# Insight / Adoption and Experiences of EU Nations while Embarking on Euro VI

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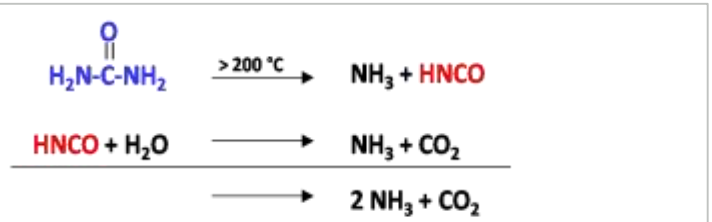
# SCR Technology

## Spray Formation of Different DEF / AdBlue® Injection Systems

### Key factors for a high SCR catalyst efficiency

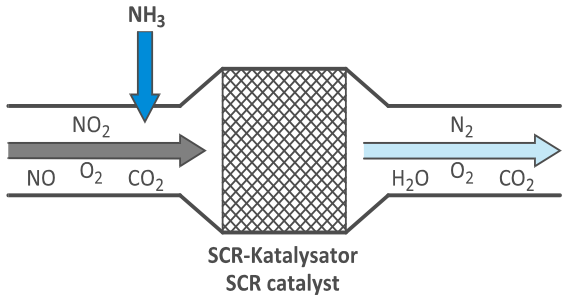
- Homogeneous distribution of the Ammonia in the exhaust
- Homogeneous distribution of the exhaust over the catalyst surface
- Avoiding of wall contacts causing urea fall out
- Fast droplet evaporation for Urea decomposition and Ammonia formation
- High Dosing Frequency at high Urea Mass Flows, .i.e. nearly continuous dosing at high rates/temperatures
- Excellent Dosing Accuracy over lifetime

### Urea decomposition




Urea is used as an aqueous solution called „AdBlue®“ or “DEF”, which is injected into the exhaust pipe

### SCR DeNO$_X$ reaction

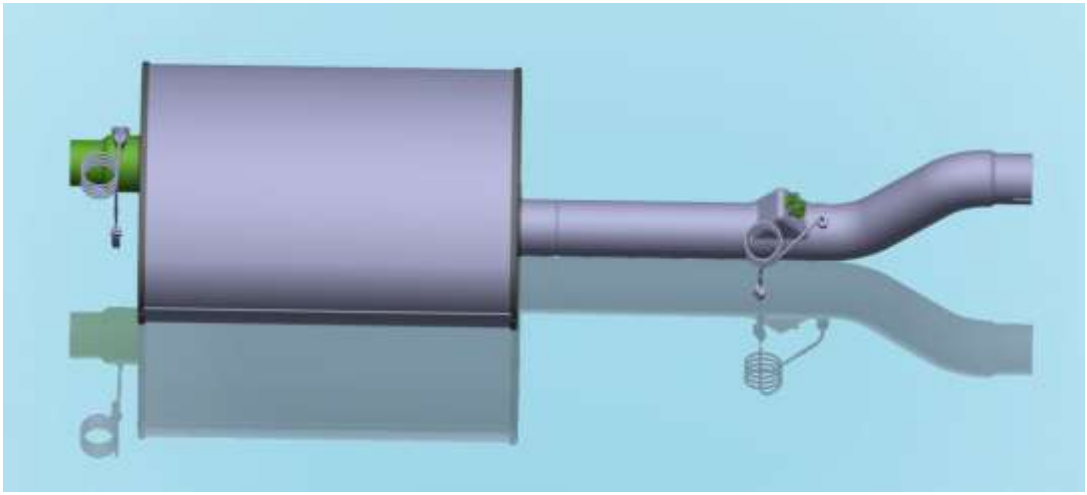


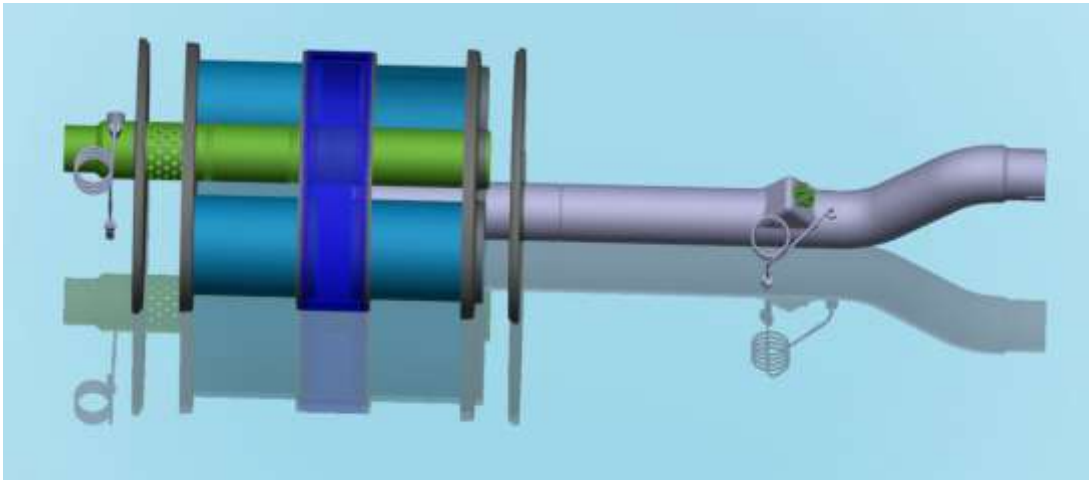

$$NO + NO_2 + 2\,NH_3 \rightarrow 2\,N_2 + 3\,H_2O$$

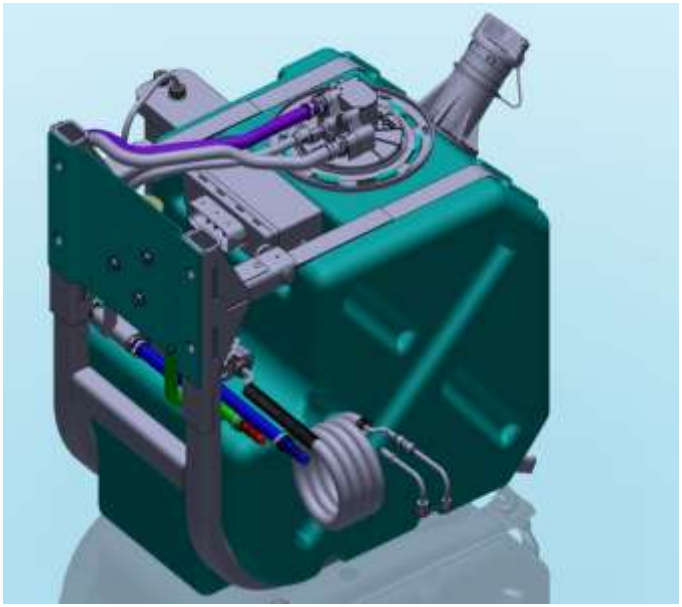
$$4\,NO + O_2 + 4\,NH_3 \rightarrow 4\,N_2 + 6\,H_2O$$

$$2\,NO_2 + O_2 + 4\,NH_3 \rightarrow 3\,N_2 + 6\,H_2O$$

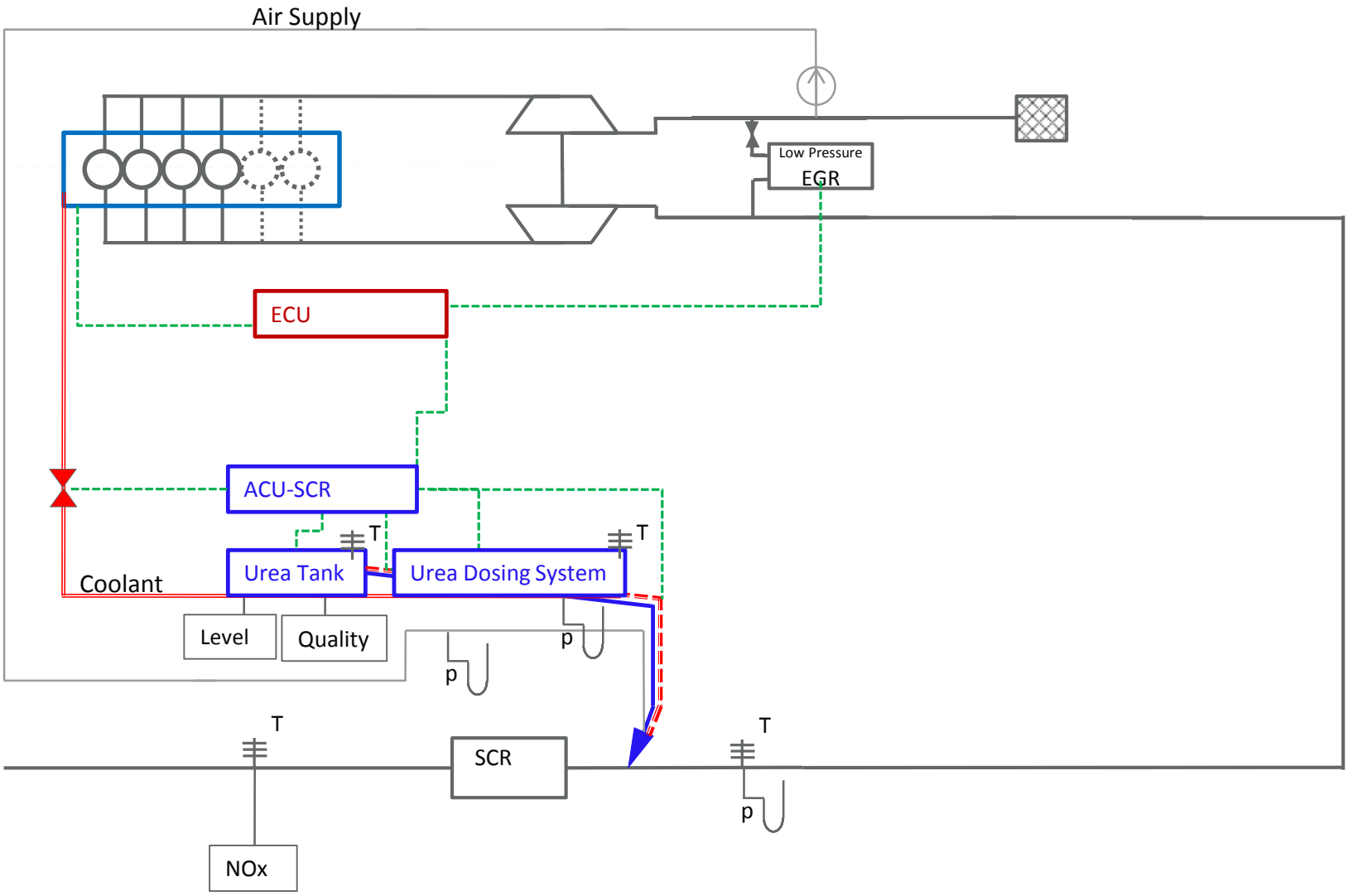
# BS 4 Catalyst Assembly with integrated Hydrolysis Pipe and Urea tank with integrated Dosing System







# Overall System Configuration Engine & ATS (Current BS4)



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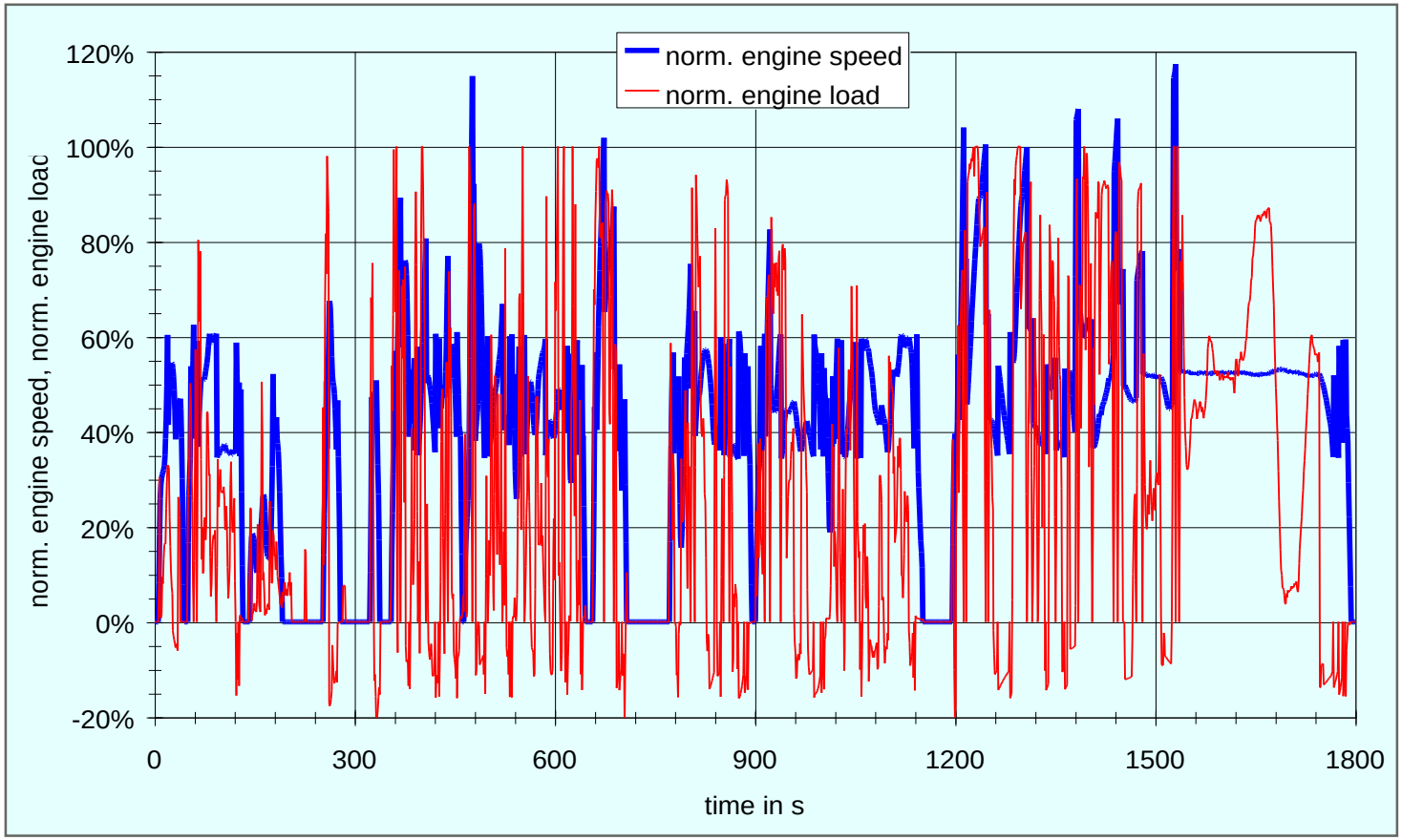
# Euro VI Limit Values

| World Harmonized Test Cycles | WHSC Limit | WNTE component | WNTE Laboratory Test<br>WNTE limit |
|---|---|---|---|
| • NOx | 400 mg/ kWh | 200 mg/ kWh (WHSC x 0,25 + 100) | 600 mg/ kWh |
| • HC | 130 mg/ kWh | 90 mg/ kWh (WHSC x 0,15 + 70) | 220 mg/ kWh |
| • CO | 1500 mg/ kWh | 500 mg/ kWh (WHSC x 0,2 + 200) | 2000 mg/ kWh |
| • PM | 10 mg/ kWh | 6 mg/ kWh (WHSC x 0,25 + 3) | 16 mg/ kWh |
| • PN | $8*10^{11}$/ kWh | | |

| | WHTC Limit | Conformity factor | ISC limit |
|---|---|---|---|
| • NOx | 460 mg/ kWh | 1.5 | 690 mg/ kWh |
| • HC | 160 mg/ kWh | 1.5 | 240 mg/ kWh |
| • CO | 4000 mg/ kWh | 1.5 | 6000 mg/ kWh |
| • PM | 10 mg/ kWh | - | - |
| • PN | $6*10^{11}$/ kWh | | |

# WHTC Test Cycle

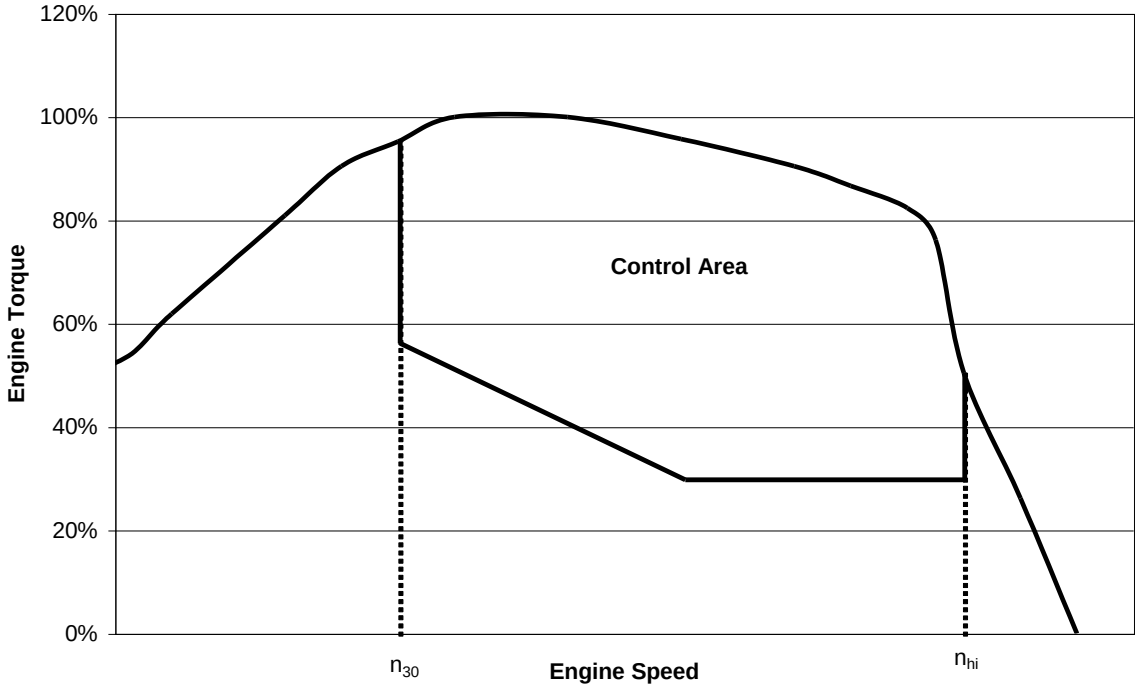


# WHSC Test Cycle

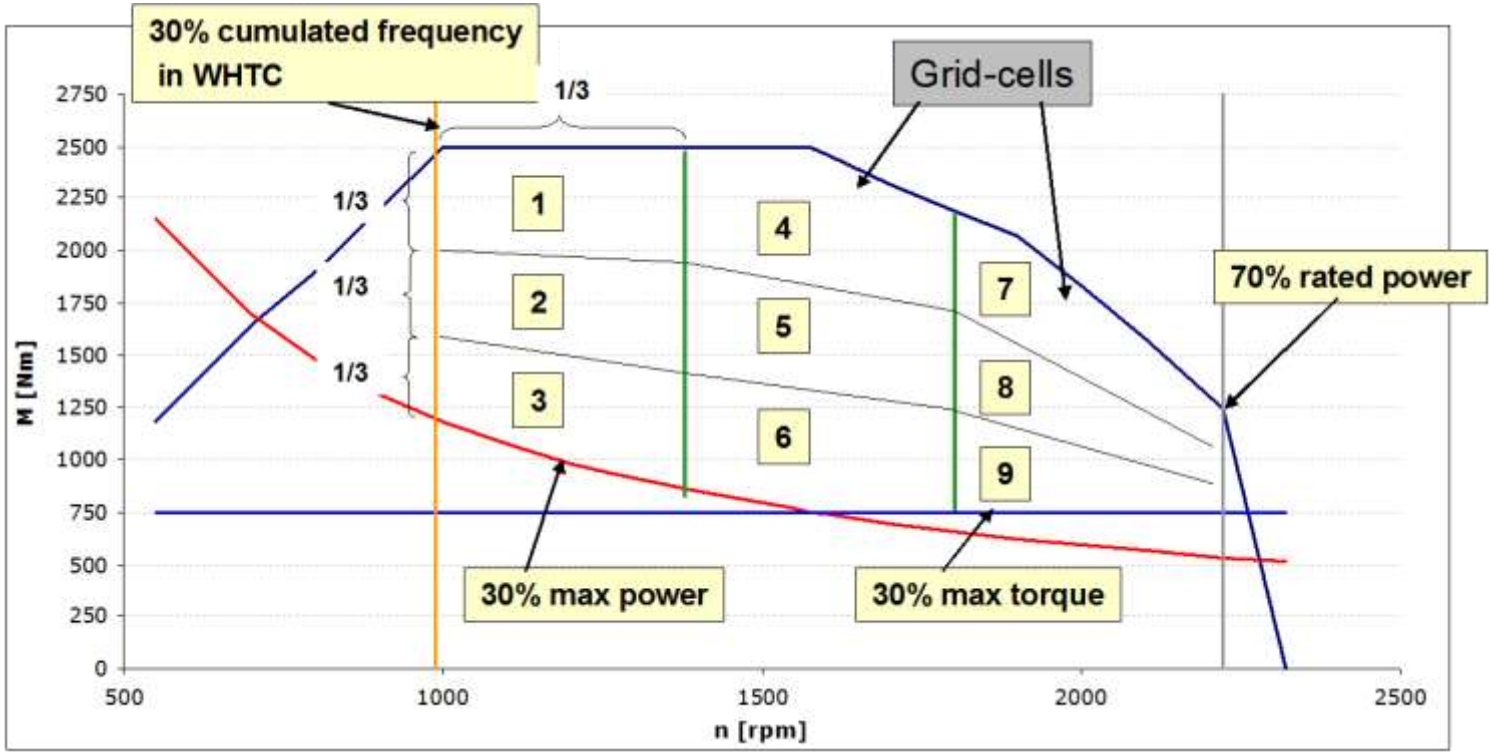
| Mode | Normalized Speed (per cent) | Normalized Torque (per cent) | Mode length (s) incl. 20 s ramp |
|---|---|---|---|
| 1 | 0 | 0 | 210 |
| 2 | 55 | 100 | 50 |
| 3 | 55 | 25 | 250 |
| 4 | 55 | 70 | 75 |
| 5 | 35 | 100 | 50 |
| 6 | 25 | 25 | 200 |
| 7 | 45 | 70 | 75 |
| 8 | 45 | 25 | 150 |
| 9 | 55 | 50 | 125 |
| 10 | 75 | 100 | 50 |
| 11 | 35 | 50 | 200 |
| 12 | 35 | 25 | 250 |
| 13 | 0 | 0 | 210 |
| | | | |
| Sum | | | 1895 |

# WNTE Control Area

- Lower engine speed range: $n_{30}$
- Upper speed range: $n_{hi}$
- Torque/power limit of 30%

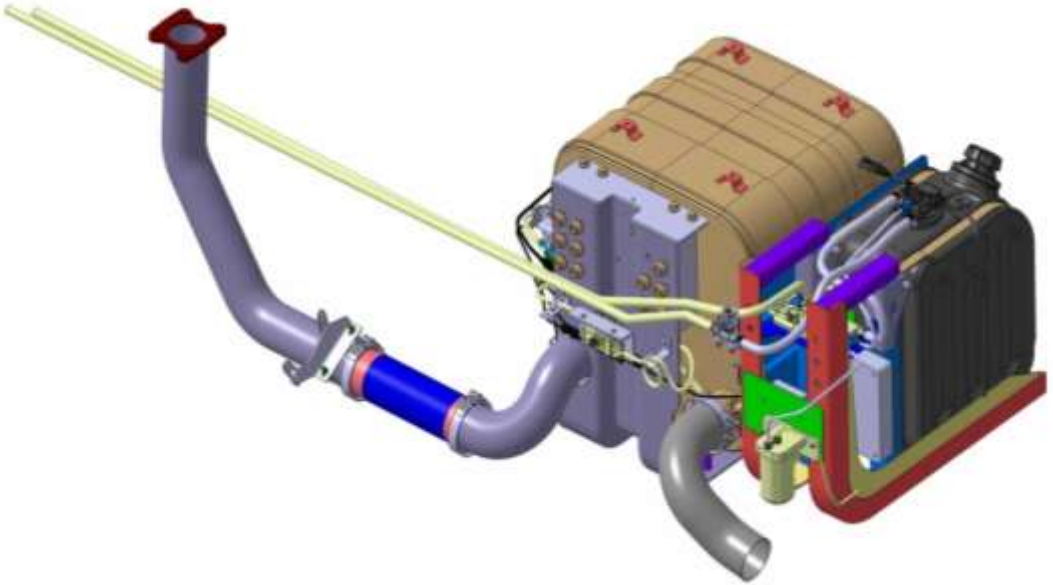


# WNTE Laboratory Test Cycle




9 grids for engines < 3000 rpm; 12 grids for engines ≥ 3000 rpm rated speed

# BS 6 Demonstrator Truck with EAS by Albonair

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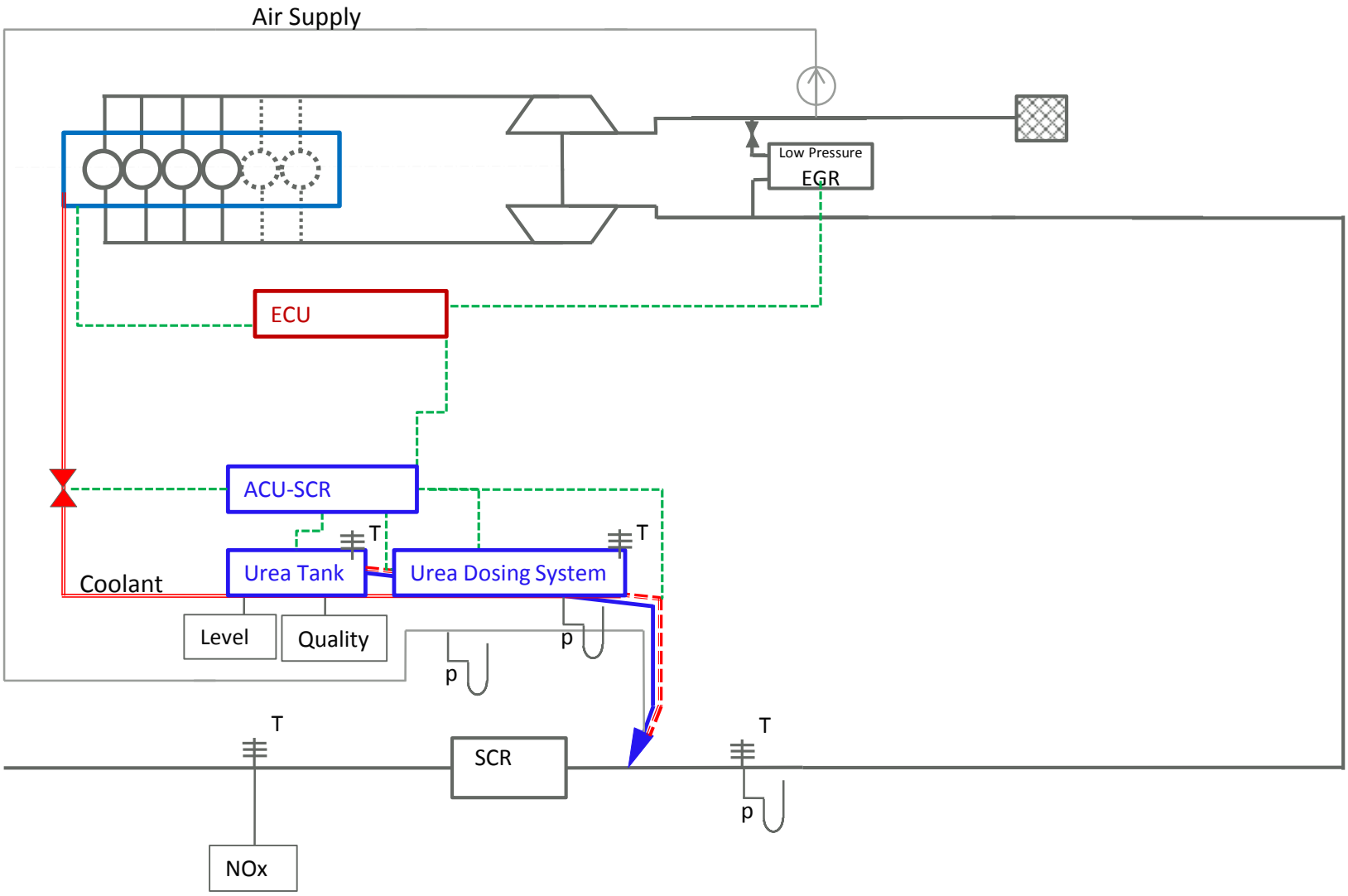
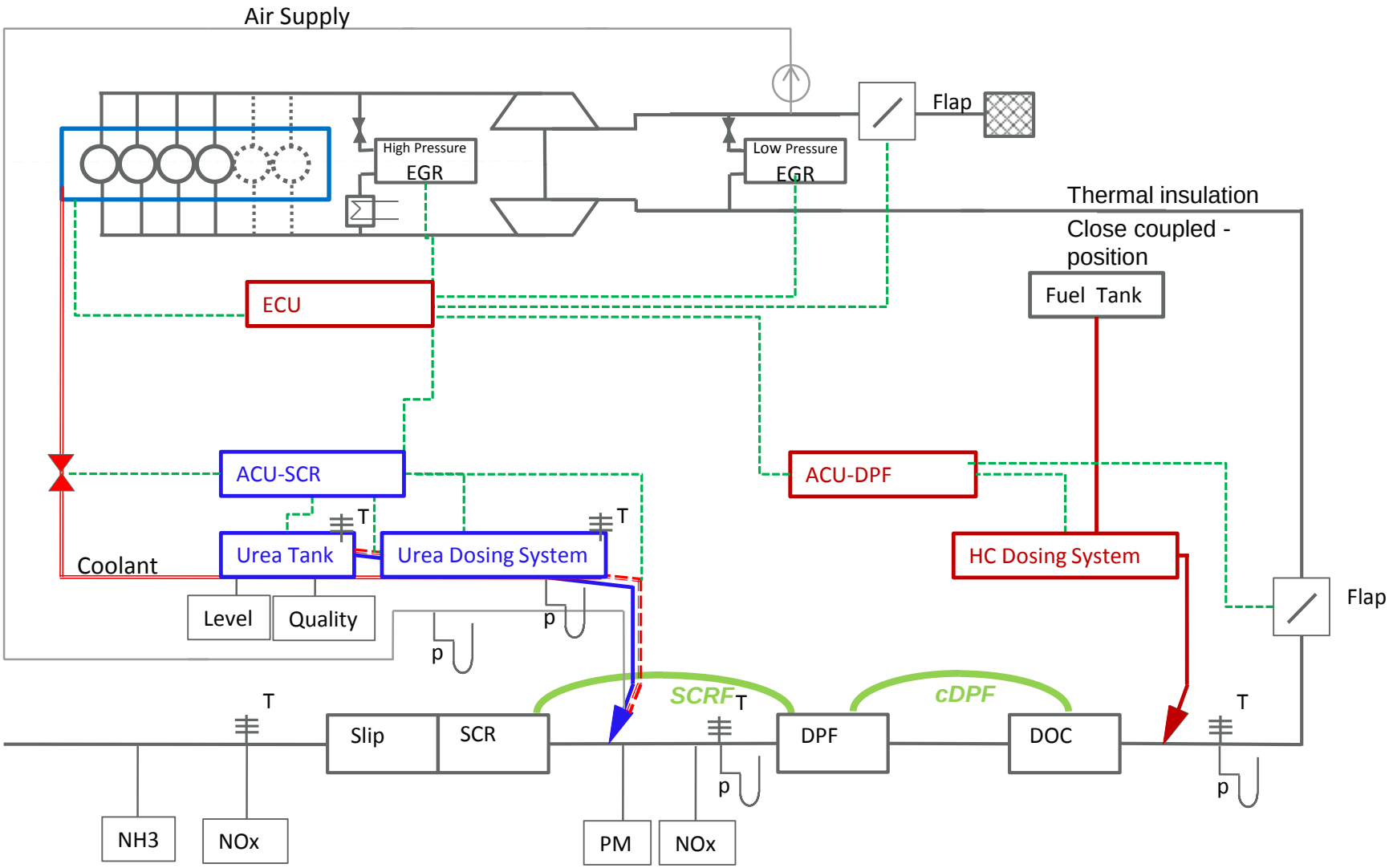


# Overall System Configuration Engine & ATS (Current EU 6)



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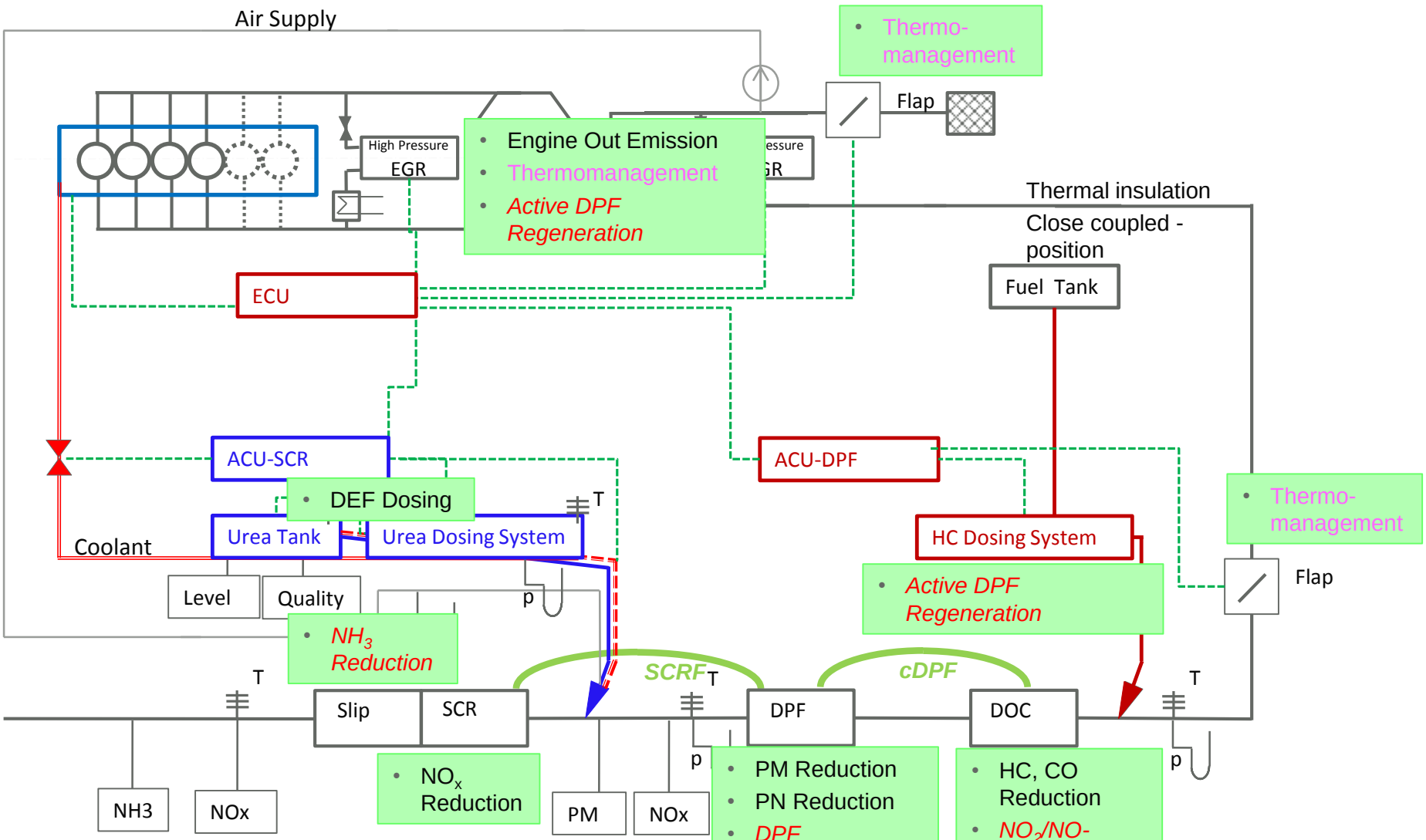

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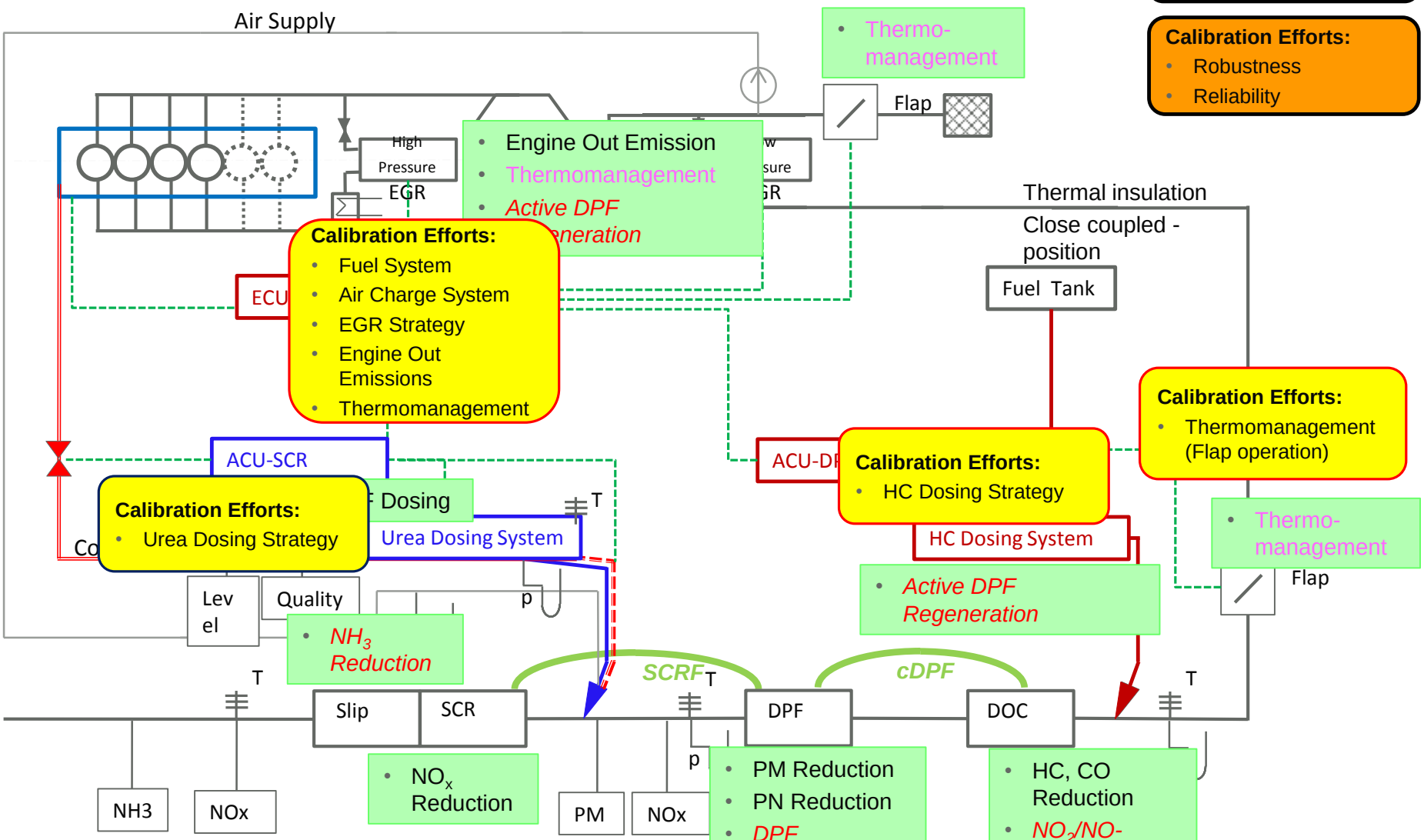

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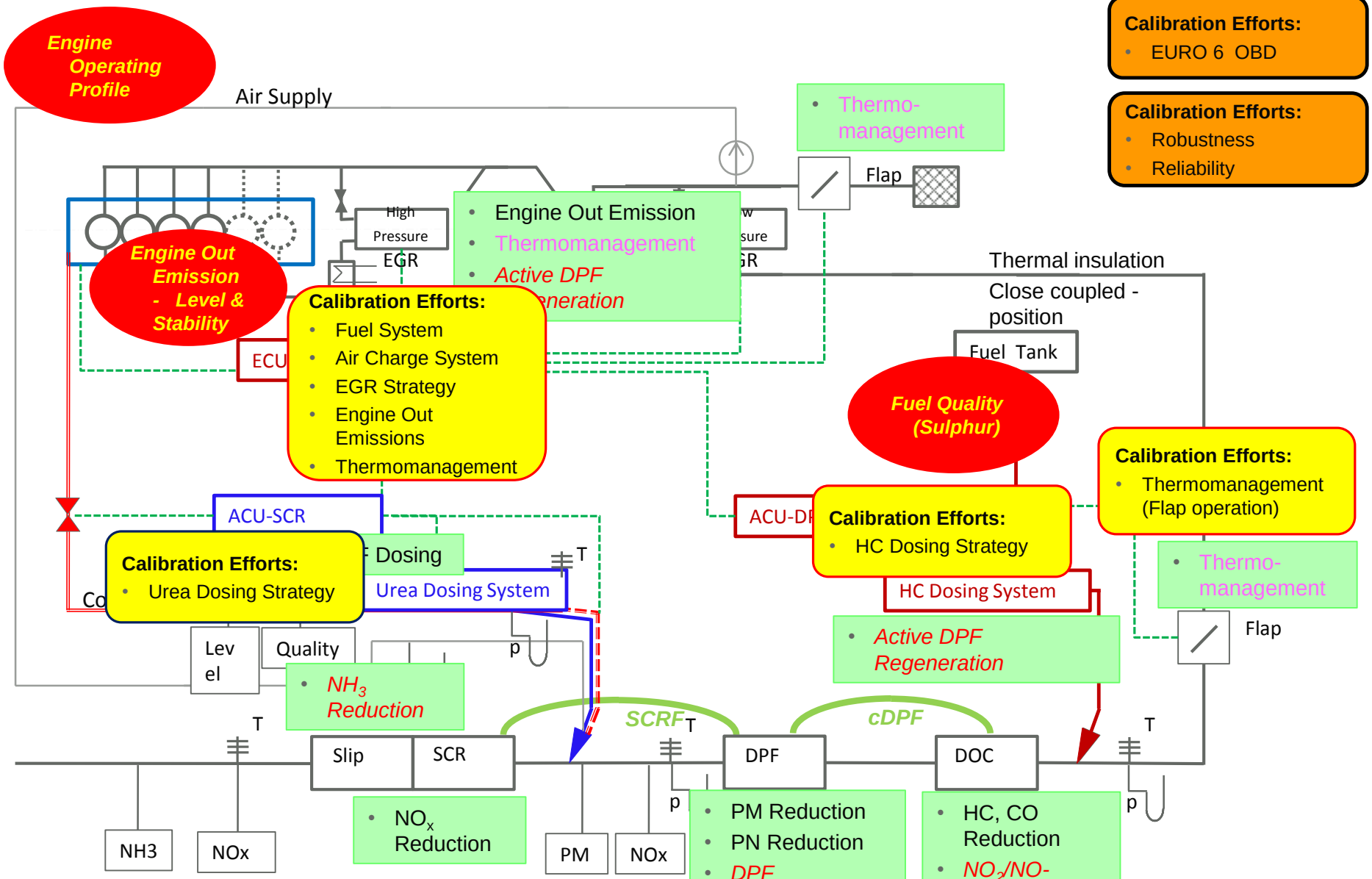


**Calibration Efforts:**
- EURO 6 OBD

**Calibration Efforts:**
- Robustness
- Reliability

# Aftertreatment Components for BS 6 Emission

## Engine out Emission concept does have influence on Aftertreatment components

| Passive DPF Regeneration | Active DPF Regeneration |
|---|---|
| • Oxidation Catalyst Pt/Pd 6:1 | • Oxidation Catalyst Pt/Pd 3:1 |
| • Exhaust Flap | • Exhaust Flap |
| • Late post injection for emergency regeneration | • HC doser for active regeneration |
| • Cordierite DPF | • SiC or Cordierite DPF |
| • Urea Dosing System | • Urea Dosing System |
| • Vanadium SCR | • Cu Zeolite SCR |
| • Ammonia Slip Catalyst | • Ammonia Slip Catalyst |
| • 2 NOx Sensors | • 2 NOx Sensors |
| • Canning of Substrates, Housing, Tubes | • Canning of Substrates, Housing, Tubes |

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1. BS 4 SCR Systems
2. BS 6 SCR Systems
3. BS 6 OBD
4. Challenges for India
5. Conclusions

# Definition from R49

"*On-board diagnostic system*" (OBD system) means a system on-board of a vehicle or engine which has the capability of:

(a) Detecting malfunctions, affecting the emission performance of the engine system;

(b) Indicating their occurrence by means of an alert system; and

(c) Identifying the likely area of the malfunction by means of information stored in computer memory and communicating that information offboard;

# Purpose of OBD

## The OBD System shall

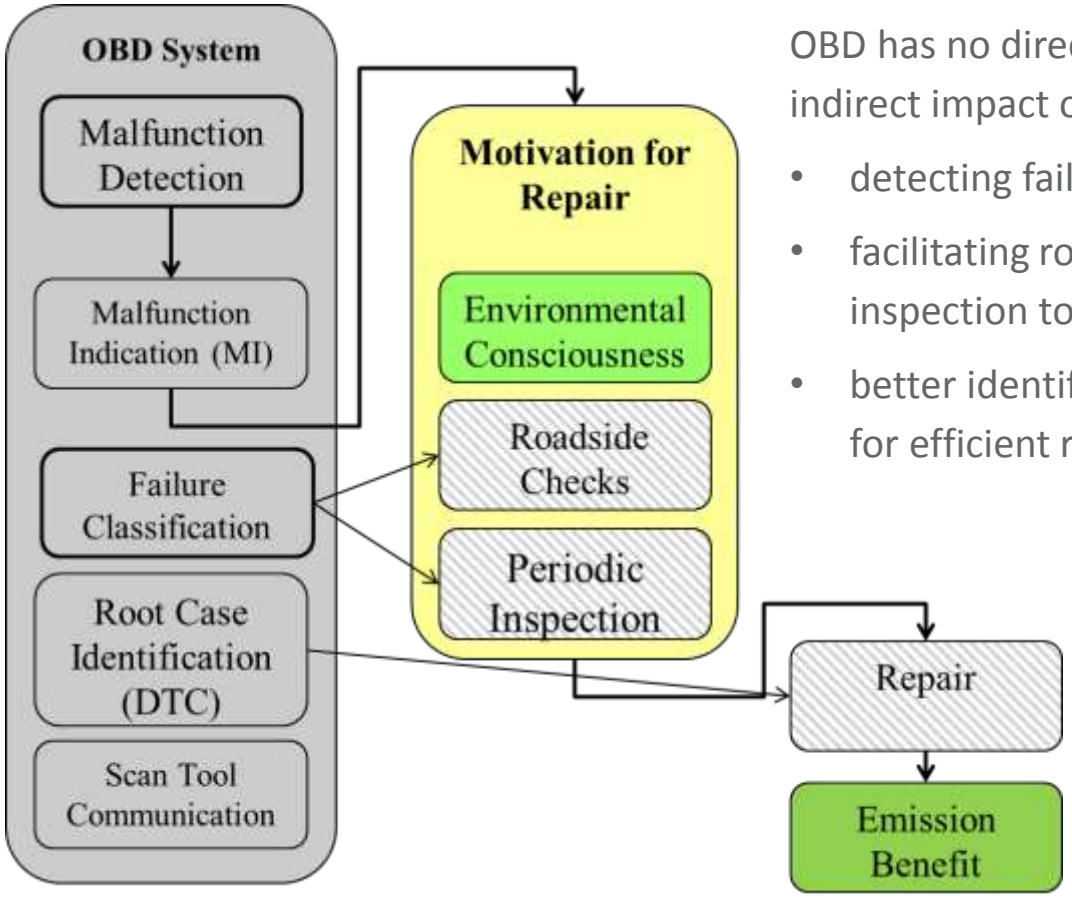
- detect malfunctions which have an impact on emissions or on the monitoring system itself
- alert the driver
- help the workshop to perform efficient repair

## The OBD System shall not

- monitor emissions
- detect normal aging

→ since emission compliance and normal aging is addressed by system design and is monitored by PEMS

# Emission Reduction by OBD




OBD has no direct impact on emissions. OBD has an indirect impact on emissions by

- detecting failures
- facilitating road side checks and periodic inspection to force repair and
- better identification of the root cause of a failure for efficient repair

## Component monitoring (input/output components/systems)

➢input components (e.g. sensors)

- the OBD system shall at a minimum detect electrical circuit failures and, where feasible, rationality failures.
- the rationality failure diagnostics shall then verify that a sensor output is neither inappropriately high nor inappropriately low

➢output components (e.g. actuators)

- the OBD system shall at a minimum detect electrical circuit failures, and, where feasible, if the proper functional response to computer commands does not occur.

# Aftertreatment Systems Monitors

| | |
|---|---|
| • DOC | |
| • HC conversion efficiency | total functional failure monitoring |
| • DPF | |
| • Presence of the DPF substrate | total functional failure monitoring |
| • Clogging of the DPF | total functional failure monitoring |
| • Filtration and continuous regeneration processes | emission threshold monitoring |
| • SCR | |
| • System's ability to regulate reagent delivery | performance monitoring |
| • System’s availability / proper consumption | performance monitoring |
| • Quality of the reagent | performance monitoring |
| • Catalyst efficiency | emission threshold monitoring |

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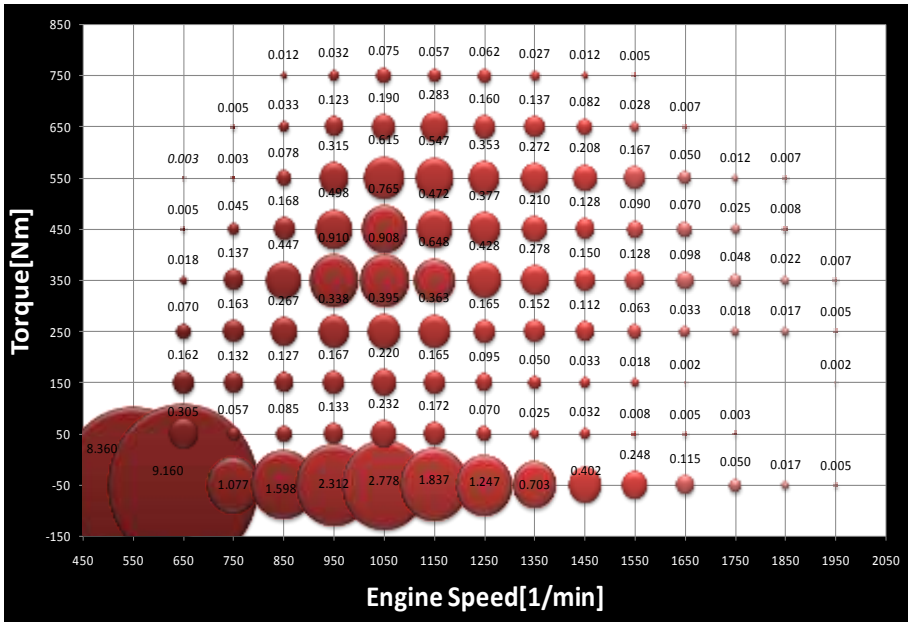
# Use case: city traffic in India

Stop-and-go-traffic in a Chennai City

A typical Indian city bus

**Stop-and-go traffic as well as low load are two aspects which lead to poor performance of catalysts due to super-low average temperatures**

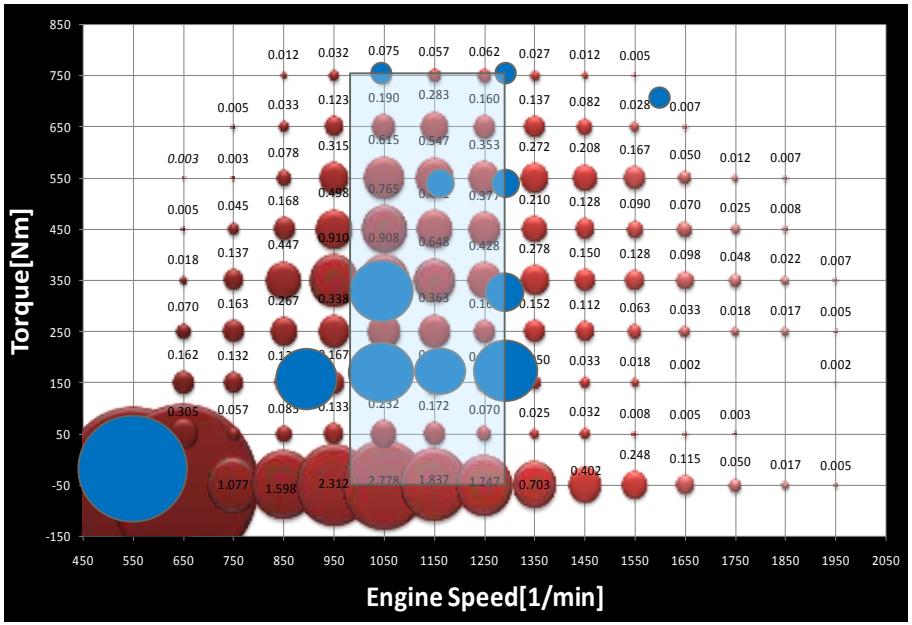
# Use case: city traffic




City bus cycle

Intra-city bus duty cycle recorded on a city bus in Chennai

# Use case: city traffic



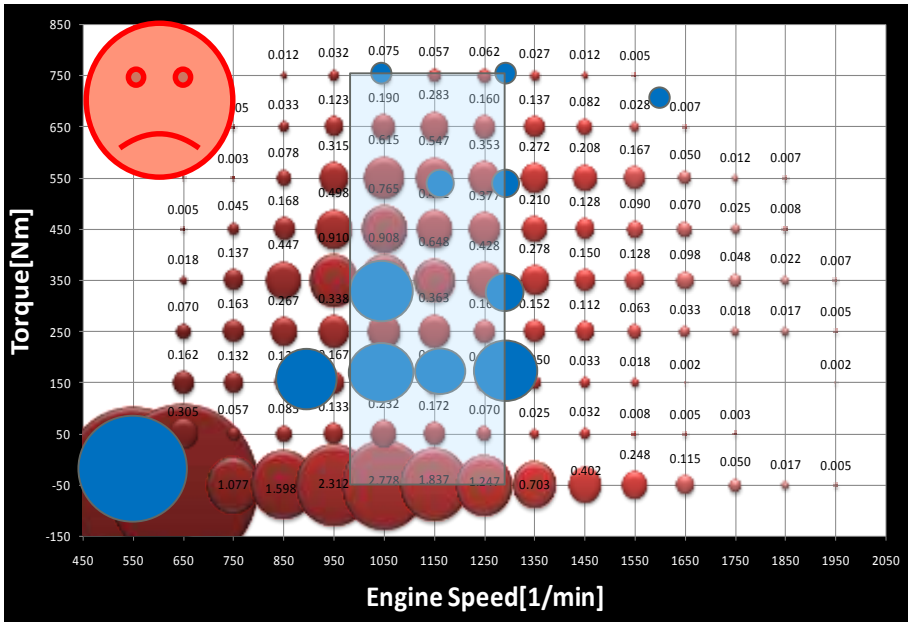

Intra-city bus duty cycle recorded on a city bus in Chennai

## Exhaust gas temperatures

Average DOC-out temperature WHTC: 258°C

Average DOC-out temperature city bus cycle: 225°C

# Use case: city traffic




Intra-city bus duty cycle recorded on a city bus in Chennai

**Within the most specific load profile of city buses the $NO_x$ emission can be increased due to insufficient SCR**

# Customer influence: Urea contamination with oil and coolant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# Introduction of BS 6 including OBD and Particulate Filters in a short time of 4 years will be very challenging for India

## Reliability of the BS 6 Systems is the issue

- Vehicles need to be redesigned for close coupled aftertreatment avoiding pipes between engine and aftertreatment of several meters
- Robust aftertreatment systems need to be developed which are tolerant for misuse
- Engines need to be updated for lower raw emissions, some engines as of today have a peak firing pressure of only 130 bar
- Service organizations have to be trained for electronic controls
- Infrastructure for fuel and AdBlue needs to be updated
- Operators have to be trained

**Huge interest of OEM to have reliable systems and prevent customer failures**
**Customer's own interest to avoid false handling**

# Boundary Conditions for Heavy Duty Trucks and Buses in Emerging Markets

- **Legal requirements of Europe will be adapted**
- **The boundary conditions are totally different to mature markets**
  - City Cycle → very low load and stop-and-go are causing cold exhaust gas which leads to poor performance of catalysts
  - Fuel and oil quality
  - Contamination of fuel
  - Contamination of AdBlue
  - Low service capability

German Engineering for Clean Air