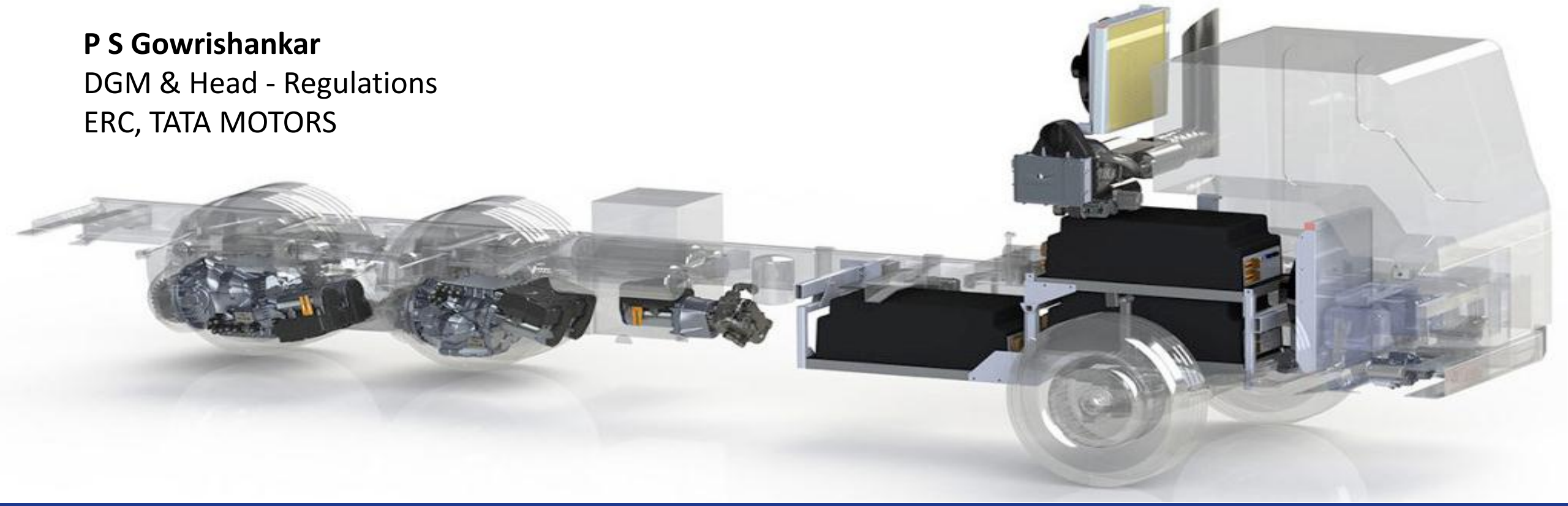
TATA MOTORS
Connecting Aspirations

TATA

CHALLENGES AND FUTURISTIC AFTER TREATMENT DEVICES FOR HEAVY DUTY COMMERCIAL VEHICLES

P S Gowrishankar
DGM & Head - Regulations
ERC, TATA MOTORS



ECMA's 10th International Conference **"Enabling Cleaner and Greener India Progressing Towards BS VI Norms"** ECT 2017
on 02nd and 3rd November, 2017 at New Delhi

TATA MOTORS
Connecting Aspirations

CONTENTS

TATA

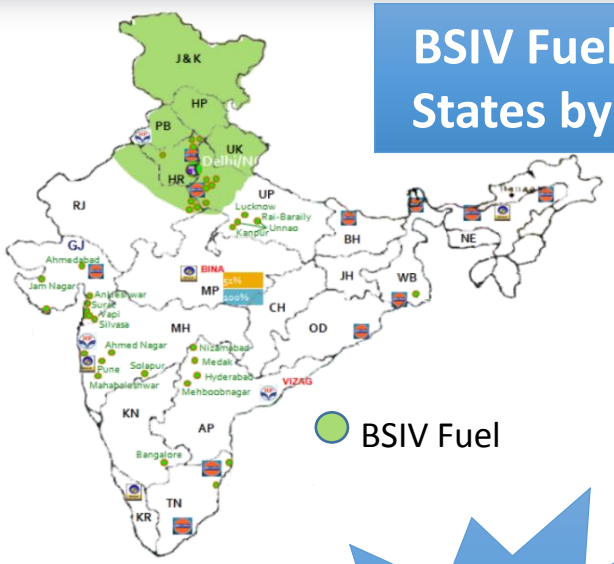
One Country-One Fuel

EMISSION NORMS & FUEL AVAILABILITY

Emission Control

FUEL AVAILABILITY ROADMAP

BSIV Fuel: Northern States by April 2015

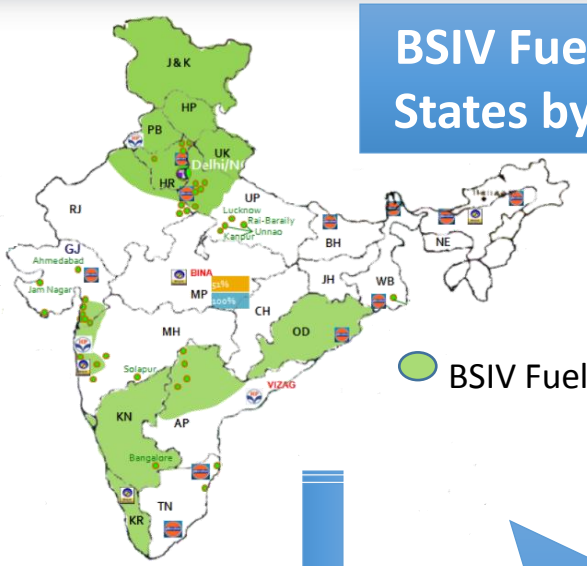


BSIV Fuel

India Moved Towards
ONE COUNTRY ONE FUEL in April 2017

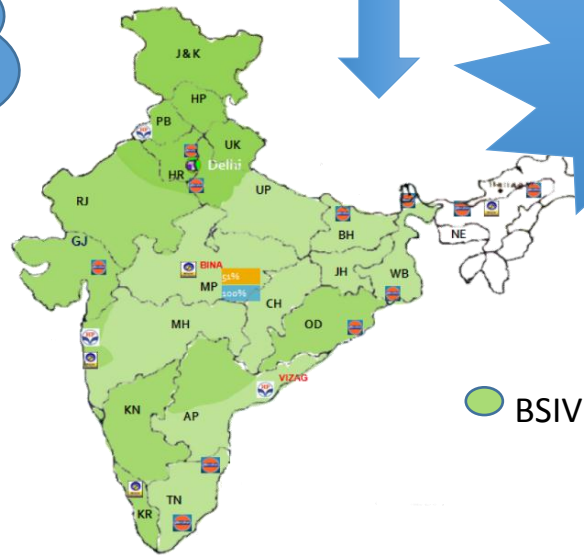
Govt. Notifications
GSR 555(E) dtd.14.07.15
GSR 643(E) dtd. 19.08.15
GSR 187 dtd. 19.02.2016
GSR 889 dtd. 16.09.2016

BSIV Fuel: Southern States by April 2016



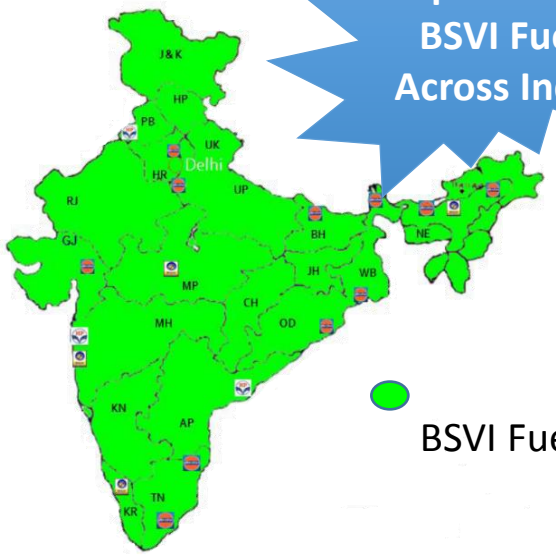
BSIV Fuel

April 2017: BSIV Fuel Across India



BSIV Fuel

April 2020: BSVI Fuel Across India

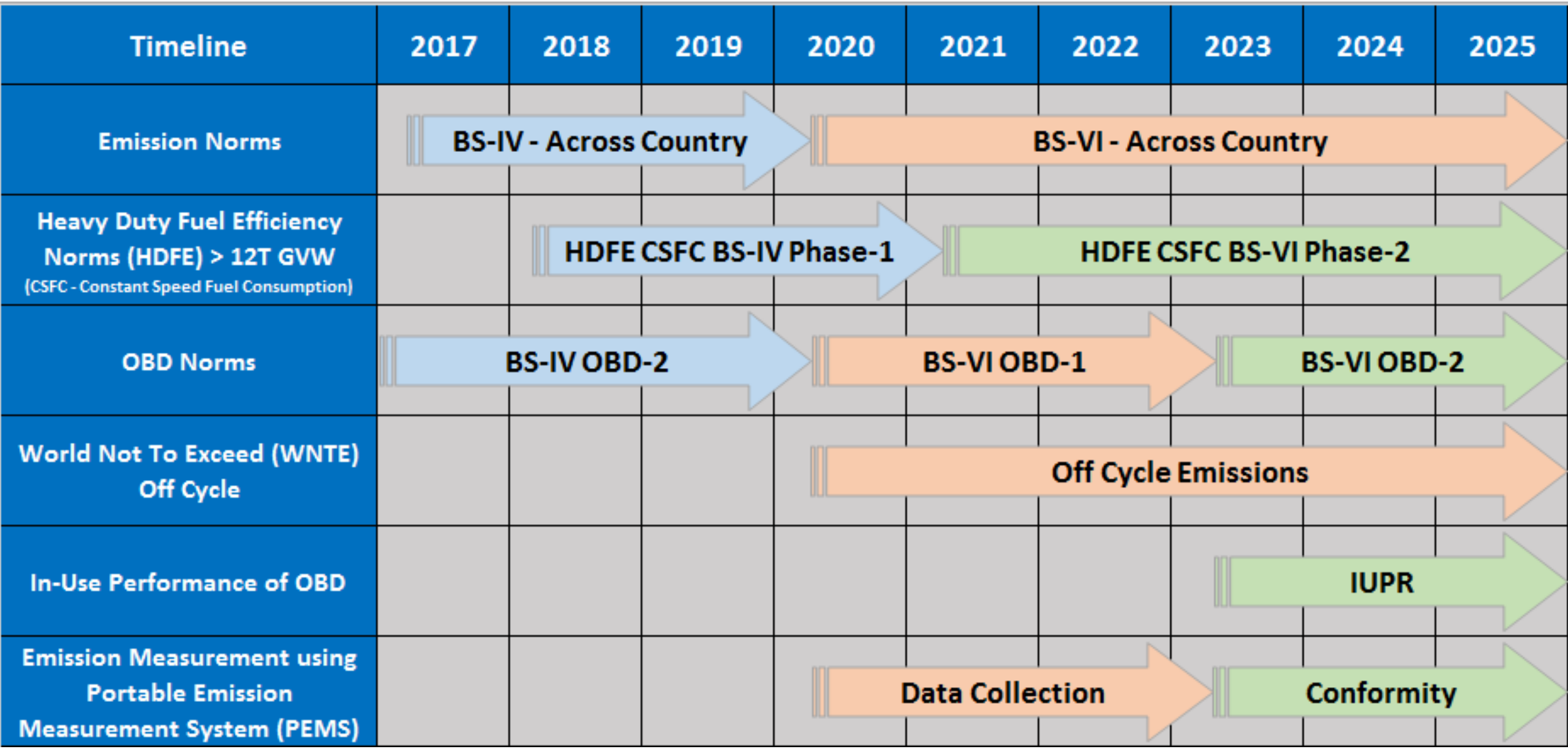


BSVI Fuel

TATA MOTORS
Connecting Aspirations

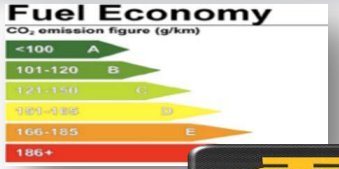
EMISSION ROADMAP FOR MORE THAN 3.5T VEHICLES

TATA



CHALLENGES : BSIV to BSVI LEAPFROGGING

CHALLENGES TO DEVELOP BSVI COMPLIANT VEHICLES



Heavy Duty Fuel Economy Norms Compliance (HDVFE)

Stringent emission norms & OBD

NVH Refinements

Light Weighting Technology & Material

Enhanced Power to Weight Ratio

High compression ratio

Innovative Packaging

Durability

Consumable replacement & optimised service intervals

New Base Engine Development

OVERVIEW

For BS VI development existing engines can't be used as base line

New engine needs to be **developed from scratch**

- Physical Phenomena Under-standing
- New concept Potential Evaluation
- Prototype Design and Optimisation
- Control Design and Validation
- Calibration Process
- Vehicle Performance Evaluation

From ideation … … to Vehicle Integration

EMISSION LINKAGE

No of engine platforms & portfolio need to be developed based on:

Optimised packaging

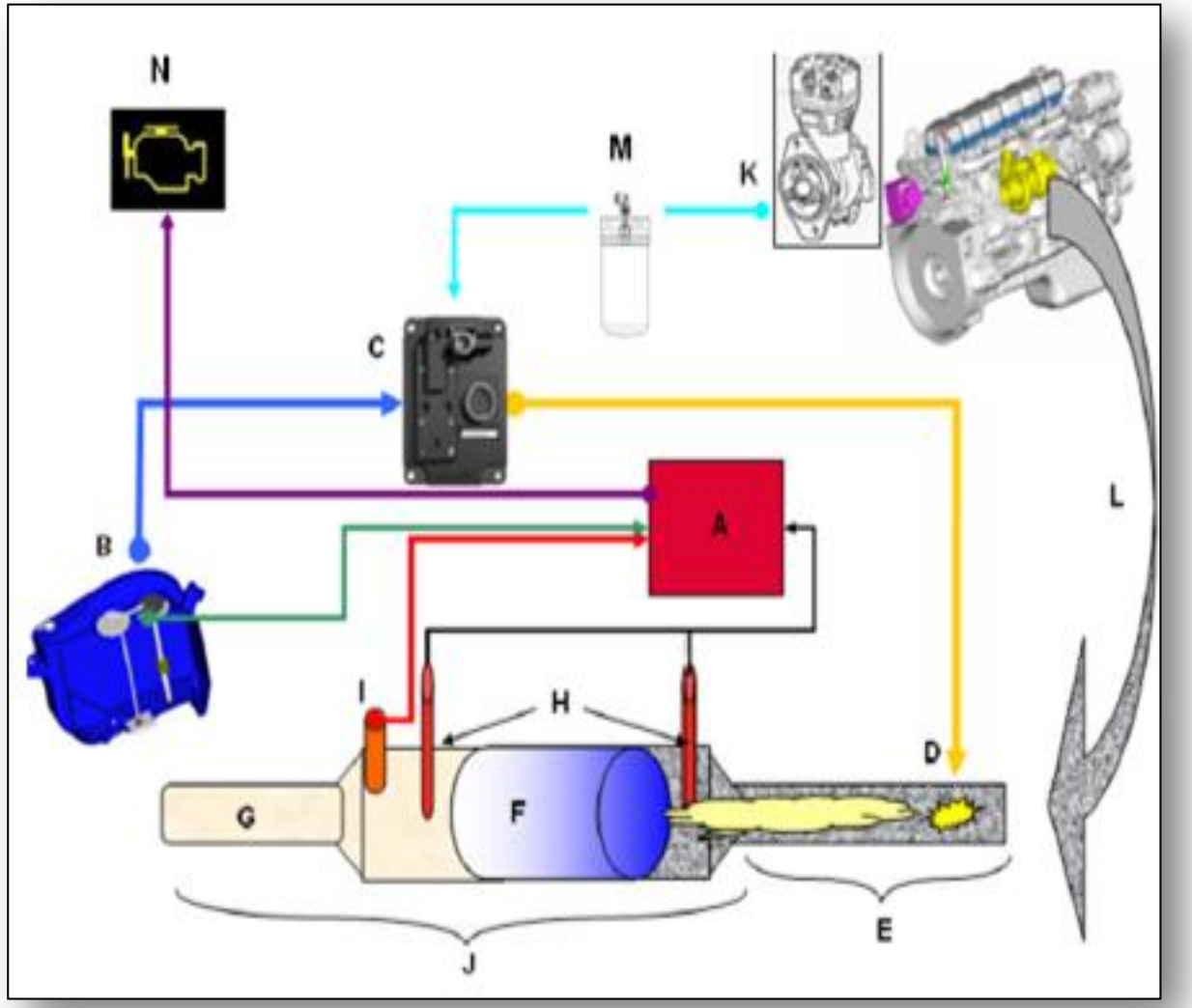
- Inlet manifold
- exhaust manifold
- EGR
- ECU
- Catcon
- SCR unit
- DOC unit
- DPF unit etc.

Subsystem development

- Cylinder block
- Cylinder head
- Crankshaft
- Camshaft,
- Inlet & exhaust valves,
- Air compressors
- Belts & chains
- Optimized cooling
- Lubrication etc.

This would require huge investments in development & manufacturing

BS VI major Engine aggregates & System architecture



A	Engine ECM
B	DEF Tank
C	Dosing Unit
D	DEF Injector
E	Decomposition Tube
F	SCR Catalyst
G	Tailpipe
H	Thermistors
I	NOx Sensor
J	Exhaust Gas Processor (EGP)
K	Vehicle compressed air supply
L	Exhaust gas
M	Compressed air filter
N	Malfunction Indicator Lamp (MIL)

EMISSIONS CONTROL TECHNOLOGY SOLUTIONS AND ADVANCEMENTS

BS VI TECHNOLOGY WAY FORWARD

Advanced Engine Technology with Fuel Economy

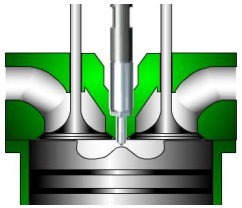
BS VI

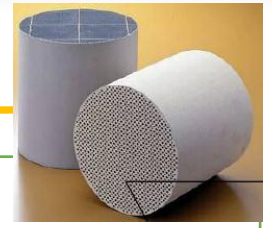
Advanced Exhaust Technology

BS IV

Advanced Control Technology, Sensors & Actuators

TECHNOLOGY ADVANCEMENT FOR CVs





- Indirect / Direct Injection
- Rotary / CR Fuel system
- Aspiration: NA / TC / TCIC
- EGR
- Diesel Oxidation Catalyst (DOC)

- Base BSIII DI Engine +
- Optimised combustion
- CR System (1600-1800 bar)
- Aspiration – TC IC
- Cooled EGR
- Advanced DOC
- Base OBD

- Base BSIV Engine +
- Optimised Combustion
- CR System (1800 – 2000 bar)
- SCR PM Sensor
- Boosting – VGT only
- Cooled EGR with by-pass
- HPCR / WGT /SCR /DPF / EGR all combinations
- Sensors for OBD
- Advanced control strategies
- LNT

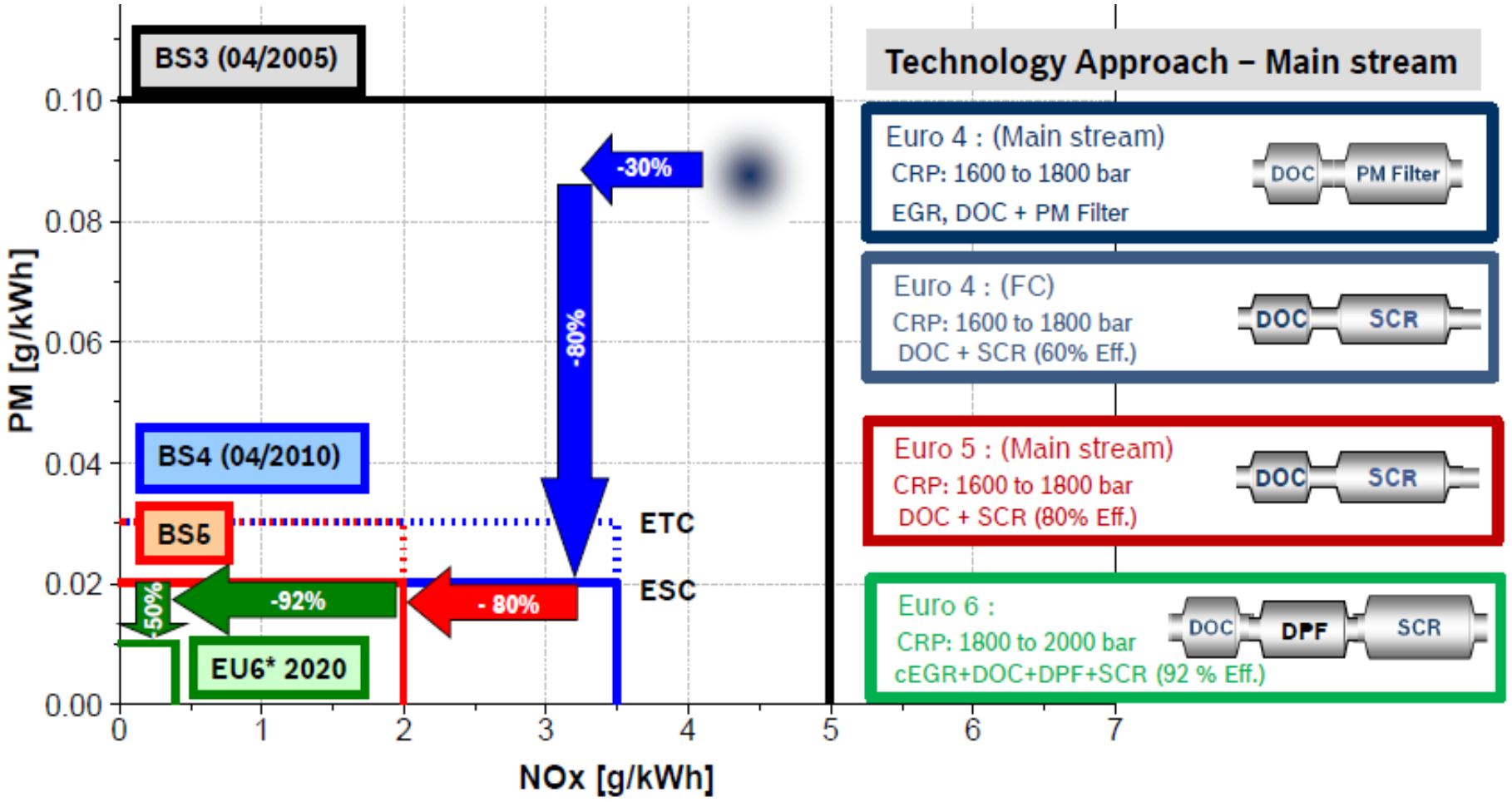
Technology Evolution

Emission Evolution

BS III → BS IV → BSVI

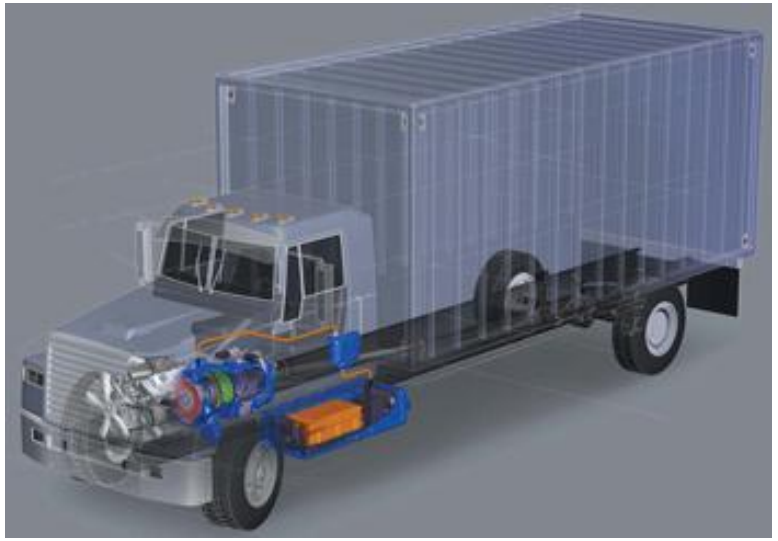
BS VI EXHAUST TECHNOLOGY COMPLEXITY INCREASE

Challenges for Future Emission Norms



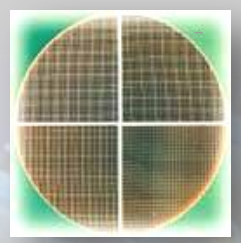
ESC = European Steady-State Cycle, ETC = European Transient Cycle, *EU6 = WHSC & WHTC

Exhaust Aftertreatment Devices



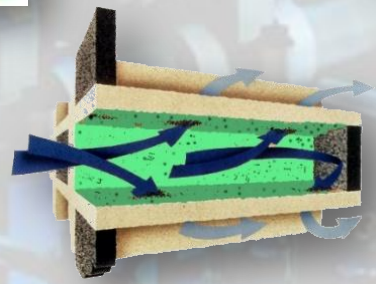
EXHAUST AFTERTREATMENT DEVICES REQUIREMENTS

Diesel Oxidation Catalyst (DOC)



- NO_2 formation
- HC, CO oxidation
- Particulate oxidation
- NH_3 oxidation

Catalyzed Particulate Filter



- Low balance point temperature
- NO_2 formation
- No secondary emissions
- Low pressure drop

Coated SCR

- Vanadia & Vanadia free
- High NO_x reduction
- Minimal NH_3 slip
- High temperature stability

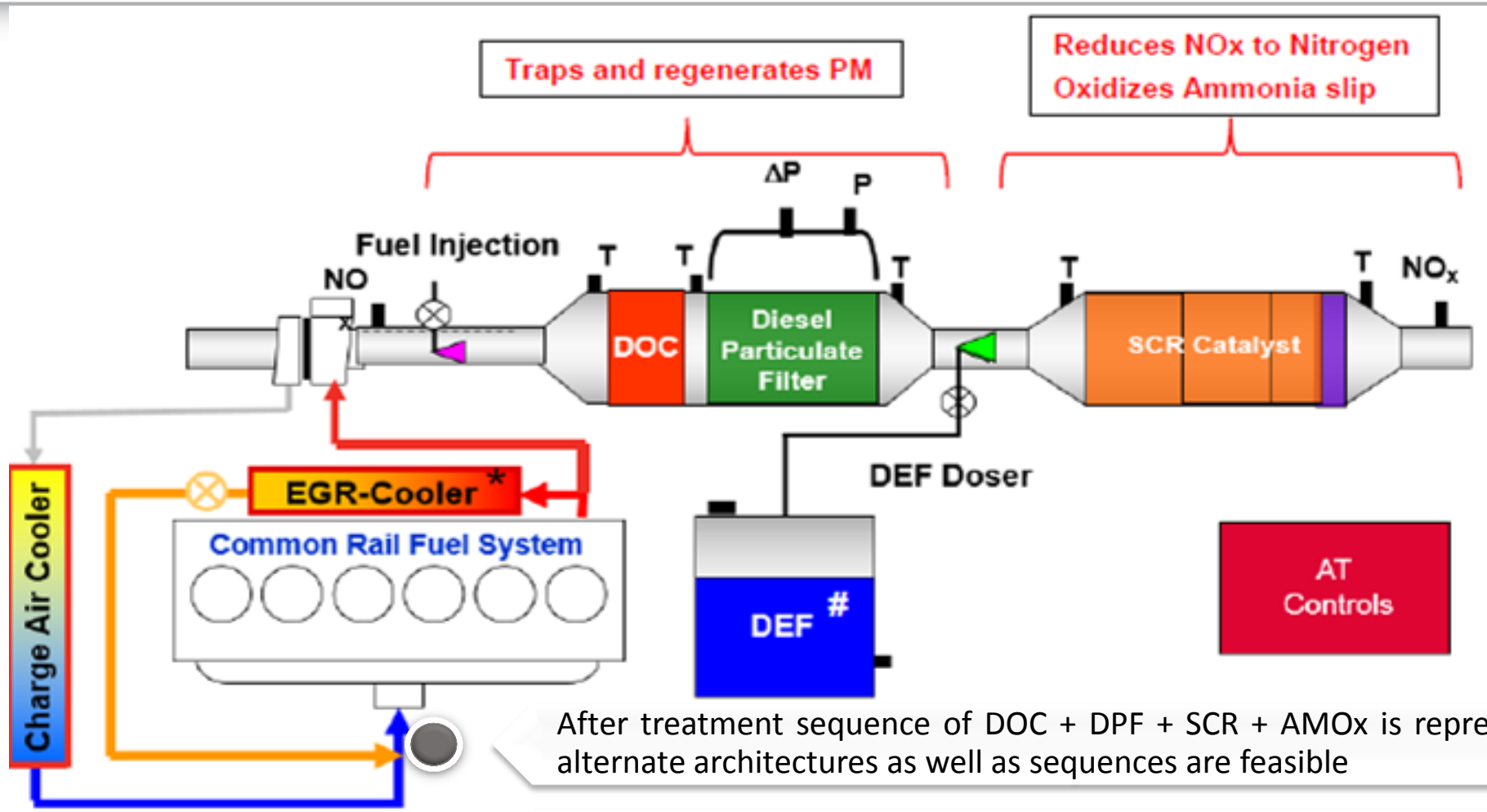
NOx Storage Catalyst

- NO_x reduction
- Regeneration behaviour
- Low temp. desulfation

HC-DeNOx

- Medium NOx reduction

BS-VI AFTER TREATMENT SYSTEM ARCHITECTURE



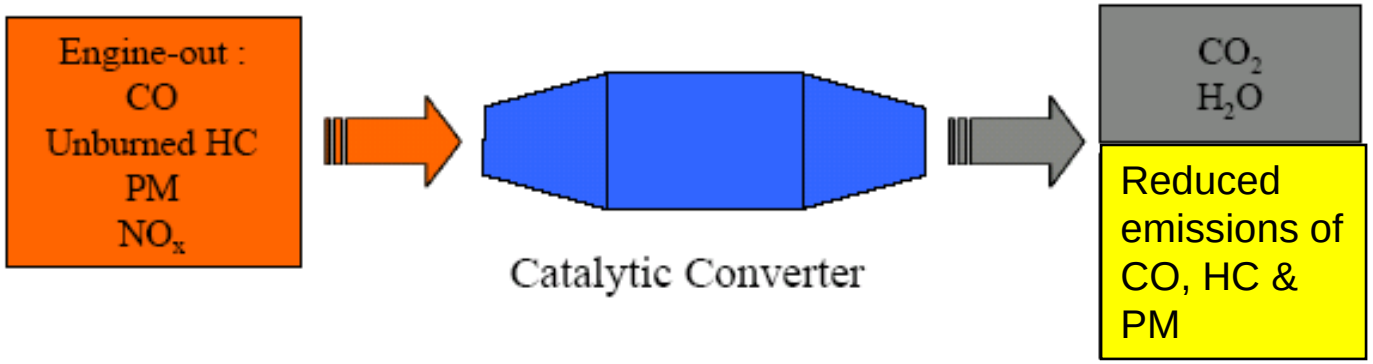
After treatment sequence of DOC + DPF + SCR + AMOx is representative only and alternate architectures as well as sequences are feasible

DPF and high efficiency SCR are essential part of after treatment system architecture at BSVI

* All engine architectures may not adopt cooled EGR solution

DEF: Diesel Exhaust Fluid also known as AUS (Aqueous Urea Solution) and 'AdBlue' in Europe is 32.5% concentration Urea solution in DI water

DIESEL OXIDATION CATALYST (DOC) TECHNOLOGY



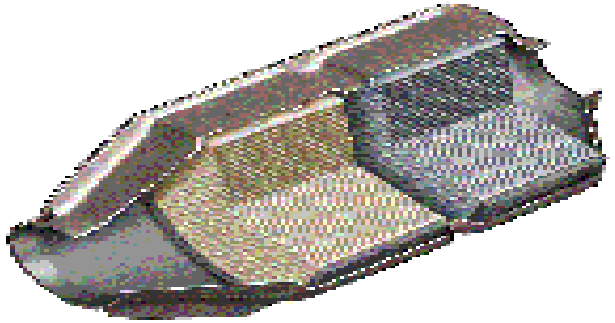
$$C_mH_n + (m+0.25n)\ O_2 = m\ CO_2 + 0.5n\ H_2O$$

$$CO + 0.5\ O_2 = CO_2$$

Benefits:

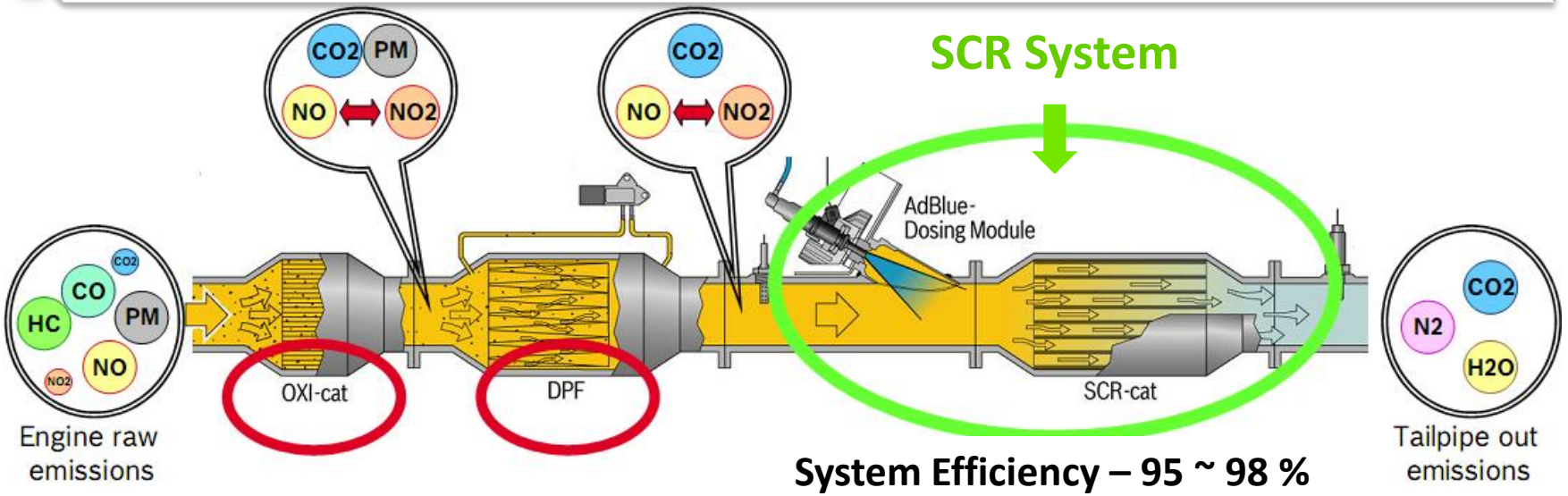
- **Over 80% reduction in CO & HC emissions**
- **About 30% reduction in particulates**
- **Widely used on light duty diesel vehicles**

- Ceramic honeycomb-Wash coat-Precious metal loading (Pt, Rd)-Canning
- Performance depends on fuel Sulphur



SELECTIVE CATALYTIC REDUCTION (SCR) TECHNOLOGY – NOx Reduction

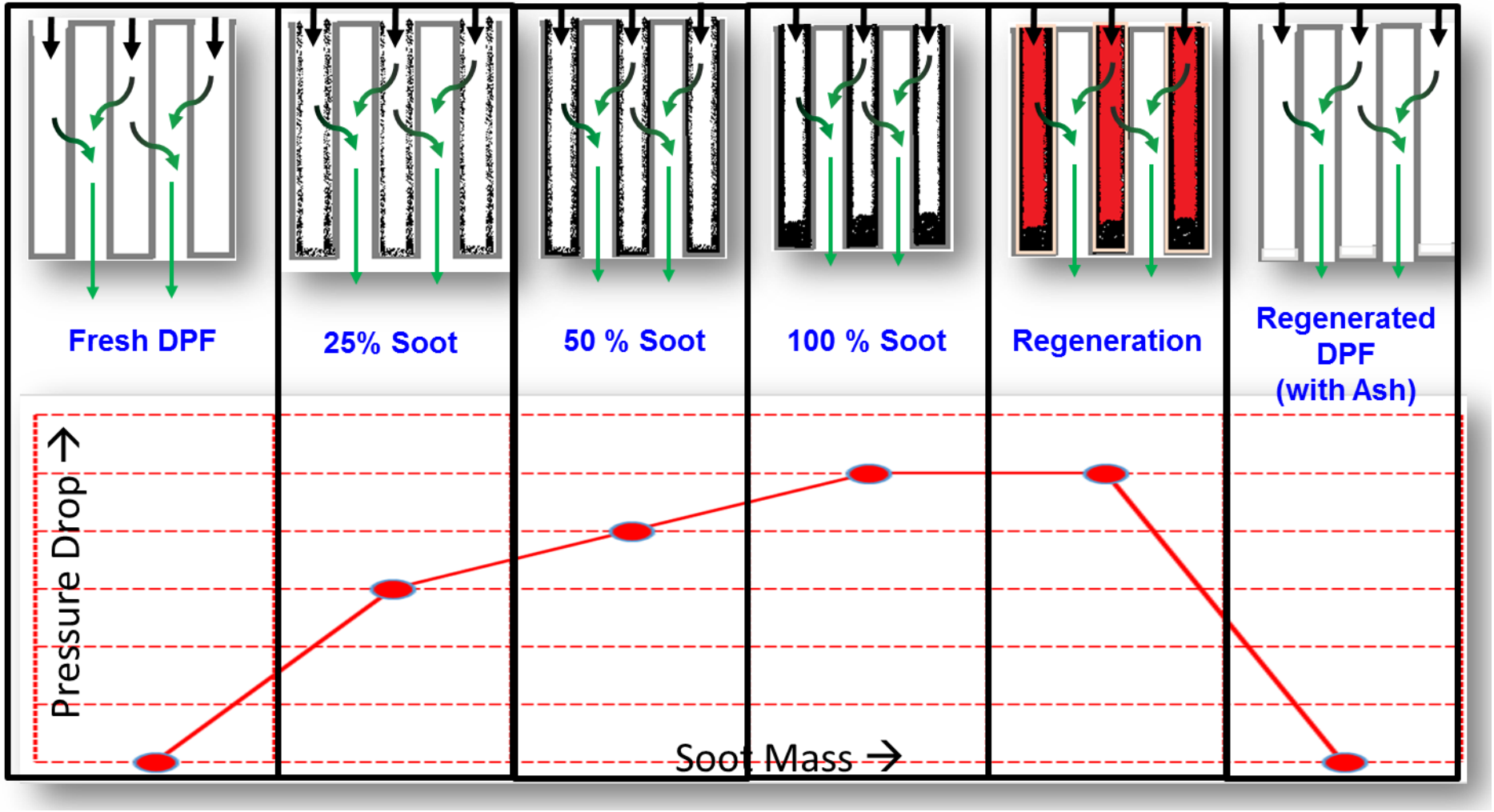
- SCR system needs aqueous urea solution for NOx reduction
- Require separate mixer for uniform distribution of urea into catalyst
- Metallic zeolites (Mainly Copper & Iron) & V_2O_5 as a catalyst in wash coat
- Higher NOx conversion between 220 °C - 450 °C of catalyst temperature



System Efficiency – 95 ~ 98 %

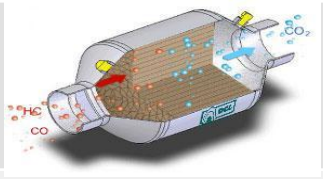
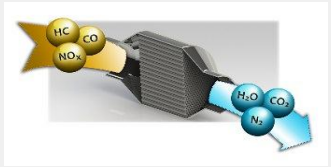
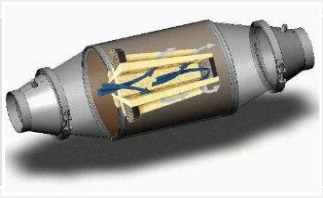
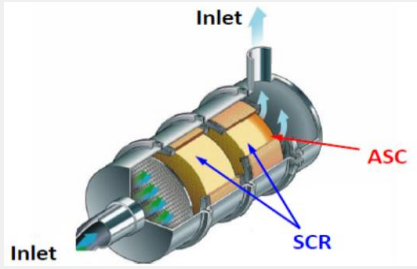
SCR needs special reducing agent & standalone reservoir & availability across country

DIESEL PARTICULATE FILTER (DPF) TECHNOLOGY – WORKING PRINCIPLE



Source : SIAM

AFTERTREATMENT SYSTEM COMPONENTS

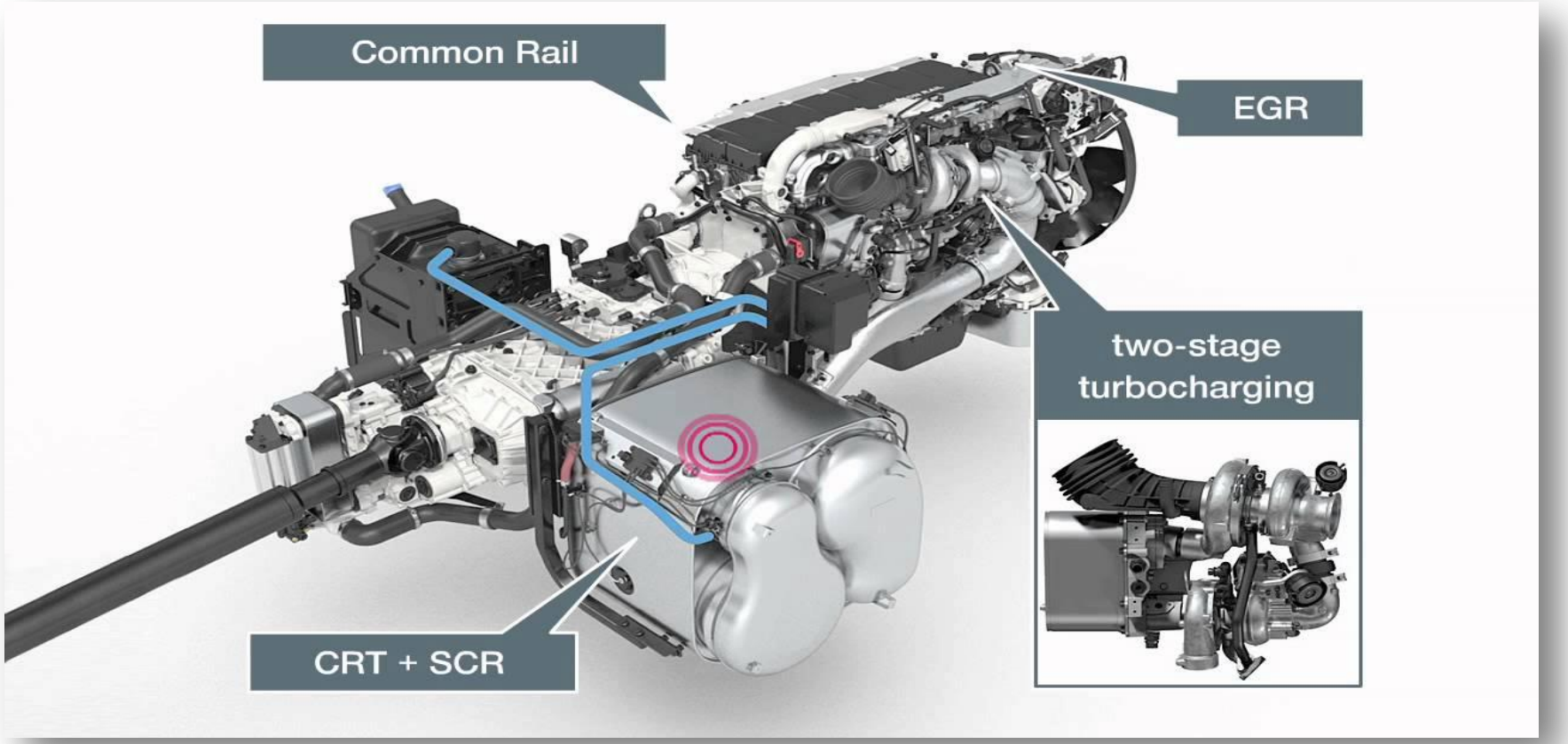
After treatment Component	Schematic	Reduction of	Conversion Efficiency
Diesel Oxidation Catalyst (DOC)		HC, CO	> 70%
Lean NOx Trap/ NOx Storage Catalyst (LNT/ NSC)		NOx	≤ 50%
Diesel Particulate Filter (DPF)		PM	> 95%
Selective Catalytic Reduction (SCR)		NOx	> 90%
Ammonia Slip Catalyst (ASC)		Ammonia (NH3)	> 90%

CHALLENGES TO DEVELOP BS VI COMPLIANT VEHICLES

Key Challenges						
	HP EGR +DPF	LP EGR + DPF	SCR+DOC	SCR+DPF	LNT	LNT+DPF
Cost to customer 	↑	↑	↑	↑↑	X	X
Fuel Economy 	↓	↓	↑	↑	↓	↓
Durability 	↓↓	↓	↓	↓	↓↓	X
Service Require. 	↑	↑	↑	↑	↑	↑
OBD Require. 	↑	↑	↑↑	↑↑	↑↑	↑↑
Back Pressure 	↑	↑	↑	↑	↑	↑
Fuel Quality 	< 50 ppm (15 ppm ideal)	50 ppm (15ppm ideal)	< 15 ppm	< 15 ppm	<1-2 ppm	<1-2 ppm

Source: EC-DG ENTR

Vehicle Application Development



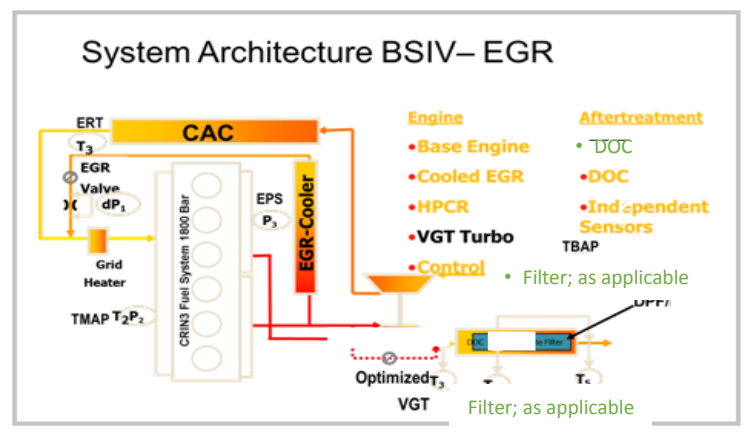
VEHICLE APPLICATION DEVELOPMENT OVERVIEW

- Engine related changes are implemented at aggregate level for compliance on Engine Dyno
- Following systems would be developed afresh for BS VI compliant from vehicle Engg. and packaging perspectives
  - New Exhaust System Development
    - After Treatment Devices such as SCR, EGR, DFP etc.
      - Engine ECU development, calibration & validation
        - New Wiring Harness
        - EOBD development and packaging
    - Urea Tank development and positioning for filling at retail pumping stations
  - Wheel Base, Masses & Dimensions changes

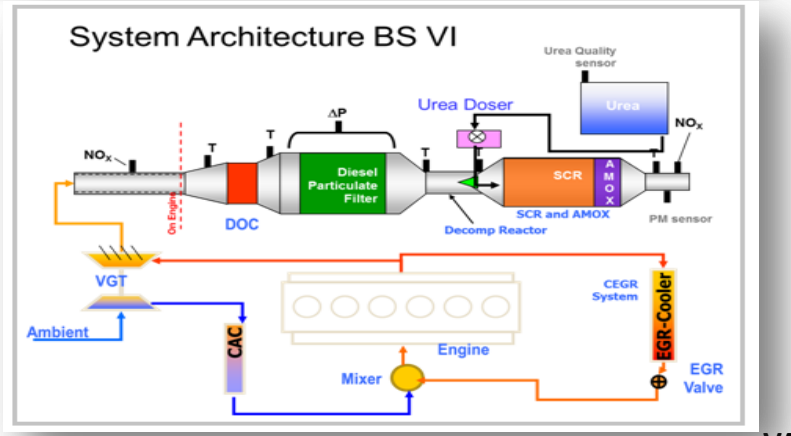
In view of the above mentioned changes the BSVI vehicles need to be validated thoroughly at Vehicle level

VEHICLE APPLICATION DEVELOPMENT REQUIREMENTS

BS-IV (EGR + DOC)



BS-VI (EGR + DOC + DPF + SCR + Ammonia Slip catalyst)



A) Engine hardware development

- ❑ Reduced engine-out emissions
  - – Improvement in air charge / control
  - – EGR control
- ❑ Engine control system including sensors

B) Exhaust after-treatment system

- ❑ Hardware development – DPF & SCR
- ❑ Industrialization of parts
- ❑ Vehicle level changes to accommodate DPF & SCR on each CV variant

C) Calibration & validation

- ❑ Calibration for Engine/Vehicle for EGR + DPF & SCR
- ❑ OBD calibration
- ❑ Fleet validation in various Indian operating conditions and Indian climatic conditions

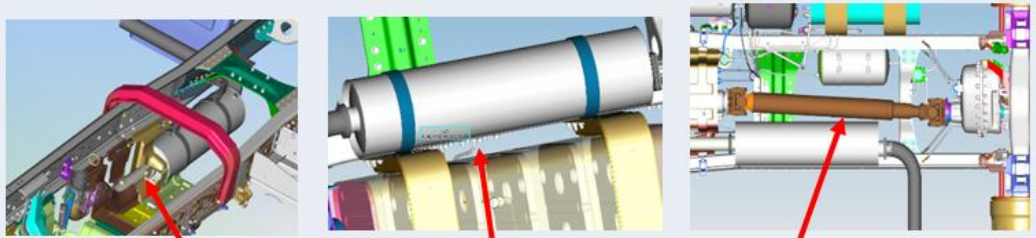
ENGINE INTEGRATION IN LEAD VEHICLE OVERVIEW

- Innovative **packaging & integration** from perspectives of **frugal** design & development methodologies
- Required **robust mechanism** at individual & collective levels
- **Integration needs to be handled** from Fuel Economy, Reliability of parts, subsystems, systems, & vehicle level
- Extensive **vehicle level validation** on Highway, urban, rural, off roads & Ghat Sections
- Trials need to be conducted during **summer & winter** months
- Engine **ECU calibration** would be finalized for proto vehicle build & subsequently for serial production
- Periodical **trials** during design & development cycle

ENGINE INTEGRATION IN LEAD VEHICLE METHODOLOGY

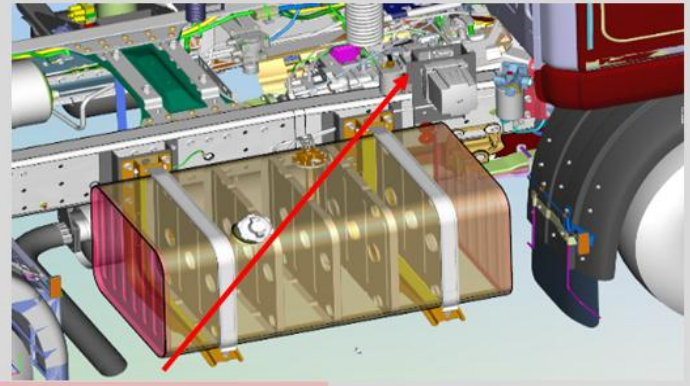
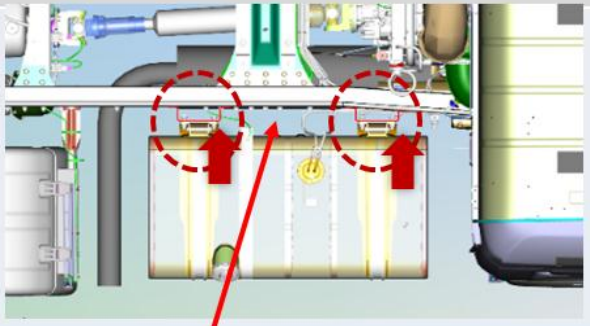
- **Extensive** development required on lead vehicles based on target market **segmentation & intended applications**
- **Minimum 20 variants** created based on lead vehicle for various applications
- Variants will **be tested** for technical changes & upgradations
- **Extensive validation** at variant level
- Compliance to pollutant limits for engine platforms & vehicles would be **serious challenge**
- Multiple trails on Engine dyno & Vehicle levels to establish conformance wrt **regulatory, internal design & validation targets**
- **Serviceability** of various parts needs to be confirmed during the proto build to avoid costly duplication
- Use of **light weighting technologies & materials**

Major Packaging & Integration challenges at vehicle level

AGGREGATE	CONSTRAINTS OR CHALLENGES FACED	ACTUAL SITUATION
Urea tank packaging	Space constraint in shorter wheel base vehicles for packaging of Urea tank	 No space for Urea tank-Fouling with other aggregates
EGP	EGP size is bigger than existing exhaust muffler and packaging issues of less clearances with fuel tank and propeller shaft needs to be addressed	 Critical clearances of EGP with Fuel tank/propeller shaft/ noise shields

ENGINE & CHASSIS INTEGRATION IN LEAD VEHICLE

Major Packaging & Integration challenges at vehicle level

AGGREGATE	CONSTRAINTS OR CHALLENGES FACED	ACTUAL SITUATION
Doser & NOx sensor ECU	Doser unit mounting constrained by injector line length Max 2 meter NOx sensor ECU mounting location constrained by sensor location on EGP as it is critical for packaging	 Doser packaging criticalities
EGP & tail pipe routing	Fuel tank gap with muffler very less	 Fuel tank to be taken out and shifted to front to maintain gap with muffler and for tailpipe routing

TAKE AWAY

- BS VI implementation – Requires significant changes to Engine & After treatment systems
- Extensive calibration effort is required for latest OBD and IUPR standards
- BS VI commercial fuel quality & availability is critical for completion of development on time
- Public awareness and strict implementation required to ensure the practical success of BS VI norms pan India
- Make in India initiatives on all new technologies to have less impact on cost and availability.
- Use of safer, affordable, fuel efficient, low cost vehicles in India will be on high rise – **A key attribute for sustainable growth & development**
- **The holistic approach requires not only vehicle technologies but also enriched infrastructure and consumer education to be addressed.**

Contact details :
P S Gowrishankar
DGM & Head-Regulations Forecasting & Management
ERC - Tata Motors Ltd, Pune, India
Phone: Office +91 20 6613 4662
Mobile +91 7276026129
Email : p.gowrishankar@tatamotors.com