Evaluation of small-scale precipitators in Denmark – results of lab- / field tests

Workshop: Aerosols from small-scale biomass combustion plants

Central European Biomass Conference 2011

26th – 29th January, Graz, Austria

Ole Schleicher

FORCE Technology

Project

Test of technologies for flue gas cleaning and/or combustion improvement for after-mounting on existing wood stove and wood boiler installations

Project financed by the Danish EPA, and carried out by a Consortium consisting of:

- FORCE Technology
- Danish Technological Institute
- National Environmental Research Institute

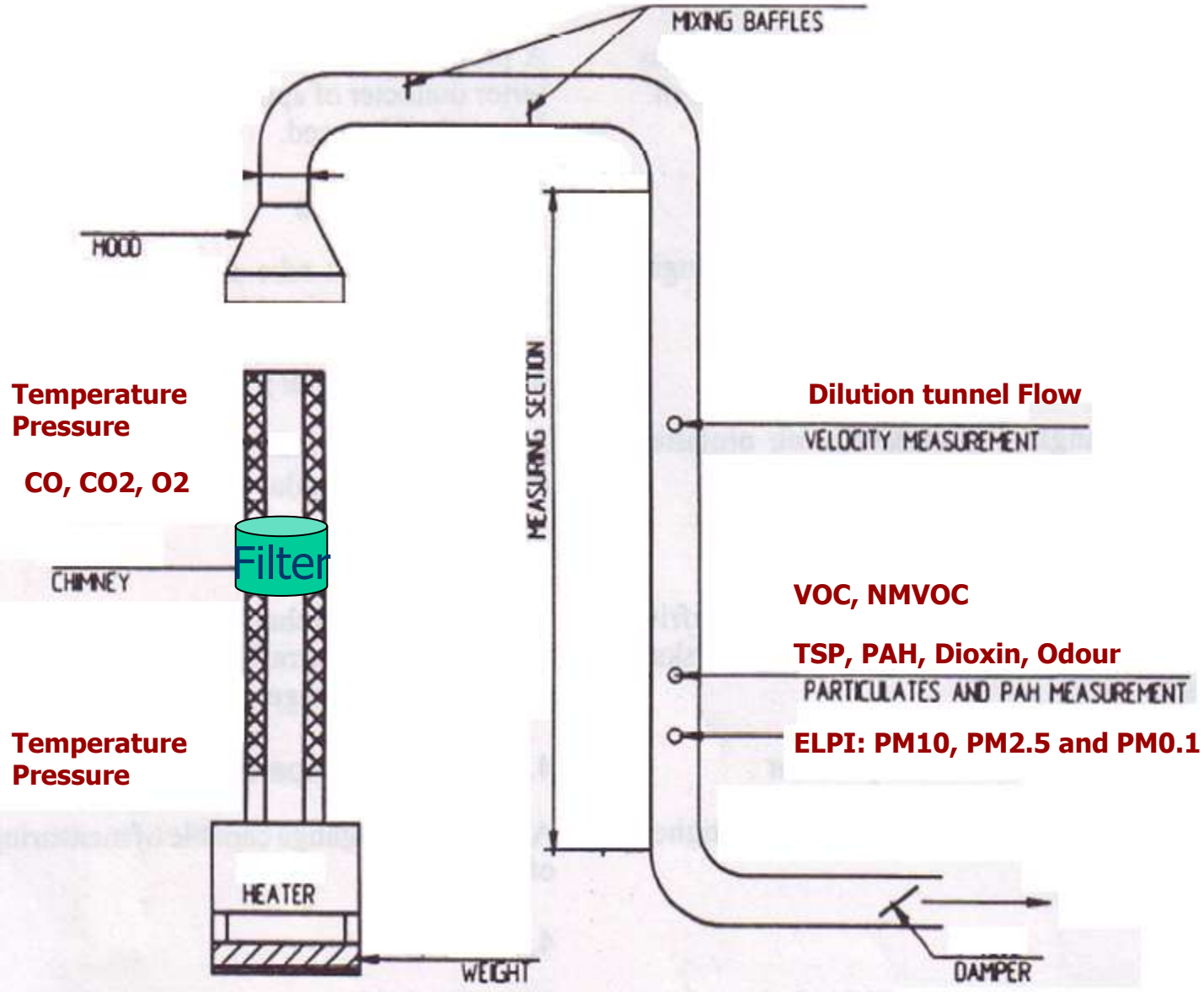
Invitation to participate

- EU tender – to reach whole Europe
- 9 technologies applied
- 5 of them was chosen for the test

1. Rüegg – ESP (Electrostatic precipitator)
2. Spartherm - ESP
3. APP - ESP
4. MoreCat – catalyst
5. Ecoxy – Afterburner (tertiary air supply)

Test

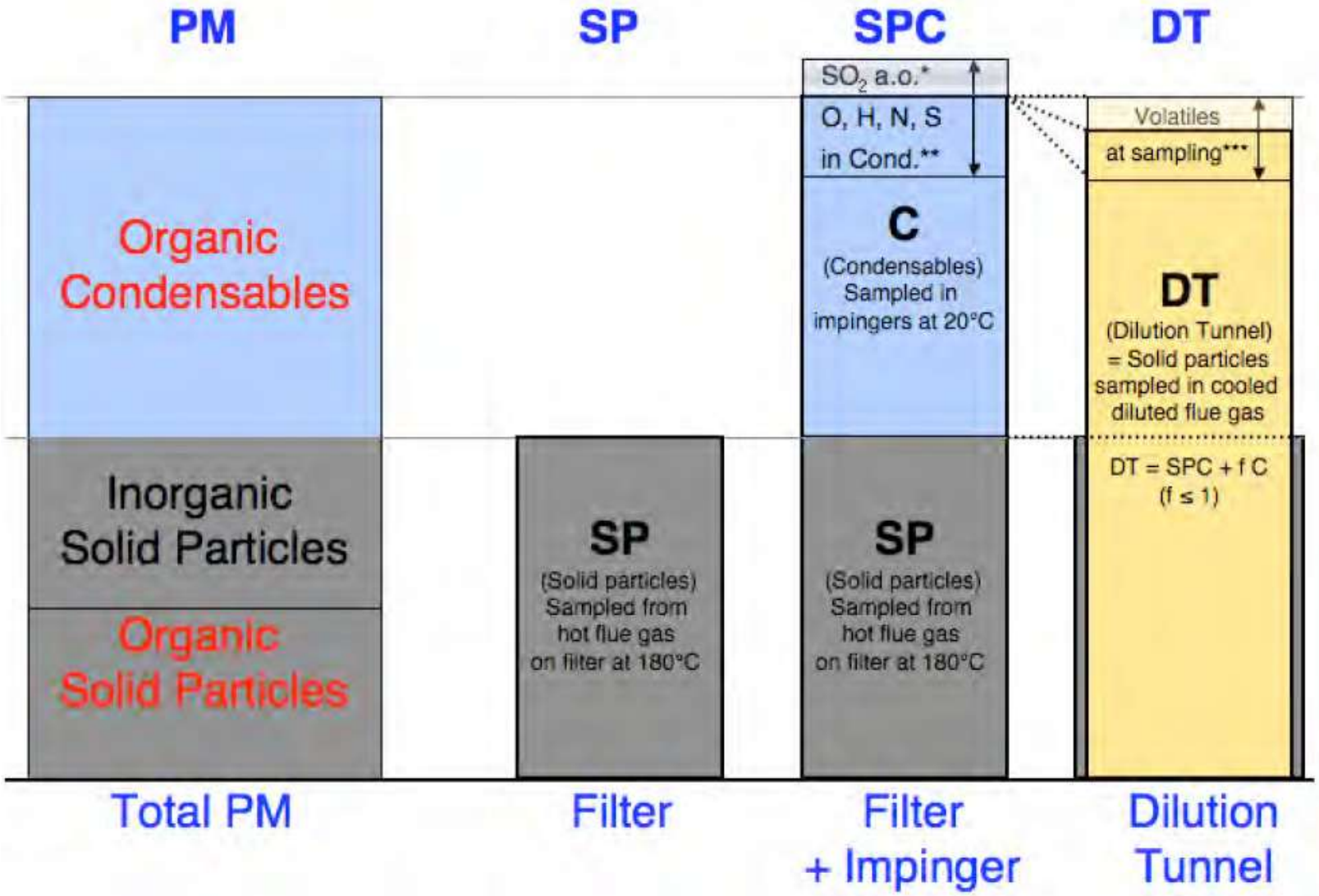
- Laboratorie test – efficiency
- Field test – effect on air quality
- Evaluation of the usefulness
  - Cost for the unit, mounting and maintenance
  - Can it be mounted on all appliances/chimmneys
  - Appearances – especially if visibel in the living room


MIXING BAFFLES
HOOD
MEASURING SECTION
Temperature
Pressure
CO, CO2, O2
Filter
CHIMNEY
Dilution tunnel Flow
VELOCITY MEASUREMENT
VOC, NMVOC
TSP, PAH, Dioxin, Odour
PARTICULATES AND PAH MEASUREMENT
ELPI: PM10, PM2.5 and PM0.1
Temperature
Pressure
HEATER
WEIGHT
DAMPER

Parameters

- PM
- Particle distribution
- CO
- VOC and NMVOC
- PAH
- Dioxin
- Odour – only some of the test

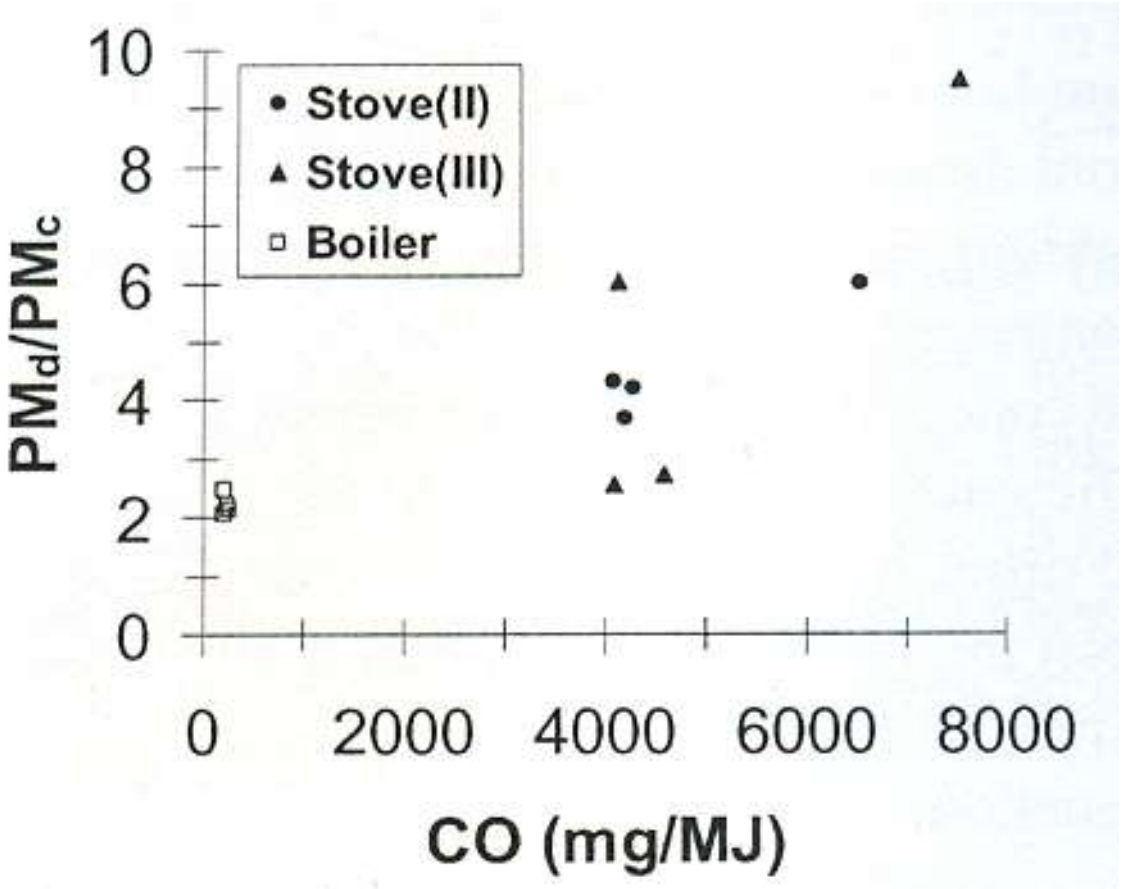
Particular Matter



Particulate Emissions from Biomass Combustion in IEA Countries
Thomas Nussbaumer, Claudia Czasch, Norbert Klippel, Linda Johansson, Claes Tullin.

Particles and point of measuring

Particles measured simultainliously in chimney and in dilution tunnel
Relation between PM in the dilution tunnel and PM in the chimney is the Y-aksis.
CO at the X-axis reflects the combustion efficiency.



PM and condensable

Wood Stove $mg/m^3(13\%O_2)$	Ideal operation 2 x 0.7 kg dry wood at a time	Typical operation 3 x 1.5 kg wood at a time	Smoldering operation air inlet closed
Salt	< 20	< 20	< 20
Soot	< 20	< 100	5.000
Tar	< 5	400	10.000
Total:	< 50	< 500	15.000
Index			
Soot	1	≈ 5	> 250
Tar	1	≈ 80	> 2.000
Total	2	≈ 10	> 300

Thomas Nussbaumer, Workshop on biomass combustion in Salzburg 2007

Test Stove and boiler

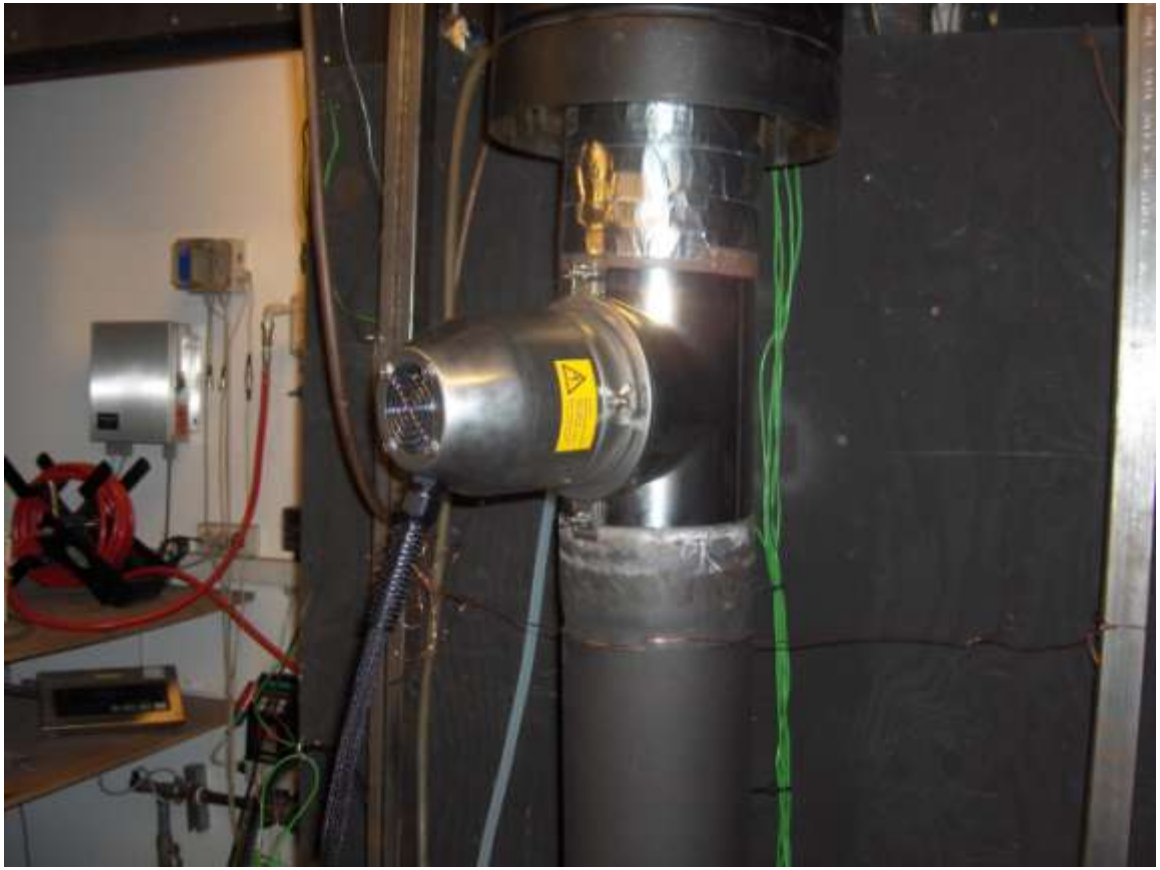
Firewood and firing procedure

Dry Birch firewood with bark

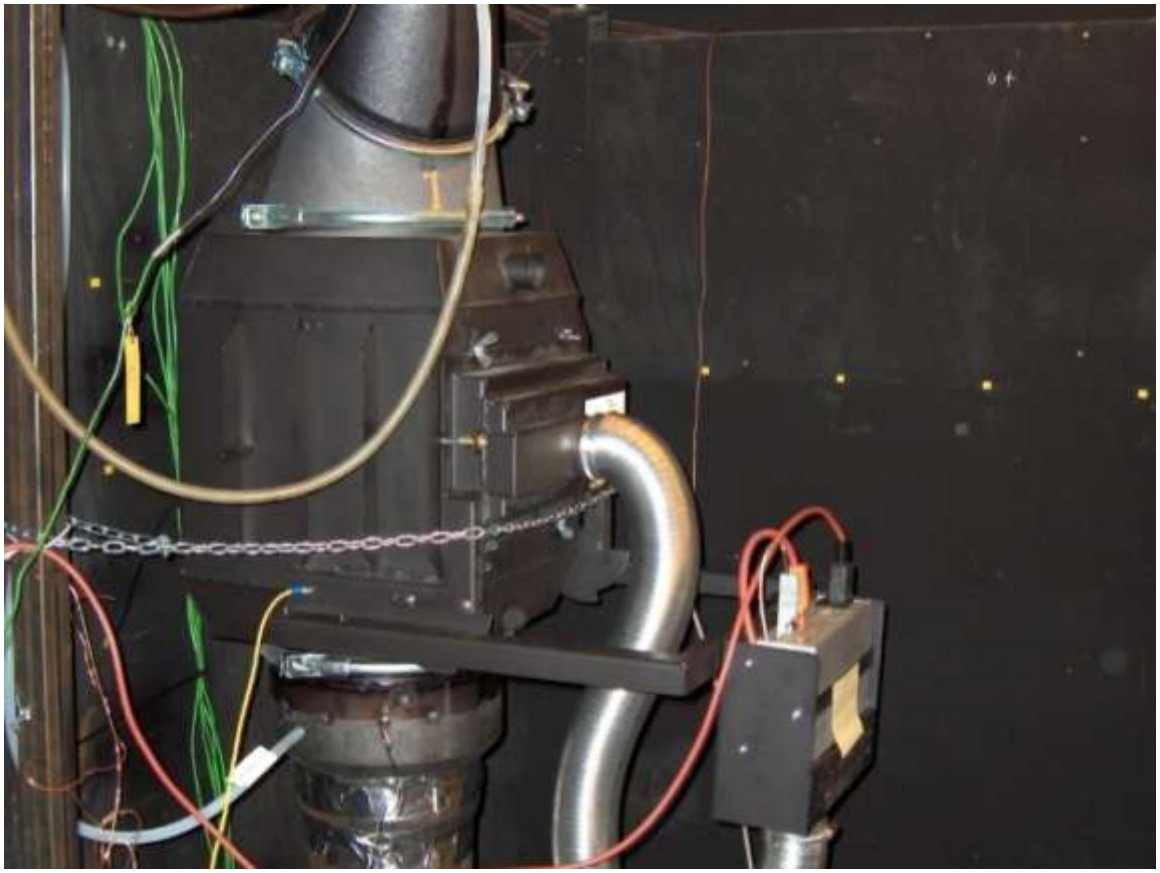
Wood stove:
Ignition: 1.6 kg small stickers
Pre-test: 3 piec. firewood - 1.8 kg
Nominal: 3 piec. firewood - 1.8 kg
Int.stage: 2 piec. firewood - 1.3 kg
Reduced: 2 piec. firewood - 1.3 kg

Wood boiler:
Ignition: 3,5 kg small stickers
Pre-test: 8 – 8,5 kg firewood
3xNominal: 8 – 8,5 kg firewood

Zumicon ESP



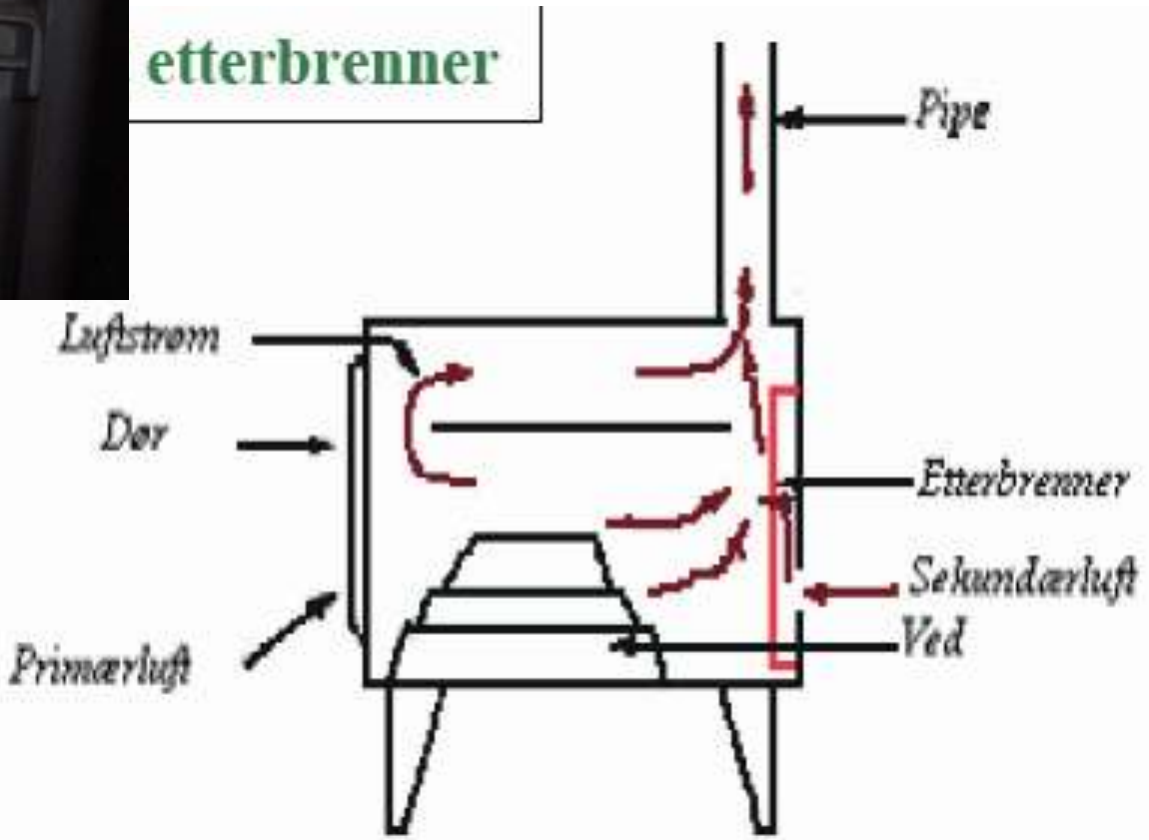
Airbox ESP



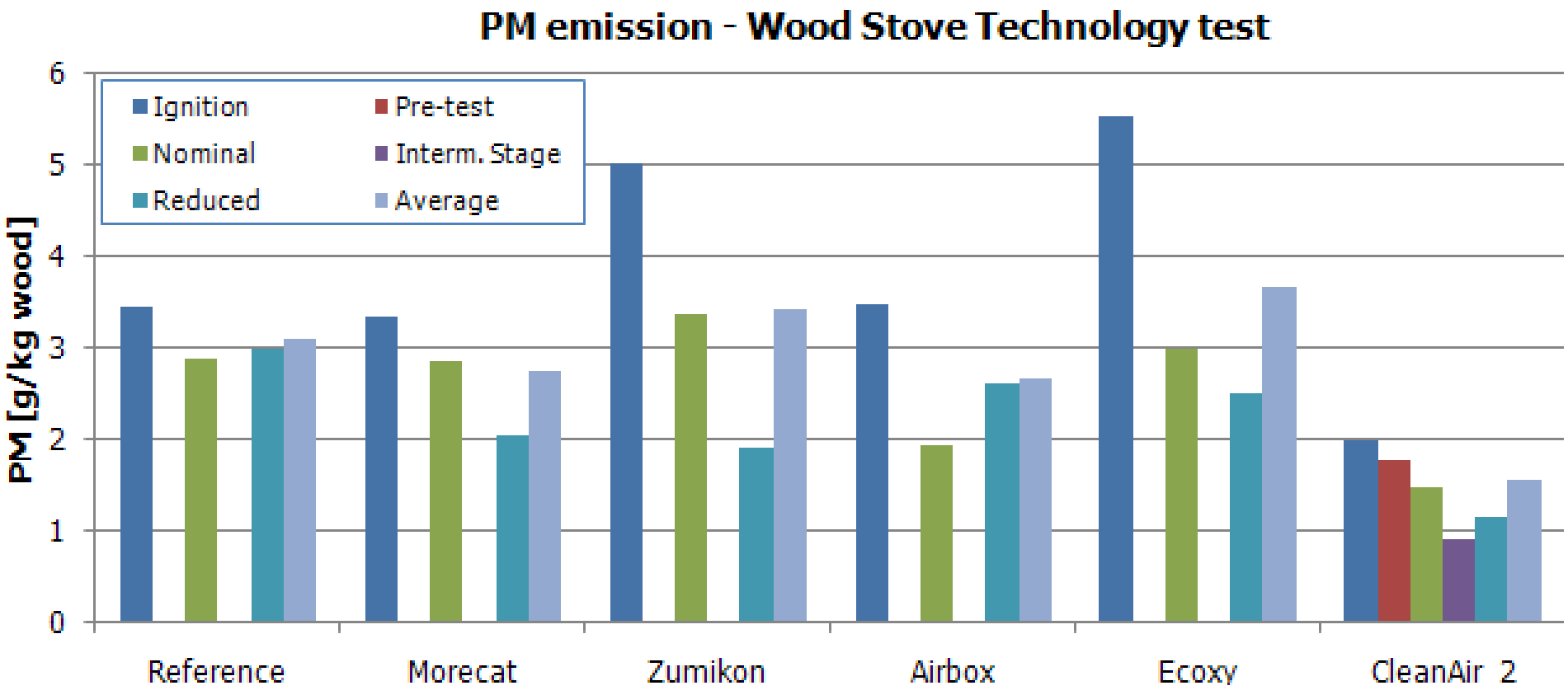
CleanAir ESP

MoreCAT catalyst

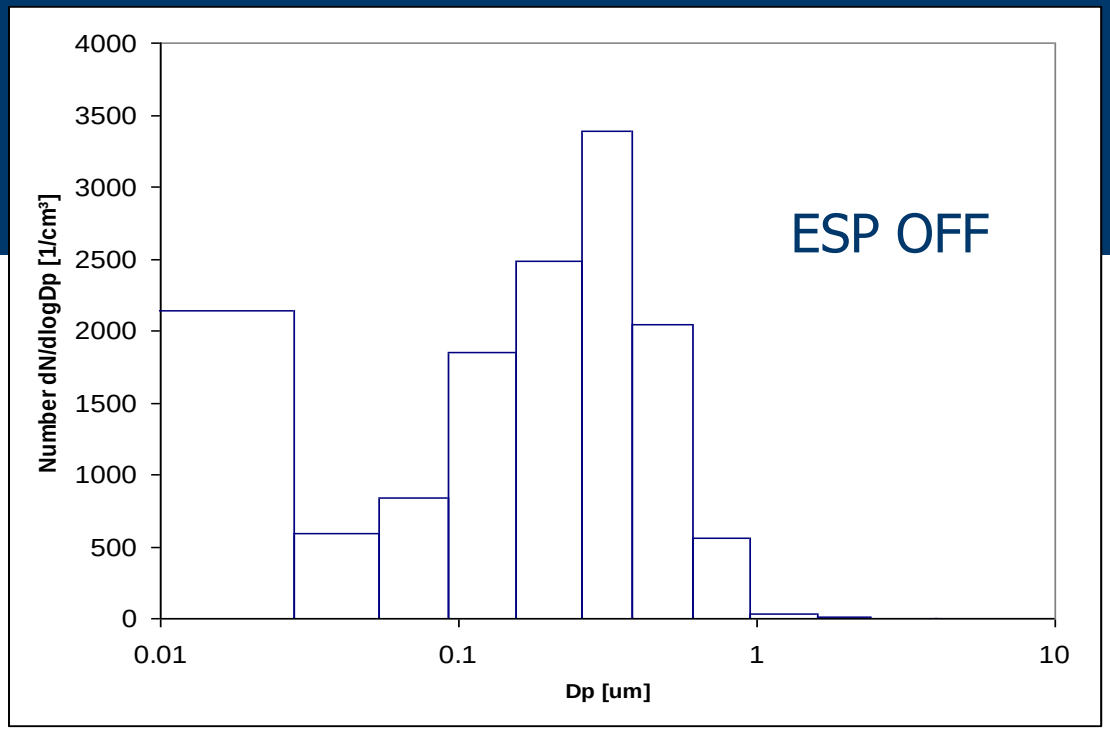
Ecoxy afterburner

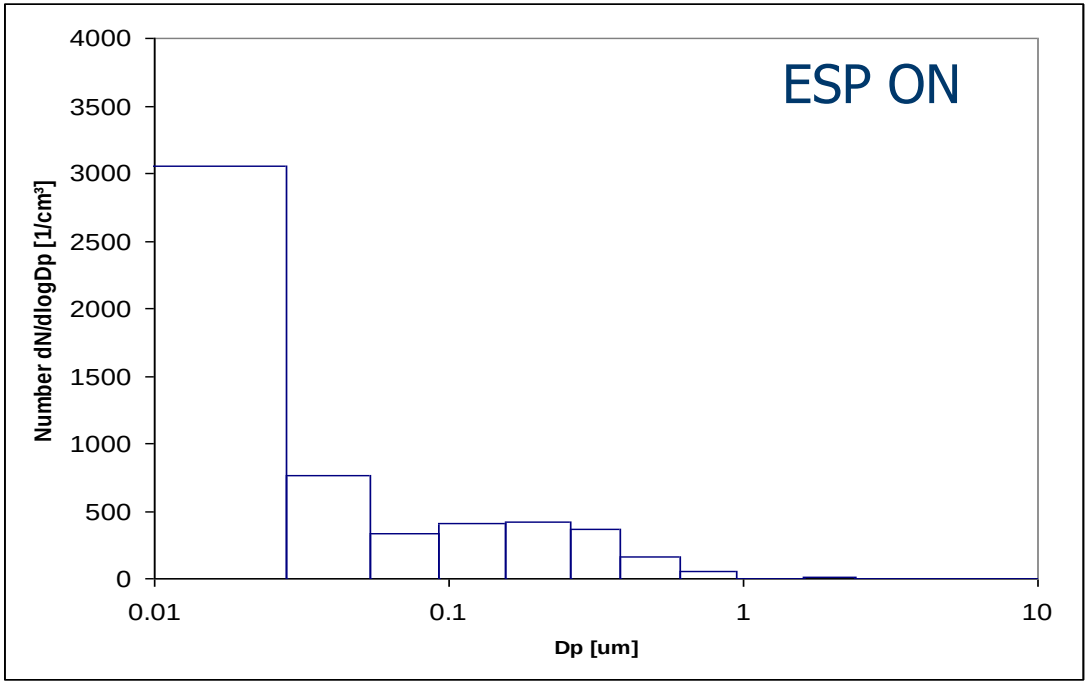


PM emission – Wood stove



PM filters from AirClean stove test


ESP OFF
Number dN/dlogDp [1/cm³]
4000
3500
3000
2500
2000
1500
1000
500
0
0.01
0.1
1
10
Dp [um]


ESP ON
Number dN/dlogDp [1/cm³]
4000
3500
3000
2500
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1500
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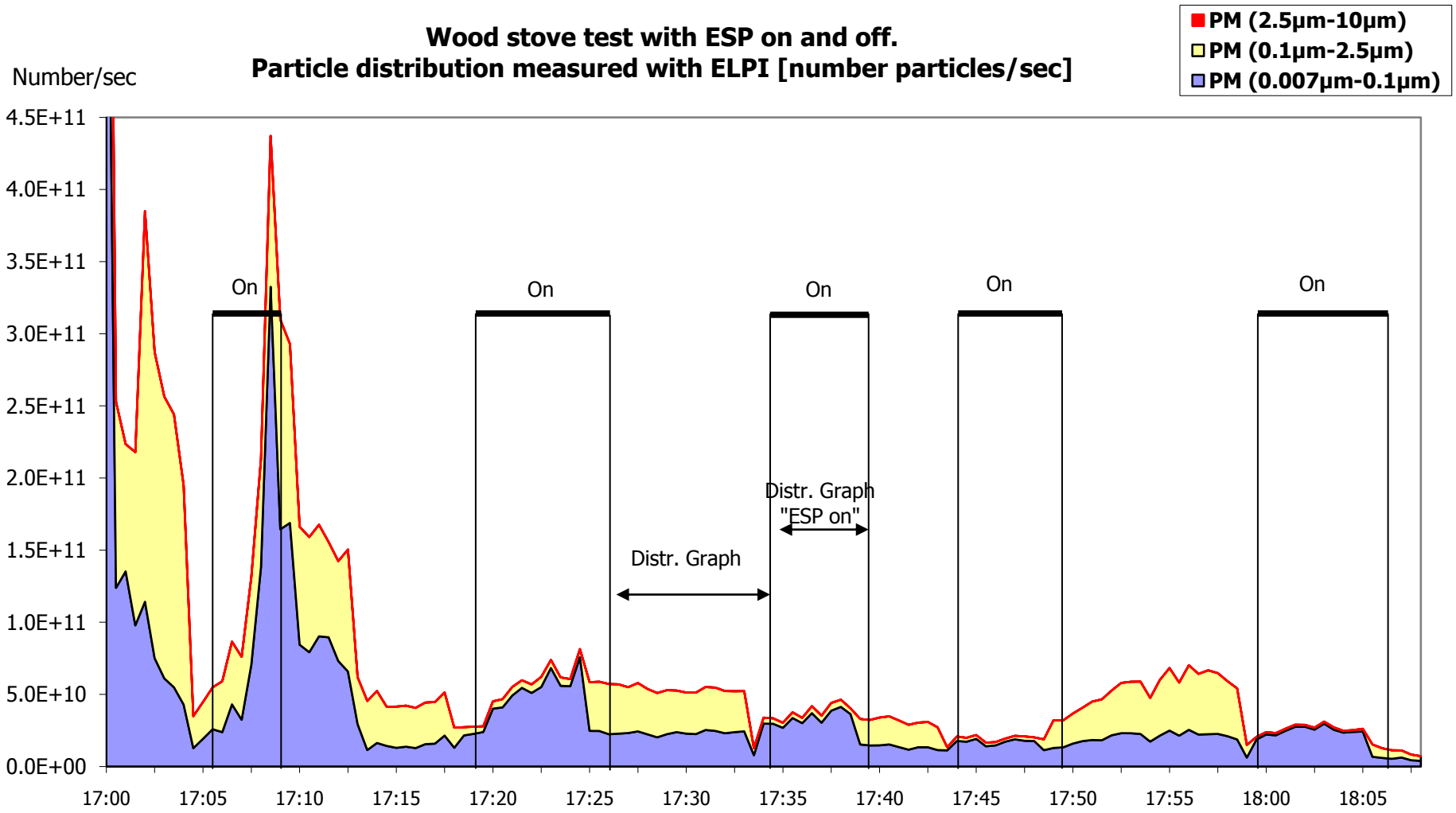
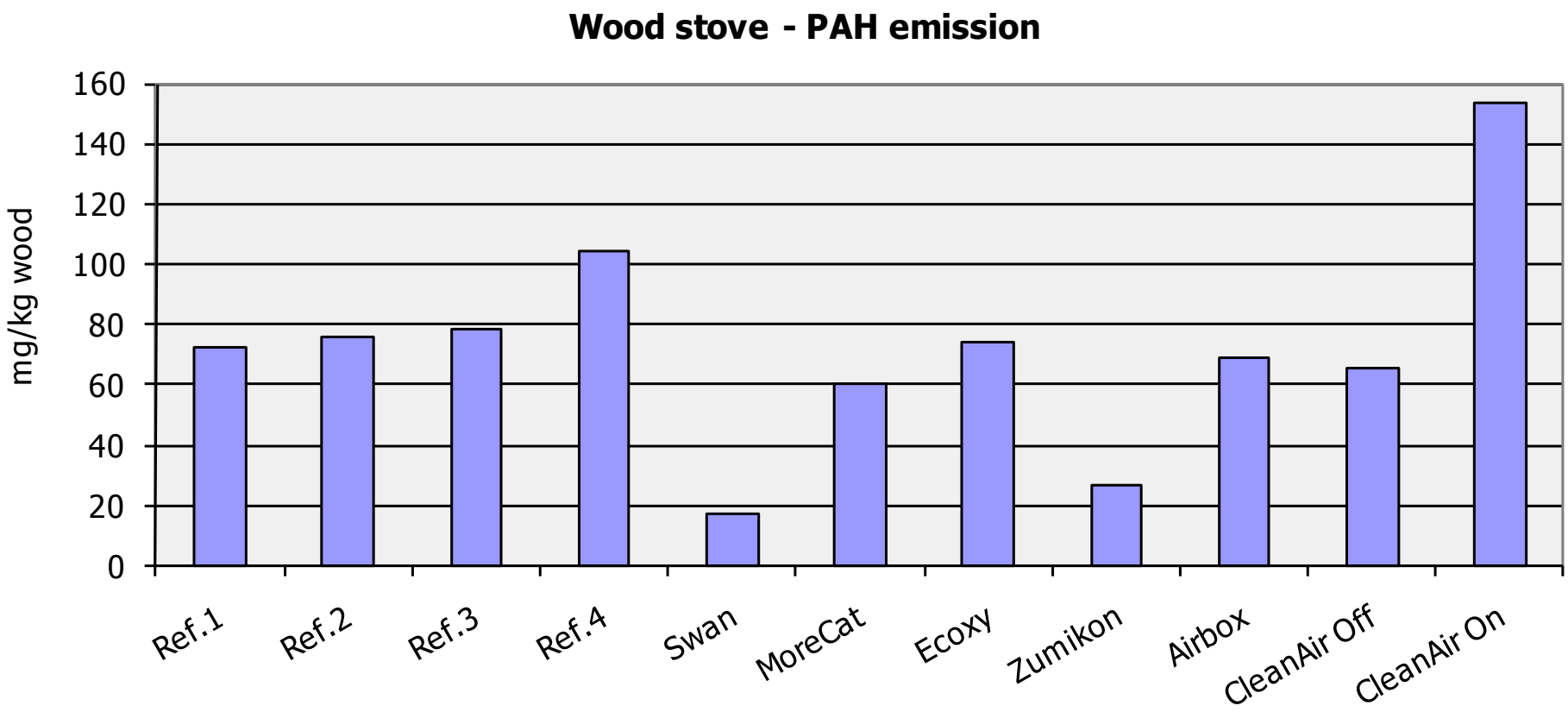
500
0
0.01
0.1
1
10
Dp [um]

Smouldering operation



PAH emission – Wood stove

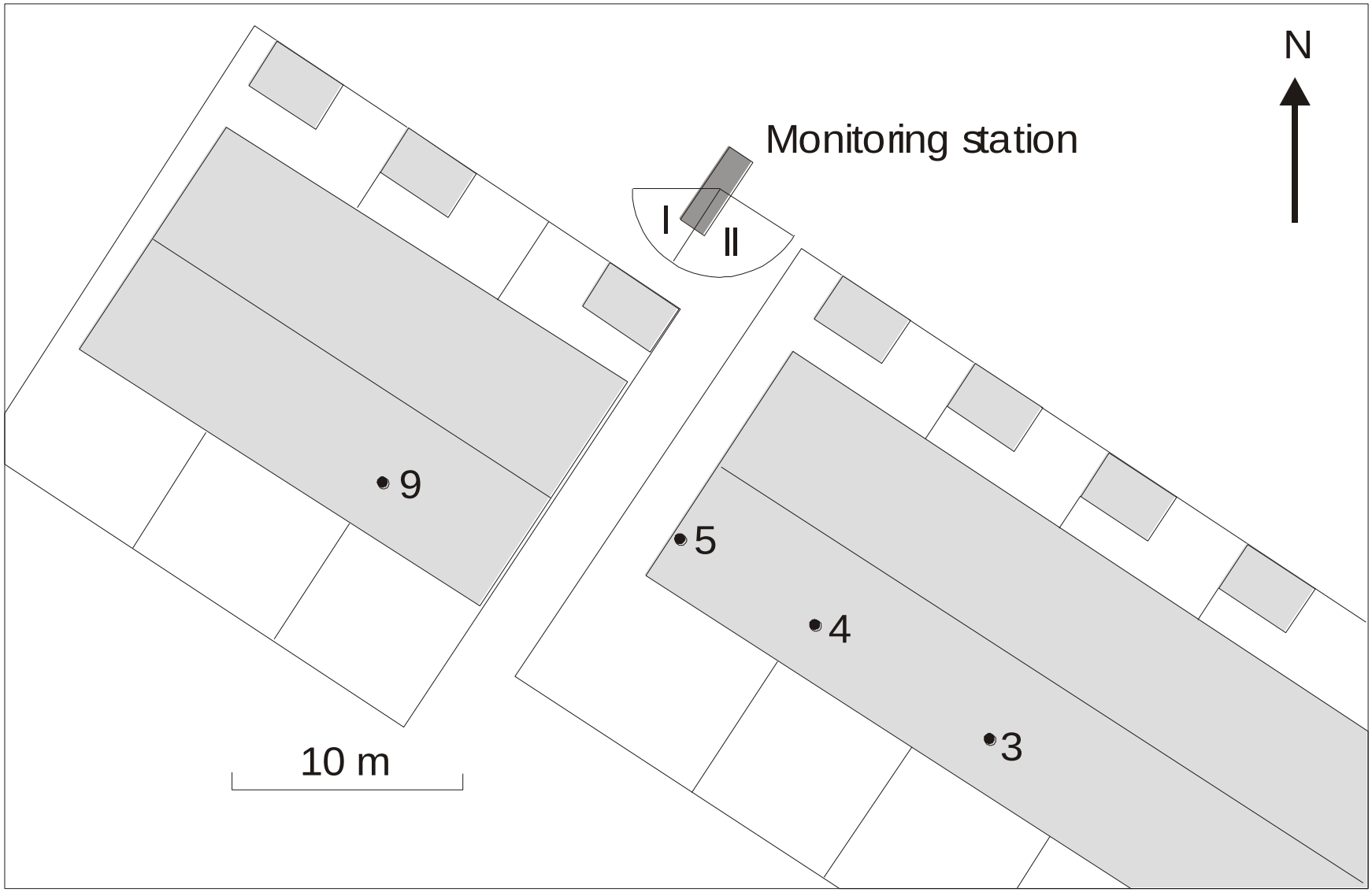


ESP efficiency

- Dioxin: Small or no reduction
- PAH: Small reduction or increase?
- VOC: No effect
- Odour: No effect
- PM: Some reduction of mass
  - but $PM_{0.1}$ apparently increases

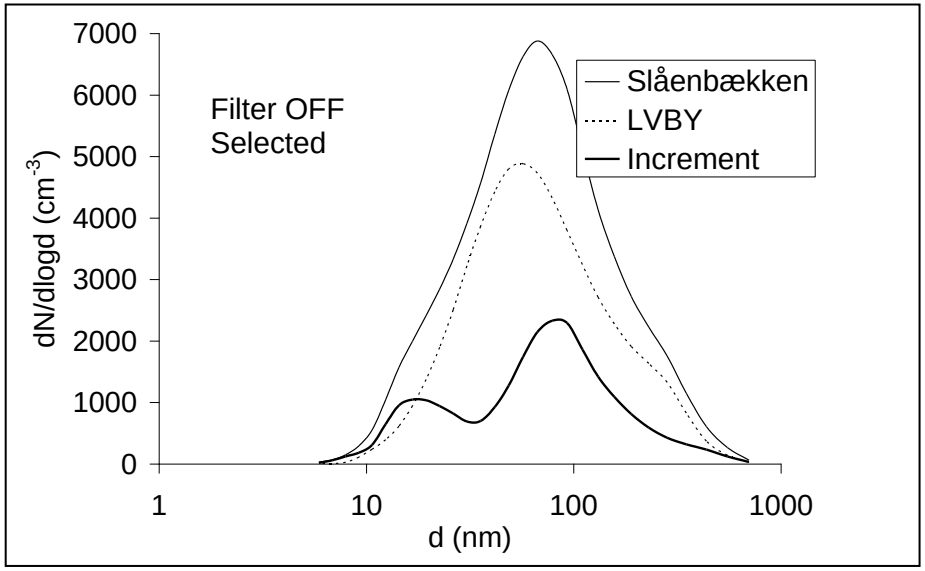
Field test

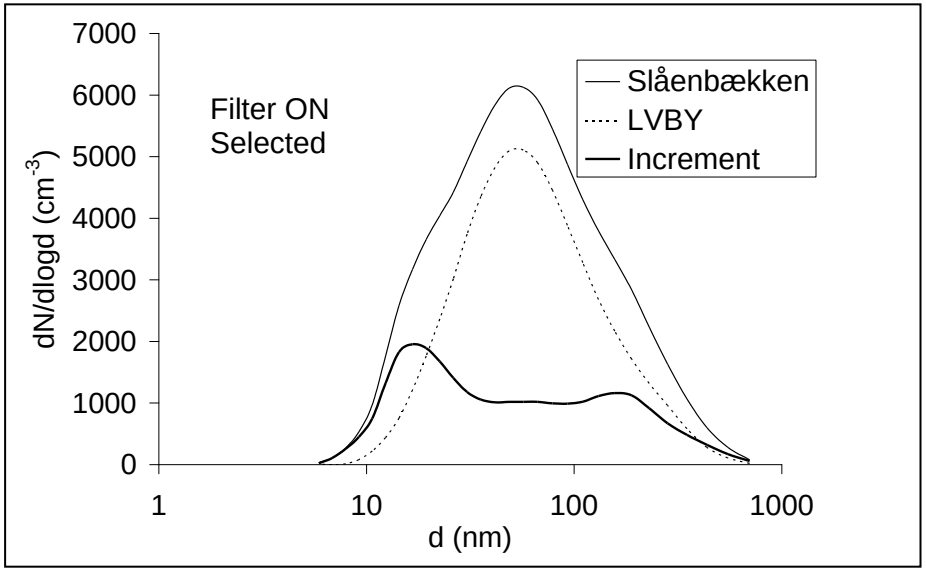
Field test – Monitoring station



Test wood stoves

Field test - results





ESP off:
Distribution with a dominating mode at 80-100 nm.

ESP on:
Distribution with a dominating mode at 10-20 nm .

Highlights

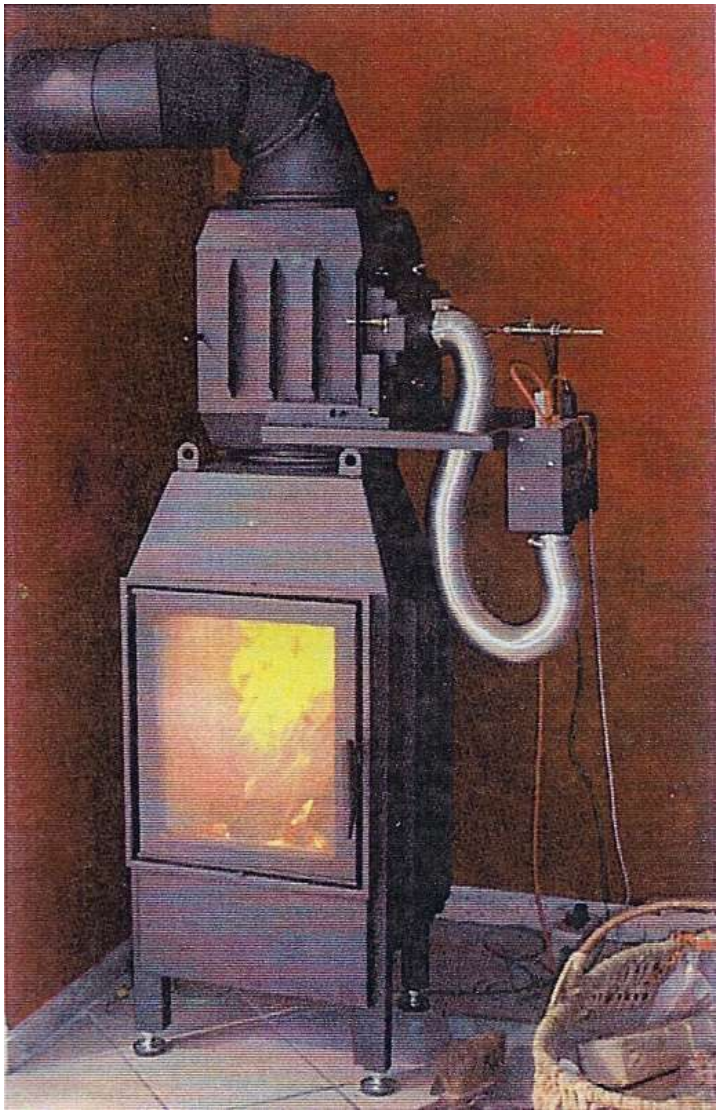
- **Will the increased number of $PM_{0.1}$ result in an emission with increased health effect for the nighbours?**

Typical Danish wood stoves

Airbox ESP

ESP – only for boilers!

> 60% reduction af particles



Zumicon ESP

After only app. 5 cm of the original 25 cm electrode remained after 6 weeks of operation

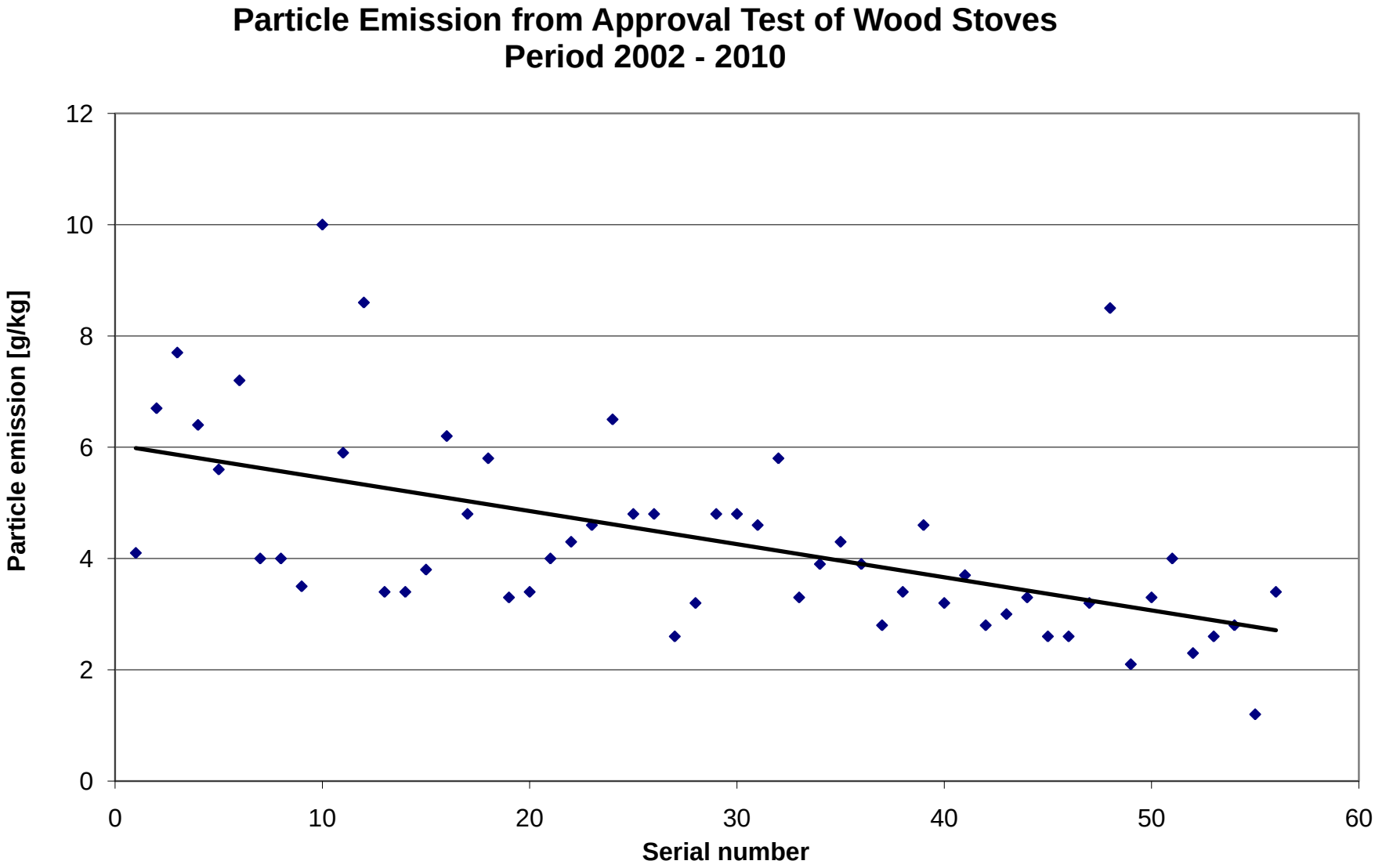
Typical danish houses and chimneys

Typical danish houses and chimneys

Wood Stove Emission Factors - Index

Wood stoves	Age	Number in 2008	PM Index	NMVOC Index	PAH-4 Index
Old stoves	→ 1990	134 100	100	100	100
DS-887 approved stoves[2)]	1990 - 2005	189 800	100	83	100
Complying with Danish Wood Stove Order 2008[3)]	2005 →	134 500	75	21	35
Swan labelled or equivalent	2005 →	52 400	29	10	18

PM emission trend for wood stoves



Wood Boiler Emission Factors - Index

Wood boilers	Age	Heat storage vessel	Number in 2008	PM Index	NMVOC Index	PAH-4 Index
Old boilers	→ 1980	No	7 400	100	100	100
		Yes	9 500	54	40	20
New boilers	1980 →	No	11 400	13	25	12
		Yes	19 700	7	10	6

Evaluation for ESP

- Reduktion of particle emissionen with ESP is possible, but:
  - Installation cost is 1.000 – 1.500 €
  - Yearly costs for cleaning shall be added
  - No VOC reduction, except what is allready condensed on the soot particles.
  - No reduction of odour emissionen
  - Can not be mounted on the chimney top on all types of houses
  - Many people will probably not accept an ESP in the flue right above the stove
  - There might be problems with sparkling noise

General conclusion

- Depollution of flue gas from old wood stoves and boilers are very problematic, because of incomplete combustions and high emission of condensables

- Old wood stoves and boilers should be replaced by new approved ones, rather than installing flue gas depollution technologies, like the tested ESPs.

Report

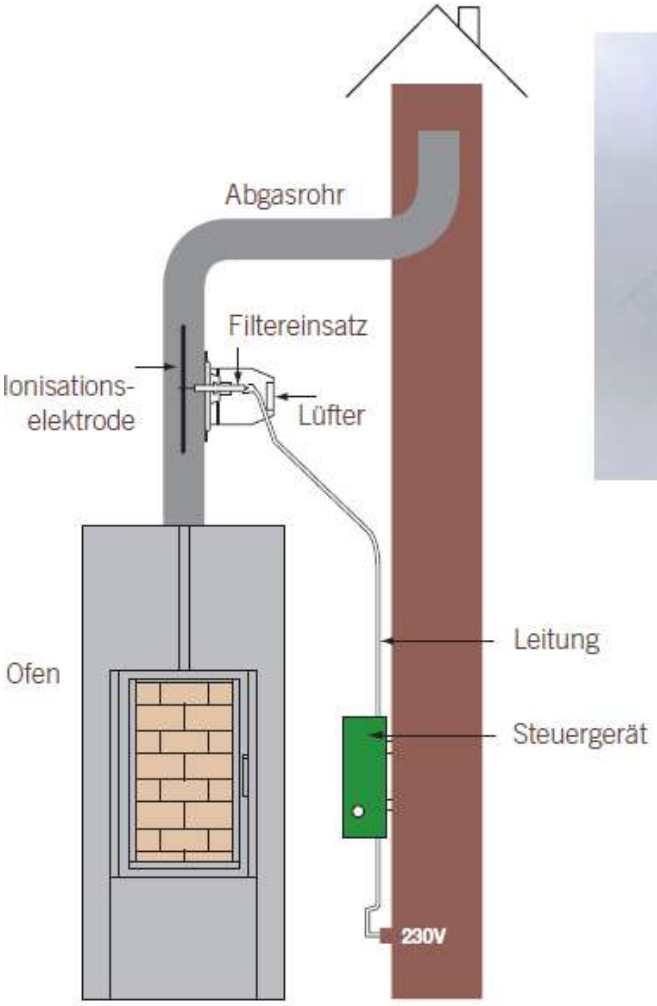
- The report in english will be published by the Danish EPA within short time.

- Send an email to osc@force.dk with the word ”Graz” in the Subject field, and I will send you a copy of the report when it is published.

Thank you for your attention

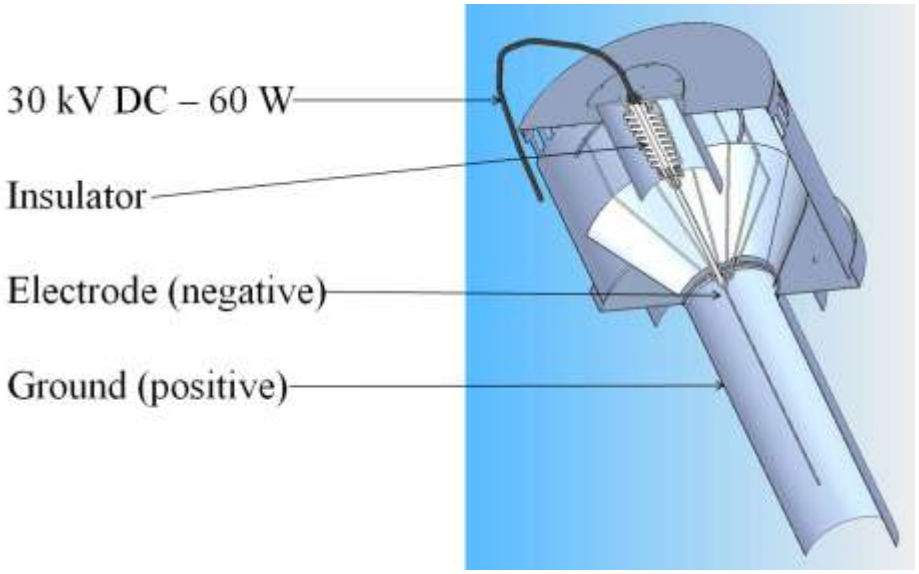
Zumikron from Rüegg

- 60 – 90 % reduktion af particles
- Demands at least 1,5 m steel flue after the ESP
- Max. Flue gas temperature 400 °C (peaks to 500 °C)
- Must be cleaned appr. every 4 week
- The electrode will be worn and has to be replaced regularly
- >500 units installed in CH og DE



APP R_ESP – Residential Electrostatic Precipitator

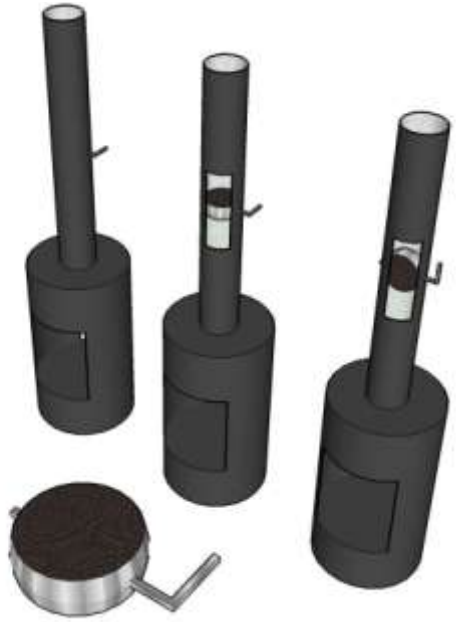
Can reduce the PM emissionen by 75 – 99 %



MoreCAT - catalyst

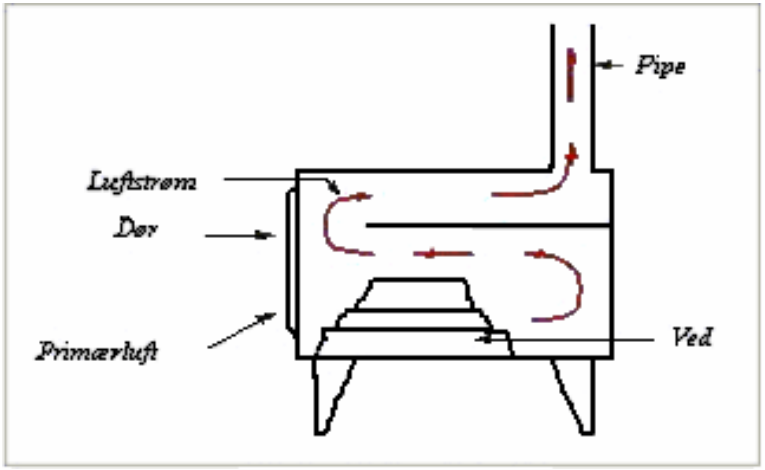
1. Demands 30 Pa chimnay draught (7 - 10 m high)
2. VOC oxidations starts by 350 °C
3. Might not be permittet in DK, because of the risk for blocking the flue
4. Must be cleaned regularly (after appr. 8 hour)

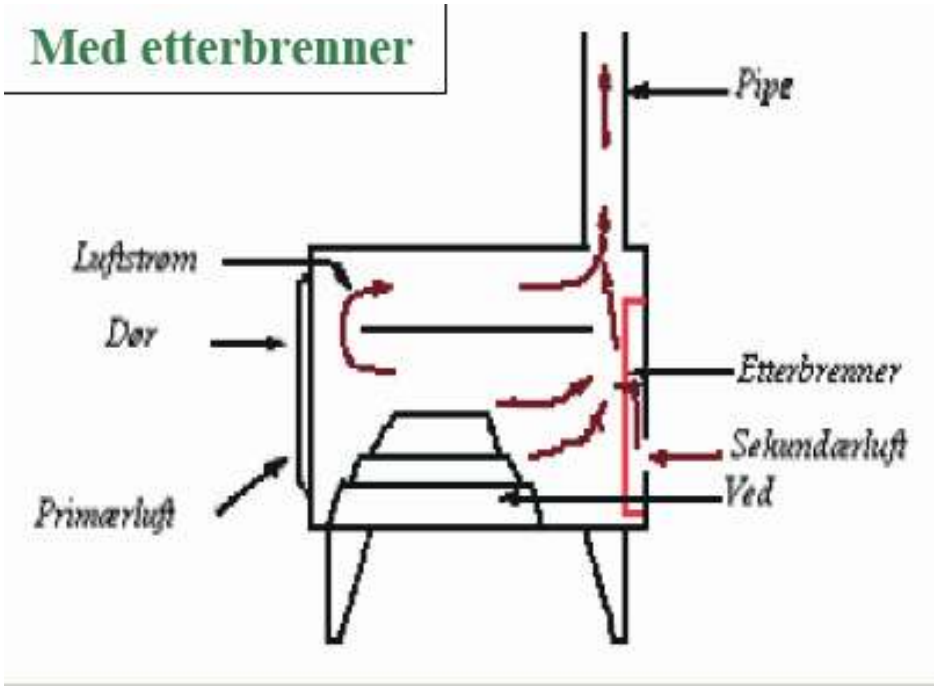
Measured reduction >350°C:
CO: 82 % VOC: 75 % Soot: 95 %



Pris: 3 - 400 €

Ecoxy afterburner





Up to 20% more heat
Reduced risk for chimney fire
Up to 75% reduktion of particles