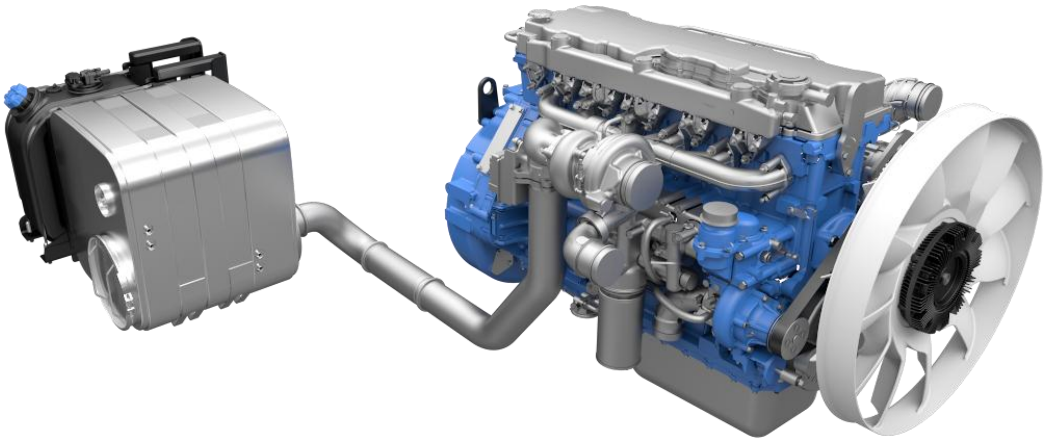
Challenging Strategies and Cost Effective Technology Options for Achieving Stringent BS VI Norms



S.Krishnan
Vice President – Ashok Leyland
Engine R&D

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Introduction - Why BS VI?

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रजिस्ट्री सं० डी० एल०-33004/99 REGD. NO. D. L.-33004/99

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सड़क परिवहन और राजमार्ग मंत्रालय

अधिसूचना

नई दिल्ली, 16 सितम्बर, 2016

सा.का.नि. 889(अ).—केंद्रीय मोटरयान अधिनियम, 1988 (1988 का 59) धारा 212 की उपधारा (1) द्वारा यथा अपेक्षित केन्द्रीय मोटर नियम, 1989 का और संशोधन करने के लिए प्रारूप नियम भारत सरकार में सड़क परिवहन और राजमार्ग मंत्रालय की अधिसूचना सं. सा.का.नि. 187 (अ), तारीख 19 फरवरी, 2016 द्वारा भारत के राजपत्र, असाधारण, भाग II, खंड 3, उपखंड (i) में उनसे द्वारा संभाव्य प्रभावित सभी व्यक्तियों द्वारा उस तारीख से जब प्रारूप नियमों से अंतर्विष्ट उक्त अधिसूचना की प्रतियां जनसाधारण को उपलब्ध करवाई गई थीं, से तीस दिन की अवधि की समाप्ति से पूर्व आक्षेप और सुझाव आमंत्रित करने के लिए प्रकाशित किए गए थे ;

उक्त राजपत्र अधिसूचना की प्रतियां जनसाधारण को 19 फरवरी, 2016 को उपलब्ध करवाई गई थीं;

उक्त प्रारूप नियमों के संबंध में जनसाधारण से प्राप्त आक्षेपों और सुझावों पर केंद्रीय सरकार द्वारा विचार किया गया है ;

अत:, केन्द्रीय सरकार, मोटर
केन्द्रीय मोटर यान नियम, 1989 का

1. (1) इन नियमों का संक्षिप्त
(2) ये राजपत्र में उनके प्रक
2. केंद्रीय मोटर यान नियम, 1989,
(क) उप-नियम (2), में-
(क) खंड (i), में "परन्तुक में, "भारत स्टेज-IV" का प्रयोग ... के स्थान पर "भारत स्टेज IV या भारत स्टेज VI" प्रविष्टि क्रमश: प्रविष्टि रखी जाएगी;
(ख) खंड (ii), की तालिका में, "भारत स्टेज-IV" की प्रविष्टि जहाँ भी हो, के स्थान पर "भारत स्टेज IV या भारत स्टेज VI" प्रविष्टि क्रमश: रखी जाएगी;
(ग) उप नियम (7), के परंतुक में, "भारत स्टेज-IV" की प्रविष्टि के स्थान पर "भारत स्टेज IV या भारत स्टेज VI" रखा जाएगा;

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REGULATION

INDIA RATIFIES PARIS DEAL: WHAT NEXT?

REPORTS ON P 10

➤ India ratifies Paris climate agreement. Instrument of ratification handed over at a UN ceremony to commemorate Gandhiji's birth anniversary

➤ Treaty comes into force when nations accounting for 55% of world's emissions ratify it. Currently, **62 nations (52% of emissions) are on board.** Threshold expected to be crossed soon

THE ROAD AHEAD

➤ Countries will start framing rules for implementing the agreement, meant for actions to be taken in 2020-30, at **climate conference (COP22) in Marrakech, Morocco, next month**

➤ Climate actions till Dec 2020 — to be taken only by rich nations — are governed by Kyoto Protocol. **India to seek action plan for 2016-2020**

➤ India will insist on concrete roadmap from rich nations to mobilise **funds to help developing countries** move to a low carbon growth path

INDIA'S POST-2020 PROMISE

➤ Reduce emissions intensity, or emissions per unit of GDP, **by at least 33% by 2030 compared with 2005 levels**

➤ **At least 40%** of power to come from non-fossil fuel sources in 2030

➤ Additional carbon sink of **about 2.5-3 billion tonnes** by adding forest/tree cover

India becomes 62nd nation to ratify Paris climate deal

Vishwa Mohan
@timesgroup.com

New Delhi: India formally joined the Paris Agreement on climate change by submitting its instrument of ratification to the United Nations in New York on Sunday, the birth anniversary of Mahatma Gandhi and also the International Day of Non-Violence.

The country, however, ratified the deal with certain conditions keeping its development agenda in mind.

Though the country has not used the word "condition", it made amply clear in its "declaration" that India would be able to take climate actions provided it got financial and technological support to move towards a low carbon growth path. India's declaration said, "The government of India declares its understanding that as

India's permanent representative to the UN Syed Akbaruddin hands over the Paris climate deal document signed by President Pranab Mukherjee to Santiago Villalpando, the head of UN treaty division

Activists say agreement not enough to contain temp rise

New Delhi: Environmentalists welcomed India's move ... mental role in addressing issues of loss and damage

Introduction

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- Advancing towards sterner fuel standards helps to tackle air pollution in India.
- India, under Prime Minister Modi led government is taking a bold step in skipping BS-V to implement BS-VI four years ahead the deadline.
- India will be the first country to skip the BS V stage and also the first to switch to BS VI in such a short span of time.
- Further BS VI fuel which is similar to the Euro 6 fuel cannot be blindly mirrored as the challenges related to driving conditions, speed and weather of India varies from that of Europe.
- If vehicles are not fine tuned to the stipulated Indian conditions then repercussions could be massive to correct the same after.

Challenging commitment

Indian auto industry ready for BS-VI Challenge

In INDUSTRY NEWS by motorindia – October 26, 2016 at 11:17 am

The Indian auto industry is committed to meet the challenge of achieving to BS-VI emission norms by 2020. The target is very stiff but the auto industry has accepted the challenge in view of the rising concerns on vehicular pollution, especially in the urban metros, stated Mr. Vinod Dasari, SIAM President, at a press briefing in the country's capital.

" India has been the fastest at adopting new safety and emission norms. This leap-frog would make India the first country in the world at accomplish such an accelerated progression in vehicular emission norms", said Mr. Dasari.

"This would not only entail a significant telescoping of long term investments into a much shorter timeframe of 3-4 years, but also deployment of a much larger technical resource drawn from world over to enable compression in the time taken for technical development, testing and validation of the vehicles in Indian conditions", he added.

10 Things you should know about BS VI

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Govt has advanced the date when new standard for cleaner auto fuel kicks in, aiming to leapfrog to BS-VI norms by April 2020

1 WHAT ARE THE NORMS?

- Bharat Stage emission standards are used to regulate output of air pollutants from internal combustion engine
- These were introduced by the Union government in 2000

2 DO OUR NORMS FOLLOW GLOBAL PRECEDENTS?

- The Bharat Stage norms are based on European regulations. Two and 3-wheeler emission norms are lenient

3 WHAT IS INDIA RUNNING ON RIGHT NOW?

- BS-IV auto fuels are being supplied in north India
- The rest of the country runs on BS-III grade fuel
- From April this year, Goa, Kerala, Karnataka, Telangana, Odisha, Daman and Diu, Dadra and Nagar Haveli and Andaman & Nicobar will get BS-IV fuel
- The remaining parts of the country will get BS-IV fuel from April 2017

4 HOW MUCH WILL SWITCH COST OIL COMPANIES?

- According to oil minister Dharmendra Pradhan, oil PSUs will invest about ₹**28,750cr** for switching over to BS-VI auto fuels

5 WHY SKIP ONE ENTIRE STAGE?

'We are not going for Bharat Stage V (or Euro-V) petrol and diesel as there is not much difference between BS-V & BS-VI (Euro-VI) fuel. We will bring BS-VI fuel by 2020' – **DHARMENDRA PRADHAN** | OIL MINISTER

6 WHAT CHANGES WILL THE SWITCH BRING TO YOUR CAR?

- Vehicles will have to be fitted with DPF (diesel particulate filter), mounted inside the engine compartment
- In small-car crazy India a DPF in the bonnet will involve major re-engineering
- Bonnet's length may have to be increased, making cars longer than 4 metres and liable to come under higher excise duty bracket

7 WILL CARS GET COSTLIER?

PETROL CARS BY	DIESEL CARS BY	TRUCKS BY
₹**10,000-20,000**	₹**80,000-1.2L**	₹**1.5L-2L**

10 Things you should know about BS VI

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8 DIFFERENCE IN NORMS?

BS-VI norms not defined yet but will be equivalent to Euro-VI standards

PETROL EMISSION NORMS

Norm	CO	HC	NOx	HC+NOx	PM
BS-III	2.30	0.20	0.15	–	–
BS-IV	1.00	0.10	0.08	–	–
Euro-VI	1.00	0.10	0.06	–	0.005

DIESEL EMISSION NORMS

Norm	CO	HC	NOx	HC+NOx	PM
BS-III	0.64	–	0.50	0.56	0.05
BS-IV	0.50	–	0.25	0.30	0.025
Euro-VI	0.50	–	0.06	0.17	0.005

All figures in g/km Source: Indian Emissions Regulations/ARAI

Illustration: Arya Praharaj

9 WHY IS INDUSTRY RESISTING?

- Oil refineries will need a substantial investment to upgrade refineries to supply fuel types that match BS-VI standards
- The shift of technology from BS-IV to BS-VI likely to cost anything between Rs 50,000cr and Rs 80,000cr to oil cos
- Skipping a step like BS-V puts extra pressure on auto manufacturers to produce compliant vehicles

INDUSTRY SAYS

"The jump from BS-IV (equivalent of Euro 4) to BS-VI (equivalent of Euro 6) standards... will be too much of a significant technological jump for the auto firms

PAWAN GOENKA | MAHINDRA & MAHINDRA EXECUTIVE DIRECTOR (March 2015, before the govt advanced the switch)

MINISTER SAYS

"I appeal to automobile industry to cooperate in the larger interest of the country

NITIN GADKARI | TRANSPORT MINISTER

10 WHY IS INDIA SPEEDING UP BID TO CURB VEHICULAR POLLUTION?

- India pledged at the recent global climate summit to improve the carbon emission intensity of its GDP by 33-35% by 2030 from 2005 levels
- It has also pledged the creation of an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide equivalent through additional forest and tree cover by 2030

Need for NOx regulation

Need for PM & PN regulation

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WHAT ARE THE HEALTH RISKS OF PARTICULATE MATTER?

Particulate matter poses a serious health risk because it can travel into the respiratory tract. PM2.5 is especially dangerous because it can penetrate deep into the lungs and sometimes even into the bloodstream.

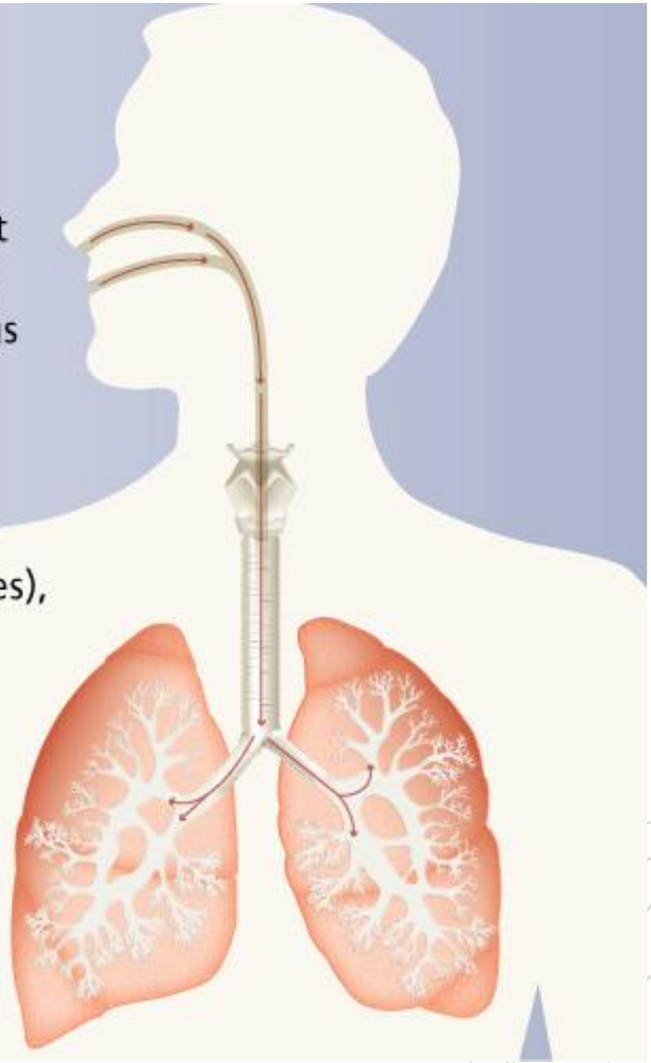
HEALTH EFFECTS

- » Decreased lung function
- » Chronic bronchitis
- » Increased respiratory symptoms
- » Cardiac arrhythmias (heartbeat irregularities),
- » Heart attacks
- » Premature death

GROUPS SENSITIVE TO PM2.5

- » People with heart or lung disease
- » Older adults
- » Children
- » Pregnant women

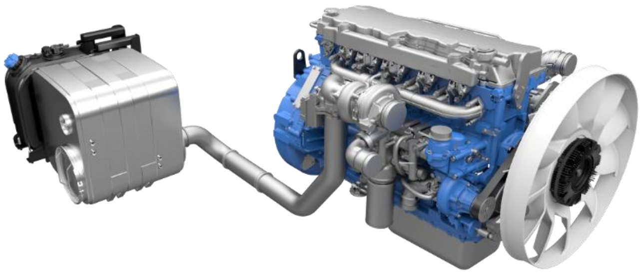
Source: www.epa.gov



BS VI – Legislation Challenges

BSVI legislation →

- World harmonized test cycle
- Emission limit: NOx; PM, PN, CO & HC
- Useful life requirements
- In-service conformity/ in- use emissions
- Certification, conformity & enforcement
- On-Board Diagnostics
- NOx control monitoring

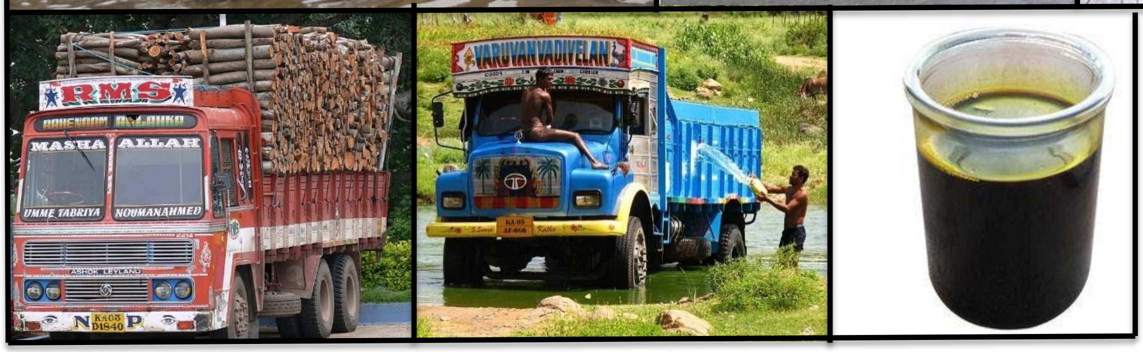


Market Requirement – Challenges

India Specific requirements

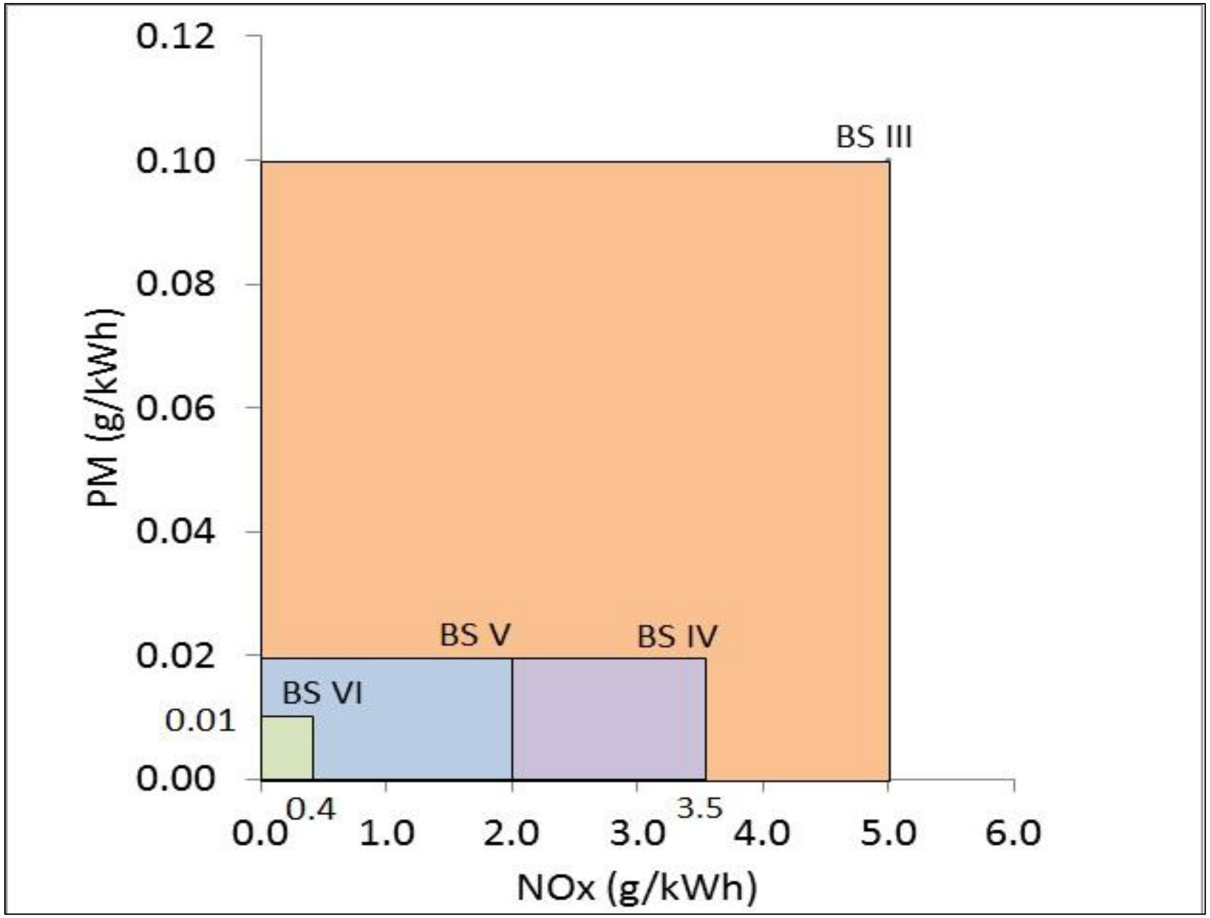
- Low cost
- Good Fuel consumption
- Easy to maintain
- Overloading capability
- Overloading capability
- NVH
- TCO

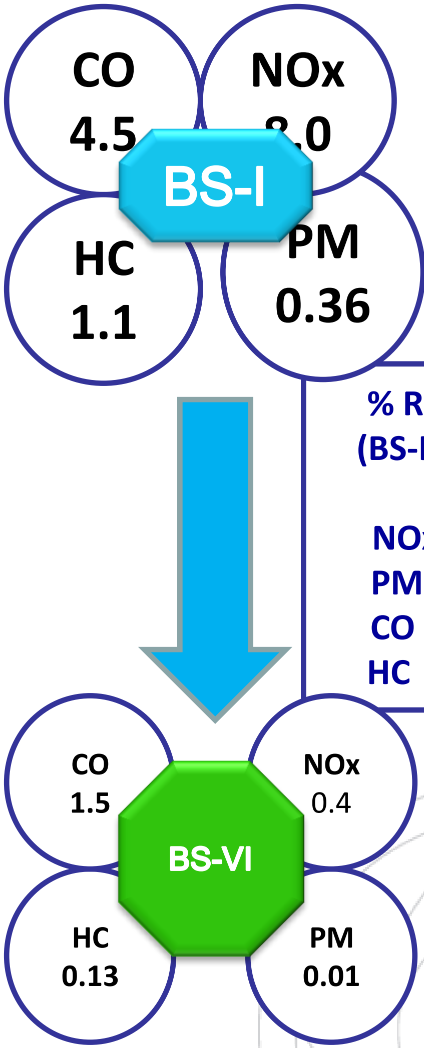
Indian market Challenges for ATS robustness



- Maintenance/ service practices still fairly basic.
- Road & infrastructure challenging condition.
- Challenging environmental conditions: Vibration, Cleanliness, fuel/ lubrication quality

Emission Norms





% Reduction (BS-I to BS-VI)

NOx – 95 %
PM – 97 %
CO – 67 %
HC – 88 %

BS VI Emission Scenario for CV & Challenges

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Norm	Year	NOx	CO	HC	PM	PN	Test Cycle
Bharat Stage I	2000	8.0	4.5	1.1	0.36	-	R 49
Bharat Stage II	2001/2005 (*)	7.0	4.0	1.1	0.15	-	R 49
Bharat Stage III	2005/2010	5.0	2.1	0.66	0.10	-	ESC
Bharat Stage IV	2010/2017	3.5	1.5	0.46	0.02		ESC , ETC (*)
Bharat Stage VI	2020 -	0.40	1.5	0.13	0.01	6×10^{11}	WHSC, WHTC(*)

NOx 90% redn.

PM 50% redn.

Limits for Steady state test cycle.

(*) Transient test cycle added from BSIV onwards. In addition, On Board Diagnostic (OBD) system is also mandated from BS IV.

BS IV to BS VI – Major Differences

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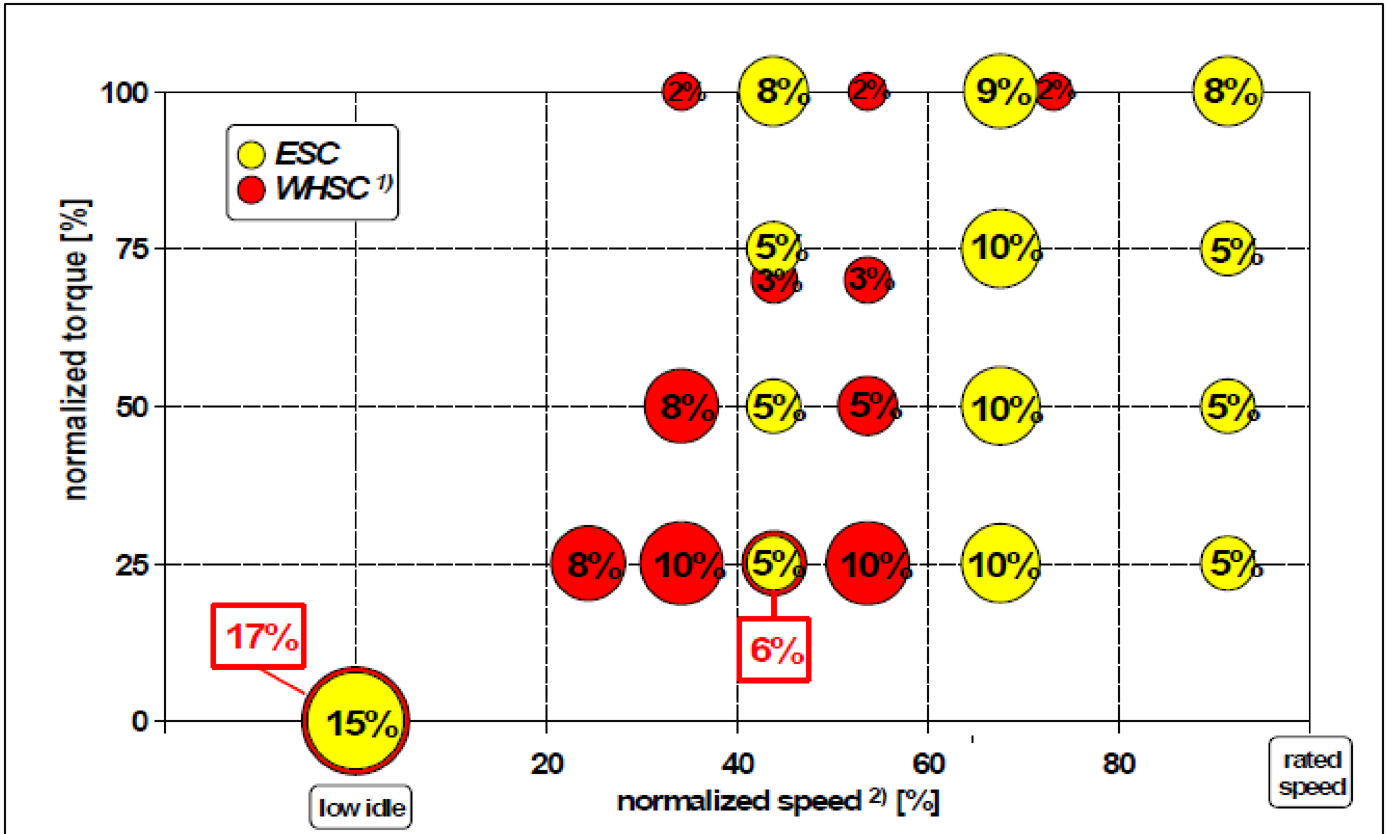
S.No.	Parameter	BS-VI	BS-IV
1.	Gaseous Mass emissions	New cycles WHSC , WHTC (Thermal loads are low)	Current cycles ESC , ETC
2.	Particulate mass emissions	New cycles WHSC , WHTC	Current cycles ESC , ETC
3.	Particle number test	New equip. and test	Not applicable
4.	Crankcase emissions	New circuit in crank case breathing	Not applicable
5	Engine power, CO_2 , Fuel consumption	Fuel consumption and CO_2 … Modified procedure	Only engine power test
6	Durability test (Optional)	Stringent	Less stringent
7	OBD	World-wide Harmonized OBD, Complex, Severe	Euro V equivalent, Simple, Less stringent
8	NOx control Monitoring	SCR systems - Limit different (Severe)	Less stringent
9	Random NOx (Off cycle emission)	Throughout the map, Severe (15 random points)	Only on ESC gap map (3 points)
10	COP	Similar to BS-IV	-
11	In-service conformity	Vehicles from field emission test PEMS tests (25K Kms) within 18 months	Not applicable
12	IUPR	In-use monitoring of OBD sensors/monitors	Not applicable
13	PEMS demo test	Prototype vehicle tested with PEMS	Not applicable

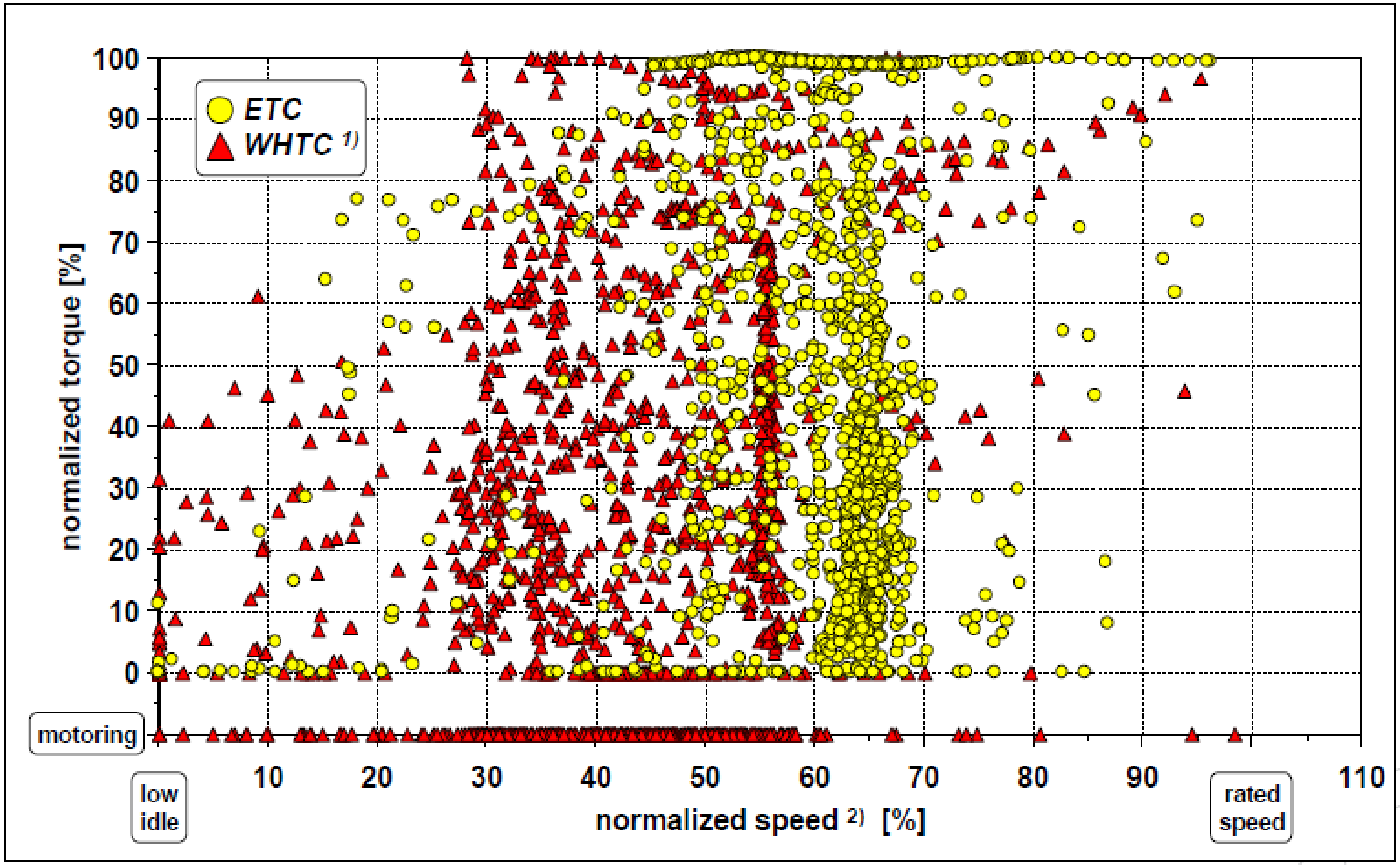
BS VI – Steady state cycle



1) WHSC: Worldwide harmonized steady state cycle, Mode 0: motoring with a weighting factor of 0.25
2) normalized speed depending on engine specification

Low operation zone – challenge for emission conversion due to lower temperature

BS VI Transient Cycle



Low operation zone – challenge for emission conversion due to lower temp

BS VI – Technology Development Challenges

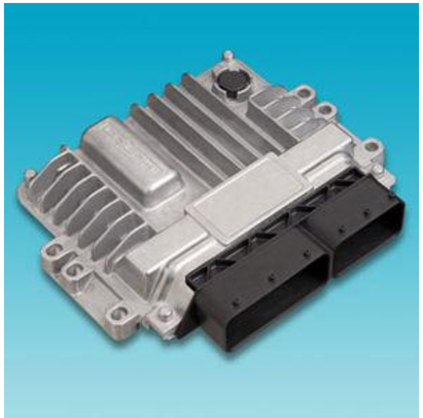
BS IV

BS VI

ADVANCED ENGINE TECHNOLOGY with FUEL ECONOMY

ADVANCED CONTROL TECHNOLOGY, SENSORS & ACTUATORS

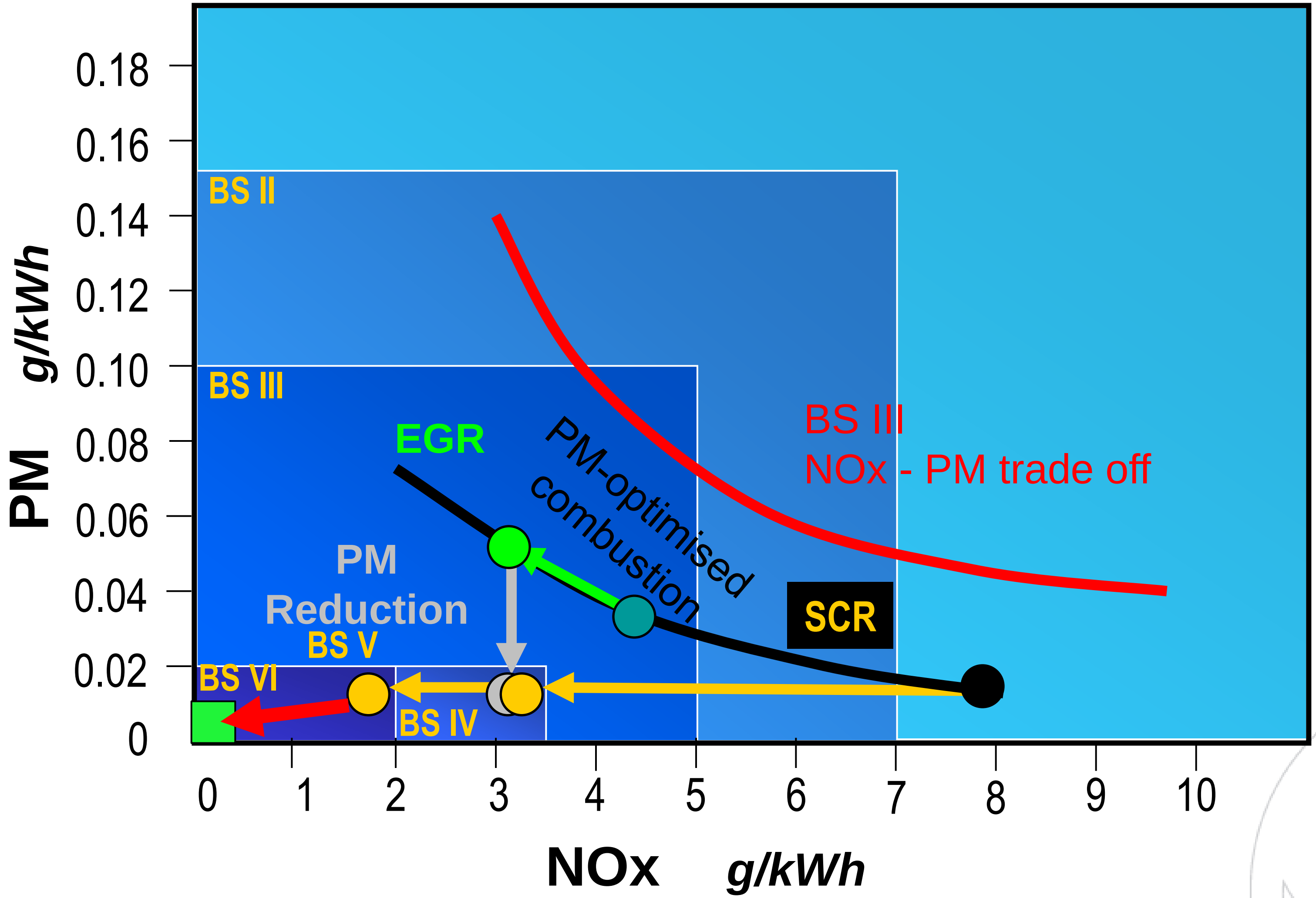
ADVANCED EXHAUST TECHNOLOGY



BS VI – NOx vs. PM Challenges

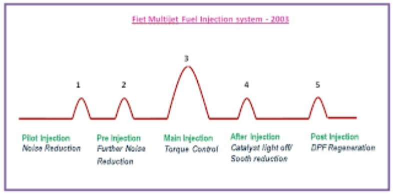
Parameter change	Effect on NOx	Effect on PM
Cycle temperature increases	↑	↓ Better combustion conditions prevails
There is excess air in bowl	↑	↓ Towards complete combustion
Longer premixed combustion phase	↑	↓ Improved initial mixing, chances of better combustion

BS norms trend – PM vs. NOx
SCR (or) EGR + SCR for BS VI



BS VI – Technology Development Combustion Challenges

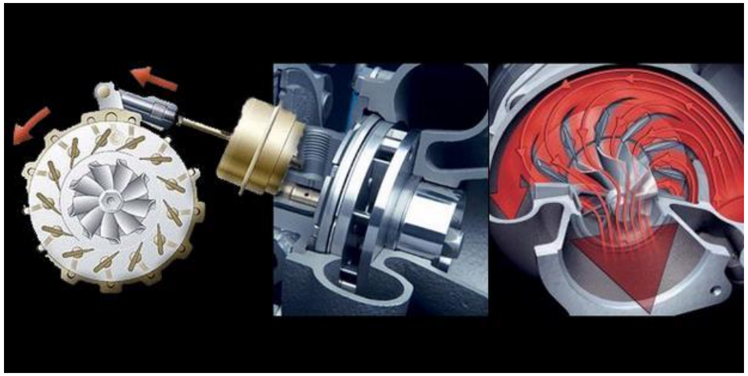
High Injection Pressure



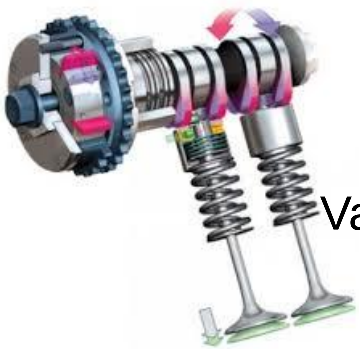
- Targeted Engine Out Emission
- Efficient Combustion
- Best Air Path Management
- Best Fuel Efficiency

Increased Combustion Control

Air Mass Flow Sensor



Advanced Turbo control



Variable Valve Actuation

BS VI – Advanced Engine Technology With Thermal Management

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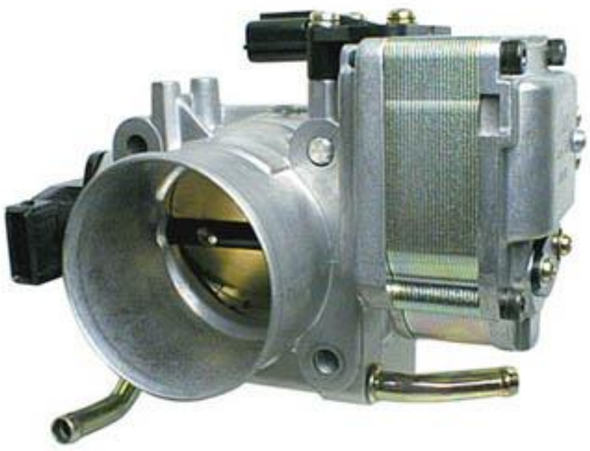
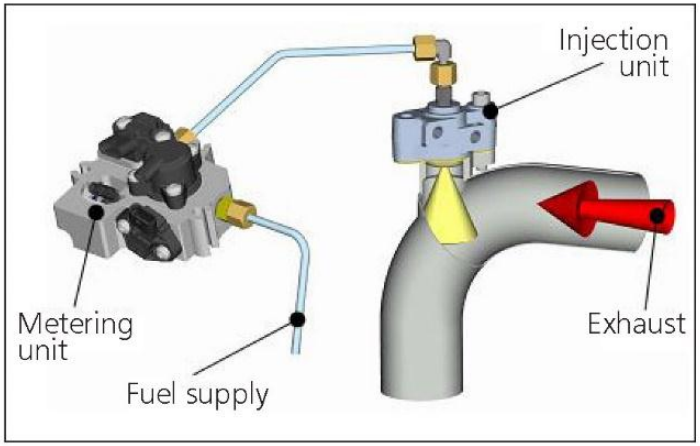


Intake Throttle

Exhaust Throttle



Hydrocarbon Injection

Temperature control for exhaust system can improve for

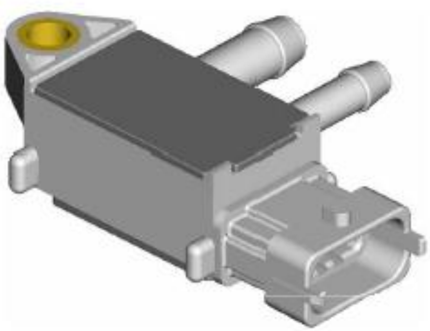
- ✓ **DPF active regeneration**
- ✓ **SCR inlet temperature improvement for Ad blue injection**

BS VI –Exhaust Sensors

High Temp Sensor

PM sensor

Differential Pressure sensor



NOx sensor

BS VI – Advance Engine & Exhaust Sensors & Actuators

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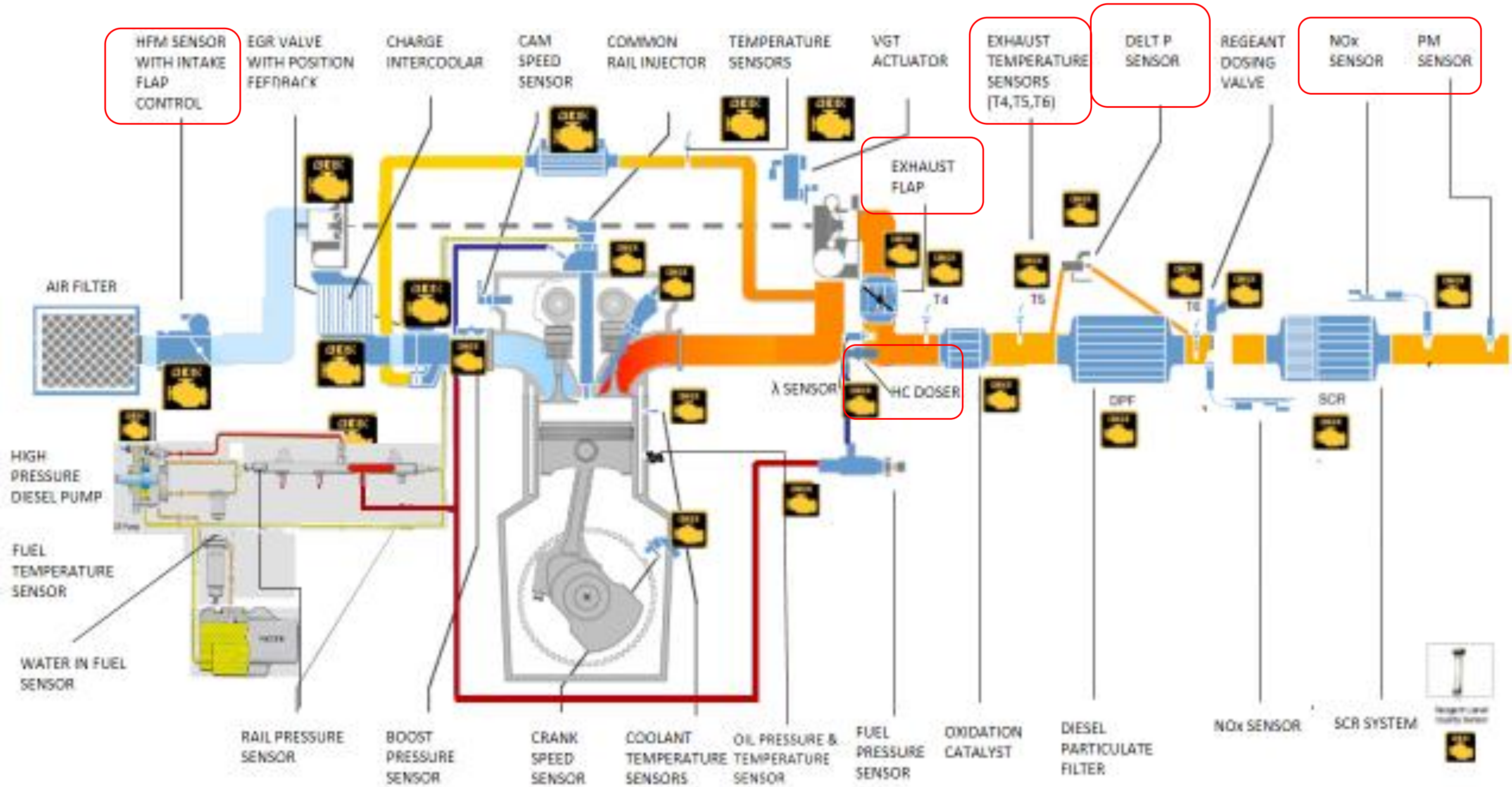
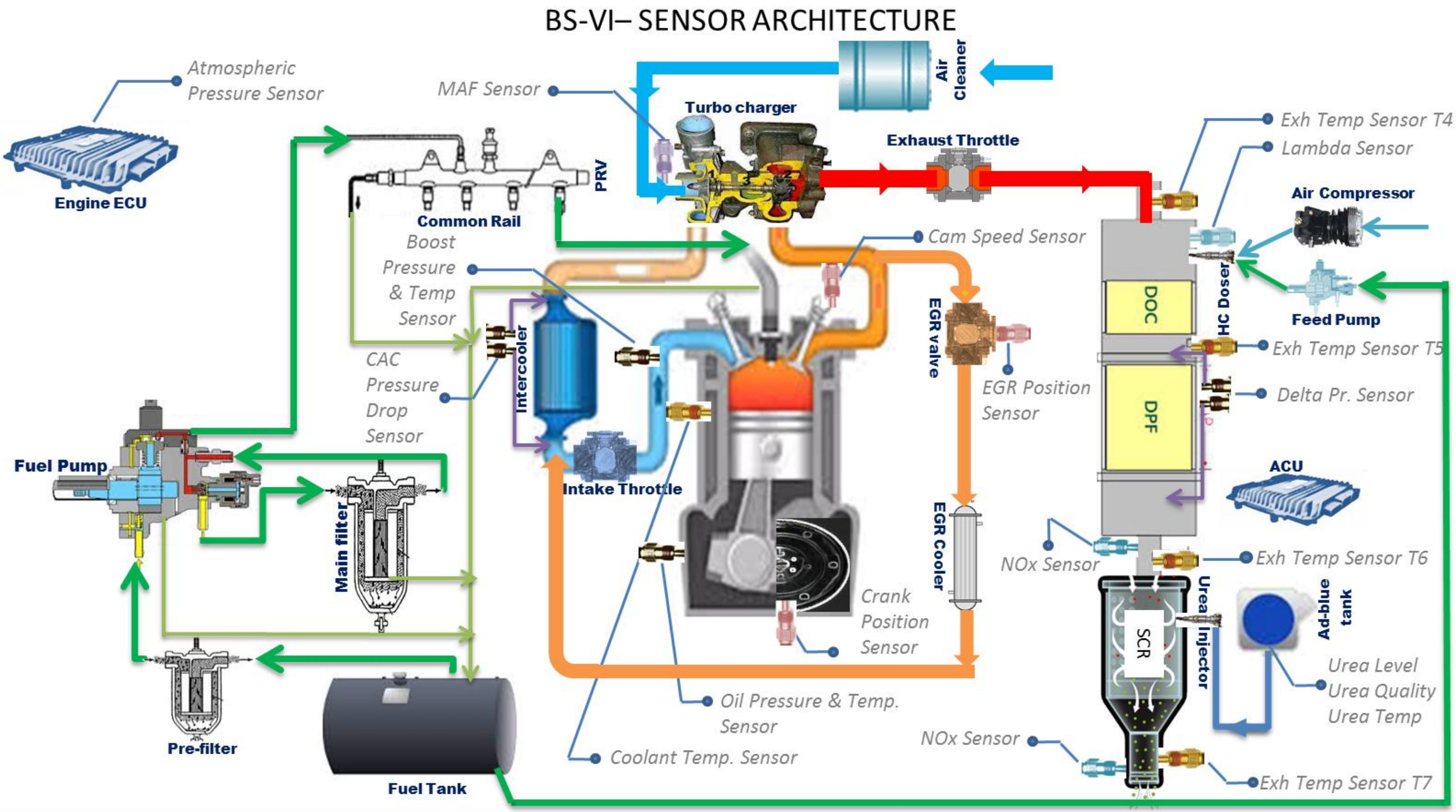


BS VI ADVANCED EXHAUST TECHNOLOGY COMPLEXITY



Engine Operating Challenges

- Duty Cycle
  - Low exhaust gas temperature
  - High NOx flux on non-EGR engines
  - Potentially long idle or low low-speed conditions (bus applications)
  - CSF regeneration under challenging conditions

- Fuel adulteration

- Urea quality

- Calibration
  - Thermal management
  - Urea dosing, deposit control and NH_3 “event” prevention
  - NH_3 storage management

Challenges in Effective Chemical Reactions

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■ Fuel burn for active regen ■ NO_2 generation for passive regen and SCR reaction ■ CO and HC oxidation	■ PM capture ■ NO_2 generation for passive regen and SCR reaction ■ CO and HC oxidation	■ NOx reduction in presence of reductant (NH_3) ■ NH_3 storage ■ Urea decomposition	■ Additional NOx reduction in presence of reductant (NH_3) ■ NH_3 slip control
DOC →	CSF →	SCR →	SCR/AMOX

Medium NOx vs. High NOx

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		High NOx	Medium NOx
LEGISLATION & DURABILITY DRIVEN	ABILITY TO MEET EMISSIONS OVER USEFUL LIFE (EATS DURABILITY : SCR CAT deterioration)	-	+
	HIGH ENGINE DURABILITY	+	-
	NEED FOR HIGHER SCR EFFICIENCY CATALYST & CONTROL SYSTEM	-	+
	IMPACT OF SCR CATALYST TEMPERATURE DURABILITY ≤ 650ºC , DUE TO ACTIVE DPF REGEN (Cu- CATALYST)	+	+
CUSTOMER DRIVEN	ENGINE COST	+	-
	EATS COST (requirement on increased efficiency/ volume)	-	+
	Total Fluid Consumption (Adblue dosing qty) * adblue estimated cost is 70% of fuel cost in India by 2020	-	+
EFFORT DRIVEN	DEVPT COMPLEXITY – Time and effort required for emission optimization	-	+

✓ **3+ for High NOx strategy vs. 6+ for Medium NOx strategy**

DOC /DPF Catalyst functional challenges

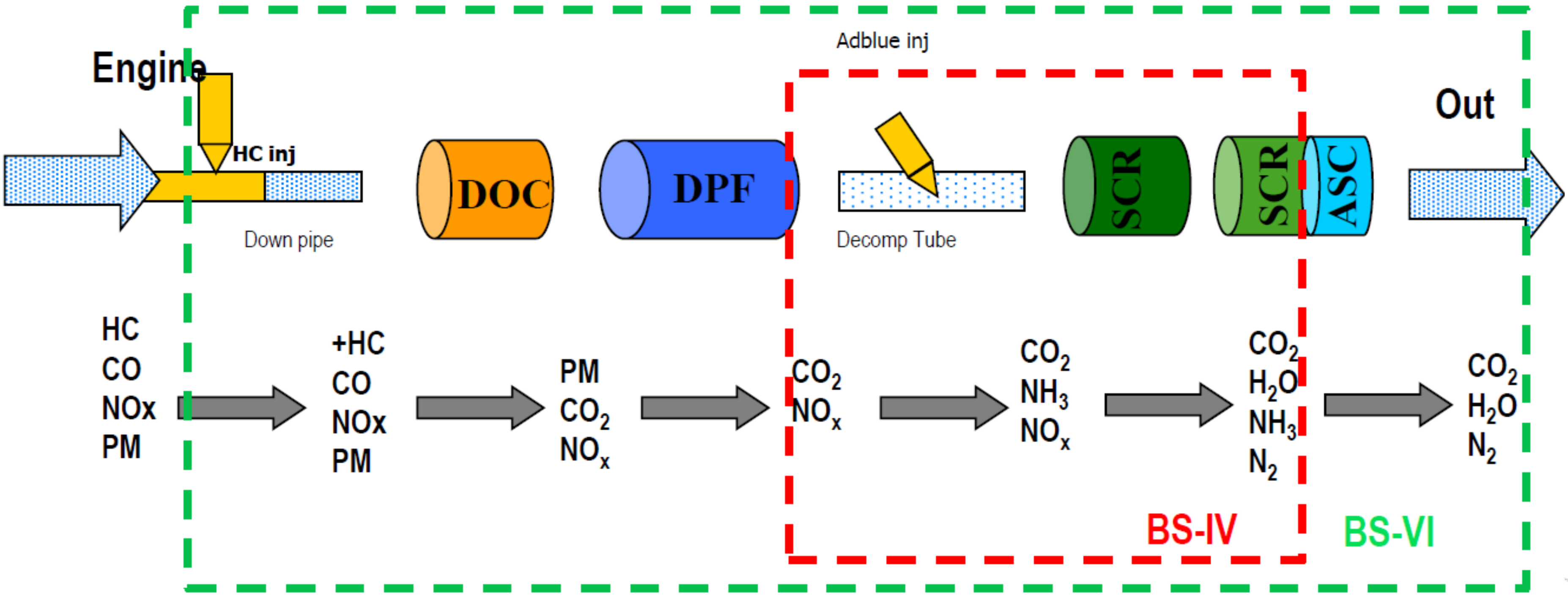
Diesel Oxidation Catalyst

- ✓ Effective soot filter and reduce PN
- ✓ Secondary HC reduction
- ✓ Generate additional NO2 for improving SCR NOx conversion
- ✓ Should have higher soot mass limit
- ✓ Low Back pressure

Diesel Particulate Filter

- ✓ Oxidize HC and CO to reduce these emissions in engine exhaust.
- ✓ Oxidize NO to NO_2 for filter passive regeneration and improving SCR NOx conversion.
- ✓ Create exotherm through HC injection to provide the temperature required for filter active regeneration.
- ✓ Allow low HC Slip during HC dosing
- ✓ Low Back pressure

Challenges in Effective Chemical Reactions



Impact of Sulphur Ash Phosphorus on DPF

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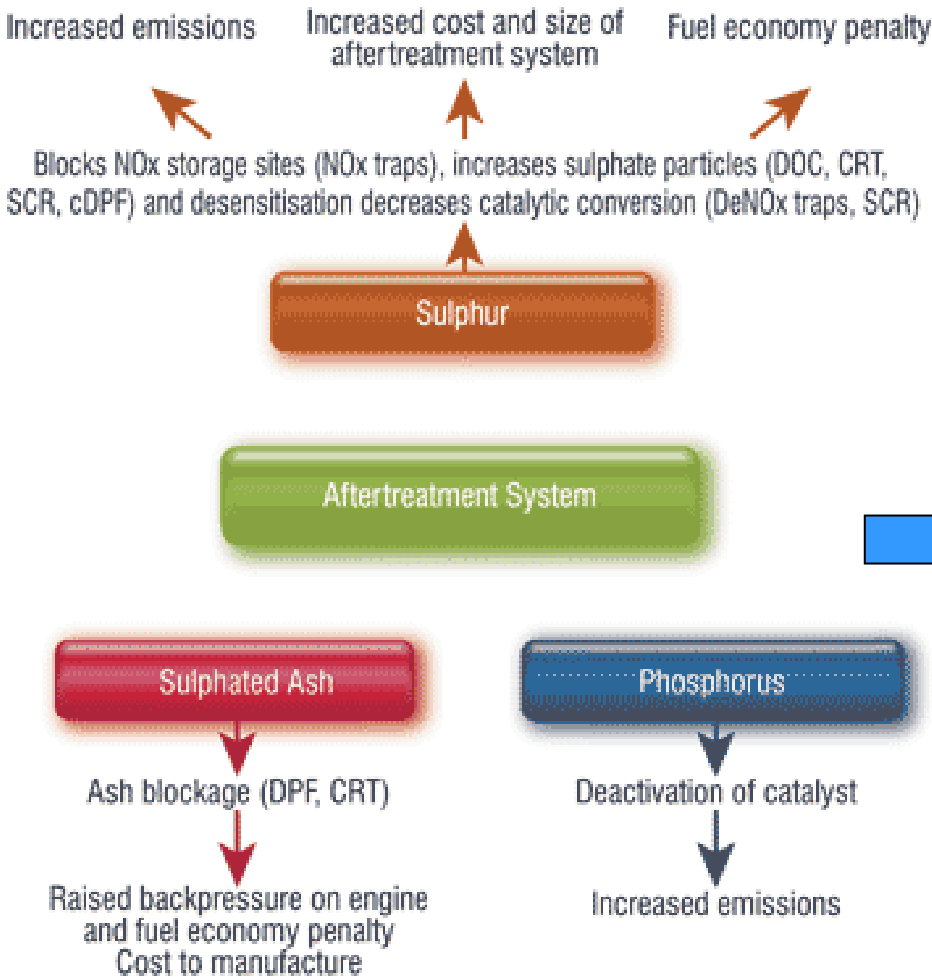

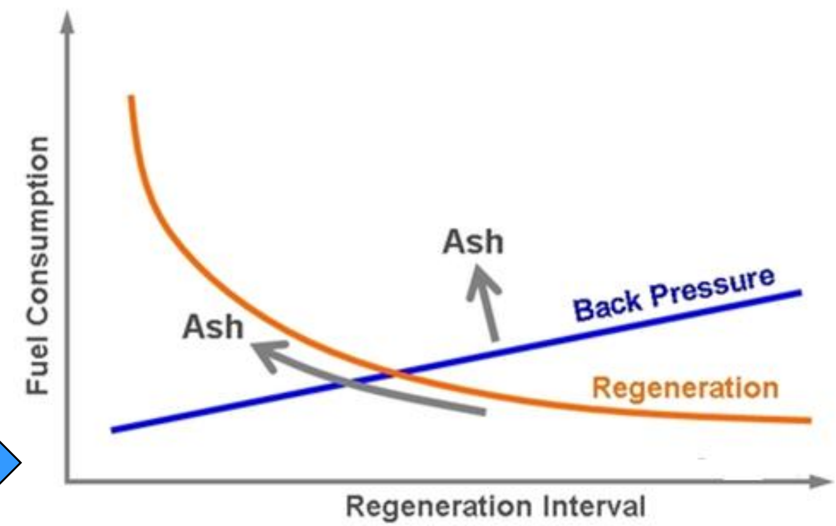

Challenges on material selection for DPF

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Diesel Particulate Filter parameters	Performance: Functionality	Robustness: Thermal Durability	Reliability: Functionality, Safety
Back Pressure Impact (mbar)			
Soot Mass Limit/ Regeneration interval			
PN			
Filtration efficiency@ 0.2g/L (%)			
Co-efficient of thermal expansion RT-800 ^{o}C (10-7/^{o}C)			
Thermal Shock Parameter ^{o}K			
Thermal Conductivity@ 1000^{o}K (W/mK)			

Green color indicates the high importance of parameter for key factor. Yellow color indicates intermediate importance for key factor.

P-Diagram for BSVI Catalyst System

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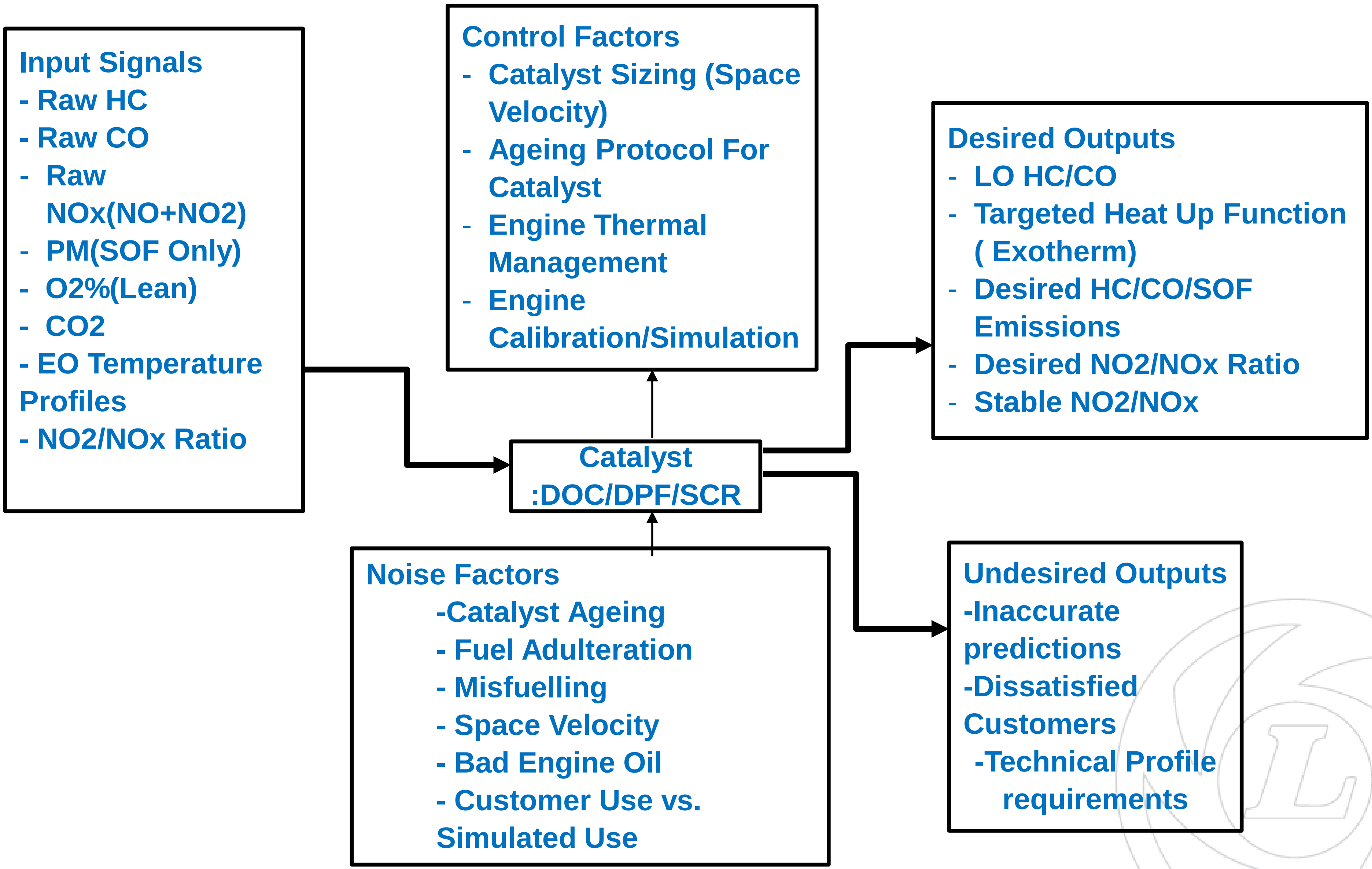

SCR Catalyst functional challenges

Selective Catalytic Reduction Catalyst

- ✓ Cu catalyst should have low temperature activity requirements for NOx conversion
- ✓ Better sulphur tolerance with fast recovery of conversion efficiency
- ✓ Low volume
- ✓ Higher Durability

Ammonia Slip Catalyst

- ✓ NH_3 oxidation and selectivity for N_2

SCR Catalyst Selection Process

Parameters	Weightage	V2O4		Cu-Z		Fe-Z		Remarks
		Rank	Total	Rank	Total	Rank	Total	
Low temperature NOx conversion efficiency	5							Less NO2 sufficient to improve conversion efficiency
High temperature stability	5							Durability -Higher thermal durability helps to have robust design and reduce DPF field failures during regeneration. V2O5 up to 550C, Fe-z 650C, Cu-Z 750Cmax temperature.
Sulfur Tolerance	3							Robustness - low Sulfur tolerance demands frequent regeneration to de-sulfate and regain SCR performance.
System Cost	4							V205 along with DOC and DPF can have 20% savings on ATS catalyst system cost.
Packaging space	4							Cu-Z will have 5% packaging space reduction compared to V2O5
Total score			166		180		149	

- **Rating based on catalyst technology applications on engine models.**
- **Active regeneration, OBD and RDE requirements can be challenging for low temperature applications with V2O5.**

SCR System Calibration Challenges

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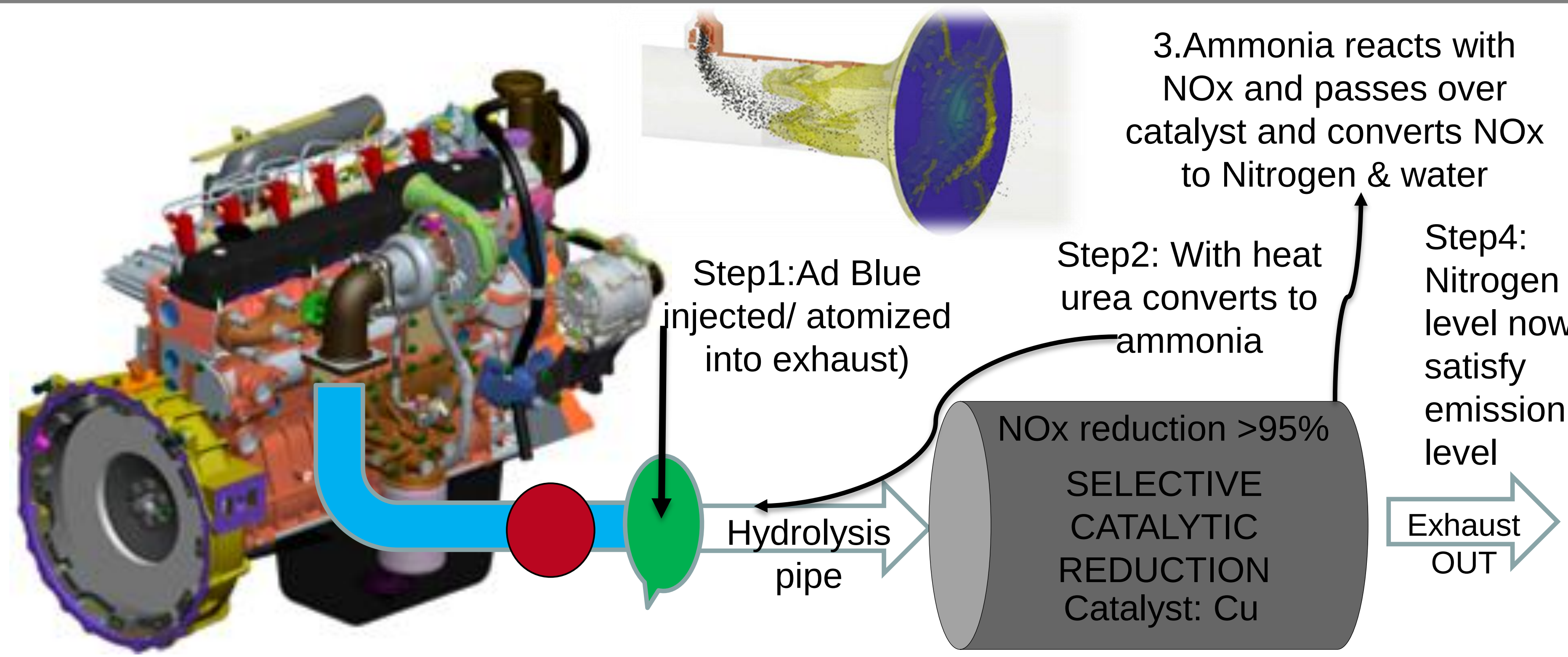

- Advanced active emissions control technology system that injects a liquid-reductant agent through a special catalyst into the exhaust stream of a diesel engine

DOC/DPF

$(NH_2)_2 + CO_{(aq)} \Rightarrow (NH_2)_2\,CO(s)$

$(NH_2)_2\,CO(s) \Rightarrow HNCO + NH3$ (Thermolysis)

$HNCO + H_2O \Rightarrow CO_2 + NH_3$ (Hydrolysis)

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

SCR System Calibration Challenges

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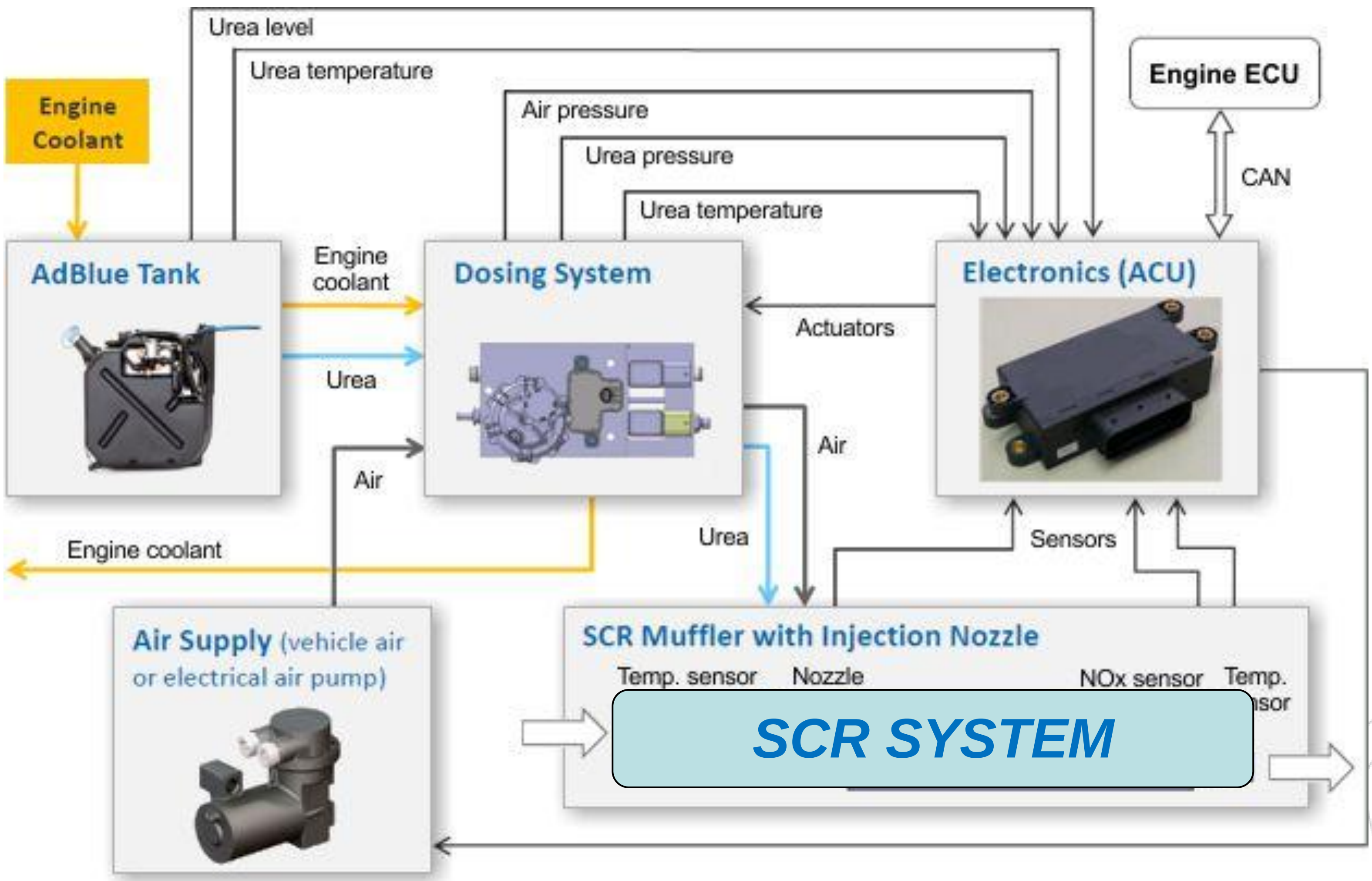

SCR System Design Challenges

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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

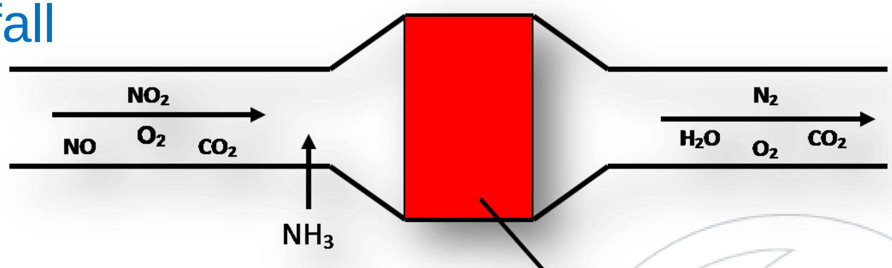
$$H_2N\text{-}C(=O)\text{-}NH_2 \xrightarrow{>200\,^{\circ}C} NH_3 + HNCO$$

$$HNCO + H_2O \longrightarrow NH_3 + CO_2$$

$$\longrightarrow 2\,NH_3 + CO_2$$

Urea decomposition

Urea is used as and aqueous solution called AdBlue, which is injected into the exhaust pipe



SCR catalyst

reactions: **SCR NO_x reaction**

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

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

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

Post BS VI:
Towards Future Fuel Economy

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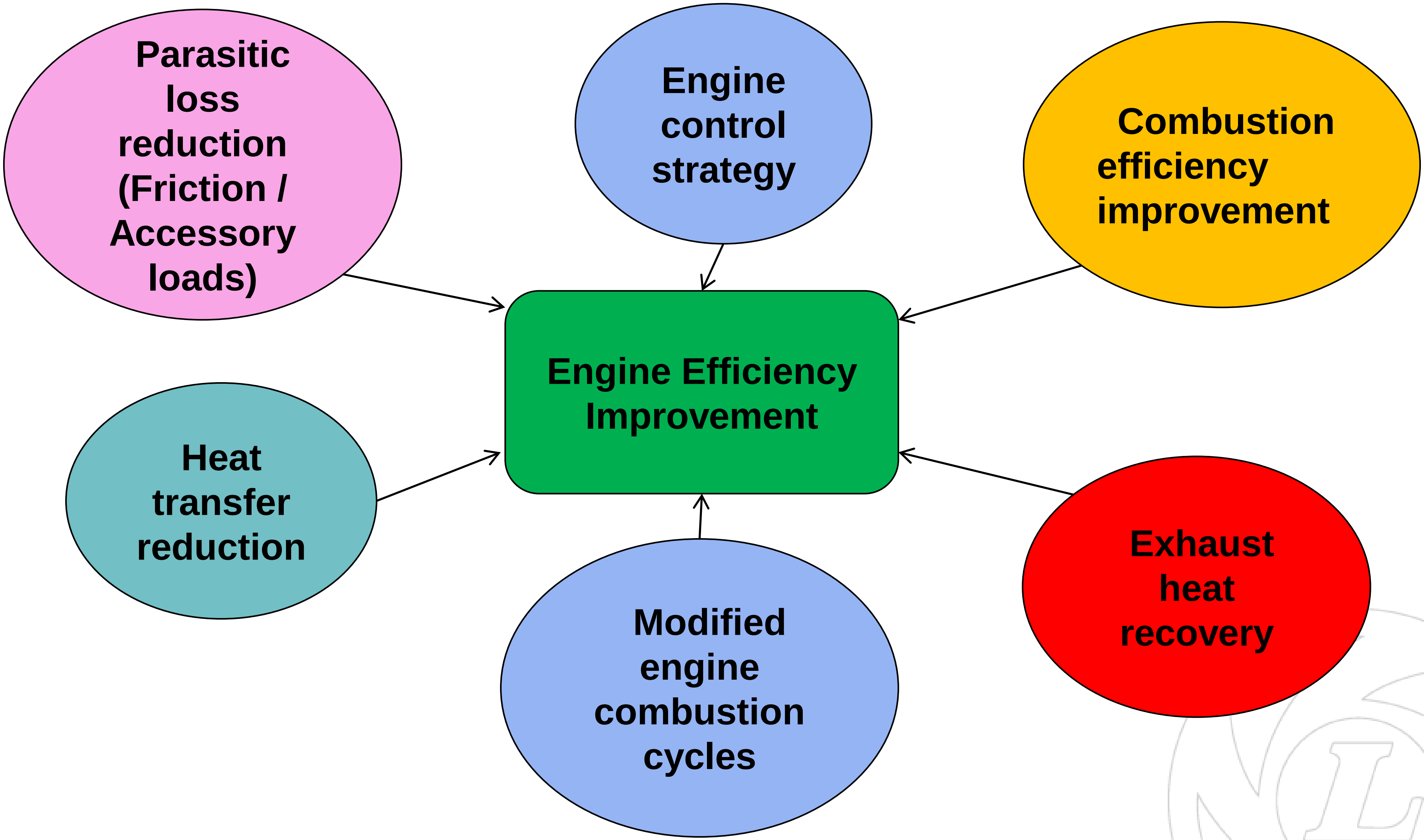
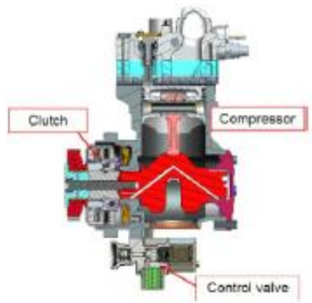


Post BS VI:
Towards Future Fuel Economy

Variable speed water pump



Clutched air compressor

Electric water pump

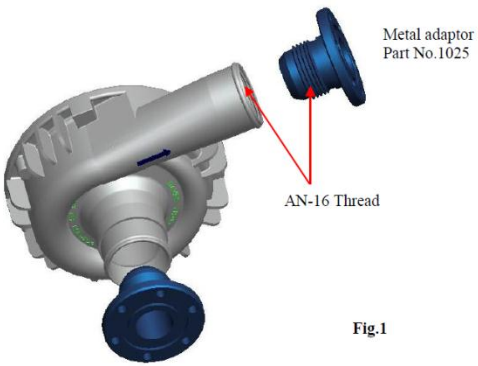


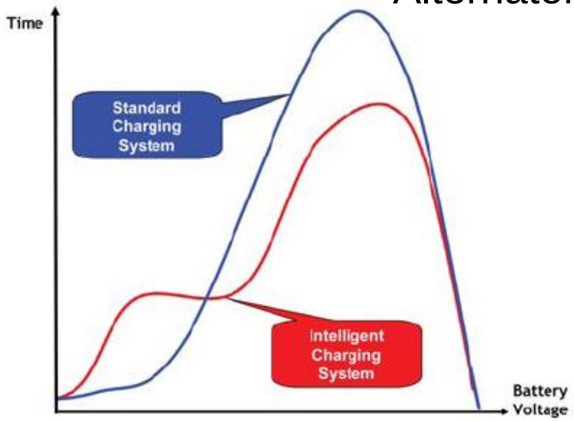
Fig.1

Reduced tension oil control rings

Miscellaneous related to pistons, liners, bearings

Low viscosity oil

Smart Alternator



OBD – Types of Monitoring

"Total functional failure" (TFF):
Total break down of system or component. Not related to emission limits.
e.g. Removal of DOC

"Component monitoring" (Comp Mon):
Monitoring for single components. Not related to emission limits.
Input components (sensors): Electrical checks, rationality
Output components (actuators): Electrical checks, functional response
e.g. Rail pressure sensor drift

"Performance monitoring" (PM):
Functional checks of system properties. Not related to emission limits.
To be working in normal range e.g. DPF performance monitoring

"OBD threshold monitoring" (Threshold monitoring):
Function must detect exceed of OBD thresholds. E.g. SCR catalyst efficiency monitoring

" Anti tampering Monitoring"
Specific failures are covered under Anti- tampering monitoring e.g. Urea quality deterioration

BS-IV and BS-VI – OBD Differences

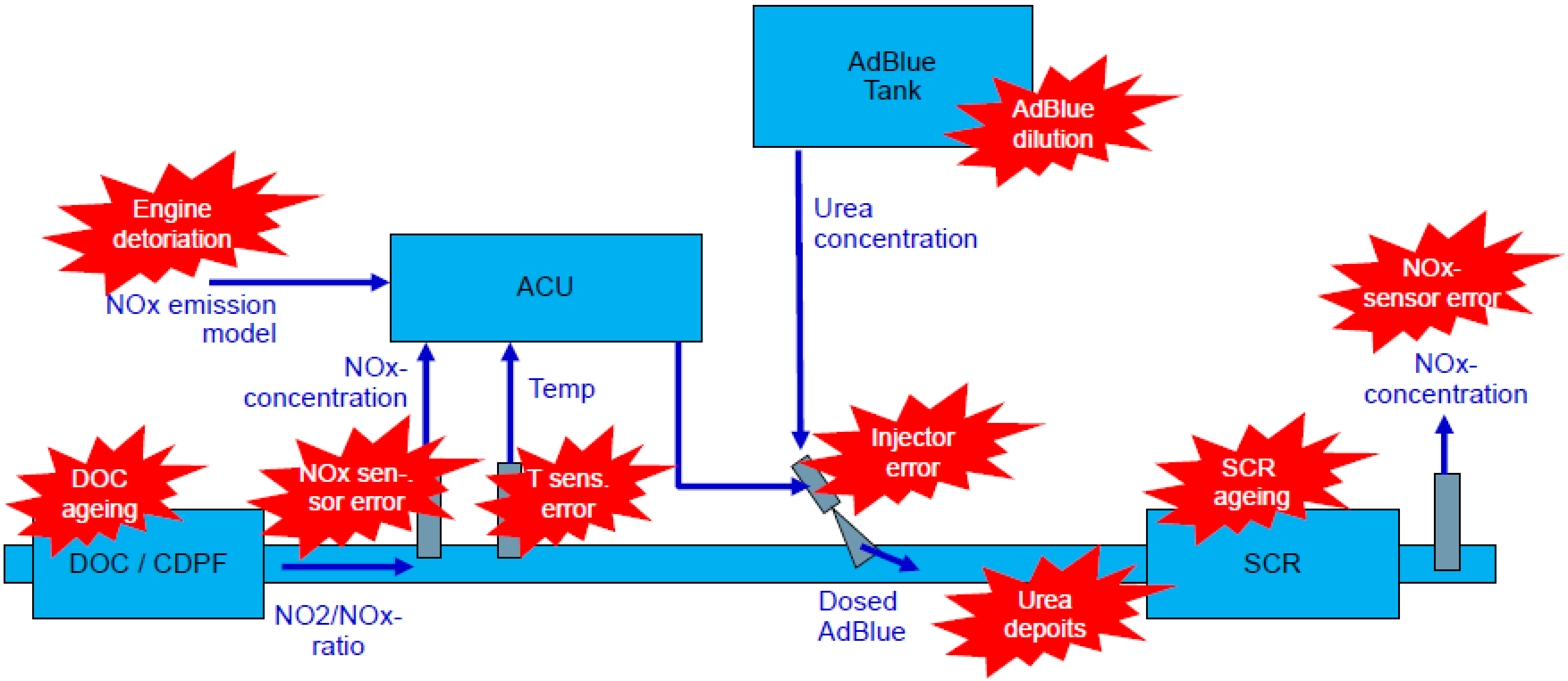
BS IV	Euro V	Euro VI
ESC and ETC for emissions	ESC and ETC for emissions	WHSC and WHTC for emissions
NOx = 3.5 gm/kWh	NOx = 2 gm/kWh	NOx = 0.4 gm/kWh (0.46 for WHTC)
PM = 0.02gm/kWh 0.03gm/kWh for ETC	PM = 0.02gm/kWh 0.03gm/kWh for ETC	PM = 0.01 gm/kWh
Durability = 100000(5yrs) / 200000(6yrs) / 500000(7Yrs)	Durability = 100000(5yrs) / 200000(6yrs) / 500000(7Yrs)	Durability = 160000(5Yrs) / 300000(6yrs) / 700000(7yrs)
NOx OBD Torque Limiter > 7.0 gm/kWh NOx	NOx OBD Torque Limiter > 7.0 gm/kWh NOx	NOx OBD torque Limiter = Performance requirements
MIL lamp ON = 5 gm/kWh OR 0.1 gm/kWh PM	MIL lamp ON = 3.5 gm/kWh OR 0.1 gm/kWh PM	MIL lamp ON : 1.5 gm/kWh (BS VI OBD-1) / 1.2 gm/kWh (BSVI OBD-2) OR PM 0.025 gm/kWh
3 DC MIL ON	3 DC MIL ON	2 DC MIL ON
OBD test cycle = Short ESC	OBD test cycle = Short ESC	OBD test cycle = Warm WHTC
Delete cycles = 40 Warm Up C	Delete cycles = 40 WUC	Delete cycles = 40 WUC / 200Hrs
No class for errors from legislation	No class for errors from legislation	A,B1,B2 and C class errors classification

BS-IV and BS-VI – OBD Differences

BS IV	Euro V	Euro VI
Distance / time since MIL on counter	Distance / time since MIL on counter	Distance / time since MIL on counter + Cumulative time during MIL on
Long term error requirement	Long term error requirement	NOx relevant error counter information
MIL Off after 3 full cycles	MIL Off after 3 full cycles	Continuous to short MIL in next heal cycle, off in 3DC
MIL ON for some time after engine start, then off, then if error is present ON	MIL ON for some time after engine start, then off, then if error is present ON	MIL has two sequences. One to show readiness and then another sequence to show errors
Emission effect due to failure checked in ESC. NOx related errors emission effect to be checked in ETC	All emission effects to be checked in ETC	Emission Effect due to all failures checked in WHTC
Reagent quality monitoring is optional	Reagent quality monitoring is optional	Reagent quality monitoring is a must

Diagnostic Monitors for SCR Failure Detection

FAILURE PIN-POINTING WITHIN THE DIAGNOSE OF A SCR SYSTEM



In Use Performance Ratio (IUPR)

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In-Use performance ratio* :

- Measure for the frequency of monitoring a component in the field
- In-Use performance ratio (IUPR) must be fulfilled by each monitor of the OBD system

$$\text{Ratio} = \frac{\text{Numerator}}{\text{Denominator}}$$

Numerator is incremented, if monitoring conditions have been satisfied

Denominator is incremented within 10 secs, if defined criteria are fulfilled, i.e.

1. 600 s since engine start
2. 35°C >Ambient temp > -7°C
3. Elevation <=2500 m
4. Engine rpm>= 1150rpm for minimum 300s
5. Accpedal not pressed and Vehicle speed < 1.6kmph/Engine speed<= Idling+200rpm

Other Challenges

- Availability of consistent quality ULSD all across India is key for BSVI successful launch.
- Use of BS VI ULSD fuel from the time of launch
- Implement lessons learnt from earlier trials related to contamination, cleanliness, water ingress, corrosion, effect of additives.
- DEF distribution network and availability at every fuel dispensing station will be key enabler.
- Ensuring DEF quality, consistency and handling / dispensing is key.
- Appropriate technology choices, robust system integration, understanding real world behavior, maintenance and service practices and end user awareness is critical for overall success and acceptance of BS VI products.

Other Challenges

Prolonged low temperature operations due to challenging duty cycles:

- **Coking of catalyst will remain a challenge needing aggressive thermal management strategies on specific applications**

- **Possibility of catalyst face plugging due to use of Bio diesel**

Over - temperature exposure during operation:

- **Effectively managing DPF soot load / soot regeneration is very critical.**

- **Pt contamination from DOC / DPF reducing De-NOx efficiency of SCR.**

- **Prolong idle – HC Desorption**

- **Frequent start – Stop and low temperature:**

- **Effect of water condensation and effective drainage**

- **Managing NOx sensor for dew point condition**

Other Challenges

- Poisoning of NOx sensors
- Prolong elemental exposures and deposits such as Fe, Si, Mg can cause NOx sensor catalyst to poison and hence making it fail to perform it's function with desired accuracy.

- Lube oil borne ash and Sulphur as well as additives.

- Based on oil consumption, origin of elements such as Sulphur, Phosphorous will be required to manage closely. Lube additive impact on catalyst performance is key

- Ash from lube oil will be another aspect to be consider for DPF sizing and service

- Other fluid exposures

- Exposure to truck wash fluid and tap water does not lead to washcoat adhesion issue or active Cu species leaching (for Cu- Z SCR)

BS VI Implementation: Concluding Statements

- BS VI implementation – Requires significant changes to ENGINE & EMISSION
- Earlier on-road trials are required more effectively to confirm the design.
- BS VI fuel availability is critical for completion of development on time.
- Further extensive calibration effort is required for latest OBD IUPR standards.
- Public awareness and strict implementation required to ensure the practical success of BS VI norms pan India.

Commitment

Besides regulations, we have the moral responsibility to pass-on a safer and cleaner planet to the Next Generation !!!

THANKS