RESEARCH CENTRE FOR ENERGY RESOURCES AND CONSUMPTION

2nd WORKSHOP Cofiring biomass with coal
Copenhagen 27-28 March 2012



Co-firing comparison of two energy crops with coal in a pulverized fuel combustion pilot plant

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- Facility description
- Fuels and test plan
- Emissions results
- Deposition results
- Conclusions

Introduction

OBJECTIVE: The aim of the study is to perform an exhaustive comparative labor to investigate the effect on **emissions** and **fouling propensity** of **2 energy crops.**

Biomass is presented as a good opportunity to:

- **Reduce emissions** from fossil fuels
- Decrease **energetic dependence** on imported fuels for some European countries.
- Stimulate local economies.

Co-firing biomass and coal as one of the **easiest strategies:**

- **Existing technologies** → lower investments
- **Improvement** of emissions in coal power stations

Introduction

Biomass
- Residues (forest, agroalimentary)
- Energy crops (woody, herbaceous)

Poplar → short rotation woody crop
- → capability of adapting to different climate conditions
- → low nutrient requirements

Cynara → herbaceous energy crop
- → scarce water needs
- → Relative high heating value

Herbaceous biomasses → high content of **Cl** and **K** → Ash deposition problems →

→ Corrosion and erosion:

1. Rupture in heat transfer tubes
2. Steam leaks
3. Boiler shutdown.

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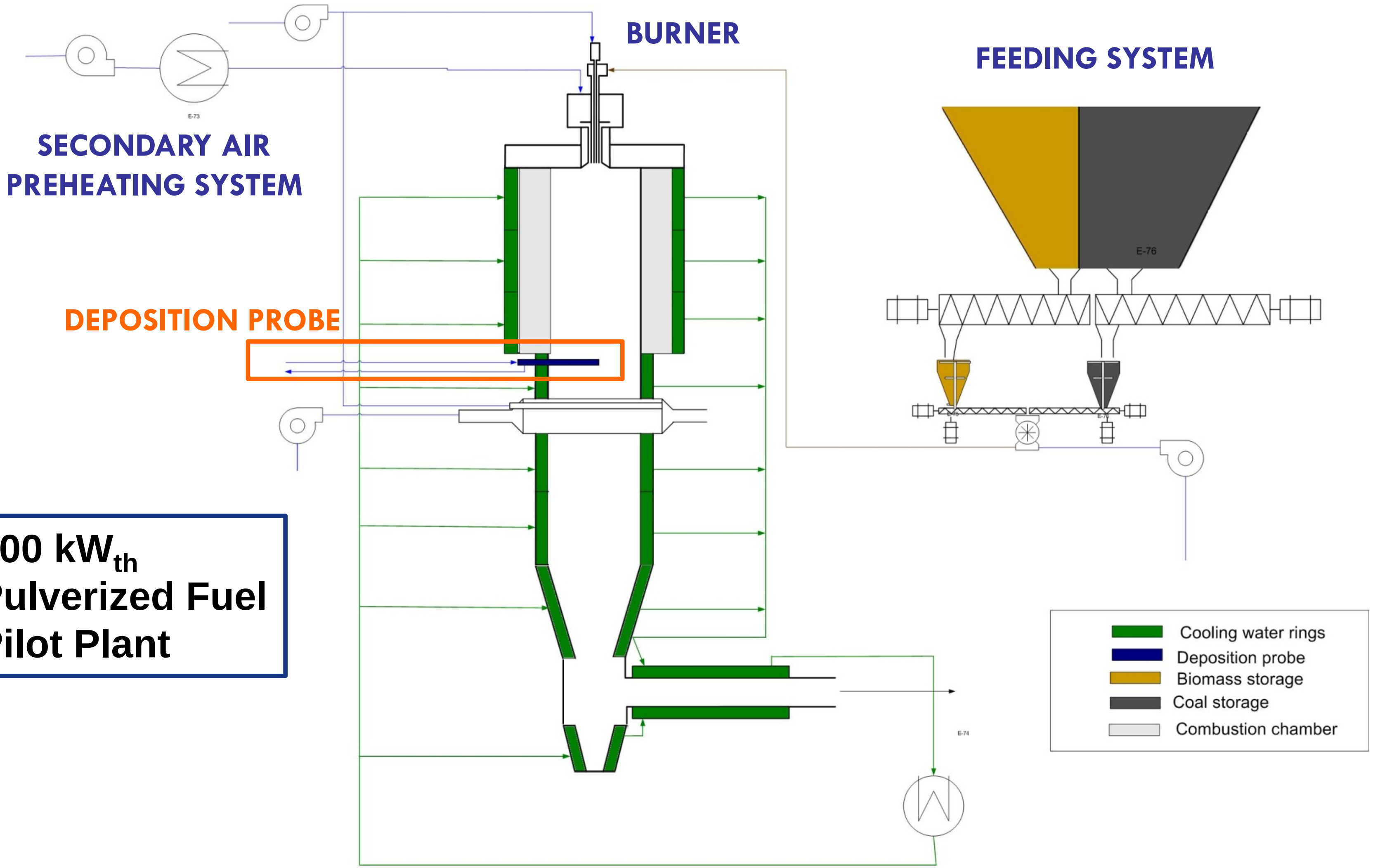
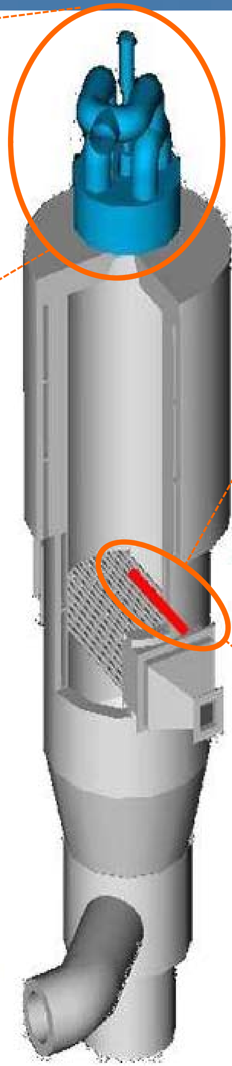
Facility description



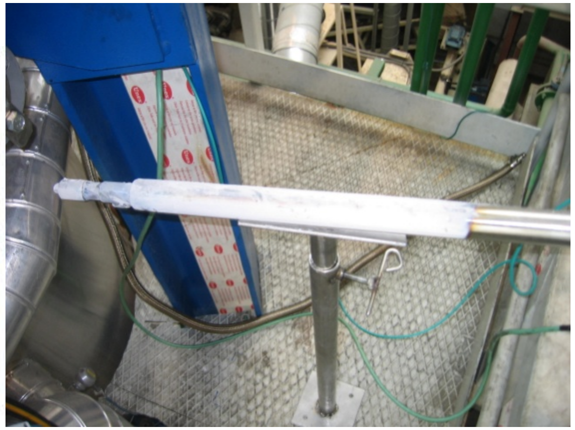
500 kW_{th}
Pulverized Fuel
Pilot Plant

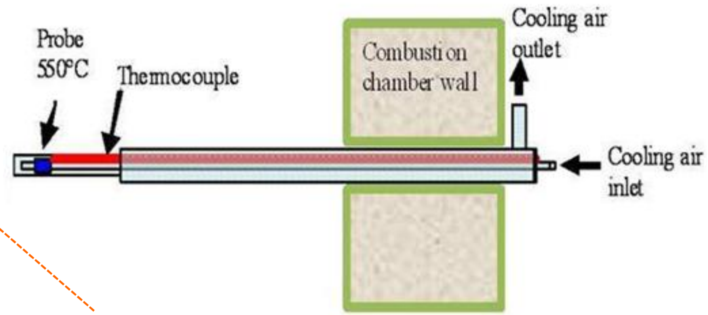
Facility description

500 kW$_{th}$ Burner



Deposition probe





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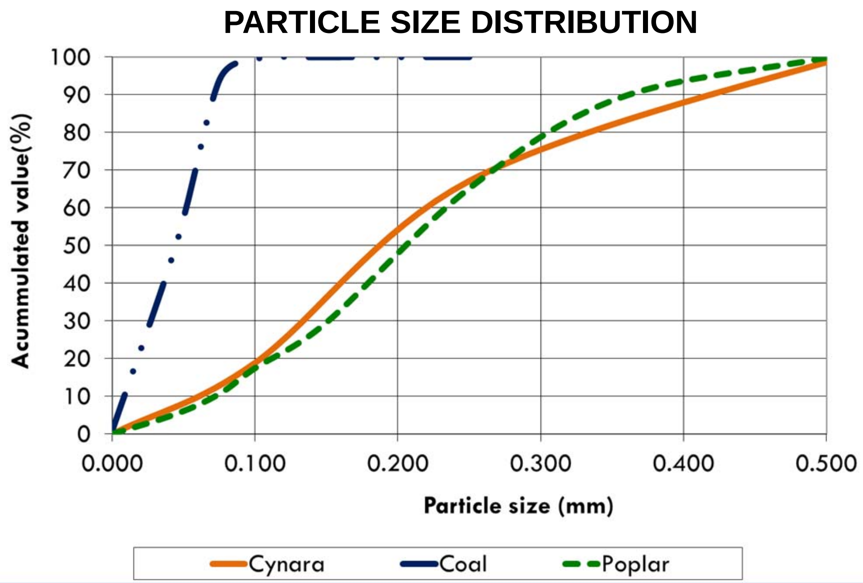
Fuels

	CYN	POP	SAC
Moisture	10.09	8.20	2.30
Proximate analysis (%wt, d.b.)			
Ash	6.61	3.24	14.60
Volatile matter	73.80	82.56	26.00
Fixed carbon	19.59	14.20	59.40
Ultimate analysis (%wt, d.b.)			
C	46.25	49.48	69.60
H	4.94	6.28	4.00
N	1.05	0.25	2.05
S	0.12	0.00	0.50
Cl	0.95	0.05	0.01
HHV (kJ/kg, d.b.)	19,320	17,220	27,800

COAL: Bituminous South African Coal (SAC)

Cofired with **2** different **BIOMASSES:**

- **Cynara** (CYN): herbaceous perennial plant
- **Poplar** (POP): short rotation woody crop



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Test plan

Base case → 100 % Coal test

Biomass shares → 5, 10, 15 %

Furnace Operating conditions:

Excess air ratio: 34%

Combustion chamber pressure : -200 Pa

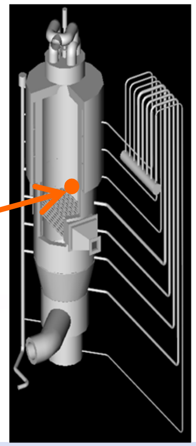
Deposition probe operation period: 1 hour

O_2 ≈ 6 % in all the tests

Average Temperature: 950-1000 °C

Deposition probe temperature: 550°C

Test	CYN	POP	SAC
1	0	0	100
2	5	0	95
3	10	0	90
4	15	0	85
6	0	10	90
7	0	15	85



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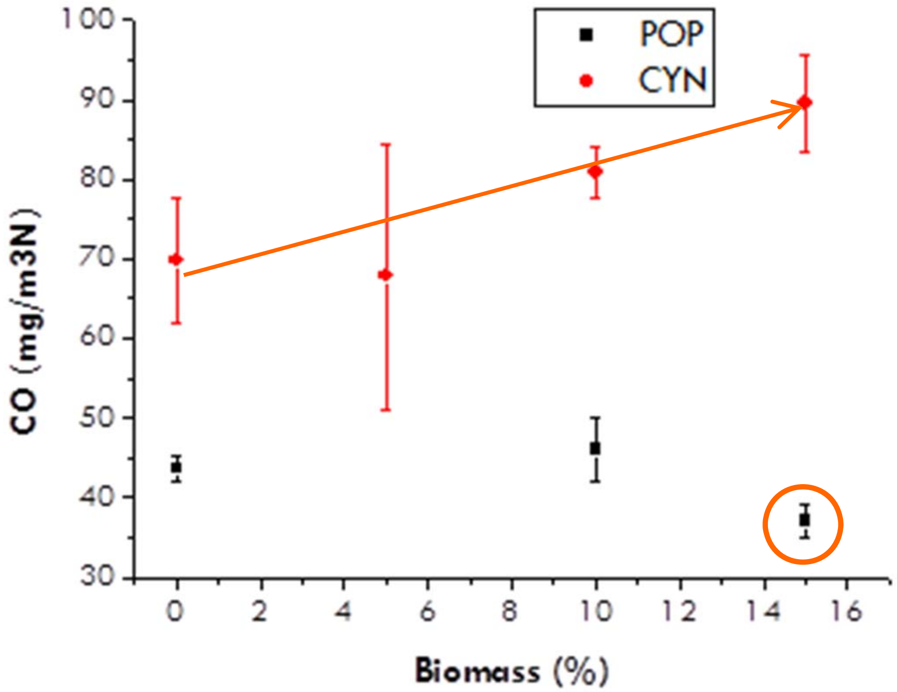
Emissions results

Carbon monoxide: CO



- **Influencing variables:** temperature, Particle size, time, mixing…

↑ biomass % → ↑ [CO] in CYN tests

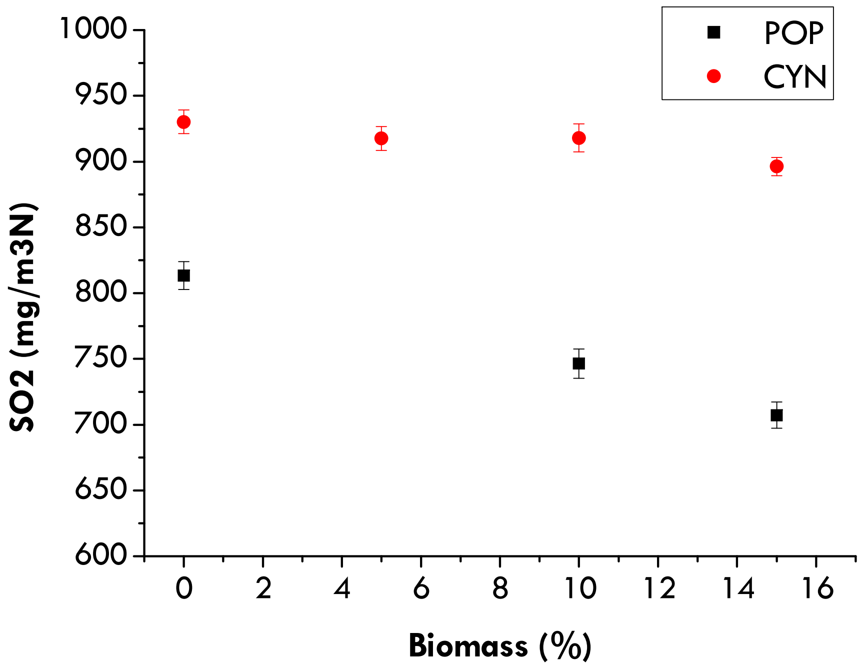
[CO] ≈ constant in POP tests

CO < 100 mg/m^3 in all the tests

Lowest [CO] achieved in POP cofiring (≈ 37 mg/m^3)

Emissions results

Sulfur dioxide: SO2

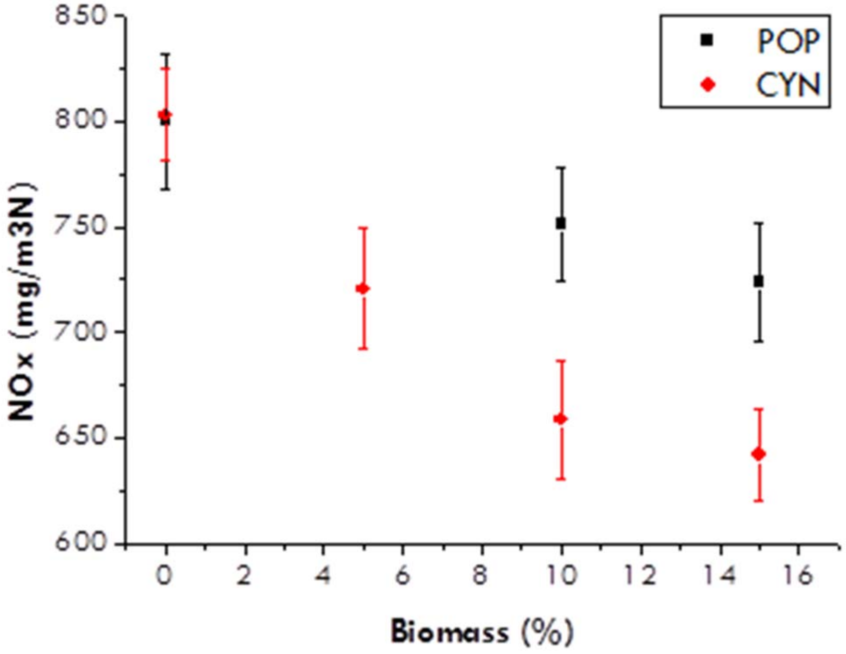


↑ biomass % → ↓ $[SO_2]$

Influencing variables:

- Combustion completion.
- Sulfur content in the fuel.
- Alkaline elements in the fuel.

Nitrogen oxides: NOx



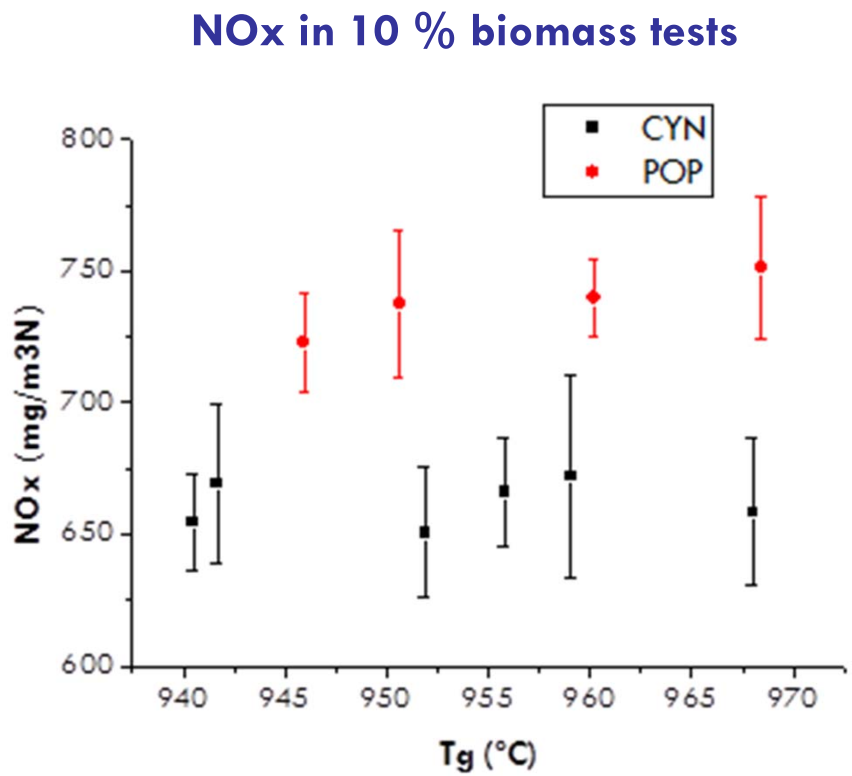
↑ biomass % → ↓ [NOx]

Influencing variables:

- Temperature.
- Nitrogen content.
- Volatile matter.
- Devolatilization conditions.
- Fuel/Oxidizer mixing patterns.

Emissions results

Temperature influence in NOx emissions



- Ascending trend in POP test → Thermal NOx formation
- No clear trend in cynara tests.
- Volatile content: POP>CYN>SAC
- Nitrogen content: SAC>CYN>POP

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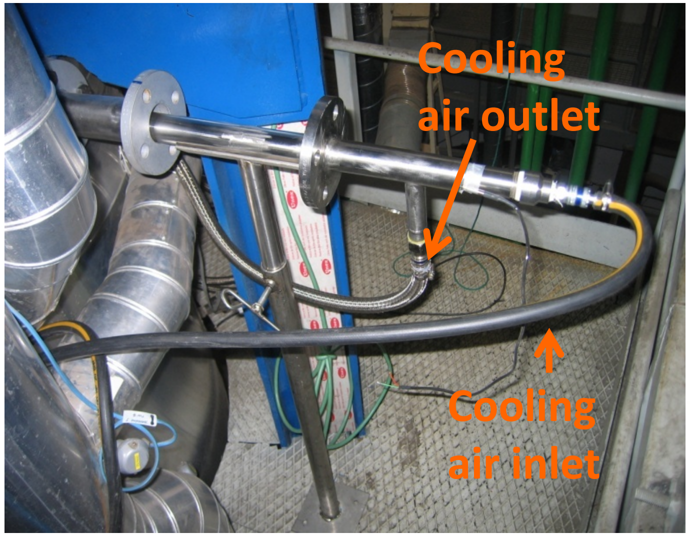
- **Deposition results**
- Conclusions

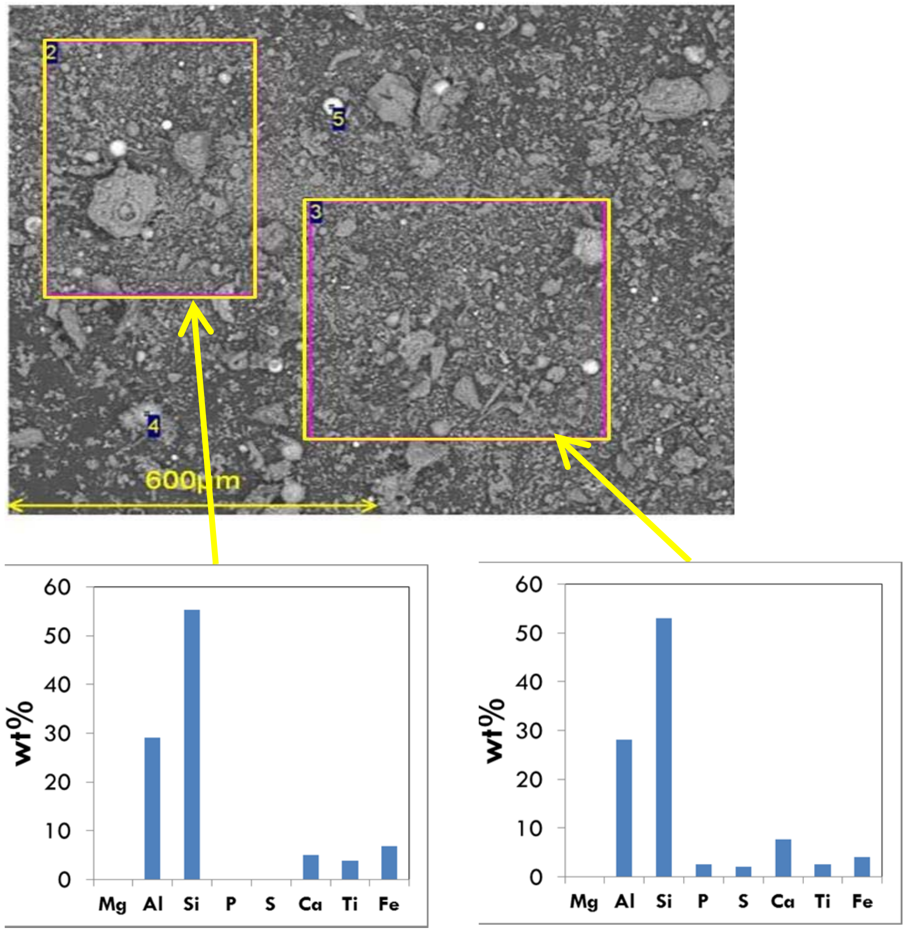
Deposition results

- **Deposition probe results: Experimental set-up photographs.**



Deposition results

- **SEM/EDS analyses:** 100% SAC



- **Morphology:** Powder deposit

- **Composition: Al, Si →**

  Aluminosilicates → main components

Particle size ≤ 100 µm (aluminosilicates)

Particle size ≤ 45 µm (Fe particles)

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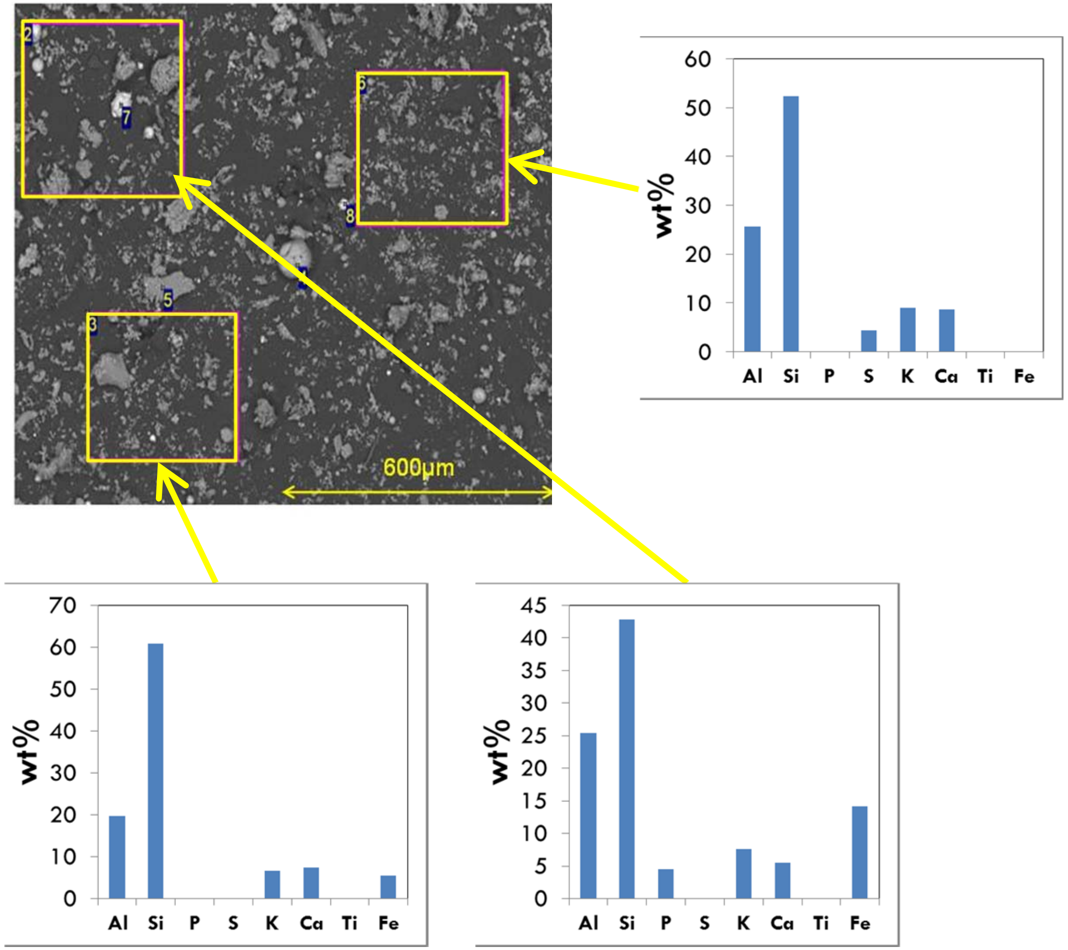
Deposition results

- **SEM/EDS analyses:** 90% SAC + 10%CYN

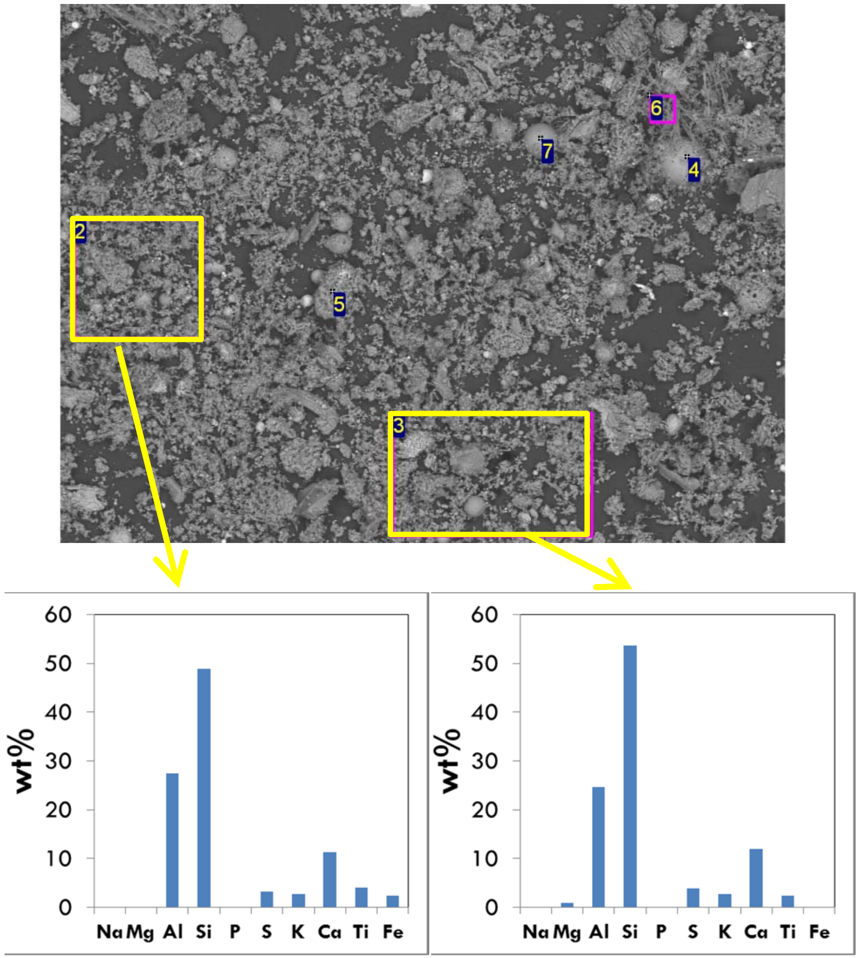


- **Morphology:** No important differences (with regard to 100%SAC tests)

- **Composition:**
  - Main components: **Al** and **Si**
  - New inorganic elements appear in this sample (K, Ca).

Deposition results

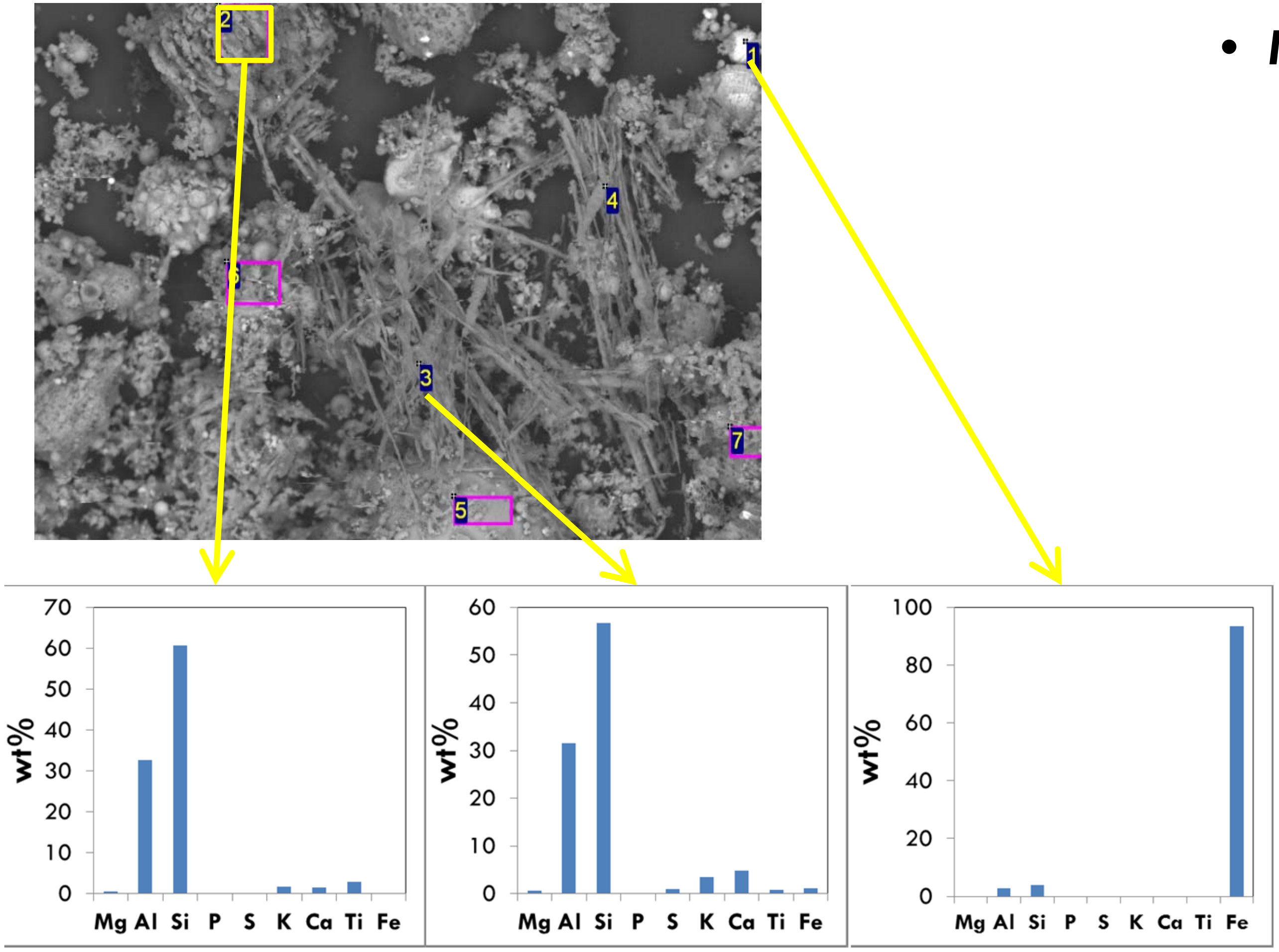
- **SEM/EDS analyses:** 90 % SAC + 10 % POP



- **Morphology :** Powder deposit
- **Composition:**
  - Main components: **Al** and **Si**
  - Less **K** than in cynara tests
  - Presence of **Ti**, probably coming from soil particles
  - Less **P** than in cynara tests

Deposition results

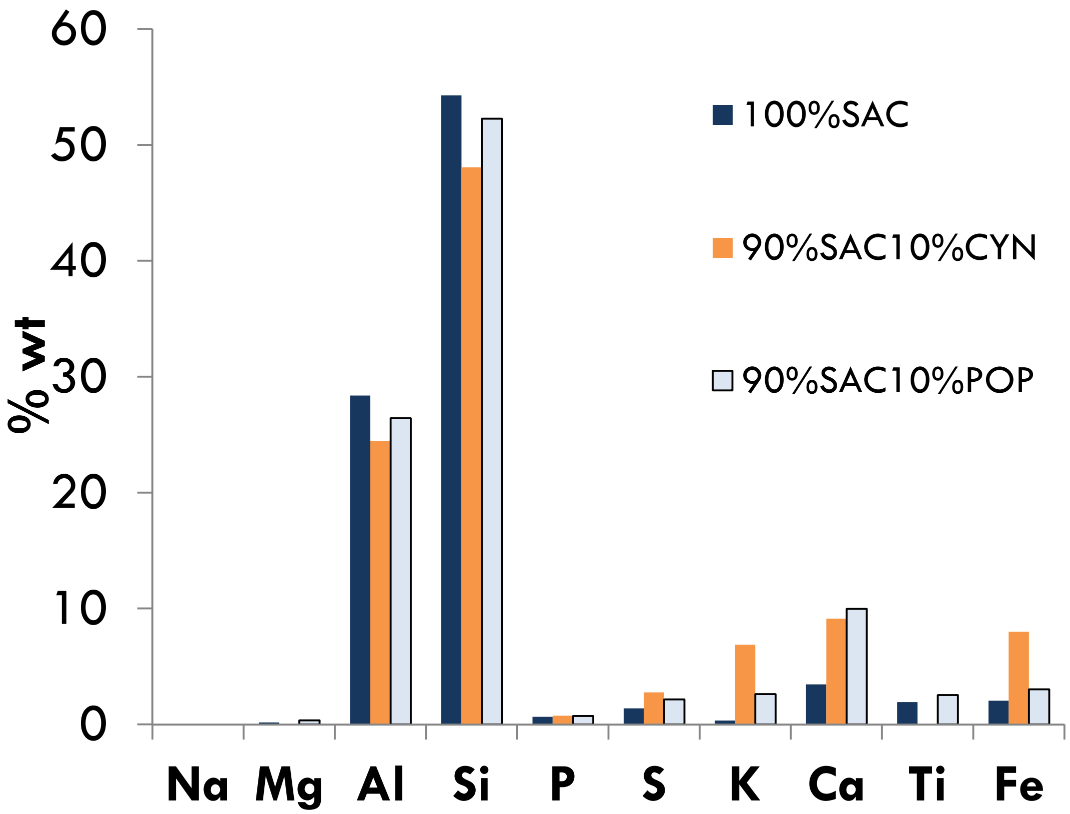
- **SEM/EDS analyses:** 90 % SAC + 10 % POP



- **Morphology:**
  - Filamentous particles: aluminosilicates
  - Condensed particles **agglomerations** (spherical particles)
  - **Fe** particles ≈ 10 µm

Deposition results

- **SEM/EDS analyses:** Averaged composition values



Aluminosilicates → major components in ash

K (CYN) > **K** (POP) > **K** (SAC)

Ca (POP) > **Ca** (CYN) > **Ca** (SAC)

Chlorine not present in ash samples

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Conclusions

- **CO** emissions were below 100 mg/m^3 in all the tests
- **CO** levels slightly increased when increasing CYN shares but remained constant in POP tests

SO_2 emissions decreased when increasing biomass share

Lower **sulfur** content and higher **alkaline** elements presence in biomass

Conclusions

- **NO_x** emissions decreased as the biomass share was increased.
- Higher NO_x emissions were reached when co-firing POP than with CYN

Main parameters influencing NO_x formation: **Nitrogen** and **volatile** content, temperature

Temperature influence in NOx formation

NOx Ascending trend in POP test → Thermal NOx formation

Conclusions

- As biomass percentages are increased, more inorganics are present in the samples:
- **K** → Decrease in Ash Melting Point
- K + Aluminosilicates → fouling + corrosion in

  convective zones
- Most of the deposits were classified as powder deposits so they did not present problems in its removal.
- Chlorine was not present in cynara samples.

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