## Contents

1. Introduction ................................................................................................................. 3  
2. Fuel refining technologies ............................................................................................ 4  
3. Advantages of refined biomass ..................................................................................... 5  
4. Limitations of refined biomass ..................................................................................... 6  
5. Conclusion and recommendations ............................................................................... 7
1. Introduction

The 2020 target of the European Commission is to produce 20 % of the overall energy consumption by renewable energy sources. To fulfill this target approx. 34 % of electricity and 18 % of direct heating and cooling have to be delivered by renewable energy sources. The co-firing of biomass in existing fossil fuel fired power plants is widely recognized as one of the most cost effective ways to produce electricity by renewable energy sources.

The major advantages of co-firing are the common utilization of existing plants, the fuel flexibility, a wide range of usable fuels together with a fall back option in cases of biomass shortage and the attainment of higher overall efficiencies compared to small scale stand-alone installation like they are preferred in Germany. Therefore, co-firing in large thermal power stations can lead to an overall saving of fuels in comparison to independent fossil and small scale biomass fired plants. The lowest emission standard limits are achievable with the installed existing flue gas cleaning devices. The enhanced power and heat flexibility of co-firing plants support the available supply and further development of wind and solar energy. Since a carbon intensive fuel is directly replaced, it is therefore cost effective per ton of CO\textsubscript{2} mitigated.

Significant challenges occur while storing large amounts of biomass fuel and co-milling of high shares of biomass in the existing coal mills might be limited by the type of biomass. In most cases biomass fuels cannot be stored outside on the coal yard. Unlike coal, they tend to absorb water, thus change their physical properties, and leach organic and inorganic compounds. Furthermore, in biomass stock piles self-heating and even self-ignition is a higher risk than in coal piles. Especially fibrous biomass fuels are difficult to mill, tend to de-mix from coal, can cause problems in the mills (accumulation, explosions), and therefore limit the throughput and share of biomass for co-milling applications.

Refined biomass is expected to overcome these limitations and consequently power plant operators are very interested in using these new bio-fuels together with coal. This white paper gives an overview of the three main refining technologies and the advantages and limitations of refined biomass for biomass co-firing in pulverized fuel boilers.
2. Fuel refining technologies

“Refining” is a generic term for different fuel processing technologies like

- Torrefaction
- Steam explosion
- Hydrothermal carbonization (HTC)

All these technologies have in common that some of the lignocellulosic biomass components that lead to the tenacious behavior (mostly hemicellulose and part of the cellulose) are destroyed resulting in more brittleness. This leads to more “coal like” milling properties and by destruction of polar components to a more hydrophobic behavior enabling outside open storage. In general the energy density is higher for the thermal processed material than for unprocessed biomass (higher specific heating value). The processing technologies are shortly described below. The information is mainly taken from literature and manufacturer information and should be verified prior to practical application of the respective fuel.

**Torrefaction**

Torrefaction can best be described as a mild pyrolysis. The biomass chipped to a uniform size is heated to a temperature typically between 250 and 320 °C (pyrolysis > 400 °C) under atmospheric pressure and in an atmosphere free of oxygen. The goal is the destruction of the hemicellulose structure. In this temperature range carbonisation and limited devolatisation of lignin, celluloses and hemicelluloses take place. Depending on the input material and process conditions chosen, about 30 % of the dry mass is typically devolatised as torrefaction gases, which are afterwards burned in a separate combustion chamber to evaporate the water of the incoming biomass and for heating the process. Typically, about 90 % of the lower heating value (LHV) of the raw material used is contained in the final product, which only amounts to about 70 % of the original dry mass. The quality of the process depends on the balance between temperature and residence time to, on the one hand, preserve a maximum of energy density and, on the other hand, to achieve certain fuel properties like grindability and hydrophobicity. The more extreme the torrefaction conditions are (as temperature and residence time) the more torrefaction gases will be released and the higher the calorific value of these gases. For densification (pelletisation or briquetting) of the product it is important to keep an amount of lignin as natural binder in the biomass in order to avoid the need for additional binders.

**Steam explosion**

Steam Explosion pretreatment is realized by exposing to a uniform size chipped biomass particles to high pressure saturated steam or slightly superheated steam, before a brusque pressure drop after a couple of minutes. The rapid expansion of steam inside the internal pores of the particles decomposes the particles surface. Hemicellulose hydrolyses and lignin depolymerize. The major operational parameters
of steam explosion are particle size of the biomass feedstock, the applied reaction pressure (10-35 bar), the reaction temperature (180-240 °C) and the residence time. Almost no energy or mass is lost compared to the raw material. The dry matter yield is > 95 %. The energy density is slightly increased compared to the feedstock.

**HTC – hydrothermal carbonization**

Hydrothermal carbonization is a thermochemical process, in which biomass is heated up in water to a temperature of 180 to 230 °C at a pressure of 10 to 30 bar for 90 min to 24 h. 70 to 90 % of the energy content is preserved in the solid product, which aggregates to 70 to 85 % of the original mass. 10 to 25 % of the original mass is dissolved in the water and 5 to 6 % is converted to gas (> 90 % CO₂). Depending on the temperature of the respective process the quality of the solid product can vary from humus like to lignite like.

The main limitation of the process seems to be the high amount of water that is needed (about 5 t of water for 1 t of biomass) and the high amount of dissolved substances (chemical oxygen demand (COD) ~ 70,000 mg/l, organic acids, salts, phosphate, ammonium, sulphate, chloride, heavy metals). But the remaining liquid is biodegradable by anaerobic digestion and if the feedstock is not contaminated the liquid fraction could be used as fertilizer, due to the high potassium content. The utilisation as fertiliser is part of current scientific investigations. Due to the solution of alkali and chloride in the liquid phase during the process the alkali and chloride content of the solid phase is reduced and thus the risk of impacting the boiler by slagging, fouling and corrosion decreases.

**3. Advantages of refined biomass**

Based on several co-firing tests by VGB member companies and information of the fuel producers the technical, economic and environmental advantages of refined biomass can be summarised as follows:

- Refining processes improve the durability of the biomass. By the different refining technologies the polar characteristics of the biomass fuel are destroyed and therefore the refined fuel is (almost) hydrophobic. Depending on the process performance and fuel quality the refined biomass may be stored outside on the existing coal yards. Additionally it is less susceptible for biodegradation.
- The disintegration of the ligno-cellulosic structures of the biomass fuel leads to better grindability of the material compared to unprocessed biomass. In most cases the existing coal mills can be used for co-milling the refined biomass without significant changes.
- The energy content of refined biomass is higher than unprocessed biomass and can even exceed the energy content of wood pellets due to the loss of...
hemicelluloses with low energy content. Therefore, the same amount of fuel energy is cheaper in logistics, requires less area for storage, less investment in handling equipment, less energy for milling, and less energy for transportation.

- Because of the coal-like properties of the refined biomass, the existing coal logistics, and downstream handling systems can be used. That leads to a high flexibility in feedstock and a fall back option in case refined fuels are temporarily unavailable at the market.
- Impact on flue gas cleaning and power plant by-products is expected to be similar to untreated biomass fuels.

4. Limitations of refined biomass

At this moment the main limitation of refined biomass products is the uncertainty concerning availability and quality.

- At this stage there are only a few facilities for refined biomass that are capable to deliver the substantial amounts required by the end users.
- For most of those facilities the big challenge remains to produce a constant biomass quality due to the variability in raw biomass specifications and the complexity of process control.
- Except for the HTC and partly the steam explosion process, the presence of inorganic fuel constituents is usually not influenced by the biomass refining process. That means if high alkali and chlorine biomass is used for the process the resulting refined fuel will typically keep this high amount of chlorine and alkali. This results in the well-known slagging, fouling and corrosion issues and limits the co-firing ratio.
- Due to the fact that part of the organic material in the biomass is evaporated, the internal surface area of the biomass fuel increases significantly through the refining process. This usually leads to a higher reactivity and certain safety issues. Though some tests revealed explosion characteristics comparable to coal, other tests showed explosion characteristics by far more critical than for coal.
- Because of the currently experienced variation in quality of the refined material (torrefaction process control & performance) and of the densified biomass (durability after pelletisation or briquetting), refined biomass may tend to emit a high amount of very fine dust and countermeasures have to be taken.
- The hydrophobicity of the refined biomass may not be taken for granted at this stage of technology development – it strongly depends on the refining process control and performance. Stability of refined biomass pellets over several months has been observed as well as disintegration after two days.
- In some cases strong odours as well as high amounts of COD (chemical oxygen demand) in the leachate have been noticed during storage which may limit the ability to store refined biomass outdoors.
- In any case the refining processes change the chemical structure of the biomass, so a REACH (Registration, Evaluation, Authorisation and Restriction of Chemical substances) registration for the European market maybe necessary.

5. Conclusion and recommendations

Refining of biomass through torrefaction, steam explosion or HTC offers significant advantages for the ecological and economical use of raw biomass. The biomass becomes more compatible to coal, with higher energy densities, better storability, and grindability. This may avoid significant expenditure in dedicated biomass handling and storage facilities as well as other power plant adaptations. Furthermore, the higher energy densities result in lower logistical costs as compared to raw biomass. However, there are still some challenges to be addressed. The commercial availability of refined biomass is still limited, and qualities and characteristics are not yet well defined. In order to establish refined biomass as a common fuel for power plants an industry wide product specification is required in the long term. Therefore further R&D is needed to support the development of refined biomass to become a true alternative for co-firing and thus reducing the coal consumption. Before using refined biomass an extensive laboratory test program should be completed regarding storage properties, milling behaviour, energy density and especially fire and explosion characteristics. Furthermore the respective country legislation regarding biomass definition and incentive system has to be considered for each business case as well as the carbon footprint of the refined material compared to unprocessed biomass.
VGB PowerTech e.V. is the European technical association for electricity and heat generation with main office in Essen. About 500 member companies from 36 countries represent an installed power plant capacity of 520,000 MW; in Europe 461,000 MW. Power plant operators, power plant manufactures, service providers and research & development institutions are members of VGB. The total installed biomass power plant capacity of our member companies amounts to 4,500 MW.

According to its statutory duties, VGB is aiming at improving power plant efficiency, economic benefits, environmental compatibility, grant supply security, technical expertise in all fields of generation. VGB coordinates international experiences and expertise and promotes the exchange of experiences.

Results of the work of VGB are published in VGB-Standards (formerly VGB Guidelines and VGB Technical Instruction Sheets) and in the international technical magazine “VGB PowerTech”.

This position paper was developed by the VGB European Working Group Biomass (EWG Biomass).