Using CFB for a new generation of fuel-flexible distributed CHP in Poland

Fortum's 145 MWt/75 MWe Zabrze CFB based plant, currently under construction, represents a major step forward for CHP in Poland, providing considerable fuel flexibility – with capabilities to burn RDF and various forms of biomass in addition to coal – combined with low emissions. Building on this, scaled down versions – in the 26 MWt/10.9 MWe size range – would be suitable for many municipalities and provide a possible trajectory for future "distributed" CHP development across Poland.

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Indigenous coal fires 83% of Poland's electricity generation and 87% of its heat energy production, according to the International Energy Agency.

Within the EU, Poland, with about 56 000 MWt, is second only to Germany in terms of district heating capacity, followed by the Czech Republic and Slovakia. In Poland, about 75% of district heating systems are simple hot water systems fuelled with coal. The remaining 25% are combined heat and power (CHP) systems, predominantly coal fuelled, with few CHP systems co-firing carbon neutral fuels with coal. CHP in Poland therefore has substantial unrealised potential for sustainable energy system development.

Small-scale district heating systems are also dependent on coal. Hard coal even fires most stand-alone home heating systems, although change has begun. The city of Krakow, for example, passed a law in January 2016 banning coal-fired stoves in response to the European Commission threatening legal action against uncontrolled air emissions. Other major cities are expected to soon follow Krakow in banning open coal burning for space heating. Even so, coal and wood continue to be used to heat 75% of rural homes and villages during the winter.

Figure 1. The Zabrze CHP plant is expected to enter commercial service by the end of 2018. The plant is owned and operated by Fortum Zabrze SA and is being built by Sumitomo SHI FW under a turnkey contract. Source: Sumitomo SHI FW

Decarbonising Poland

Decarbonising Poland's power and heat generation network is central to Poland's energy policy framework, as described in the policy statement, Energy Policy of Poland until 2030. This calls for increased diversity in the country's fuel mix, particularly greater use of carbon neutral fuels, increased efficiency through CHP development, and reduction in CO_2 emissions. This policy statement and recent EU directives make it unlikely that any new coal-only plants will be constructed in Poland in the future.

Other EU directives further complicate new coal plant development. For example, European Commission Directive 2009/28 requires EU members to increase the amount of energy consumed for power generation from renewable sources to 20% by 2020. Also, the Waste Framework Directive (WFD) 2008/98 (among many directives on this subject) sets rules for waste separation and recycling, reuse, and limits disposal of waste materials. New EU rules state that refuse derived fuels (RDF) with a heating value greater than 6000 kcal/kg cannot be landfilled in the future {article also says "Since 2016, landfill of any product with a LHV of more than 6 MJ/kg has been prohibited in the EU"?}.

In Poland, waste materials are already collected and sorted, including metals separation, by regional municipally-owned facilities. These facilities produce about four million tonnes of refuse derived (RDF) fuels each year. Furthermore, the Industrial Emissions Directive (IED) 2010/75 requires CO_2 emissions from industrial activities, such as CHP plants burning RDF and biomass fuels, to remain under 550g/kWh to remain eligible for support through capacity market mechanisms. The CO_2 limit in future CHP systems can only be met by burning a mixture of coal and biomass or RDF.

An elegant way to address these current challenges is to replace aging coal-fired district heating plants with fuel flexible circulating fluidised bed (CFB) CHP plants burning coal, RDF, biosludge and biomass mixtures. This approach increases the energy efficiency of the district heating network, produces dispatchable electricity, ensures CO_2 emissions remain below the EC 2016 "Winter Package" limits, and meets WFD RDF/biofuels reuse requirements. Waste derived fuels when burnt locally also reduce transportation costs and emissions while extending the life of landfill facilities. There are also a variety of CHP production and other renewable energy system financial incentives for early adopters that can bolster a plant's bottom line economics.

Zabrze CHP plant

The Zabrze CHP plant (ZCP), located in Upper Silesia in southern Poland, once completed, will be the largest of a new generation of such fuel flexible CHP plants to be built in Poland (Figure 1). ZCP will supply electricity and steam heat for about 70 000 households in the municipalities of Zabrze and Bytom. The project also includes a new 10 km long heating pipe network that will interconnect the two municipalities. Construction of ZCP began in June 2016.

The €200 million CHP plant was developed and will be owned and operated by Fortum Zabrze SA. The boiler island is being built by Sumitomo SHI FW under a turnkey contract that includes the design, supply, construction, and commissioning of the plant. In addition to the new CHP plant and pipe network, two new peaking boilers were constructed within each municipality as part of the project, replacing boilers built in the 1950s. When ZCP is commissioned, the new peaking boilers will revert to backup service. The plant is scheduled for commissioning by the end of 2018.

ZCP will have an installed capacity of 145 MWt of heat and 75 MWe of electricity, with estimated annual production of about 730 GWh and 550 GWh of heat and electricity, respectively. Full thermal load represents 270 tonnes/h of steam flow at 92 bar and 536°C with a feedwater temperature of 242°C.

The plant's fuel flexible CFB, supplied by Sumitomo SHI FW, can burn a wide range of locally sourced fuels. The plant is initially configured to burn 0-100% domestic hard coal with 0-40% RDF, satisfying WFD and IED requirements.

This translates into about 200 000 tons of RDF each year burned in the plant's CFB boiler. The fuel supply system is designed with separate day silos and chain conveyors that supply each fuel to the CFB boiler front and rear walls.

There are also provisions in the plant design to add the capability to burn 0-100% biomass (including agro biomass) and 0-60% coal slurry. Agro biomass includes energy willow, agro pellets (including agricultural byproducts from wheat, barley, rye, oat), PKS, sunflower pellets, corn chips, shea nut cake, and olive cake. By combusting these locally sourced domestic and industrial wastes, the facility reduces the region's CO_2 emissions while concurrently reducing the amount of waste product and helps achieve compliance with limits on the LHV of material that can be landfilled (as noted above).

The plant's SO_2 and NOx emissions will remain well below the IED requirement of 150 mg/Nm3 when burning design coal and biomass mixes using only furnace limestone injection and SNCR, respectively. When firing RDF, the existing WID (Waste Incineration Directive) and the new LCP BAT (Large Combustion Plant, Best Available Techniques) standards ratified on 28 April 2017 (which require compliance by 2020) define the emission limits for many other pollutants. These pollutants are removed by an external flue gas cleaning system consisting of a CFB scrubber (for SO3, HF, and HCl removal) and a pulverised activated carbon injection system (for heavy metals, TOC, furan, and dioxin removal). Stack gas particulates are controlled by a four-compartment pulse jet fabric filter. Provisions for more stringent emissions limits were also considered in the boiler design, such as space to accommodate a future SCR catalyst (see Figure 2) and excess capacity designed into the external flue gas cleaning system.

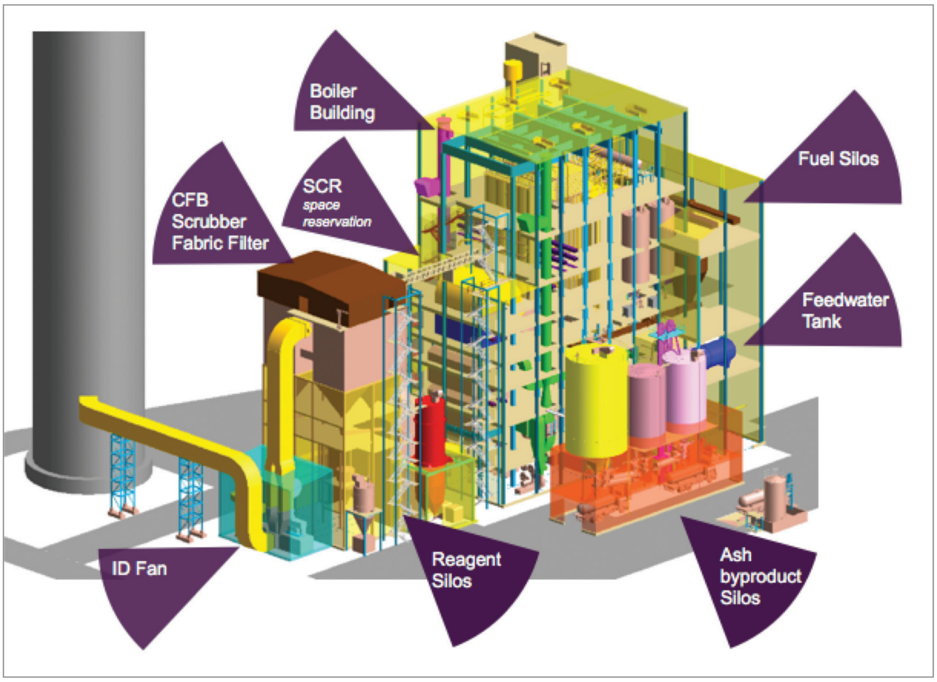

Figure 2. The Zabrze CHP plant is able to efficiently combust a wide range of coal and RDF mixtures while remaining under SO2 and NOx emissions limits. The plant will also have provisions to burn biomass and coal slurry. Source: Sumitomo SHI FW

Decentralised CHP model

The CFB based Zabrze CHP plant is unusual in Poland in terms of its relatively large size and shared use by two municipalities. There are few plant sites in Poland that can leverage the same combination of economics, energy efficiency, energy security and environmental benefits. However, there are many smaller municipalities and rural areas with inefficient district heating systems that do not generate electricity, and fire coal.

Each of these municipalities could benefit from a small CHP plant employing a fuel flexible CFB. Small scale distributed CHP plants that integrate heat and power production, waste recycling, and burn indigenous and carbon neutral fuels suggest a future trajectory for CHP plant development in Poland.

Such a development model is sustainable for a number of reasons. The plant produces heat and electricity reliably and efficiently. Plant operations are flexible and electricity produced can be locally dispatched to support intermittent renewable resources when the sun doesn't shine or the wind doesn't blow. The fuel flexible CFB can maximise use of locally available fuels, including opportunity fuels. The plant design also anticipates environmental regulations that will likely require an increase in the use of carbon neutral fuels in the future, in the same manner as the Zabrze CHP plant. Furthermore a modern multi-fuel CHP plant will reduce local air emissions when antiquated coal-fired hot water boilers are shuttered.

Most (about 55% of the total) district heating systems in Poland can be considered small or middle sized, with a water heating capacity of between 10 and 200 MWt provided by grate type hot water heaters fired by hard coal. Existing plants average 25-30 MWt heating load. For the purposes of this discussion, let's consider an average size "small" district heating system sized at about 26 MWt of district heating. This size of CHP plant is applicable to hundreds of municipalities in Poland. A conceptual drawing of such a plant, using CFB technology, is shown in Figure 3.

The design of the plant is based on a scaled down version of the Zabrze CHP plant. The CFB boiler will produce about 41 tonnes/h of 67.5 bar(a)/490°C steam over a load range of 40-100%. An extraction-condensing steam turbine will produce 10.9 MWe with a maximum district heating capacity of 26 MWt when supplied with feedwater at 140°C. The boiler concept also allows the use of higher steam parameters (90 bar, 520°C).

The emissions mirror the Zabrze CHP plant design because it is configured with the same emissions controls, including activated carbon injection, dry CFB scrubber, and pulse jet fabric filter.

Based on these design parameters, the multifuel CHP plant will produce 74 GWh of electricity and 76 GWh of heat per year. An annual average fuel mix of 50% coal, 40% RDF, and 10% biosludge equates to around 22 800 tonnes of coal, 32 200 tonnes of RDF, and 16 300 tonnes of biosludge consumed each year. The plant has all of the advantages inherent in the Zabrze CHP plant but in a smaller package.

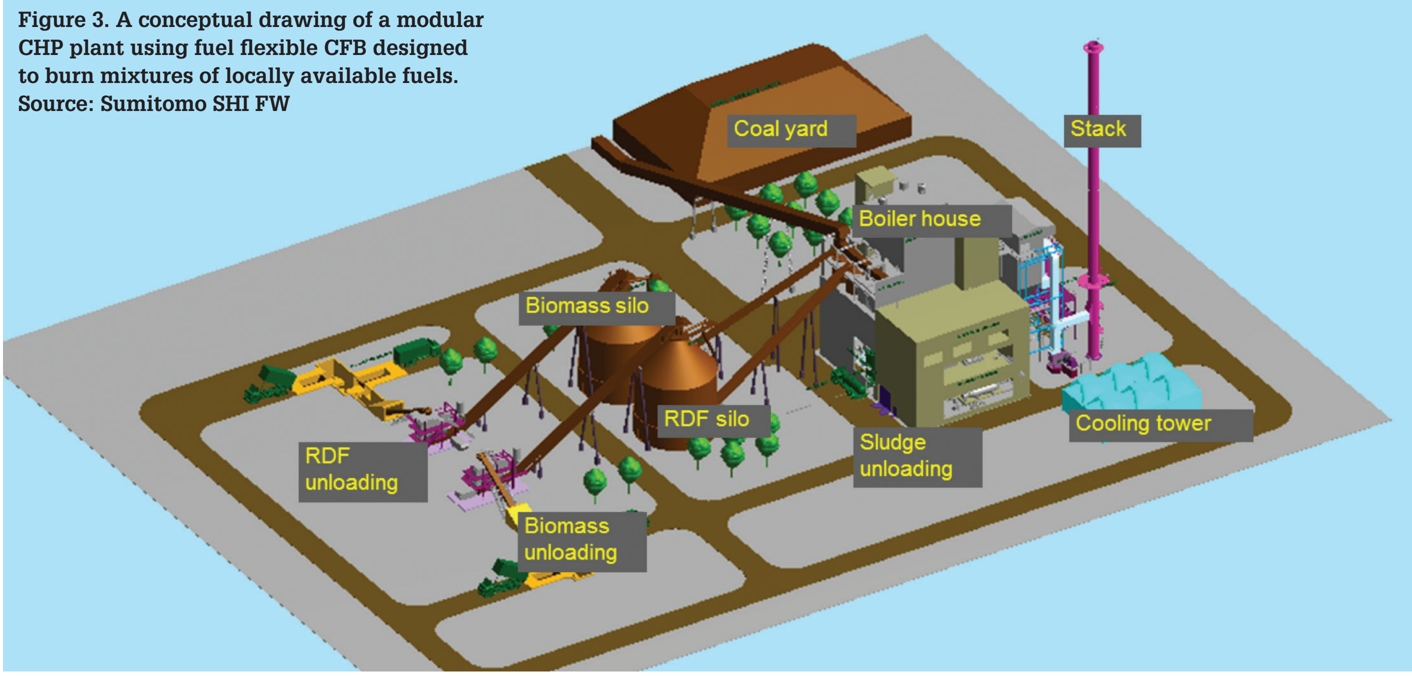

Figure 3. A conceptual drawing of a modular CHP plant using fuel flexible CFB designed to burn mixtures of locally available fuels. Source: Sumitomo SHI FW

The small CHP plant design has many additional advantages compared with the ZCP plant in terms of operational flexibility. For example, in many areas the plant can produce electricity matching the local distribution grid voltage, avoiding the cost of new high voltage transmission interconnection, transformers, and switchgear. An additional benefit is that distributed electricity generation improves grid stability in areas currently served with long power line extensions. Also, for many municipalities, a new fuel-flexible CFB will allow shuttering of old inefficient municipal solid waste incinerators that will require expensive emission reduction equipment upgrades in the near future.

Another advantage of a small CHP plant is high efficiency power generation. An efficient, fuel flexible plant can compete in the spot energy market against larger central station coal plants because recycled waste fuels typically have low or negative prices. Moreover, operating flexibility is maintained because all the design fuel mixtures will not exceed 550 g/kWh of CO_2, which means the plant is deemed eligible for support through capacity market mechanisms in the EU.

To put the CO_2 emissions reductions possible into perspective, the example 26 MWt CHP plant produces CO_2 emissions that are more than 50% less than the national average for coal-fired district heating plants (Figure 4).

The smaller, distributed CHP design also has many life cycle cost advantages. As indicated in Figure 3, plant components can be modularised to reduce manufacturing and field construction costs. Modular construction also reduces the field construction schedule and therefore reduces overall project cost. The plant's compact footprint will be important to municipalities that must build in a constrained space. For others, the modular nature of the plant allows it to be constructed in a location that optimises economics (grid tie location, location of thermal load connection, location of local fuel supplies and processing facilities for carbon neutral fuels, and the like).

There is one additional advantage for first movers that wish to build a showcase small-scale CHP plant: economic development. The plant's fuel flexibility and superior emissions performance can be the cornerstone of the economic renaissance in municipalities where coal-fired grate hot water boilers are the norm. A new CHP plant burning locally-sourced fuels can spur creation of many new plant-related businesses. Reducing the amount of landfilled or stored waste will allow municipalities to meet recycling and landfill regulations while often avoiding the cost of transporting RDF hundreds of kilometers just to burn it in cement kilns, for example. Also, new income received from selling electricity under the renewable energy legislation will be a welcome addition to already strained municipal infrastructure and services budgets.

Future investment in smart electricity and transportation systems plus local energy self-sufficiency provide a sure path to a low-carbon economy. Some municipalities will further enhance environmental and resource efficiency by using CHP to augment existing or new wind and solar renewable energy systems. Others will augment with smart grids and modern transportation systems to develop a dynamic city centre. As Krakow residents recently learned, the status quo is no longer an option. Progressive municipalities can build a sustainable energy future on the foundation of fuel flexible, reliable, and efficient CHP systems based on CFB boilers.

Figure 4. The multifuel CHP plant achieves much lower CO_2 emissions per kWh than a coal fired CHP unit, well below the upper limit of eligibility for support through the capacity market. For comparison the CO_2 intensities for ultrasupercritical coal fired and combined cycle plants are also shown. Source: Sumitomo SHI FW