Innovative Utilization of Renewable Energy Sources to Combat Climate Change

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Global warming has become a difficult challenge for both legislators and technologists. The need to reduce atmospheric CO_2 has resulted in several new global and local agreements (the Kyoto protocol, Bali agreement etc., EU-emission trading directive) all driving tightening environmental legislation. /1/ Foster Wheeler as a global supplier of power equipment, has taken the challenge to respond to these environmental, social and political challenges. Products such as state-of-the-art boilers and gasifiers for heat and electricity generation from biomass are offered and further developed. Generally, biomass is considered to be a clean renewable energy source. Emissions are lower when firing biomass instead of fossil fuel, and the amount of SO_2 released to the atmosphere is minimal due to the low sulfur content of the fuel. Life-cycle CO_2 emissions are zero. /2/

Even though biomass can locally have a fairly large contribution in energy production, it will not be a global solution alone to mitigate the climate problem. Biomass currently accounts for about 10 % of world primary energy use, two thirds of which is used for small scale cooking and heating in developing countries. Biomass production is subject to a range of sustainability constraints, such as: scarcity of arable land and fresh water, loss of biodiversity, competition with food production, deforestation etc. Coal will remain an important source for energy also in the future. Therefore it is important to develop clean coal solutions. The first, already existing solution is to burn coal in high efficiency large Circulating Fluidized Bed (CFB) boilers and cofire biomass. This way the biomass can be burned with much better efficiency than in small biomass fired plants. The co-firing of biomass in CCS (Carbon Capture and Storage) power plant will even enable a carbon negative solution for coal firing. The future solution will be CCS. A possible future solution to combat global warming and ensure sustainable power production can be large power plants fuelled by algae combined with CCS. Algae grows faster than any other plant, and as it grows it consumes CO_2 . When the algae is combusted in a power plant with CCS, the CO_2 consumed from the atmosphere will end up stored underground. /8/ Foster Wheeler developes its CFB technology (Flexi-Burn^{TM}) for oxyfuel combustion for CCS. The Flexi-Burn technology will enable also biomass cofiring for carbon negative power production.

The effort in developing the new, more advanced technologies to quickly reduce atmospheric CO_2 is huge and cannot be managed by the equipment suppliers and power companies alone. It will require political and financial support from EU and local governments. Research and development work in universities, research institutes and companies as well the demonstrations of the technologies in large, industrial scale must increase and need additional public funding in order to reach the set targets to reduce CO_2 production.

State-of-the-art combustion technology

Foster Wheeler boilers are offered for a variety of fuels and mixes, including fossil-derived fuels (e.g. coal, waste coal, petcoke), peat, biomass-derived fuels (e.g. wood, agricultural residue, bio-sludge), and waste fuels (e.g. contaminated wood, REF, TDF). When biomass or waste is considered, fluidized bed boilers are often the technology of choice: bubbling fluidized bed boilers (BFB) have often been favored in small-scale industrial applications, while circulating fluidized bed boilers (CFB) are most advantageous in larger applications /5/.

CFB's for biomass firing and co-firing

At modern power plants, the traditional pollutants are well under control. When considering either new plants or repowering of old plants, efficiency and environmental performance are key issues. High efficiency means lower fuel requirements, and lower levels of emissions, including CO_2. Utilization of proven high efficiency CFB technology is an ideal solution both for repowering and for new plants. CFB technology has proven excellent fuel flexibility and offers the option to both fire biomass and co-combust biomass with different grades of coals, which further reduces CO_2 emission (Figure 1) /4/.

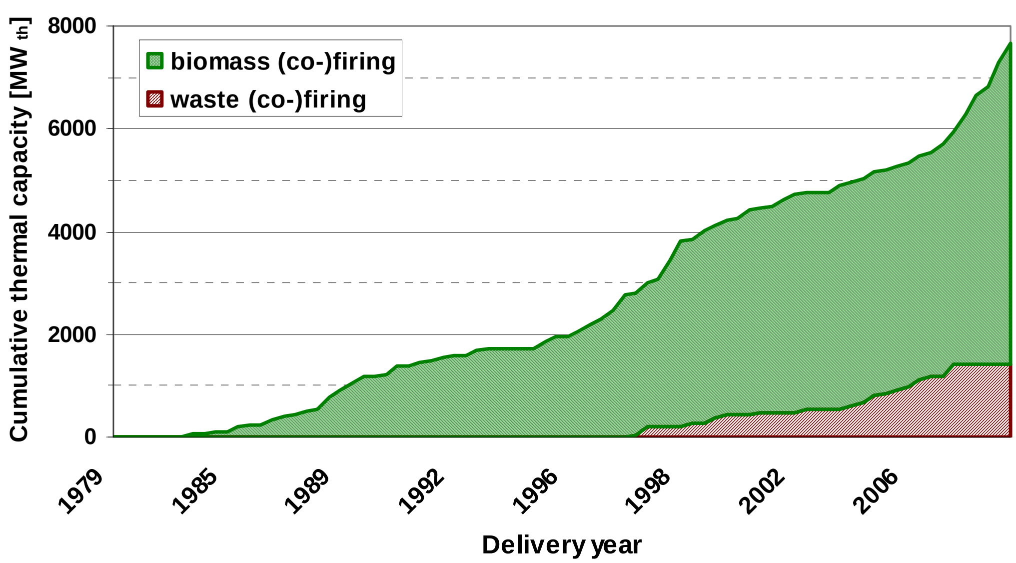

Figure 1: Foster Wheeler's CFB references for biomass* and waste* (co-)firing /5/.

*Biomass here includes wood derived fuel such as wood pellets and chips, saw dust, bark, forest residues, straw and rice husk.
*Waste here includes recycled and reject wood, demolition wood, industrial sludge, and bio-waste from food production. Coal co-firing is not included.

The multifuel capability of Foster Wheeler's CFB technology makes it ideal when using biomass with properties such as high moisture content and challenging ash content. Bark, wood chips, sawdust, forest residue, and sludge have all been specified for use in Foster Wheeler boilers – as well as industrial waste and RDF produced from municipal solid waste. As the fuels get more difficult to burn, for example agro biomasses, challenges such as chlorine corrosion and fouling of heating surfaces caused by alkalis call for advanced technical solutions. This has been one major focus area of the company's product development. Foster Wheeler has experience from the widest fuel mix in the market. From 350 units and 24 GW_e supplied, 36 plants/1400 MW_e is fired with biomass or RDF and 33 plants/2300 MW_e use biomass as a secondary fuel together with coal.

Other CFB benefits include lower levels of NOx, SO_2, and volatile organic carbon (VOC) emissions compared to more conventional solid fuel boiler systems, without the use of secondary emissions reduction; excellent availability; and high efficiency. The latter is largely due to the higher steam temperatures that can be generated without the danger of corrosion, even with fuel chlorine content as high as 0.1%, thanks to the use of unique design features such as Foster Wheeler's INTREX™ integrated heat exchangers.

As a summary, features of a large co-fired CFB include /2/:

•Small investment cost/MW_e of bioelectricity
•Larger investment capital required than in smaller biomass plant
•Not largely dependent on biomass availability
•Technical issues (slagging and fouling, erosion & corrosion) are reduced in co-firing
•Higher plant efficiency than in a small biomass plant (scale effects).

As the CFB technology has been scaled up, the largest co-firing scale under development is 800 MWe, planning to be offered commercially in 2010 and largest operating unit in Lagisza, Poland, 460 MWe with the efficiency of 45% (based on the fuel's LHV).

BFB's for industrial applications

Foster Wheeler has supplied 135 BFB boilers mainly for industrial sites, such as paper mills (see Figure 2). This is a technology of choice when there is a need to combust biomass with a very high moisture content and lower calorific value. BFB technology is a proven concept for biomass combustion. BFB boiler is fuel-flexible, has an availability of typically over 94%, low maintenance costs, high efficiency compared to grate technology, for example, and low emissions.

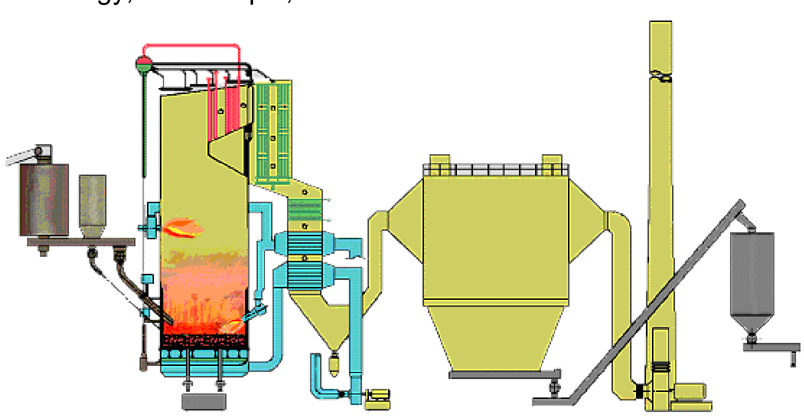

Figure 2: Cross-section of a BFB boiler /2/.

As a summary, the features of a small power plant based on BFB technology include /2/:
•Small investment capital required
•Large investment cost/MW_e of bioelectricity
•Dependent on biomass availability
•Technical issues have to be considered in design: erosion and corrosion, slagging and fouling of heating surfaces.
•Lower plant efficiency than in large co-fired CFB (scale effects)

State-of-the-art gasification technology

Gasifiers for biomass

Foster Wheeler has also supplied biomass gasifiers, both atmospheric and pressurized applications.

With fluidized-bed gasification, cheap and potentially CO_2-neutral solid fuels can be converted into combustible gas for replacing expensive oil, natural gas or coal. Locally available low-grade fuels such as wood chips, wood waste, bark, demolition wood, straw and wastes such as REF (in-origin classified recycled fuel) and refuse-derived fuel (RDF) have been successfully gasified. A CFB gasifier is a true multifuel unit with good fuel flexibility, i.e. the above-mentioned fuels can be used in the same unit - though the heat output varies with the heat value of the fuel /6/.

In Europe, typically about 30 - 150 MWth of biofuel energy is available within a 50 km radius of a power plant. By connecting a gasifier for instance to a mid- or large-size coal-fired boiler with a high efficiency steam cycle, local biomass sources can be converted to CO_2-neutral power and heat at very high efficiency, compared with stand-alone boilers with the same fuel input. The gasifier-PC boiler process connection also offers low investment and operating costs, utilization of existing power plant capacity with small modifications to the main boiler, high plant availability and reduction of the boiler emissions /6/.

The clean gas concept with pre-combustion cleaning of the product gas makes it possible to safely utilize difficult-to-burn, waste-based fuels in a high efficiency PC boiler without the risks associated with direct co-firing, such as fouling, high temperature chlorine corrosion and poisoning of the DeNOx catalyst /6/.

A stand-alone power plant can also be based on the clean gas gasification technology. In such a concept, clean gas is fired alone in a new gas-fired boiler, which can be designed for clearly higher steam data than normal boilers utilizing waste-based fuels, resulting in high efficiency in electricity production /6/.

Foster Wheeler Atmospheric CFB Gasification

The atmospheric CFB gasification system developed by FW is relatively simple. It consists of a gasification reactor, a cyclone to separate the circulating-bed material from the gas, and a return pipe to return the circulating material to the bottom part of the gasifier. All these components are entirely refractory-lined. From the cyclone, the hot product gas flows into an air preheater located below the cyclone /6/.

Gasification air is blown with a high-pressure air fan through an air distribution grid at the bottom of the reactor, below a bed of particles. The air velocity is high enough to fluidize the bed particles and convey some of them out of the reactor and into the cyclone, where most of the solids are separated from the gas and returned to the lower part of the gasifier. Both the gas and solids are extracted from the bottom of the cyclone /6/.

The circulating solids contain char that is combusted with the fluidizing air, generating the heat required for the pyrolysis process and subsequent, mostly endothermic, gasification reactions. The circulating material also serves as a heat carrier and stabilizes the process temperatures. Coarse ash accumulates in the gasifier and is removed from the bottom with a water-cooled screw. The following Figure 3 shows the main components of a CFB gasifier and Table 1 shows the reference list /6/. The latest reference is limekiln gasifier of StoraEnso, 2008.

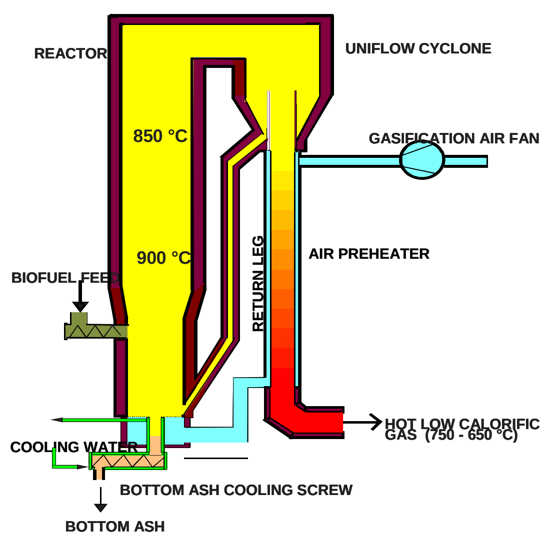

Figure 3. The Foster Wheeler Gasifier.

Table 1. *Foster Wheeler atmospheric gasifier references.*

Gasifier for liquid biofuel applications

Interest towards gasification has lately increased due to political decisions to substitute conventional fuels by alternative biofuels in the road transport sector. Total EU liquid biofuel demand is assumed to be 18 Mtoe/a in 2010 while production in 2004 was around 2 Mtoe/a /3/.

By 2020 the estimate for required production of 2nd generation Fisher-Tropsch (FT) -biofuels is about 10 % of of all petrol and diesel for transport purposes, which means about 30 Mtoe/a. Concentrating on the production of FT-liquids seems to be the most promising option in the short and medium term. Synthetic diesel, which is produced via Fisher-Tropsch synthesis, can be used directly in diesel engines either on its own or mixed with conventional diesel fuel. No new distribution networks are needed /3/.

Foster Wheeler, together with Neste Oil and other Finnish-based industrial partners has participated in Finnish Ultra Clean Gas (UCG) development program led by Technical Research Centre of Finland, which was realised in years 2004 – 2007. Program was targeted to develop of an advanced process for producing multi-purpose synthesis gas from solid biofuels. The experimental work was focused on optimised fluidised-bed gasification process and development of the gas conditioning and cleaning process to meet the requirements for the FT liquids, synthetic natural gas (SNG) and other possible synthesis gas utilization technologies e.g. hydrogen and methanol production. The Finnish concept for biodiesel production is presented as a Figure 4 /3/.

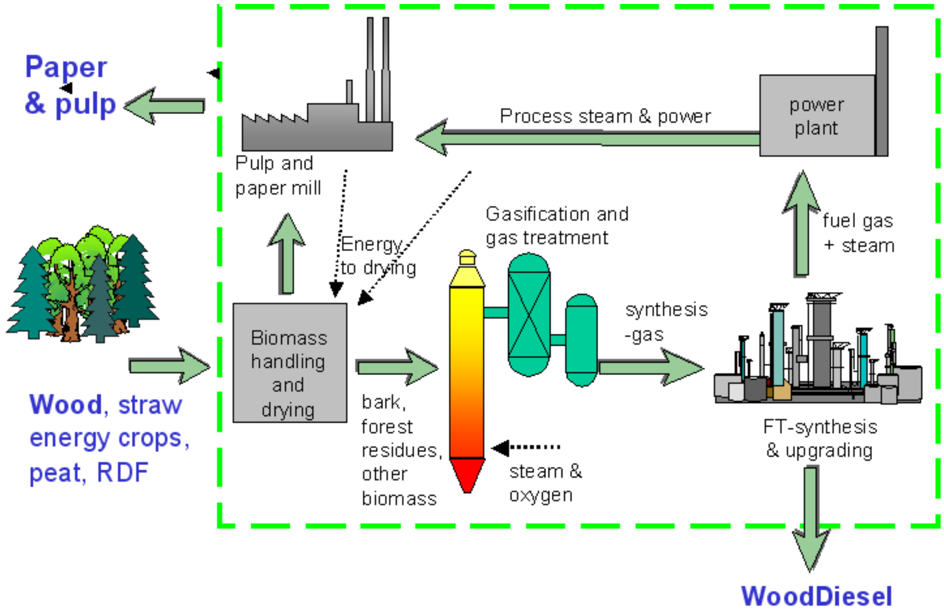

Figure 4: Finnish concept for biodiesel production from biomass

The developed process is based on pressurized oxygen-steam blown fluidized-bed gasification followed by novel catalytic gas reforming technology. The new gasification process is designed for a wide range of feed stocks including woody biofuels, peat, straw and other agro biomasses, as well as various waste-derived fuels. The novel gas cleaning technology eliminates the tar problem, maximizes the syngas yield and makes it possible to adjust the H_2/CO ratio of the syngas. The synthesis gas can be raw material for various end products: Fisher-Tropsch liquids, methanol, synthetic natural gas (SNG) and hydrogen /3/.

The Finnish development work is aimed at intermediate-size syngas plants that will be economically feasible at 200-300 MW fuel input, especially when integrated with energy-consuming plants of other industries, e.g. pulp and paper industries. The process was developed on a 500 kW-scale process development unit during the period 2005-2007 /3/.

The next step of the development path is the long-term testing of ultra-clean gas production. The production of ultra-clean multi-purpose synthesis gas will be demonstrated on a long-term basis at Stora Enso's mill at Varkaus in Finland /7/.

Objectives of the long-term demonstration are:

- demonstration of O_2/steam-blown gasification using different types of solid biomass
- demonstration of product gas filtration and cooling
- implementation, testing and demonstration of catalytic reforming in order to establish the optimal operating conditions

Both the gasifier and the long-term gas cleaning demonstration are constructed at Stora Enso's mill at Varkaus in Finland, as where the gasifier is at the moment in operation. The 12 MW_{fuel} atmospheric gasifier enables oil to be substituted in the lime kiln process. During the demonstration phase the gasifier process. From the whole gas stream produced in the gasifier a portion will be taken to the slip stream in order to demonstrate the clean-up. Product gas goes through several cooling and cleaning stages in the slip stream process and after that it is returned to the main stream going on to the burner of the lime kiln /7/.

Following the development and demonstration phase and completion of the technical concept, and after the partners have gained sufficient experience from the demonstration plant, the target of the Neste Oil - Stora Enso JV company “NSE Biofuels” will be to build a full-scale commercial production plant at one of Stora Enso’s mills. The size for the commercial plant has been set roughly in the range of 100 000 t/a FT-waxes, meaning biomass gasification at 200 - 300 MW scale. /7/

The plant will be based on pressurised O_2/steam CFB gasification technology and novel gas treatment technology /7/. Other future possibilities for the pressurised O_2/steam CFB gasification technology in utilizing biomass can be to produce gas to methanization to produce synthetic natural gas (SNG) or chemicals.

Conclusions

Biomass as a CO_2-neutral energy source has an important role in combatting climate change. Foster Wheeler's existing technologies, CFB and BFB boilers and gasifiers are capable of fuel flexible power production from biomass. An economic alternative is to cofire biomass with coal in high efficiency CFB boilers or to retrofit an existing PC boiler with a biomass gasifier. Foster Wheeler developes fluidized bed technology for even higher efficiency and wider utilization of biomass in energy production. Foster Wheeler is developing pressurized biomass gasification for the production of transportation fuels. CFB gasification technology can also be adopted to produce other biomass based products, such as synthetic natural gas (SNG) or chemicals.

Fluidized bed technology provides solid basis for developing other future products for reducing CO_2-emissions, such as near zero CO_2- emission fossil fuel (coal) Flexi-Burn CFB boiler based on oxyfuel technology.

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