

## A comprehensive approach of using agricultural residues to substitute fossil fuels and producing biochar in a 3 MW pyrolysis plant

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### Introduction

Minimizing carbon dioxide emissions whereas keeping up the high living standard of today is only possible by increasing the efficiency of energy consumption and the change to a mix of renewable fuels.

Huge amounts of unused biomass in terms of agricultural residues like straw, that is a cheap and local feedstock, are often available. But as a reason of the high amount of corrosive ash elements (K, Cl, S, etc.), the residues are not suitable for co-firing in a thermal power plant. Therefore the feedstock is converted by low temperature pyrolysis into pyrolysis gases and biochar. The aim of this process is to hold the corrosive elements back in the char and to produce a high calorific pyrolysis gas that can be co-fired in the power plant.

The pyrolysis pilot plant is located in Dürnrohr/Austria just next to the coal fired power plant. The pilot plant is in operation since 2008. Figure 1 shows the flow sheet of the pyrolysis pilot plant.

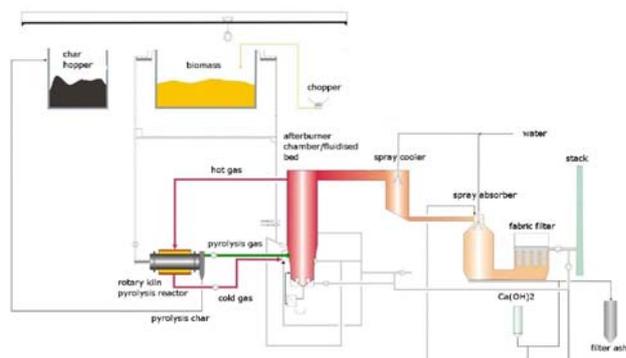


Figure 1. Flow sheet of the pyrolysis pilot plant.

The design fuel power is about 3 MW; the pyrolysis gas capacity is about 1.5 MW. Approximately 0.6 to 0.8 t/h straw, as the primary feedstock can be processed in the rotary kiln. The two most important components are the externally heated rotary kiln pyrolysis reactor, where the thermal decomposition of the

biomass takes place, and the fluidized bed combustion chamber. A broad range of different agricultural residues have been under investigation.

### Results and Discussions

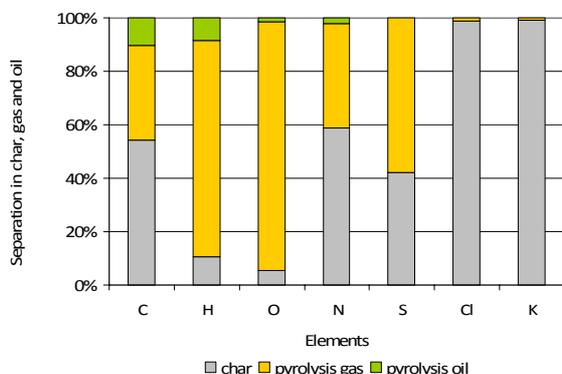
For the balances, test runs with pyrolysis temperatures of 450, 500, 550 and 600 °C have been performed. An important part is the output of gas, oil and char for the different pyrolysis temperatures. For comparing the four operating points the energy and mass contents of those three fractions were each converted to the reference of the sum of the energy or mass contents of gas, oil and char.

It can be seen that by increasing pyrolysis temperature, the produced amount of pyrolysis gas increases significantly whereas the amount of char slightly goes back and the mass of pyrolysis oil is reduced heavily. This strengthens the already known fact that a higher pyrolysis temperature forces the production of gas at the expense of the formation of pyrolysis oil. The higher temperature causes the decomposition of oil to gas. Slightly less mass of char results in the fact more volatile compounds are used to be stripped due to higher temperatures.

Increasing pyrolysis temperatures cause a raise of energy delivered by pyrolysis gas and char and a drop of the energy delivered by pyrolysis oil. Most of these effects are caused by the different amounts of the products that are produced. A further reason is that due to different pyrolysis temperatures the chemical composition of the products is slightly different. So, at lower temperatures in the rotary kiln reactor there are more polyaromatic compounds with a high boiling point formed that have a high heating value.

In addition to the consideration of the energy and mass fractions of pyrolysis gas, oil and char the distribution of the chemical elements of the feedstock in pyrolysis gas, oil and char is also an important aspect. It is of major

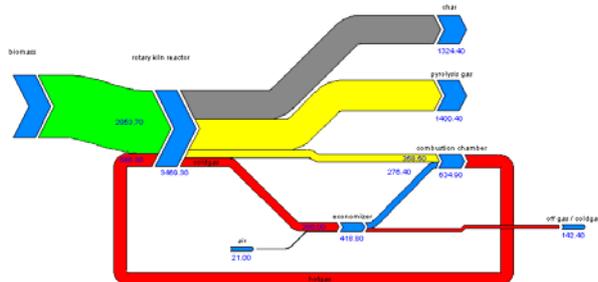
significance that the pyrolysis process is operated in a way that prevents the undesired components, which could lead to hot temperature corrosion in the boiler, to enter the gaseous pyrolysis products. Figure 2 shows the distribution of each chemical element in pyrolysis gas, oil and char.



**Figure 2.** Separation of the chemical elements in the pyrolysis products for indoor stored straw at a pyrolysis temperature of 550 °C.

In the actual pyrolysis pilot plant there is the whole pyrolysis gas burned in the afterburner/fluidized bed. If the process would be used for producing burnable gas for co-firing, the thermal energy for the rotary kiln has to be produced externally. This could happen by firing a part of the produced gas in a separate combustion chamber, by firing straw or another feedstock in a fluidized bed combustion or extraction of hot flue gas from the coal fired power plant.

Some results of this balance concerning the energy of the streams are shown in the following Sankey-diagram (Figure 3).



**Figure 3.** Sankey-diagram for straw pyrolysis for the case of energy supply by pyrolysis gas, energy flows [kW].

### Conclusions

The most important reason for the construction and operation of the pilot plant was to gain fundamental information about the start of a pyrolysis plant that produces gaseous pyrolysis products that are suitable for co-firing at coal fired power plants. To keep as much of undesired components, like chlorine, potassium

or sodium, back in the pyrolysis char to prevent the boiler from high temperature corrosion requires an intelligent process management of the pyrolysis parameters. This leads one to suspect that there is always a discrepancy between getting as much chemical energy from the feedstock to the gaseous products as possible and keeping the undesired components back in the char. But it has already been proven that the used process technology is proper for producing a gas, whose combustion products do not cause corrosion. It turned out that the operation, handling and control of the pilot plant, especially the pyrolysis reactor, can be done without serious problems with the current state of knowledge. The ruggedly designed rotary kiln reactor is also unsusceptible for a contamination of the feedstock with soil or small stones. The pyrolysis char has a very high heating value and is nearly free of any water content. So the pyrolysis char is a very good fuel for combustion systems. The biochar could also be brought back to the fields where the feedstock came from. Biochar is excellently suitable for the improvement of soil. Due to certain reasons the biochar should not be used as fuel but for biosequestration and atmospheric carbon capture and storage. Using the pyrolysis char as reducing agent in the non-ferrous metallurgy is also under investigation. The char could also be used for providing the thermal energy to run the pyrolysis process. The plant efficiency is calculated for the case that the thermal energy that runs the pyrolysis process is provided by combustion of a part of the pyrolysis gas in a separate combustion chamber. The rest of the produced gas can be used in the power plant. In this case and for the pyrolysis of indoor stored straw a net efficiency of 0.48 would be reached. The Dürnröhr power station has an electrical efficiency of 0.42 [1] so if the pyrolysis process would be connected to the power station there would be an electrical efficiency of 0.20 for the generation of electrical energy of straw. This efficiency is significantly higher than the electrical efficiency of smaller biomass fired power stations or CHP.

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<sup>†</sup> Böhmer, S., Schindler, I., Szednyj, I., Winter, B., 2003, Stand der Technik bei kalorischen Kraftwerken und Referenzanlagen in Österreich, Wien, Umweltbundesamt GmbH, ISBN 3-85457-682-X.