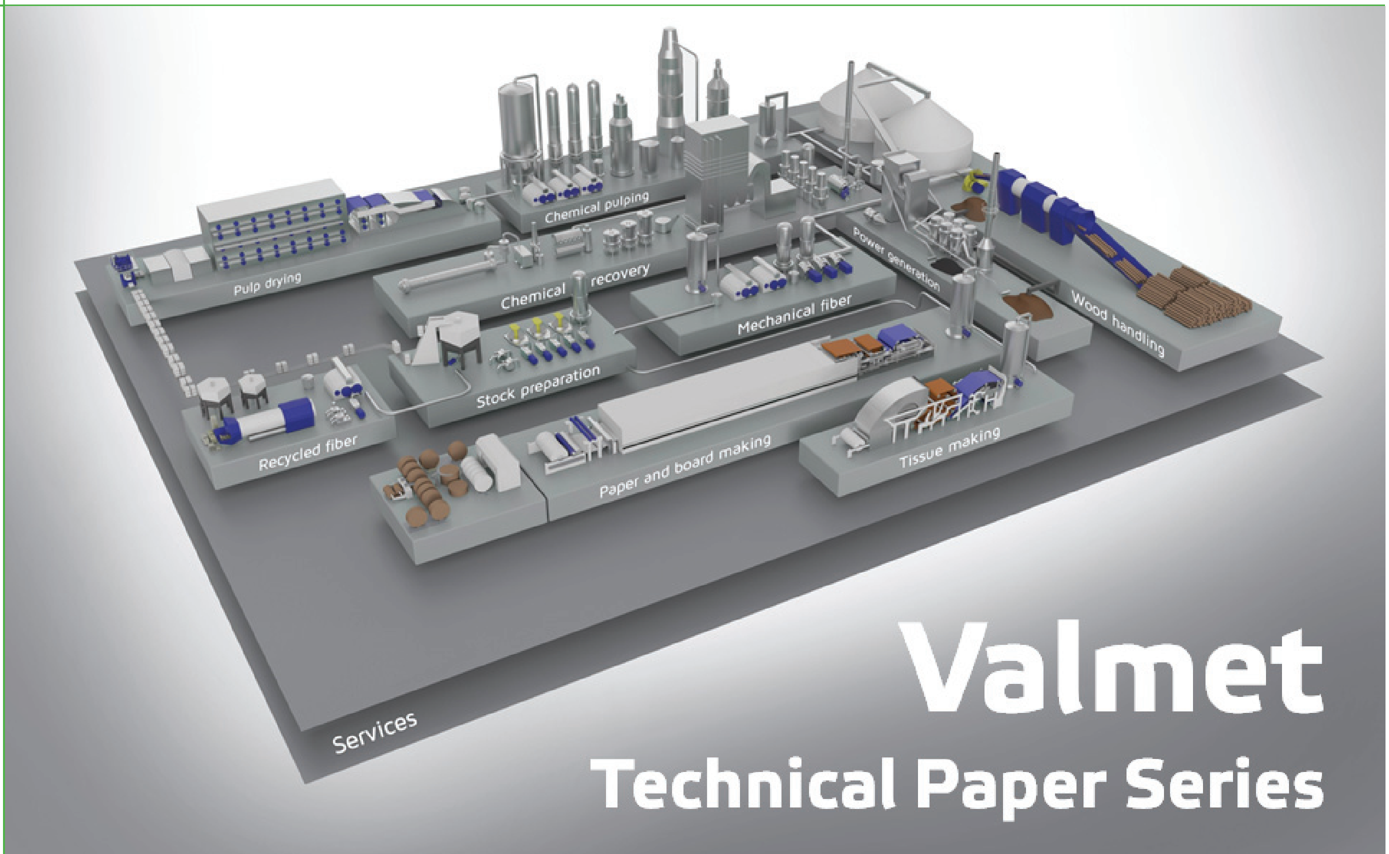

HOFOR moves toward CO_2 neutrality by utilizing the capabilities of CFB

Executive Summary

Denmark's largest utility company, HOFOR, started erecting a new power plant in September 2016. The power plant is located at Amagervaerket in Copenhagen, and is a big step toward the CO_2-neutral Copenhagen targeted by 2025. The new power plant is scheduled to begin operations in 2019. The plant will use 100% clean, wood-based biomass, and will replace an old, coal-fired unit. The reduction in CO_2 emissions will be 1.2 million tonnes per year.

Amagervaerket is located almost in Copenhagen city center, and the new plant will produce district heating and electricity for the greater Copenhagen area. The district heating capacity is 415 MJ/s, with electricity production of 150 MWe. The biomass fuel arrives at the plant by ship. The design range for the calorific value of the biomass is 6–15 MJ/kg, with a moisture content of 25–60%. The steam values of the boiler are a 560°C and 140 bar steam flow of 184 kg/s.

The boiler supplier for the new plant is Valmet. The boiler is based on circulating fluidized bed (CFB) technology. Valmet has a long history with CFB boilers – the brand name CYMIC is well known in the market, with more than 85 boiler references. Valmet is also delivering a fuel storage and conveying system. The fuel storage capacity is seven days' worth of fuel.

Introduction

This paper will introduce the HOFOR Amagervaerket power plant in detail, including all sub-systems. It also explains the technical challenge, as well as the solution for it, a combination of a wide selection of biomass properties and high steam temperature. Valmet has previously delivered large CFB boilers for biomass, such as the Alholmen Kraft 260 MWe boiler, and TSE's 150 MWe boiler. The paper will compare these three units and present the experience gained in these projects.

HOFOR – greater Copenhagen utility

HOFOR is the largest utility company in Denmark in these business areas:

- Water supply (HOFOR provides water to about 1,000,000 customers)
- Wastewater management/handling (HOFOR handles wastewater from 800,000 waste water customers)
- District heating (HOFOR provides distribution and sells district heating to approximately 600,000 customers)
- District cooling (HOFOR provides 50 MW of district cooling to 54 customers)
- Gas supply (HOFOR provides gas for over 300,000 customers)

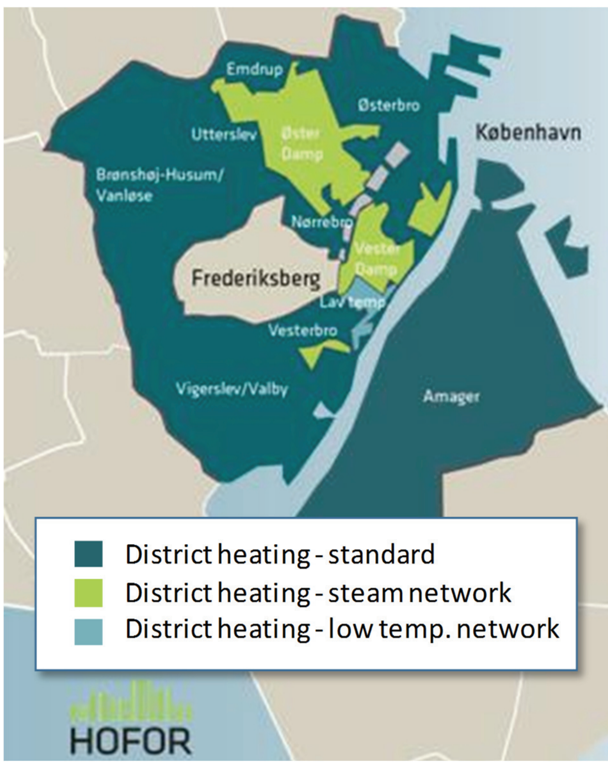

Figure 1. HOFOR areas for supply of district heating

HOFOR also builds and operates wind turbine farms and runs the Amagervaerket power plant.

One million Danes (20% of the total Danish population) depend on supplies from HOFOR (**Figure 1**). The company is owned by eight municipalities, and the City of Copenhagen owns 73% of the company and 100% of the power plant. HOFOR is focusing on sustainable supply, renewable energy, adjusting to climate change and improved handling of extreme rain. The aim of the activities is to create sustainable cities – in cooperation with municipalities, other companies and customers. HOFOR is investing, developing and establishing wind turbine farms, with the aim of having an installed capacity of 360 MW by the year 2025. HOFOR distributes and sells district heating to most of the Copenhagen District heating network. In total, more than 1,100 employees manage the activities of HOFOR.

Valmet as technology provider

One very efficient way to utilize demanding fuels, like high-ash or high-moisture fuels, is fluidized bed technology. The available fluidized bed technologies are bubbling fluidized bed (BFB) and circulating fluidized bed (CFB). Valmet has been manufacturing fluidized bed boilers since the 1970s. Initially, it built BFB boilers for low-calorific biofuels. In the 1980s, Valmet's product range expanded with the addition of CFB boilers for any combination of fossil fuel and biomass. To date, Valmet has delivered close to 300 fluidized bed boilers for different kind of fuels and fuel mixtures.

Valmet has its own fluidized bed technologies for BFB and CFB, and is actively developing these technologies. The brand names of Valmet's CFB boiler is CYMIC, the BFB boiler is called HYBEX.

Valmet's Research Center in Tampere, Finland, provides excellent possibilities to test new fuels. It has three different sizes of test reactors for testing fuel, and the main focus during the last fifteen years has been to utilize renewable fuels and low-cost fossil fuels.

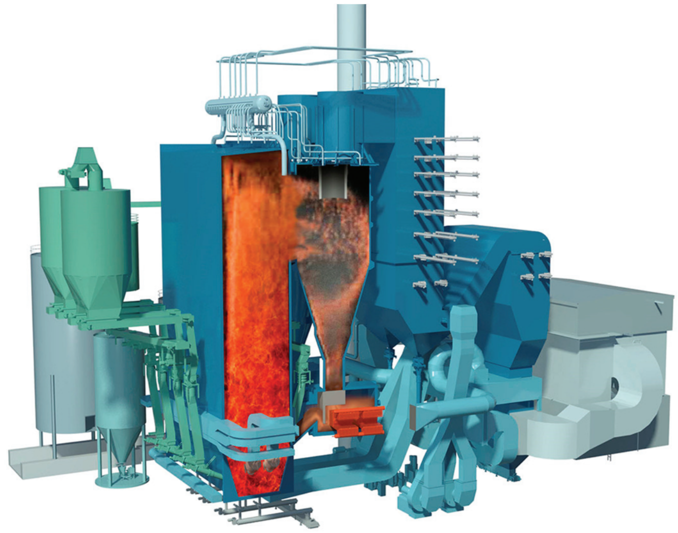

Figure 2. CYMIC boiler process overview

HOFOR BIO4 project introduction

Background of the BIO4 project

HOFOR strives to be green, secure and cost-efficient in every part of the business. In relation to the acquisition of the power plant, this means the following:

GREEN: The City of Copenhagen aims to be the world's first CO2-neutral capital by 2025. Green district heating is an important prerequisite for achieving this goal. The precondition for the purchase was that the existing unit 3, using coal as fuel, would either be converted to wood pellets, or a new biomass power plant would be established, replacing the existing unit 3 in order to move away from fossil fuels in the district heat supply. The conditions are set out in the climate change plan for Copenhagen, "KBH 2025 Klimaplan," as prepared by the municipality of Copenhagen. The report can be found at:
http://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=930

SECURE: The greatest possible security is desired for the supply. With decreasing capacity from thermal district heat production in Copenhagen, there is a need for new capacity. HOFOR will ensure this by taking over the Amagervaerket power plant.

COST-EFFECTIVE: Heating prices for customers are higher than in most other major cities in Denmark. HOFOR wants to reduce the price for customers. By producing district heat from wood chips with high efficiency, the price of district heat in the greater Copenhagen area will fall.

As the sole owner of the plant, the City of Copenhagen is realizing these plans.

The existing power plant

HOFOR took over the Amagervaerket power plant from Vattenfall on January 1, 2014, with the aim of ensuring safe and reliable heat production in the greater Copenhagen area for the future.

The existing power plant consists of two power units:

Unit 1: Began operating in 1971. Converted from coal to biomass (wood pellets) in 2009. Combined heat and power production. Total thermal input of 350 MW.

Unit 3: Began operating in 1989. Uses coal as fuel. Combined heat and power production. Total thermal input of 600 MW.

Figure 3. Amagervaerket located at the tip of the island of Amager, Copenhagen

The power plant (**Figure 3**) provides 30% of the heat production in the greater Copenhagen area. HOFOR currently uses approximately 300,000 tonnes of wood pellets and 400,000 tonnes of coal per year.

Feasibility study of new CHP unit based on sustainable biomass

An analysis of the most feasible alternatives was finalized at the end of March 2014.

The main alternatives were to convert the existing, coal-fired unit 3 to use wood pellets as fuel, or to establish a new combined heat and power (CHP) plant using wood chips as fuel.

The conclusion was that the technically and economically most feasible alternative would be to establish a new CHP plant. The existing unit 3 will be permanently shut down once the new unit 4 is continuously running.

The existing coal-fired unit 3 has reasonable electrical efficiency, as it was designed in the late 1980s with a focus on high electrical efficiency. The fuel input is 600 MW, and unit 3 can produce 250 MW net of electrical output in condensing mode, and 200 MW net of electrical with 330 MJ/of s district heat in backpressure mode.

The electrical market for Copenhagen and the Nord Pool area has changed significantly over the past ten years. Electrical production from thermal power plants is being challenged by wind and solar production. Hourly prices have generally decreased and are often very low, since in winter when there is a lot of wind, there is also significant production of electricity from thermal power plants, when producing district heat. At the same time, electrical production must be ensured even when there is no wind or the sun is not shining.

Currently there are no incentives in Denmark for energy companies to contribute to higher electrical back-up capacity. Many business cases for initiatives to create higher electrical efficiency were conducted in relation to the new power plant, and many turned out not to be feasible, whilst increasing heat production had better business cases. The new plant therefore has a fairly low electrical efficiency, but very high heat efficiency.

For central power plants in Denmark, it is regulated by law that they must be designed as combined heat and power plants. HOFOR therefore considers flexibility between electrical and district heat production very important so that a future new plant can bypass the turbine in order to produce heat only in cases of very low electricity prices or when alternative heat production costs are very high, e.g. peak load based on oil.

Based on different business cases with varying plant sizes, a CFB plant using wood chips with a fuel input of 500 MW was chosen as the best alternative for a new CHP plant at Amagervaerket.

The plant will be able to produce 150 MW net electrical, with 415 MJ/s district heat in backpressure mode and up to 600 MW of district heat, when thermal production of electricity is not needed, but there is high demand for district heat. The total efficiency of the plant will reach approximately 115%, based on the lower heating value.

Project organization

The project is organized by a small number of people from HOFOR. The rest of the project organization is made up of consultants from various consultant companies in Denmark and Sweden. The organization consists of a project director and deputy project director in charge. To execute the project, there are seven individual project managers handling contractors for process equipment, electrical/DCS and civil. More information about the project can be found at the website:

http://www.hofor.dk/amagervaerket/bio4-projektet/

Design conditions

The new biomass-fired CHP plant (**Figure 4**) will be located at the Amagervaerket site in Copenhagen, Denmark. Amagervaerket is located close to Øresund and can be accessed with ships with drafts of up to 11 meters to transport wood chips and logs to the new plant. Annual consumption of biomass is estimated at 1.2 million tonnes. Wood chips will be supplied by ships, with cargo loads of 2,400–10,000 tonnes. The wood chips will be unloaded by cranes and conveyed to the storage facility at a rate of approximately 3,000 m^3/h. Logs can also be handled with new cranes and chipped in the new wood chipper at the plant.

Fuel flexibility is vital for the new plant. The primary biomass fuels will be chipped wood. HOFOR is investigating alternative fuel types, which will be considered as secondary fuels. If possible, secondary biomass fuels will be used occasionally in a mixture with the primary fuels.

Figure 4. An overview of the power plant located close to Copenhagen city center.

The best utilization of the fuel supports the effort to be green – energy efficiency is therefore essential for the design of the CHP plant, and the plant is therefore designed with a condensation unit for heat recovery, including humidification of combustion air in order to utilize the high vapor content in the flue gas. District heating water at approximately 50 °C is used as the cooling medium for the condenser unit, making it possible to cool the flue gas down for optimal heat recovery. The new plant can operate either in backpressure mode, or district heat production without any electricity production.

The plant is equipped with DeNOx, DeSOx, and dust-reducing technology (baghouse filter) in order to comply with the new Industrial Emissions Directive (IED). The limit values given in the environmental permit reflect emission data from the best available techniques (BAT) document.

HOFOR wants to have a high environmental profile for the new plant. The contracts stipulate significantly lower values than the new IED predicts as BAT values (**Table 1**).

Emission	Unit	Guarantee value	Environmental permit
Dust	mg/Nm^3, dry	1	10
SO_2	mg/Nm^3, dry	1.5	50
NO_x	mg/Nm^3, dry	20	150

Table 1. Emission data. Guaranteed value at nominal load hourly. Environmental values as daily mean value.

Layout

The layout of the new power plant is shown in **Figure 5** in a 3D model.

The new unit is placed in free space north of the existing unit 3. Storage is located in a former coal yard. The harbor is extended to handle more ships arriving at the plant.

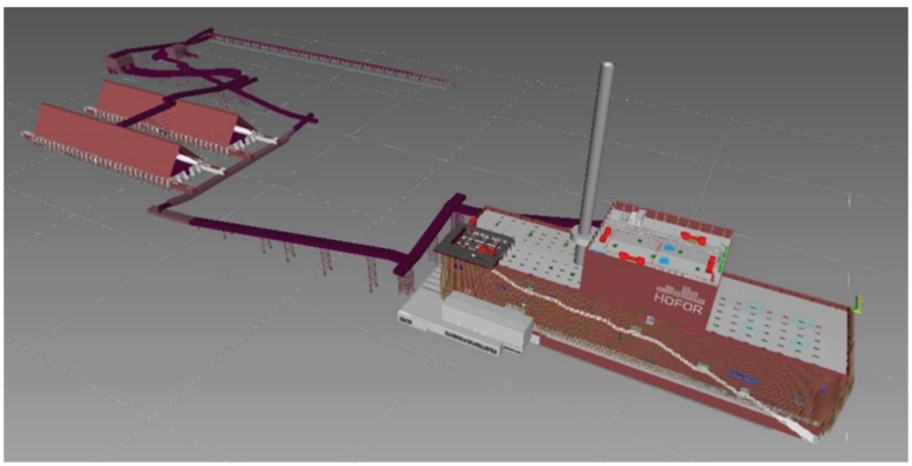

Figure 5. Power plant layout

Architect

In 2015, there was an architectural competition. The objective was to create a building that could support the transition from fossil fuels to sustainable energy production. The winner was the Danish architectural company Gottlieb Paludan Architects.

The building's façade will be clad with thousands of debarked tree trunks (**Figure 6, next page**) to form a gentle, yet significant addition to the skyline. Glistening silver, the trunks open the power plant up to the city and invite citizens to take a closer look.

There will be a platform 40 meters above ground with a good view over the power plant area and a panoramic view of Copenhagen. Along the north façade, there will be a stairway to the platform.

From the stairway, citizens can look in to the plant from 3–4 different locations/platforms.

Figure 6. Architectural images of the power plant. Left: a view from the city center. Right: the stairway to the observation platform with a view into the plant. [Drawings by Gottlieb Paludan Architects]

Time schedule

The project was initiated in January 2014. An invitation to tender for process equipment was sent out in late June 2015. The contracts with process contractors and some civil contractors were signed in May 2016. The activities at the site started in June 2016 with the site preparation. In September 2016, all the necessary approvals from the authorities were in place and piling work began, followed by foundation work later in 2016. Erection of the first process contract began in May 2017. Commissioning takes place in 2018, and in spring 2019, the plant will begin test runs.

Authorities

The new power plant required a number of approvals from the authorities. This includes an environmental impact assessment (EIA) and an environmental permit (EP). The process started in spring 2014, and approvals were given in late August 2016. There were very few questions about the project during the period of assessment. HOFOR has aimed to involve both authorities and the public from an early stage. Agreements on terms were made with the authorities, and the public has been kept informed via public hearings as open sessions, and general information about the project and activities at the site via the website and newsletters.

Subsidies

Heat production based on biomass is free of energy and CO_2 taxes – unlike fossil fuels such as coal, oil and natural gas. Further electricity generation based on biomass is supported by the state with a subsidy of 15 øre per kWh (fixed prices) – approximately two euro cents per kWh.

Sustainability of biomass

The wood chip supplies will originate from a range of countries and regions. Preferably, shipping distances should be short and forest density should be high, thus the Scandinavian and Baltic countries are likely supply regions. HOFOR also expects some supplies from longer distances.

Sustainability in forestry and along the supply chain is a fundamental prerequisite. Formal requirements follow the Danish agreement on sustainability of solid biomass fuels. On the forestry side, the requirements are met either by sourcing from certified forestry under the FSC or PEFC schemes, or based on an independent third-party sustainability assessment. One fundamental criterion is to maintain the long-term productivity of the forests, i.e. to make sure that energy utilization of forest residues does not contribute to the degradation or reduction of forests. HOFOR uses certification according to the

Sustainable Biomass Partnership as the main tool for documentation. More information can be found here: https://sbp-cert.org/

Boiler plant concept

Valmet was selected to supply a fuel pre-handling, storage and conveyor system from the harbor to the boiler plant. Valmet is also supplying the CFB boiler plant. The technical concept of these two deliveries is described in this section.

Fuel pre-handling system

The design fuel of the plant is wood chips, which are mainly transported by ship to the plant's own harbor. The design moisture of wood chips varies from 25% to 60%, meaning that the calorific value of the fuel varies in the range 6–14 MJ/kg. With the design fuel and nominal load, the actual fuel consumption is 600 m^3/h of wood chips, but with the worst fuel, the fuel consumption is 950 m^3/h. The conveyor system is designed to achieve 2 × 1,500 m^3/h from harbor to storage, and 2 × 900 m^3/h from storage to the boiler silos. All these conveyors are covered. The plant consumes approximately 1.2 million tonnes of wood chips per year, meaning that fuel logistics need to work well in any condition.

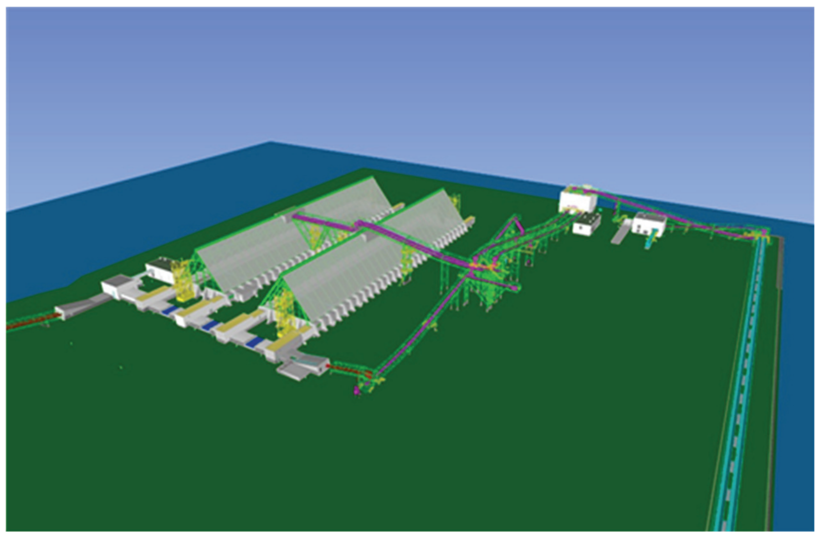

Figure 7. Fuel pre-handling system

The storage consists of two covered, A-shaped storage units, each with a capacity of 75,000 m^3, giving a total storage capacity of 150,000 m^3. The storage facilities will be designed to minimize risk of fire and be prepared for safe firefighting if heat or fire are detected in the storage facility.

Valmet's delivery consists of conveyors from harbor to storage, a screening house, a receiving station for truck-transported chips, two A-type closed wood chip storage facilities and conveyors from storage to the boiler silos. There is also 10,000 t of storage for logs. The log storage capacity for the chipping system is two to three days of operation. The capacity of the A-type storage (2 × 75,000 m^3) is enough for roughly seven days of operation.

The fuel conveyors to the four boiler fuel silos are duplicated. There are two independent parallel conveyors from the storage to the boiler fuel silos, and the distribution conveyors with four metering screws are duplicated.

CFB boiler plant

Boiler

The CFB boiler is a core piece of equipment at this biomass power plant. The capacity of the Valmet CYMIC boiler is 458 MWth, and the steam data is 184 kg/s, 560 °C, and 140 bar. The feedwater temperature is 230 °C. The electricity output is 150 MWe, and despite the large size of the boiler, it does not have a reheater, since the main product is district heating.

Pressure parts

The boiler (**Figure 8**) furnace is 19.9 × 9.2 m and its height is 40 m. After the furnace, there are two water-cooled membrane cyclones with diameters of 9.3 m. The furnace and cyclones work on the water-steam side in natural circulation and act as boiler evaporative surfaces. A secondary superheater is located on the top of the second pass, followed by two primary superheater packages.

The finishing superheater is located in two parallel sections inside the cyclone loop-seals. After the primary superheater in the second pass, there is an evaporator surface followed by one economizer section. An evaporator surface is needed to prevent the economizer from steaming. The rest of the economizer (six sections) is located in the third pass, below the slip catalyst. The economizer in the third pass is a finned tube type.

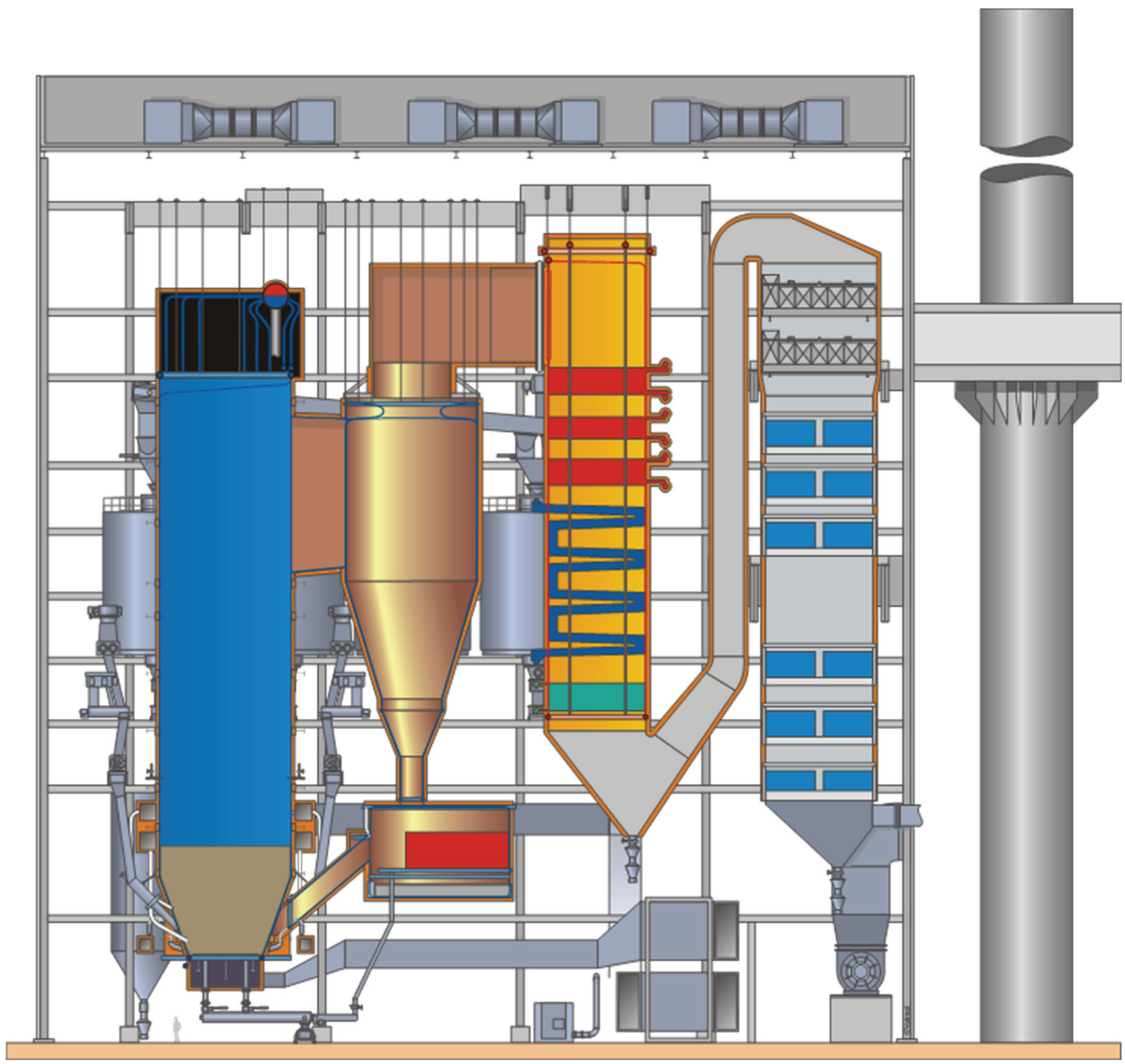

Figure 8. Side view of the boiler

The reason for locating the finishing superheater inside the loop-seals is to mitigate the risk of high-temperature corrosion. In the loop-seal, the superheater surface is not in contact with flue gases, since it is immersed in the circulating bed material. The loop-seal forms a lock between the furnace and cyclone, and a special design with double locks in both directions prevents any flue gas leakage. Only fluidizing air has access to the chamber where the superheater is located. The design wood chips have a chlorine content of 0.02% and an ash content of 1.6%, which are both quite low numbers, but the range of ash content is up to 10%, and the alkali metal content can be 20% of the ash. Also, the steam temperature is reasonably high, and the risk of fouling, and later of high-temperature corrosion, is remarkable. That is the reason for this arrangement.

Fuel feeding system

The fuel feeding system (**Figure 9**) consists of four round silos with a rotating spreader on the top of the silo. The purpose of the spreader is to distribute fuel evenly in the silo so it does not drop in one spot. A silo discharging screw slews around the silo, and the discharging point is in the middle. After the silos, four drag chain conveyors transfer the fuel inside the boiler building, where another four drag chain conveyors feed the fuel to the front and rear wall fuel chutes. Each line has two metering screws which feed the right amount of fuel to each of the eight feeding chutes. Each fuel chute is equipped with a rotary lock feeder. All the fuel feeding equipment, except the rotary feeder, are speed-controlled, allowing very accurate and consistent fuel distribution into the furnace.

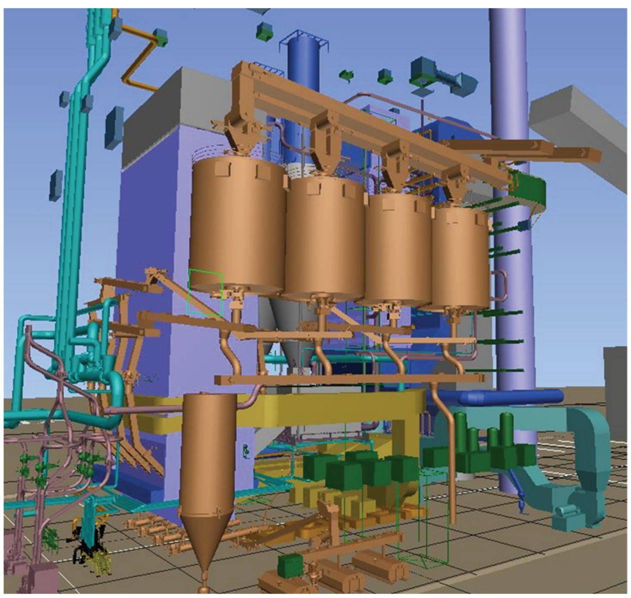
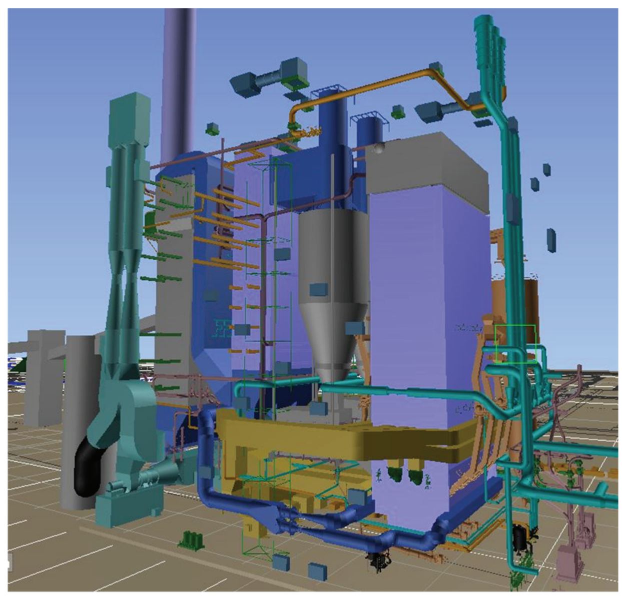

Figure 9. Boiler fuel feeding system

Combustion air system

The combustion air system consists of a total air fan, a primary air fan and ductwork to the furnace. Combustion air can be taken inside or outside of the boiler building, and the split is determined by the ventilation system. Combustion air can go also through an air humidifier, and moisturized air is connected to the suction side of the total air fan. Additional moisture in the combustion air increases the amount of flue gas and improves the heat pick-up in the flue gas condenser.

Most combustion air goes first through the total air fan. After the total air fan, some of the air goes to the primary air fan, which increases the air pressure to a level suitable for bed fluidization. The rest of the air after the total air fan goes to the secondary air system. There are secondary air nozzles at two elevations on both the front and rear walls. Combustion air is heated by feedwater heaters before going to the furnace. There is no flue gas air preheater in this boiler.

Flue gas system

The boiler is equipped with a flue gas recirculation system. Clean flue gas is taken after flue gas cleaning. Recirculation gas goes into the bed in the lower furnace. The reason for the system is the wide range of design fuels – the moisture content can vary between 25% and 60%. Flue gas recirculation is used to control the furnace temperature. Too high a furnace temperature leads to fouling on heat surfaces.

Emission control system

The emission control system in the Valmet delivery consists of an ammonia injection system (SNCR) and a slip catalyst (SCR) for NOx reduction. The ammonia–water concentration is 25%, and it is injected into cyclone inlets at two levels into the furnace for lower boiler loads. The catalyst located on the top of the third pass utilizes the ammonia slip in flue gases and further reduces NOx emissions.

Bottom ash system

The bottom ash system removes impurities coming with the fuel from the bed. Impurities are typically stones and gravel, and sometimes even pieces of metal. The furnace is equipped with eight ash chutes, which are connected to four water-cooled screw conveyors. The screw coolers feed the cooled ash to a drag chain conveyor. This conveyor feeds the bottom ash to a rotary screen, which separates oversized fractions in two different stages from the bottom ash. The fine fraction is transferred back to the furnace by a pneumatic conveyor. If there is no need for additional bed material in the furnace, the bottom ash is transferred with the medium oversize fractions to the bottom ash silo. The largest oversized fractions from the screen go to containers underneath the screening station.

Comparison to existing similar plants

Valmet has delivered similar CFB boiler plants earlier. Here is a brief introduction of those plants and a comparison of the technical concepts. The drivers in these projects are different, but the common element is to maximize the use of biomass fuels and to reduce net CO_2 emissions.

Alholmen Kraft 260 MWe CFB

The Alholmen Kraft power plant in Pietarsaari, Finland, was the first real multifuel CFB boiler in the world when it started up in 2001. This CYMIC boiler was originally designed to burn peat, wood and bituminous coal in any fuel combination. The steam data of this reheat unit is 194/179 kg/s, 545/545 °C, and 165/40 bar, meaning capacity of 260 MWe. This plant has been in operation since 2001. The fuel mixture has varied year by year for many reasons. In some years, biomass availability has been poor, and in some years, peat quality and availability have been very bad due to rainy summers.

The Alholmen boiler consumes 800–1,000 m^3/h of fuel at full load when burning peat or biomass. Fuel storage for those fuels on the site is less than one day. Coal storage is about one month, meaning that coal is a good backup for the plant, securing operations in any condition. The coal backup feature was important in the project development phase in order to convince the financier. Coal and biomass have their own silos and silo dischargers, but the rest of the feeding system is common for all the fuels. This boiler has been able to maintain high availability figures, mainly due to the fuel options available.

The Alholmen power plant can operate in full condensing mode when needed, but the operating mode has recently been combined heat and power production (CHP) due to the low electricity price in Finland. Process steam is sold to the neighboring paper mill, and district heating to the town of Pietarsaari. This boiler is still the world's largest CFB boiler capable of burning 100% biomass.

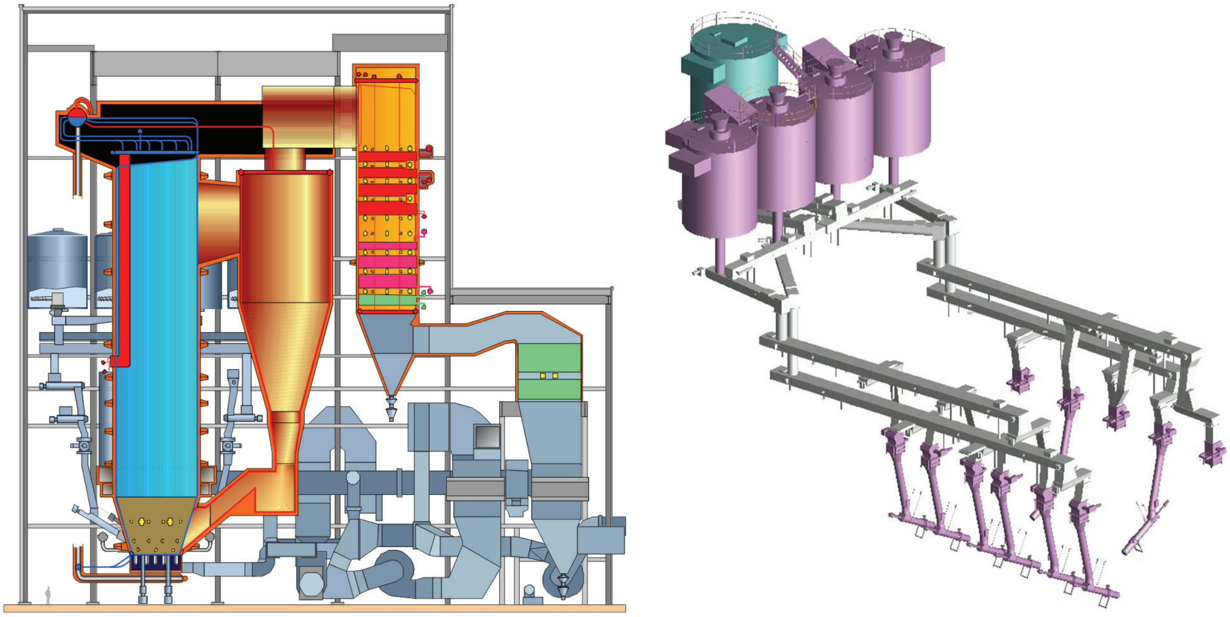

Figure 10. Left: Alholmen multifuel boiler. Right: fuel feeding system for multifuel application.

Lessons learned in this boiler were related to challenges coming from the biomass fuel. The first challenge was on the plant owner side: to collect enough biomass at a reasonable price. Also, the small biomass storage capacity compared to fuel consumption imposes requirements for fuel logistics. On the boiler side, wear in the fuel feeding system, in the primary air nozzles, and in the cyclone target area refractory caused some additional maintenance in the beginning. Wear in the feeding system was solved with preventive maintenance. Primary air nozzle wear was solved by developing a new nozzle with a new material (high chromium cast) that can withstand very abrasive conditions. Wear in the cyclone target area was caused by sharp ash (crushed gravel) coming with stumps. The refractory was changed in the target area to prefabricated tiles, and the lifetime of the refractory increased dramatically. High-temperature corrosion has not been an issue in the Alholmen boiler. The explanation for this is the fuel combination –there is almost always some coal in the fuel mixture, making the chemistry much easier than in the 100% biomass case.

TSE Naantali 142 MWe CFB

Turun Seudun Energiantuotanto (TSE) is repowering a 50-year-old, coal-fired power plant in Naantali, Finland, by building a new power plant block based on CFB technology. Valmet is delivering a CFB boiler island for this project. This is a long-lead project – the contract was signed in April 2014, and commercial operation will start in November 2017. The production capacity of the new power plant will be 142 MWe of electricity and 244 MWth of heat, and the annual production will be 900 GWh of electricity and 1,650 GWh of heat.

This new boiler will replace the old, coal-fired capacity, and it will also have 100% coal-firing capability. Besides that, this boiler is a real multifuel boiler, since the design fuel mixture includes wood-based biomass (0–75%), agro-based biomass (0–15%), peat (0–95%) and RDF (0–5%). The plant will use approximately 0.7 million solid cubic meters of wood chips annually. Later on, the amount of wood chips may be as high as 1.2 million solid cubic meters annually. The owners are really utilizing the CFB's biggest benefit: fuel flexibility. Construction of this boiler started in February 2016, and start-up will be in 2017.

The steam cycle values are quite high, leading to high plant efficiency. Also, this boiler is equipped with a reheater. The steam flow is 144/130 kg/s (HP/RH), steam pressure is 164/44 bar, and the steam temperature is 555/555 °C. Some of the design fuels, like agro-biomass and RDF, contain quite high amounts of chlorine (0.2–0.4%), meaning that there is a risk of high-temperature corrosion in both the finishing superheater and the finishing reheater. In order to mitigate this risk, both surfaces are located inside bed material in cyclone loop seals. The bed material protects the heat surface against corrosive gases. This design is similar to the HOFOR design.

The flue gas cleaning system in the TSE boiler consists of SNCR for NOx control, limestone injection for SO_2, and BHF for particulates. On top of that, there are space reservations for the slip catalyst and dry sorbent feeding system before the BHF. This is preparation for stricter emission limits in the future.

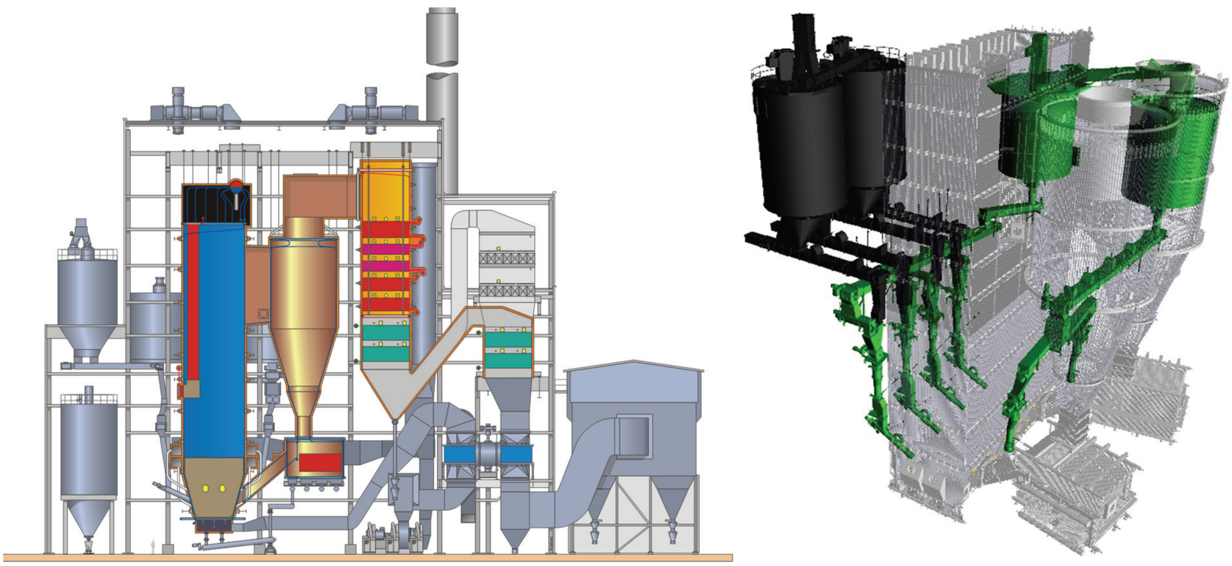

Figure 11. Right: TSE multifuel CFB. Left: fuel feeding system for five design fuels: coal, wood biomass, agro-biomass, peat and RDF.

The comparison **Table 2** (**next page**) shows that there are some differences in the concepts of these three projects. Alholmen was designed to always use some sulfur-containing fuel, like peat or coal, and the design was according to that – no need to design for high temperature mitigation. At that time, free fuel selection was a driver, without knowing the positioning of different fuels. This was a real breakthrough in multifuel thinking.

In both Naantali and HOFOR, the biggest driver was to replace old, coal-fired capacity with biomass. That also requires a different superheater design, since there is no sulfur-containing fuel in HOFOR, and it can be the same case in Naantali as well. All these plants are located on the coast, and have harbors close by, making high-volume biomass transportation by ship possible.

Looking at the physical size of these three boilers, there is no big difference in height, since the cyclone always determines the furnace height. The cross-section comes from the fuel properties. Naantali's smaller flue gas amount comes from the different design fuel mixture.

Project location		Alholmen, FIN	Naantali, FIN	HOFOR, DK
Design in fuel side	% of energy input	Wood 0–100% Peat 0–100% Coal 0–100%	Wood 0–75% Agro 0–15% Peat 0–95% Coal 0–100% SRF 0–5%	Wood chips 100%
Capacity	MW_e	260	142	150
Superheated steam data	°C/bar	545/165	555/164	560/140
Reheated steam data	°C/bar	545/38	555/44	N/A
Furnace dimensions • Height • Cross-section	m m m^2	24 × 8.5 40.5 206	17.85 × 7.65 36.2 136	19.9 × 9.2 40 183
Cyclones, D	m	3 × 9.1	2 × 8.2	2 × 9.3
Flue gas amount, max	Nm^3/s	266	178	248
Fuel flow, max	m^3/h	800	460	600
Number of fuel feeding points	pcs	11	6	8

Table 2. Comparison of Alholmen, Naantali and HOFOR technical concepts

Summary

The HOFOR BIO4 project is a showcase in how to change fuel from coal to biomass in large power plants. CFB technology allows the use of biomass with very different properties – in this case the moisture content can vary from 25% to 60% (calorific value 6–14 MJ/kg). That offers a lot of freedom in fuel supply and cost-effective fuel.

The HOFOR project also shows well the situation in the European power market – there is no need for new capacity, but securing capacity is an issue when the wind is not blowing or the sun is not shining. Heat becomes the main product, and electricity is a byproduct. Electricity will only be generated when it is feasible. The plant is designed for maximum heat output and to secure the future district heat supply of the City of Copenhagen.

HOFOR has a very unique architectural design compared to other plants. The location close to the center of Copenhagen and providing public access to the plant requires special attention.

Previous CFB projects of the same size proved the design, and long-term experience ensures that the selected technology is reliable and fits very well for this purpose.

This white paper combines technical information obtained from Valmet personnel (Ari Kokko & Jonas Wallén), HOFOR (Carsten Schneider & Lars Fenger) and published Valmet articles and papers.