Waste gasification improvements

A.J. Grootjes **(ECN)**
G. Aranda Almansa **(ECN)**
W. Willeboer **(RWE)**
M. Spanjers **(RWE)**

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Your energy. Our passion.

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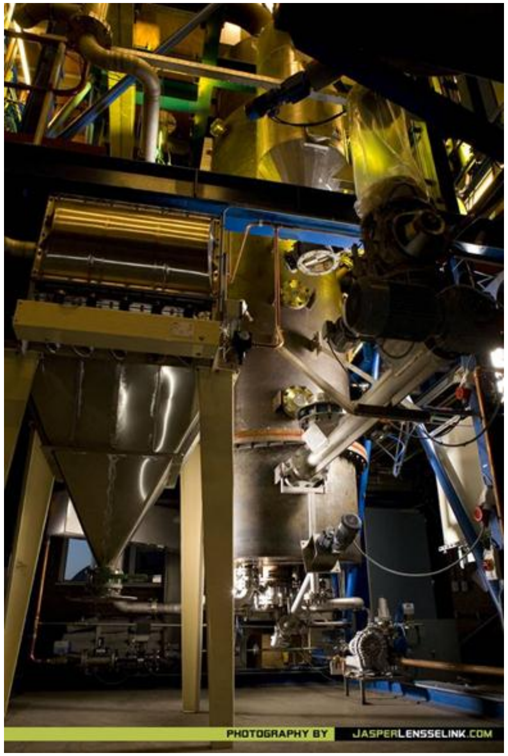

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The Energy research Centre of the Netherlands (ECN)

- Largest Dutch R&D centre for renewable energy.
- Units: solar, wind, bio energy, policy studies
- Partly financed by Netherlands and EU government grants, and partly by contract R&D.
- Main products: technology licenses and contract R&D
- 600 staff

1. Introduction

- Increasing obligations for replacement of fossil fuel consumption in power plants with biomass and waste for reduction of CO_2 emissions.

- Combination of gasification + boiler (indirect co-firing) for conversion of waste into heat and/or power (gasification as fuel pre-treatment).

Amer 9, The Netherlands

1. Introduction

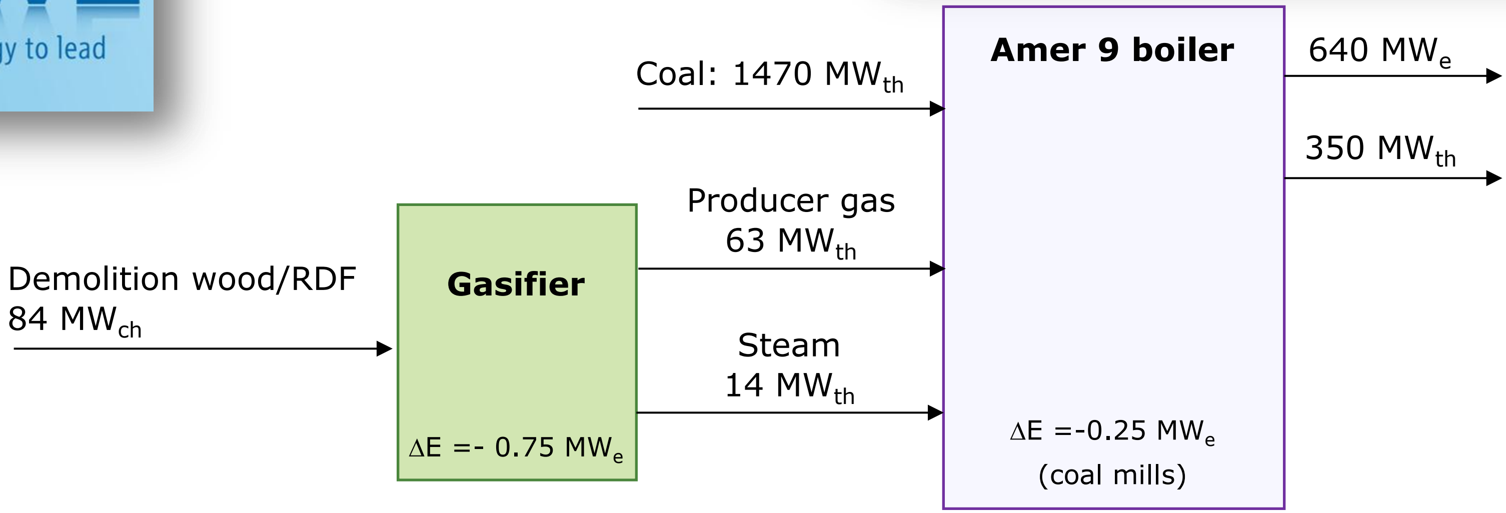
- ✓ High efficiency (economy of scale).
- ✓ Use of existing infrastructure.
- ✓ Reduction of CO_2 emissions.
- ✓ Fuel flexibility.
- ✓ Possibility of keeping biomass ash separated from coal ash.
- ✓ High co-firing ratios possible.
- ✓ No significant impact on the performance of boiler (capacity, stability and availability).
- ✓ Less strict requirements in producer gas quality as compared to other applications (e.g. gas turbines, engines).

- ✘ Relatively high unit investment costs compared to direct co-firing (investment costs:300-1100 €/kW_e).

- ✘ Risk of fouling, erosion and hot corrosion due to Cl, S and alkalis (but lower compared to direct co-firing).

1. Introduction

80 MW_{th} CFB gasifier,
Amer 9 plant
Geertruidenberg, the Netherlands



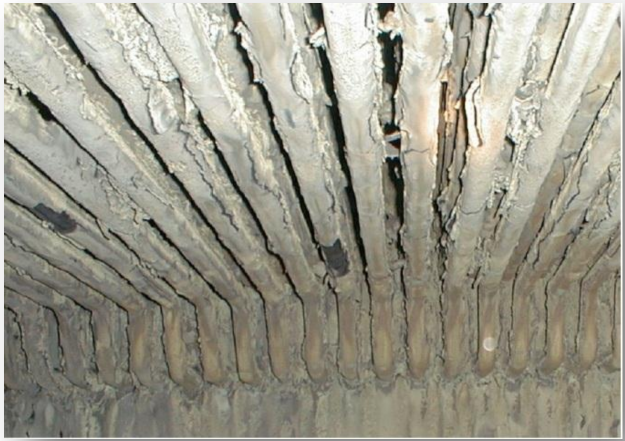
Equivalent electricity production on biomass/waste: 33 MW_e

1. Introduction

Aim: reduction of production cost of renewable electricity → Expected decrease of future governmental subsidies

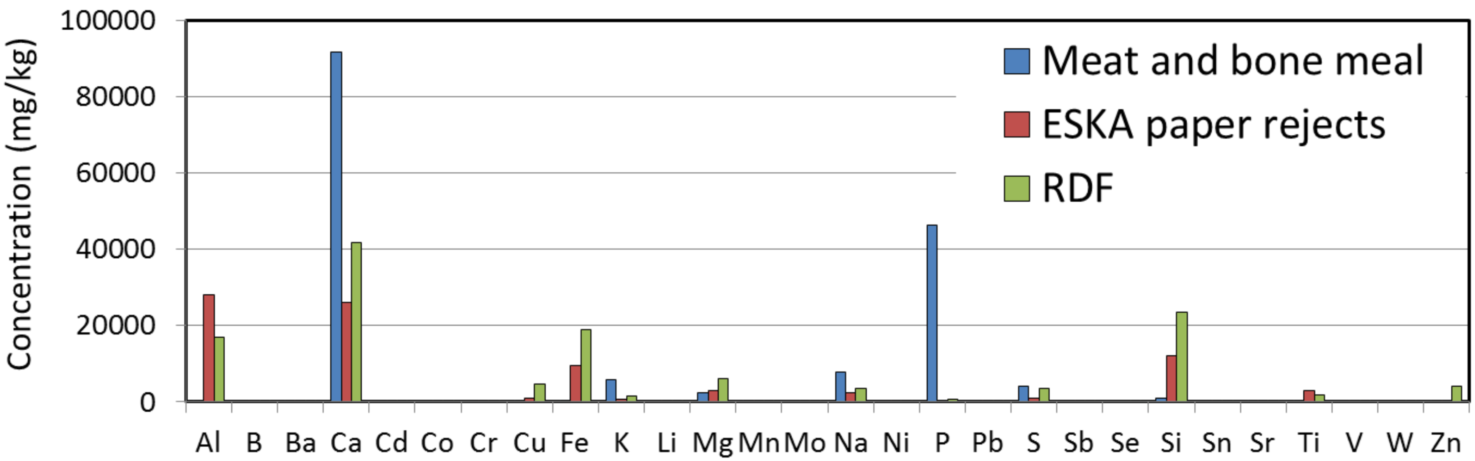
Main technical challenges of waste fuels: fouling, deposition and corrosion.

Need for cheaper (yet troublesome) waste fuels



1. Introduction

	Ash 550°C	Volatile matter	HHV	C	H	N	O	S	Cl
	% wt. dry	% wt. dry	MJ/kg, dry	% wt. dry	% wt. dry	% wt. dry	% wt. dry	mg/kg	mg/kg
Meat and bone meal	26	65	18.8	42	6.0	8.6	19.0	3800	5000
Paper rejects	14	75	26.3	57.0	8.1	0.30	23.0	894	18014
RDF	24	67	22.6	49.0	6.7	0.95	23.0	2933	14381



1. Introduction

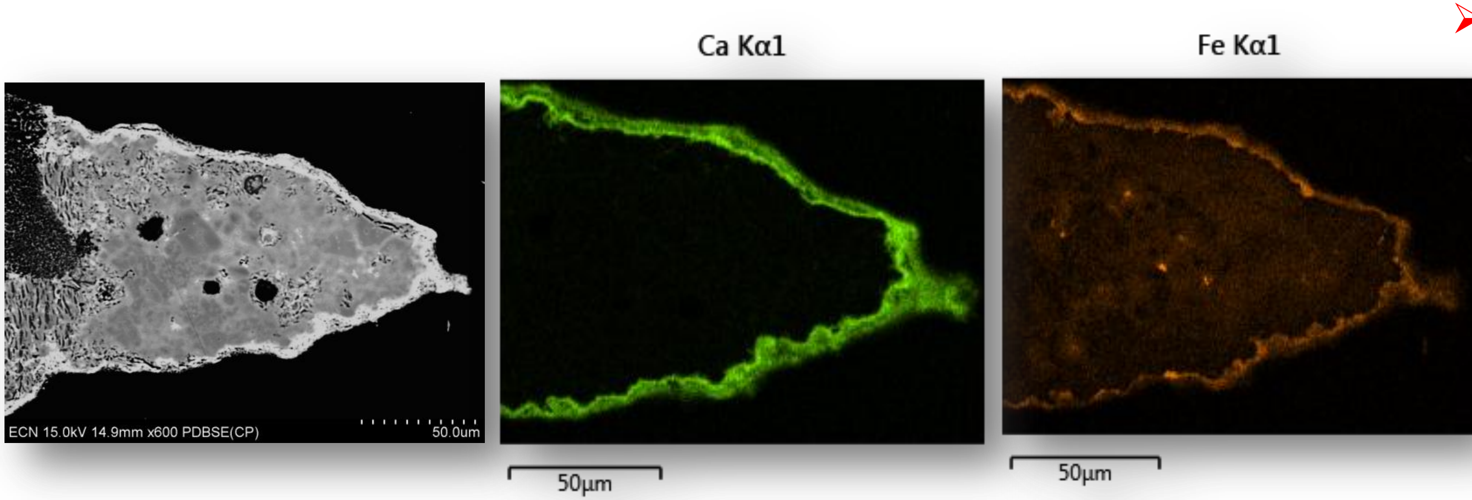
Strategies for mitigation of ash-related challenges (slagging, fouling, corrosion):

- Fuel management (e.g. fuel additives, smart fuel mixtures).

- Operating conditions

1. Introduction

- Smart blending can have combined effects, like:
- Chicken manure lowers tar dew point => less fouling issues
- Potassium rich feedstock acts as bed material activator => in bed tar reduction, less fouling
- Smart blends can reduce O&M cost by lowering bed inventory replacement, influencing ash Q, etc



- *Layer formation around olivine*
- *Calcium & iron rich, potassium intermediate layer*
  - *Catalysts known for WGS & tar reforming*

1. Introduction

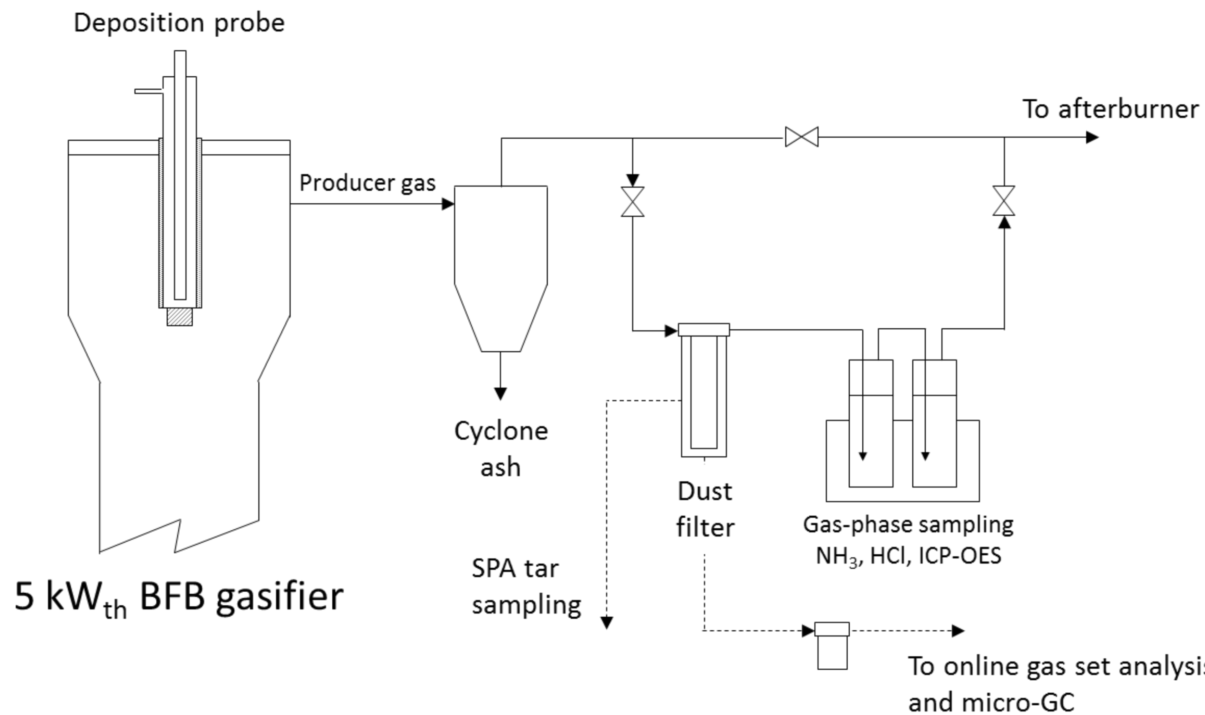
- Fuel additives: effective option, particularly in FB equipment (good mixing).
- Types: aluminosilicate-based, S-based, Ca-based, P-based.
- Parameters: additive/feedstock ratio, reaction atmosphere, combustion/gasification technology.
- Mechanisms:

Chemical adsorption and chemical reaction (i.e. alkali-getter effect) → increase of ash melting temperature.
Physical adsorption and elutriation of troublesome ash species.
Diluting and powdering effects.

1. Introduction

- Halloysite ($Al_4(OH)_8/Si_4O_{10} \cdot 10\ H_2O$): aluminosilicate clay mineral of low hardness, high specific surface area (~70–85 m^2/g), high temperature resistance and high reactivity.
- Kaolinites are relatively expensive -> high operating costs.
- Identification of alternative additives -> coal fly ash?

1. Introduction



5 kW_{th} BFB gasifier, ECN

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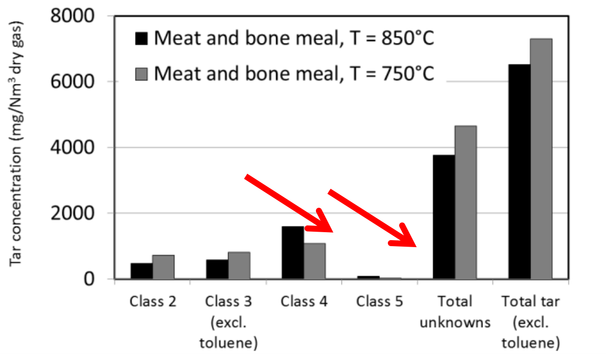
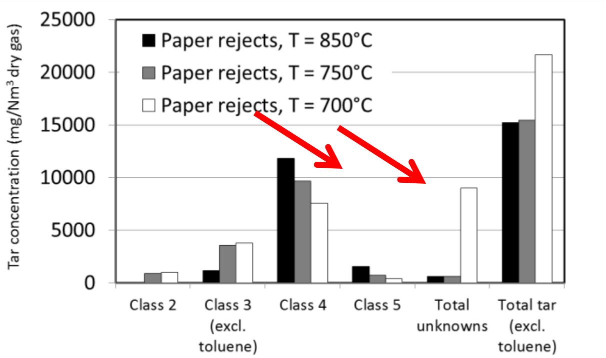
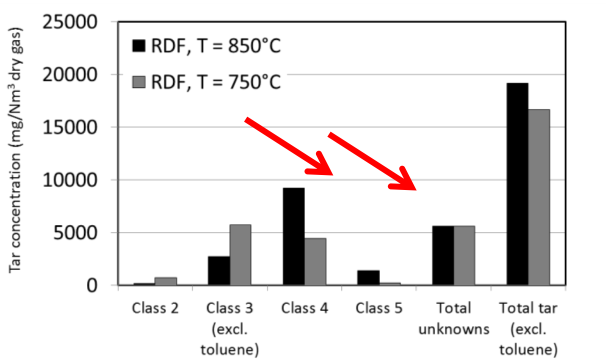
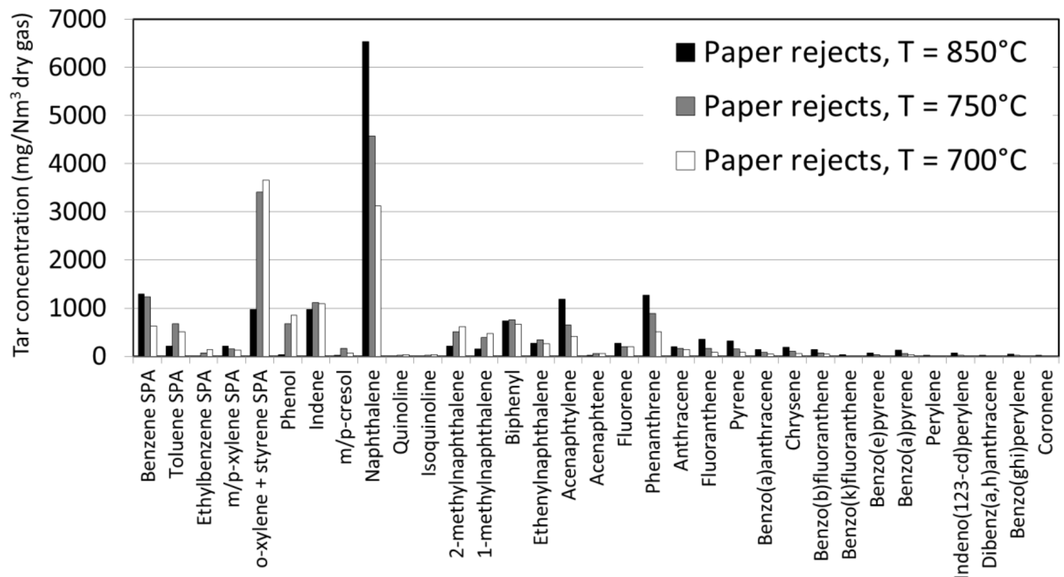




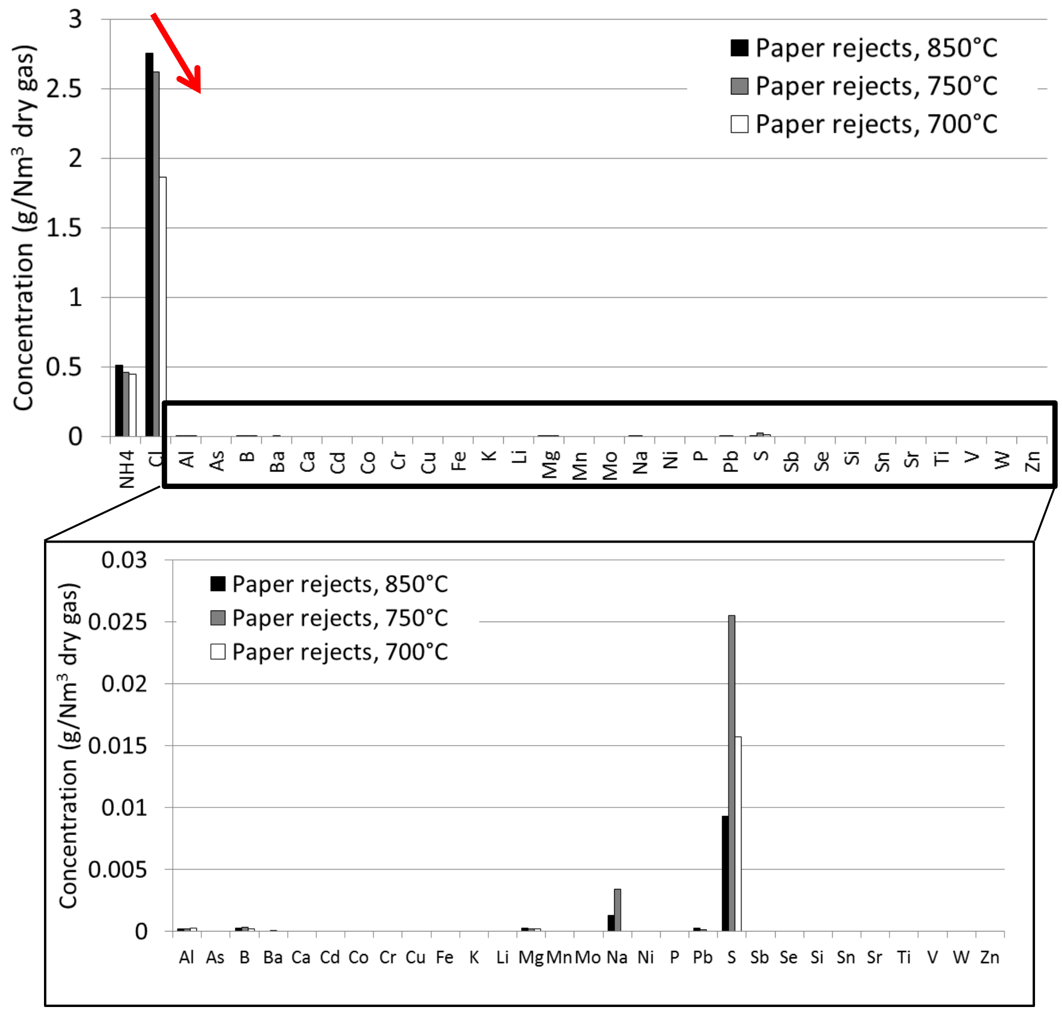




2. Effect of temperature

Producer gas

- Lower T → decrease of Cl
- Increase of S at lower T
- S : Cl molar ratio very low, corrosion highly likely



2. Effect of temperature

Cyclone ash

- Lower T → more elements retained in cyclone ash.

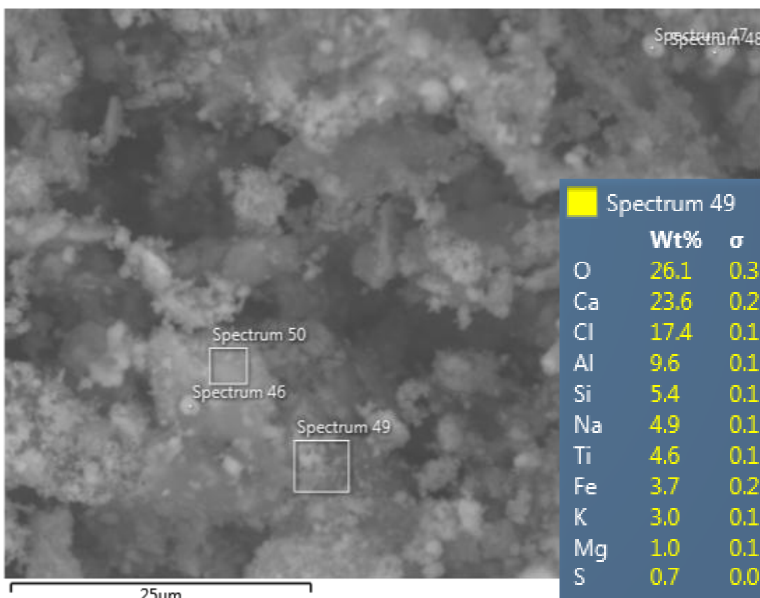
Conclusion: lower T: different quantitative distribution of Cl in products: less Cl released in gas and filter dust, more Cl in cyclone ash/bed material.

Filter dust

- Lower T → less contaminants captured in the dust.
- Dust from MBM: mainly composed of Ca and P, with less significant concentrations of Cl, K , Mg and Na.
- Dust from paper rejects and RDF : similar composition, (Ca most abundant compound, followed by Si, Al, Cl, Fe).

2. Effect of temperature

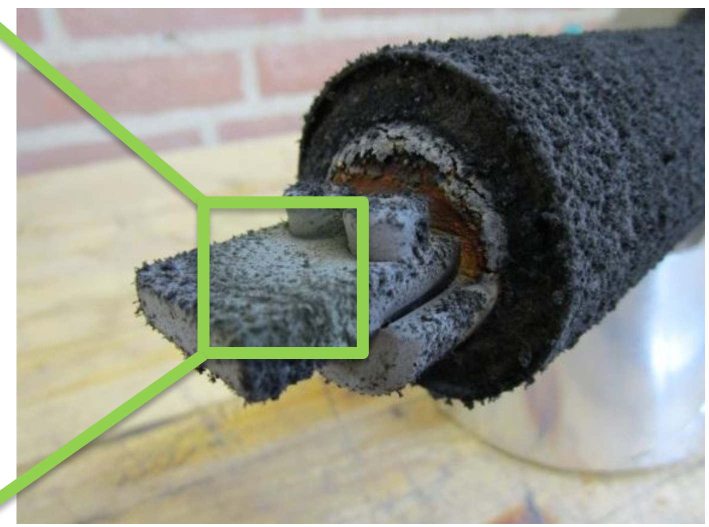
SEM/EDX analysis of deposits



Spectrum 49

	Wt%	σ
O	26.1	0.3
Ca	23.6	0.2
Cl	17.4	0.1
Al	9.6	0.1
Si	5.4	0.1
Na	4.9	0.1
Ti	4.6	0.1
Fe	3.7	0.2
K	3.0	0.1
Mg	1.0	0.1
S	0.7	0.0
P	0.2	0.0

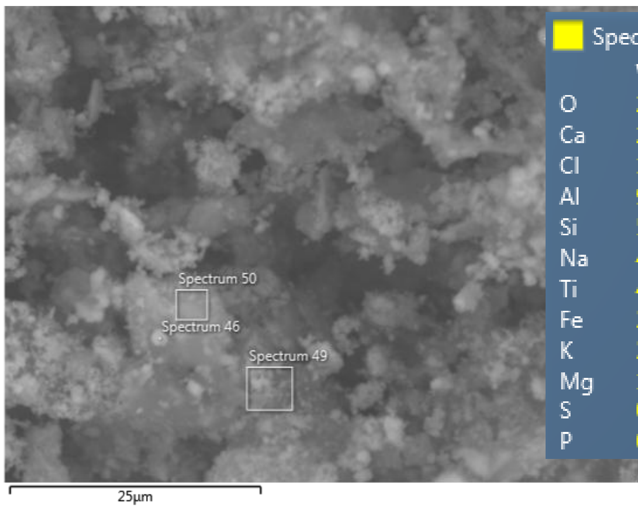
Deposition probe, paper rejects, 750°C



2. Effect of temperature

SEM/EDX analysis of deposits: paper rejects

Low-temperature gasification:



Spectrum 49	Wt%	σ
O	26.1	0.3
Ca	23.6	0.2
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Al	9.6	0.1
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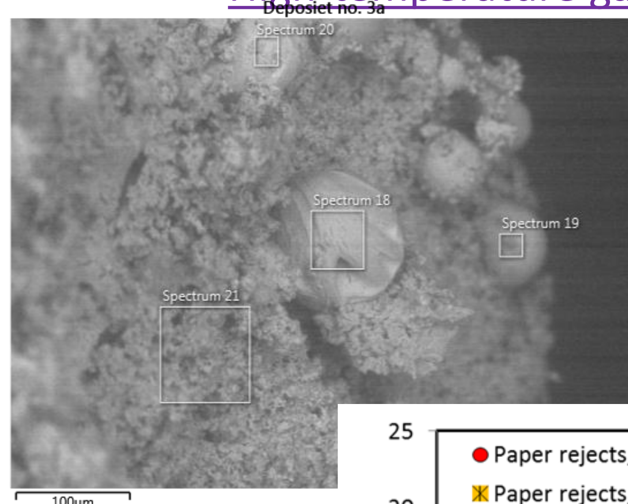
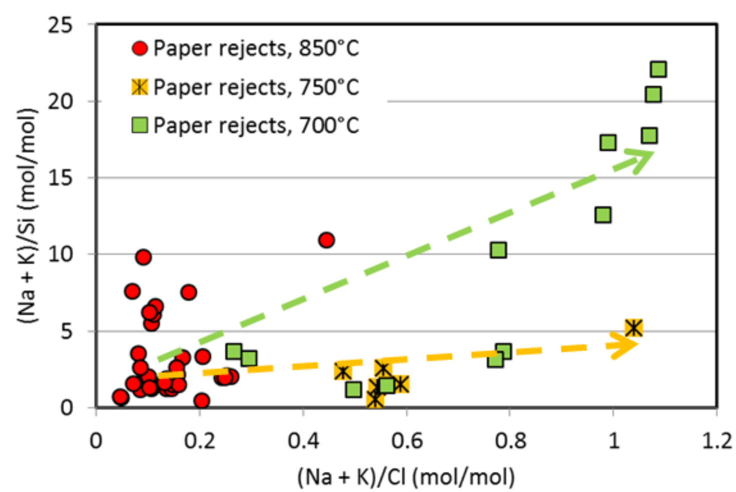
Ti	4.6	0.1
Fe	3.7	0.2
K	3.0	0.1
Mg	1.0	0.1
S	0.7	0.0
P	0.2	0.0

High-temperature gasification:



Spectrum 18	Wt%	σ
Cl	42.4	0.2
O	23.9	0.3
Ca	23.1	0.2
Al	3.6	0.1
K	3.0	0.1
Fe	2.1	0.2
Si	0.8	0.0
Na	0.5	0.1
Mg	0.5	0.0

- More dense, partially molten and sintered deposits at 850°C, with higher Cl content.
- More porous deposits at 750°C, with lower Cl content (i.e. salts) → less prone to fouling and corrosion.



2. Effect of temperature

- RWE Essent Amer 9 indirect co-firing tests:
  - Optimize process conditions for RDF/wood
  - Conversion
  - Ash volumes and quality
  - Availability
  - Gas cooler fouling
  - Emissions

2. Effect of temperature

- Results of 1st RWE Essent tests:

- 25% RDF with wood resulted in rapid fouling (sticky ashes) of HT section of gas cooler.
- Decrease the gasification temperature, 840°C to 750°C
- Gasification of 100 % wood showed no increase in fouling
- Adding up to 20% RDF did not result in measureable fouling.

2. Effect of temperature

- Results of 2nd RWE Essent tests:

- 40% RDF with wood resulted in stable CFB operation.
- Less bed material make-up necessary, no agglomeration issues.
- Slight increase in fly ash flow.
- Fine ash load to boiler slightly higher.
- Heavy metal load to boiler within emissions bandwidth.
- Gas cooler got fouled at the end of the test but ash was not sticky.
- Modification of the gas cooler by increasing the distance between HT surfaces is possible without loss of capacity

- **Conclusion: blending RDF with wood has economic perspective for the RWE Essent co-firing case**

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1. Introduction

2. Effect of temperature

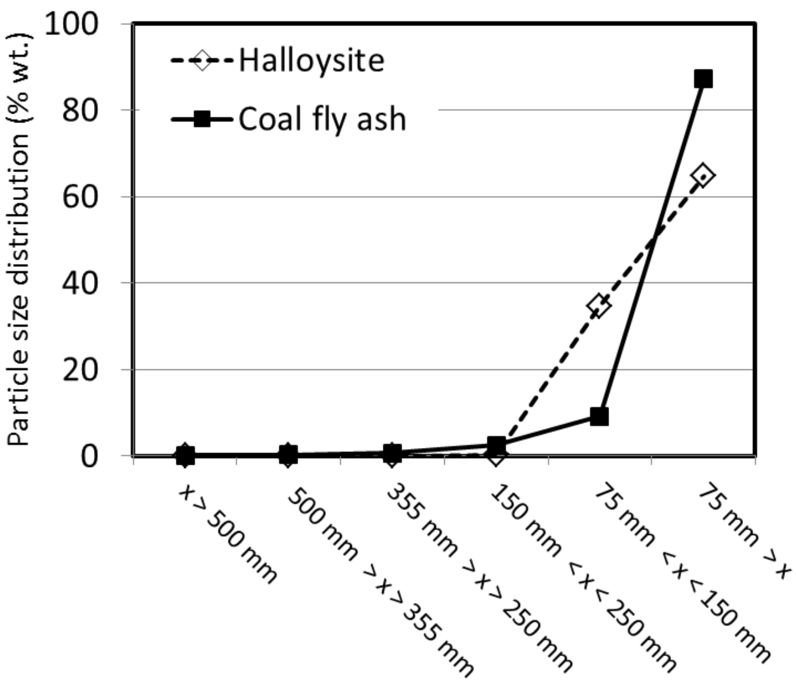
3. Effect of fuel additives

4. Conclusions and future work

3. Effect of fuel additives

- Selected additives:

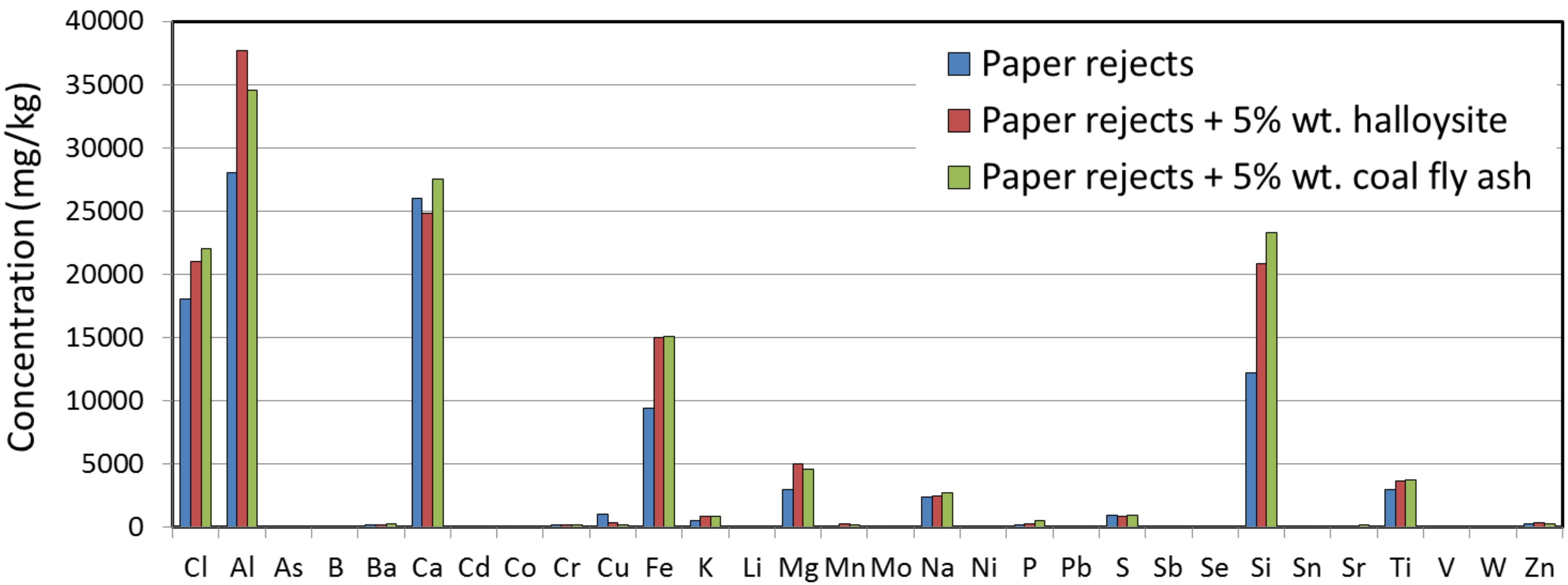
- Halloysite ($Al_4(OH)_8/Si_4O_{10} \cdot 10\ H_2O$)
- Coal fly ash from Amer power plant: low-cost additive
- In all cases, 5% wt. additive in gasification feedstock.



	Specific surface area (m^2/g)
Halloysite	68
Coal fly ash	3

3. Effect of fuel additives

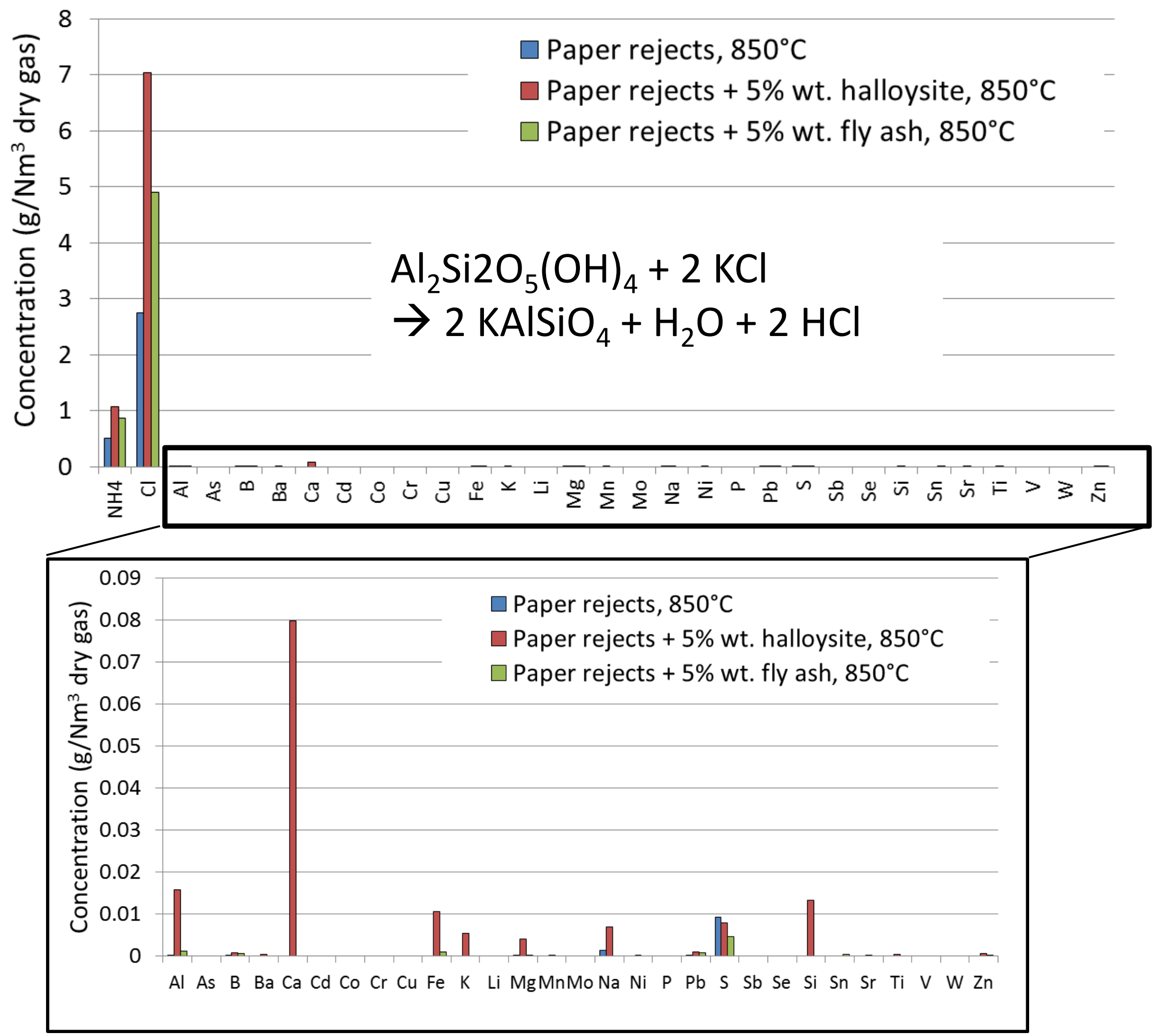
Feedstock tested



3. Effect of fuel additives

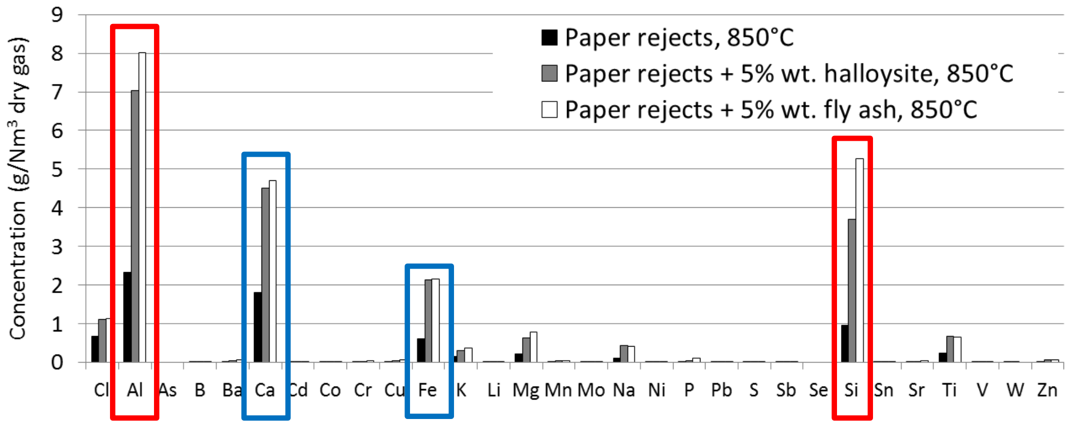
Gas phase composition

- No significant influence on producer gas composition or fuel conversion/ cold gas efficiency.
- No significant influence on tar content/composition.

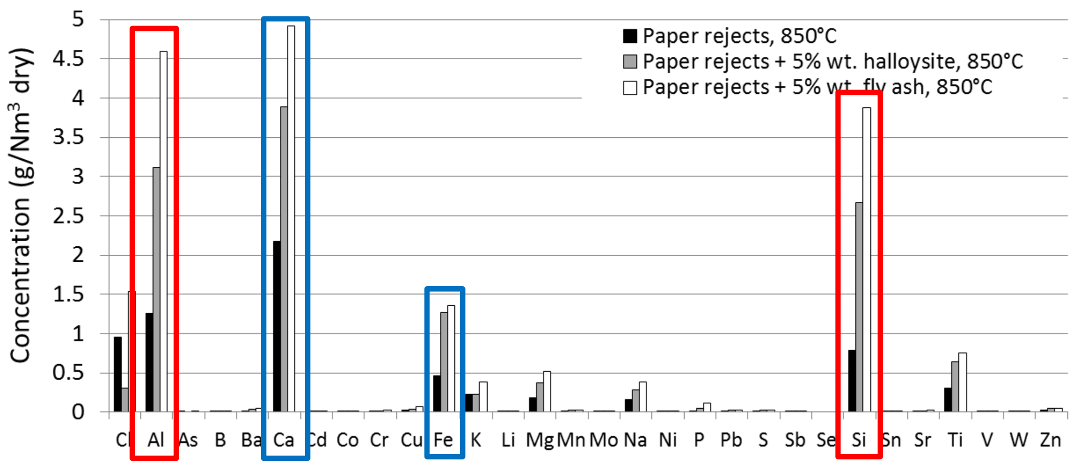


3. Effect of fuel additives

Cyclone ash

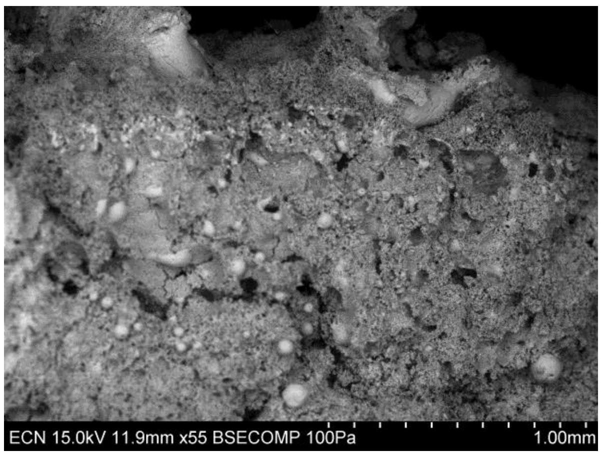


Filter dust

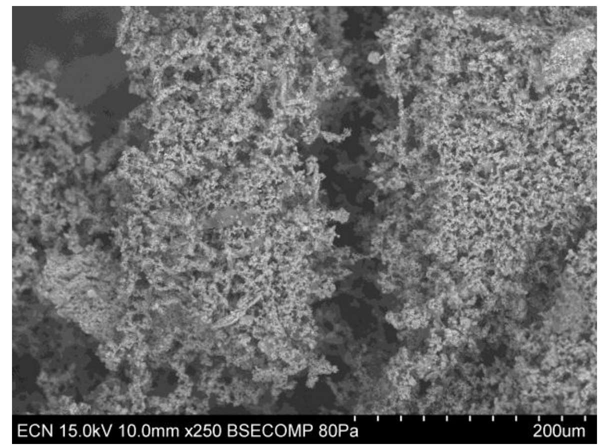


3. Effect of fuel additives

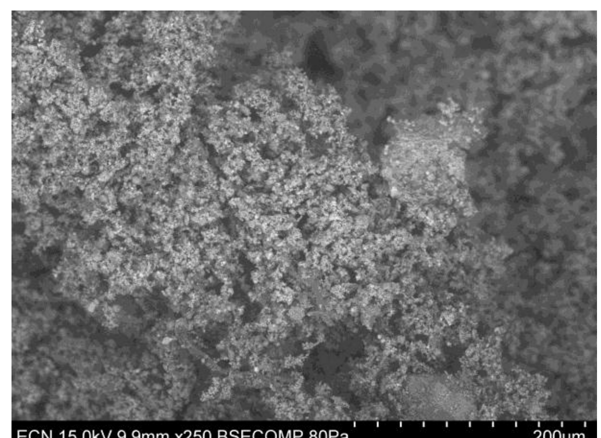
Paper rejects, 850°C



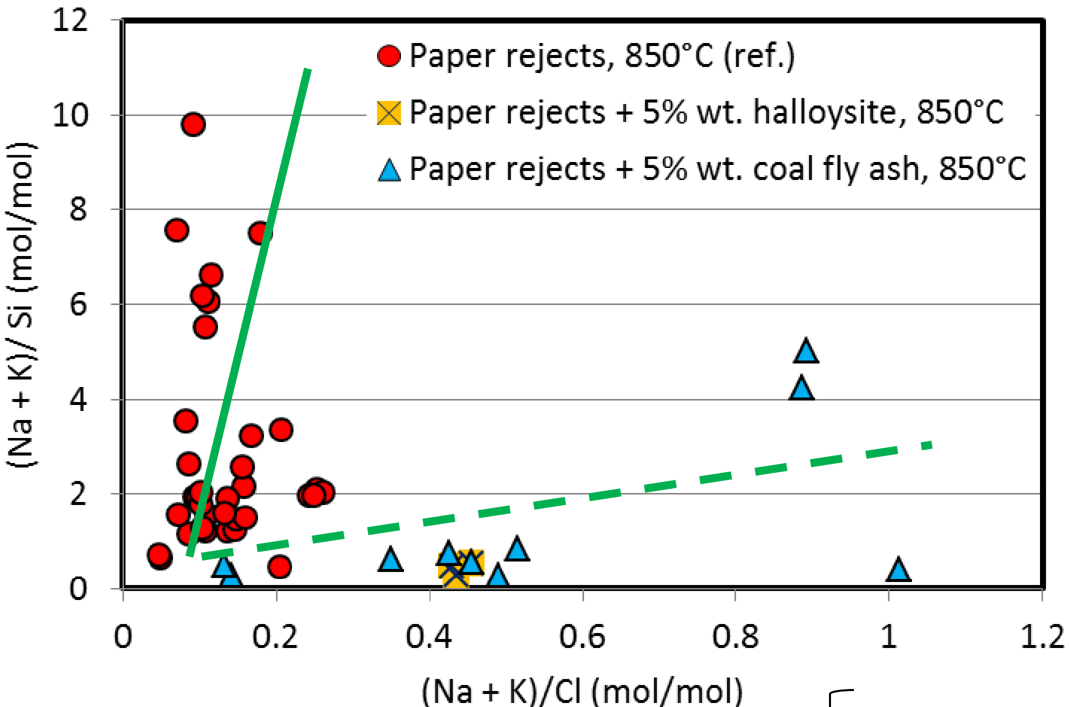
Paper rejects + 5% wt. halloysite, 850°C



Paper rejects + 5% wt. coal fly ash, 850°C



3. Effect of fuel additives



Addition of halloysite or coal fly ash

↓ (Na + K)/Si → more (alumino)silicates

↑ (Na + K)/Cl → less salts

Alkalis increasingly bound to less troublesome structures →Deposits less prone to fouling and slagging.

Contents

4. Conclusions and future work

- Reduction of production cost of renewable electricity → **Increasing need for waste fuels**
- The fuel (blend), temperature and fuel additives largely influence the release of Cl and alkalis to the gas/solid phase.
  - Lower T:
    - Different quantitative distribution of Cl: less Cl released in gas and filter dust, more Cl in cyclone ash/bed material.
    - More dense, partially molten and sintered deposits at 850°C; more porous and fluffy deposits at 750°C.
    - Consistent results in 80 MW_{th} wood/RDF tests.
  - Addition of halloysite/coal fly ash: capture of alkalis as aluminosilicates → less troublesome deposits. Coal fly ash attractive low cost alternative.
- Smart selection of the fuel, additives and gasifier operating conditions → reduced problems associated to low-value feedstock → increased plant availability.

4. Conclusions and future work

Future work

- Further study of additives, e.g. halloysite. Optimization along the entire process chain (cost/effectivity) → project proposal "Smart Blends":
  - Lower feedstock cost
  - Higher availability (due to less agglomeration, fouling, etc.)
  - Lower O&M (Operational and Maintenance) cost (due to less cleaning, bed material make-up, etc.) and lower ash disposal cost.
  - Sounding board consisting of major European players (end-users) in the renewable energy industry yet to be formed.

Thanks for your attention

ECN
A.J. Grootjes
T +31 88 515 49 83 grootjes@ecn.nl
F +31 88 515 44 80 www.ecn.nl

RWE Essent
W. Willeboer
wim.willeboer@essent.nl

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Ministerie van Economische Zaken

ECN

Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 LG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ ecn.nl
www.ecn.nl