University of Applied Sciences
Biel-Bienne, Switzerland
IC-Engines and Exhaust Gas Control

Analysis of ultrafine particle emissions by in-use buses of different generations

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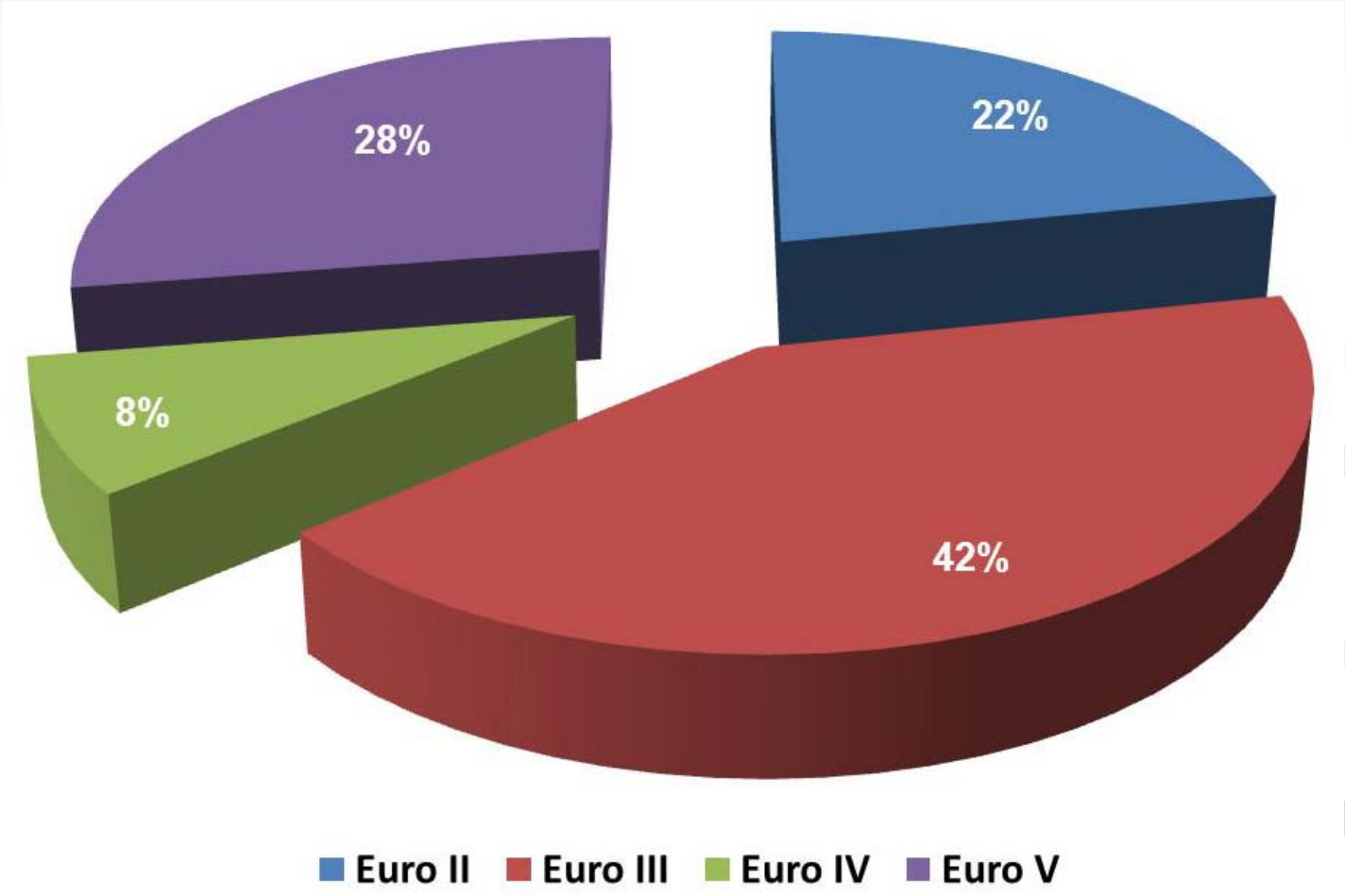
June 22-25 2014

Motivation

- ✓ **Transportation is the main source of air pollution in Israel's cities and population centers**
- ✓ **The Israeli economy will lose NIS 8.8 billion in 2015 to pollution-related illnesses**
- ✓ **Public transportation is almost entirely based on diesel engines**
- ✓ **The Israeli government authorized a major plan to battle air pollution in Israel, approving a NIS 140 million program**

Israeli Bus Fleet Composition



Goals

- Main goal - demonstrating a potential of nanoparticle emissions mitigation from in-use diesel buses of different technologies by application of diesel particle filter

- Additional goals - assessment of nanoparticle emission levels from in-use buses of different technologies – from Euro II till Euro V and reasonability of the work continuation with DPF retrofitting

Buses tested

Technology	Maker/ Model	Traveled distance, km	Engine type	Power, kW/Speed, rpm	Number of cylinders/ Displacement, cm^3	EGR system, Yes/No	Exhaust gas aftertreatment
EURO II, interurban	MAN/ HOCL 1835	1,227,503	D2066LOH12	257/2200	6/10,518	NO	NO
EURO II, urban	Mercedes/ O-405	994,600	OM447-hLA	176/2,200	6/11,967	NO	NO
EURO III, urban	MAN/ NL 313F	595,560	D2866LUH24	228/1,900	6/11,967	YES	NO
EURO IV, urban	MAN/ NL 313F	328,990	D2066LUH12	228/1,700	6/10,518	YES	PM-KAT®*
EURO V EEV, urban	MAN/ NL 323F	162,283	D2066LUH47	235/1,900	6/10,518	YES	CRTec®**

* **PM-KAT** is a trade name of the Emitec partial flow filter with an upstream Diesel DOC
** **CRTec** is a trade name of the HJS-made continuously regenerating trap based on the wall-flow sintered metal filter with electronically controlled thermal management.

Methodology

Operation modes:

- Low idle
- High idle
- Partial load
- Free acceleration

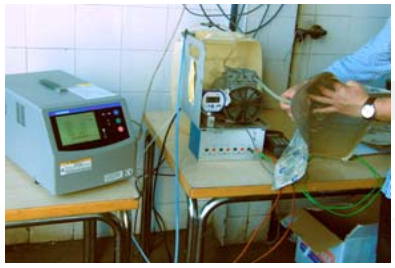
Measured parameters:

- Particle number (PN) concentrations and summary active surface
- Concentrations of NO_x, CO, CO_2 and O_2
- Smoke
- Gas temperature and pressure at the DPF inlet
- Engine speed, vehicle velocity, power on the wheels

All the measurements - with and without DPF

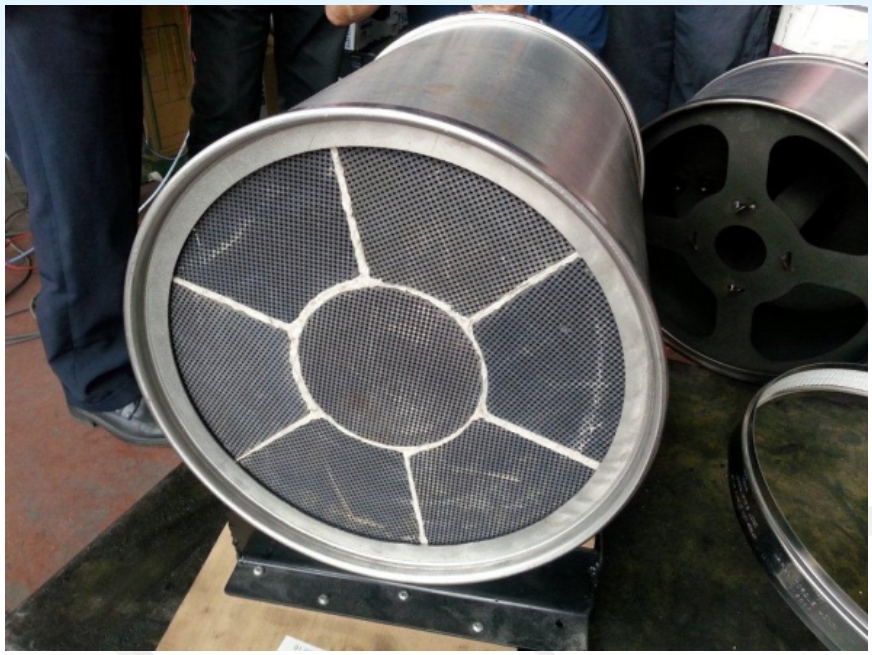
Experimental setup

DINEX DiSiC DPF: left –assembled; right – with covers removed



DPF inlet and outlet surfaces

DPF inlet surface

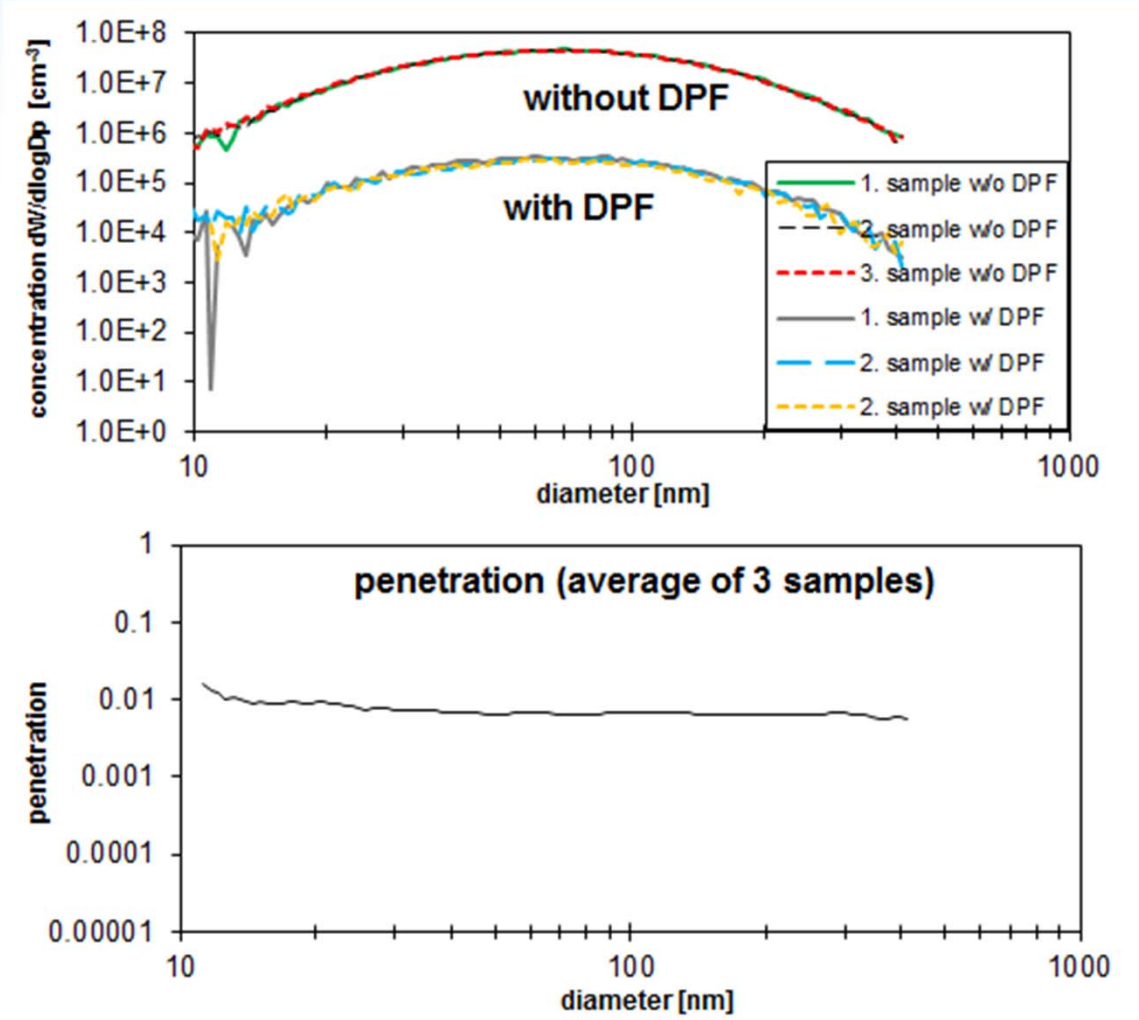


DPF outlet surface

Only best available technology (BAT) and appropriately certified filters should be considered for retrofitting!

Vert Quality of the used DINEX DPF

SMPS – size spectra with / without DPF Dinex DiSiC catalsysed on the engine MB OM 926 LA; fuel (S < 10 ppm); op 7: 1480 rpm / 650 Nm



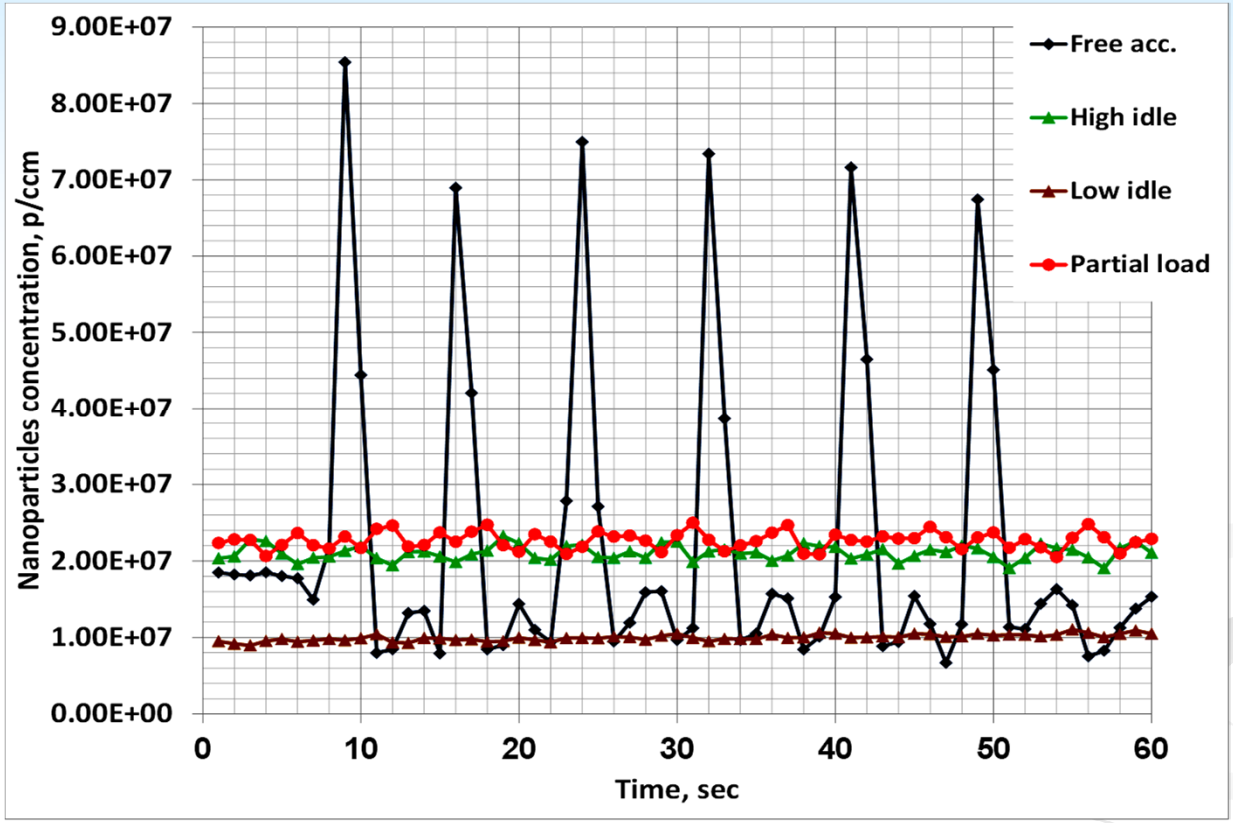
Comparison of trapping efficiencies of mass (PMFE) and counts 20- 300 nm (PCFE) of the DPF Dinex DiSiCcatalysed on the engine MB OM 926 LA; fuel (S < 10 ppm)

PMFE [%]						
operating point	5	7	3	1	5 (r.)	
speed	1480	1480	2250	2250	1480	rpm
torque	1310	650	490	1010	1310	Nm
DPF delivery state	**91.21**	**94.78**	**94.26**	**93.97**	**86.74**	%
average of all points	**92.19**					

PCFE [%]						
operating point	5	7	3	1	5 (r.)	
speed	1480	1480	2250	2250	1480	rpm
torque	1310	650	490	1010	1310	Nm
DPF delivery state	**98.75**	**99.32**	**99.42**	**99.19**	**99.08**	%
average of all points	**99.15**					

Results

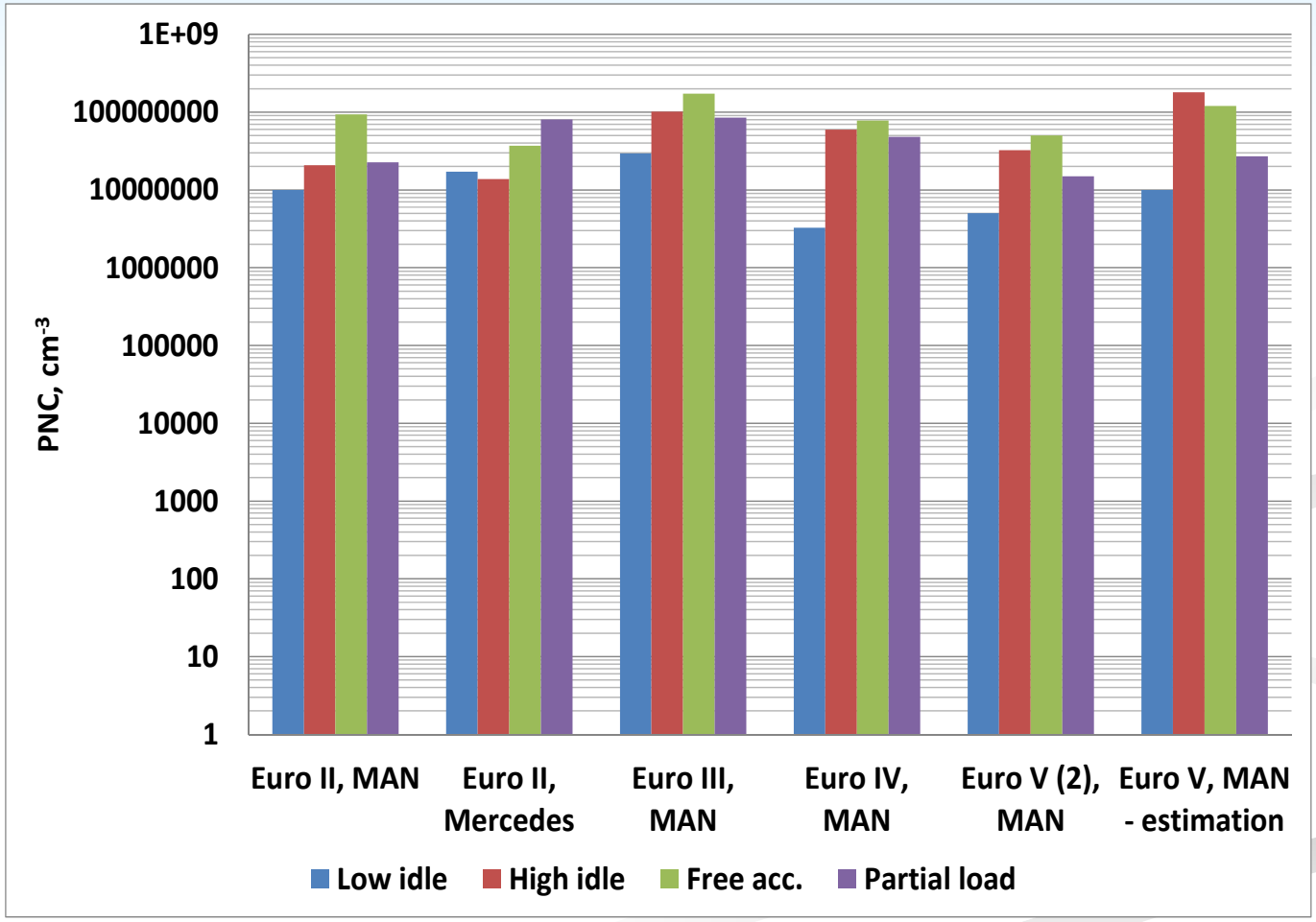
Example of instantaneous PN number concentrations



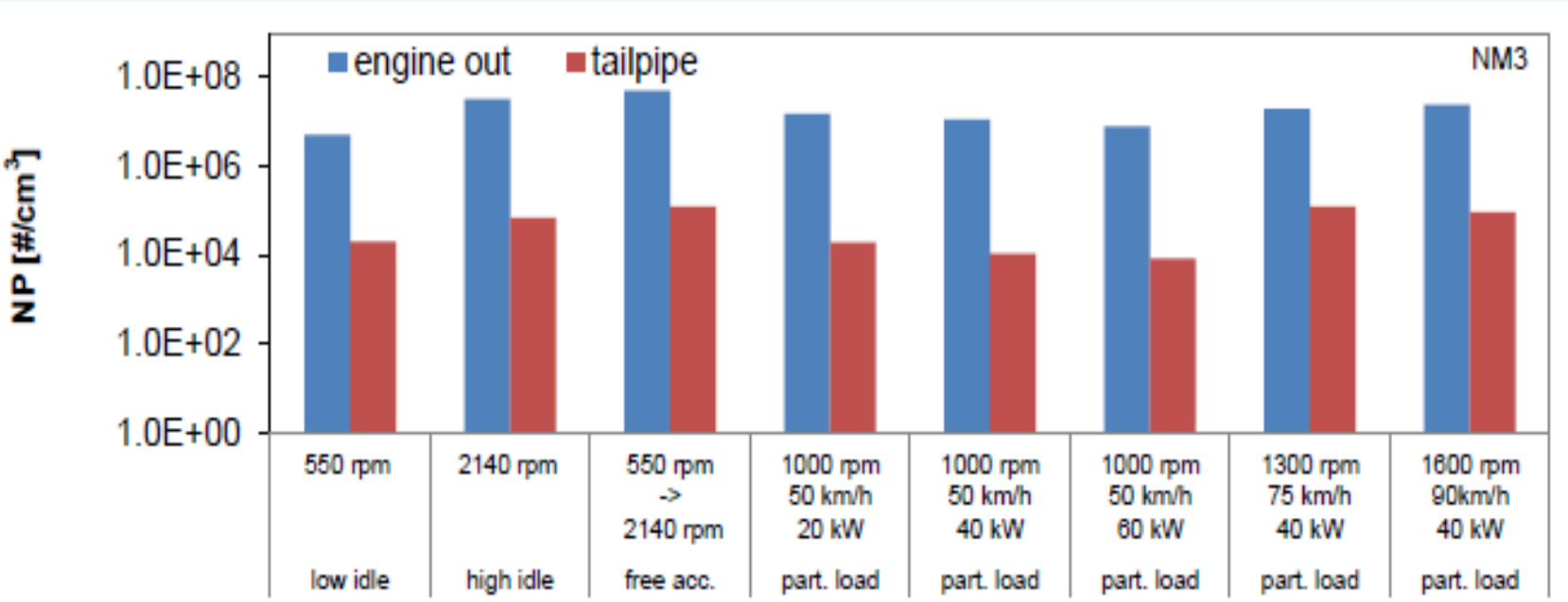
Under steady-state regimes 60 readings were measured with the frequency of 1 Hz

Under free acceleration test six free accelerations were performed

Nanoparticle number concentrations w/o DPF

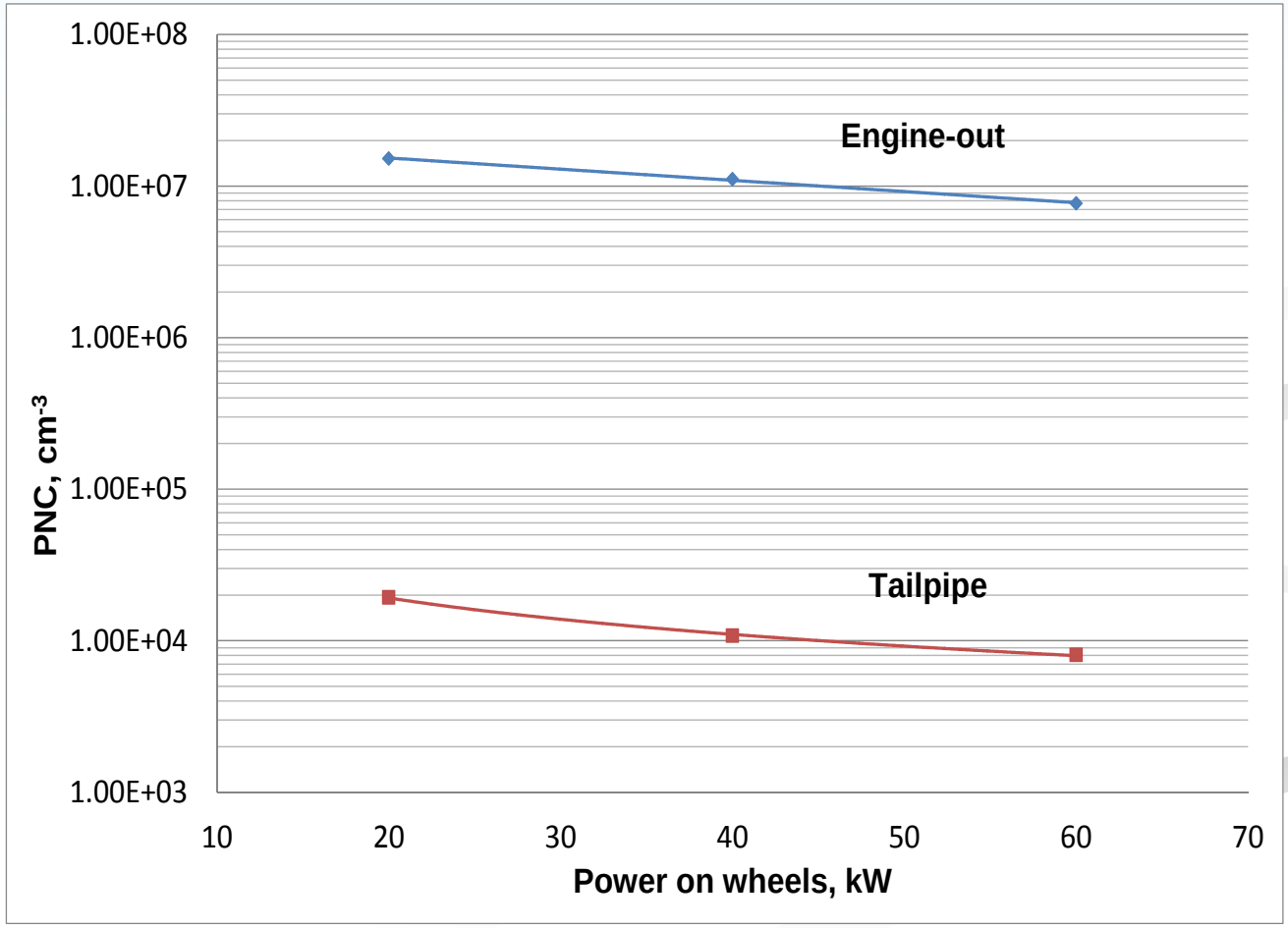


Engine-out and tailpipe PNC of the Euro V bus with CRTec

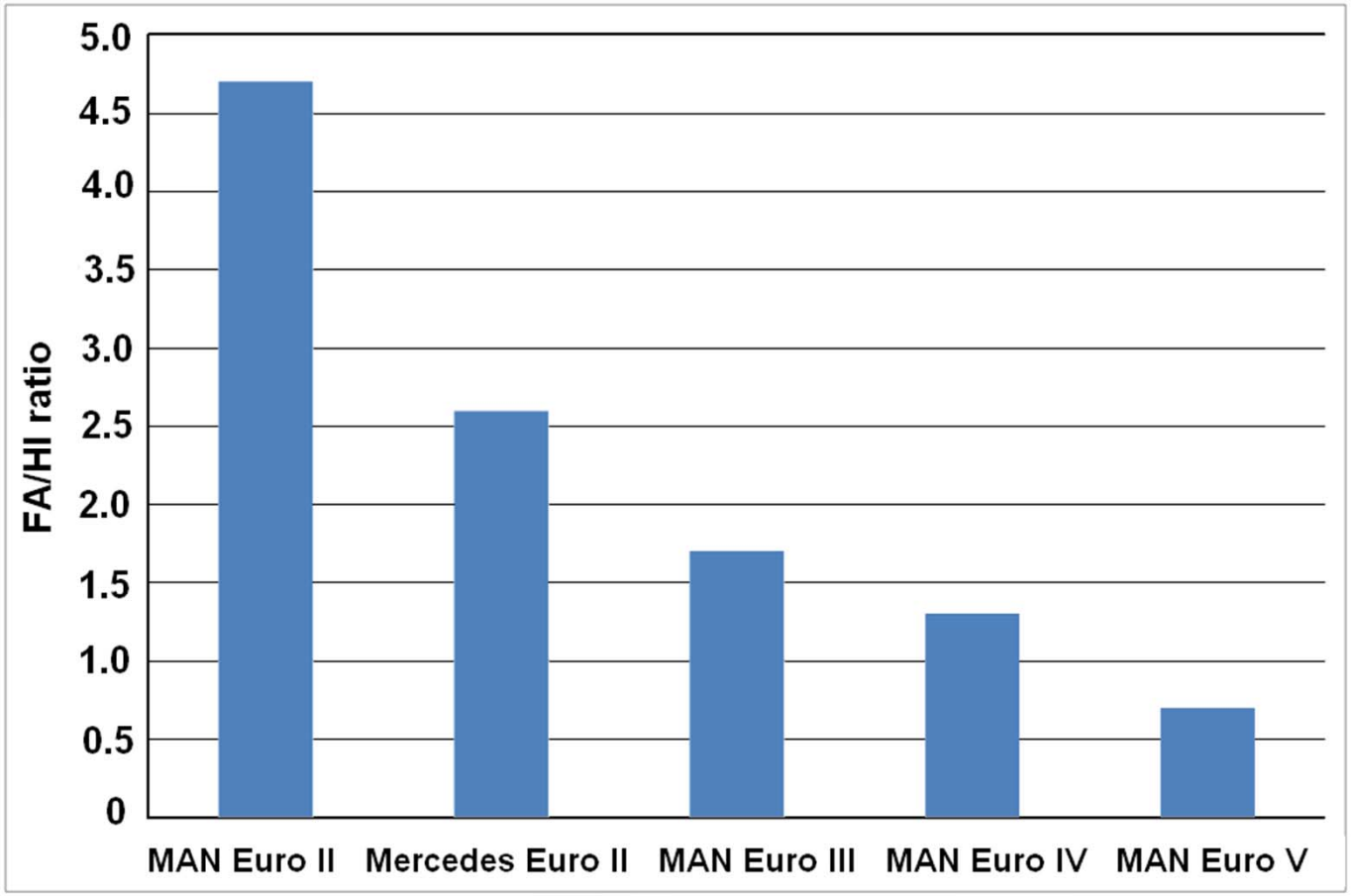


Influence of load on UFP number concentrations with CRT

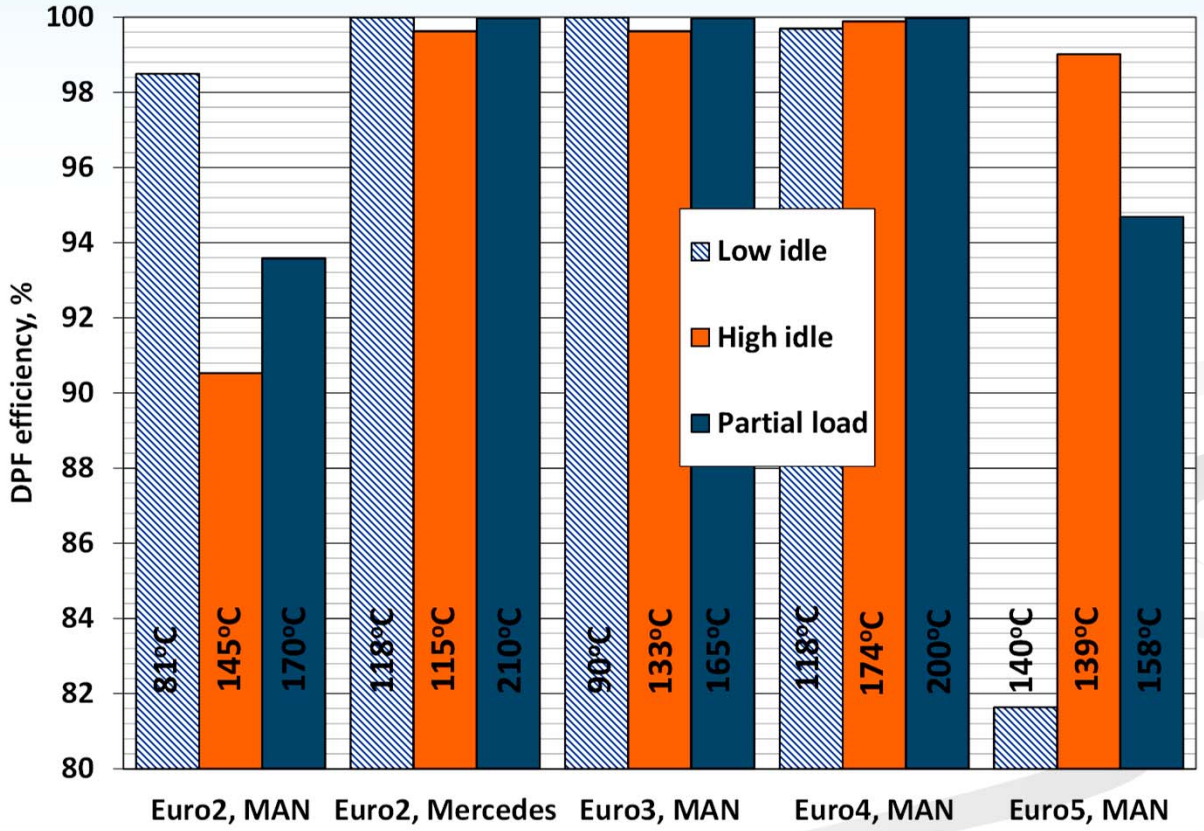
Euro V bus, 1000 rpm



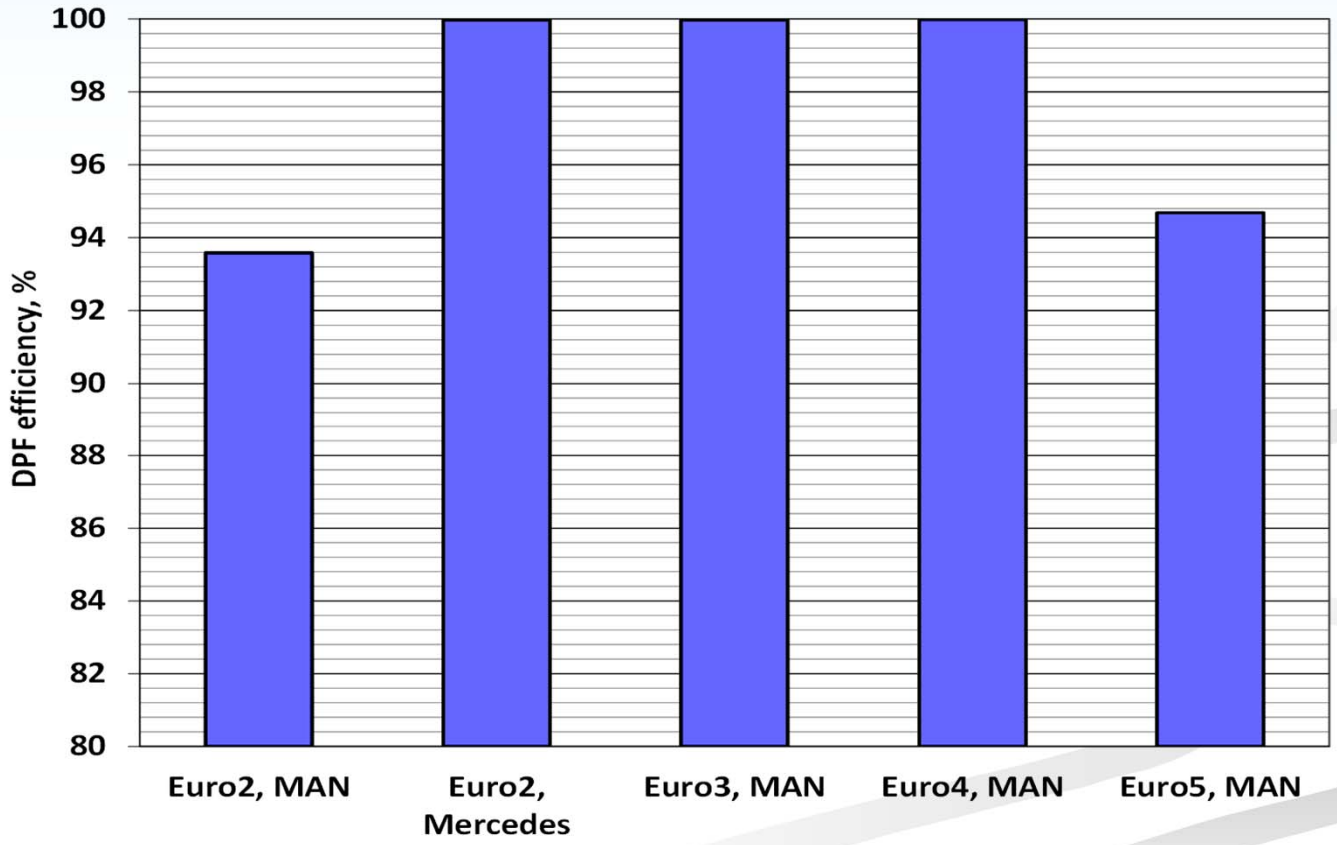
Ratios of the pick values of PN concentrations at free acceleration and at high idle w/o DPF



DPF efficiency
Steady-state regimes



DPF efficiency
Free acceleration



Conclusions

✓ **A comparison of engine-out PN emission of the EURO V bus with those of the Euro II and III buses provides an indication on very high engine-out PN emissions of the EURO V bus. This most probably is a result of high EGR ratios applied in this engine.**

✓ **A danger of extremely high PN emission by the EURO V buses in case of the DPF malfunction**

✓ **A strong correlation between PN levels under high idle and free acceleration operation regimes was observed**

✓ **Ratios of PN concentrations at free acceleration and high idle operation modes were substantially higher for the older buses and decreased with advancement of the engine's technology**

✓ **High efficiency of DPF in reduction of nanoparticle emissions by all buses was confirmed**

✓ **DPF efficiency with all buses at almost all operation regimes was above 94% and in some cases reached near 99.9%**

Acknowledgments

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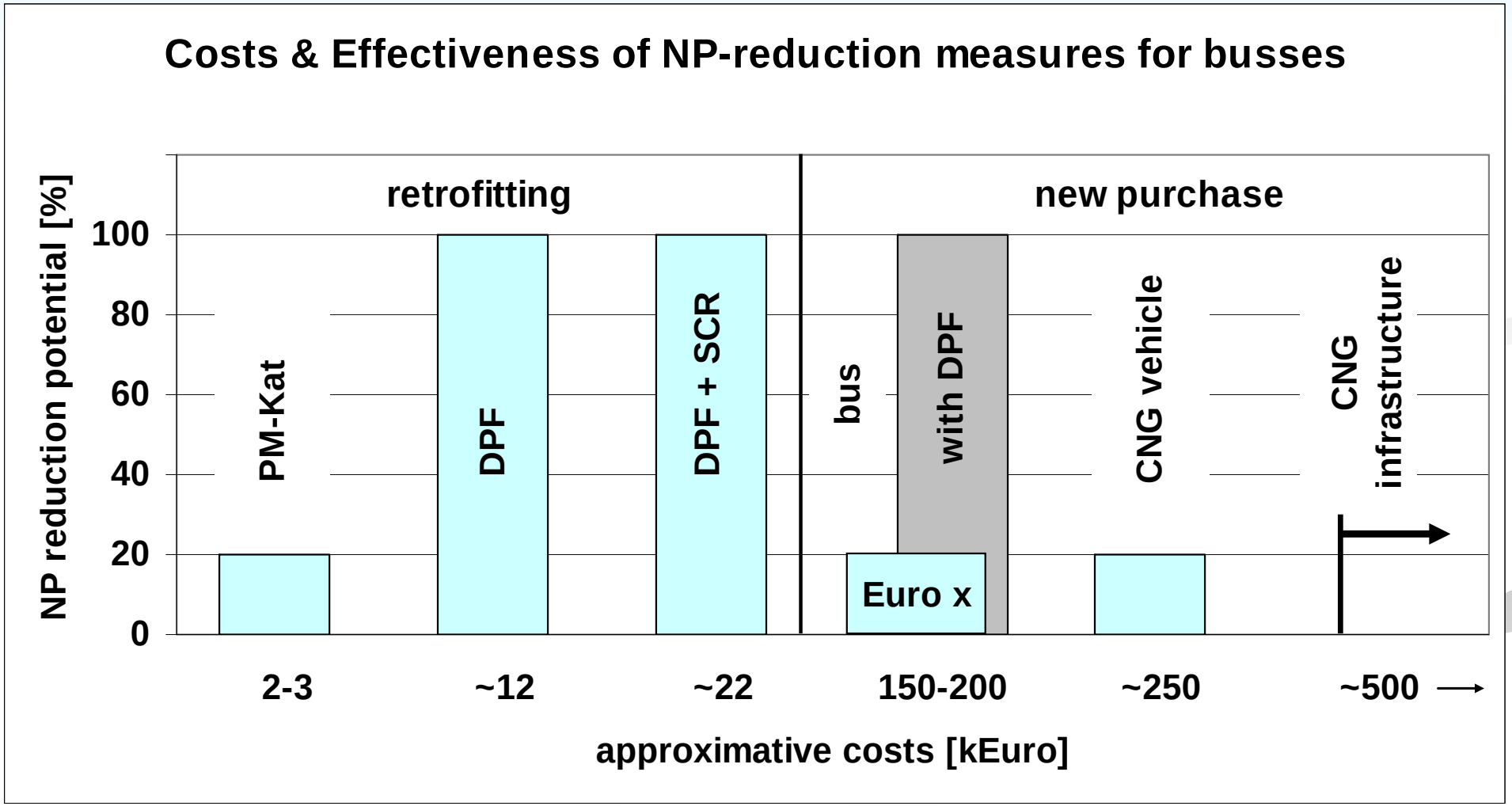
Successful Retrofitting of City Busses in Switzerland since 2001

Field control equipment:
Gaseous components, opacity, FSN

Retrofitting,
or new vehicles ?


Costs & Effectiveness of NP-reduction measures for busses
NP reduction potential [%]
0
20
40
60
80
100
retrofitting
new purchase
PM-Kat
DPF
DPF + SCR
bus
with DPF
Euro x
CNG vehicle
CNG infrastructure
2-3
~12
~22
150-200
~250
~500
approximative costs [kEuro]

Thank you for your attention!

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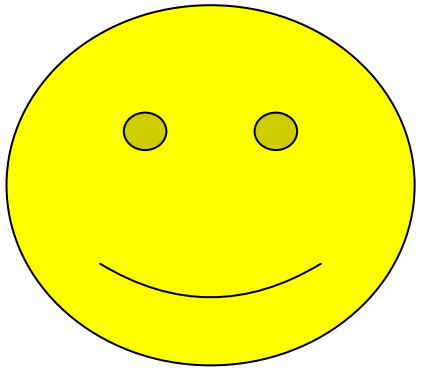

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