

ECMA's 14th International Conference & Exhibition - 2023

on



Leaping to Cleaner Air for Tomorrow

(ECT 2023)

2nd and 3rd November 2023

Hotel Radisson BluePlaza, New Delhi Airport

TREM-V : Off-road Application - Aftertreatment strategy and challenges

**Shakti Kumar Singh,
GM and Head, Engine R&D, Escorts Kubota Limited**



Agenda

- 1 Escorts Kubota Limited (EKL) Overview
- 2 Off road Emission : Overview
- 3 Indian Tractor Industry : Volume and Power wise distribution
- 4 TREM V impact on Tractor Industry
- 5 TREM V impact on Tractor Industry : Demystifying TREM V
- 6 Summary
- 7 Thanks



Escorts Kubota Limited (EKL) Overview



WE ARE NOW



Escorts Kubota Limited

A large light blue rectangular area containing the text 'WE ARE NOW' at the top, a large Kubota logo in the center, and 'Escorts Kubota Limited' at the bottom.

Agri Machinery



Construction Equipment



Railway Equipment Division



Engine Application Business*



* Engine Applications Business currently operates under the Agri Machinery Group



Agri Machinery



Powering The Dreams Of Farmer

Construction Equipment

1) Material Handling



2) Earth Moving



3) Road Construction



Railway Equipment Division

We specialise in design, development and manufacturing of railway products like brake system, suspension system, dampers, rubber and friction products etc.



- Loco Brake
- EP Brake
- Wheel Mounted Disc Brake System (In collaboration with Yujin South Korea)
- Axle Mounted Disc Brake System
- Axle Mounted Brake Disc
- Distributor Valve
- Vacuum Toilets
- Air Spring (In collaboration with Nitta Japan)
- Couplers & Draft Gear
- Dampers
- Brakes Block & Brake Pad

- We are ISO TS/22163 (IRIS Rev : 03) certified for Design, Development & Manufacturing activities
- Certified to ISO 9001 :2015, ISO 14001 :2015, RDSO, UIC and AAR

Ensuring Safety and Comfort in Rail Transport

Engine Application Business

Variable Speed Engines

25-110 HP



Fix Speed (Genset) Engines

7.5-125 KVA (18-156 BHP)



Our Global Presence



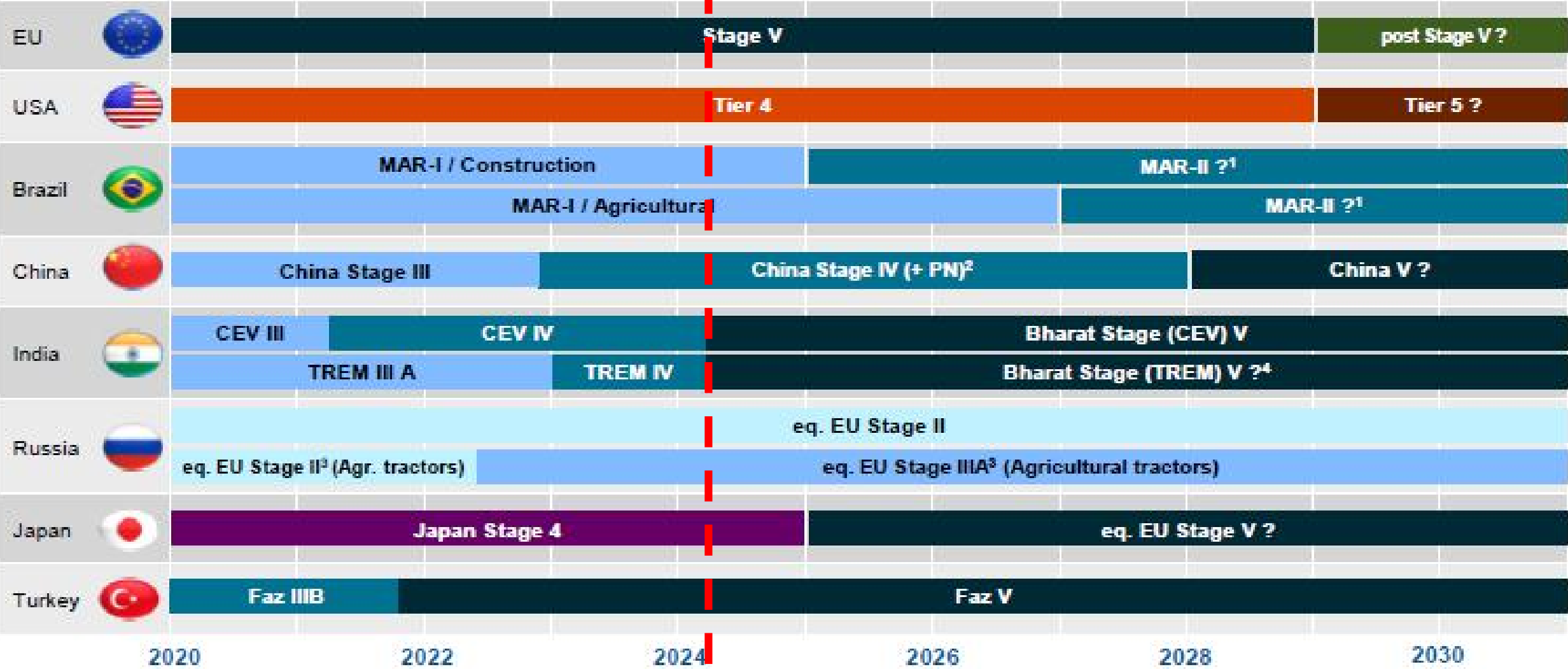
TRACTORS PRESENT IN

70 COUNTRIES



Off road Emission : Overview

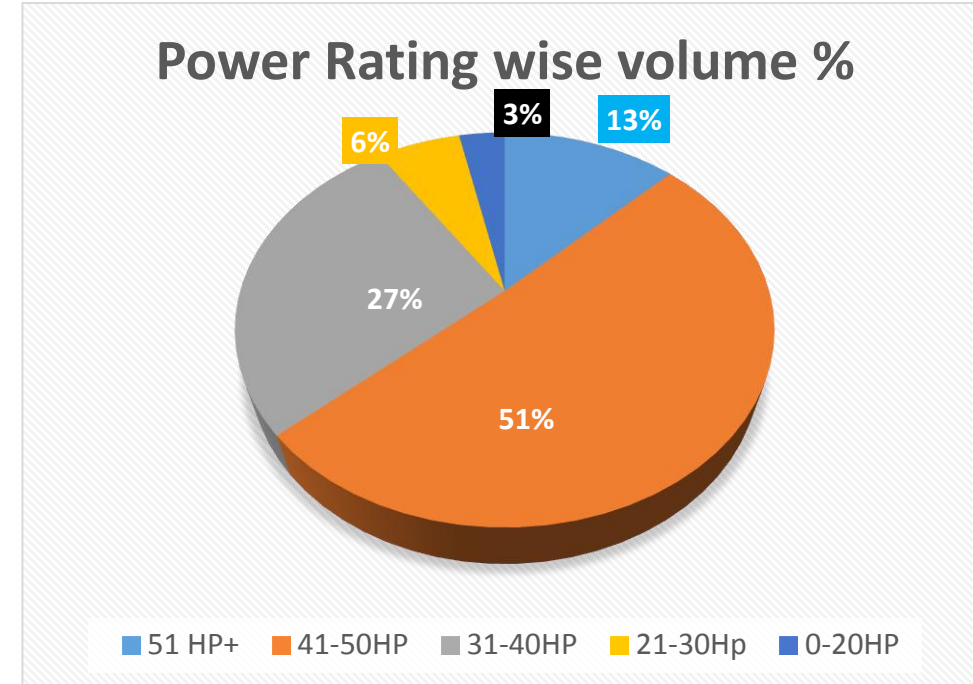
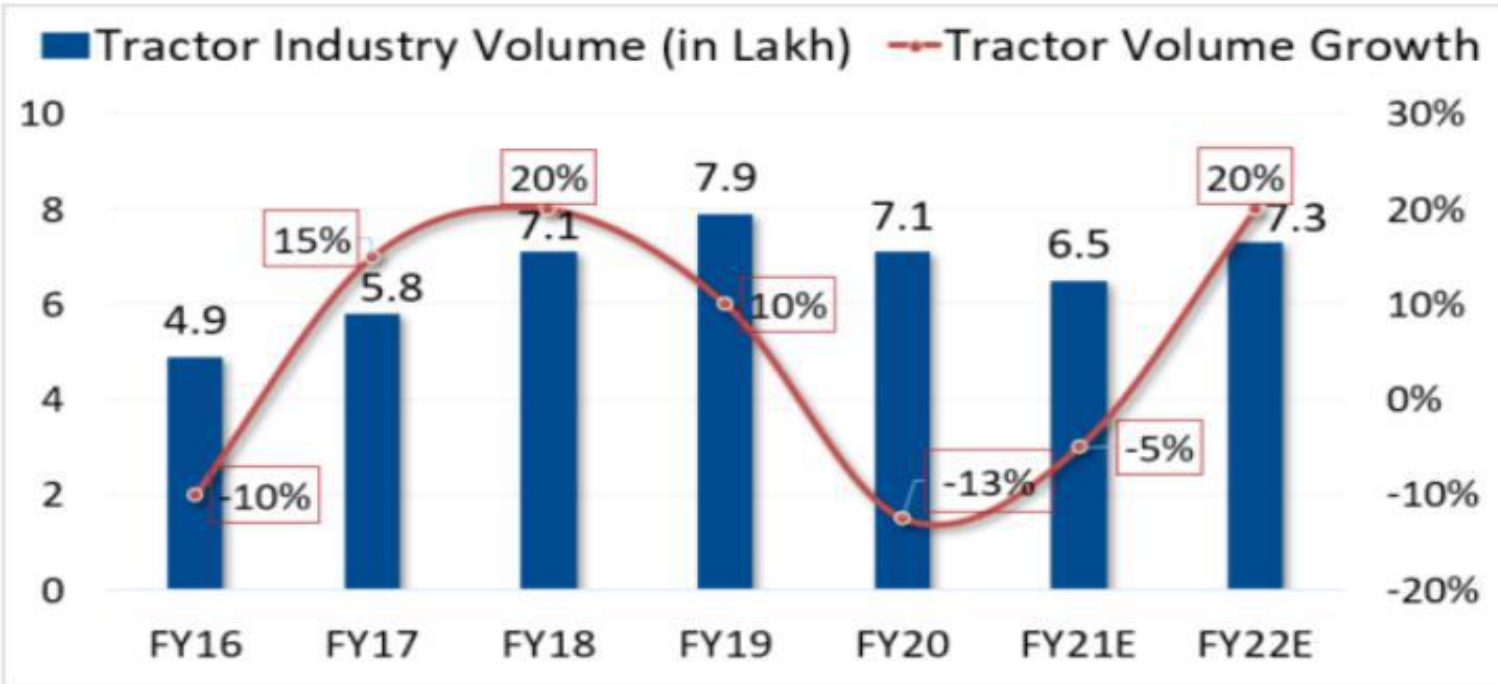
37 ≤ P < 56



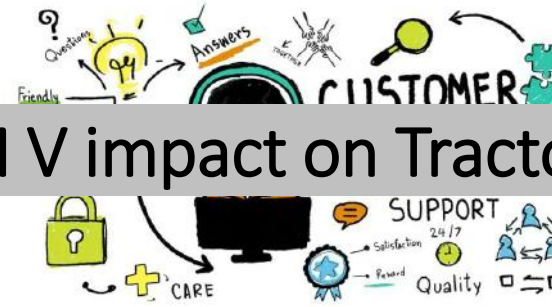
1st April-24



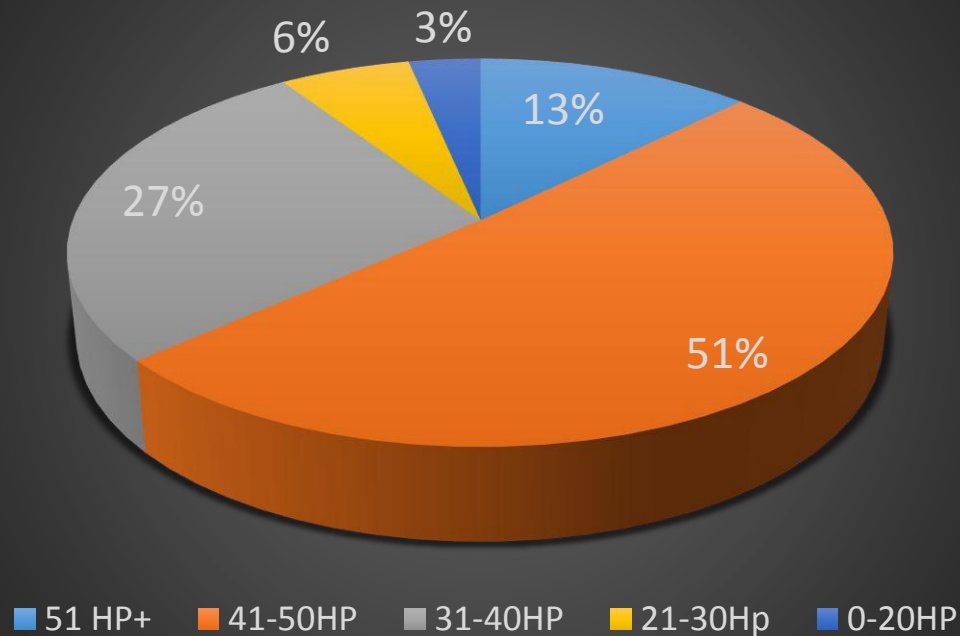
Indian Tractor Industry : Volume and Power wise distribution



TREM V impact on Tractor Industry



Power Rating wise volume %



After TREM IV

~ 10 % of Tractor Engines upgraded with Electronically controlled engines.

After TREM V

Electronic controlled Engine Volume will increase to ~ 90 %
All ~90% engines will be updated with DOC+DPF for PM and PN control.





TREM V impact on Tractor Industry : Demystifying TREM V

Old Tractor Engines
to be replaced by
CRDI
Tractor Engine





Demystifying TREM V



Stringent Emission norms

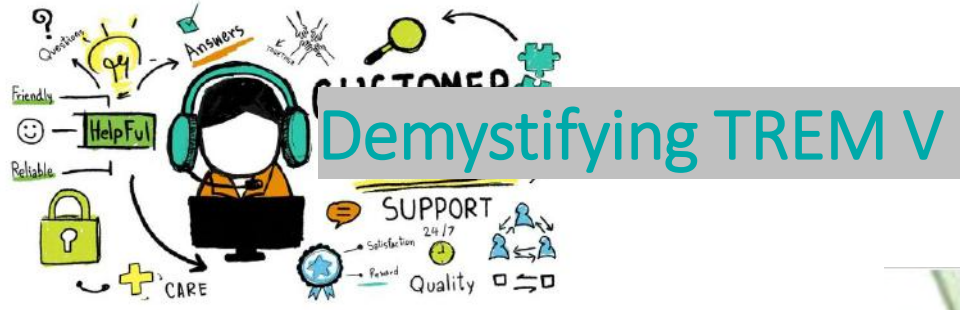
Category - P /kW	CO		HC	NOx	HC	NOx	PM		PN	
	Bharat IV	Bharat V	Bharat IV		Bharat V		Bharat IV	Bharat V	Bharat IV	Bharat V
P < 8	-	8,0	-	-	7,5 (HC+NOx)		-	0,400	-	-
8 < P < 19	-	6,6	-	-	7,5 (HC+NOx)		-	0,400	-	-
19 < P < 37	-	5,0	-	-	4,7 (HC+NOx)		-	0,015	-	1 10 ¹²
37 < P < 56	5,0	5,0	4,7 (HC+NOx)		4,7 (HC+NOx)		0,025	0,015	-	1 10 ¹²
56 < P < 130	5,0	5,0	0,19	0,40	0,19	0,40	0,025	0,015	-	1 10 ¹²
130 < P < 560	3,5	3,5	0,19	0,40	0,19	0,40	0,025	0,015	-	1 10 ¹²
P > 560	-	3,5	-	-	0,19	3,50	-	0,045	-	-

Applicable Test Procedures: NRTC, NRSC, NTE



In-service monitoring





Demystifying TREM V

BT3 >>>>> BT5

8 ≤ P < 19	
Nox	11.80%
PM	50%

~10 %

BT4 >>>>> BT5

37 ≤ P < 56	
Nox	0%
PM	40

~10 %



BT3 >>>>> BT5

19 ≤ P < 37	
Nox	37.30%
PM	97.50%

~80 %

BT4 >>>>> BT5

56 ≤ P < 130	
Nox	0%
PM	40

~0 %

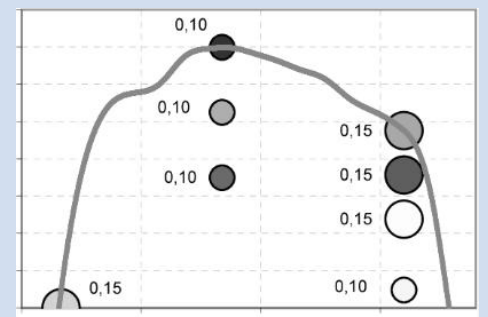




Demystifying TREM V

Current TREM 3A	TREM V
Emission Cycle : NRSC	No Change
Injection : DI FIP : up to 600 bar, Mechanical	No Change
EGR : NO	Direct Orifice controlled (Need Based)
Combustion Bowl : Reentrant type	No Change

Combustion Preoptimization to improve combustion efficiency for TREM V emission norms.



BT3 >>>>> BT5

8 ≤ P < 19	
Nox	11.80%
PM	50%

Summary : No Major change w.r.t. current Technology



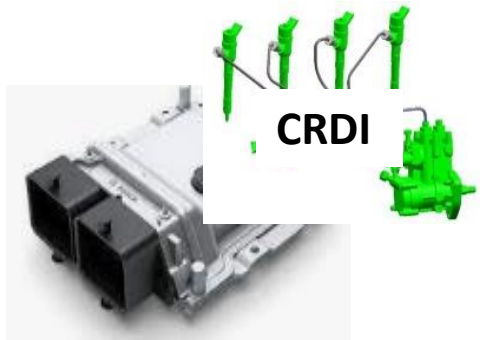
Demystifying TREM V

BT3 >>>>> BT5

19 ≤ P < 37	
Nox	37.30%
PM	97.50%

&

PN 1 10¹²



Controlled Cooled EGR

**+
TVA**

**+
HFM Sensor**

DOC+ DPF

**+
T4 & T5 Sensor**

**+
DP Sensor**

- Improved Combustion
- Emission
- Thermal Management
- Diagnostics management
- Safety control
- Driver Assistance

- NOX Control
- Thermal management

- PM & PN control
- Regeneration control & Thermal management

Summary : Major change w.r.t. current Technology





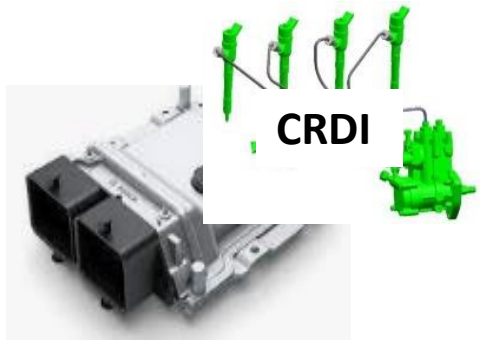
Demystifying TREM V

BT4 >>>>>BT5

37 ≤ P < 56	
Nox	0%
PM	40

&

PN	1 10 ¹²
----	--------------------



Controlled Cooled EGR

+
TVA
+
HFM Sensor

DOC+ DPF

+
T4 & T5 Sensor
+
DP Sensor

- Improved Combustion
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- NOX Control
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Summary : DPF adaptation and Thermal Management



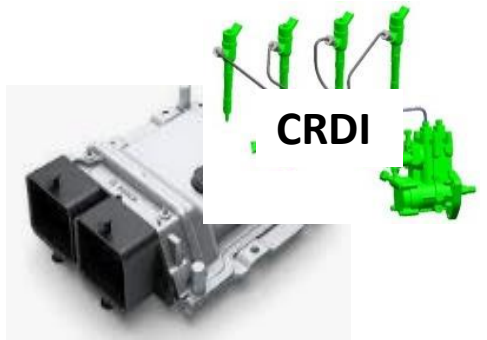
Demystifying TREM V

BT4 >>>>>BT5

56 ≤ P < 130	
Nox	0%
PM	40

&

PN	1 10 ¹²
----	--------------------



Controlled Cooled EGR

+
TVA
+
HFM Sensor

+
DOC+ DPF
+
T4 & T5 Sensor
+
DP Sensor

+
SCR system

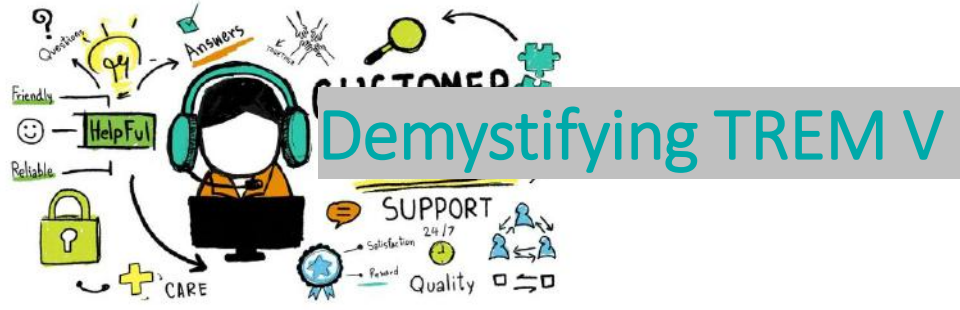
- Improved Combustion
- Emission
- Thermal Management
- Diagnostics management
- Safety control
- Driver Assistance

- NOX Control
- Thermal management

- PM & PN control
- Regeneration control & Thermal management

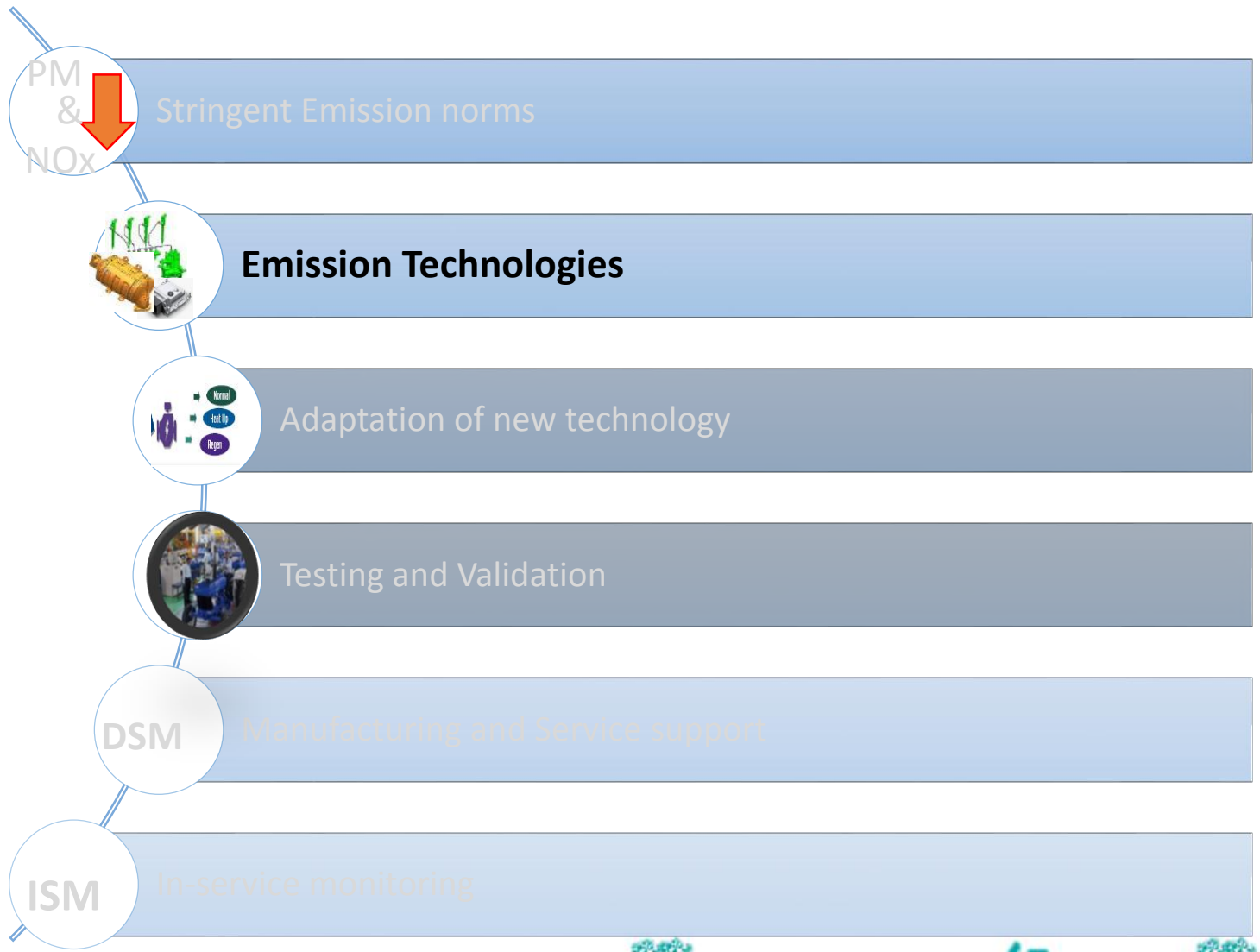
➤ NOx control

Summary : DPF adaptation and Thermal Management



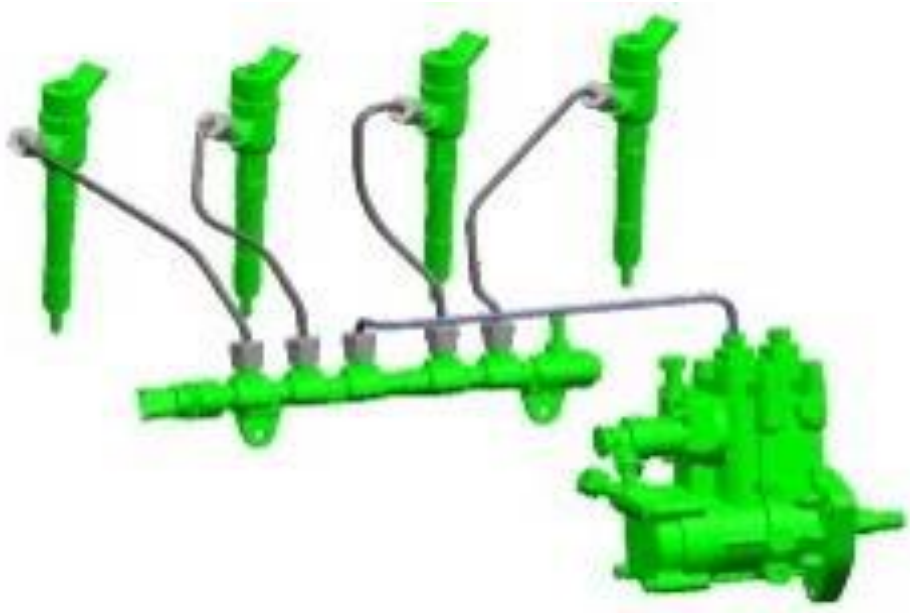
Demystifying TREM V

Old Tractor Engines
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CRDI
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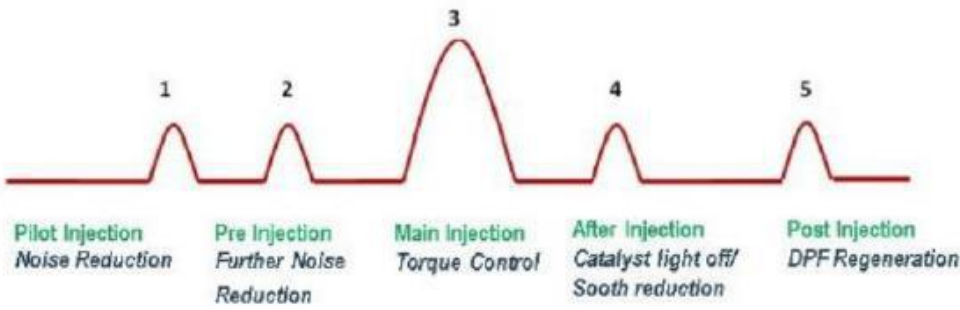


Demystifying TREM V

Emission Technologies : CRDI System

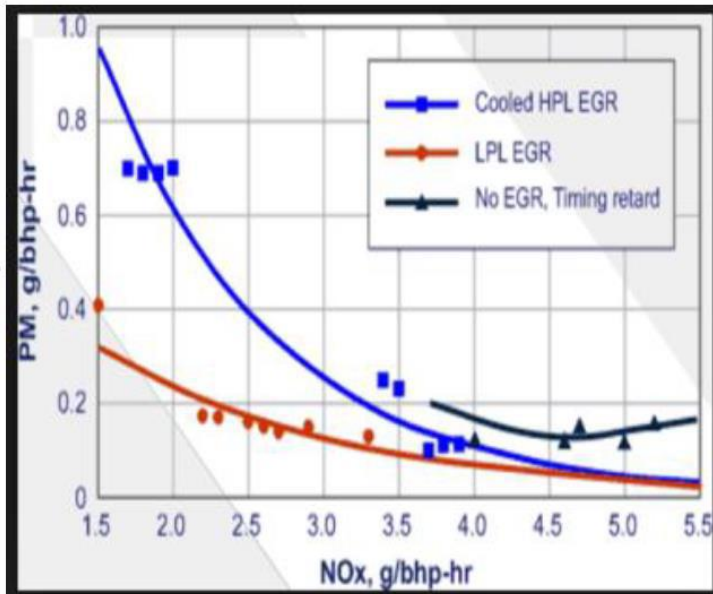


- 1: Capability to achieve > 1600 Bar Injection Pressure for improved combustion efficiency
 - 2: ~85% PM reduction can be achieved
 - 3: Flexibility of the injection pattern for Thermal management & DPF regeneration
 - 4: Enable to achieve Onboard Diagnostic
 - 5: Multiple Driver Assistance function
- etc....

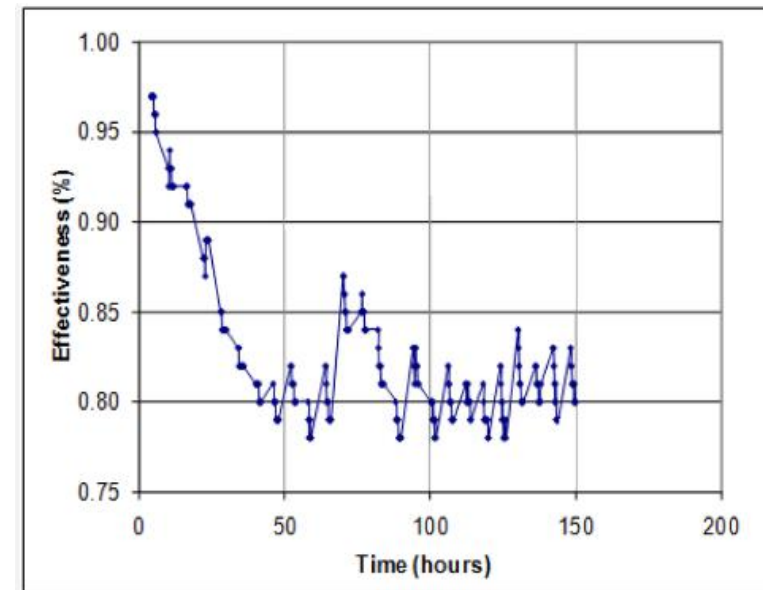


Demystifying TREM V

Emission Technologies : EGR System



➤ EGR cooler Effectiveness : One of the important factor for meeting reliability and consistency of Engine out emission



- Engine EGR valve response is very critical for TREM V.
- Valve to Valve consistency is key for reliable Asmod calibration and DPF Soot model.

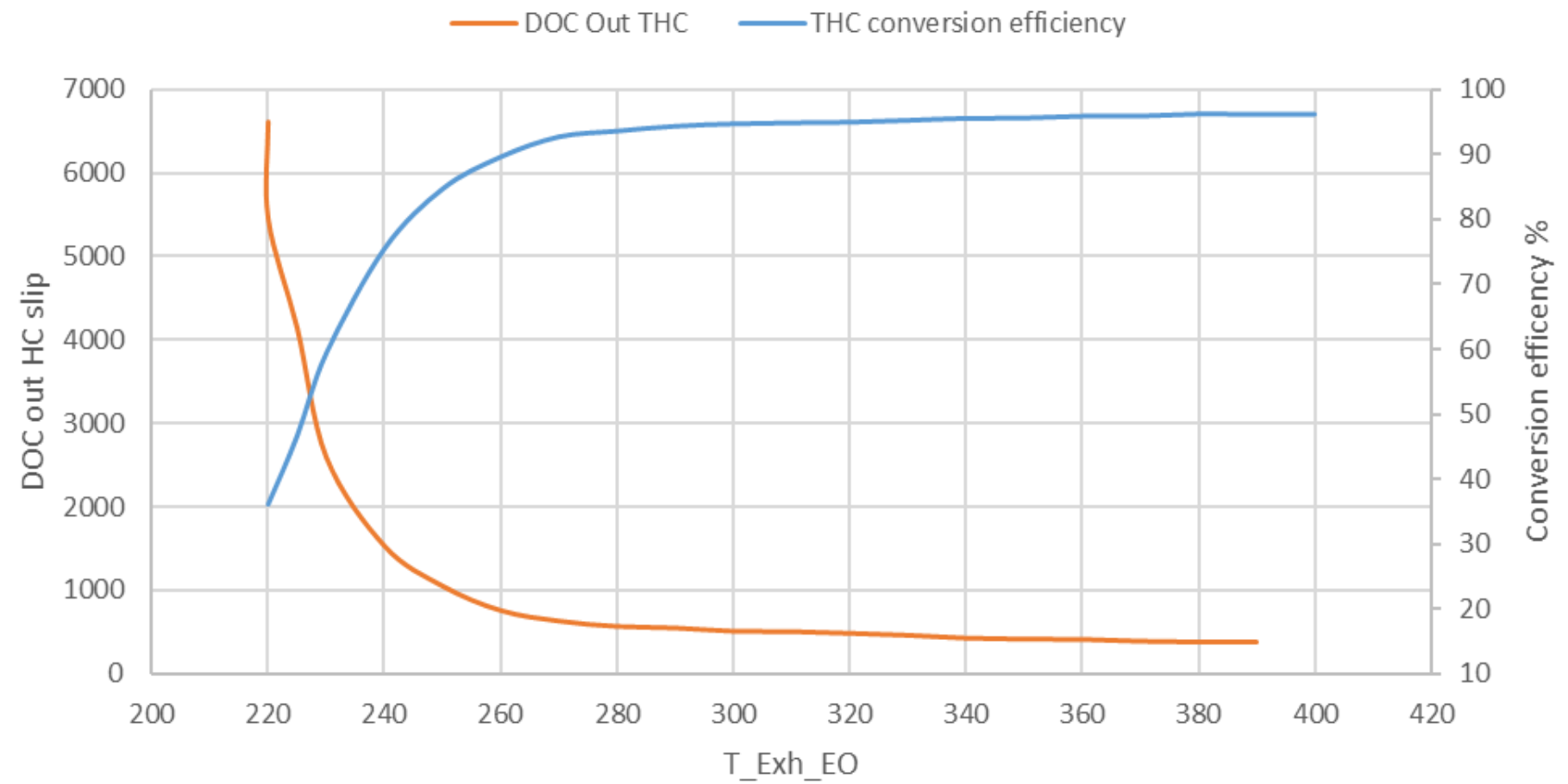




Demystifying TREM V

Emission Technologies : EAT System (DOC+DPF)

DOC Light-off Test



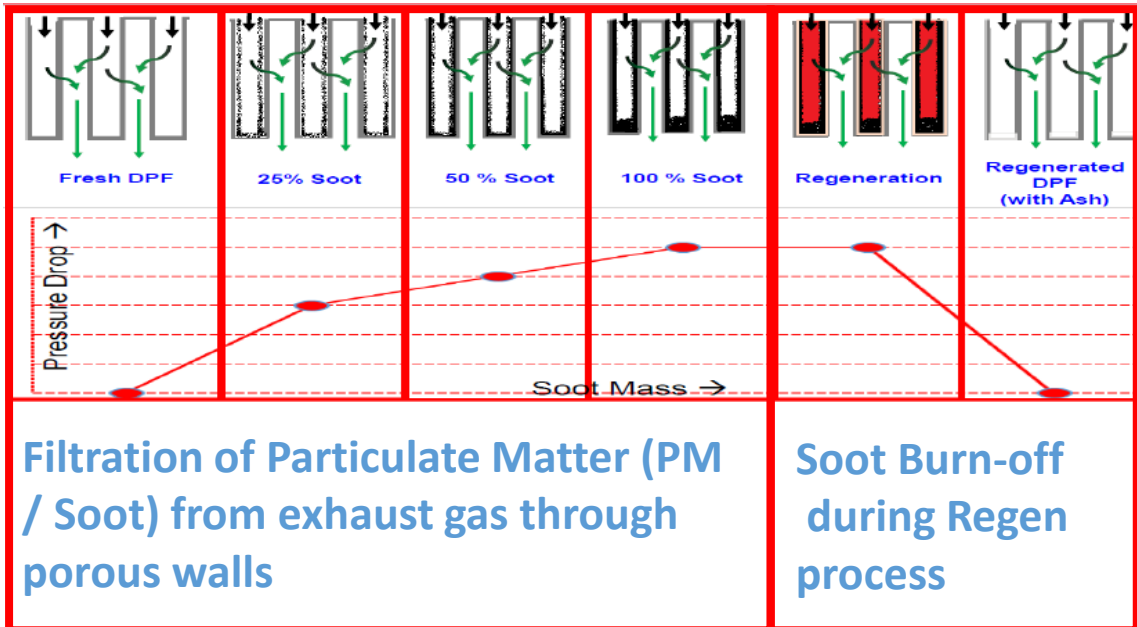
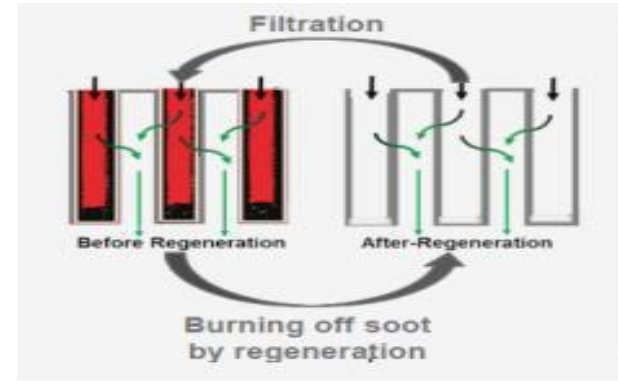


Demystifying TREM V

Emission Technologies : EAT System (DOC+DPF)

SiC-DPF	Cordierite (Cd)-DPF
Segment structure - High thermal expansion 	Monolith structure - Low thermal expansion → Lower Pressure Drop 
High Soot Mass Limit - Higher thermal conductivity - Larger heat capacity	Good light-off property - Lower weight - Lower heat capacity

The process of burning the particulates accumulated in the DPF is called “Regeneration”



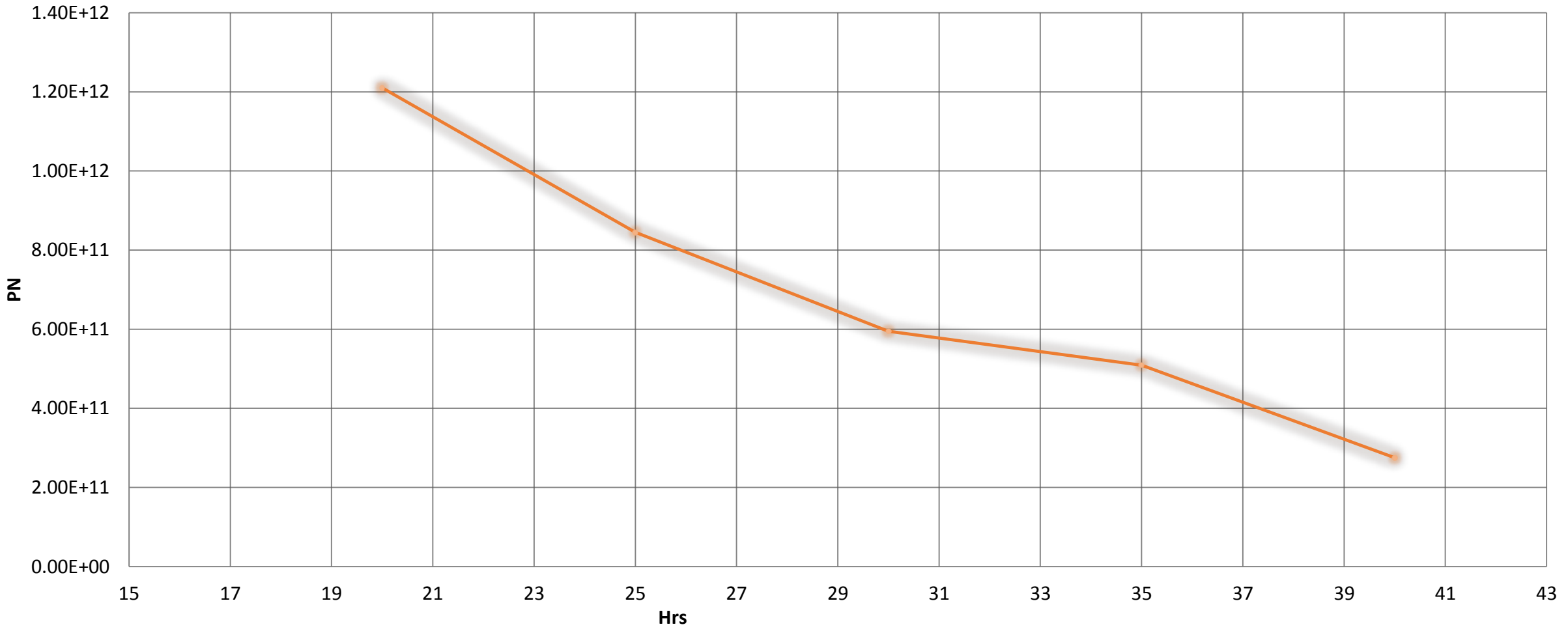
- **Active regeneration** needs temperatures $\sim 600^{\circ}\text{C}$ in the presence of O_2
- **Passive regeneration** required temperatures are $250 \sim 450^{\circ}\text{C}$ with the presence of NO_2





Demystifying TREM V

Emission Technologies : EAT System (DOC+DPF)

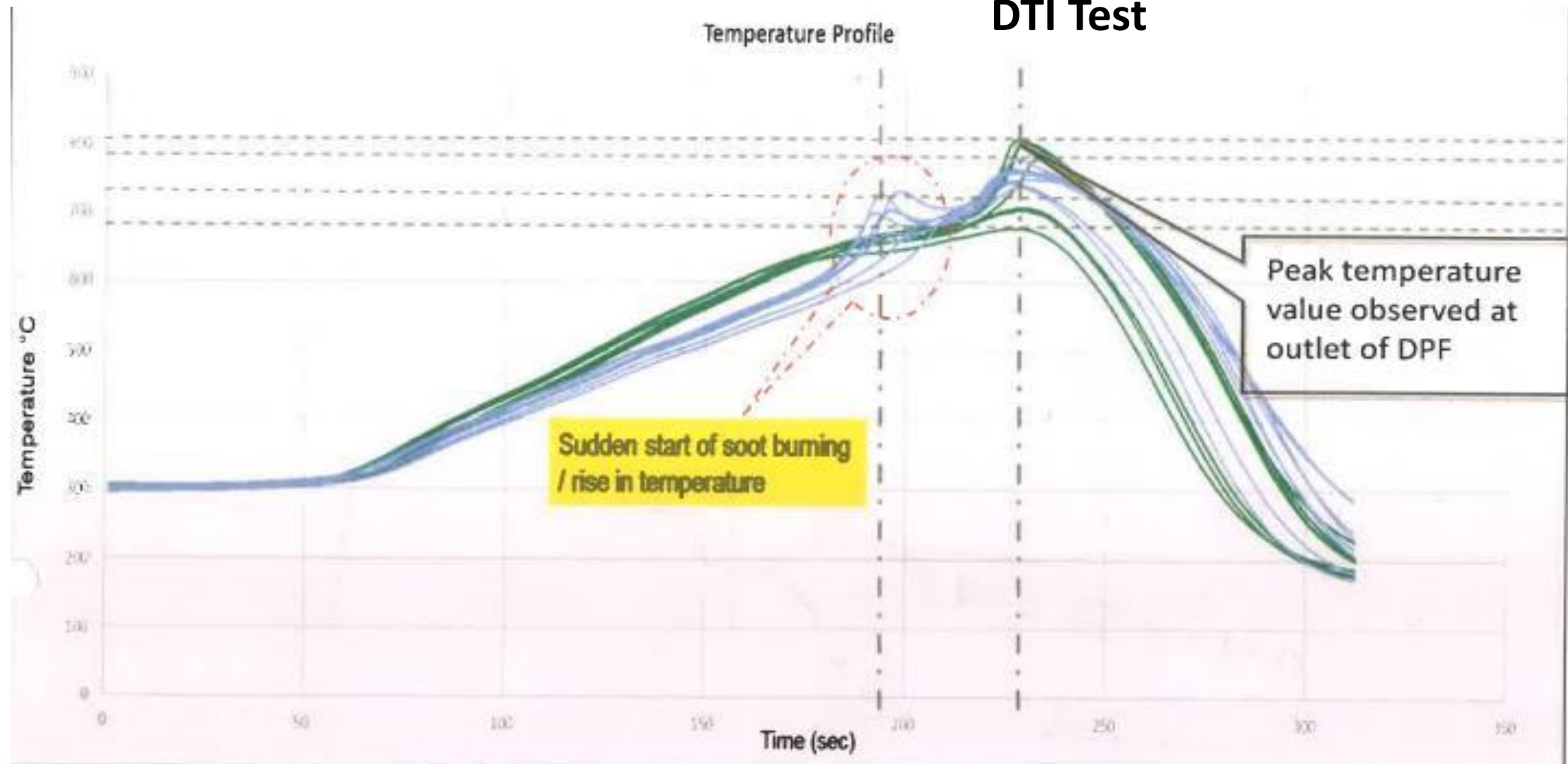




Demystifying TREM V

Emission Technologies : EAT System (DOC+DPF)

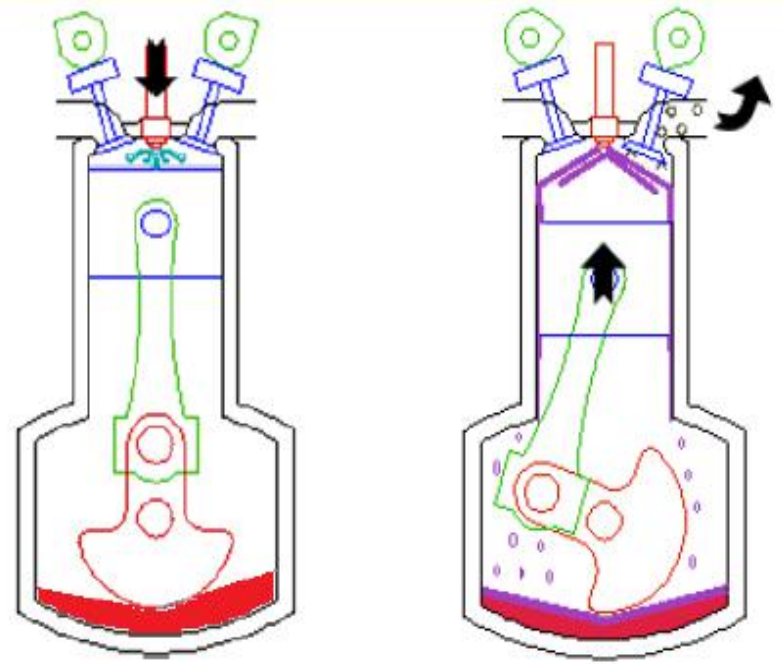
DTI Test



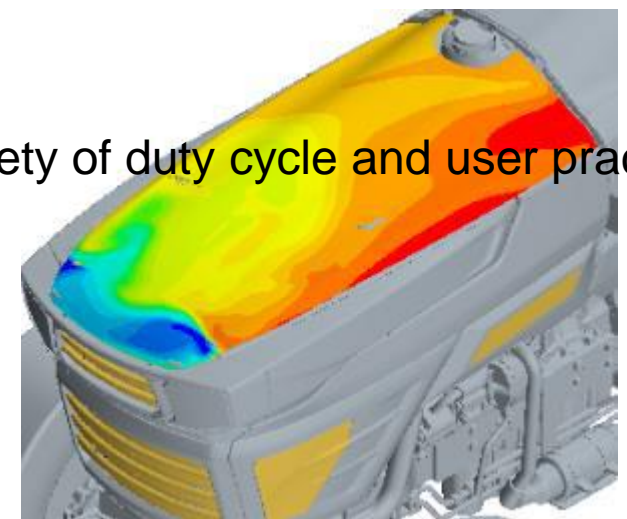


Demystifying TREM V

Emission Technologies : EAT System (DOC+DPF)



- **Oil Dilution** where the engine lube oil gets mixed with diesel fuel is the one of the challenge linked with DPF thermal management.
 - **Increased Temp** inside Bonnet
 - **Delta P sensor** packaging
 - **Soot Modelling** against variety of duty cycle and user practices
- etc.....





Demystifying TREM V





Demystifying TREM V

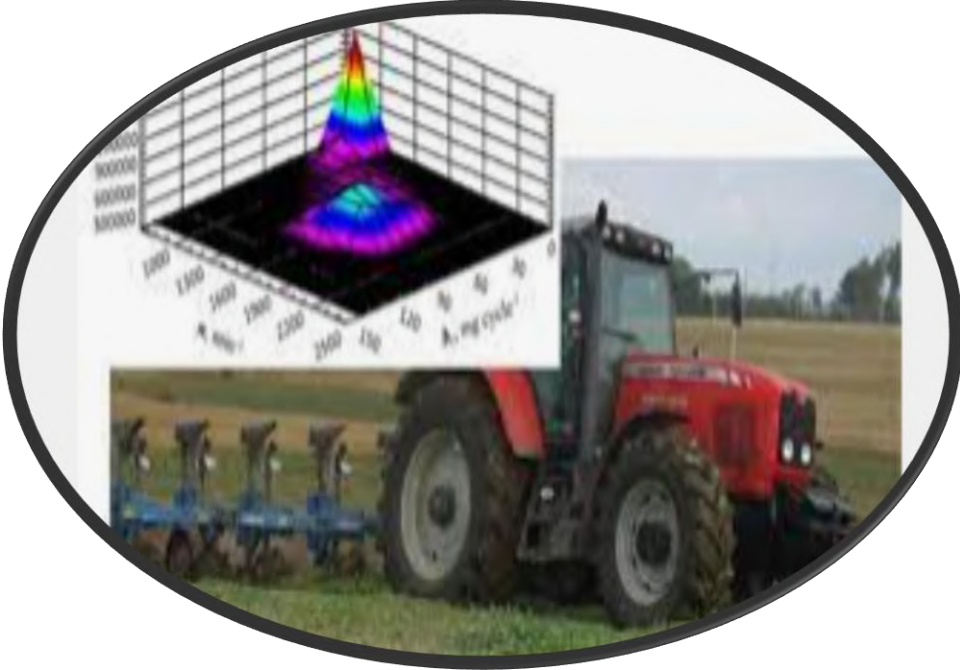
Adaptation of new technology : Key changes



- Redesign of Intake layout for HFM, EGR & TVA packaging
- Redesign to adopt CRDI system and Combustion Pack
- Redesign of Breather System
- Redesign of Exhaust layout for adopting EAT system
- Packaging of Sensors, Actuators along with wiring harness routing



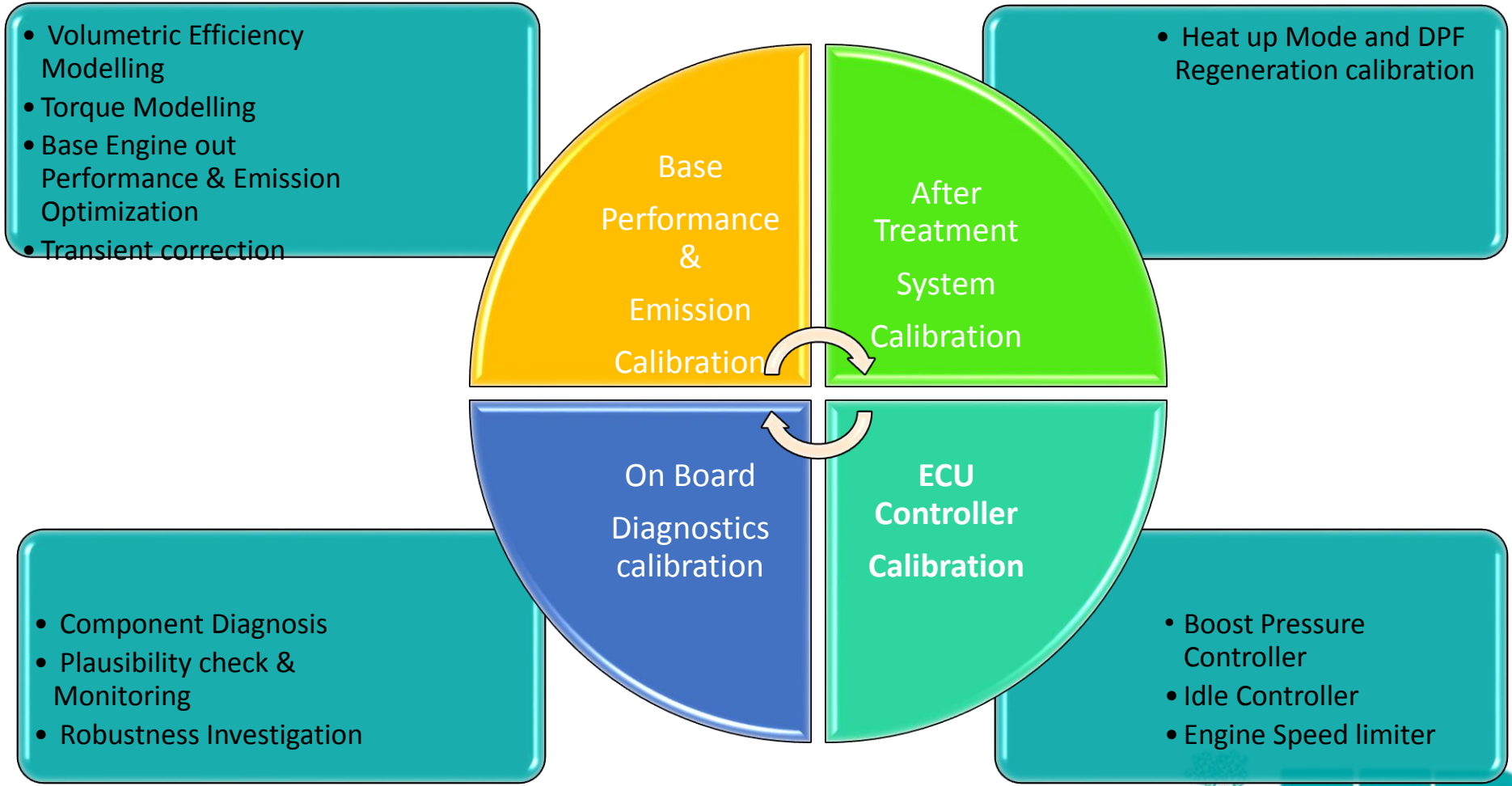
Demystifying TREM V





Demystifying TREM V

Engine Calibration : Performance and Functional development

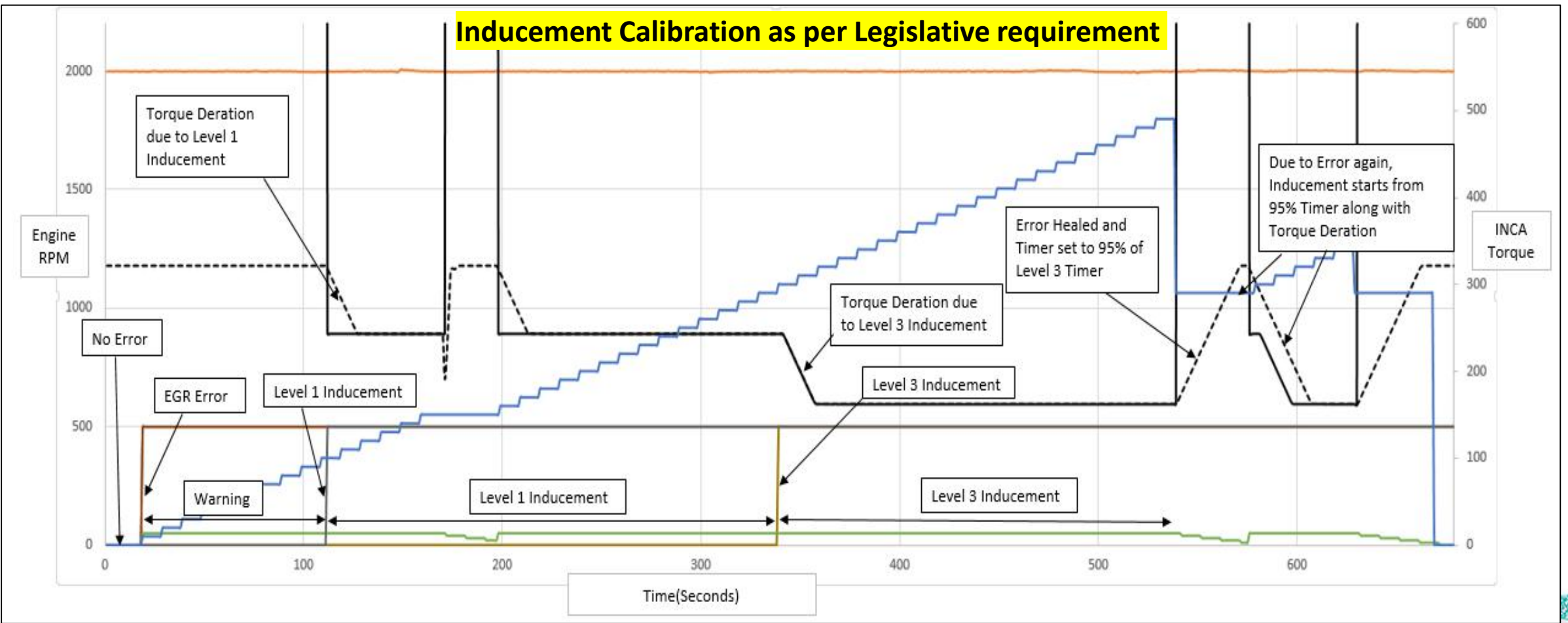




Demystifying TREM V

Engine Calibration : Performance and Functional development

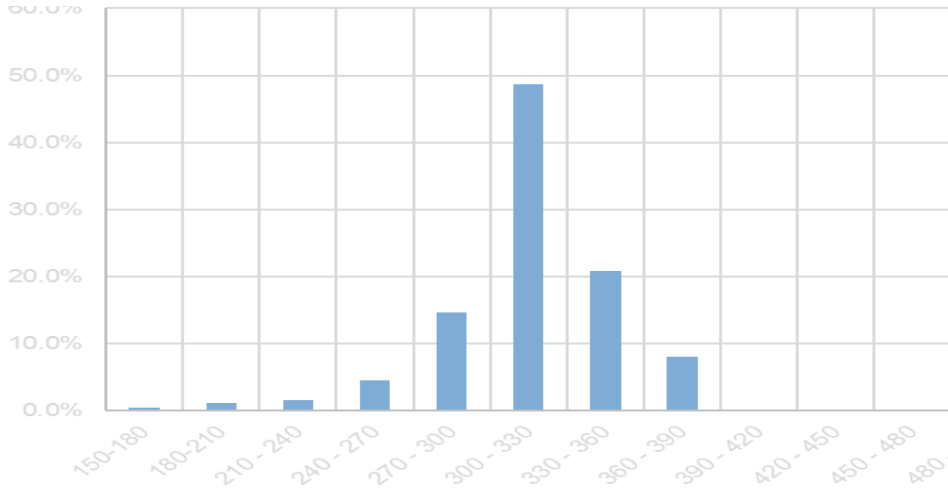
Inducement Calibration as per Legislative requirement



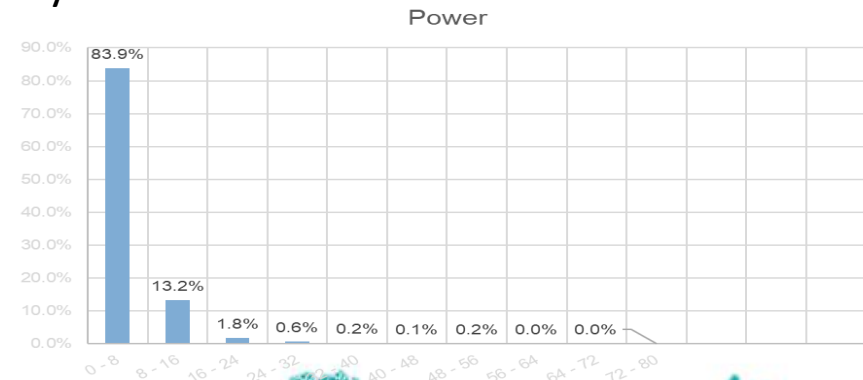
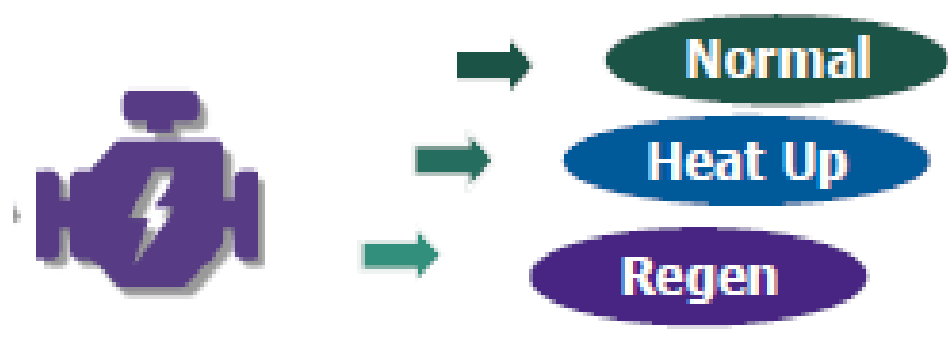
Demystifying TREM V



EAT selection : Performance and Functional development

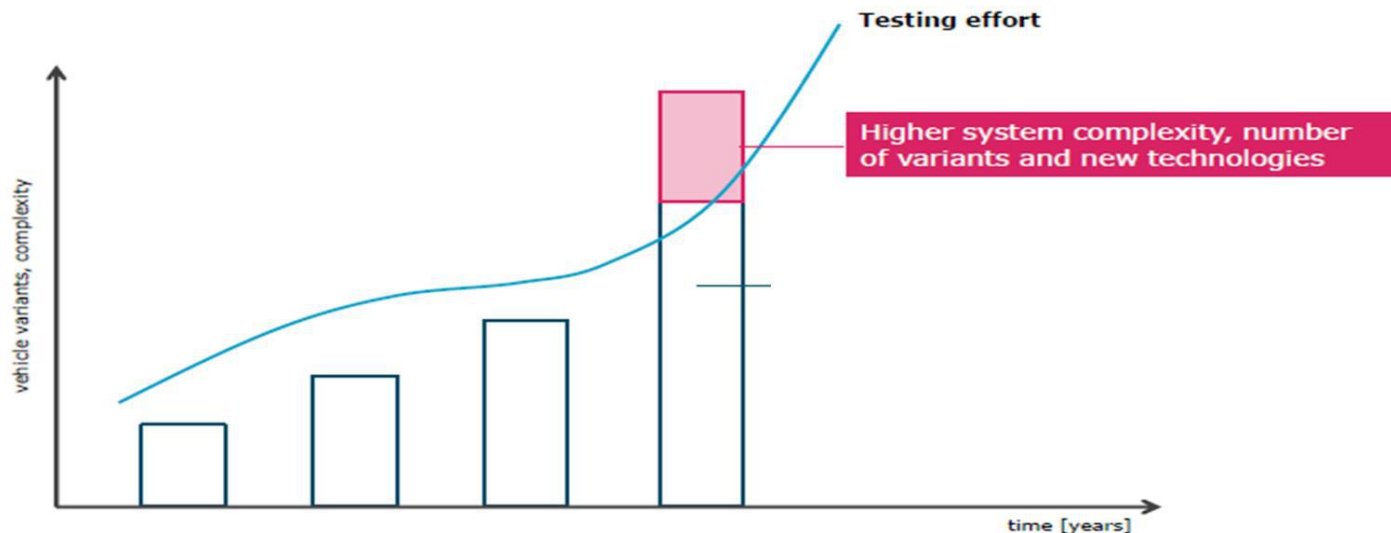


- Definition of coated or non-coated DPF and **Passive Regeneration** Performance establishment
e.g : Soot burn-off, Soot modelling in application duty cycle.
- Regeneration strategy definition
- Heat-up mode calibration as per Strategy
- Establishment of Auto, Manual and Service regeneration pre-condition and Regen efficiency



Demystifying TREM V

Testing : Complexity



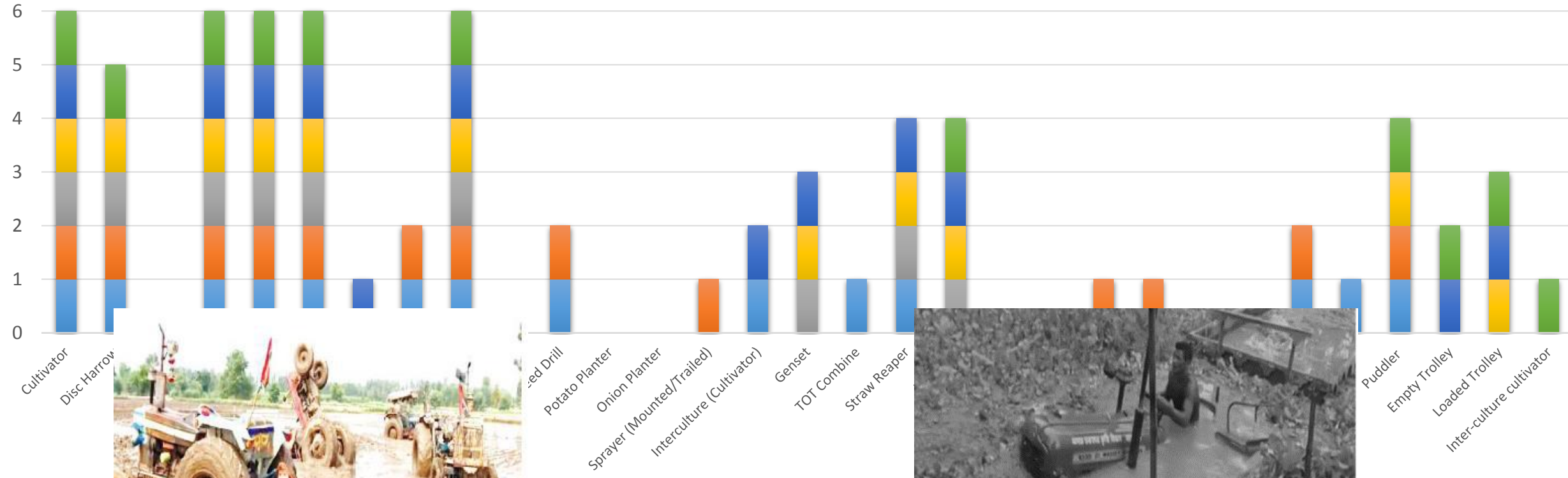
- Testing efforts application data generation
- Testing efforts for calibration verification
- Testing efforts for product Validation
- Testing efforts for variants validation





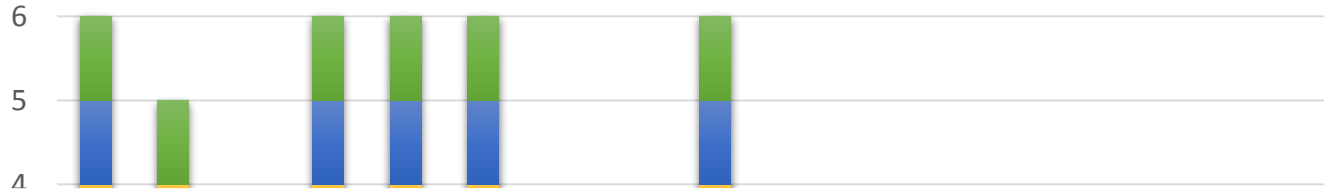
Demystifying TREM V

Application variety and Challenges



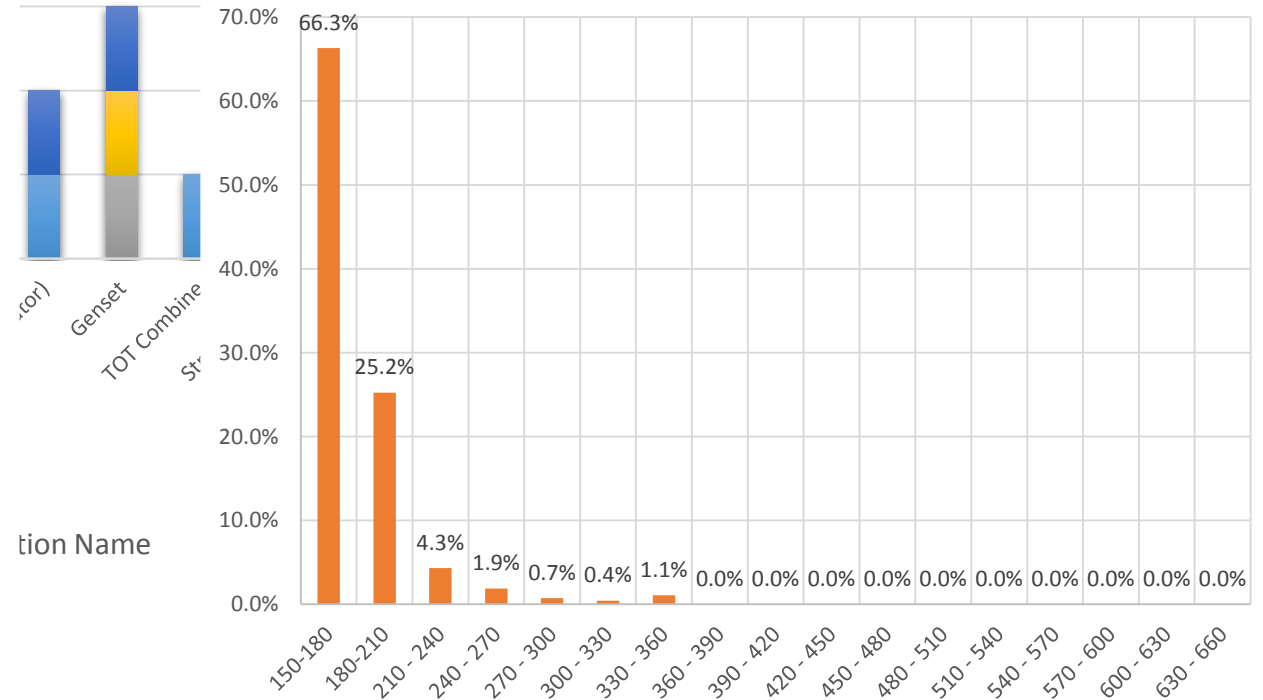
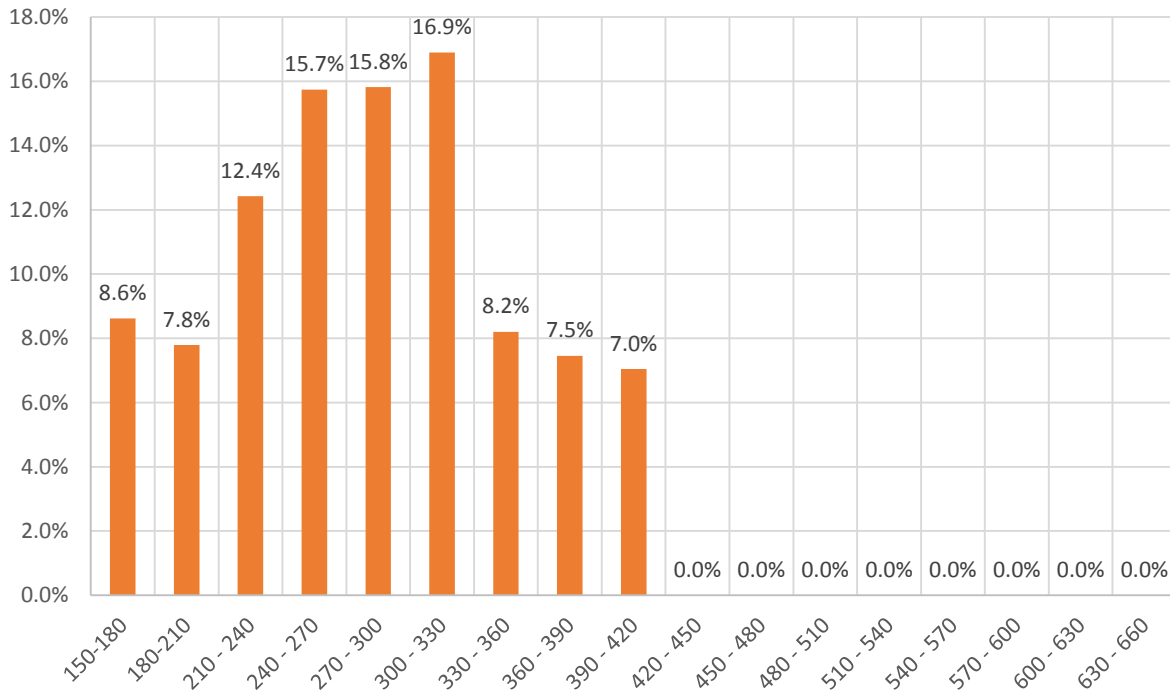
Demystifying TREM V

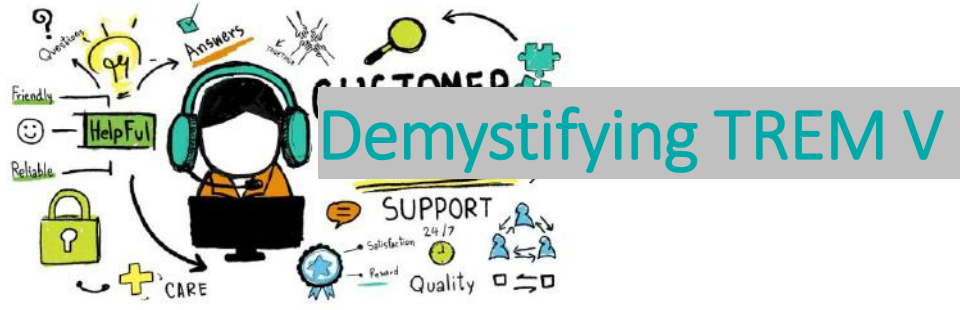
Application variety and Challenges



Temp in NRTC

Temp in one of Duty Cycle





Demystifying TREM V





Demystifying TREM V

Manufacturing : Key Changes



- Production line upgrade to handle the assembly CRDI, sensors and actuator and DOC+DPF
- Optimization of assembly process to meet assembly time
- Production team skill-set upgrade to handle sophisticated engine parts
- Production line upgrade for ECU and Wiring harness challenges
- PDI checkpoint establishment





Demystifying TREM V

Field Service : Key Changes

In current scenario Mechanic skills & Experience is the only way to understand the problem and rectify.

After Trem V, DSM understanding setup along with mechanical skills & Experience will be mandatory to understand the problem and rectify.



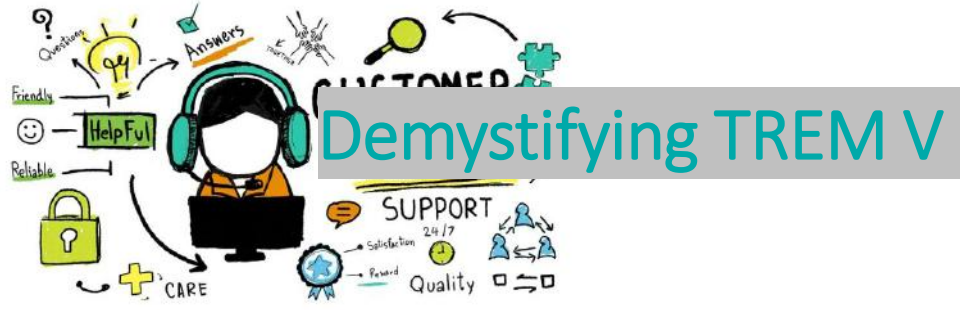
Demystifying TREM V



Overview of Diagnostic system and Advantages



Process at Workshop >>>>	Find root cause	Repair fault	Check quality of repair
Benefits to Technician	Guided troubleshooting helps to find root cause	Step by step repair procedure to help technician and adherence to OE repair instructions	
Benefit to Organisation Aftersales	Lower warranty costs as root cause would avoid trial and error methods with respect to component replacement	Adherence to OE repair instructions	No repeat visits of vehicle/to vehicle for same issue
Benefits to Development team	Feedback to team with activities carried out by technician and reference CAN log, in case support requested	Data from field helps to build Data Analytics use cases to improve vehicle performance, keep warranty costs down and improve efficiency → Warranty forecast → Global Diagnostics dashboard → Identify most likely repair → Field quality monitoring	

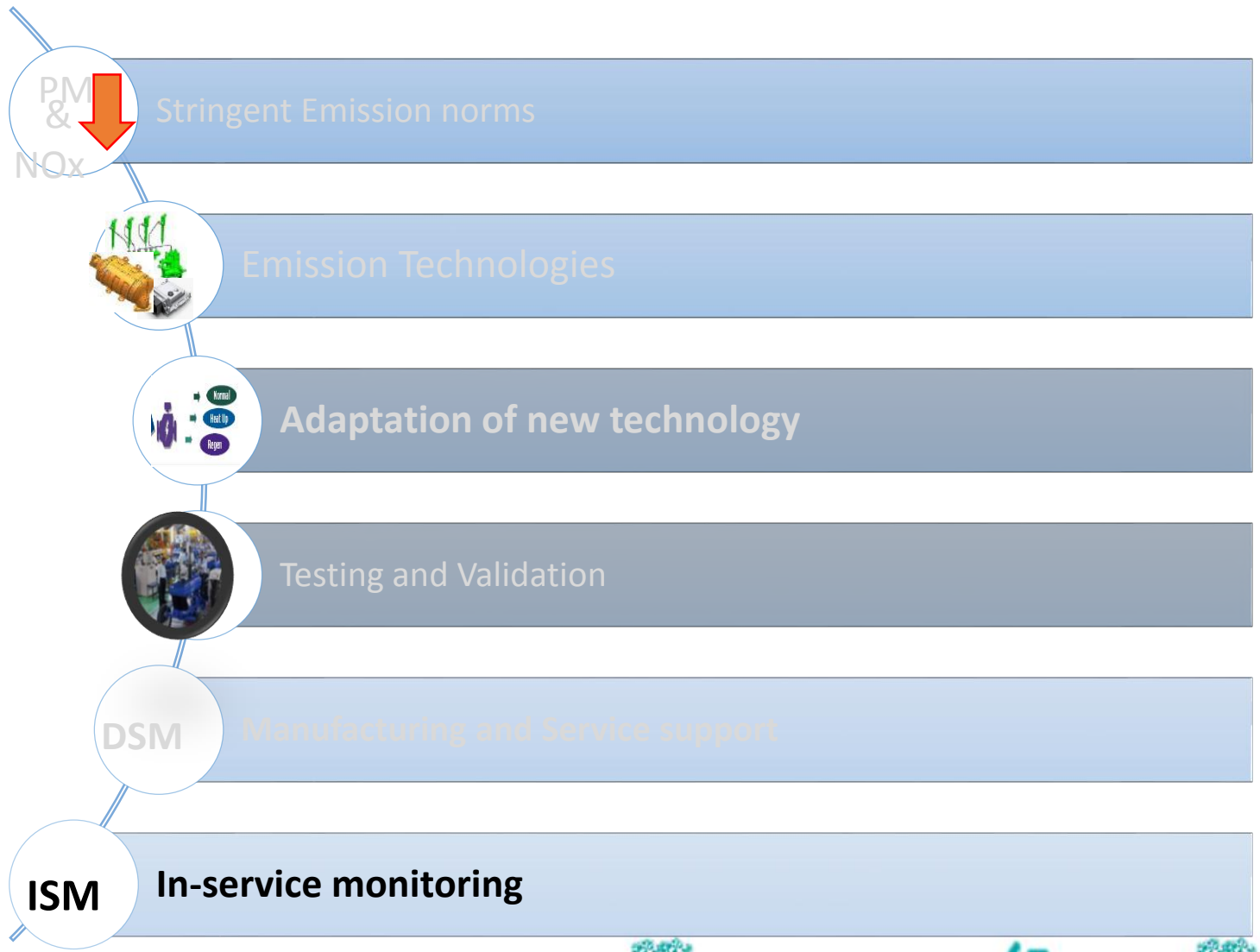


Demystifying TREM V

PEMS on Tractor & RDE



PEMS installed on a lawn mower (Source : Kubota)





Demystifying TREM V

The diagram features a central figure of a customer support agent wearing a headset and working at a computer. Surrounding this figure are various icons and text elements: a question mark, a lightbulb, a magnifying glass, a puzzle piece, a speech bubble, a padlock, a plus sign, a globe, and a ribbon. Text labels include 'Questions', 'Answers', 'Helpful', 'Friendly', 'Reliable', 'CARE', 'SUPPORT', '24/7', 'Satisfaction', 'Reward', and 'Quality'. The word 'CUSTOMER' is partially visible at the top.

In-service monitoring

Bharat Stage (CEV/TREM) IV and V emission regulations notified vide GSR 201 (E) dt. 5 th March 2018. As per GSR, In-service conformity check will be mandatory for all Bharat Stage V engines from April 2026

Actual duty cycles will differ from NRSC and NRTC test cycles. So, similar to automotive applications, monitoring of real driving emissions (RDE) by using Portable Emission Measurement systems (PEMS) will be required





Demystifying TREM V

In-service monitoring



PEMS installed on a car (Source : Bosch)



PEMS installed on Compact Tractor (Source : Kubota)





Demystifying TREM V

In-service monitoring

Challenges:

- 1: Special setup for PEMS installation.
- 2: Identification of worst duty cycle from variety of applications available in India
- 3: Managing valid test with specified work done without any interruption (continuous operation)
- 4: Definition of RDE acceptance limits
- 5: ISM test cost

System Configuration



PEMS Service Providers in India

- 1: AVL
- 2: HORIBA



Summary

We as EKL Engine R&D Team have developed all the capability inhouse to meet TREMV challenges. EKL is equipped with state of the art engine testing facility, design facility and simulation facility inhouse.

EKL in past have developed BT-3A, BT-4, EU Stage V engines and geared up for developing TREMV engines now. EKL R&D inhouse capability, manufacturing setup are improving day by day after our association with Kubota Corporation.

As Kubota is No-1 industrial engine manufacturer in up to 100HP power segment having >100 yrs of Diesel engine design and development experience. Annual production of Kubota Engines were ~ 1.1 million last year and now after EKL joining to Kubota Corporation all the technology, learning and experience transfer will be applicable for EKL Engine R&D.

This is opportunity for all the suppliers, technology partners, service provider and Engineers to develop reliable, cost effective TREM V engines for Indian tractor as well as off road Market.

For Tractor Industry : we are going to experience Transformational Change in Technology as well as culture and would be an experience in itself.



THANK YOU |

