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Biomass based energy intermediates boosting biofuel production

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Deliverable

Report on economy of energy carrier-based CHP systems for market implementations

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Publishable Summary

The overall objective of the BioBoost project is to pave the way for de-central conversion of biomass to optimised, high energy density carriers, which can be utilised in large scale applications for the production of transportation fuels and chemicals or utilisation directly in combined heat and power (CHP) plants.

Therefore, the de-central conversion of dry and wet residual biomass and waste feedstocks by fast pyrolysis, catalytic pyrolysis and hydrothermal conversion to the intermediate energy carriers catalytic oil (from catalytic pyrolysis), biocoal (from hydrothermal conversion) and bio-syncrude (mixture of biocoal and liquid (organic and aqueous) phases from fast pyrolysis) is studied. These energy carriers are suitable for large-scale gasification, but due to additional applications, the economics of the whole chain may be improved.

One possible additional application is the direct use in combined heat and power plants. Within the Partners from the BioBoost Project, only hard coal fired power plants are available. Due to the low self-ignition temperature of the bio-char (either from fast pyrolysis or from hydrothermal carbonisation), self-ignition or explosion is to be expected, if the same fuel feed for bio-char would be used than for hard coal. In the conventional fuel feed, hot air from the air preheater is used to transport the milled coal from the coal mill into the boiler. Therefore, retrofitting measures are inevitable to burn the bio-char in a commercial power plant based on hard coal.

This deliverable gives an overview, what kind of modifications need to be implemented to use bio-char and pyrolysis oil from the fast pyrolysis process and from hydrothermal conversion in a commercial power plant based on hard coal. Also the economical aspect of such modifications is considered.

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1 Introduction

Combined heat and power (CHP) applications can be an environmental and economic benign way to use pyrolysis oils and chars. In CHP applications with hard coal fired power plants, the char can be used as a coal substitute, and the pyrolysis oil can serve as a replacement for heavy fuel oil, used in particular coal fired power plants for starting and preheating purposes.

Possible retrofitting measures which need to be implemented to use bio-char and pyrolysis oil in power plants based on hard coal are identified.
Since each boiler construction is different (e.g. tangential firing or opposed wall fired boiler) an overview over basic measures will be given in this deliverable.
Furthermore, the economic framework for such measures will be considered.

2 Technological assessment

Essential modifications for the utilization of bio-char

To achieve a maximum burnout and to enhance the efficiency of commercial CHP plants based on hard coal, the coal is milled prior to combustion. Via conveyor belts, the coal is transported from the stockyard to the bowl mill crushers. In the coal mill hot air from the air preheater is used to transport the coal dust into the combustion chamber. Due to the usage of this hot air, the temperature in the mill can reach temperatures above 250°C. Since the self-ignition temperature of the bio-char (from both processes, fast pyrolysis and hydrothermal conversion) is at approximately 110°C, this conventional feeding system possesses a serious risk for the whole power plant and therefore cannot be applied for co-combustion of bio-char.

To avoid self-ignition of the bio-char in the coal mill, another way of injecting the bio-char into the combustion chamber has to be identified. To avoid major modifications at the power plant, as much as possible existing equipment should be used.

Since the bio-char after the HTC or the pyrolysis process is available in powdered form with a grain size distribution similar to milled hard coal, no milling or other crushing method is necessary before injecting the bio-char into the combustion chamber. For storage purposes of the powdered bio-char, a silo installation or a similar container including appropriate charging (e.g. from railway wagons or trucks) and discharging devices is necessary. The storage facility needs to be equipped with an air recirculation system. To avoid problems occurring during longer storage times (i. a. molding and self-ignition), the storage has to take place under inert gas (nitrogen). As discharging device, a screw conveyor can be used. This has also the advantage, that the screw conveyor can meter the amount of bio-char which will be co-fired.
Due to space constraints in existing power plants, the bio-char storage will probably be located on the ground floor level outside, in the vicinity of the boiler house. To

transport the bio-char from the storage facility into the combustion chamber onto the burner level area, an air blower is required.

Since a sophisticated technology is the basis of modern power plants, any alteration in the process needs to be simulated and examined carefully to avoid any behavior which can be distracting or harmful to the combustion process and the system itself. To minimize the alteration for the combustion process, the amount of bio-char needs to be injected as evenly distributed as possible. This means, that the whole amount cannot be injected in one opening in the boiler casing, but four openings are necessary to inject the bio-char into the combustion chamber (comparable to conventional coal burners). Therefore, four additional openings need to be installed in the boiler casing including appropriate burners. The piping system from the storage facility to the additional burners needs to be equipped with flaps and shut-off valves.

Considering the properties of bio-char (very high contents of chlorine, alkaline and phosphorus compared to hard coal), and the results from the combustion tests of USTUTT (see Deliverable 6.2), only co-firing in very low shares (app. 5%) is advisable to avoid problems regarding corrosion, slagging and fouling as well taking into account utilization issues of fly ash.

Essential modifications for the utilization of pyrolysis oil

Prior of burning hard coal in a power plant, the boiler has to be preheated. This preheating is normally done either by gas or by fuel oil (light or heavy fuel oil). In power plants where the preheating is done by heavy fuel oil, pyrolysis oil can serve as an alternative and substitute the heavy fuel oil. Due to the high content of particles in pyrolysis oil filtering of the pyrolysis oil prior to application is necessary to avoid blockage of the piping and injector nozzles. Regarding the high viscosity of the pyrolysis oil, preheating to around 50 – 80°C is required to allow proper atomization. Since the heavy fuel oil has to be preheated as well, no major modifications of the equipment for vapor atomization are expected, except for the filtering.

Other constraints

Since the co-firing of bio-char and the usage of pyrolysis oil as a substitute for heavy fuel oil is a major interference is the sensitive system of a large power plant based on hard coal, not only reconstruction measures need to be considered if such co-firing / heavy fuel oil substitution will be implemented.

As already mentioned, large commercial power plants are based on sophisticated technology. Therefore, each alteration has a significant impact on the whole combustion process and needs to be investigated in detail. This results in respective tests and simulations in collaboration with the manufacturer of the boiler. Afterwards, optimization of the combustion is necessary to ensure a proper process and to comply with all emission values. Since the usage of the bio-char means an additional inflammable substance which is used on the premises of the power plant, the fire protection concepts as well as the valid ATEX regulations for the power plant need to be adjusted. The usage of an additional fuel requires also modifications or additional permits from the legal authorities.

3 Economical assessment

Regarding the economic scale for co-firing of pyrolysis oil and bio-char in a power plant based on hard coal, investment costs as well as operational costs have to be considered.

For investment costs, all required modifications have to be taken into account. This applies mainly for necessary modifications in the fuel feed of the hard coal respectively the bio-char.
Since no power plant is identical from the setup (different sizes, combustion chamber construction, etc.), all necessary modifications for each particular plant have to be investigated in more detail. Here, only a rough estimation is given.

The following table gives a rough estimation about the approximate investment costs:

Storage facility including charging and discharging devices, as well as air recirculation system and nitrogen supply unit	700.000€
Air blower	150.000€
Reconstruction boiler casing for four openings	300.000€
Duct work	250.000€
Four Burners	120.000€
Filtering system for pyrolysis oil	800.000€
Process Control	300.000€

The second table specifies additional costs, arising from regulations etc. which need to be kept:

Approvals and Permits	750.000
Simulations and combustion optimization	3.500.000€

Compared to the sole use of hard coal, the co-firing of bio-char leads to higher operational costs. This is mainly due to additional storage costs (inert gas) and due to efficiency losses (additional air blower which injects the bio-char with cold air).

4 Conclusions

Since all power plants based on hard coal of EnBW are unique, the mentioned retrofitting measures are only a rough abstract, what needs to be done to co-fire bio-char in commercial power plants based on hard coal.
Taking into account all arising investment costs amounting to more than 6 million Euros, as well as the expected higher operational costs and considering the working

time left for most of EnBW's hard coal power plants, those costs will not be redeemed within the residual working time.