AVL List GmbH (Headquarters)

Impact of particle number limitations on engine and exhaust aftertreatment layout

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Brier, Bernd
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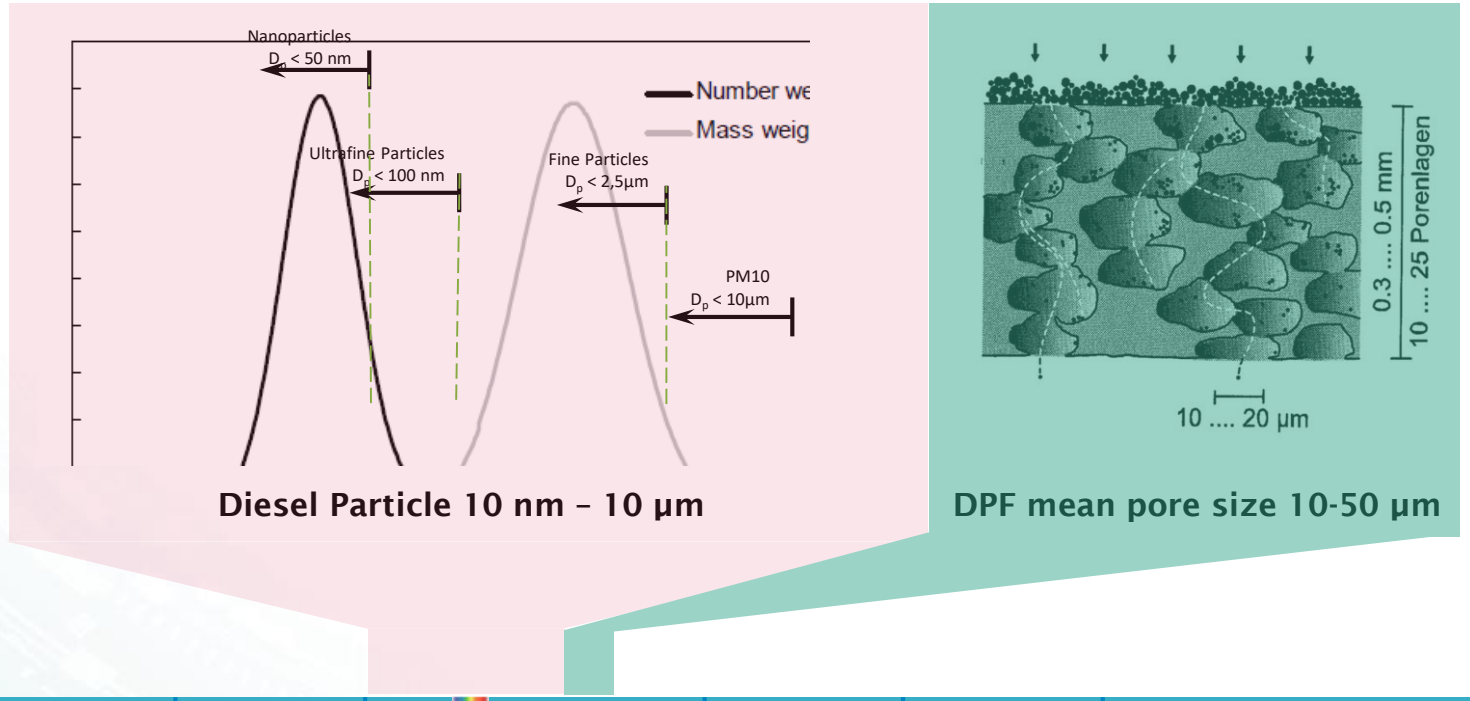
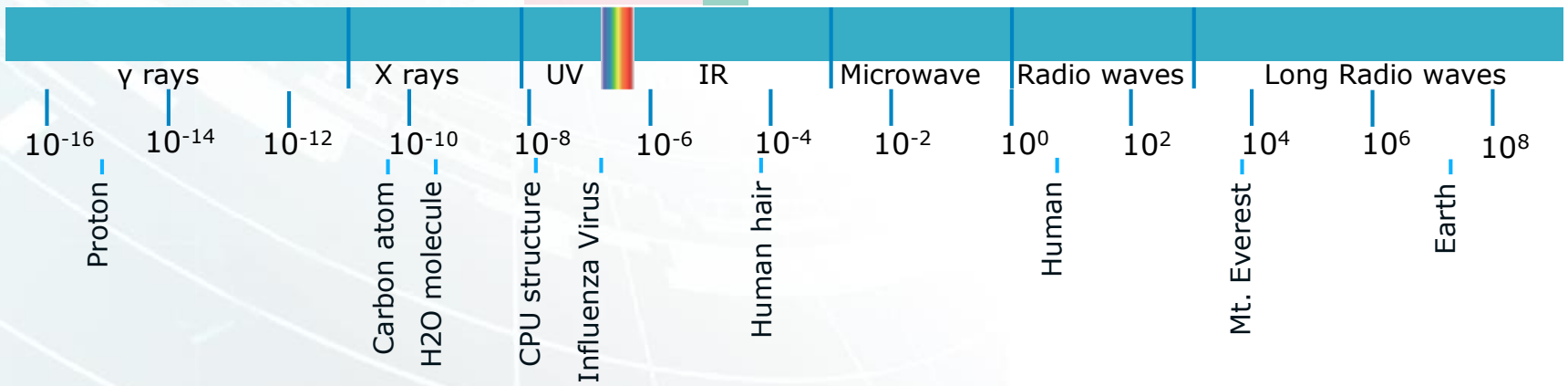
Size ranges of diesel particles





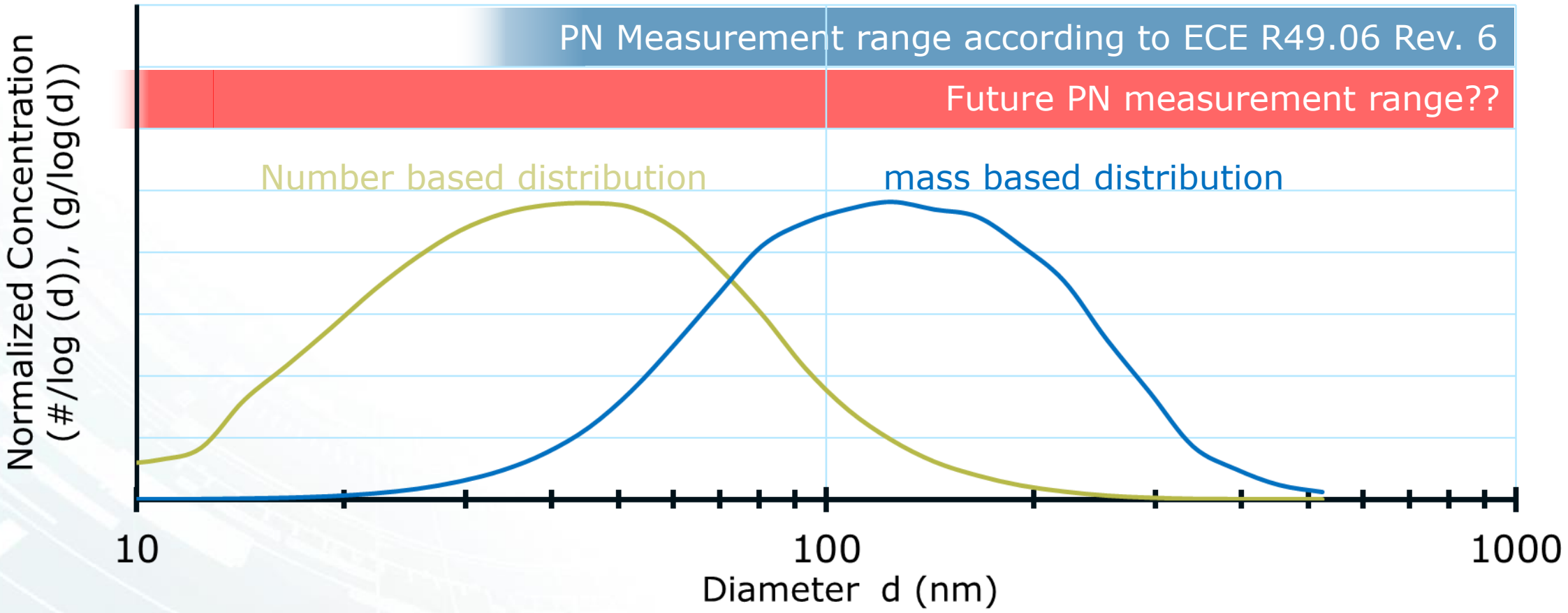
Picture Sources:

HdT-presentation, A. Mayer/TTM Munich 16./17.05.2006

Marko Marjamäki and Jorma Keskinen, Vehicle exhaust particulates characterisation, properties, instrumentation and sampling requirements,
2001, EU Programe: Characterisation of Exhaust Particulate Emissions from Road Vehicles

Measurement range for particle number

Particle size distribution at engine out, during NRTC



Initiative of the UNECE to widen PN measurement range down to 10 nm.
This widening has significant impact on measured PN number (e.g. + 40 %)

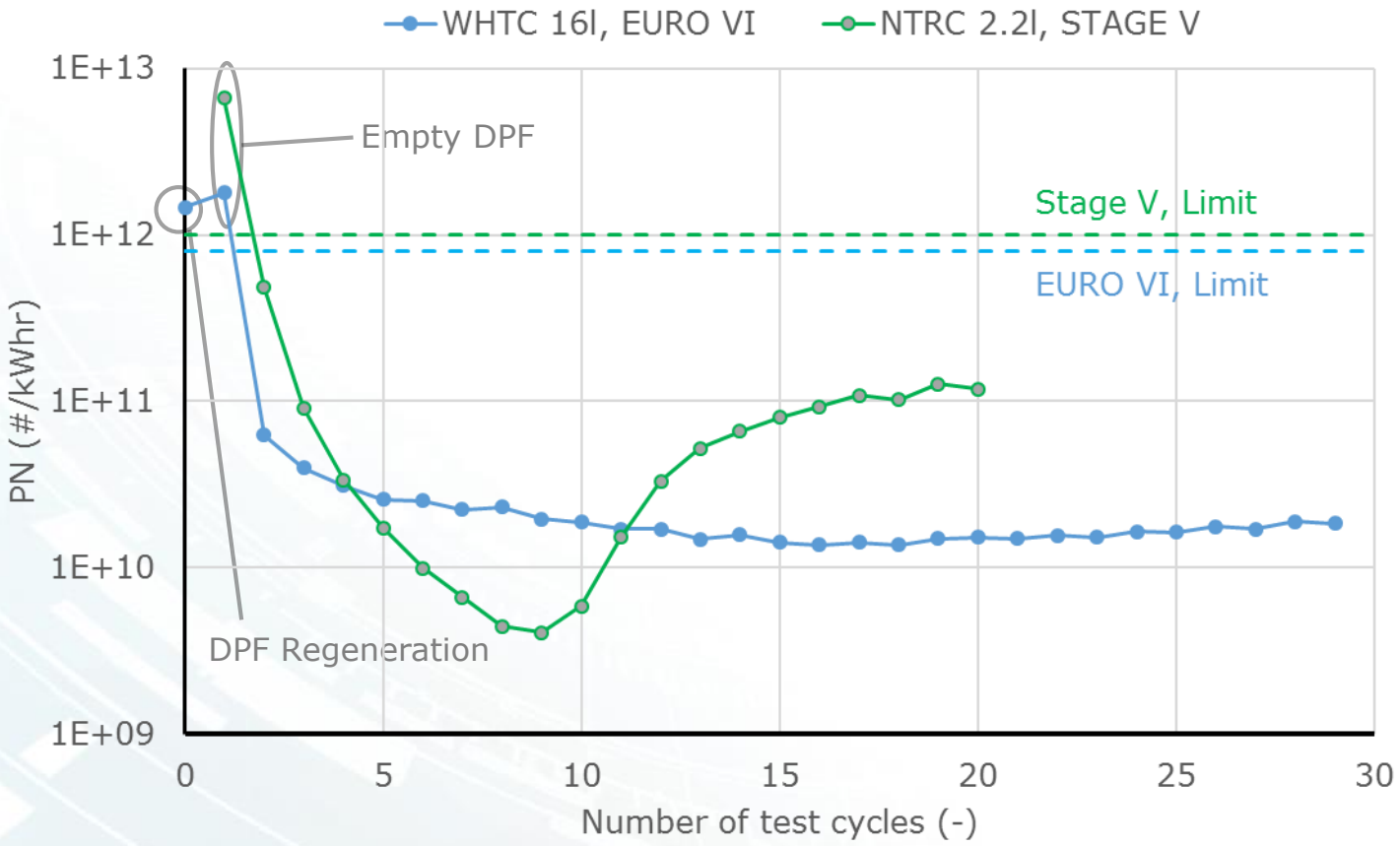
Legislative requirements for particle number emissions (EU EURO VI vs. EU Stage V)

	CO (mg/kWh)	THC (mg/kWh)	NOx (mg/kWh)	NH3 (ppm)	PM (mg/kWh)	PN (#/kWh)
HD EURO VI (CI)						
WHSC	1.5	0.13	0.40	10	10	8e11
WHTC	4.0	0.16	0.46	10	10	6e11
NTE	2.0	0.22	0.60	--	16	--
NRMM EU Stage V (CI, 56 kW < P < 560 kW)						
C1	5.0 / 3.5 **	0.19	0.40	--	15	1e12
NRTC	5.0 / 3.5 **	0.19	0.40	--	15	1e12
NTE	10 / 7	0.38	0.80		30	2e12

** 5.0 for 56 kW < P < 130 kW, and 3.5 for 130 kW < P < 560 kW

Legislative limit for PN quite comparable for EU Euro VI and EU NRMM Stage V (6e11 .. 1e12). However, differences in test conditions increase the difficulty significantly for NRMM application.

Influence of DPF soot loading on DPF filtration efficiency



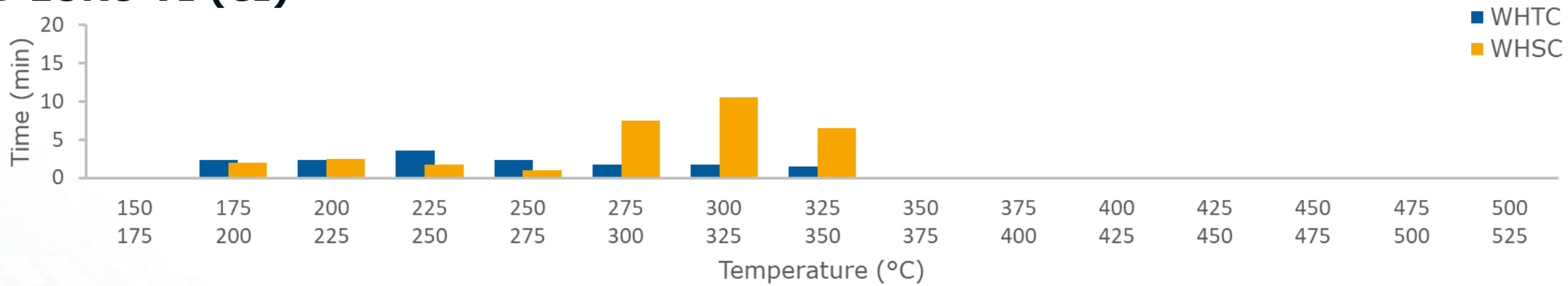
Filtration efficiency of empty DPF typically not sufficient to fulfill PN emission targets.

Small amount of soot cake significantly improves filtration efficiency.

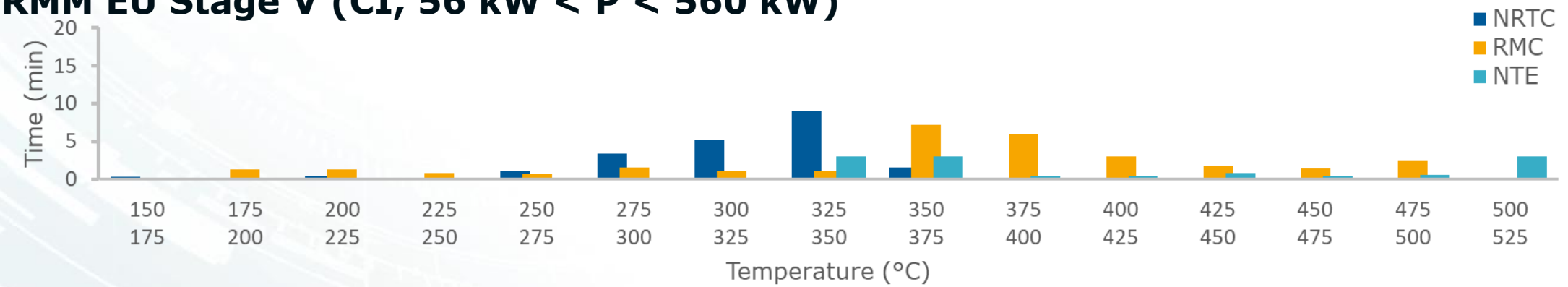
Preconditioning of the DPF is required to fulfil PN emission targets.

Temperature distribution in legislative testcycles

HD EURO VI (CI)



NRMM EU Stage V (CI, 56 kW < P < 560 kW)



Test cycles for NRMM legislation are significantly more challenging in terms of PN emissions. The higher exhaust gas temperatures there suppress soot cake build up at the DPF. Therefore, the DPF PN filtration efficiency is lower.

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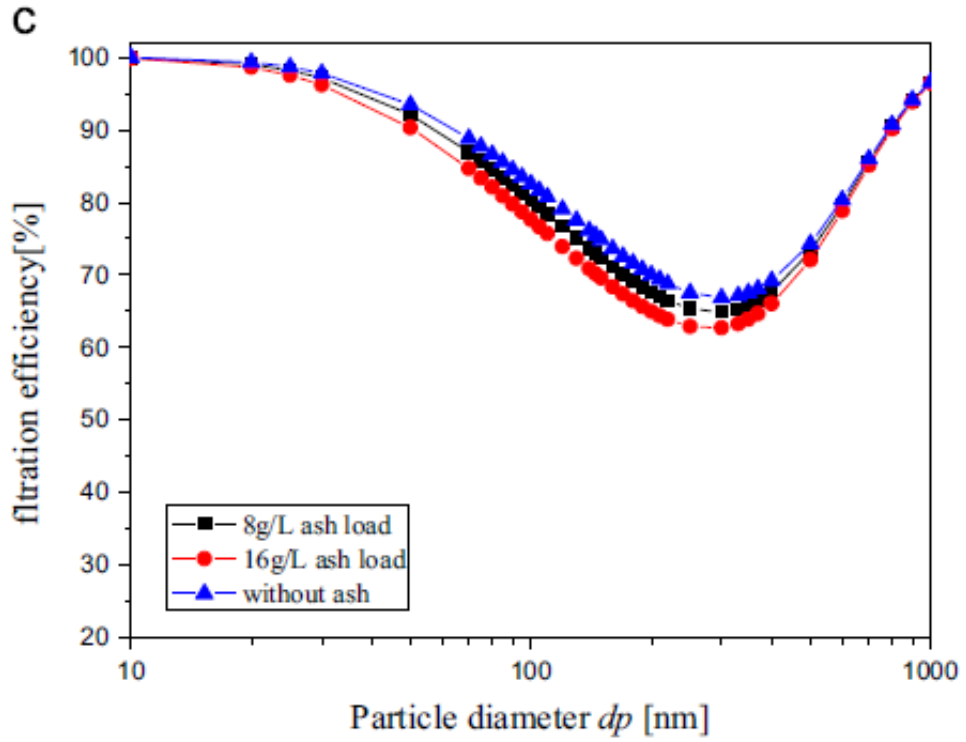
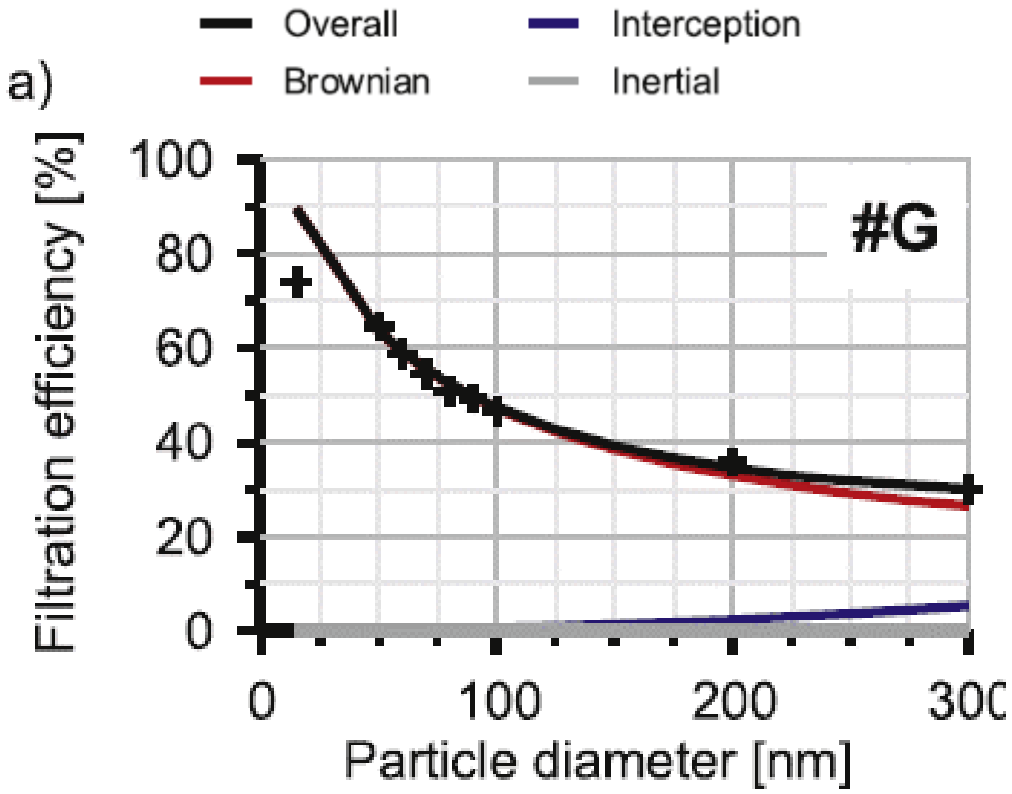
DPF filtration efficiency



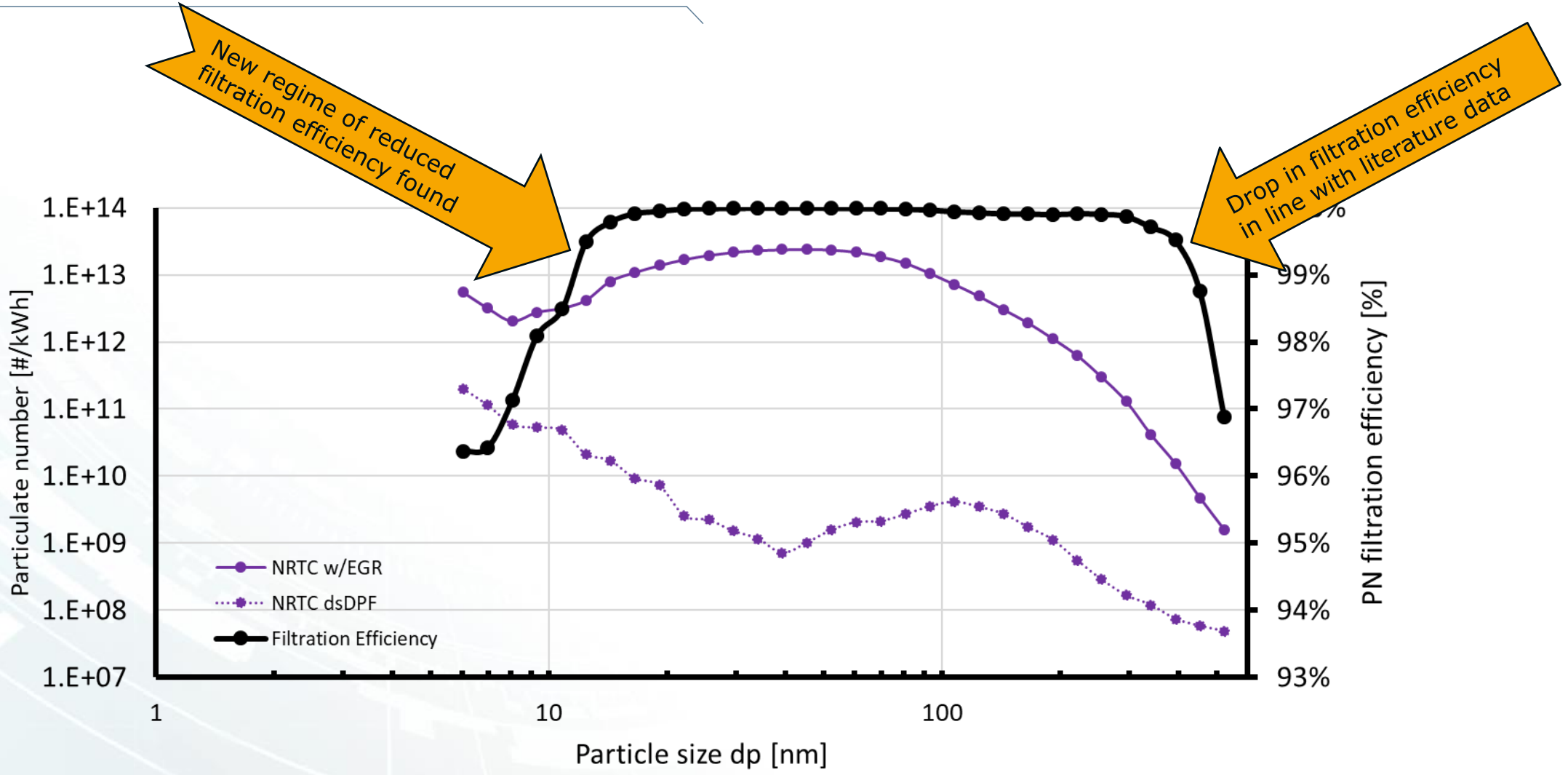
Source: J. Jinag et al., J. Aerosol Sci. 95(2016)
DPF 100/17, Simulation result



Source: Serrano et al., Energy 112 (2016)
Empty DPF 200/12, 18 µm pore

Number based PN filtration efficiency shows minimum in the range of 100 .. 1000 nm.

DPF filtration efficiency



Source: AVL Measurement. Filtration efficiency during NRTC
Empty DPF 300/9, asym

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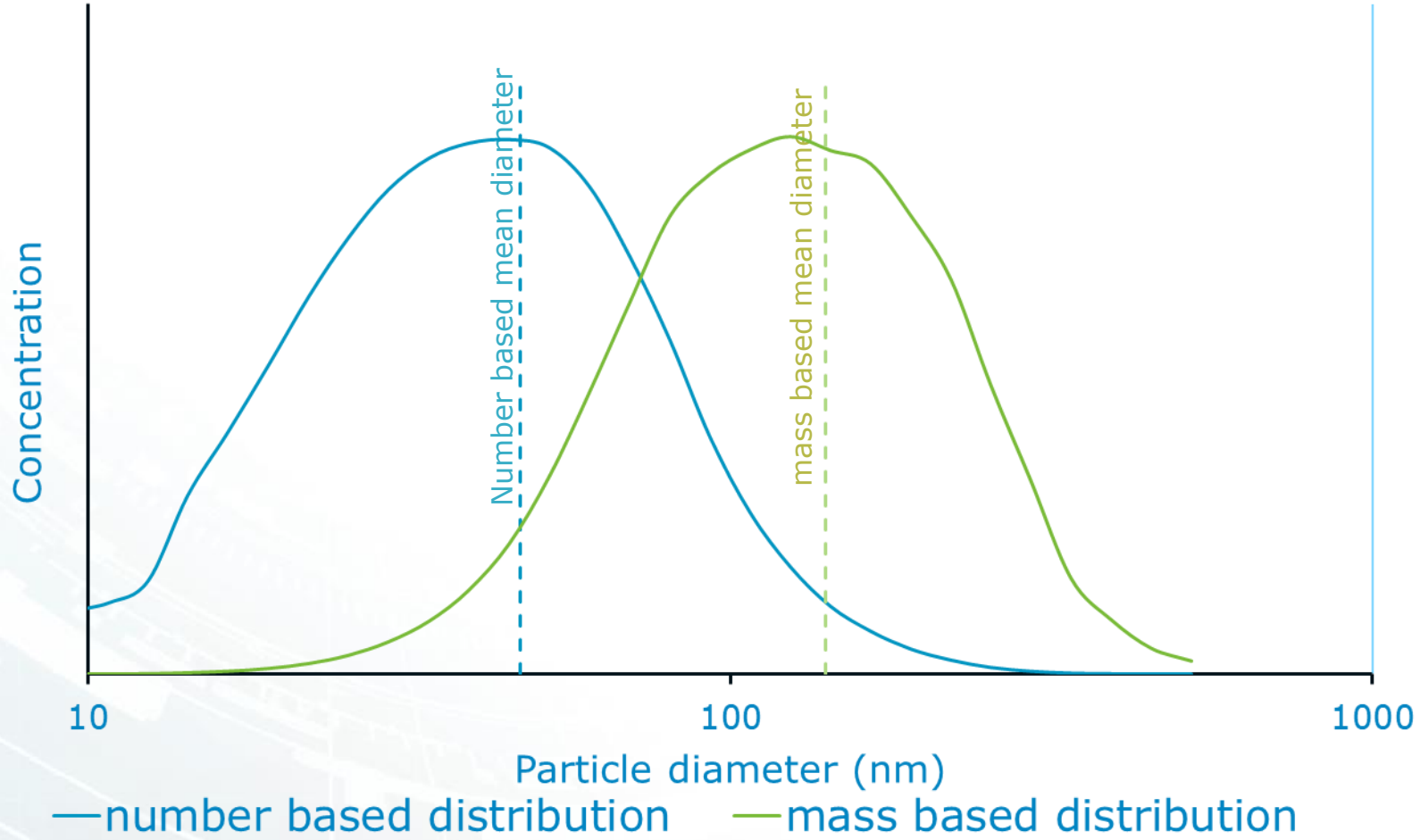
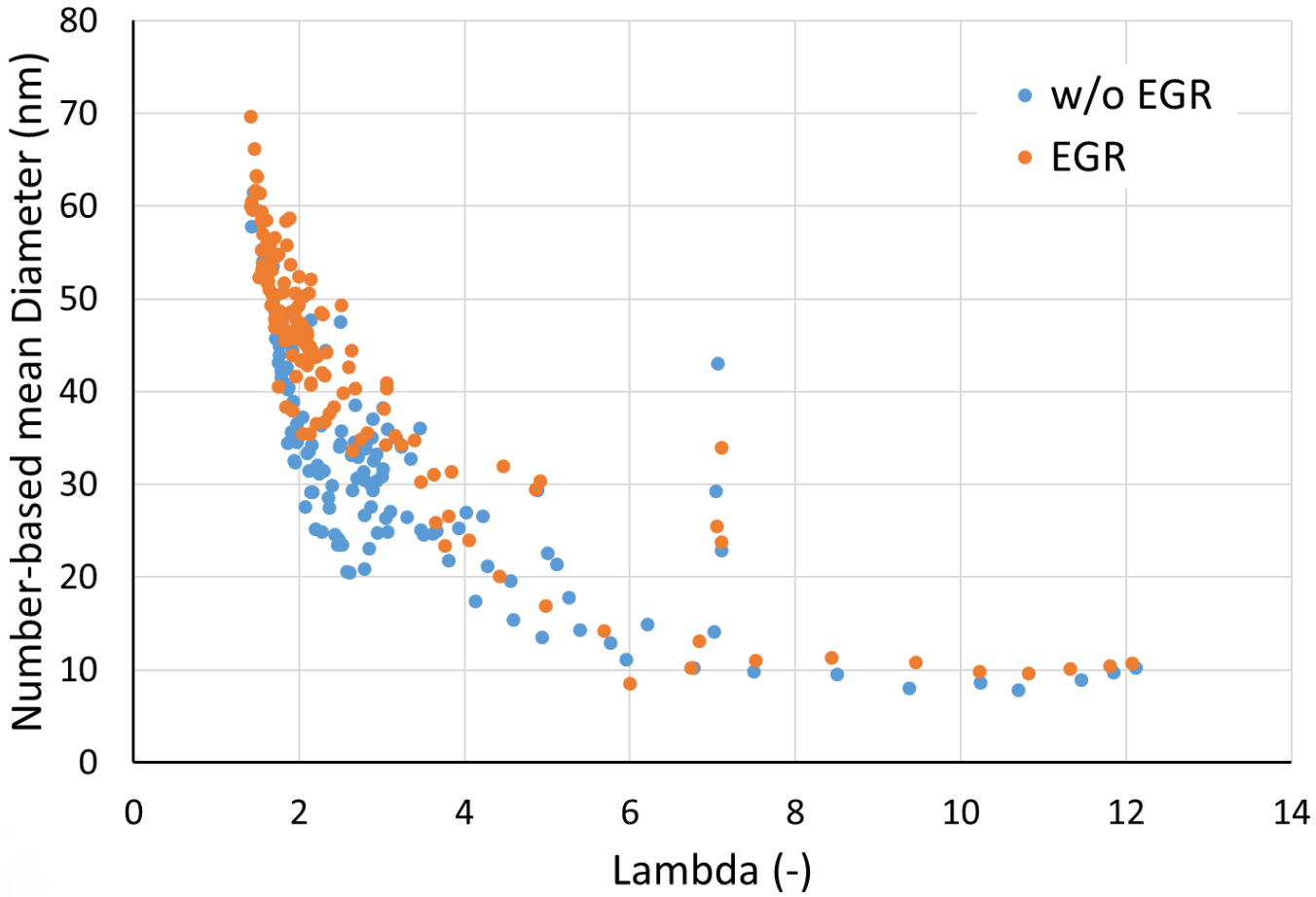
Definition of mean particle diameters



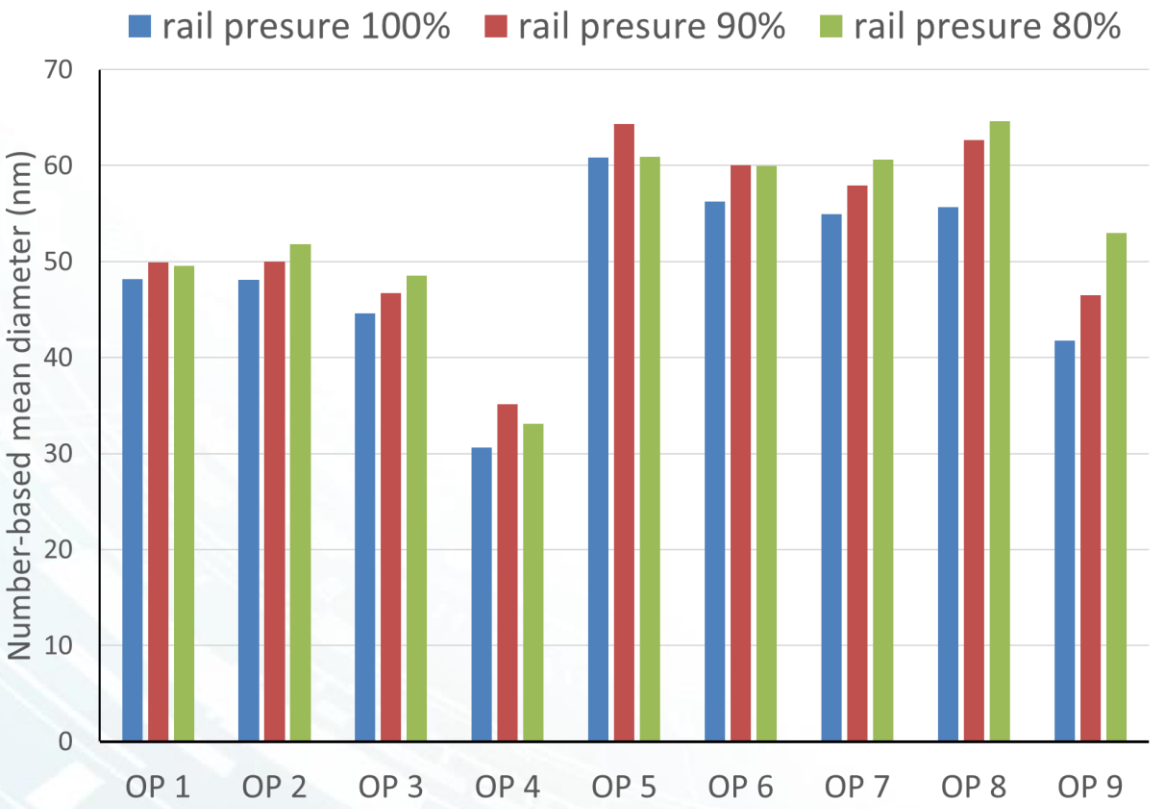
Influence of air excess ratio

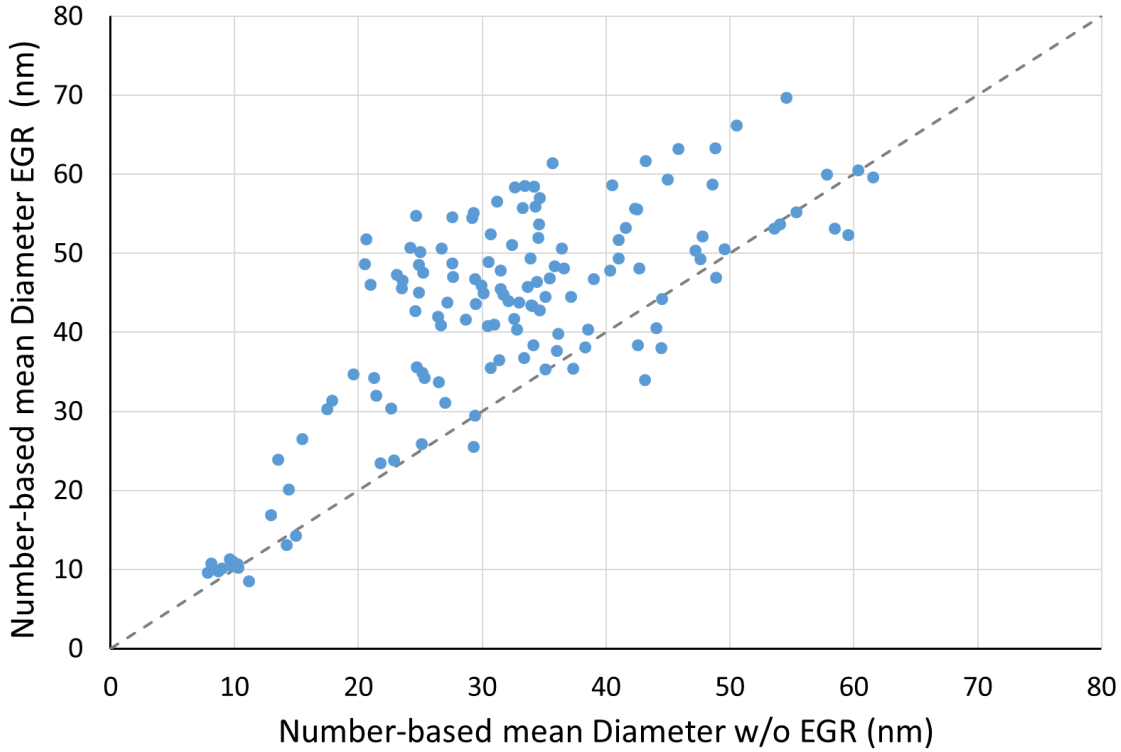
Particle size	Filtration efficiency	Soot burn rate
bigger	higher	slower
smaller	lower	faster



Strong dependency of mean particle size on air excess ratio found.

Influence of EGR and rail pressure





No dependency of mean particle size on rail pressure found.

Influence of EGR can be attributed to changes in excess air ratio.

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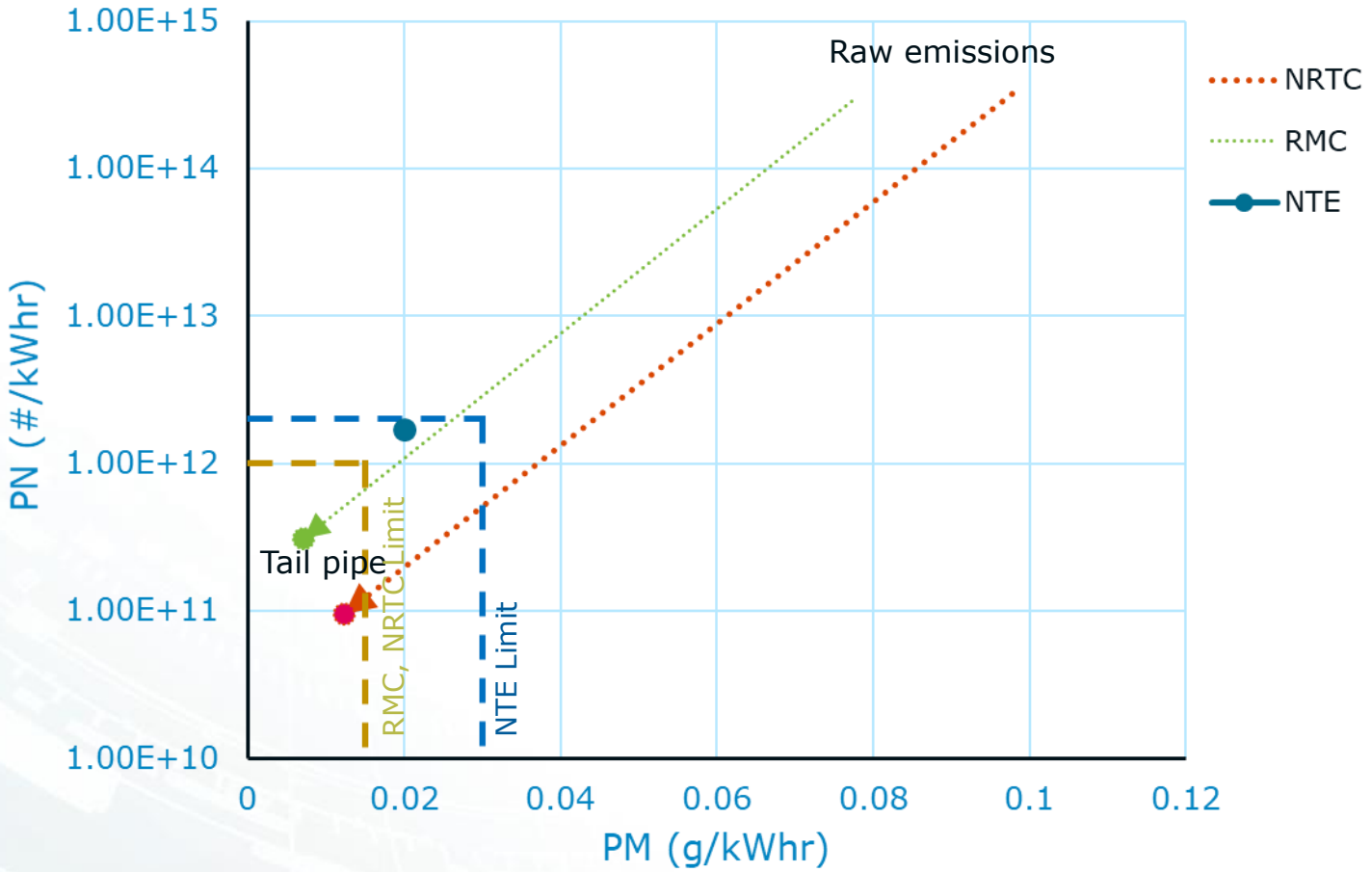
Example of Stage V particle emissions



Summary & Conclusions

Stage V emission targets are significantly more challenging than EURO VI targets due to higher exhaust temperatures.

Proper DOC and DPF selection is essential to fulfil emission targets.

Possibility to influence particulate size by variation of combustion parameters.

Feasibility to fulfil Stage V emission targets shown.

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