Technical University of Munich
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Measurements of NOx emissions from biomass combustion in small to medium-scale power plants

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Motivation

Biomass remains a large part of the energy mix in Europe. Its combustion, while generating energy, also produces nitrogen oxide gases (NO_x), which pose significant environmental and health risks [1-2]. Since biomass encompasses a myriad of materials, it contains different contents of fuel-bound nitrogen, leading to varying NO_x emissions depending on the used biomass.

In order to understand the behaviour of nitrogen species such as oxides (NO_x) and their intermediates in small to medium-sized power plants, a two-point measurement is conducted in the combustion chamber and the exhaust gas line of two distinct power plants. The small-sized power plant is an injection furnace (0.85 MW_{th}) using waste wood from pencil production for in-house heating. The medium-sized power plant is a bubbling fluidized bed (40.4 MW_{th}) producing heat and power with waste wood and screen overflow used as fuel.

Measurement Set-Up

A two-point measuring system was used:

- Exhaust gas was measured with a portable multi-component analyser from *MRU Messgeräte für Rauchgase und Umweltschutz GmbH*
- Gases from the combustion chamber were sampled at high temperatures through a specially designed air-cooled steel probing lance, passed through a heated filter and analysed by a portable multi-component FTIR gas analyser *Gasmet DX4000* (see **Figure 1**)

Characteristics of the measured points:

- Sampling from the exhaust gas line
- The depth of the high-temperature measuring probe was varied
- Measurements were conducted for at least 30 minutes for each point

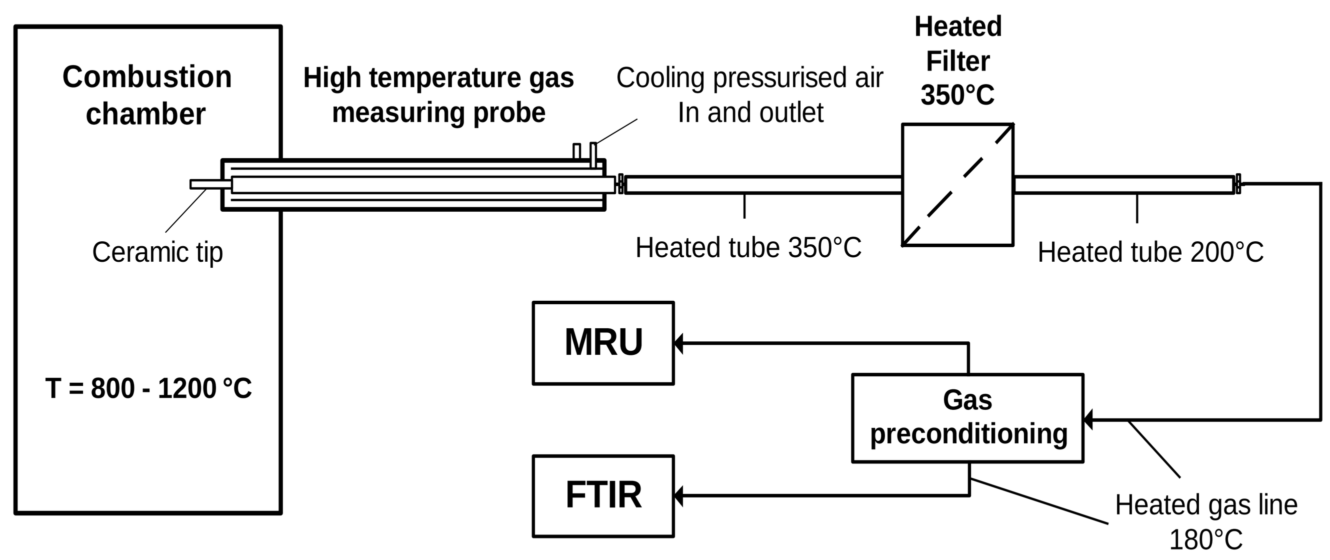

Figure 1: Schematic representation of the employed measurement system

Power plants

The measurements were conducted at a 0.85 MW_{th} injection furnace (PP1) and a 40.4 MW_{th} fluidized bed (PP2). A schematic drawing of the power plants with the measuring points is given in **Figure 2**.

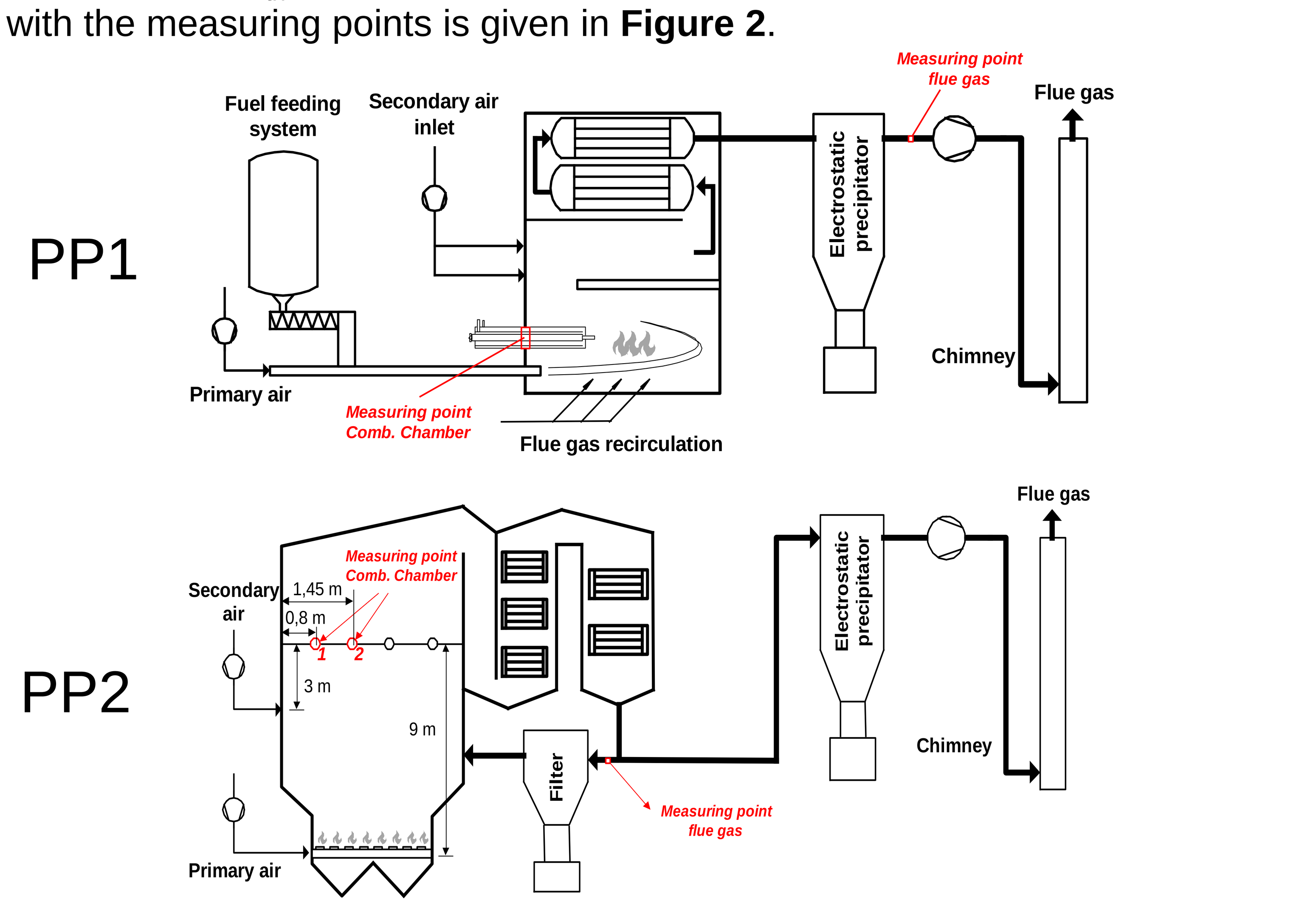

Figure 2: Schematic drawing of the investigated power plants

Results

The results from the fuel analysis are summarised in **Table 1**. It becomes evident that the fuel from PP2 contains a significant amount of inorganics.

The gas analysis of the in-furnace measurements displays a decreased available oxygen with increasing sampling depth. For PP1, this effect leads to the rapid increase in available nitrogen species (NO, NH_3 and HCN) at 60 cm depth, whereas the other points are likely in a dead zone (see **Figure 3**). The average of the nitrogen species is given in **Figure 4** and **6**. The sum of the nitrogen species for PP2 does not display the same behaviour since it was measured after air staging (see **Figure 5**).

Table 1: Fuel analysis with emission and concentration values

	PP1	PP2	
C	47.48	35.92	wt-% (db)
H	5.31	4.00	
N	0.58	1.77	
S	0.06	0.17	
O	46.28	35.13	
Ash	0.30	23.00	
Volatiles	80.46	56.22	
Water	6.35	7.70	wt-% (ar)
LHV	19.50	15.23	MJ/kg
Emission limit [3]	365.40	97.44	ppm 6% O_2
Stack NO_x	61.67	72.46	
NO_xᵃ at λ=1.2	83.99	120.77	
N-Speciesᵃ	143.88	152.93	

ᵃ deepest measurement in-furnace

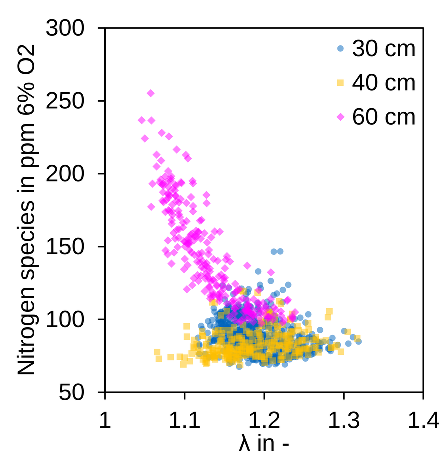

Figure 3: Sum of the nitrogen species from PP1

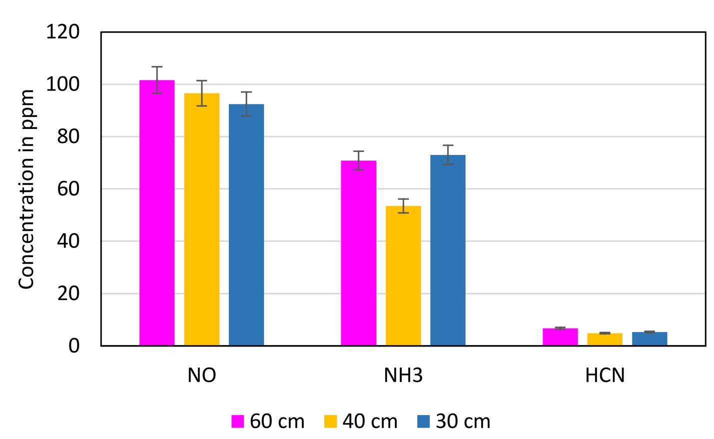

Figure 4: Average of the nitrogen species from PP1

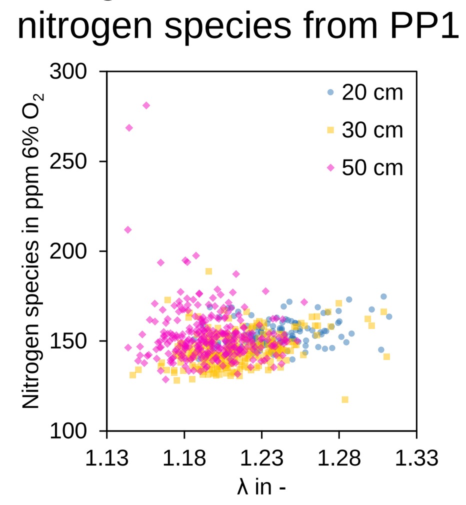

Figure 5: Sum of the nitrogen species from PP2

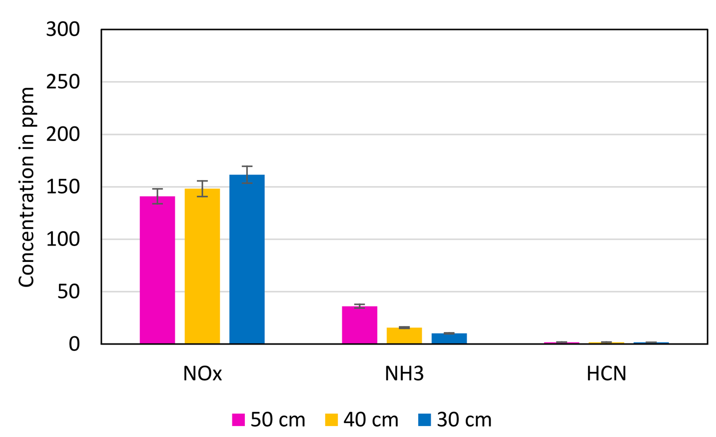

Figure 6: Average of the nitrogen species from PP2

Conclusion & Outlook

Combustion and exhaust gas from an injection furnace (0.85 MW_{th}) and a fluidized bed power plant (40.4 MW_{th}) were sampled and analysed. Both power plants displayed average emissions below the allowed limit.

The measurements from the combustion chamber exposed a dominance of NH_3 over HCN for both power plants. The NO_x concentration from the combustion gas was further reduced compared to the stack NO_x, with the fluidized bed having a more significant reduction. NH_3 must have reacted with the available NO and reduced it.

Furthermore, the sum of the nitrogen species displays a minimum value for both firing concepts.

The gathered data will be used in computational fluid dynamic simulations and compared to lab-scale experiments to gain further insight into the possible reduction potential of the NO_x emission from solid biomass combustion.

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[1] European Commission, Directorate-General for Energy, EU energy in figures – Statistical pocketbook 2023, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2833/502436
[2] US Environmental Protection Agency: Integrated Science Assessment for Oxides of Nitrogen–Health Criteria.
[3] 44. BImSchV https://www.gesetze-im-internet.de/bimschv_44/BJNR080410019.html

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