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Remote sensing for identifying high emitters and validating emission models

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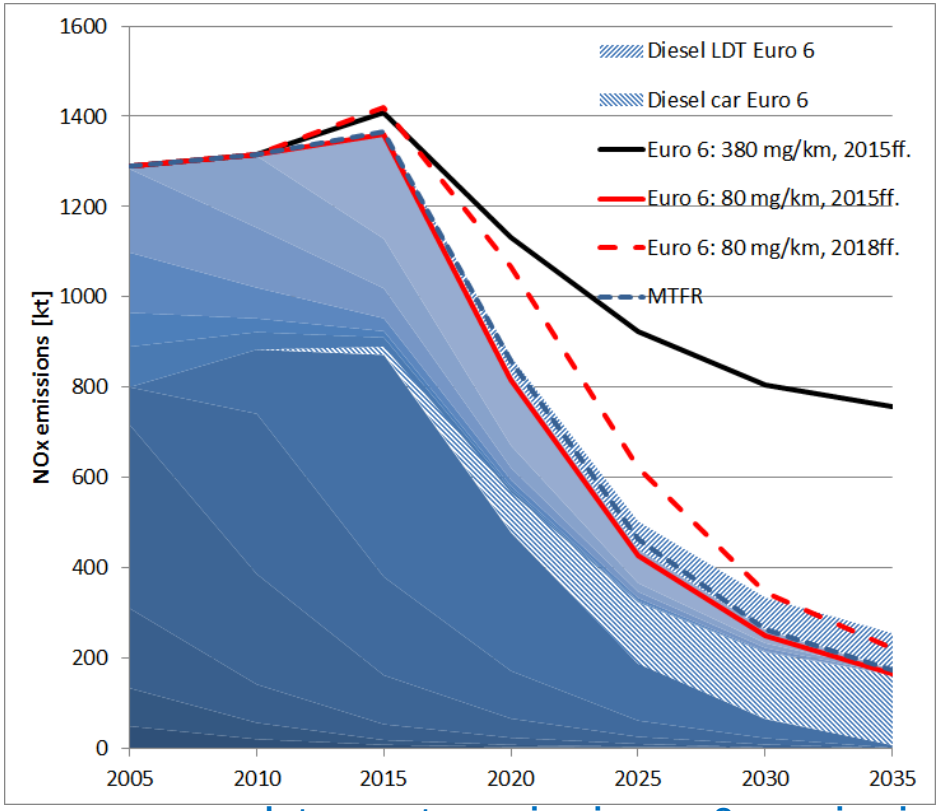
IIASA core competence:
Analysis of emissions, environmental and health impacts & identification of cost-effective measures for whole Europe for all sectors up to 2035

e.g. for Review of EU Strategy on Air Pollution

Future emissions of NO_x from light-duty diesel vehicles in EU27 as function of performance of Euro 6 diesel cars & light trucks



Therefore we are concerned to get emissions & emission factors right.

Main findings

Method:

- High emitting vehicles ≠ vehicles with highest instantaneous emissions

Base emission factors:

- Some high emitters included in ARTEMIS DB, hence implicitly in HBEFA!
  - Are levels and shares, hence average emission factors correct?

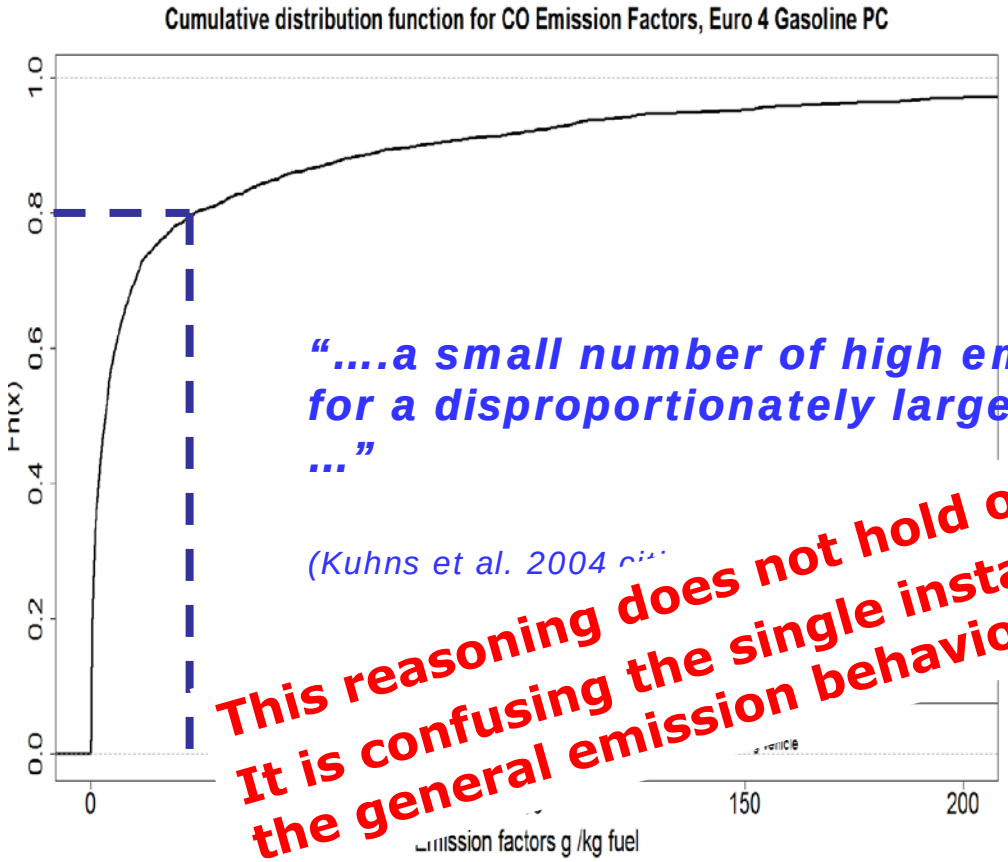
- Share of high emitters estimated for several European sites
  - Preliminary results (and some problems) for Gothenburg & Zurich

- Comparison of instantaneous emission factors from RSD with PHEM model (=average emission factor)
  - Trends reproduced well for NOx but difficulties for CO

Emission modeling

- High emitters important for both urban and highway fleet emissions

Traditional interpretation of RSD

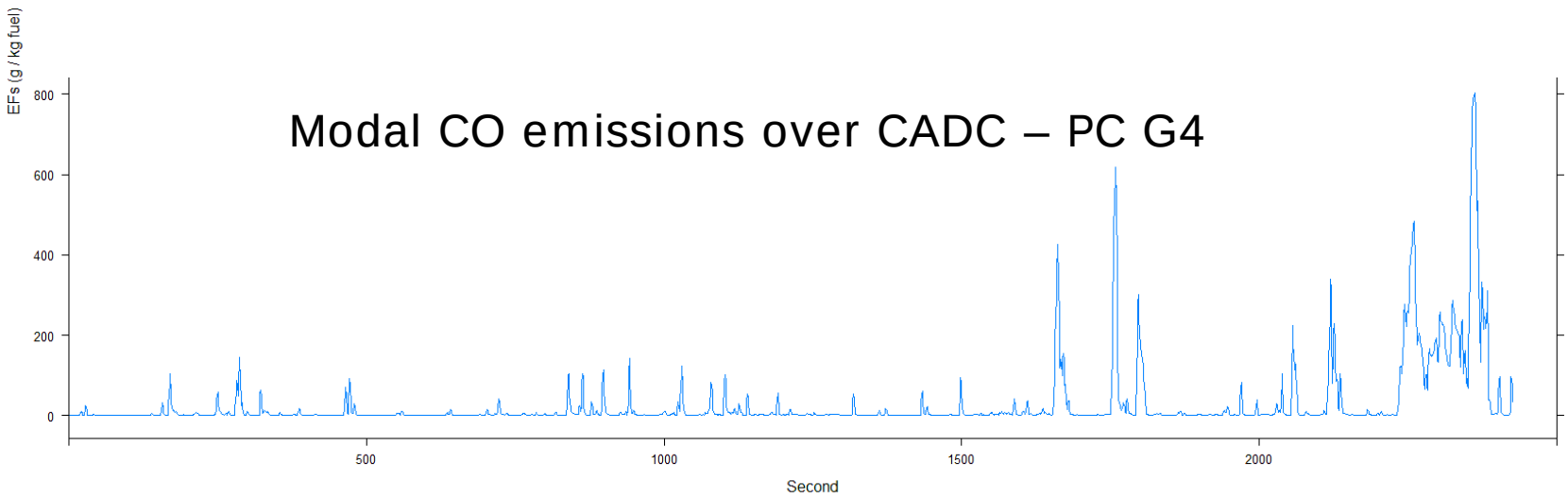


"....a small number of high emitting vehicles ... for a disproportionately large fraction ..."

(Kuhns et al. 2004 cit...

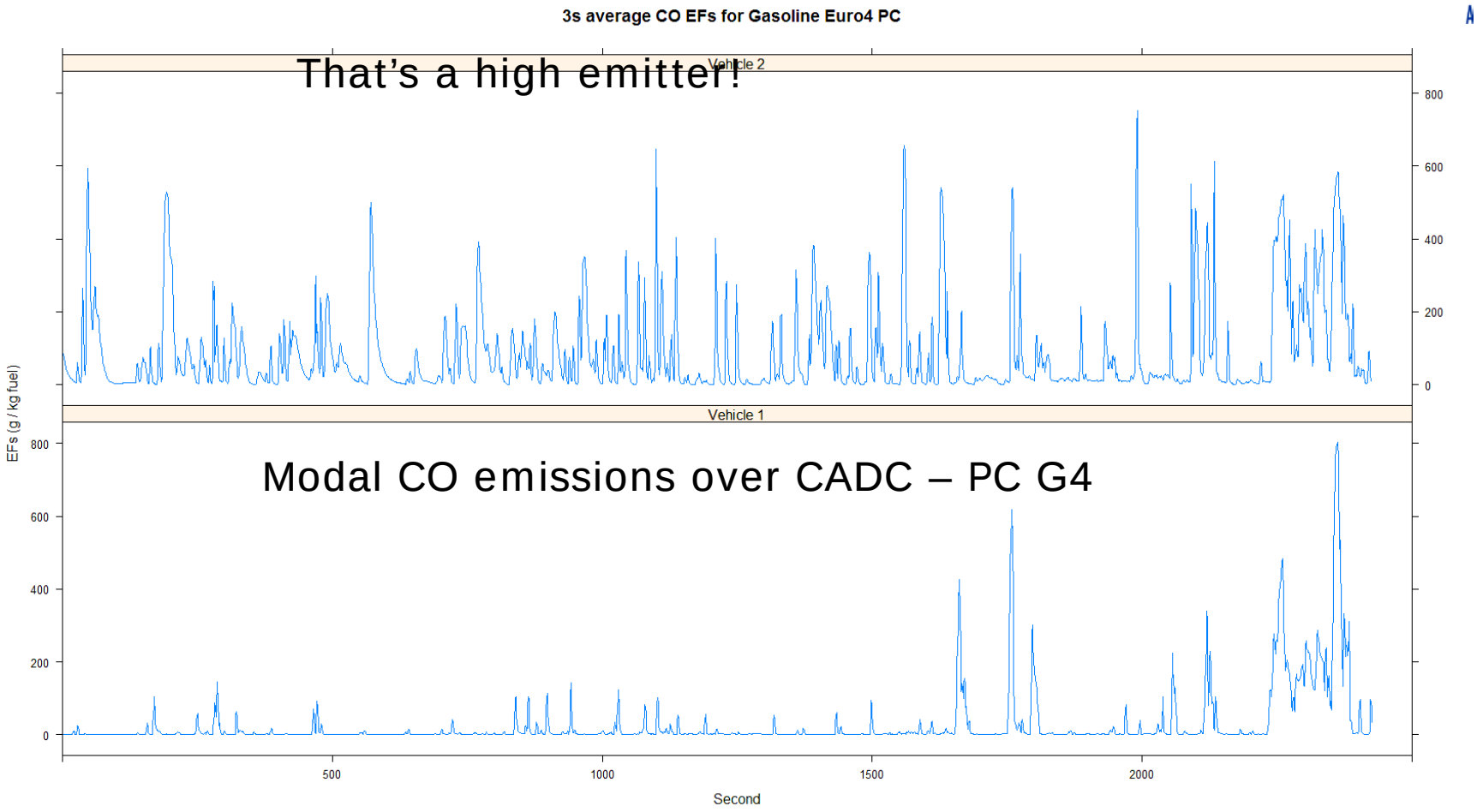
This reasoning does not hold over whole driving cycle. It is confusing the single instantaneous record with the general emission behaviour of a vehicle.

Emission spikes part of normal operation



Modal emission measurements: TUG

Emission spikes part of normal operation



Modal emission measurements: TUG

New approach

- Establish a reference distribution from chassis dynamometer data
- Identify high-emitters from the difference between Remote Sensing Data and clean reference chassis data

Working definition for a high emitting vehicle:

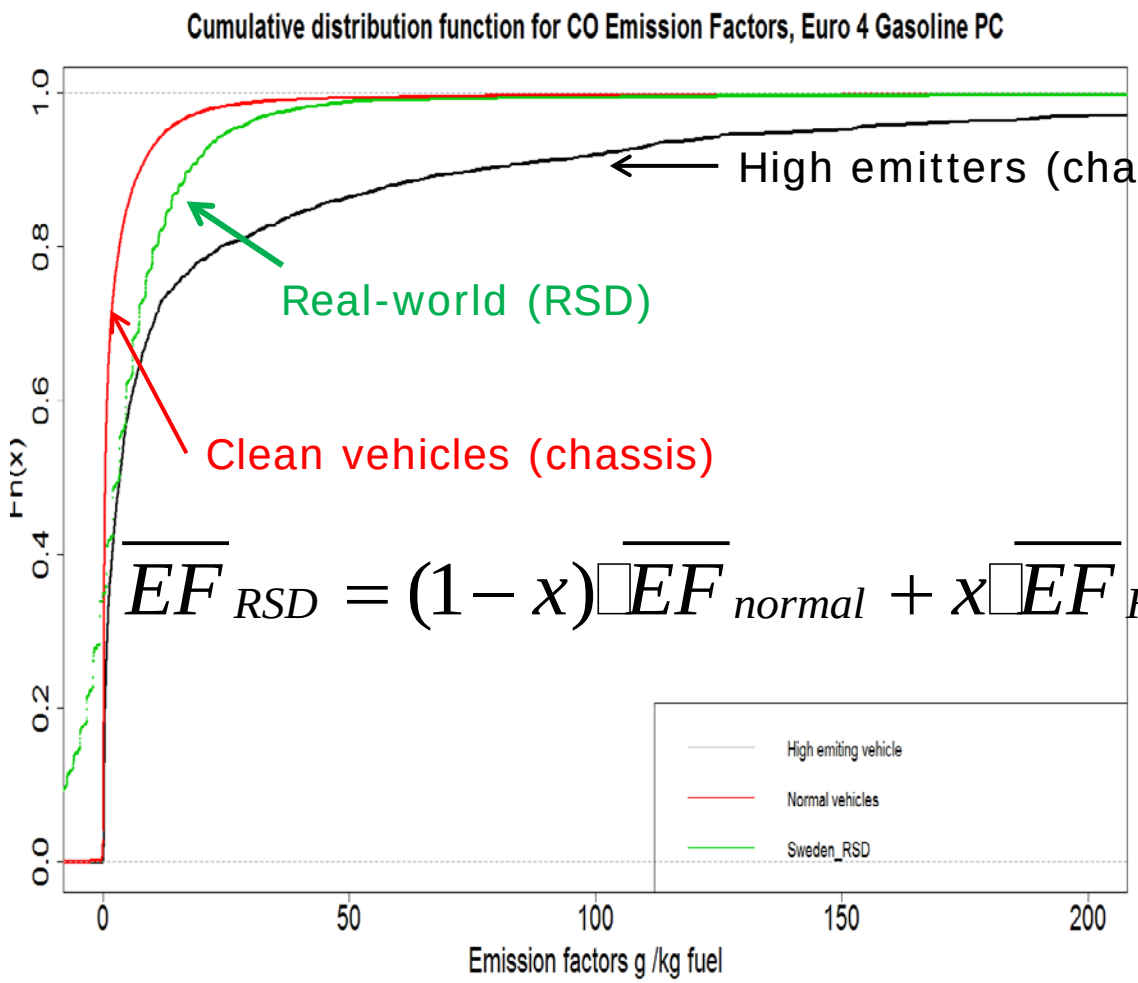
A vehicle whose average emissions are

by at least 2 standard deviation

higher than the average emissions of the sample tested.

New approach: RSD vs. Chassis benchmark

using CO from PC-G4 to illustrate method



PC-G4: CO	g/kg
EF_RSD	4.6
EF_normal	3.5
EF_HE	16.5

$$x_{SE}(CO) = 5\%$$

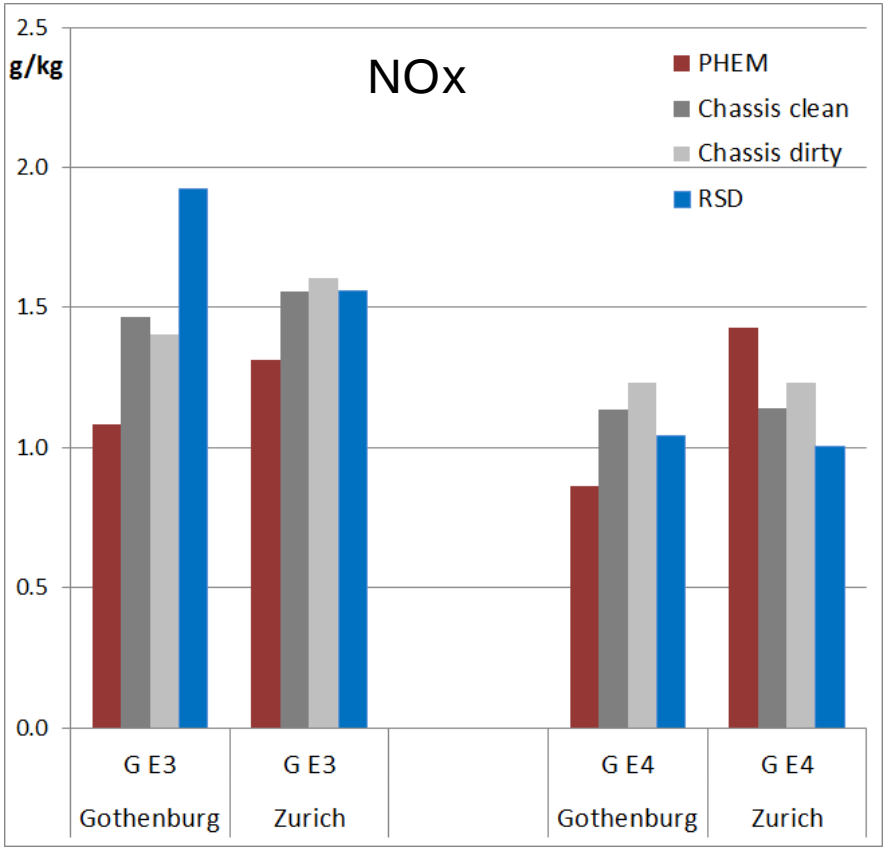
$$\overline{EF}_{RSD} = (1-x)\overline{EF}_{normal} + x\overline{EF}_{HighEmitter}$$

Key: Mean EF for "normal" and "high emitting" vehicle => sufficient sample needed!

SE RSD for Gothenburg: IVL

NOx EF: PHEM vs. chassis dyno vs. RSD

PC Gasoline Euro 3 & 4 (no HE data for other techologies)
Gothenburg 2007 & Zurich 2011



Gothenburg (2007): 0-2° grade, NO+NO2
Zurich (avg. 2000-2011): 9° uphill, NO measured, NO2 calculated from HBEFA 3.1 shares

For PC Gasoline Euro 3:

- PHEM lower than RSD,
- opposite load behavior
- Chassis dyno relatively stable
- Some NOx HE in Gothenburg!?

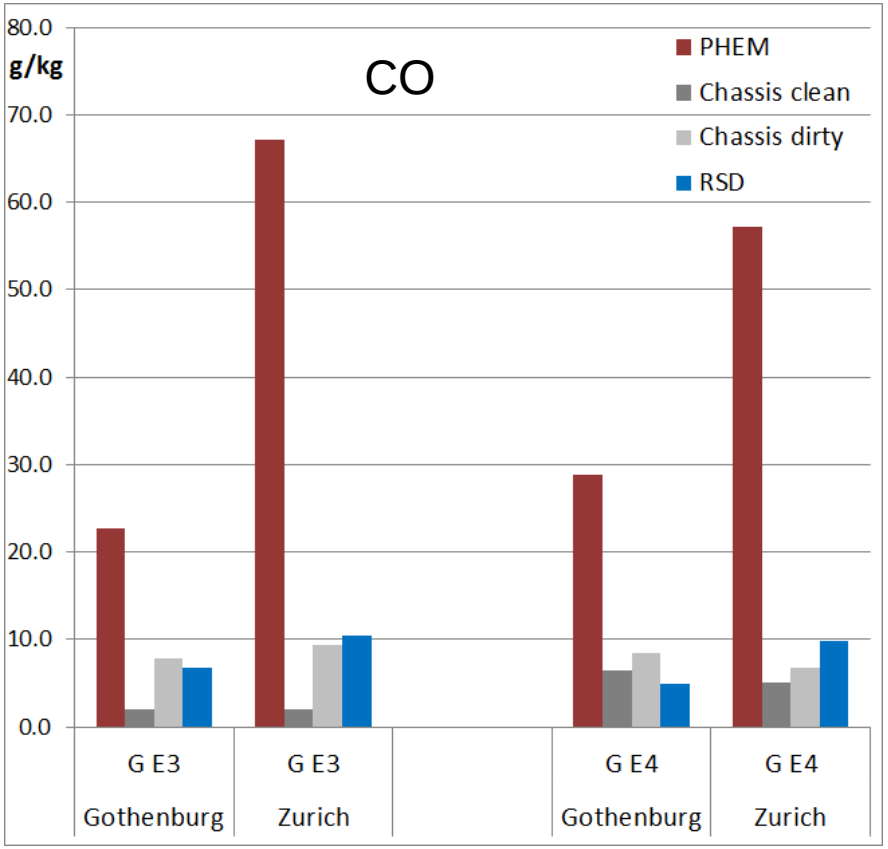
For PC Gasoline Euro 4:

- PHEM -20%/+40% vs. RSD,
- Opposite load behavior
- Chassis data and RSD at same levels
  ⇔ no NOx HE at these sites?

SE RSD for Gothenburg: IVL; CH RSD for Zurich: Baudirektion Zurich; PHEM simulation: TUG

NOx EF: PHEM vs. chassis dyno vs. RSD

PC Gasoline Euro 3 & 4 (no HE data for other technologies)
Gothenburg 2007 & Zurich 2011



Gothenburg (2007): 0-2° grade,
Zurich (avg. 2000-2011): 9° uphill

For PC Gasoline Euro 3:

- PHEM >> RSD (?)
- Chassis clean << RSD (?)

=> Many CO HE PC-G3 (?)

For PC Gasoline Euro 4:

- PHEM >> RSD (?)
- Chassis clean > RSD Gothenburg
  << RSD Zurich

⇒ Many CO HE in Zurich (?)

PHEM CO for these urban driving conditions not correct.

SE RSD for Gothenburg: IVL; CH RSD for Zurich: Baudirektion Zurich; PHEM simulation: TUG

Approach depends on credibility of input data

modal data with high emitters only for PC-G3 & G4

PC-Gasoline	Share HE: NOx			Share HE: CO		
	Chassis dyno	RSD Zurich (2000-2011)	RSD Gothenb. (2007)	Chassis dyno	RSD Zurich (2000-2011)	RSD Gothenb. (2007)
EURO 3	33% (3 in 9)	(neg.)-1%	18%-24%	33% (3 in 9)	22%-29%	22%
EURO 4	17% (4 in 24)	(neg.)	(neg.)	17% (4 in 24)	23%-33%	(neg.)-5%

Method nice (?) but not yet robust **as devil is in details**

- Modal chassis data available and reliable !!!
- Correct data treatment, e.g.
  - match records form speed and emissions instruments
  - conversion volume increments to fuel specific EF
- Correct filtering for comparing RSD and Chassis data

Strongly affects calculated share of HE

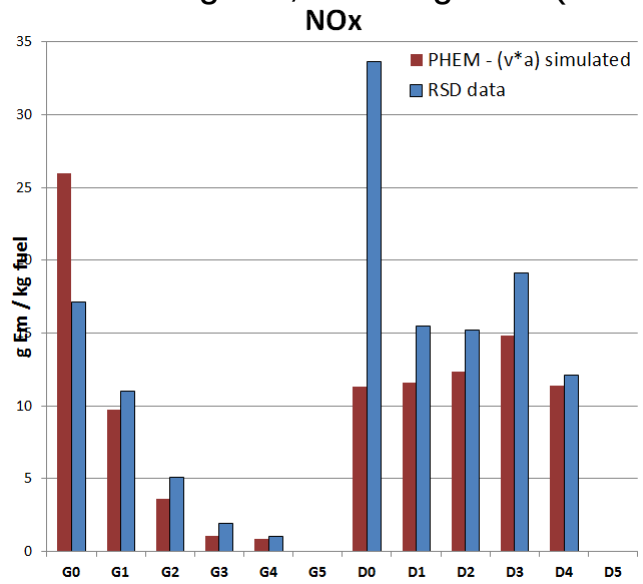
Note: Here, RSD indicate different shares than in base data!

Anything suitable for work program 2013!?

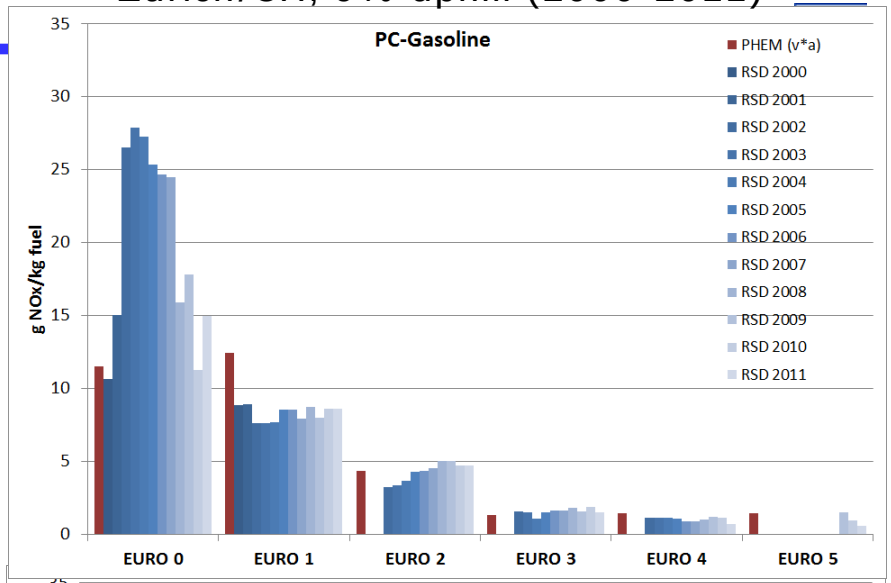
NOx: PHEM simulated EF vs. mean RSD EF

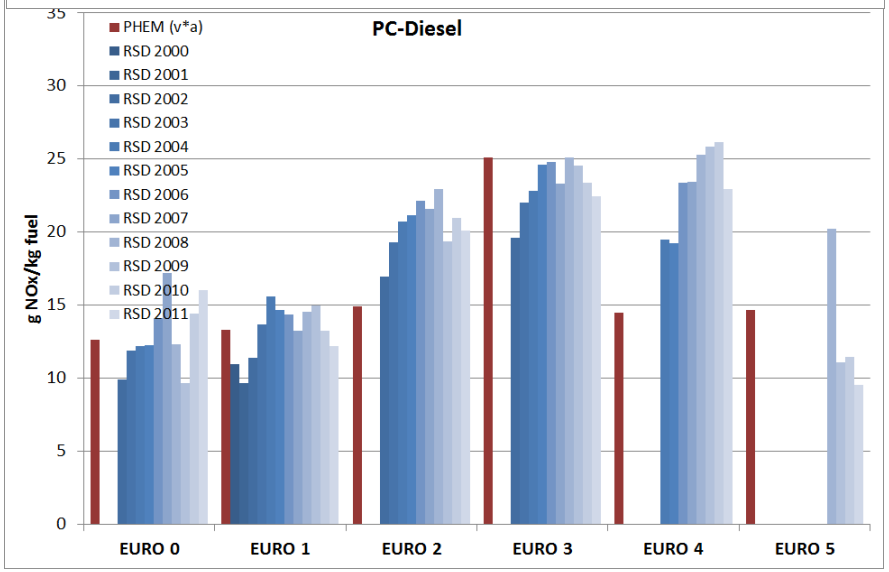
calibrated to 30-160 vehicles each incl. unknown high emitters

Gothenburg/SE, 0-2% grade (2007)



Zurich/CH, 9% uphill (2000-2011)





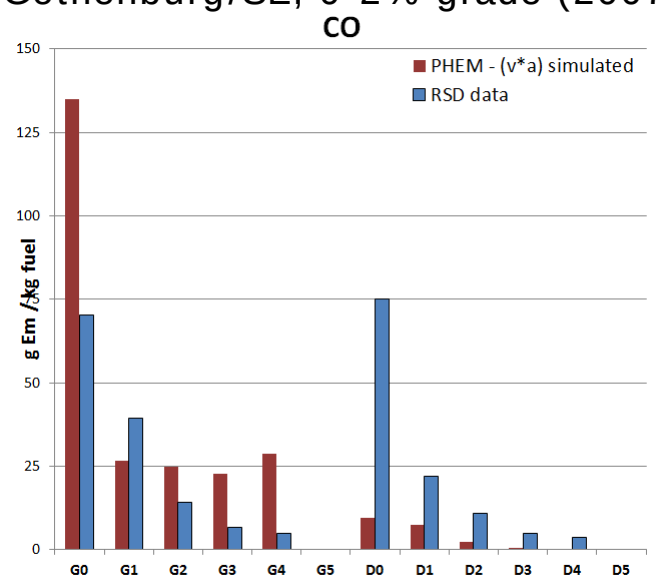
PHEM very good

- For PC gasoline at both sites
- For PC diesel somewhat lower

CO: PHEM simulated EF vs. mean RSD EF

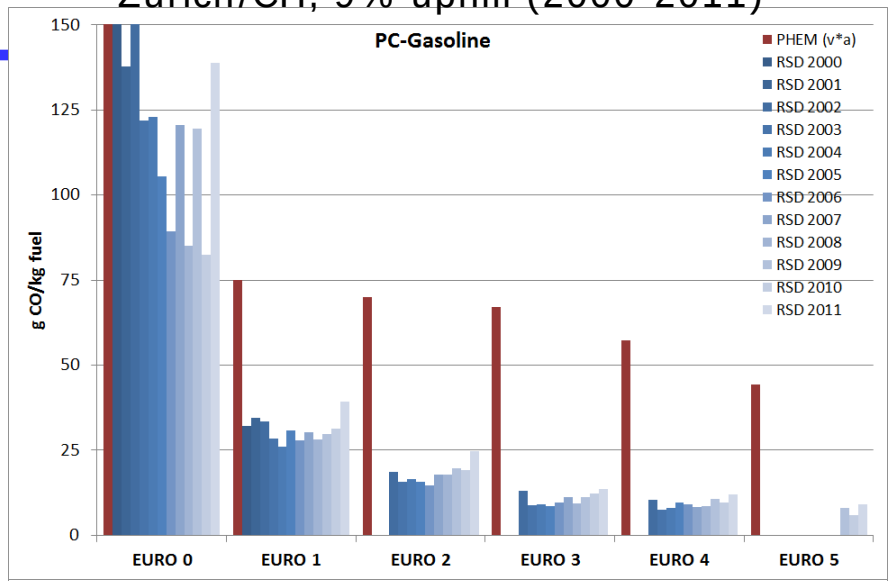
calibrated to 30-160 vehicles each incl. unknown high emitters

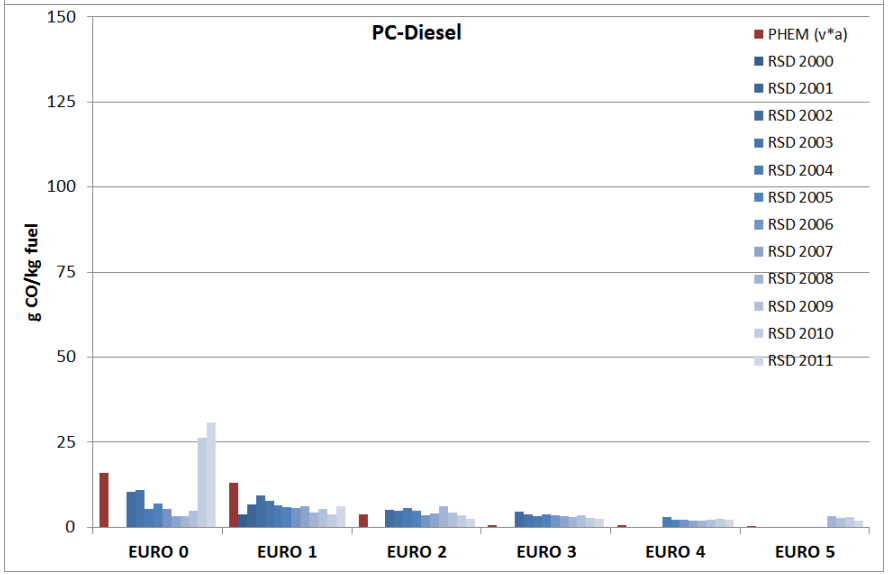
Gothenburg/SE, 0-2% grade (2007)



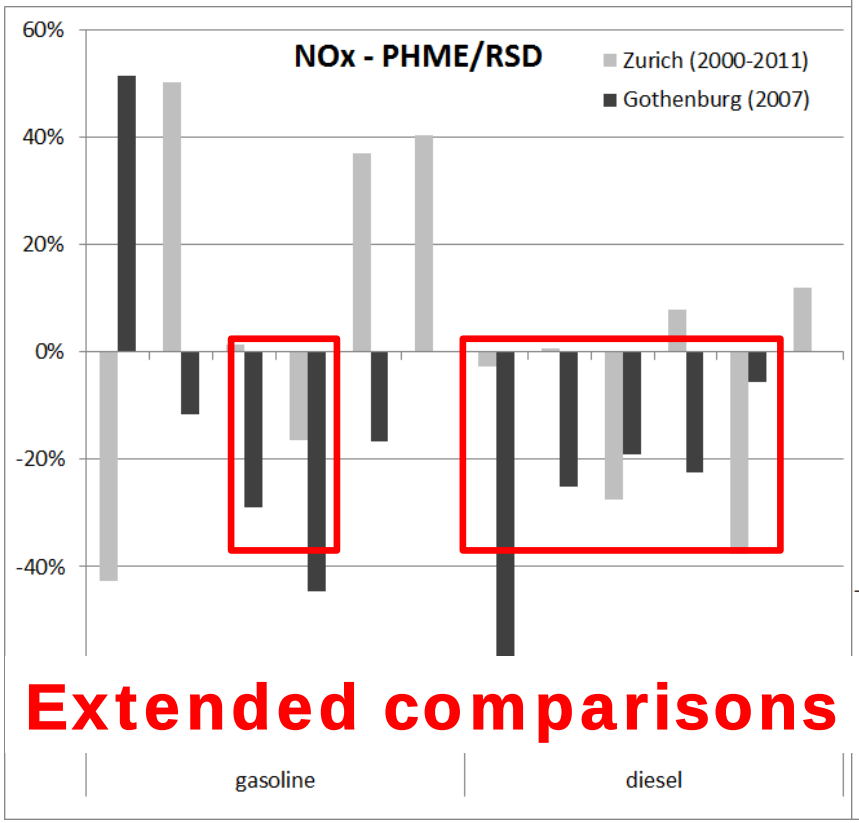
PHEM higher for Euro G2 – G5, calibration to engine maps difficult

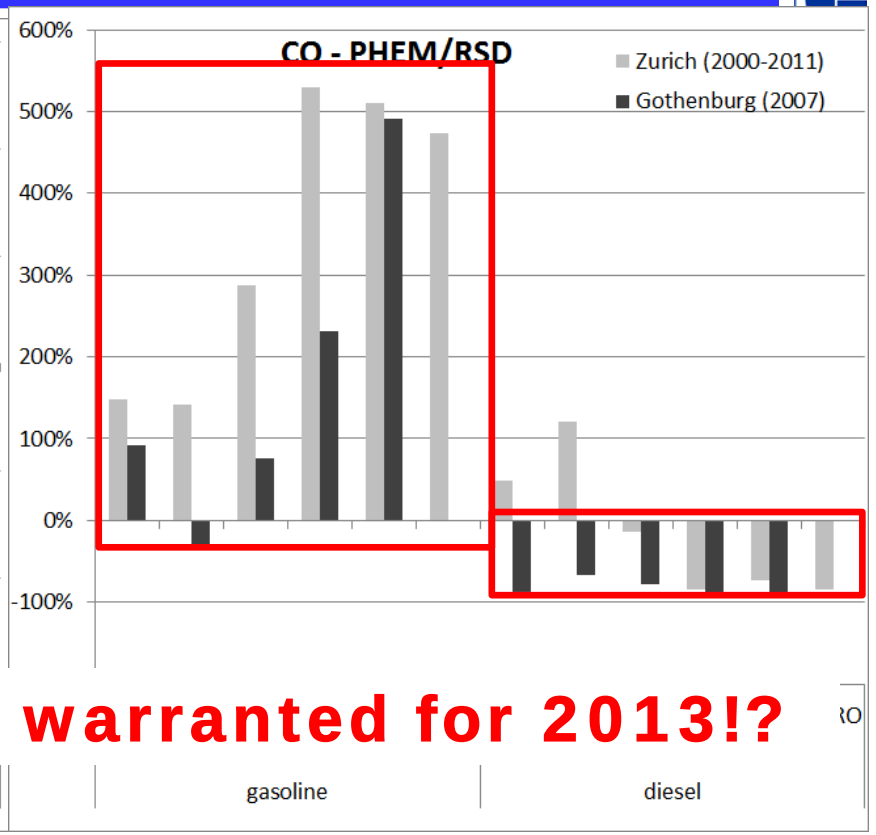
Zurich/CH, 9% uphill (2000-2011)





%difference **mean** EF: PHEM simul. vs. RSD





Extended comparisons warranted for 2013!?

PHEM for (urban) driving situations

- gasoline E3-E4 30-40% lower,
- diesel E1-E3 20-30% lower.

PHEM for (urban) driving situations

- gasoline cars much higher,
- diesel cars lower.

Outlook

Identifying high emitters:

- Some high emitters included in ARTEMIS DB, hence implicitly in HBEFA!
  - Are levels and shares, hence average emission factors correct?
  - More modal emission measurements available?

Validation of average emission factors:

- Share of high emitters estimated for several European sites
- Comparison of instantaneous emission factors from RSD with PHEM model
  - We continue with data from UK (ITS Leeds)
  - **More RSD sites? NL?**
  - **Analyse aging effects from RSD spanning 2000 to 2011/2?**
  - **Analyse cross-country effects between CH-SE-UK – NL?! sites?**

If share high emitters is known, we can generalize on whole driving cycle