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An insight into effective emissions reduction on NRMM

ECT 2017
2nd November 2017
New Delhi, India

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Vice President (R&D)
TAFE Motors & Tractors Limited

TRACTORS AND FARM EQUIPMENTS LIMITED

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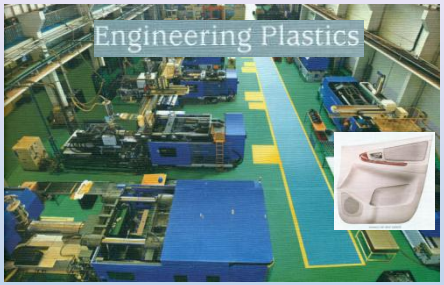
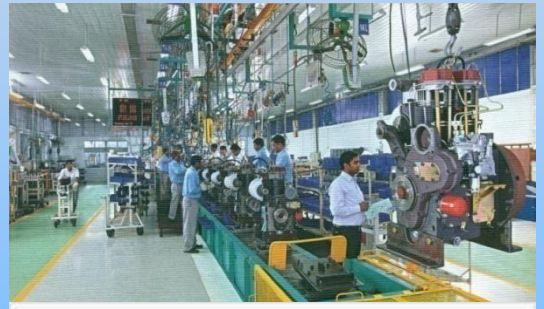
TAFE Motors & Tractors Limited

- Eicher Engines is a unit of TAFE Motors and Tractors Limited (a wholly owned subsidiary of TAFE), & part of Amalgamations Group, which is one of India's largest light engineering conglomerates





- Alwar plant produces a wide range of Air cooled and Water cooled engines in the brand names of EICHER ENGINES and TMTL ENGINES

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An insight into effective emissions reduction on NRMM

Contents

- The new Norms
- Impact on Industry / Products
- Overview on Agricultural Scenario & Indian NRMM Industry
- On Road Vs. Off Road vehicle emission contribution
- Global Alignment & Bench Marks
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Draft Notification – New Emission Norms for NRMM

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Bharat Stage (CEV/TREM) -IV
Applicable emission limit for Non Road Steady Cycle (NRSC) and Non Road Transient Cycle (NRTC)test cycle

	Applicable with effect from	CO	HC	NOx	PM	Test Cycle*
Category, kW		g/ kWh				
37 ≤P < 56	1st October, 2020	5.0	4.7 (HC+NOx)		0.025	NRSC & NRTC
56 ≤P < 130		5.0	0.19	0.4	0.025	
130≤P < 560		3.5	0.19	0.4	0.025	

*Test cycle as described in AIS: 137and as amended from time to time.

Bharat Stage (CEV/TREM)- V
Applicable emission limit for Non Road Steady Cycle (NRSC) and Non Road Transient Cycle (NRTC)test cycle

	Applicable with effect from	CO	HC	NOx	PM	PN	Test cycle
Category, kW		g/ kWh				#/kWh	
P < 8	1st October, 2023	8.0	7.5 (HC+NOx)		0.4	----	NRSC
8 ≤P < 19		6.6	7.5 (HC+NOx)		0.4	----	
19 ≤P < 37		5.0	4.7(HC+NOx)		0.015	1×10^{12}	NRSC and NRTC
37 ≤P < 56		5.0	4.7 (HC+NOx)		0.015	1×10^{12}	
56 ≤P < 130		5.0	0.19	0.4	0.015	1×10^{12}	
130 ≤P < 560		3.5	0.19	0.4	0.015	1×10^{12}	
P > 560		3.5	0.19	3.5	0.045	----	NRSC

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Impact on Industry / Products – Y 2020

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Year 2020 – New norms for power range >50 HP

- The predominant Power sector of <50HP Tractor Industry not affected
- Further Growth of 40-50HP segment due to heavy cost increase of >50HP engine technology (Shift from the power range of >37kW with likely reduction in rated speed)
- A few products with cost effective Common Rail FIE + cEGR + DOC would emerge for >37kW

- CEV power range 37 to 56kW will grow adopting following changes (Shift from >56kW with likely reduction in rated speed due to heavy cost impact)
  - Common Rail Fuel Injection System for NRTC
  - DOC introduction for PM reduction
  - Some of the engines may undergo downsizing with TCI + cEGR
- CEV power range >56kW will adopt CRS FIE & SCR in addition to DOC

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Impact on Industry / Products – Y 2023

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New norms for whole Power Range from Year 2023

- The predominant sector of Tractor Power range 25 to 75HP will adopt
  - 1600bar Injection Pr. Common Rail FIE
  - DOC + DPF

(50 to 75HP sector will grow fast as the cost difference will get narrowed)

- Tractors with >75HP Power range will adopt cEGR + DPF + SCR

- CEV product range 50 to 75HP will adopt DPF & >75HP will adopt SCR
  - Scope for electric hybrid systems

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Agricultural Market Scenario

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Source: FICCI-YES Bank-2009

Developing Low Cost, Light Weight Multi-purpose Farm Equipments

About 85% farmers are having less than 2 hectares cultivated land and their livelihoods depend on agriculture. Thus, it is necessary to focus on these small farmers by introducing & developing low cost, light weight, multi –purpose farm equipments.

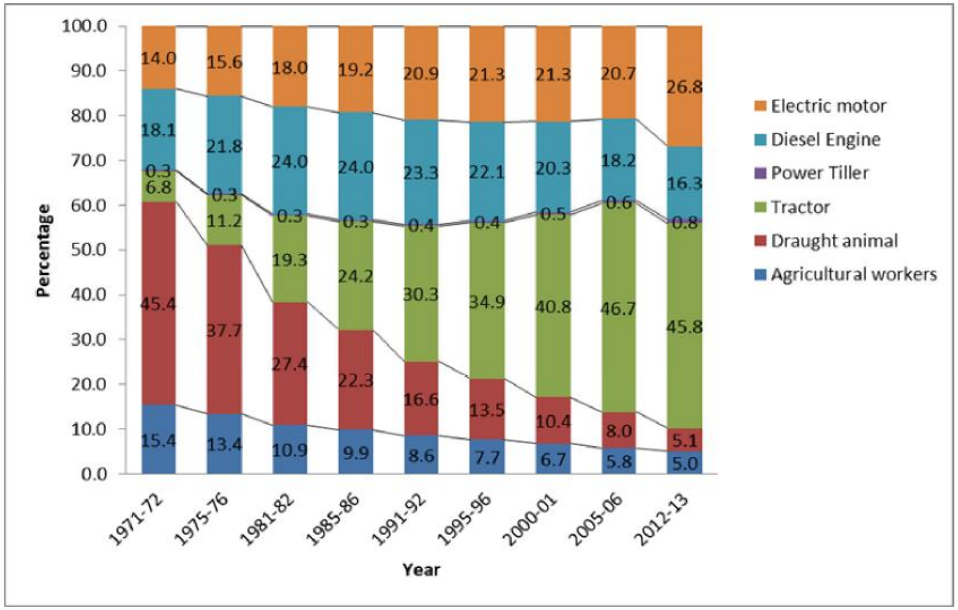

Fig. 1 Trend in use of power sources in Indian agriculture

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Indian Tractor Industry profile

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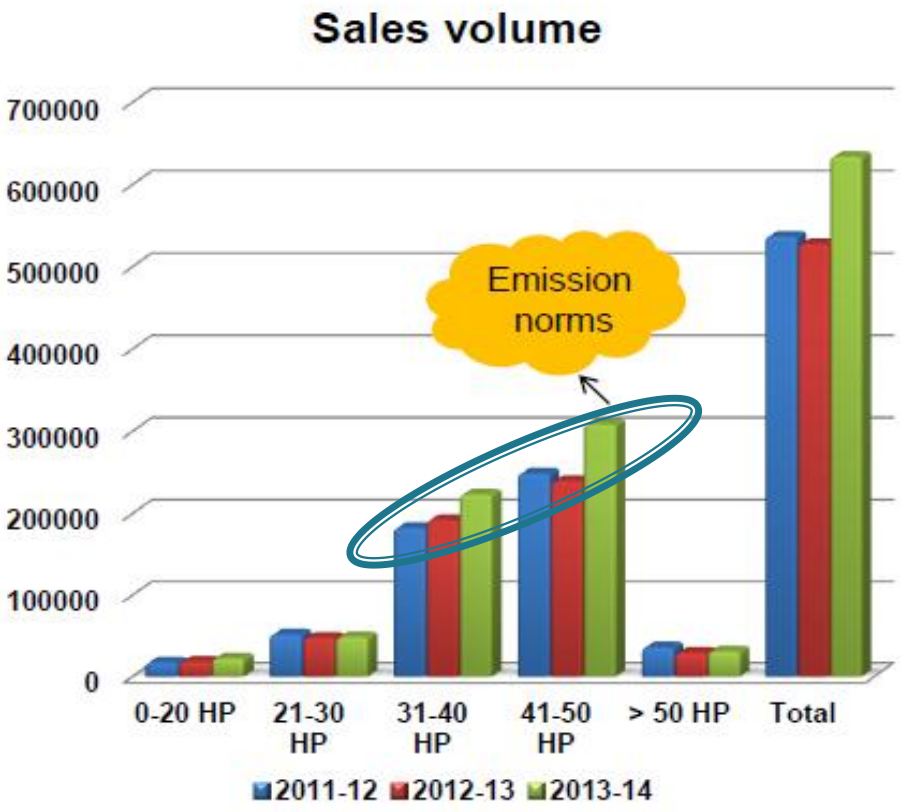
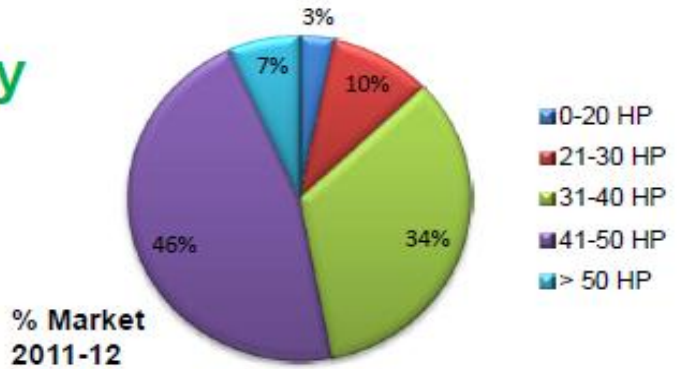
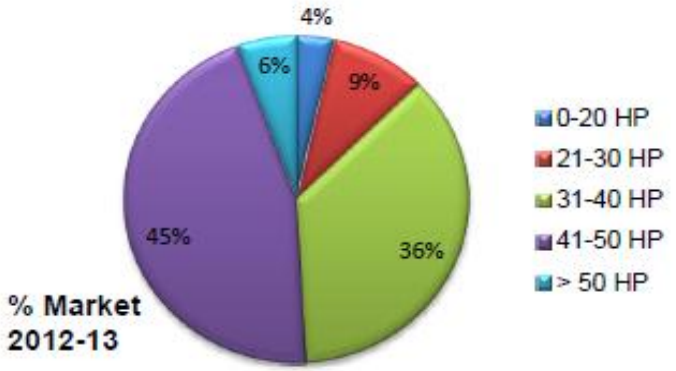
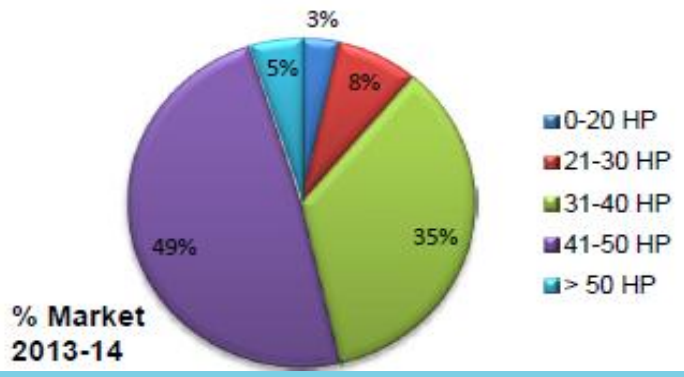
Brief overview - Agri. Machinery



- Power Range is limited to 75HP
- Growth rate in 40-50HP range is high
- Low HP range 21-30 HP is shrinking







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On Road Vs Off Road (NRMM) – Emission contribution

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Special thanks to

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

As majority of the data referred on statistical analysis & projections here are from their working papers & research findings published recently such as

"Tim Dallmann and Zhenying Shao http://www.theicct.org/non-road-emissions-inventory-india",

Tim Dallmann, Aparna Menon, Technology pathways for diesel engines used in non-road vehicles and equipment (ICCT: Washington DC, 2016).

http://www.theicct.org/technology-pathways-for-non-road-diesel-engines etc.

On Road Vs Off Road (NRMM) – Emission contribution

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Particulate matter (PM) and nitrogen oxides (NOx) emissions between 2000 and 2015 from agricultural tractors are estimated to have increased by 80% and 150%, respectively.

For construction equipment, PM and NOx emissions are estimated to have increased by 450% and 410% over the same period.

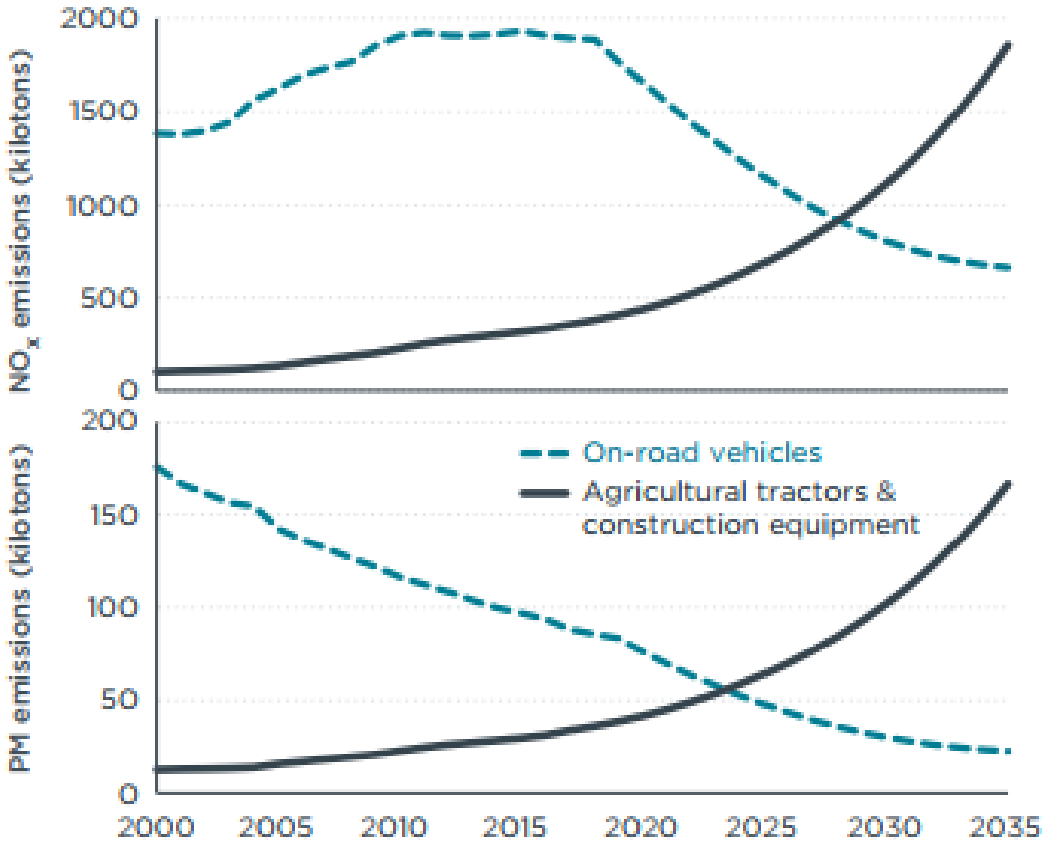

Figure 1. Historical trends and projections for emissions of NO_x and $PM_{2.5}$ from on-road vehicles and non-road equipment in India, 2000-2035.[4]

Source ICCT

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On Road Vs Off Road – Emission contribution

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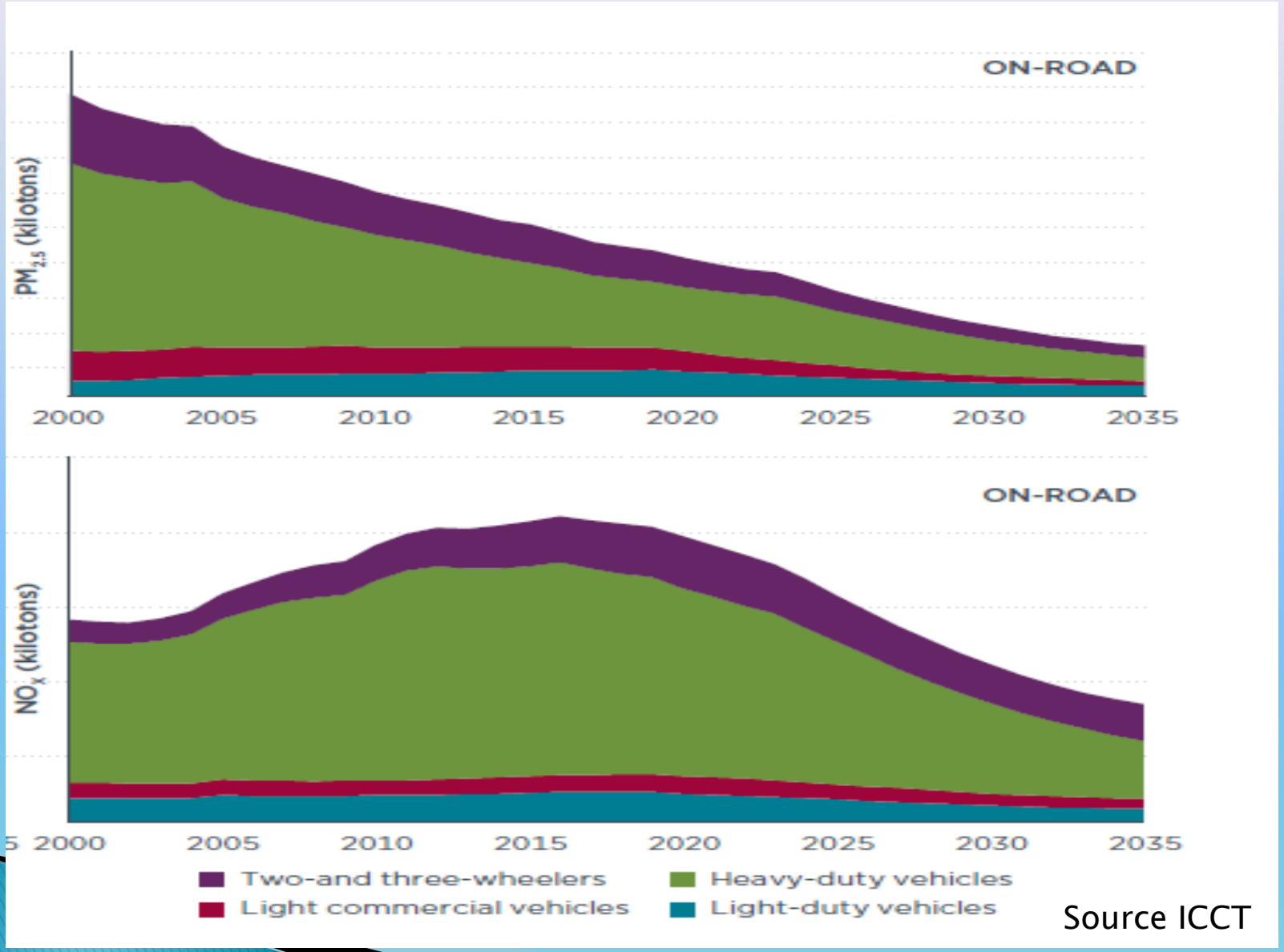

Source ICCT

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On Road Vs Off Road – Emission contribution

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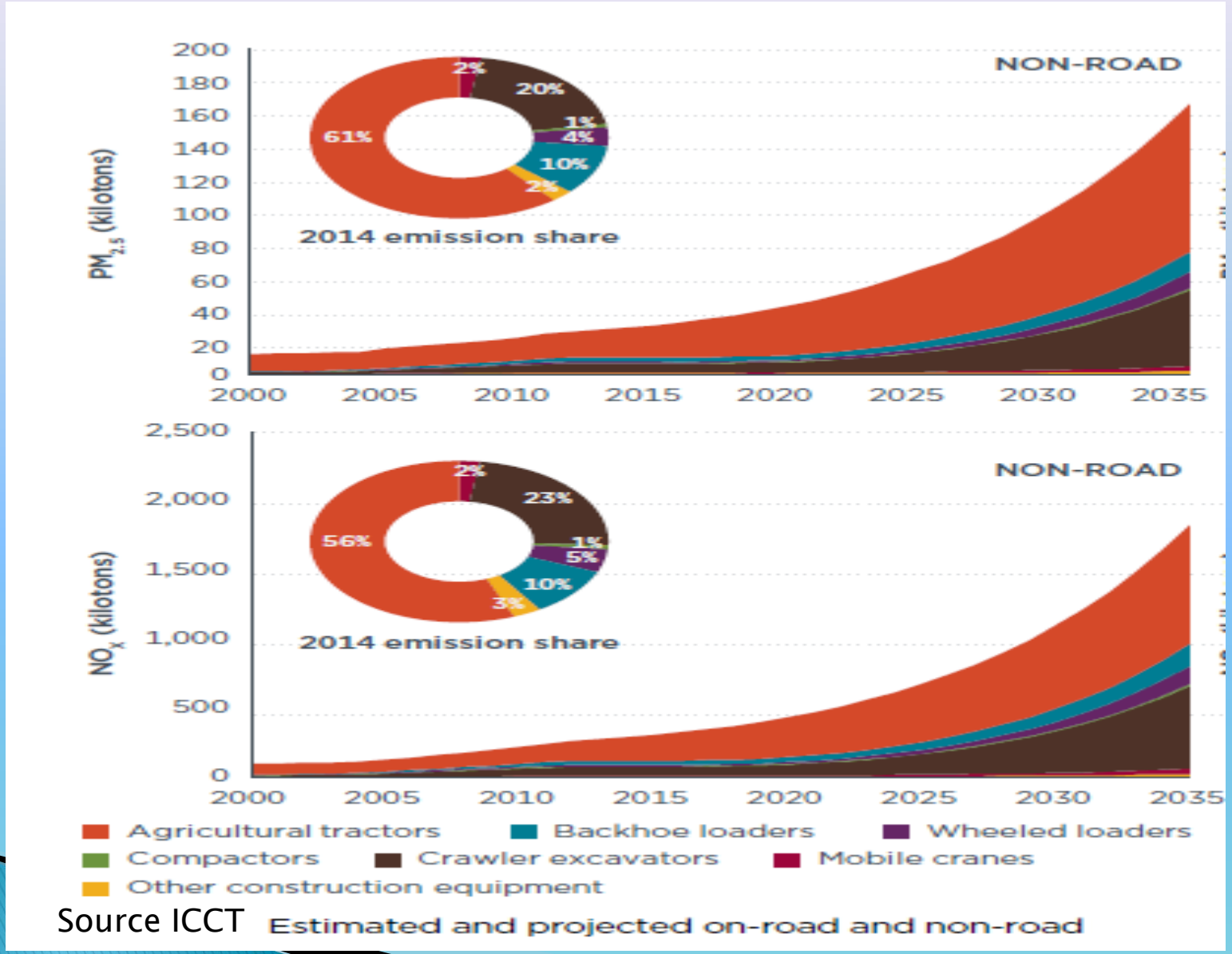

Source ICCT Estimated and projected on-road and non-road

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Environment Impact from Ag Tractors in field

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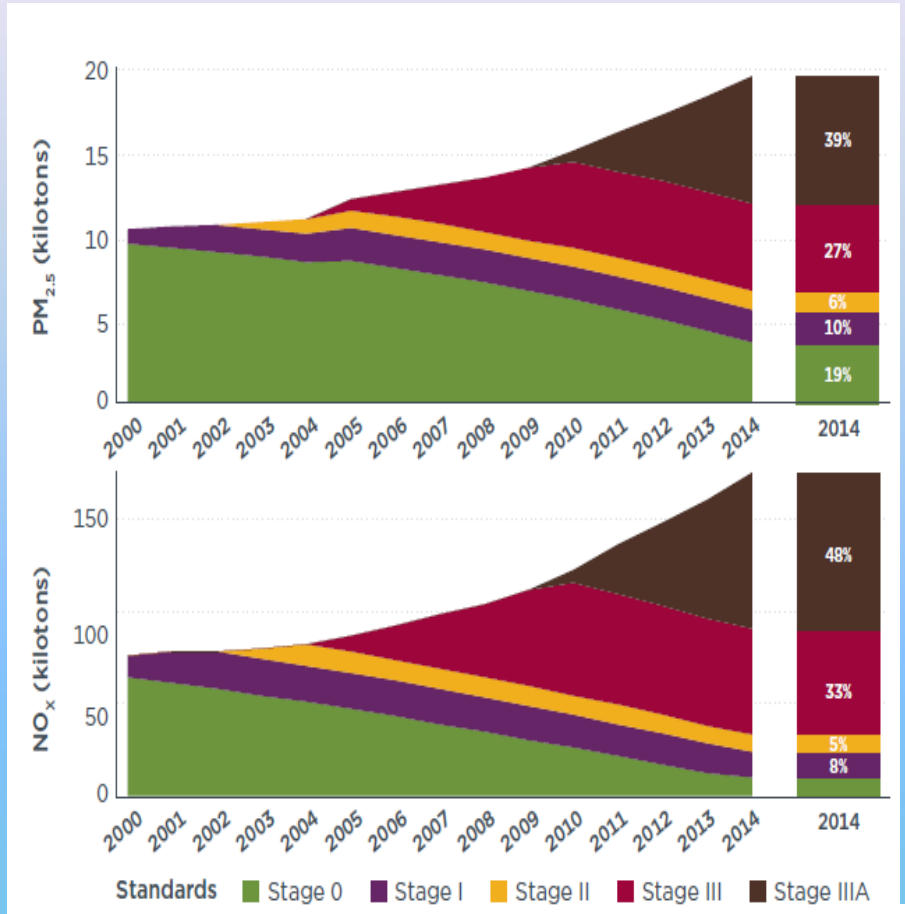
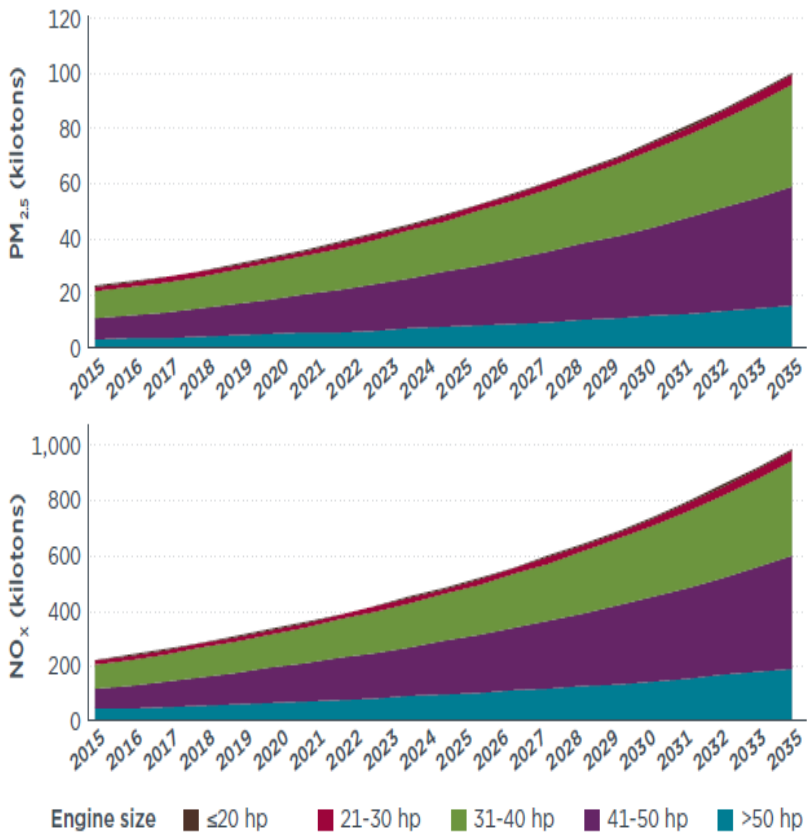


Source ICCT Estimated $PM_{2.5}$ and NO_x emissions for agricultural tractors, 2000–2014.



Source ICCT Projected $PM_{2.5}$ and NO_x emissions for agricultural tractors by engine size, 2015–2035.

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Environment Impact from CEV in Field

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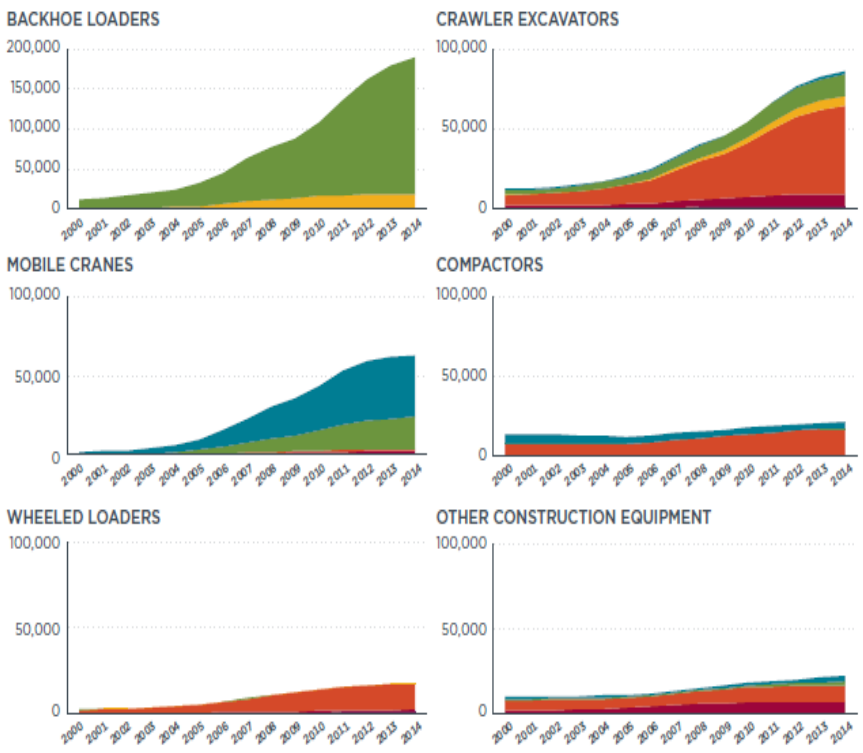
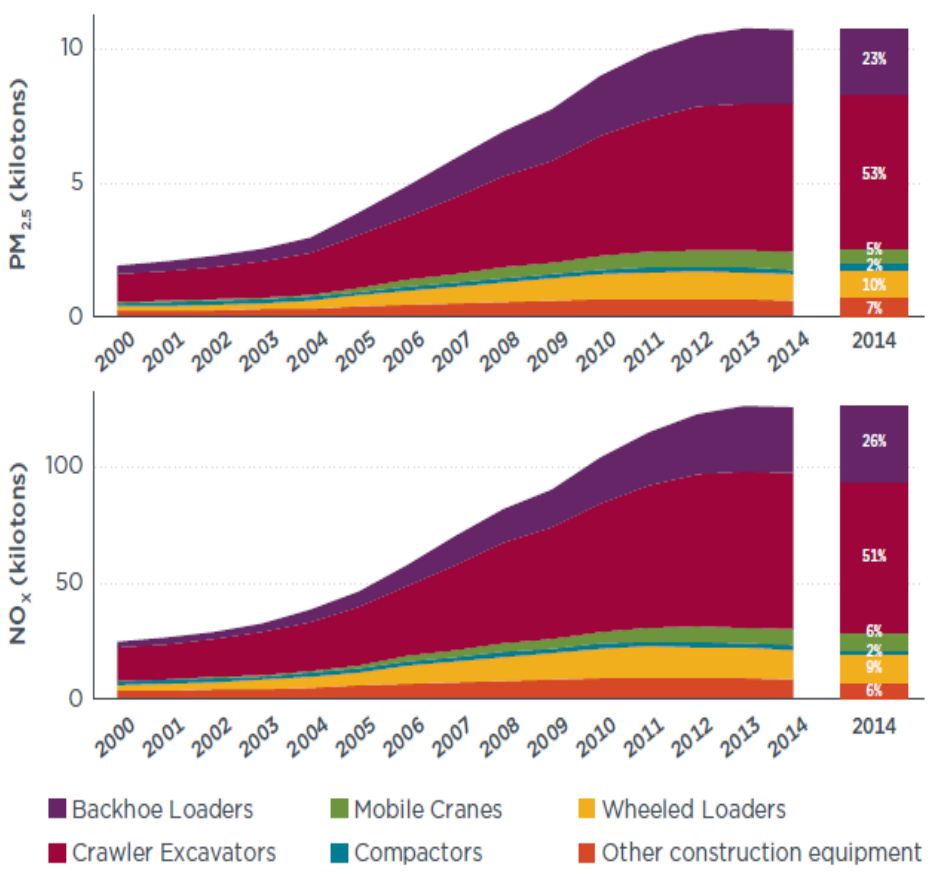


Source ICCT Estimated stock for major construction equipment by engine size, 2000–2014. Note that because of their high market share, backhoe loaders are show.. on a scale of 0–200,000, while other equipment is shown at a scale of 0–100,000.



Source ICCT Estimated $PM_{2.5}$ and NO_x emissions for construction equipment by equipment type, 2000–2014.

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On Road Vs Off Road – Emission control challenges

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Engines for on Road	Engines for Off-Road
High Speed Engines	Medium –high Speed engines
Smaller engine swept Volume with less weight with AVMs (TC& TCI)	Bigger Capacity Engines (NA) mounted directly on Chassis
Protected from dusty & climatic variations to a large extend	Exposed to severe dusty & climatic conditions & vibratory loads due to field conditions
Natural cooling of exhaust systems due to high air draft on the move	Less air velocity to the engine parts on move & near nil for stationary applications
Relatively defined duty cycle & mostly matched to one vehicle configuration	Varying duty cycle & multiple applications matched to various equipment
Less cost sensitive	Very cost sensitive – specifically the Agricultural tractors
High Volume production	Low volume production

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Global Alignment / Bench Marks

The History of NRMM Emissions

- In India, emissions of agricultural tractors, construction equipment & Stationary applications such as Gen-sets are regulated through separate standards.
- Current emission standards, Trem Stage IIIA and CEV Stage III, were fully implemented in 2011& Gen-set engine emission norms in 2014
- For engines with rated power between 19 and 560 kW, Trem IIIA and CEV III standards are equivalent and adopted from EU Stage IIIA/U.S. Tier 3
- Engines smaller than 19 kW are not included in the EU program and thus, U.S. Tier 2 emission limits were adopted in the CEV III standard. Trem IIIA standard for engines in this range differ slightly from Tier 2, with less CO limit and more HC + NOx limit.

After treatment technologies were not necessary to meet any of above norms

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Global Alignment / Bench Marks

EUROPEAN UNION

EURO STAGE III AND STAGE IV Dir 97/68/EC as amended by Dir 2004/26/EC and Dir 2006/105/EC and Dir 2010/26/EU (01Apr10)

Test cycle (see pages 96-99)

NRSC: variable speed engines: Stage III A (gaseous pollutants)

NRSC: variable speed engines: Stage III B and Stage IV (gaseous & particulate emissions): ISO 8178-4: [illegible] speed engines: ISO 8178-4 D2

NRTC: variable speed engines: Stage III B and Stage IV (gaseous & particulate emissions)

Category	Net Power (kW)	CO (g/kWh)	HC (g/kWh)	NOx (g/[illegible]	[illegible]kWh)	TA	NR
Stage III A [1]							
H	130 ≤ P < 560	3,5	NOx + HC[illegible]		0,2	30Jun05	31Dec05
I	75 ≤ P < 130	5,0	NO[illegible]		0,3	31Dec05	31Dec06
J	37 ≤ P < 75	5,0	[illegible]		0,4	31Dec06	31Dec07
K	19 ≤ P < 37	5,5	[illegible]		0,6	31Dec05	31Dec06
Stage III B							
L	130 ≤ P < 560	3,5	[illegible]	2,0	0,025	31Dec09	31Dec10
M	75 ≤ P < 130	5,0	[illegible]	3,3	0,025	31Dec10	31Dec11
N	56 ≤ P < 75	5,[illegible]	[illegible],19	3,3	0,025	31Dec10	31Dec11
P	37 ≤ P < 56	[illegible]	NOx + HC: 4,7		0,025	31Dec11	31Dec12
Stage IV							
Q	130 ≤ P < 560	[illegible]	0,19	0,4	0,025	31Dec12	31Dec13
R	56 ≤ P < [illegible]	[illegible]	0,19	0,4	0,025	30Sep13	30Sep14

[1] Other than constant speed [illegible]

So far Tractor followed the EU Norms with a Time lag
Now, one stage is skipped i.e. EURO 3B

NRMM - EMISSIONS STANDARDS

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Global Alignment / Bench Marks

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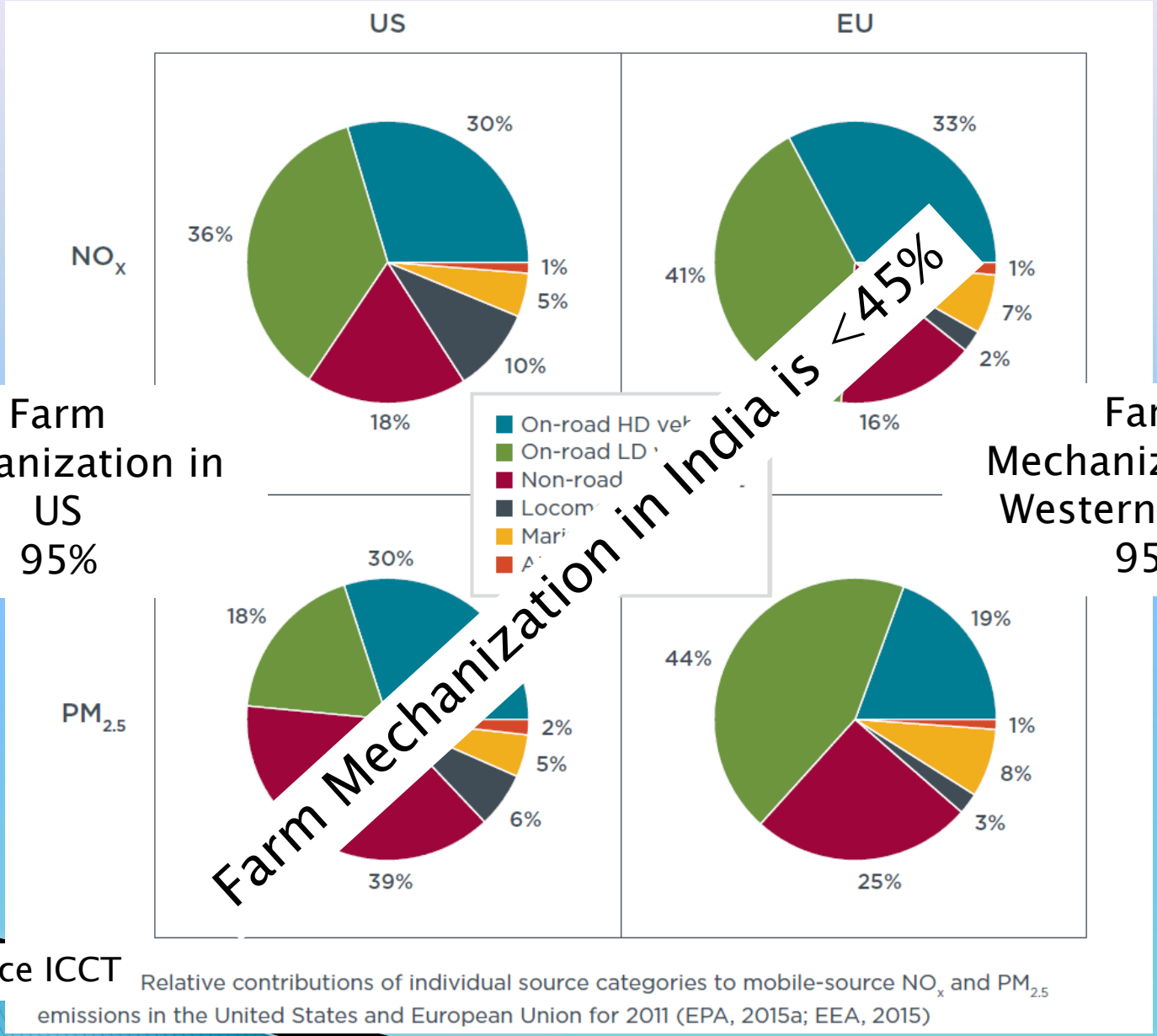

Farm Mechanization in US 95%

Farm Mechanization in Western Europe 95%

Farm Mechanization in India is <45%

Source ICCT

Relative contributions of individual source categories to mobile-source NO_x and $PM_{2.5}$ emissions in the United States and European Union for 2011 (EPA, 2015a; EEA, 2015)

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Global Alignment / Bench Marks

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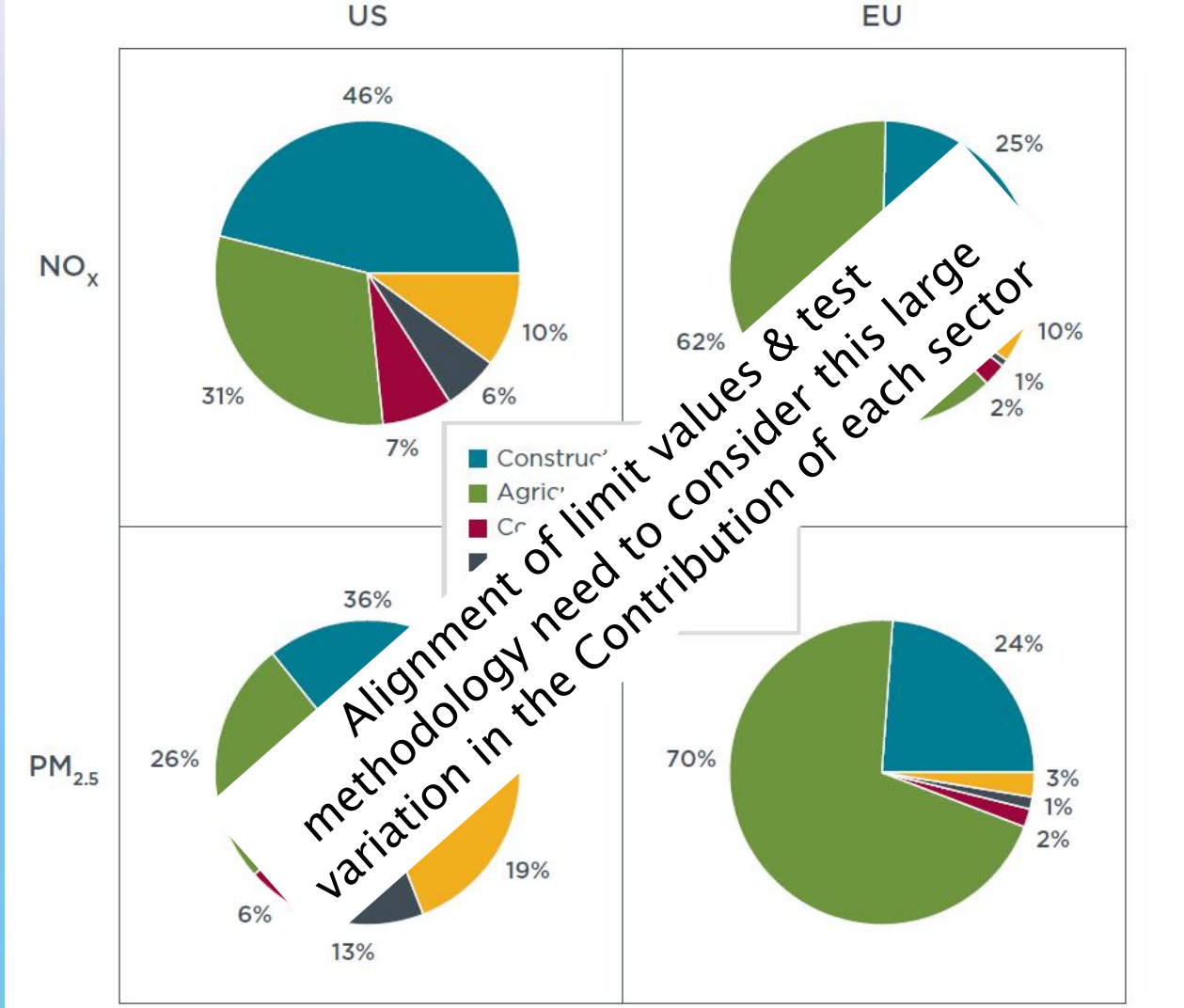

Source ICCT

Relative contributions to non-road vehicle and equipment NO_x and $PM_{2.5}$ emissions in the United States and European Union by end-use sector for 2011 (EPA, 2015a; EEA, 2015)

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Global Alignment / Bench Marks

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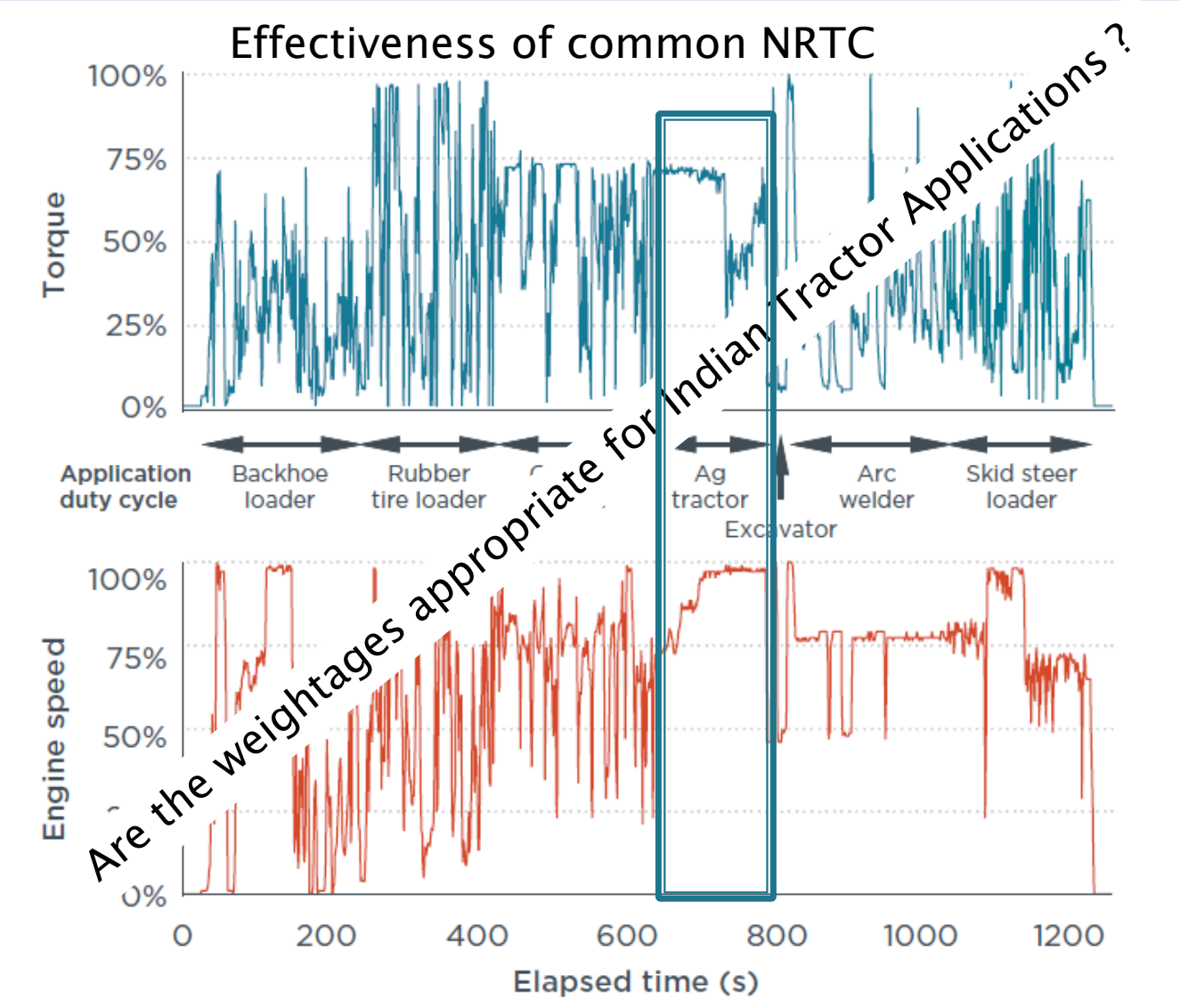

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Global Alignment / Bench Marks

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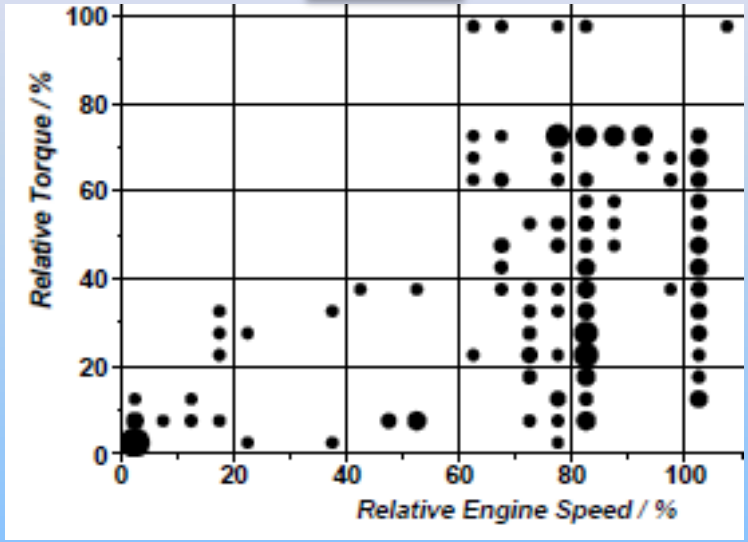
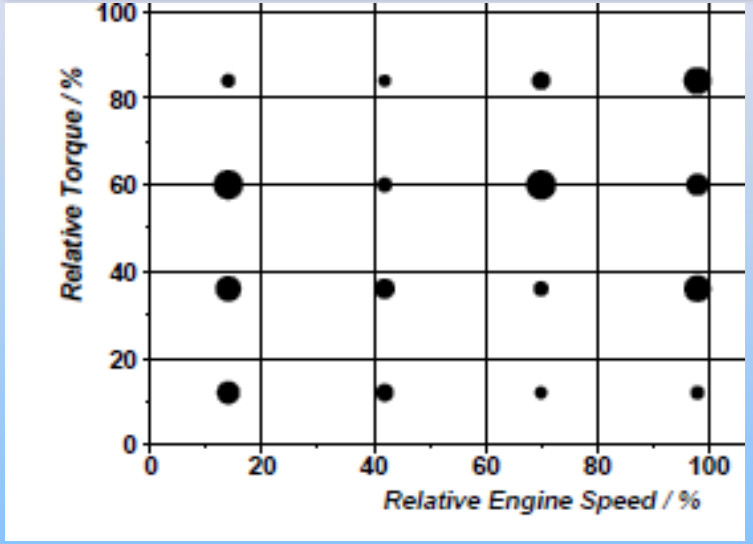
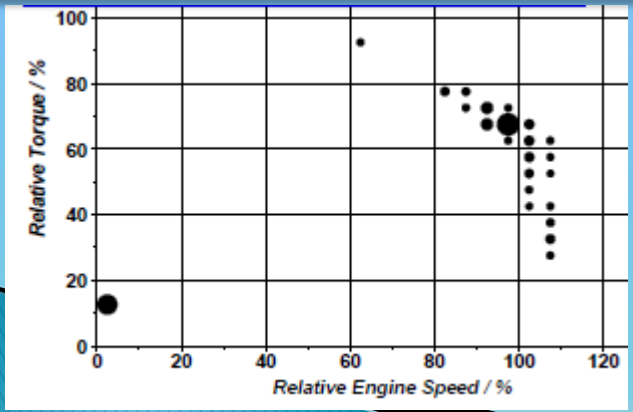
NRTC



Agri. Tractors Various Operations



Construction Equipment Vehicle



Diverse Applications of NRMM in India & distinctively different power range for applications question the effectiveness of selected common NRTC

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Technologies demonstrated already abroad

Tier 4i/Stage IIIB and Tier 4f/Stage IV emission control technology packages for major non-road engine manufacturers

Manufacturer	Tier 4i/Stage IIIB	Tier 4f/Stage IV
Agco	37-75 kW: cEGR+DOC > 75 kW: DOC+SCR	37-56 kW: cEGR+DOC 56-75 kW: DOC+SCR >75 kW: cEGR+DOC+SCR
Caterpillar	45-560 kW: cEGR+DOC+DPF >560 kW: cEGR+DOC	37-56 kW: DOC+DPF 56-75 kW: cEGR+DOC+SCR 90-560 kW: cEGR+DOC+DPF+SCR >560 kW: cEGR+DOC
Cummins	56 – 130 kW: cEGR+DOC 130-560 kW: cEGR+DOC+DPF >560kW: cEGR+DOC	19-56 kW: cEGR+DOC 56-130 kW: cEGR+SCR/cEGR+DOC+SCR 130-560 kW: cEGR+DOC+SCR/ cEGR+DOC+DPF+SCR/DOC+DPF+SCR
Deutz	19-56 kW: cEGR 56-520 kW: cEGR+DOC+DPF 56-520 kW: Ag engines = SCR only	19-56 kW: cEGR+DOC 56-520 kW: cEGR+DOC+DPF+SCR
FPT Industrial	75-560 kW: SCR	75-560 kW: DOC+SCR
JCB	56-130 kW: cEGR	37-56 kW: cEGR 56-560 kW: SCR +cEGR
John Deere	<56 kW: No aftertreatment technology 56-130 kW: cEGR+DOC+DPF 130-560 kW: cEGR+DOC+DPF	19-56 kW: DOC+DPF 56-130 kW: cEGR+DOC+SCR 130-560 kW: cEGR+DOC+DPF+SCR
Kohler	No aftertreatment technology	19-56 kW: cEGR +DOC
Komatsu	56-130 kW: cEGR +DOC 130-560 kW: cEGR +DOC+DPF	37-56 kW: cEGR+DOC 56-130 kW :cEGR+DOC+SCR 130-560 kW:cEGR+DOC+DPF+SCR
Kubota	37-56 kW: cEGR 56-130 kW: cEGR+DOC+DPF	19-56 kW: cEGR +DOC/ cEGR+DOC+DPF 56-130 kW: cEGR+ DOC+DPF+SCR
Liebherr	75-560 kW:cEGR+DPF+DOC for earth-moving and material-handling machinery, SCR for mobile and crawler cranes	>130 kW: SCR
Mitsubishi	56-560 kW: cEGR+DOC+DPF	19-37 kW: cEGR+DOC/DOC+DPF 56-75 kW: cEGR+DOC+DPF
MTU	< 560kW: SCR > 560kW: cEGR	100-460 kW: cEGR+SCR 560-730 kW: cEGR+DOC
New Holland	> 80 kW: SCR ; < 80kW: EGR+DOC+DPF	75-560 kW: SCR +DOC 56-75 kW: cEGR +SCR 19-56 kW: iEGR+DOC+DPF
Perkins Engine Co.	56-560 kW: cEGR+DOC+DPF	< 56kW: DOC+DPF >56 kW: cEGR+DOC+DPF+SCR/cEGR+DOC+SCR
Scania	SCR	<560 kW: cEGR+DOC+SCR/cEGR+SCR >560 kW: SCR
Volvo Penta	130-560 kW: SCR	75-560 kW: cEGR + SCR
Yanmar	37-56 kW: cEGR 75-130kW: cEGR+DOC+DPF/cEGR+DPF	8-19kw: cEGR 19-56kW: cEGR+DOC+DPF/cEGR+DPF

Source ICCT

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Overview on Technology Requirements

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Technology requirements for meeting the TREM IV / BSIV CEV Norms

- For all Engines >37kW
  - ✓ Cooed EGR
  - ✓ 1600bar Common Rail Fuel Injection System – With life >8000hrs?
  - ✓ DOC

- For all Engine >56kW
  - ✓ SCR System for NOx Reduction
  - ✓ Particulate Trap subject to PM levels in NRTC & to meet PN from 2023

Availability of 10ppm sulphur fuel is critical for performance of Oxidation Catalysts and Open Particulate Traps

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Challenges – Pollution reduction from Indian Tractors

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Costs for the end-user (incremental operational costs)

- Additional costs for end-users are mostly the preventive maintenance cost of CR Fuel Injection Systems & after-treatment systems
- Based on the Indian population of Agricultural Tractors, the biggest emission reduction potential exists from the 19-37 kW power range The contributions of the other categories in which stringent norms are applied would be negligible
- 19-37 kW which need to adopt DPF technologies to meet TREM V from 2023 emission standards are expected to have around 3% higher fuel consumption with the existing configurations

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Challenges – Pollution reduction from Indian Tractors

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- **The entire segment might therefore be ultimately exposed to the risk of a serious loss of competitiveness, being of particular relevance in the light of the possible shift towards spark-ignited / Natural Gas engines or IDI engines with more impact on fuel economy**

- **Though significantly less pronounced, the 37-56 kW power range too has to cope with a considerable financial burden relative to its size and overall contribution**

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Challenges – Pollution reduction from Indian Tractors

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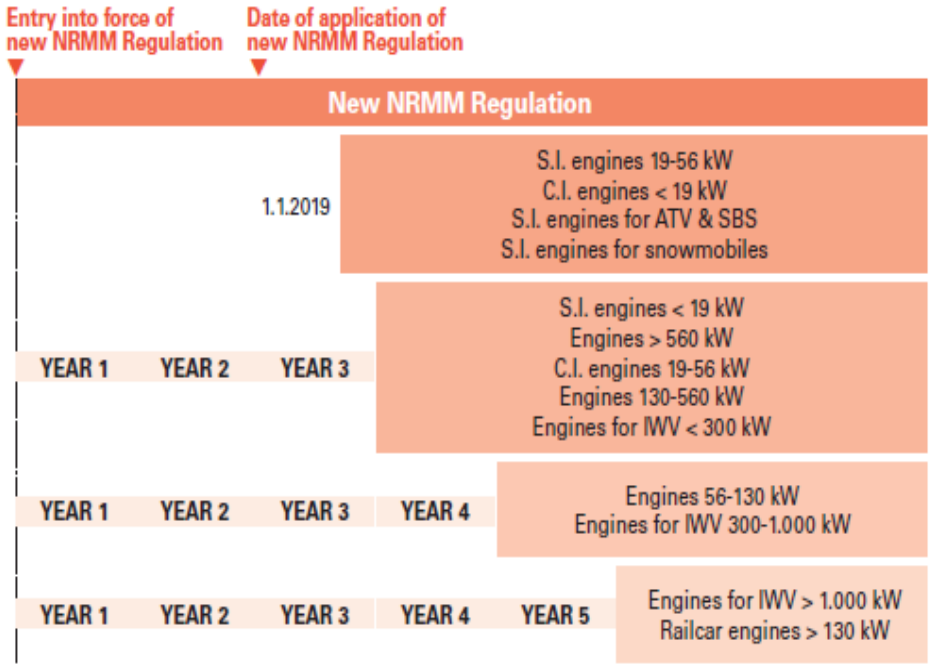
EUROPEAN UNION

In-Service Conformity ?

EU STAGE V NRMM EMISSIONS PROPOSAL - Timeplan for Stage V introduction



In-Service Conformity (ISC)

- The proposed Stage V regulation will include a requirement for engine OEMs to test engines installed in machines over their normal operating duty cycle. This will be done by the use of a PEMS.
- The current proposal requires only that the ISC emissions results are monitored and reported - currently there are no specified ISC emissions limits in the proposal
- The Commission "shall then review the situation and propose final prescriptive requirements for ISC". There is currently no timetable for these requirements
- The new Stage V legislation will be in the form an an EU Regulation, not a Directive (as it has been set up to Stage IV). This means that it applies to all member states immediately it is adopted, and does not require transposition into the National Law of each Member State (which is time-consuming).
- The < 19 kW and 19-56 kW Stage V limits are applied earlier than the 56-130 kW. This is because research (in Berlin) showed that a large contribution to poor air quality in cities was from smaller engines that are quite "dirty" under Stage IV Directive. Hence need to attend to this sector first.
- The new regulation will ban "replacement" engines being built and certified to the old emission levels. OEMs can only supply spares to rebuild a broken engine, but it must adopt the identity (serial nr) of the old engine. Industry concerned this will extend the downtime period of the machine following a major engine failure.

- A tough task to be undertaken in India as well – Initiatives on the On-road Vehicles are yet to reach any satisfactory level

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Challenges – Pollution reduction from Indian Tractors

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- **Old tractor population will be forced to continue in service as the decision to buy expensive new ones will be postponed by end user**
- **Switching over to a better cost effective power segment such as 50HP barrier (recent growth) would be a major threat if sharp differentiation exist**
- **Global alignment could be achieved at relatively high cost, as the necessary R&D activities have not been carried out else where**
- **Production & maintenance cost increase with oxidation catalysts / CR FI Systems to meet strict standards are exponential**
- **There is very less chance that the above costs are likely to be outweighed by the benefits that internationally harmonized limits would create for Indian manufacturers**

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Summary

- The contribution of NRMM engine exhaust emissions to over all environment pollution need to be captured systematically for upgrading the standards else the benefits from adopting global standards would be minimal & would be from selective categories such as CEVs till 2023
- NRTC for the whole NRMM power range prevailing in India may not be the right choice & need to be revalidated for duty cycles in field operations
- The most prevalent 19 to 37kW power range for Agricultural Tractors need innovative solutions for TREM V, to not affect dearly the growth in farm mechanization initiatives

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THANK YOU