

# Occupational Health Constraints of Construction Machines in Indoor Operations



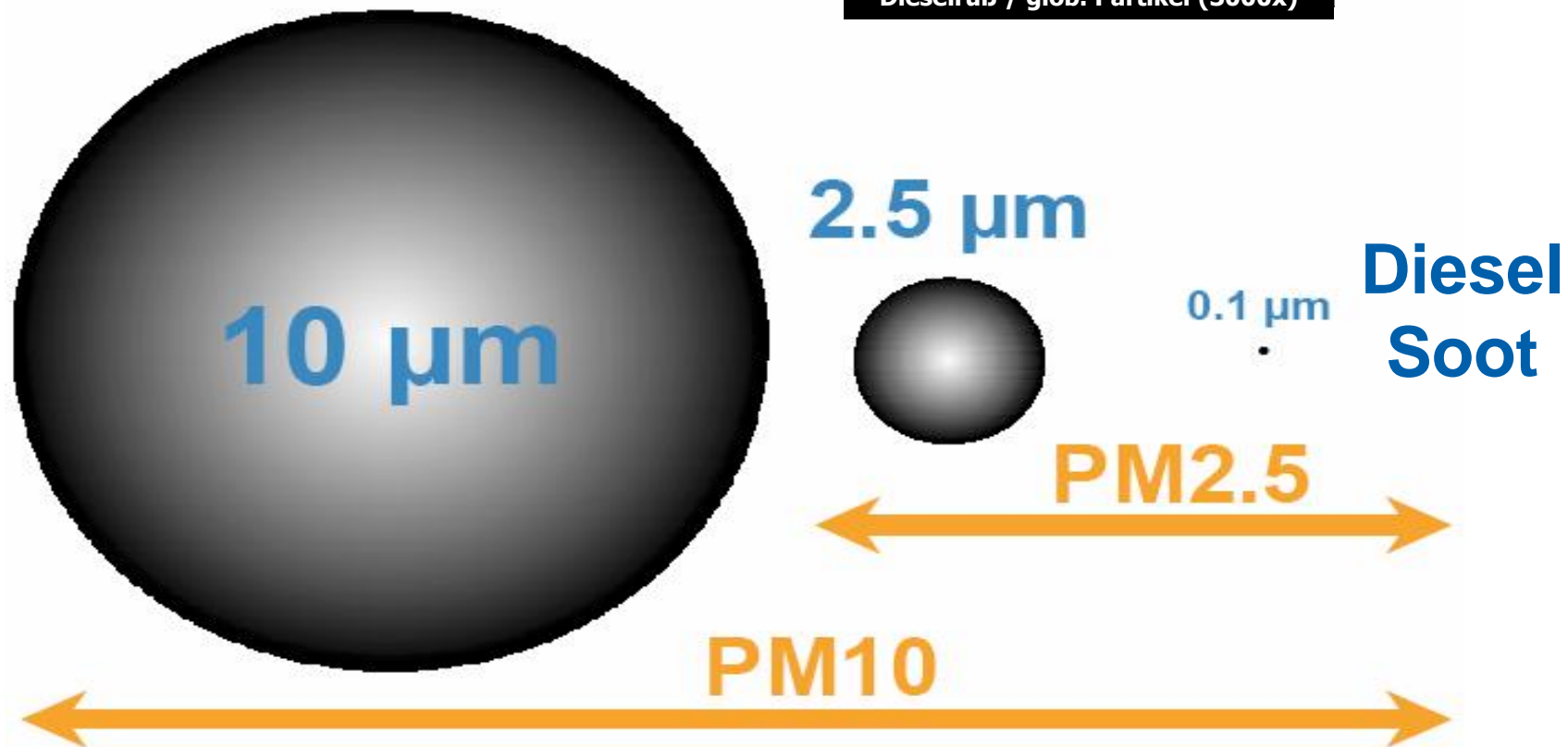
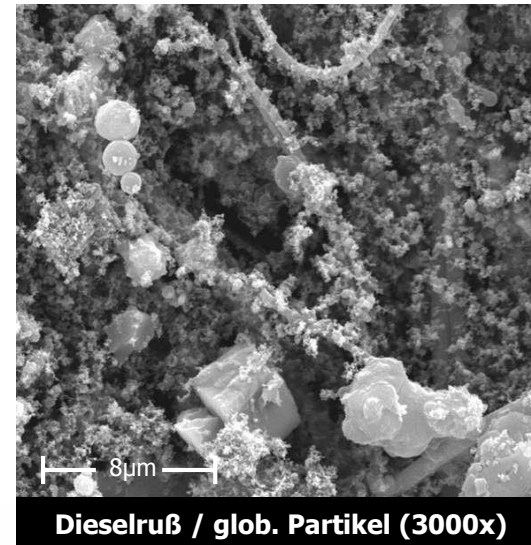
7. VERT Forum  
EMPA Switzerland, 18<sup>th</sup> of March 2016  
Thomas Kaltwasser – Member of VERT Board

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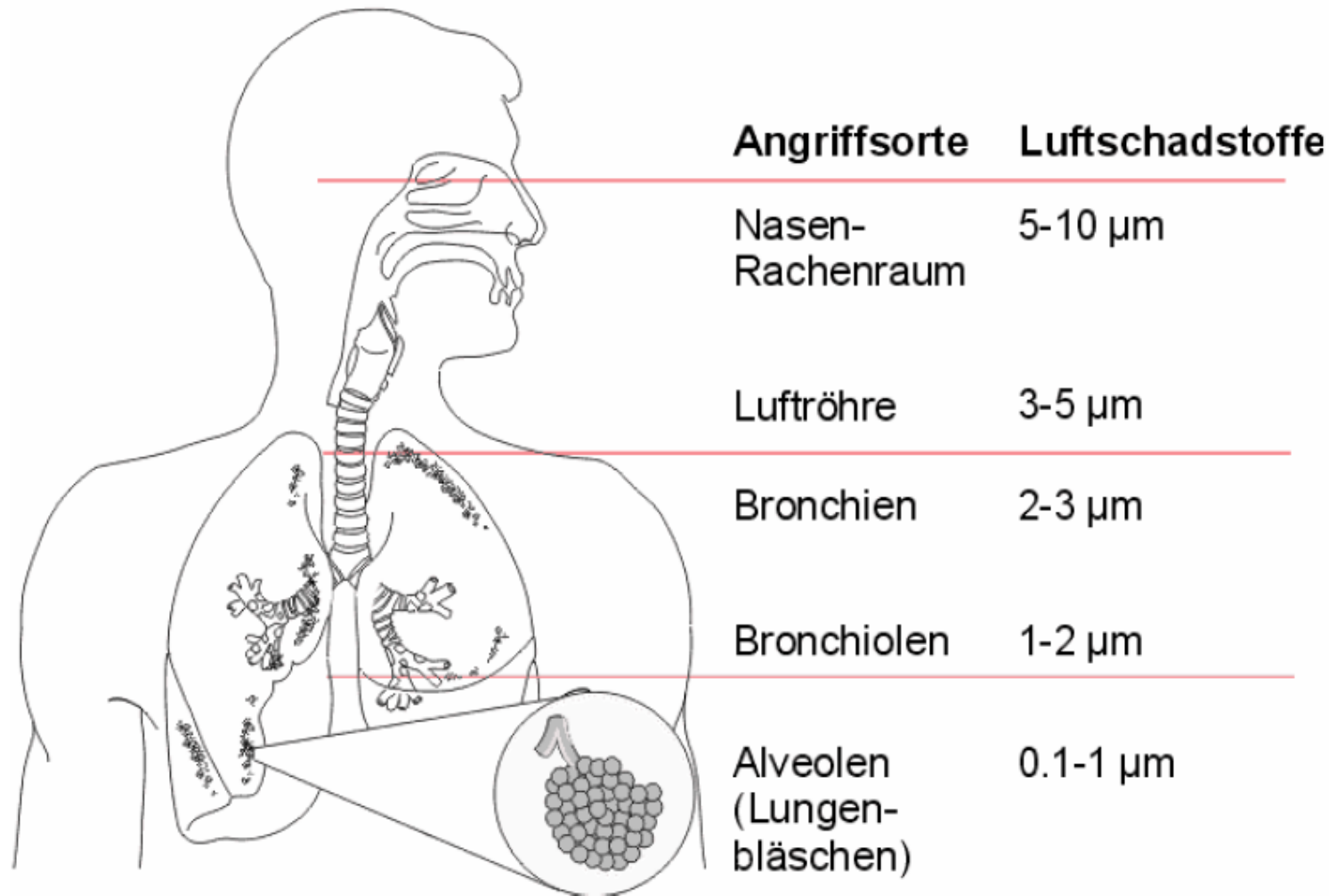
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# PM & PN

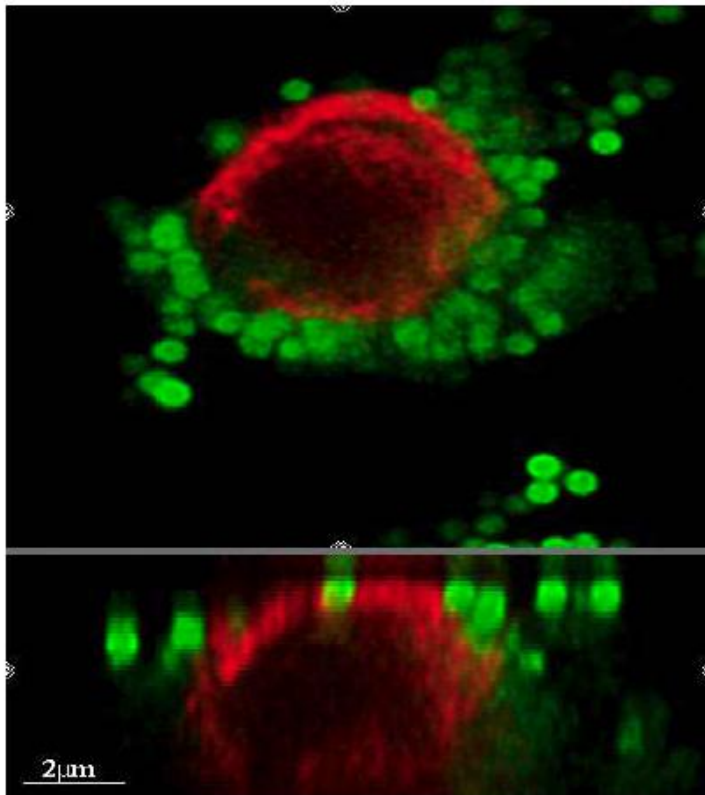


# Health Effects

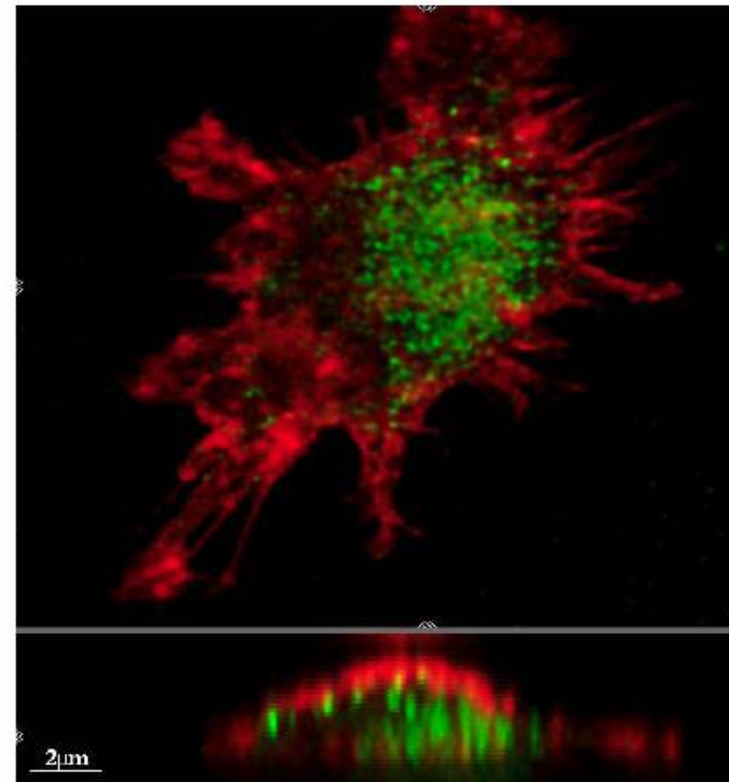


# Health Effects

■ 1000 nm  
Polystyrol Partikel



■ 78 nm  
Polystyrol Partikel



# Health Effects

**SPIEGEL ONLINE WISSENSCHAFT**

Politik | Wirtschaft | Panorama | Sport | Kultur | Netzwelt | Wissenschaft | Gesundheit |

Nachrichten > Wissenschaft > Mensch > Stickstoffdioxid: Diesel-Abgas gefährlicher als gedacht



## **Stickstoffdioxid: Diesel-Abgas gefährlicher als gedacht**

*Von Vlad Georgescu und Marita Vollborn*

**Stickstoffdioxid in der Luft ist offenbar schädlicher als bisher angenommen. Eine Analyse der Gesundheitsdaten von 60 Millionen Europäern hat ergeben, dass das vor allem aus Dieselmotoren stammende Gas schon nach wenigen Tagen die Sterblichkeit messbar erhöht.**

# Tailpipe & Ambient Air Emissions

## Tailpipe

<b>HDV EURO VI 595/2009/EG</b>	<b>NRMM Stage 4 97/68/EG</b>
<b>PM</b> < 0.01 g/kWh	<b>PM</b> < 0.025 g/kWh
<b>PN</b> < 6x10 <sup>11</sup> 1/kWh	
<b>NO<sub>x</sub></b> < 0.46 g/kWh	<b>NO<sub>x</sub></b> < 0.4 g/kWh

## Ambient Air

<b>EU Cities 2008/50/EG</b>	<b>Occupational Health TRGS554 (Germany), MAK</b>	
<b>PM 2.5</b> Annual average < 25 µg/m <sup>3</sup>	<b>DME</b> Minimisation Order	
<b>NO<sub>2</sub></b> Annual average < 40 µg/m <sup>3</sup>	<b>NO<sub>2</sub></b> 0.95 mg/m <sup>3</sup>	<b>NO</b> 0.63 mg/m <sup>3</sup>



# Occupational Health

- Different regulations country by country
- BMAS → BAuA → TRGS554: DME
- Policed by Occupational Insurance Association (BG) & Trade Control (GWA)

## DME:

- cancerogenic according to MAK list Cat 2, lung cancer
- cancerogenic for humans according to IARC (WHO) Group 1
- Minimisation order



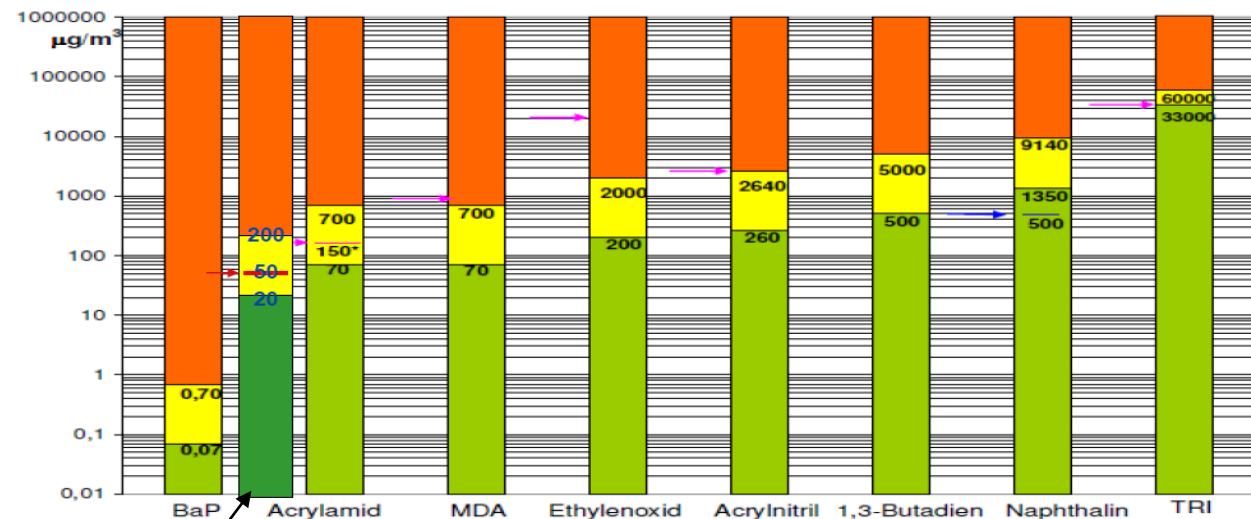


# Minimisation Order

Current policy of BG for indoor operations:

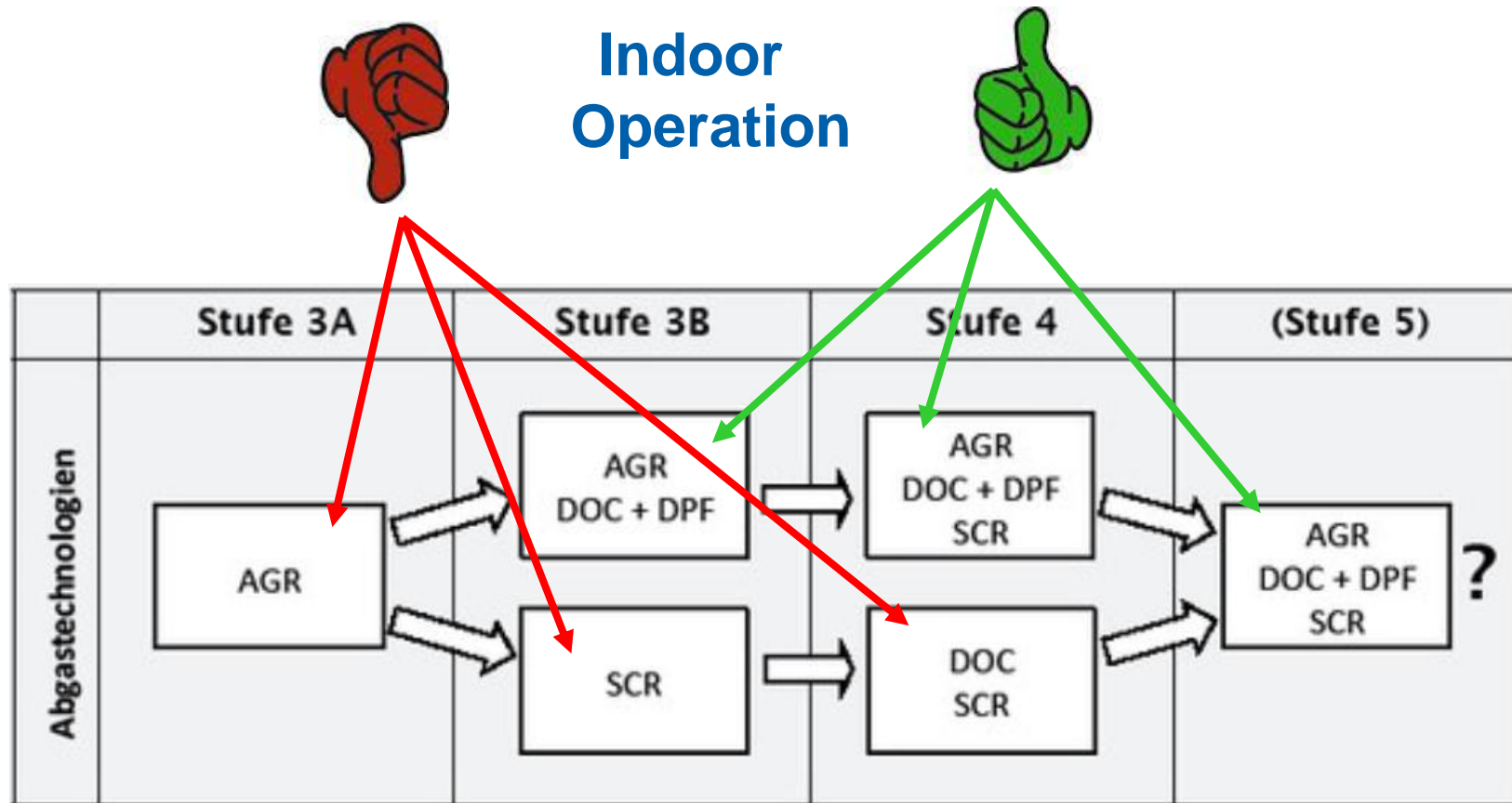
- Diesel equipment okay if fitted with DPF (min. 90% efficiency)
- Stage 3b/4 is not okay without DPF
- Indoor definition: at the latest when roofed over

Future standard for TRGS554 renewal:  
50 µg/m<sup>3</sup>



DME Level for  
new TRGS554 (in  
discussion)

# Emission Technologies for NRMM



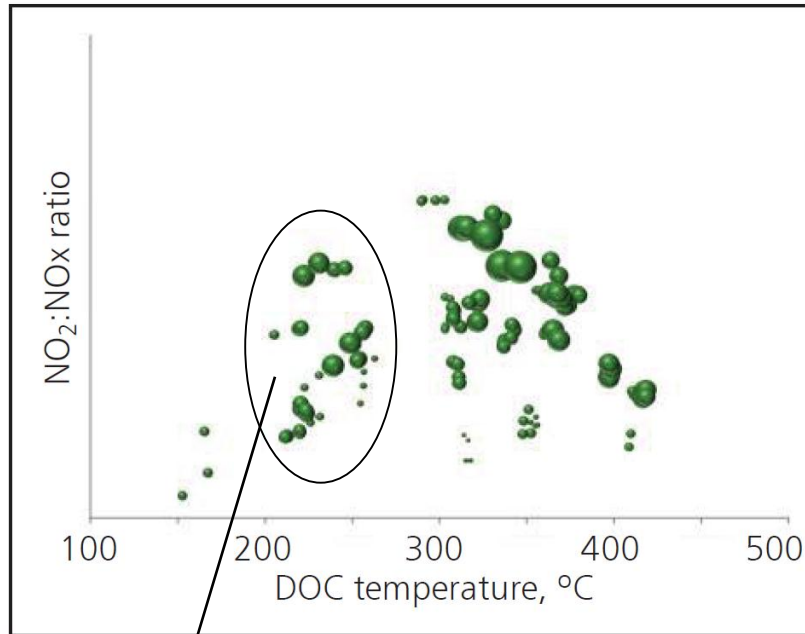
**Current  
standard**  
19 – 37 kW

**Current  
standard**  
37 - 56 kW

**Current  
standard**  
56 – 560 kW

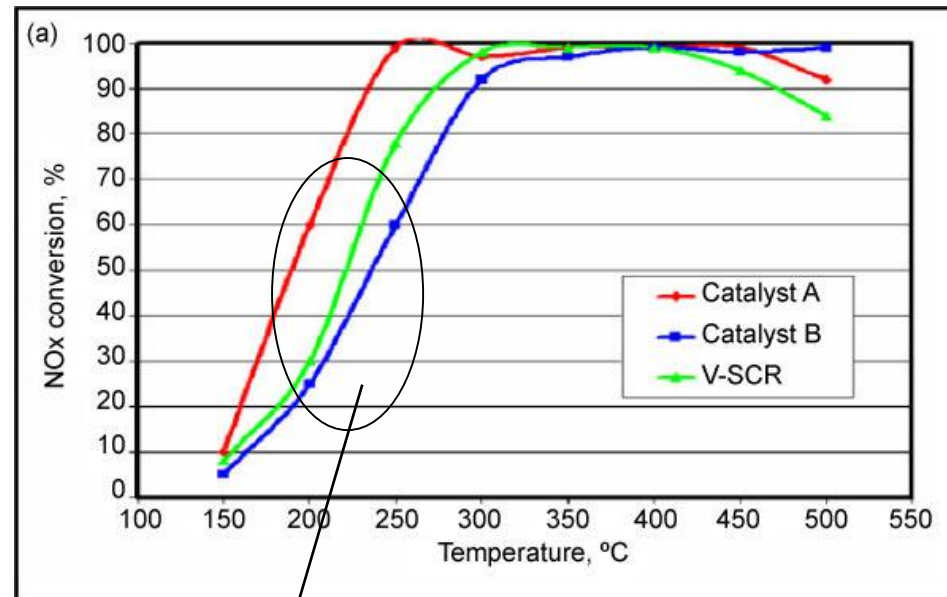
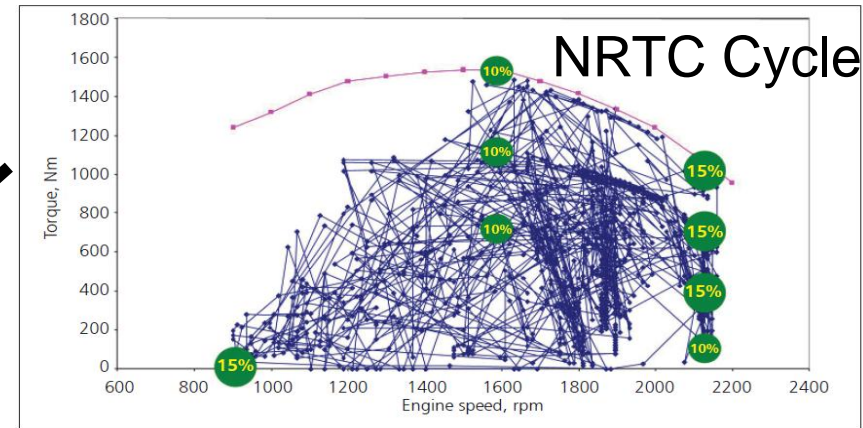
**Future  
standard**  
19 – 560 kW

# NO<sub>2</sub> Challenge



Elevated NO<sub>2</sub> concentrations generated by DOC from 200°C onwards

TRGS554 Renewal:  
Proposal to reduce  
NO<sub>2</sub> MAK value to 0.05 mg/m<sup>3</sup>



SCR Catalyst cannot fully compensate for elevated NO<sub>2</sub> output

Source: *Platinum Metals Rev.*

# Solutions for Non-Indoor Compliant Vehicles

	OE Solution	Retrofit Solution
<b>Stage 3a</b> <b>EGR only</b>	<ul style="list-style-type: none"> <li>• No DPF First Fit</li> <li>• Occasionally DPF Optional Fit</li> <li>• Delegation to Dealer Level</li> </ul>	<ul style="list-style-type: none"> <li>• DPF Retrofit Commonly Available</li> <li>• EGR challenging for DPF Application → Backpressure</li> </ul>
<b>Stage 3b/4</b> <b>SCR</b> <b>DOC + SCR</b>	<ul style="list-style-type: none"> <li>• Occasionally DPF First and Optional Fit</li> <li>• No DPF Retrofit Allowance or Delegation to Dealer Level</li> </ul>	<ul style="list-style-type: none"> <li>• DPF Retrofit Available</li> <li>• SCR challenging for DPF Application → Space → Temperature → NO<sub>2</sub> → Backpressure</li> </ul>

# OE Strategies for DPF First Fit

Hersteller	DPF	kein DPF	beide Strategien
Caterpillar	X		
John Deere	X		
Volvo	X		
Volvo Penta		X	
CNH		X	
FPT		X	
JCB		X	
MTU		X	
AGCO		X	
Cummins			X
Deutz			X
Perkins			X
Quelle: [Integer, 2013]			IFEU 2014

	Mobilbagger	Raupenbagger	Radlader	Traktoren
DPF	15-20%	20-30%	30-40%	13%
Quellen: [KBA, 2014], [GB, 2011], [Off-Highway Research, 2010] und eigene Annahmen				IFEU 2014

# Challenges for Retrofit Systems

## EGR Challenge

EGR rate increases due to backpressure imposed by DPF (@ partial load)



Engine produces more soot



Filter imposes more backpressure



Engine stalls

**Fix: Larger sized DPF,  
Low BP warning threshold**



## SCR Challenges

Backpressure too high → OBD failure

DPF downstream SCR  
Temperature too low → Regeneration problems

NO<sub>2</sub> low after SCR → Regeneration problems

Space availability

**Fix: Larger sized DPF, Active  
Regeneration, Thermal Insulation**

# Retrofit Solutions



## Mobile Filters

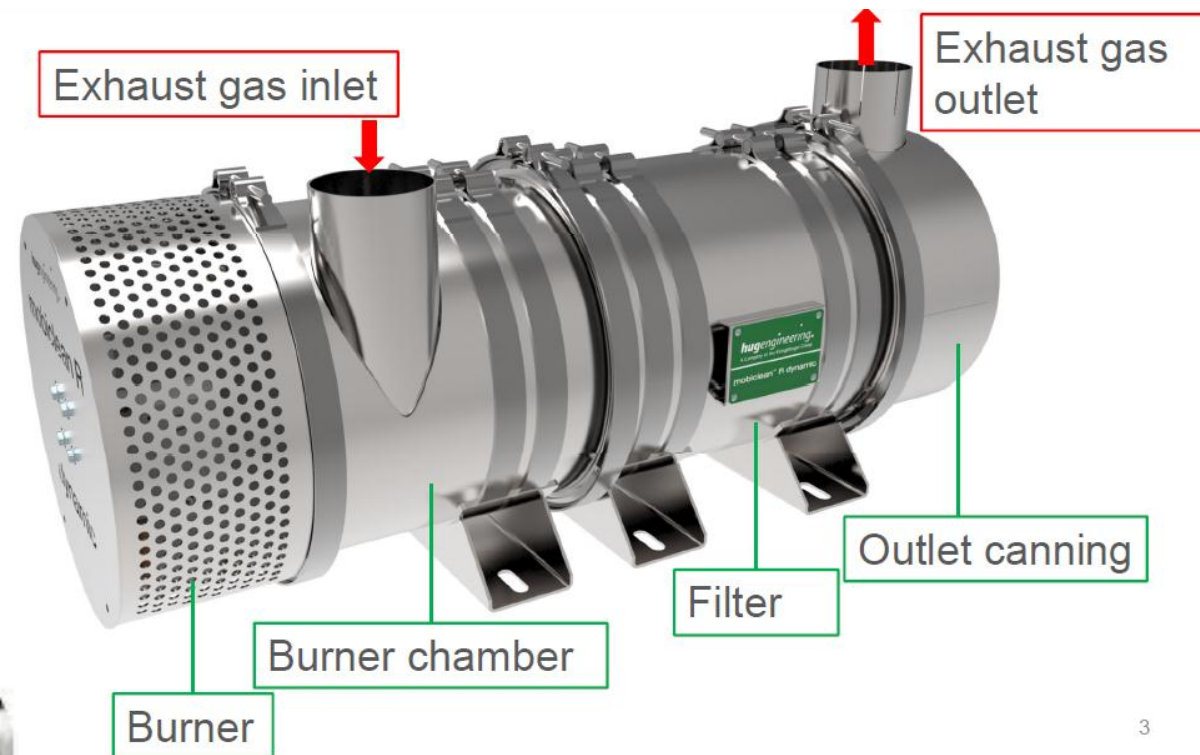
- Useful for short-term operations
- High flexibility
- Economic
- Off-board thermal regeneration or water cleaning



# Retrofit Solutions after SCR

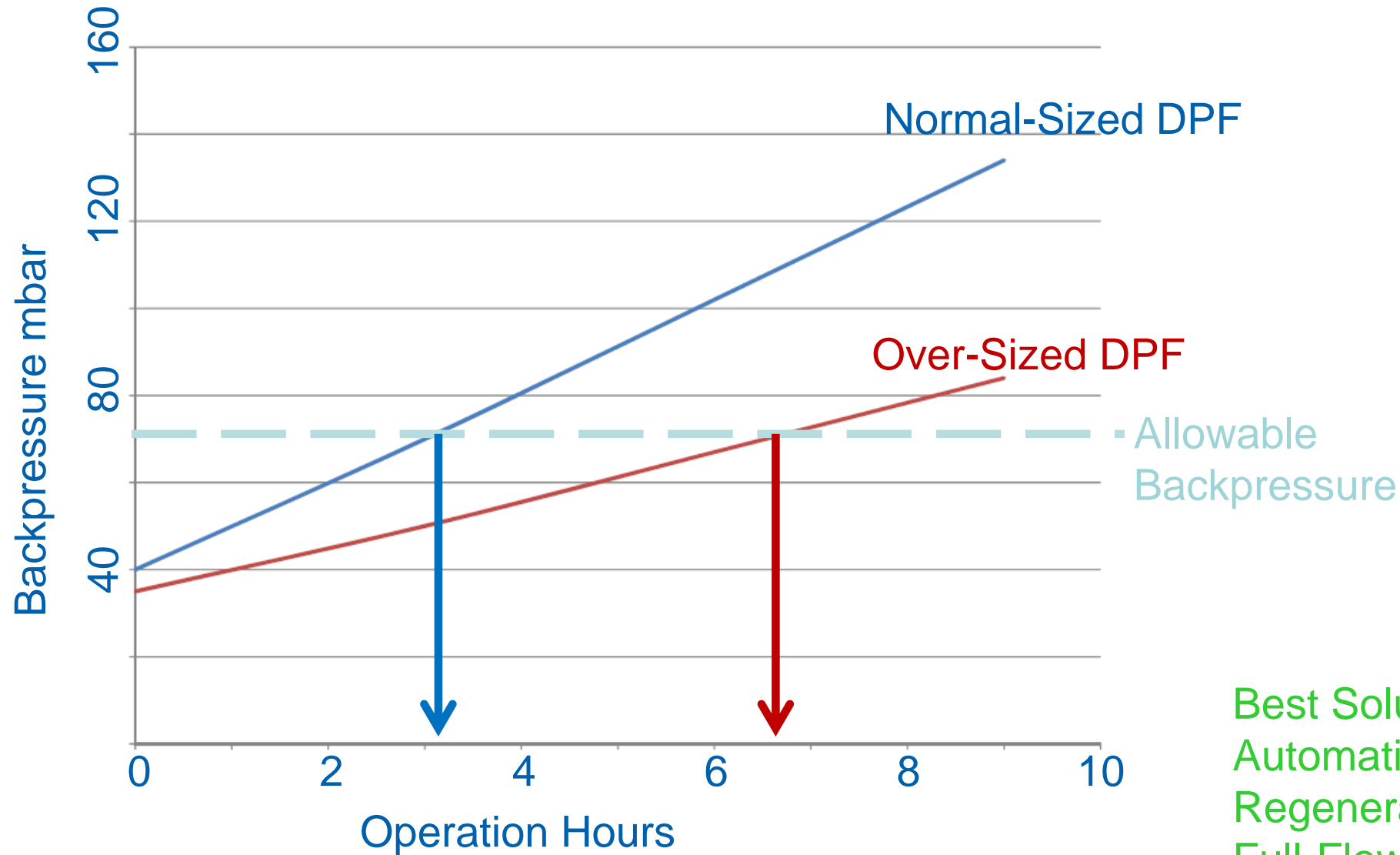
## Active DPF Systems

- Fully integrated
- Independant from engine management
- Active thermo-electric regeneration with FBC
- Active regeneration with burner
- Active regeneration with electric heating





# Problem: Timed Regeneration



Best Solution:  
Automatic On-Demand  
Regeneration with  
Full-Flow Burner

# Examples of Retrofit Systems



## HUG mobilcean R dynamic

- Full-Flow Diesel Burner
- Engine Rating up to 260 kW
- Up to 100 kW Burner Power
- Own Air Supply (electric)
- Automatic Regeneration @ any Operation Point
- Sophisticated Controls and Safety Features
- Compact Design

# Prospects: NRMM Stage 5

Category	Ign.	Net Power	Date	CO	HC	NO <sub>x</sub>	PM	PN
		kW						1/kWh
NRE-v/c-1	CI	P < 8	2019	8.00	7.50 <sup>a,c</sup>		0.40 <sup>b</sup>	-
NRE-v/c-2	CI	8 ≤ P < 19	2019	6.60	7.50 <sup>a,c</sup>		0.40	-
NRE-v/c-3	CI	19 ≤ P < 37	2019	5.00	4.70 <sup>a,c</sup>		0.015	1×10 <sup>12</sup>
NRE-v/c-4	CI	37 ≤ P < 56	2019	5.00	4.70 <sup>a,c</sup>		0.015	1×10 <sup>12</sup>
NRE-v/c-5	All	56 ≤ P < 130	2020	5.00	0.19 <sup>c</sup>	0.40	0.015	1×10 <sup>12</sup>
NRE-v/c-6	All	130 ≤ P ≤ 560	2019	3.50	0.19 <sup>c</sup>	0.40	0.015	1×10 <sup>12</sup>
NRE-v/c-7	All	P > 560	2019	3.50	0.19 <sup>d</sup>	3.50	0.045	-

**New:**  
Particle Number  
Criterion → closed DPF  
systems mandatory!

**New:**  
Engines >560 kW

Occupational Health:



**Thank you!**

**Questions?**