Modeling Needs for SIDI Lean NOx Aftertreatment Systems

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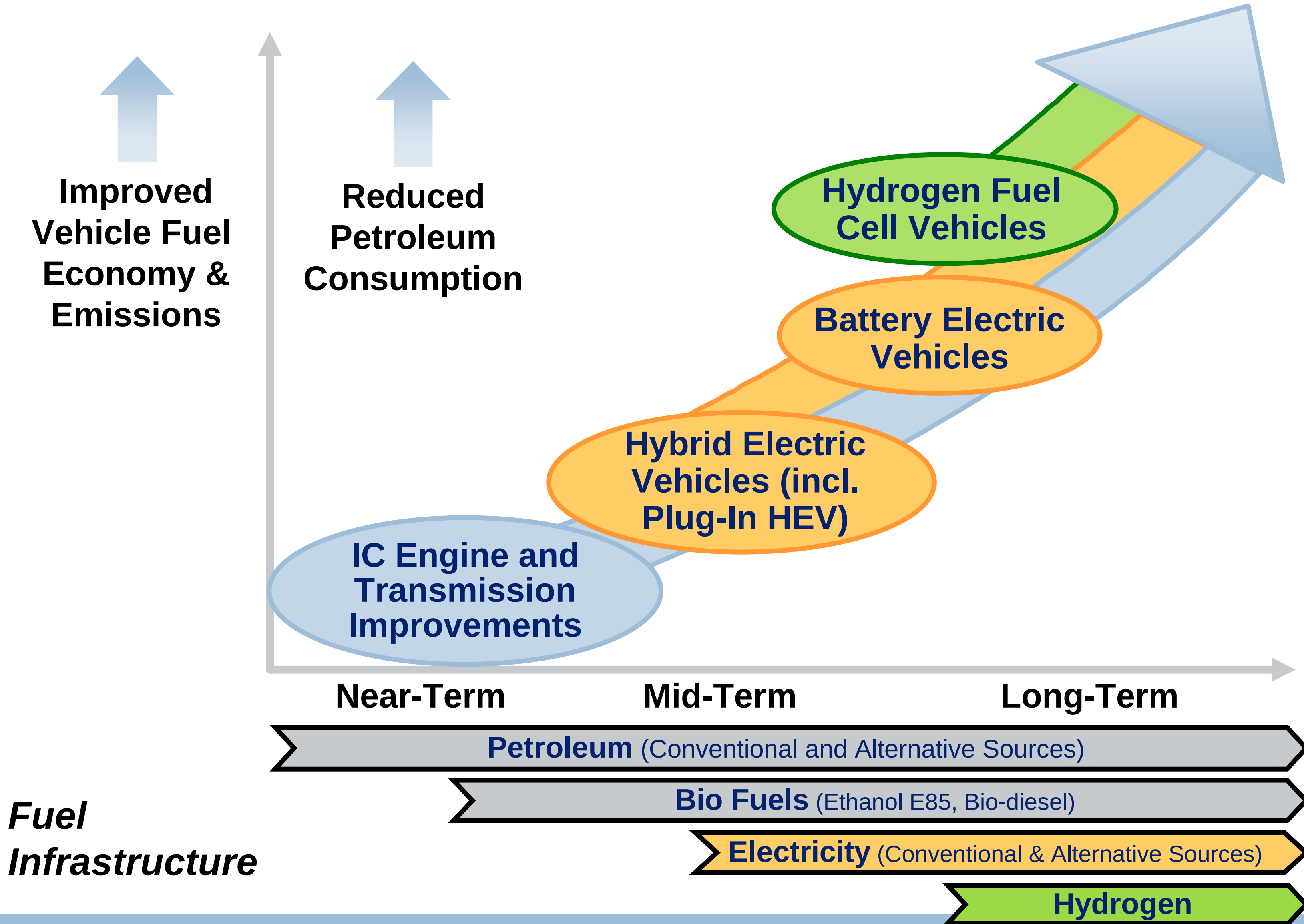
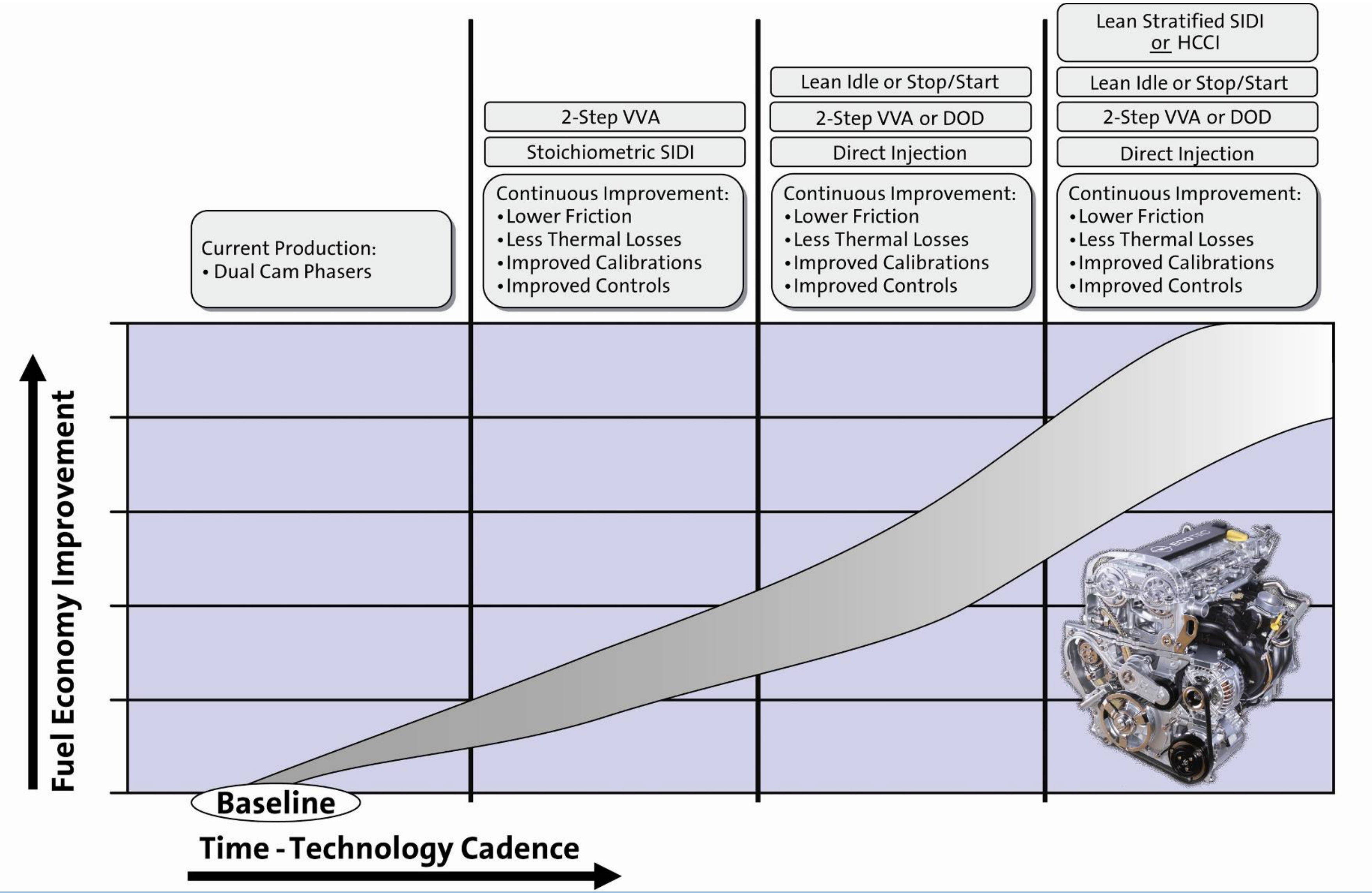
Outline

- GM propulsion strategy
- Fuel economy technology rollout for SI engines
- SIDI technology description
- Key issues with SIDI Lean NOx Systems
  - Mercedes and BMW production vehicles in Europe
- Modeling needs for SIDI lean NOx systems

Advanced Propulsion Technology Strategy



SI Engine Technology Rollout



Summary of Stratified SIDI Engines

Wall-Guided

+ good ignition stability
- small fuel economy gain
- requires lean NOx catalyst & low S fuel
- pool fires and smoke

Status:

- In Production
- Limited regional markets
- Not expanding

Spray-Guided

- random misfires
- lean NOx catalyst (low S fuel)
+ lower soot and hydrocarbon emissions
+ wider stratified-charge operating range
+ 10 – 15% better fuel economy than PFI

Status:

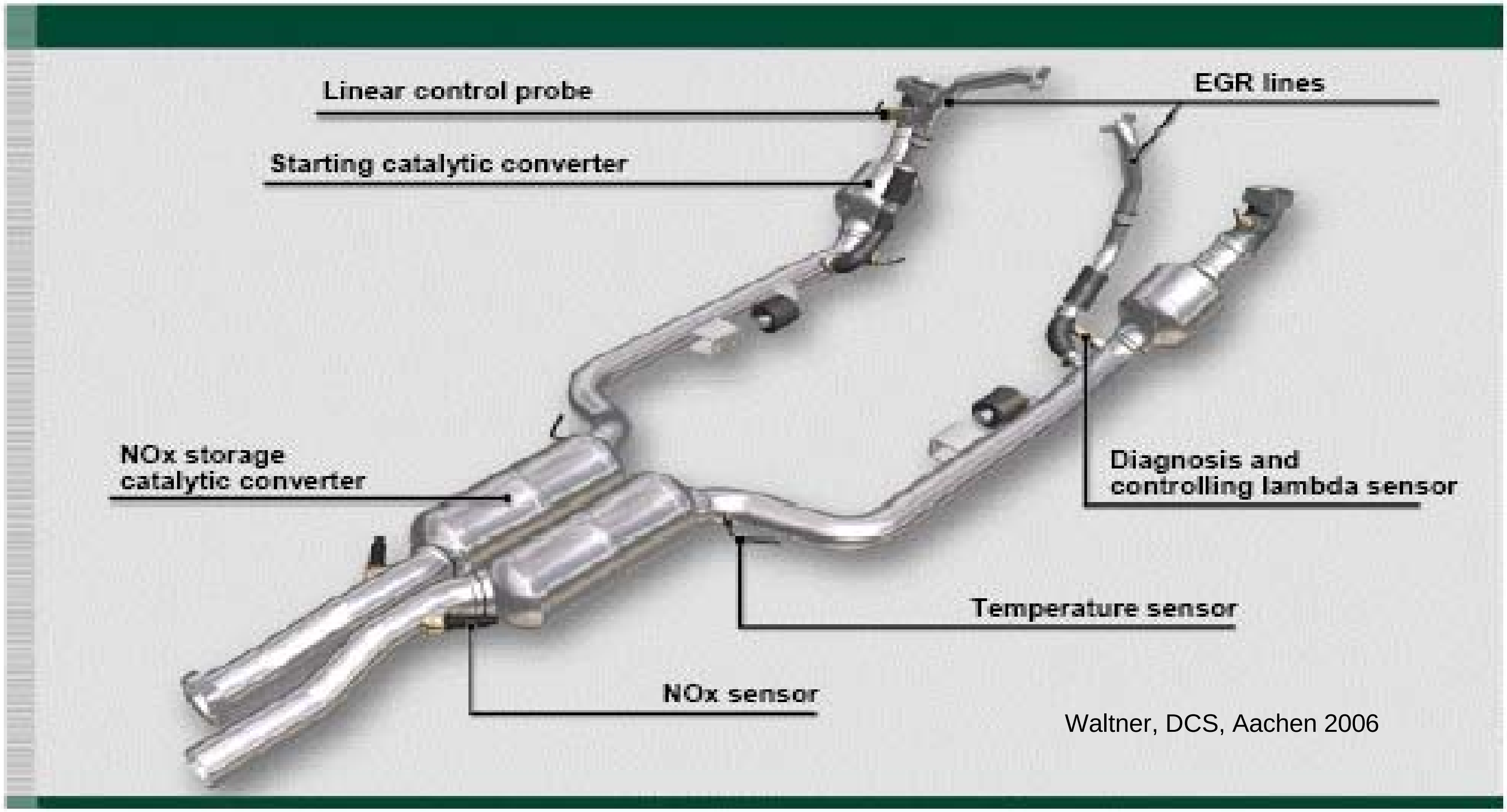
DC and BMW in Production with Piezo Inj.

Research with Multihole Injectors

Key Issues for SIDI Lean Aftertreatment Systems

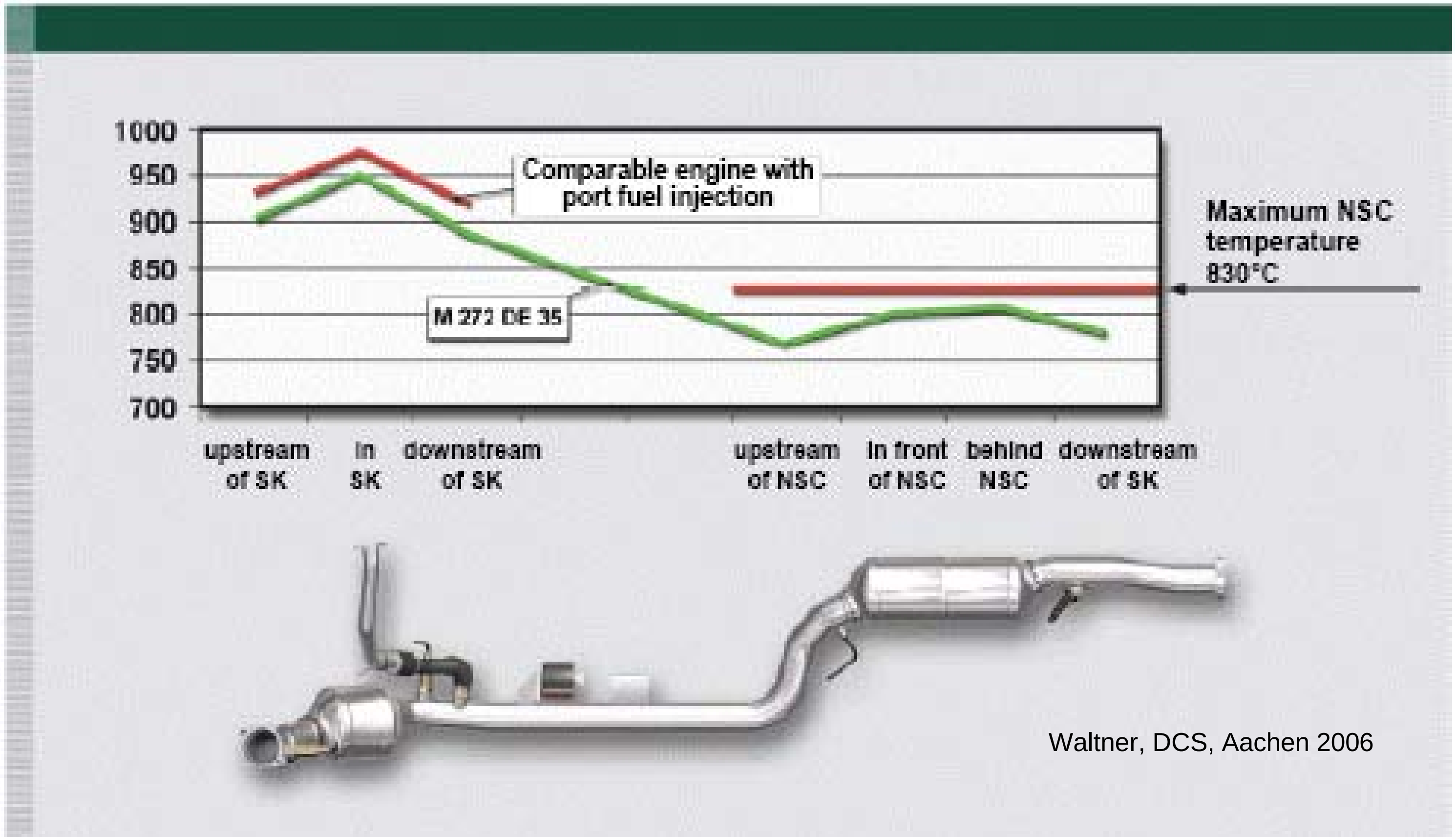
- Fuel economy penalties related to aftertreatment system
  - Limitations due to catalyst temperature windows
    - Fuel penalty for system warmup
    - Homogeneous operation at high loads
- Ability to meet current and future emissions standards
  - Thermal aging
  - Impact of sulfur
  - Unregulated emissions
  - Particulates
- System cost
  - Platinum group metal (PGM) usage

Exhaust Configuration of Mercedes-Benz CLS 350 CGI



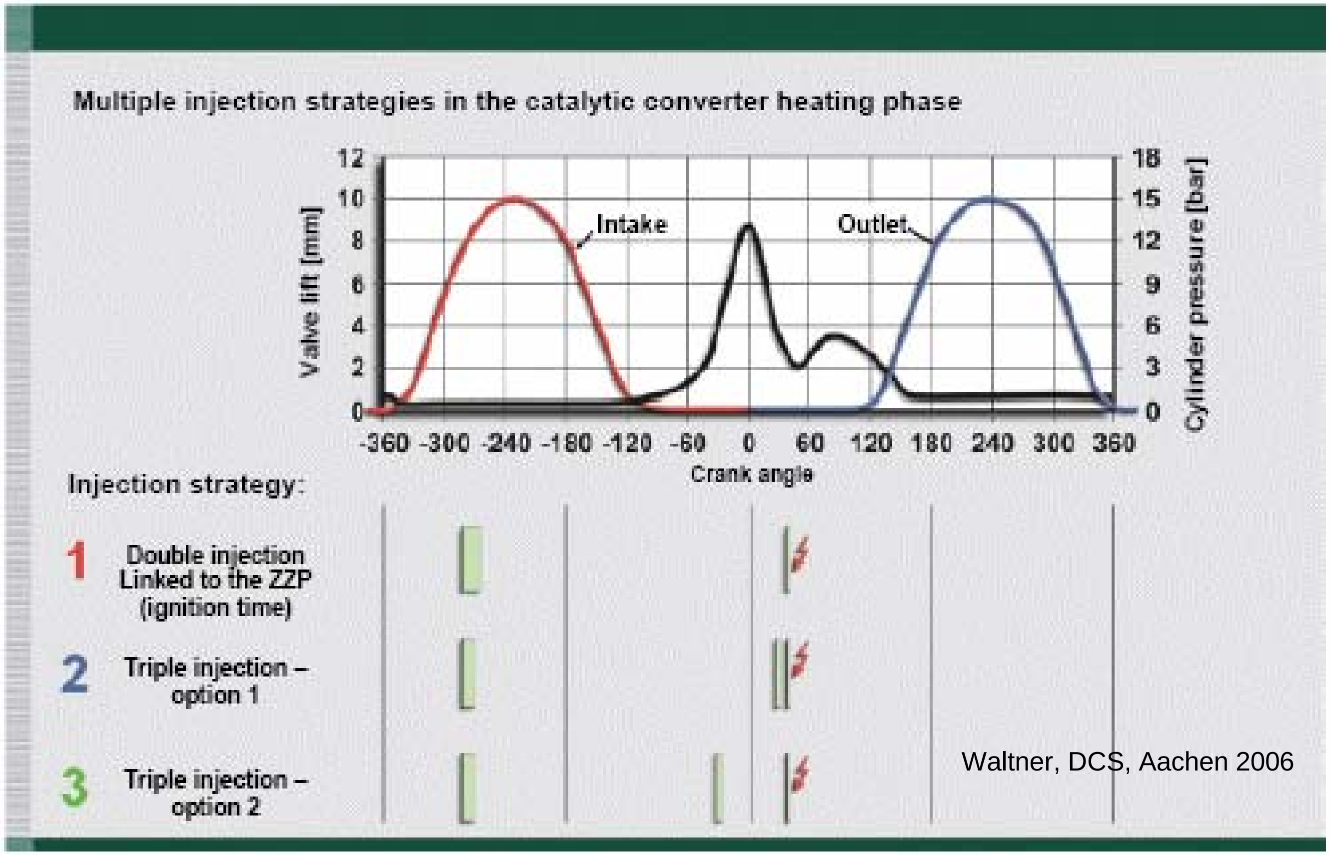
- Dual pipes and rear location keep NOx catalysts cool
  - Cause slow warmup after cold start
  - Rear catalyst location required to limit aging at maximum speed

Mercedes exhaust temperatures at maximum speed



- Lean NOx catalyst positioned where maximum inlet exhaust temperature about 770 ^{o}C
  - Keeps maximum catalyst temperature below 830^{o}C

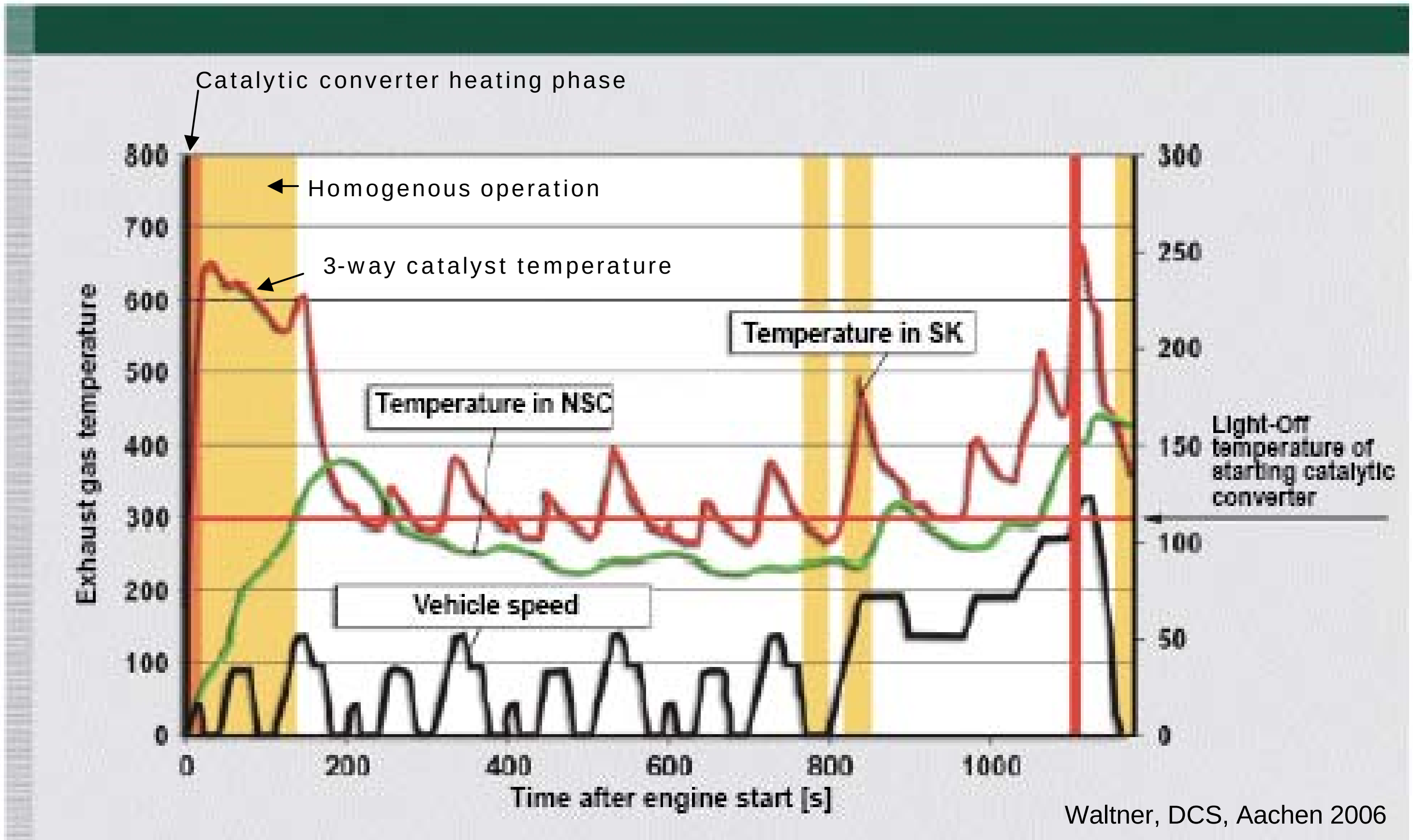
Mercedes fast catalyst warmup strategy



Waltner, DCS, Aachen 2006

- Combustion strategy required to heat catalysts system
  - Multiple injections and retarded spark
    - Late combustion event produces high exhaust temperature
    - Increases fuel consumption

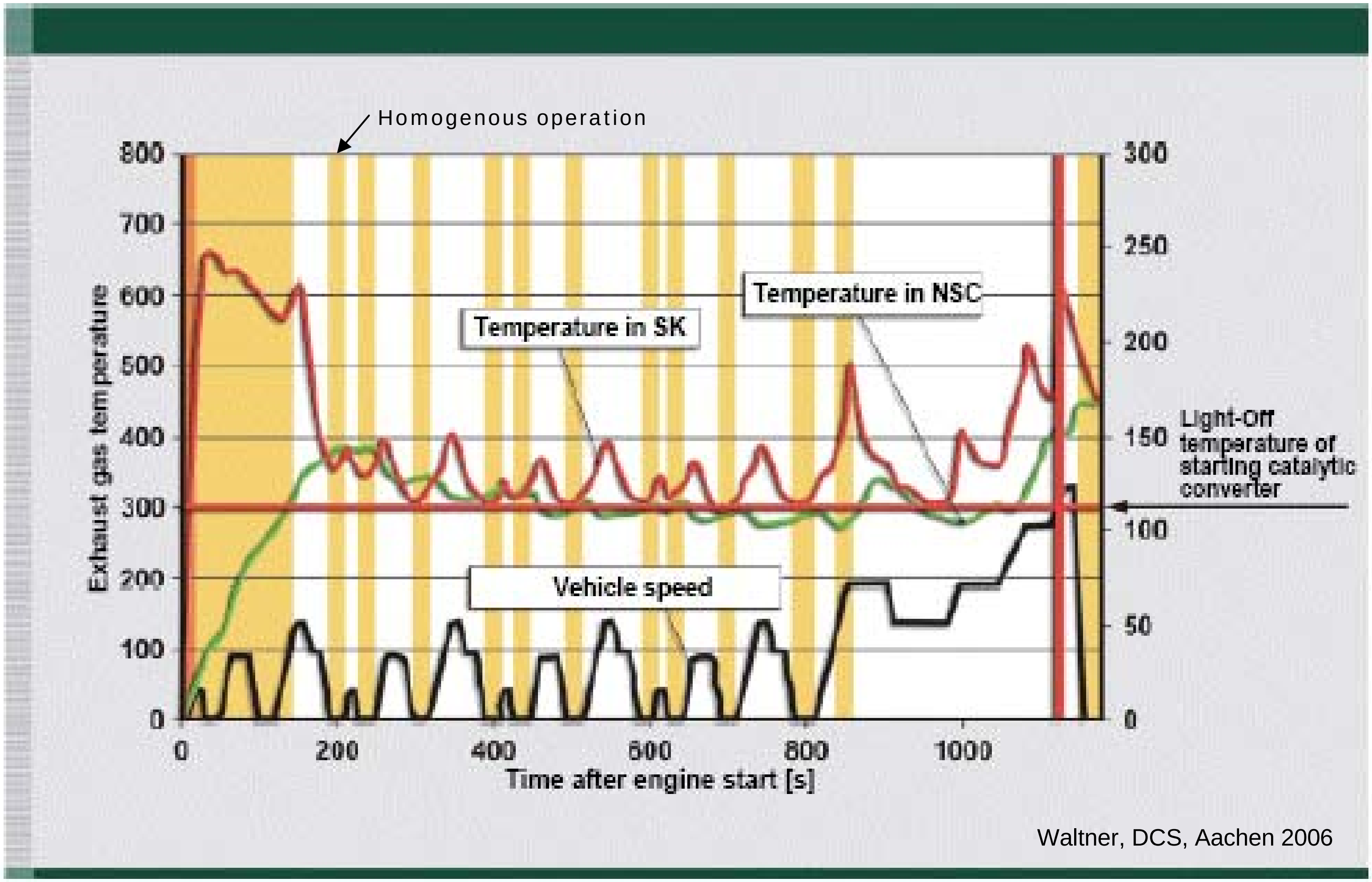
Catalyst system temperatures during NEDC



Waltner, DCS, Aachen 2006

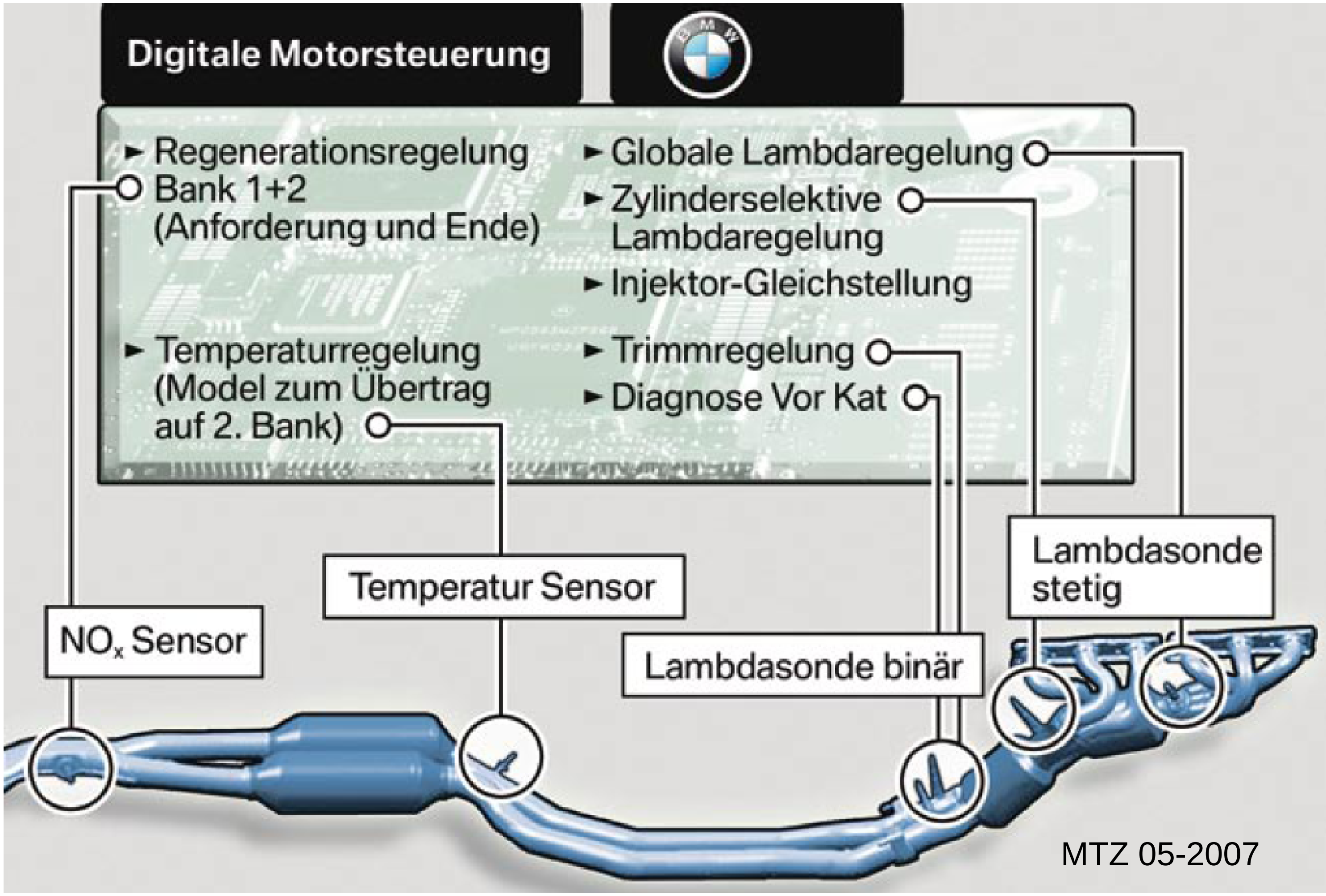
- Combustion strategy provides fast warmup of 3-way catalyst
- Slow warmup of lean NOx catalyst requires homogenous combustion for 150 s.
- Low 3-way catalyst temperature leads to high HC emissions

Homogeneous idle added to manage temperatures



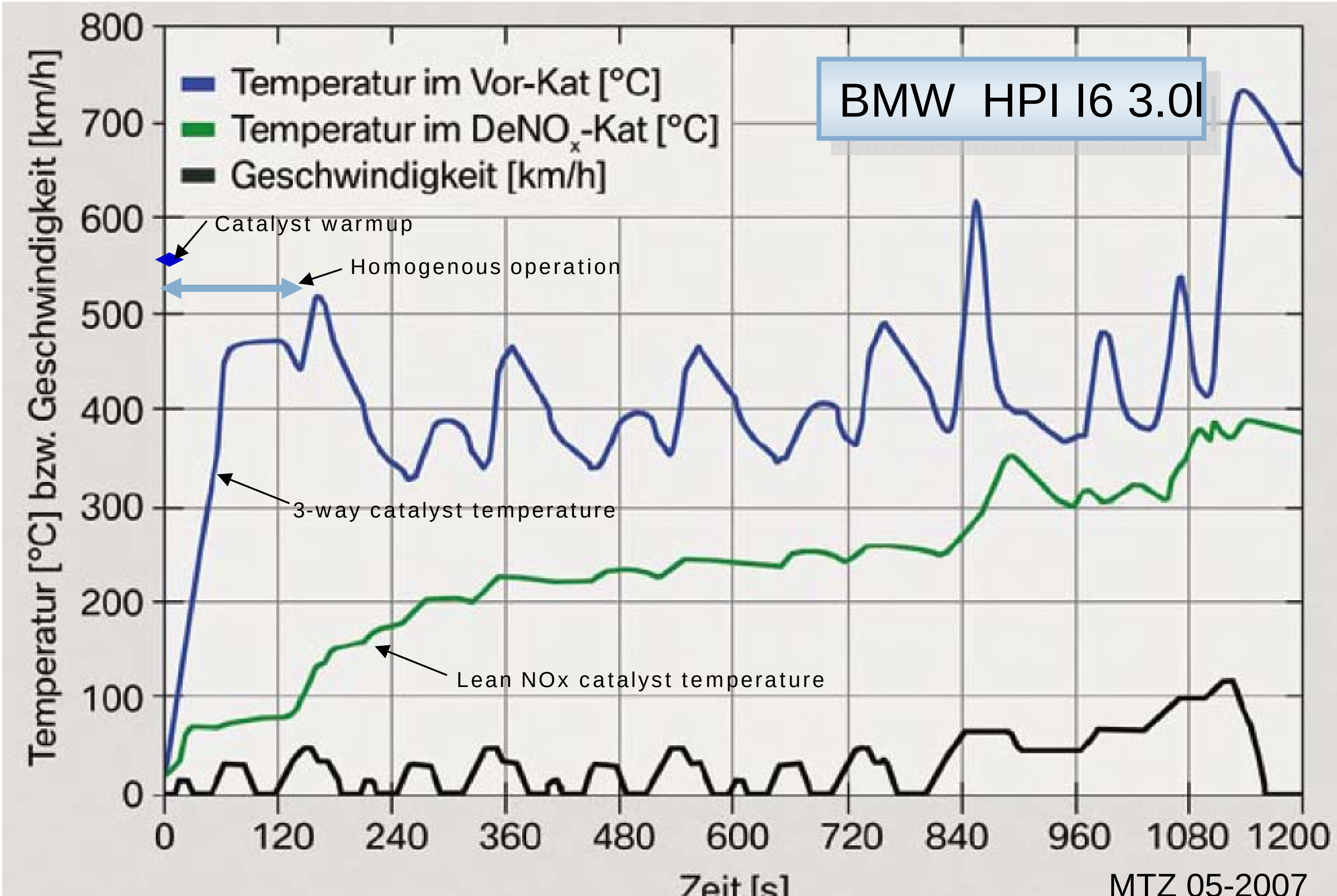
- Addition of homogeneous idle used to maintain 3-way HC control
- Additional fuel penalty impacts cost-benefit of stratified charge system

Exhaust architecture of BMW HPI I6 3.0L



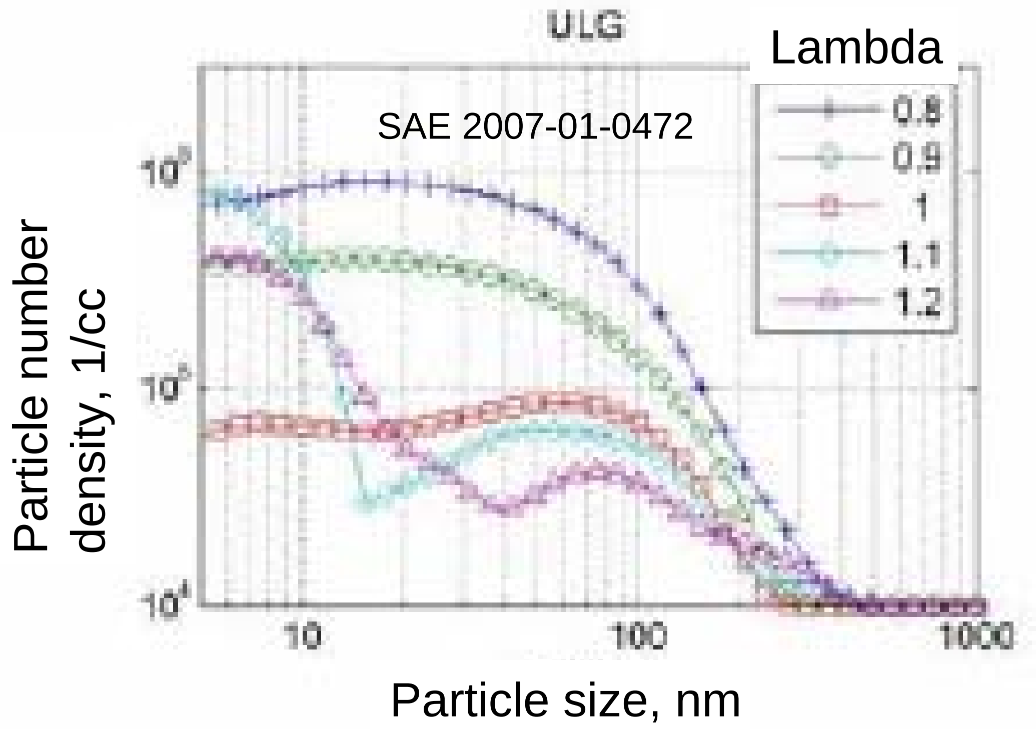
- BMW's I-6 architecture also designed to keep lean NOx catalyst cool

BMW system NEDC catalyst temperatures



- Slow warmup of lean NOx catalyst, despite aggressive heating

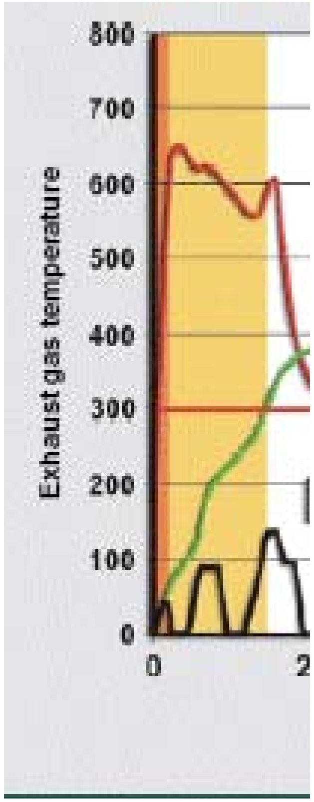
What about gasoline engine particulates? - under consideration in Europe



- Data with some lean engine operation show distributions with numbers of small particles
- No proven technology for gasoline engine control

Modeling needs for SIDI systems

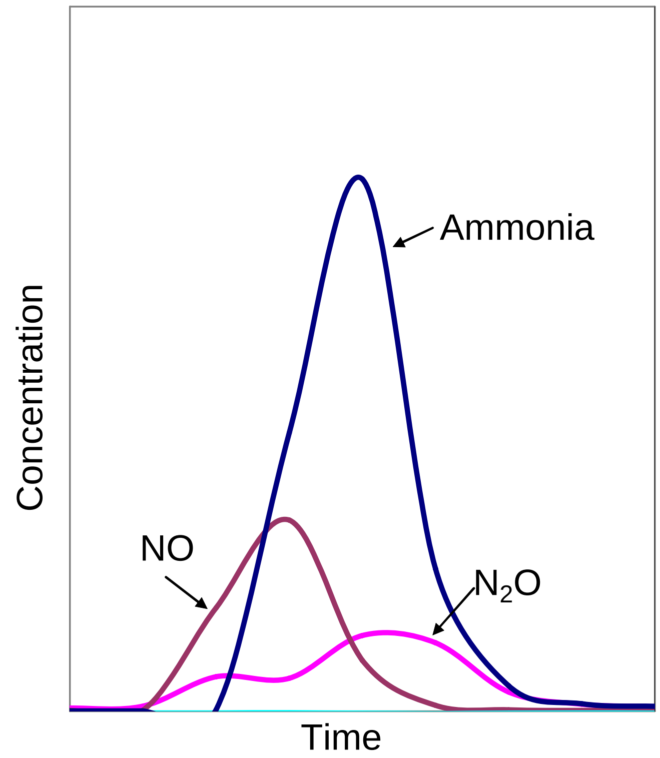
1. 3-way catalysts
   - Impact on fast lightoff and HC emissions
     - Temperature
     - PGM content
     - Cell density
     - Space velocity
     - Aging
     - Feedgas concentration



Modeling needs for SIDI systems (cont.)

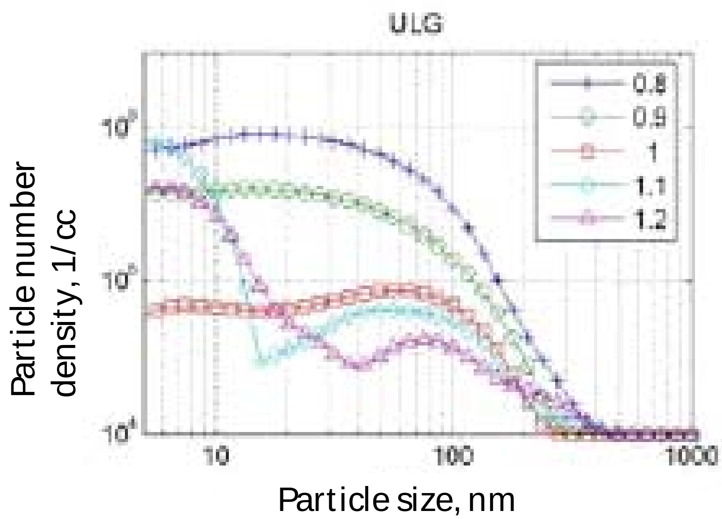
2. Lean NOx storage catalysts
   - Impacts on NOx storage
     - Temperature
     - PGM content
     - Cell density
     - Space velocity
     - Aging
     - Feedgas concentrations
   - NOx → N2 regeneration selectivity
     - Temperature
     - PGM content
     - Space velocity
     - Aging
     - Feedgas concentrations
   - Sulfation/desulfation
   - Other lean NOx technologies, such as urea SCR

Typical lean NOx breakthrough during regeneration



Modeling needs for SIDI systems (cont.)

3. Particle control
   - Filter trapping efficiency and pressure drop
     - Particle size and number
     - Substrate characteristics
     - Loading
   - Regeneration kinetics
     - Temperature
     - Soot characteristics
     - Feedgas concentration
     - Space velocity
   - Innovative approaches to particle control
     - Low pressure drop
     - High efficiency on small particles



Modeling needs for SIDI systems (cont.)

4. Complete exhaust system
    - System architecture
        - Catalyst location
        - Catalyst properties
        - Pressure drop
        - Particle control
        - Interactions between components
        - Active thermal management systems
    - Performance of complete system
        - Emissions performance on and off cycle
            - High precision required (future standards)
            - Nonregulated emissions
        - Fuel economy on and off cycle
        - Optimizing control strategy
        - Optimization to reduce system cost

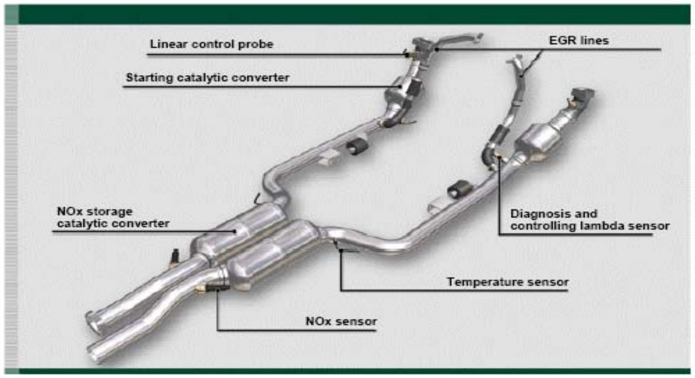


Diagram 9: *Configuration of the exhaust system of the Mercedes-Benz CLS 350 CGI*

Summary

- Spray-guided SIDI stratified charge systems are a key technology to improve fleet fuel economy
- Large-scale introduction requires innovation to achieve future emissions levels while improving fuel economy at a reasonable cost
- Optimization of SIDI lean aftertreatment requires complex interactions between engine controls, exhaust architecture, and catalyst design
- Improved component and system models are critical to success of SIDI stratified charge system design