Teesside goes big on biomass

When it begins commercial operation, the 299 MW Tees Renewable Energy Plant in the UK will be the largest and most efficient dedicated biomass fired power plant in the world. **Junior Isles** examines the plant, which marks a new milestone for circulating fluidised bed technology.

Like many parts of Europe, the United Kingdom has been making a concerted effort to reduce its carbon emissions. This has seen significant growth in renewables such as wind and solar. Although to a lesser extent, there has also been an increase in the use of biomass for power generation.

While projects like the conversion of Drax (formerly Europe's largest coal fired plant) from coal to biomass have been dominating the headlines in recent years, other notable biomass fired power plants have also been making progress. Perhaps the most significant of these is a £650 million project being built on Teesside in the northeast of England.

At 299 MW, the plant will be the world's largest dedicated biomass power station and heralds a leap into 300 MW-class biomass fired units. Teesside not only marks an important milestone in the UK's efforts to tackle climate change but also demonstrates the versatility of circulating fluidised bed (CFB) technology and its ability to be scaled up.

The project, owned by MGT Teesside Limited, is being constructed by Technicas Reunidas in a consortium with Samsung C&T and will use an Advanced Bio CFB (ABC) boiler supplied by Sumitomo SHI FW.

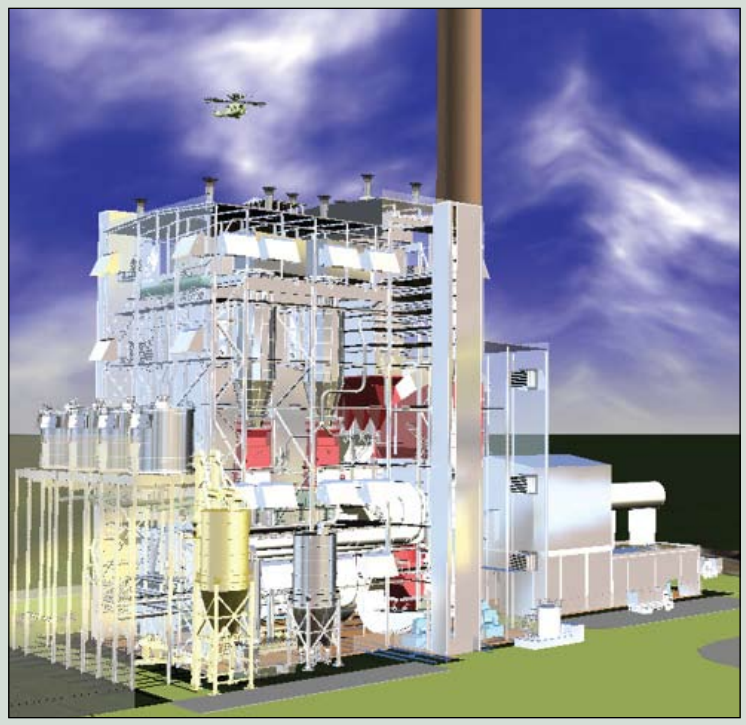
Following the contract award for the boiler in August 2016 boiler steelwork erection is about to start, with commercial operation planned for January 2020. At this time, the plant will not only be the biggest biomass-only power plant ever built but also the most efficient.

Commenting on the project drivers, Robert Giglio, Senior Vice President, Strategic Business Development of Sumitomo SHI FW said: "The UK has been doing everything it can to reduce its carbon profile; it has done a great job of moving away from coal. But the problem is, it still needs power. With nuclear being slow to build, the emphasis has been on gas and renewables. But while gas is good for base load and can support intermittent renewables, it is a fossil fuel. Biomass, however, is considered carbon neutral and unlike wind and solar, it's dispatchable."

The power output of the boiler at the plant is the latest step in demonstrating what is possible in terms of building large biomass units.

Of the more than 480 CFB boilers sold to date, approximately 120 are designed to burn some portion of biomass, with 54 units firing biomass as the primary fuel. Further, since 2008 Sumitomo SHI FW has commissioned over 20 CFB plants firing 100 per cent biomass (Table 1). The largest of these, and still currently the biggest biomass-only, utility-scale power plant in the world, is the 205 MWe (447 MWth) Polaniec 8 boiler in Poland owned by Engie.

Known as the 'Green Unit', it fires a mixture of 80 per cent wood chips and 20 per cent agricultural wastes sourced within a 100 km radius of the plant. The boiler island, which was supplied by Sumitomo SHI FW on a turnkey basis, has been in commercial operation since November 2012.



CAD cutaway of the 299 MW Tees Renewable Energy Plant biomass project. The project is being built on a brownfield site at the Teesport port facilities near Middlesborough

Polaniec 8 is currently the world's most efficient biomass-only power plant

In 2016, the Green Unit operated with a net efficiency of 36.5 per cent and produced 1.52 TWh, representing about 25 per cent of Poland's renewable energy market. Notably, Polaniec Unit 8 builds on the technology and experience base of earlier plants that burn 100 per cent biomass fuel, such as Kaukas Kaukaan Voima Oy's power plant, located UPM-Kymmene Oyj Paper Mill site in Lappeenranta, Finland (385 MWth), Kraftringen Energi AB, Örtofta, Lund, Sweden (110 MWth), and ZE PAK, S.A., Konin, Poland (154 MWth).

As the industry moves to the next size-class with Teesside, Sumitomo SHI FW says that scaling up is not really a technology challenge. Today, utility-scale 300 MWe-class units are available for 100 per cent biomass applications with subcritical steam conditions, 600 MWe-class units for fossil fuel applications with 50 per cent biomass co-firing, and up to 800 MWe for 20 per cent biomass with ultra-supercritical steam conditions.

Timo Jäntti, Senior Vice President of Technology at Sumitomo SHI FW, said: "From a technical point of view, we do not see any scale-up limitation. We have 100 CFBs burning different types of biomass and projects burning this type of fuel. So we know the design criteria for the process and how to dimension the boiler for this type of fuel. Also, at 299 MW the boiler dimensions are big but we have built boilers at a similar scale, such as Lagisza in Poland. So we know the issues with regard to scale. It's very much a proven design that we are utilising."

According to Sumitomo SHI FW, it is already possible to achieve biomass-only CFB boilers capable of producing 500-600 MW. The more difficult challenge, it says, is fuel sourcing. "We can do the sizes," said Giglio, "but the fuel supply is what becomes the limiting factor."

To gather the amount of biomass needed at Teesside, MGT Teesside will have to source fuel from both domestic and international sources. "They will also have to procure biomass pellets from the US and Canada," said Giglio.

The fuel for the plant will be 70-100 per cent wood pellets sourced from sustainable forest by-products in North America delivered to the port at Teesport. The remainder of the biomass fuel will be in the form of sustainable wood chips delivered overland, primarily from the UK. Fuel will meet a sustainability threshold in terms of sustainable timber harvesting and CO_2 footprint based on fuel supplier guarantees.

Biomass properties vary considerably depending on their biological origin, location, seasonality, farming and harvesting practices, and ultimately their preparation and processing. This leads to broad variations in chemical composition and physical properties across different biomass types and even within the same type. Design fuel data for both 100 per cent wood pellets and a mixture of pellets and chips is shown in Table 2.

In addition to providing nearly CO_2-neutral energy by using renewable

Table 1. Sumitomo SHI FW has commissioned over 20 CFB plants firing biomass alone

Start-up year	Sumitomo SHI FW	Country	MWe
2020	Teesside Ltd.	UK	299
2016	Spectrum Coal & Power Ltd.	India	50
2016	United Renewable Energy	Japan	20
2016	Emami Cement Ltd.	India	30
2016	Monbetsu Biomass	Japan	45
2016	Summit Energy	Japan	75
2015	Kirisima mokushitsu Hatsuden	Japan	5
2015	Miyazaki shinrin Hatsudensyo	Japan	5
2015	Oji Engineering Green Energy Hokuriku	Japan	5
2015	Oji Green Energy Ebetsu	Japan	25
2015	Green Biomass Factory	Japan	6
2015	GS E&C	South Korea	105
2015	Oji Green Energy Nchinan	Japan	25
2014	Kraftringen Energi AB	Sweden	35
2013	Green Energy	Japan	6
2015	Nihon Kaisui	Japan	19
2012	GDF Suez Energia Polska	Poland	205
2012	Asahi Kasei Chemicals	Japan	186
2012	PAK, S.A.	Poland	55
2010	Prokon Nord	Belgium	26
2010	Kawasaki Biomass Power	Japan	33
2010	Kaukaan Voima Oy	Finland	125
2009	Söderenergi	Sweden	85
2008	NV Huisvuilcentrale Noord-Holland (HVC-NH)	Netherlands	28
2008	Nippon Paper Industries	Japan	41

fuels, Teesside will fulfil the most stringent emission limits set for traditional (35 mg/m³n SO_2, 140 mg/m³n NOx, 50 mg/m³n CO, and 5 mg/m³n dust) air emissions.

The use of wood pellets is not only important in terms of emissions but also with regard to the physical dimension of the boiler. Although Teesside will be the largest of its kind in terms of power output, it will be smaller than the latest CFB units firing fossil fuels.

Giglio explained: "The sizing of the unit depends on the fuel. Biomass typically contains a lot of moisture, which turns into gas. So the furnace has to be big enough to accommodate that gas. You therefore end up with a big furnace, without making a lot of steam.

"In the case of Teesside, however, we have dry pellets. Pellets are a very compact way of transferring the most energy in biomass. Because you take the air and moisture out of the cargo, you're shipping more BTUs. Pellets give you that concentrated form of energy from the biomass. That's why when you go to this size, you need to use pellets for a large, secure supply of fuel."

The dry, high-quality fuel essentially gives Teesside a 50 per cent increase in plant rating. Its use also makes fuel transport and handling easier. On arrival at the plant, the fuel will be unloaded using a ship unloader rated at 1600 tonnes/hr. Conveyors then move the fuel to 16 circular silos. Each silo measures 27 m in diameter and is 30 m high, providing a total storage capacity of 260 000 m³. The silos will include a sloped bottom to accommodate the vibrating floor, necessary for the correct reclaiming of the fuel from the silos.

The plant can be fed from any silo, which allows separation of different cargoes along with fuel blending. The fuel delivery system is designed to supply wood pellets and chips to the boiler at a rate of 660 tonnes/h and the plant will burn more than one million tonnes of biomass fuel each year. When completed, the fuel unloading and handling system will be one of the largest in the world for a biomass power plant.

3-D aerial view: Teesside is built around a Sumitomo SHI FW CFB boiler and a single steam turbine, along with a fuel storage area and conveyor system, a wood chip drier, and air-cooled condenser

The low-sulphur wood pellets contain little moisture (5 per cent), ash (1 per cent), and sulphur (0.02 per cent) and therefore produce low emissions. The emission limits set for this project are in line with the new IED and LCD BREF emission limits covering multiple pollutants. The controlled pollutants include sulphur dioxide/trioxide (SOx), nitrogen oxides (NOx), dust, carbon monoxide (CO), ammonia (NH_3) slip, mercury (Hg), hydrogen chloride (HCl) and hydrogen fluoride (HF).

The pellets also have an excellent fuel heating value of 17.8 MJ/kg. When the wood pellets are mixed with 30 per cent domestic wood chips with 18.5 per cent moisture content, the fuel heating value is reduced to 14.95 MJ/kg. The mixing ratio is highly variable and the boiler is capable of burning up to 100 per cent pellets at full load.

Steam conditions in the Teesside boiler reflect recent technology advances that will also produce increased efficiency. For example, Polaniec Unit 8 produces steam at 127.2/20 bar[a] at 535°C/535°C (superheat/reheat). Although higher steam parameters have been applied to some extent in smaller industrial boilers, it has become more important in large utility size boilers firing biomass aiming for maximum steam cycle efficiency.

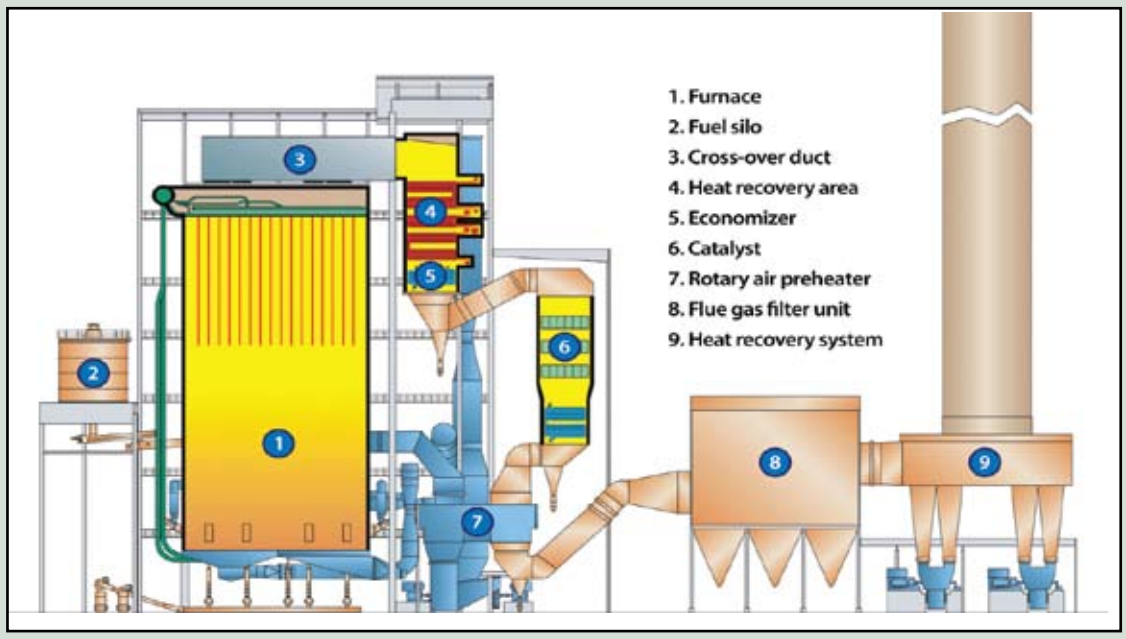
The Teesside boiler SH/RH (superheat/reheat) steam conditions will therefore be 229/205 kg/s, at a pressure of 176/43.8 bar[a] and temperature of 568/568°C. The clean fuel selected allows these high steam pressures, which is about the maximum applicable in natural circulation boilers. These higher steam conditions will ensure plant efficiency exceeds the 36.5 per cent achieved at Polaniec 8.

The steam cycle design also includes provisions to deliver low-pressure steam to a wood chip dryer, on the order of 6 MWth, to reduce the moisture content of the incoming wood chips.

According to Sumitomo SHI FW, the Teesside boiler will be its most advanced biomass CFB to date. "It is the first time that steam parameters will be at such a level for a biomass-only plant," noted Jäntti. "The boiler utilises the highest steam parameters, which contributes to the highest efficiency. It will also utilise advanced flue gas heat recovery systems to reduce the flue gas temperature before it goes to the stack. It will be the most efficient biomass fired plant when it begins commercial operation."

Sumitomo SHI FW says that with

A 3-D view of the boiler island



A cross-sectional view of Teesside

sufficiently clean biomass and a state-of-the-art design, high availability and acceptable lifetimes of boiler pressure parts can be maintained at the advanced steam pressures and temperatures.

CFB boilers operating on 100 per cent biomass have typically used steam conditions of approximately 540°C and up to about 140 bar[a]. Steam conditions have been limited by commonly identified corrosion issues in the combustion of biomass and waste derived fuels, attributed to ash forming elements such as halogens (notably chlorine), alkali metals (mainly sodium and potassium), phosphorous and heavy metals (e.g. lead, zinc).

Sumitomo SHI FW's ABC technology has specific features which control ash agglomeration, fouling, and corrosion.

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 issues related to biomass firing, but also considers plant requirements such as operational load range and steam data, as well as investment factors such as plant availability.

The Teesside steam plant is designed to operate in a sliding pressure mode in order to maximize efficiency over its load range and to allow the unit to respond to rapid load changes when operating at base load conditions. The plant is designed to fulfil the frequency response required by the United Kingdom's national grid.

Primary frequency control is 5 per cent load change within 30 seconds. Secondary frequency control requires 3-5 per cent of maximum continuous rating near minimum and near maximum load between 30 seconds and 15 minutes. Also, the plant must respond to a 10 per cent load change in 10 seconds and maintain that load for 30-60 seconds.

For short-term transients, sufficient steam pressure is maintained upstream of the steam turbine control valves in order to effectively respond to grid frequency dips. For long-term transients, the CFB firing rate changes in order to respond to a grid transient. Also, the Teesside CFB can use overfiring to achieve a 10 per cent step change in load in 10 seconds.

Teesside's operational and fuel flexibility, as well as its size, create more opportunities for plant developers and utilities looking to produce green, more sustainable energy. But while it is possible to build boilers of higher output than Teesside, Sumitomo SHI FW believes the real opportunities still lie in the smaller units. The economics of large biomass projects mean that, currently, they still require subsidies. And as governments seek to balance budgets against high-cost environmental solutions, financial support for larger projects will reduce.

Giglio said: "There are other environmental solutions that you could select, like wind and solar with gas as a backup. So we don't see a lot of strong support for the large units. There is also the logistical issue of getting the fuel, so most of the market will continue to be in the smaller to medium 50-100 MW range. A lot of countries can source the biomass locally in this range."

He also noted that avoiding imports means governments are less dependent on other countries for their energy needs. In addition, using locally supplied fuels in CFBs presents the opportunity for the development of community-type schemes.

"A community can get together with a developer and source fuel from waste and biomass, or even locally available coal which can be blended in. What's good about this model is that they can source the fuel locally as long as they have a flexible technology that can adjust its fuel appetite; and a CFB does that. That same plant can then provide the community with heat and power and even steam for industrial plants. We see this model becoming more viable on a small scale," said Giglio.

In the medium-scale 100 MW range, Sumitomo SHI FW sees projects that still work like the Teesside project, i.e. they have to import some fuel but most of the fuel is sourced locally. In this case, to increase the scale of the plant for better economics, a developer would typically over-size the plant so it can use the domestic fuel first and then import the remainder.

South Korea is a good example of this, where Sumitomo SHI FW executed an interesting project called the Dangjin 1 Biomass Power Plant. When it began operation just over two years ago the 105 MW plant, owned by private utility GS EPS, became the largest renewables power plant in the country.

Giglio said: "It was originally designed for coal with some wood pellets and palm kernel shells but the government has now said that no coal can be burned in the plant. The coal has therefore been replaced with locally produced recycled wood chips. Although we had to modify the boiler at Dangjin 1, due to an increase in debris in the waste fuel, generally speaking the technology allows you to do that."

In situations where fuel flexibility is key and greening the power sector is crucial, CFB technology has an important role to play and the start-up of Teesside will go a long way to demonstrating what is possible.

Table 2. Design fuel data for both 100 per cent wood pellets and a mixture of pellets and chips

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

Dangjin 1 Biomass Power Plant: South Korea's largest renewable energy project

A New Global Leader in Sustainable Energy Solutions

Our advanced biomass CFB will cleanly and efficiently produce 299 MWe of power from carbon neutral biomass at MGT's Renewable Energy Plant in Teesside, UK.

We are excited about our new company, **Sumitomo SHI FW**, as it allows us to dedicate our talent and quality of service on our fluidized bed technologies, which we see as the future for converting biomass and waste into clean and sustainable energy.

Key attributes of the new company are:

- Largest and most experienced team of fluidized bed experts
- Largest global delivery network for fluidized bed technology
- OEM of nearly 50% of the operating CFBs in our served markets
- Largest global network of fluidized bed R&D resources and capability

Please visit our new website at shi-fw.com and come see us at trade shows to learn more about our exciting new company.

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- Waste-to-energy