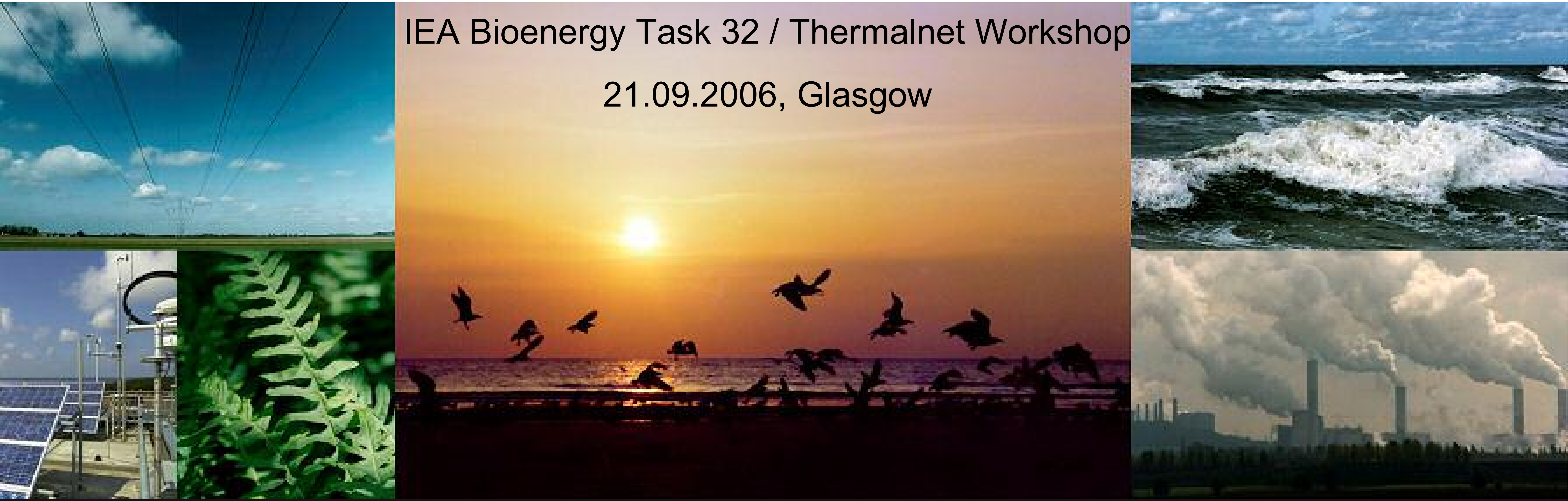
ECN

Energy research Centre of the Netherlands

Ash: what happens when biomass is co-fired with coal ?

- Rob Korbee -



IEA Bioenergy Task 32 / Thermalnet Workshop

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Everything changes,

…

and it can be controlled !

Biomass co-firing maturing in the Netherlands

- Concrete 2002 agreement with government to reduce 3.2 Mton CO_2 by 2012, equivalent to 475 MW_e biomass capacity:

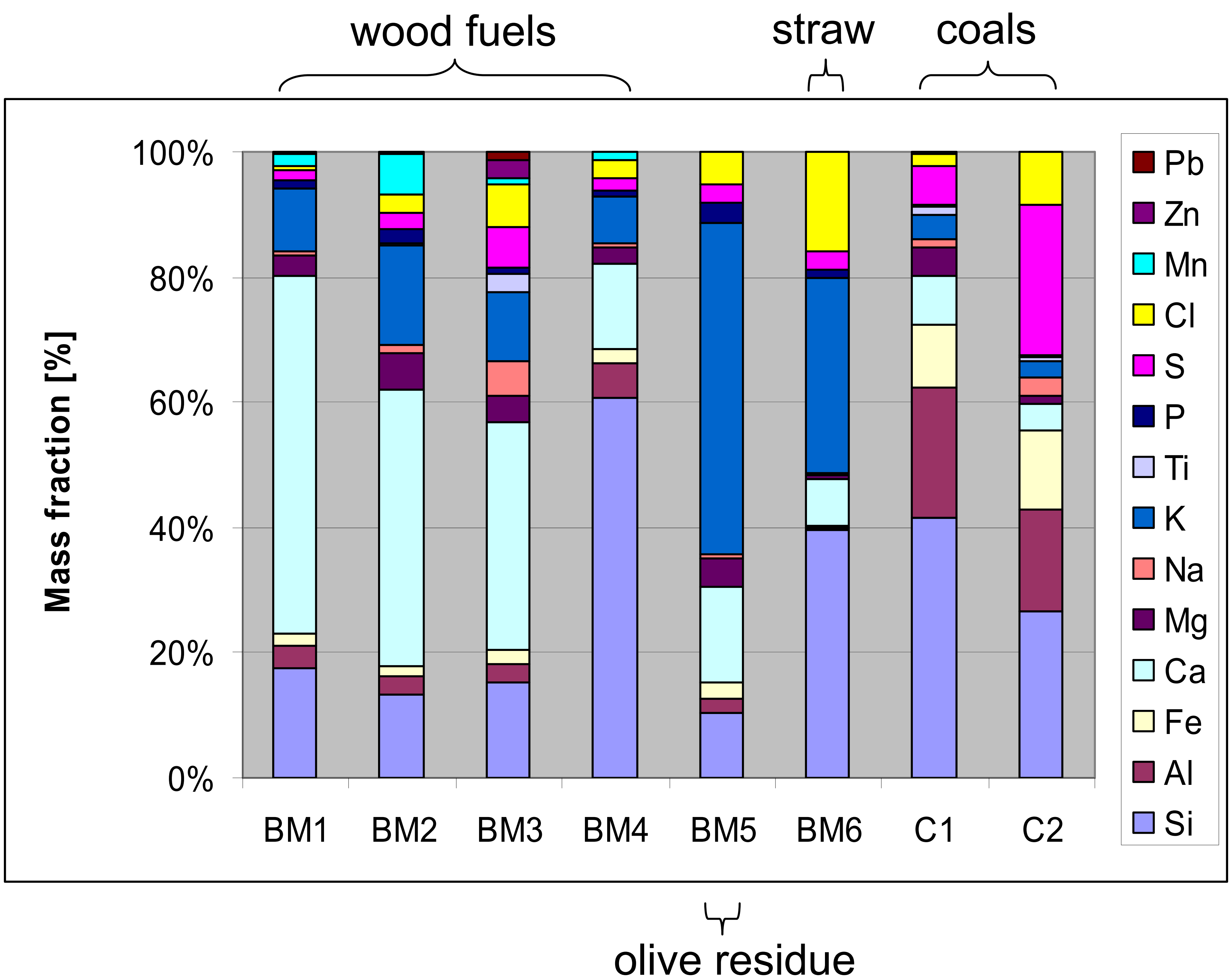
	Coal plants	Expected (2000) capacity (MW_e)	Ambition (MW_e)
Electrabel	Gelderland 13	74	new plant
NUON	Hemweg 8	77	new plant
E.On	Maasvlakte 1+2	128	new plant
Essent	Amer 8+9	147	250
EPZ	Borssele 12	49	160

- Capacity realised in 2002: 177 MW_e, of which 147 co-firing without any other thermal pre-processing [Raven, 2005]
- Main fuels used: wood pellets, food industry residues, mixed waste pellets, MBM, paper sludge, waste wood (gasification)
- Projects between 1 July 2003 and 18 August 2006 supported by subsidies up to 9.7 ct per kWh of renewable energy; new initiatives uncertain !

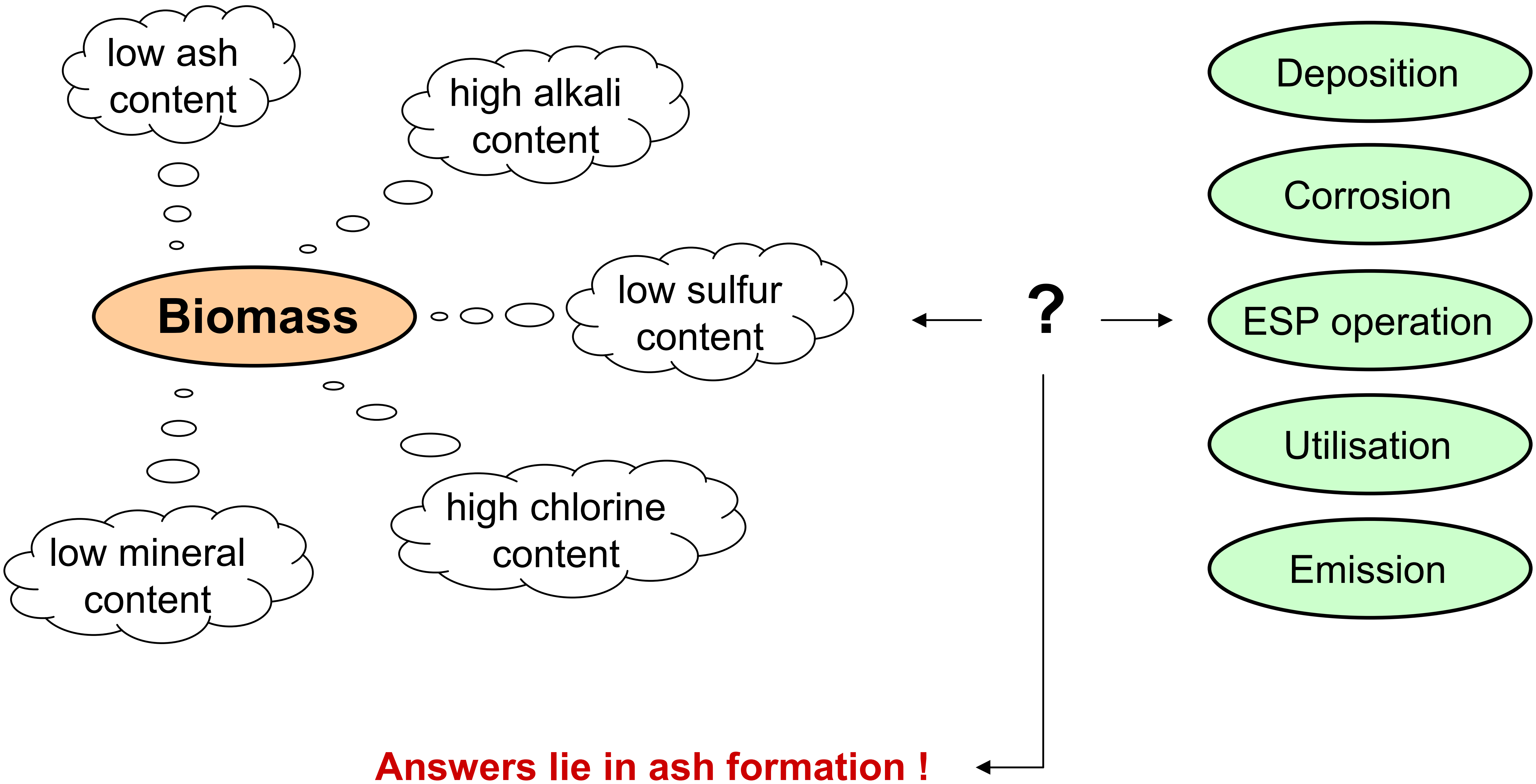
New challenges to address

- High biomass shares, up to 35% (m/m) for conventional PF plants and 30^{+}% (e/e) for future high efficiency plants
- Fuels with higher ash content and more ash complex chemistry (ref. wood), e.g. residues from households, industrial or agricultural activities
- New high efficiency, low emission technologies, such as ultra supercritical boilers producing 750 °C steam, or oxygen enriched combustion with flue gas recirculation
- Combinations of the above possibilities

Ash forming elements in biomass vs coal

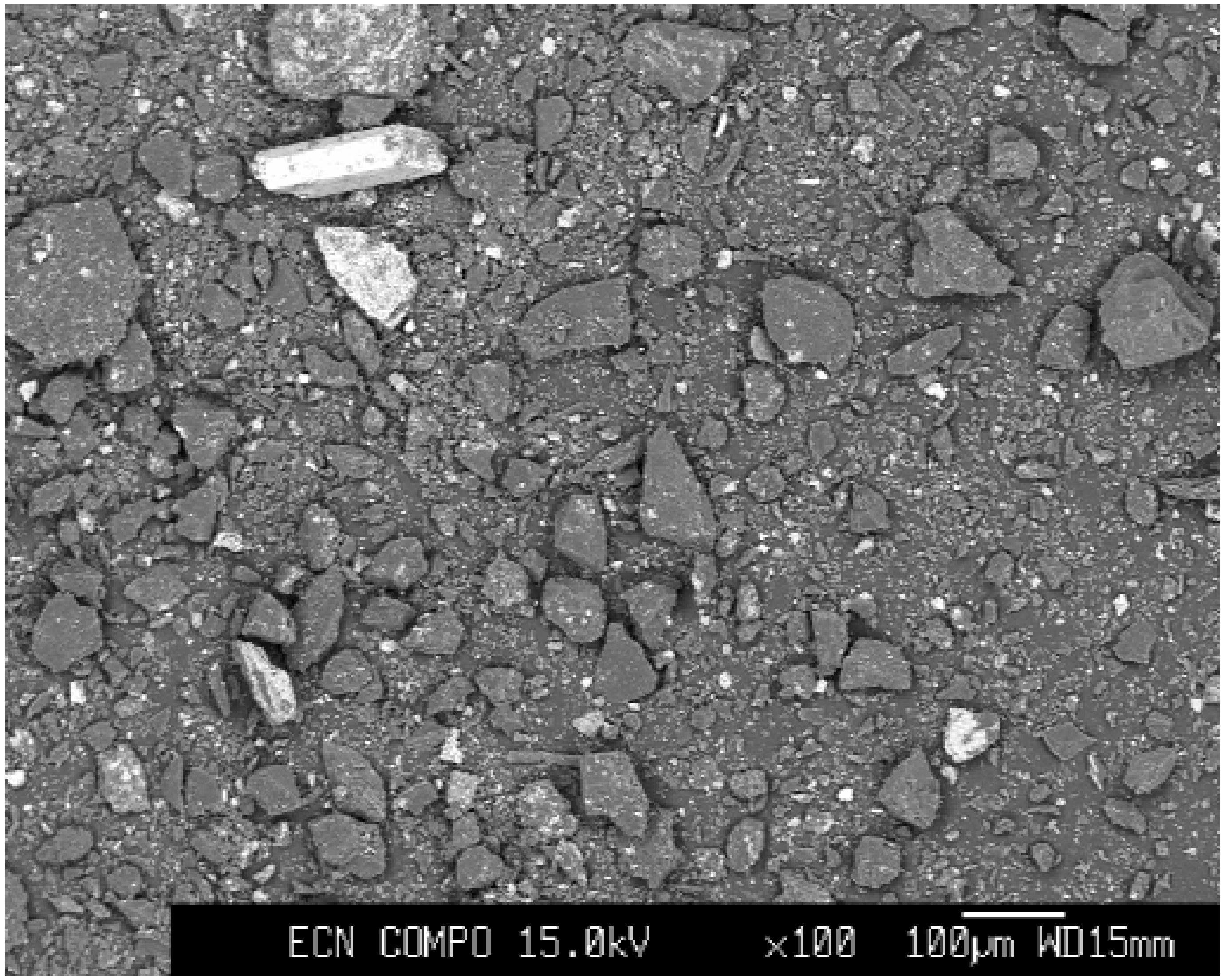


Ash related issues to consider for a ‘typical’ biomass

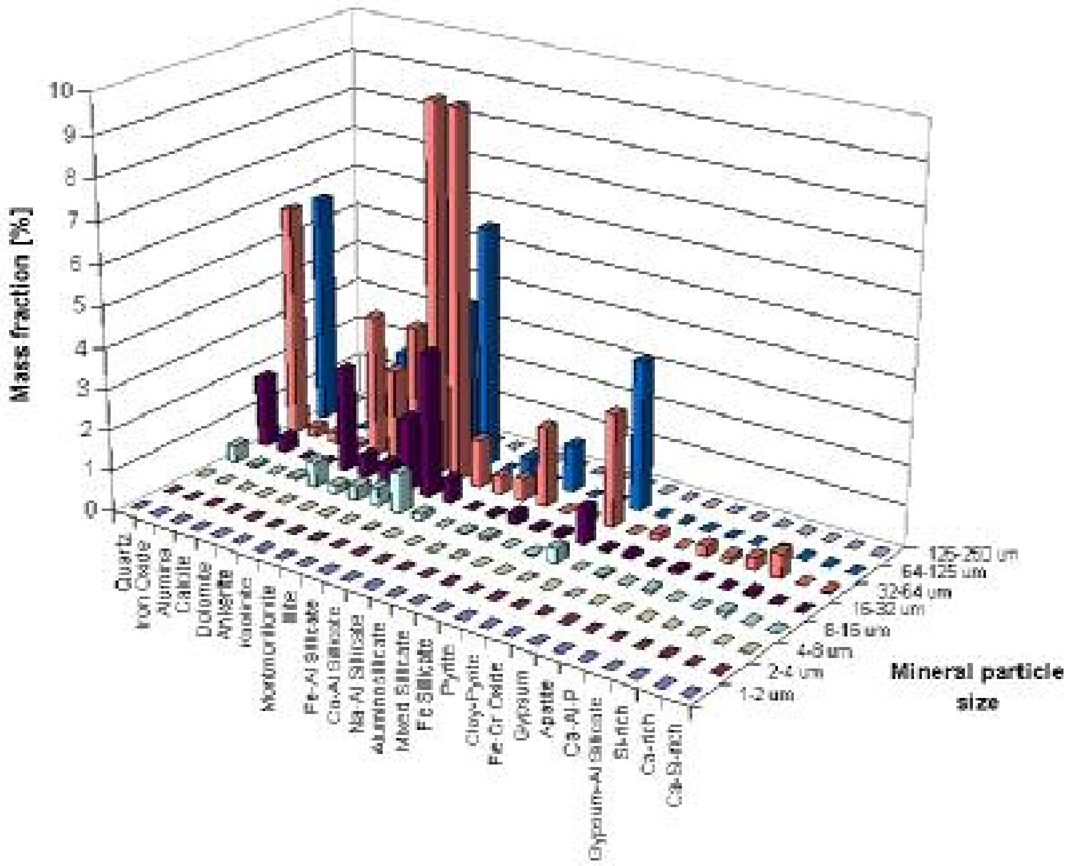


Ash forming species in coal

Pulverised coal sample in electron microscope

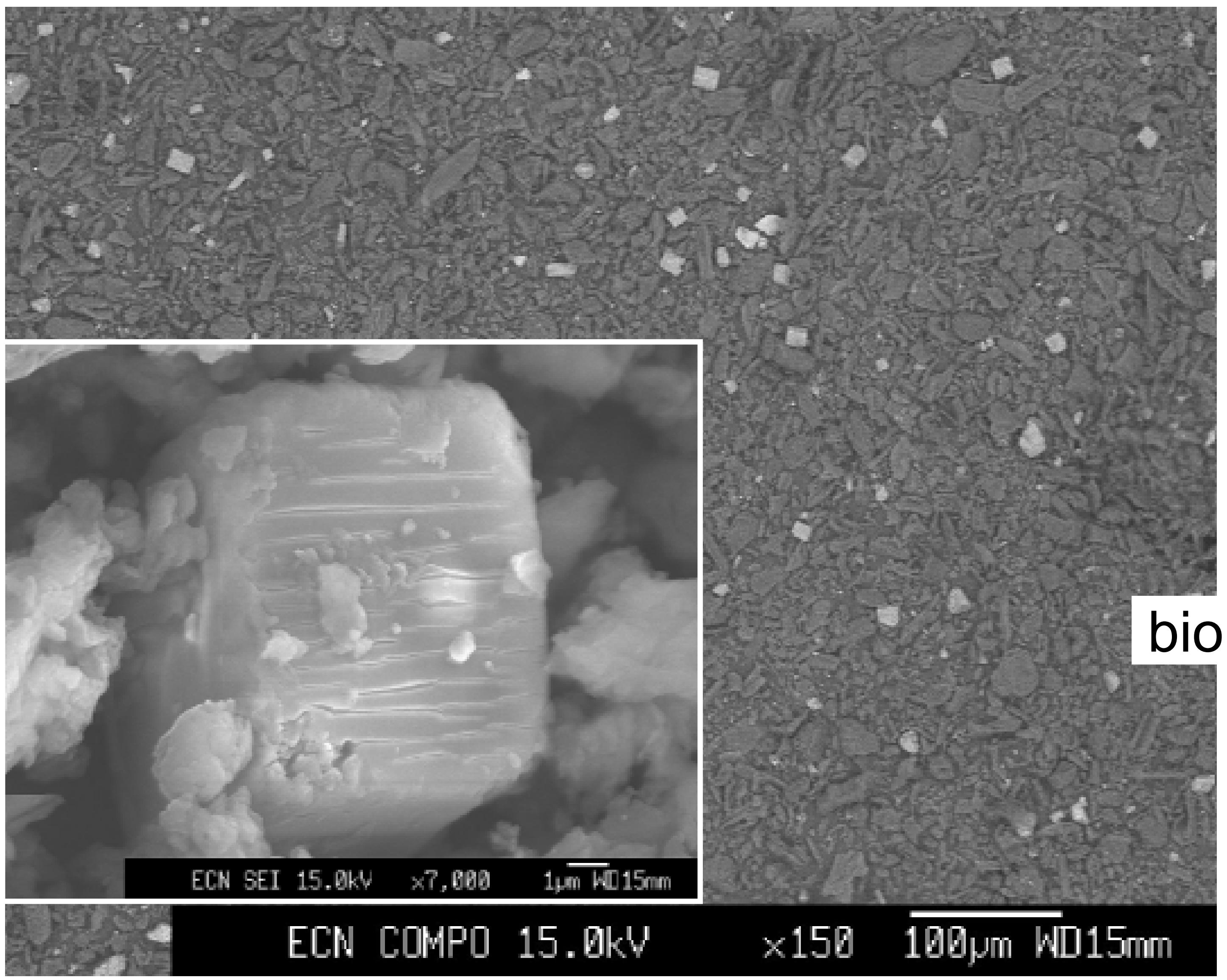


- typically mineral particles
- minerals mostly non-volatile
- minerals quantified by CCSEM



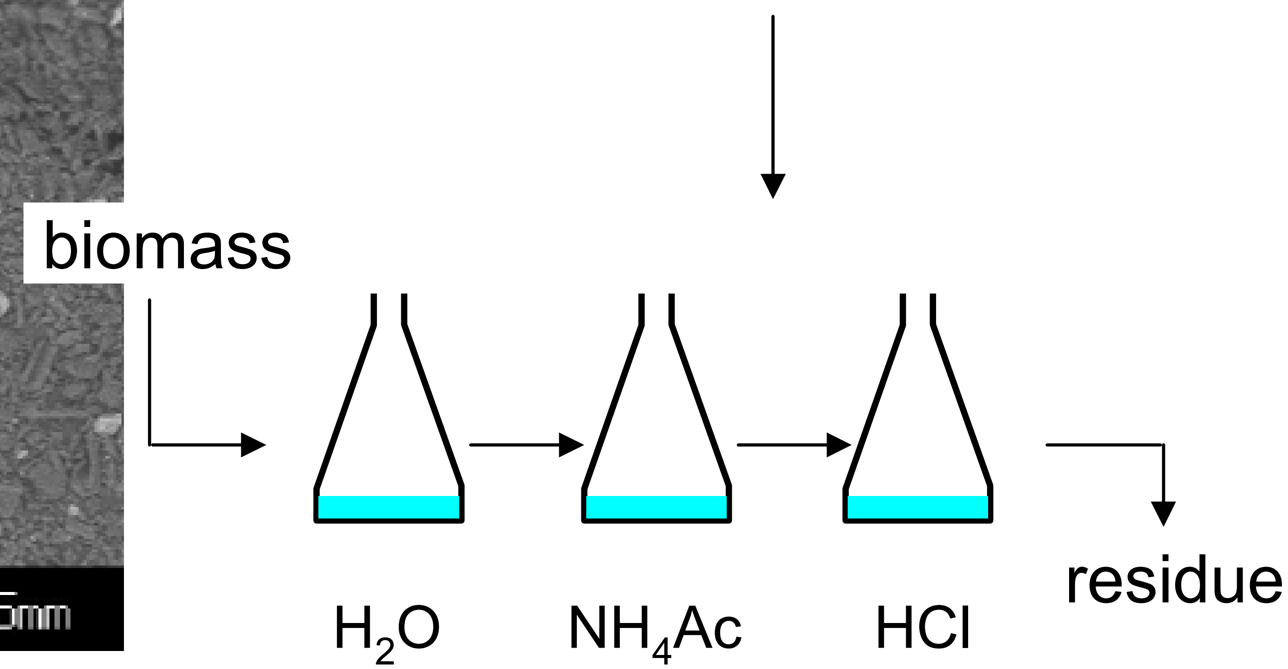
Ash forming species in biomass

Biomass (bark) sample in electron microscope

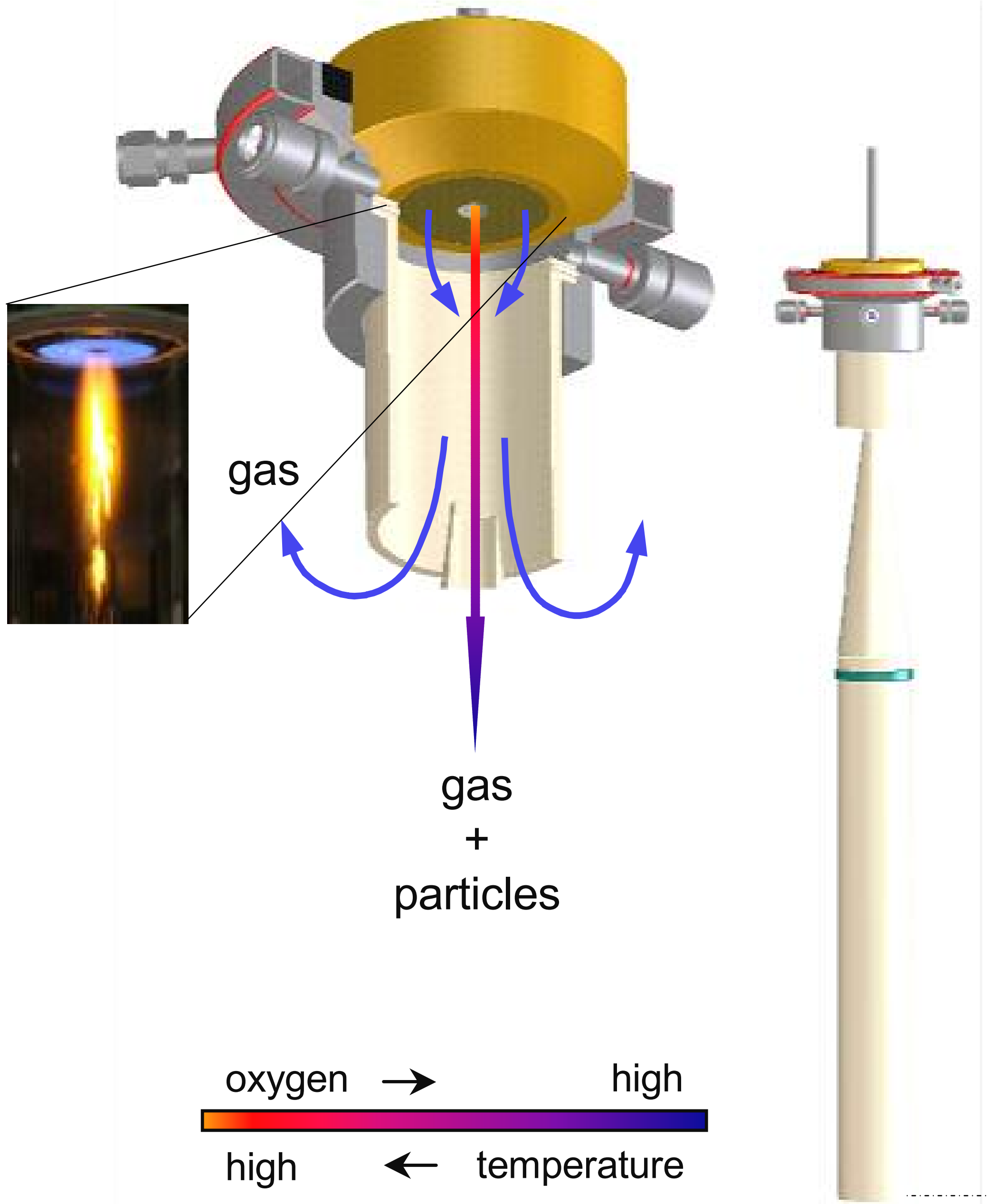


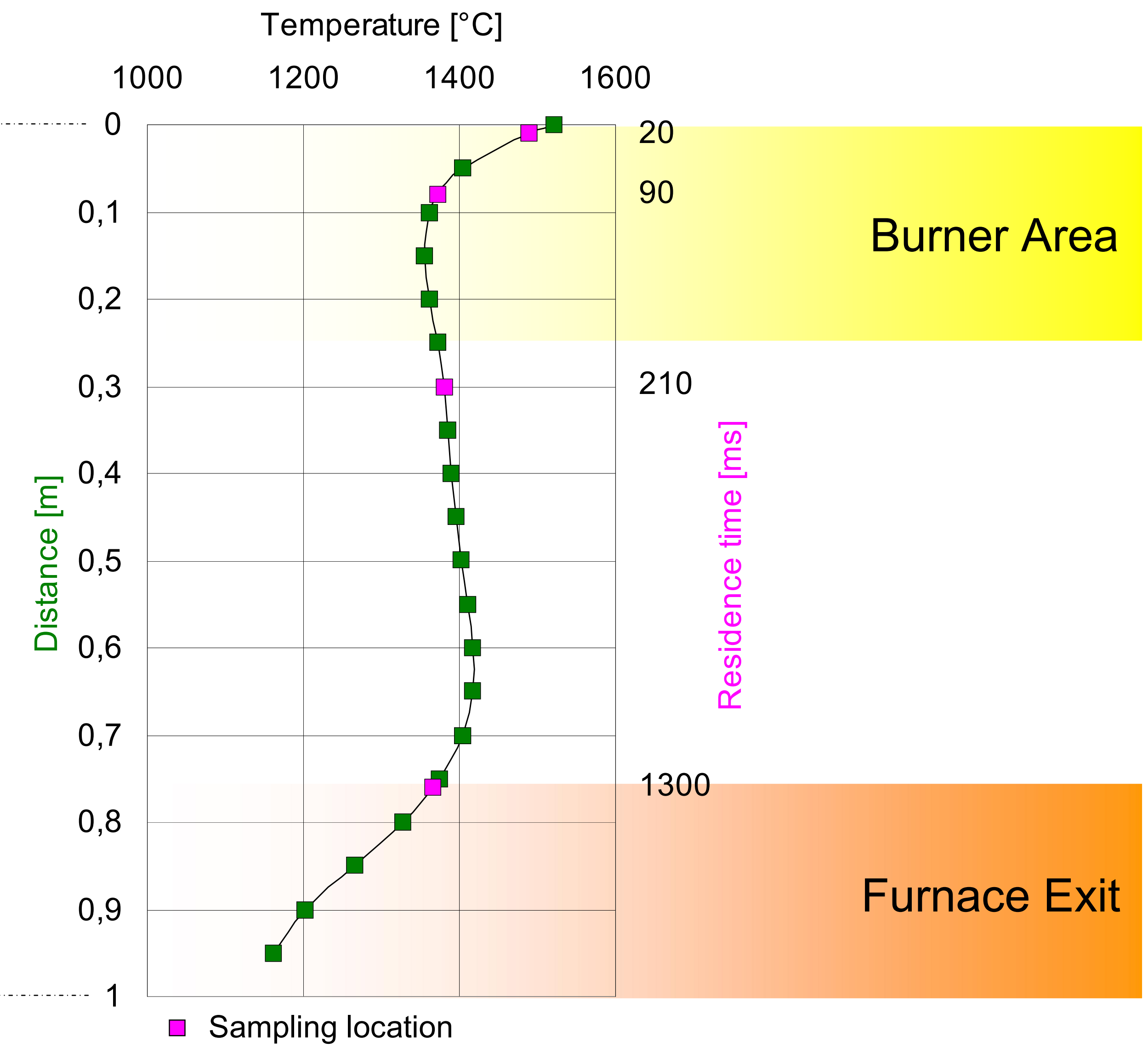
- typically three reactivity groups
  - (1) biominerals
  - (2) organically associated
  - (3) water soluble salts
- minerals quantified by CCSEM
- non-minerals quantified by CF

reactivity



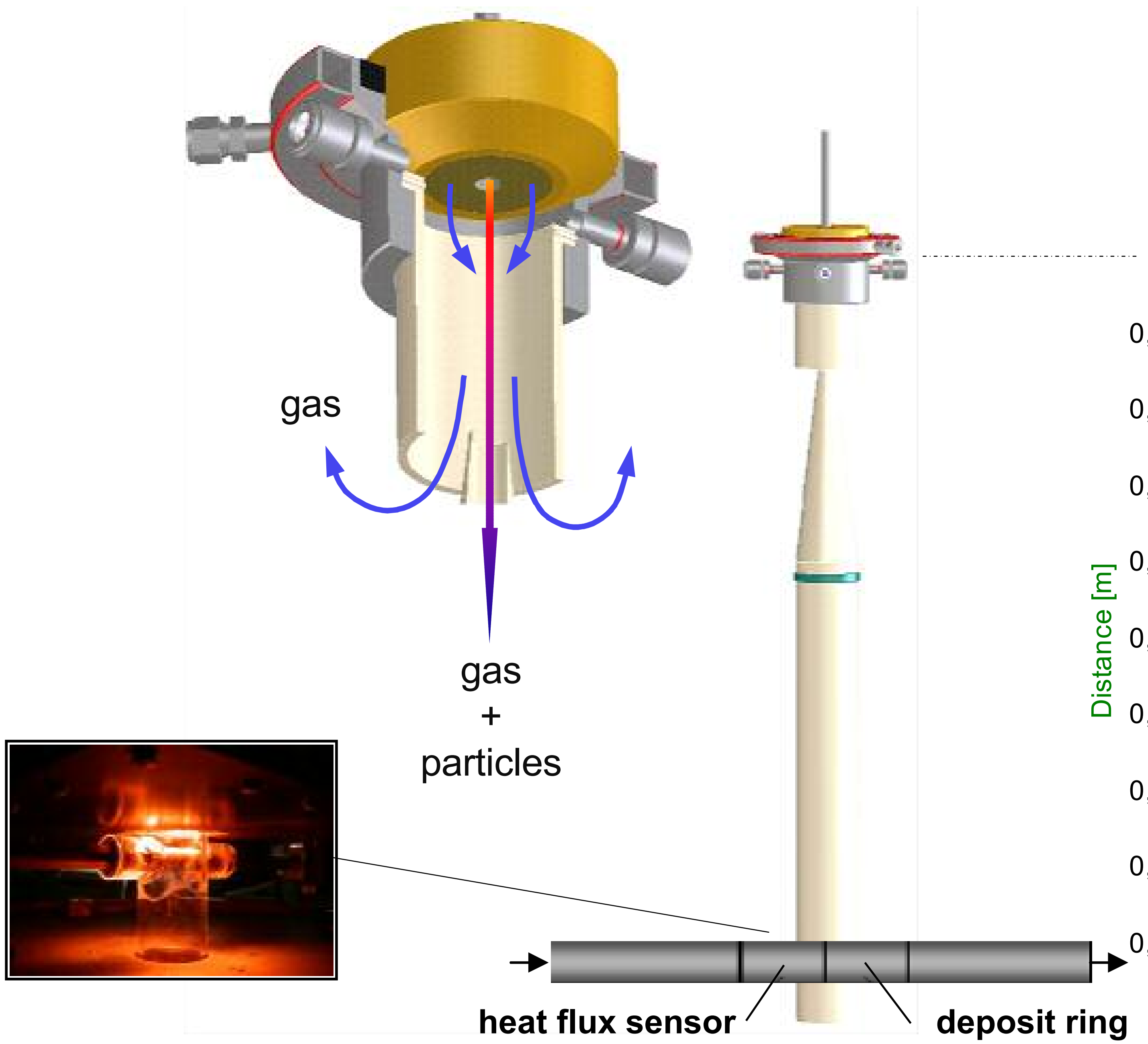
Experimental study of ash formation

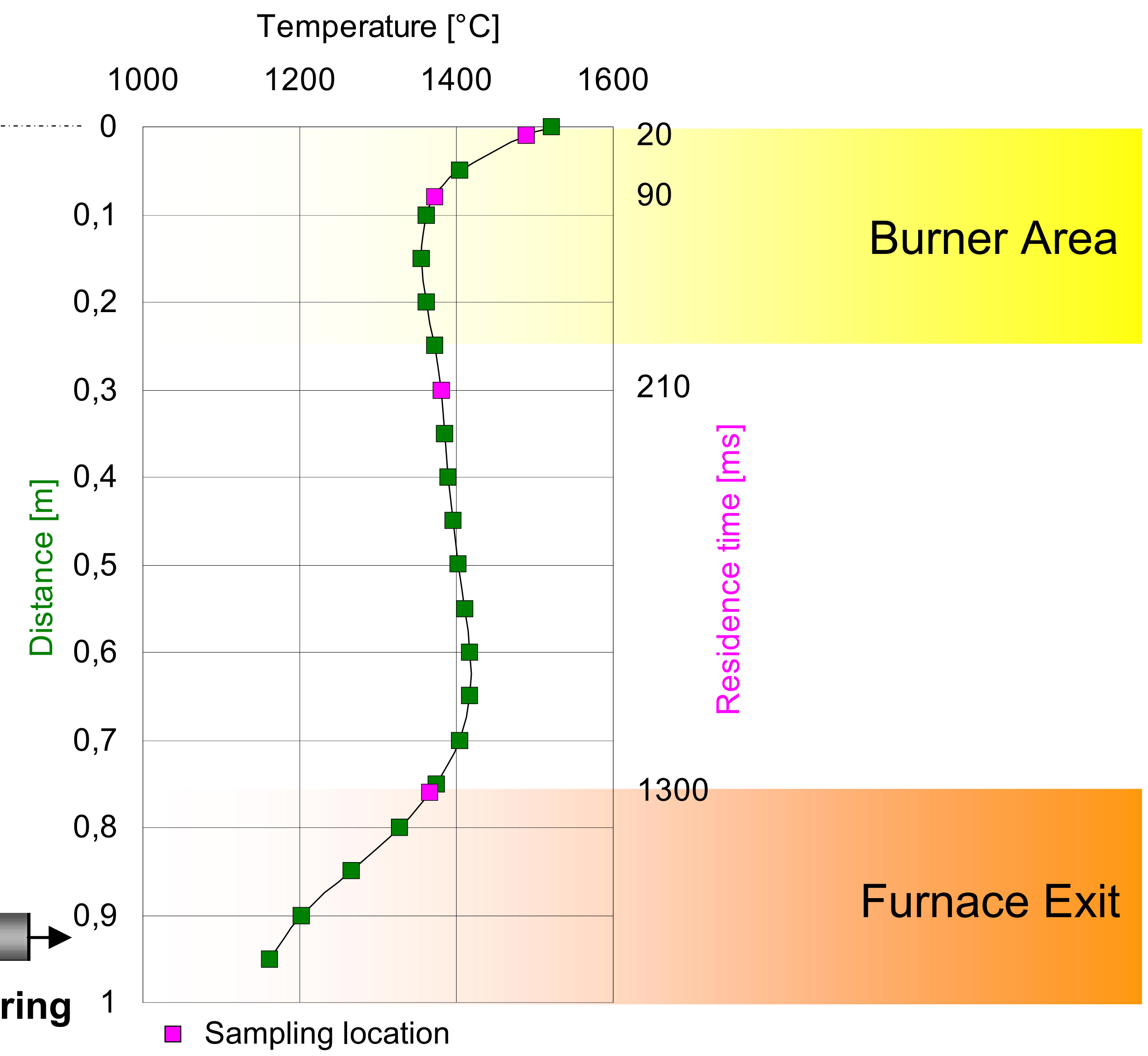




Lab-scale PF combustion facility

Experimental study of ash deposition



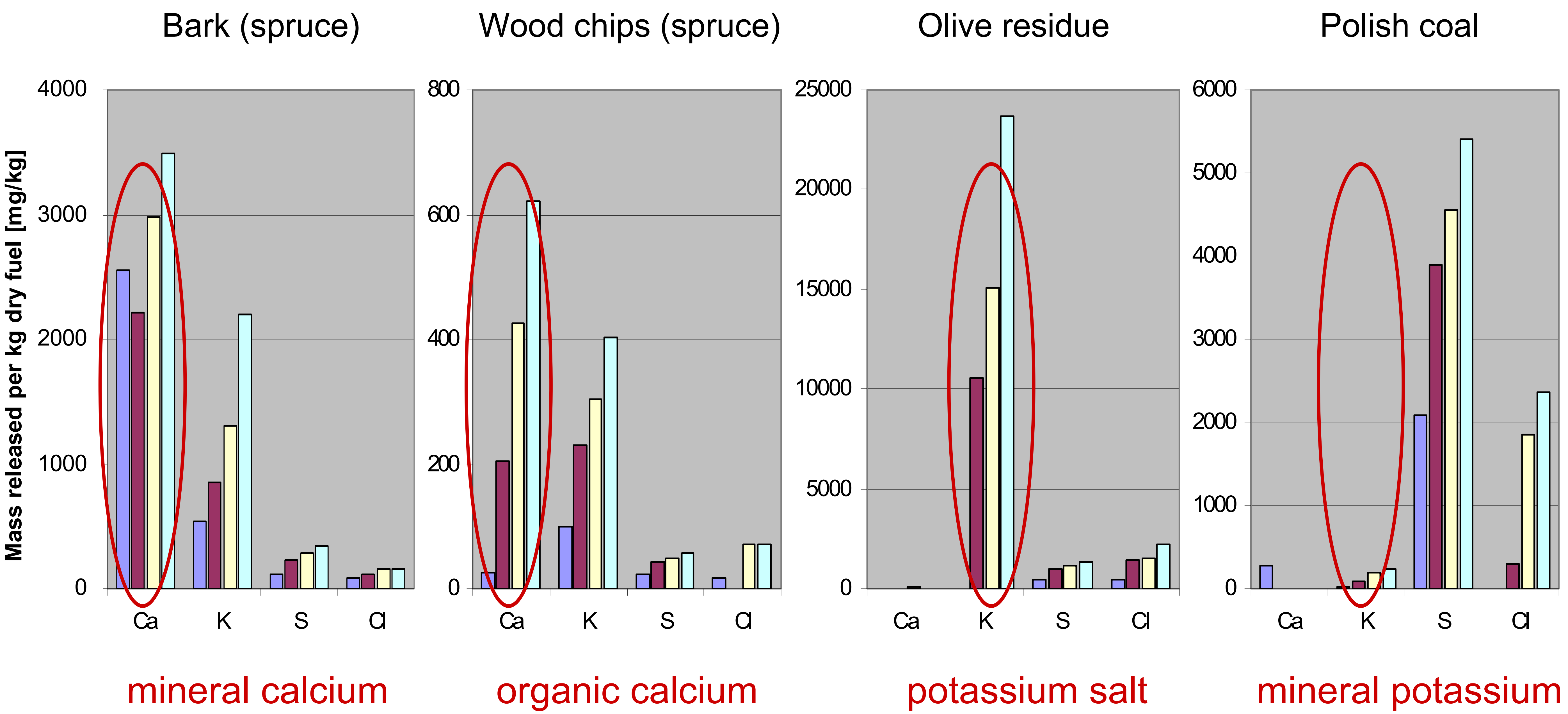


Lab-scale PF combustion facility

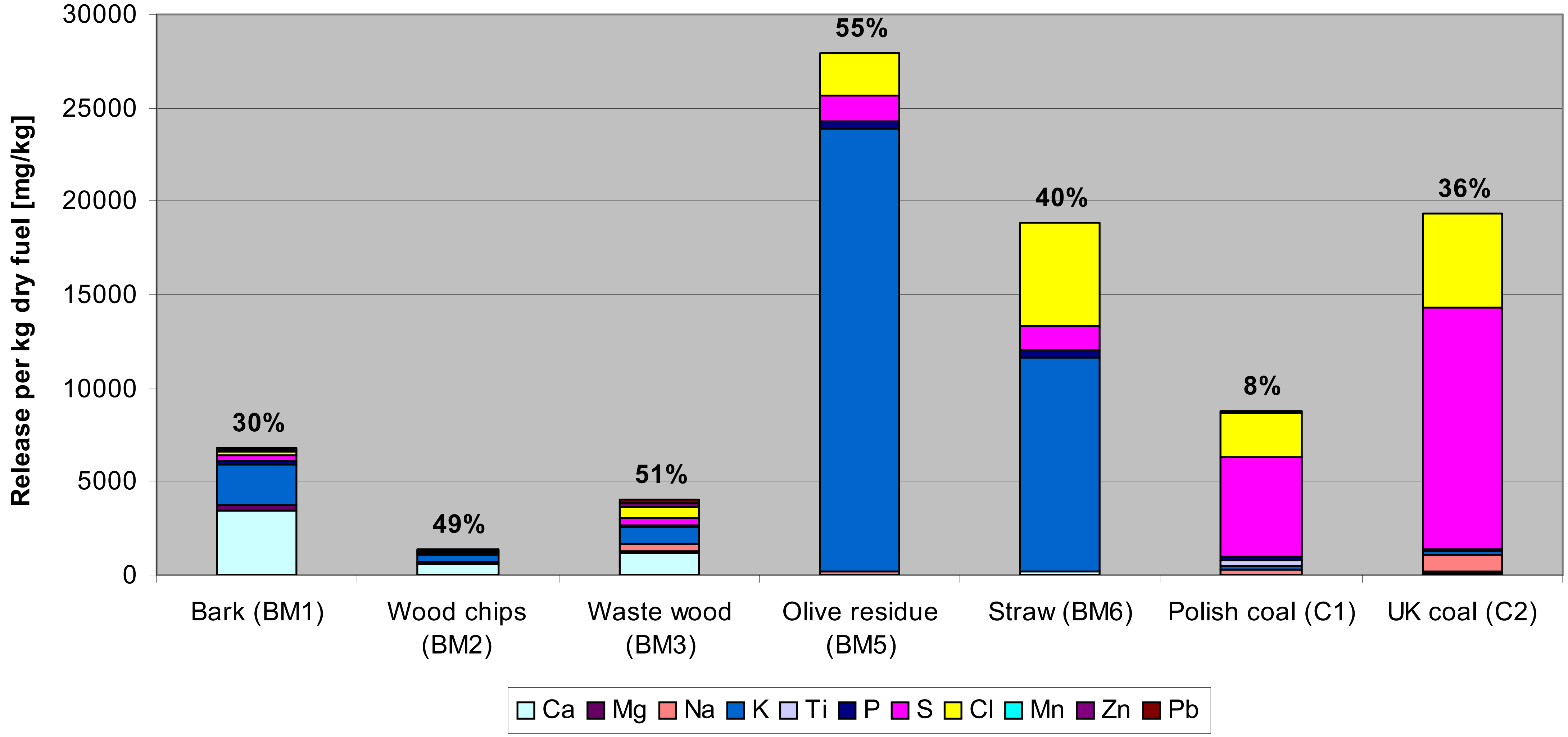
Ash formation test program

- Single fuel combustion tests with bark, wood chips, waste wood, saw dust, olive residue, straw, coal
- Analysis: proximate, ultimate, elemental composition, CCSEM (coals)
- Method developed to determine release of inorganic matter (excl. Si, Al, Fe) in Lab-scale pf Combustion Simulator
- Release determined as *any* inorganic matter released from fuel particles, being gaseous (volatile) or liquid/solid (non-volatile) species with a size ≤ 1 μm
- Release determined under same conditions for all fuels as a function of time in the range 20-1300 ms, covering devolatilisation to burnout

Ash release results – top-4 elements



Comparison of ash release between fuels



Release biomass very different from coal:

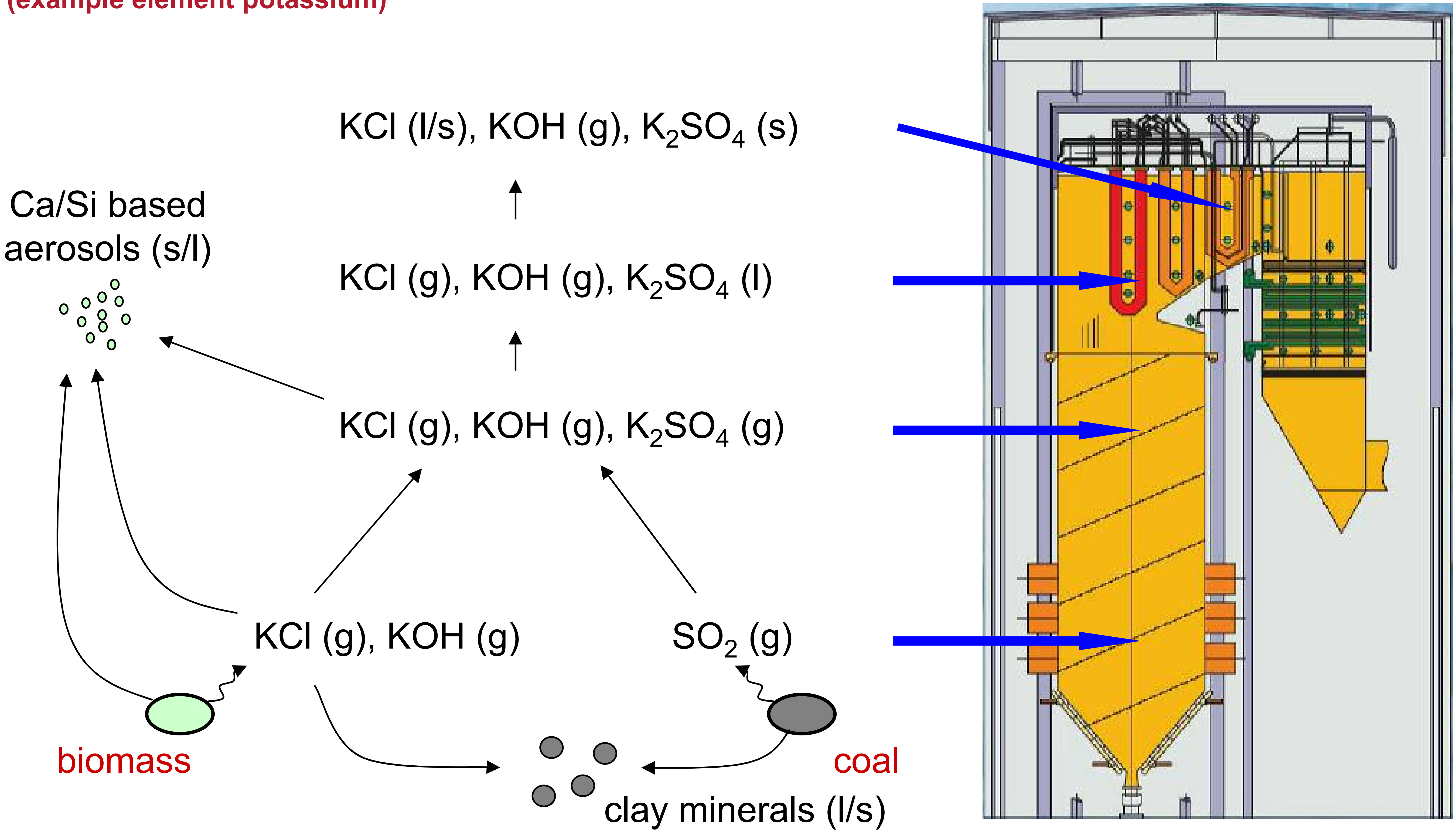
- total release biomass 30-55% (incl. S and Cl)
- total release coal 0.3-2.6% (excl. S and Cl) or 8-36% (incl. S and Cl)

Ash release - conclusions

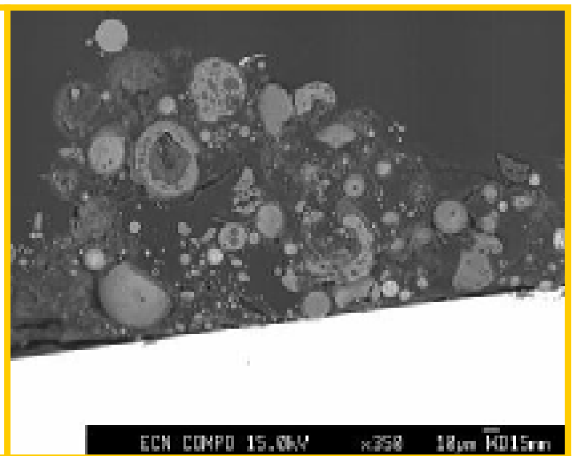
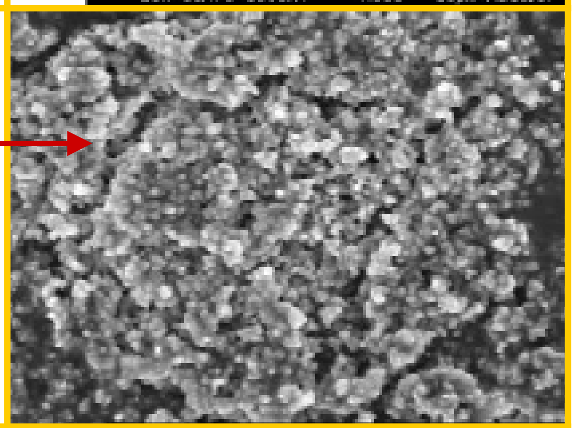
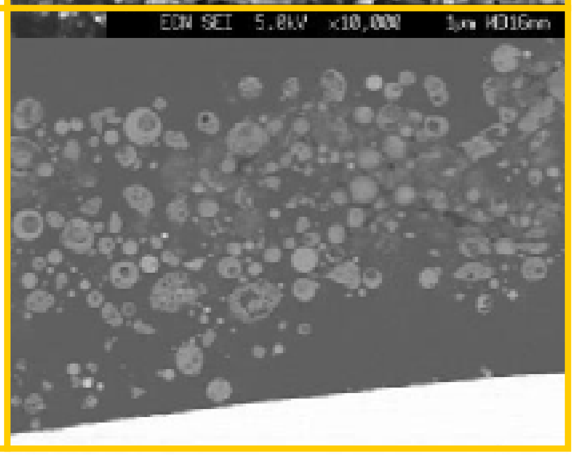
- Release different wood fuels very similar, in range 49-51%; release bark, straw and olive residue 30%, 40% and 55% respectively; a typical coal releases ~8% (S)
- Huge difference in absolute release; measurements ranging from 1350 to 27600 mg / kg dry material (~8000 mg / kg for typical coal)
- Release is time dependent; significant release observed already at 20 ms, 70-80% release observed around 200 ms, additional release observed into burnout phase up to 1300 ms
- Release kinetics of individual elements believed to depend on their speciation
- Generalisation of data across biomass fuels results in three element groups:
  - Si, Al, Fe: negligible release (exceptions may exist for specific mineral fragmentation)
  - Ca, Mg, Mn, P, Ti (waste wood): 20-50% released
  - Na, K, Cl, S, Zn, Pb: 80-100% released, with Na and K at lower end of range
- Release from coal largely determined by mineral composition
  - Release dominated by S and Cl (nearly completely released)
  - Up to 50% release of Na observed when not bound to clay in coal

General understanding of fuel interactions

(example element potassium)



Interaction demonstrated in ash deposition

coal		minerals	
straw		KCl + silicates	
straw + coal (20/80)		minerals; no KCl !	

What does it mean ? (intermezzo)

- Biomass not necessarily problematic
- Solutions possible
- Perhaps even opportunity for improvement of operation (synergy)

It also means:

- Bulk analyses biomass inorganics such as Ash Fusion Test insufficient

Straw (pre-ashed) | 0 | DT | ST | HT | FT

Ash deposition – how to avoid problems ?

Preventive

- Appropriate fuel analysis to determine speciation or even specific thermal behavior
- Produce fuels with better properties, e.g. through torrefaction
- Blend fuels to reduce problems like strong thermal insulation, sintering, low-T melts, or high-Cl compositions; requires knowledge / predictive tools

Control

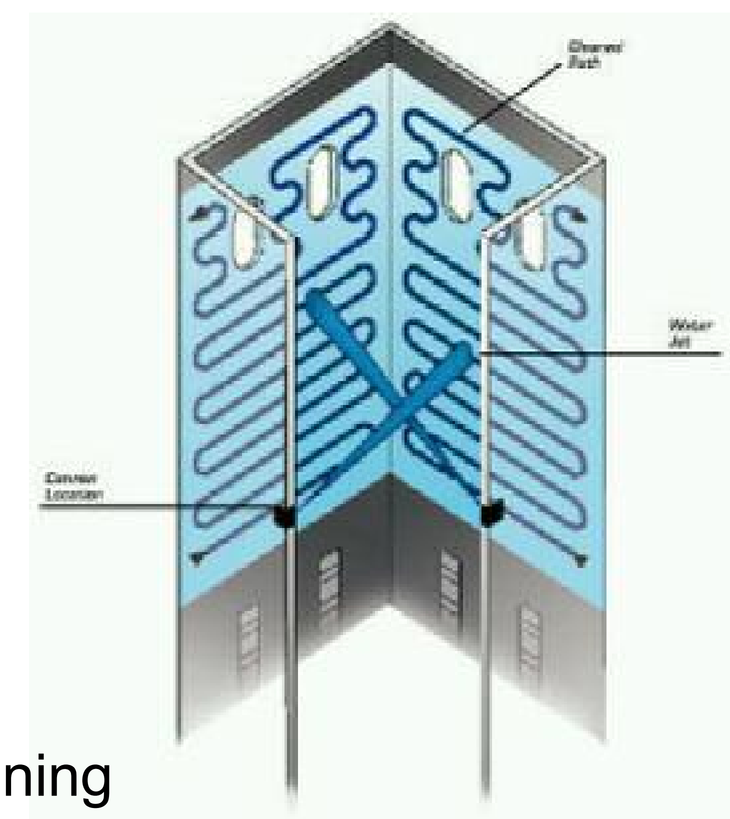
- On-line monitoring of ash deposition combined with ‘smart’ cleaning
  - Membrane walls: heat flux measurement + water cannons (Clyde Bergemann)
  - Super-/reheaters: section-wise evaluation using cleanliness factors (ratio of actual vs theoretical heat transfer rate)

Smart cleaning

Membrane walls

Clyde Bergemann system

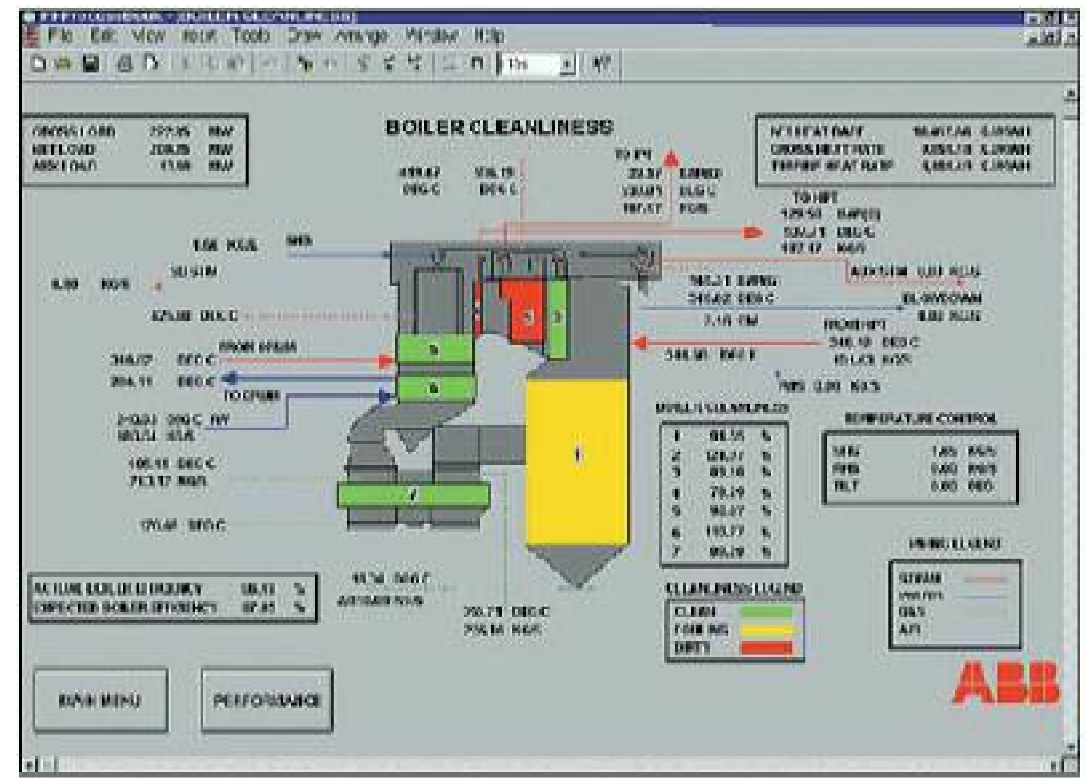
Heat flux measurement



Water cannon cleaning

Super-/reheaters

e.g. ABB system



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So, what else do we need ?

1. Data to quantify interactions and their impact on ash deposition
2. Technology for direct monitoring of super-/reheater fouling

Ongoing developments

Parametric ash deposition studies

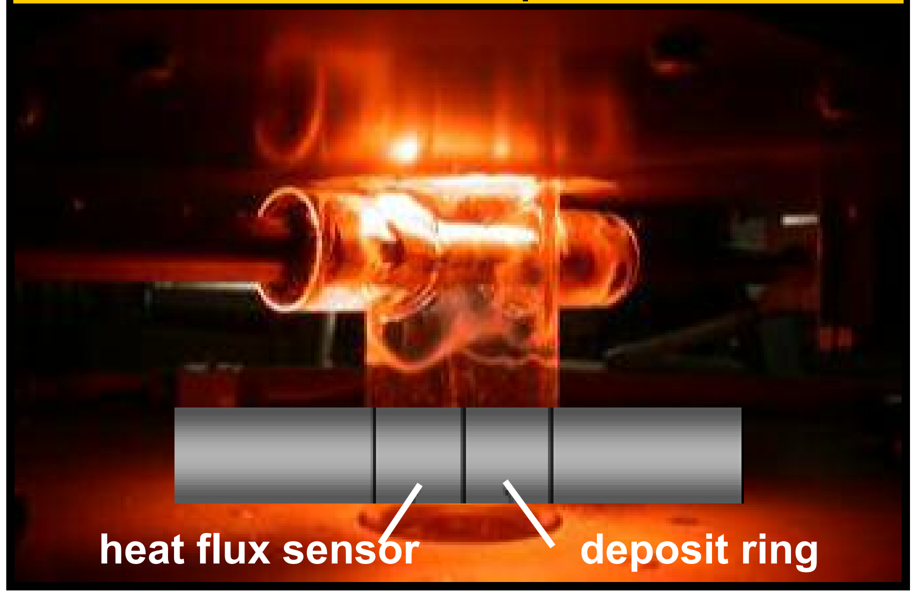
- Lab-scale testing

  parameters: fuel types, p_{SO2} (0-1000 ppm), biomass share (0-50%), surface temperature (450-750 °C), high-T alloys
- Full-scale testing & verification
- Thermodynamic calculations
- Model development

Technology development

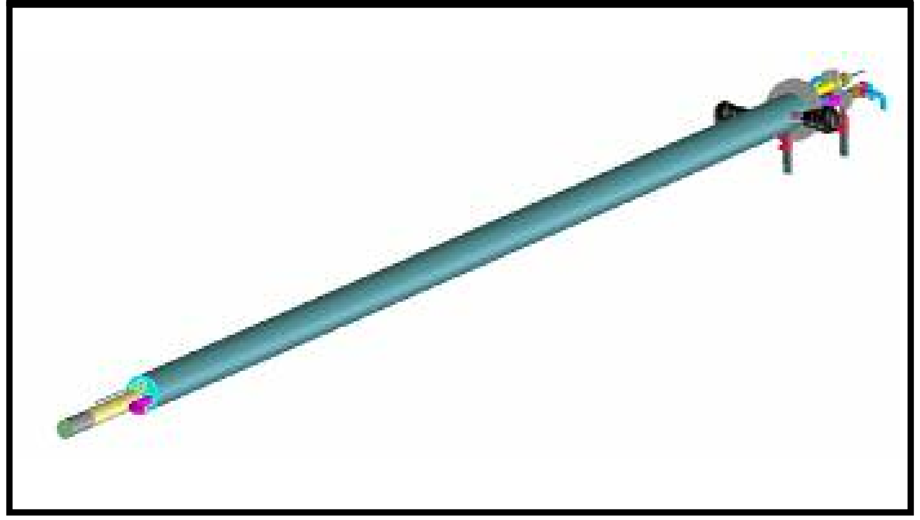
- Heat flux measurement convective area
  - access, wiring issues
  - signal interpretation
- Novel sensor systems

Lab-scale probe



deposit structure, bonding chemistry & initial corrosion: SEM-EDX
deposition rate in g/m^2s
heat flux in W/m^2K

Full-scale probe



Concluding remarks

- Ash from biomass and coal differ (a lot) in terms of formation and behaviour
- Low shares and clean biomass successfully handled
- Different biomass, or higher shares and more extreme conditions could also be handled, provided that fuel interactions can be predicted
- Ash formation of main-stream fuels has been mapped, providing essential input (knowledge) to deal with ash related issues
- Focus now on experimental quantification of fuel interactions to be used for deposition and related corrosion control
- Combination of predictive modelling and on-line monitoring key to successful management of ash behaviour

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Thank you !