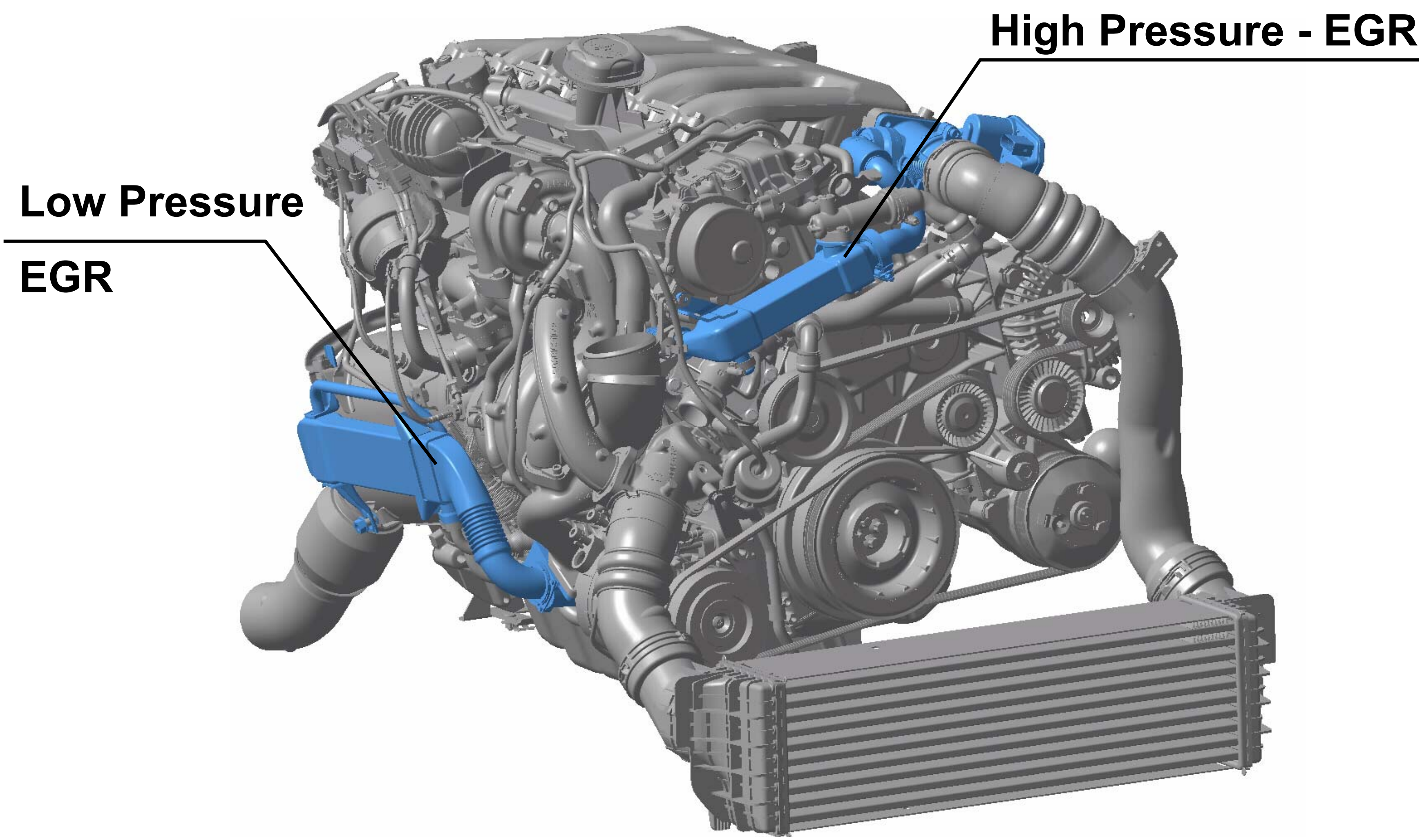
BMW Diesel.
Variable Twin Turbo – even more powerfull.



BMW Diesel.
Variable Twin Turbo – compact design.



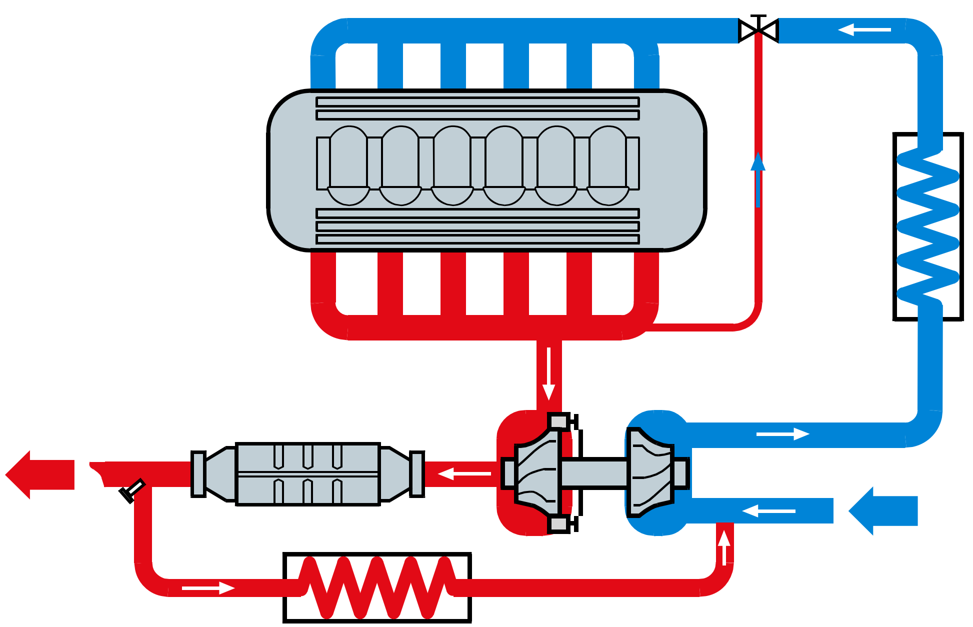
BMW Diesel.
EGR-System.

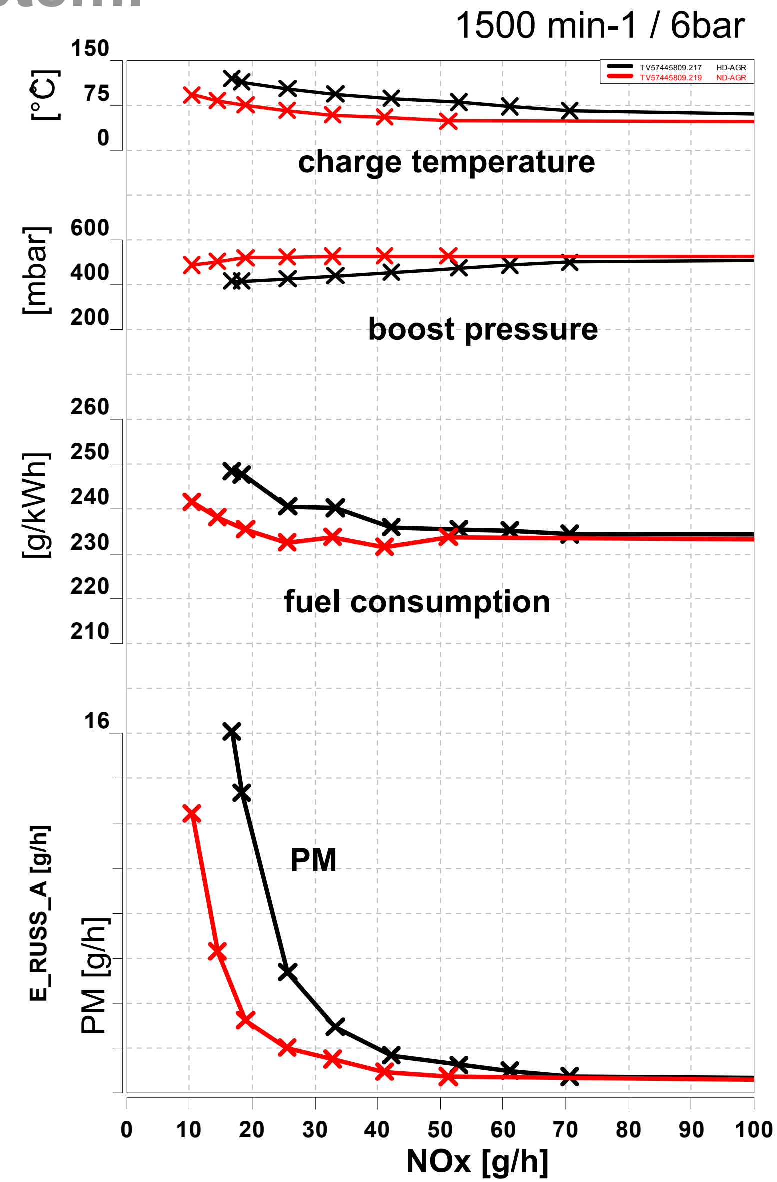


BMW Diesel.
Low Pressure EGR-System.

Effect of Low Pressure EGR:

- Reduced charge temperature
- Higher boost pressure (efficiency turbocharger)
- Better fuel economy
- 30% NOx-advantage

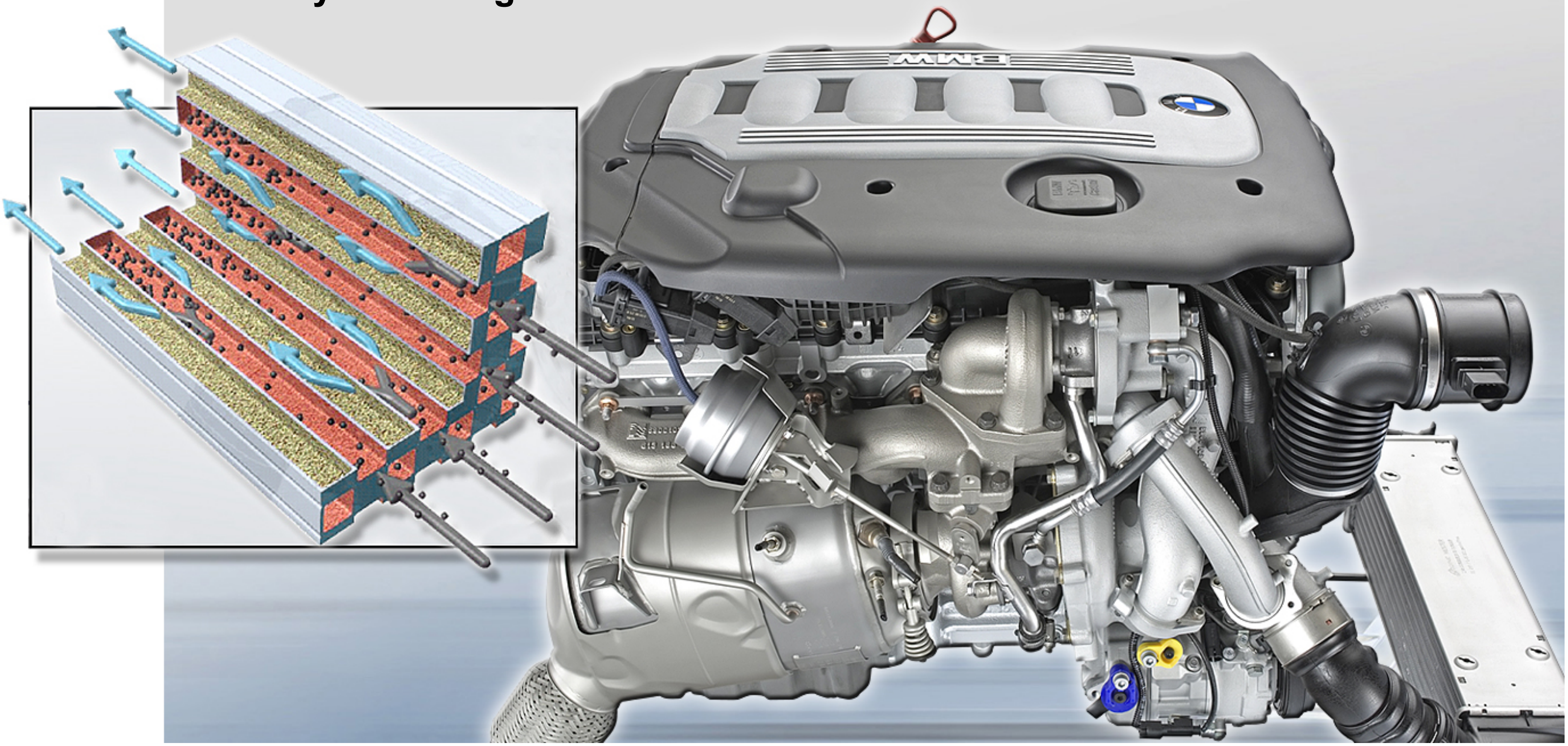




BMW Diesel.
Closed Coupled Particulate Filter.

Particles are filtered and burnt off in the ceramic filter with its catalytic coating.

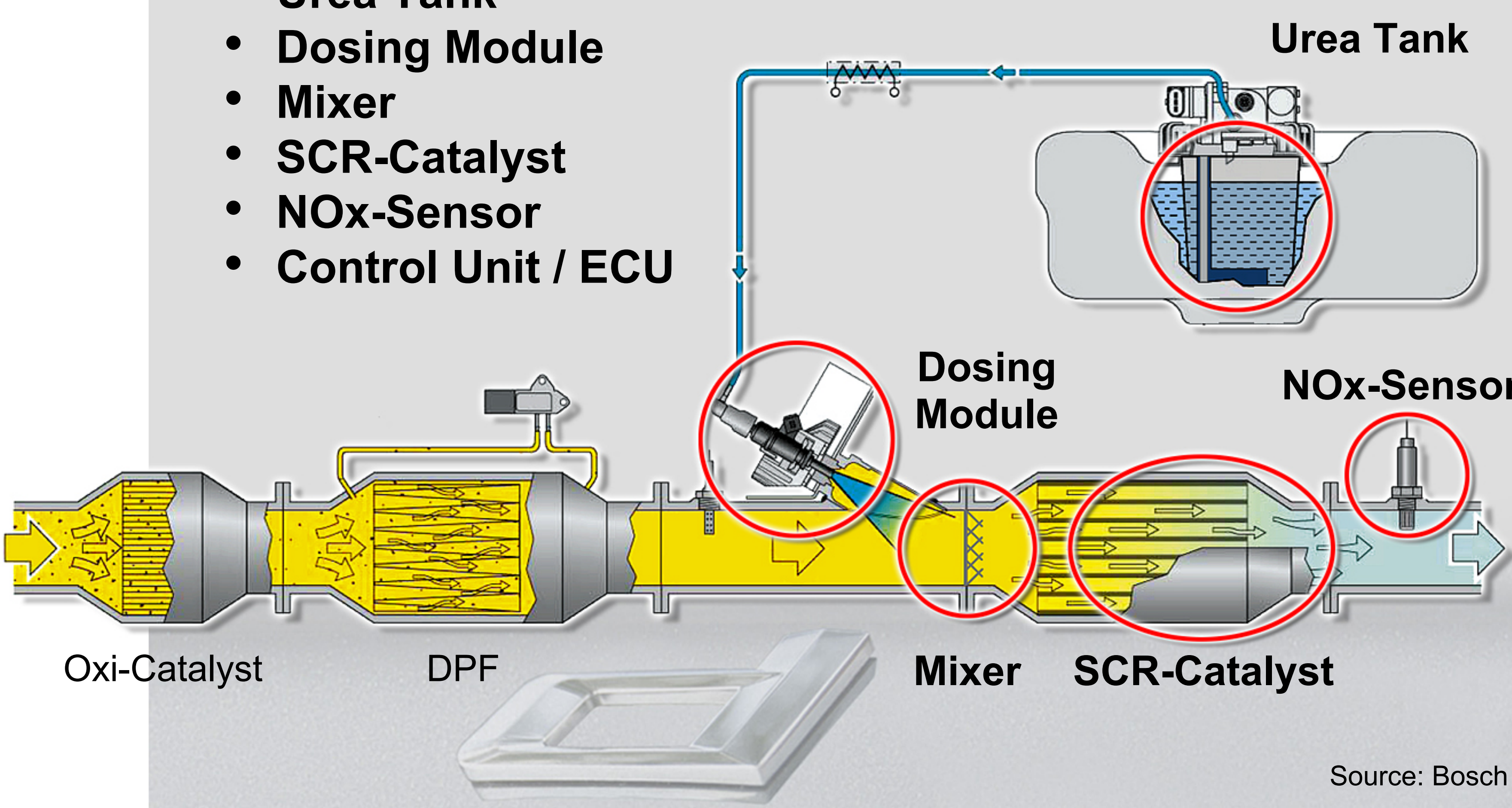
- ➔ **No power loss (low flow resistance)**
- ➔ **No significant increase in FC**
- ➔ **Reduced HC/CO-emissions**
- ➔ **Reduced system effort**



BMW Diesel.
SCR System Overview.

Core Components:

- Urea Tank
- Dosing Module
- Mixer
- SCR-Catalyst
- NOx-Sensor
- Control Unit / ECU



Source: Bosch

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SCR – Chemical Reactions.

Reduction

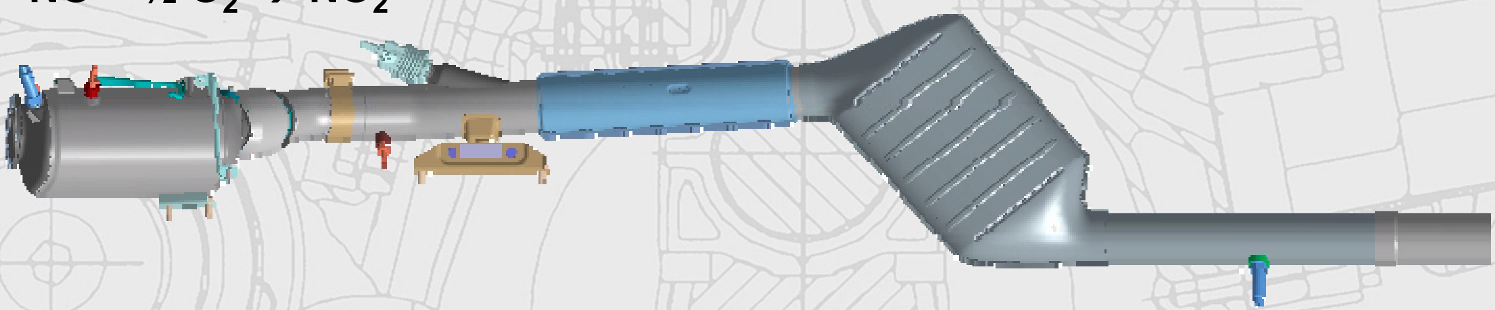
$NO + NO_2 + 2\,NH_3 \rightarrow 2\,N_2 + 3\,H_2O$

$4\,NO + O_2 + 4\,NH_3 \rightarrow 4\,N_2 + 6\,H_2O$

$6\,NO_2 + 8\,NH_3 \rightarrow 7\,N_2 + 12\,H_2O$

Oxidation

$NO + \frac{1}{2}\,O_2 \rightarrow NO_2$



$(NH_2)_2CO \rightarrow NH_3 + HNCO$ **Thermolysis**

$HNCO + H_2O \rightarrow NH_3 + CO_2$ **Hydrolysis**

BMW Diesel.
CFD-Simulation of NH_3-Distribution.

Targets

- Improve Ammonia distribution → maximum conversion
- Reduce Ammonia slip, because of overloaded catalyst cells
- Best possible usage of mixing element
- Analysis of pressure drop and optimisation

Modelling Approach

- Transient CFD Simulation with StarCD
- Two component droplets (water, urea)
- Spray break-up and wall interaction
- Turbulenz modelling: k-ε RNG
- Modelling of wall film

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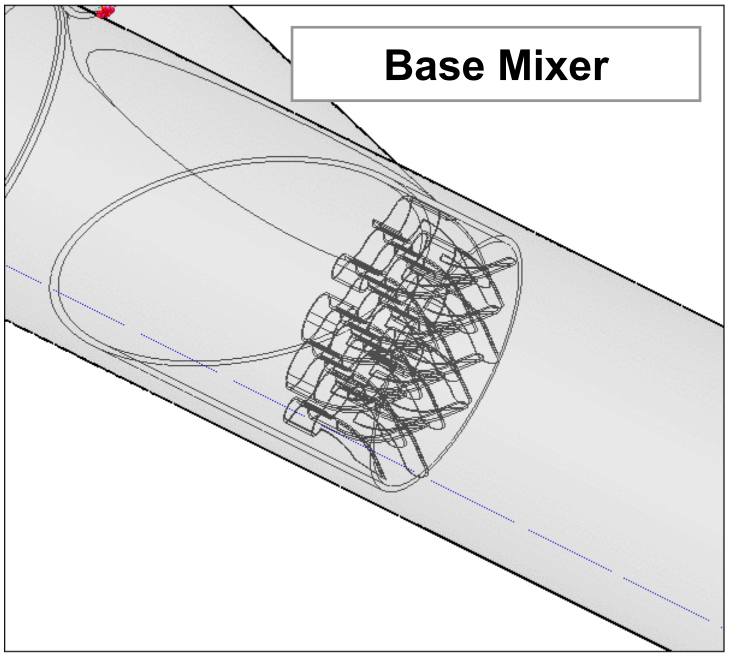
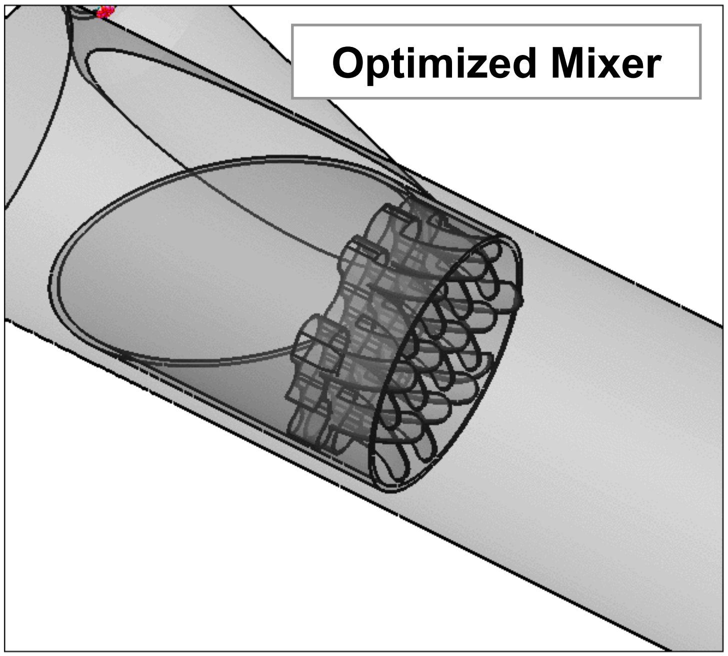
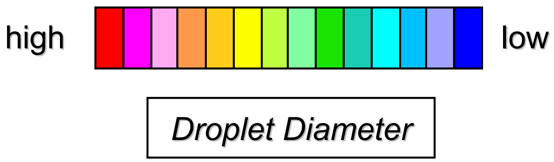
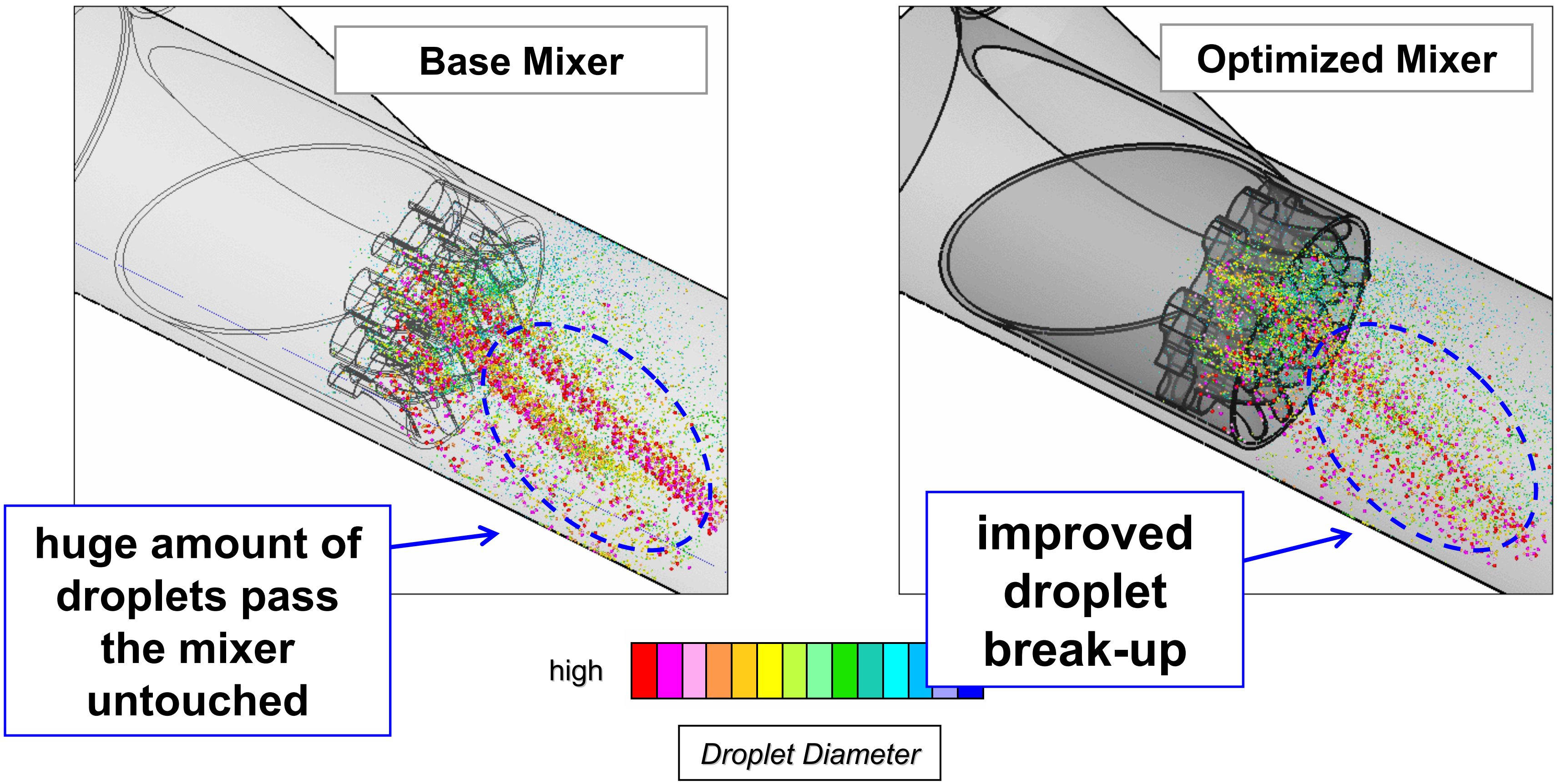
BMW Diesel.
Droplet Distribution.



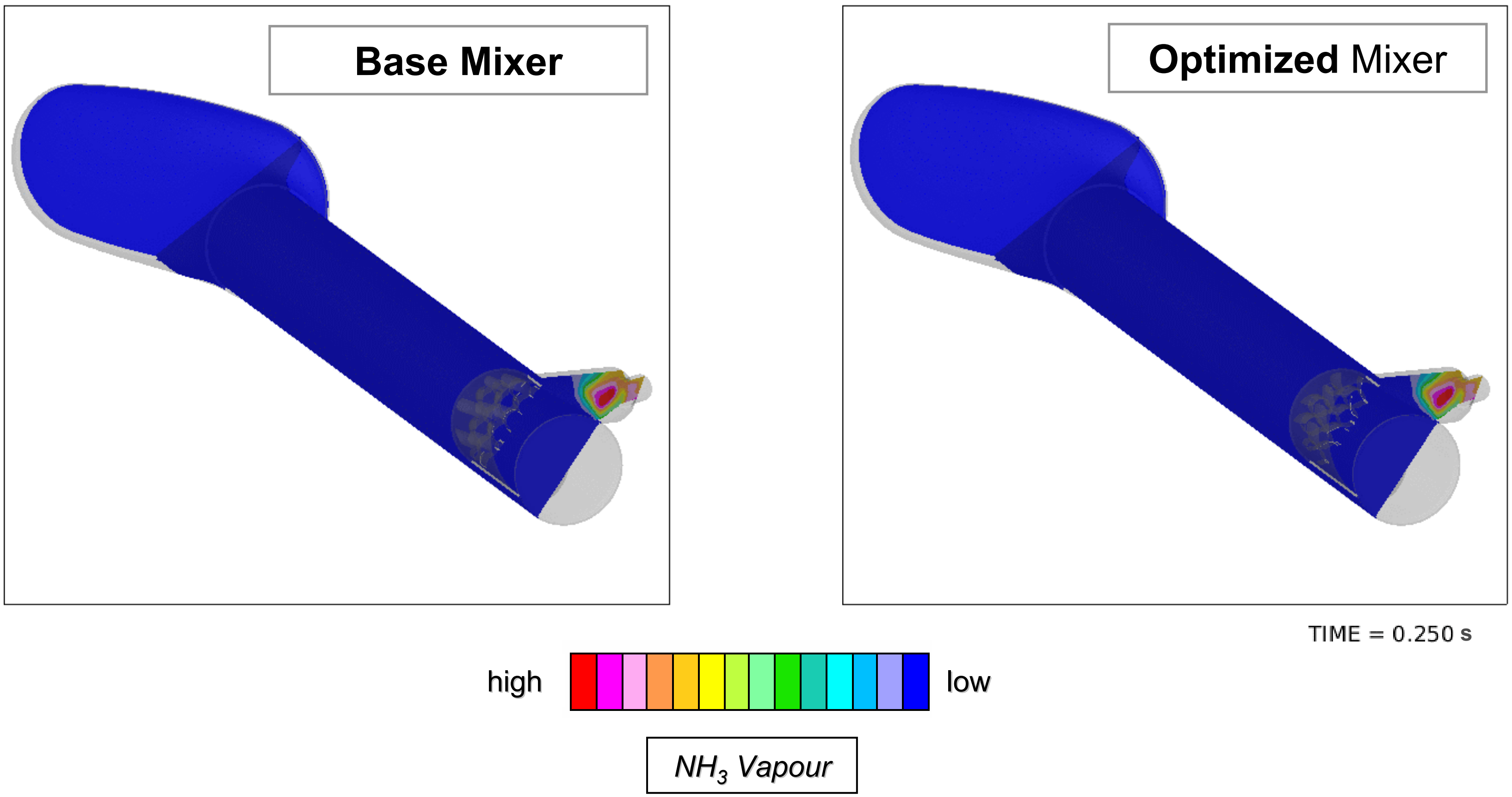




BMW Diesel.
Droplet Distribution.



BMW Diesel.
NH_3-Vapour Distribution.



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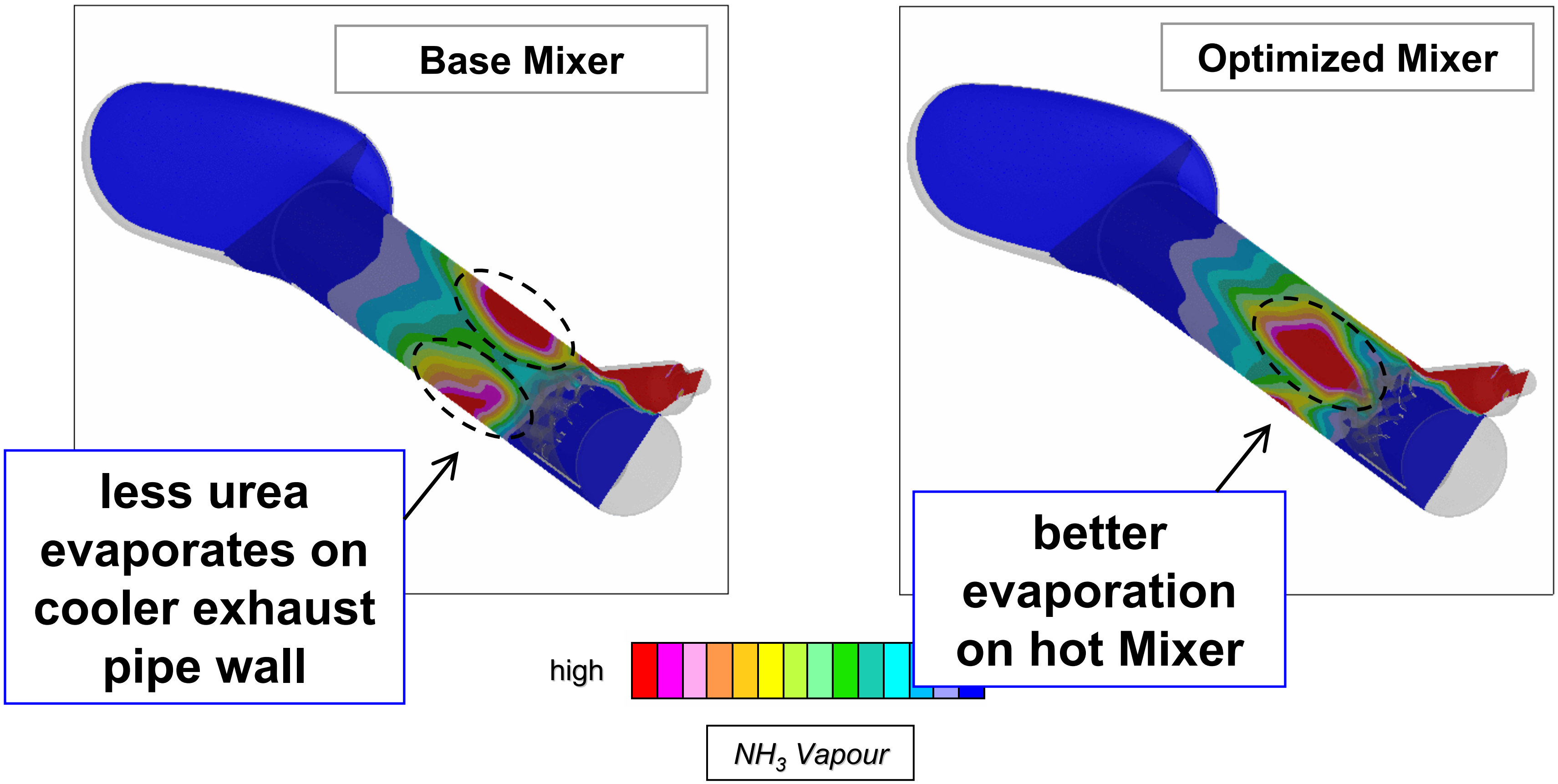
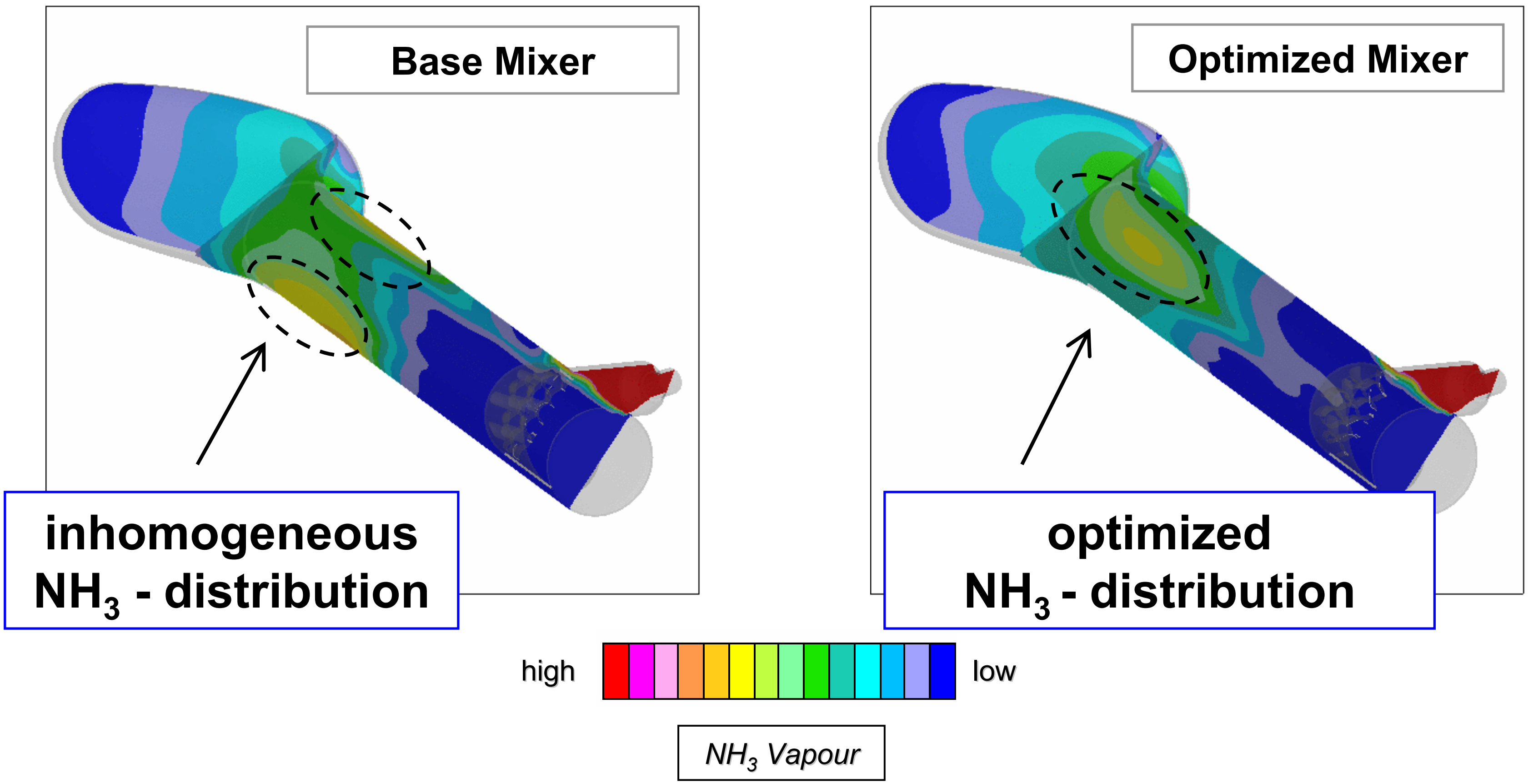
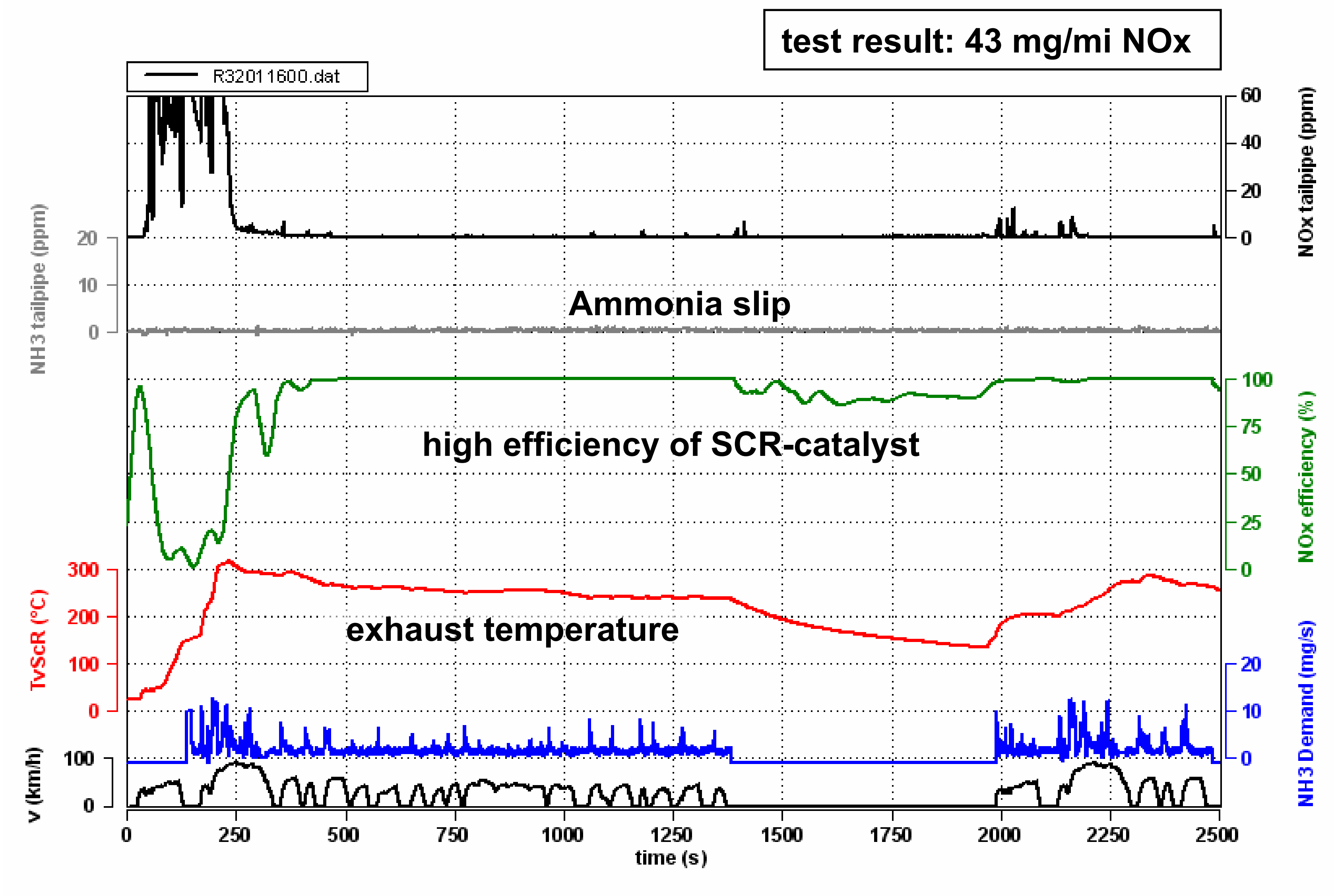
NH_3-Vapour Distribution.



BMW Diesel.
NH_3-Vapour Distribution.



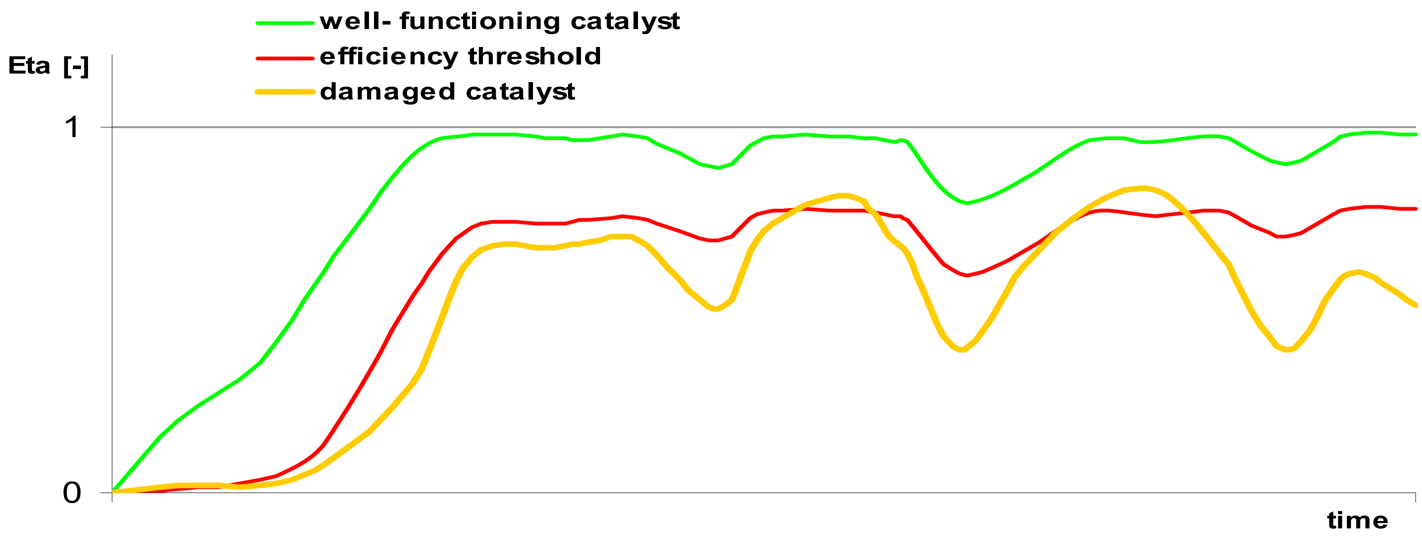
BMW Diesel.
NOx-Conversion @ FTP 75.



BMW Diesel.
OBD Monitoring Concept of SCR-System.

SCR-Catalyst Monitoring

→ NOx converting efficiency of the SCR-catalyst is calculated using downstream and upstream NOx-concentration



$$\eta = 1 - \frac{\int NO_{x\ downstream}}{\int NO_{x\ upstream}}$$

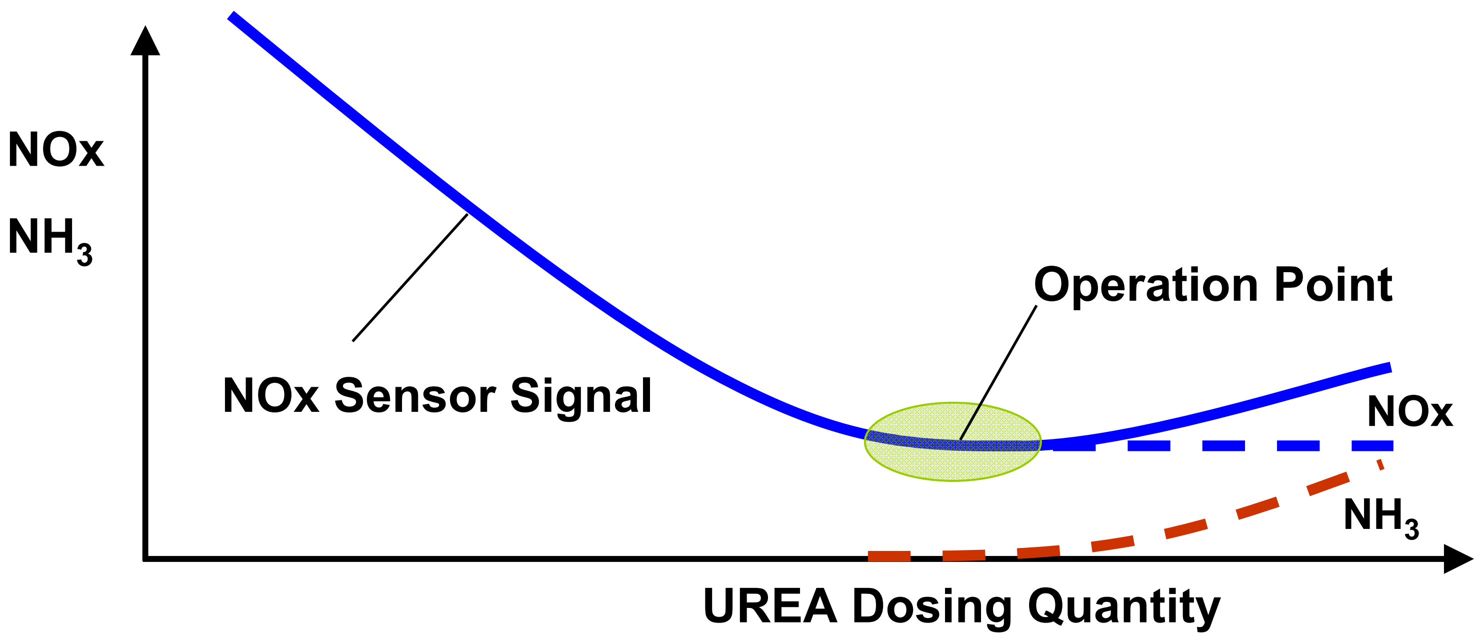
NOx-sensor tolerances are very important !

BMW Diesel.
OBD Monitoring Concept of SCR-System.

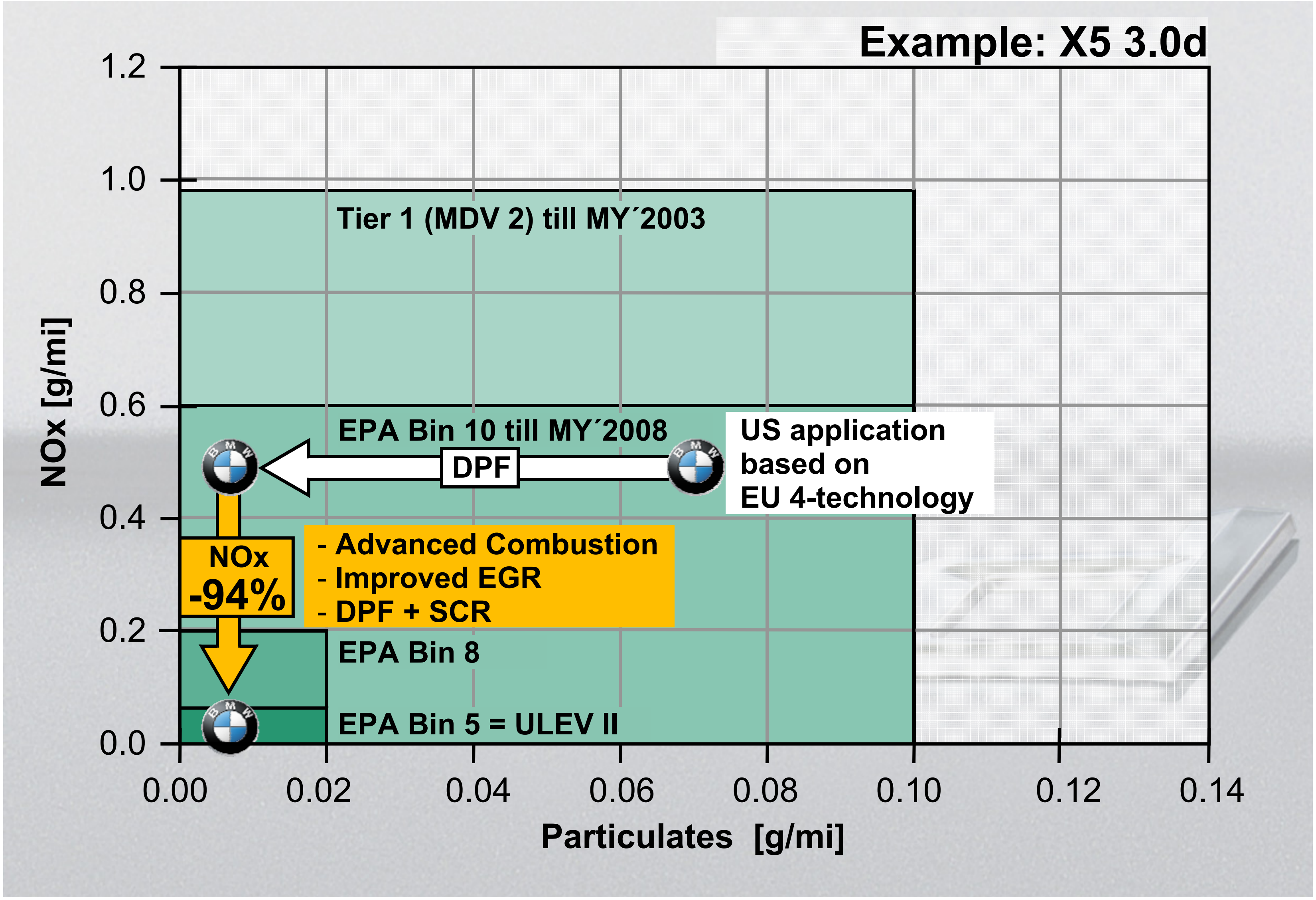
Monitoring of Dosing / Long Term Adaptation of the System

→ Deviation from optimum converting efficiency is detected by NOx-sensor and adaptation is carried out

- Ammonia cross sensitivity of the sensor is used
- Progression of signal curve is elementary to keep the optimum



BMW Diesel.
Summary.



BMW Diesel.
Summary.

- BMW at leading edge of Diesel technology.
- A whole package of technologies is necessary to fulfill the challenging Tier2 Bin5 limits
  - Engine internal measures (combustion, boost-concept, EGR)
  - Aftertreatment (DPF + Urea-SCR)
- Clean Diesel technology can contribute a lot to save the future mobility.
- Mid- and long-term potentials for further reduced emissions, fuel consumption and increased power are under development.

BMW Diesel.
Leading Edge Engine Technology.

Thank You for Your Attention!