Svenska Luftvårdsföreningen
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Partikelemissioner från småskalig vedeldning och framtida biobränslen

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Småkalig vedeldning och luftkvalitet

Vedpannor

Vedkaminer

Öppna eldstäder

I många Europeiska samhällen/bostadsområden är detta förknippat med lokals luftförorenings-problem!

”Outdoor wood boilers” (i USA)

Bidrag till primära $PM_{2.5}$ emissioner inom EU-15 med läget 2000 och en prognos fram till 2020 (Amann M et al. 2005)

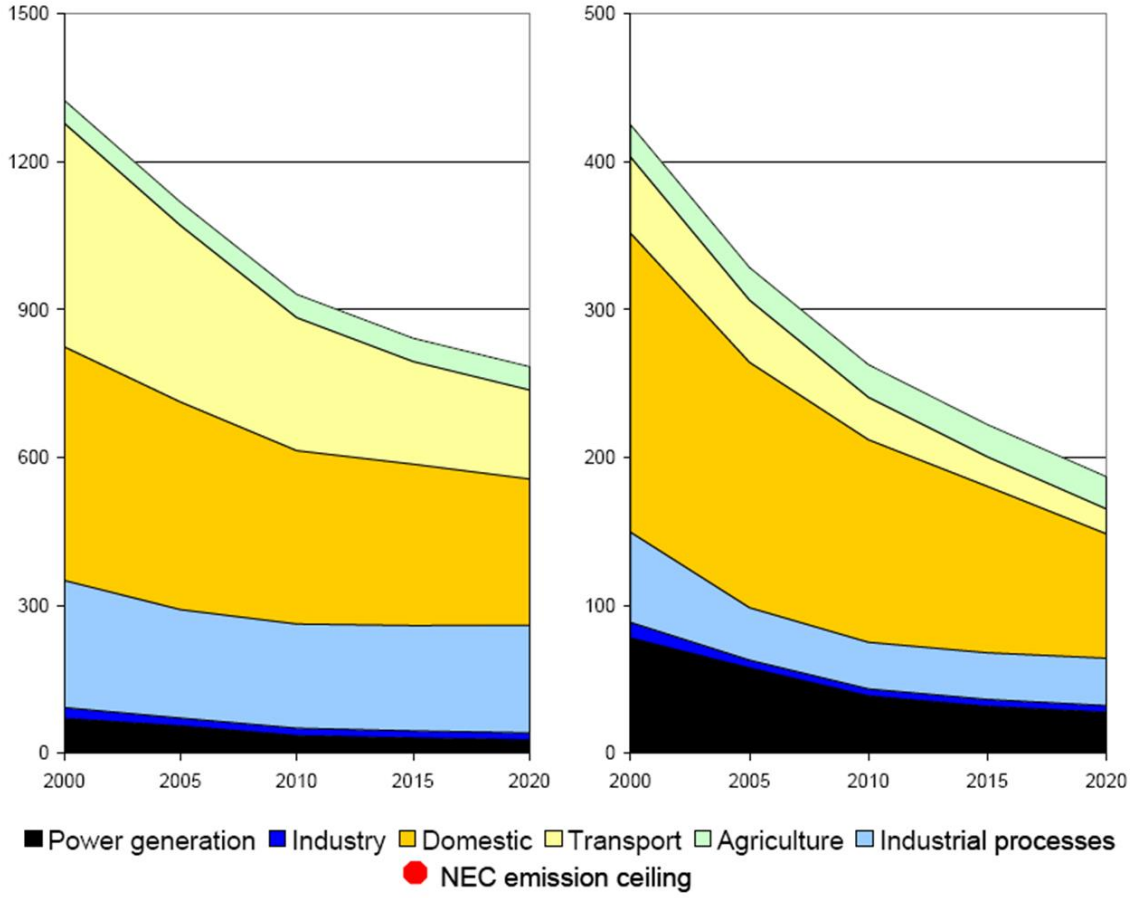
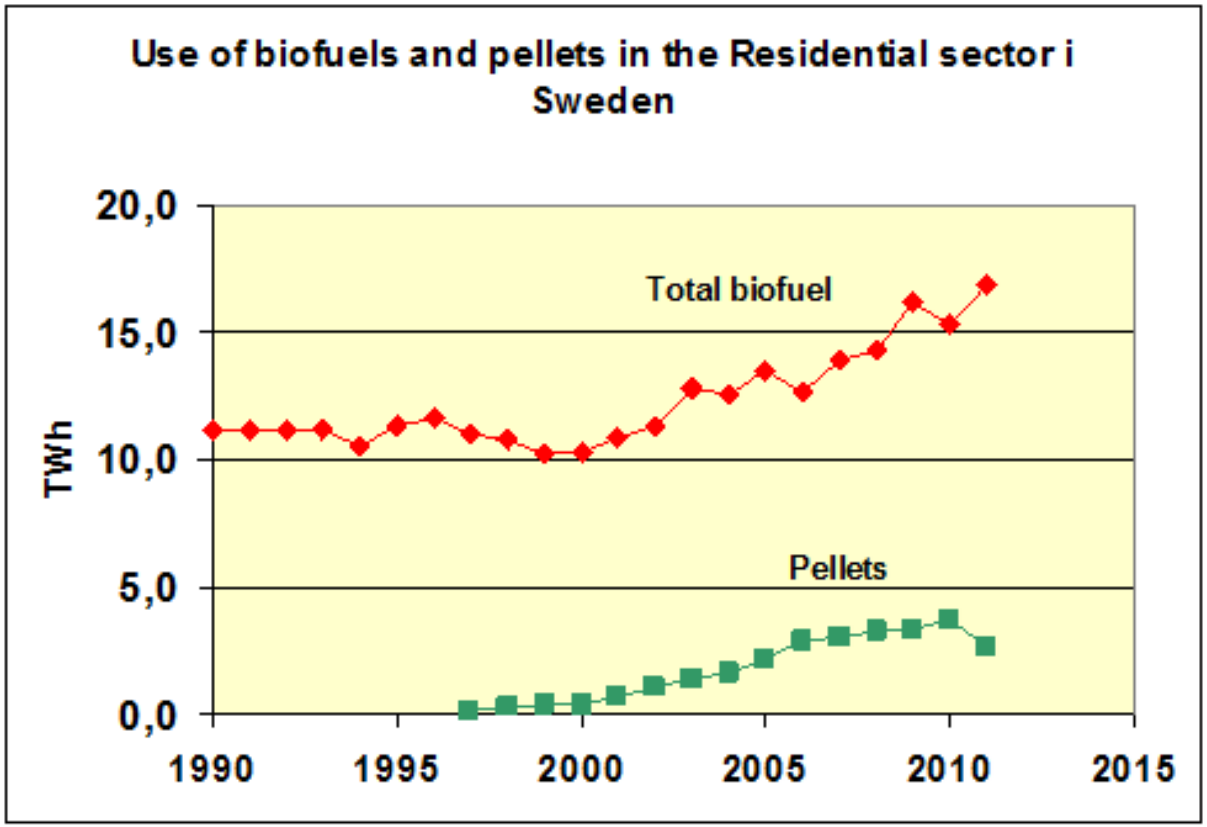


Figure 4.21: PM2.5 emissions by sector (in kt) for the EU-15 (left panel) and the New Member States (right panel) for the "with climate policies scenario

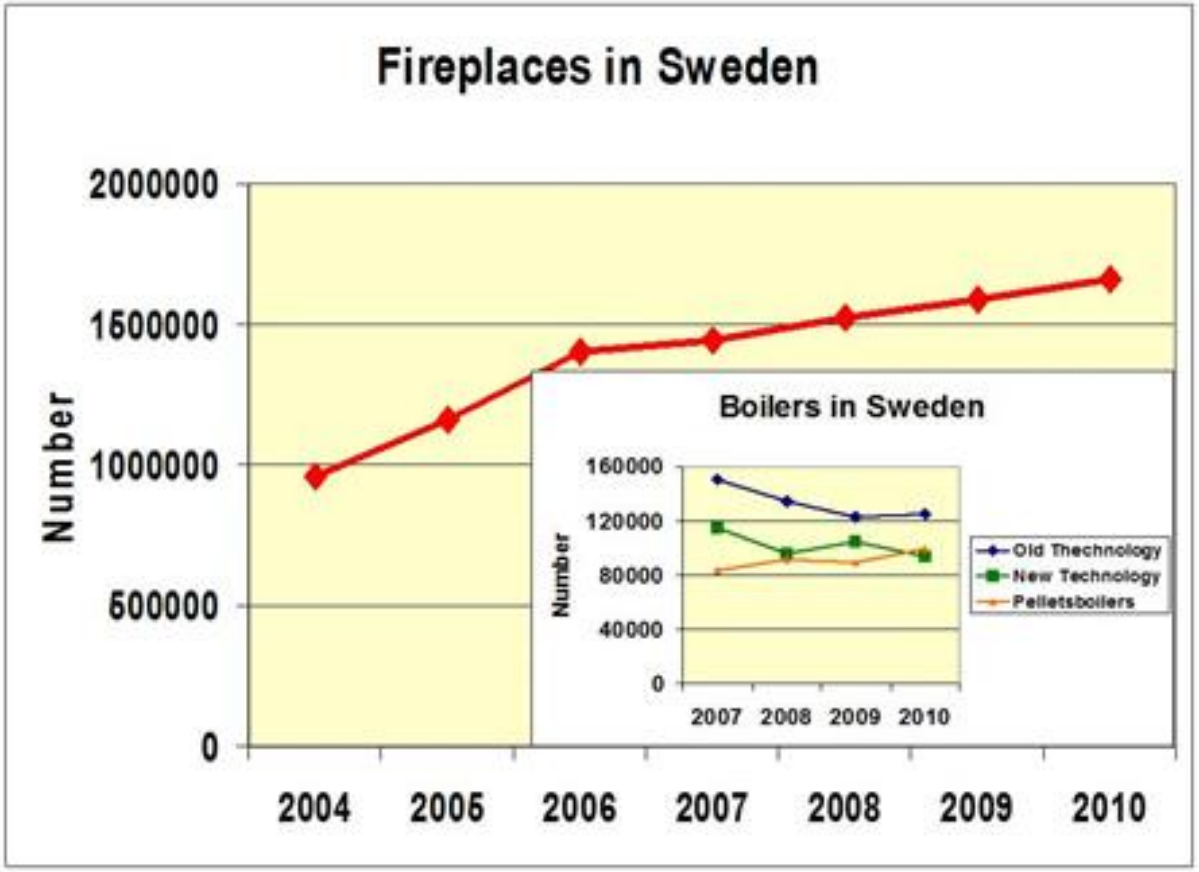
Amann M, Bertok I, Cofala J, Gyarfas F, Heyes C, Klimont Z, Schöpp W, Winiwarter W. **Baseline Scenarios for the Clean Air for Europe (CAFE) Programme** (Final Report, 2005). On commission from the European Commission, Directorate General for Environment, Directorate C – Environment and Health. International Institute for Applied Systems Analysis, Luxenburg, Austria.

Användning av biobränslen (ved och pellets) i huhållen i Sverige



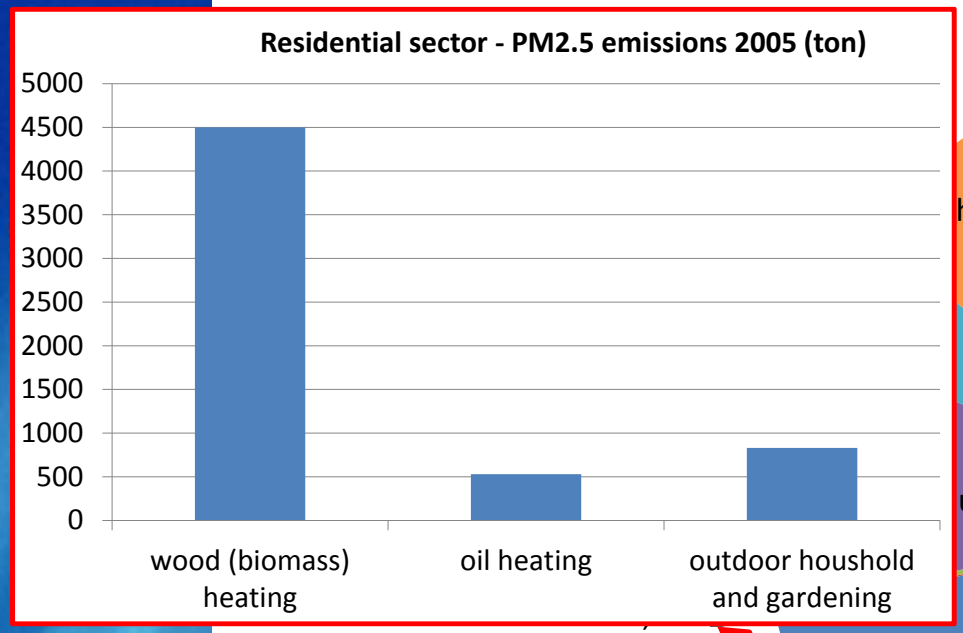
Källa: Energimyndigheten (taget från International Cryosphere Climate Initiative Rapport till NMR, 2013)

Antal eldstäder/kaminer och pannor i Sverige



Källa: Räddningsveket (taget från International Cryosphere Climate Initiative Rapport till NMR, 2013)

$PM_{2.5}$ emission distribution in Sweden 2005 (%)



Total emissions ~29 000 ton

Other waste; 0.7

Other ?; 0.0

Public Electricity and Heat Production; 9.9

Petroleum refining; 3.4

her production; 13.7

ucs; 9.5

Manufacturing Industries and Construction; 14.8

Road Transportation; 16.3

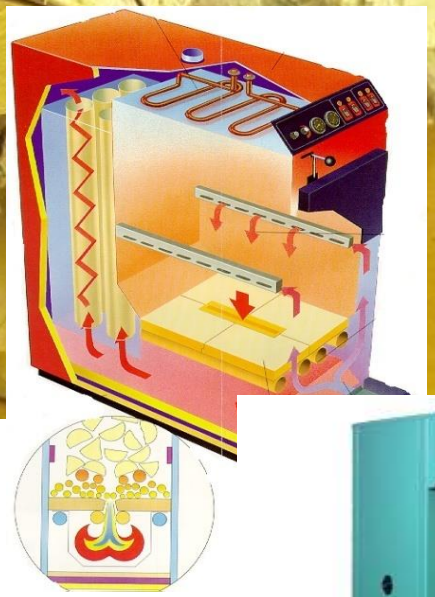
Agriculture / Forestry / Fishing; 5.6

Residential; 18.2

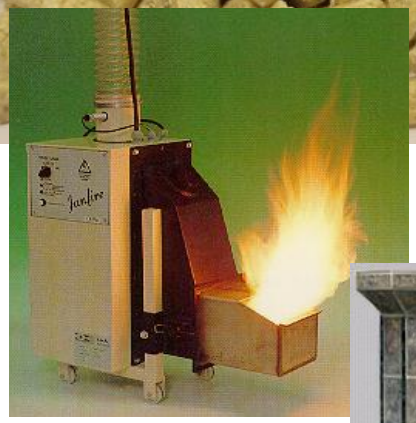
Other Transportation; 3.5

Wood stoves –
dominates in number

Wood log boilers –
dominates in wood use



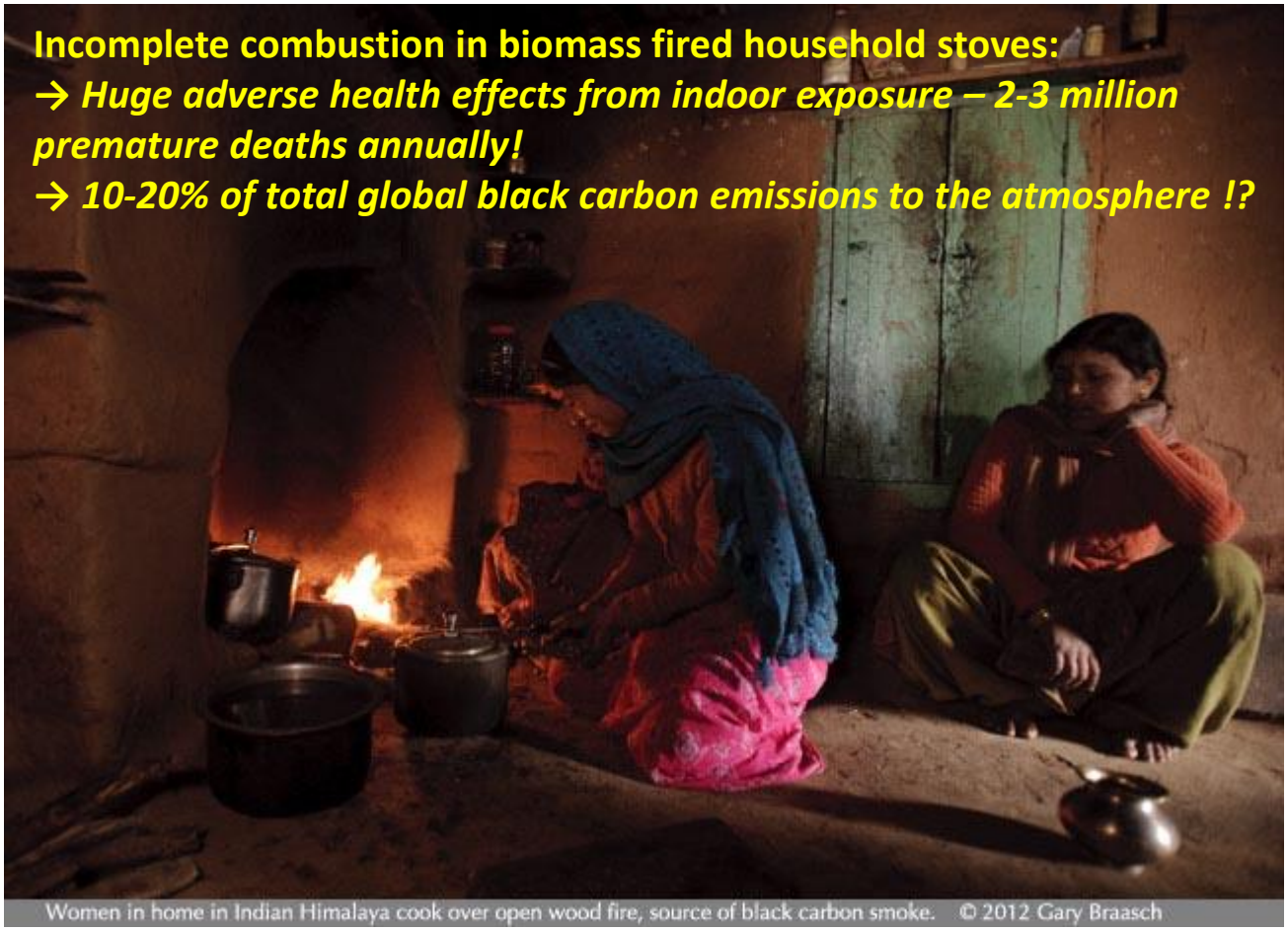
Pellet boilers, burners
and stoves –
dominates in potential



Incomplete combustion in biomass fired household stoves:

→ Huge adverse health effects from indoor exposure – 2-3 million premature deaths annually!

→ 10-20% of total global black carbon emissions to the atmosphere !?



Women in home in Indian Himalaya cook over open wood fire, source of black carbon smoke. © 2012 Gary Braasch

Litteratur t ex: Venkataraman C et al, Science 2005;307:1454-1456

Complete fuel conversion and combustion!

Emissions of gases and particles!

Complete combustion …
(total oxidation of all fuel bound carbon and hydrogen)

$$C + O_2 \rightarrow CO_2 + \text{energy}$$

$$H_2 + \tfrac{1}{2} O_2 \rightarrow H_2O + \text{energy}$$

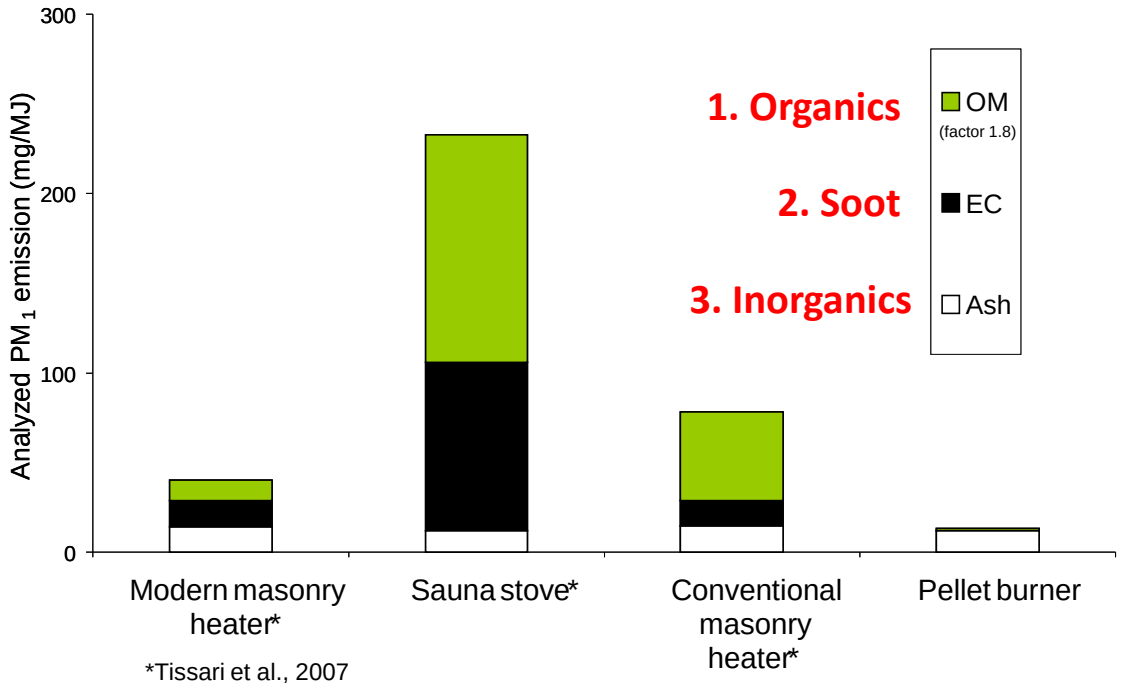
Complete combustion requires;

1. Sufficient amount of oxygen
2. High temperature (e.g. >850°C)
3. Long residence time (e.g. some seconds)
4. Good turbulence (i.e. mixing of fuel gases and air)

→ But, that is never the case practically, especially not in small scale wood combustion appliances!

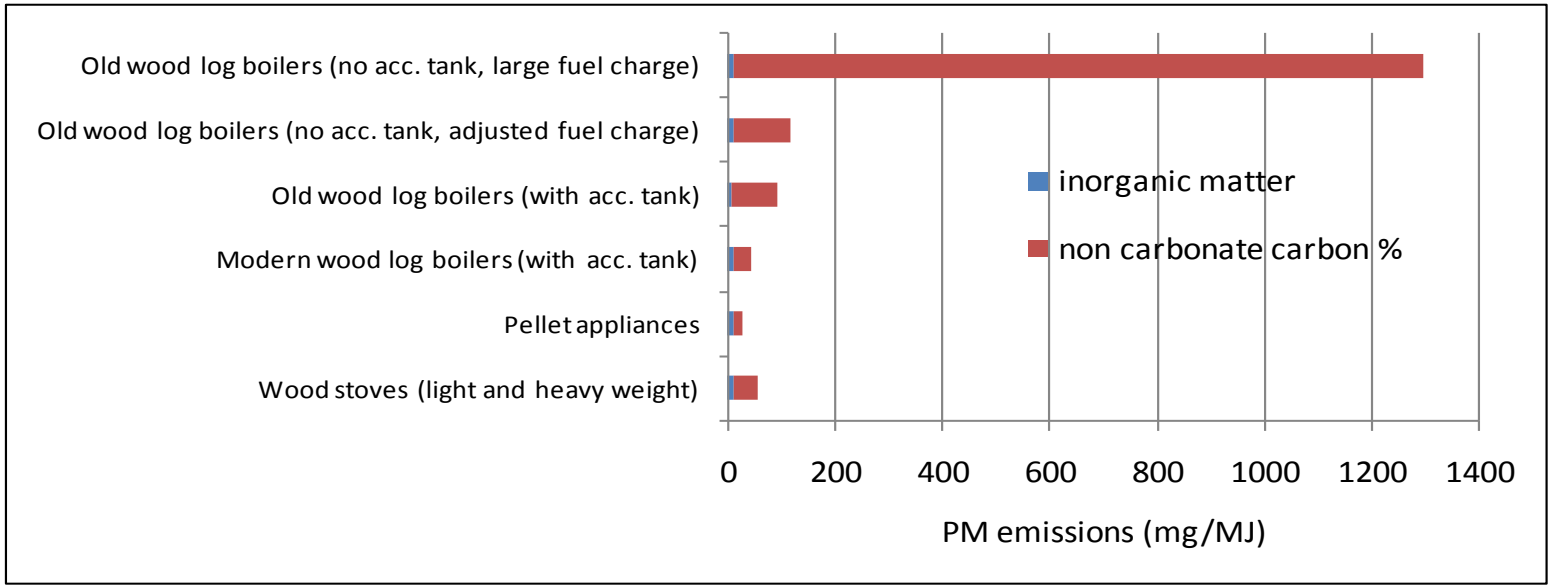
PM emission and composition from small scale biomass combustion

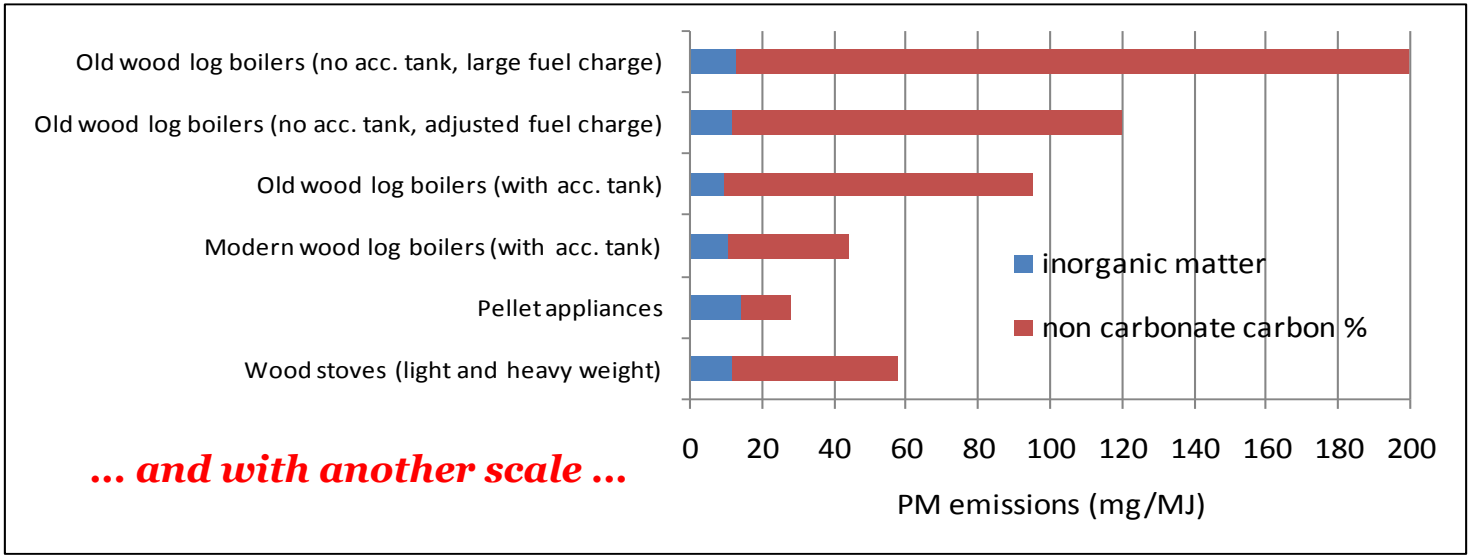
From: Tissari et al, Atmos Environ 2007:41:8330-8344



*Tissari et al., 2007

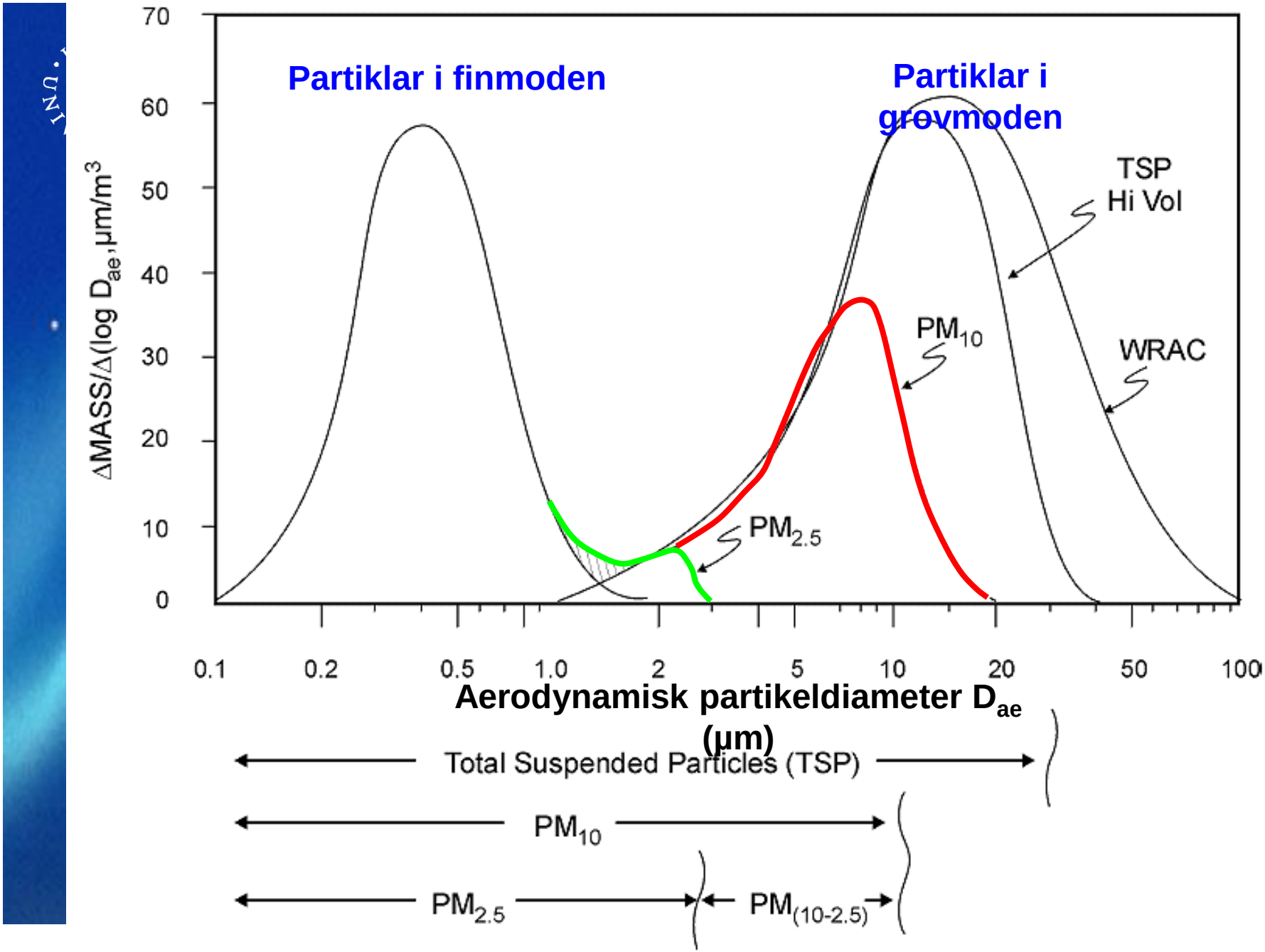
Emission factors (mg/MJ) for residential biomass appliances in Sweden (2007)





... and with another scale ...

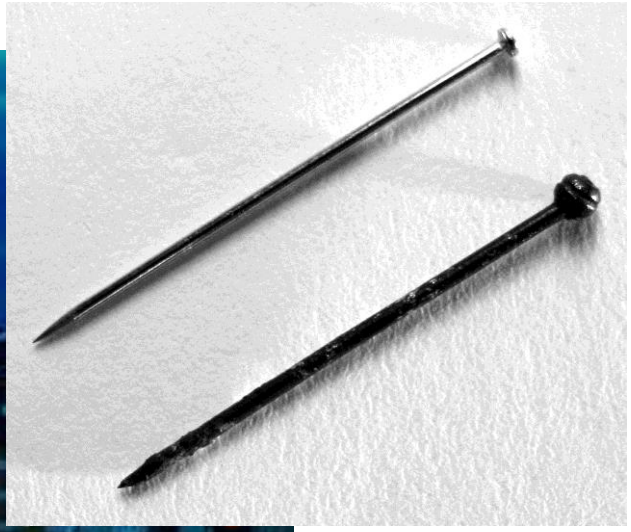
Source: Todorović et al, 2007, Swedish report

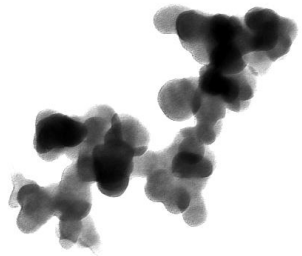

Partiklar i finmoden
Partiklar i grovmoden
TSP Hi Vol
PM10
WRAC
PM2.5
ΔMASS/Δ(log Dae,µm/m3
70
60
50
40
30
20
10
0
0.1
0.2
0.5
1.0
2
5
10
20
50
100
Aerodynamisk partikeldiameter Dae (µm)
Total Suspended Particles (TSP)
PM10
PM2.5
PM(10-2.5)

Aerosolpartiklars storlek

Globen (→100 μm)

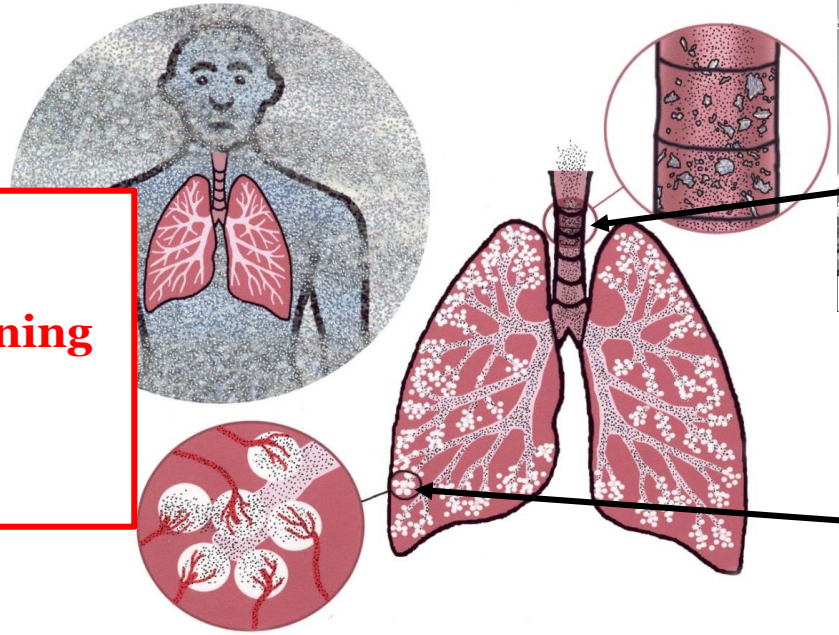
Knappnålshuvud (→1 nm)

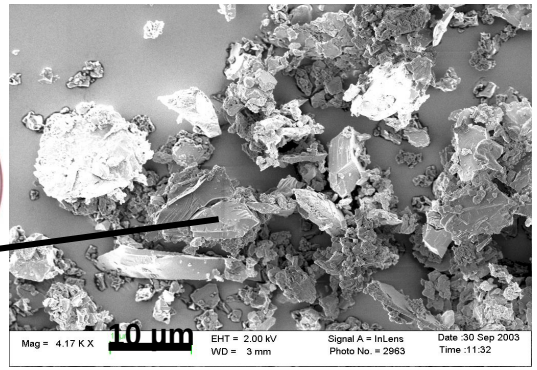


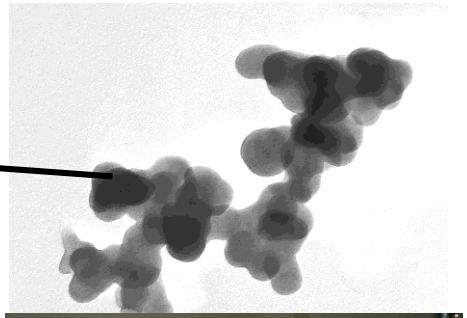


Particles and health effects – deposition in the respiratory tract

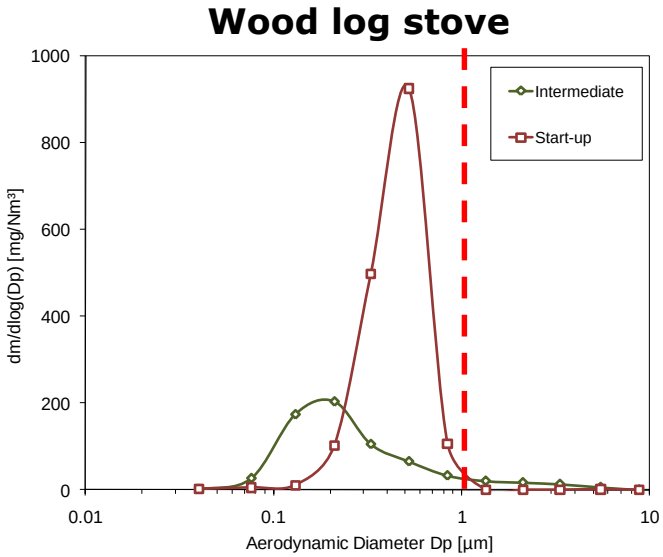
Idag regleras luftkvaliteten (hälsoriskbedömningar) baserat på partikelmassa (PM10/PM2.5)!

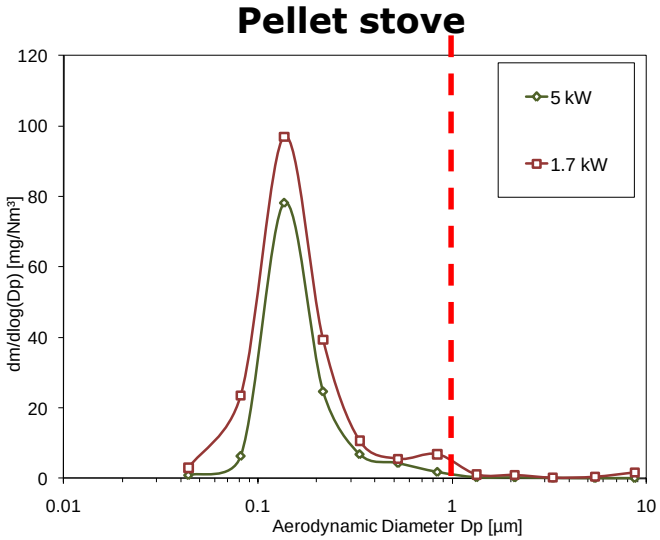




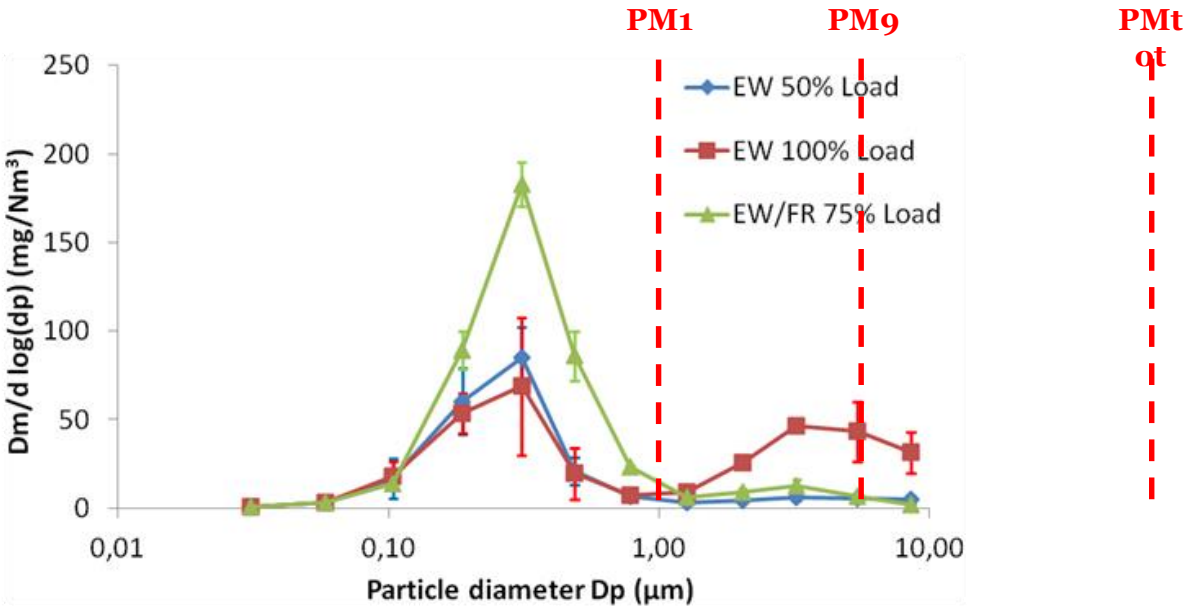


Typical PM mass size distributions in residential biomass combustion appliances (Petterson et al, Energy and Fuels 2010)





Particle size distributions in flue gases from a 2 MW grate boiler using Energy wood (EW) and Forest Residues (FR)



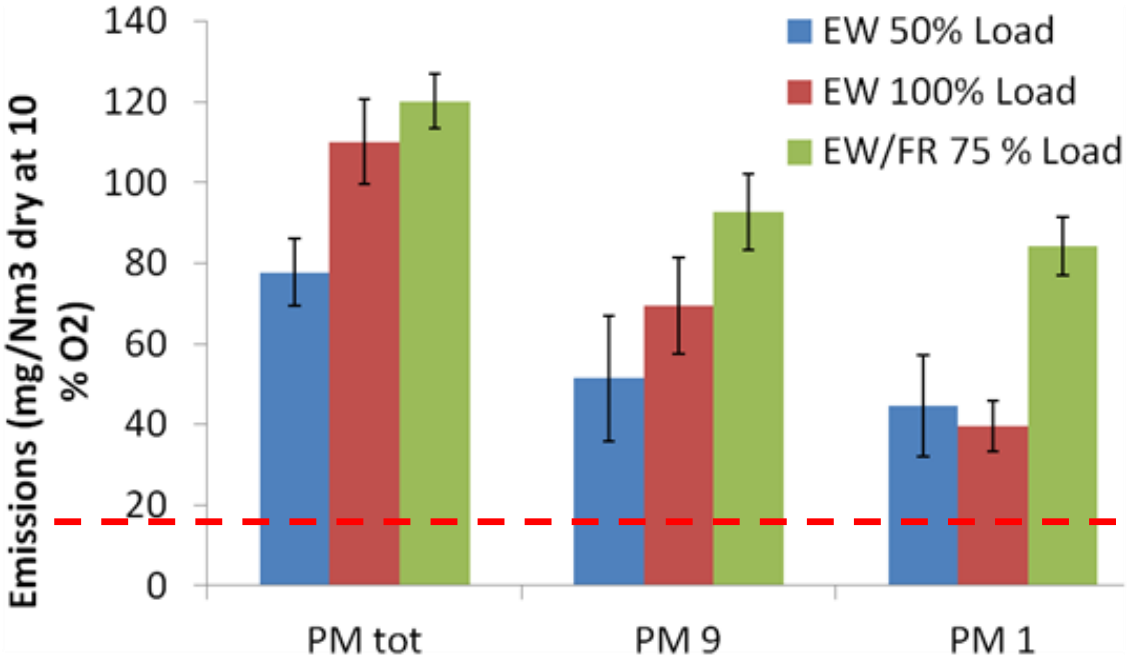
Low CO (good combustion): 600-1200 mg/MJ

Ash content:

EW 0.6-0.8% (d.s.)
FR: 1.2-1.8% (d.s.)

Data from Forest Power, Botnia Atlantica, Umeå University 2011

Particle mass concentrations in flue gases from the same 2 MW grate boiler using Energy wood (EW) and Forest Residues (FR)



18 mg/Nm3 vid 10% O2
motsv
25 mg/Nm3 vid 6% O2

Aerosol particle formation in biomass combustion

From Olli Sippula, Thesis 2010, UEF/Kuopio

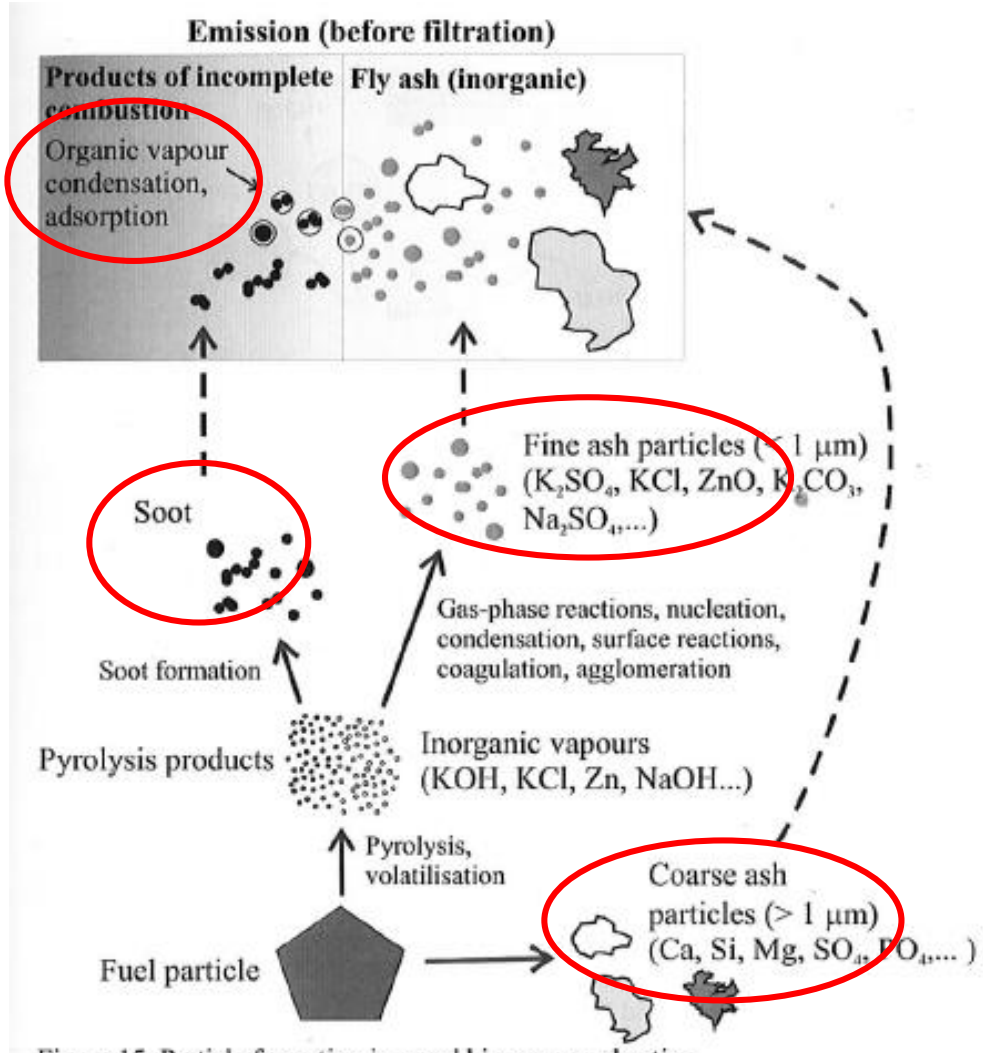
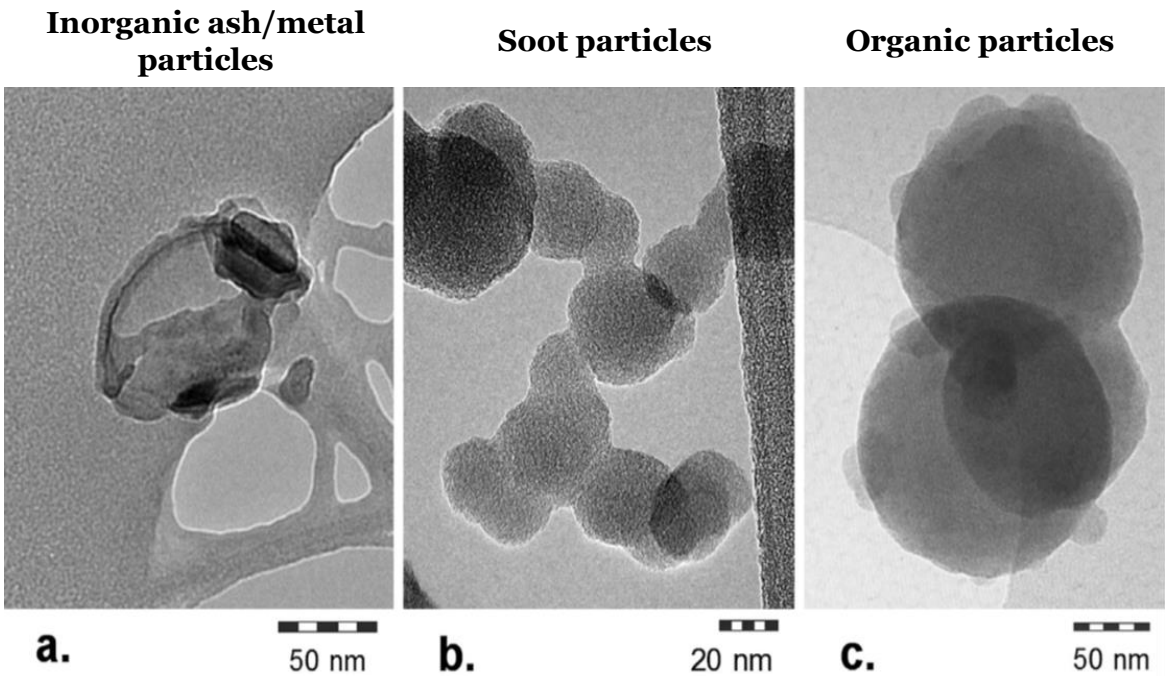


Figure 15. Particle formation in wood biomass combustion.

Different types of fine (<1 um) particles in biomass combustion:

→ **Conceptual model presented in Kocbach et al , Particle Fibre and Toxicology 2009;6:29**

→ **Later also identified by TEM by e.g. Torvela et al, Atmospheric Environment 2014;87:65-76**



Torvela T et al, 2014

Classes of organic components formed during incomplete biomass combustion

Methane

Other Alkanes (C_xH_y)

VOC´s (C_2-C_7) (e.g. ethene, propene)

Aldehydes

Substituted Furans

Benzene

Alkyl Benzenes (Toluene, Xylenes)

Aliphatic Carboxylic Acids
Aliphatic Alcohols
Phenols etc. etc.

Suger derivates (Levoglocosan, Galactosan…)

Oxygenated monoaromatics (Guaiacol, Syringol and Phenols etc.

Naphtalene

Substituted Naphtalens

PAH´s

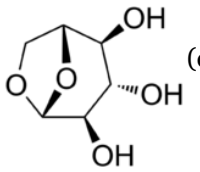
Oxygenated PAH´s (e.g. quinones)

Gases (ambient conditions)

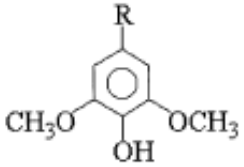
Semi-volatiles/Particulates (ambient conditions)

Amounts and relative distribution are strongly varying under different combustion conditions!

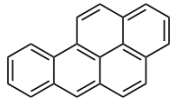
Precursers for primary organic aerosols and soot



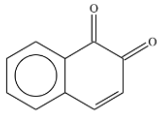
Levoglucosan (cellulose pyrolysis product)



Syringyl compounds (lignin pyrolysis products)



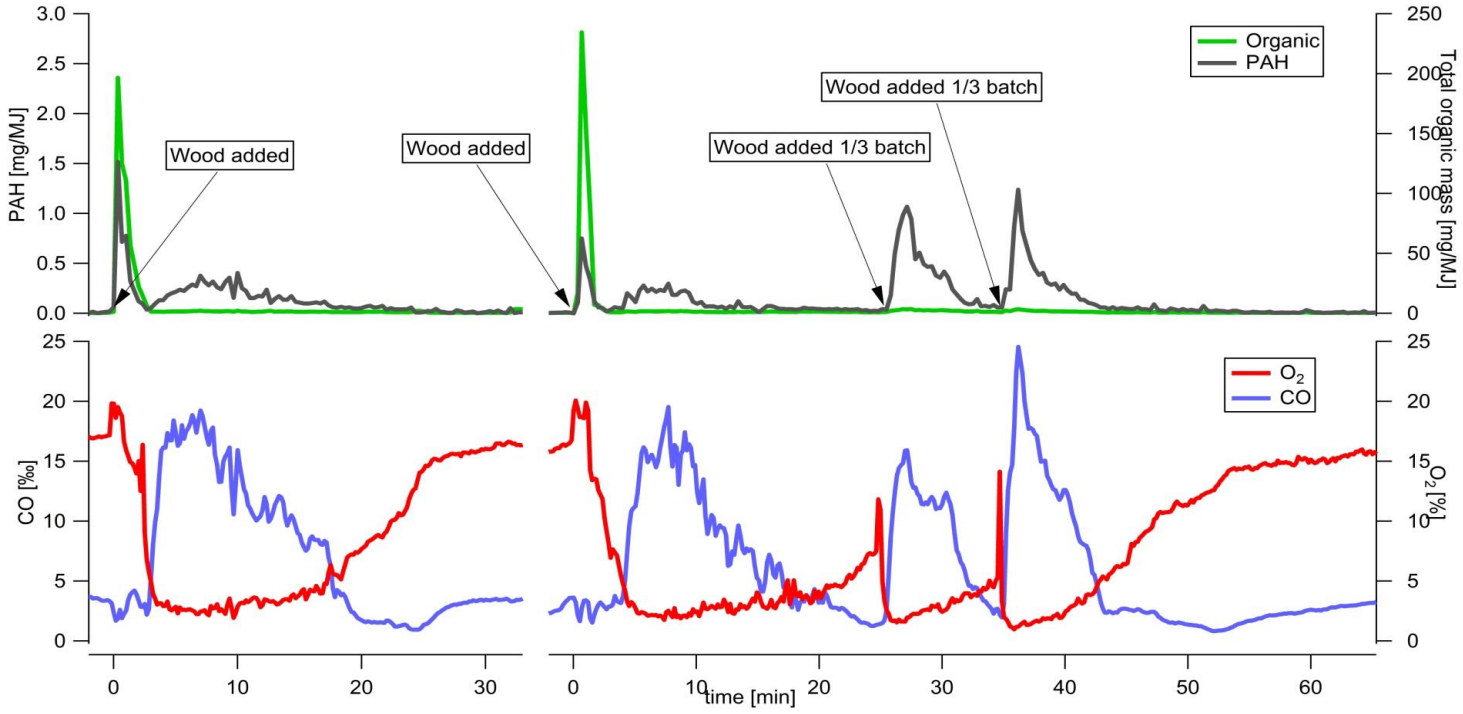
Pure PAH (fuel or combustion related)



Oxy-PAH ?

Time resolved emission measurements of PAH and other organics in a wood stove -

AMS measurements by LU and UmU (2010)



Eriksson et al. Environmental Science and Technology 2014;48(12):7143–7150.

Feedstocks for bioenergy - today and in the future!

Forestry material (saw dust, bark, residues, stumps, …)

Woody energy crops (e.g. Salix, Poppel, …)

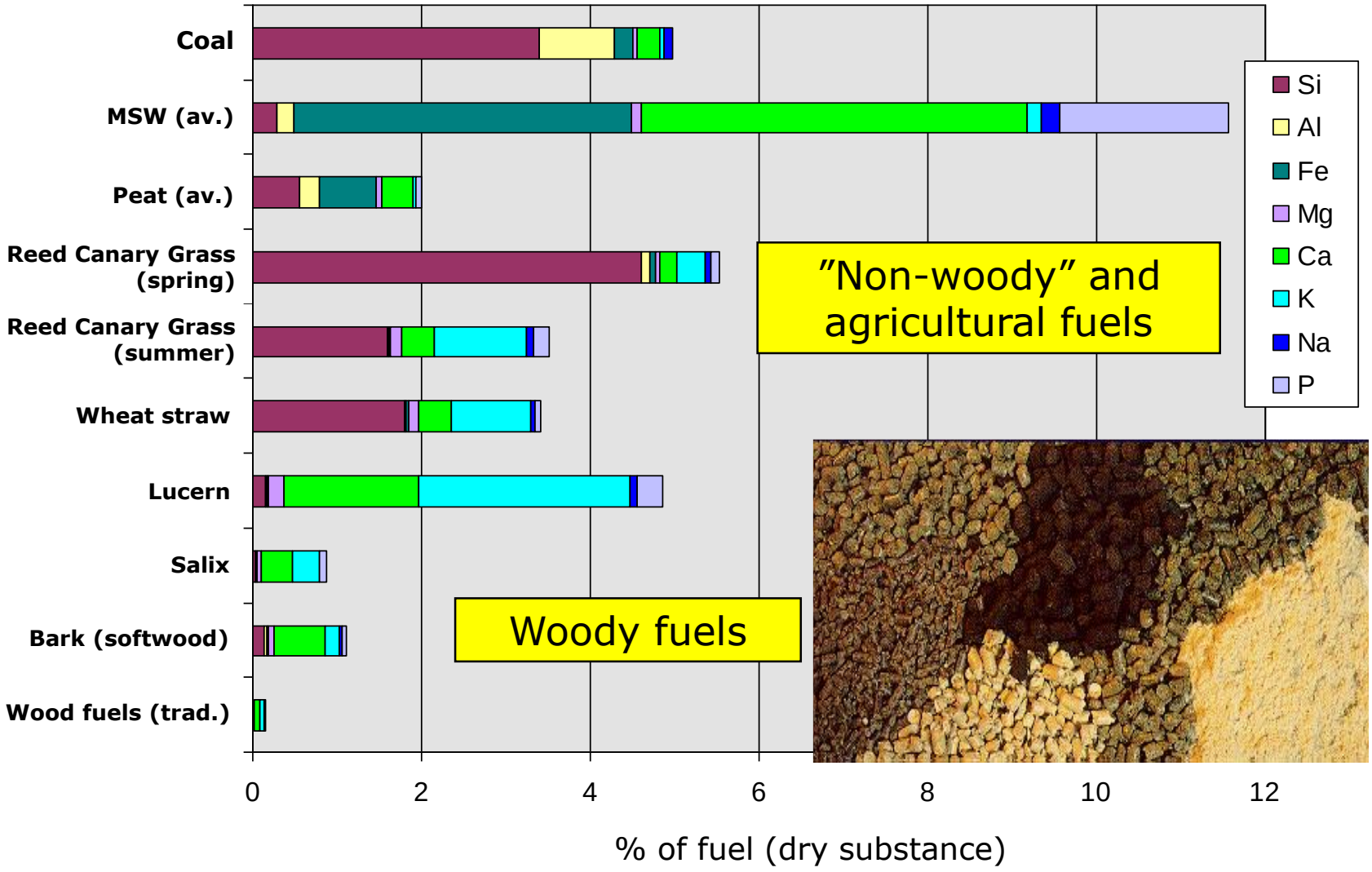
Peat

Non-woody energy crops (e.g. wheat straw, brassica, …)

Grass fuels (e.g. reed canary grass, miscanthus, …

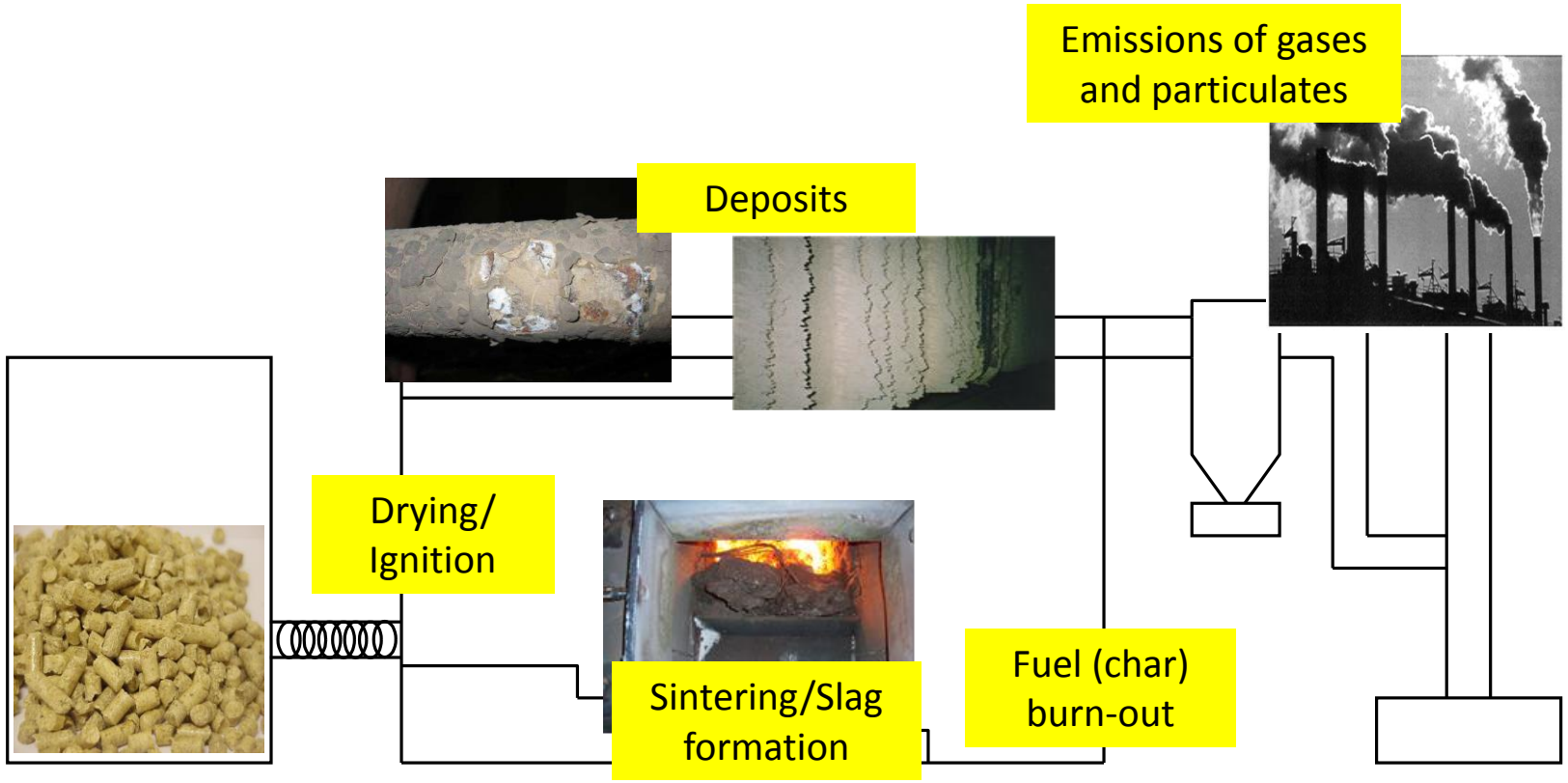
Hemp

Other biomass fuels than wood and stemwood pellets will be used
→ higher content of ash forming and trace metal elements

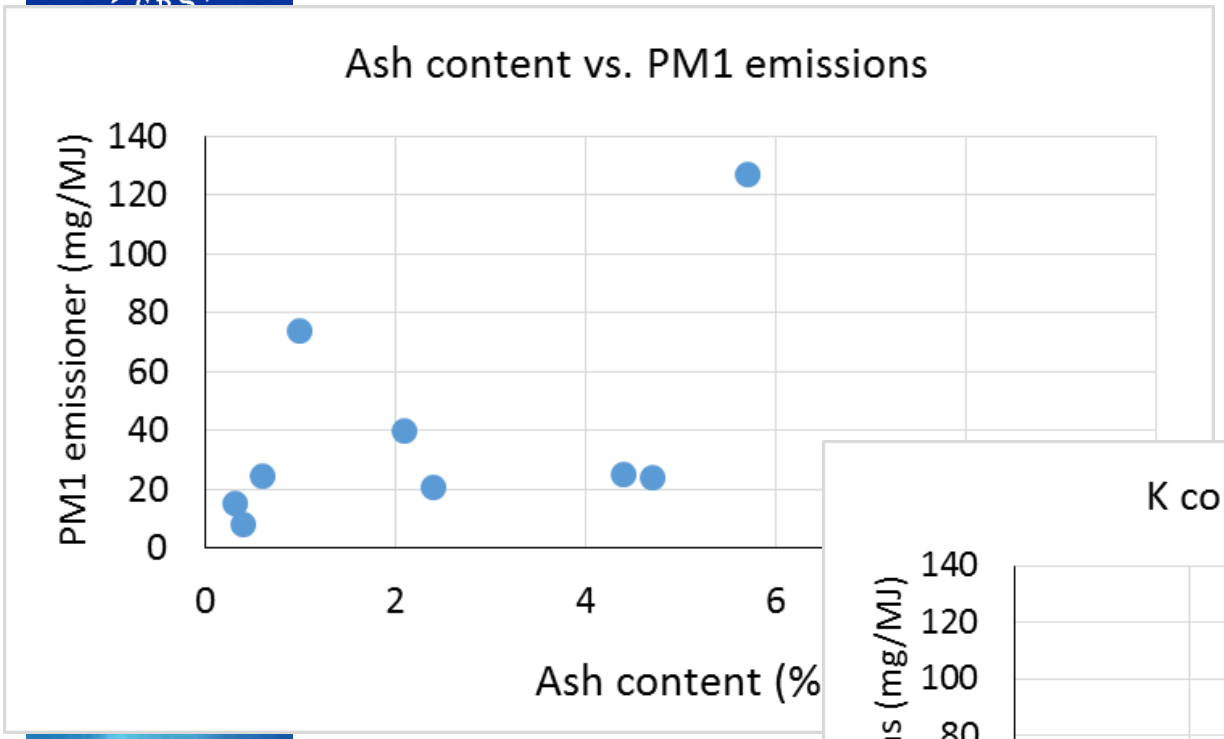


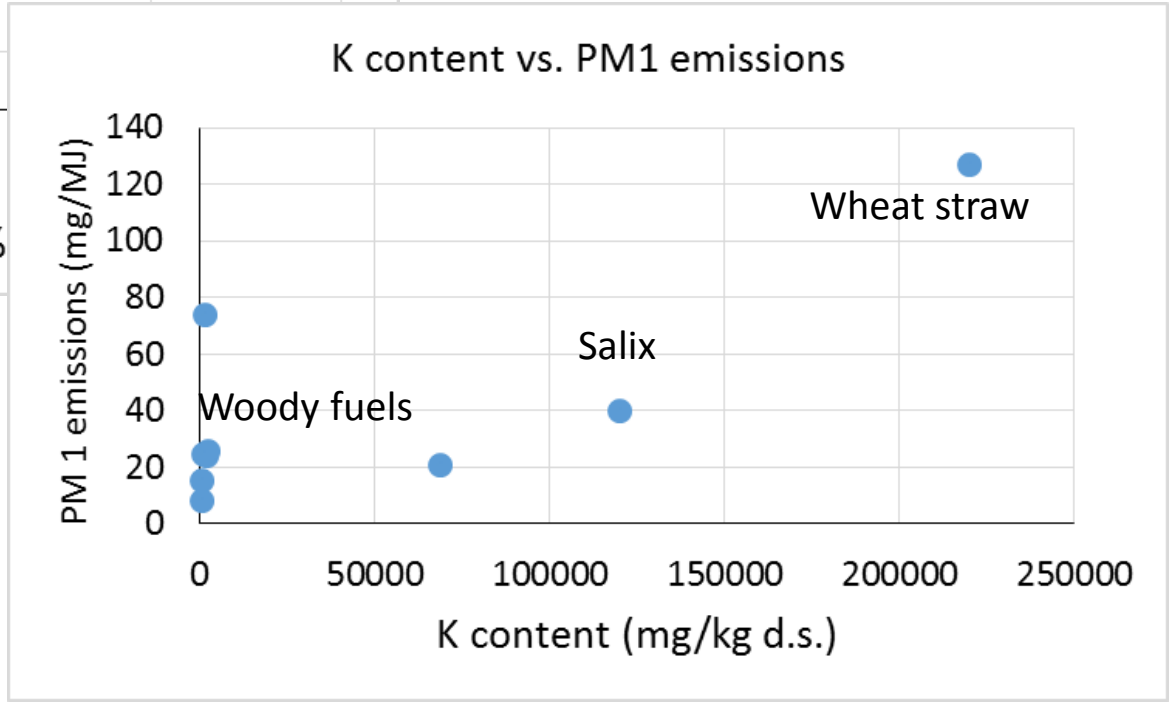
What is happening with the fuel and ash elements inside a boiler?

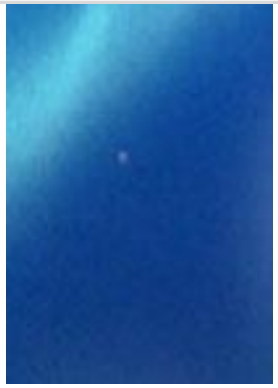
→ Fractionation (bottom ash and flue gases) are crucial (K, Na, Si, P, S, Cl, ….)



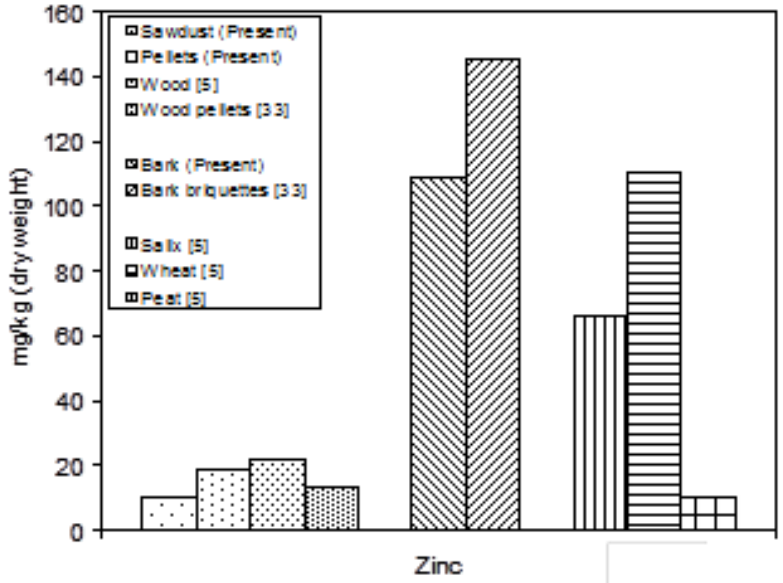
Influence of biomass fuel on PM1 ash particle emissions

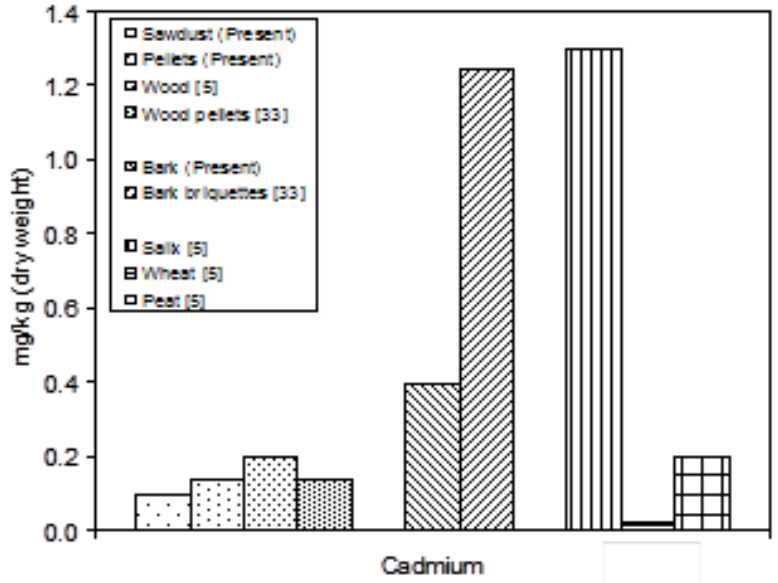


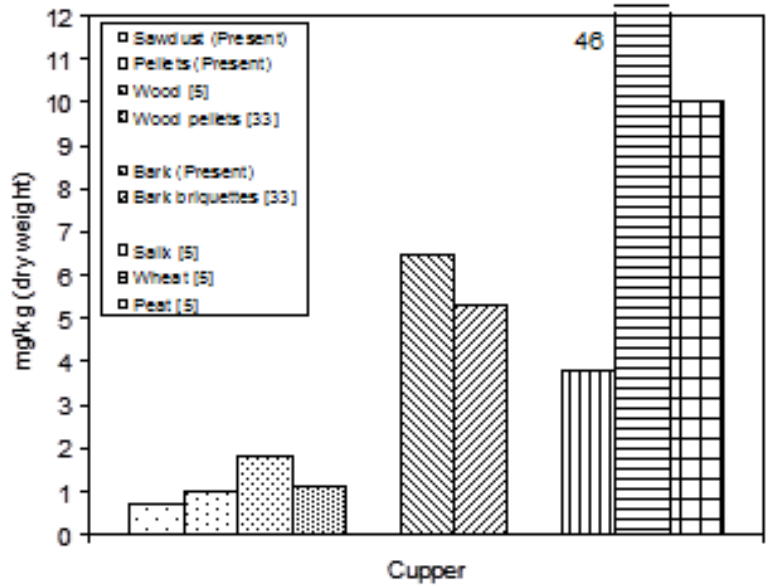


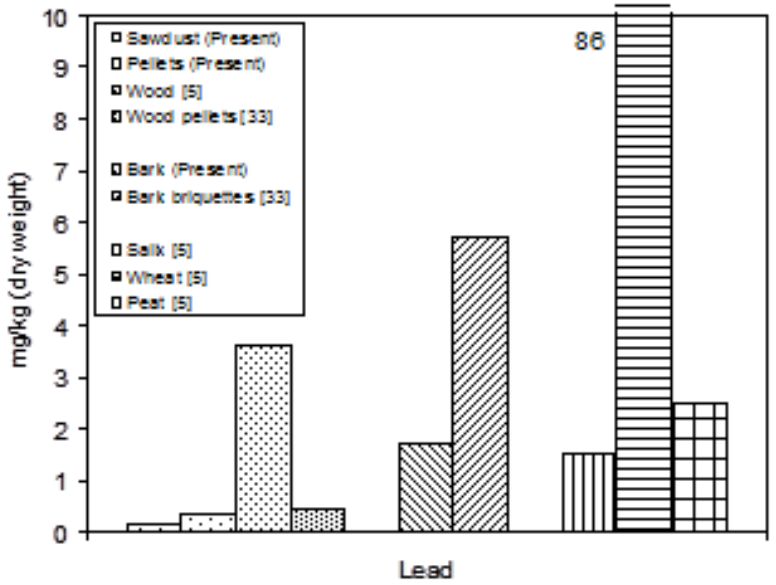


Tungmetaller i olika biobränslen (Boman et al 2006)



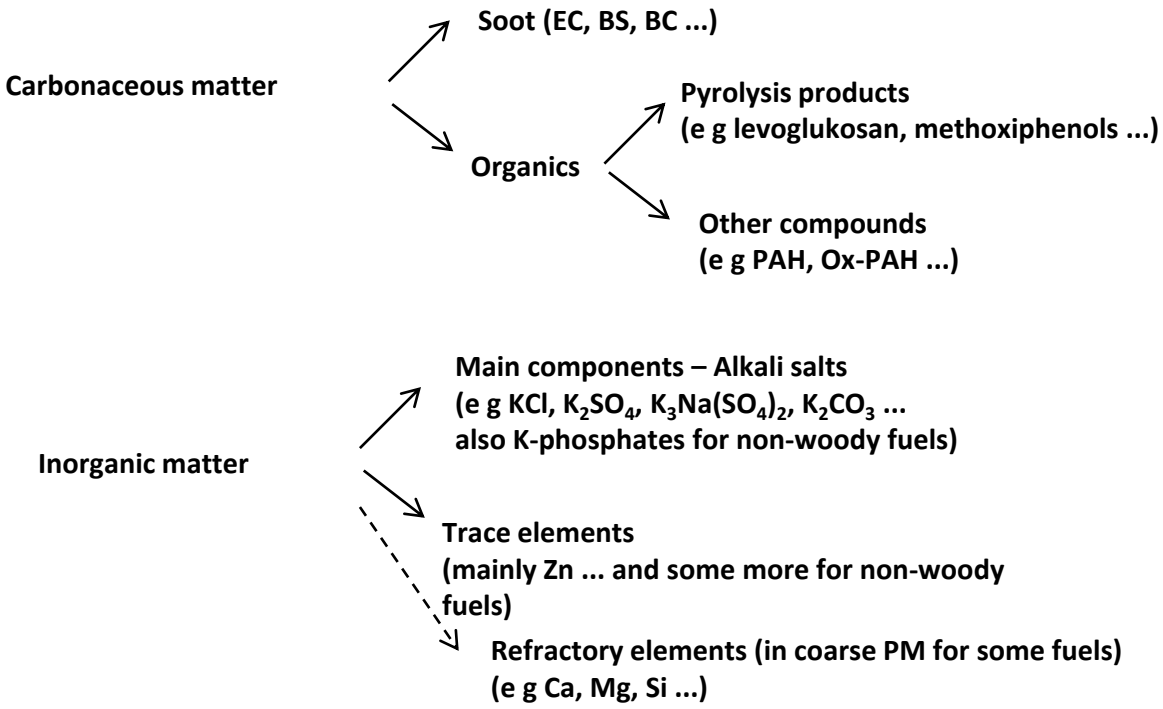




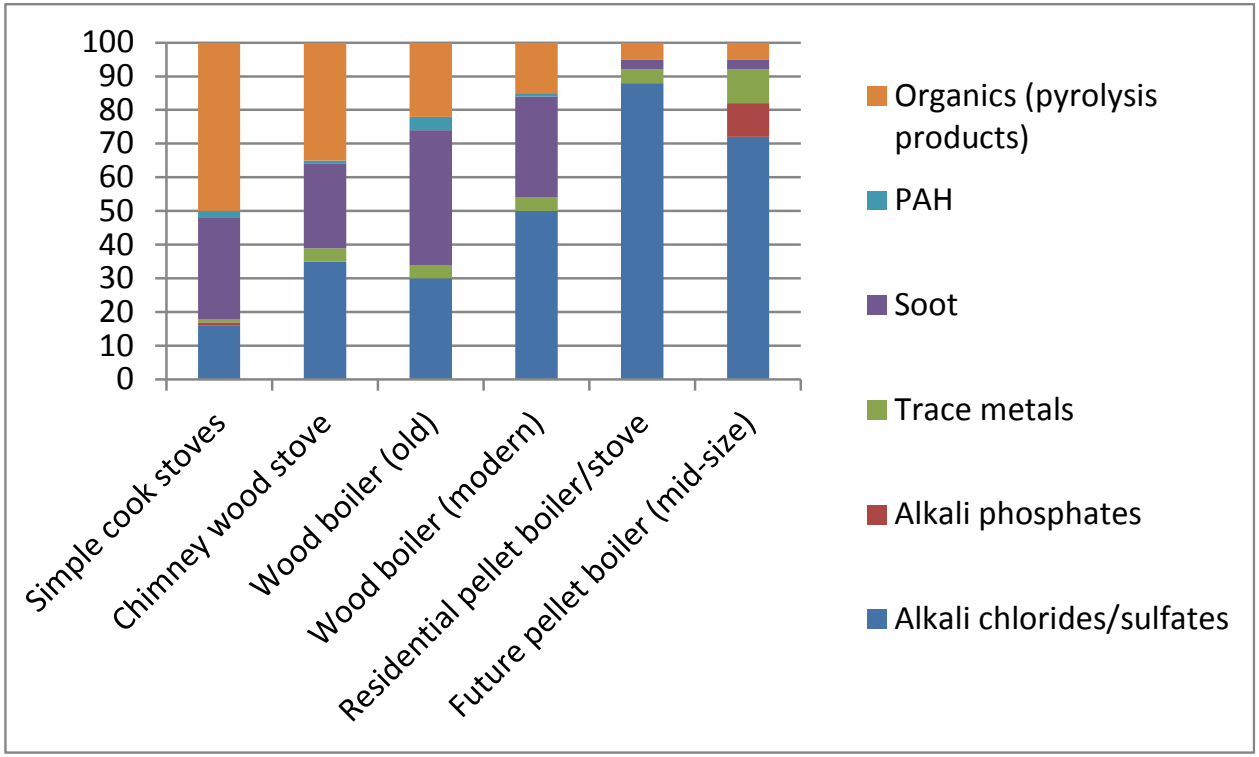


Chemical fractionation/speciation of relevance for biomass combustion fine PM

From *ERA-NET BiomassPM* project report, Jokiniemi et al 2008



Relative chemical compostion of fine (<1 um) PM emissions from different biomass combustion systems



Summary

- In Europe residential wood combustion causes (ambient) air quality problems with significant soot and organic particle emissions!
- Combustion processes with solid fuels are very complex and it exists a great number of different fuels and applications – process and fuel influence the particle properties
- Both fine (<1 um) and coarse PM are formed although with a clear focus on the fine fraction in most cases
- In general, three classes of fine combustion aerosols are defined; soot, organic and inorganic (ash) particles
- Biomass combustion aerosols are (probably) more complex to understand than diesel exhaust particles, BUT relatively little is known and measures taken compared to the trafic sector!
- In larger plants with good control and efficiency, the ash PM dominates
- In small scale (residential) systems, a great variation exists depending on technology, operation and fuel used (modern well working small appliances resembles large scale systems!
- Many of the details in these processes are still to be elucidated and the implications for the toxicity and human health are still rather poorly understood!
- Some conclusive statements have been made concerning culprit biomass PM components, e.g. soot and Zn have been identified – still the organic fraction of biomass PM are becomming of more and more interest
- Combined aspects of climate and health implications – stronger mitigation rationales

Tack för mig!

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Umeå Universitet

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