



Off-Road Equipment Legislation and Technology Overview

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International Management & Technology Consultants



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Sources

- All data based on KGP and Off-Highway Research data and estimates
- Based on production database
- Copyright 2011 Knibb, Gormezano and Partners

Equipment Scope¹

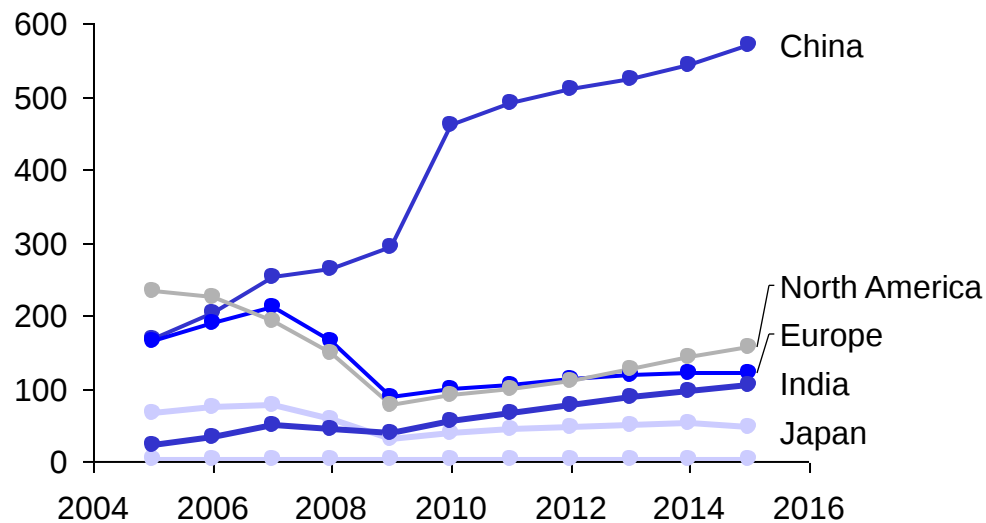
- Agricultural Tractors
- Articulated Dump Trucks
- Asphalt Finishers
- Backhoe Loaders
- Crawler Dozers
- Crawler Excavators
- Mini Excavators
- Motor Graders
- Motor Scrapers
- Rigid Dump Trucks
- RTLTs - Masted
- RTLTs - Telescopic
- Skid-Steer Loaders
- Wheeled Excavators
- Wheeled Loaders
- Combine Harvesters

¹ Mobile cranes, diesel forklift and compaction equipment to be added to Multi-Client

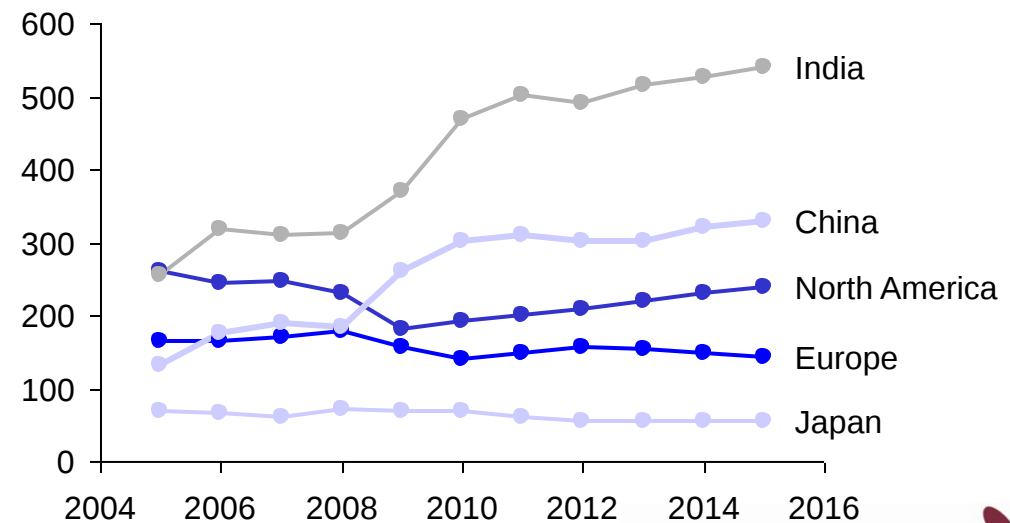
Global Markets

- Global Markets are rebounding after severe recession in 2009/2008
- China and India lead the way
- In value terms (Construction only) China also way ahead, but with a lower per unit price
- Ag Tractors volume accounts for over highway of NRMM market with India market leader by some way. China growth puts it into 2nd place, but still behind India
- China growth leading to global restructuring of production

Construction Equipment Sales (000s)



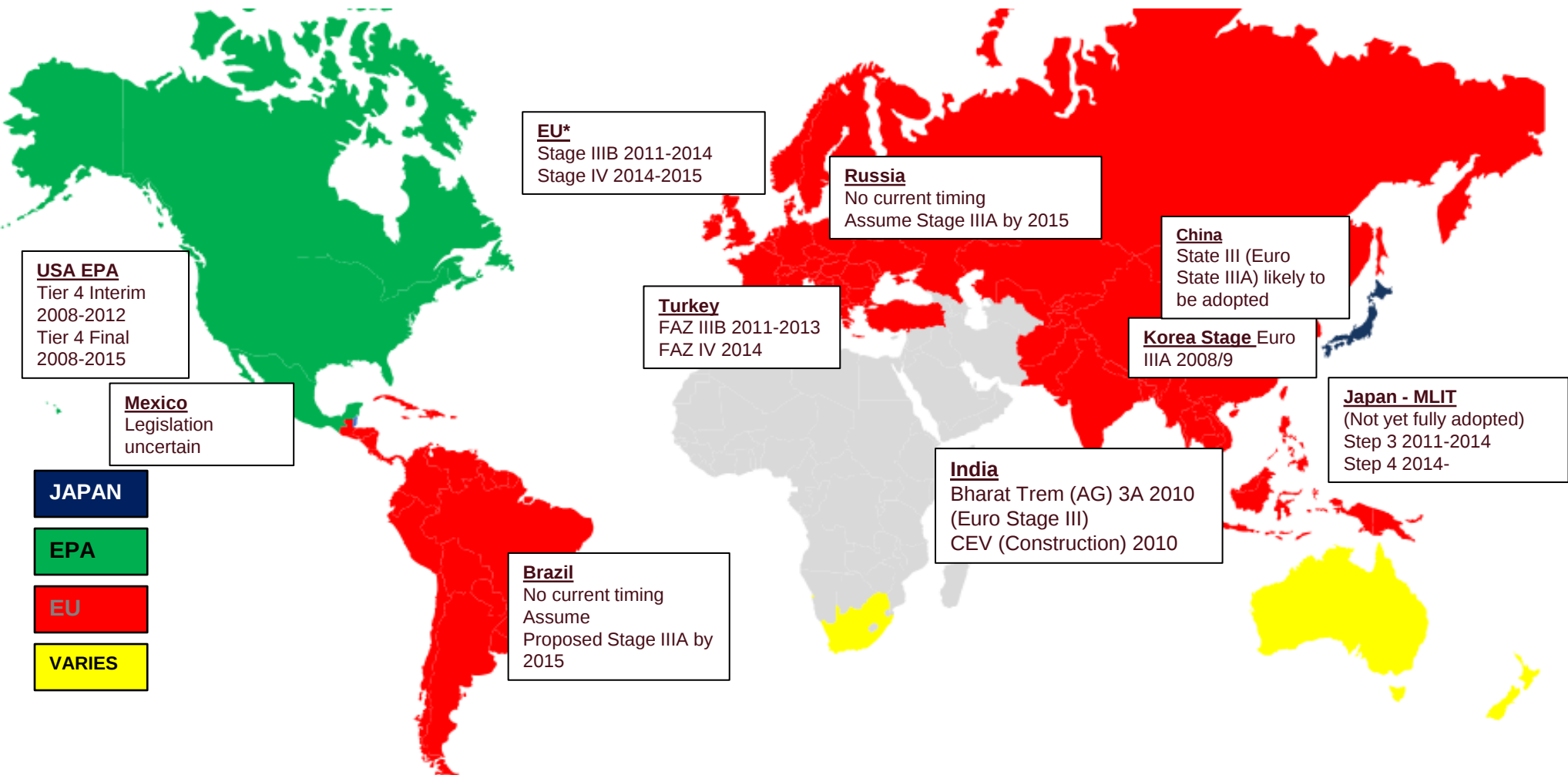
AG Tractor Sales (000s)



Key Drivers – Off-Road

Driver	Details	Impact	Key Technologies
Noxious Emissions	Tier 4 Interim, Final, Stage IIIB, IV, MLIT Step 4	2011-2015	Base Engine, Air Management, Aftertreatment, FIE, Optimisation
CO ₂ /Fuel Economy	US EPA Tier 5, Stage V?	2018-2020	Optimisation, Hybridisation, Waste Heat Recovery, Transmission, Hydraulics
OBD	OBD, PEMS	2015-2020	Additional Sensors, Feedback Control
Safety	EU legislation, ECE Regulations	2012-2015	Stability, Electro-Hydraulics
Comfort	Operator Driven	Ongoing	HVAC, Transmission Automation, Electro-Hydraulics
Globalisation	Market Driven	Ongoing	Production Consolidation. Modularity
Cost of Ownership	Operator Driven	Ongoing	Various
Productivity	Operator Driven	Ongoing	Various, Electro-Hydraulic Controls
Manufacturing	OEM Drive	Ongoing	Hardware Modularisation, Modularisation of Software allowing customisation

Global Emissions Compliance – Off-Road



Majority of off-road legislation is still not fully adopted, and timing includes some derogations and flexibility schemes including Averaging, Banking and Trading in the US. *European flexibility scheme may be widened to 35% of sales

Emissions Legislation Timing

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020			
USA	8-19kw	Tier 1	Tier 2			Tier 4 Interim															
	19-37	Tier 2			Tier 4 Interim							Tier 4 Final									
	37-56	Tier 2			Tier 3/Tier 4 Interim*							Tier 4 Final									
	56-75	Tier 2			Tier 3						Tier 4 Interim			Tier 4 Final							
	75-130	Tier 2			Tier 3						Tier 4 Interim			Tier 4 Final							
	130-560	Tier 2		Tier 3						Tier 4 Interim				Tier 4 Final							
	560+	Tier 1		Tier 2						Tier 4 Interim				Tier 4 Final							
Europe	19-37	Stage II			Stage IIIA																
	37-56	Stage II				Stage IIIA							Stage IIIB								
	56-75	Stage II				Stage IIIA							Stage IIIB		Stage IV*						
	75-130	Stage II		Stage IIIA																	
	130-560	Stage II		Stage IIIA							Stage IIIB			Stage IV							
China	19-37	State I				State II									State III?						
	37+					State II						State III?			State IV?						
India	19-37	Trem II-III/CEV II/III							Trem IIIA/CEV IIIA												
	37+	Trem II-III/CEV II/III							Trem IIIA/CEV IIIA						Trem IV/CEV IV?						

*Timing may vary for new models and all models

Flexibility schemes have major impact

US 37-56 has 2 options, EU 56-130 from 9/2014

Post 2015 CO₂/Fuel Economy likely to be addressed

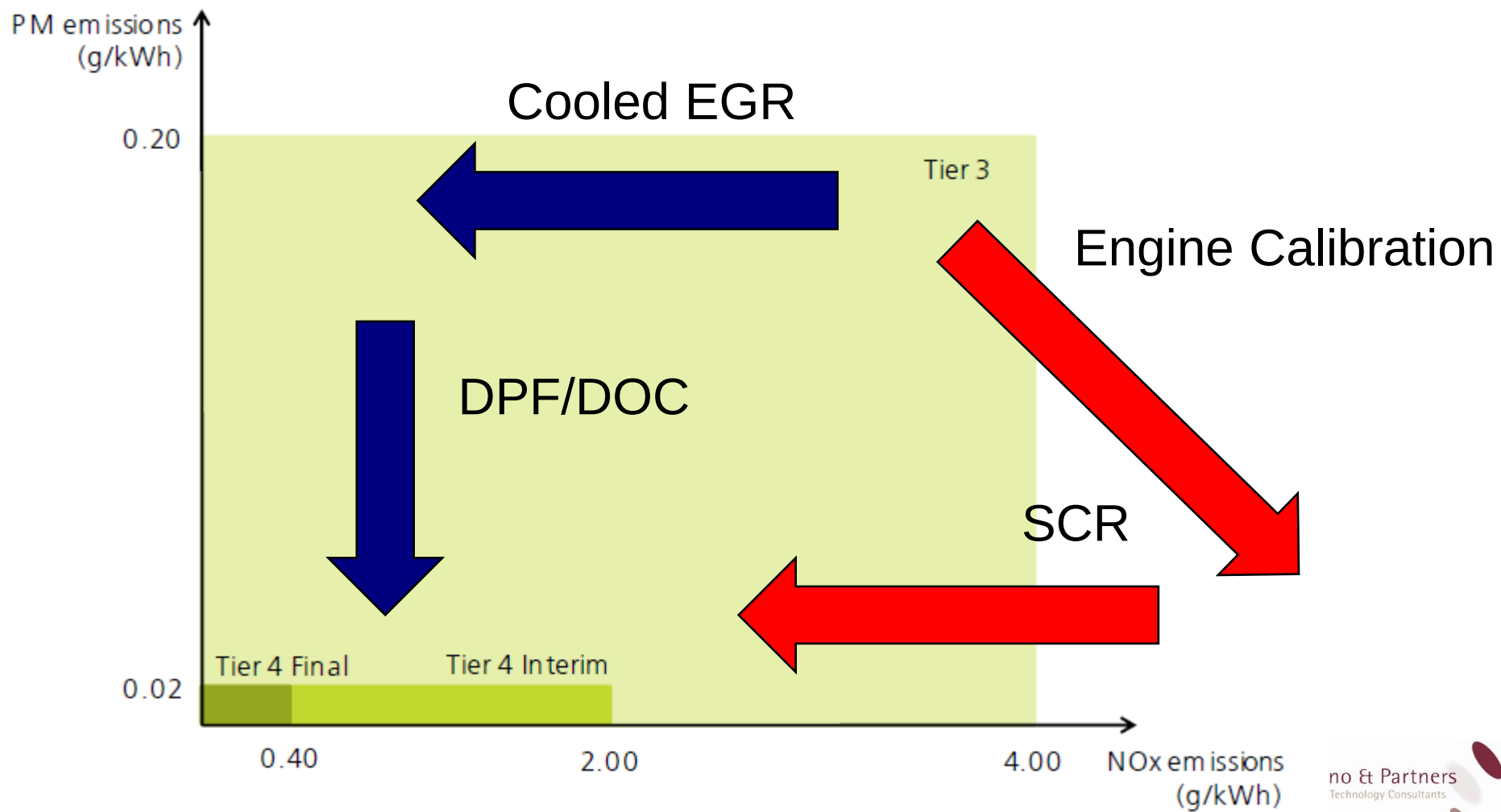
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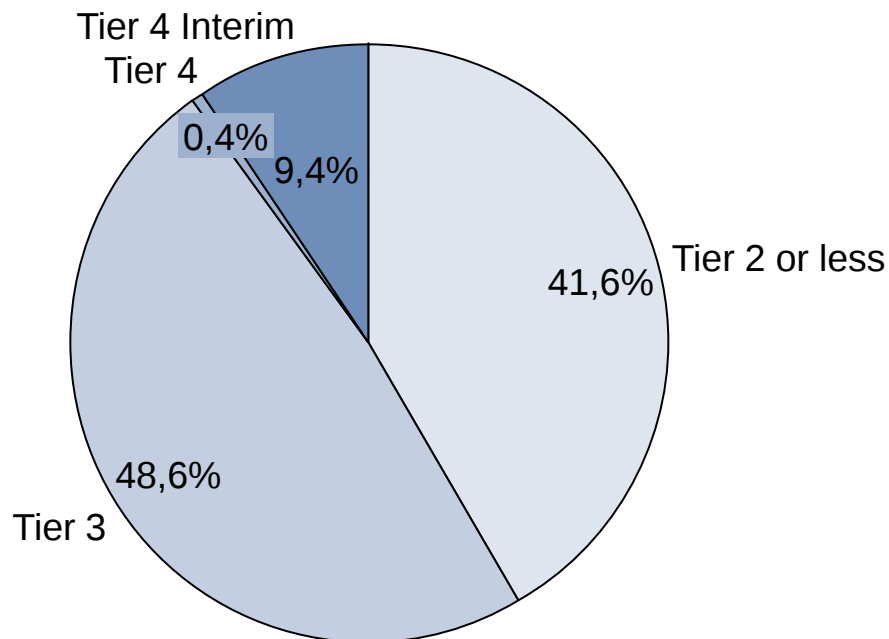
EPA Emissions Limits

EPA Tier 4 Emission Standards for Non-Road Mobile Machines (g/kWh)						
Category	Standard	Date	NMHC + NO _x	NMHC	NO _x	PM
W < 8	Tier 4 (Interim)	01/01/2010	7.50	--	--	0.60
8 ≤ kW < 19	Tier 4 (Interim)	01/01/2008	7.50	--	--	0.40
19 ≤ kW < 37	Tier 4 (Interim)	01/01/2008	7.50	--	--	0.30
	Tier 4 (Final)	01/01/2013	4.70	--	--	0.03
37 ≤ kW < 56: Option 1	Tier 4 (Interim)	01/01/2008	4.70	--	--	0.30
	Tier 4 (Final)	01/01/2013	4.70	--	--	0.03
37 ≤ kW < 56: Option 2	Tier 4 (Final)	01/01/2012	4.70	--	--	0.03
56 ≤ kW < 130	Tier 4 (Interim)	01/01/2012	--	0.19	3.40	0.02
	Tier 4 (Final)	01/01/2015	--	0.19	0.40	0.02
130 ≤ kW < 560	Tier 4 (Interim)	01/01/2011	--	0.19	2.00	0.02
	Tier 4 (Final)	01/01/2014	--	0.19	0.40	0.02
560 ≤ kW < 900 (Generator Sets)	Tier 4 (Interim)	01/01/2011	--	0.40	3.50	0.10
	Tier 4 (Final)	01/01/2015	--	0.19	0.67	0.03
kW ≥ 900 (Generator Sets)	Tier 4 (Interim)	01/01/2011	--	0.40	0.67	0.10
	Tier 4 (Final)	01/01/2015	--	0.19	0.67	0.03
kW ≥ 560 (other equipment)	Tier 4 (Interim)	01/01/2011	--	0.40	3.50	0.10
	Tier 4 (Final)	01/01/2015	--	0.19	3.50	0.04

Emissions Compliance (Tier 4 130-560kw)

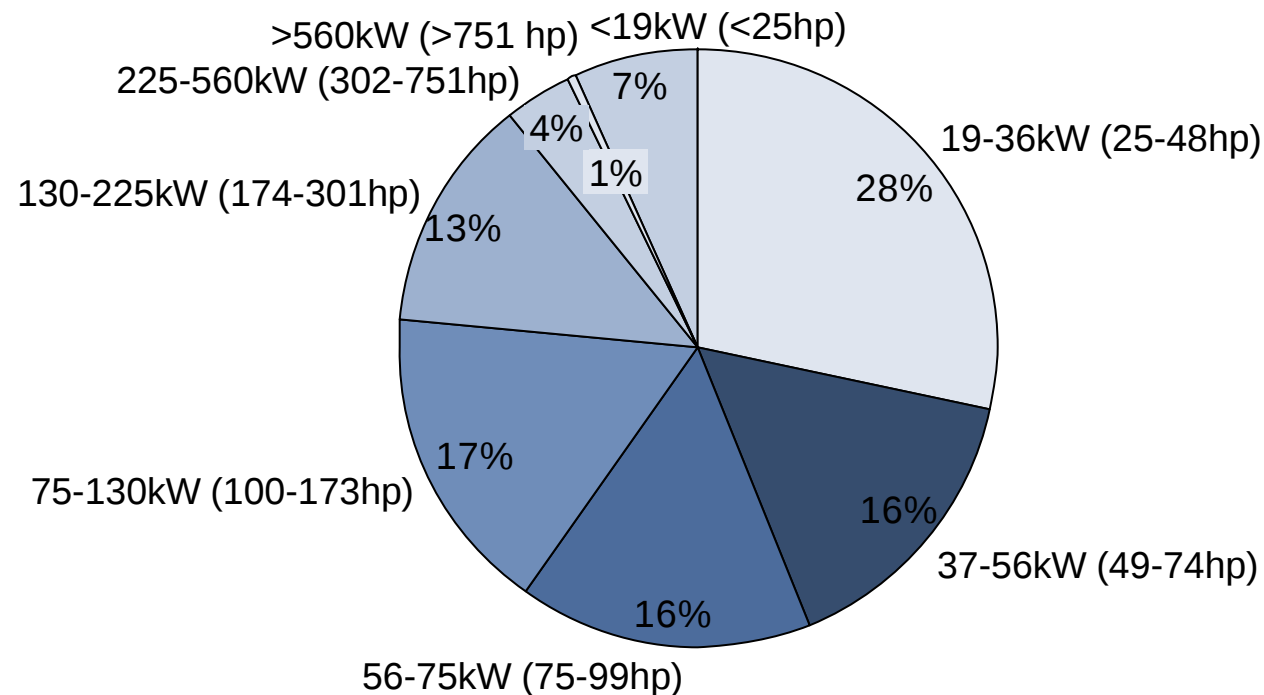


Off-Road Mobile Equipment Global Emissions Compliance 2011



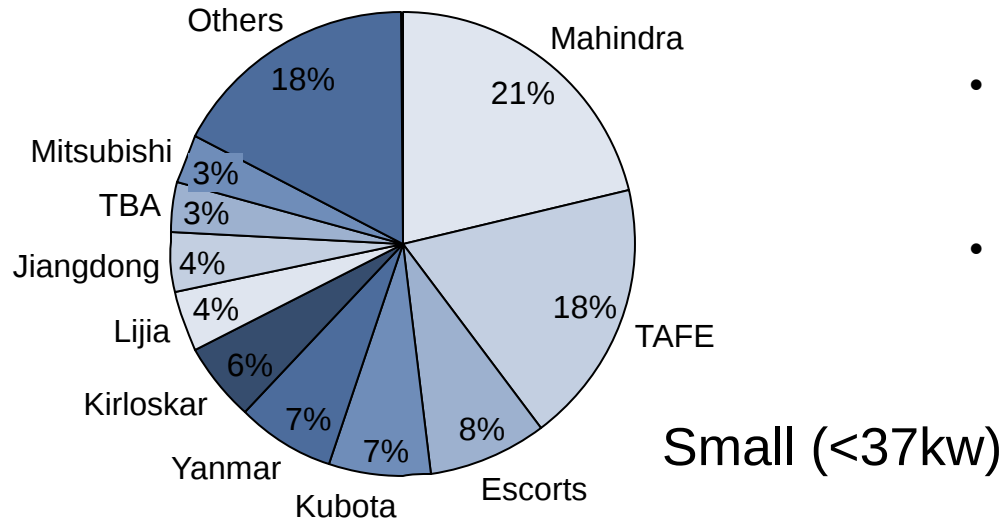
- Equivalent of Interim Tier 4/Stage 3B driving after-treatment
- Requires electronic control in most segments
- SCR or EGR+DPF for larger engines, EGR or EGR+DPF for smaller engines
- Limited advanced compliance overall due to China and Indian dominance of volumes
- Averaging Banking and Trading/Flexibility in US and Flexibility in Europe allows delayed introduction of Tier 4 Interim/Stage 3B equivalent

Off-Road Mobile Equipment - Global Engine Usage 2011

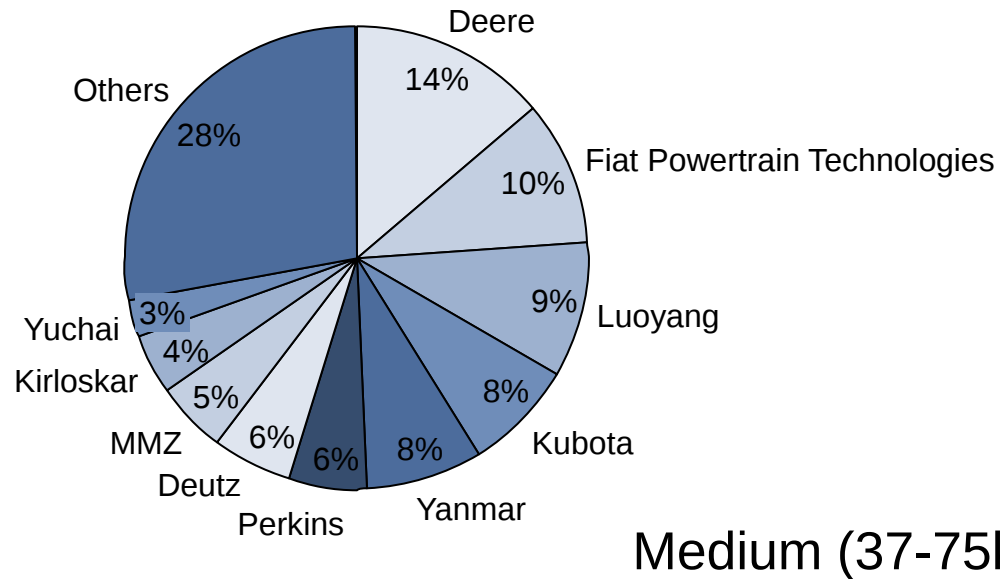


- Global Engine use is split by power band, small segment <56kw dominant in Asia-Pacific due to size of tractor market and volume of mini-excavators and small products exported
- 56-130kw is the largest segment outside these markets
- 130kw plus is limited to large tractors and equipment in all market
- Mechanical/Electronic, TC/Normally Aspirated switch in 19-36kW band for Tier 4 Final

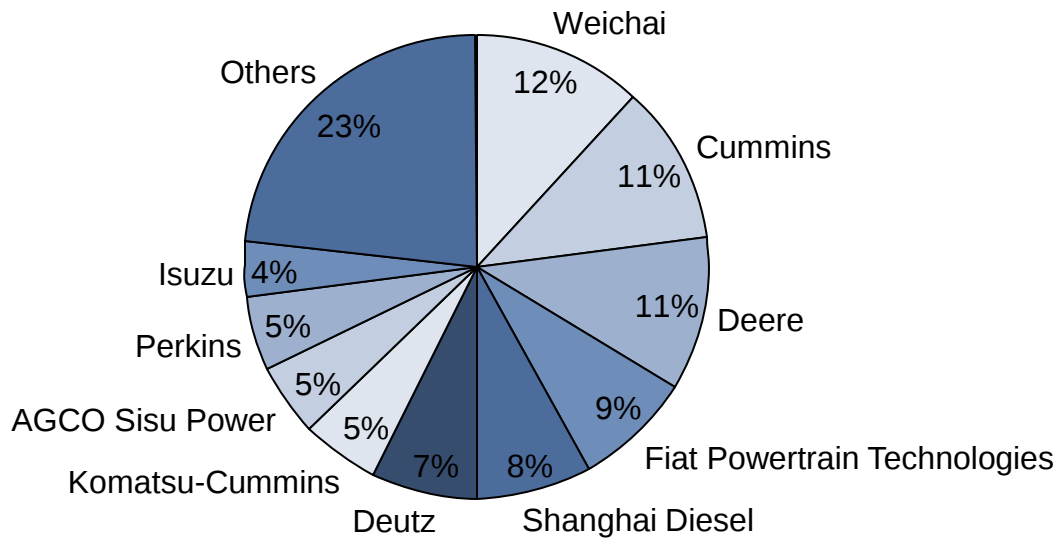
Top Engine Manufacturers 2011



- Top 20 manufacturers account for 80% of total production in 2015, down from 85% in 2010.
- Small engine volume for this equipment dominated by Indian tractor manufacturers and Japanese small engine producers

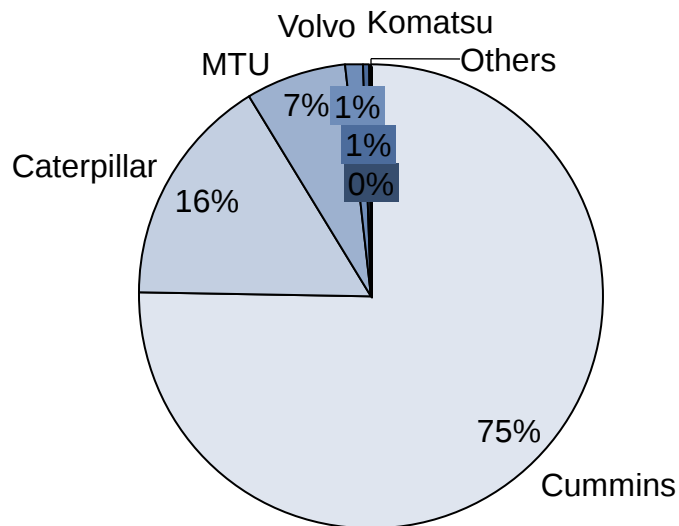


Top Engine Manufacturers 2011



Large (75-225kw)

- Many large engines common with on-road platforms, similar technology



Extra-Large (>225kw)

Technology Packages

kW	Tier 2/Stage 2	Tier 3/Stage 3A	Interim Tier 4/Stage 3B	Tier 4/Stage 4
19-37	Mech IDI	Mech IDI	Mech IDI NA or TC	Electronic DI NA or TC
37-56	Mech DI or Electronic DI NA or TC	Mech DI or Electronic DI NA or TC	Mech DI or Electronic DI NA or TC	Electronic DI NA or TC
56-75	Mech DI or Electronic DI NA or TC	Mech DI or Electronic DI NA or TC	Electronic CR DI TC CEGR	Electronic CR DI TC CEGR+DPF/DOC
75-130	DI TC	Electronic CR DI TC	Electronic CR DI/HP DI CEGR +DPF/DOC or SCR TC/VGT	Electronic CR DI/HP DI VGT or TC SCR+CEGR+DPF/DOC
130-560	Electronic DI TC	Electronic CR DI/HP DI CEGR or SCR TC/VGT	Electronic CR DI/HP DI VGT or TC CEGR+DPF/DOC or SCR	Electronic CR DI/HP DI VGT or R2S SCR+CEGR+DPF/DOC

NA – Normally Aspirated
 TC Turbocharged
 DI Direct Injection (Common Rail)
 CEGR – Cooled EGR
 DPF – Diesel Particulate Filter
 DOC – Diesel Oxidation Catalyst
 VGT Variable Geometry Turbocharger
 SCR – Selective Catalytic Reduction

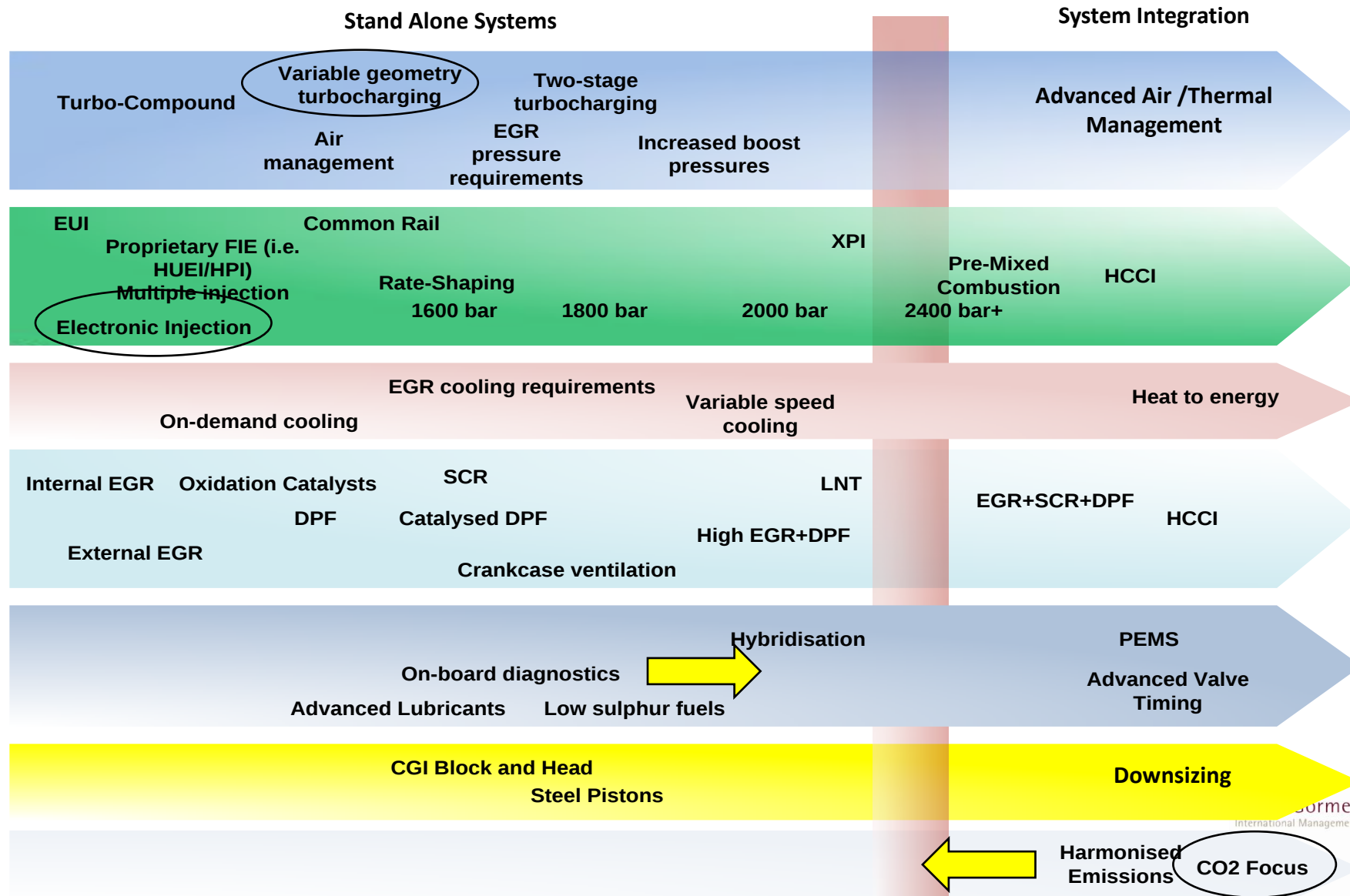
Lower Emissions (down 90%)

Increased Cost (2x)

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Technology Developments – On Road*



*Off-Road is ~5 years behind. Various power bands have different packages

System Content – Fuel Economy Technologies

Potential combination of technologies to meet future CO₂ legislation

Technology	On-Road	Off-Road
Advanced emissions aftertreatment (Inc. SCR)	Low	Low
Downsizing and downspeeding	Medium	Medium
Electrical/hydraulic accessories	Low	Low
Engine turbo-compounding and other advanced turbo technologies	Medium	Medium
HCCI /PCCI	Low	Low
Hybridisation	Medium	High*
Hydraulic System optimisation	Low	High
Improved combustion (massive EGR and ~3000 bar injection pressures)	Low	Low
Lubricants	Low	Low
Reduced engine parasitic losses	Low	Low
Regenerative Braking /Energy Recovery	Low	Medium*
Transmission efficiency improvements	Low	Low
Variable valvetrains	Low	Low
Vehicle aerodynamic drag , tyre and driveline friction	High	Low
Waste heat recovery systems (electro-mechanical & electro-thermal)	Medium	Medium

*Depending on vehicle/equipment type, duty cycle

NB Off-Road has different duty cycle and durability requirements than on-road



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