# Relevant findings concerning the application of additives and fuel blending

Christoffer Boman (Associate Prof., Dr.)

International Workshop
Technologies for clean biomass combustion
20th of September 2012
Graz University of Technology, AUSTRIA

# Participants and contributions

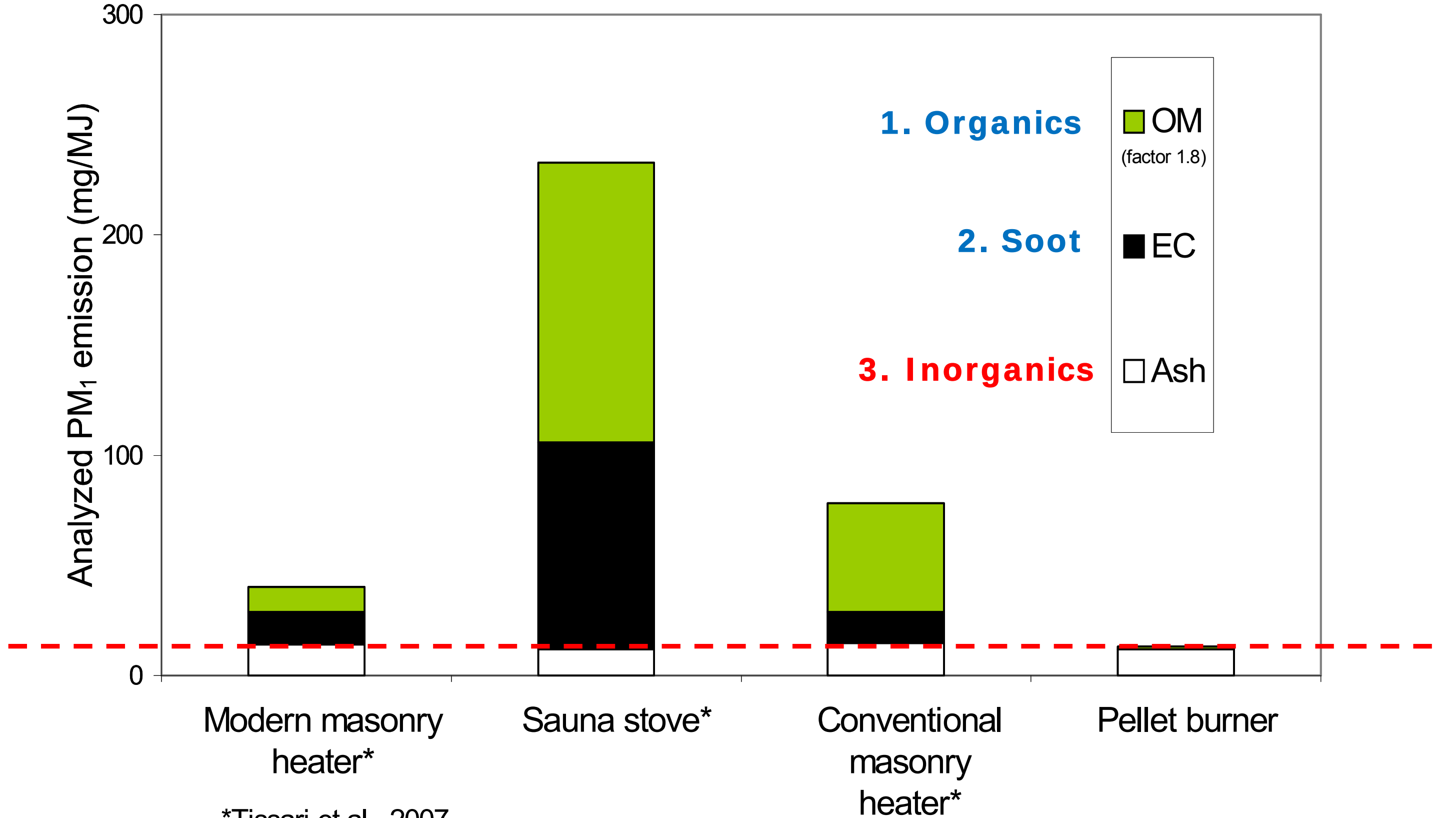
| | |
|---|---|
| **Sweden** | |
| Umeå University: | Christoffer Boman (Prof)<br>Dan Boström (Prof)<br>Jonathan Fagerström (PhD stud)<br>Erik Steinvall (PhD stud) |
| Luleå University of Technology: | Marcus Öhman (Prof)<br>Ida-Linn Näzelius (PhD stud) |
| SP Techical Research Institute of Sweden: | Linda Bäfver (Dr)<br>Fredrik Niklasson (Dr) |
| **Austria** | |
| Technical University of Graz: | Ingwald Obernberger (Prof)<br>Thomas Brunner (Dr)<br>Fritz Biedermann (Dr)<br>et al. |
| **Ireland** | |
| Teagasc, Crops Research Centre | John Carroll (Dr)<br>John Finnan (Dr)<br>et al. |

# Content

- Background of ash chemistry, aerosols and additives
- Fuel additives
  - state of the art
  - examples
  - recent work
  - regulatory issues and costs
- Fuel blending - state of the art summary
- Conclusions
- Research needs/Critical issues

# Background of ash chemistry, aerosols and additives

## Particulate emissions (< 1 um) from different small scale wood burning appliances – an example

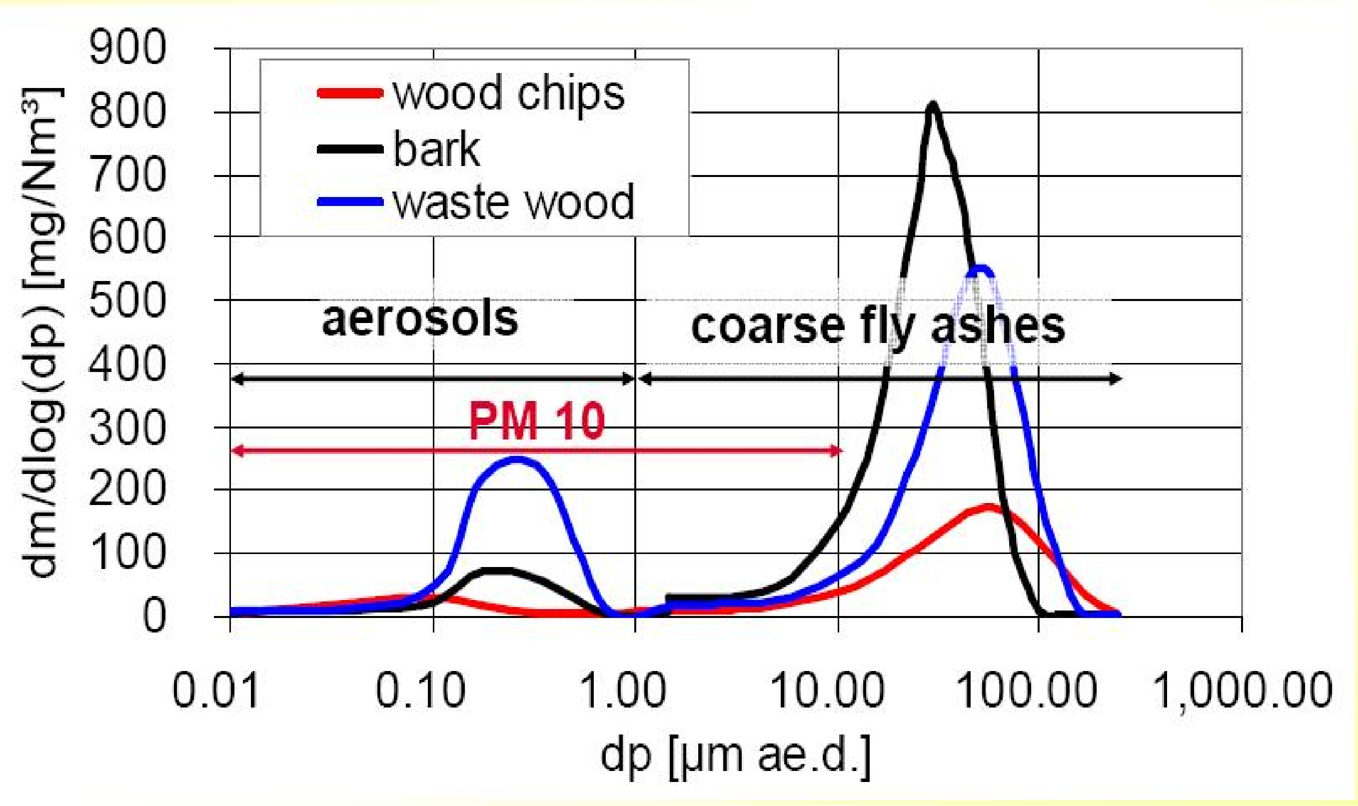



*Tissari et al., 2007

# Background of ash chemistry, aerosols and additives

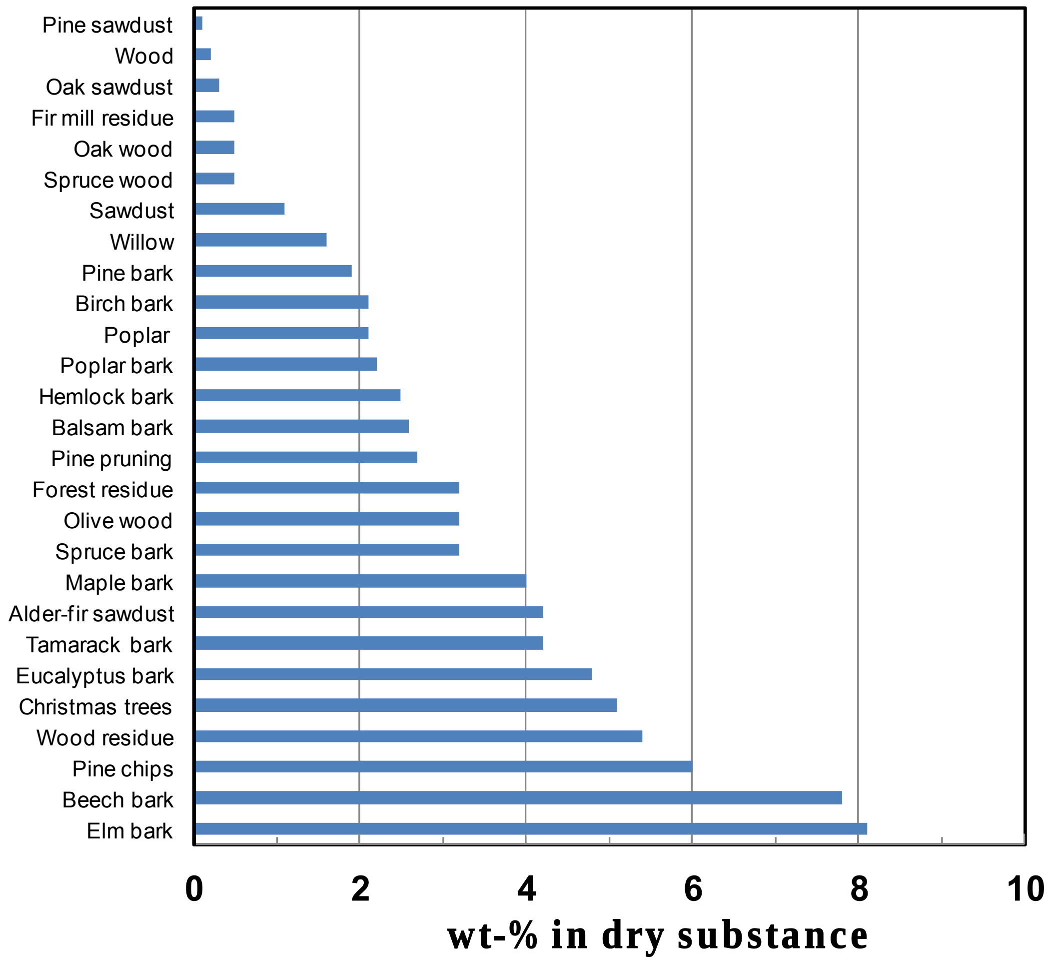
**Typical PM size distributions from a mid-size (0.44 MW) biomass combustion plant – effecient combustion → no soot and organics!**

(from Ingwald Obernberger, Graz Tech Univ.)



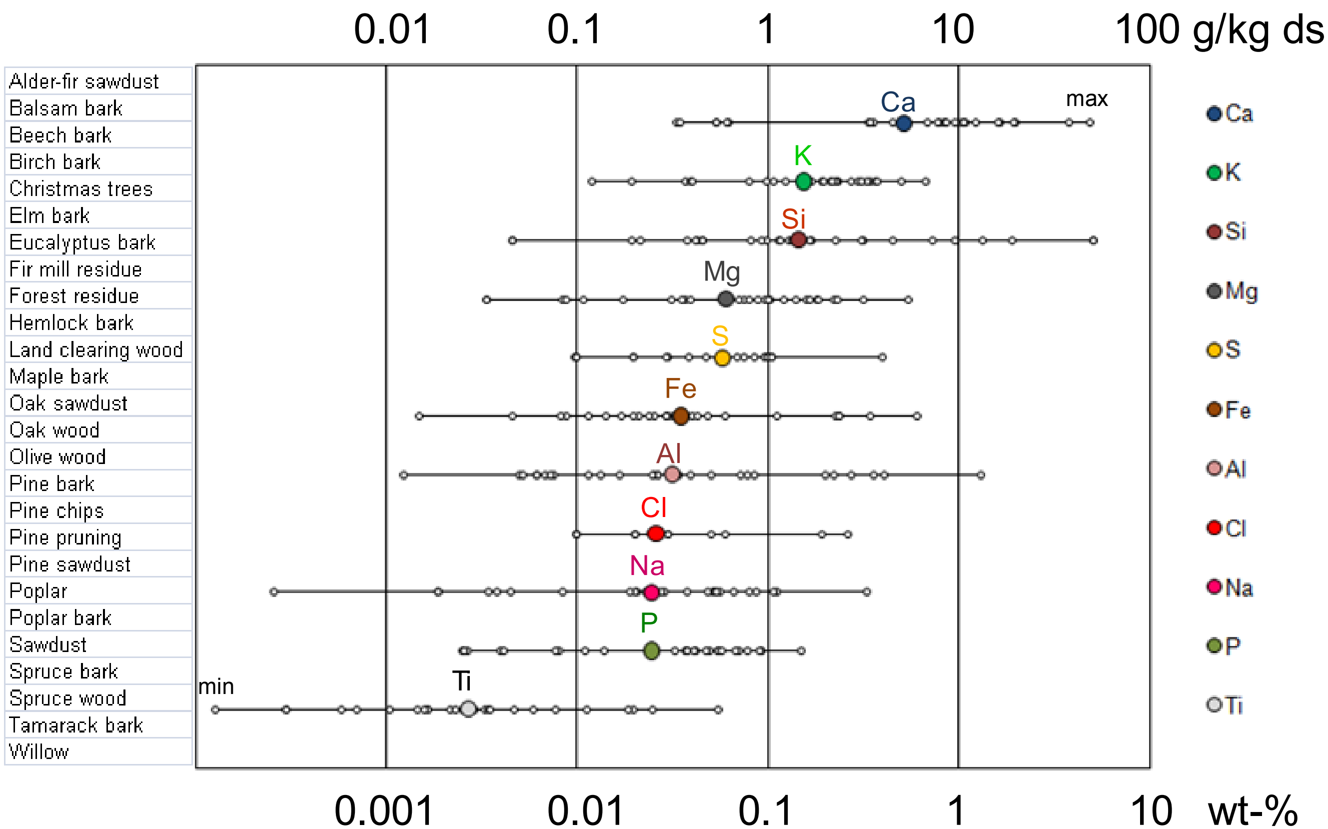
# Background of ash chemistry, aerosols and additives

## Ash content in some forest assortments



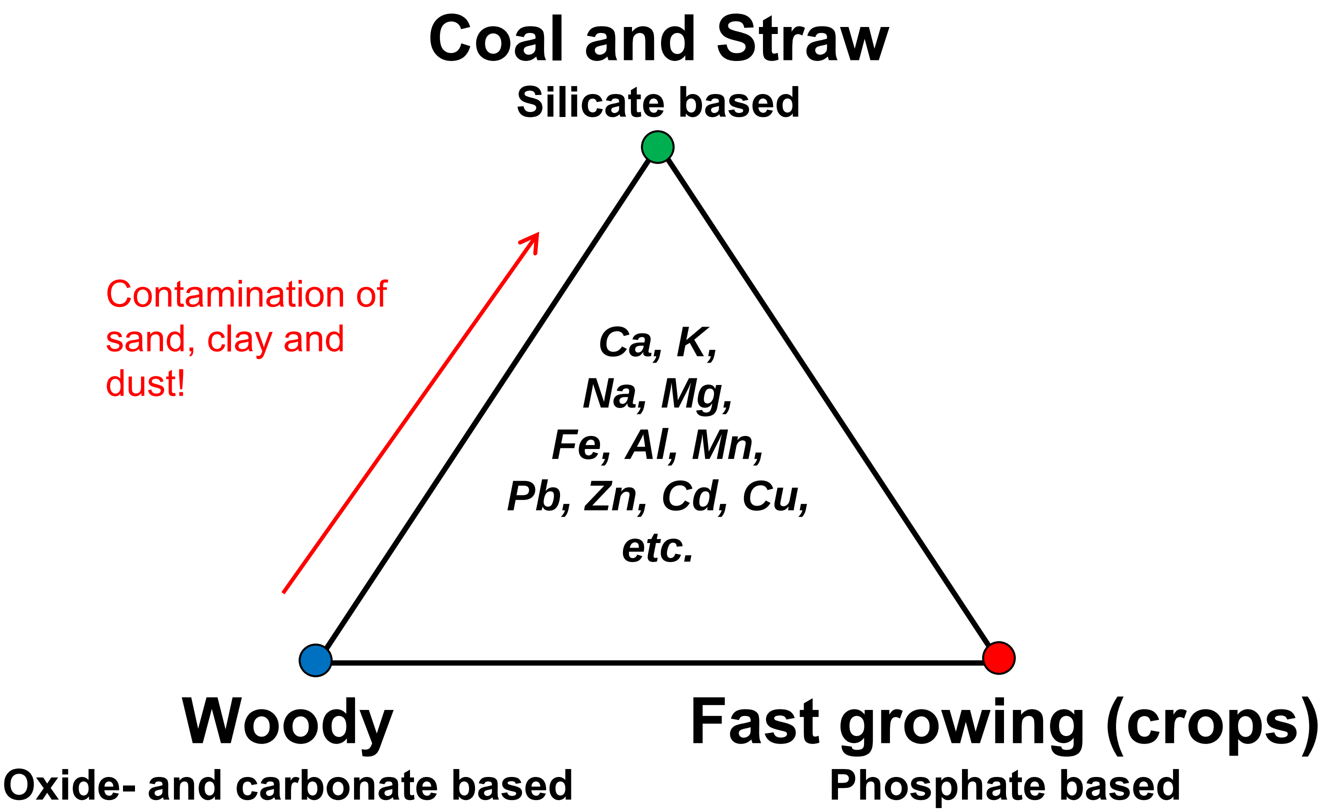
# Background of ash chemistry, aerosols and additives

## Ash forming (inorganic) elements in woody fuels



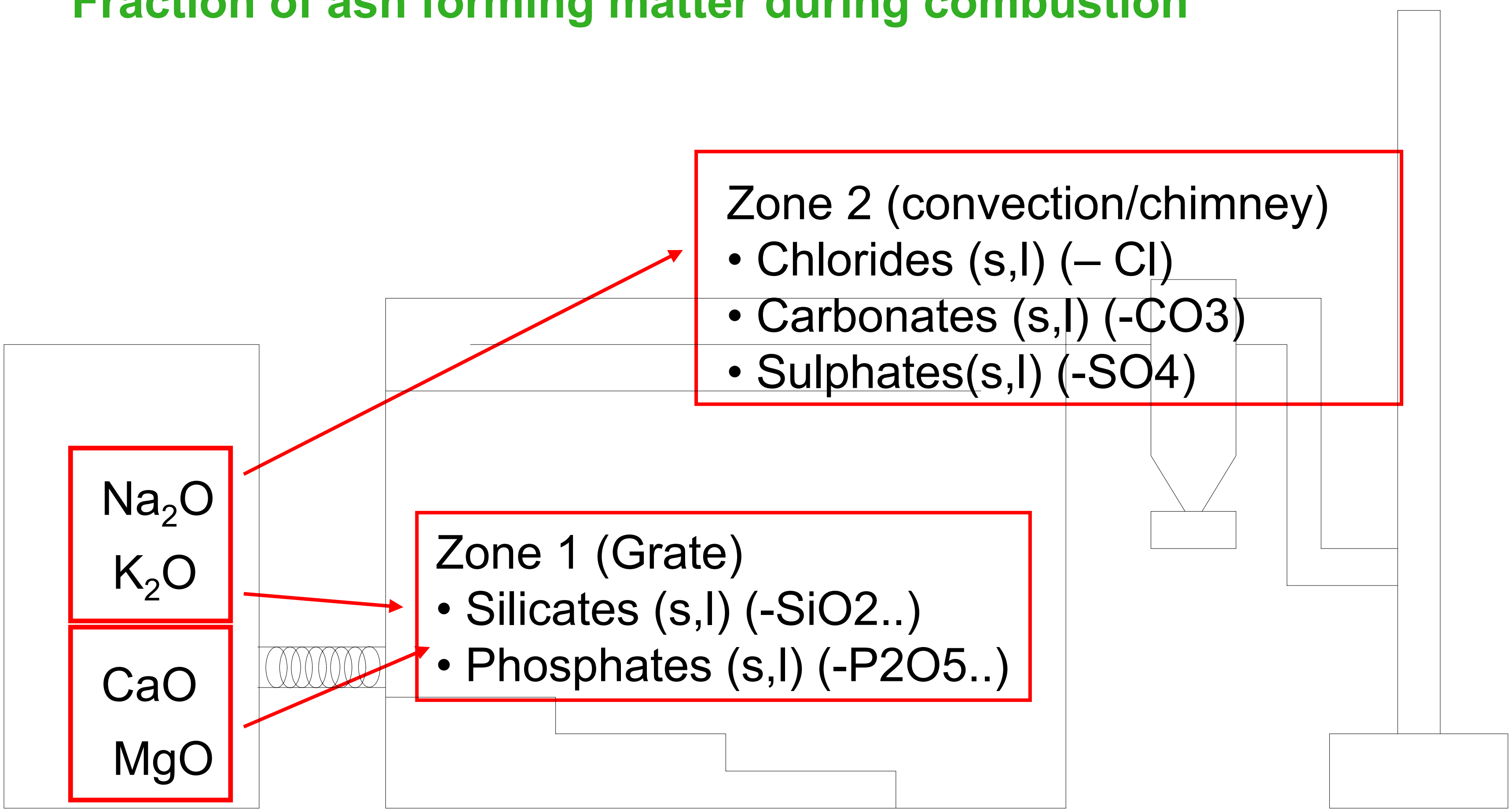
# Background of ash chemistry, aerosols and additives

## Different fuels – different ash chemistry



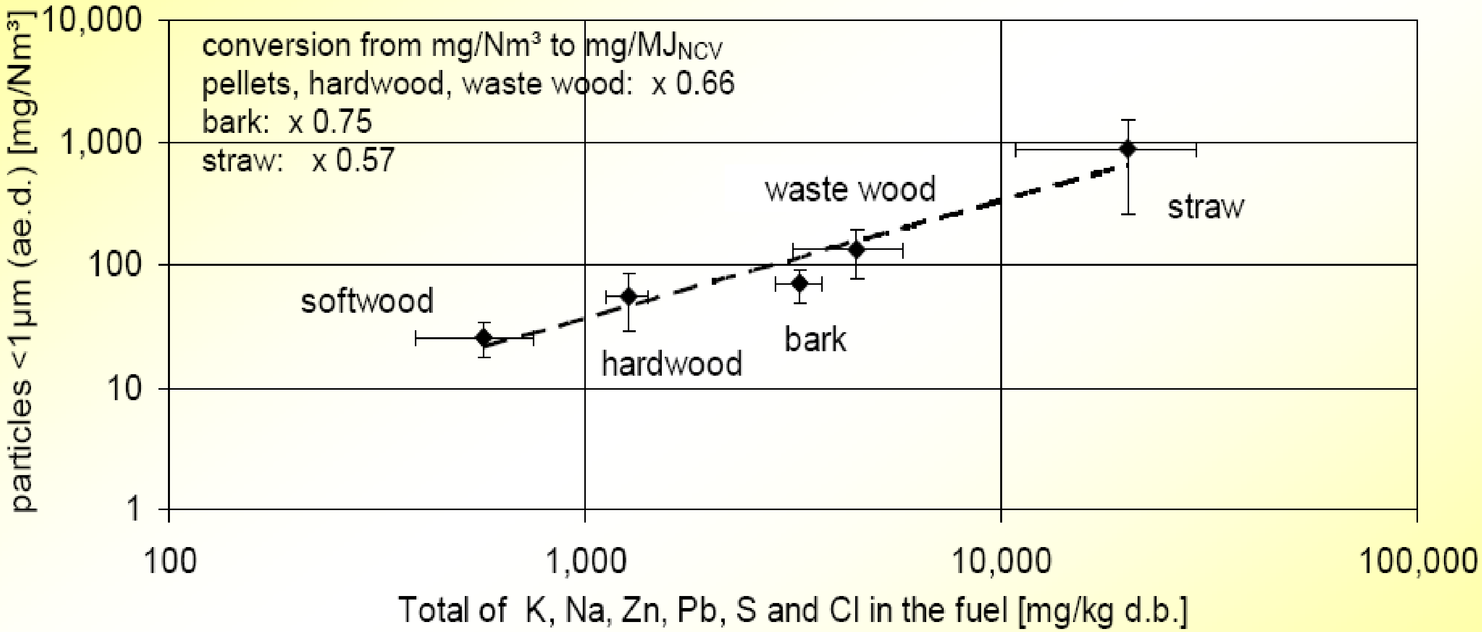
# Background of ash chemistry, aerosols and additives

## Fraction of ash forming matter during combustion



# Background of ash chemistry, aerosols and additives

## Higher ash content → higher fine ash PM emissions




Aerosol emissions in medium and large-scale biomass combustion plants compared with the concentration of aerosol forming elements in the fuel used

Explanations: emissions related to dry flue gas and 13 vol.% $O_2$; d.b. ... dry basis; results from measurements at grate-fired combustion plants in a capacity range between 400 $kW_{th}$ and 50 $MW_{th}$



from Ingwald Obernberger, Tech Univ. Of Graz

# Fuel additives – state of the art

**Basic principle of using fuel additives:**

Affecting the ash chemisty → Increased melting temperature and/or capture of K (and Na) in bottom ash → less slaggning and/or reduction of fine ash PM emissions!

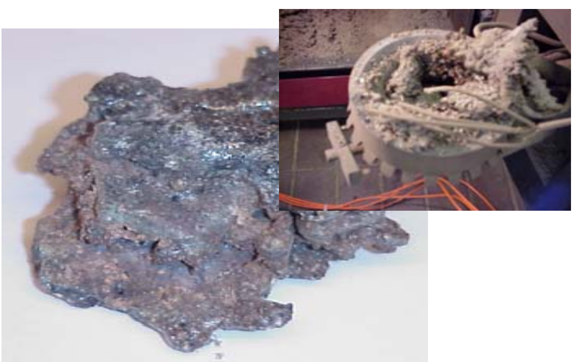
Main groups of additives, containing;

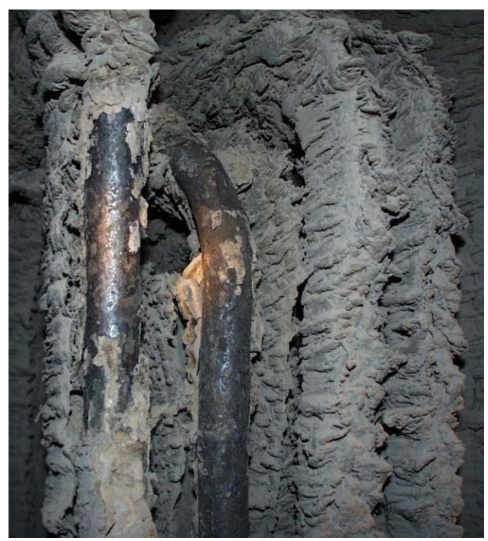
1. **Calcium**
2. Phosphorus
3. Sulfur
4. Aluminum
5. **Aluminum-Silicates**

- Either mixed and introduced together with the regular biomass fuel (e.g. chips or grains) or mixed into the raw material for pellets production
- Either via “dry” powder ad-mixing or via nozzel injections of a water slurry.

# Fuel additives – state of the art

- **In larger heat and power plants** fuel additives can be used to decrease the tendencies of bed agglomeration, sintering/slagging, deposit formation and corrosion.
- **In smaller (residential and medium sized) grate fired appliances** fuel additives may be used both for combating slagging problems and as a measure for reduction of fine particle formation.





# Fuel additives – state of the art

## Ca-based additives – summary:

■CaO, $Ca(OH)_2$, $CaCO_3$ and $CaMg(CO_3)_2$ has been used, both in fuel/bed and in flue gases, but **$CaCO_3$** is the main used Ca-additive (in one case also CaO) in studies of relevance for this area

■**Woody fuels (low P content, varying Si content):**

In fuel/bed, Ca-additives have mainly been used to prevent slagging in grate fired systems using woody fuels (low P, varying Si) – *rather limited number of studies performed though:*

***→ less slagging by formation of high-temperature melting Ca/Mg/(K)-silicates and oxides in stead of pure and low temperature melting K-silicates!***

***→ BUT, no direct reduction of K-release!***

■**Non-woody fuels (often P-rich fuels)** *very scaresly studied*:

→ potential to both reduce and increase the slagging tendencies, depending on the Si/P ratio!
→ no direct reduction on K-release!
→ changed composition of the fine aerosols (from K-phosphates to K-chlorides/sulphates)!

# Fuel additives – state of the art

## Kaolin based additives - summary:

- Kaolin is composed mainly of the mineral *kaolinite*; $Al_2Si_2O_5(OH)_4$

- Captures gaseous alkali compounds by binding potassium to the mineral, forming **K-Al-silicates** which have higher melting temperatures than the pure K-silicates!

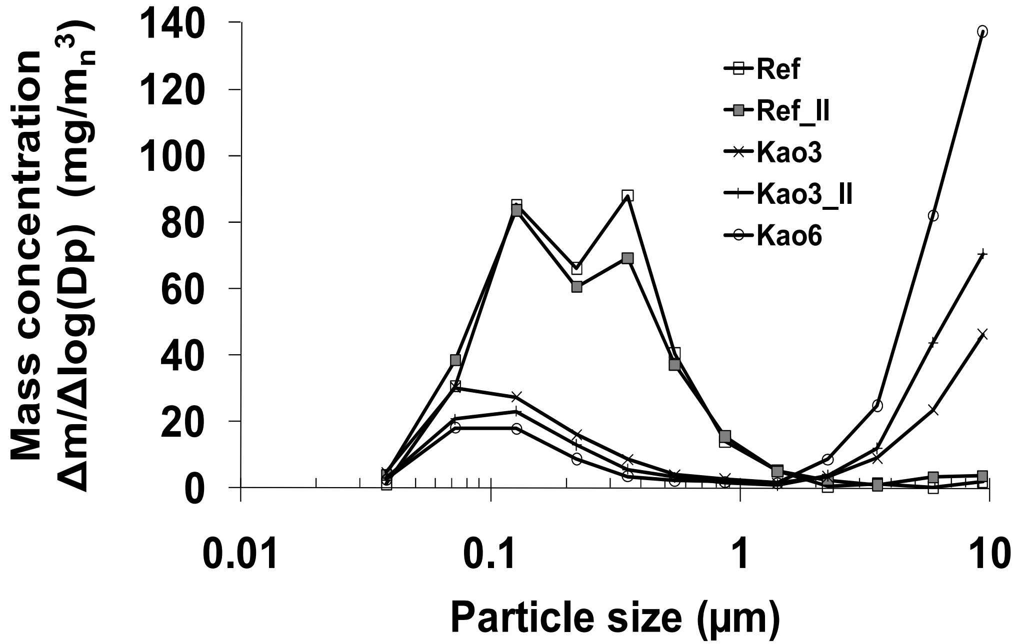
→ ***Slagging prevention and fine PM reduction possible in parallel!***

- Addition of kaolin have shown reduction of “released” K for fine ash PM formation in both woody and agricultural fuels!

- Increased HCl and $SO_2$ emissions as well as potential coarse fly ash, must be considered!

# Fuel additives – state of the art

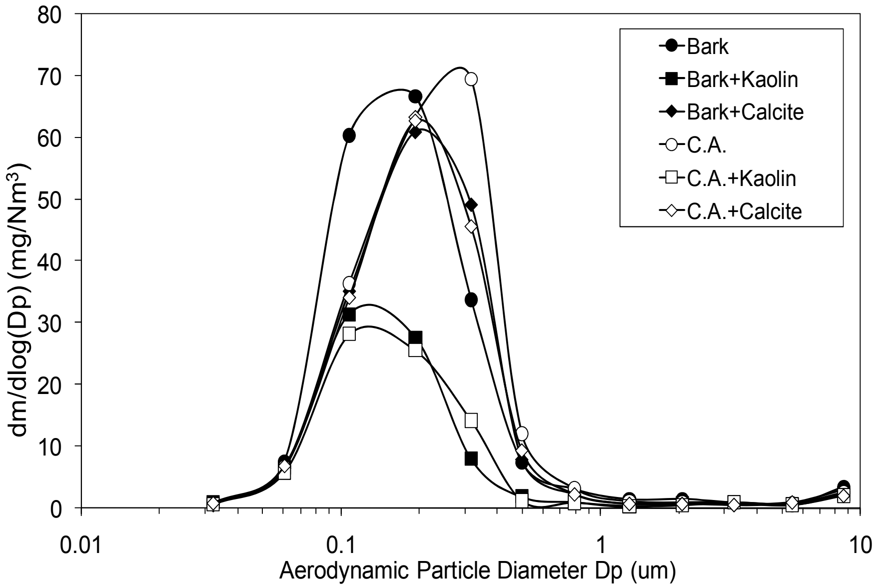
## Example 1:
## Kaolin addition to wheat straw in a multi stoker (65 kW)

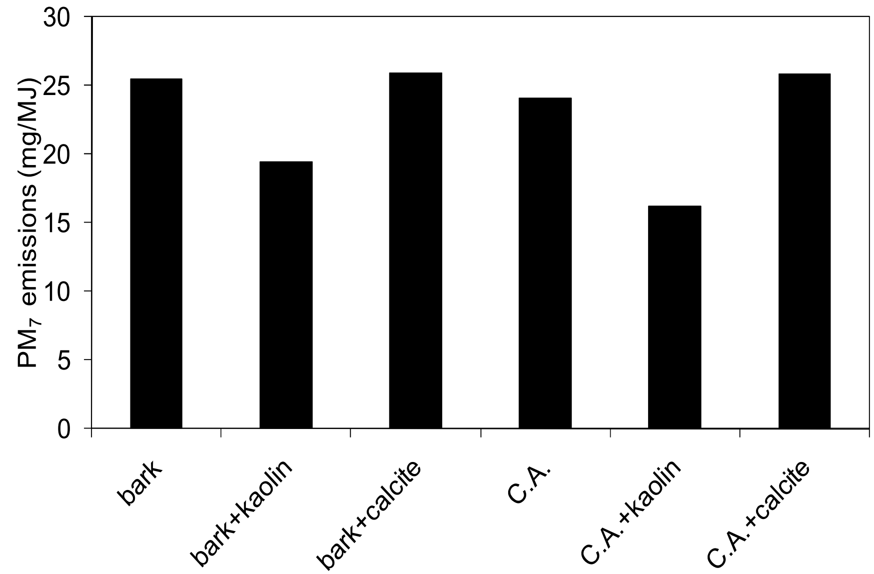



Bäfver L, Rönnbäck M. Case study: Small-scale combustion of straw pellets with kaolin as additive. Proc. Central European Biomass Conference, 26-29 January 2011, Graz, Austria.

# Fuel additives – state of the art

## Example 2:
## Kaolin and calcite addition to bark and cleaning assortment in a pellet burner (20 kW)




Boman C, Boström D, Öhman M. Effect of fuel additive sorbents (kaolin and calcite) on aerosol particle emission and characteristics during combustion of pelletized woody biomass. Proc. 16th European Biomass Conference and Exhibition, 2-6 June 2008, Valencia, Spain.

# Regulatory issues (standards)

## Standards for fuel additives

**The limiting levels for the use of additives in biomass fuels is regulated in the**
**CEN standard EN 14961.**

In part 1 (EN 14961-1:2010) ”Solid biofuels - fuel specification and classes - Part 1: General requirements”, a maximum level of 20 wt-% for addítives used in solid biofuels in general is given.

In part 2 (EN 14961-2:2011) ”Solid biofuels - fuel specification and classes - Part 2: Wood pellets for non-industrial use”, a maximum level of 2 wt-% for the use of additives is given.

In part 6 (EN-14961-6:2012) ”Solid biofuels - fuel specification and classes - Part 6: Non-woody pellets for non-industrial use”, no maximum level for additives is defined but should be stated for each fuel *(”type and amount to be stated”)*.

# Regulatory issues (standards)

- In the previous studies as reviewed in this report, the maximum additive level used (all studies, all fuels) has been 6 wt-%. However, for woody fuels the limiting level of 2 wt-% (i.e. for *wood pellets for non-industrial use*) was not exceeded in any case.
- In the present *Futurebiotec* project the maximum additive level used in the experimental studies in WP2 was 3 wt-% for softwood pellets and 7 wt-% for wheat straw pellets.
- A final remark here is that previous fuel blending studies as reviewed in this report have included admixtures of biomass and; rapeseed meal up to 30 wt-%, peat up to 40 wt-% and DDGS up to 50 wt-%.

# Costs of using fuel additives

- Costs of using fuel additives (direct and ash disposal) must be compared to the benefits and profits associated with the use of a specific fuel additive. (e g reduction of; investment costs in advanced flue gas cleaning (fine particle precipitation), operational/maintainance costs (e.g. slag, deposit and corrosion related) and potential emission charges.

- Example of direct costs for using two potential fuel additives, e.g. kaolin (clay) and calcite ($CaCO_3$) have been estimated in this report:

→ *Cost for the calcite additive (excl. shipping):* ***0.00010 €/kWh*** *(0.3% increased fuel cost)*

→ *Cost for the kaolin additive (excl. shipping):* ***0.00043 €/kWh*** *(1.3% increased fuel cost)*

- Example of additive related costs (excl. transpost etc.) for ash disposal

→ ***0 – 0.00043 €/kWh,*** *in this example up to 100% increase in ash disposal costs is seen, corresponding to an up to 1.3% increase in fuel cost!*

# Fuel blending – state of the art summary

## Fuel blending:

- Blending problematic biomass fuels with **peat** is an applicable measure to combat ash related operational problems (e.g. slagging, deposit formation and corrosion) and fine PM emissions. The considerable heterogeneity of different peat types (variation in ash forming elements) must be considered and specific co-combustion applications evaluated separately → Some general recommendations have still been defined.
- The use of **phosphorus-rich industrial residues** for co-combustion with low P-containing biomass fuels is a powerful measure for changing the total ash transformation. Residues tested so far are; rape seed meal (RM), wheat distillers dried grain with solubles (DDGS) and municipal sewage sludge. In addition, pure phosphoric acid has also been used in one research study.
- For grate fired systems very limited experience exist, with RM as the most studied, but it seems that a risk for increased fine PM emissions exist in parallel with a potential for reduction of slagging as well as HT-corrosion ($KCl \rightarrow K_2SO_4$).

# Fuel additives – Conclusions (I)

- Fuel additives of main interest; ***calcium*** based and ***aluminum-silicate*** based (e.g. clay minerals). In addition, the use of ***phosphorus*** based/containing additives may be of interest.

- Rather limited number of studies performed with focus on the use of fuel additives as a measure for fine PM reduction, in this project 7 studies reviewed.

- Ca-additives (mainly $CaCO_3$) have mainly been used with good results to prevent slagging in grate fired systems using woody fuels, but with no direct reduction shown of K-release (i.e. fine particle formation)

- Kaolin clay (mainly composed of kaolinite, $Al_2Si_2O_5(OH)_4$) are well known by its ability to capture gaseous alkali compounds, forming e.g. K-Al-silicates which have higher melting temperatures than the pure K-silicates

  → Both slagging prevention and fine PM reduction have been shown possible!

- Aspects of limiting additive levels (standards) and ash disposal handling/costs must be considered, still probably of no great concern presently.

# Fuel additives – Conclusions (II)

- Fuel additives is well applicable for changing the ash chemistry during combustion of “problematic” biomass fuels and combat both operational ash related problems and fine PM emissions. However, very few demonstration/implementation projects have been performed.
- Pelletized biomass enables a perfect fuel form for designing the fuel and its combustion properties by applying the use of co-pelletized fuel additives.
- Kaolin clay is a well suited and available fuel additive to reduce both slagging and fine alkali PM emissions in combustion of more ash rich biomass fuels. **Up to 90% reduction of fine PM emissions have been shown.**
- The use of fuel additives should be considered as a case-specific measure since also effects on e.g. coarse fly ash formation, ash disposal and fuel costs should be considered. Based on this project, these aspects seems however not to be of any major drawback compared to the significant potentials of using fuel addives.

# Research needs/Critical issues – Fuel additives

- Optimal additive-to-fuel ratios for specific fuels/mixtures with simultaneous respect to;
  → Reduction of fine ash PM emissions (alkali release)
  → Reduction/avoiding slagging
  → Considering the influences on coarse mode PM
  → Considering the influences on acidic gases emissions ($SO_2$ and HCl)

- Potentials of using different additives together to achieve a multi-purpose concept

- Technical issues related to additive/fuel preparation and supply in different combustion technologies and type of applications, including fuel monitoring and process control

- Details related to the function of kaolin (or other clay minerals) in P-rich fuels

- Function of different studied additives under different combustion conditions, primarily regarding process conditions in grate fired small- and mid-size boilers

- (Function and suitability of fuel additives in gasification applications and powder boilers)

ERA-NET Bioenergy Future Bio Tec

# Research needs/Critical issues – Fuel blending

- Optimal fuel blends for specific fuels/mixtures with simultaneous respect to;
  → Reduction of fine PM emissions (alkali release)
  → Reduction/avoiding slagging
  → Considering the influence on coarse PM emissions
  → Considering the influence on acidic gases emissions (SO2 and HCl)
- Details of ash transformation and phase chemistry in systems with both Si and P
- Influence of fuel properties (fuel particle size, mixing, etc.) on the wanted ash chemical effects
- Technical issues related to fuel preparation and supply in different combustion technologies and type of applications, including fuel monitoring and process control
- Industrial implementation of an appropriate use of peat in co-combustion with biomass
- Studies of new potential industrial residues/fuels suitable for blending with biomass
- (Function and suitability of fuel blending in gasification applications and powder boilers)

ERA-NET Bioenergy

Future Bio Tec

# Acknowledgement to all national funders


Austrian Research Promotion Agency (FFG)

Tekes – the Finnish Funding Agency for Technology and Innovation

Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten

Swedish Energy Agency

NCBiR – National Centre for Research and Development, Poland

Sustainable Energy Authority of Ireland

# *Thank you for your attention!*