Fate of Nitrogen During Biomass Combustion

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Introduction

- The stringent NOx emission limits for large power stations will decrease from 500mg/Nm^3 to 200mg/Nm^3 in 2016. New control measures will be required in order to meet these new targets.
- Understanding fuel-nitrogen behaviour during combustion is needed for the development of a firing strategy that would help achieve low NOx emissions.

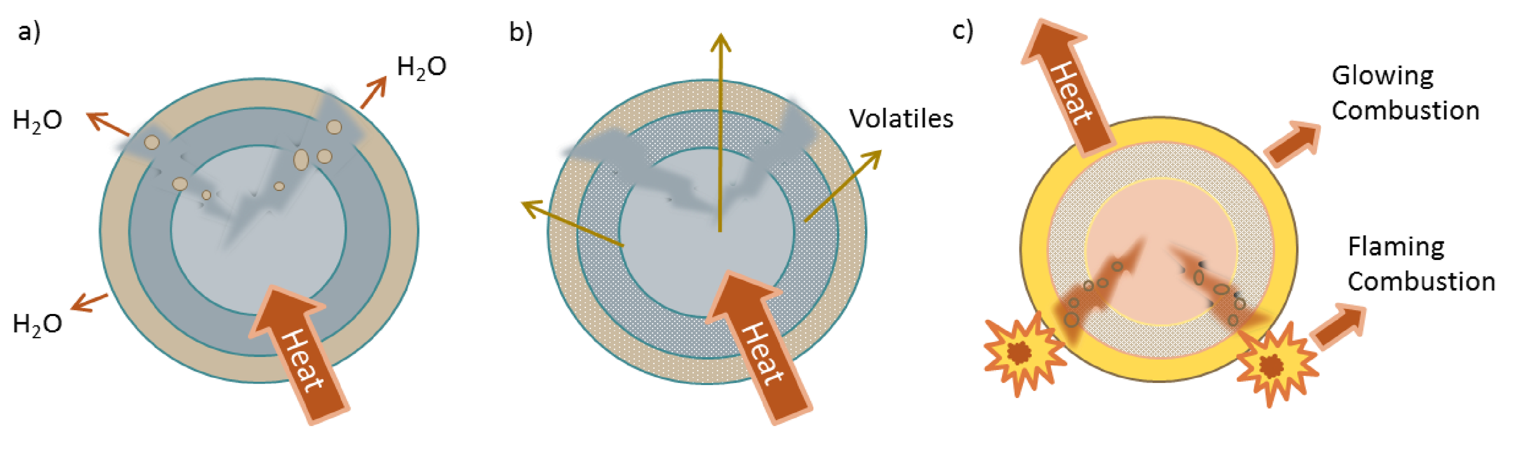

Figure 1: Stages during biomass combustion: a) drying, b) devolatilisation, c) char combustion, adapted from Van Loo et al. [1].

Aims

For fuels such as pine and wheat straw:

- To study the evolution profiles of NOx precursors at different heating rates and compare the laboratory results with FG-Biomass software predictions.
- To understand how heating rate affects the split of fuel-N into volatile-N and char-N for raw fuel and torrefied fuel.

Evolution profile of NOx precursors

- During devolatilisation, the evolution profiles of NOx precursors (NH_3, HCN, HNCO) are not the same for each fuel.
- FG-BioMass software can model the evolution profiles of these NOx precursors, as shown in Figure 2.

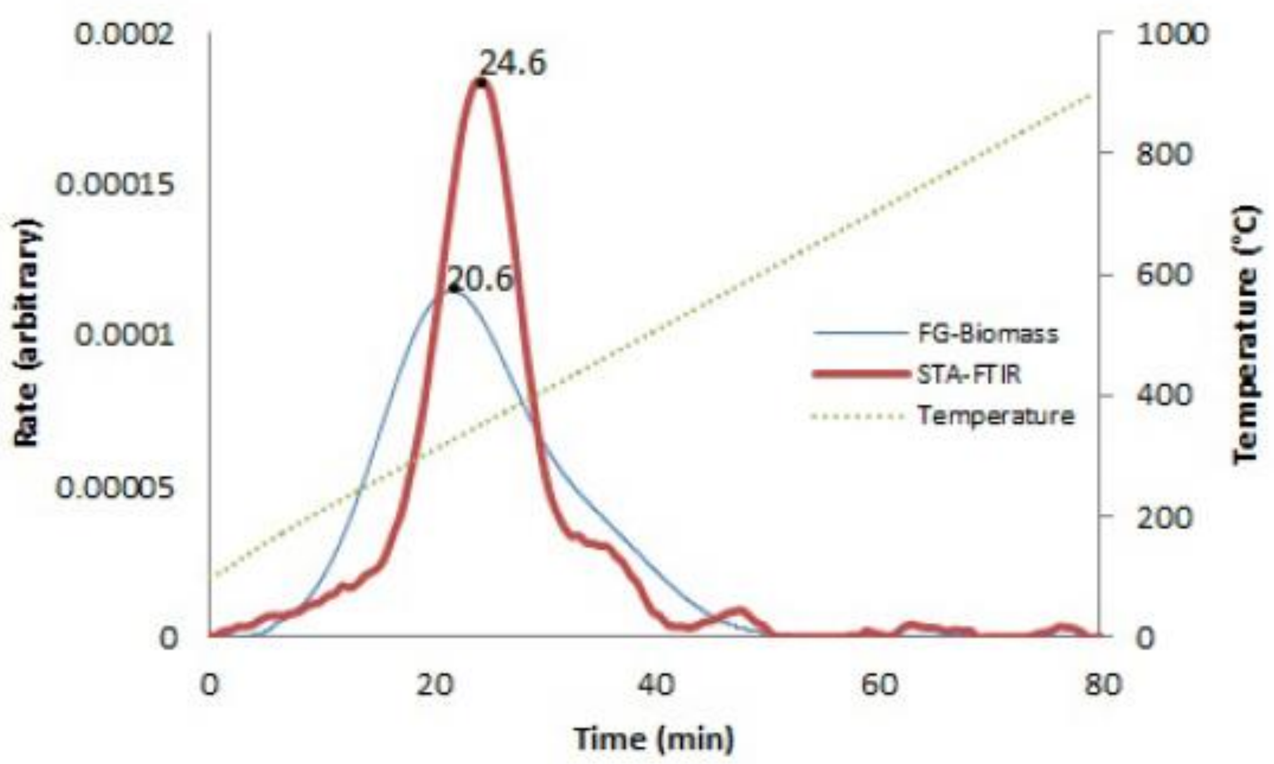

Figure 2: Comparison of the measured and predicted NH_3 evolution profile for the devolatilisation of wheat straw at a heating rate 10°C/min.

Effect of heating rate on nitrogen partitioning

- Wheat straw and pine fuel were combusted using a two stage process with initial devolatilisation in a nitrogen atmosphere followed by char combustion in 12.5% oxygen in helium.
- Two heating rates were used for devolatilisation. Low heat rate (LHR) was 10°Cmin^{-1} and high heat rate (HHR) was 1000°Cmin^{-1}.
- The nitrogen partitioning during the HHR and LHR pyrolysis were calculated by a material balance from the nitrogen content of the fuel and that of the char.

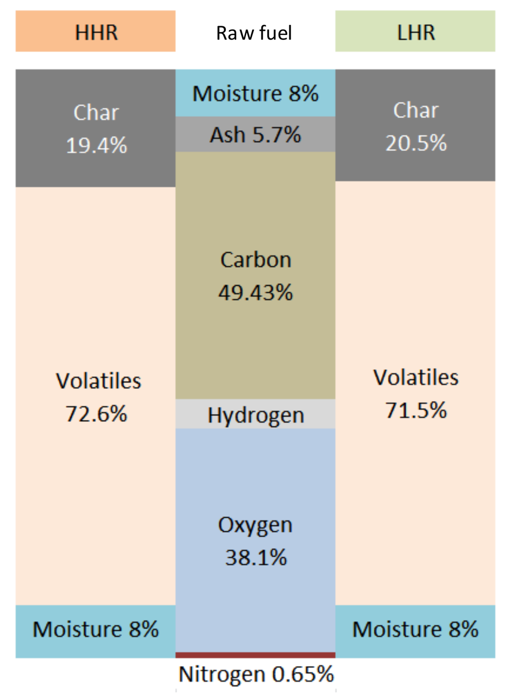

Figure 3: Changes in composition during HHR and LHR pyrolysis of wheat straw.

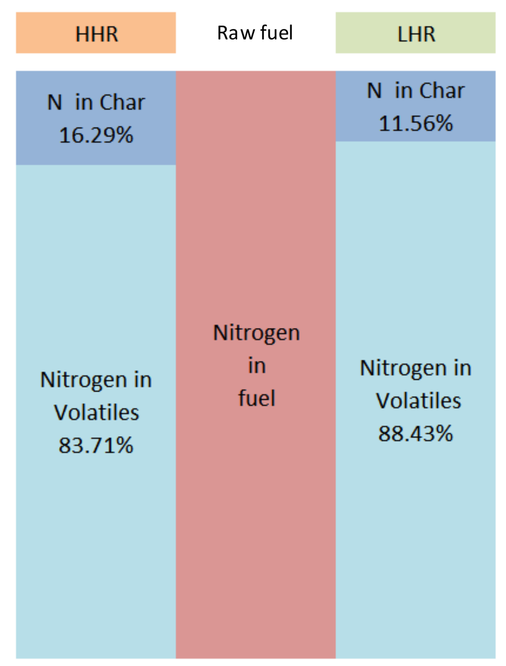

Figure 4: Nitrogen partitioning during the HHR and LHR pyrolysis of wheat straw.

- It was found that LHR pyrolysis produced a slightly lower proportion of volatiles than HHR pyrolysis.
- However, during LHR pyrolysis a greater proportion of the nitrogen was released in the volatiles rather than retained in the char.
- The higher proportion of nitrogen released in the volatiles is preferable to char nitrogen for several power station de-NOx strategies.

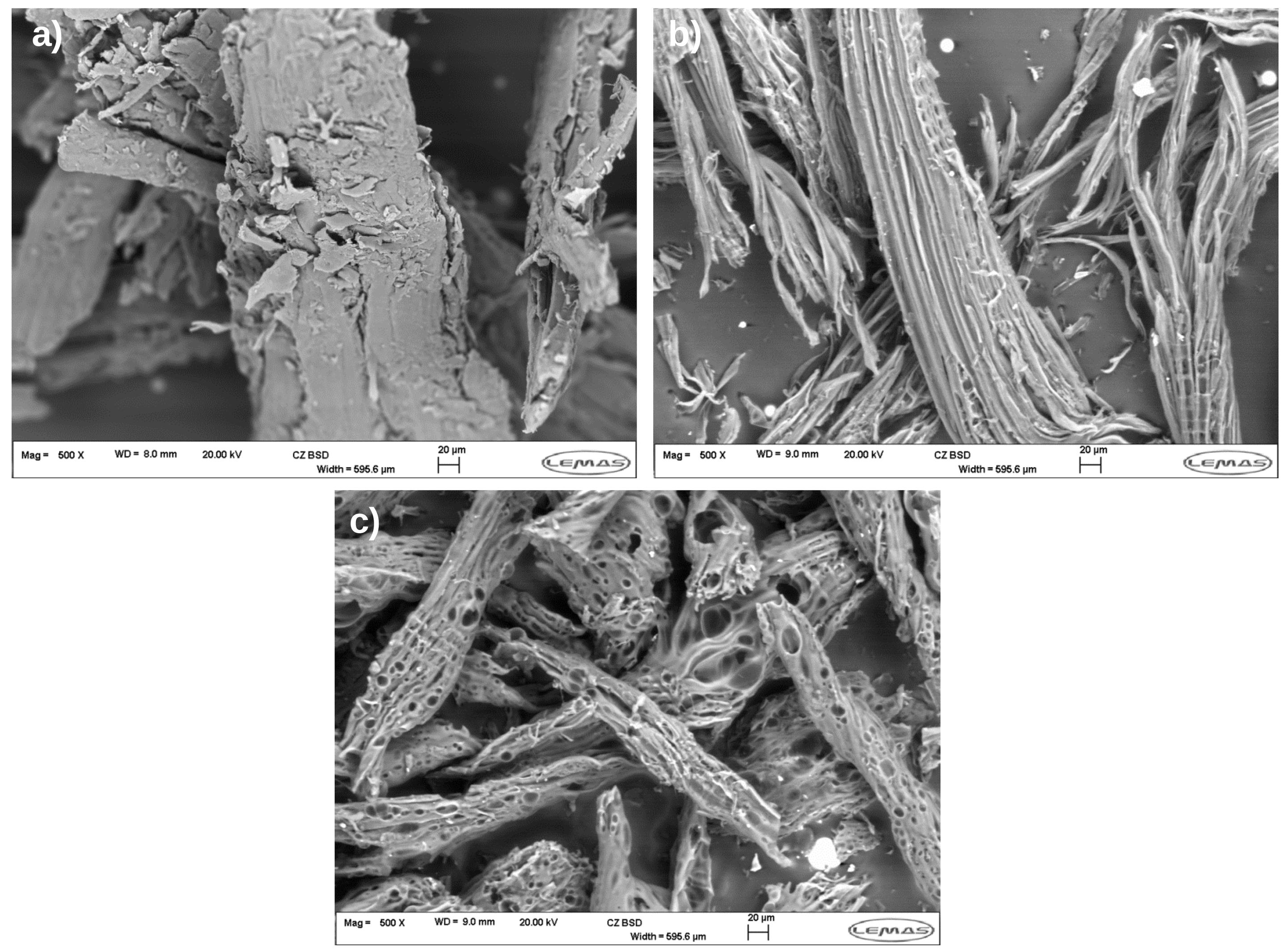

Figure 5: SEM images of pine samples (500x magnification), where a) Raw pine, b) LHR pine char, and c) HHR pine char.

Pyrolysis of torrefied biomass

Torrefaction:

- Improves grindability, allowing for more efficient co-firing
- Increases energy density, improving energy output compared to raw biomass and lowering transportation costs.
- Results in a hygroscopic fuel, less prone to degradation upon storage.

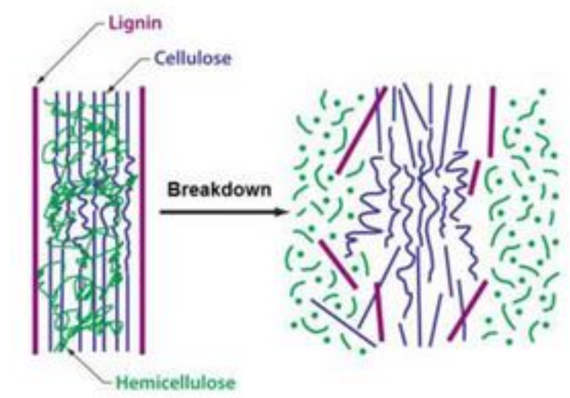

Figure 6: Breakdown of lignocellulosic components during torrefaction.

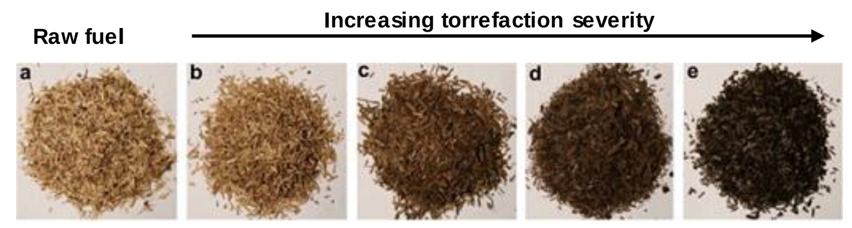

Figure 7: Changes in fuel colour due to torrefaction conditions.

The nitrogen partitioning between the volatiles and char for the raw and torrefied pine samples that were pyrolysed at HHR was calculated by a material balance, as shown in Figure 8. Results indicated:

- Increasing the torrefaction temperature may promote the release of nitrogen from the resultant solid.
- However, higher percentage of nitrogen may be retained in the chars after torrefaction, when compared to raw biomass.

Nitrogen in char/Raw Nitrogen	%
Raw Char N/Raw N	10.79
270 Char N/Raw N	14.76
290 Char N/Raw N	13.36

Figure 8: The percentage of fuel-nitrogen retained in the chars during the pyrolysis of raw pine, and pine torrefied at 270°C for 30 minutes and 290°C for 30 minutes.

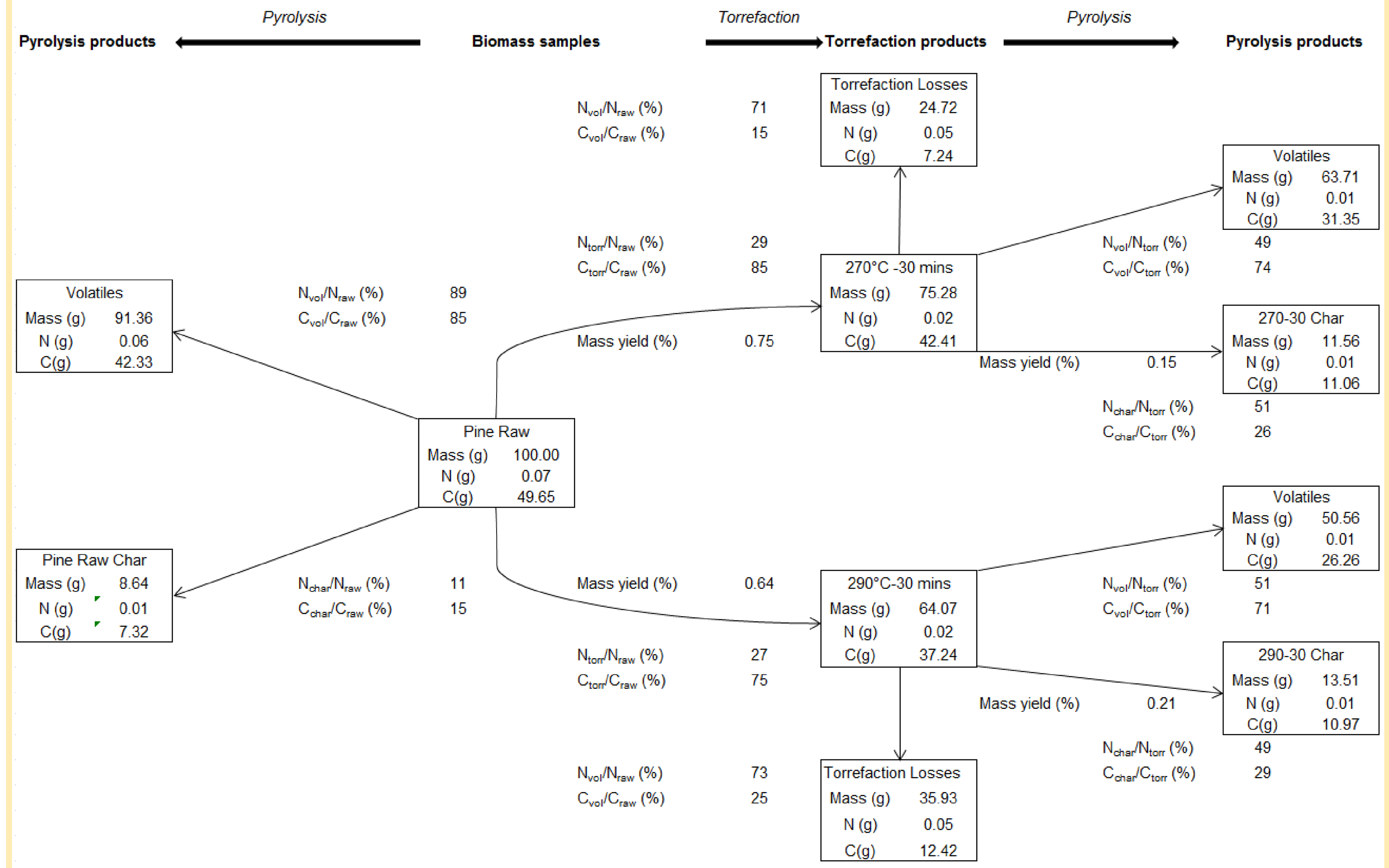

Figure 8: A comparison of carbon and nitrogen balances for the pyrolysis of raw and torrefied pine.

Conclusions

- The combustion environment affects the fate of the nitrogen present within the fuel. Varying the heating rate directly affects the partitioning of nitrogen between volatiles and chars.
- Although torrefied fuel was found to contain less total nitrogen than the raw pine, the nitrogen concentrated within the torrefied chars was greater in comparison to the raw fuel.

References

[1] Diagram adapted from VAN LOO, S. & KOPPEJAN, J. 2008. *The handbook of biomass combustion and co-firing,* London, Earthscan.
[2] Kasparbauer, R. D., 2009. The Effects of Biomass Pretreatments on the Products of Fast Pyrolysis. *Graduate Theses and Dissertations,* p. Paper 10064.

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