REPORTED PM EMISSIONS & CONDENSABLES

With a focus on wood combustion | Jeroen Kuenen

TNO innovation for life

OUTLINE

- The first part of this presentation is based on the paper
  - *Denier van der Gon, H. A. C., Bergström, R., Fountoukis, C., Johansson, C., Pandis, S. N., Simpson, D., and Visschedijk, A. J. H.:* ***Particulate emissions from residential wood combustion in Europe – revised estimates and an evaluation****, Atmos. Chem. Phys., 15, 6503-6519, doi:10.5194/acp-15-6503-2015, 2015.*
  - available for download at: http://www.atmos-chem-phys.net/15/6503/2015/
- It is a collaborative effort from several different research institutes.
- In the study we compared bottom-up emissions with reported data by countries for the year 2009, as reported in 2011.

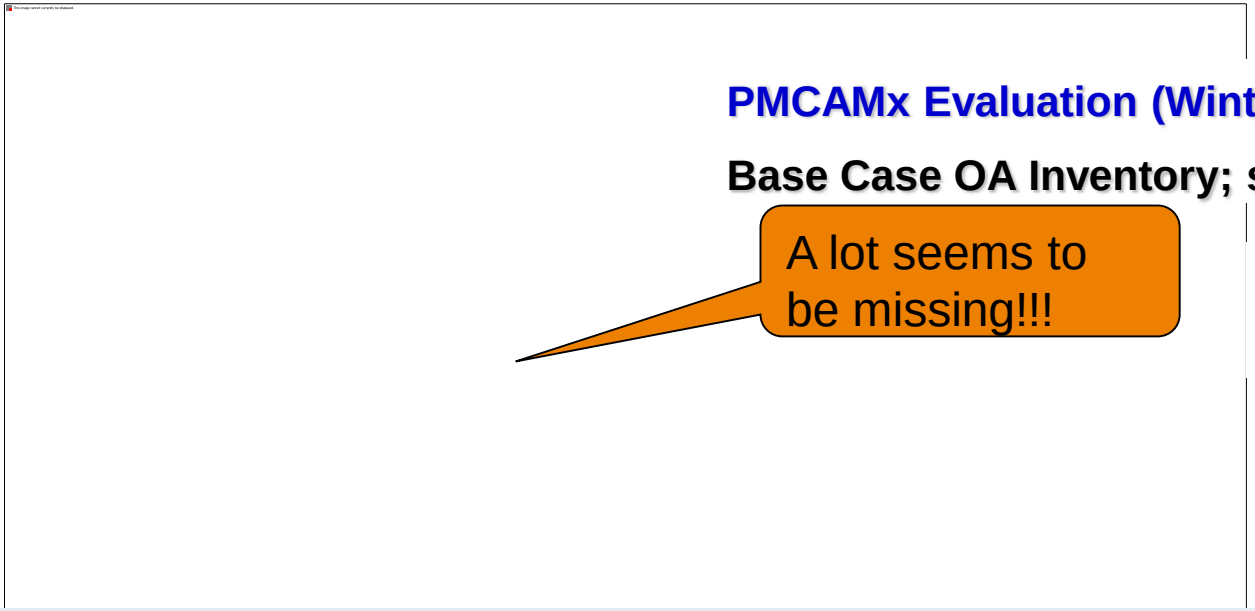
- Second part of presentation: a few slides about current reporting of PM, and the potential impact on overall emissions

FIRST PART – OUTLINE & BACKGROUND

1. In EU FP6 project EUCAARI a novel PM_EC and PM_OC inventory was made by TNO
2. Application in 2 CTMs (EMEP and PMCAMx) – revealed overall good performance but large underestimation in winter at sites dominated by wood combustion (illustrated on next slide)
3. Comparison of country emissions per unit of wood combusted showed large discrepancies between countries
4. Digging deeper revealed that this was a.o. related to inclusion or exclusion of the condensable fraction of PM in the emission factors
5. TNO made an alternative inventory for wood combustion by improving activity data for wood use AND applying consistent EFs including the condensable fraction
6. Repeated application in the models showed large improvements

WHY RETHINK PM FROM WOOD COMBUSTION?

- In 2010 good results EUCAARI EC / OC inventory but….major model vs observed discrepancies during episodes influenced by residential wood combustion (RWC).



PMCAMx Evaluation (Winter 2009)

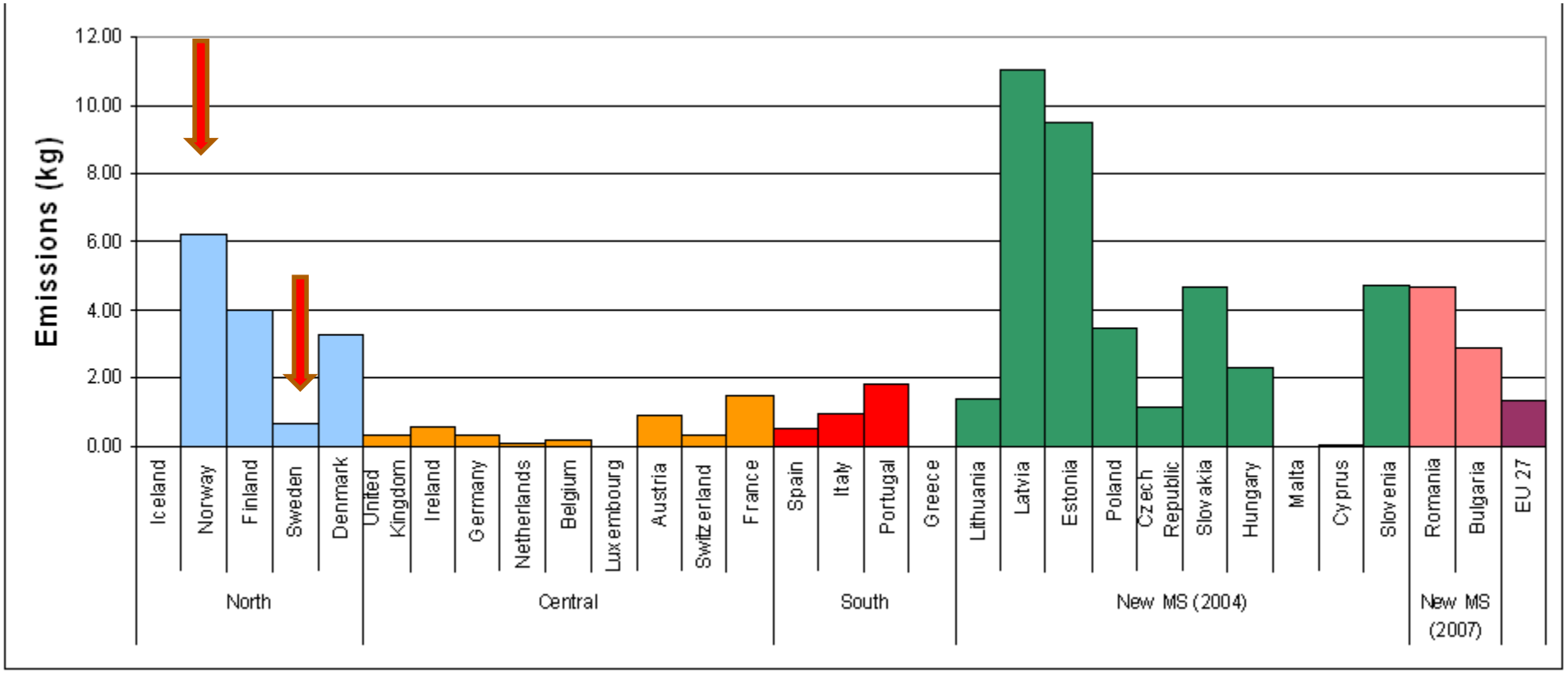
Base Case OA Inventory; site Vavihill (Sweden)

A lot seems to be missing!!!

Similar performance in e.g. Payerne, Melpitz

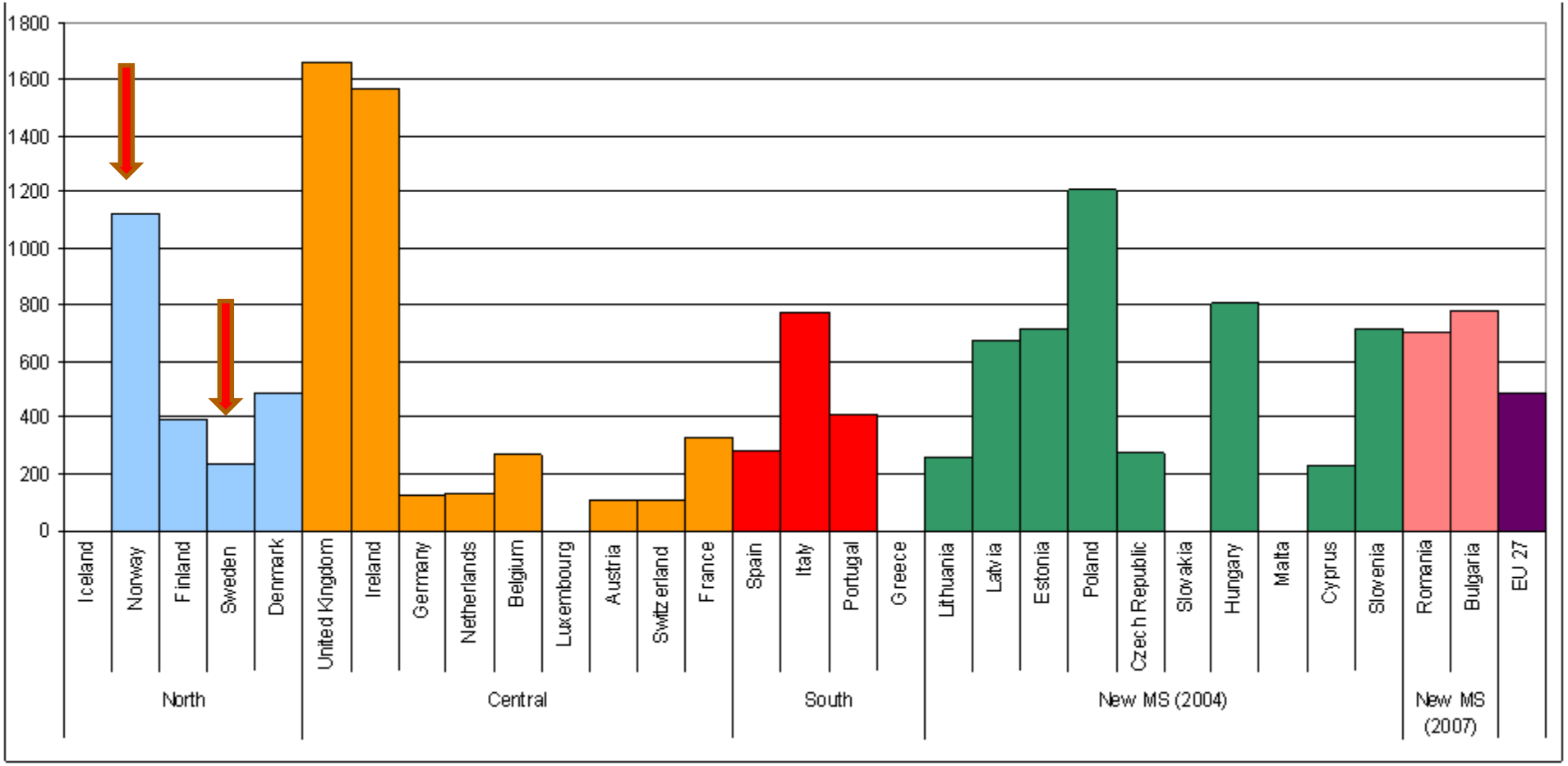
Regional CTMs have a problem with mass closure for PM – mostly an “OC problem”. At the time we thought the VBS approach would solve it, now we see it helps but there is still a substantial gap, especially close to the sources……

EMISSIONS OF PM10 (SECTOR RESIDENTIAL & COMMERCIAL) PER CAPITA IN 2009 (AS REPORTED IN 2011).



Purely for illustration of the issues we focus on 2 countries Norway and Sweden

EMISSIONS OF PM10 PER UNIT OF WOOD COMBUSTED IN THE RESIDENTIAL SECTOR IN 2009 (G/GJ)



AN ALTERNATIVE INVENTORY BASED ON FILTERABLE PM AND CONDENSABLE PM

- the US EPA defines particulate matter (PM) as consisting of a filterable fraction (FPM) and a condensable fraction (CPM).

<u>Filterable PM is directly emitted:</u>

- Solid or liquid
- Captured on filter
- PM_{10} or $PM_{2.5}$

<u>Condensable PM is in vapor:</u>

- Reacts upon cooling and dilution
- Forms solid or liquid particle
- Always $PM_{2.5}$ or less

where should the PM mass be that forms almost instantaneously?

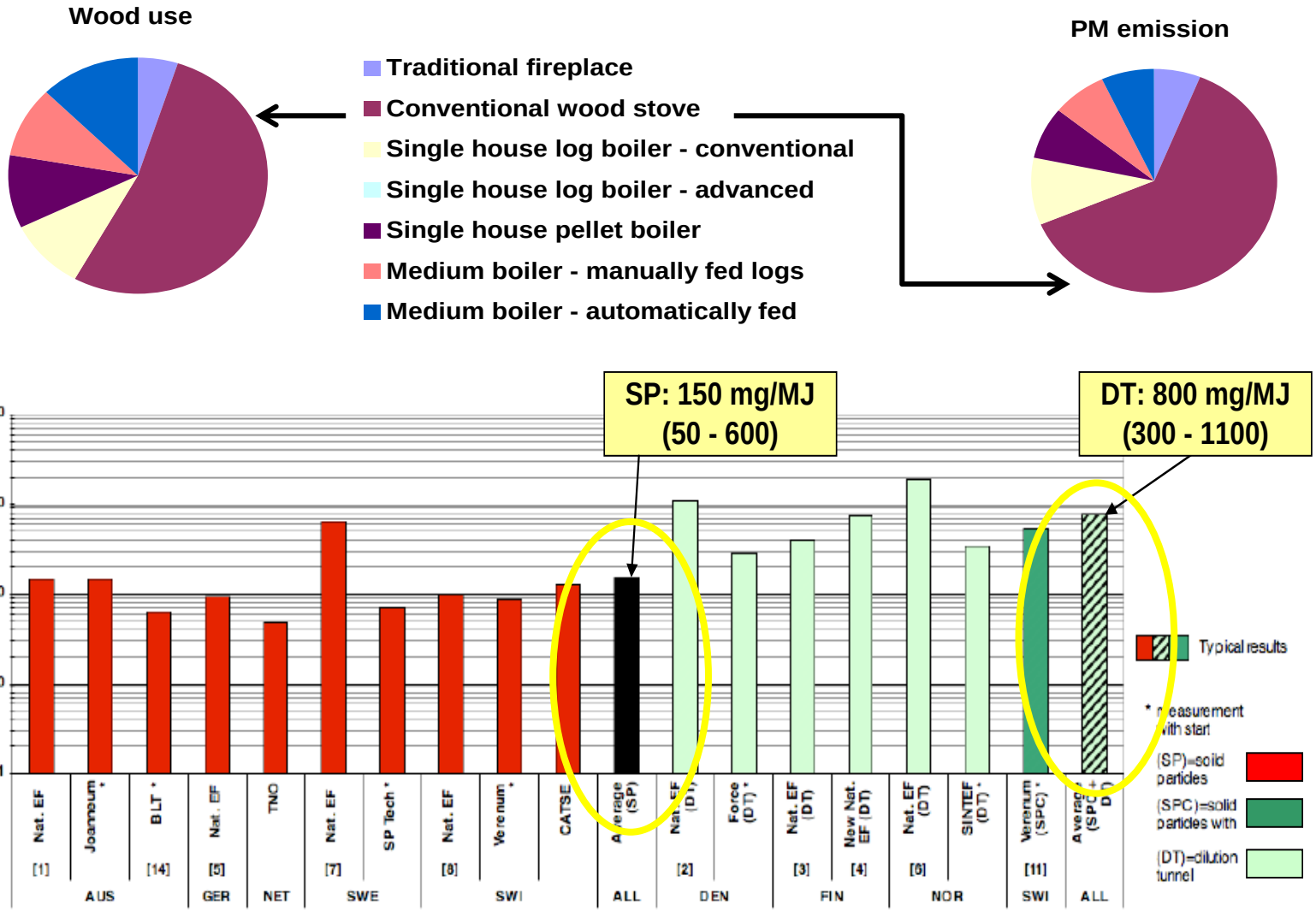
FRACTION OF WOOD USE BY APPLIANCE TYPE IN EUROPE (2005) AND SOLID PARTICLE (SP) AND DILUTION TUNNEL (DT) PARTICLE EMISSION FACTORS

Appliance type[a]	Fraction of wood consumption	Emission factor (g GJ^{-1}) [b] SP avg	SP range	DT avg	DT range
Fire place	6%	260	23 – 450	900	[d]
Traditional heating stove	52%	150	49 – 650	800	290 – 1932
Single house boiler automatic	9%	30	11 – 60	60	[d]
Single house boiler manual	15%	180	6 – 650	1000	100 – 2000
Medium boiler automatic	12%	40	[c]	45	[c]
Medium boiler manual	6%	70	30 – 350	80	30 – 350
Total Europe	100%				

Denier van der Gon et al., ACP, 2015

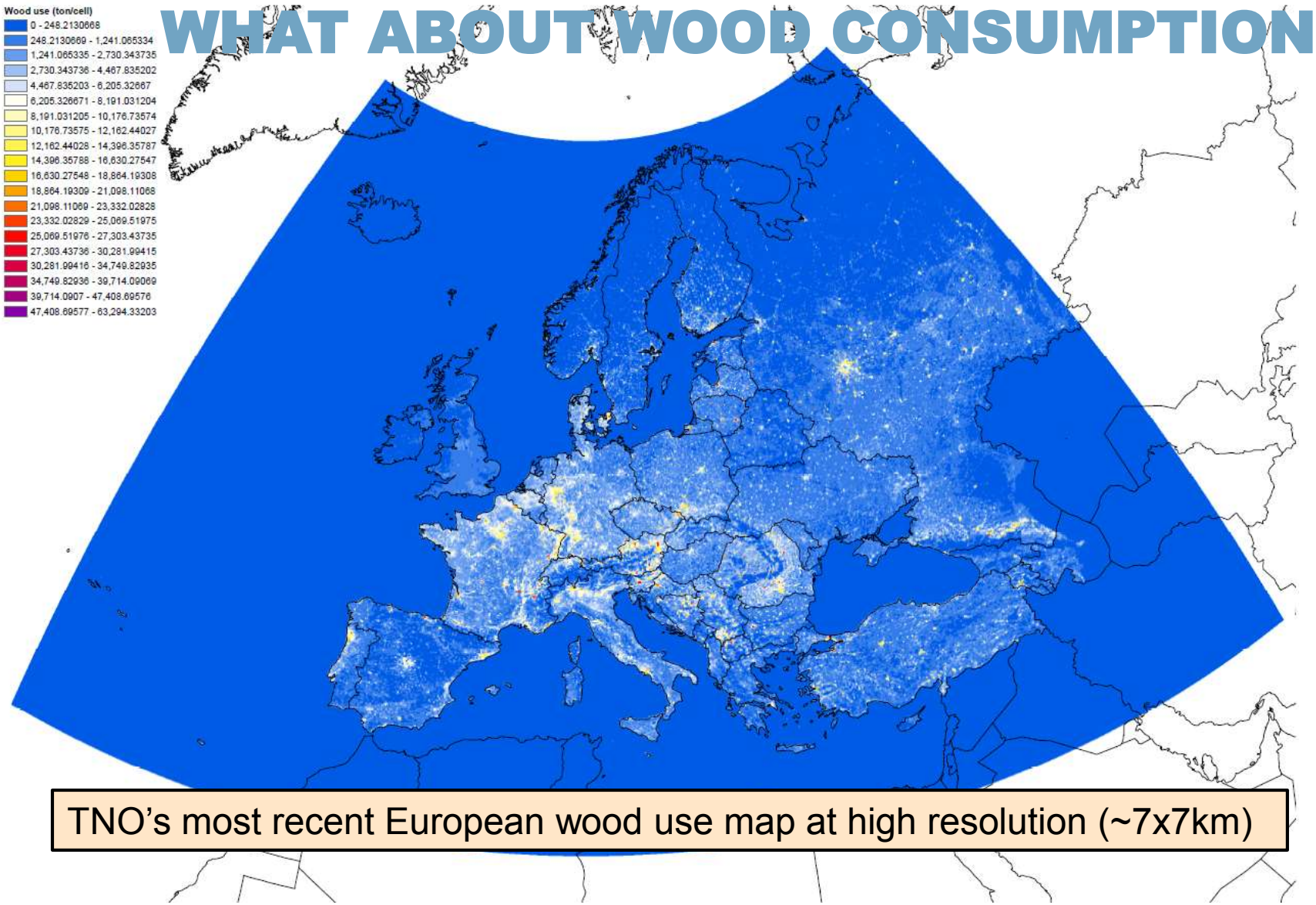
- Note that DT is always higher than SP but for (new) automatic boilers (and pellet stoves) the difference is much less than for traditional stoves – appliance type is crucial information!

PM EMISSION FACTORS FOR RWC
EXAMPLE: CONVENTIONAL WOODSTOVE



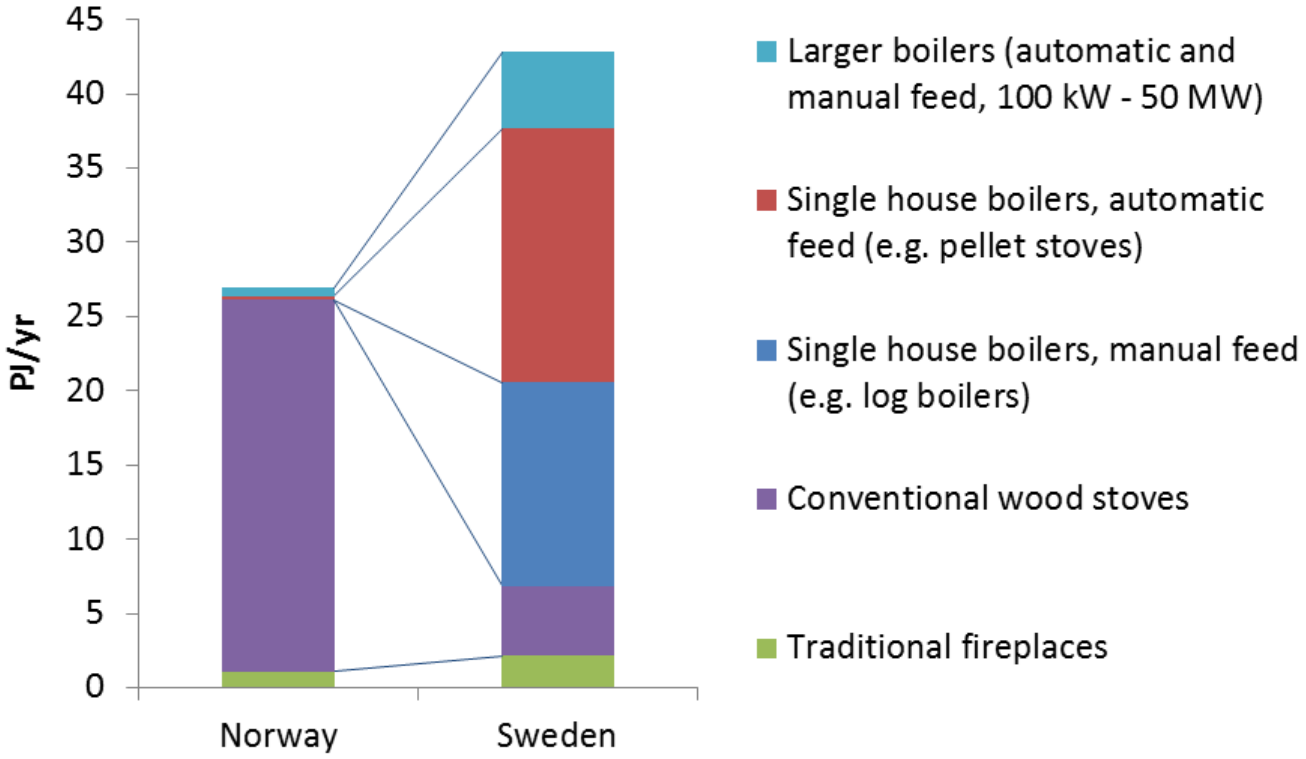
- Source: Nussbaumer et al. (2008)

WHAT ABOUT WOOD CONSUMPTION



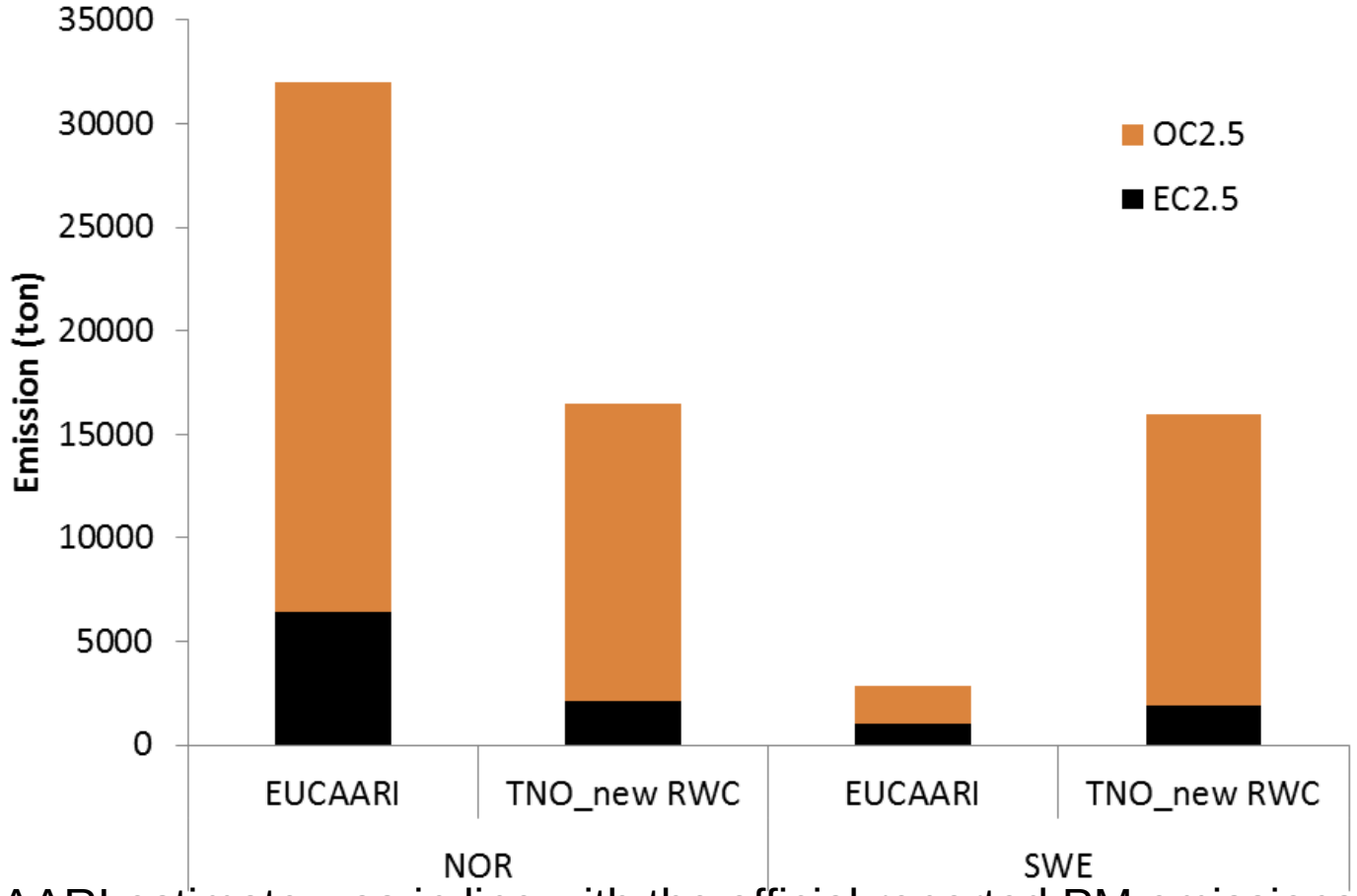
TNO's most recent European wood use map at high resolution (~7x7km)

A CASE TO EXPLAIN THE IMPACTS: WOOD USE (2005) IN NORWAY < SWEDEN



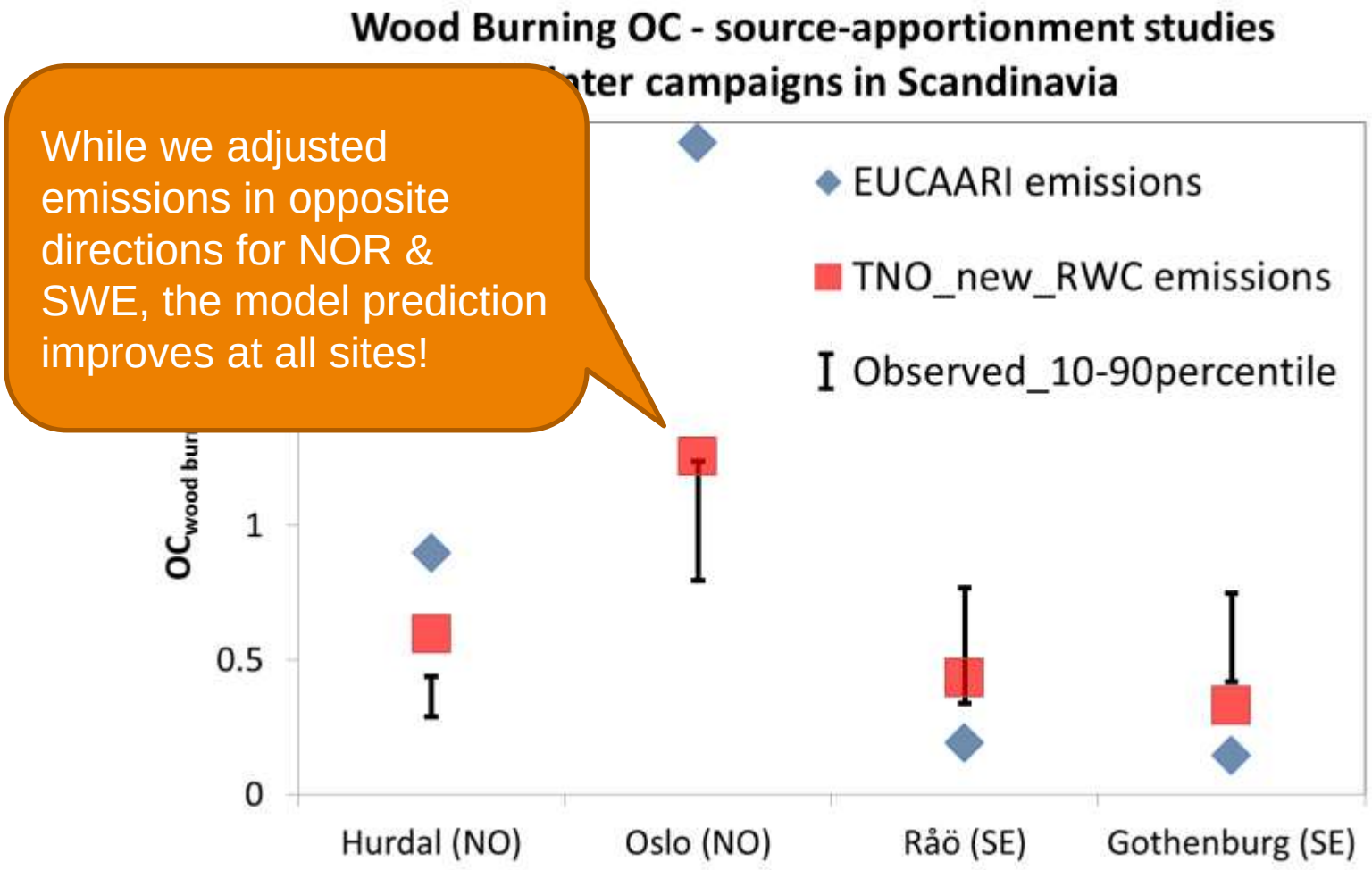
- Wood use in Sweden larger but in different appliances
- Countries use their own methods to calculate PM emissions

NORWAY & SWEDEN TOTAL RWC EMISSIONS YEAR 2005



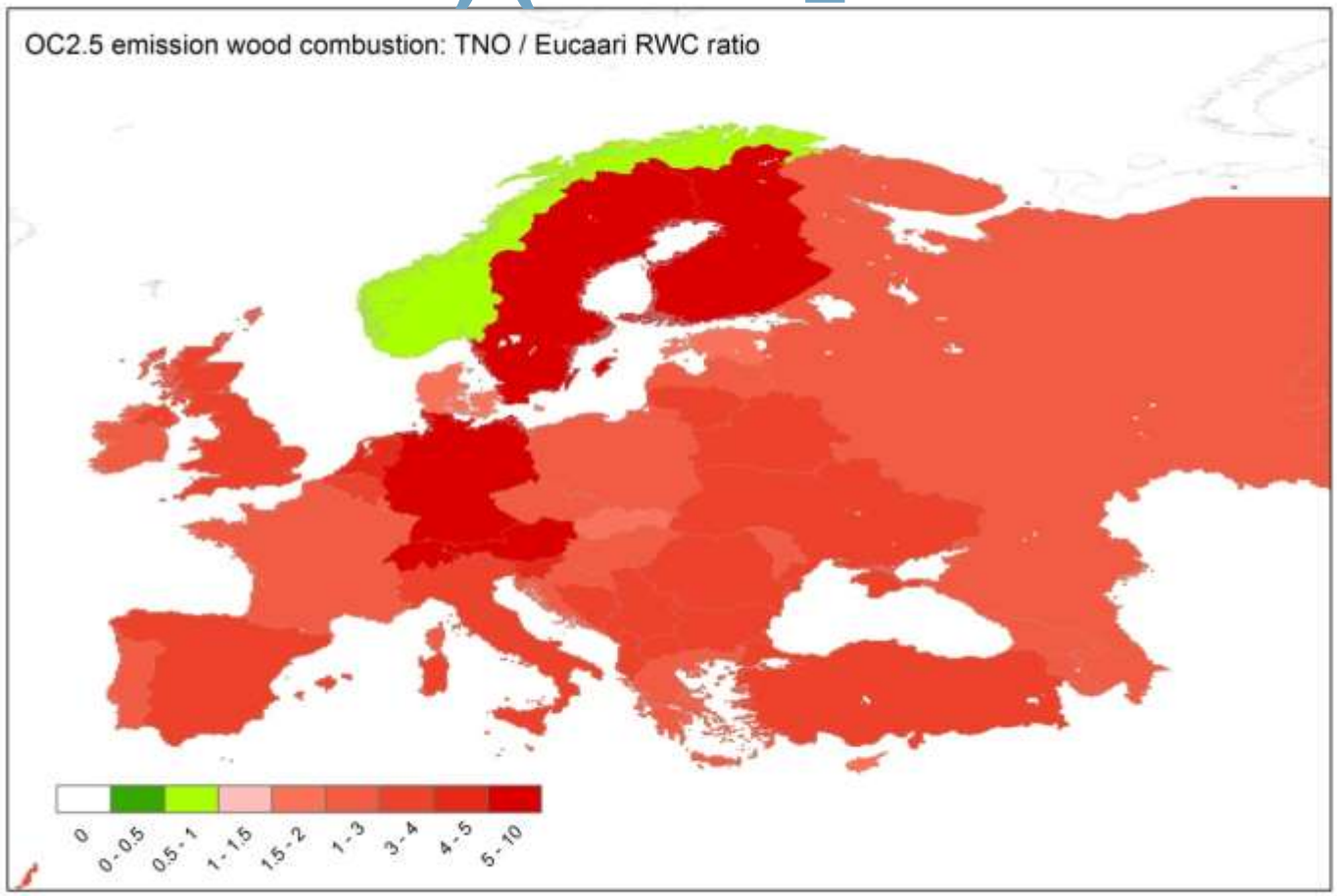
Note the EUCAARI estimate was in line with the official reported PM emissions, only the EC / OC split was added.

Models using the new RWC emissions were much better able to reproduce measured ambient PM_OC concentrations in Norway & Sweden



Comparison of model calculated OC from wood burning to source-apportionment data from measurement campaigns during winter in Norway and Sweden
(SORGA, 1 - 8 March 2007, Yttri et al.,2011) (GÖTE, 11 Feb - 4 Mar 2005, Szidat et al., 2009). Unit: µg(C) m^{-3}

RATIO RWC OC EMISSION BY COUNTRY (NEW/ORIGINAL) (SNAP2_WOOD ONLY)

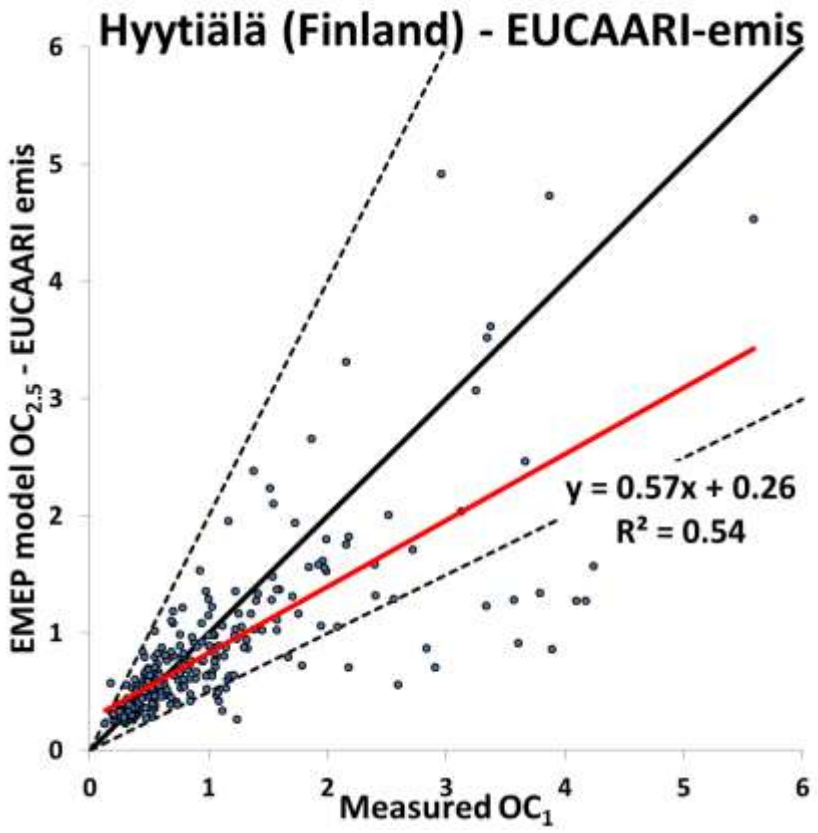


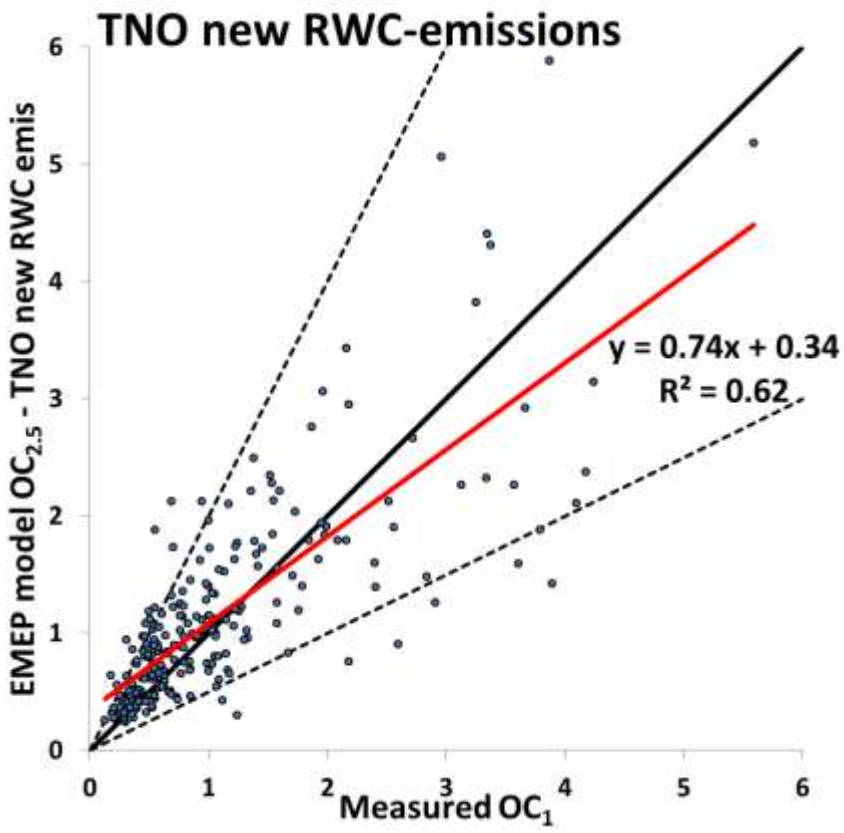
Red new inventory is higher; Green new inventory is lower

THE NEXT SLIDES JUST PROVE THAT ACROSS EUROPE THE INCLUSION OF CONDENSABLE PM CREATES A GREAT IMPROVEMENT IN PREDICTED PM CONCENTRATIONS

- See also presentation by David Simpson

MEASURED AND MODELLED OC CONCENTRATIONS WITH THE EMEP MSC-W MODEL





Denier van der Gon et al., ACP, 2015

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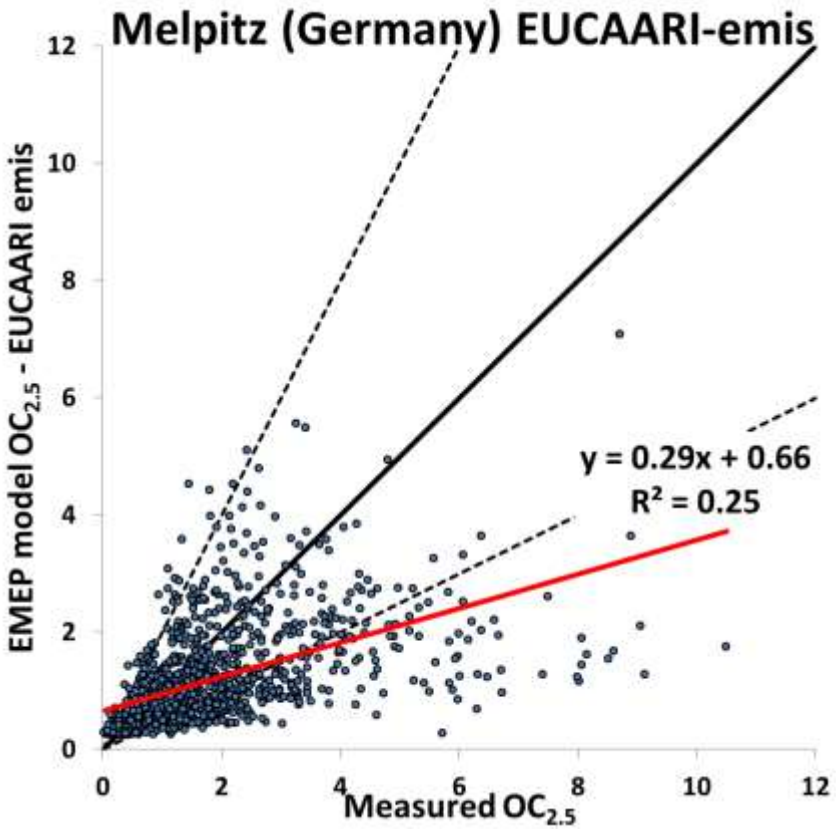
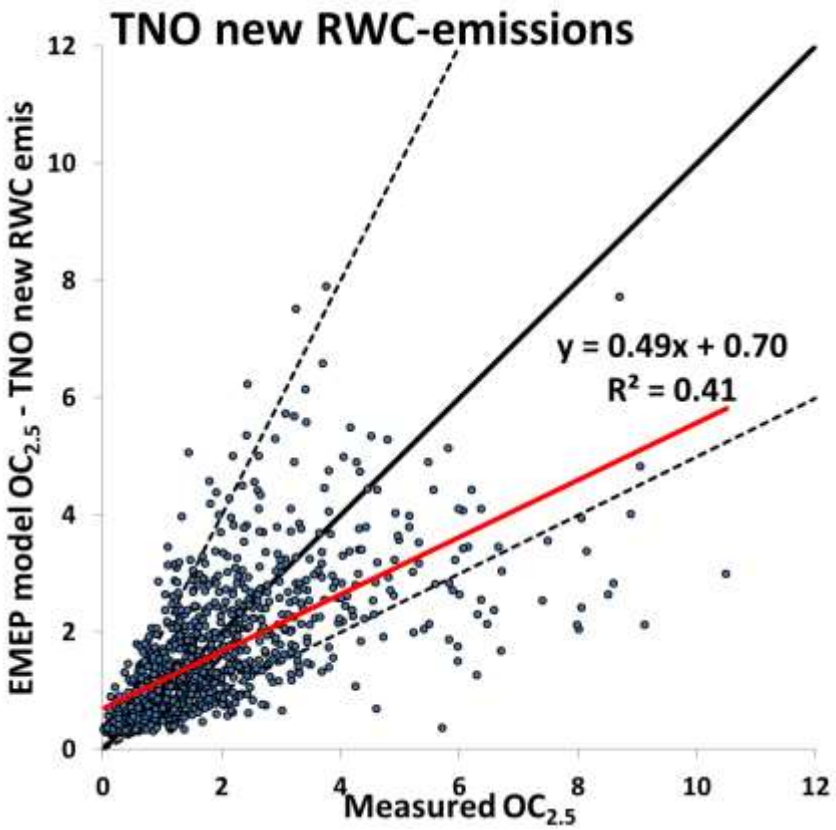




Denier van der Gon et al., ACP, 2015

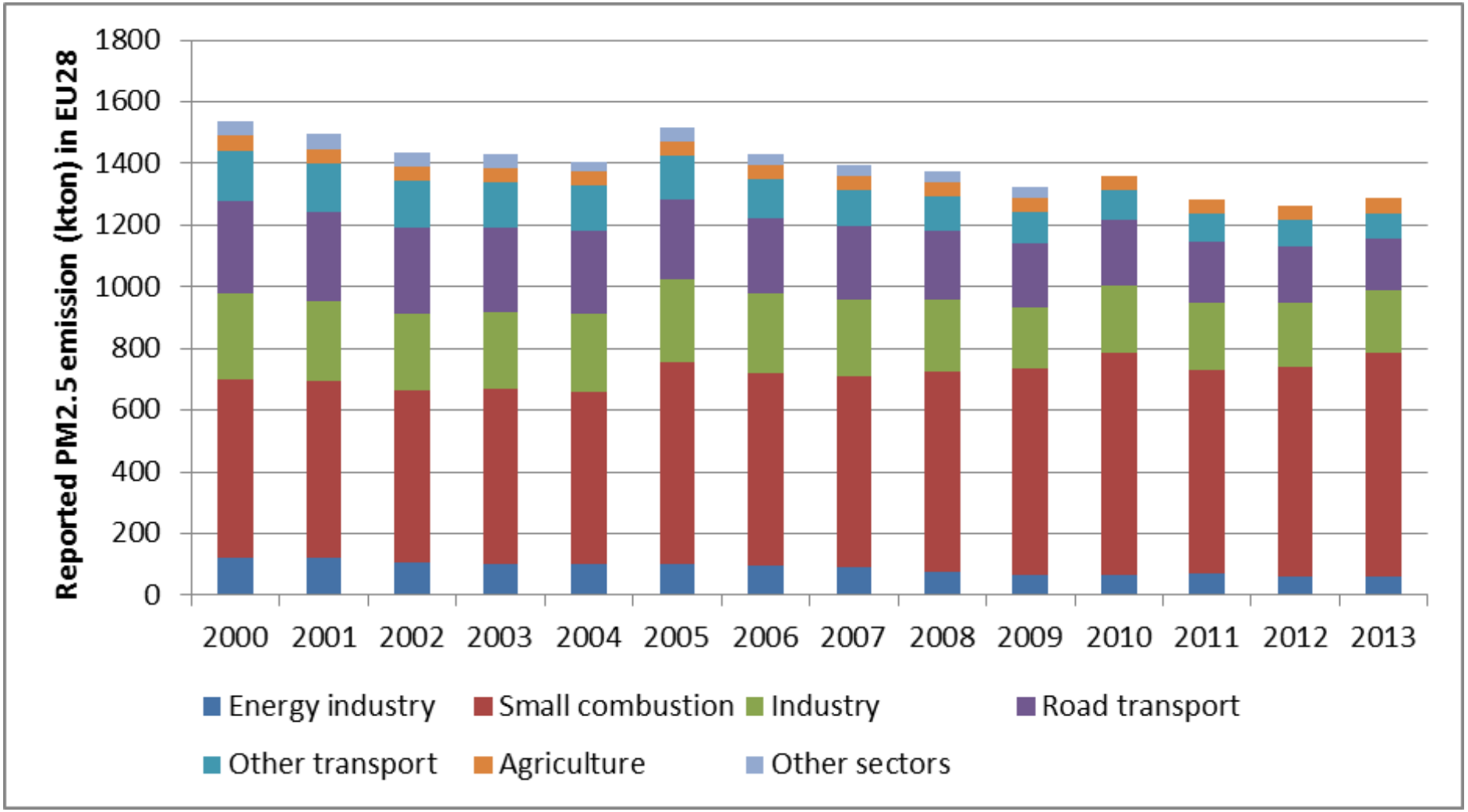
CONCLUSIONS_ FIRST PART

- Including condensable PM emissions for RWC greatly improved our understanding of measured OC (and thereby PM2.5) in ambient air at all locations.
- In line with US-EPA findings: *"the emission-based RWC contribution to ambient carbonaceous PM2.5 predicted by the model is approximately a factor of two lower than indicated by observations"*. [Napelenok et al., 2014.]
- Measurement data are crucial for "proofing" but needs more than PM2.5 (tracers)
- We argue that condensable PM should be included in the PM inventories but it's not "free" ; it will change estimated PM2.5 emissions (next slide)

- **Our current primary PM emission inventories are "apples and oranges" and might well be a whole fruit basket….**

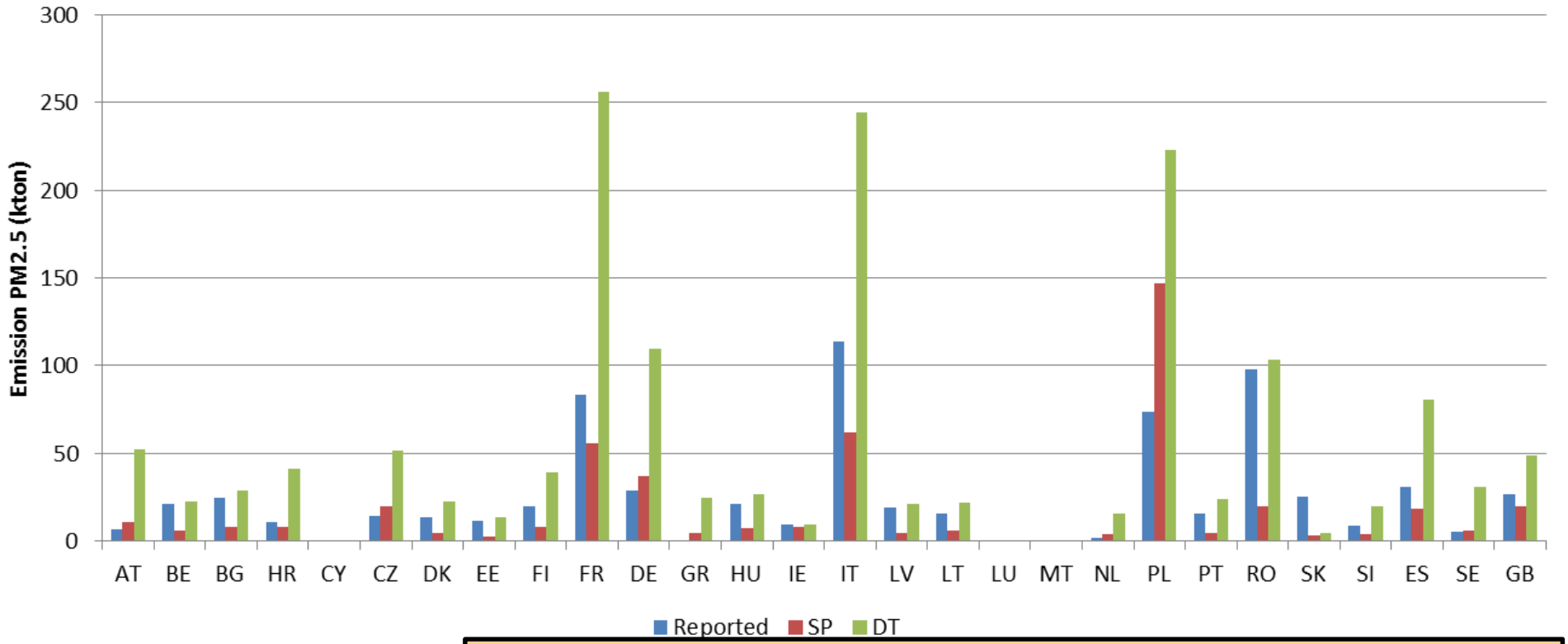
Disclaimer: This revised TNO RWC inventory is NOT included in the TNO-MACC inventories

WHAT WILL HAPPEN TO THE REPORTED EMISSIONS?



IMPACT OF DIFFERENT PM EFS

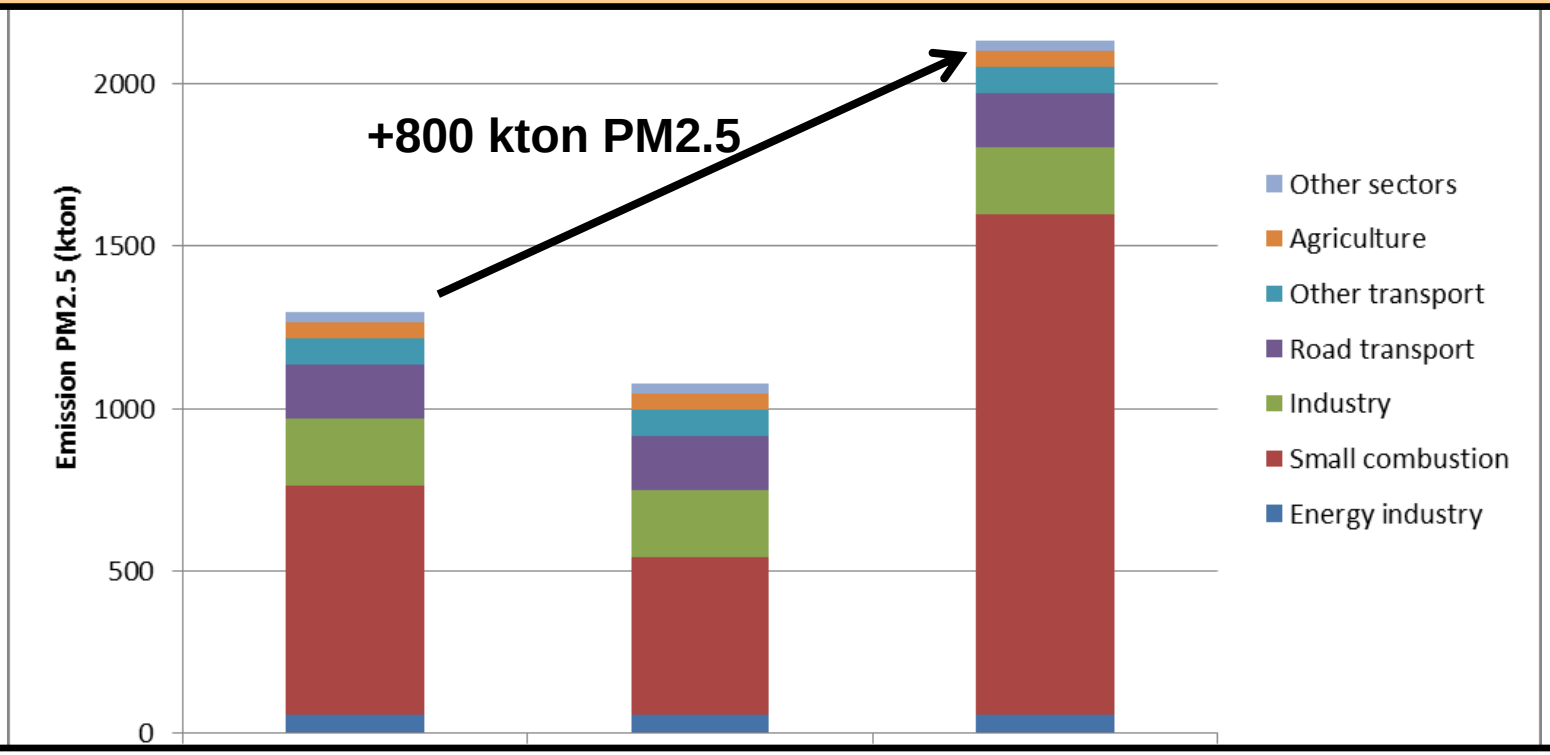
- Preliminary calculation based on Eurostat fuel consumption figures & use of wood in different appliance types (GAINS and TNO information) – combined with SP & DT emission factors (Denier van der Gon et al. 2015) for wood and Guidebook emission factors for other fuels



***Note**: These are preliminary figures based on a relatively simple calculation!*

IMPLICATIONS FOR EU-28 (2013)

Increase much higher than 20% estimated in ACP paper - mostly due to increased wood consumption and increased relative importance of residential combustion



This is a major impact and needs further investigation and verification!

Research is needed both at

- **the emissions side** (PM condensables by source type, better activity and appliance types information and emission factors)
- **the model side** (PM, NMVOC, SVOC, IVOC and volatility base set approach – see D. Simpson)

WHY SHOULD CONDENSABLE PM BE PART OF THE EMISSION INVENTORY?

- The combination of appliance type (fire place, pellet stove, boiler) and amount of solid fuel (wood, coal) determines how much PM_condensable is emitted. Using one overall fudge factor will give bad results. The information on appliance type and activity data can only come from the inventory community.
- If not present in the EI, any analysis on dominant sources gives misleading information, leading to non cost-efficient measures e.g. when complying with NEC.
- In transport EFs PM_condensable is already (mostly) included –because the cooling goes to 51^{o} · This is not quite ambient ;-) …. Especially during wintertime some will still be missing, but the bulk is captured.
- It is inconsistent and confusing if some anthropogenic sources are dealt with by modellers others by inventories
- RWC is not the only, nor the last source with PM_cond….a quick fix now by asking modellers to modify reported emissions leads to parallel diverging universes…

FOR DISCUSSION: SOME THOUGHTS ON THE OPTIONS OF TFEIP BACKGROUND PAPER

- A **short-term** solution….can also be that TNO makes an alternative emission estimate for the modellers (and/or grid) available upon request (some financial support may be needed but limited). Only a fudge factor is too simplistic!
- **Longer-term option 1 –** Our preferred option from a scientific and inventory expert point of view
- **Longer-term option 2** – Parties harmonise reporting to ensure PM emissions **exclude** condensables. This implies a major revision of the road transport PM exhaust emissions! The relation between emission inventories and ambient air pollution will further diminish (as everything is “added” in the models like seasalt and biogenics). Modellers lack the connection to activity data to do it properly.
- **The “compromise” option** – in our view creates confusion and additional workload, if reporting condensables it seems just as easy to do it every year

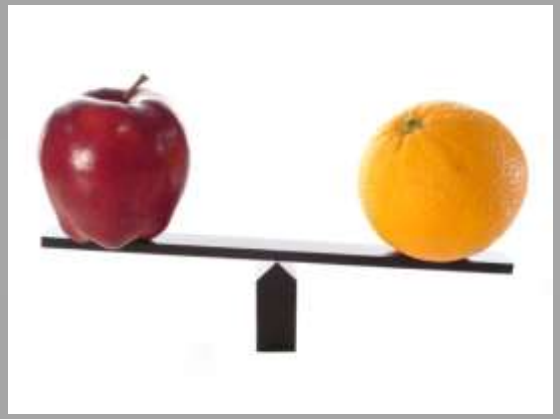
HOW WILL THIS WORK IN PRACTICE?

- Need to be careful about additional workload for inventory compilers
- We would propose inventories only include condensable PM fraction in the reported emissions (leave the VOC speciation with modellers). Essentially this would mean just updating emission factors
- Be aware that this changes national PM emissions – ceilings are relative but weight of residential combustion in overall emissions will increase!
- If too sensitive... we could condensable PM separately as memo item? Possible but additional work because of the need to split PM
- But... we need to realize this is not implemented overnight
  - The Guidebook would need to be adapted accordingly
  - We need some kind of official decision about including condensables
  - Until then, an expert judgement would be needed to make a consistent emission dataset including condensable fraction – TNO could contribute ☺

RELATED & SUPPORTING PUBLICATIONS

- Denier van der Gon, H. A. C., Bergström, R., Fountoukis, C., Johansson, C., Pandis, S. N., Simpson, D., and Visschedijk, A. J. H.: **Particulate emissions from residential wood combustion in Europe – revised estimates and an evaluation**, Atmos. Chem. Phys., 15, 6503-6519, doi:10.5194/acp-15-6503-2015, 2015.
- Simpson, David, and Hugo Denier van der Gon, **"Problematic emissions - particles or gases?"**, chapter 5 in: European Monitoring and Evaluation Programme (EMEP) Status report 2015,
- Fountoukis, C., T. Butler, M. G. Lawrence, H.A.C. Denier van der Gon, A. J. H. Visschedijk, P. Charalampidis, C. Pilinis, and S. N. Pandis, **Impacts of controlling biomass burning emissions on wintertime carbonaceous aerosol in Europe**, Atmospheric Environment, 87, p. 175-182. DOI: http://doi.org/10.1016/j.atmosenv.2014.01.016, 2014.
- Genberg, J., Denier van der Gon, H. A. C., Simpson, D., Swietlicki, E., Areskoug, H., Beddows, D., Ceburnis, D., Fiebig, M., Hansson, H. C., Harrison, R. M., Jennings, S. G., Saarikoski, S., Spindler, G., Visschedijk, A. J. H., Wiedensohler, A., Yttri, K. E., and Bergström, R.: **Light-absorbing carbon in Europe – measurement and modelling, with a focus on residential wood combustion emissions**, Atmos. Chem. Phys., 13, 8719-8738, doi:10.5194/acp-13-8719-2013, 2013.
- Bergström, R., Denier van der Gon, H. A. C., Prévôt, A. S. H., Yttri, K. E., and Simpson, D.: **Modelling of organic aerosols over Europe (2002–2007) using a volatility basis set (VBS) framework: application of different assumptions regarding the formation of secondary organic aerosol**, Atmos. Chem. Phys., 12, 8499-8527, doi:10.5194/acp-12-8499-2012, 2012.

THANK YOU FOR YOUR ATTENTION



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