Challenges in assessing air pollution from residential wood combustion

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A task for modellers and economists:

Please assess the health costs of using wood stoves!

- If citizens were to pay for the health related damages that their wood stove causes, how much should they pay?

What is the health cost for using an old wood stove for one hour in the city of Copenhagen?

Sources: A report by the "Danish Economic Councils" and a scientific background report

An independent board with representatives from government, unions, employers etc.
Has a secretariat of economists

- "**Economy and Environment, 2016**". Danish Economic Councils. In Danish with summary in English.
- Brandt, J., S.S. Jensen, M.S. Andersen, M.S. Plejdrup, O.K. Nielsen, 2016: **Health effects and health costs from emission sectors in Denmark**. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 47 s. – Scientific report from DCE - National Center for Environment and Energy no. 182. http://dce2.au.dk/pub/SR182.pdf . In Danish.

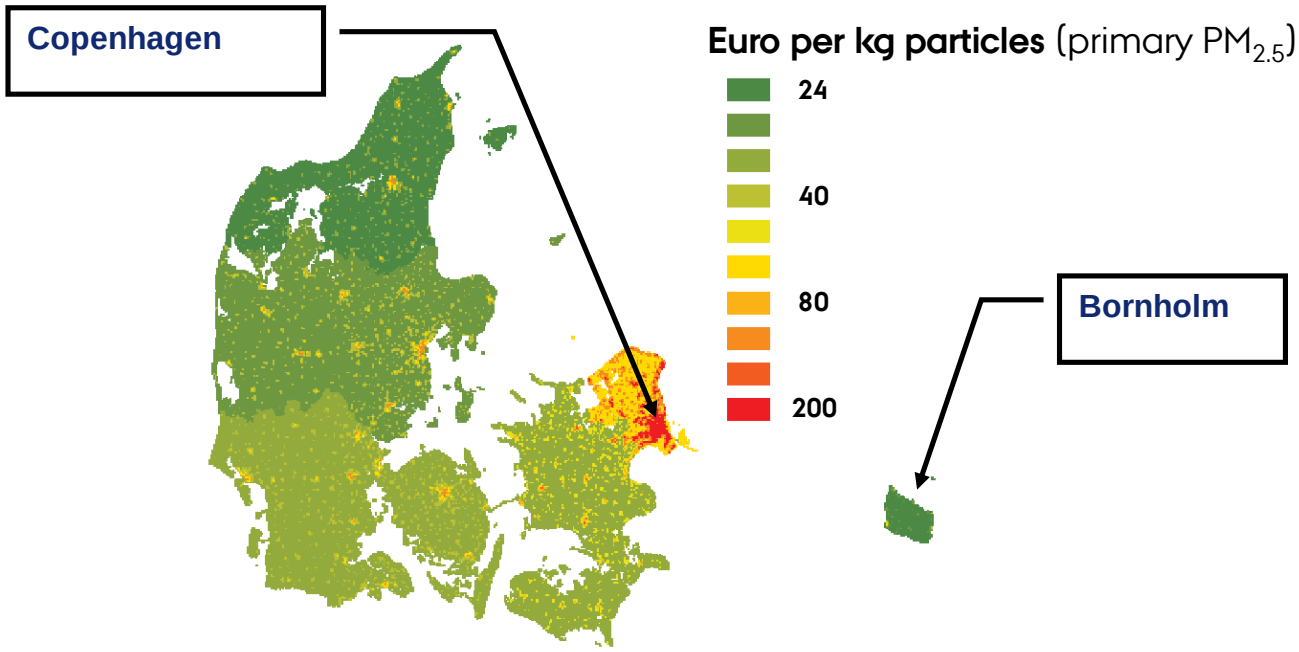
What is the health cost for using an old wood stove for one hour in the city of Copenhagen?

The health costs are not always that high...

- For an **old stove in Copenhagen**: **5.5 Euro/hour**.
- It is less costly to use a **modern stove** – the health cost is **1Euro/hour** for a modern stove in Copenhagen.
- It is less costly to use a stove **in the countryside** – the health cost is **13 Eurocents/hour** for a modern stove in the isle of Bornholm.

The examples are calculated from information in this map

- Health costs per kg particles that are emitted at the indicated location.



Focus of my talk

- Some of the challenges involved in reaching results like those you have just seen.

What is the health cost for using an old wood stove for one hour in the city of Copenhagen?

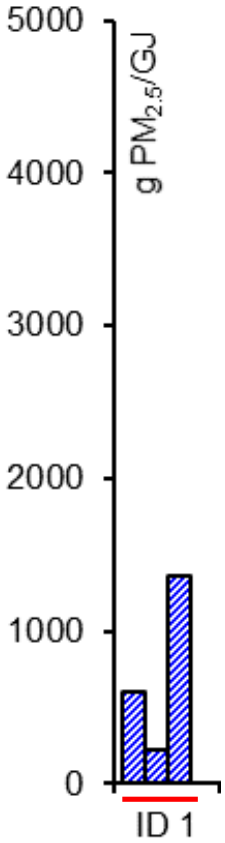
The challenge of determining representative emission factors

- We are interested in **real-world emissions**.
  Test bench results cannot simply be considered representative of real-world emissions.

Emission factors measured in homes of users

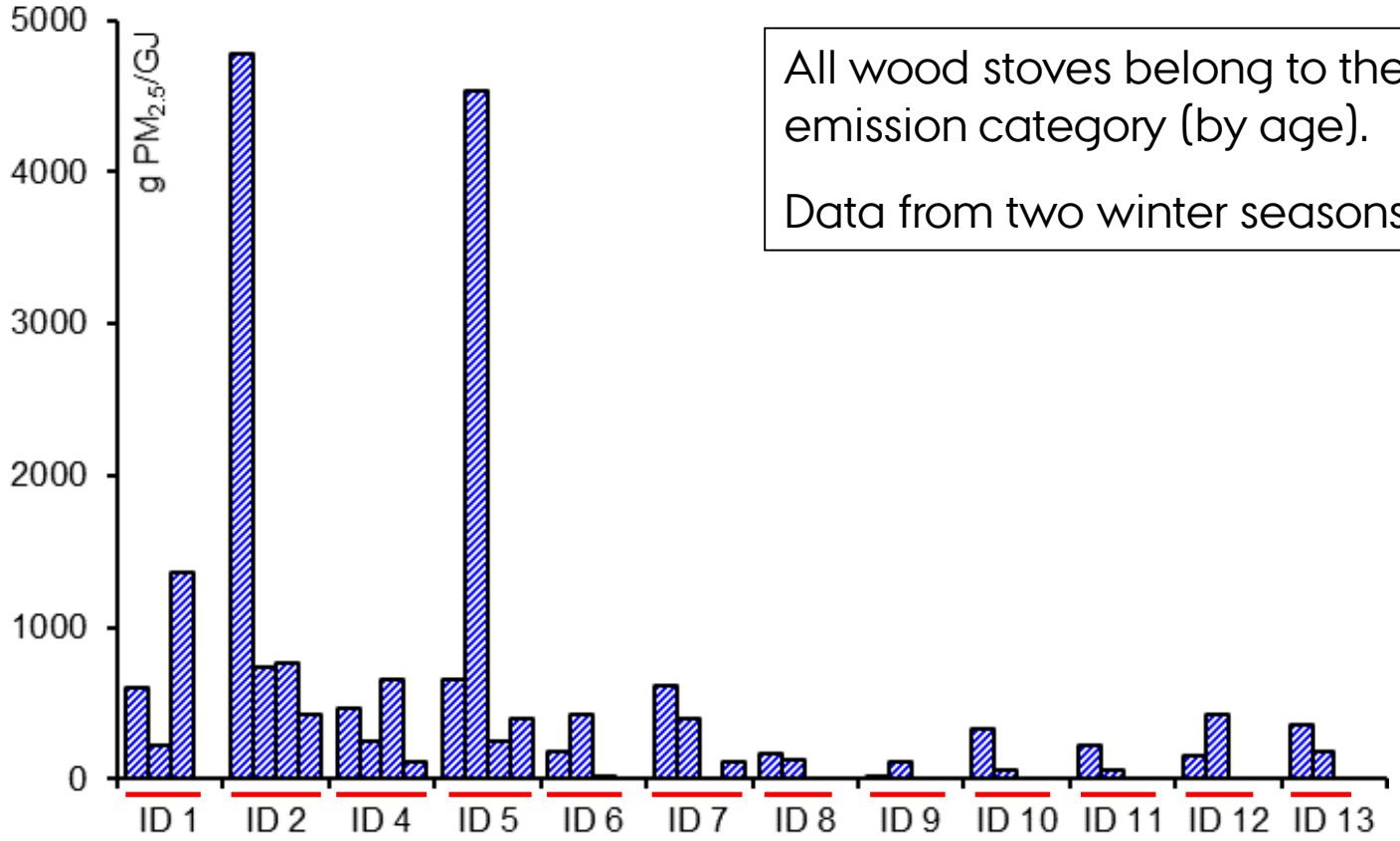
Data from Glasius et al., 2005; Glasius et al., 2007.

Emission factors measured in private homes – $PM_{2.5}$



Data from Glasius et al., 2005; Glasius et al., 2007.

Emission factors measured in private homes – $PM_{2.5}$



All wood stoves belong to the same emission category (by age).

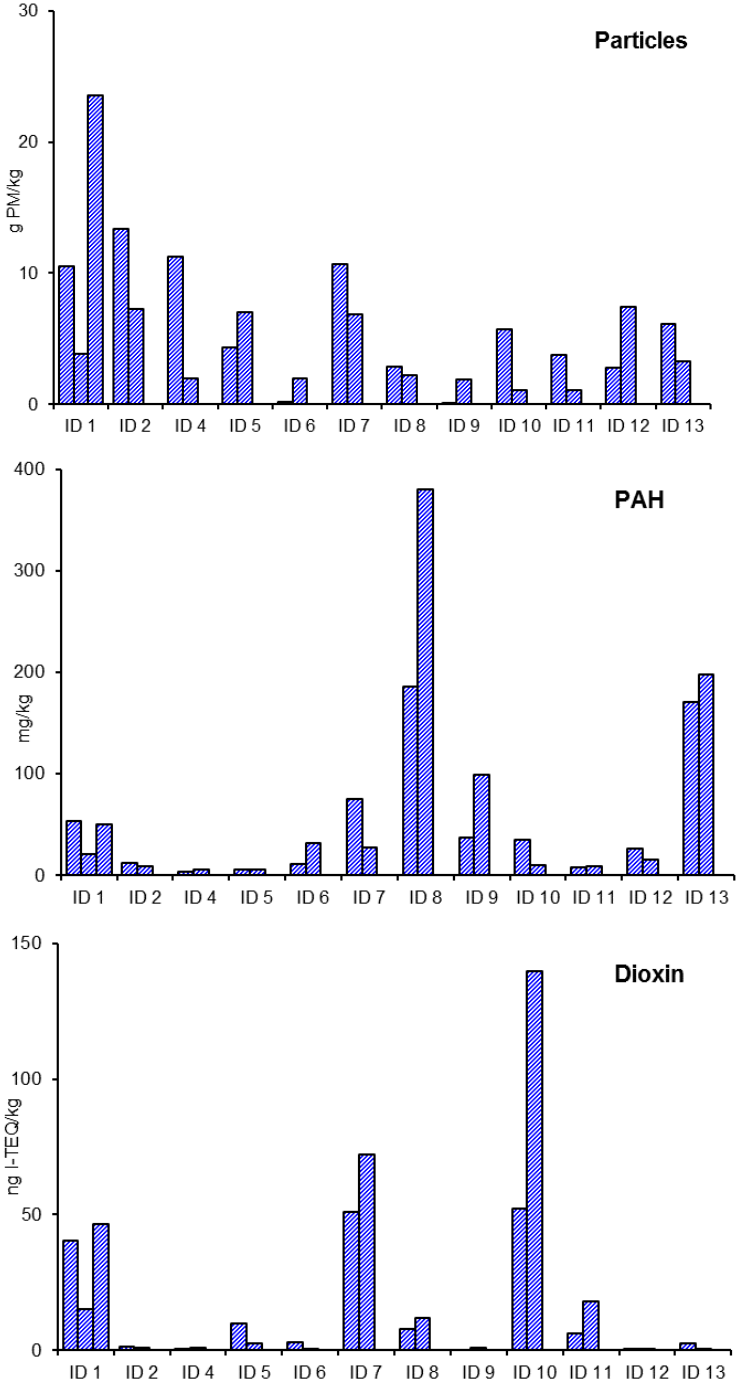
Data from two winter seasons.

Data from Glasius et al., 2005; Glasius et al., 2007.

Emission factors for several substances

All wood stoves belong to the same emission category (by age).

Data from one winter season.



Data from Glasius et al., 2005; Glasius et al., 2007.

An important point to be made

- **It is a grossly simplifying assumption that for a given combustion technology, emissions are just proportional to the amount of wood consumed.**
- Other factors than the type of combustion device are crucial for real-world emissions.
- In particular: The behaviour of the user!
- = > The challenge of combustion conditions.

The challenge of combustion conditions

- A wealth of studies of the influence of combustion conditions on emissions of pollutants.
- Some main results...

Insufficient oxygen supply provokes particle emission – and so does overload

- Examples from study on effect of combustion conditions by Klippel and Nussbaumer (2007).

Combustion conditions	Emission: Particle concentration in flue gas	Comments
Optimal conditions	16 mg/m3	1.5 kg wood per batch, very dry wood (12 % moisture)
Typical conditions	220-240 mg/m3	4 kg wood per batch, 20% moisture content in wood.
Typical conditions, but too late refill	3000 mg/m3	As above, but next batch on weakly burning remains from previous fill.
Poor conditions	6000 mg/m3	Filled stove and shut air inlet. (Actually recommended in user's guide as a way to maintain heat without refilling.)

Factor 14

Ignition method is very important

- A large part of the total particle mass is released during the ignition period.
- The method of “top-down ignition” or “ignition from above” is in general recommended. Nussbaumer et al. (2008) reported reduction of total particle emission by 50 – 80 % in comparison to traditional ignition from the bottom. The reduction potential is not so large for all wood stoves.
- This method has been promoted in some countries.
- Again, it is a challenge to reflect this parameter in an emission inventory.

Further combustion conditions of importance

- Moisture content in the firewood.
- Log size.
- Chimney construction, ventilation, the resulting draft in chimney.
- The type of wood consumed: Spruce, beach or...? Wood logs or briquettes.

Studies on combustion conditions – lessons to learn

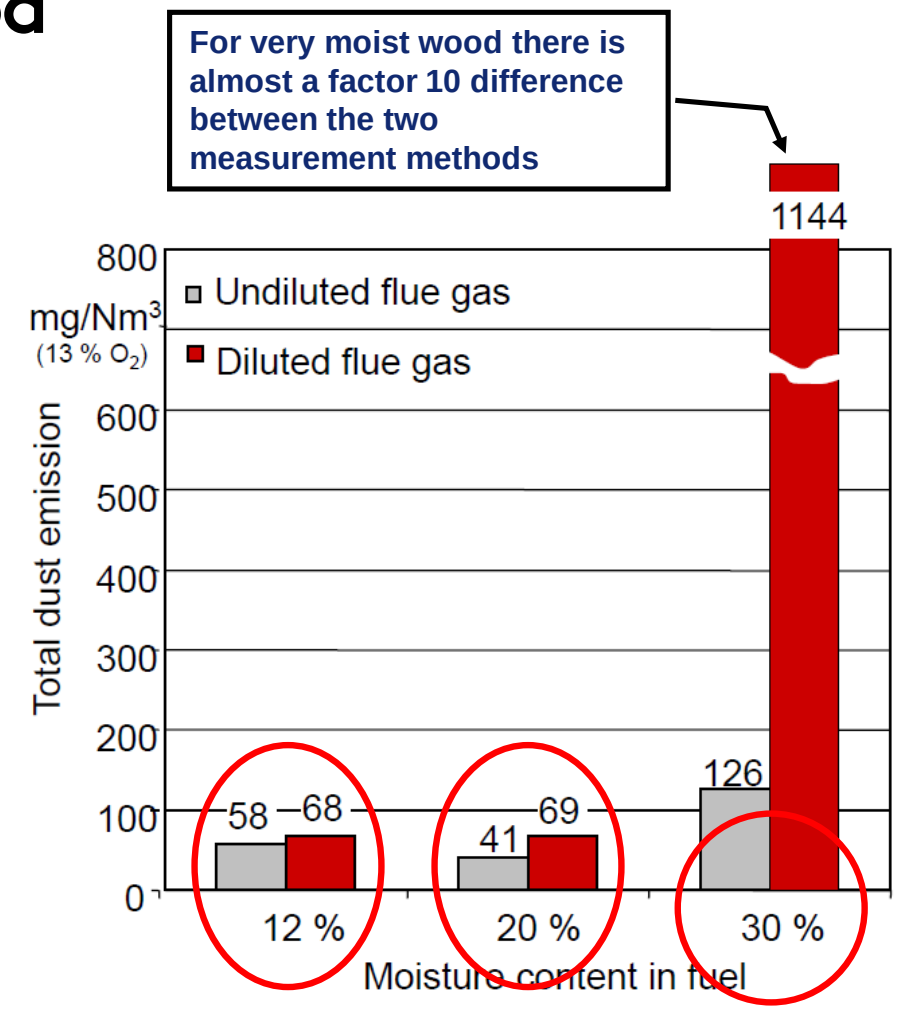
- There are numerous challenges.
- It is important to be well aware of the challenges.
  If they are neglected decision makers may draw wrong conclusions and adopt inappropriate solutions.

The challenge of condensable gases

- **There is an important pitfall when comparing emission factors for PM between countries**.
- Emission factors determined in laboratories depend very much on the measuring method.
  - The Norwegian standard (used in several countries) makes use of a dilution tunnel, implying that **concentrations are measured in cooled gases** (35 degrees C).
  - The German standard (DIN+) estimates **concentrations in hot gases** (>70 degrees C).
- The implication is that the German standard ignores condensable gases, while the Norwegian includes them in particle mass.
  Particle mass results according to the Norwegian standard are a factor of 2-10 (typically 5) higher than according to the German.
  The Norwegian is better related to concentrations in the ambient air. It mimics the formation of secondary particles right after the gas leaves the stack.

Particle emission: Importance of moisture content – and of measuring method

Particle emission factors for three values of moisture content



From Hans Hartmann, TFZ, 2012.

van der Gon et al. (2015)

Atmos. Chem. Phys., 15, 6503–6519, 2015
www.atmos-chem-phys.net/15/6503/2015/
doi:10.5194/acp-15-6503-2015

Atmospheric Chemistry and Physics Open Access

Particulate emissions from residential wood combustion in Europe – revised estimates and an evaluation

H. A. C. Denier van der Gon[1], R. Bergström[2,3], C. Fountoukis[4], C. Johansson[5,6], S. N. Pandis[4,7], D. Simpson[8,9], and A. J. H. Visschedijk[1]

- van der Gon et al. (2015) suggest to use a harmonized approach to inventories. Their results suggest **that the contribution to particle pollution in terms of OC (organic carbon) from residential wood combustion should be augmented by a factor of 2-3 in most European countries.**

The challenge of activity data

- Few countries – if any – have good inventories of wood stoves and other wood burning appliances in private homes.
- Methods for estimating wood consumption are not always adequate. One of the better is to make use of telephone surveys.
- Improved methods can dramatically change the result of inventories.
- Example: Lefebvre et al. (2014) reported a 13-fold increase in particle emission from residential wood combustion in Flanders compared to earlier estimates.
  A factor of 3.4 could be ascribed to wood consumption, and a factor of 4 to more realistic emission factors.

Conclusions...

How to meet the challenges

- It is inevitable that modelling results for residential wood combustion are more uncertain than for most other emission sectors.
- Keep your eyes open when considering emission factors: How are they determined? Do particle emission factors include condensables? For modelling purposes that is pertinent.
- The German and Norwegian standards differ in other ways than use of a dilution tunnel and temperature (also in the burn rates they test). Be aware that there are such differences..
- A response to some challenges is the EU BeReal project:
  Aims to develop test methods that better reflect real life operation of wood stoves, pellet stoves etc.
- Interesting presentations at a recent seminar: *Real-world emissions from residential wood combustion* held in Copenhagen (URL in paper).

A fact: The user is a crucial component

- Positive implication:
  - There is potential for a dramatic reduction of pollution from residential wood combustion.
- Possibilities:
  - Education of users
  - Introduction of automatic solutions, such as automatic regulation of air supply.