Emission behavior of different city bus concepts

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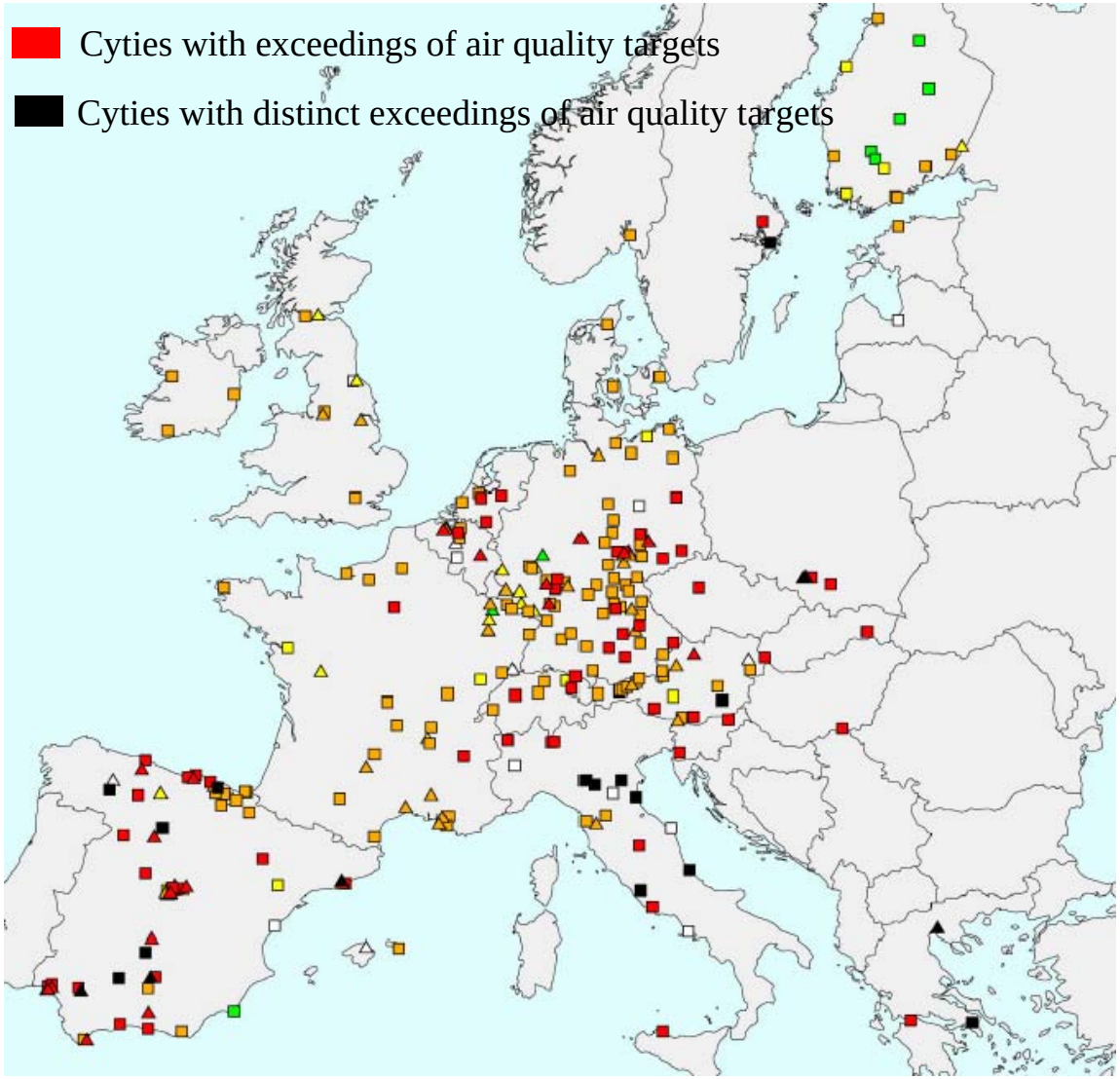
PM 10 and NO_2 air quality problems in many areas

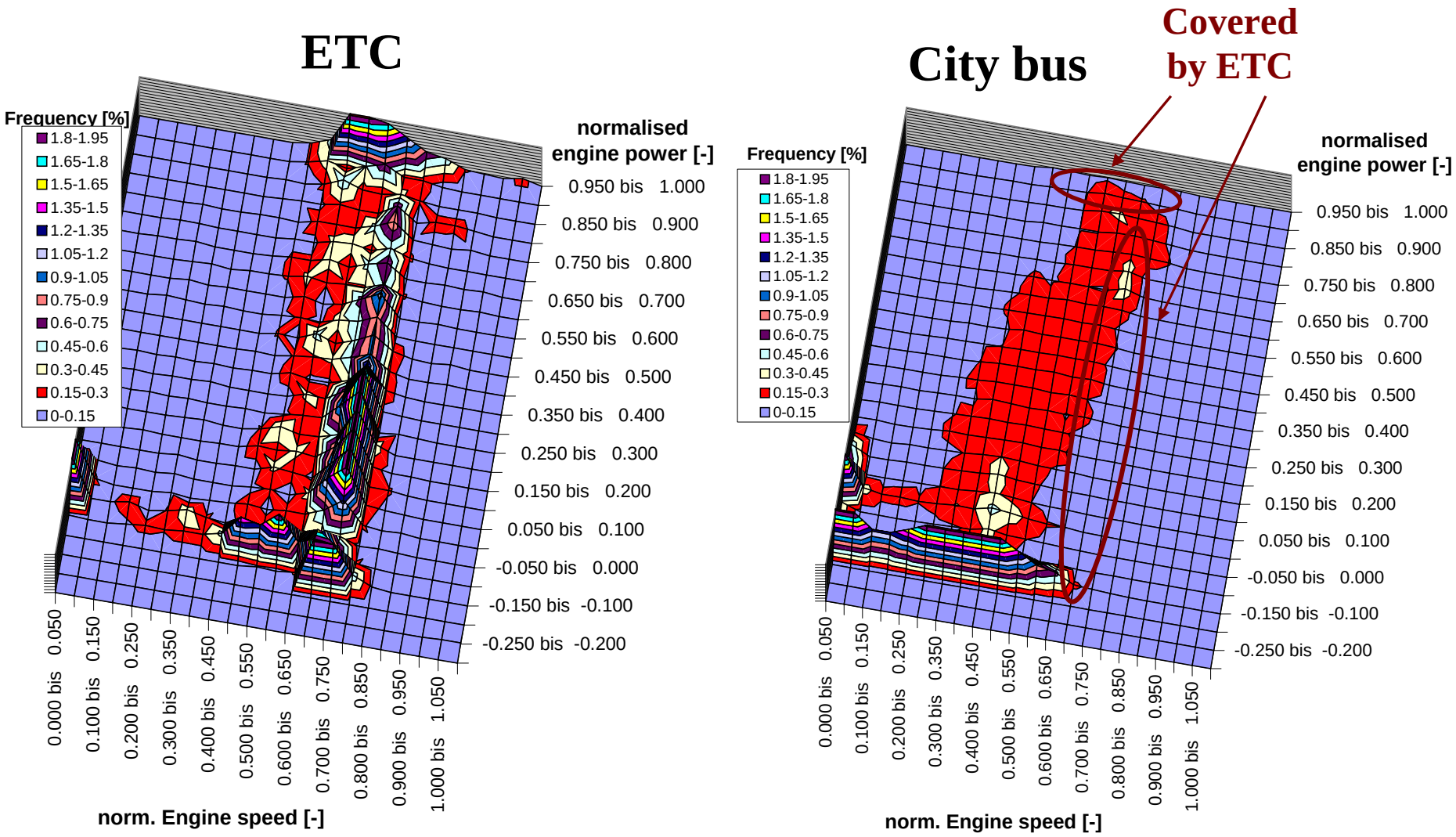


Local authorities look for „clean“ city buses

Source: Second position paper on Particulate Matter

CAFÉ (Clean Air For Europe)-Working group on PM, 20.8.2003

Type approval tests (ETC and ESC) are not representative for city bus driving at all

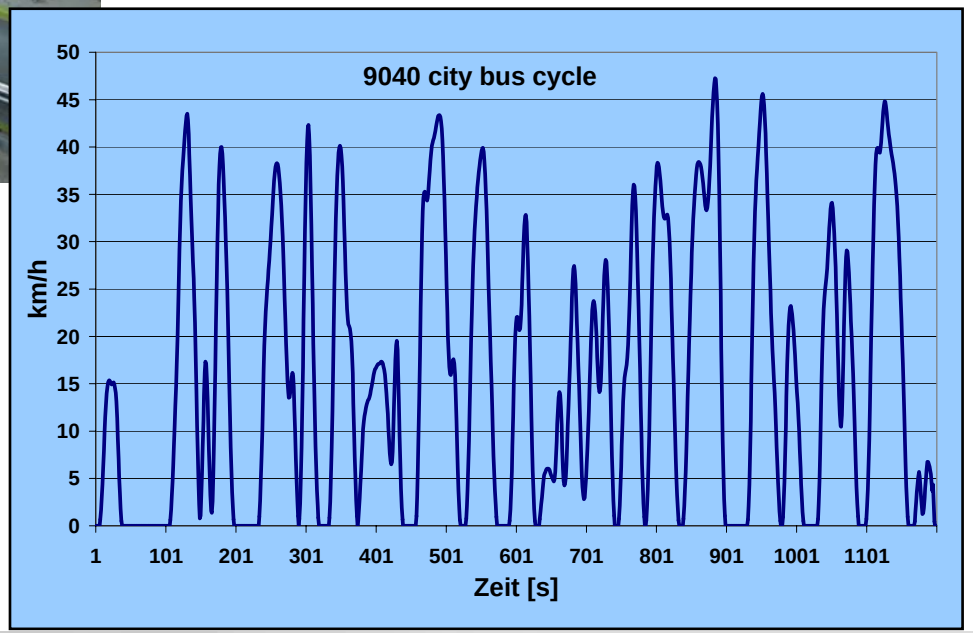


Measurements on HDV roller test bed to gain easy information on real world emission behavior

Transient roller test bed for HDV up to 38 tons and 360 kW

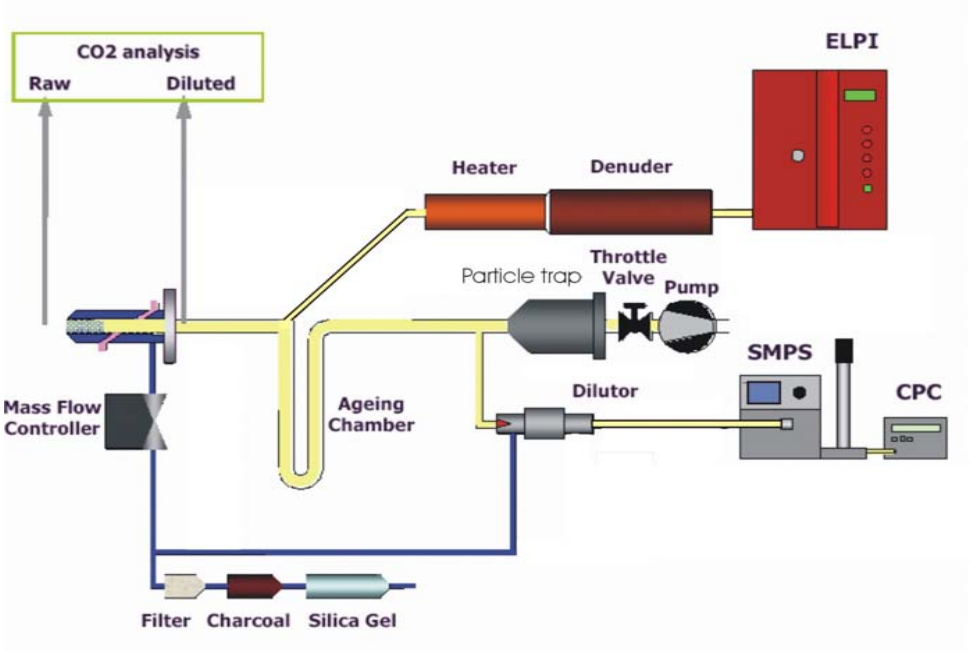
With full flow CVS system

Test Cycles:
*** Braunschweig cycle**
*** 9040 City bus cycle**
*** 3 constant velocities**



Particulate matter measurement equipment used

- **Mass from full flow CVS tunnel**
- **Number and size distribution from SMPS, ELPI, TSI CPC 3010**
- **„PARTICULATES“ dilution system 1:12 primary and 1:8 secondary dilution**



Engine technologies under consideration

Vehicles tested

Diesel Euro 2 (2)

Diesel Euro 3 (2)

- with retrofit Oxidation catalyst (1)
- with retrofit PM-catalyst (2)
- with retrofit PM-catalyst and biodiesel(*) (1)
- *with retrofit DPF* *(1)*

CNG

- Euro 3 (λ=1) (2)
- EEV (lean burn) (2)

LPG

Diesel Euro 4/5 with oem DPF

Related projects

ÖKODRIVE
gefördert von trend setter CIVITAS
www.trendsetter-graz.at

Particulates (EU FP 5)

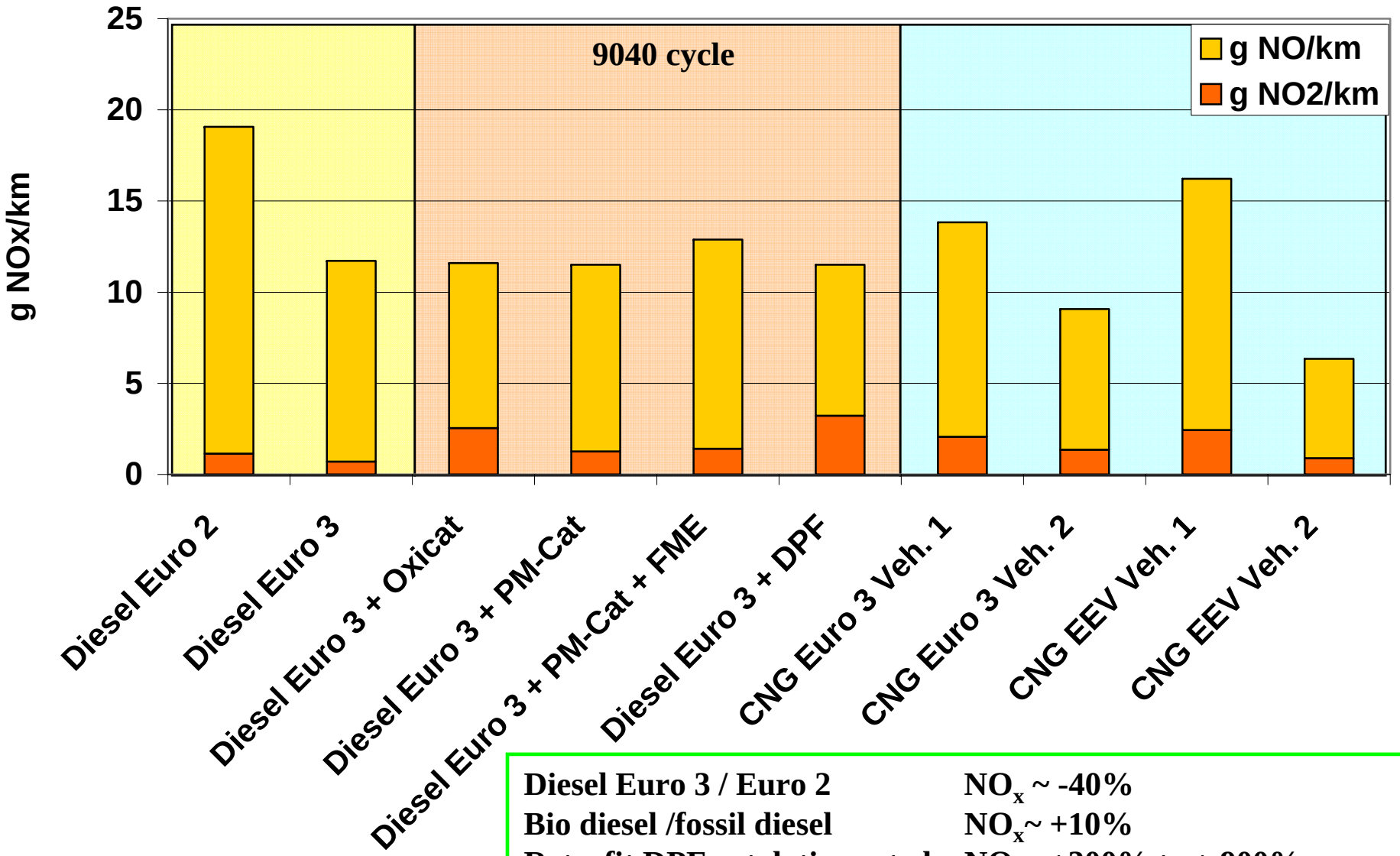
D.A.CH.-NL-S Cooperation on vehicle emission factors

+ national projects

not finalized yet

(*) methyl ester of used cooking oil

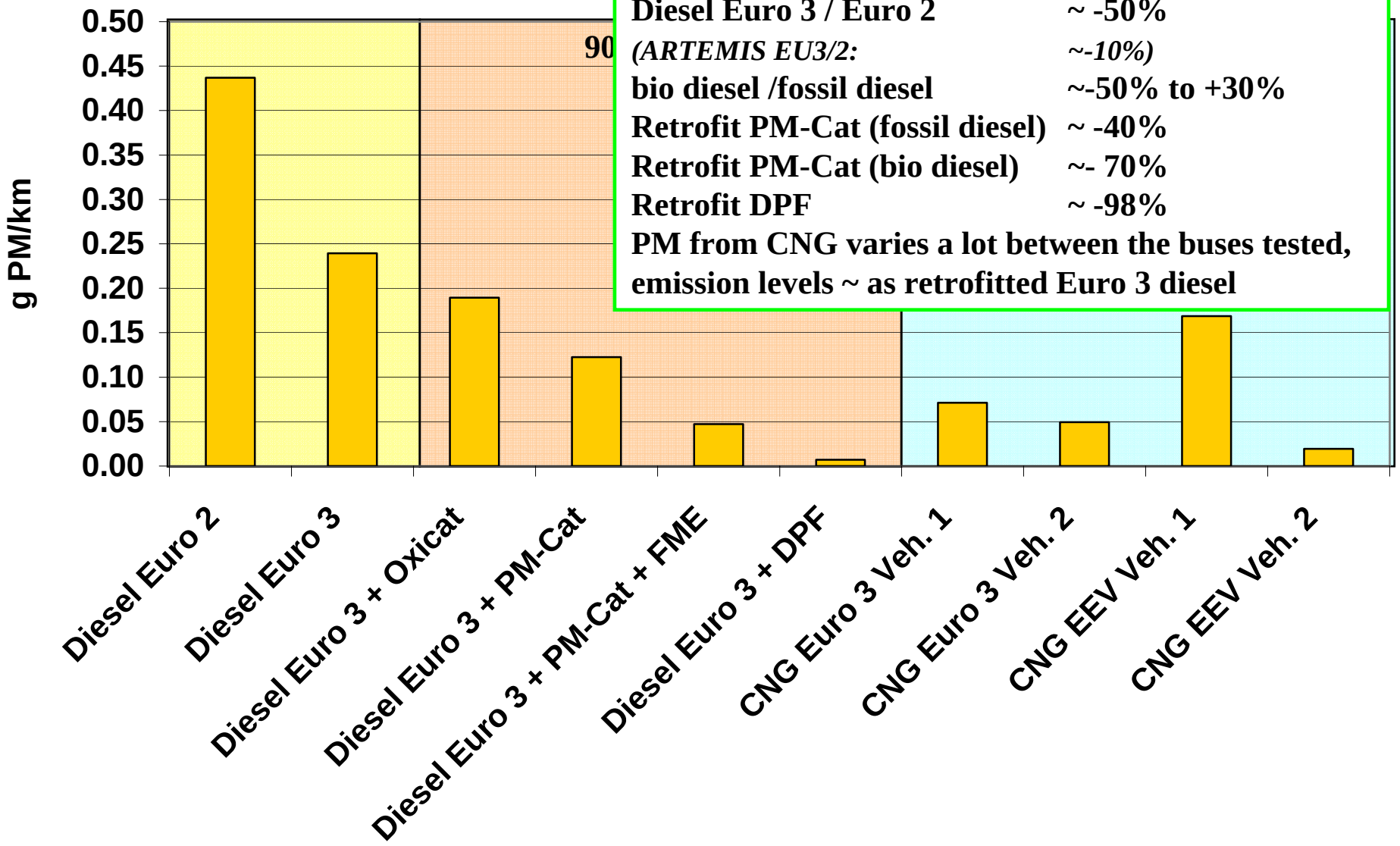
Results for regulated pollutants (e.g. NO_x)



Diesel Euro 3 / Euro 2	NO_x ~ -40%
Bio diesel /fossil diesel	NO_x~ +10%
Retrofit DPF catalytic coated	NO_2~ +300% to + 900%

NOx from CNG similar to diesel, but EEV has much higher NOx in real bus cycles than in the type approval

Results for regulated pollutants (e.g. PM)

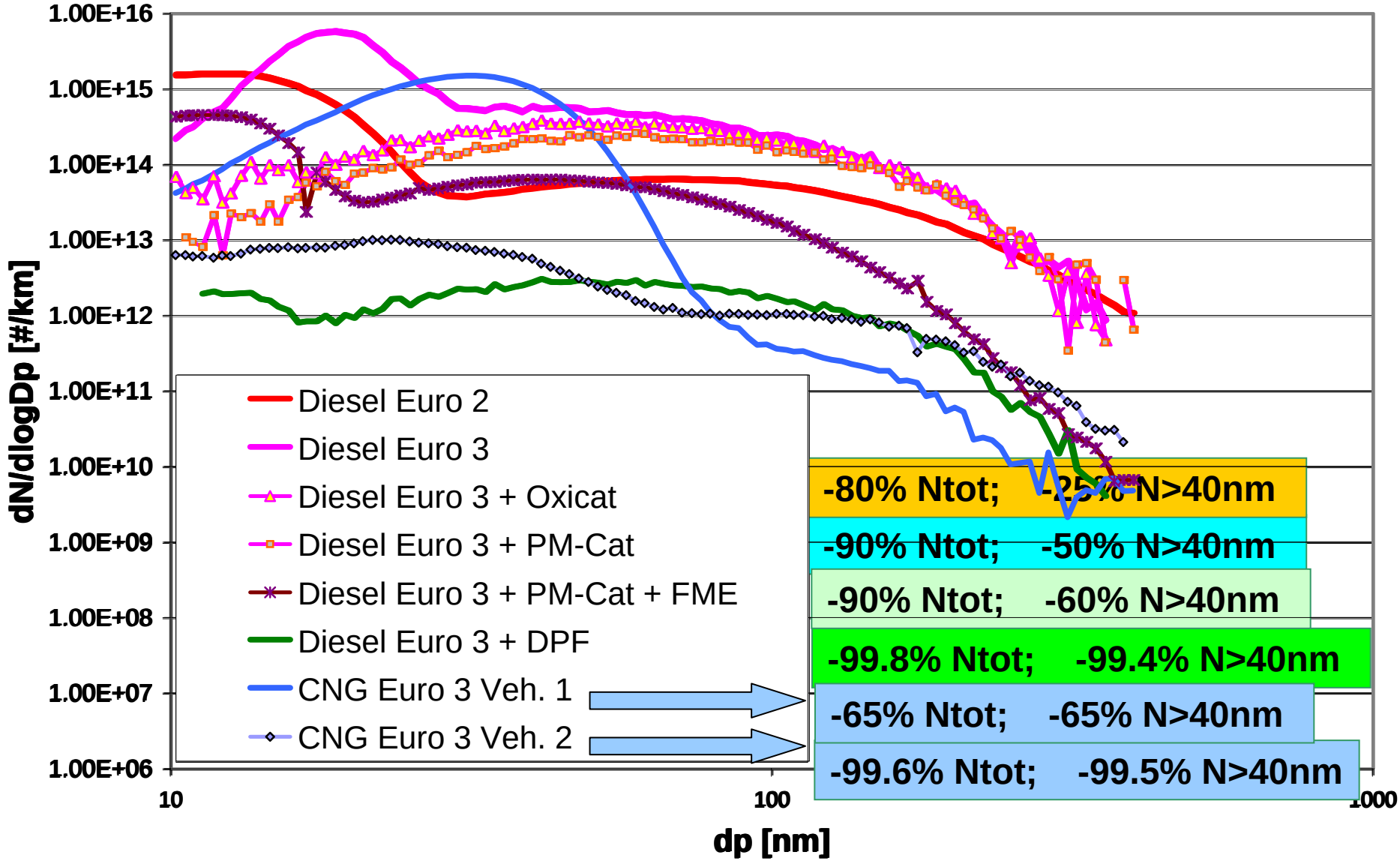


Diesel Euro 3 / Euro 2	**~ -50%**
(ARTEMIS EU3/2:	***~-10%)***
bio diesel /fossil diesel	**~-50% to +30%**
Retrofit PM-Cat (fossil diesel)	**~ -40%**
Retrofit PM-Cat (bio diesel)	**~- 70%**
Retrofit DPF	**~ -98%**

PM from CNG varies a lot between the buses tested, emission levels ~ as retrofitted Euro 3 diesel

Durability not tested for all technologies yet

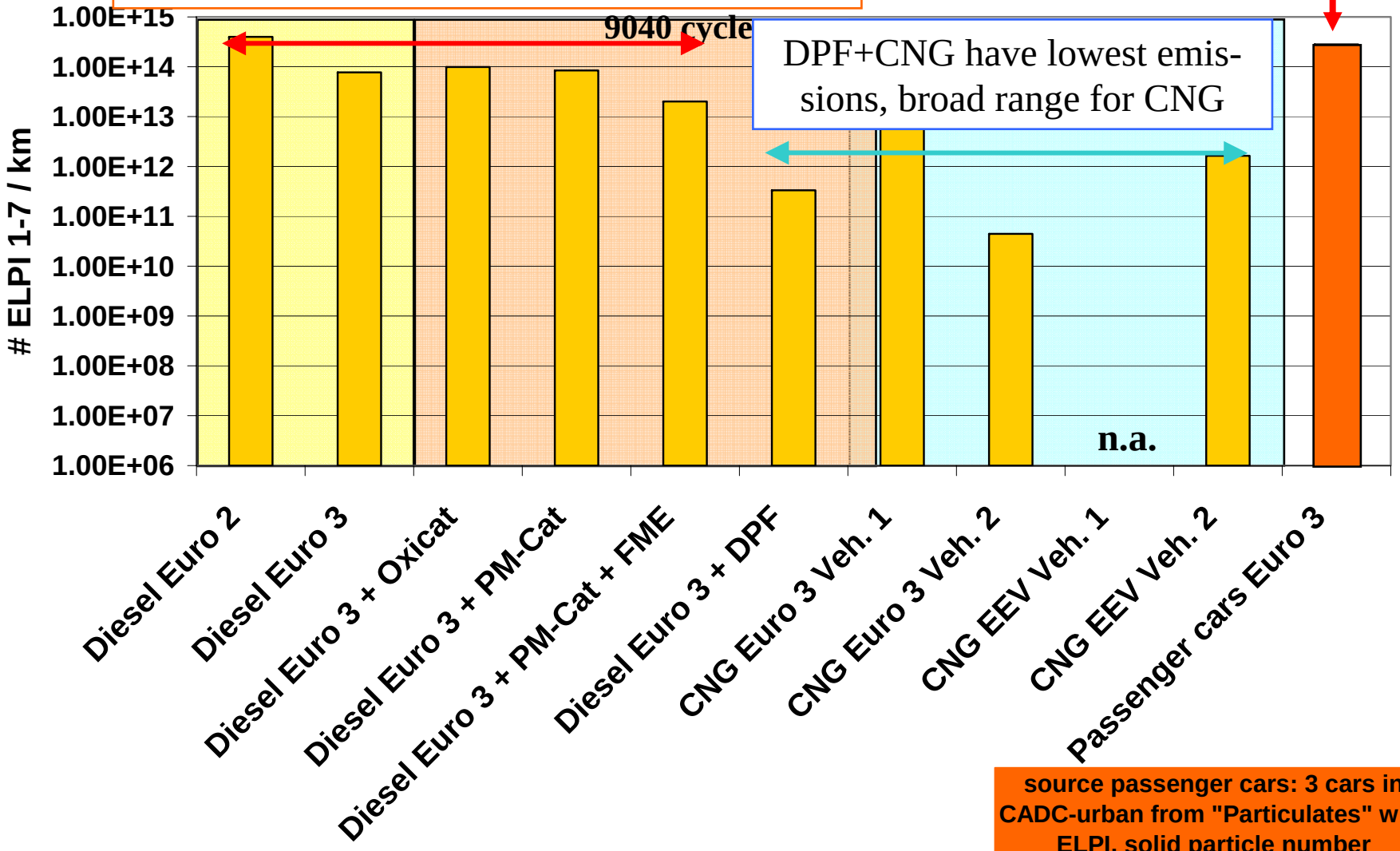
Results for PM # at 60 km/h (wet branch)



PM # in the 9040 bus cycle (dry branch)

ELPI&Thermodenuder don‘t give reasonable values for „small changes“ in PM#

Diesel cars emit ~ same #/km than HDV



source passenger cars: 3 cars in CADC-urban from "Particulates" with ELPI, solid particle number

Summary

- **Emission values in real world city bus driving can be very different from engine type approval data. Reason is, that**
  - **the ETC and ESC are not representative for the engine load population of city buses**
  - **and modern electronic engine control systems allow different settings at different points of the engine map**

-> each model can have special emission behavior in „off-cycle points“

-> results of the few vehicles tested are not representative for the fleet

- **PM mass and NO_x emissions of EURO 3 are lower than EURO 2**
- **CNG emission levels depend very much on the model tested, ranges are from „like Diesel EU3 with DOC“ to „like Diesel EU3 with DPF“**
- **Pm # from tested EURO 3 were higher than from tested EURO 2 in steady state (lower in transient tests but with high uncertainties)**
- **retrofitted DPF showed highest separation rates, DOC lowest, both in terms of PM mass and number concentration (durability?)**
- **LDV emit similar PM #/km than HDV**

Thank you for your attention!

Test vehicles

City buses ~ 11,5 t vehicle weight

Half loaded (i.e. approx. 45 persons)

Engine: ~200 kW

automatic gear box

Tested as delivered (after service from bus owners)

Test fuels

Diesel	**S: ~8ppm**
BioDiesel:	**Methyl Ester of cooking oil**
CNG:	**>98% CH_4**

Comparison of engine specific type approval limits