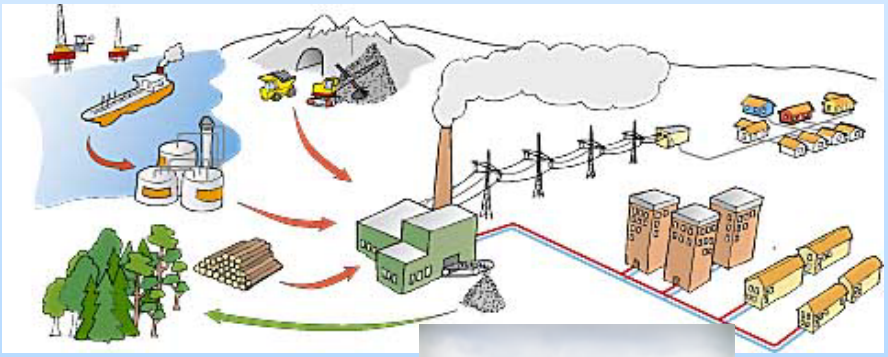
# Bioenergy utilization in Sweden

Claes Tullin

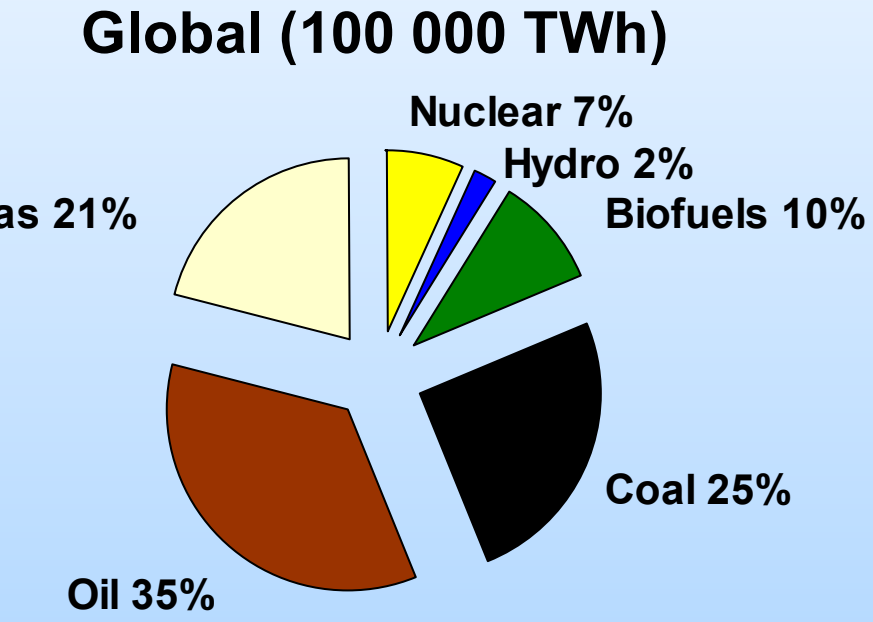
SP Swedish National Testing and Research Institute

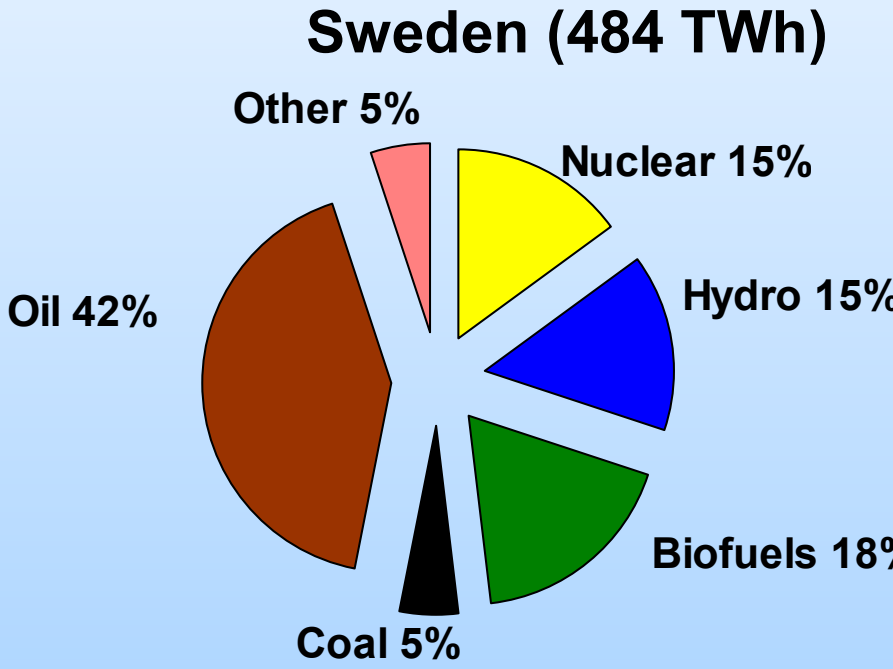
# Outline

- Introduction to biomass in Sweden
- Waste wood combustion
- Increasing market for refined fuels (pellets)

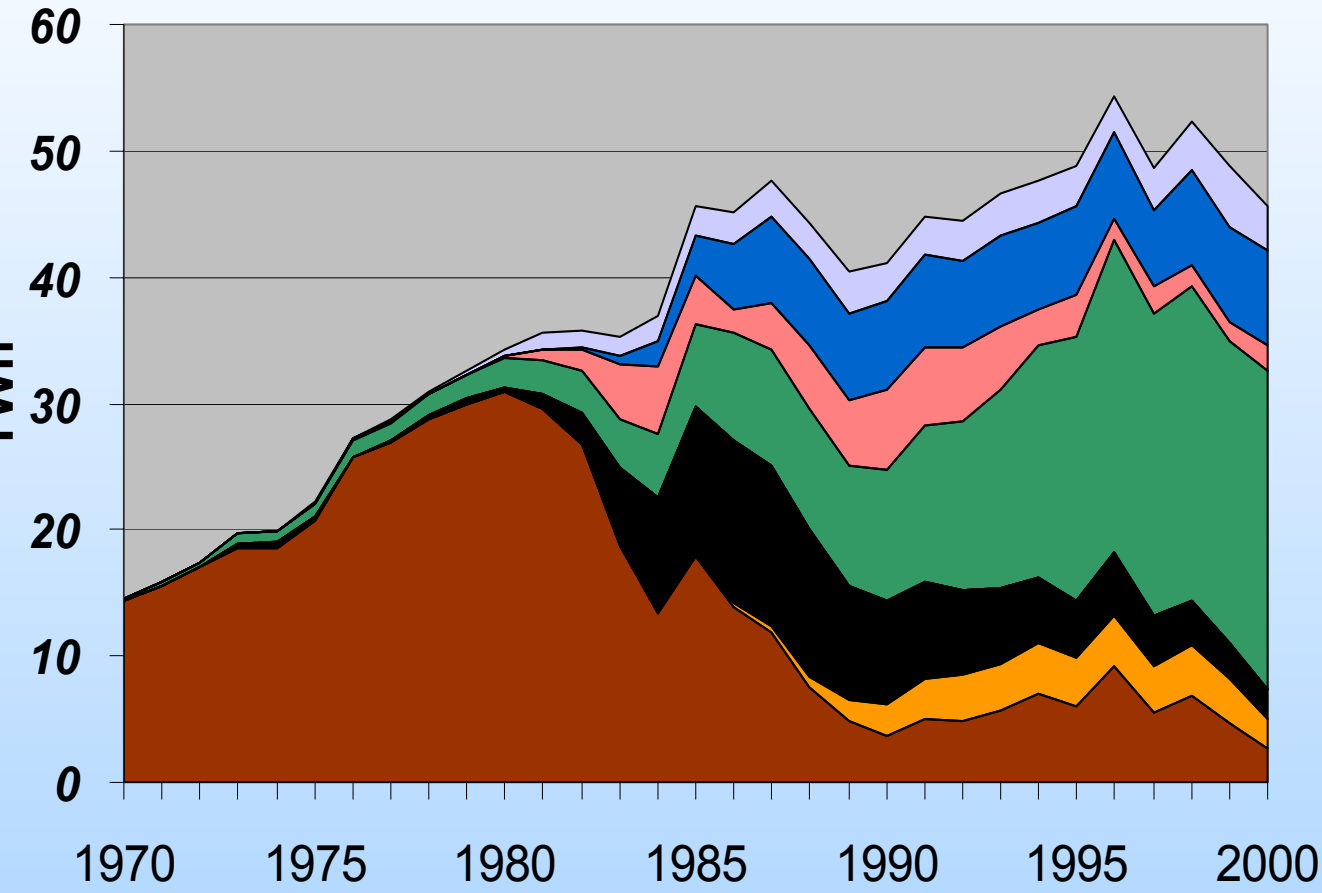


# Energy sources



# Supply of district heating



# Driving mechanisms (1)

- Emissions of fossil CO2 do enhance the green-house effect = a political truth!! => CO2 reductions important!
  - Tax on CO2 from fossil fuels
- Ban on landfilling of combustible wastes (from jan. 2002)
- Closing of nuclear reactors
- Power shortage

# Increasing use of Bioenergy

| | |
|---|---|
| 1970 – 2000: | + 2 TWh/year |
| 1980 – 2000: | + 2.5 TWh/year |
| 1990 – 2000: | + 3.1 TWh/year |
| 2000 – 2010: | + ?? TWh/year |

# District heating

- Forest residues
- Briquettes, pellets
- Sorted wastes
  - Waste wood
  - RDF
  - Sludge
- MSW

# 2. Dedicated waste wood combustion

- Contaminants due to treatments
  - CCA (Cu, Cr, As)
  - Paints (Zn, Pb, Cd, ..)
  - Boards (N, Cl, S)
- Increased fouling/corrosion
- Emissions (EU incineration directive)
  - Metals and HCl

# Waste wood project

## Swedish Thermal Engineering Research Institute

- Literature data ash chemistry
- Detailed fuel analysis
- Detailed field measurements
- Numerical simulation
- Laboratory studies on Zn/Pb chemistry

➢ Two case studies:

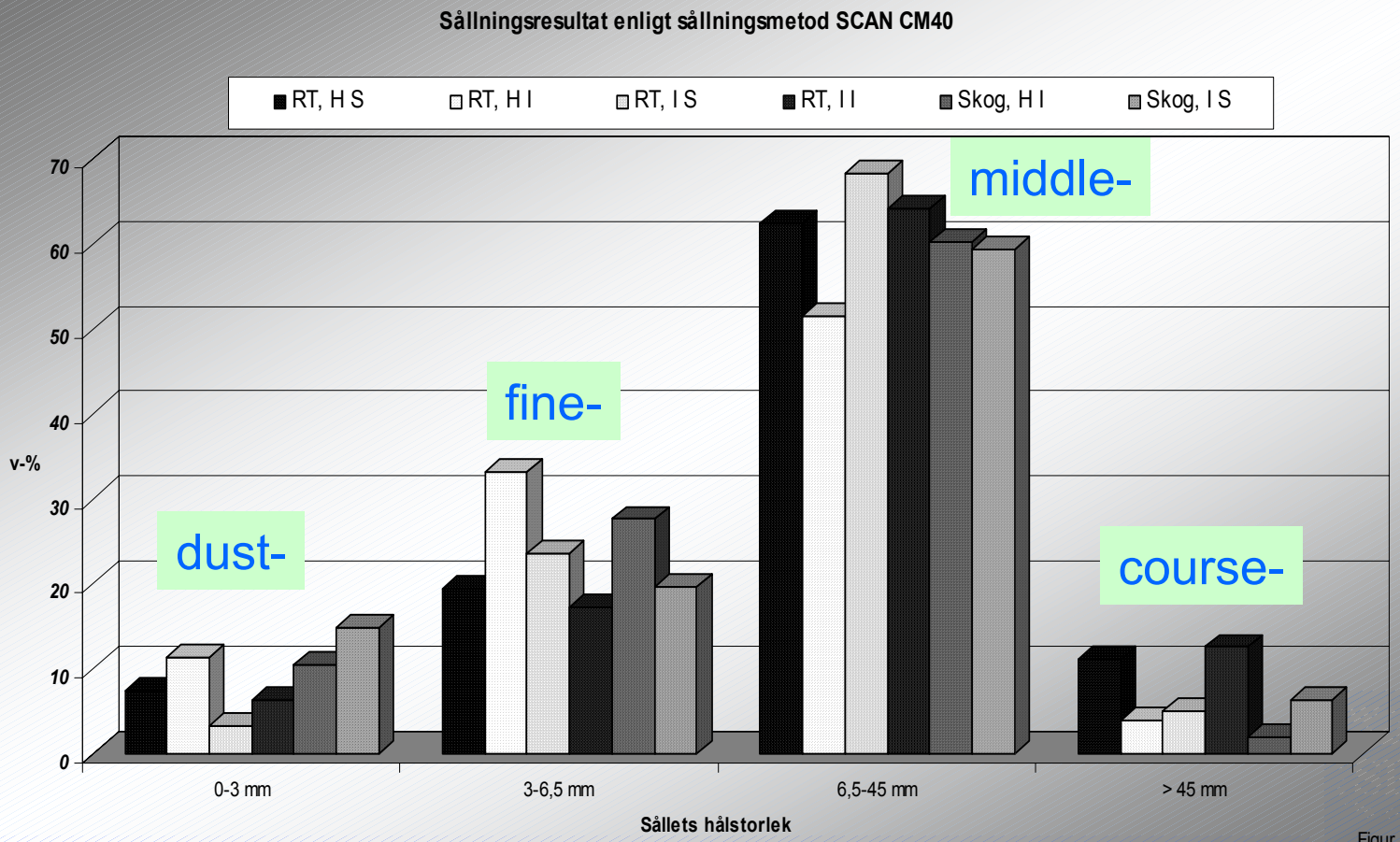
- Grate combustion (vibrating grate; 117 $MW_{th}$)
- Fluid bed (BFB; 98 $MW_{th}$)

# Detailed fuel analysis

- Characterisation of fuel fractions
  - Painted, boards, plastics, metals
- Size distribution
- Chemical analyses

# Laboratory sieve => 5 fractions

# Sieving result




Figur 1

# Sieving result

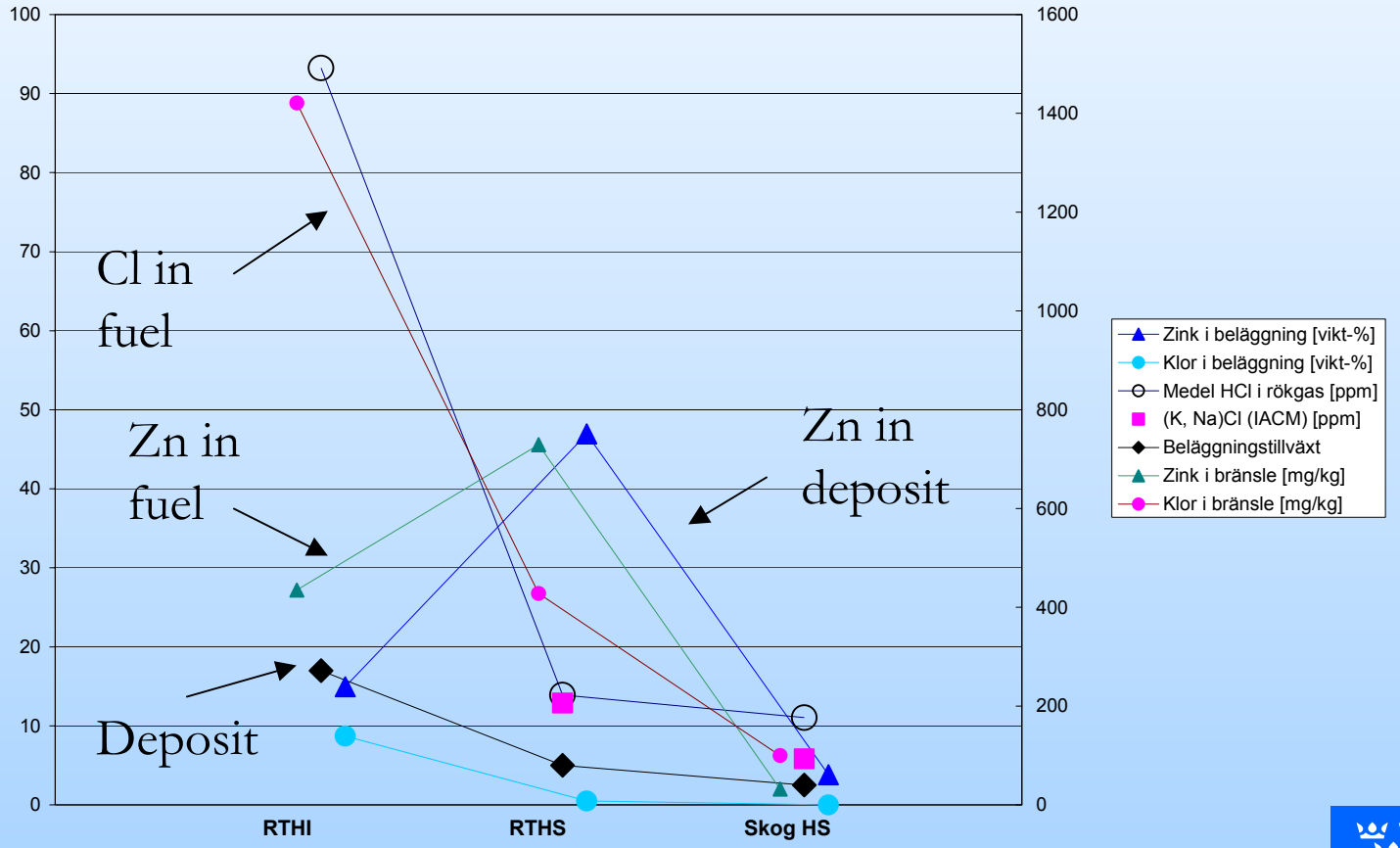
**Fines + dust = 30 w-%**

- 60 % of the deposit related compounds (Zn, Pb, Na, K)
- 40 % for Cl

**Dust = 7 w-%**

- 40 % of deposit related compounds (Zn, Pb, Na, K)
- 10 % för Cl

# Fuel quality – deposit formation



# Deposit probe test
# 50% biomix/50% recycled wood, 12 h exposure, $t_{ring}$ 500 °C

Without ChlorOut;

chloride conc ~25%

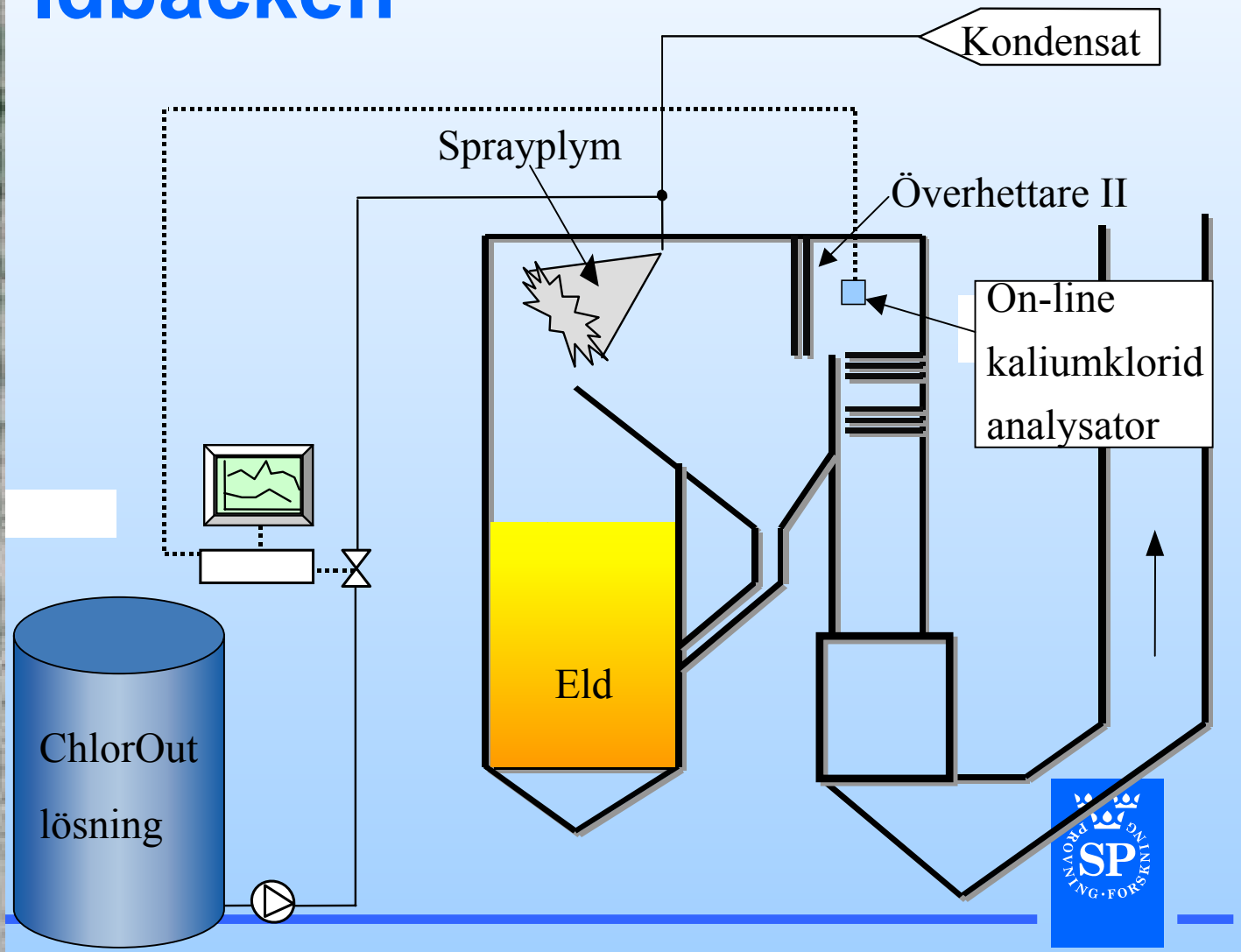
grow rate 21 g/m2/h

With ChlorOut;

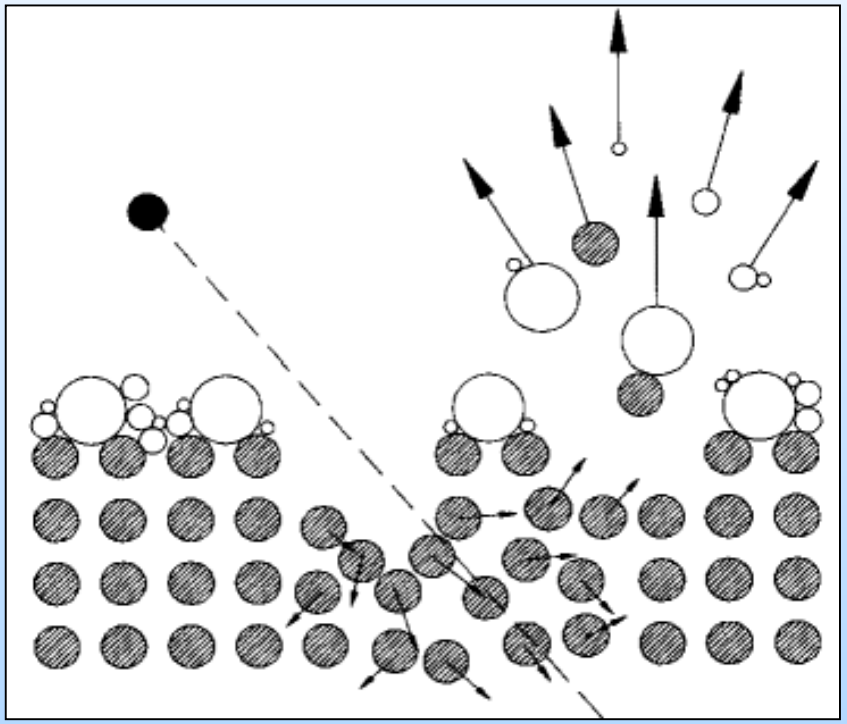
chloride conc <0.2%

grow rate 6 g/m2/h

# ChlorOut installation Idbäcken



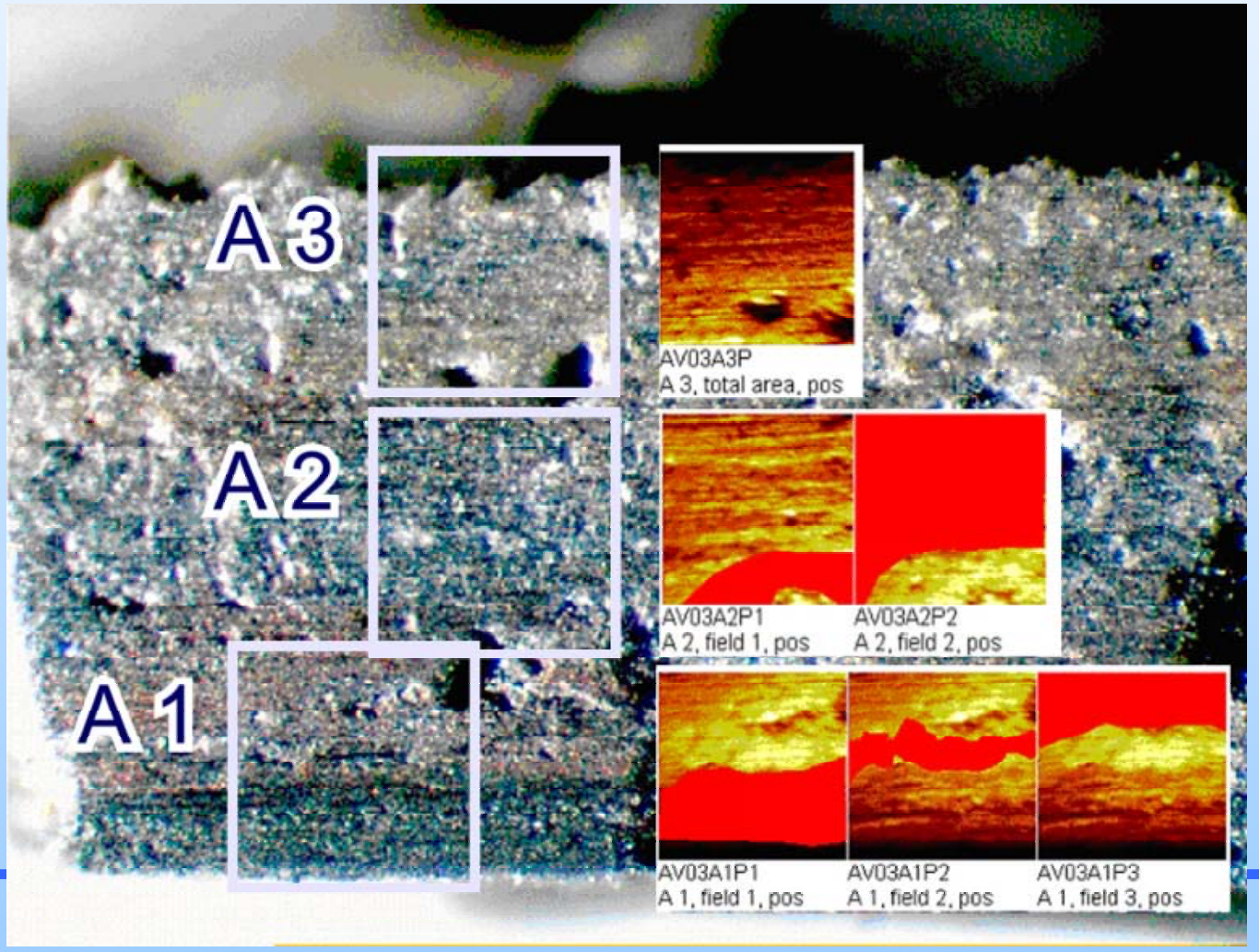
# TOF-SIMS - Time-of-Flight Secondary Ion Mass Spectrometry

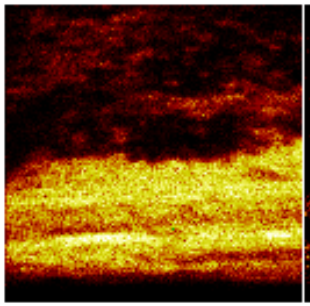


A high energy ion hits the surface and gives rise to a cascade of secondary ions from the outermost 1-2 atomic layers of the sample surface. The secondary ions are detected by a mass spectrometer.

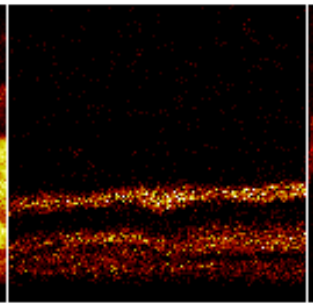
Schematic picture of the SIMS process.

# TOF-SIMS analysis of SH-deposit

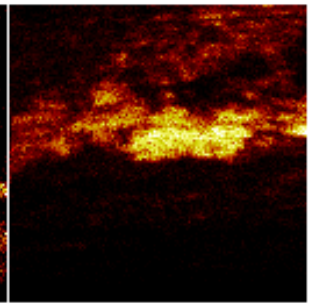




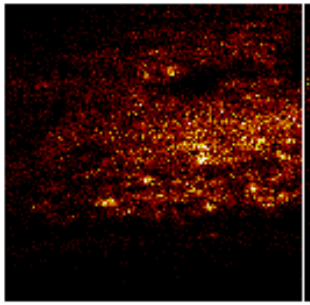
Fe
tc:228846



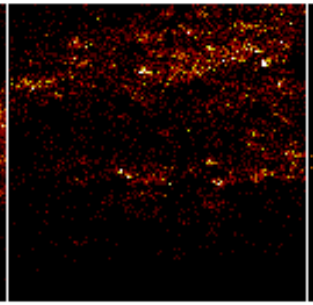
Cr
tc:7247



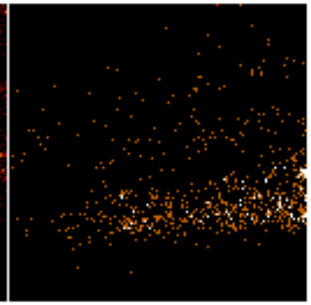
CaOH
tc:85726



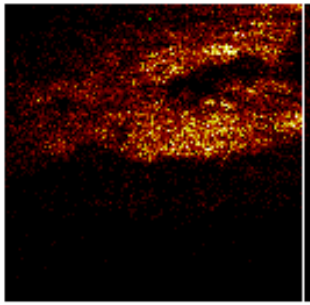
$K_2Cl$ (KCl)
tc:15272



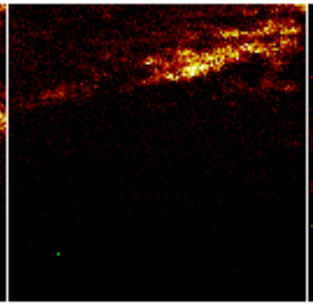
$Na_2Cl$ (NaCl)
tc:4852



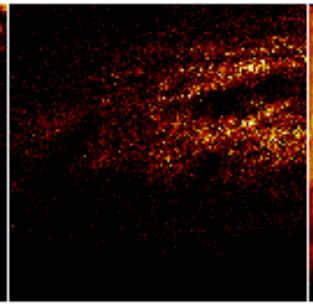
$ZnCl_3$ (ZnCl2)
tc:689



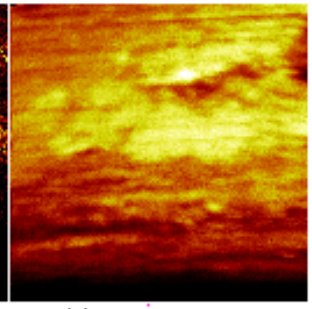
$K_2O$ (K2SO4)
tc:16502



$Na_2O$ (Na2SO4)
tc:10644

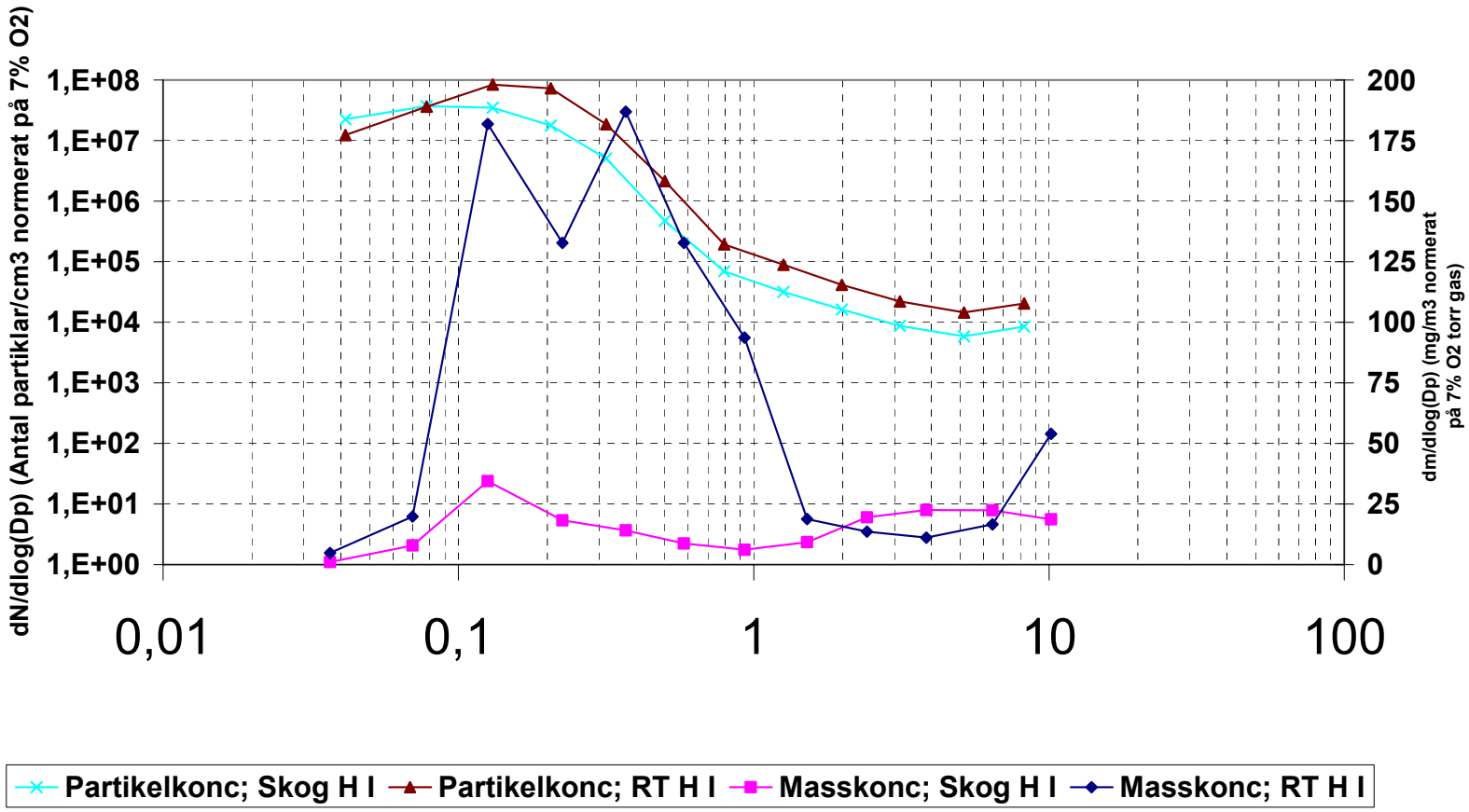


$^{64}ZnO_2$ (ZnO)
tc:7823

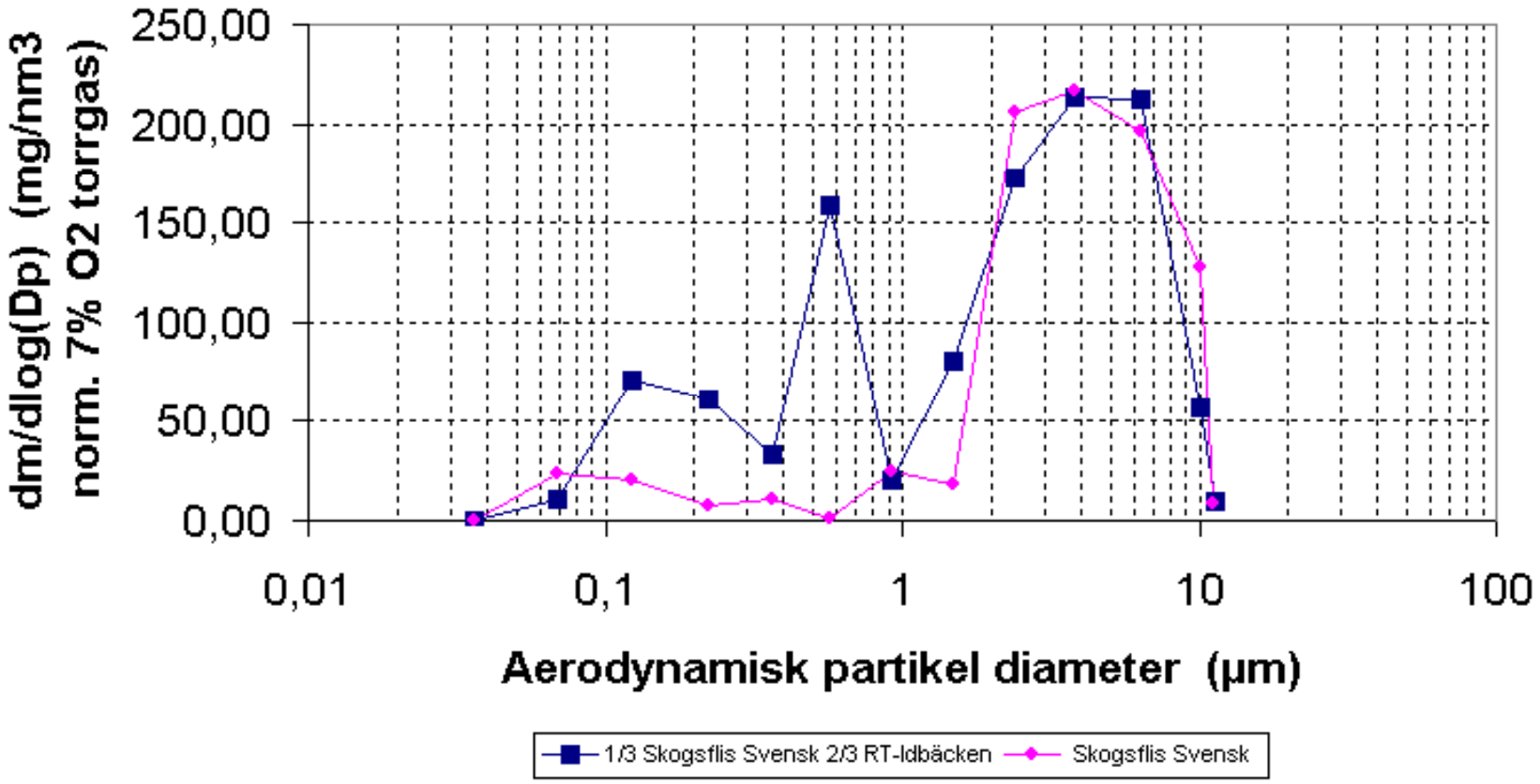


total ion
tc:2897932

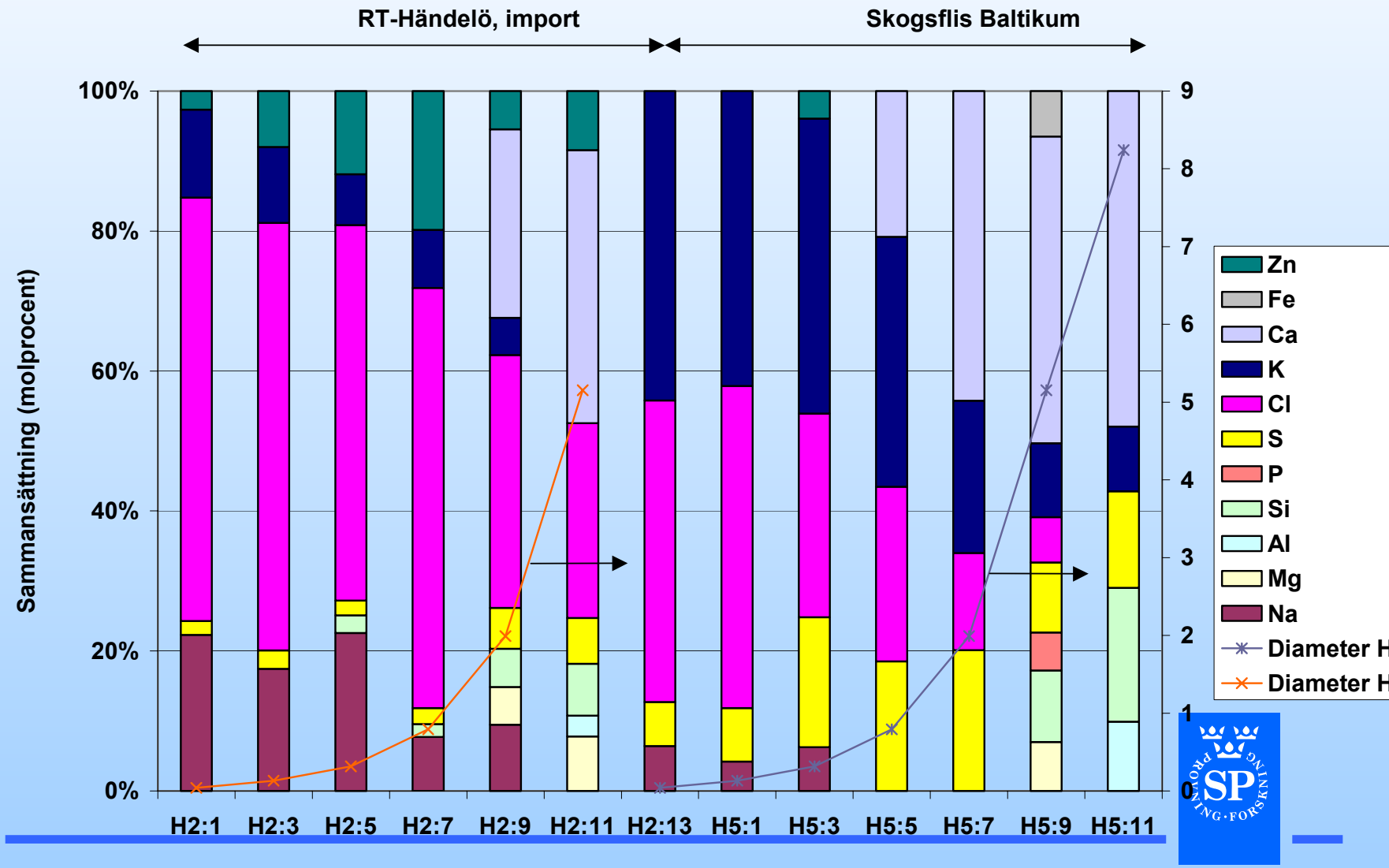
# Aerosol characteristics (grate)



# Aerosol characteristics (BFB)



# Chem analysis of PM fractions



# Conclusions: deposit formation

- In comparison with forest residues, combustion of waste wood =>
  - Higher rate of deposit formation
  - More Zn, Pb, K, Cl in the deposits
  - Increased corrosion
- Less Zn in FB deposits

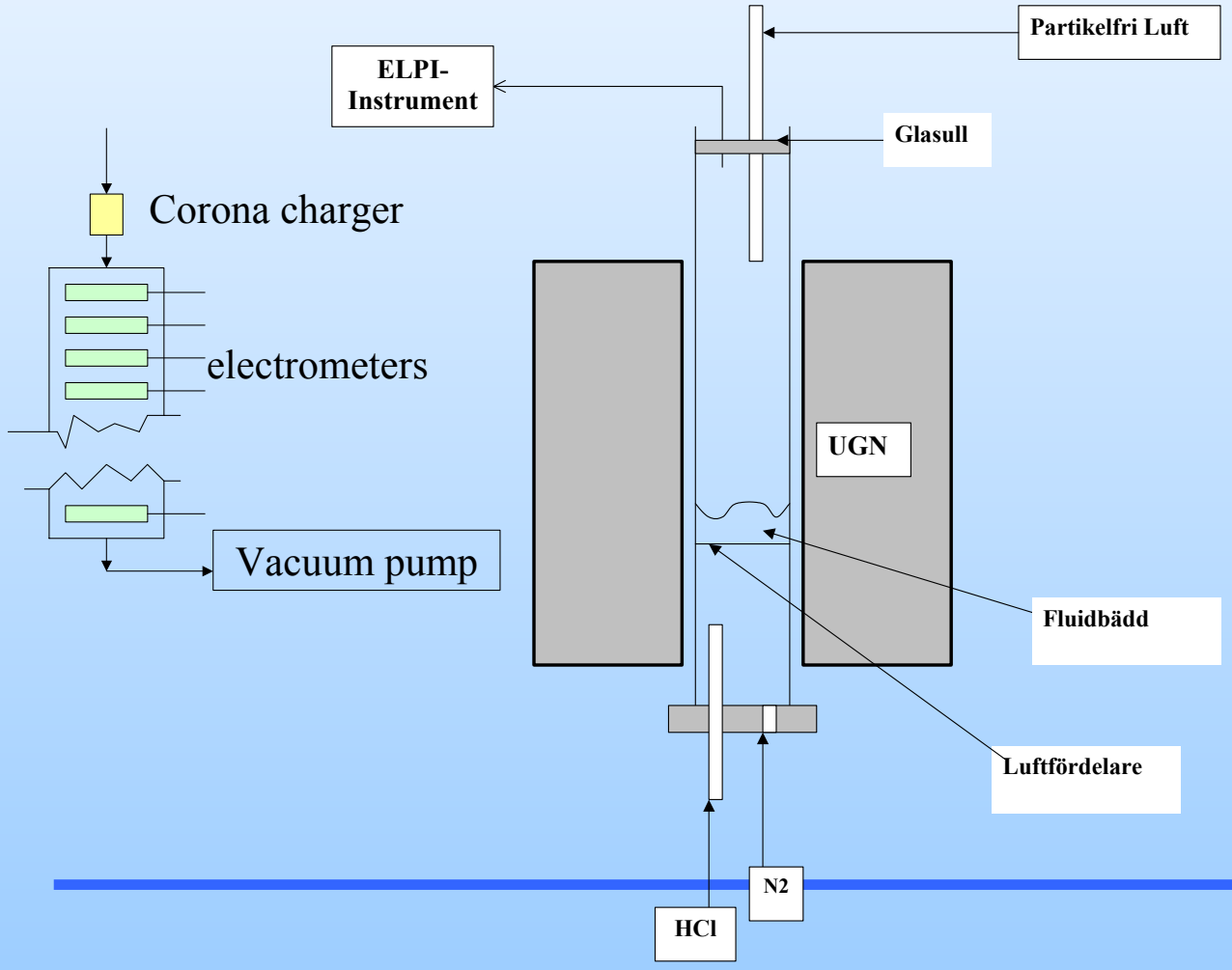
# ZnO thermally stable….

… but Zn still found in deposits and submicron particles:

Transport mechanisms from fuel bed to heat exchangers:

- ZnO pigment particles as such
- ZnO reduced to Zn which evaporates
- ZnO + HCl => ZnCl2 which evaporates

# Experimental set-up




$ZnO(s) + HCl(g)$

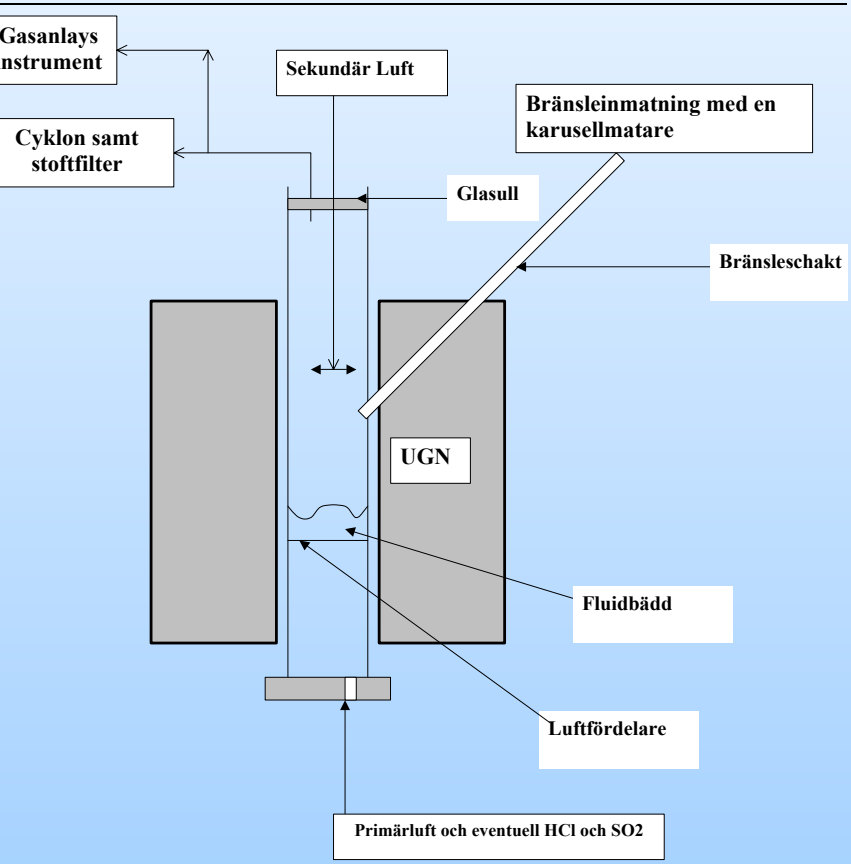
$\Rightarrow ZnCl2\ (s)$

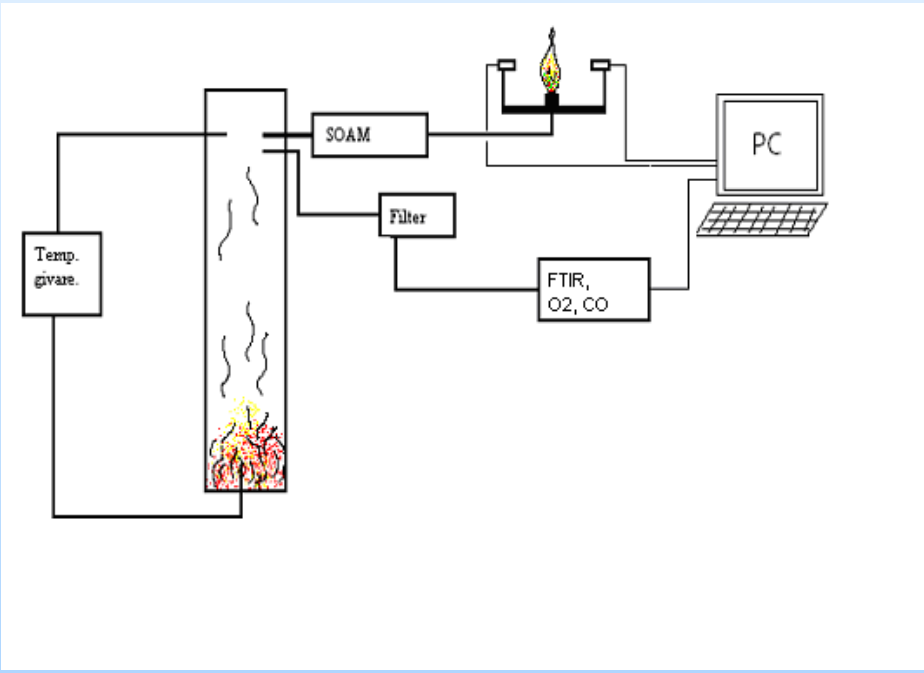
$\Rightarrow ZnCl2\ (g)$

$\Rightarrow Cooling$

$\Rightarrow ZnCl2(s)$ with $dp < 1\ \mu m$

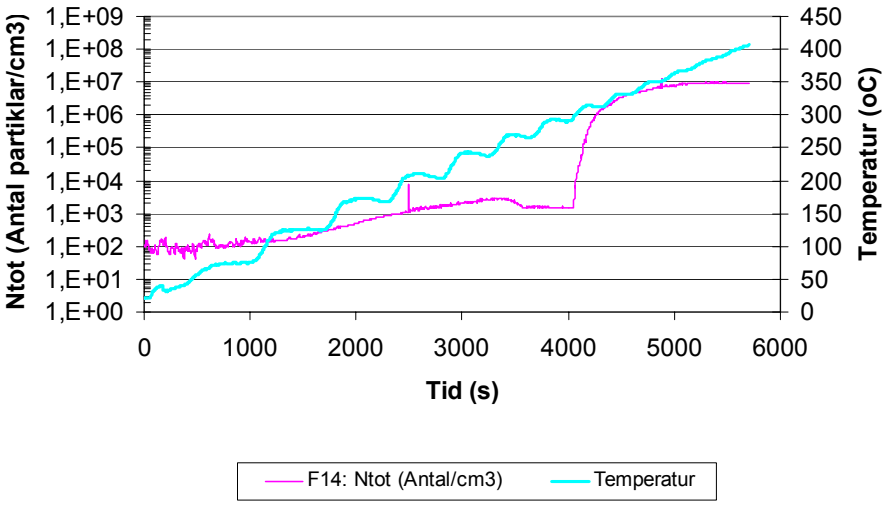
# Combustion tests with (1) waste fuel samples and (2) doped reference fuels



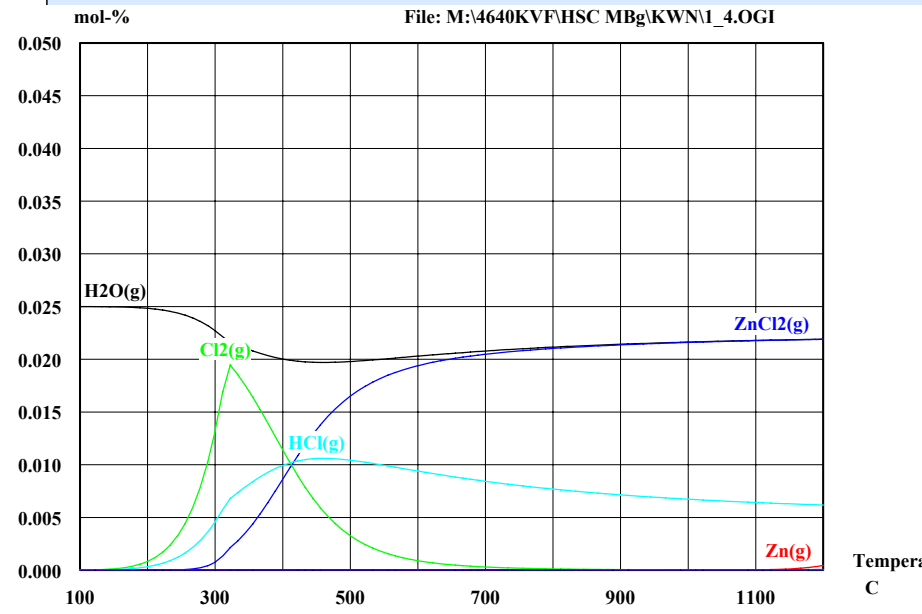



# Results - 1

## ZnO + 500 ppm HCl



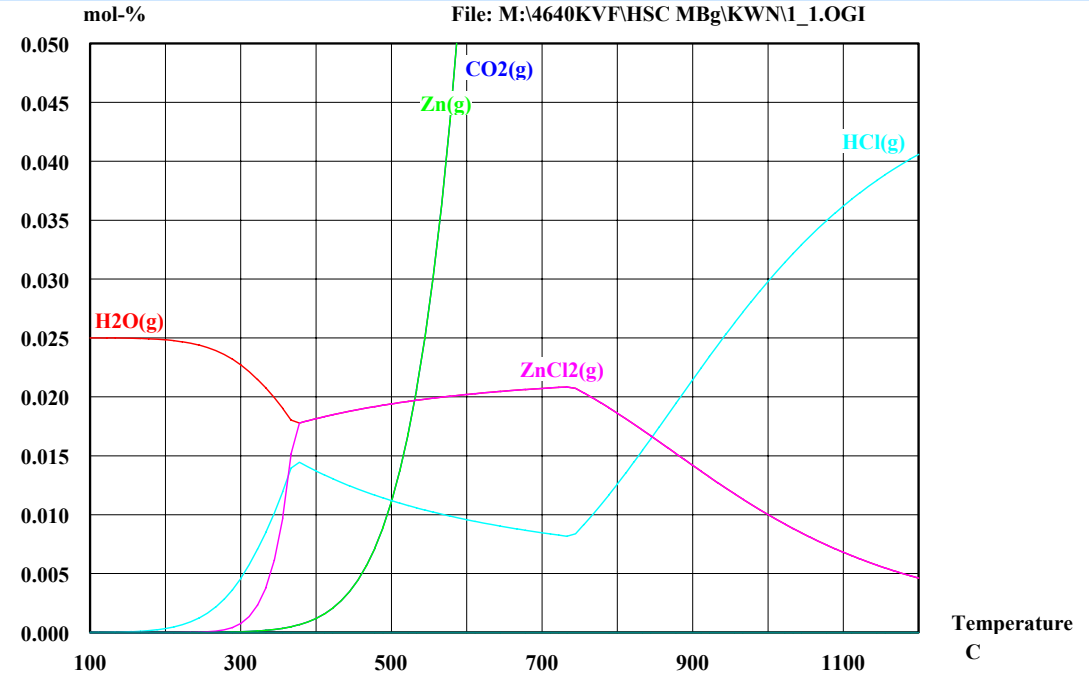

## Thermodynamic predictions



# Results: Formation of Zn

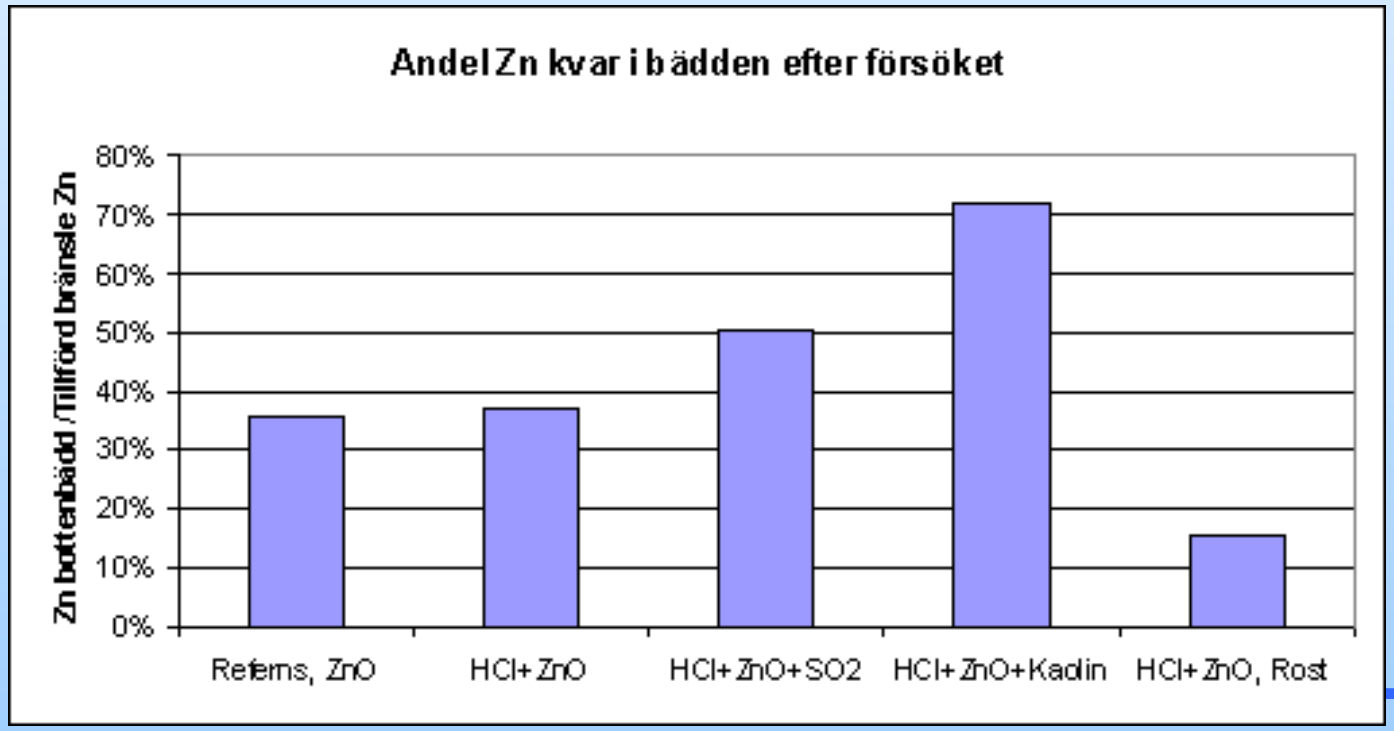
- Thermodynamic calculation predict Zn(g) formation but….
- this cannot be confirmed in experiments (CO, T = 850-1050 °C)

  => kinetic limitations!?

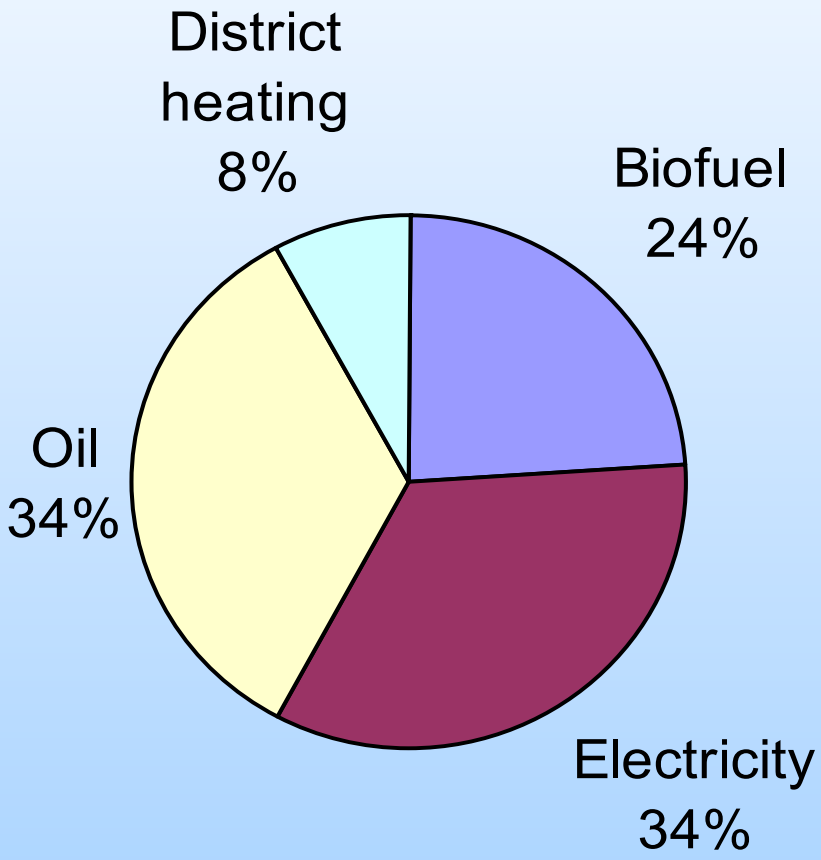


# Continuous combustion of painted wood -Additives reduce evaporation

- Addition of SO2 and Kaolin reduce the vaporation of Zn
- Large difference between fluid bed and grate combustion conditions



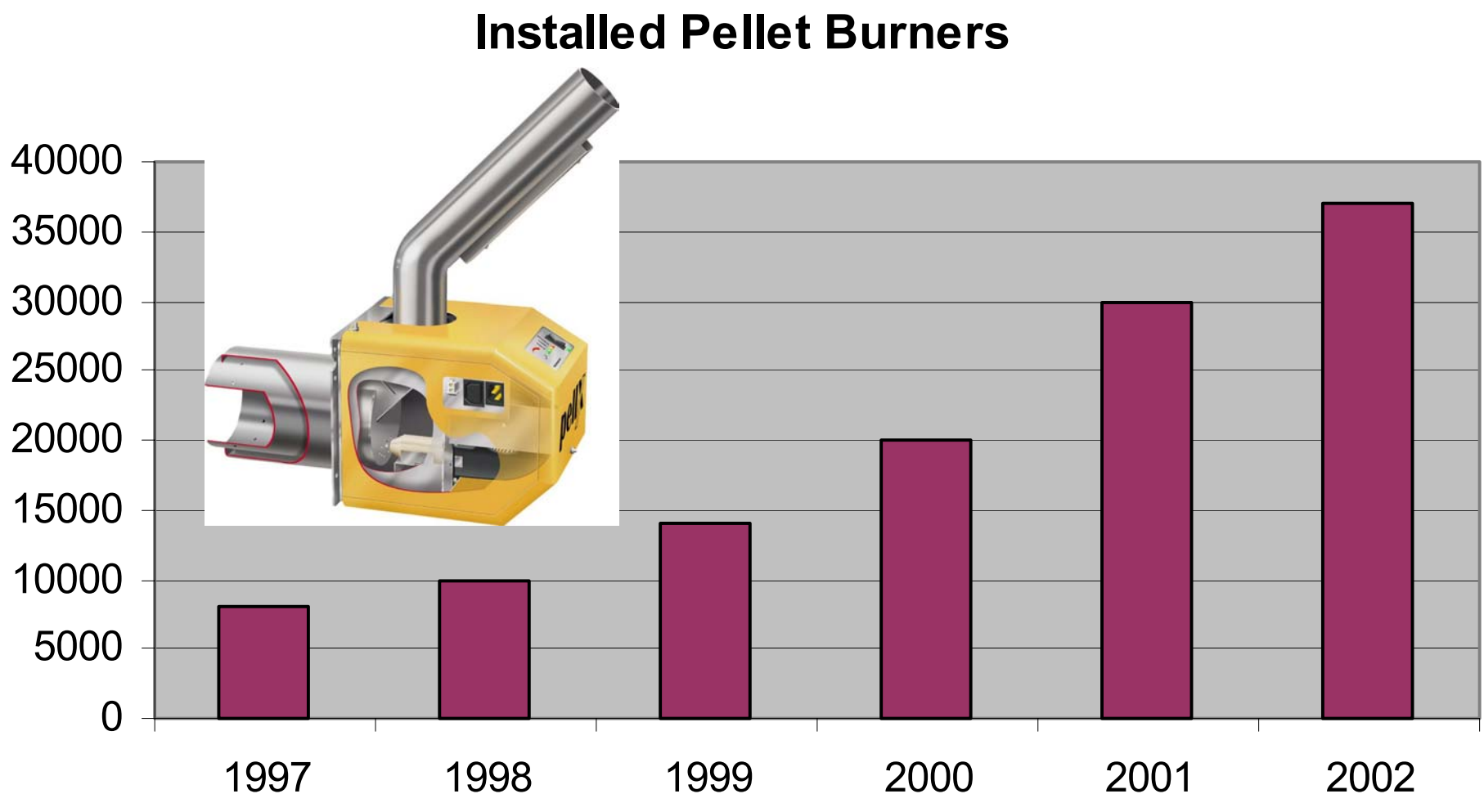
# 3. Domestic heating in Sweden



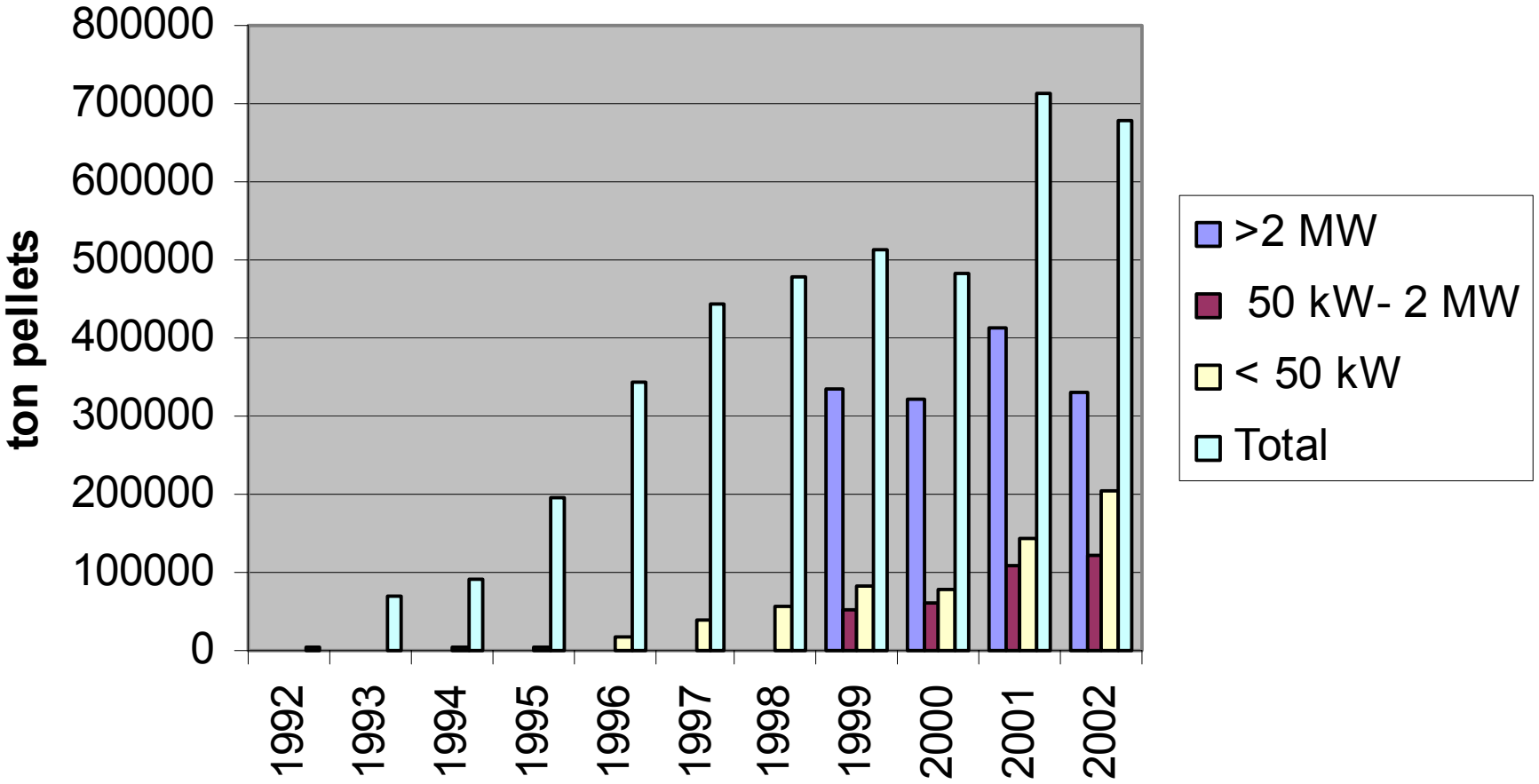
# Emissions from different domestic combustion equipment per net kWh

| Type of combustion | Tar, mg | VOC, mg | NOx, mg | Particles, |
|---|---|---|---|---|
| | | | | |
| Trad. wood boiler | 2 500 | 10 000 | 350 | 1 800 |
| Modern wood boiler | 30 | 300 | 520 | 80 |
| Modern wood stove | 50 | 700 | n.a. | 80 |
| Pellet boiler | 20 | 160 | <270 | 160 |
| Pellet stove | 20 | 120 | <270 | 160 |

# Pellet burners



# Delivered pellets (Sweden)

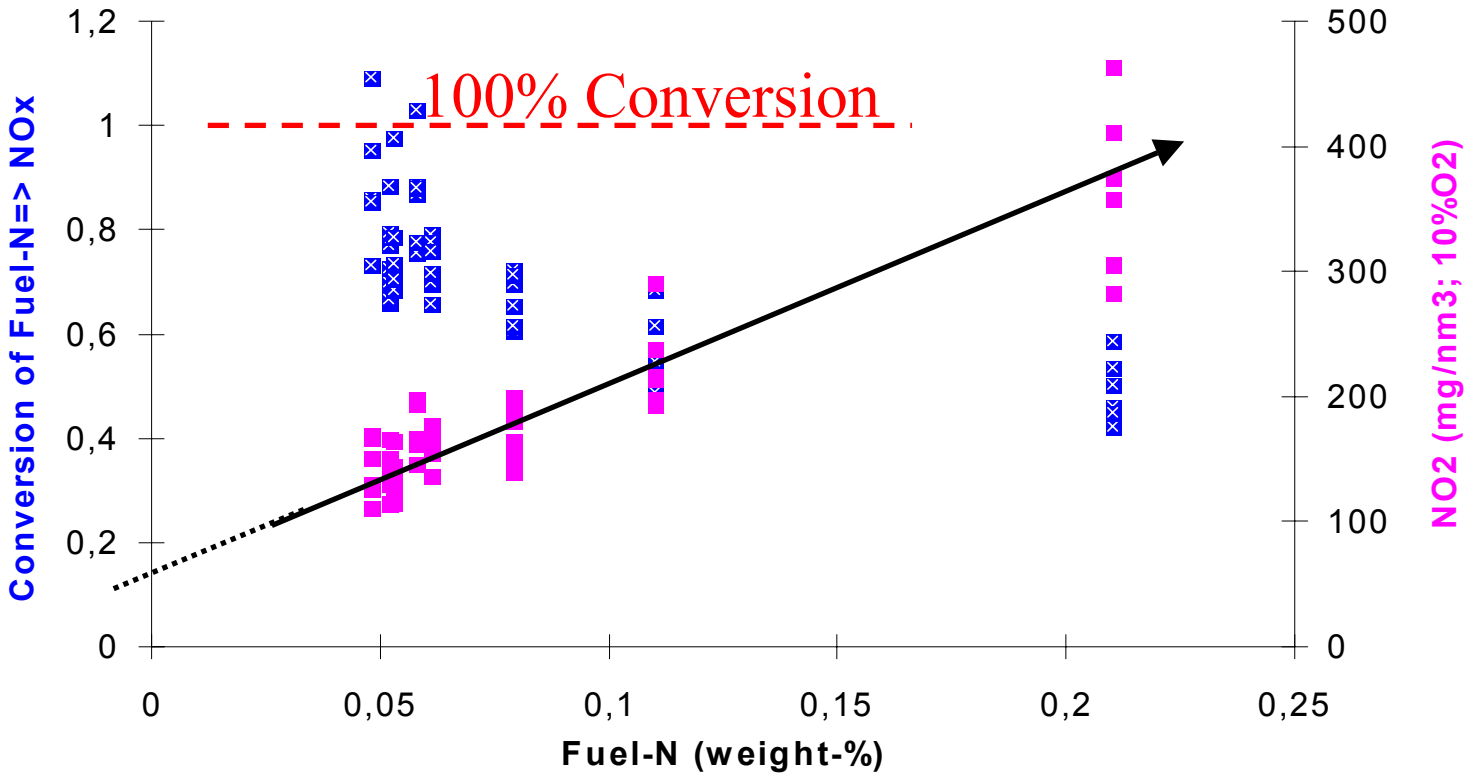



Source: PIR

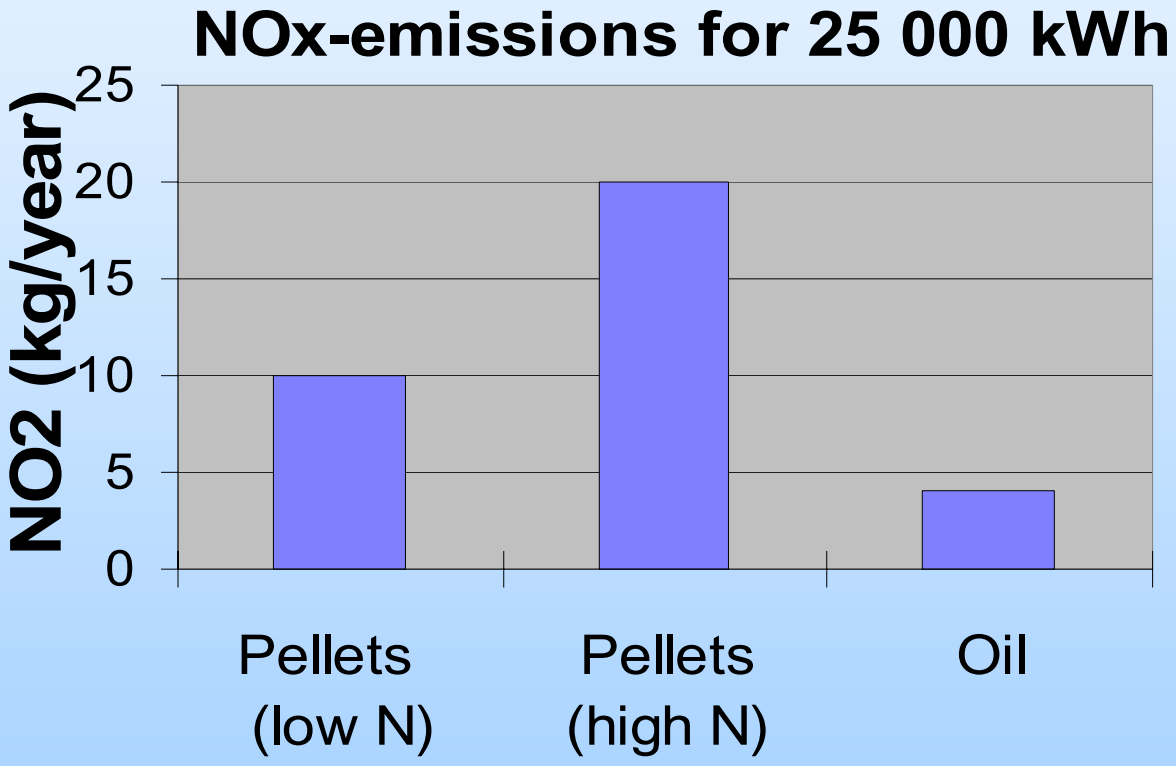
# Issues in Pellet Combustion

- Environmental problems?
  - NOx
  - Particulates
    - If replacing oil burners/electricity
- Technical issues
  - Pellet quality
  - Maintenance
  - Operator independent
  - Installation
- Economy/Market
  - Supply
- Safety

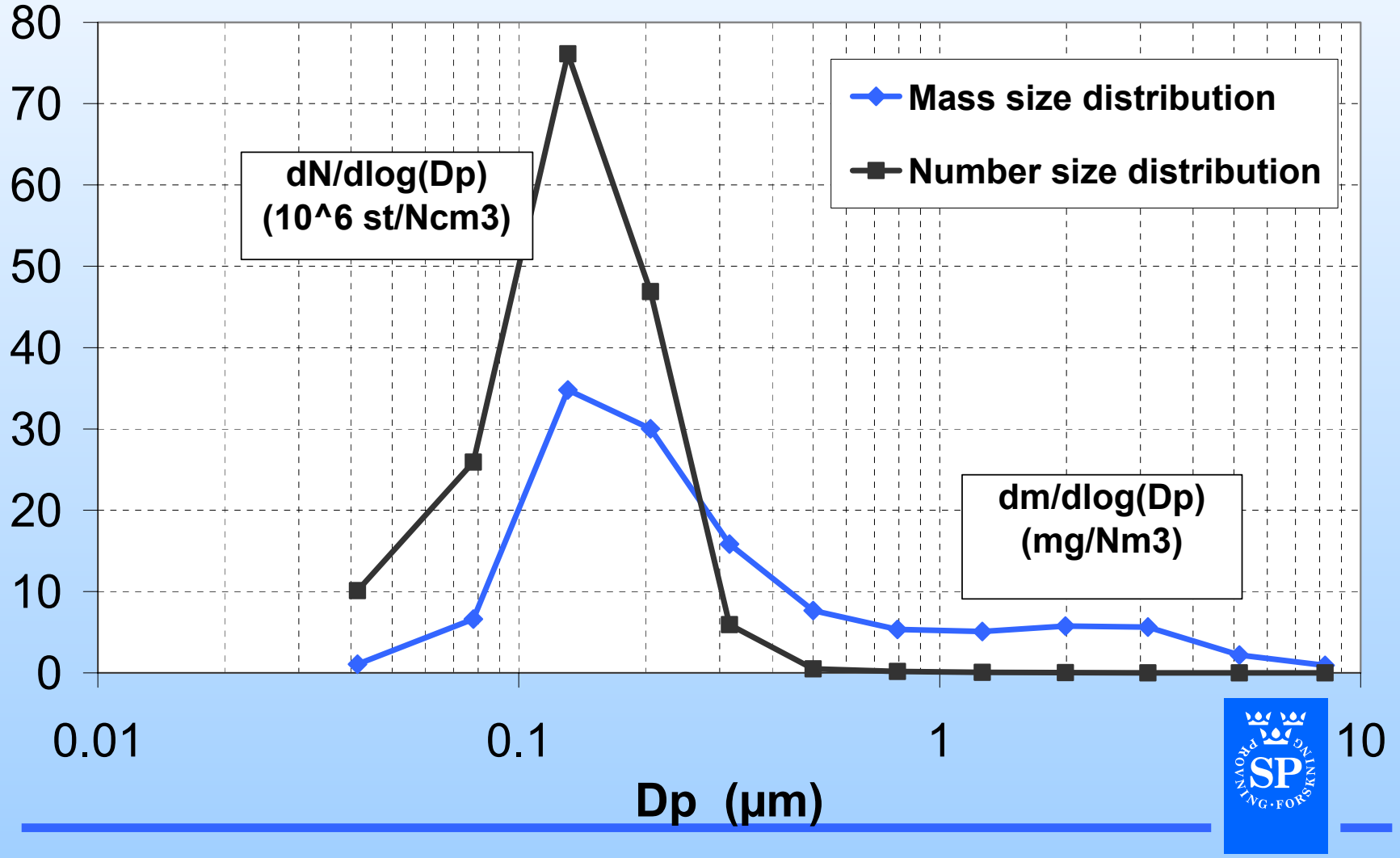
# Fuel-N conversion to NOx is high in pellet burners/stoves



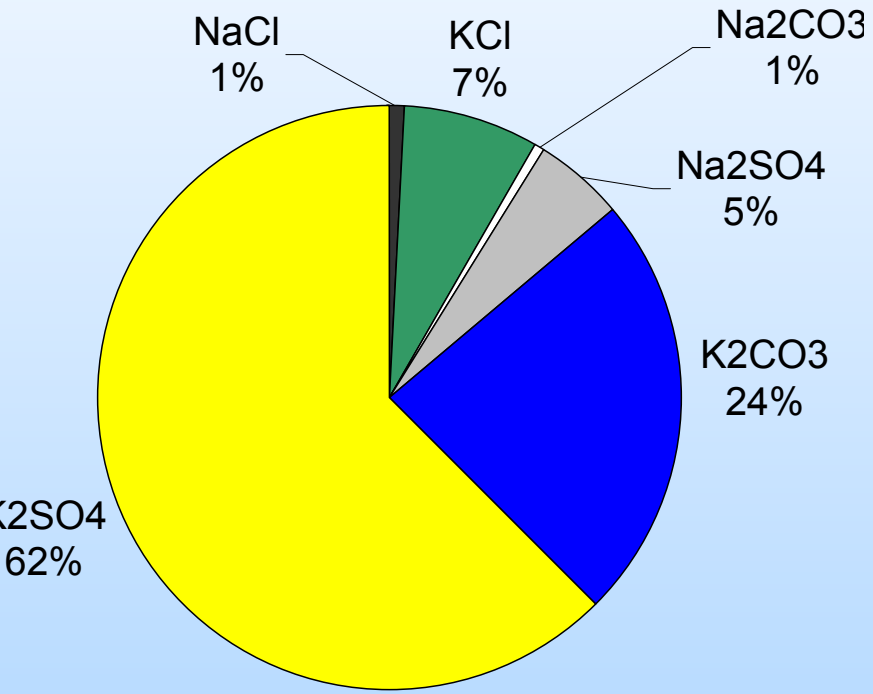
# Oil => Pellets
# Higher NOx- emissions



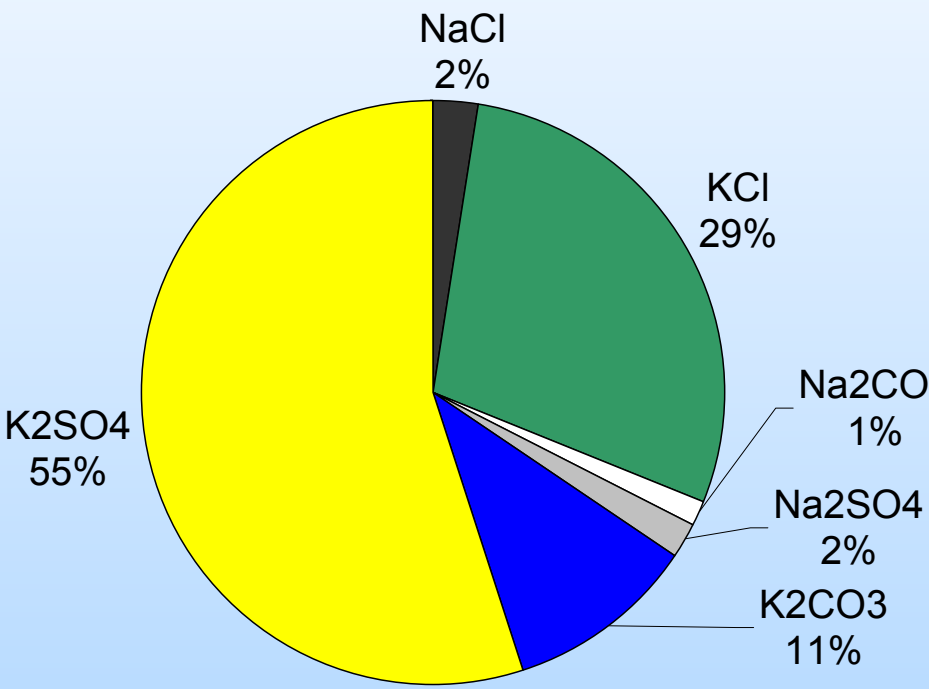
# Grate Boiler, 2,5 MW, Wood Briquettes



# TOF-SIMS Results - Pellet Stove




$D_i = 0.1\ \mu m$




$D_i = 0.3\ \mu m$

# General conclusions

- Steady increase in the use of Bioenergy
- Increasing use of ”waste” fuels
- Waste wood
  - Problems with deposit formation/corrosion
    - Fuel quality (Cl, Zn, Pb)
    - Primary/secondary combustion actions
- Increasing use of pellets (small scale)
  - NOx
  - Particles