Emission control technology for nonroad-engines

8th Vert Forum
Combined particle filter and deN0x-technologies
03-17-2017 in Dübendorf

François Jaussi
Liebherr Machines Bulle S.A., 1630 Bulle, Switzerland

Agenda

1 Global market with different specific requirements on EAT systems for off-highway applications
- 1.1 Legislative requirements
- 1.2 Market and in use requirements

2 Field experience with different EATS Solutions
- 2.1 DPF or SCR Solutions for Stage IIIB / Tier 4i Engines
- 2.2 SCR Solution for Stage IV / Tier 4f
- 2.3 Second life for mobile machinery
- 2.4 SCRFilter Solution for Stage V
- 2.5 Modular concepts

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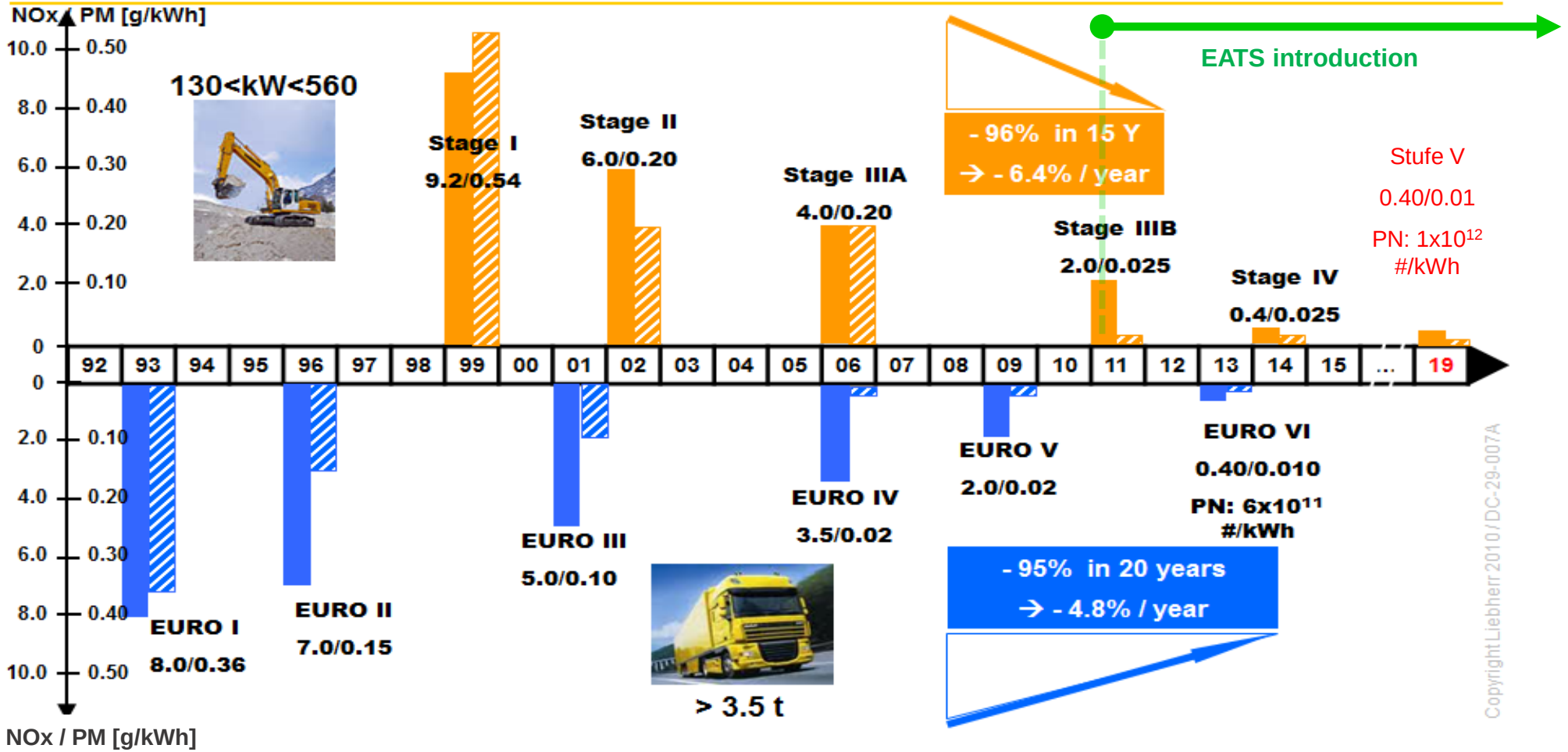
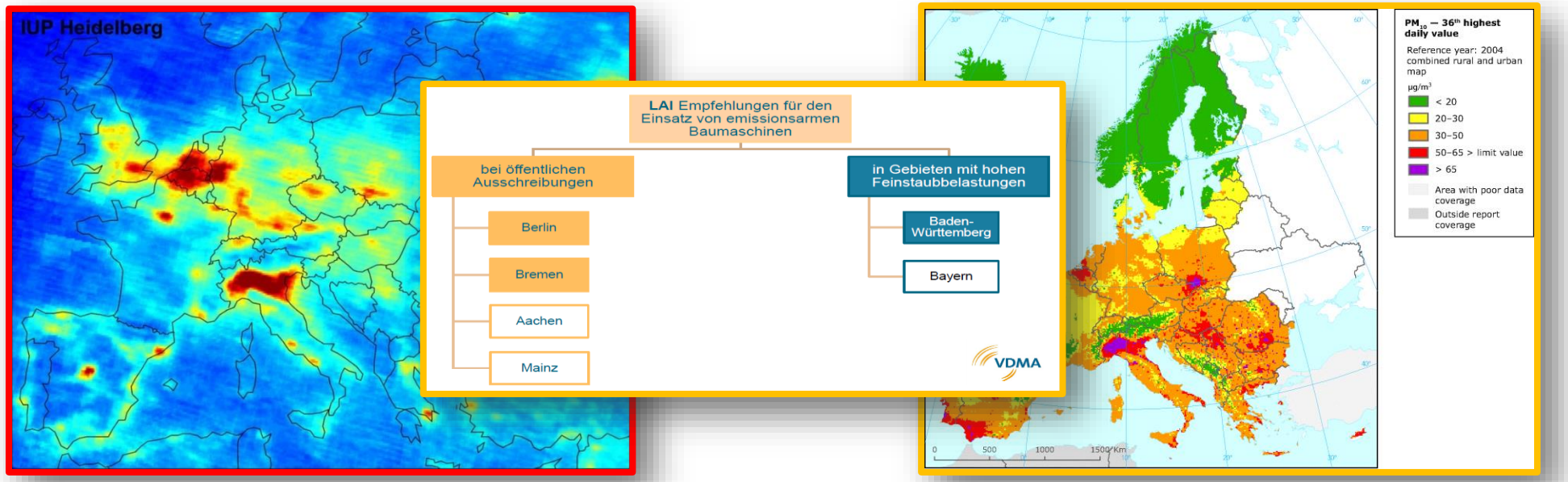
Chronology of Exhaust Legislation: On- vs. Off-highway



Local Emission – ambient air quality - Directive 2008/50/EC

Relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air

- Requires that action plans be developed for zones within which concentrations of pollutants in ambient air exceed limit values
- LEZ (Low Emissions Zone)



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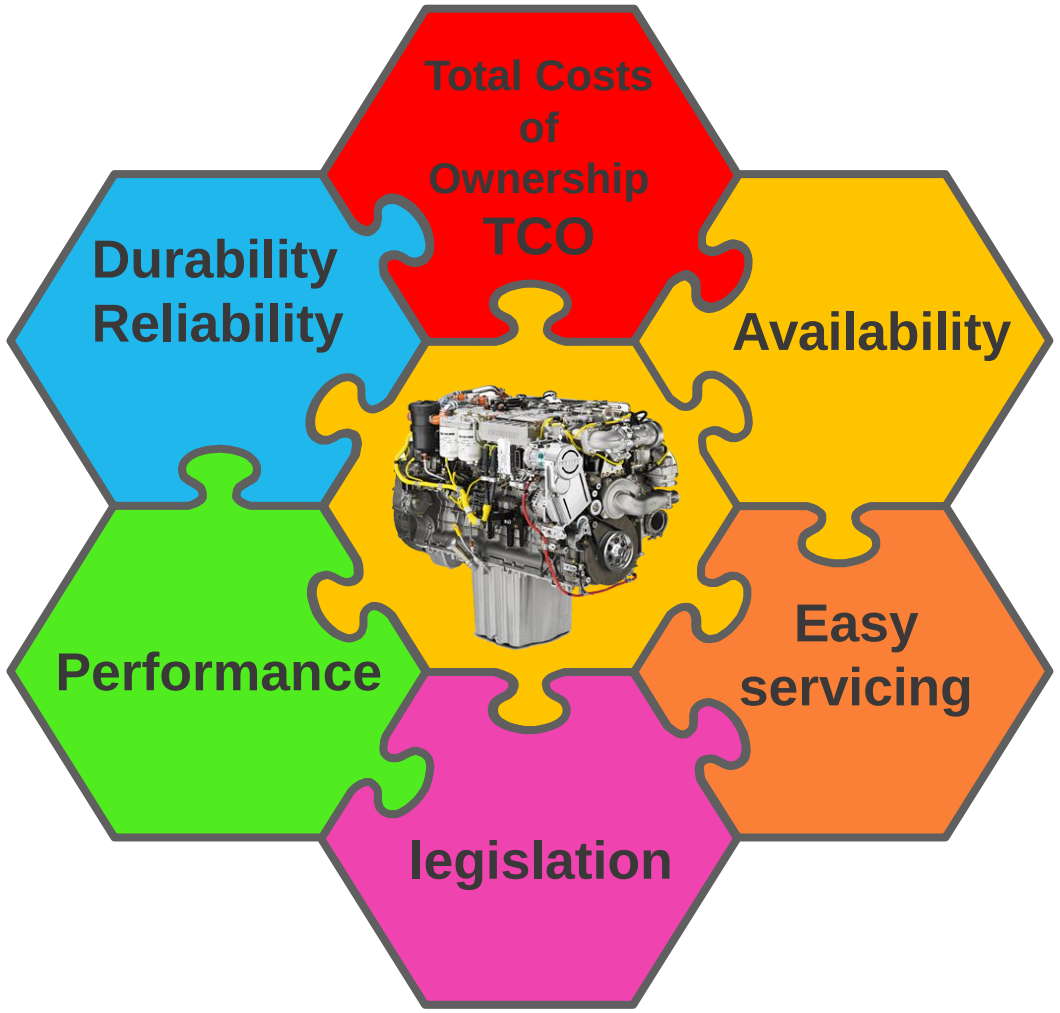
Requirements (end customer) on heavy-duty Diesel engines for on- and off-highway applications



Same Emission Target as on-highway applications, Different Conditions

Water

Dust

Inclined position

Heat

Applications with Liebherr-Diesel engines


Crawler excavators 20-100t


Crawler tractors 12-60t


Duty cycle excavators


Wheeled excavators 20-200t


Mobile construction cranes


Harbour mobile cranes


Mining excavators 100-150t


Pipelaying machines


Mobile cranes <1200t


Crawler cranes <300t


Reachstackers


Wheel loaders


Articulated trucks


Material handling excavators


Ship & offshore cranes


Trucks


Pipe bending machines


Racing trucks


Agricultural machines


Agricultural machines


Generator sets

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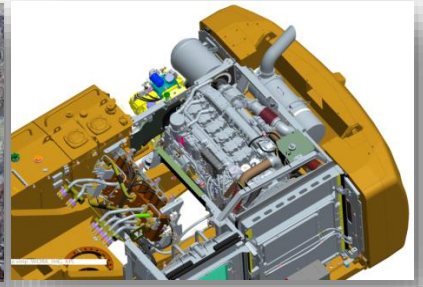
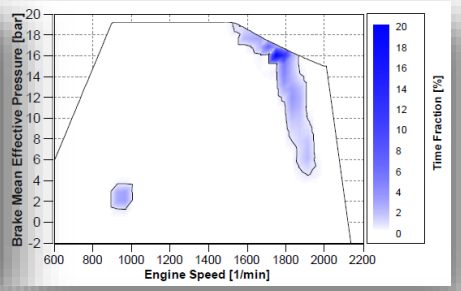
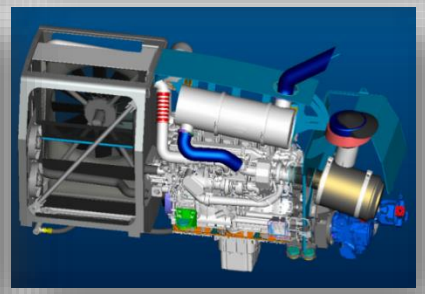
Diversity of EAT Variants: Machine-specific Application

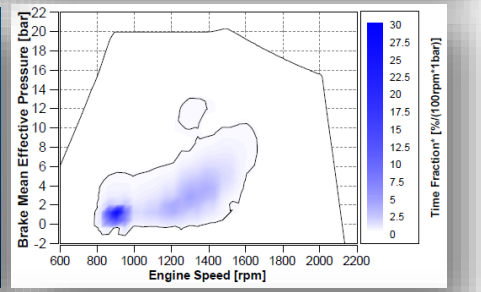
Base engine → Application → EAT integration → Duty cycle

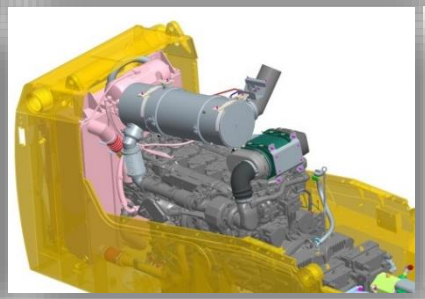
D936 A7 DPF
230 kW @ 2000 min-1

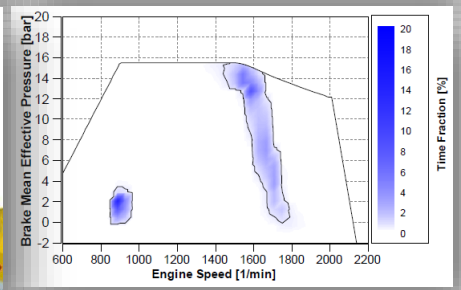












Goal: Common DPF regeneration strategy

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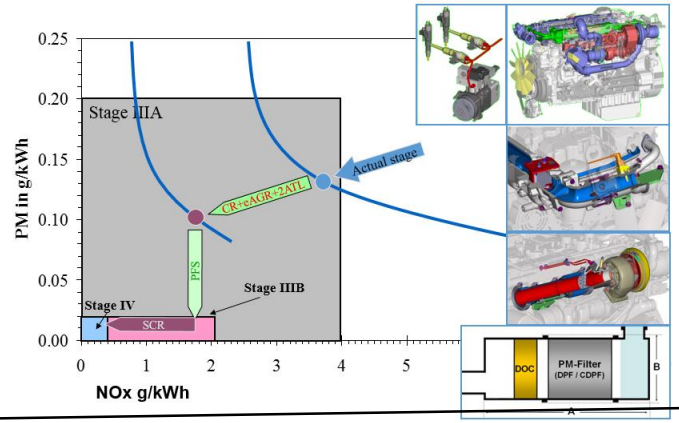
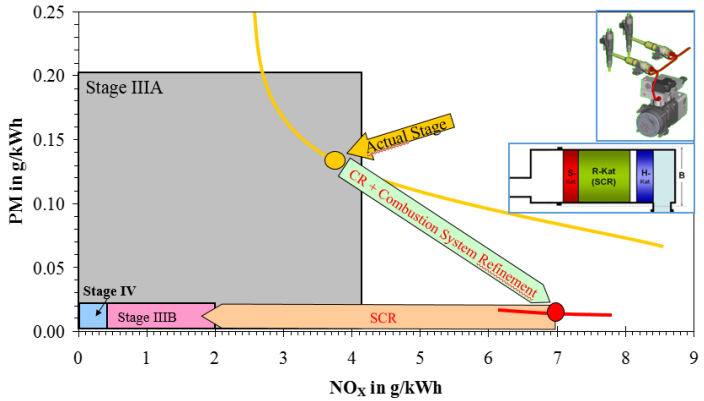
Liebherr diesel engines & ATS solutions vs applications Stage IIIB /Tier4i (P<560 kW)

Application	ATS	ATS Layout
Earthmoving 	**EGR-DPF**	
Cranes 	**SCR**	

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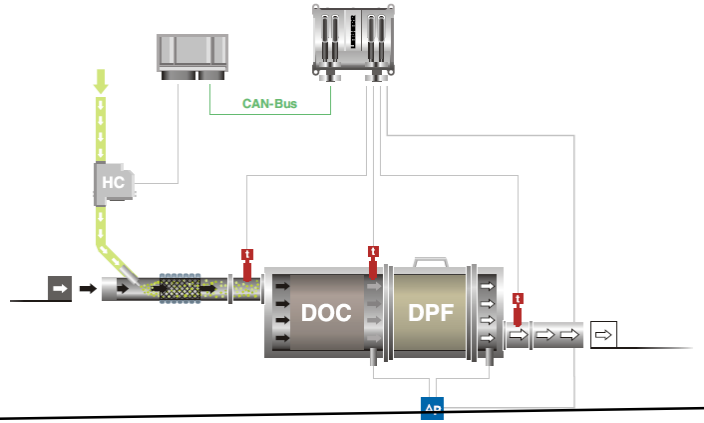
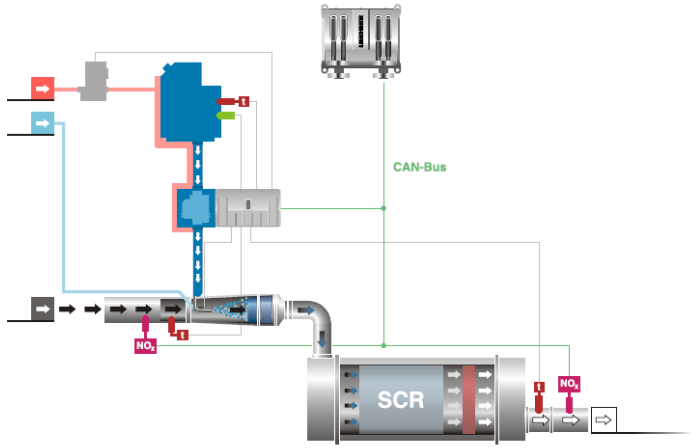
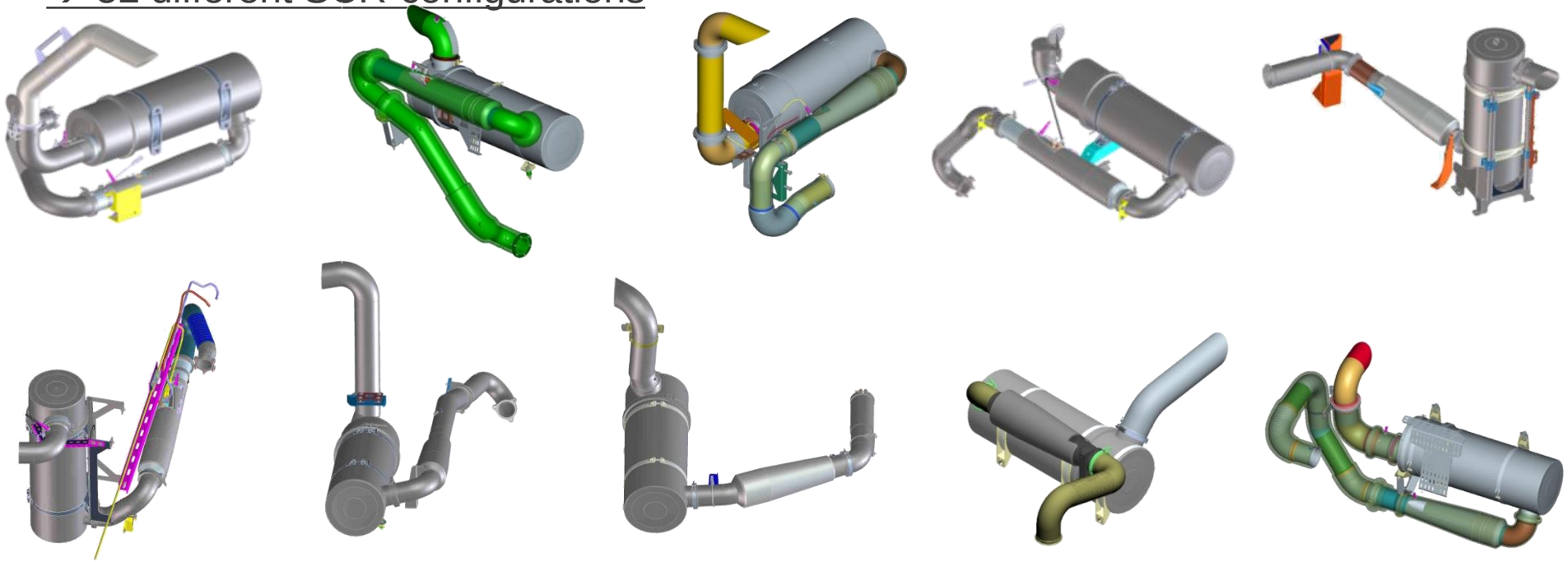
Earthmoving 	**EGR-DPF**	
Cranes  	**SCR**	

Diversity of variants - Modular SCR-only Concept for Stage IIIB / Tier 4i

Two overall sizes:

- high power system (engines D856, D946, D9508 power 350 – 505 kW)
- low power system (engines D934, D936 power 129 – 300 kW)

→ 52 different SCR-configurations



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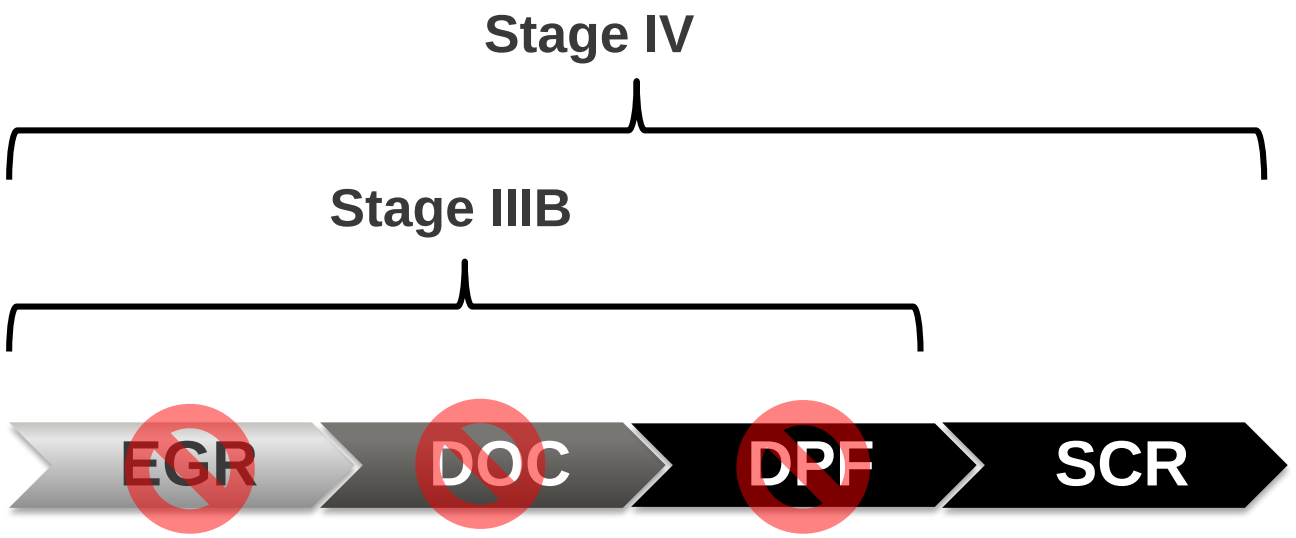
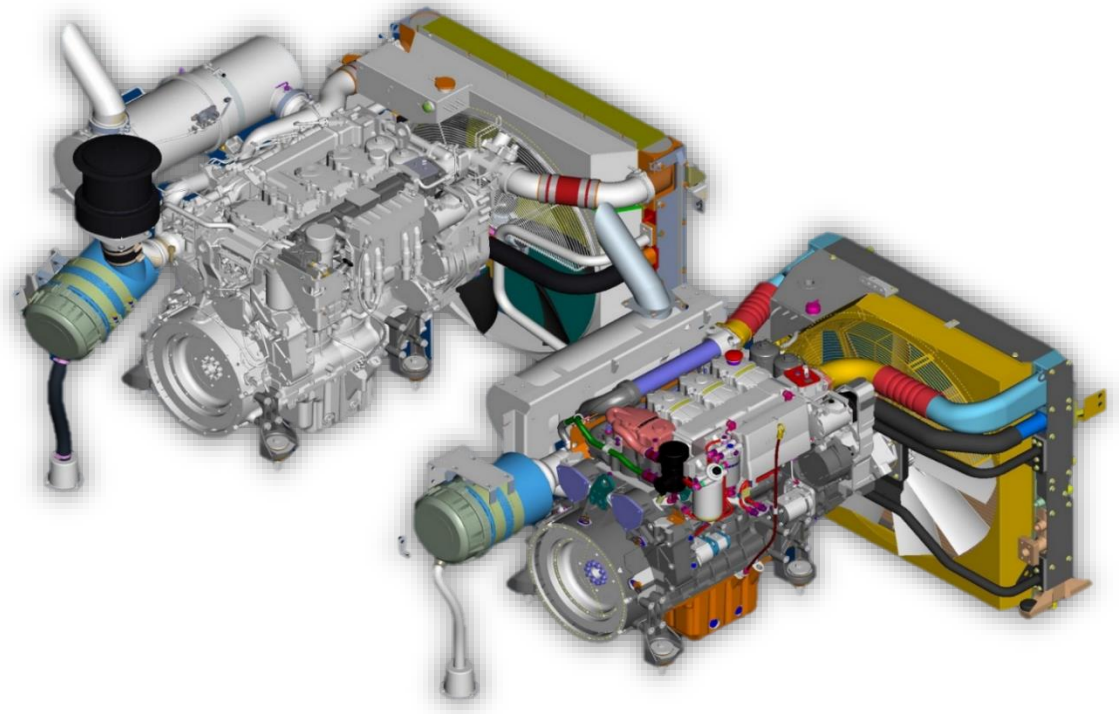
EATS Concepts for Stage IV

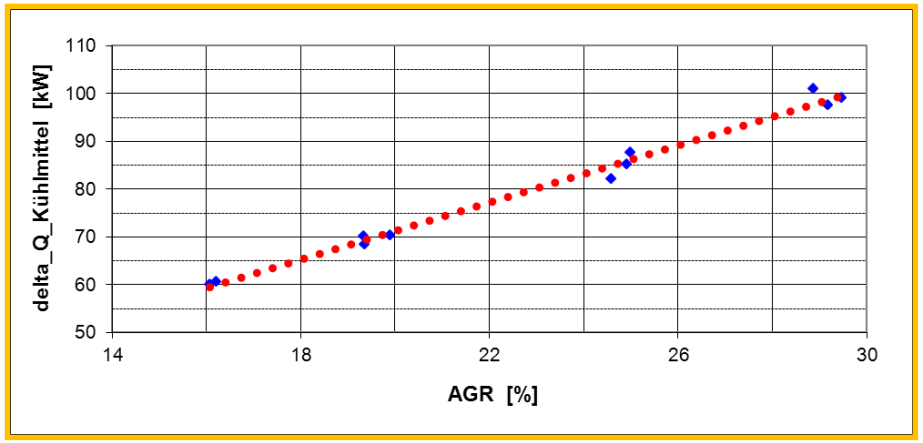


SCR **Liebherr SCR Technology**

Concept with SCR & without EGR - Less need for cooling

- **Powerpack comparison IIIB (EGR-DPF) vs. IIIA**
- Increase in the engine cooling power demand as a function of the EGR rate
- **Basis IIIV-Engine, rated power: 260 [kW]**

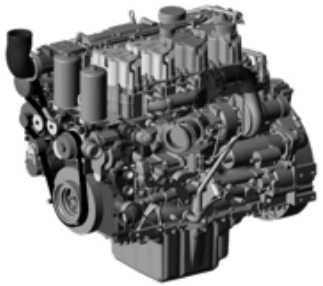




SCR Concept without EGR - Easy detiering from Tier 4f to Tier 0

Easy detiering from Tier 4f to Tier 0

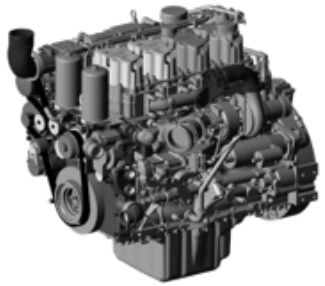
Stage IV / Tier4f



detiering

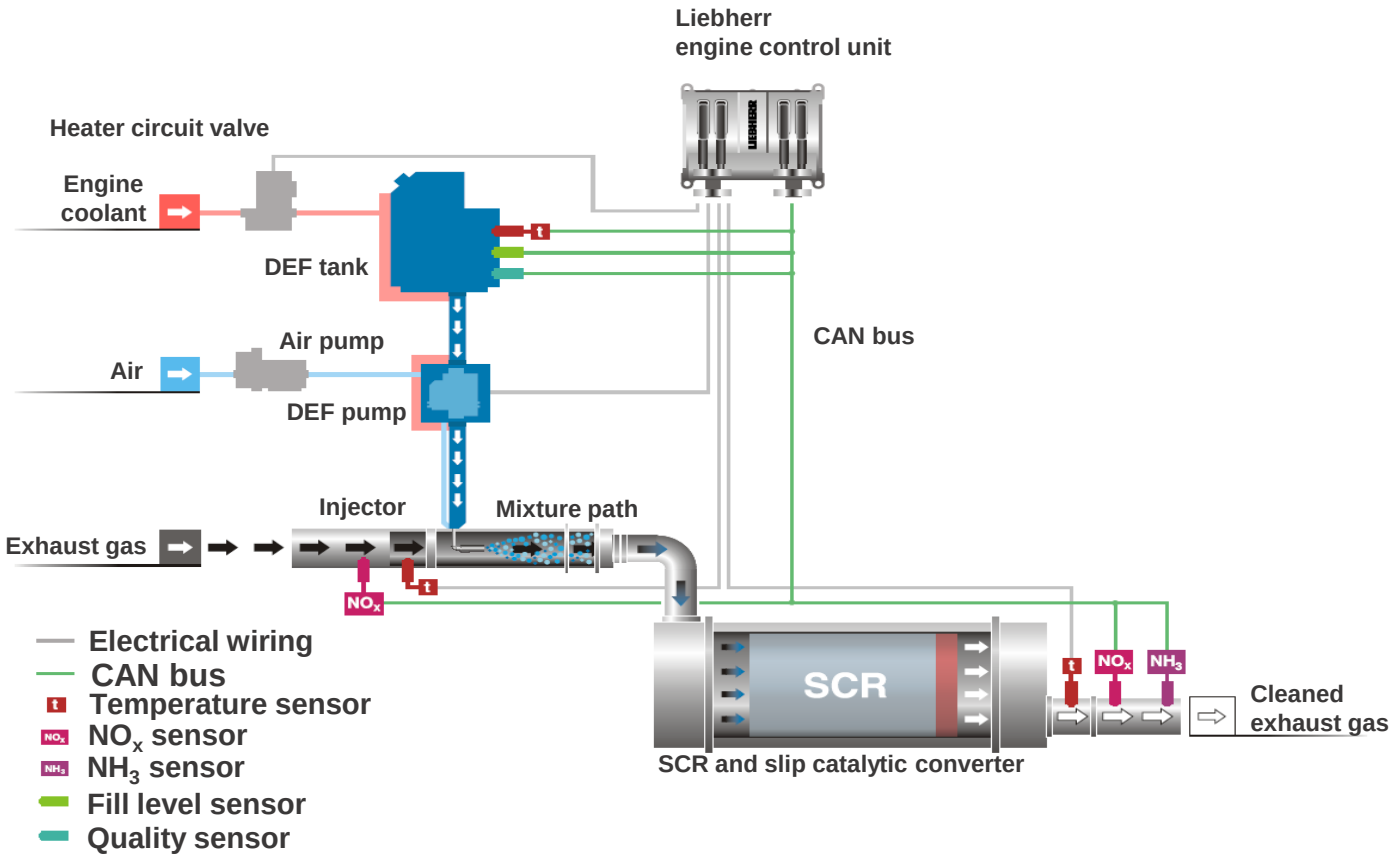
- new dataset
- new engine plate
- SCR :
  - Inactivate
  - or remove

Tier 0



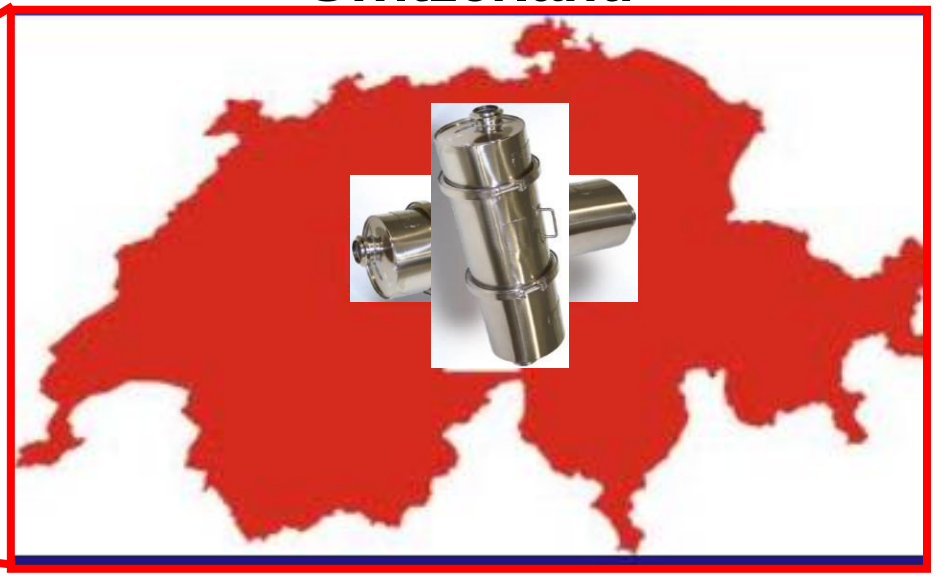
After a detiering from Tier 4f to Tier 0, an uptiering back to Tier 4f is possible

SCR System for Stage IV



Swiss Market: OAPC « Ordinance on Air Pollution Control » Tunneling in Switzerland, Germany & Austria (SUVA, TRGS, AUVA)

Switzerland



Closed DPF mandatory since 2009

Since January 2000, Wall flow DPF are mandatory at Swiss underground sites.

In addition, since 2009 a PN limit was introduced (OAPC) which forced the OEM to use closed DPF for new construction machine.

As for EURO VI, the PN limit will come for the next EU-NRMM emissons stage V

→ Incentives for Liebherr to develop a robust and cost effective solution for those specific markets and toward the new EU stage V (~ 2019)

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EATS Concepts Stage IV towards Stage V

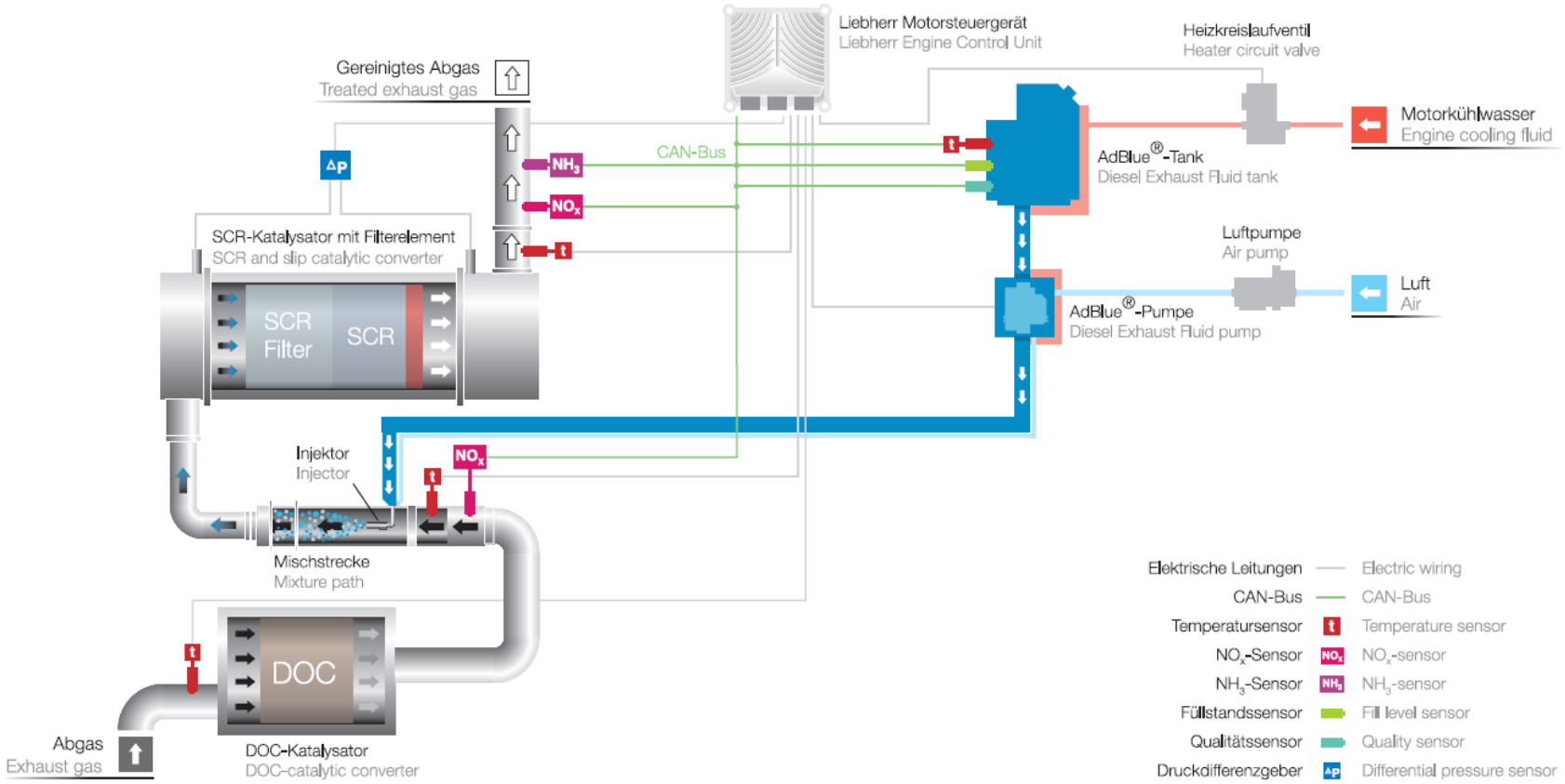
Stage IV

SCR **Liebherr SCR Technology**

Stage V

DOC SCRFilter

SCRFilter System (SCRonFilter)



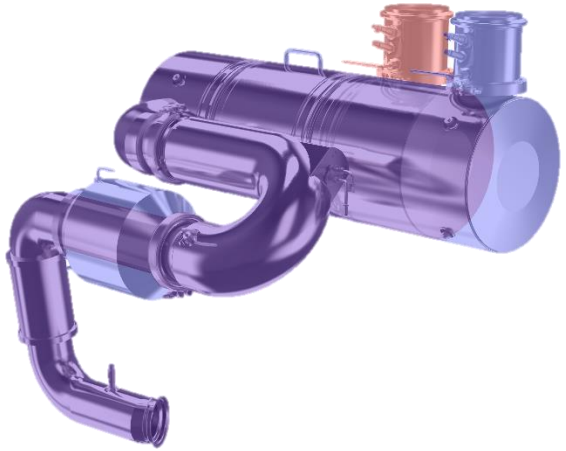
SCRFilter vs SCRonly

SCR only – Tier4F

		CO	HC	NOx	PM
		g/kWh	g/kWh	g/kWh	g/kWh
230kW	NRTC	0.4899	0.0225	0.3376	0.02
	RMC	0.1778	0.0106	0.3182	0.0128

SCRFilter – Stage IV + LRV

CO	HC	NOx	PM	PN
g/kWh	g/kWh	g/kWh	g/kWh	#/kWh
0.0445	0.0056	0.2967	0.0005	6.97E+10
0.0147	0.0018	0.3197	0.0008	1.87E+11

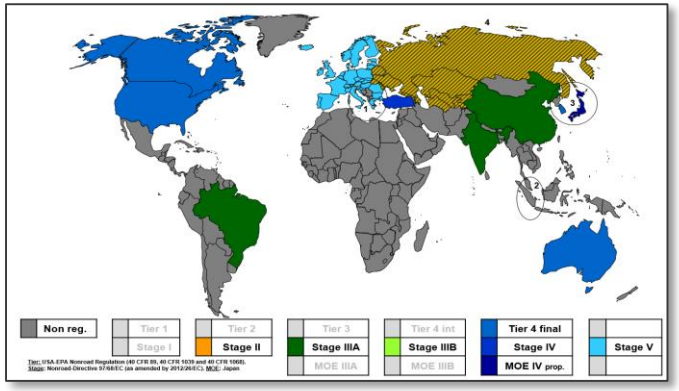


Compared to the SCRonly, the SCRFilter

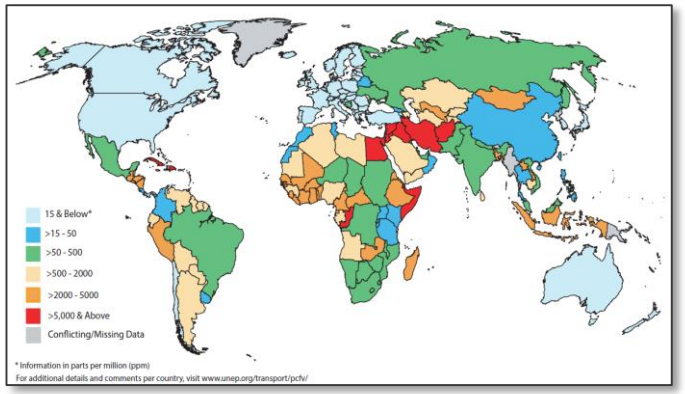
- length is about 20% longer
- is able to reduce the CO of about 90%, the HC of about 75% and the PM of about 95%.
- Is able to filtrate the PN in order to be below the 1E12 #/kWh particulate number tailpipe

Flexible Solution for Global Market

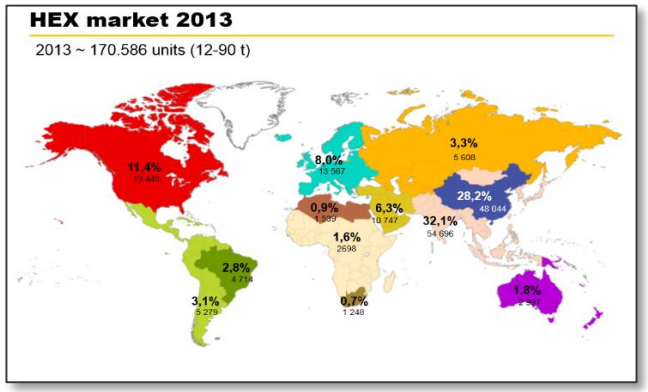
Emission limits



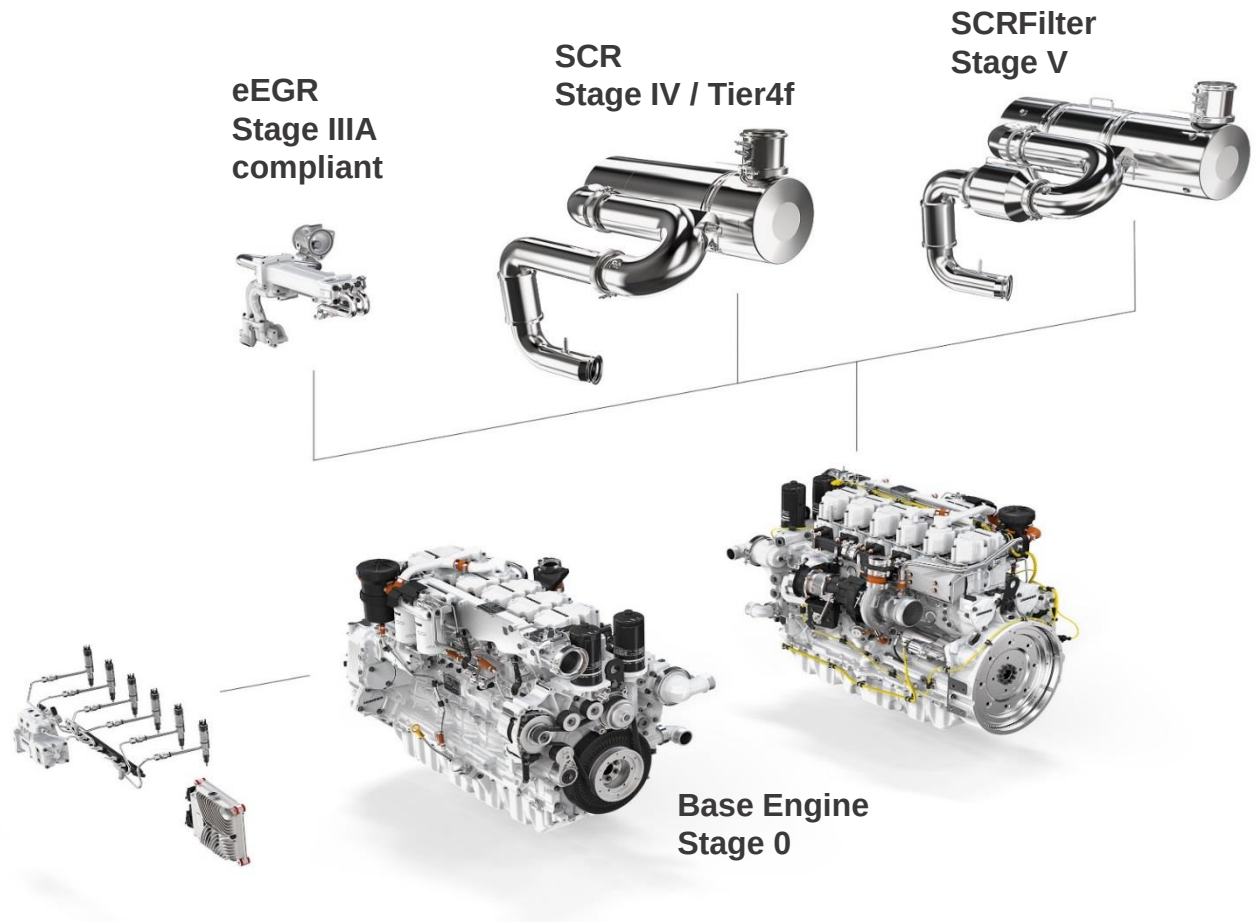
Fuel quality (sulfur)



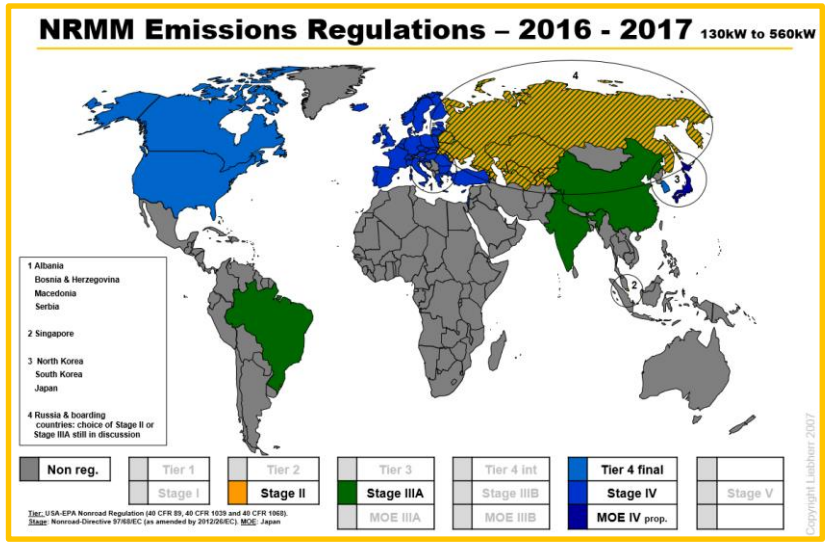
Market share

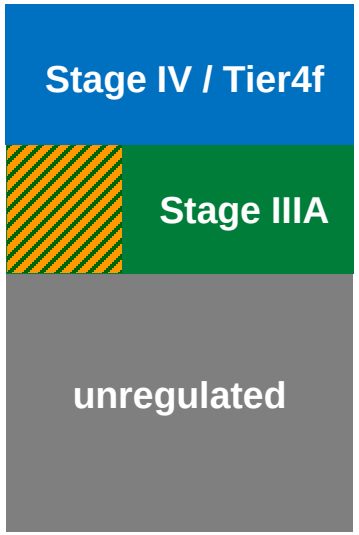


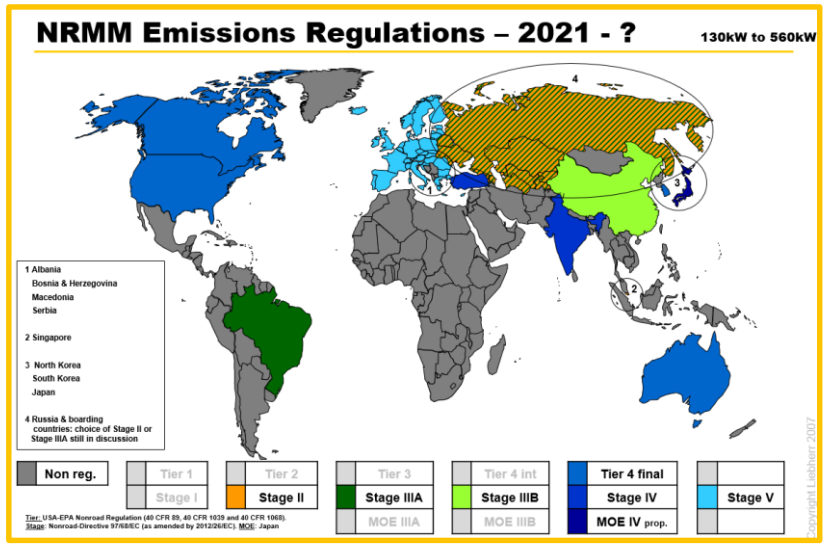
Modular concept – 1 Single Basis for 4 Emission Levels

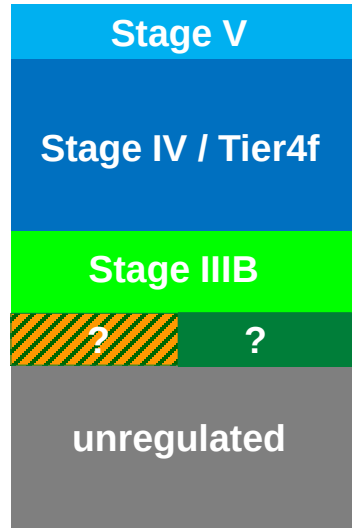


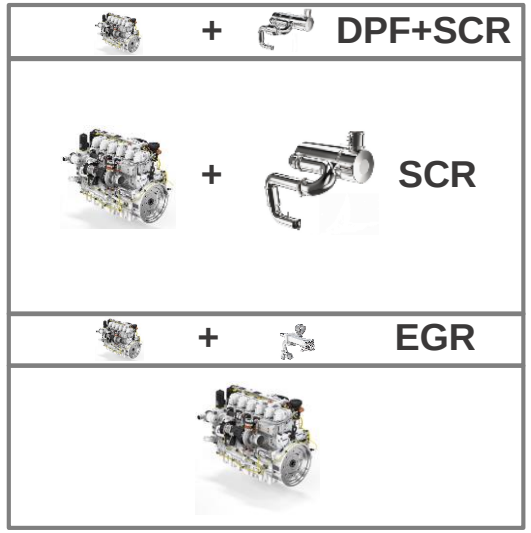
WW Emission solutions 2016 – 2021…2030 ?

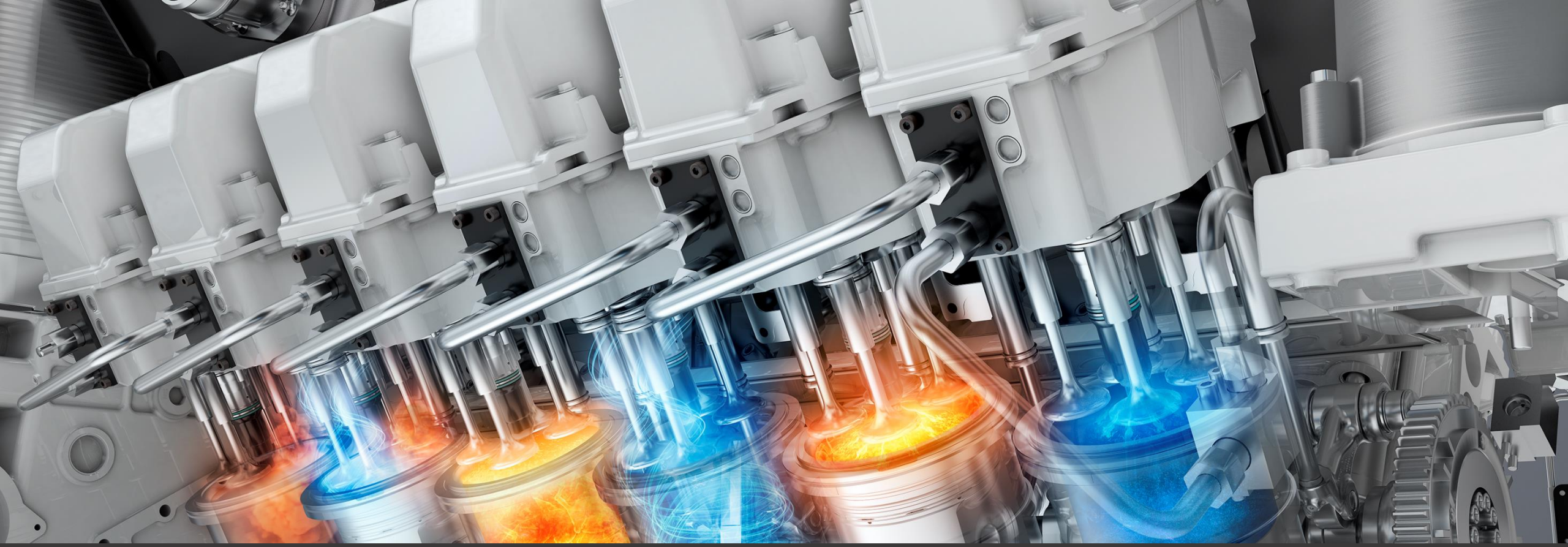












Thank you!