

How CFB addresses the challenges of biomass burning at utility scale

Combustion of biomass poses a number of problems, particularly in utility scale boilers. The circulating fluidised bed has features that control ash agglomeration, fouling, and corrosion, and therefore make it particularly suitable for biomass applications, with inherent characteristics that favour low emissions. The technology also has considerable potential for scale up, and adoption of greatly improved steam conditions.

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Biomass as a boiler fuel is considered carbon dioxide neutral in that sustainably managed forests act as a net sink for CO₂ from the atmosphere. Carbon dioxide released during biomass combustion returns to the atmosphere but is

removed by the forest system. While wood chips and wood pellets are predominant as biomass fuels, the range of available biomass materials for use as fuel is vast and growing. Worldwide, there is a growing utilisation of agricultural (agro) biomass and wastes such as wheat stalks, sugar cane bagasse, palm kernel shells and rice husks. As utilisation of biomass fuel changed from a predominantly EU and US based market around 2010 to an increasingly global market (currently and projected), the use of biomass as a stand-alone fuel for large scale power generation is gaining acceptance. As shown in Figure 1, worldwide power generation capacity using woody biomass and agricultural biomass wastes is projected to grow by a factor of more than 2.5 from 2015 to 2025.

However, increased biomass use for utility scale power generation poses significant challenges associated with variations in biomass chemical composition and physical properties.

Agro biomass, in particular, varies considerably depending on its biological origin, location, seasonality, farming and harvesting practices, and, ultimately, preparation and processing. Broad variations in properties are evident not only across different biomass types, but even among samples of the same type.

This is also the case with woody biomass (wood chips and pellets), which is the

primary fuel used in biomass fired power generation boilers installed to date. Figure 2 shows variation in moisture and ash contents among woody biomass from Europe, Asia, the Americas and Africa.

As the graph shows, moisture contents are higher in chips relative to pellets. Moreover, the variation of moisture content in chips is broad and highly influenced by season and location. Moisture content in chips from African and South American wood harvested during the dry season can be as low as the moisture content in pellets.

Ash content in woody biomass is typically low, from less than 1% (dry) to a few per cent. Slightly lower ash contents have been noticed in European and North American wood species compared with Asian and African hardwoods. Reported ash contents in woody biomass as high as 10% (dry) are usually attributable to soil and stone contamination during harvesting.

The challenges that arise in using biomass as a fuel for power and steam production are mainly due to the ash forming elements (Cl, Na, K, Ca, Mg, P, Si, Al, Fe), where differences among biomass types can be more than an order of magnitude. Ash related problems may include furnace slagging, bed agglomeration, boiler fouling, localised erosion, and extended corrosion. Two elements in biomass commonly implicated (in relation to problems such as unscheduled shutdowns, prolonged downtime (loss of availability), increased costs of maintenance and more frequent replacement of pressure parts) are potassium and chlorine. Variations in both of these elements is shown in Figure 3 for woody biomass from various sources. In addition to total potassium, Figure 3 also includes the weak-acid-soluble fraction, which is considered a reactive form.

Biomass fuel challenges and CFB

Given the high degree of variability within biomass fuels, circulating fluidised bed (CFB) boilers bring a number of benefits, and indeed can be seen as the ideal technology when firing biomass fuels, either alone or co-fired with fossil fuels. As shown in Figure 4, CFB technology is applicable to the full

Figure 1. Worldwide projected biomass power generation capacity
(Source: IRENA)

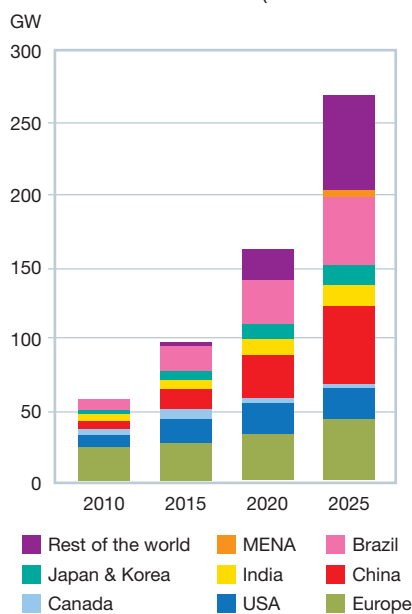


Figure 2. Comparison of moisture and ash contents in woody biomass.

Source: Sumitomo SHI FW chemical analyses database, including samples from recent projects and proposals

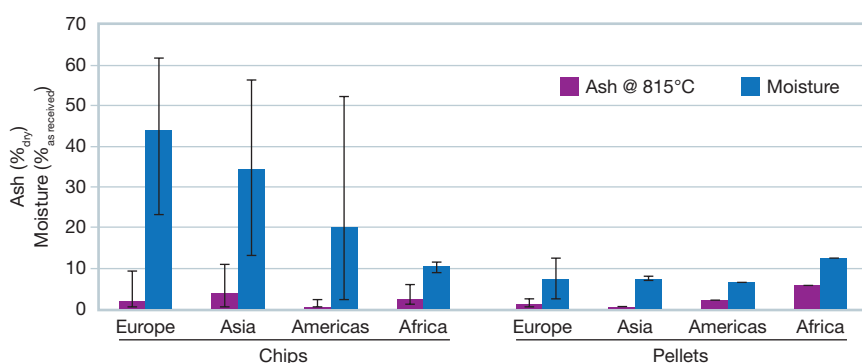
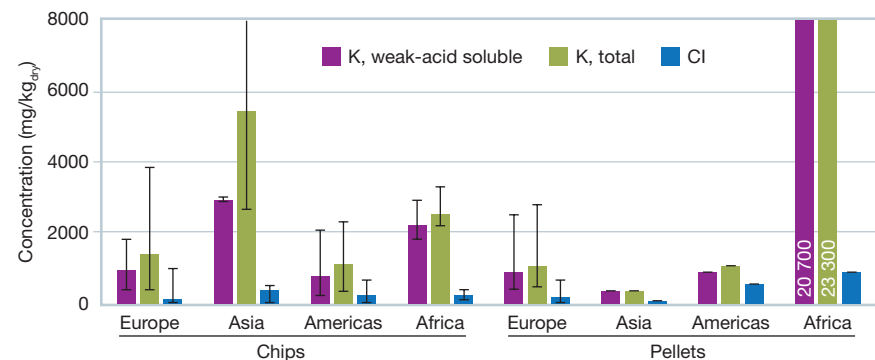


Figure 3. Comparison of potassium (weak-acid soluble and total) and chlorine contents in woody biomass. Source: Sumitomo SHI FW chemical analyses database, including samples from recent projects and proposals



range of fossil fuels and biomass. CFB also provides inherently low emissions, usually eliminating the need for downstream flue gas treatment systems such as SCR to reduce NO_x and FGD to control SO₂.

Since the 1980s, Sumitomo SHI FW has progressively advanced and scaled-up CFB technology for biomass firing, from small multi-fuel boilers firing wood residues from the Nordic pulp and paper industry. Sumitomo SHI FW's Advanced Bio CFB (ABC) technology can be regarded as state-of-the-art for biomass combustion. ABC builds on experience with a large number of CFB commercial references combined with continuous research. As shown in Figure 5, the ABC design has specific features which control ash agglomeration, fouling, and corrosion.

Also, the ABC design employs a water-cooled fluidising grid in combination with a sloped step grid for efficient removal of unfluidised particles through discharge bottom ash outlets uniformly distributed across the grid. The single continuous fluidising grid helps to simplify control and results in stable and uniform furnace operation. The lower furnace is refractory-lined and tapered such that the grid area is smaller than that of the upper furnace. This achieves a high degree of turbulence within the fluidised bed and promotes mixing of the fuel and secondary air.

From the top of the furnace, flue gas flows into steam-cooled high efficiency solids separators. Separated solids are conveyed to the return leg and discharged into INTREX heat exchangers, which contain high conduction heat transfer coils submerged in the bubbling hot solids. The INTREX units serve as the final main steam superheaters and extraction steam reheaters and, as the coils are submerged, they are protected from corrosive elements in the flue gas.

The ABC technology not only addresses the fuel quality issues related to biomass firing, but also can accommodate differing plant requirements and provide optimisation across a range of investment factors. Plant requirements include choice between utility and industrial boiler, capacity, operational

load range, steam data, and emissions limits. Investment factors include plant availability, fuel flexibility requirements, capital costs and operation costs. Boiler designs have thus been developed to fire easy-to-burn biomass, while more robust solutions are implemented as the biomass quality degrades and the material becomes more difficult to burn reliably.

Growing experience base

Since 2008, over twenty 100% biomass fuelled CFB plants employing Sumitomo SHI FW technology have been commissioned. The largest operating utility scale ABC installation to date, the 205 MWe Polaniec plant of GDF Suez Energia Polska plant, located in Poland, has been in commercial operation since 2012. Steam conditions are 158/135 kg/s, 127/20 bar(a), and 535/535°C (RH/SH). The plant fires a mixture of 80% wood chips and 20% agro biomass, and NO_x and SO₂ emissions are both less than 150 mg/Nm³.

Sumitomo SHI FW was awarded the contract for the CFB boiler for the 103 MWe Dangjin Biomass 1 facility in Korea in February 2013. The plant, currently the largest operating dedicated biomass plant in Asia, was commissioned in August 2015.

Recent orders received by Sumitomo SHI FW for biomass fired CFB plants employing include several in Japan, all employing reheat:

- A 112 MWe dedicated biomass power plant – the largest such facility to date in Japan – from Kaita Biomass Power Co, Ltd, a special purpose joint venture of Hiroshima Gas Co and Chugoku Electric Power Co. Fuels will include wood pellets and waste forest thinning and commercial operation is scheduled for March 2021.
- A 75 MWe facility being developed by Biopower Kanda Goudou Gaisha (a subsidiary of Kansai Electric Power Company) to be located at Kanda-machi, Miyako-gun, Fukuoka Prefecture. Using wood pellets as its main fuel, the scheduled commercial operation date is October 2021.
- A 75 MWe dedicated biomass plant ordered by Nishinippon Plant Engineering and Construction for a facility in Shimonoseki City, Yamaguchi Prefecture, being developed by Shimonoseki Biomass Energy GK (a joint venture of three Kyushu Electric Power Group companies, Kyuden Mirai Energy Company, Nishinippon Plant Engineering and Construction and Kyuden Sangyo). The plant will use wood pellets and palm kernel shells as its main fuel sources. As well as the CFB boiler, SHI will supply the steam turbine and other equipment to Nishinippon Plant Engineering and Construction, which is the plant's EPC (engineering, procurement, and construction) contractor.

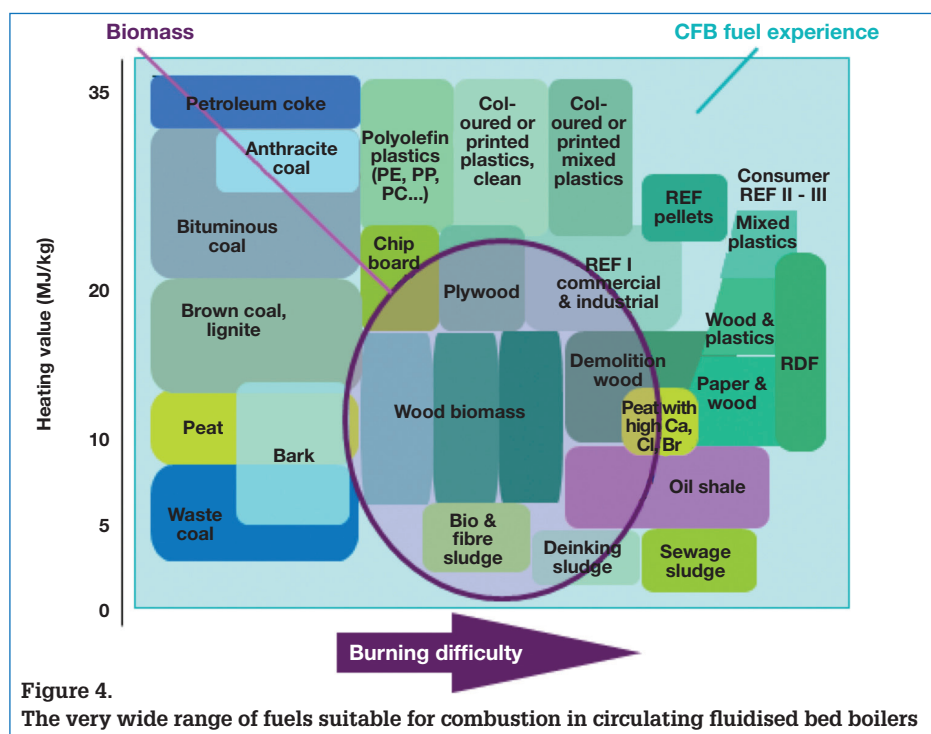
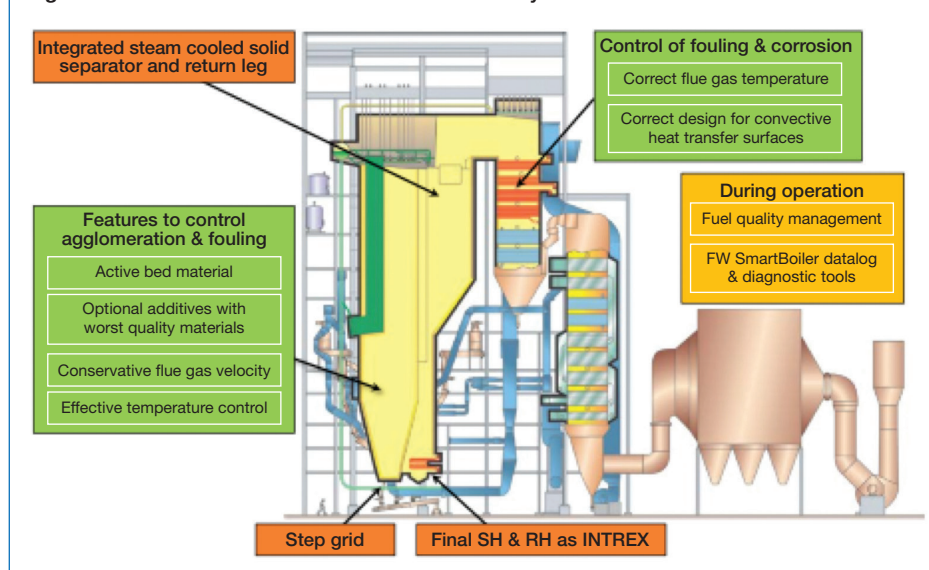


Figure 4. The very wide range of fuels suitable for combustion in circulating fluidised bed boilers

Figure 5. Sumitomo SHI FW Advanced Bio CFB System



The scheduled commercial operation date is January 2022.

- A 49 MWe biomass plant to be supplied for the Yokkaichi thermal plant site of Chubu Electric. To implement this project, SHI has established a joint venture with Chubu Plant Service Co. Fuels for this plant, which has a scheduled commercial operation date of April 2020, will include wood pellets and palm kernel shells.

Steam conditions go to the next level

The live steam conditions for CFB boilers operating on biomass only have to date not exceeded about 540°C and 130 bar. This has mainly been due to corrosion issues commonly encountered in the combustion of biomass and waste derived fuels. The ash forming elements, which largely determine the degree of challenge encountered with burning such fuels, are principally halogens (notably chlorine), alkali metals (mainly sodium and potassium), phosphorous and heavy metals (eg, lead and zinc).

Potential customers of utility size biomass boilers are however aiming at maximum steam cycle efficiency, and are therefore targetting live steam parameters of the order of 170 bar, 570°C, and better, with clean biomass as the fuel.

This level of performance is, for example, expected at the Tees Renewable Energy Plant (TeesREP), currently under construction in the UK (see *Modern Power Systems*, November, pp 21-26). Slated for start up in 2020, it will be the world's largest greenfield fully biomass power plant and will take 100% biomass fueled CFB combustion technology to the 300 MWe scale. Steam conditions will be 229/205 kg/s, 176/43.8 bar(a), and 568/568°C (RH/SH).

Fuel for the plant will be 70-100% wood pellets sourced from sustainable forestry byproducts in North America, with the remainder in the form of sustainable wood chips primarily from the UK. Design fuel data

for both 100% wood pellets and a mixture of pellets and chips is shown in the table below.

The emission limits set for this project are in line with the new IED and LCP BREF requirements. The controlled pollutants include sulphur dioxide/trioxide (SO_x), NO_x , dust, carbon monoxide, ammonia slip, mercury, hydrogen chloride and hydrogen fluoride. CFB combustion technology has inherent features that reduce pollutants to a low level, but the stricter requirements arising from LCP BREF call for additional measures. Several technologies are available for control of acid gases (SO_x , HCl, HF) and

Design fuel data for Tees Renewable Energy Plant

Fuel component	100% wood pellets	Mixture of pellets and chips
Sulphur	0.02%	0.03%
Nitrogen	0.05–0.6%	0.16%
Moisture	5.0%	18.5%
Ash	1.0%	1.0%
Heating value (LHV)	17.8 MJ/kg	14.95 MJ/kg

heavy metals (Hg) in CFB installations, eg, CFB scrubbers and spray dry absorbers (SDA), but when combusting biomass, the simple and proven technique of dry sorbent injection (DSI) is considered most economic.

In a DSI system, powdered sorbent is pneumatically injected into the flue gas, acid gas is adsorbed onto the sorbent and dry waste product is removed via a particulate removal device. It is a relatively simple system with low capital cost and also low operation cost when the required level of acid gas removal is moderate.

The emissions control concept to be deployed at TeesREP, which will have a boiler efficiency of 93.3%, includes the following gas clean-up facilities: high-efficiency fabric filter to control particulate matter; DSI with hydrated lime sorbent (in conjunction with fabric filter) for control of acid gases (SO_2 , SO_3 , HCl and HF) (this is not needed when firing clean biomass but could be required with some high sulphur biomass); activated carbon injection (if required) for Hg control; selective non-catalytic reduction (SNCR), ie, ammonia injection into separators and/or into furnace depending on load, for NO_x control; slip catalyst between two economiser stages to minimise NH_3 slip while utilising SNCR for DeNO_x .

Emissions guarantees for TeesREP include the following (O_2 6% in dry gases): NO_x , 140 mg/Nm^3 ; SO_2 , 35 mg/Nm^3 ; CO, 50 mg/Nm^3 ; particulates (dry), 5 mg/Nm^3 .

Scaling up

Of the more than 490 CFB boilers sold to date by Sumitomo SHI FW, about 125 are designed for firing biomass, with around 60 units firing biomass as the primary fuel. Further scale-up, well beyond the 300 MWe class boiler to be deployed in the TeesREP project mentioned above, is technically feasible. As of today, boiler concepts have been developed to 600 MWe scale for 100% biomass with subcritical steam parameters or for 50% biomass with supercritical steam parameters, and to 800 MWe scale for 20 % biomass share with ultra-supercritical steam parameters.

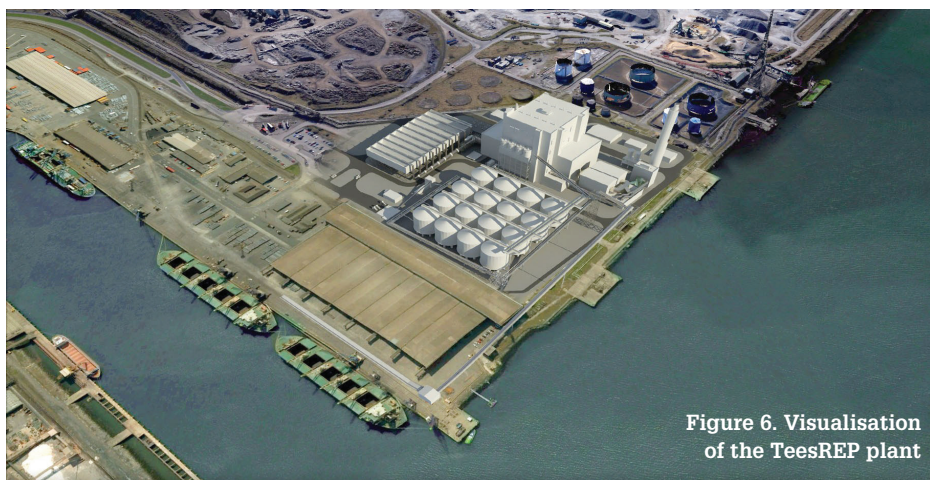


Figure 6. Visualisation of the TeesREP plant