Investigating Potential Problems and Solutions of Renewable Fuel Use in Steel Reheating Furnaces

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Outline

1. **The reheating furnace (RHF)**
    1. **Potential CO2 reductions**
    2. **Apparent challenges when switching fuels**
2. **Experimental study of ash behavior in a simulated RHF environment**
3. **A theoretical study based on tertiary phase diagrams, to analyze risk of volatile and low melting point compounds in a RHF**
4. **Gasification as method to use of renewable fuels and overcome ash related-problems in the RHF**
5. **Performance of the integrated system (process model)**

1. The reheating furnace (RHF)

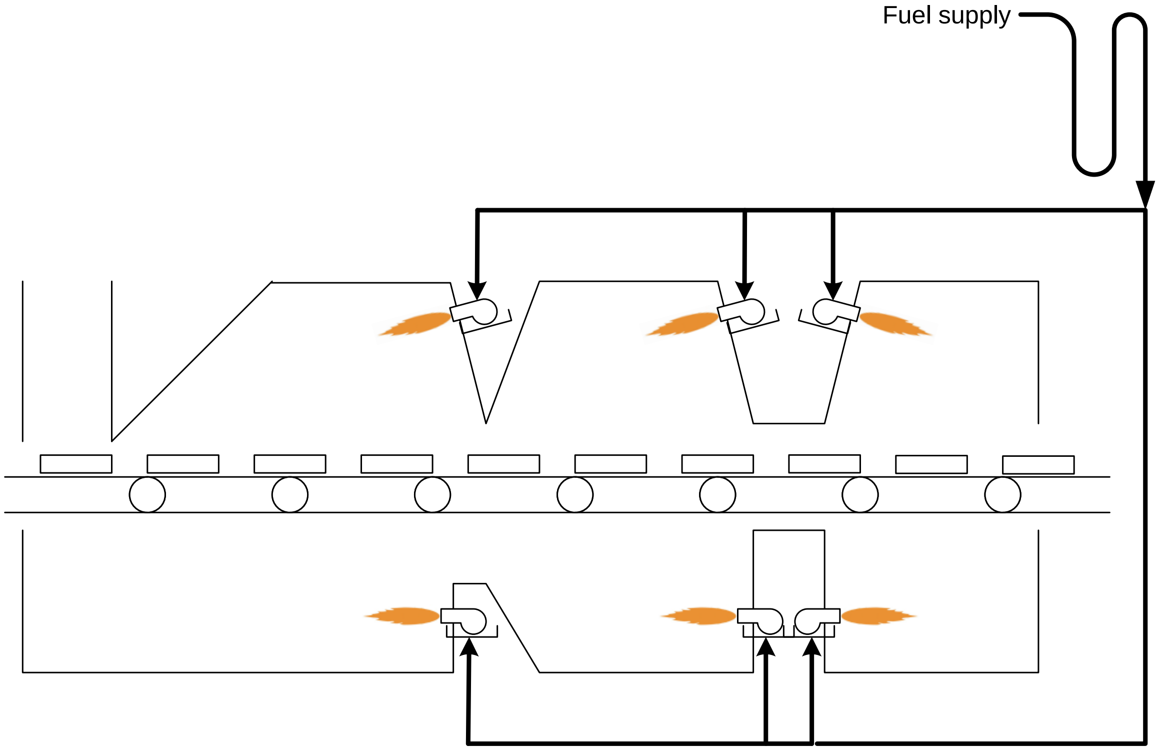


Figure 1. The reheating furnace

1.1 CO2 reductions are possible by switching to a biobased fuel.

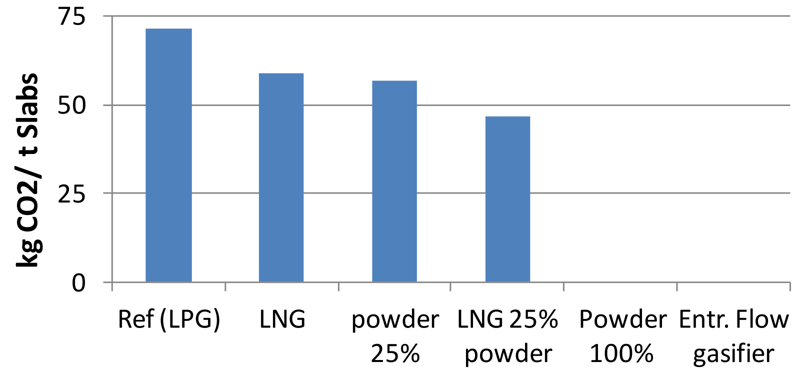


Figure 2. CO2 reduction with different fuels

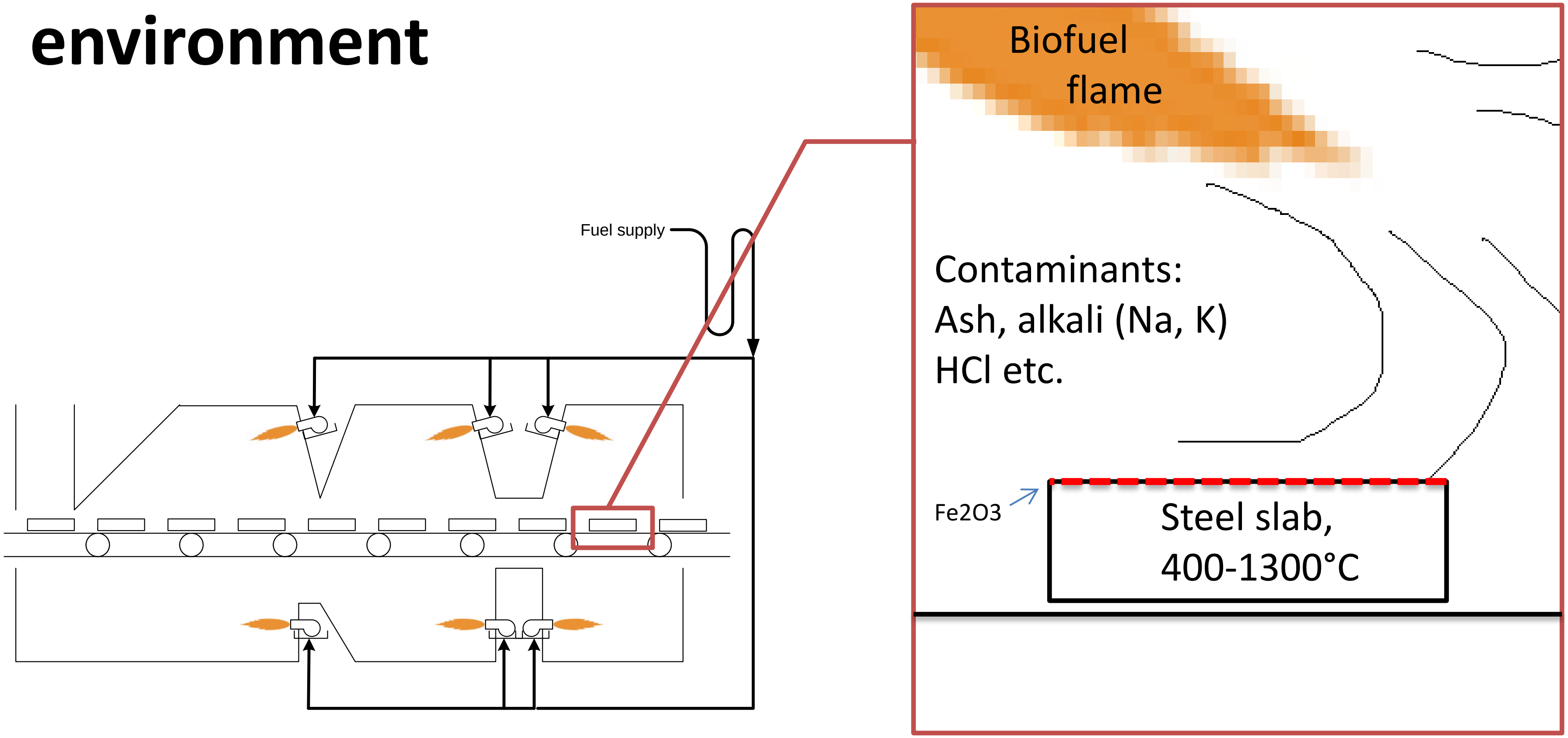
1.2 The challenges of switching fuel are numerous: altered flame shape, different thermal profiles in furnace, different flue gas flow in the furnace, AND most importantly different contaminants from combustion

Property	Light fuel oil (equivalent to EO5)	LPG	Softwood powder
Ash content (wt%)	<0.01	0	2*
S (wt%)	0.15-0.5	0	0.04
N (wt%)	0	0	

*Lower for Swedish wood ≈ 0.26

Figure 3. Contaminants in fuel

2. Experimental study of ash behavior in a simulated RHF environment



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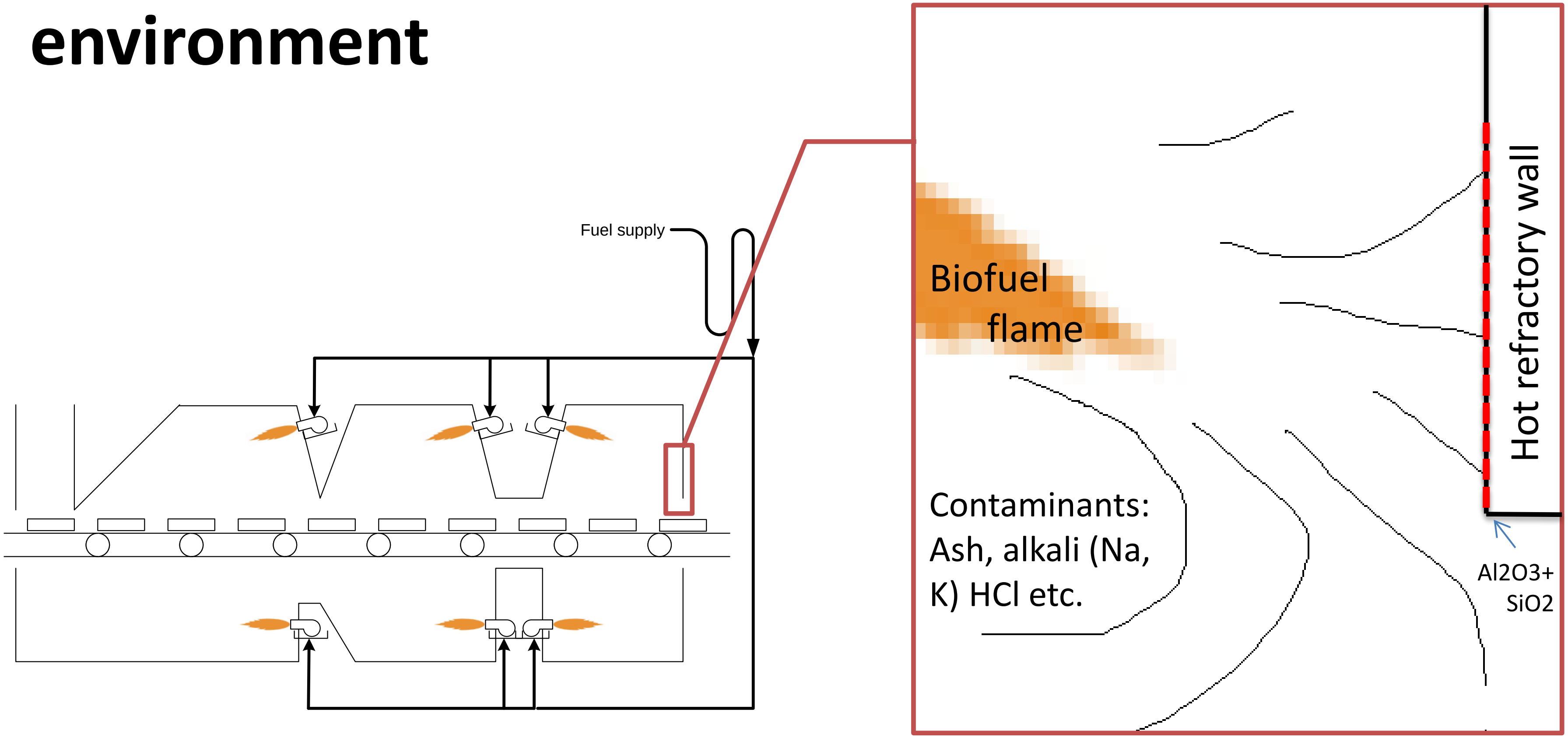

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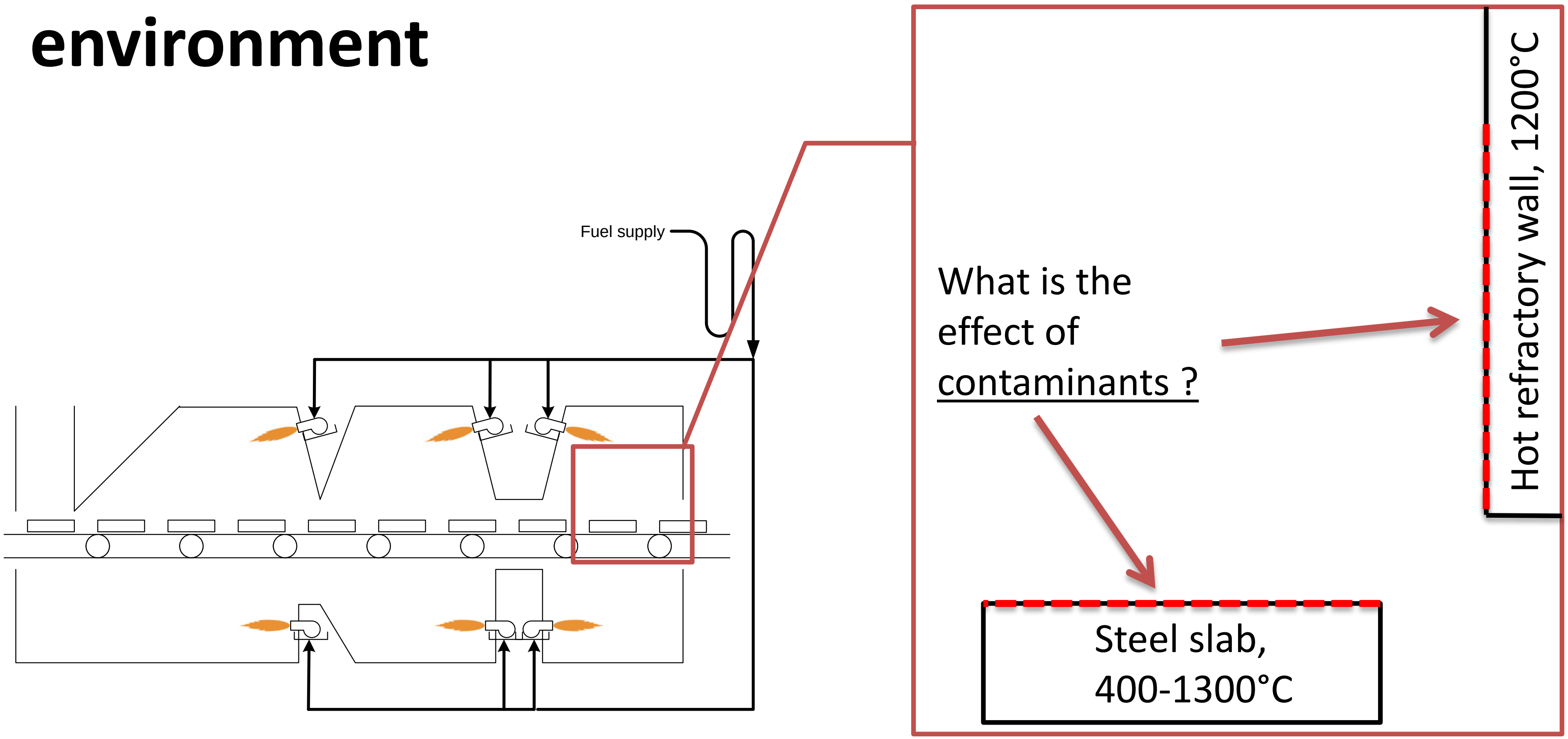
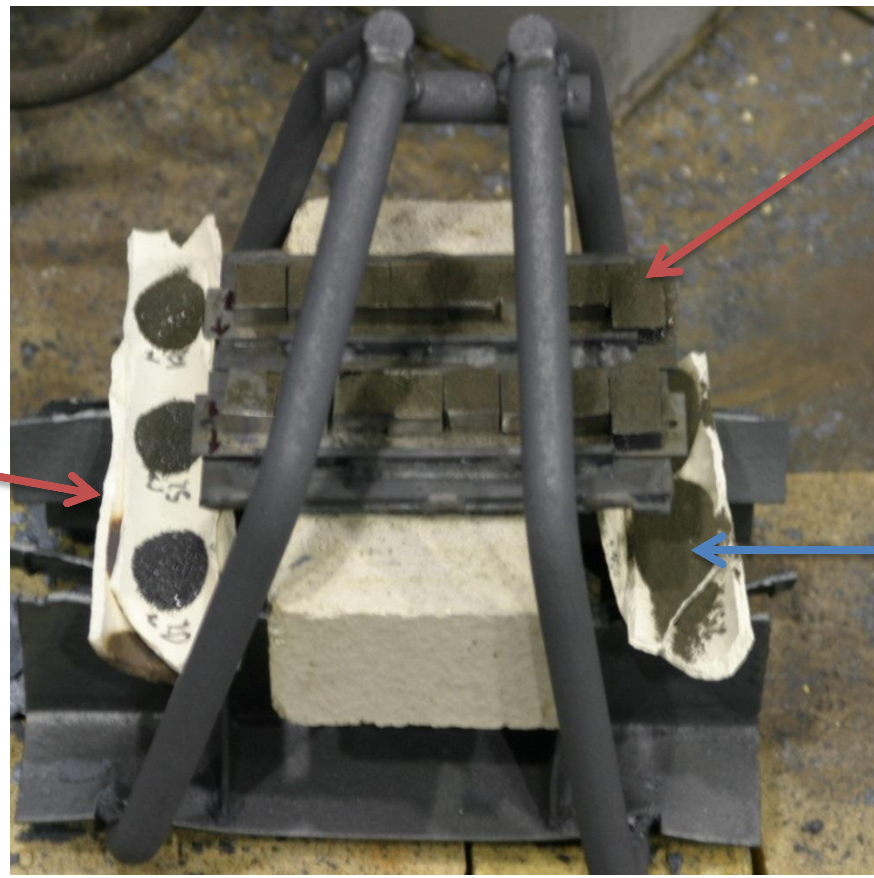


2. Experimental study of ash behavior in a simulated RHF environment

Test during 1h with 2% O2, 1150°C and 1250°C with LPG

Small steel workpieces



Refractory wall
Material
Al2O3+SiO2

Mix of ash and scale
ash contains:
CaO (44.4%)
SiO_2 (14.6%)
MgO (10.1%)
Na_2O (3.5%)
K_2O (6.2%)
etc.

2. Experimental study of ash behavior in a simulated RHF environment

Figure 8. The small steel workpieces

Figure 9. The refractory material

2. Experimental study of ash behavior in a simulated RHF environment

Figure 10. Scale easy to remove

%-wt ash[1]	1150C	1250C
0	Hard	Hard
5	Hard	Hard
10	Hard	Hard
25	Soft	Melting phase
50	Soft	Melting phase

[1] balance is a steel scale powder (Fe_2O_3, Fe_3O_4 and FeO) formed at 1250 C

Therefore: This particular ash mixed with and scaling can give a **molten phase at 1250°C but not at 1150°C**. Wood powder are therefore suitable in reheating furnaces up to 1150°C.

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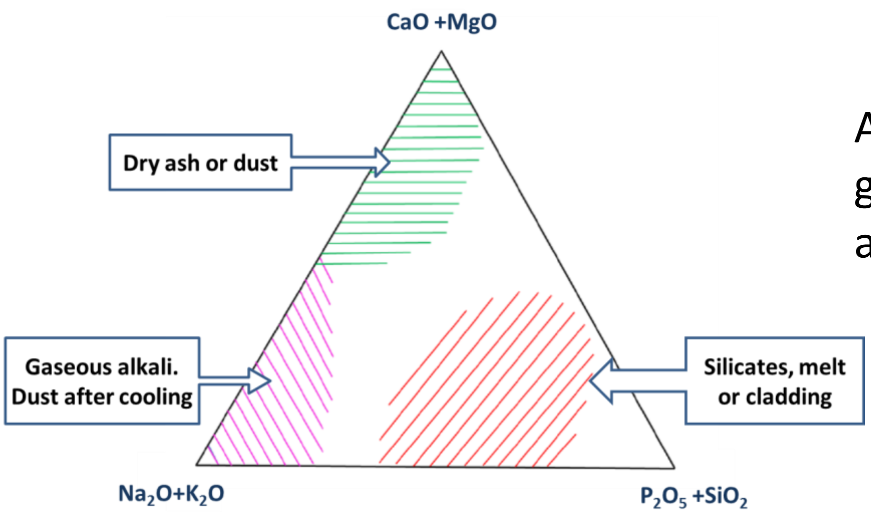
3. Theoretical risk analysis of volatile and low melting point compounds in a RHF

- For investigation of a wider range of fuels, when do we get a problematic melting phase?

This can be investigated by equilibrium studies. The phases are here presented as function of composition (at one T).



Ash from stem wood pellets gives formation of a glassy phase. Biofuels with more twigs, leaves and bark could give even greater problems.

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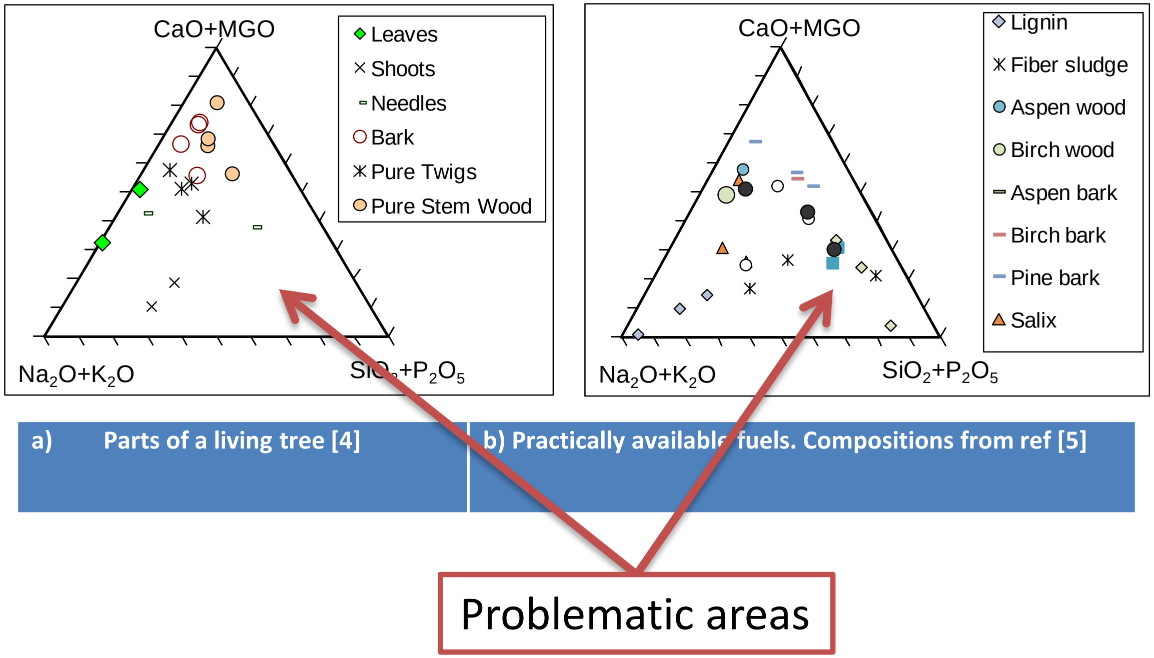

Figure 12. a) Parts of a living tree [4] b) Practically available fuels. Compositions from ref [5]

3. Theoretical risk analysis of volatile and low melting point compounds in a RHF

- What additional problems is possible in a RHF?

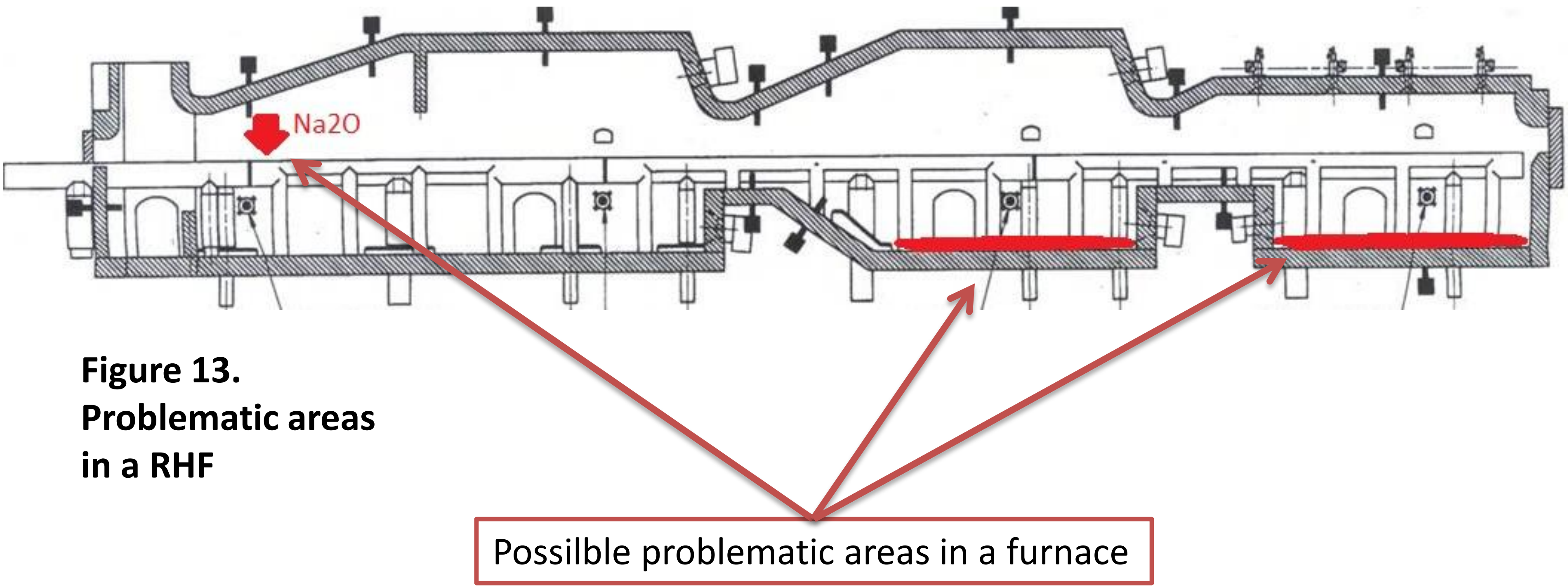

Figure 13. Problematic areas in a RHF

4. With all these problems associated to solid fuels, what about other fuels?

- Gasification is used in many other parts of the world and in other high-temperature combustion applications

Gasification of biomass for combustion in:
Lime production
Glass production
Heating in boilers

Gasification of coal for reheating furnaces:
In many developing countries most notably China, India.

However no large scale use of gasification of biomass for reheating furnaces yet.

4. Gasification as method to use renewable fuels

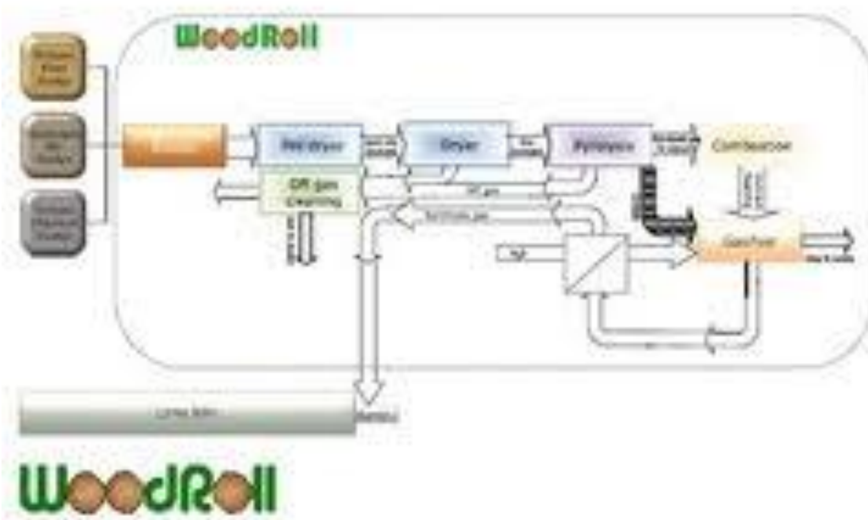

Figure 14. Woodroll, a gasification technology from Cortus. In this figure: integration to Lime kiln with gasification from biomass

System configuration: 42 units (D3 two-stage gasifiers, see Table 21) + gas pressure station + sulfur removal
Syngas: cold and clean producer gas
Syngas pressure: 15 kPa
Syngas heating value: 6.51 MJ/Nm3
Syngas flow rate: 250000 Nm3/h (with 34 gasifiers used and 8 backup)

Figure 15. Chinese steel plant in Dalian, east China. Reheating furnace with syngas from coal

4. Gasification as method to use renewable fuels

Contaminants in syngas:

- Tar
- Sulfur compounds
- Nitrogen containing compounds
- Particulate matter
- Halogen species (mainly HCl)
- Alkali metal species
- Other contaminants(trace metals, Phosphorus species etc)

All are quite low, according to the performed literature study

4. Gasification as method to use renewable fuels

Gasification technology	Fixed bed		Fluidized bed		Entrained flow
	Updraft	Downdraft	Bubbling	Circulating	
Scale up limit	<10 t/h	<15 t/h	No scale limit	No scale limit	Up to 700 MW_{th}
Operating pressure (bar)	Atmospheric	Atmospheric	1-35	1-19	20-50
Operating temp. (°C)	300-1000	300-1000	650-950	800-1000	>1200
Tar content in Syngas (mg/Nm3)	35000	500-1000	13500	Low	Almost tar free
Syngas quality	Low (Syngas contains high tars)	Low (syngas contains high CO_2)	Medium (syngas is rich in particulates)	Medium (syngas is rich in particulates)	High quality (syngas with tar free)
Complexity	Simple	Simple	Quite advanced	Quite advanced	Quite advanced

Summary and conclusions

For normal pelletized powder, combustion should be possible in the colder parts of the furnace. No effect on the steel, other than the normal scaling, could be found at these temperatures.

Although a system for dealing with the particular matter must be designed to remove ashes in the furnace.

For other wood residue, problems can occur due to melting of ashes (without the impact of FeOx).

Gasification is a proven method to use renewable fuels in high-temperature combustion processes. It has yet to be used for reheating furnaces however. Gasification is primarily pursued in future work.

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