BS-VI Norms for Two/Three Wheeler
After treatment approach

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SÜD CHEMIE INDIA PVT. LTD.

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Contents

- 2W Segment
  - Market
  - Impact of BSVI Norms
  - Expected After treatment System
  - Challenges and Approach
  - OBD-II
- 3W Segment
  - Similar sub sections as above

Indian 2W Market

- High Volumes
- Smaller Engines (move to performance and sporty bikes)
- High Fuel efficiency conscious
- Lean tuned vehicles
- Low speed driving
- Move to electronic based systems

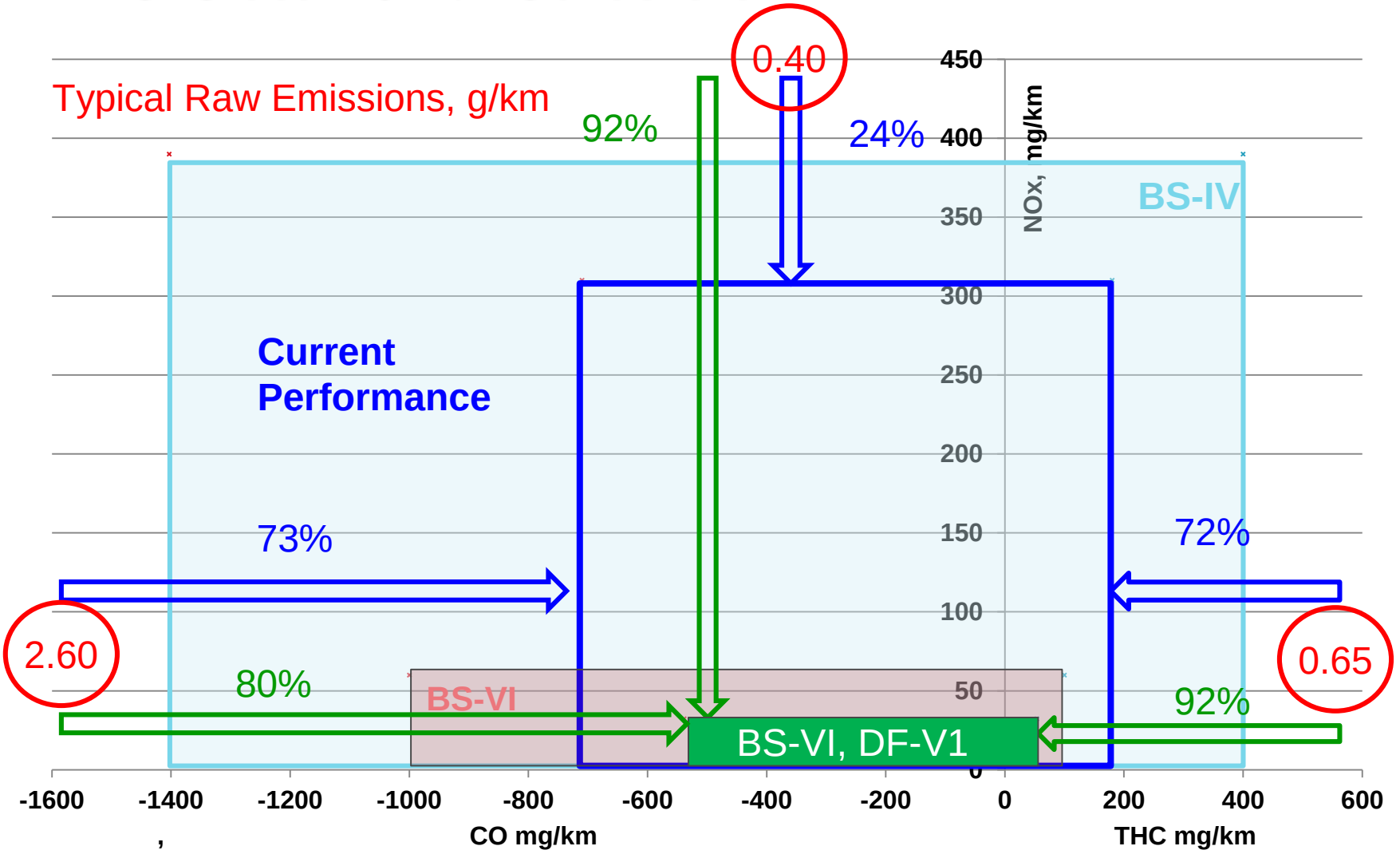
BS-VI Norms for 2W

Vehicle Class	CO, g/km	THC, g/km	NOx, g/km	NMHC, g/km	THC (NMHC) + NOx, g/km*	PM, g/km	EVAP g/test	Durability (km)
All Classes	1.0	0.10	0.06	0.068	0.16 (0.128)	0.0045**	1.50	35K
DF	1.3	1.3	1.3	1.3	1.3			
BS-VI (with DF)	0.77	0.077	0.046	0.052	0.123 (0.098)			
BS-IV (inbuilt DF); class 2.1	1.403	-	0.39	-	0.79***	-	2/6	
Reduction, %	45	-	88	-	84 (89)	-		
OBD-II	1.9	--	0.3	0.25		0.05		

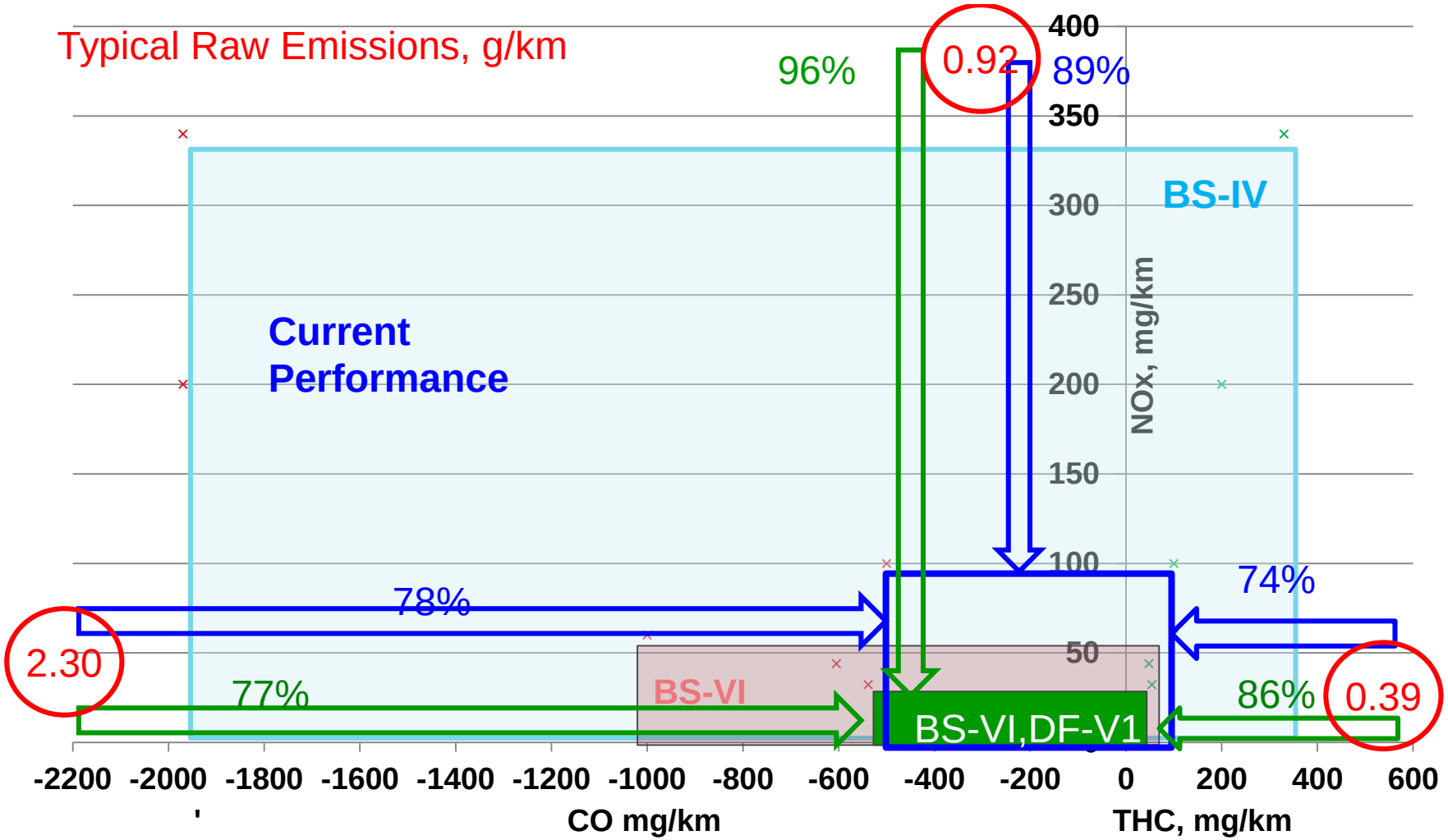
*Does not have norms – only for evaluation
**For GDI engines only
*** This is for evap norm of 2 g/test. If evap norm of 6 g/test is chosen; then THC +NOx norm shall be 0.59 g/km

In general, about 90% of Engine out THC emissions of 2W are NMHC; Hence NMHC limit more applicable – making it more stringent

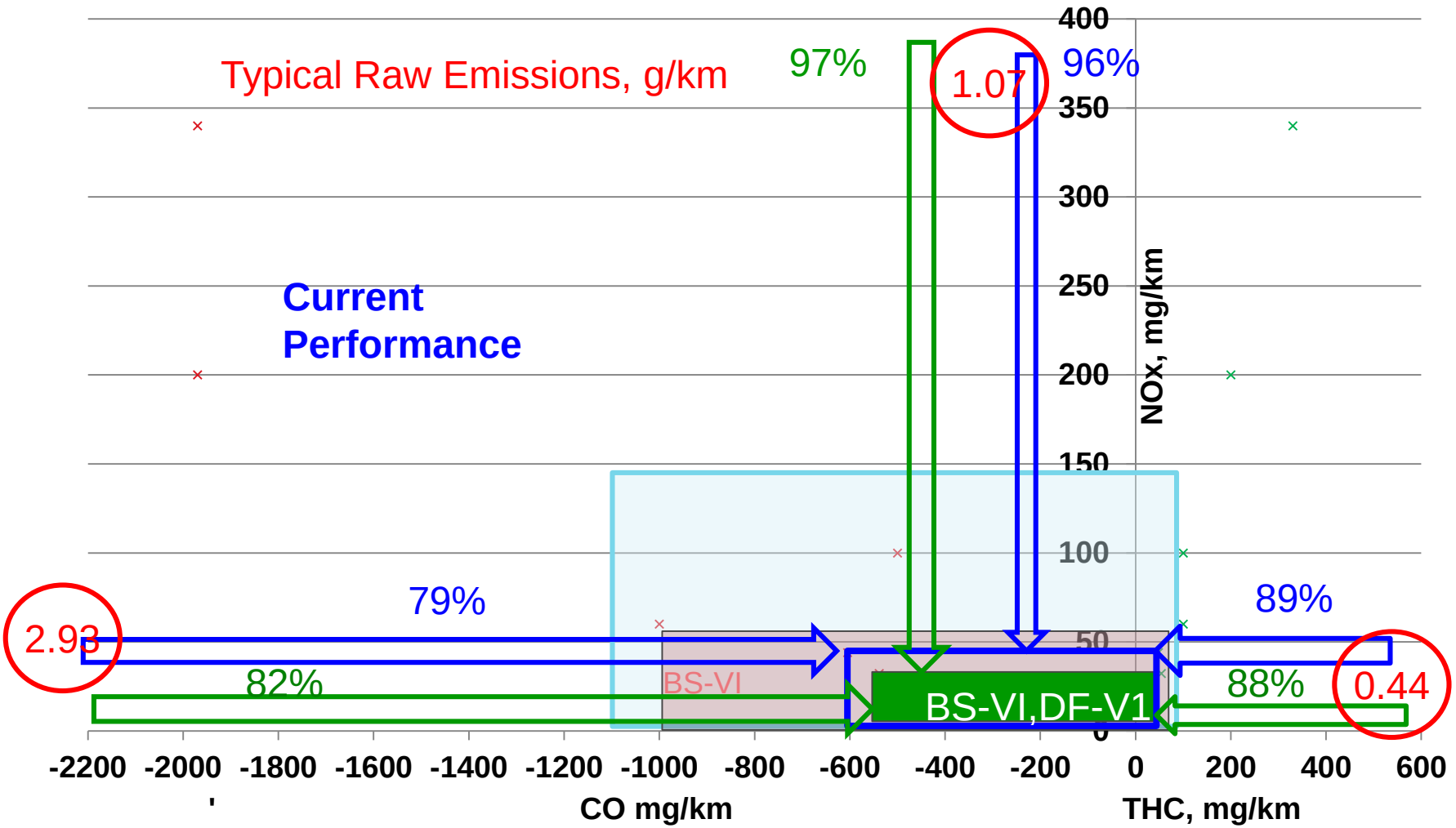
WMTC-Class 1 & 2.1 Carburetor



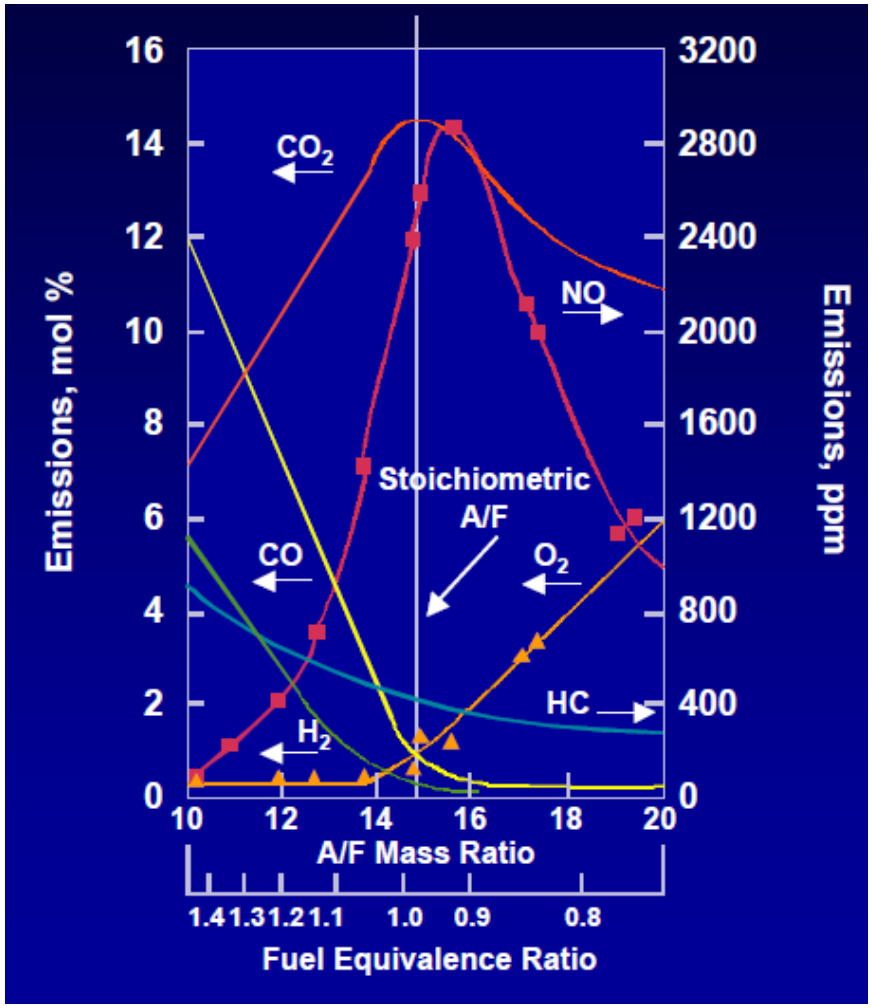
WMTC-Class 2.2

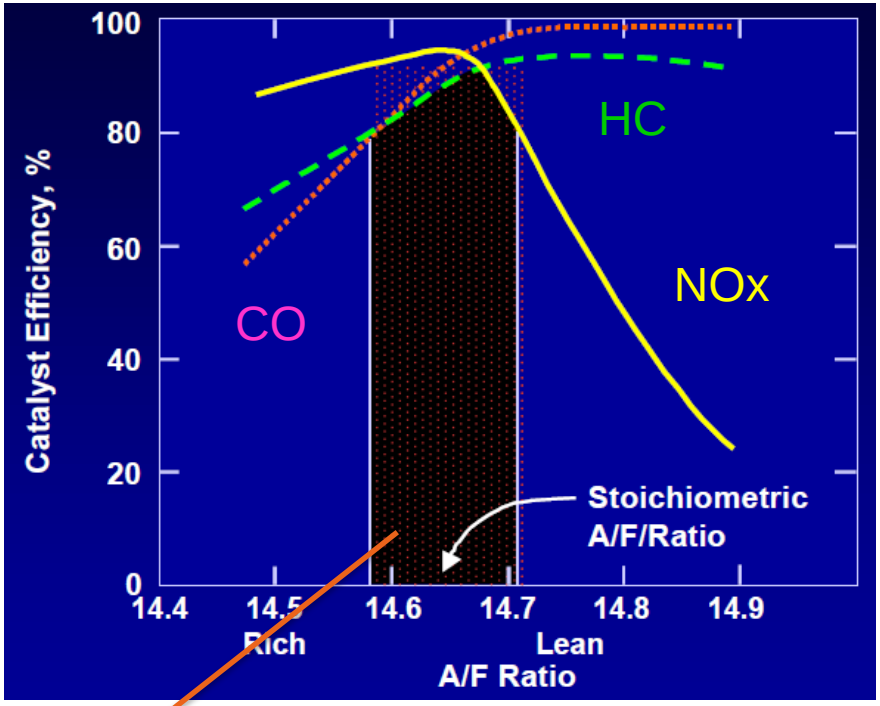


WMTC-Class 3.2



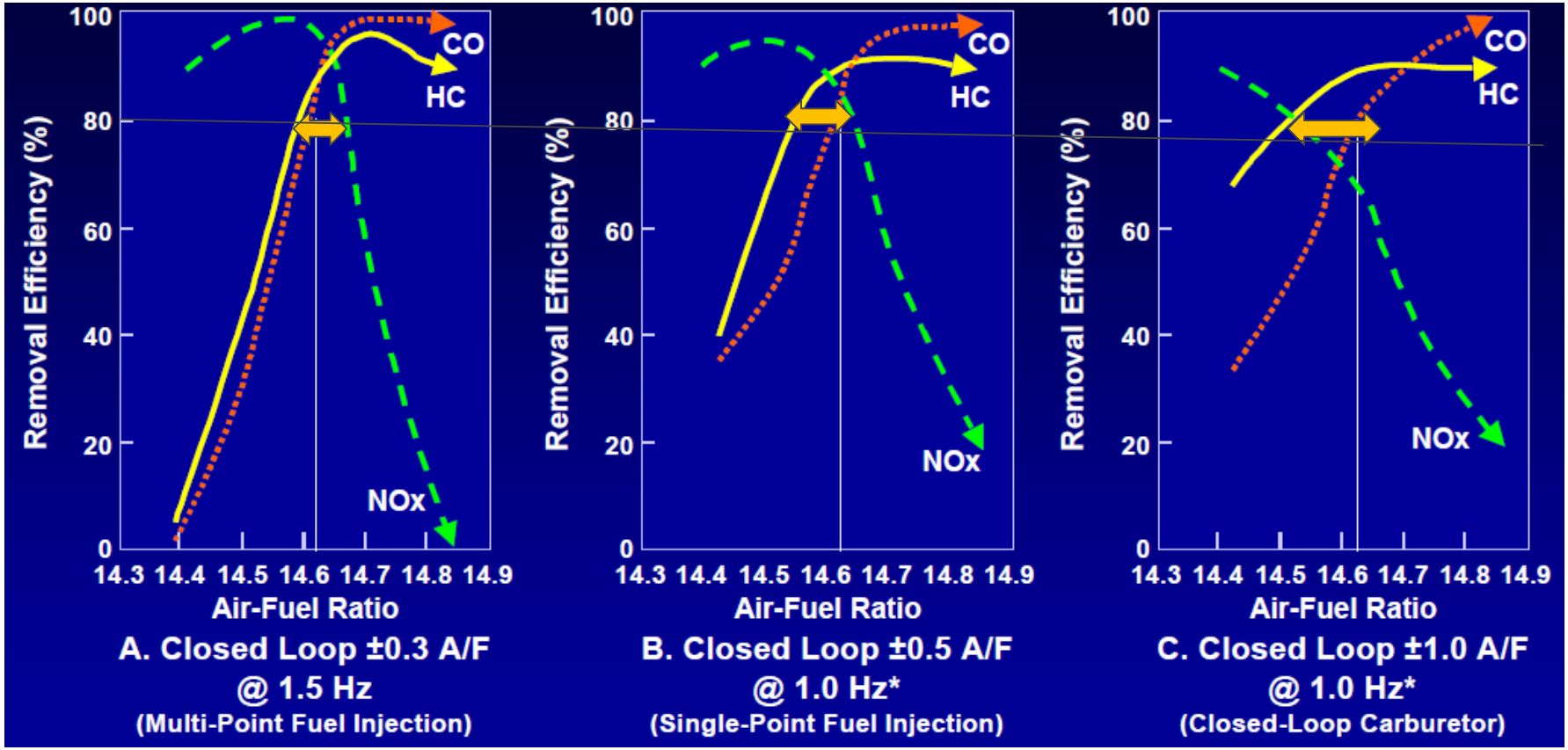
Effect of A/F on Engine out emission and Catalyst conversion Efficiency





A/F Ratio window for 80% catalyst efficiency at 400 C

Close Loop System and Catalyst Efficiency



Performance of TWC Catalyst is improved with Fuel Metering Control – Narrower the lambda band the better

Challenges and Approach

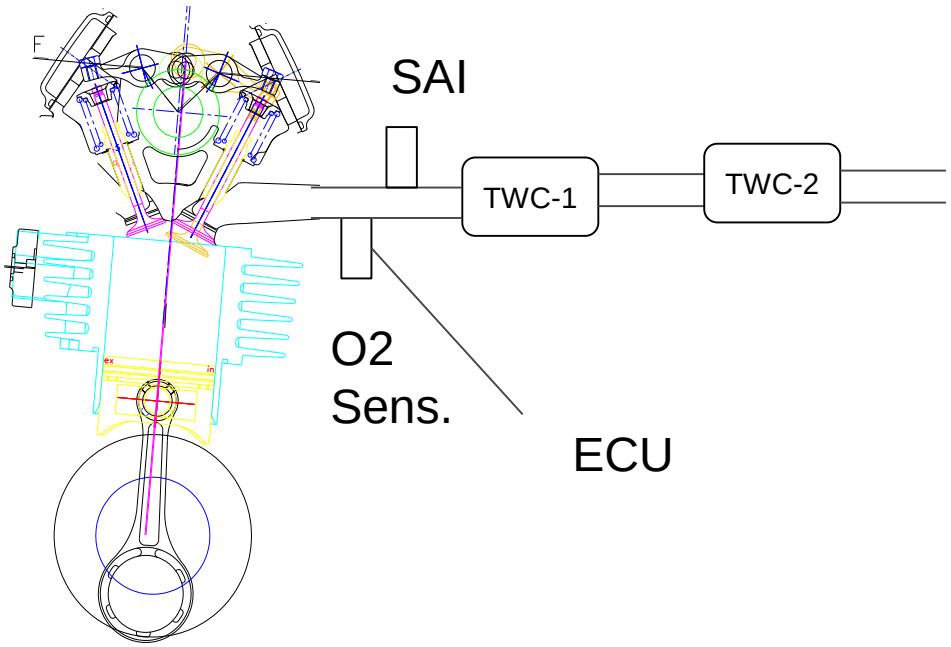
- Separate Norm for HC and NOx
- Separate NOx limit may lead to a reduction in fuel efficiency
- Stringent NMHC norm has been introduced
- Tighter Engineering Targets
- Challenges in implementing OBD-II
  - Single cylinder Engine – non uniform exhaust flow
  - Fast reaction times (FI and actuators) – High RPM
  - Cost sensitive Market

Catalysts for BS-VI Emission Norms

- **High activity and selectivity**
- **Low LOT**
- **High thermal stability**
- **High OSC**
- **Optimum PGM density and ratio**
- **Judicious utilization of PGM**
- **PGM Dispersion**
- **2 Catalysts required for thermal management**
- **Available on structured substrates**
- **NOx is space velocity sensitive: larger and higher cpsi substrate**
- **Wash coat chemistry**
  - PM support interaction
  - Oxygen Storage materials (OSC)
- **Wash coating technology**
  - Segregated : to minimize potential alloying
  - Layered / Zone
  - Wash coat Properties and Rheology

All Classes

- **EFI with Closed-loop (Stoichiometric A/F) control**
- **May need SAI if engine has to run rich for combustion stability and/or performance**
- **Three Way catalyst(s)**



Typical Reactions on TWC Surface

$CO + 0.5O_2 \rightarrow CO_2$

$CO + H_2O \rightarrow CO_2 + H_2$

$HC + O_2 \rightarrow CO_2 + H_2O$

Oxidation

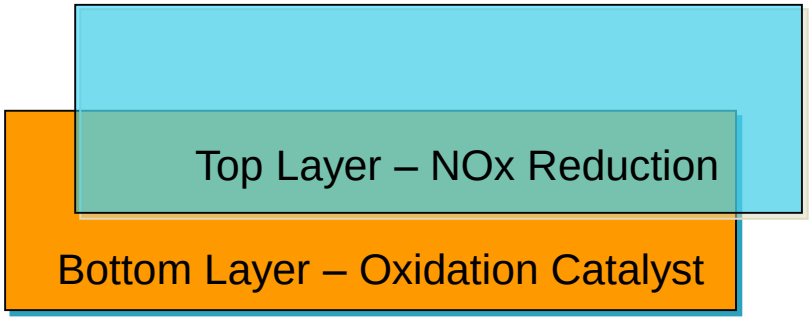
$NO + CO \rightarrow CO_2 + 0.5N_2$

$NO + H_2 \rightarrow 0.5N_2 + H_2O$

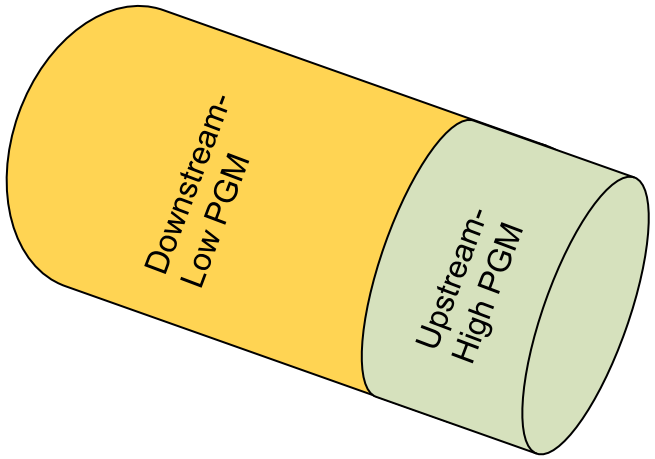
$NO + HC \rightarrow CO_2 + H_2O + 0.5N_2$

Reduction

Typical Layering / Zone Coating Technology



Scheme 1



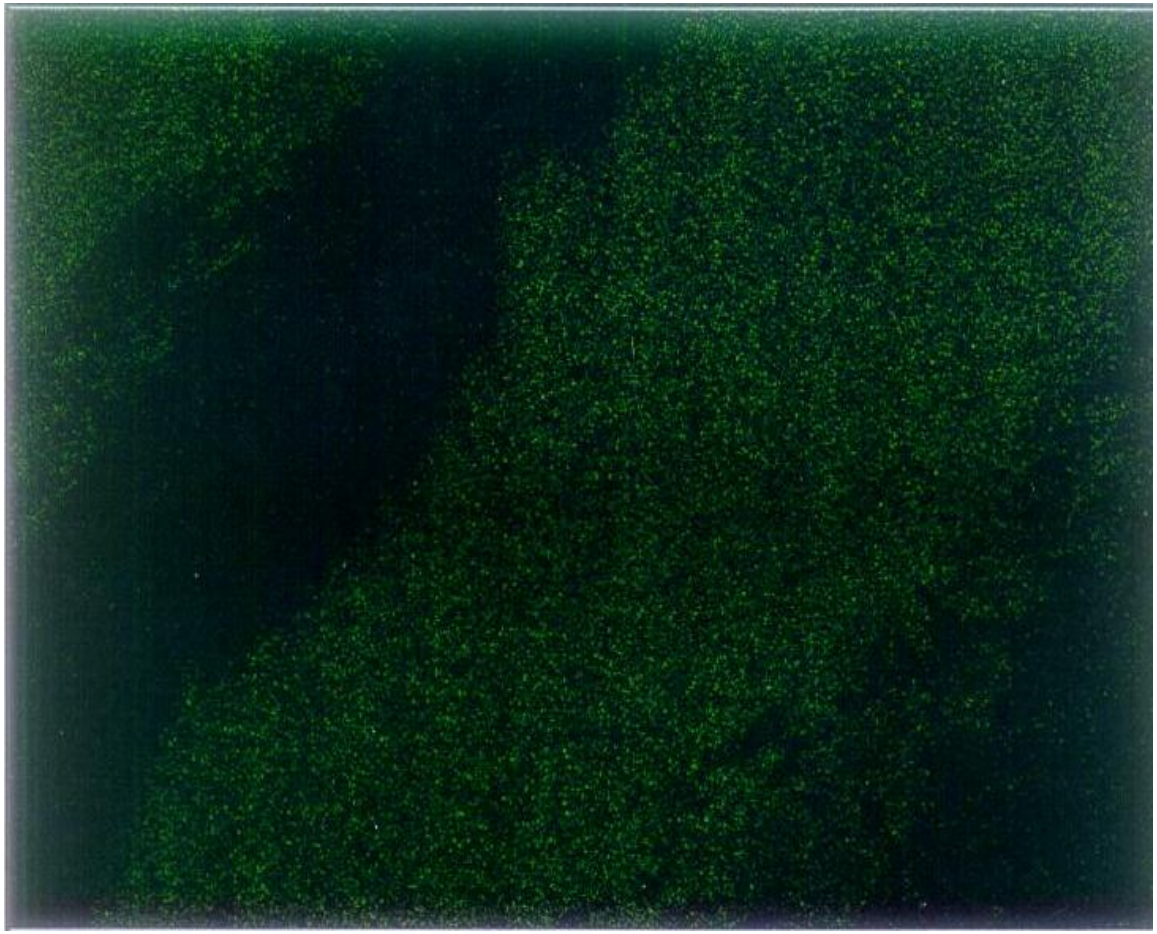
Scheme 2

- ✓ Lower light-off temperature and better cold start conversion
- ✓ Control of emissions at high speed / high temperature
- ✓ Improved conversions of CO, HC & NOx
- ✓ PGM loading can be lowered

Every layer is :

- ✓ Optimized for metal support interactions / devoid of negative interactions
- ✓ Improved utilization of Rh & durability
- ✓ Specifically targeted to individually abate HC and NOx

Washcoat/PGM Dispersion



High Dispersion catalysts important for better PGM utilization

OBD -2W

OBD systems for emission control shall have the capability of identifying the likely area of malfunction by means of fault codes stored in the computer memory

Monitoring Items	**OBD-I (1st April, 2020)**	**OBD-II (1st April 2023)**
Circuit continuity for all emission related powertrain component (if equipped	✓	✓
Distance Travelled since MIL (malfunction indicator lamp) ON	✓	✓
Electrical disconnection of Electronic Evaporative purge control device (if equipped & if active)	✓	✓
Catalytic Converter Monitoring	X	✓
EGR system Monitoring	✓	✓
Misfire Detection	X	✓
Oxygen Sensor Deterioration	X	✓

OBD-II Emission thresholds for BS-VI

Vehicle Class	OBD-II Stage			
Type	CO g/km	NMHC g/km	NOx g/km	PM g/km
Class -1 & 2-1 (BS-VI Norm)	1.90 (1.00)	0.250 (0.068)	0.30 (0.060)	0.050* (0.0045)
Class- 2-2 (BS-VI Norm)	1.90 (1.00)	0.250 (0.068)	0.30 (0.060)	0.050* (0.0045)
Class - 3-1 & 3-2 (BS-VI Norm)	1.90 (1.00)	0.250 (0.068)	0.30 (0.060)	0.050* (0.0045)

* GDI Vehicles only

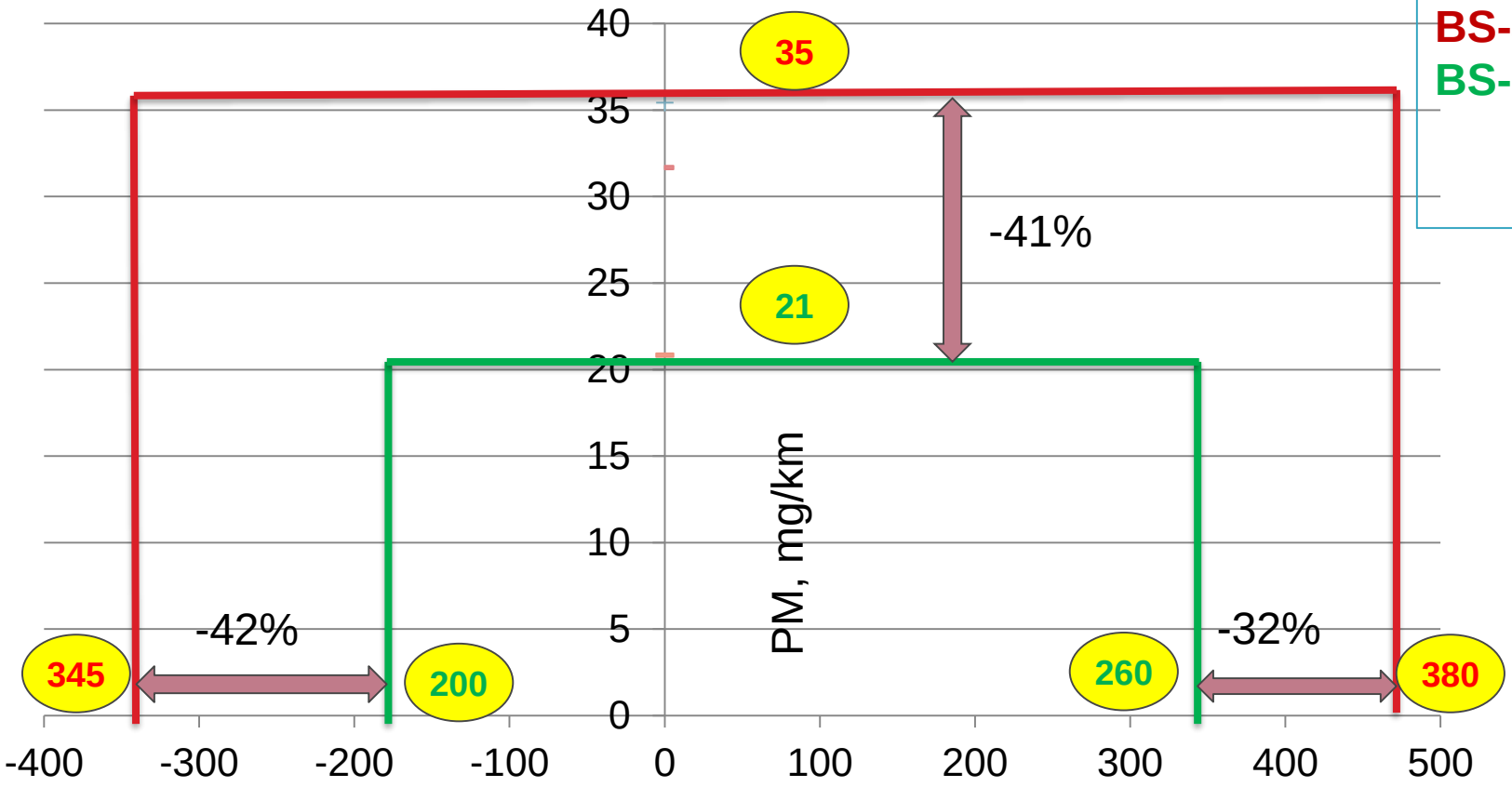
3W - Diesel

3W Market info - India

- Low cost market
- Small Engines, low speeds
- Space constraints
- Most cost effective AFT solution expected
- Major Urban short distance transportation system – high volumes
- Can carry 3-5 persons or light freight
- Largely run on Diesel – but some on CNG, LPG and Gasoline

3 Wheeler – Diesel Norms

All norms with DF

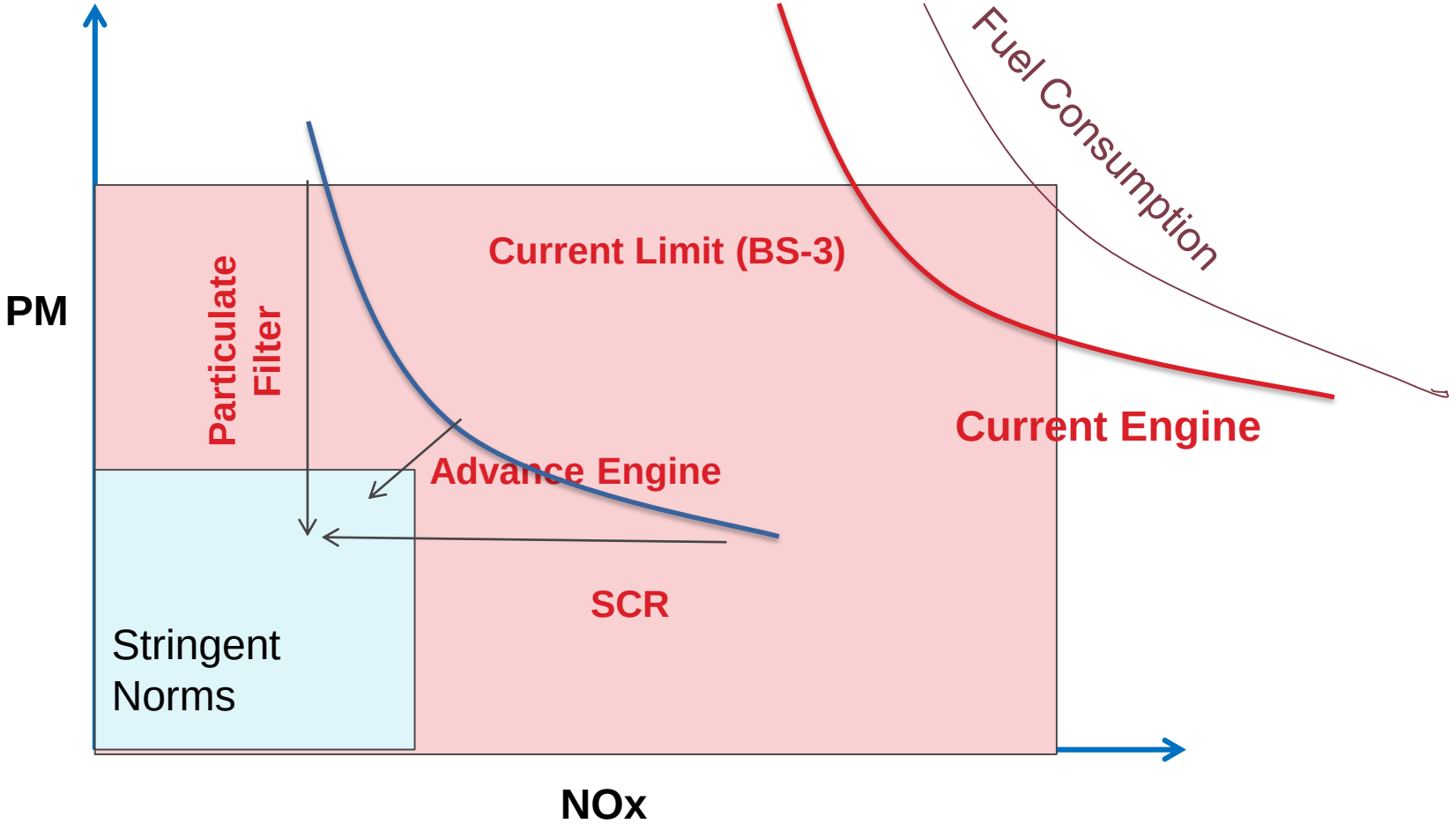


NOx Limit relaxed from 100 mg/km to 160 mg/km

HC	NOx
100	160

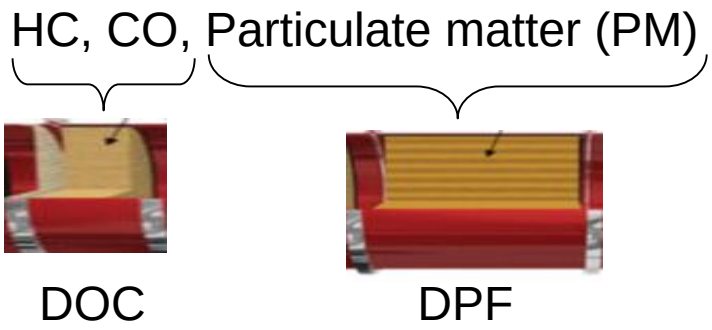
HC and NOx separated in BS VI

NOx-PM Trade Off



NOx PM Trade off – One has to be controlled at the expense of the other

DOC + DPF System – Overview

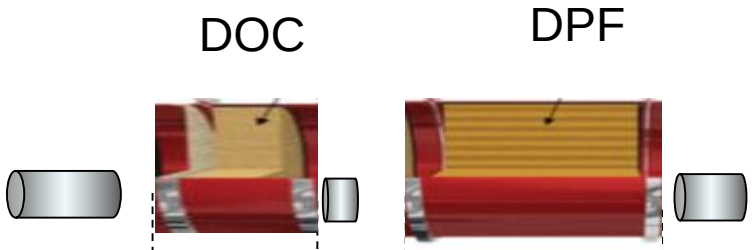


Challenges

- **DOC:**
  - **Must have low Light Off performance for HC and CO conversion**
  - **Needs resistance & robust stability against thermal deactivation.**
- **DPF:**
  - **High filtration efficiency reqd for efficient soot trapping .**
  - **Additional CO/HC Clean up functionality a must to avoid secondary emissions during regeneration.**
  - **High stability against thermal degradation is mandatory for meeting durability /life in field .**

DOC + DPF System - Mechanism

Functions of DOC and Diesel Particulate Filter



HC, CO

Supports DOC Function

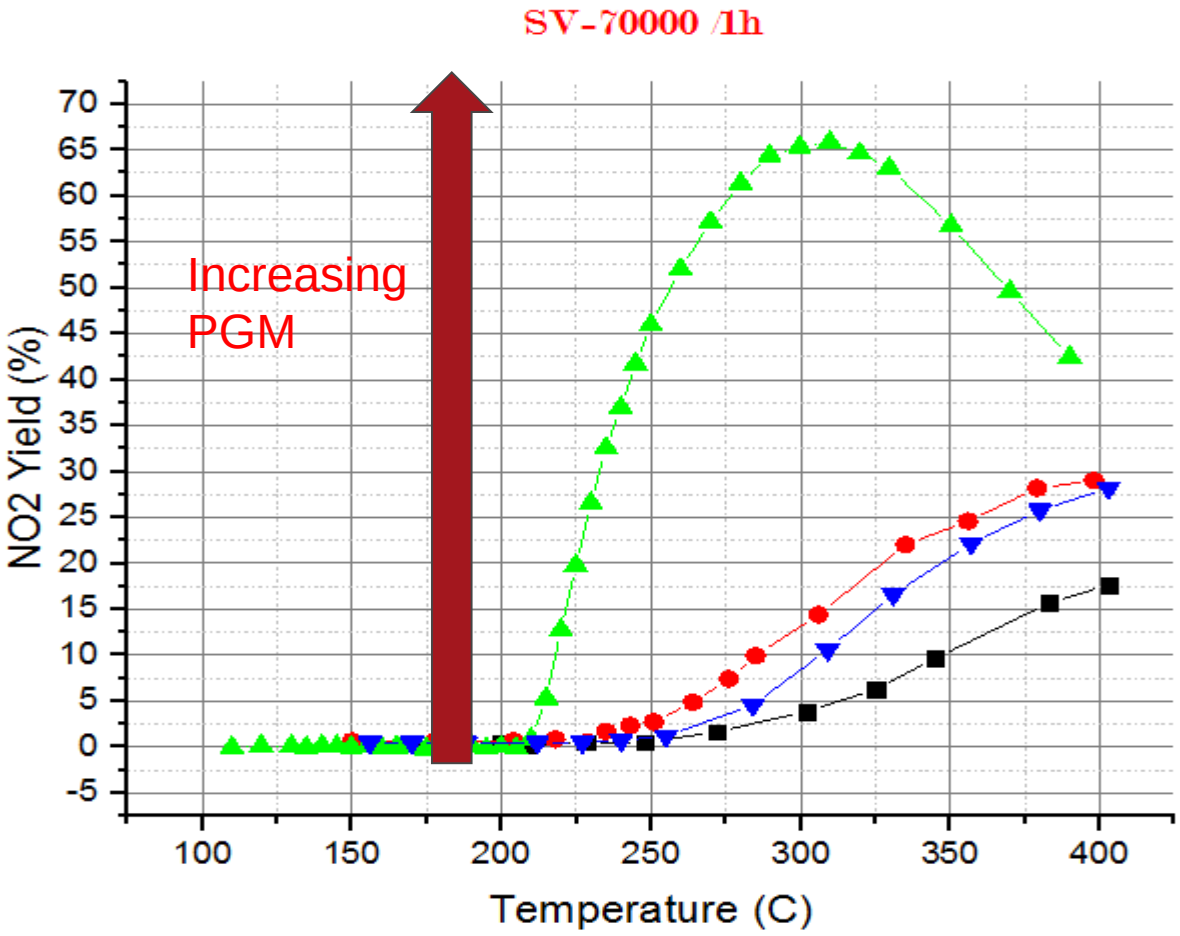
Particulate Matter

Supports Soot Burning via NO_2

NO_x
NO
NO_2

Minimizes NO_2

SCIL NO2 make Catalyst



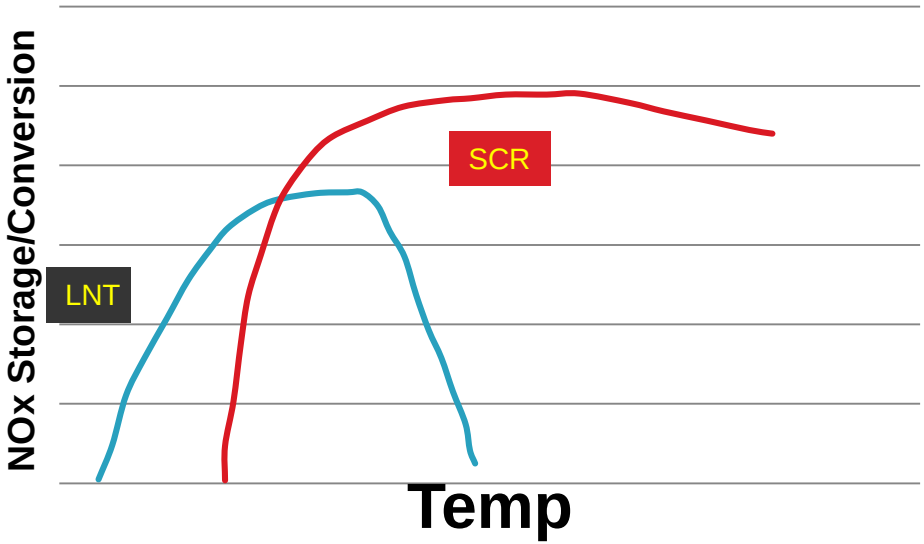
EnviCat® DOC: Different PGM Loadings

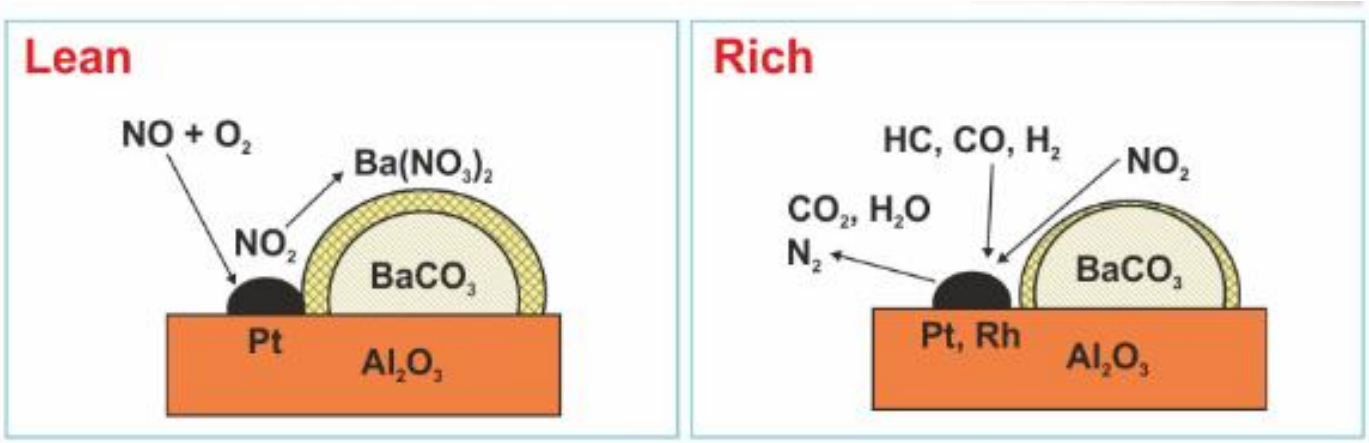
NOx control Strategies – LNT & SCR

- NOx control is difficult for Lean tuned Engine (Diesel)
- LNT: Also called NSC, stores NOx and reduces during a rich pulse
- SCR: NOx may be reduced by adding an additional Reactant (NH3)

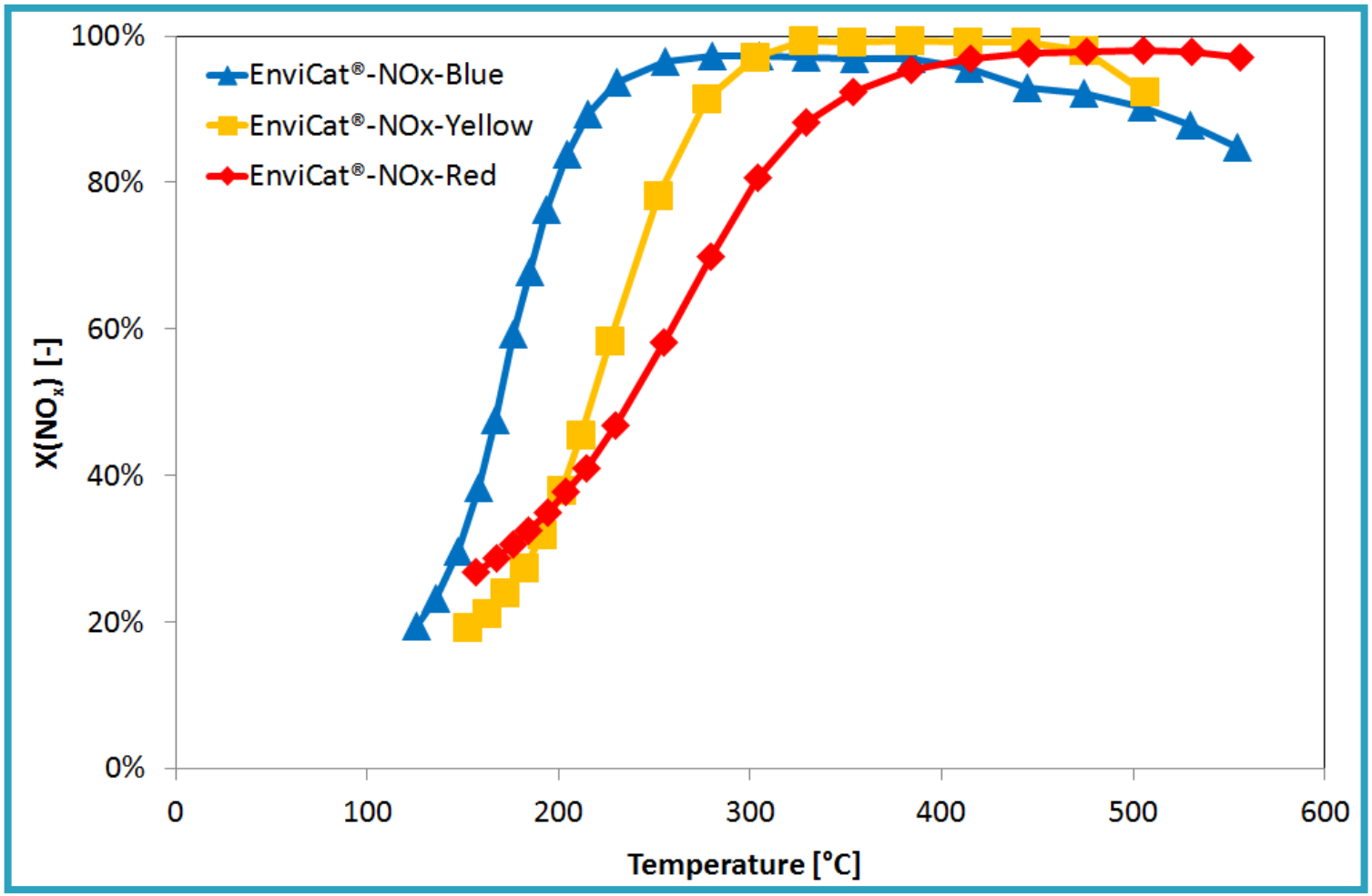
LNT (NSC)

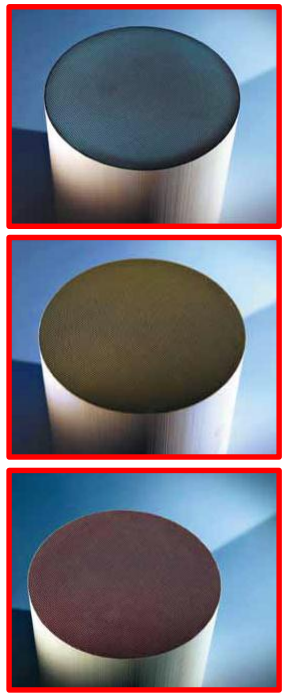
- Lean NOx Trap/ NOx Storage Catalyst
- At low temperature will store NOx and release at High temperature/ Rich Pulse
- Reduction happens during the High Temperature pulse





Selective Catalytic Reduction

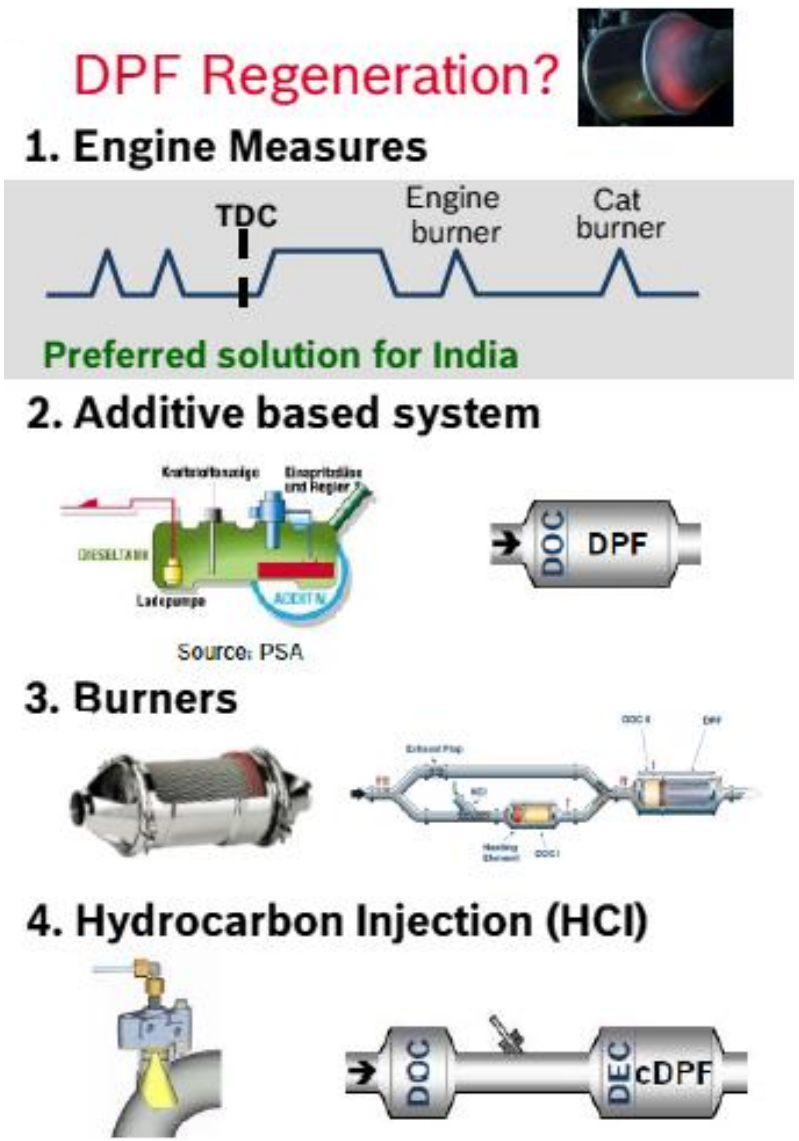




DPF Regeneration Strategies

- Active regeneration requires system changes
- HC pulses via engine or into exhaust line is needed
- Electric burners or fuel additives maybe available
- The objective is to burn soot with air

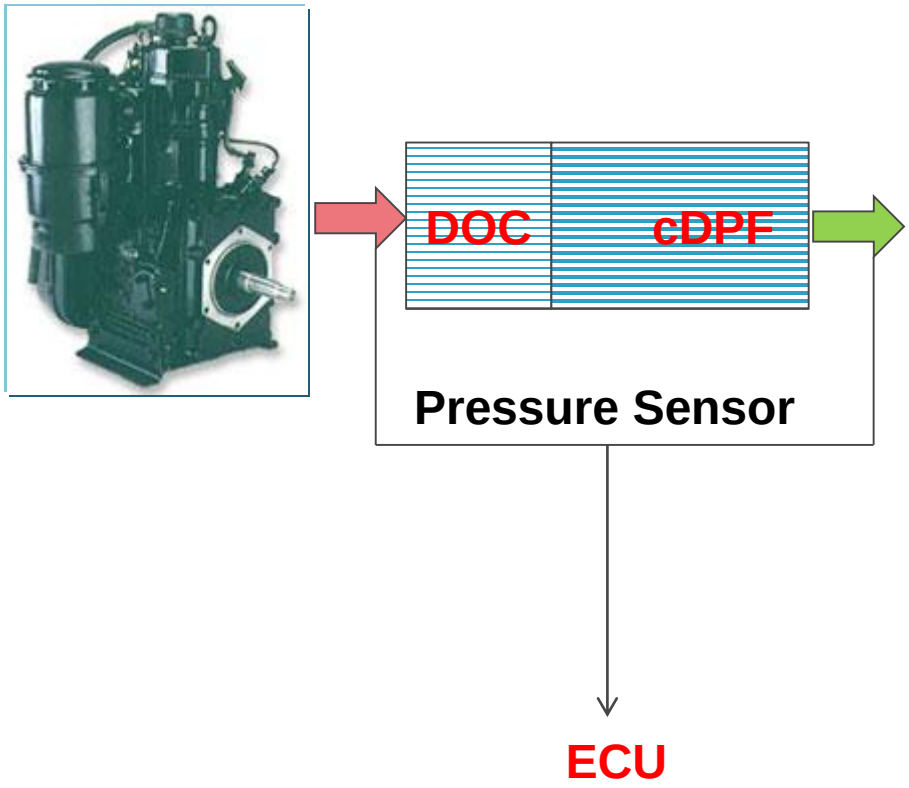
Source: BOSCH



Option 1: DOC + cDPF

Condition: NOx controlled from Engine

- Electronic Fuel Injection
- Calibrate for low NOx (EGR)
- Closed Coupled DOC+cDPF
- DOC for oxidation of CO/HC and NO2 make for passive soot oxidation
- Pressure sensor for OBD-II monitoring and signaling to ECU for late cylinder injection for active cDPF regeneration when needed
- Less penalty on fuel for active regeneration

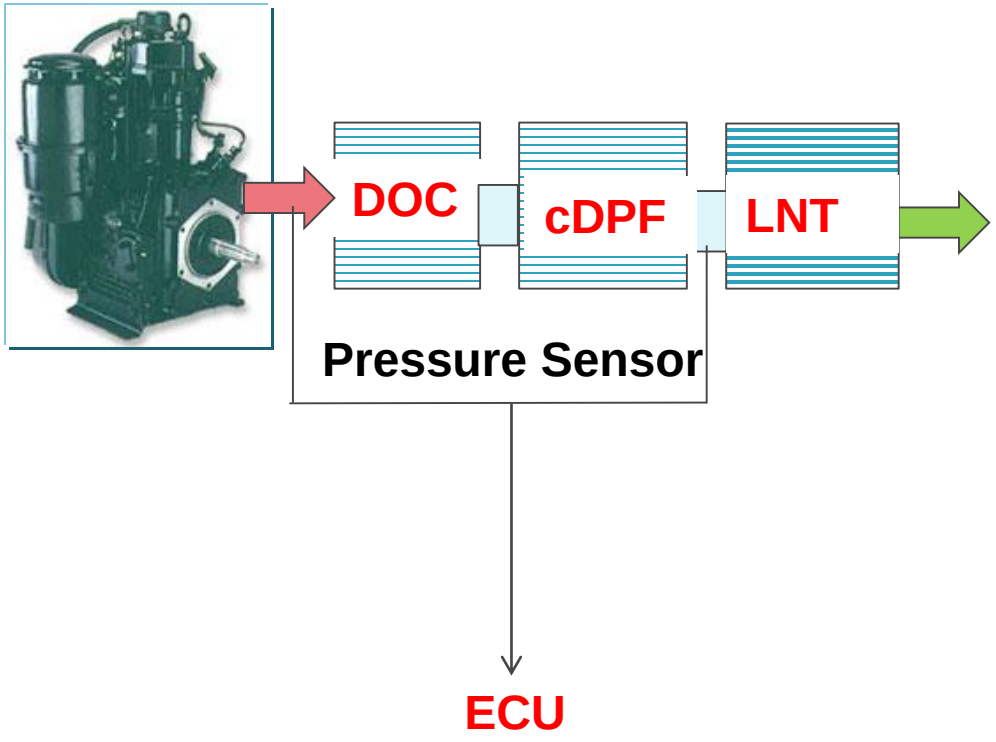


NOx Limit relaxed from 100 mg/km to 160 mg/km

Option 2: DOC + cDPF + LNT

Condition: NOx reduction requirement of <70%

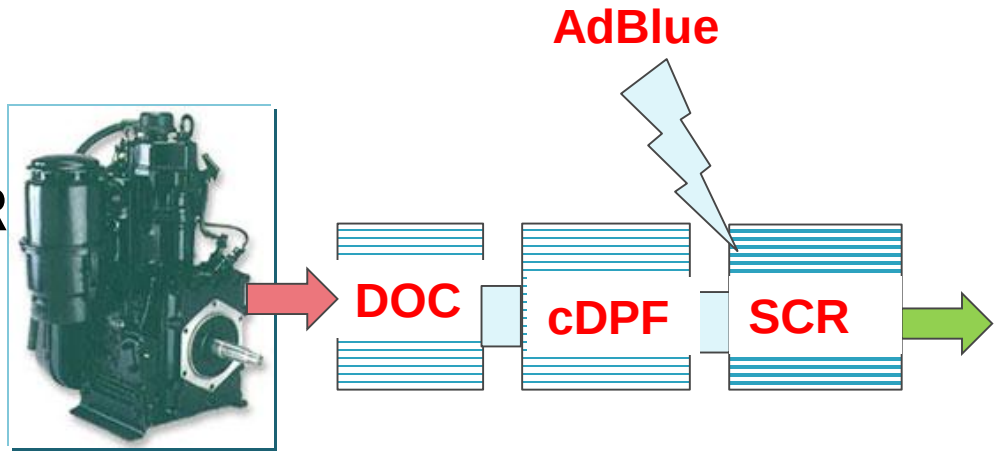
- LNT Approach
  - Control NOx through LNT
  - Rich pulse needed for Regeneration
  - High PGM loaded catalyst
- The role of DOC and cDPF shall be as before
- Active Regeneration



Option 3: DOC + cDPF +SCR

Condition: NOx reduction requirement of >70%

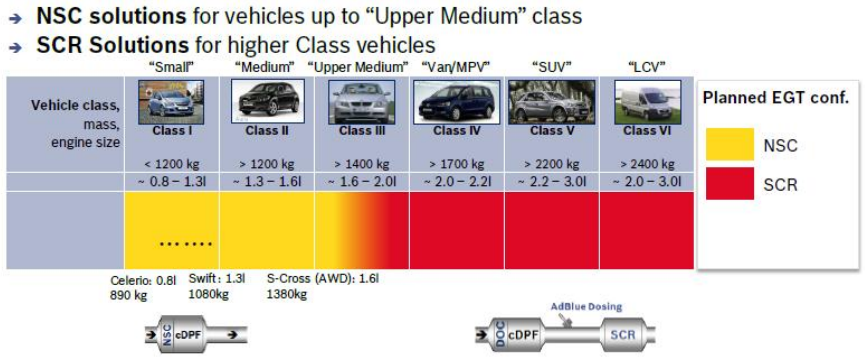
- SCR Approach
  - Control NOx through SCR
  - Maximum > 90% conversion possible
- The role of DOC and cDPF shall be as before



SCR Vs LNT for NOx Conversion

- **SCR**
  - Conversion: >90%
  - Non PGM catalyst
  - Can be tuned for various operating conditions
  - Needs several accessories
    - Adblue Tank
    - Pump
    - Mixer
    - NH3 slip measurement
    - Ammonia Slip catalyst
  - Space Constraints

- **LNT/NSC**
  - Conversion: 70% max
  - High PGM Loadings
  - Best operating temperature of 200 – 450 C
  - No Accessories needed
  - Rich Pulses needed for regeneration- ECU programed



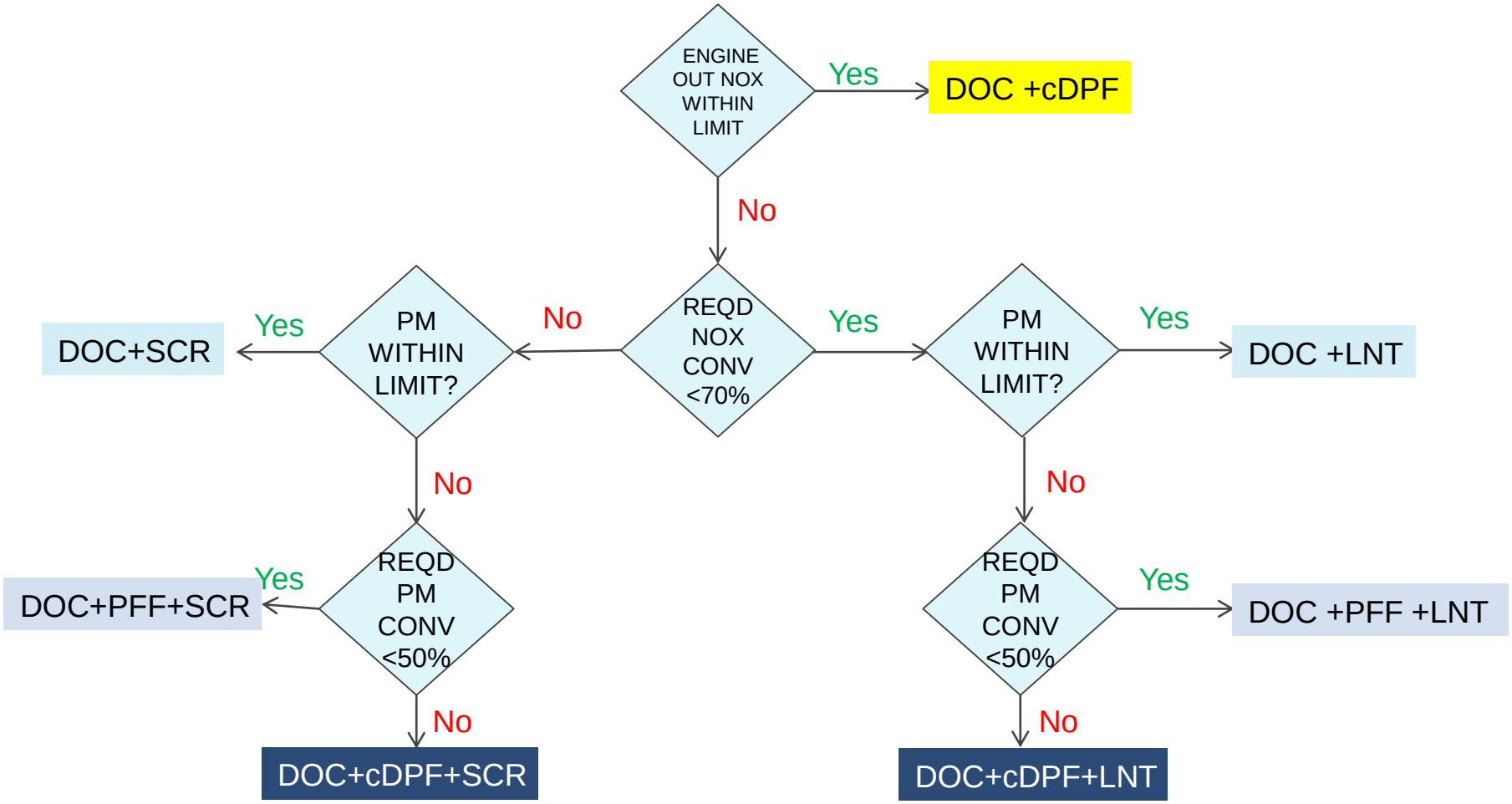
Source: Bosch

3W Reductions - Solutions

	CO	HC	NOx	PM
Baseline, g/km (No EGR)	0.4	0.1	0.6	0.350
BS-VI norm	0.2	0.1	0.16	0.021
Conversion needed				
To meet norm with DF, %	50	0	72%	95%

With EGR, NOx could be brought down by ~50%, 43% further NOx reduction Needed

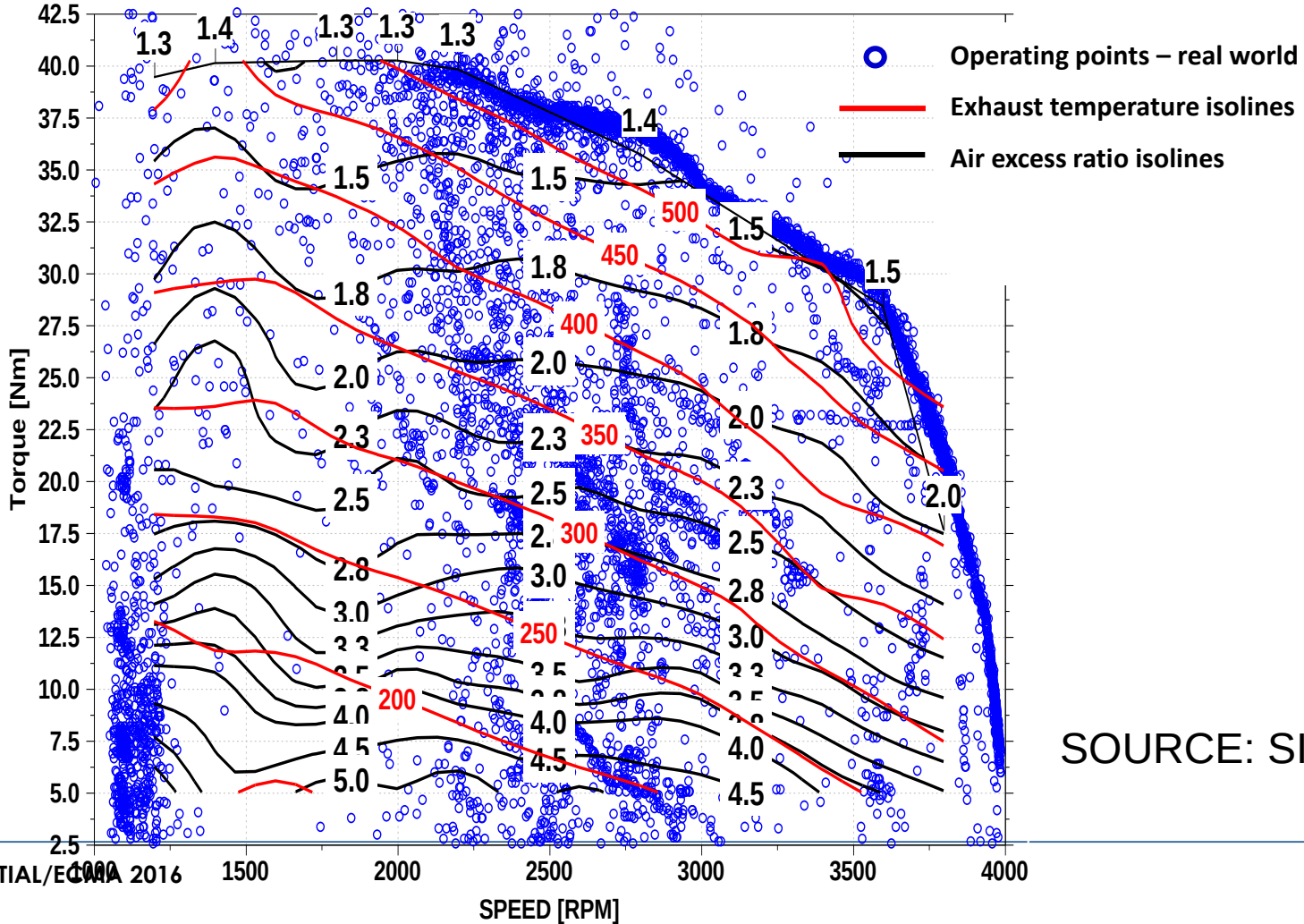
Decision Matrix



Final AFT system configuration depends on Engine out emissions

Challenges – Single cylinder & Two Cylinder NA engine

- More than 70% of operating points are at full load and peak temperature for an NA single cylinder/Two cylinder engine is ~ 520 °C at an air excess ratio of ~ 1.4; Minimum temperature required regenerating soot in DPF is ~ 600 °C.
- Throttling of NA engine for temperature rise will result in significant reduction of air flow and significant increase in soot emission.



SOURCE: SIAM

Catalytic Systems

- DOC+cDPF+LNT/SCR
- DOC coated with Pt-Pd based WC
- cDPF with Pt-Pd based WC with moderate PGM
- Both DOC and cDPF to withstand high exotherms
- LNT with high PGM loading

Sud Chemie Product Portfolio

- EnviCat® DOC
- EnviCat® cDPF (Passive Regeneration)
- EnviCat® Catburner (Active Regeneration)
- EnviCat® SCR (VWT)
- EnviCat® Clean up Catalyst
- EnviCat® Hydrolysis Catalyst
- EnviCat® SCR (Zeolite)
- EnviCat® LNT

Facilities @SCIL

1. Chassis Dynamometer
2. Horiba Emission Analyser Mexa 7400D & CVS 7100
3. Synthetic Rig for TWC/DOC/SCR Cat Testing
4. Catalyst Aging in Progress
5. Diesel Engine Test Bed – SCR Cat Testing
6. Horiba Mini Dilution Tunnel MDLT 1303

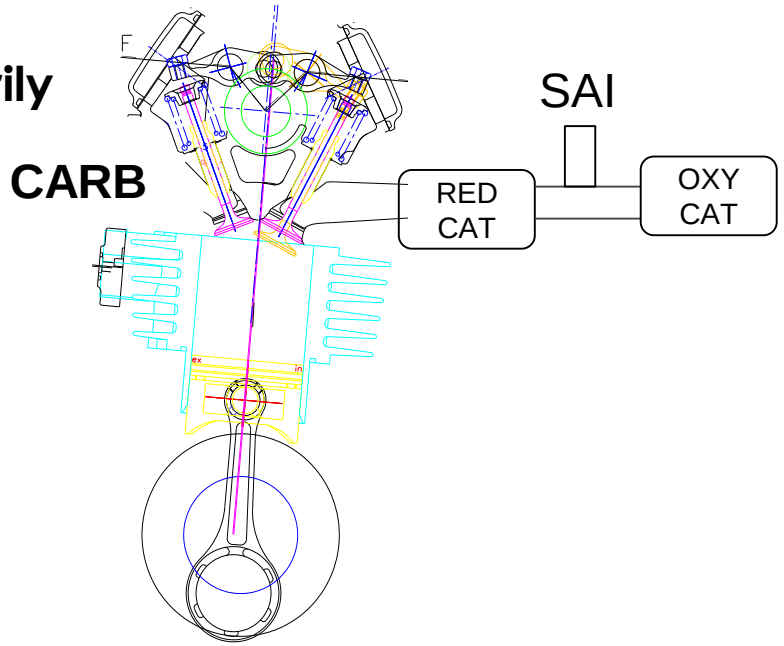
Conclusion

- 2W
  - Move to TWC
  - EFI closed loop control
  - SAI may be needed (in specific cases)
- 3W
  - DOC + cDPF with Active Regen needed
  - LNT/SCR may play a role on at least in higher inertia vehicles
  - Cost implications have to be studied
- Engine out emissions on BSVI Engines will determine AFT system strategy
- SCIL offers all product ranges

THANK YOU FOR YOUR ATTENTION!!

Meeting BS-VI With CARB Engines

- Tune engine richer to minimize NOx
- Use special reduction catalyst, primarily Rh, to reduce NOx
- Add SAI after reduction catalyst
- Use oxidation catalyst to primarily convert remaining CO and HC
- Issues:
  - Need secondary air injection into muffler
  - Need SAI port and piping
  - Requires two catalysts – higher cost



OBD - 3W

OBD systems for emission control shall have the capability of identifying the likely area of malfunction by means of fault codes stored in the computer memory

	OBD II Limit, mg/km
CO	440
NOx	300

Monitoring Items	**OBD-I (1st April 2020)**	**OBD-II (1st April 2023)**
Circuit continuity for all emission related powertrain component (if equipped	✓	✓
Distance Travelled since MIL (malfunction indicator lamp) ON	✓	✓
Electrical disconnection of Electronic Evaporative purge control device (if equipped & if active)	✓	✓
Catalytic Converter Monitoring	X	✓
EGR system Monitoring	X	✓
Misfire Detection	X	✓
Oxygen Sensor Deterioration	X	✓