REPORTED PM EMISSIONS & CONDENSABLES
With a focus on wood combustion | Jeroen Kuenen
OUTLINE

- The first part of this presentation is based on the paper
  - available for download at: [http://www.atmos-chem-phys.net/15/6503/2015/](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
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)

- 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).

Filterable PM is directly emitted:
- Solid or liquid
- Captured on filter
- PM$_{10}$ or PM$_{2.5}$

Condensable PM is in vapor:
- 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?
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

Wood use

- Traditional fireplace
- Conventional wood stove
- Single house log boiler - conventional
- Single house log boiler - advanced
- Single house pellet boiler
- Medium boiler - manually fed logs
- Medium boiler - automatically fed

PM emission

DT: 800 mg/MJ (300 - 1100)
SP: 150 mg/MJ (50 - 600)

Source: Nussbaumer et al. (2008)
Activity data are also a crucial input. Likely that a substantial part of wood consumed for residential heating in Europe is not part of the statistics. Therefore, any calculation using official statistics on wood consumption is likely underestimating.

To assess the possible impact, TNO has made a bottom-up calculation of wood use, taking into account statistical information, availability to wood (living close to forest?), and expected heating demand based on population and climatology.

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
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.

While we adjusted emissions in opposite directions for NOR & SWE, the model prediction improves at all sites!

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

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?

Condensables are mostly organic matter, thus captured in the Organic Carbon component of PM (BC/EC not much affected). Overall PM2.5 (and PM10/TSP) emissions will increase. Denier van der Gon et al. (2015) estimated a conservative 20% increase in PM2.5 emissions across Europe – here will show an update based on latest data.

Note that emissions in this presentation only include condensable PM from wood combustion, while there are other sources that may be important!
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!
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°. 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


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,


THANK YOU FOR YOUR ATTENTION