Particles from Gasoline Direct Injection Engines: Abatement Options

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17th ETH Conference on Combustion Generated Nanoparticles
24th of June- 26th of June 2013, Zürich

The effect of particle size on cardiovascular disorders — The smaller the worse

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A R T I C L E   I N F O

Article history:
Received 27 January 2011
Received in revised form 23 May 2011
Accepted 25 May 2011
Available online 10 August 2011

Keywords:
Ultrafine particles
Health effects
Time series analysis
Environmental medicine

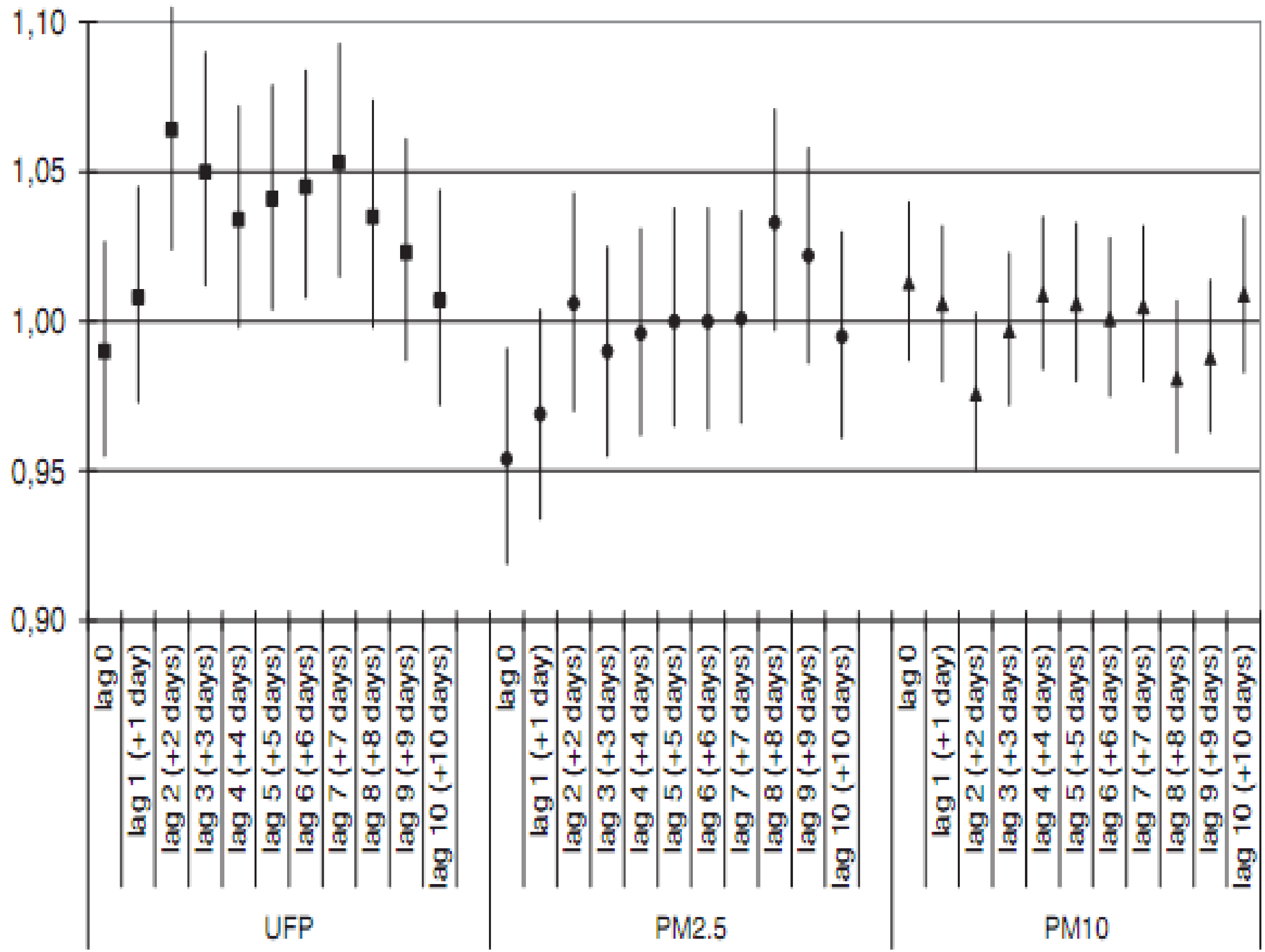
A B S T R A C T

Background: Previous studies observed associations between airborne particles and cardio-vascular disease. Questions, however, remain as to which size of the inhalable particles (coarse, fine, or ultrafine) exerts the most significant impact on health.

Methods: For this retrospective study, data of the total number of 23,741 emergency service calls, registered between February 2002 and January 2003 in the City of Leipzig, were analysed, identifying 5326 as being related to cardiovascular incidences. Simultaneous particle exposure was determined for the particle sizes classes <100 nm (UFP), <2.5 µm (PM2.5) and <10 µm (PM10). We used a time resolution of 1 day for both parameters, emergency calls and exposure.

Results: Within the group of cardiovascular diseases, the diagnostic category of hypertensive crisis showed a significant association with particle exposure. The significant effect on hypertensive crisis was found for particles with a size of <100 nm in diameter and starting with a lag of 2 days after exposure. No consistent influence could be observed for PM2.5 and PM10. The Odds Ratios on hypertensive crisis were significant for the particle size <100 nm in diameter from day 2 post exposure OR = 1.06 (95%CI: 1.02–1.10, p = 0.002) up to day 7 OR = 1.05 (95%CI 1.02–1.09, p = 0.005).

Conclusion: Ultrafine particles affect cardiovascular disease adversely, particularly hypertensive crises. Their effect is significant compared with PM2.5 and PM10. It appears necessary, from a public health point of view, to consider regulating this type of particles using appropriate measurands as particle number.



OR and 95% confidence interval in emergency calls related to hypertensive crises depending on time of exposure to airborne particles and size of particles (ultrafine[UFP]–fine [PM2.5]–coarse [PM10])

Source: U. Franck et al. / Science of the Total Environment 409 (2011) 4217–4221

EU Emission Limits

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Regulation	**Euro 6b**			**Euro 6c**				Euro 7*			
Test	**NEDC**			**NEDC or WLTP++**				**WLTP**			
Real Driving Emissions	**RDE Step 1** PEMS*			**RDE Step 2** PEMS*							
Particle Number Limits	**CI: 6x10^{11} #/km** **PI-DI: 6x10^{12} #/km**			**CI and PI-DI: 6x10^{11} #/km**				TBD			
Particle Mass Limits	**4,5 mg/km**							TBD			
CO_2 Fleet Average	**130 g/km**						**95 g/km**				

PEMS: Portable Emission Measurement System

*not finalized

CI: Compression Ignition

PI-DI: Positive Ignition-Direct Injection

Source: Harth et al, Wiener Motorensymposium 2013

Emission Abatement

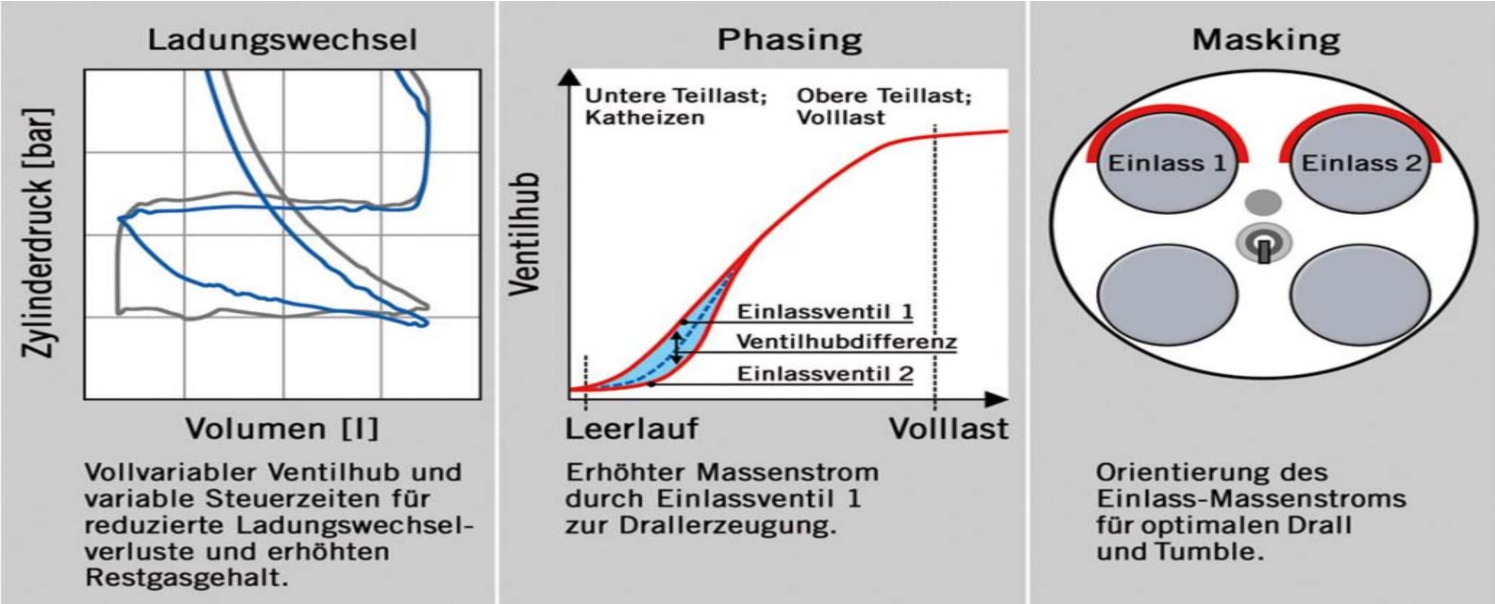
Options for Emission Abatement

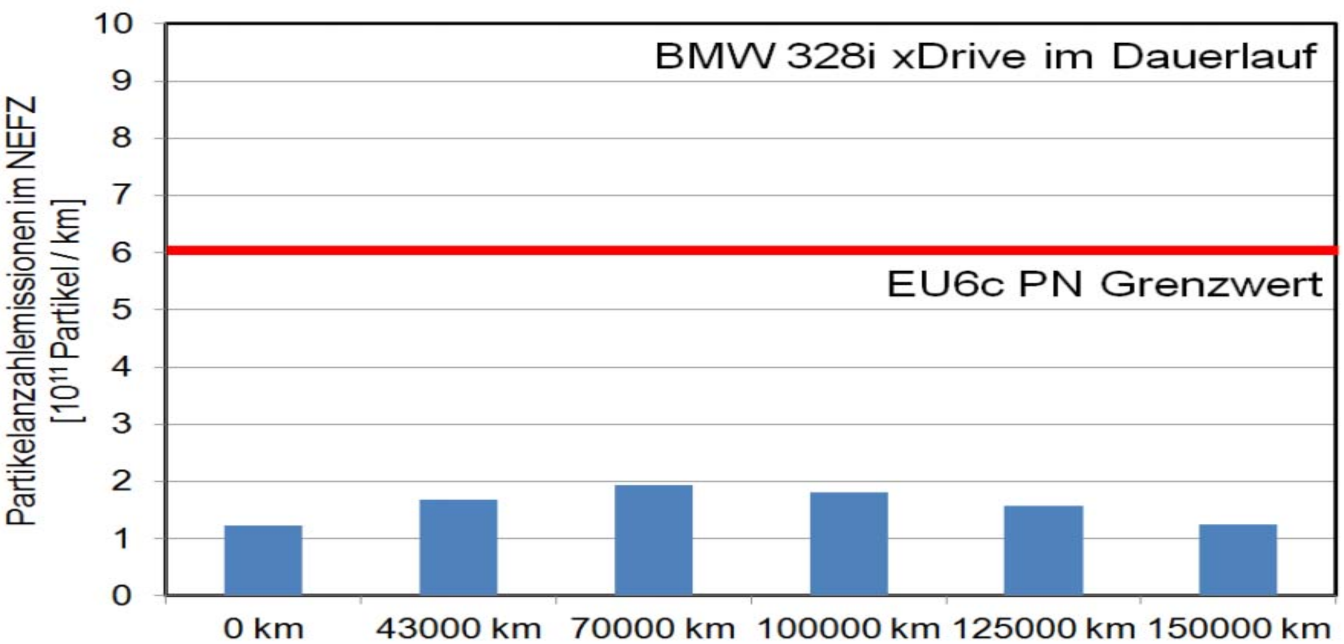
- From the beginning of the introduction of stricter emission limits always two option were followed:

1. Internal engine measures
2. Exhaust after treatment

- Examples are the conflict between lean burn engine and three way catalyst or between diesel particle emission control by high injection pressure and diesel particle filter.

Example of an Internal Engine Approach

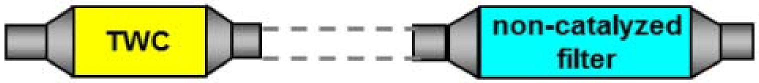




Source: Klauer et al. Wiener Motorensymposium 2013

Examples of an Exhaust Aftertreatment Approach

Solutions with non-catalyzed filter

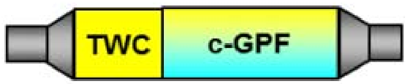


Filter added in under-floor position
- Solution to ensure low particle number emissions over lifetime
- Reference system for solutions with filter
- Low porosity substrate needed to ensure high filtration efficiency

Solutions with c-GPF

UF-TWC replaced by c-GPF
- Use in CC+UF systems with no space for c-GPF in CC position
- Use instead of uncoated filter for system optimization: potential to reduce volume of TWC and gain advantage for OBD

CC-TWC replaced by c-GPF-only
- Euro 6 emission limits with similar amount of PGM achievable
- OBD functionality to be further evaluated
- Optional use of underfloor TWC for OBD purposes



c-GPF replaces 2nd TWC in close coupled CC1+CC2 system
- Euro 6 emission limits with similar amount of PGM achievable
- OBD handled by CC TWC

Source: Harth et al, Wiener Motorensymposium 2013

Estimated Cost of Gasoline Particulate Filters 2011

Engine Displacement	Estimated Long-Term Production Cost (USD 2010)
1.5	$88
2.0	$106
2.5	$124
3.0	$143

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Measurements of GDI Engines by DUH and VCD

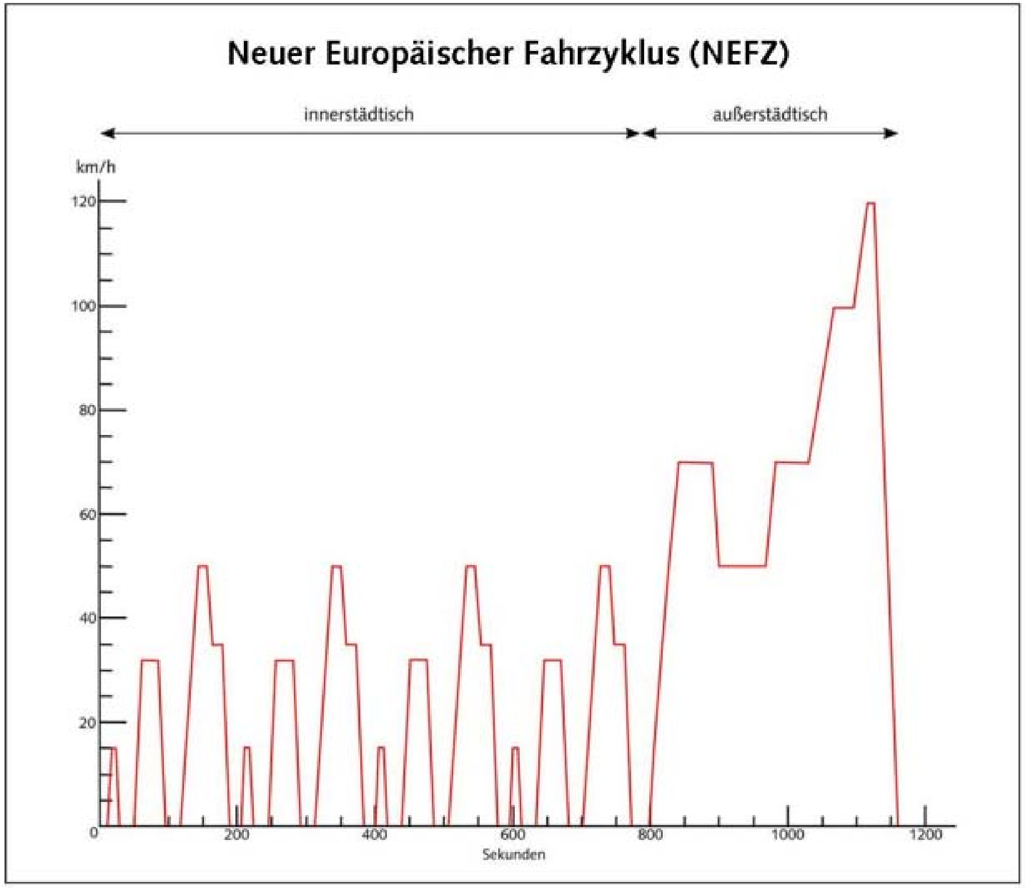
Two measurement series were performed in 2011 and 2012 by ADAC and TÜV Nord.

Different testing cycles and conditions were measured.

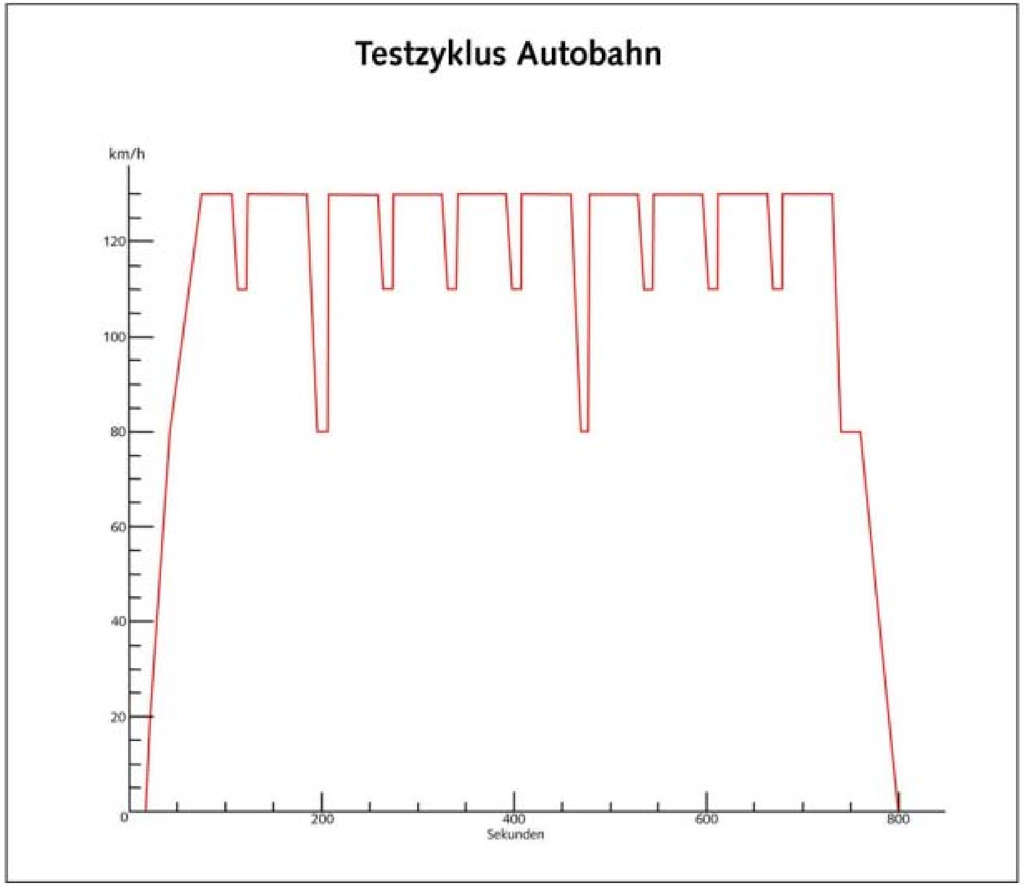
Conventional pollutants and particle mass and particle number were measured.

One vehicle has been retrofited with an particle filter.

Test Cycles

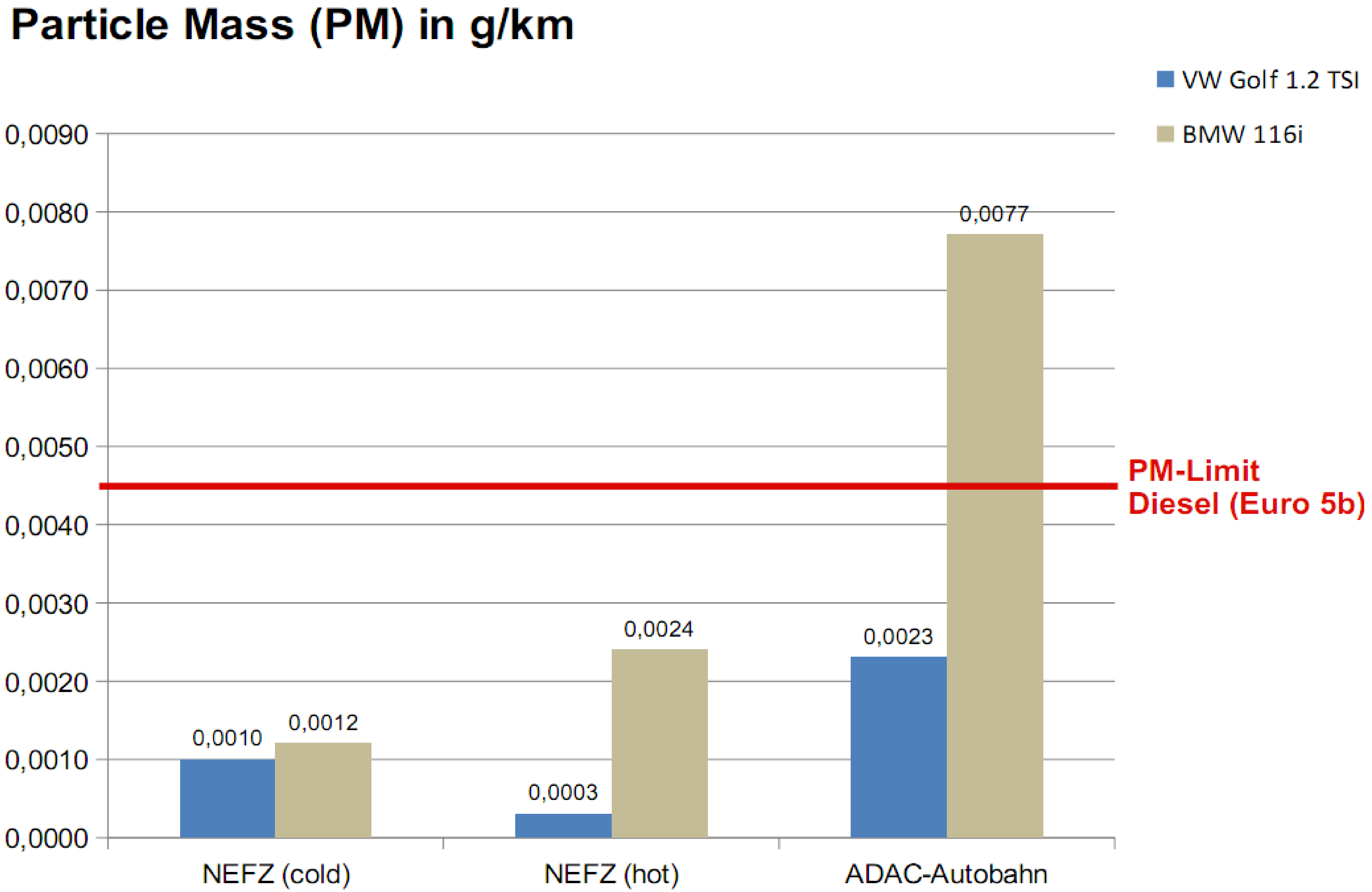


Neuer Europäischer Fahrzyklus (NEFZ)
innerstädtisch
außerstädtisch
km/h
120
100
80
60
40
20
0
200
400
600
800
1000
1200
Sekunden



Testzyklus Autobahn
km/h
120
100
80
60
40
20
0
200
400
600
800
Sekunden

Particle Mass (mg/km) in different Test Cycle



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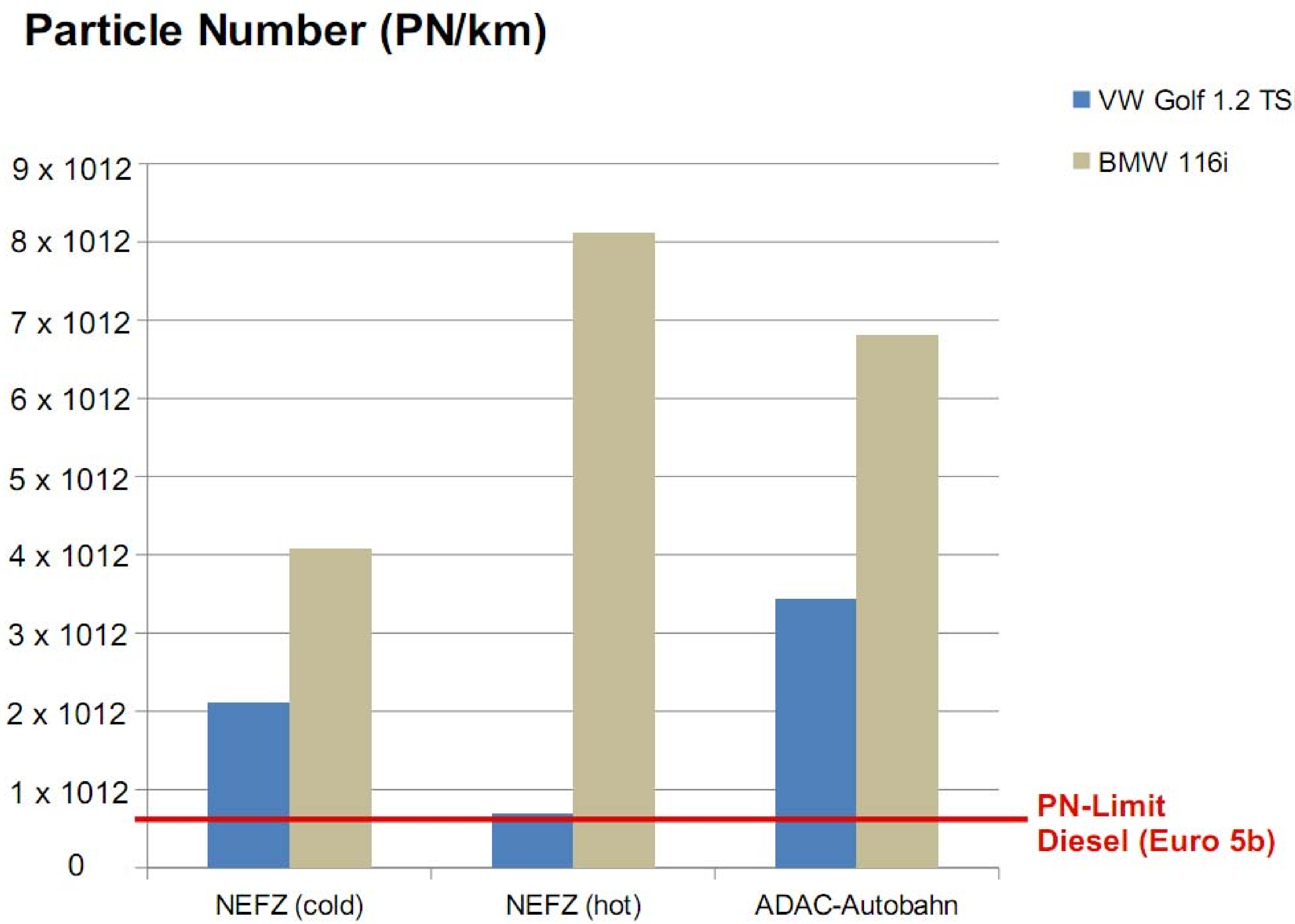
Particle Number (PN/km) in different Test Cycle



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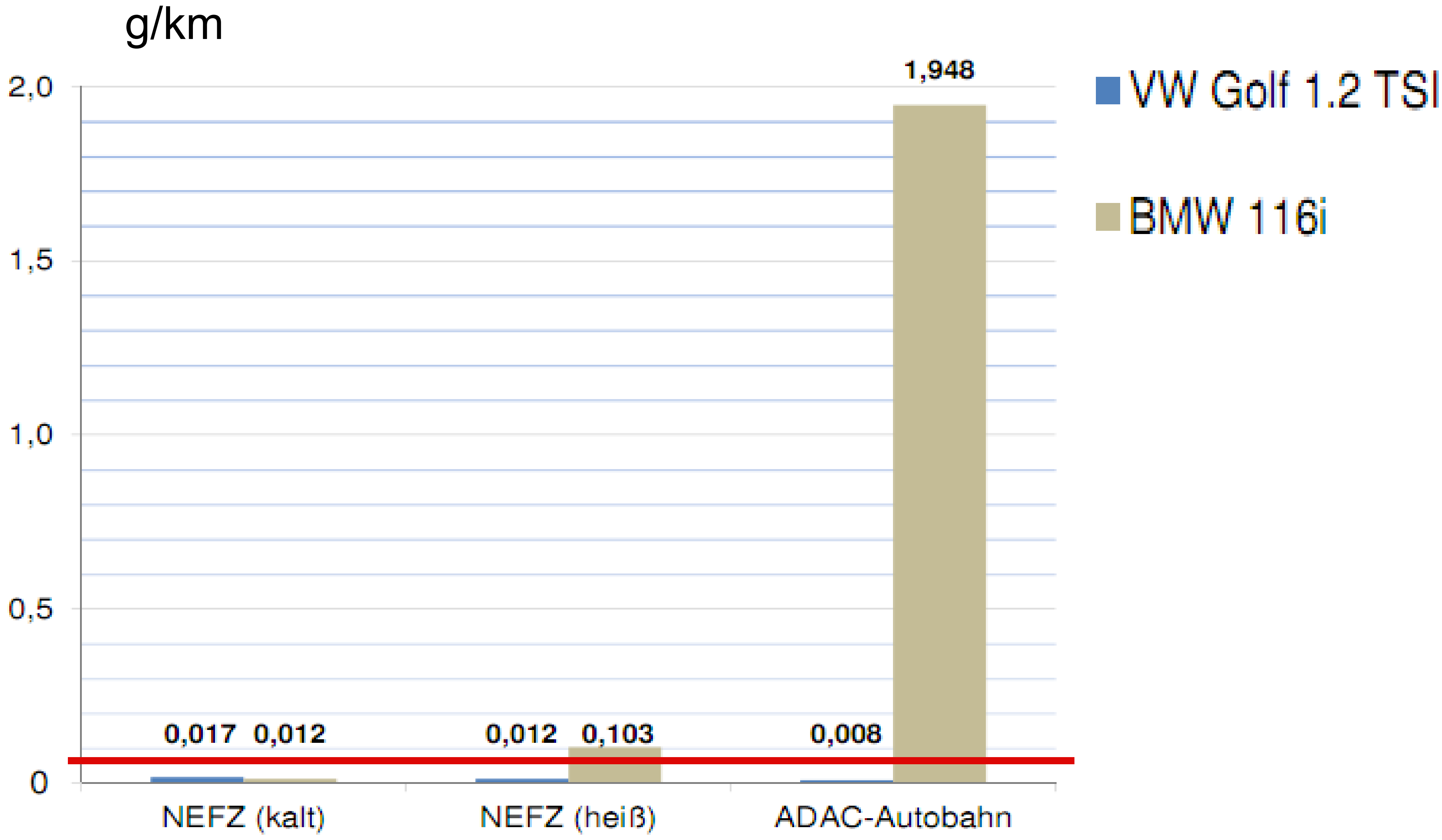
NO_x -Emissions of GDI vehicles in different Driving Cycles



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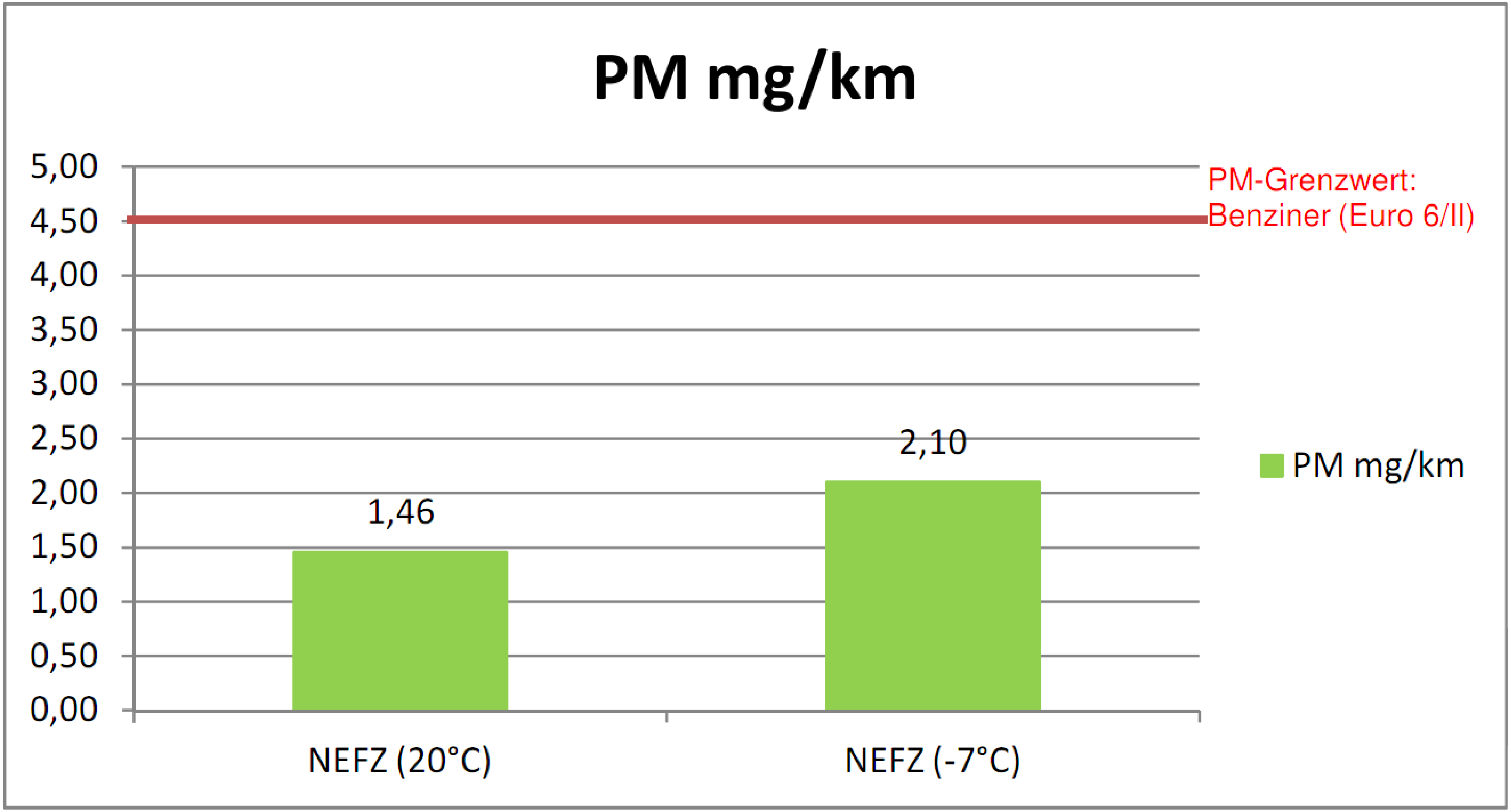
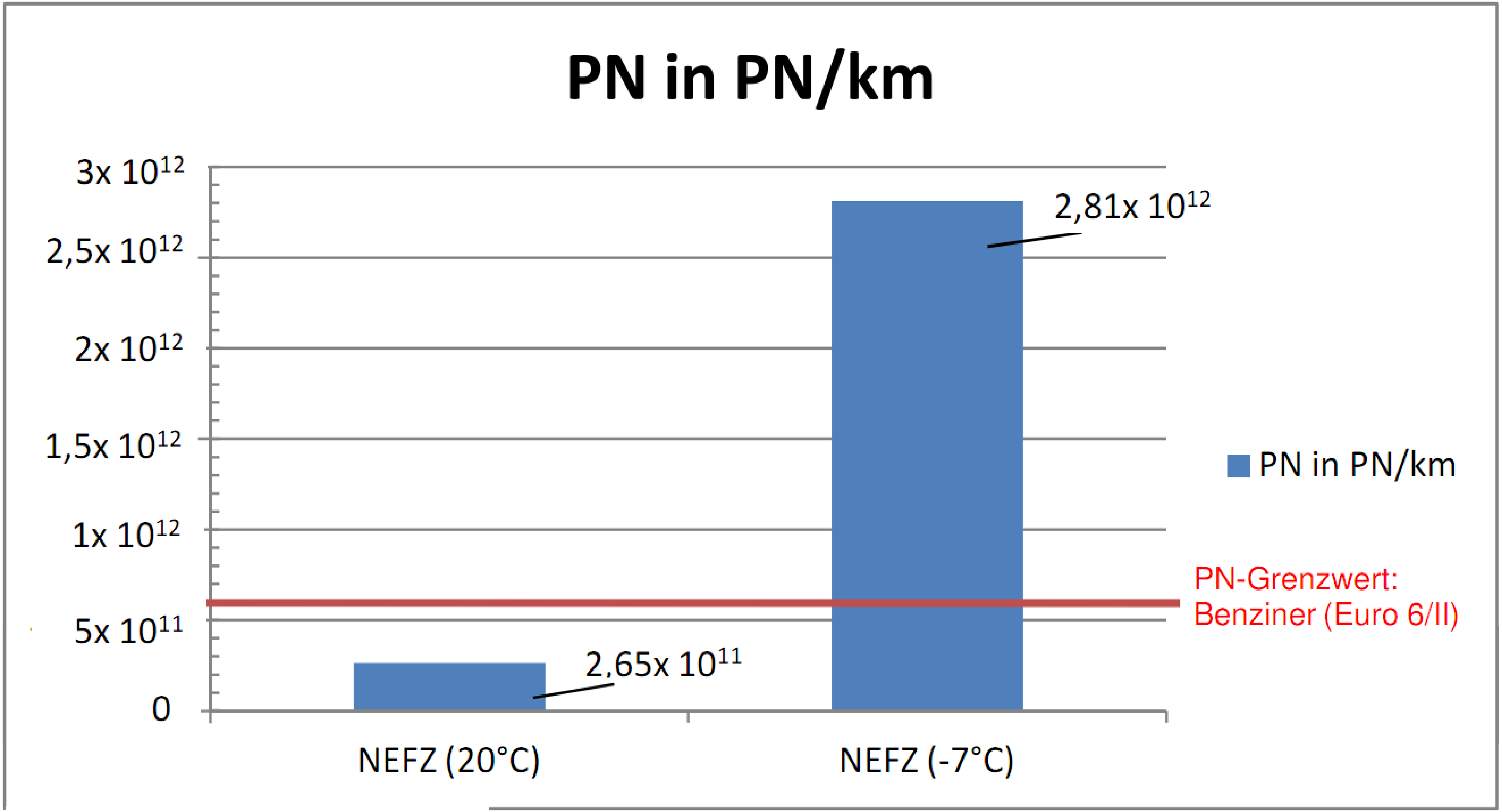
Particle Emission in the NEFZ at different Temperatures



Mercedes B180 GDI

Particle Emission in the NEFZ at different Temperatures



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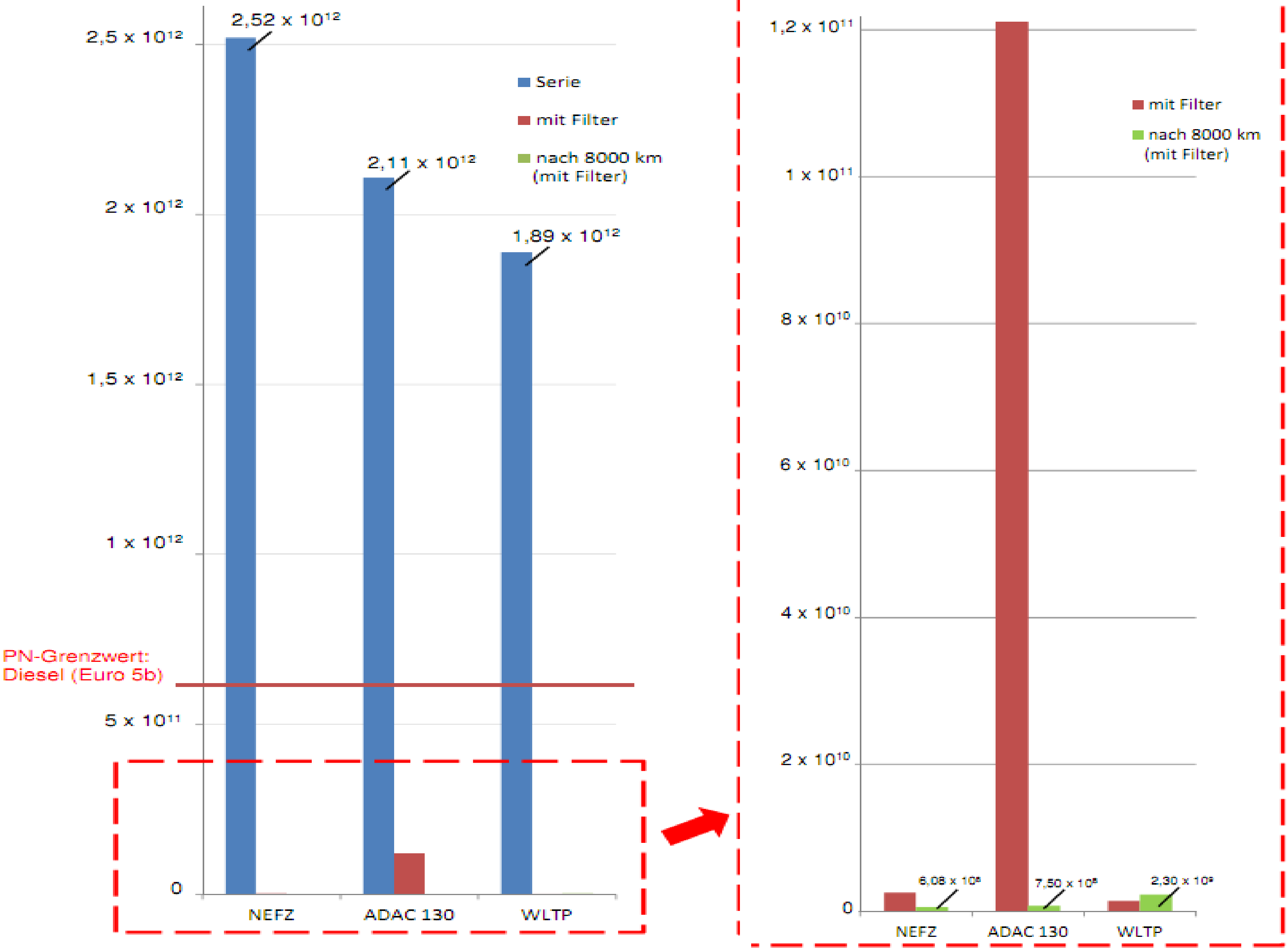
Mercedes B180 GDI

Particle Number (PN/km) Comparison of the PN- Values without Filter, with Filter and after 8000 km Driving (with filter)



BMW 116i GDI

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Conclusion

1. Particle emissions of GDI vehicles should not be higher than these of Diesel vehicles.
2. Particle emission should be minimized (best available technology) under all driving conditions, e.g. all speeds and temperatures.
3. Today only particle filters fulfill these requirements.
4. GDI vehicles should be equipped with closed particle filter as this is state of the art with Diesel vehicles

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