

---

# Low PN emission and BAT as well for engines > 560 kW?

---

12<sup>th</sup> VERT Forum 2022

François Jaussi

24.03.2022

**LIEBHERR**



Low PN emission and BAT as well for engines > 560 kW ?

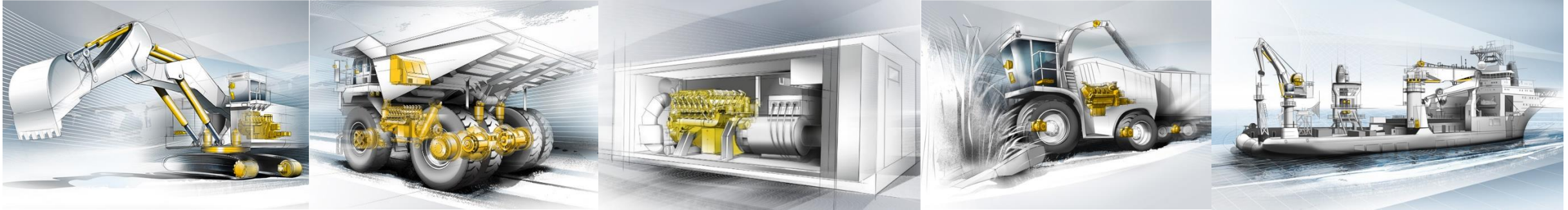
# Agenda

- 1 NRMM >560kW: Applications / population**
- 2 current Emission Legislation Stage V / T4f
- 3 future emission regulations Stage VI /Tier5
- 4 emission Reduction technologies
- 5 risk of electricity shortages & increased need for decentralized Diesel Power Stations
- 6 summary



Low PN emission and BAT as well for engines > 560 kW ?

## Applications P>560kW



### Applications for Power ranges above 560kW are:

- Mining excavators (power packs) and trucks (diesel electric propulsion)
- GenSet
- Agriculture
- Harbour & Maritime cranes
- Other C&I applications

**Fleet of construction machinery with engines > 560 kW in Europe is comparably small and these large machines usually do not operate in urban environments. Moreover, it is difficult to obtain reliable figures on the population of such machines/engines in Europe. Emission inventory reports are generally limited to categories below 560kW**

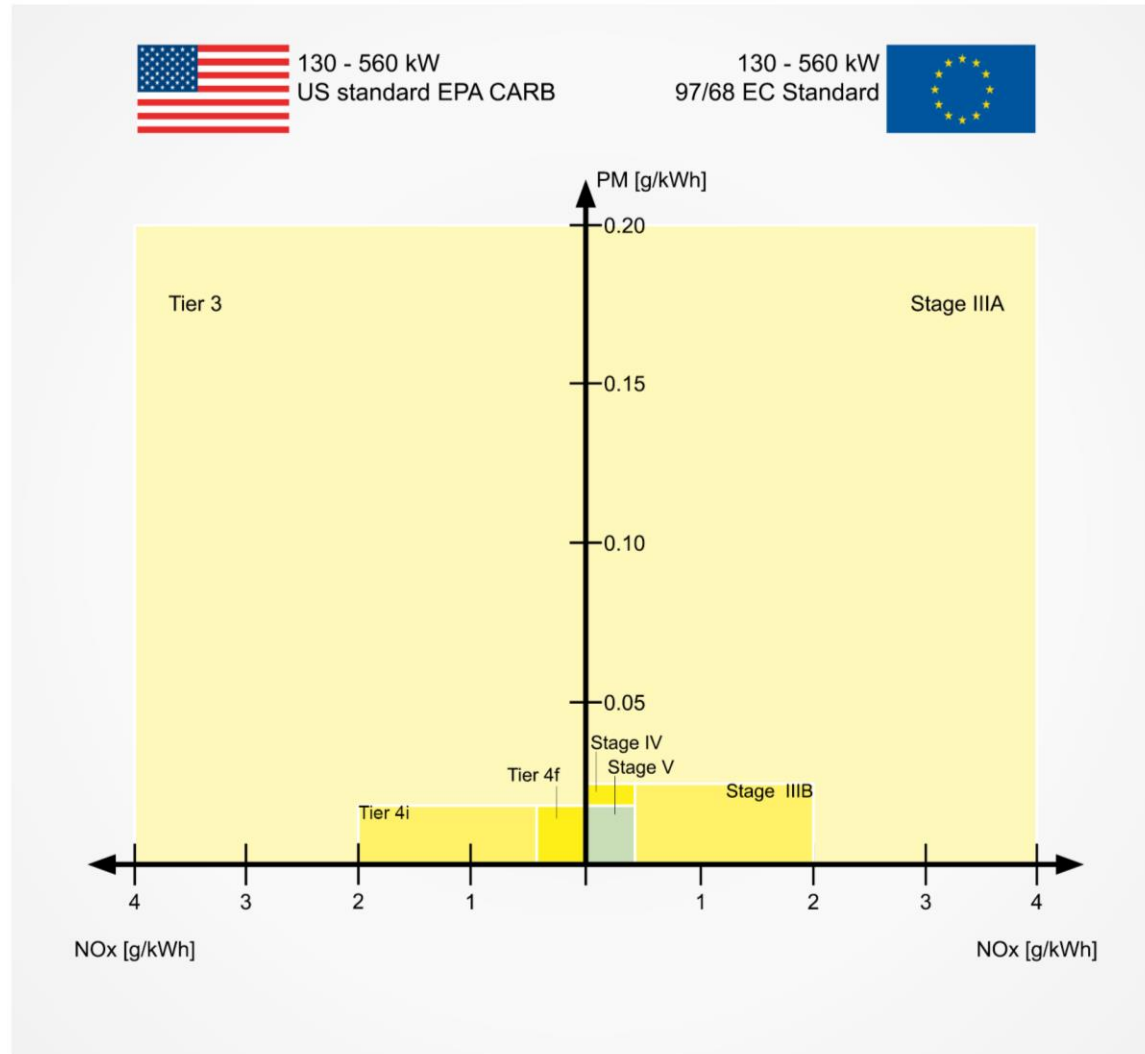
Low PN emission and BAT as well for engines > 560 kW ?

# Agenda

- 1 NRMM >560kW: Applications / population
- 2 **current Emission Legislation Stage V / T4f**
- 3 future emission regulations Stage VI /Tier5
- 4 emission Reduction technologies
- 5 risk of electricity shortages & increased need for decentralized Diesel Power Stations
- 6 summary

Low PN emission and BAT as well for engines > 560 kW ?

## Legislation : Stage V starting from 01.01.2019 in the EU



130<P[kW]<560

	NOx [g/kWh]	PM [g/kWh]	PN [#/kWh]
Tier 3	4	0.2	
Stage IIIA	4	0.2	
Tier 4i	2	0.02	
Stage IIIB	2	0.025	
Tier 4f	0.4	0.02	
Stage IV	0.4	0.025	
Stage V	0.4	0.015	$1 \times 10^{12}$

P>560 [kW]

	NOx [g/kWh]	PM [g/kWh]	
Tier 4f	3.5	0.04	
Stage V	3.5	0.045	--

there are no PN limits  
for the Power range  
>560kW

Low PN emission and BAT as well for engines > 560 kW ?

## Legislation : Stage V starting from 01.01.2019 in the EU

Power [kW]	CO [g/kWh]	HC [g/kWh]	NO <sub>x</sub> [g/kWh]	Particulate [g/kWh]	Particulate [#/kWh]	Date <sup>A</sup>
		NMHC + NO <sub>x</sub>				
Stage IV						
56 ≤ P <sub>n</sub> < 130	5.0	0.19	0.4	0.025	—	Oct. 2014
130 ≤ P <sub>n</sub> ≤ 560	3.5	0.19	0.4	0.025	—	2014
Stage V						
0 ≤ P <sub>n</sub> < 8	8.00	7.50 <sup>C</sup>		0.40 <sup>B</sup>	—	2019
8 ≤ P <sub>n</sub> < 19	6.60	7.50 <sup>C</sup>		0.40	—	2019
19 ≤ P <sub>n</sub> < 37	5.00	4.70 <sup>C</sup>		0.015	1*10 <sup>12</sup>	2019
37 ≤ P <sub>n</sub> < 56	5.00	4.70 <sup>C</sup>		0.015	1*10 <sup>12</sup>	2019
56 ≤ P <sub>n</sub> < 130	5.00	0.19 <sup>C</sup>	0.40	0.015	1*10 <sup>12</sup>	2020
130 ≤ P <sub>n</sub> ≤ 560	3.50	0.19 <sup>C</sup>	0.40	0.015	1*10 <sup>12</sup>	2019
P <sub>n</sub> > 560	3.50	0.19 <sup>D</sup>	3.50 <sup>E</sup>	0.045 <sup>F</sup>	—	2019

A Date for placing the engine on the market, type approval one year earlier.  
B 0.60 for hand-startable, air-cooled direct injection engines.  
C A = 1.10 for gas engines.  
D A = 6.00 for gas engines.  
E 0.67 for gensets.  
F 0.35 for gensets.

130 < P[kW] < 560

	NOx [g/kWh]	PM [g/kWh]	PN [#/kWh]
Tier 3	4	0.2	
Stage IIIA	4	0.2	
Tier 4i	2	0.02	
Stage IIIB	2	0.025	
Tier 4f	0.4	0.02	
Stage IV	0.4	0.025	
Stage V	0.4	0.015	$1 \cdot 10^{12}$

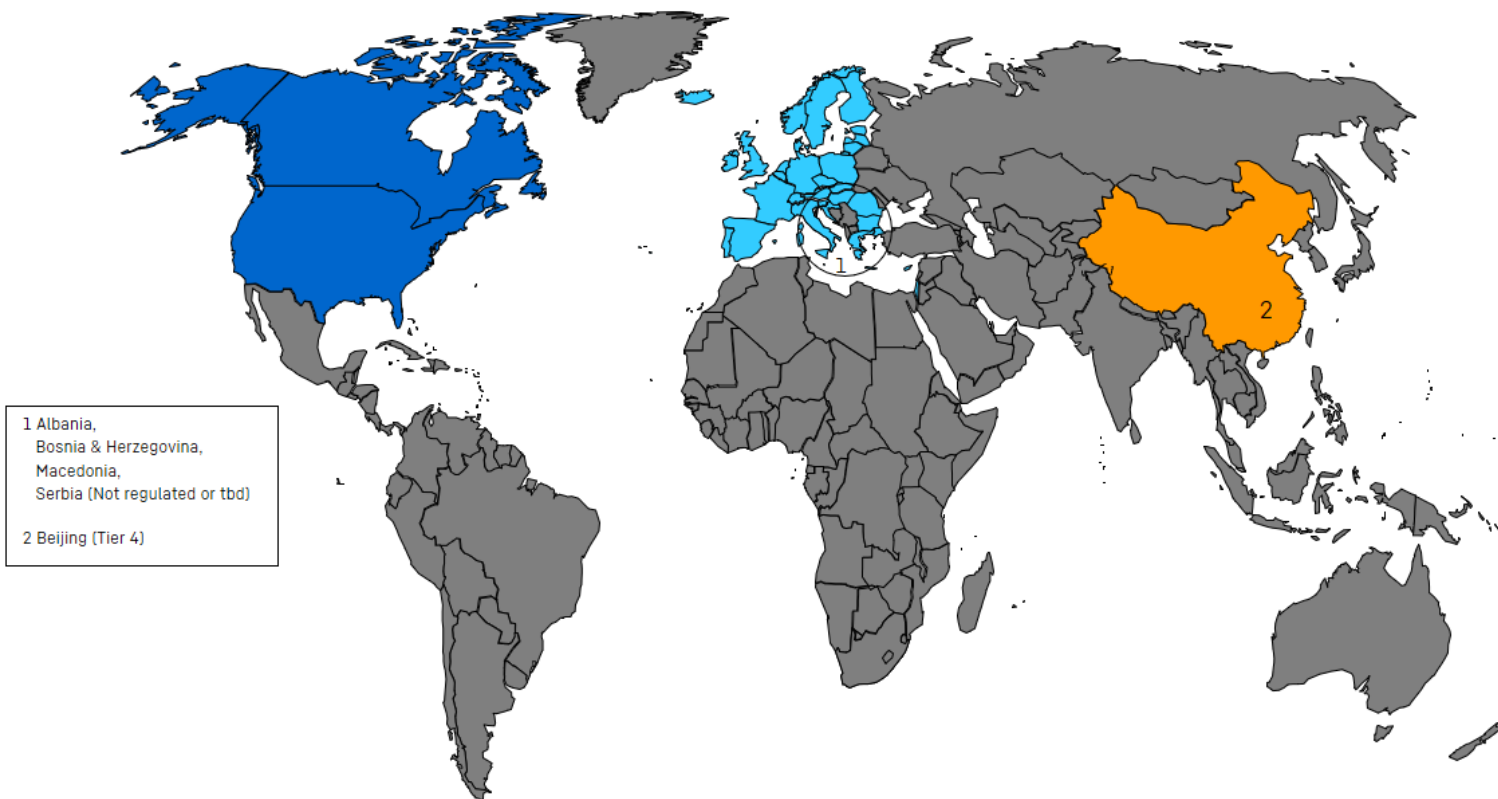
P > 560 [kW]

	NOx [g/kWh]	PM [g/kWh]	PN [#/kWh]
Tier 4f	3.5	0.04	
Stage V	3.5	0.045	--

there are no PN limits  
for the Power range  
>560kW

Low PN emission and BAT as well for engines > 560 kW ?

# NRMM Emissions Regulations P > 560 kW



	Non regulated		GAO III (Tier 2)		Tier 4 final
					Stage V

Tier: USA-EPA Nonroad Regulation (40 CFR 89, 40 CFR 1039 and 40 CFR 1068).  
Stage: Nonroad-Regulation (EU) 2016/1628.

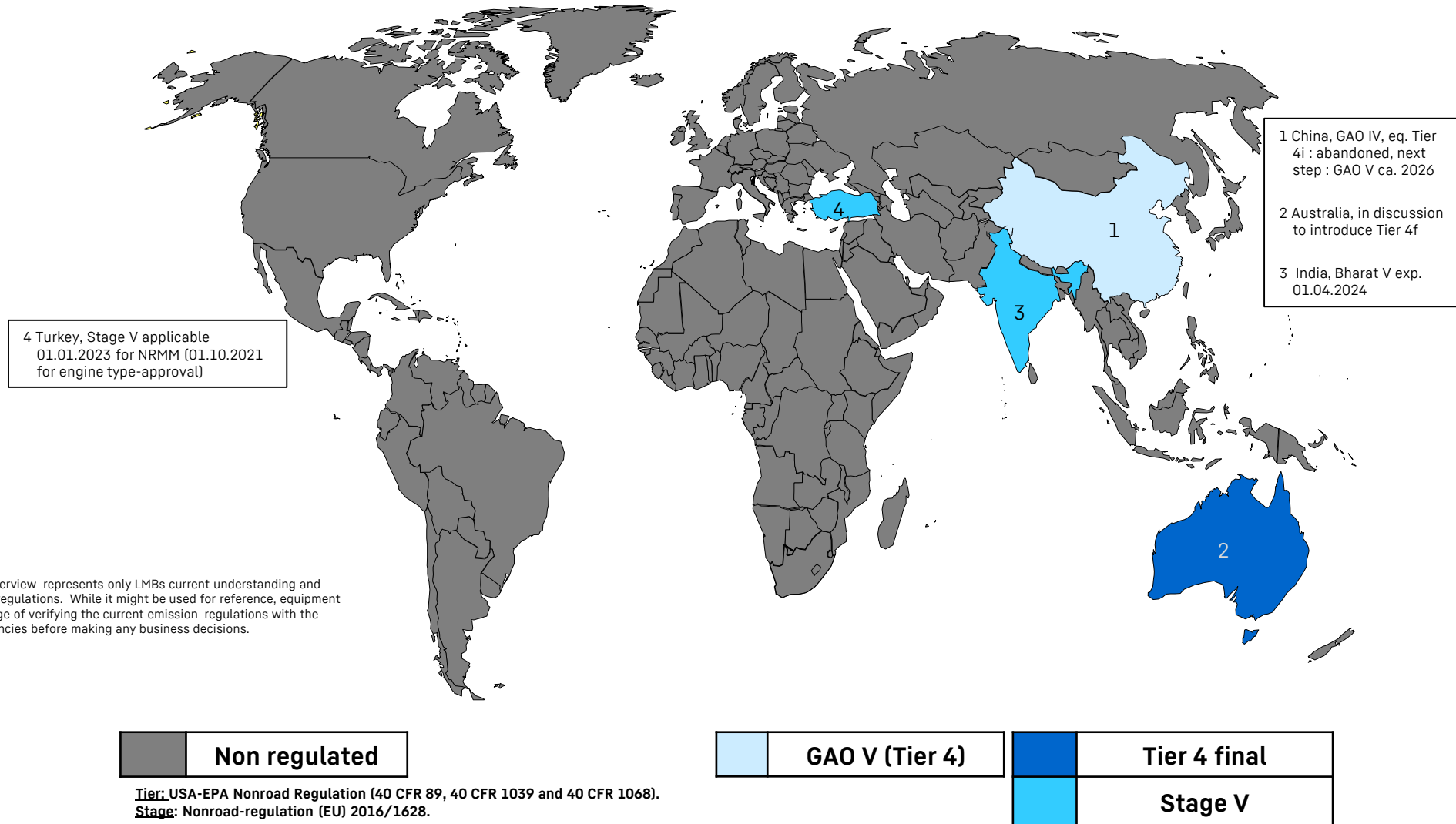
EPA Tier 4 f – P >560kW (1.1.2015)					
Emissions in g/kWh	CO	NO <sub>x</sub>	NMHC	PM	PN
Other than Gen Set	3.5	3.5	0.19	0.04	-
Gen Set	3.5	0.67	0.19	0.03	-

Euro Stage V – P >560kW (1.1.2019)						
Emissions in g/kWh		CO	NO <sub>x</sub>	NMHC	PM	PN
Var. speed		3.5	3.5	0.19	0.045	-
Const. speed	Other than Gen Set	3.5	3.5	0.19	0.045	-
Const. speed	Gen Set	3.5	0.67	0.19	0.035	-

The following emissions overview represents only LMBs current understanding and interpretation of emission regulations. While it might be used for reference, equipment manufacturer's are in charge of verifying the current emission regulations with the appropriate regulatory agencies before making any business decisions.

Low PN emission and BAT as well for engines > 560 kW ?

# NRMM Emissions Regulations P > 560 kW – voted / in discussion





Low PN emission and BAT as well for engines > 560 kW ?

# Agenda

- 1 NRMM >560kW: Applications / population
- 2 current Emission Legislation Stage V / T4f
- 3 **future emission regulations Stage VI /Tier5**
- 4 emission Reduction technologies
- 5 risk of electricity shortages & increased need for decentralized Diesel Power Stations
- 6 summary

## What is the plan in Europe after Stage V?

- EU on road: the EU Commission has delayed the publication of Euro 7, now expected to be in July 2022
- EU NRMM: the EU Commission has cancelled the meeting planned in March, next meeting will be in November. Not much is moving currently in the Non-road sector at EU level.

### WHAT'S THE PROBLEM?

On January 1st 2019, the Regulation entered into its final phase for construction machinery. **Currently, there are no plans for a 'Stage VI'.**

The rules only applies to **new machines entering the market.**

Machines last around 15 years. **It will take minimum 15 years for all construction machinery to be Stage V.**

In the meantime, **CO2 emissions from NRMM remain unregulated at EU-level.**



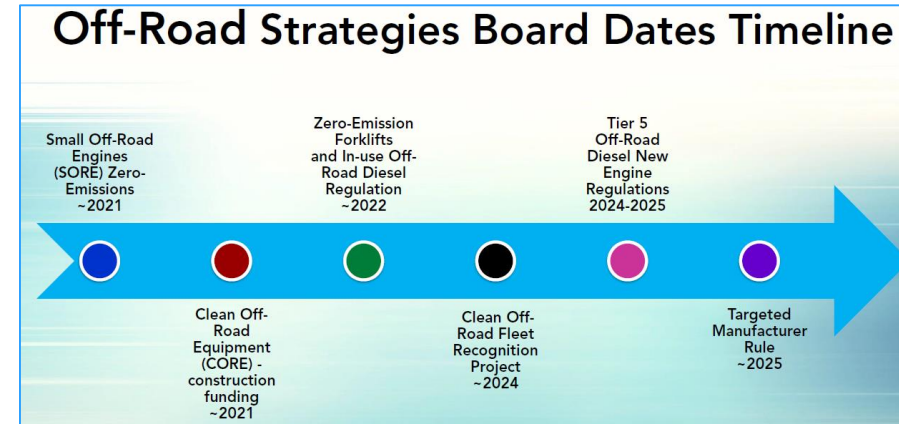
Low PN emission and BAT as well for engines > 560 kW ?

## What is the plan in the USA after Tier4f ? : CARB Proposal



**CALIFORNIA**  
AIR RESOURCES BOARD

**Tier 5 Rulemaking Workshop**  
Potential Amendments to the  
Off-Road Diesel New Engine Regulations  
November 3, 2021



### The Need for Tier 5 Standards

- Current Tier 4 Final off-road diesel standards for new engines do not reflect best available control technologies (BACT)
  - Over 50% of Tier 4 Final engines are certified without Diesel Particulate Filters (DPFs)
- Additional emission reductions are needed for attainment of federal and State ambient air quality standards
- Off-road emissions disproportionately affect disadvantaged communities
- Current test cycles may not adequately demonstrate emissions control during low load off-road engine operation

Low PN emission and BAT as well for engines > 560 kW ?

## What is the plan in the USA after Tier4f ? : CARB Proposal

### Potential Tier 5 Standards

#### Criteria Pollutants

- Staff is considering (with respect to Tier 4f standards):
  - Up to 75% reduction in NO<sub>x</sub> and PM for diesel engines < 56 kW
  - 90% / 75% reduction in NO<sub>x</sub> / PM for engines 56 ≤ kW ≤ 560
  - 50% reduction in NO<sub>x</sub> and PM for engines > 560 kW
  - No changes for NMHC and CO
  - Equipment ≤ 19 kW to be zero emission
    - Electric equipment is already commercially available

Standards						
Current U.S. EPA and CARB Emission Standards						
Tier 4 Final Criteria Pollutants						
Tier 4 Final Exhaust Emission Standards after 2014 Model Year (g/kW-hr)						
Power Category	Application	PM	NO <sub>x</sub>	NMHC	NO <sub>x</sub> +NMHC	CO
< 19 kW (< 25 HP)	All	0.40			7.5	6.6
19 ≤ kW < 56 (25 ≤ HP < 75)	All	0.03			4.7	5.0
56 ≤ kW < 130 (75 ≤ HP < 175)	All	0.02	0.40	0.19		5.0
130 ≤ kW ≤ 560 (175 ≤ HP ≤ 750)	All	0.02	0.40	0.19		3.5
> 560 kW (> 750 HP)	Gen Sets	0.03	0.67	0.19		3.5
	Mobile Machines	0.04	3.5	0.19		3.5



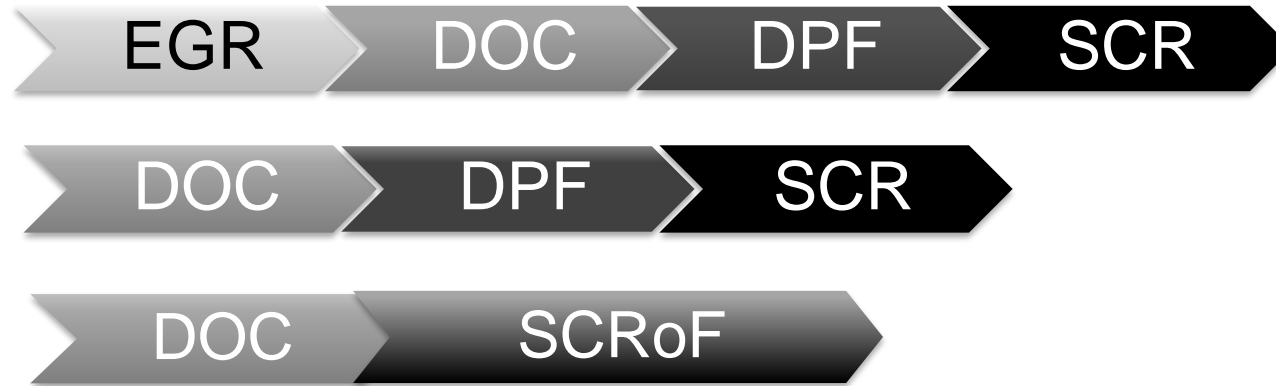
Low PN emission and BAT as well for engines > 560 kW ?

# Agenda

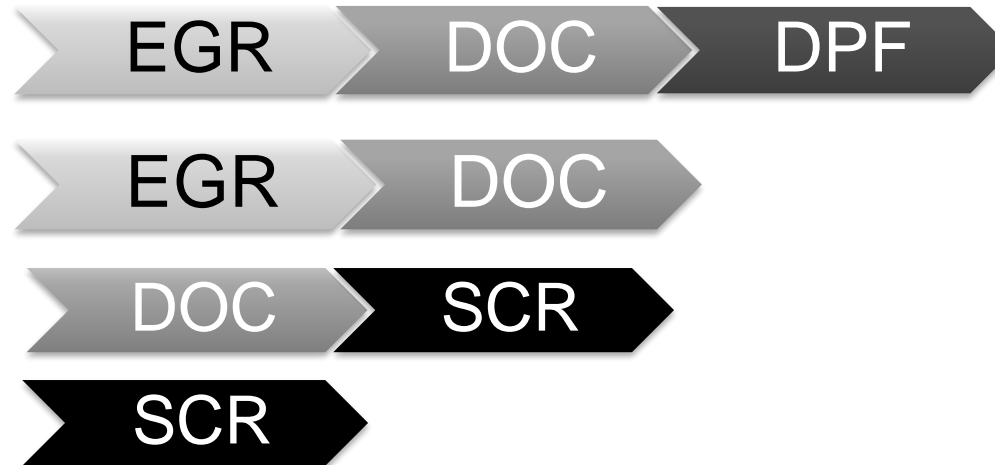
- 1 NRMM >560kW: Applications / population
- 2 current Emission Legislation Stage V / T4f
- 3 future emission regulations Stage VI /Tier5
- 4 **emission Reduction technologies**
- 5 risk of electricity shortages & increased need for decentralized Diesel Power Stations
- 6 summary

Low PN emission and BAT as well for engines > 560 kW ?

## **19 < P[kW] < 560: different solutions to achieve stage V → DPF necessary**

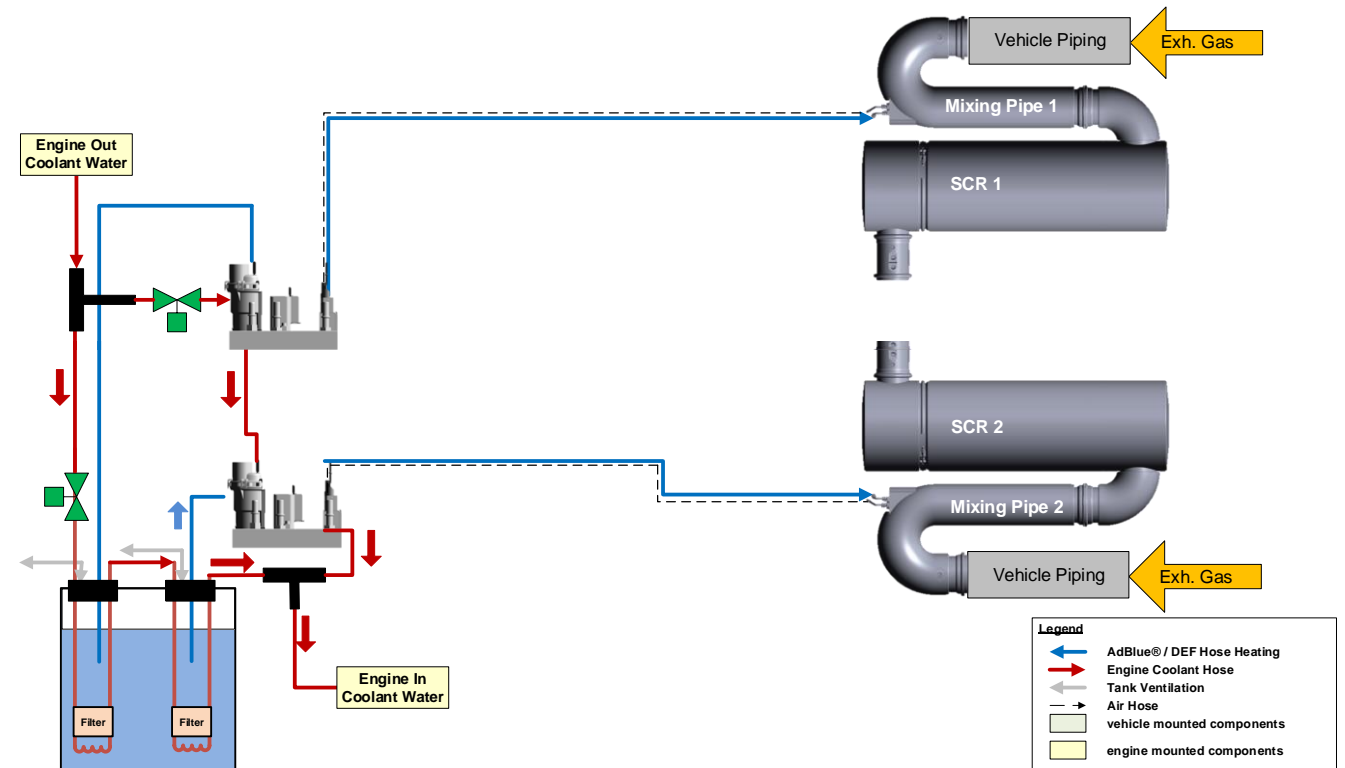
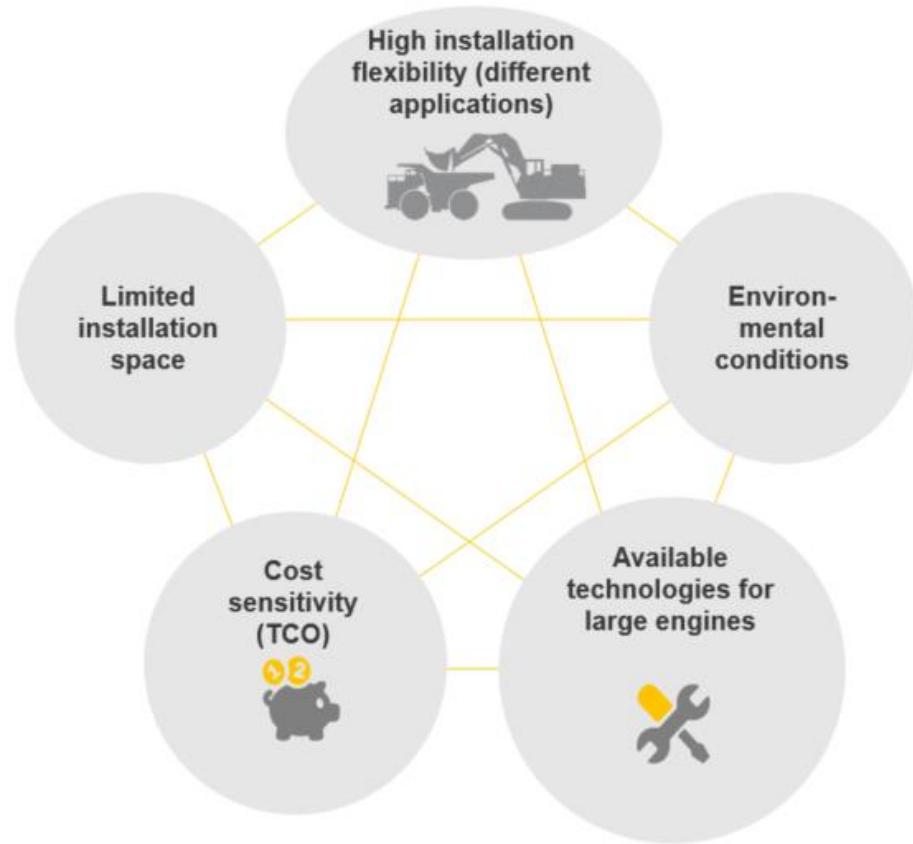


## **P[kW] > 560: different solutions to achieve stage V → DPF not necessary**



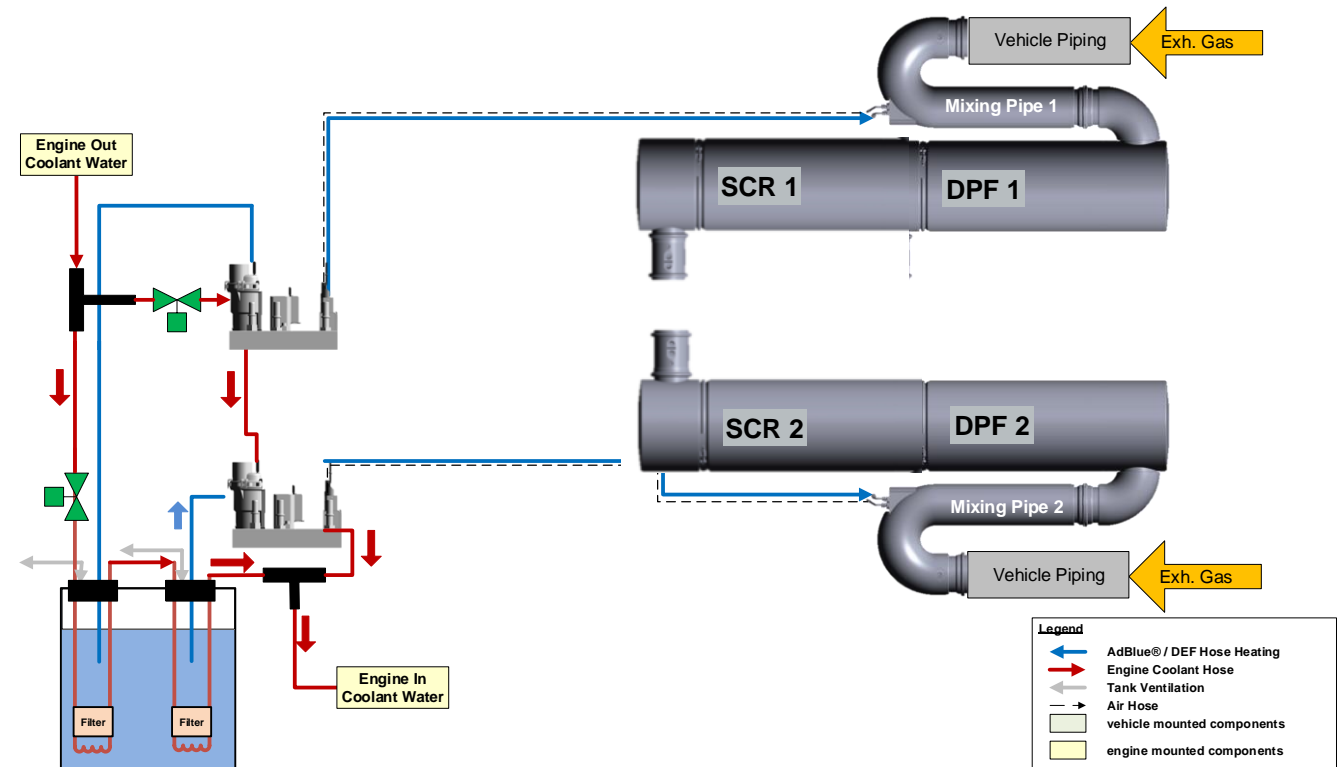
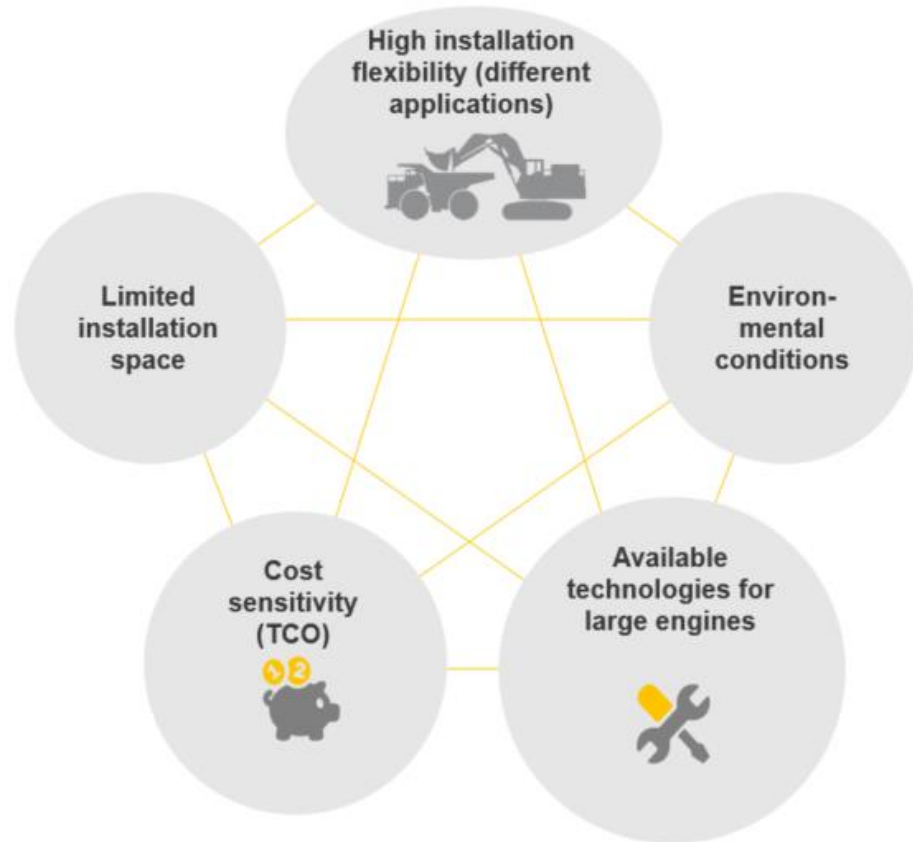
Low PN emission and BAT as well for engines > 560 kW ?

# Challenges for the development of EATS for engines P>560kW



Low PN emission and BAT as well for engines > 560 kW ?

# Challenges for the development of EATS for engines P>560kW





Low PN emission and BAT as well for engines > 560 kW ?

# Boundary Conditions for Engine & EATS : an Overview

Humidity



Altitude



Thermal Management



Fuel Sensitivity



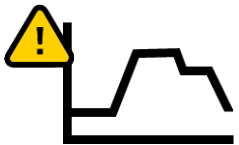
Dust



Shock & Vibration



Transient Operation



Costs



Operation Time



Water



Heat



Dust



Inclined position



Low temperature

Low PN emission and BAT as well for engines > 560 kW ?

# Agenda

- 1 NRMM >560kW: Applications / population
- 2 current Emission Legislation Stage V / T4f
- 3 future emission regulations Stage VI /Tier5
- 4 emission Reduction technologies
- 5 **risk of electricity shortages & increased need for decentralized Diesel Power Stations**
- 6 summary

Low PN emission and BAT as well for engines > 560 kW ?

# risk of electricity shortages → need for decentralized Diesel Power Stations

**THE HINDU**

MENU  
HOME NEWS OPINION BUSINESS SPORT ENTERTAINMENT CROSSWORD+ SCIENCE

STATES ANDHRA PRADESH KARNATAKA KERALA TAMIL NADU TELANGANA OTHER STATES

NEWS > NATIONAL > KERALA

**KERALA**

## Power shortage: KSEB to operate diesel plant

 Tiki Rajwi

THIRUVANANTHAPURAM OCTOBER 18, 2021 18:13 IST  
UPDATED: OCTOBER 18, 2021 18:15 IST

SHARE ARTICLE | f | t | r | w | e | p | PRINT | A | A | A

**128-MW KDPP at Nallalam last saw operations in February this year**

The Kerala State Electricity Board (KSEB) has given the go-ahead for operating its Kozhikode Diesel Power Plant (KDPP) as part of the efforts to overcome the power shortage triggered by a coal crisis.

The 128-MW KDPP at Nallalam last saw commercial operation between December 2020 and February this year.

According to the KSEB, running the plant on light diesel oil (LDO) will be less expensive than purchasing power from the open market where per unit prices had touched ₹20.

**FINANCIAL TIMES**

HOME WORLD US COMPANIES TECH MARKETS CLIMATE OPINION WORK & CAREERS LIFE & ARTS HOW TO SPEND IT

Become an FT subscriber to read:

## China power crisis sparks rush for generators from factories

## Should we expect more power cuts in future?

**BBC NEWS**

By Douglas Fraser  
Business and economy editor, Scotland



1 February 2022

**SWI** swissinfo.ch

**#NOTHING TO HIDE**

Swiss Politics

Swiss perspectives in 10 languages

## Swiss companies told to brace for electricity shortages

Low PN emission and BAT as well for engines > 560 kW ?

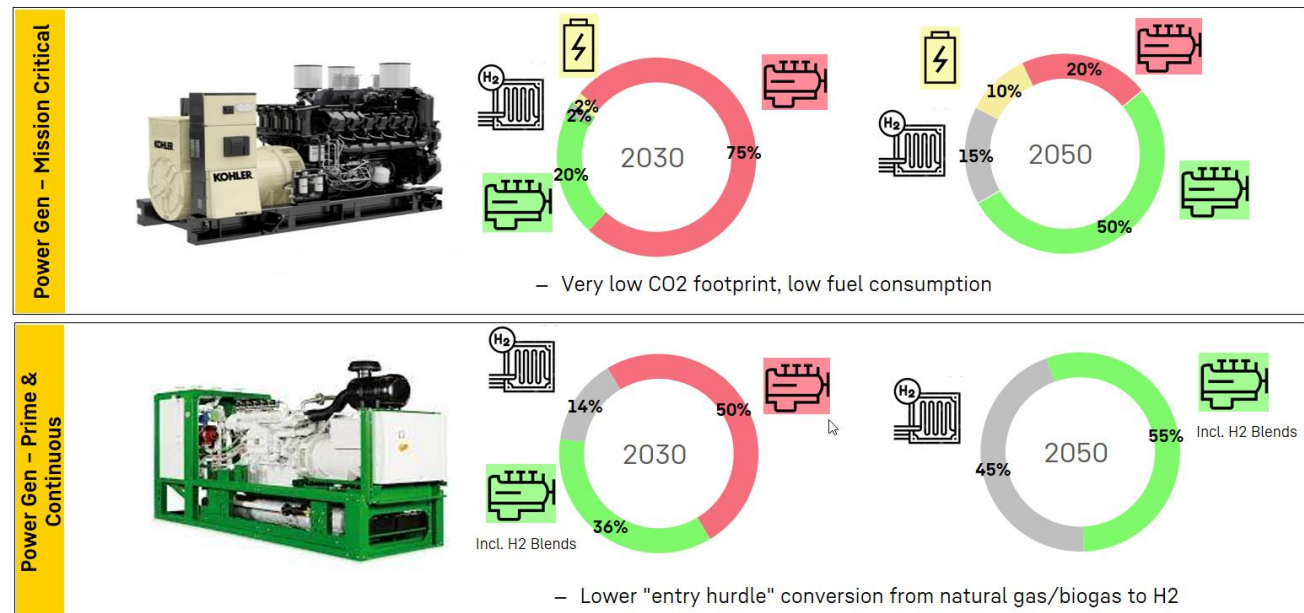
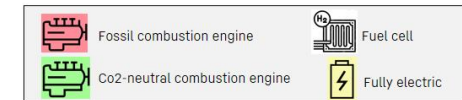
## Risk of electricity shortages → need for decentralized Diesel Power Stations

There is a trend to introduce decentralized electric power stations powered by combustion engines to cover the risks of energy shortages during the difficult transition period to zero CO<sub>2</sub> energy generation by solar and wind energy only. **These plants will be close to consumers in urban areas, thus the question of BAT and the use of DPF to reduce the exhaust gas particles, will gain importance.**

Despite the development of alternative fuels & solutions, the main fuel for emergency GENSETs will remain Diesel for the next years

Future drive technology for off-road applications

### Future scenario 2030/2050 – PowerGen





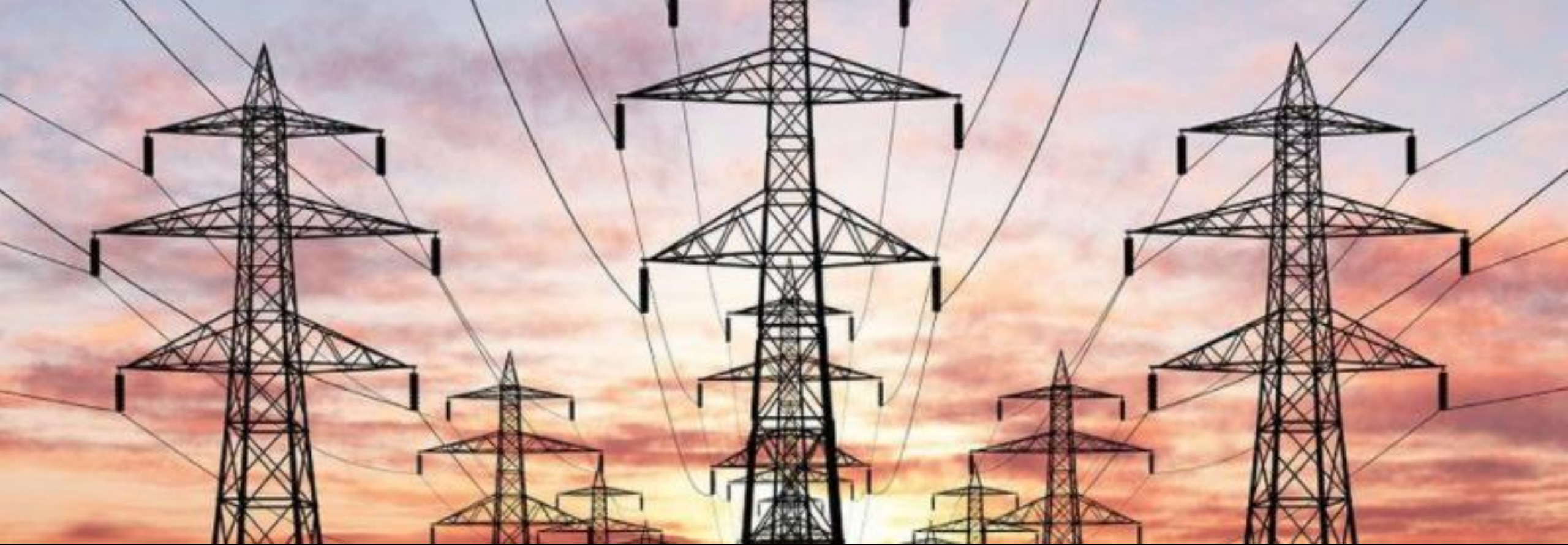
Low PN emission and BAT as well for engines > 560 kW ?

# Agenda

- 1 NRMM >560kW: Applications / population
- 2 current Emission Legislation Stage V / T4f
- 3 future emission regulations Stage VI /Tier5
- 4 emission Reduction technologies
- 5 risk of electricity shortages & increased need for decentralized Diesel Power Stations
- 6 **summary**

## Summary

- With emission standard “stage V” [2019] also emissions of diesel engines > 560 kW are now limited in Europe. However, the limit values for engines > 560 kW are higher than for engines < 560 kW and there is no particle number limit PN, which means that the gravimetric limit values can be achieved without the use of a wall flow DPF.
- The reasons for this decision were, that the fleet of construction machinery with engines > 560 kW in Europe is comparably small and these large machines usually do not operate in urban environments.
- Since 2019 however, new elements have been considered to also use best available technology for this high performance range: there are reflections in Europe and also in the U.S.A. concerning the introduction of a follow up emission stage [Stage VI? / Tier5?]
- There is a trend to introduce decentralized electric power stations powered by combustion engines to cover the risks of energy shortages during the difficult transition period to zero CO<sub>2</sub> energy generation. These plants will be close to consumers in urban areas, thus the question of using BAT, in particular for exhaust gas particles, will gain importance.



**Thank you  
for your interest!**