Particle Emissions from Residential Biofuel Boilers and Stoves – Old and Modern Techniques

Claes Tullin[1]

Linda Johansson[1], Lennart Gustavsson[1], Bo Leckner[2], David Cooper[3], Annika Potter[3], Morten Berntsen[4]

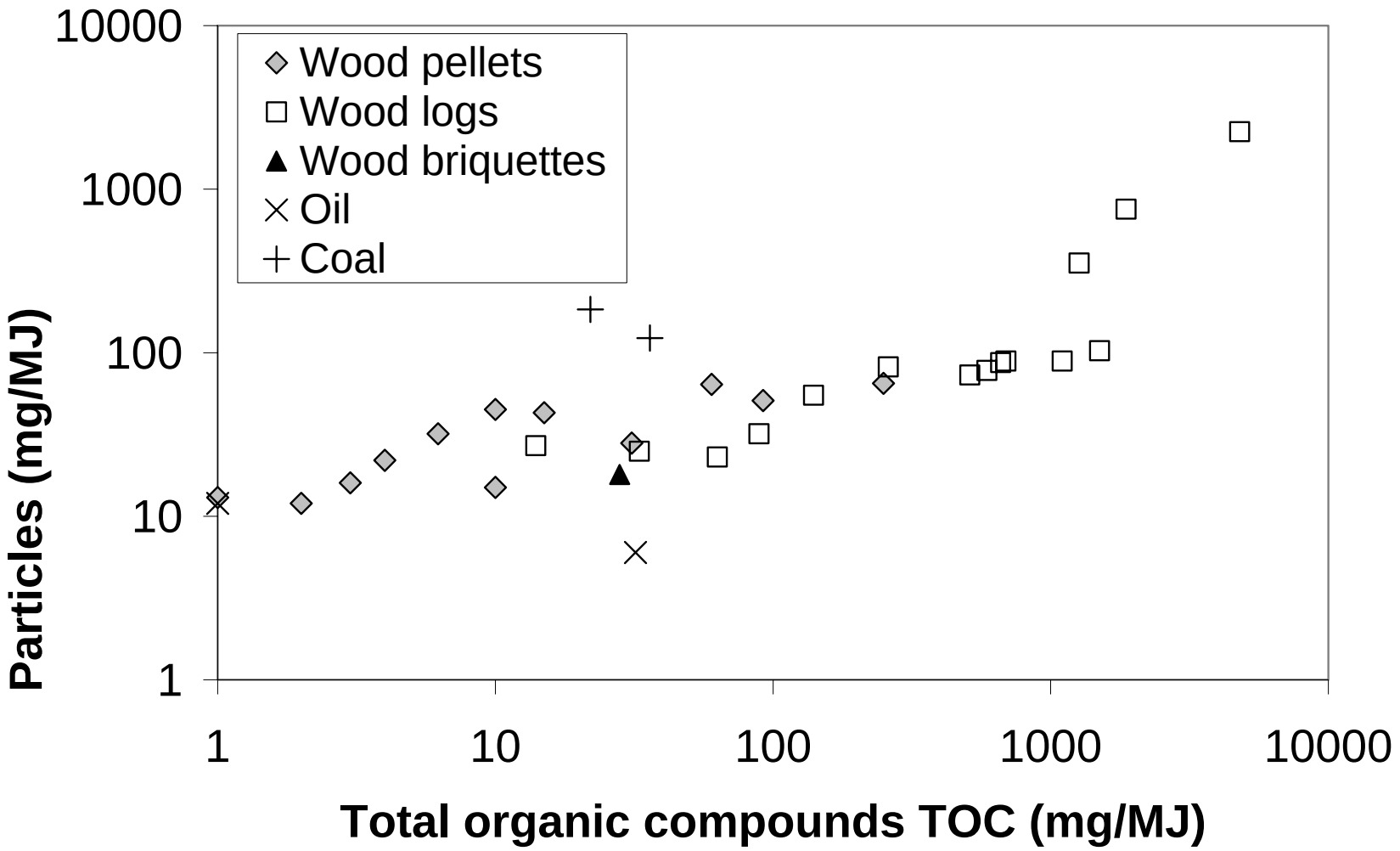
[1]SP Swedish National Testing and Research Institute, Borås, Sweden

[2]Department of Energy Conversion, Chalmers University of Technology, Göteborg, Sweden

[3]IVL Swedish Environmental Research Institute, Göteborg, Sweden

[4]The National Institute of Technology, Environment and Safety, Oslo, Norway

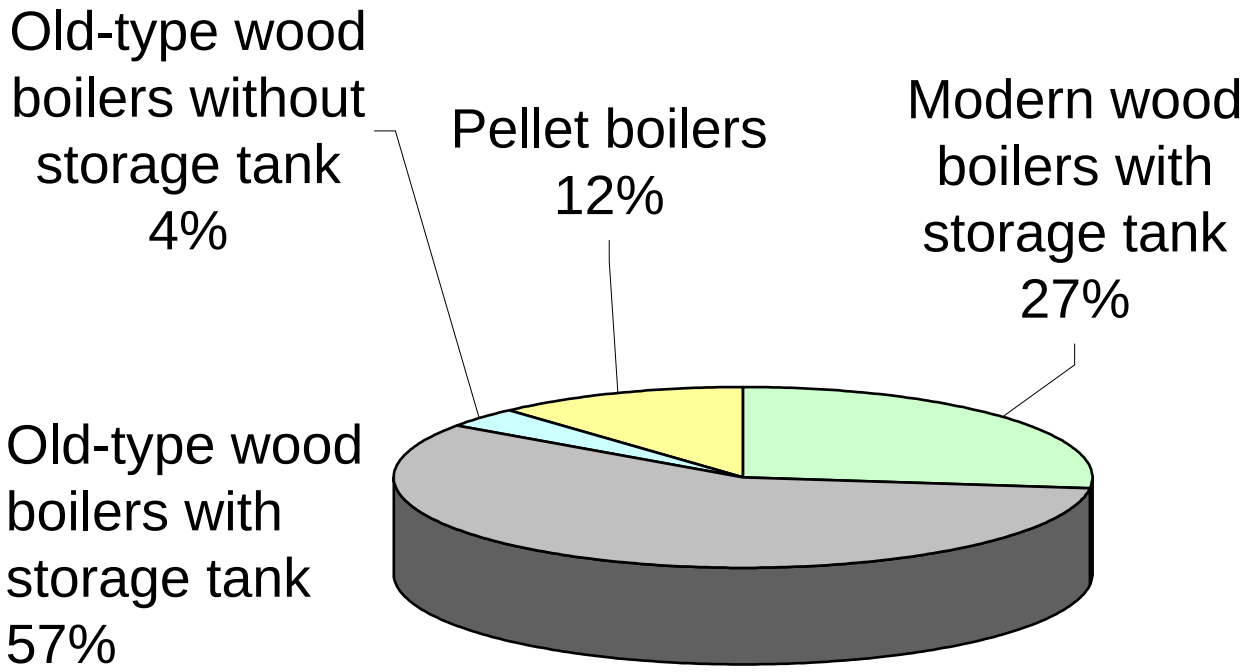
Large variations in mass concentration



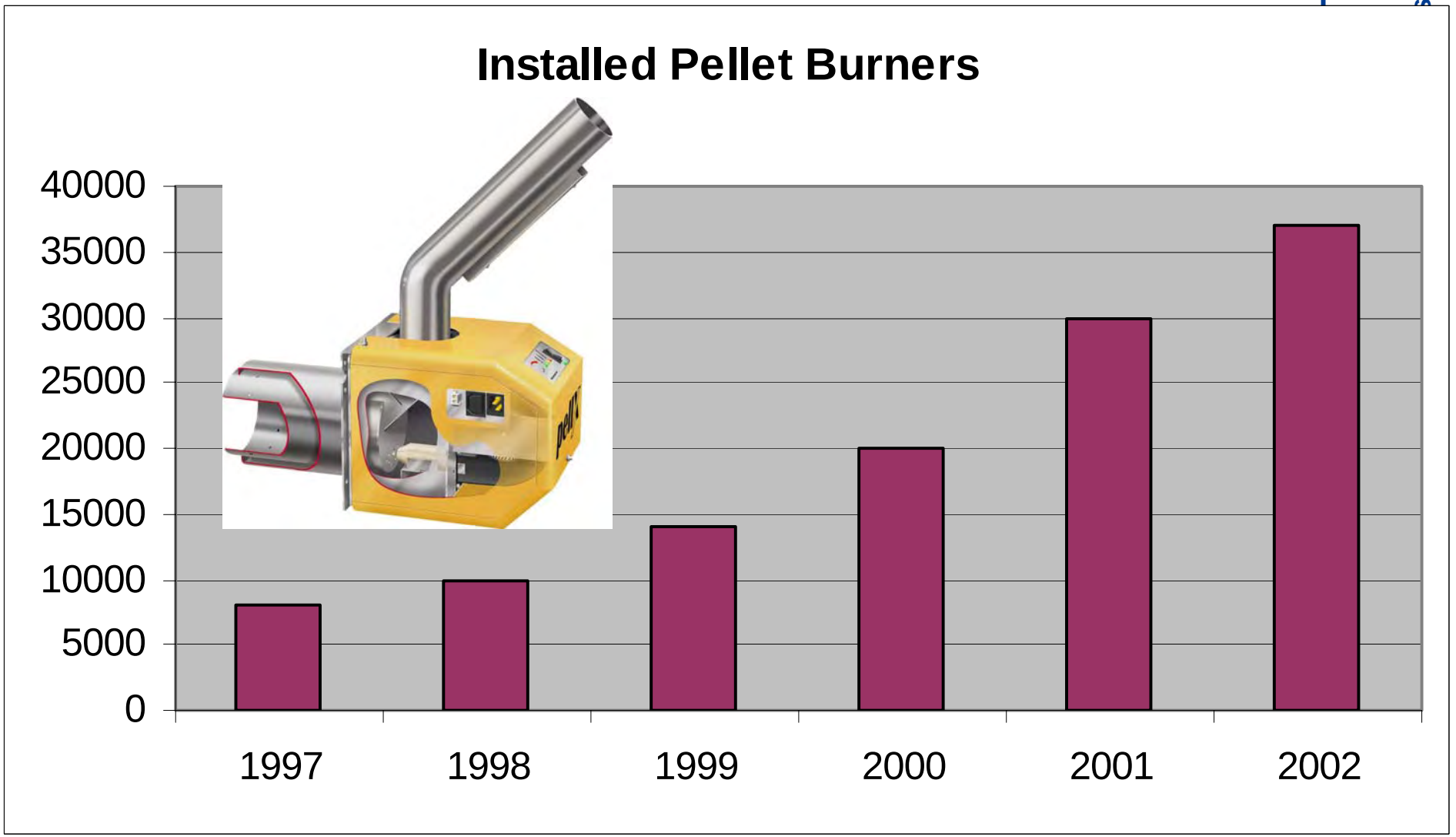
Residential biofuel boilers and stoves in Sweden

12 – 13 TWh

- **260 000 residential boilers fired with wood logs and wood pellets**
- **1 100 000 wood stoves and open fires**



Installed pellet burners (Sweden)



Small–scale combustion in Sweden, fuel comparison

	Oil	Wood pellets	Oat
Density (kg/m3)	850	650	540
Heating value (kWh/kg)	11	4.8	4.2
Volume equivalent to 1 m3 oil	1.0	3.0	4.1
Price (Swedish Kr)	8500 kr/m3	2200 kr/ton	860 kr/ton
Price, SEK/kWh	**0.91**	**0.46**	**0.20**

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Small – scale biomass combustion: A sustainable renewable energy technology?

Old technology

⇒ large emissions of particles, VOC, CH4 etc (PM from wood combustion larger than from traffic!?)

Modern technology

⇒ **potentially** low emissions, but depends on fuel quality, operation, maintanance etc

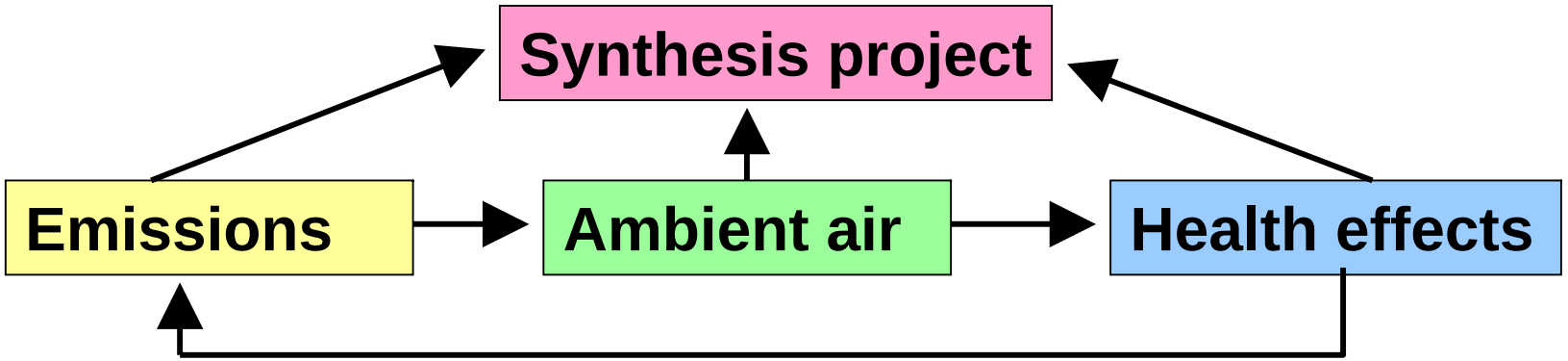
⇒ Oil to biomass may increase local emissions

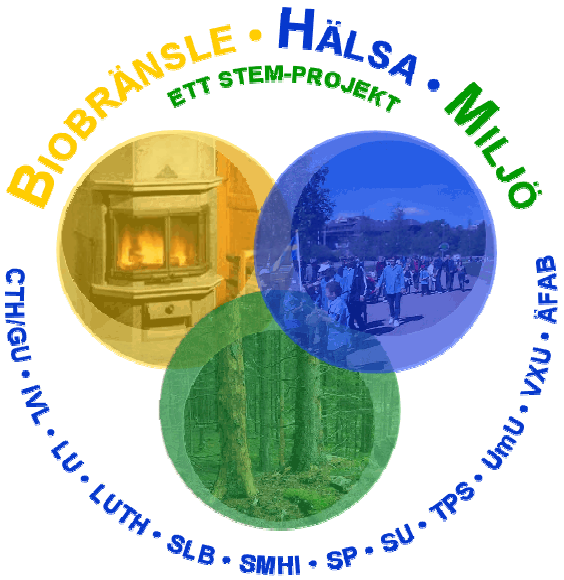
Very large uncertainties regarding the environmental impact of both old and modern technology

=> Detailed emission inventory required

Project Biofuel Health and Environment

Biofuel Health and Environment is a frame project financed by the Swedish Energy Agency.





- Year 2000 - 2003
- ~3.3 million Euro
- Totally 25-30 participating Universities, Research Institutes, and Companies

http://www.itm.su.se/bhm

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Experimental work
– Emission studies in three projects

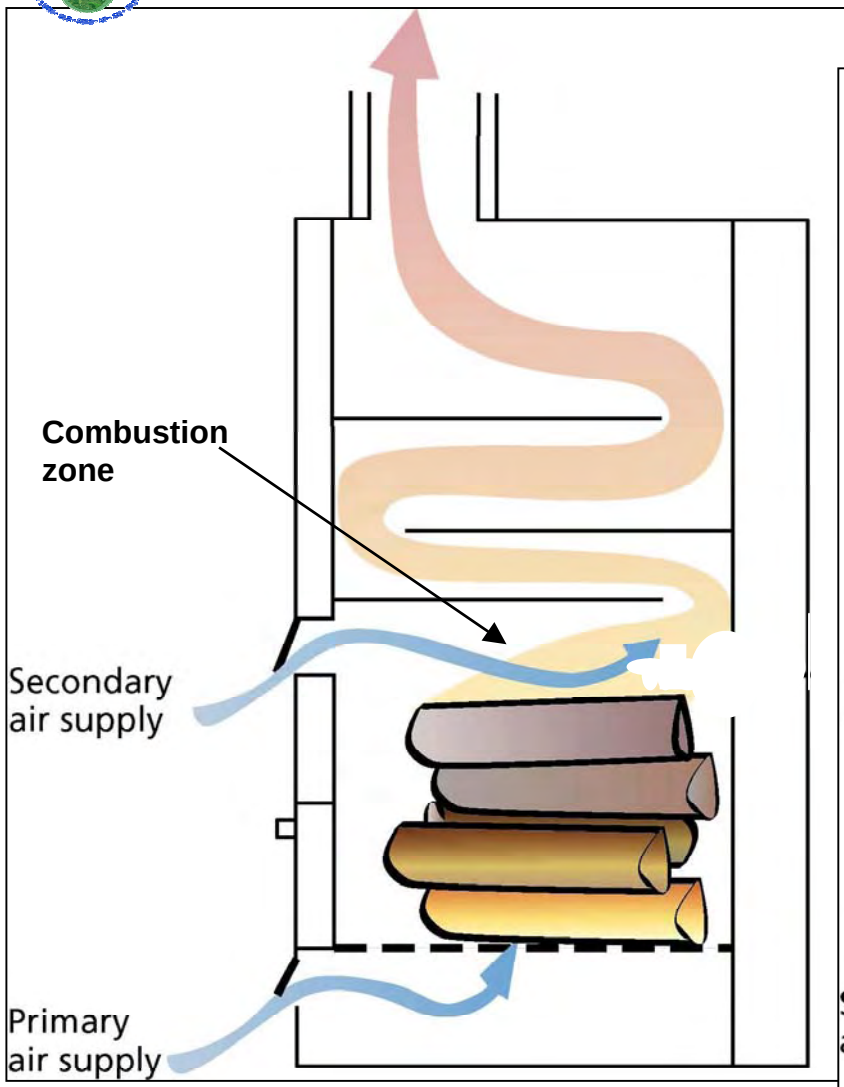
1) Old-type and modern wood boilers & pellet boilers.

   A project within the project Biofuel, Health and Environment

2) Open fireplaces, old-type stoves fired with wood (as well as coal), modern wood stoves and pellet stoves

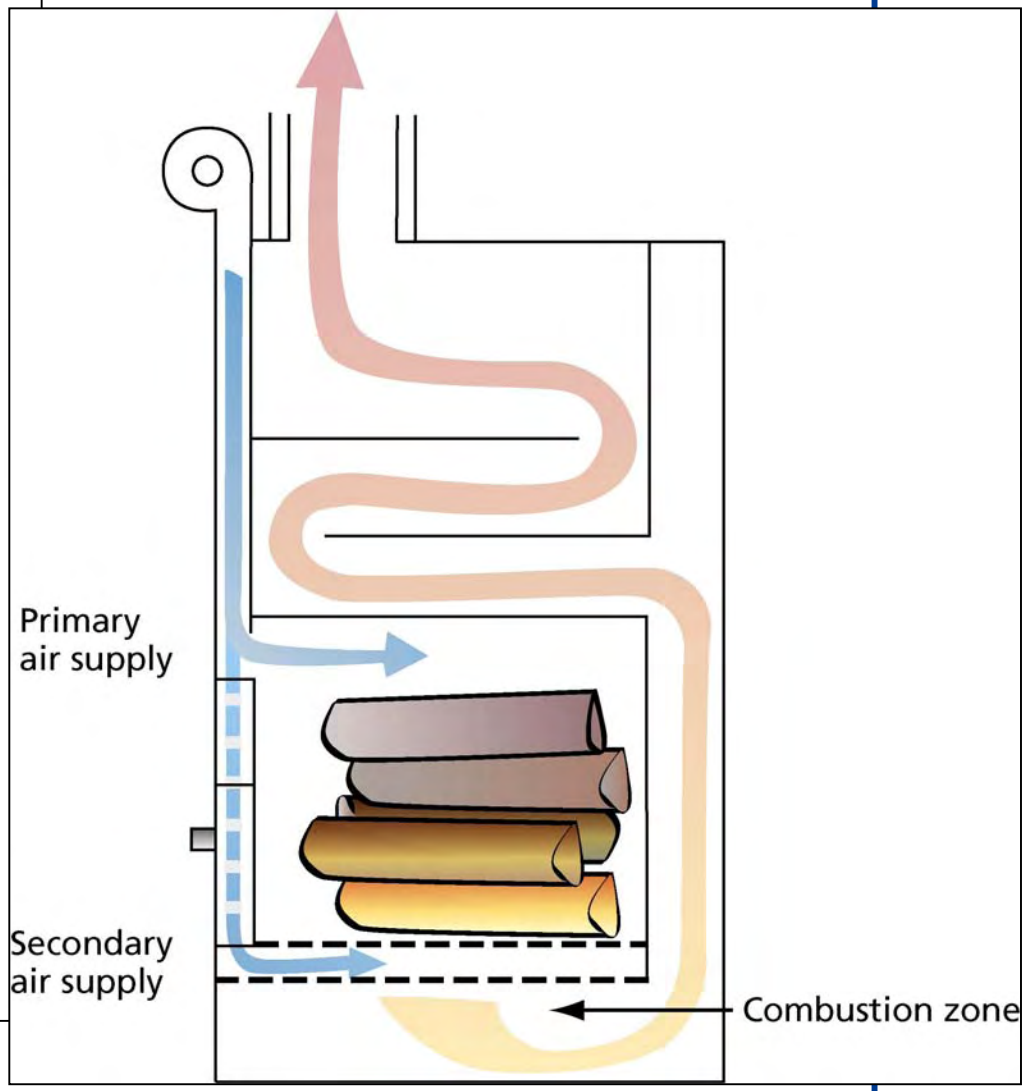
3) A novel electrostatic precipitator (ESP) for residential combustion was developed and tested in the EU CRAFT project CleanAir.

Old-type wood boiler



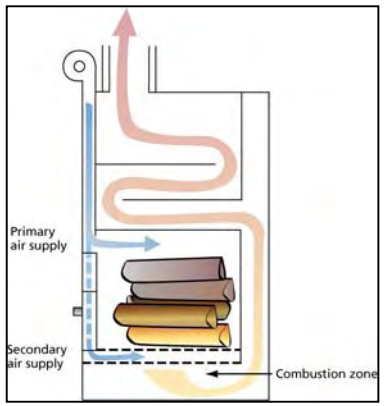
- **Up-draught combustion**
- **Water-cooled**

Modern wood boiler



- **Down-draught combustion**
- **Ceramic**

Modern wood combustion: Boiler + heat storage tank

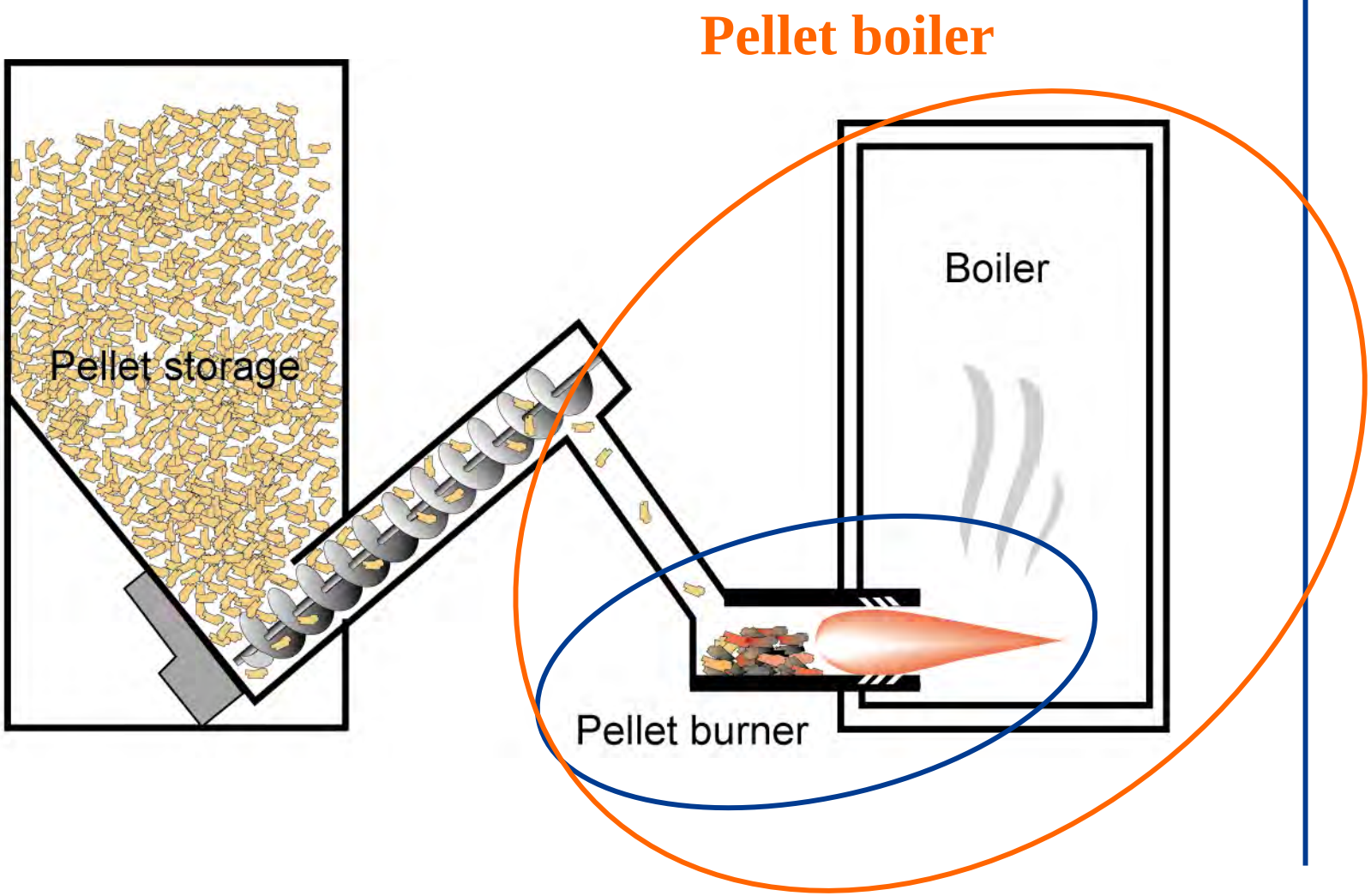


More optimal combustion conditions => **Lower emissions** and **higher efficiency**

The boiler can be run at a constant heat output (instead of being intermittently operated to directly follow the heat load of the house)

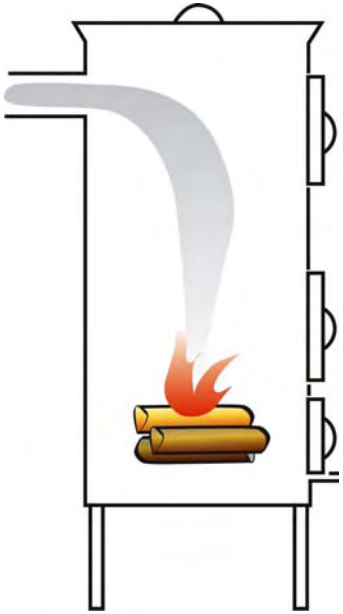
=> **Increased convenience**

Pellet boilers and burners

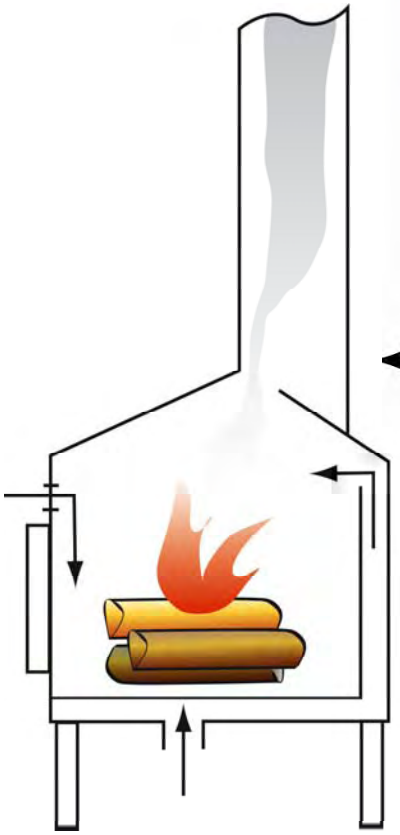


Open fires, stoves for wood and pellets

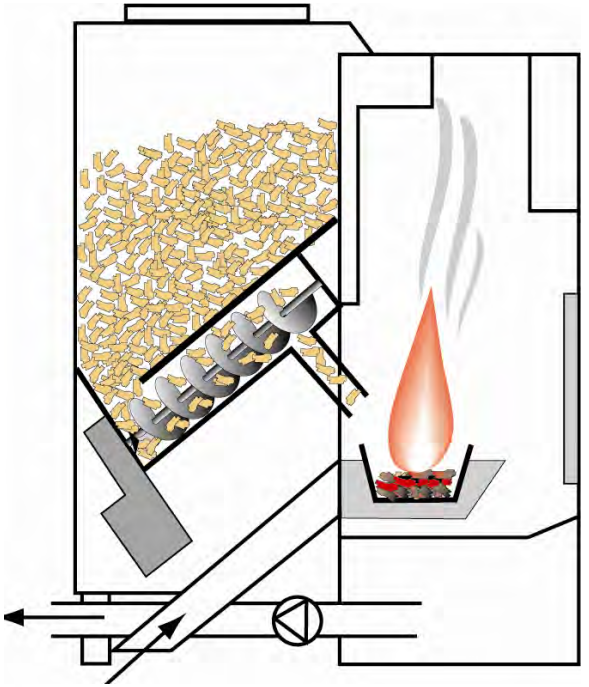
Open fire



Old-type wood stove



Modern wood stove



Pellet stove

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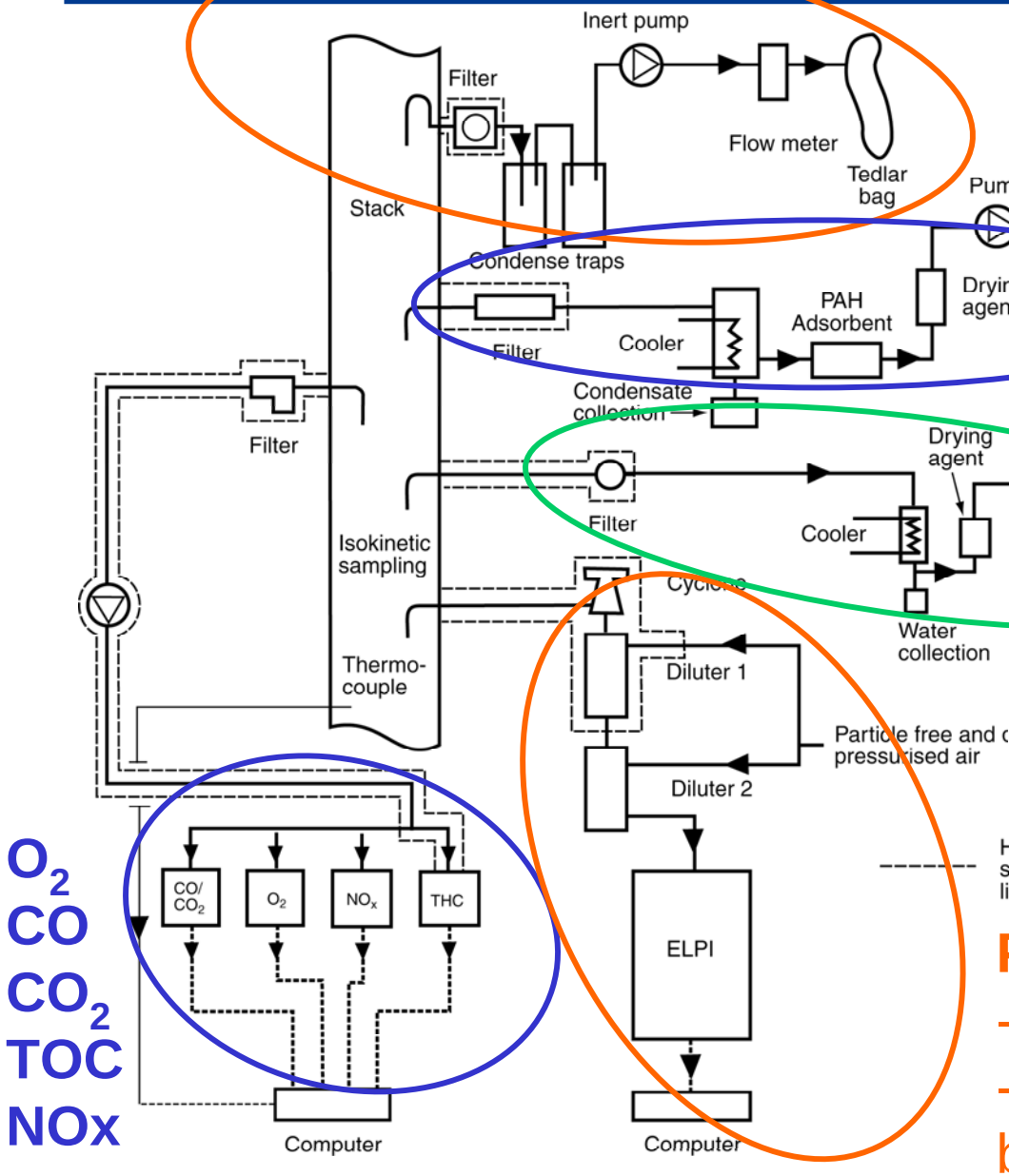
Measurement techniques



VOC, volatile organic compounds

PAH, polycyclic aromatic hydrocarbons

Particles/Dust
- Mass concentration

O_2
CO
CO_2
TOC
NOx

Particles/Dust
- Number concentration
- Size distributions, both number and mass

Measurement cases in the 1st project

1. Old-type wood boilers
   - (a) Large and small wood batches fired without heat storage tank, (b) combustion with connection to heat storage tank
   - Dry birch wood (15 % moisture content)
2. Modern wood boilers
   - Connected to a heat storage tank
   - Dry and moist (26/38 %) birch wood, wood briquettes
3. Pellets boilers (and burners)
   - Nominal load, intermittent operation, high draught
   - Wood pellets, bark pellets
4. Oil boiler (and burner)

Measurement cases in the 2nd project

1. Open fire place (1)
2. Old-type wood stoves (2)
3. Modern wood stoves (2)
4. Pellet stoves (2)

Fuels

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Wood/Pellets: 19 MJ per kg dry fuel

Content, mass-% in dry fuel.

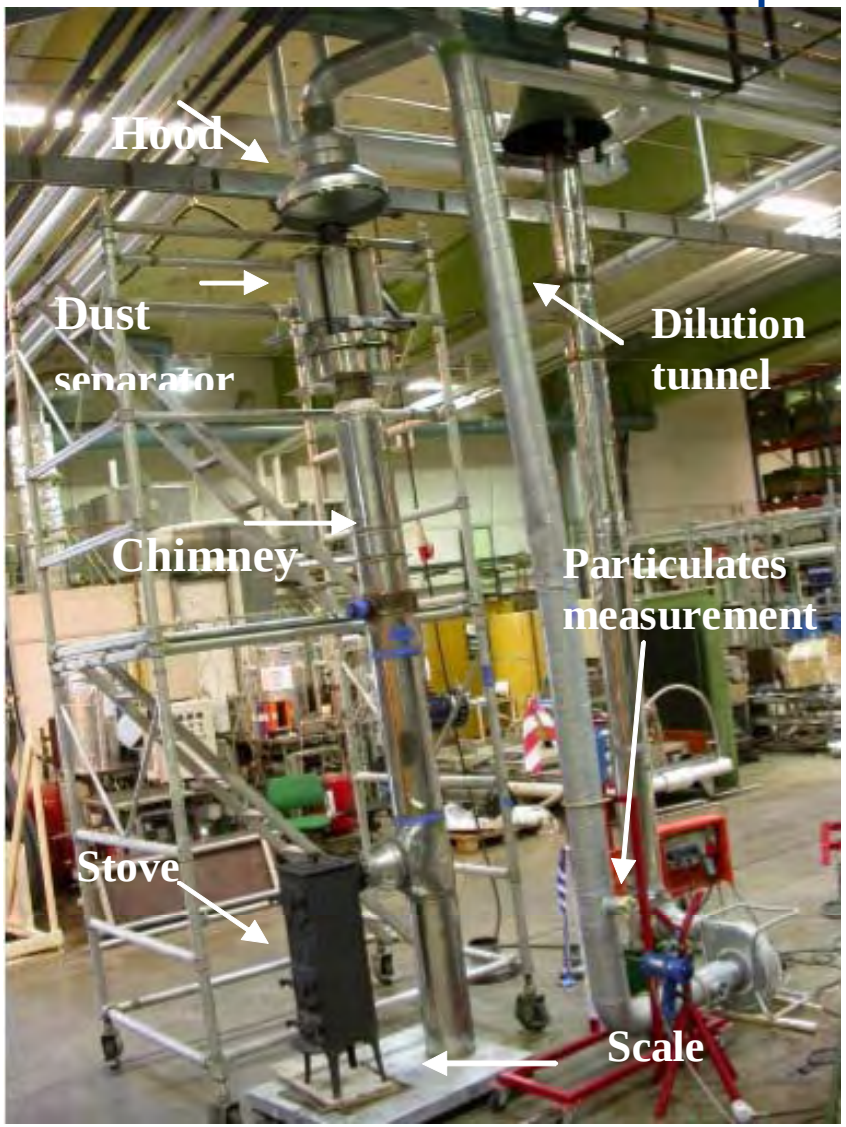
C	O	H	N	S	Ash
50-51	43-44	~6	0.05-0.08	<0.01	0.3-0.5

Moisture: 7 – 8 % for pellets, 16 % for dry wood logs and 26 and 38 % in the cases of moist wood logs.

Coal: Coalite (Coalite ltd). ~50 % higher heating value than wood/pellets, 15 times more ash. More carbon, nitrogen and sulphur, but lower content of hydrogen and oxygen than in the biofuels.

Oil: Slightly twice as high heating value as wood/pellets, about the same ash content. More carbon, hydrogen, nitrogen and sulphur, but lower content of oxygen than in the biofuels

Novel residential ESP – CleanAir, 3d project



Prototype tests

- Laboratory tests
- Validation at household site

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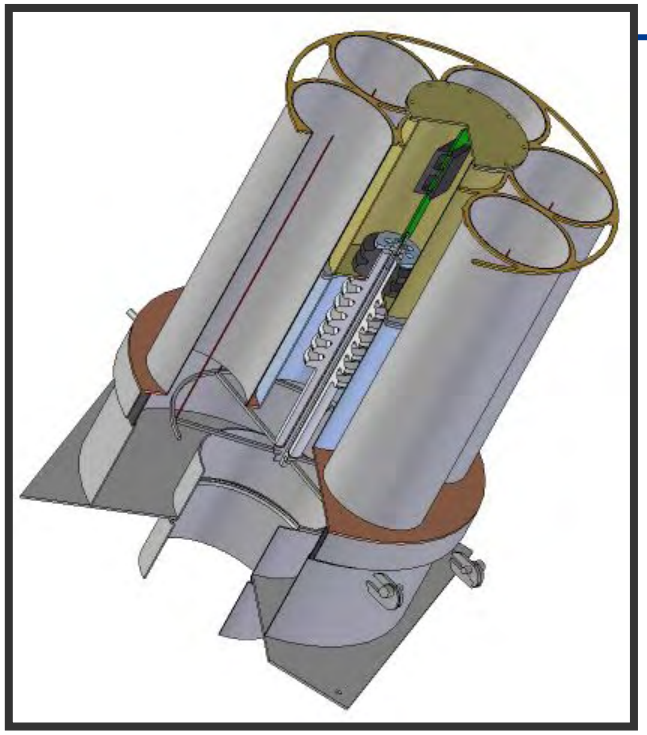
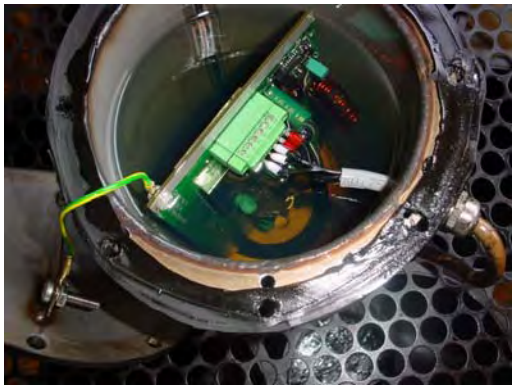
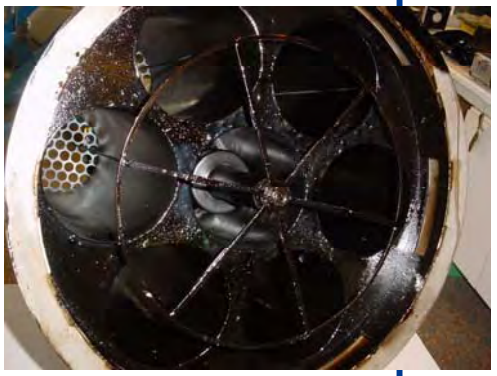
The CleanAir unit







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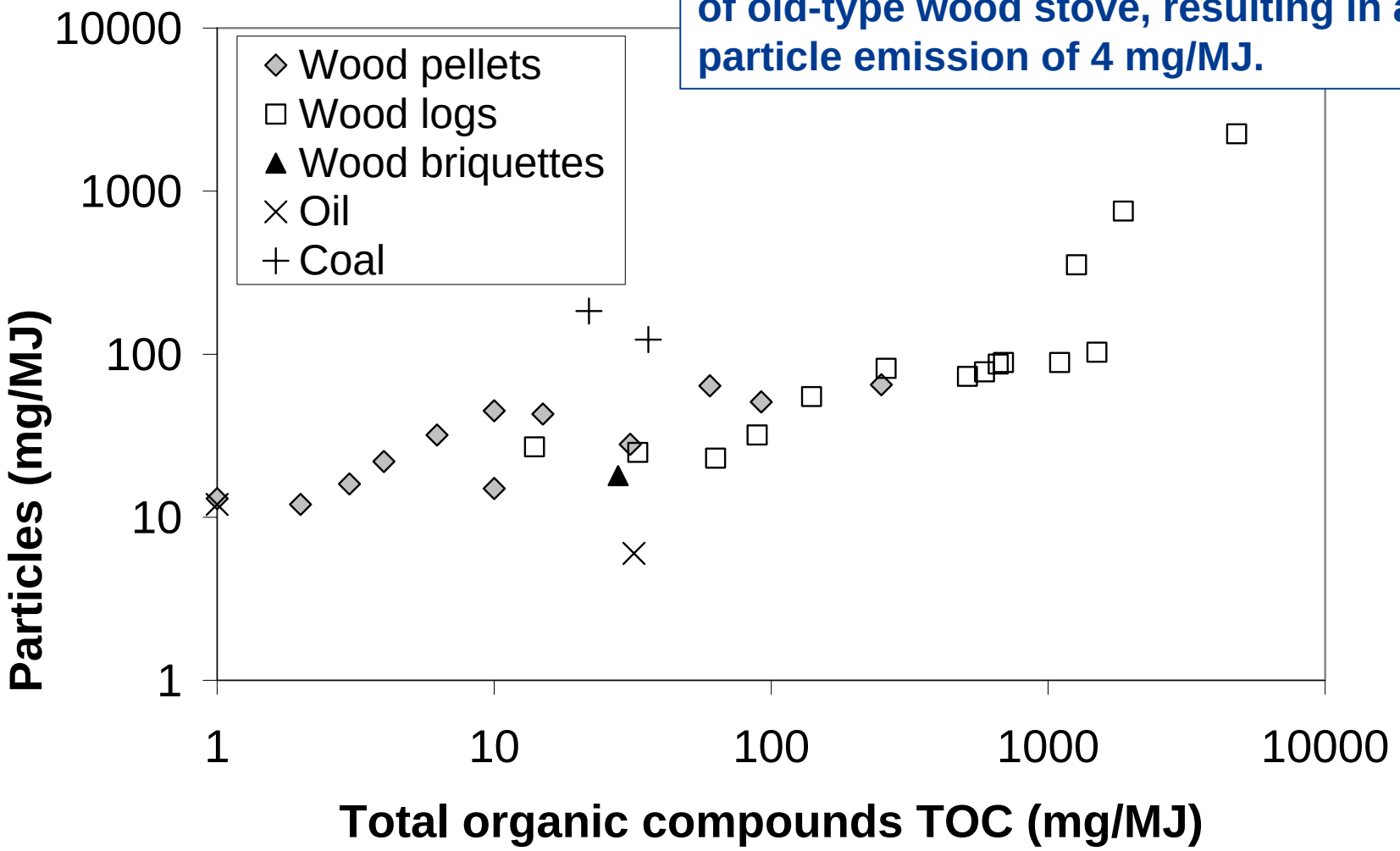
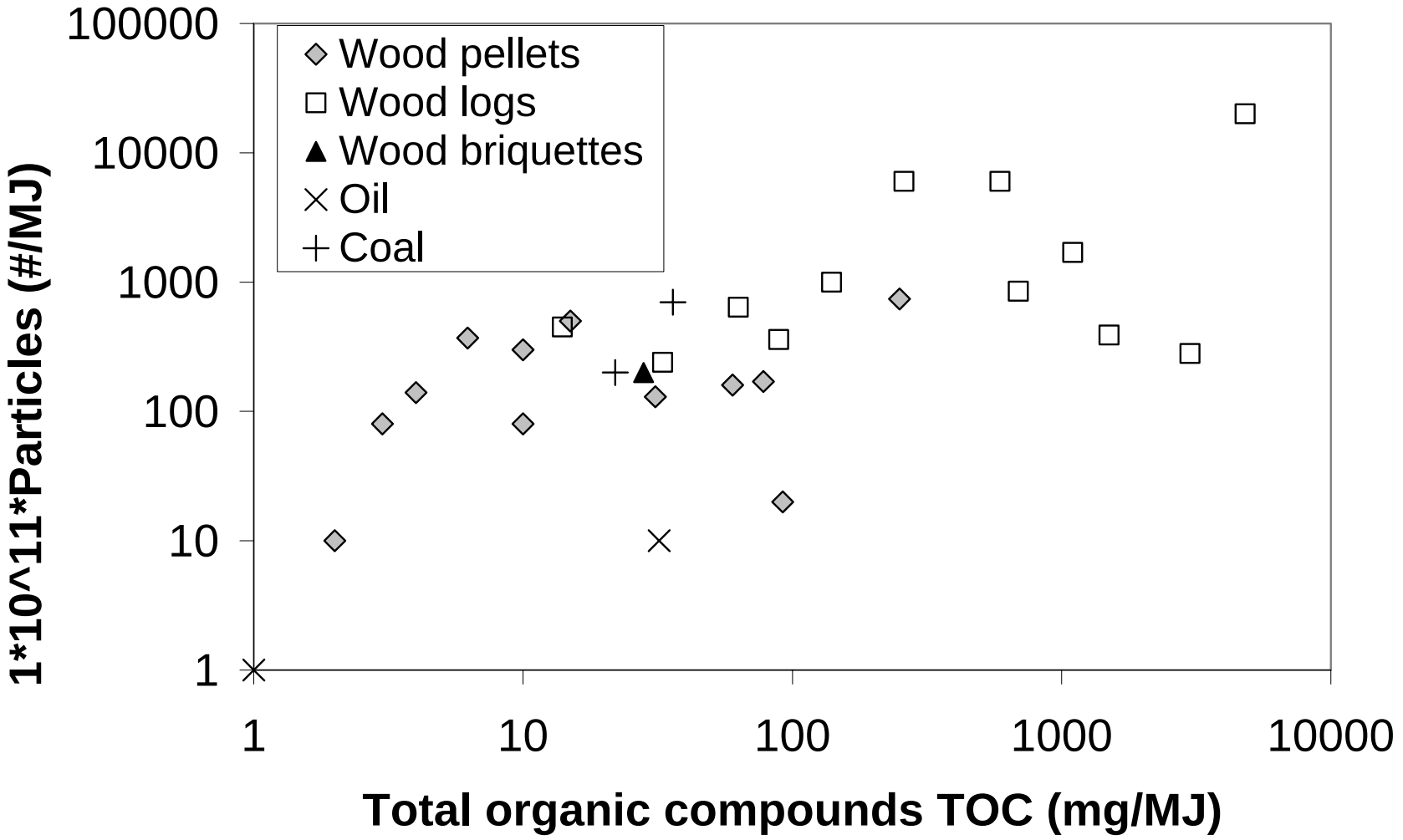
Large variations in mass concentration

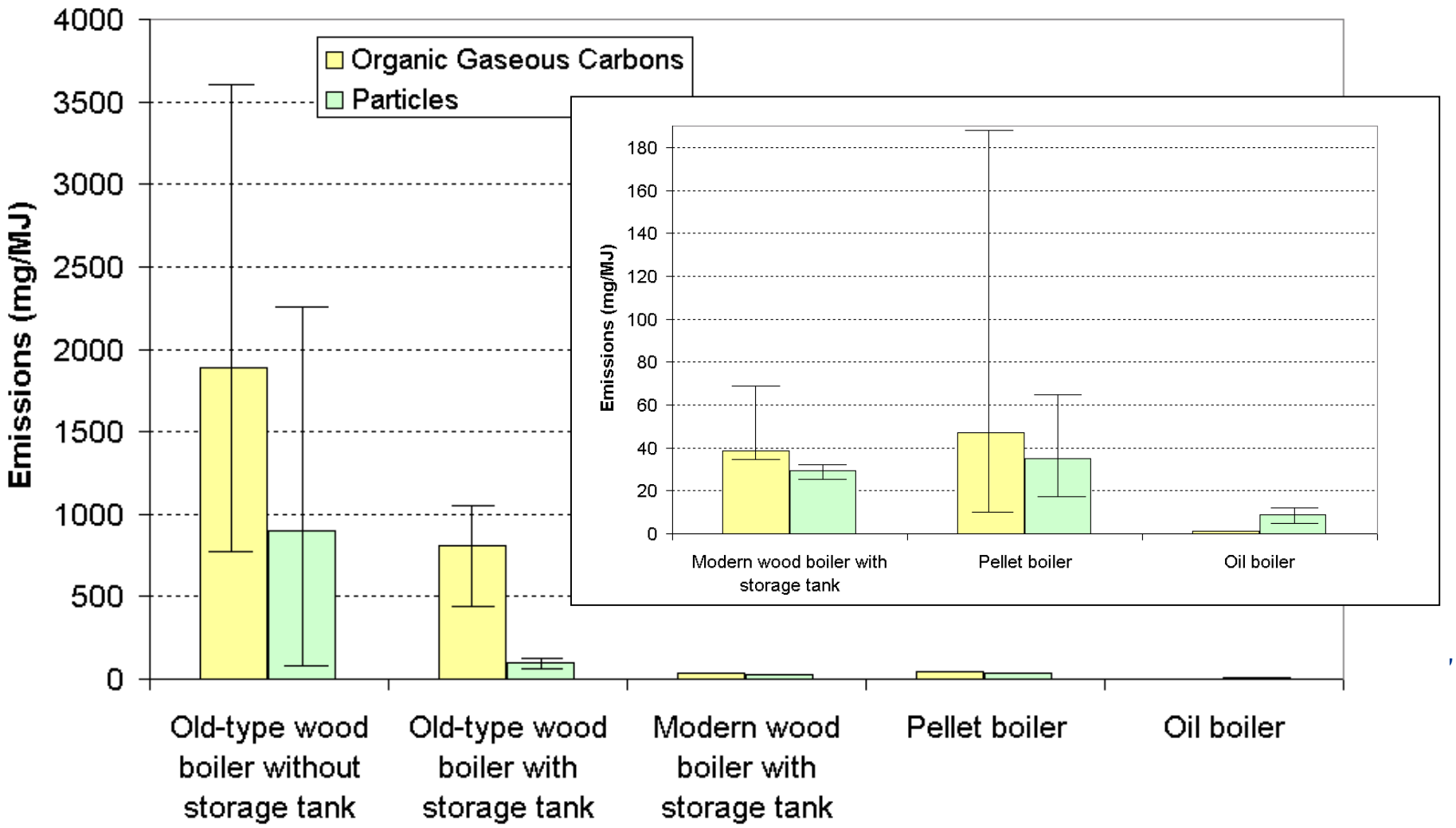
The novel ESP was shown to reduce 86 ±4 % of the particle mass, in case of old-type wood stove, resulting in a particle emission of 4 mg/MJ.



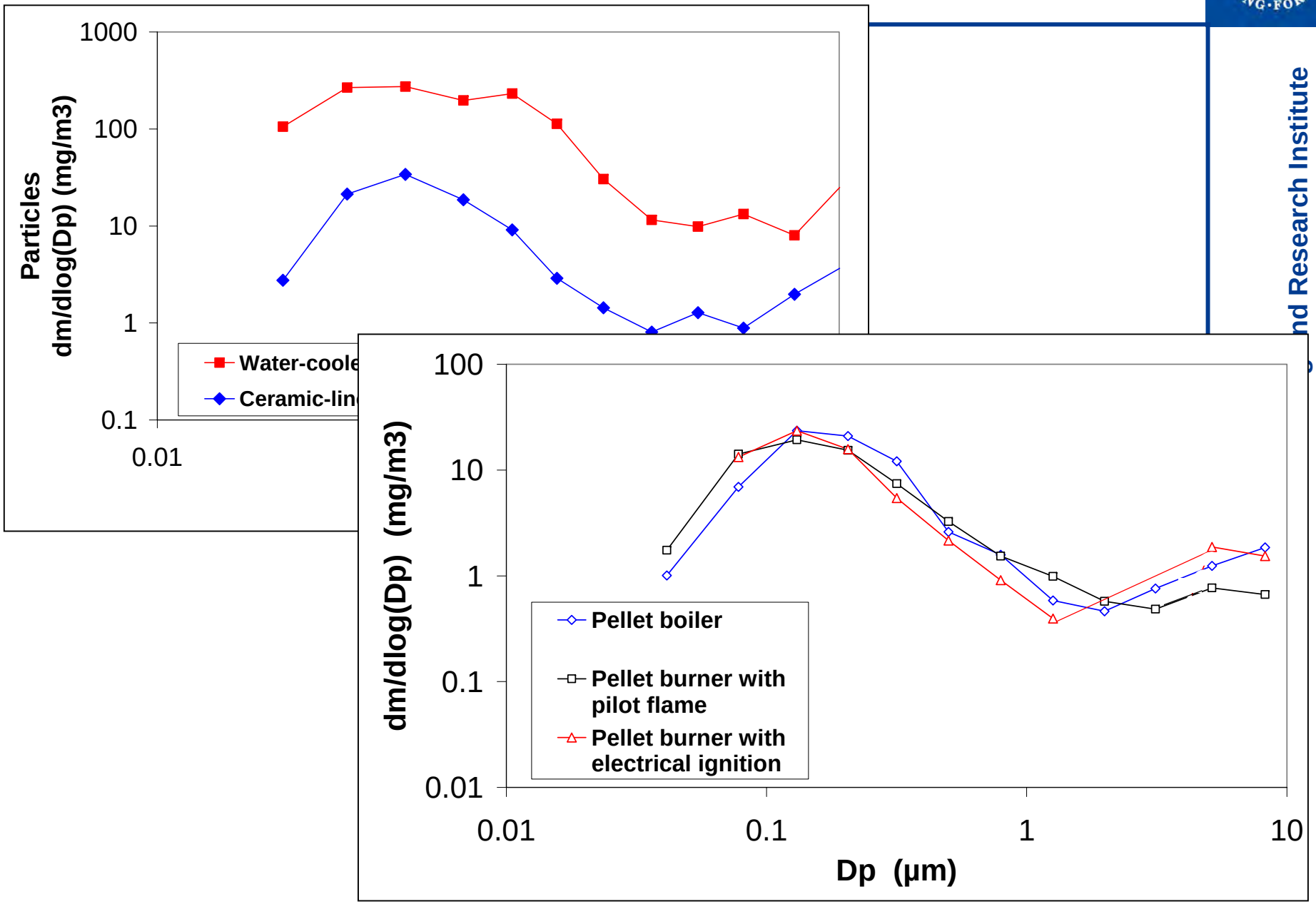
Large variations in number concentration



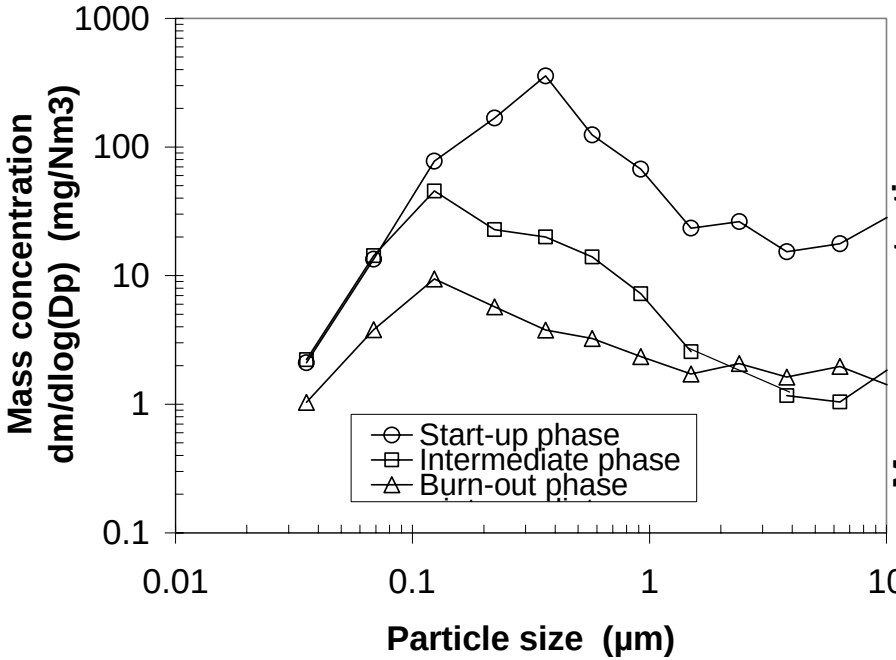
Large differences between boiler types

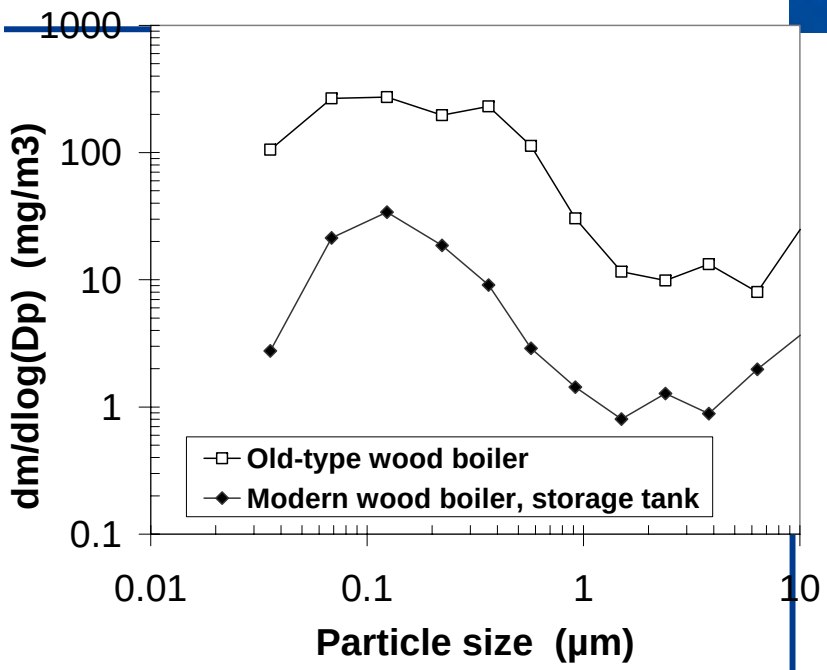


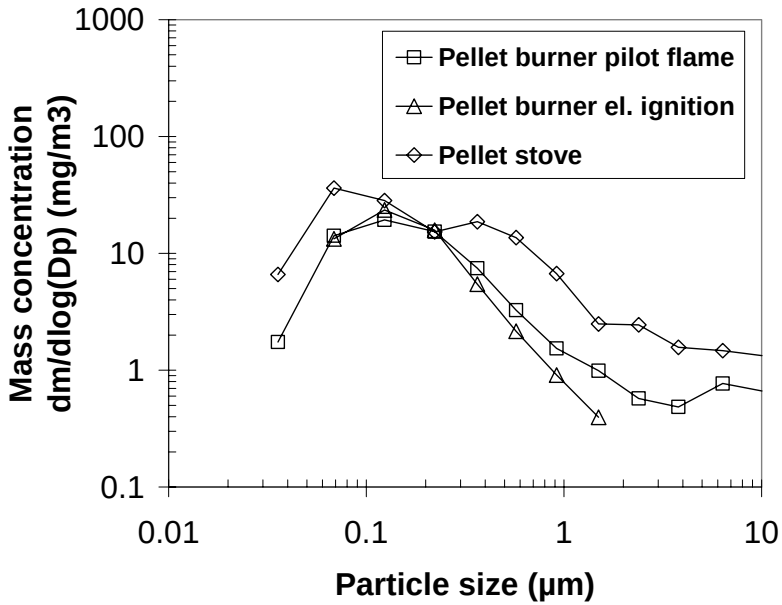
Mass size distributions 1 (2)



Mass size distributions 2 (2)







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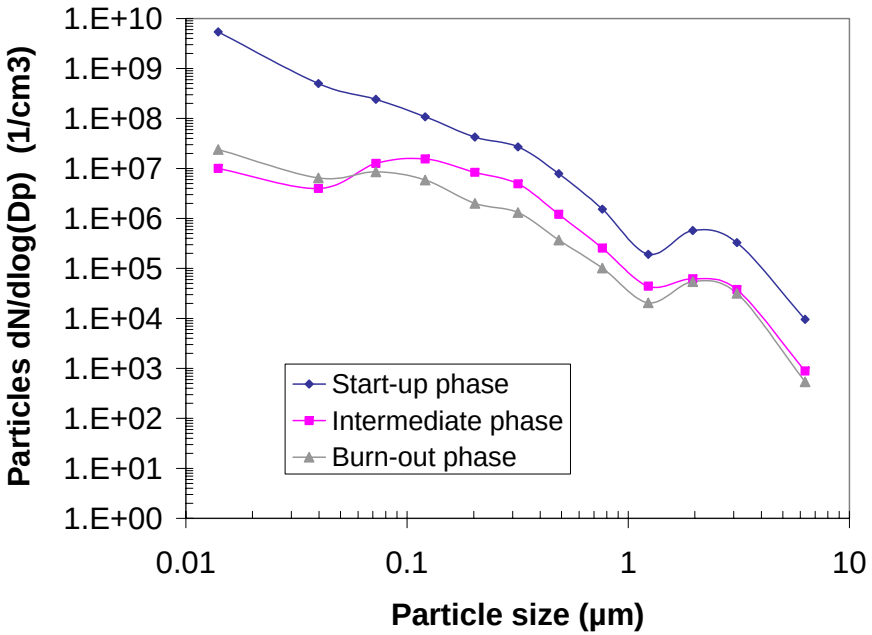
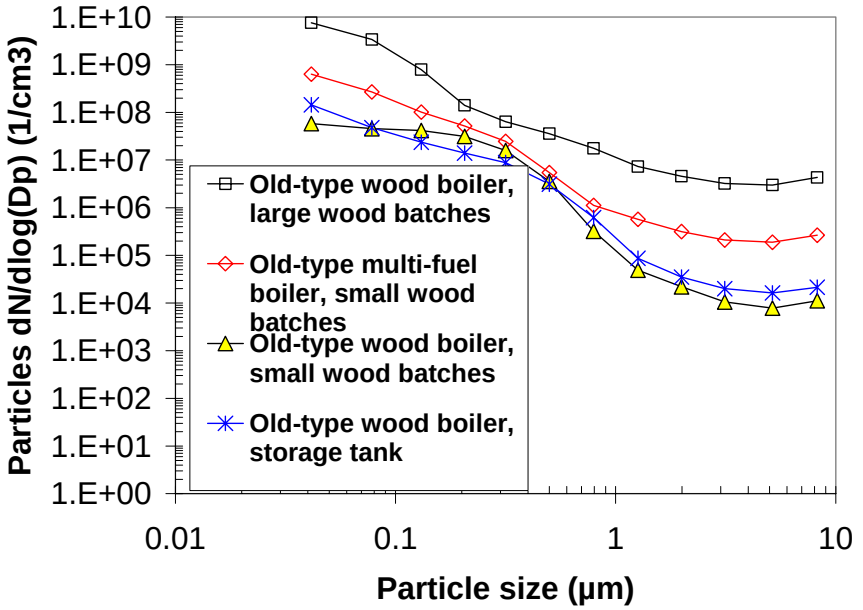
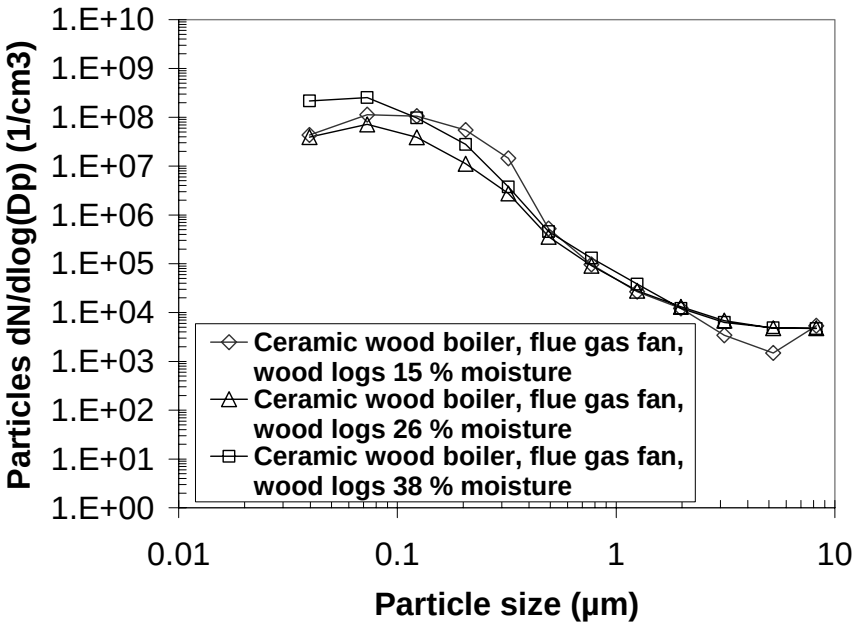
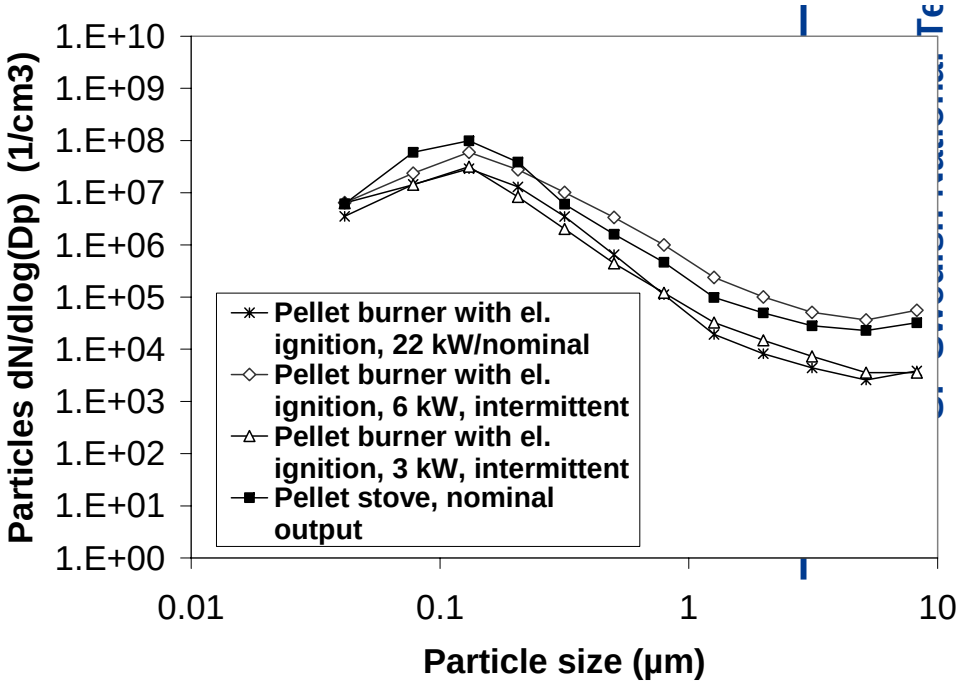
Number size distributions 2 (2)









Conclusions

1. The residential biofuel boilers in Sweden are dominated by old-type wood boilers with high emissions => There are large possibilities to decrease the emissions by changing to modern boilers and install heat storage tanks
2. Particle emissions are dominated by submicron sizes, with respect to mass as well as number
3. The variations in emissions are large => emission data for particles need to be further investigated with respect to real conditions at people´s homes (on-going work today)
4. The novel ESP indicates future possibilities to further reduce particle emissions

Financial support from

- The Swedish Energy Agency

- The Swedish Environmental Agency

- The EU CRAFT-project CleanAir