ECT 2015 | Strategies for Compliance of BS V / BS VI

Ashwin Thondavadi, DGS-ES/EET-IN
GM Engineering – Exhaust Gas Treatment & Starting Devices

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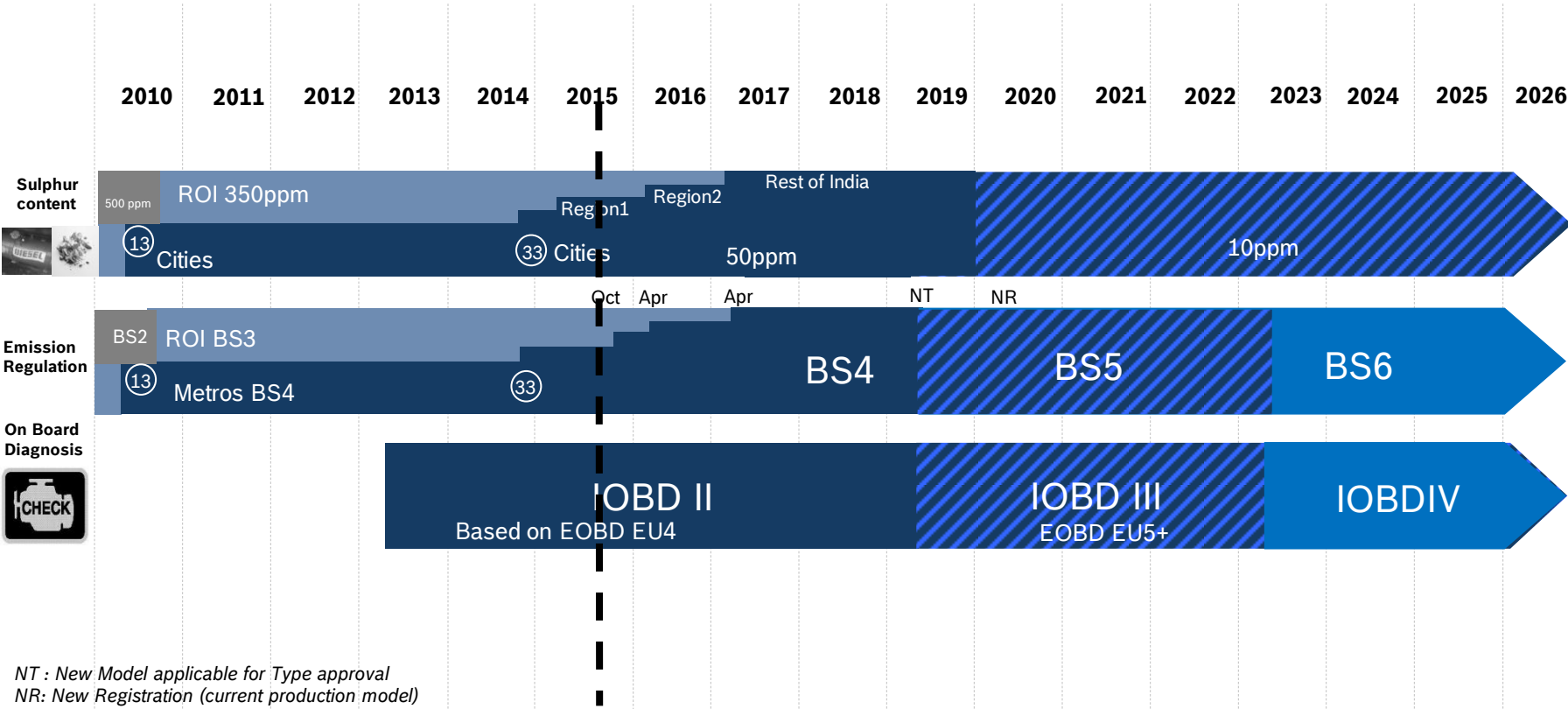
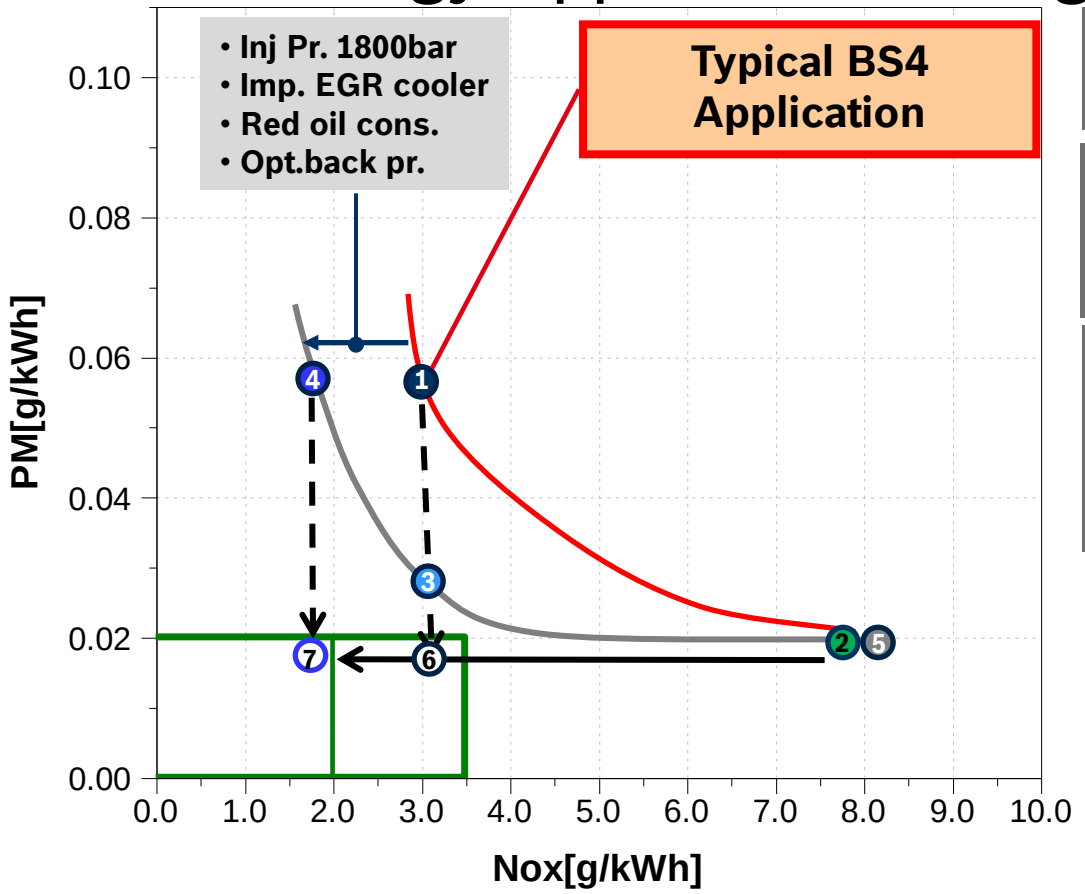
CV Emission Legislation Roadmap India



NT : New Model applicable for Type approval
NR: New Registration (current production model)

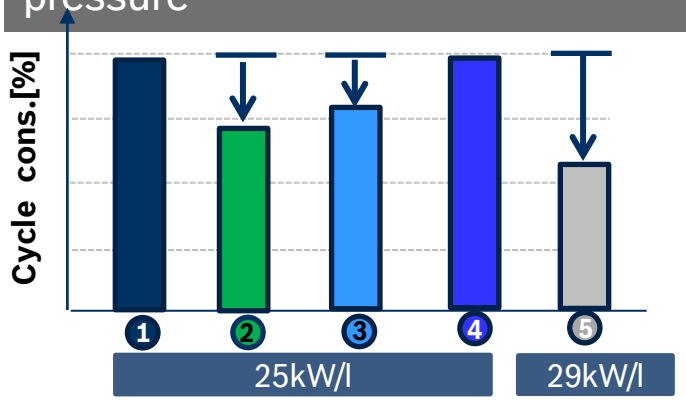
Technology Approach: CV engines BSV



Main stream (2–7): 1600bar CRS, SCR η >75, TCIC

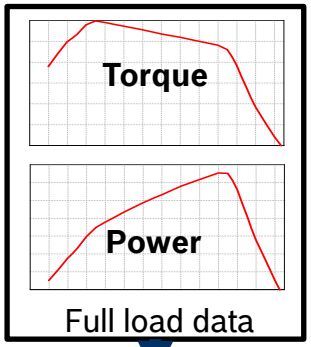
Alternative (4–7): 1800bar CRS, DOC + Open Filter η >65%, TCIC, enhanced cEGR

Niche 2V (3-6-7): 1800bar CRS, DOC + Open Filter + SCR, TCIC, enhanced cEGR, Optimised back-pressure

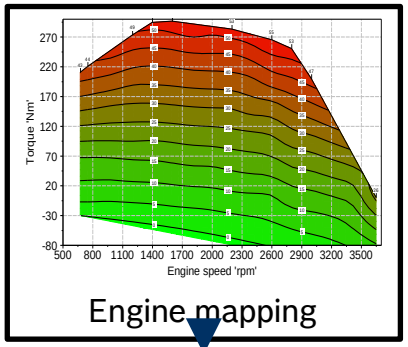


SCR is the proposed mainstream for BS5 in Commercial Vehicles

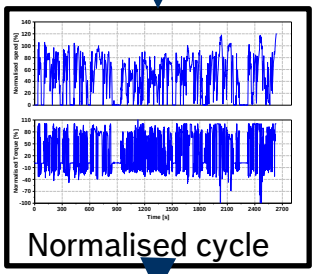
Fuel Consumption Evaluation: SCR v/s EGR

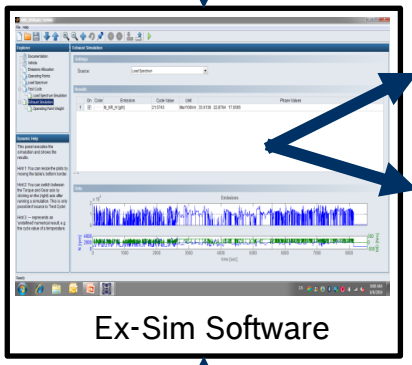


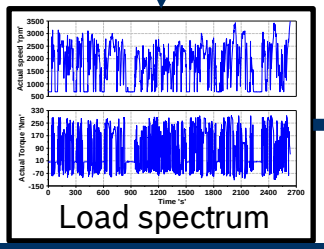
Full load data



Engine mapping


Normalised cycle


Ex-Sim Software



Load spectrum

Low Mileage Segment: Specific Power <25kW/l (City bus)

Annual Mileage ≤ 70 tkm	Fuel consumption (km/l)			
	City (30%)	Rural (20%)	Highway (50%)	Weighted Average
EGR	2.97	4.37	5.86	4.695
SCR	3.06	4.55	6.14	4.898
% FE benefit	2.7%	3.9%	4.5%	4.3%
TCCE @ 3.5% DEF	0.4%	1.5%	2.1%	1.7%

Pay back period for SCR hardware : 36 to 40 months

High Mileage Segment: Specific Power >30kW/l (Long haulage)

Annual Mileage ≥ 90 tkm	Fuel consumption (km/l)			
	City (0%)	Rural (10%)	Highway (90%)	Weighted Average
EGR	-	1.25	1.7	1.655
SCR	-	1.3	1.81	1.754
% FE benefit	-	4.0%	6.5%	6.0%
TCCE @ 5% DEF	-	0.3%	2.8%	2.6%

Pay back period for SCR hardware : 6 to 9 months

EGR solution could be used for low mileage segments, high FC!

DEF Consumption – MD: 3.5%, HD: 5% of Diesel; Cost s – Diesel: 60 INR/l, DEF: 45 INR/l

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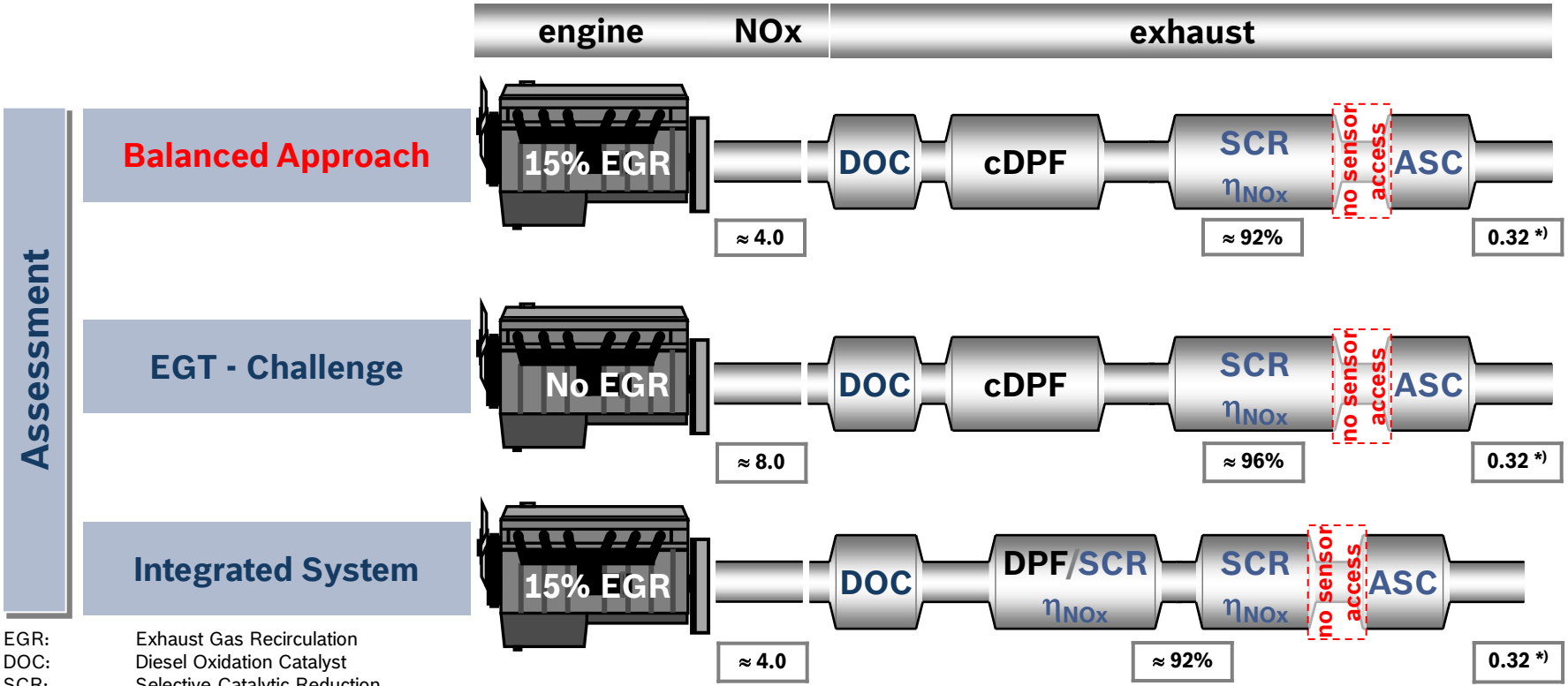
Trucks & Buses Emission Solutions for BSVI



EGR:	Exhaust Gas Recirculation
DOC:	Diesel Oxidation Catalyst
SCR:	Selective Catalytic Reduction
cDPF:	Coated Diesel Particulate Filter
DPF/SCR:	SCR on Filter
ASC:	Ammonia Slip Catalyst

*) Nox emission values including engineering targets

"Balanced Approach" is the proposed system, balance of engine and EGT measures

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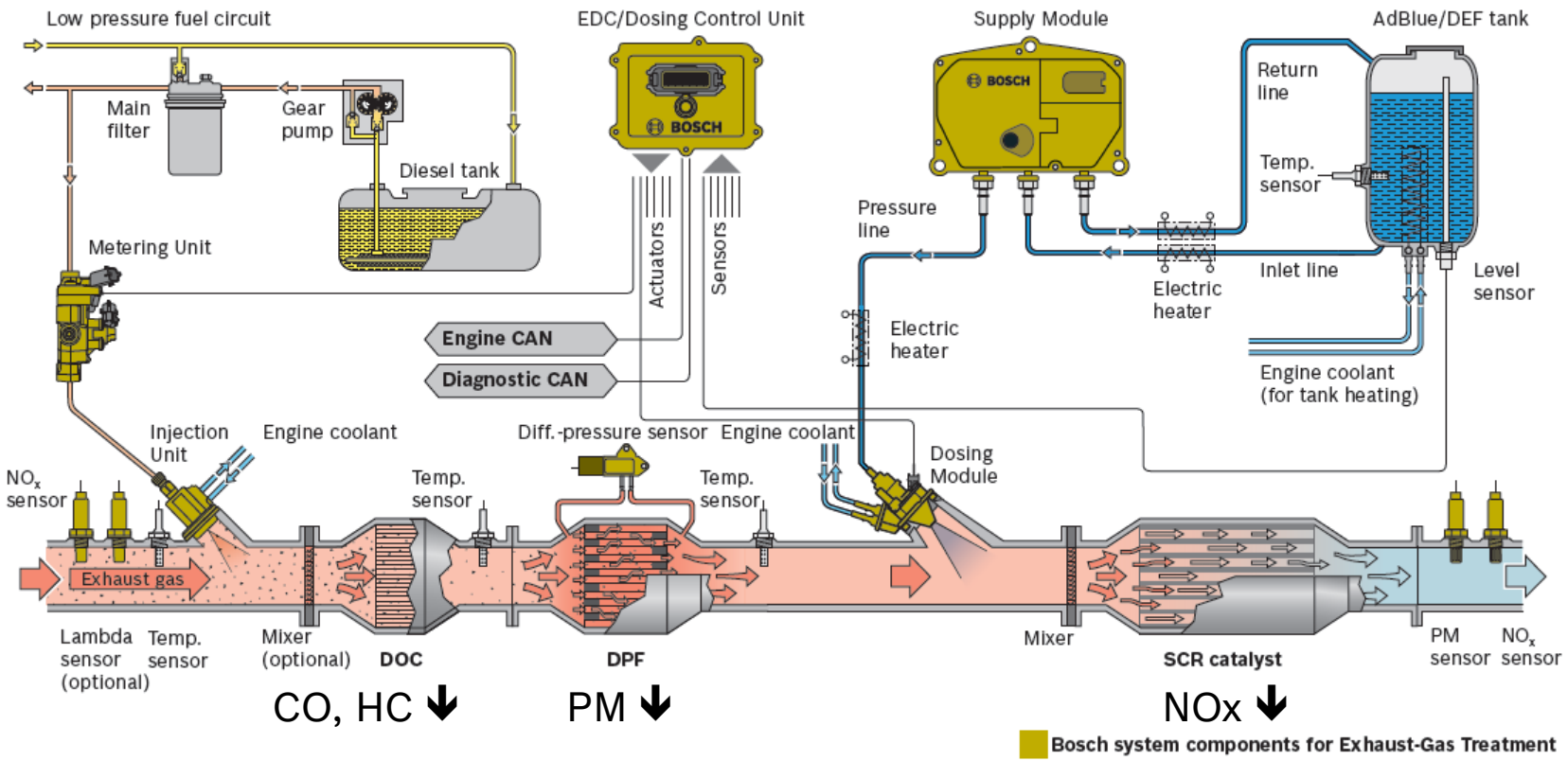
Example Exhaust Layout for BSVI



System Integration poses a double challenge : DPF + SCR

Exhaust gas system layout protected by US patent US7,498,010 and Japan Patent application JP 2002502927

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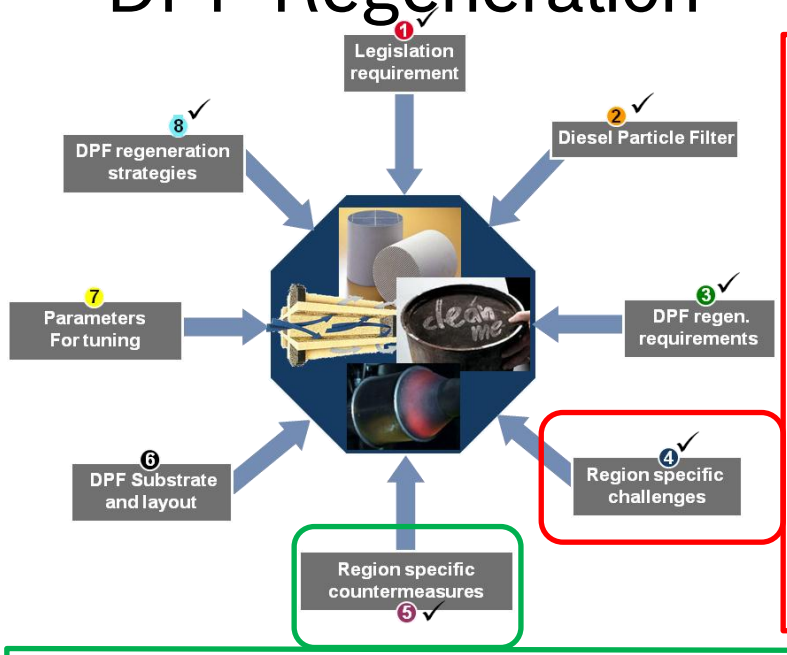
DPF Regeneration – Challenges and Solutions




Low vehicle speed

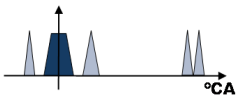
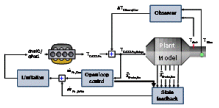
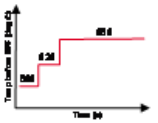
Long Idle


Overrun (Cooling)

Start-stop (Mech)

Limitation with DOC Light-Off → insufficient DPF regeneration → high oil consumption → DPF damage

Software functions developed for Efficient DPF Regeneration

Closed coupled DOC+DPF in single canning	Heat-up optimisation to enable DPF regeneration	Low Idle optimisation to maintain DOC light-off	Split POI1 Injection	Adaptive Heat Control function	Multi-stage Temp Governor
					

Functions developed for PC can be adapted and extended to CV

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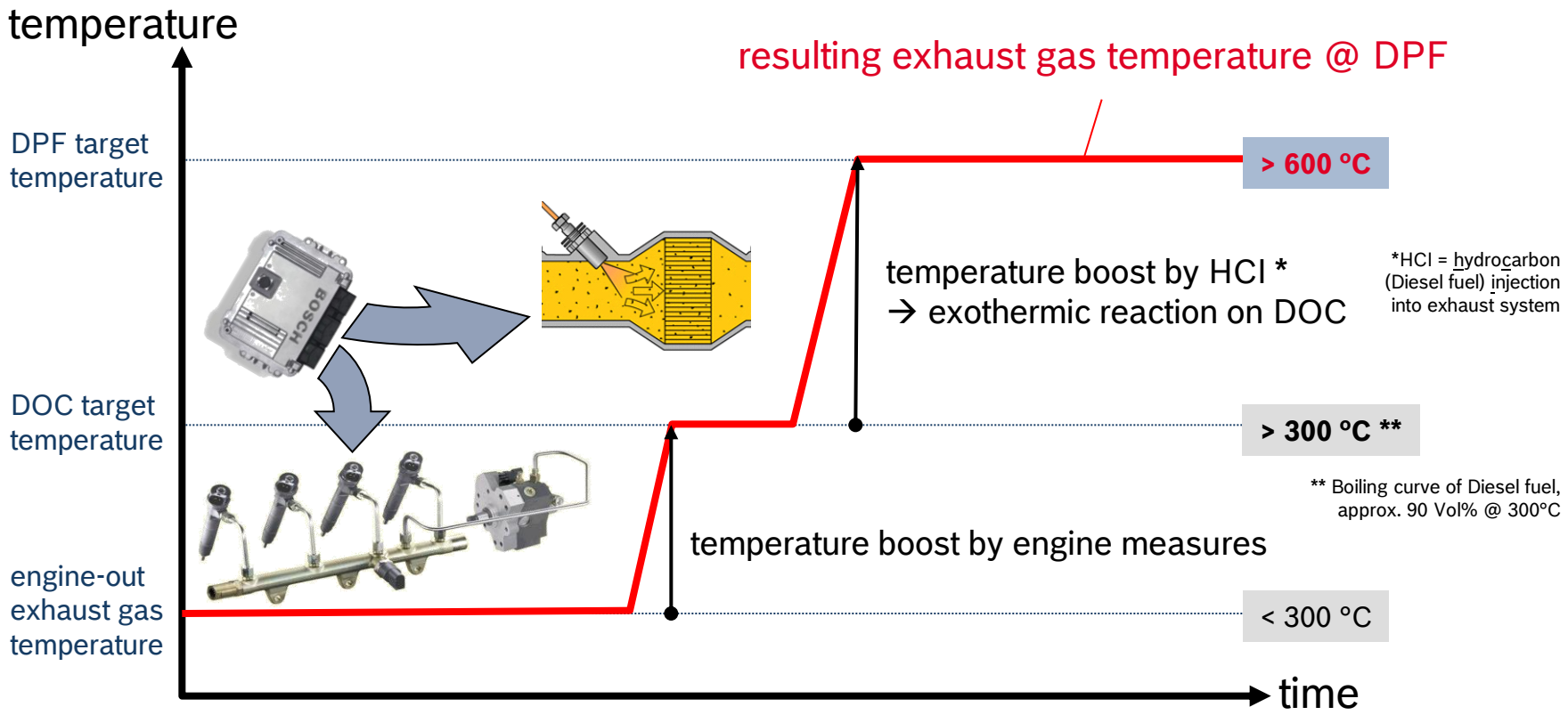
Active DPF Regeneration (Engine + Cat Burner)



Combination of engine-based and post-engine measures enable thermal DPF regeneration.

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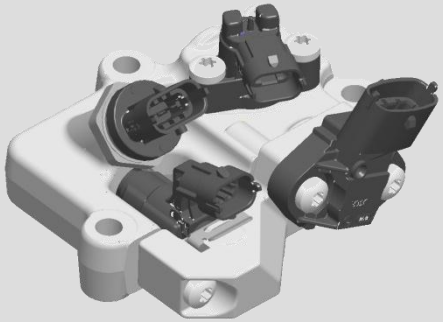
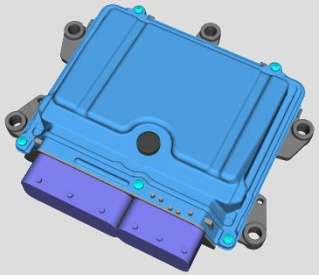
Hydro Carbon Injection (HCI) System for CV

Departronic 2 components



Metering Unit (MU)

Injection Unit (IU)



Dosing Control Unit (DCU) / Engine control Unit (EDC)
(optional)

Customer Benefits

- HC-dosing system for efficient DPF-regeneration with less or without engine measures
- Avoidance of oil dilution
- Robust and maintenance-free
- Supports achievement of (future) emission legislation (JPNLT, US13, Euro VI, Tier 4 /Stage IV,V)

Features

- Power supply 12 / 24 V
- Improved spray quality compared to first generation
- Maximum dosing quantity: 8.6 g/s @ 6 bar
- Control by stand alone DCU or engine ECU
- Useful lifetime of 3000 dosing hrs

Schedule

- In series production

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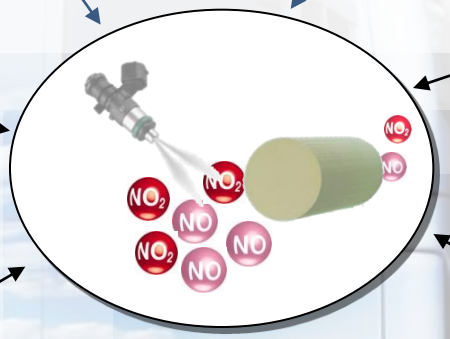
NOx Reduction – Challenges and Solutions

Space velocity

Exhaust gas temperature

NO_2/NO_x ratio, HC
- DOC
- DPF (if in front of SCR)

NO_x raw emissions



SCR catalyst type
- V-based
- Fe-exchanged zeolite-based
- Cu-exchanged zeolite-based

dosing strategy

Uniformity [gas + reductant]
- primary atomization
- exhaust system geometry
- secondary atomization (i.e. static mixer)

High NOx reduction needs thorough optimization of the EGT System

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CFD Simulation USP at Bosch

- Linux-Workstation/AVL Fire 2011.1
- Standard Simulation models:
  - Porosity, Species transport and general gas phase
  - Spray model covering droplet distribution probability
- Extended model (**BOSCH patented development**):
  - Evaporation of droplets (two-components)
  - Thermolysis and Hydrolysis
  - Spray breakup & Spray / wall interaction (wall film model)
- SCR catalyst modeled as porous medium (pressure loss calculation)

Robust simulation with empirically proven models is essential

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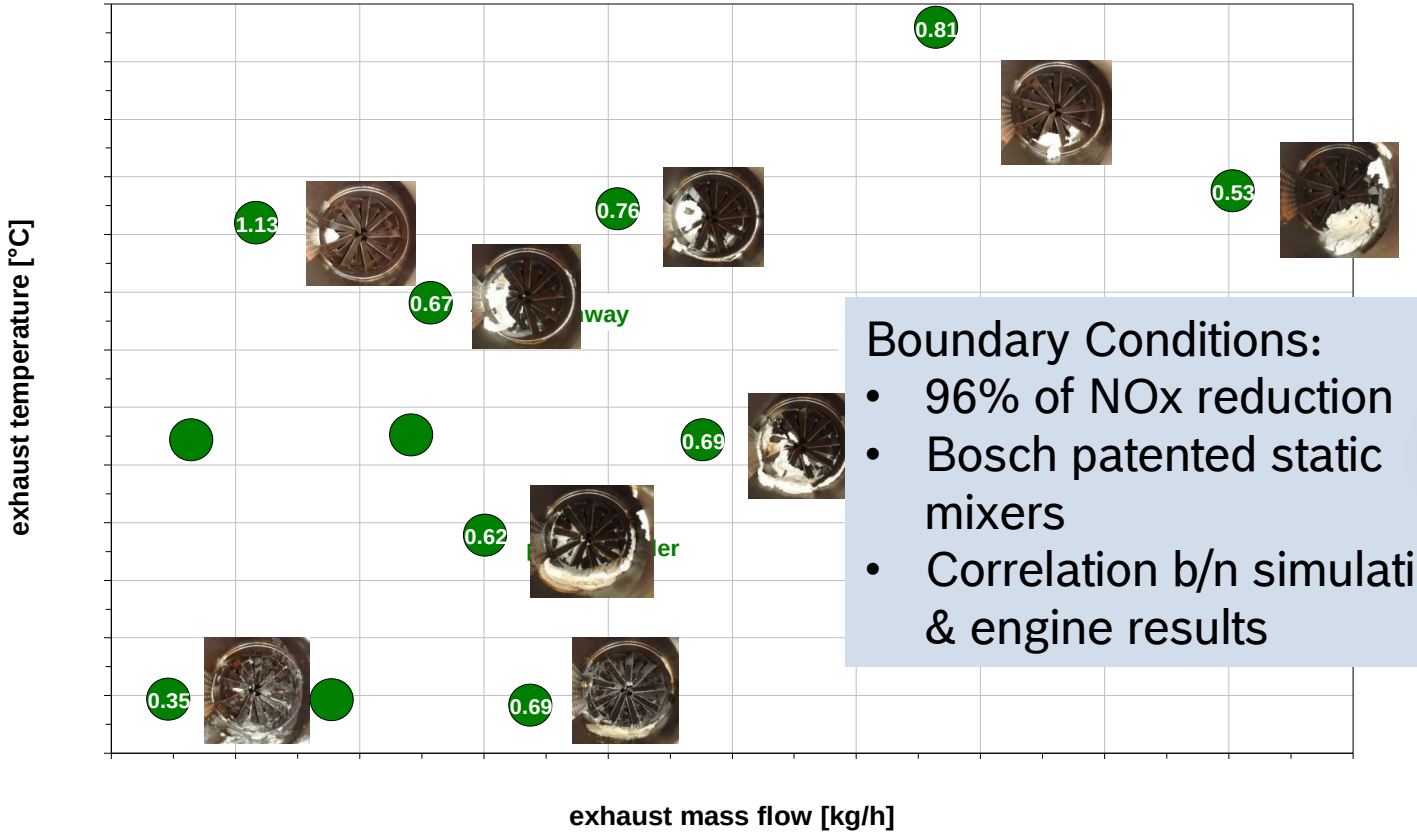
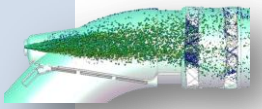
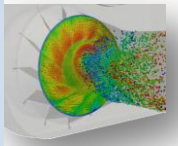
Alpha threshold for start of deposit formation



Boundary Conditions:

- 96% of NOx reduction
- Bosch patented static mixers
- Correlation b/n simulation & engine results





Robustness against deposit is an important development topic for high NOx-cal.

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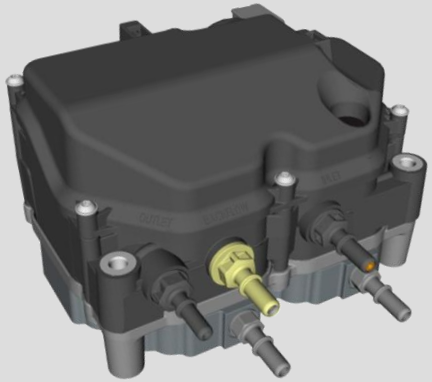
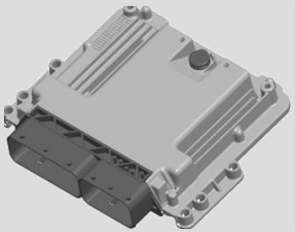
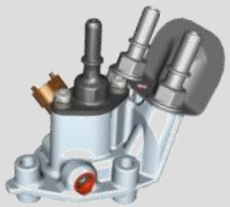
Denoxtronic System for DEF Dosing



Supply Module



VD1CC001
(SOP 09/2016)



Dosing Module 2.5

Customer Benefits

- Supports highest NO_x conversion rate and thus fuel efficient engine calibration
- Modular design for variety of vehicle applications
- Fully OBD compliant with EU VI, US 13 and JPNLT, T4f, EU StgV

Features

- Dosing quantity 0,04 ... 7,2 kg/h (optional 12 kg/h)
- Spray*: SMD 65 µm, angle 25 °
- 12 V or 24 V supply voltage
- Electrical, engine coolant heating
- Control by Standalone or Engine Control Unit
- Useful lifetime** of components
  SM, DCU: 30.000 hrs
  DM: 24.000 hrs

Schedule

- In series production since 2009

* For max dosing quantity of 7.2 kg/h with 6-hole injector

** for Trucks & Buses

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Denoxtronic Injector module

Innovation step

Evolutionary development derived from previous module

SOP 2009

DM 2.2

Water cooled

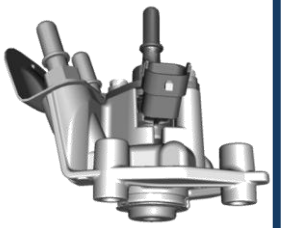
Dosing module

24000h lifetime

SOP 2013

DM 2.5

Improved water cooling

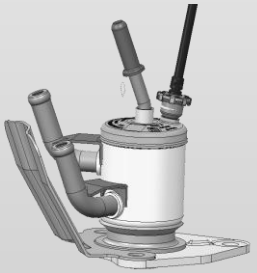


24000h lifetime

SOP 01/2018

DM 2.6

Fully housed, metal , water cooled dosing module



35000h lifetime

On Highway

Technological drivers

Close coupled application:

Temperature↑ → improved material

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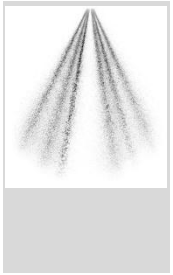
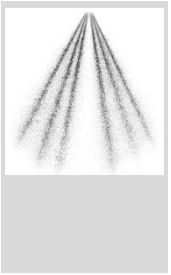
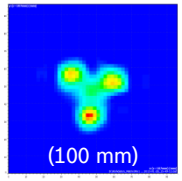
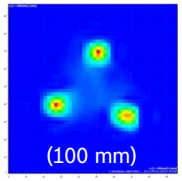
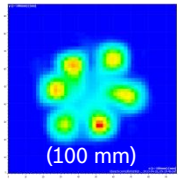
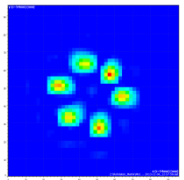
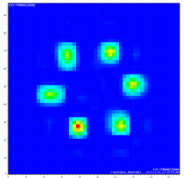
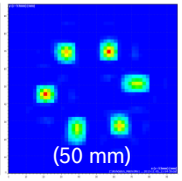
Spray Variants CV for 9 bar Systems

type	Turbulent					
$\dot{m}$	4.2 kg/h	7.2 kg/h				
α vis	16°	23°	25°	35° **	45° **	55° **
typical optical spray						
typical spray pattern (distance)	 (100 mm)	 (100 mm)	 (100 mm)			 (50 mm)
SMD Dv90	70 µm 230 µm	75 µm 250 µm	65 µm 170 µm	100 µm** 270 µm**	100 µm** 270 µm**	90 µm** 260 µm**
δ_h	0°	58°	-	-	-	-
status	Sample	Series	Series	Sample	Sample	Sample

*) feasibility supplier tbc. **) value tbc.

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System Integration as Enabler

Sub-Systems

- **FIE**
- **Exhaust System**
- **OBD & Service Diagnosis**
- **Air system**

Engine Mgmt System EMS

Software & System Integration by Bosch

Market Requirements

Customer Specific Requirements

Go Global | Emissions | Fuel economy | Invest | Fuel properties | Diagnosis

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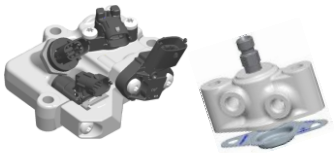
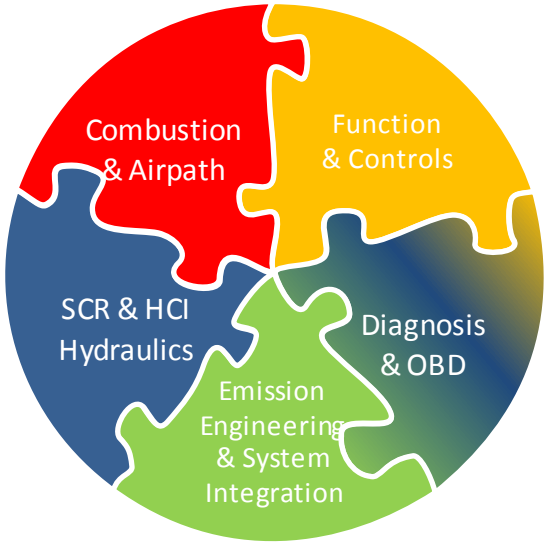
Approach: Comprehensive Emission Competence

Combustion

HC Dosing





System Control & OBD

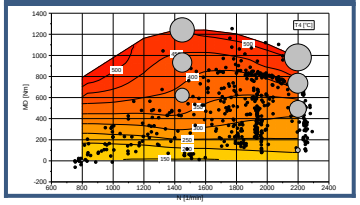
Sensors

Dosing System & Mixer

Canning & Converter

Catalyst & Substrate (external cooperation)

Application



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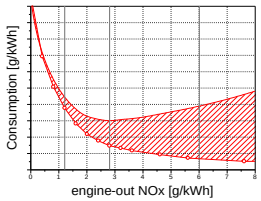
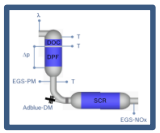
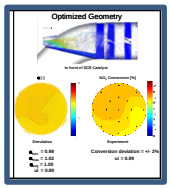
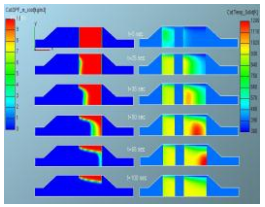
Approach: Comprehensive Emission Competence

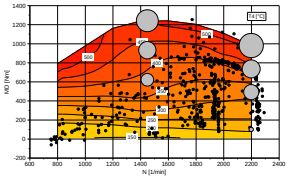
System Layout & Emission Engineering	Mechanical Engineering	Application & Calibration	Series Production & Aftermarket preparation
→ Functional analysis → System configuration → Performance simulation → Parameter fitting → Proof of concept → Deterioration / Aging → Engine & Vehicle verification	→ Exhaust design → Vehicle Packaging / Integration → CFD (1D/3D) & FEA → Sensor Positioning → Pressure drop optimization → Urea Distribution → Crystallization → Structural Reliability	→ Component & System Integration → Calibration incl. OBD * → Subsystem Release → Vehicle verification** → Variant application** → Customer fleet testing → Summer & Winter Testing	→Product release →Dataset release →Technical document release →Service function devleopment →Launch support











Bosch offers Turnkey Solutions or Provide full Engineering Service

* DPF (Soot Loading Model, Soot Burning Model), SCR (Dosing Strategy, Hydraulic Calibration), Departronic HCI, NSC, OBD

* * Performance Verification, Surface Temperatures, Crystallization, Hot/Cold-Testing, Altitude-Testing, Fleet-Evaluation

BOSCH

We shape the future of ***CLEAN DIESEL***
& appreciate your interest.

BOSCH