

MGT TEESSIDE HERALDS A NEW 300-MW CLASS BIOMASS POWER PLANT

Construction work is well underway for MGT Teesside Ltd's biomass power plant in Teesside, near Middlesbrough, UK. Once operational in early 2020, the 299-MWe facility will become the world's largest circulating fluidised bed (CFB) plant solely fired on biomass. Robert Giglio, Senior Vice President Sumitomo SHI FW, gives some background into the new boiler class.

Originally, the GBP 650 million (≈ EUR 729 million) Tees Renewable Energy Plant (Tees-REP) plant near Middlesbrough was to be built on a turnkey engineering, procurement and construction (EPC) contract by a consortium headed by Abengoa, the Spanish environmental and energy technology group. Following the Abengoa bankruptcy in late 2015, the EPC contract was subsequently jointly awarded to compatriot industrial and energy infrastructure contractors Técnicas Reunidas (TR) and Samsung C&T, the engineering and construction arm of Korean industrial major Samsung.

The brownfield project will receive revenue from the sale of electricity under a combination of a market price power purchase agreement (PPA) and a contract for difference (CfD), which provides a variable "top-up" between the market price and a fixed strike price that will grow with inflation.

Pellets and woodchips

At Teesside, 70-100 percent of the fuel used will be wood pellets that are derived from sustainable forest by-products in North America and shipped to the port at Teesport. US-based pellet producer Enviva is one of the main suppliers, and is contracted to supply close to 1 million tonnes per annum with deliveries to begin in 2019. Its 600 000 tonne-per-annum plant currently under construction in Hamlet, South Carolina (SC) is expected to produce for the MGT Teesside contract.

The remainder of the fuel will be woodchips and this is to be sourced primarily from within the UK. The fuel will meet a sustainability threshold in terms of sustainable timber harvesting and carbon dioxide (CO₂) footprint based on fuel supplier guarantees. PD Ports that own and operate Teesport, the fifth largest port by volume in the UK, will provide biomass discharge services.

PHB Weserhütte, the material handling arm of Spain-headed TSK Grupo, was awarded the contract for the design, manufacturing and installation of the complete 700 tonne-per-hour woodchip and pellet handling system – from ship



When commissioned in January 2020, the 299-MWe Tees Renewable Energy Plant will become the largest 100 percent biomass-fired power plant in the world. The Teesside plant is built around a Sumitomo SHI FW CFB boiler and a single steam turbine, along with a fuel storage area and conveyor system, a woodchip drier, and air-cooled condenser.

and truck unloading, drying, screening, storage, fire detection and suppression, belt conveying systems and connections to the boiler days silos.

World's first 300 MW class biomass CFB

The 300 MWe class CFB boiler is being supplied by Sumitomo SHI FW as originally planned under the Abengoa consortium.

– Scale economics, fuel availability, and environmental impact have historically determined utility-scale power plant design options. That axiom is being proved with the construction of Tees Renewable Energy Plant, the world's first 300-MW-class 100 percent biomass-fired plant, said Robert Giglio, Senior Vice President Sumitomo SHI FW.

According to Giglio, utility-scale biomass-fired power plants have all of the advantages of a fossil-fired plant and none of the disadvantages commonly associated with other renewable technologies. For example, when biomass is burned in a circulating fluidized bed (CFB) boiler in a conventional steam cycle the plant produces firm baseload capacity, unlike intermittent solar and wind technologies.

"Flexi-fuel" advantage

– While woodchips and wood pellets are the dominant biomass fuels in use today, the range of available biomass materials for use as a fuel is vast with new sources regularly entering the fuels market, Giglio said.

The biomass fuel market is no longer dependent upon locally produced biomass but may now be procured from a variety of sources in a grow-

ing global fuel market. He pointed out that CFB technology also provides the owner with additional fuel supply options, such as burning agricultural biomass and other forms of locally sourced "opportunity fuels" with high moisture content.

Sumitomo SHI FW has commissioned more than 490 CFB boilers to date of which approximately 120 are designed for firing some portion of biomass, with 54 units firing biomass as the primary fuel and over 20 CFB plants firing 100 percent biomass.

Size matters

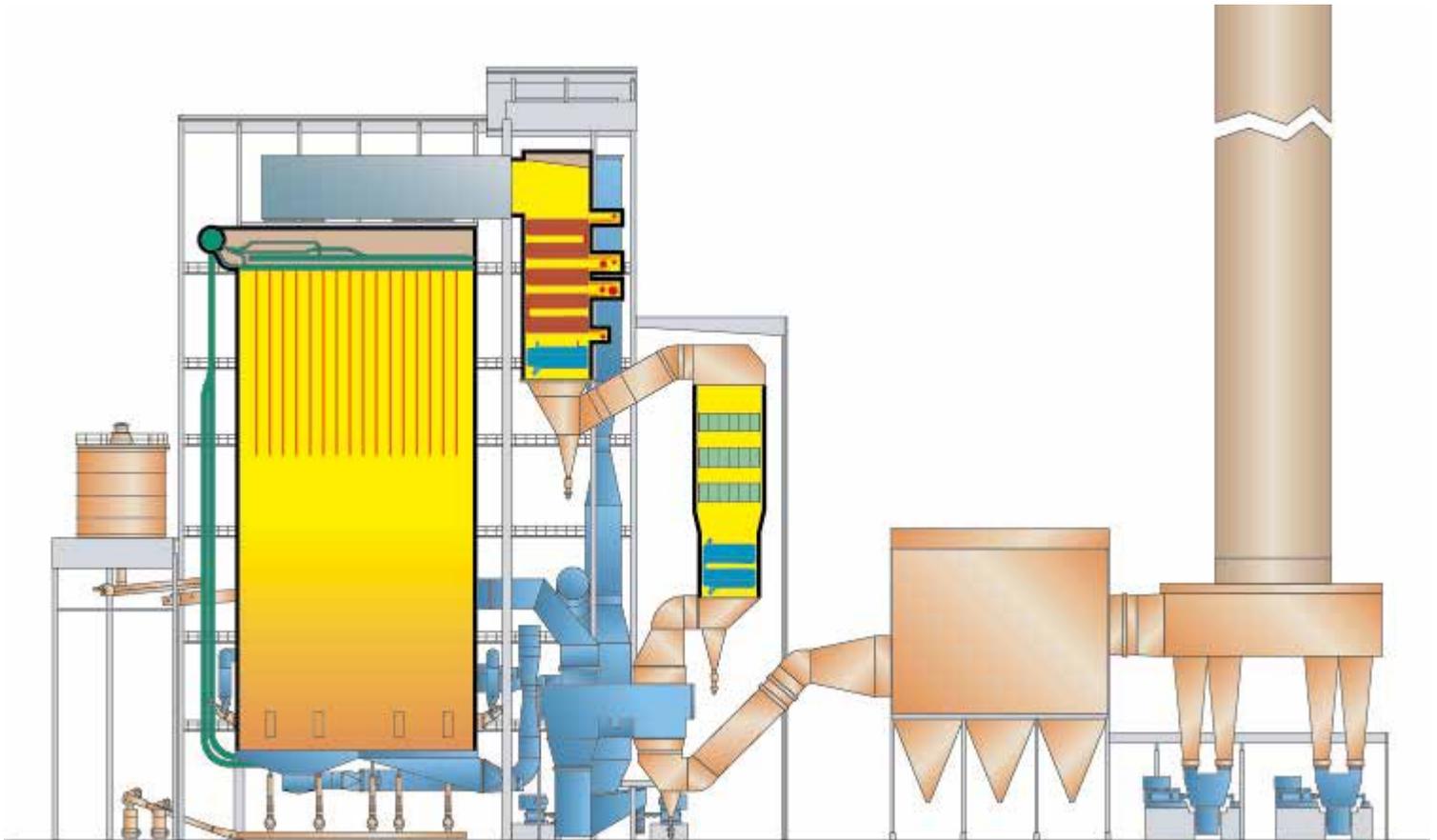
Unlike other fossil-fuelled technologies, the carbon footprint of biomass plants does not change with plant size but the increasing size of CFB plants does improve project scale economics.

– Dispatchable, utility-scale, CFB biomass projects are an elegant solution to this fuel selection dilemma said Giglio.

Until Teesside is commissioned, the world's largest utility-scale power plant firing 100 percent biomass is ENGIE's 205 MWe (447 MWth) Polaniec Unit 8, located in Polaniec, Poland. The "Green Unit" has been in commercial operation since November 2012.

In 2016, the Green Unit operated with a net efficiency of 37.5 percent and produced 1.52 TWh, representing roughly 25 percent of Poland's renewable energy market. Unit 8 fires a mixture of 80 percent wood chips and 20 percent agricultural wastes sourced within a 100 km radius of the plant.

Sumitomo SHI FW provided a turnkey delivery of the boiler island, fuel yard, and other



A cross-sectional view of the Teesside CFB boiler.

auxiliary equipment. The Teesside CFB design is scaled-up technology successfully used by the Green Unit.

Likewise, Polaniec Unit 8 was built on the technology and experience base of earlier plants that burn 100 percent biomass fuel, such as Kaukas Kaukaan Voima Oy's 125MWth power plant, located UPM-Kymmene Oyj Paper Mill site in Lappeenranta, Finland (385 MWth), Krafringen Energi AB, Örtofta, Lund, Sweden (110 MWth), and ZE PAK, S.A., Konin, Poland (154 MWth).

Larger but not bigger

Although Teesside will be the largest of its kind it will not be physically bigger than the latest CFB units firing fossil fuels because of the dry, high-quality fuel supply. In addition to a 50 percent increase in plant rating, Teesside's steam conditions reflect recent technology advances that will also produce increased efficiency.

For example, Polaniec Unit 8 CFB boiler produces steam at 127.2/20 bar(a) at 535°C/535°C (superheat/reheat). Teesside steam conditions have been pushed up to 176/43 bar(a), and 568°C/568°C.

– With sufficiently clean biomass and a state-of-the-art design, high availability and acceptable lifetimes of boiler pressure parts can be maintained at these steam pressures and temperatures, Robert Giglio explained.

The low-sulfur wood pellets contain little moisture (5 percent), ash (1 percent), and sulfur (0.02 percent) and therefore produce low emissions. The pellets also have an excellent fuel heating value of 17.8 MJ/kg. When the pellets are mixed with 30 percent domestic woodchips

at 18.5 percent 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 percent pellets at full load, he said.

Advanced steam cycle design

The steam cycle design includes provisions to deliver low pressure steam to the woodchip dryer, on the order of 6 MWth, to reduce the moisture contents of the incoming woodchips, thus maintaining the plant's combined heat and power (CHP) status.

– In addition to providing nearly carbon dioxide (CO₂) free energy by using renewable fuels, the plant will fulfill the most stringent emission limits set for traditional (35 mg/m³n SO₂, 140 mg/m³n NO_x, 50 mg/m³n CO, and 5 mg/m³n dust) air emissions, said Giglio.

Teesside boiler steam conditions of 570°C and 170 bar(a) were selected for maximum steam cycle efficiency.

– The clean fuel selected allows these high steam pressures, which is about the maximum applicable in natural circulation boilers. Steam temperatures that produce high cycle efficiency also yield acceptable superheat and reheat boiler tube life with clean biomass, Giglio said.

The Teesside CFB boiler and auxiliary equipment are located in an enclosed building.

Gas side

Flue gas leaving the top of the furnace first enters steam-cooled high-efficiency solids separators. Separated solids are conveyed to the return leg and returned to the furnace. After the back pass convective heat exchanger and catalyst, the

flue gas stream is divided for the rotary air preheater (RAPH) followed by the bypass economizer, which heats up part of boiler water extracted from the turbine island, thereby reducing the demand for steam turbine extraction steam. These parallel streams are joined before the flue gases are cleaned in a high-efficiency baghouse. Between ID fans and stack, gases are cooled down to a potentially corrosive temperature so a corrosion resistant flue gas water heat exchanger with plastic tubes is used.

Steam side

A regenerative steam cycle with reheat that produces the highest plant efficiency is used at Teesside. A high-performance steam turbine, with four stages of low pressure and three stages of high-pressure feedwater heating, turns the generator. A 40-cell air-cooled condenser designed for 10C operation is used to condense the steam from the steam turbine exhaust.

Steam leaving the high-pressure turbine is brought back to the boiler for reheating. The first stage reheater is located in the convection pass and it is equipped with a steam side bypass used for reheat steam temperature control. At higher loads, part of the reheat steam bypasses the first reheater (RH I), which reduces heat absorption and hence reduces RH II inlet steam temperature.

– In this design configuration, reheat steam control is normally not required thereby avoiding the reduction in plant efficiency usually experienced by typical fossil-fuelled plants, explained Robert Giglio.

Final reheating (RH III) is performed in two INTREX heat exchangers submerged in the bubbling hot solids in the lower furnace



Biomass fuels are now available from a growing list of global suppliers.

and protected from corrosive elements in the combustion gases.

A closed cooling water circuit transfers heat into combustion air upstream of the RAPH, replacing auxiliary steam normally needed in the first stage of air preheating. As a result of lower flue gas exit temperature, lesser steam extraction and auxiliary steam consumption, the boiler efficiency and overall process efficiency are improved.

– A similar system has been in successful operation in Finland since 2010, at the 458 MWth biomass CFB boiler in Jyväskylä, Giglio added.

Sophisticated plant controls

The 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. To do so, the high pressure (HP) steam pressure is set based upon the operator's load demand signal and the CFB boiler operates to maintain the desired HP steam header pressure, when operating between 40 percent and 100 percent load.

Meeting EU emissions targets

The emission limits set for this project are in line with the new Industrial Emissions Directive (IED) and anticipated Large Combustion Plants – Best Available Technology (BAT) Reference

(LCP-BREF) requirements for plant with an output of 50 MW or more. The controlled pollutants include sulfur dioxide/trioxide (SO_x), nitrogen oxides (NO_x), dust, carbon monoxide, ammonia (NH₃) slip, mercury (Hg), hydrogen chloride (HCl) and fluoride (HF).

The CFB combustion technology, by its very nature, provides the mechanisms to reduce various pollutants to permissible levels.

– The strict BREF limits also require additional measures. For example, several technologies are available for control of acid gases (SO_x, HCl, HF) and heavy metals (Hg) such as CFB scrubbers and spray dry absorbers. However, in biomass combustion applications the simple and proven dry sorbent injection (DSI) technology is considered more economical, said Robert Giglio.

In DSI, powdered sorbent (calcium hydroxide or sodium bicarbonate) 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 straightforward system with low capital- and operation costs when the required level of acid gas removal is moderate. However, DSI has limited SO₂ removal capability.

– For Teesside, DSI may be required with some high-sulphur wood supplies but isn't needed with normal clean biomass. Also, by injecting powdered activated carbon, mercury and dioxins and furans can be absorbed. The sorbent is

then removed in the high efficiency filter before the combustion gases are released into the atmosphere via the stack, explained Giglio.

Selective non-catalytic reduction (SNCR, ammonia injection into separators and/or into furnace depending on load) is used for NO_x control. A slip catalyst in-between two economizer stages minimizes NH₃ slip while utilizing SNCR.

Scaling up for larger units

For a wide range of biomass and waste fuels CFB provides the broadest fuel flexibility, highest steam parameters without compromising availability and reliability.

– Today, utility-scale 300 MWe-class units are available for 100 percent biomass applications with subcritical steam conditions, 600 MWe-class units for fossil fuel applications with 50 percent biomass co-firing, and up to 800 MWe for 20 percent biomass with ultra-supercritical steam conditions. MGT Teesside will be the first of this 300 MWe-class, concluded Robert Giglio.

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