Multifuel CFB solutions – Producing power in a flexible environment

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Kurzfassung

Multifuel CFB-Lösungen – Energieerzeugung in einem dynamischen Umfeld

Die Europäische Union legt den Fokus auf die erneuerbare Energieproduktion sowie die Kreislaufwirtschaft. Jedoch fehlen heute Investitionsanreize in erneuerbare Energien, da fast alle nationalen Unterstützungen gekürzt oder eingestellt wurden. In Europa ist durch die verstärkte Nutzung der Biomasse der Preis soweit angestiegen, dass ohne Einspeisevergütung oder Förderungen neue Biomasseanlagen wirtschaftlich nicht mehr darstellbar sind. Zusätzlich trägt der sehr niedrige Ölpreis zu Verwerfungen am Energiemarkt bei. Der Kraftwerkspark in Europa altert zusehends, wobei viele dieser Anlagen noch mit Kohle befeuert werden. In diesem herausfordernden Umfeld ist die zirkulierende Wirbelschichttechnologie der einzige Weg die bestehenden Kraftwerksstandorte zu adaptieren. Der größte Vorteil besteht in der Brennstoffflexibilität der Anlagen, wobei in einer Anlage 100 % Kohle oder 100 % Biomasse und andere Abfallprodukte in allen Mischungsverhältnissen verbrannt werden können. Dieser Ansatz ermöglicht die zukunftsgerichtete Auslegung einer Anlage mit flexiblen Brennstoffportfolio. In diesem Beitrag werden mehrere Projekte, die sich in der Errichtungs- beziehungsweise Inbetriebnahmephase befinden und die herausragenden Eigenschaften der zirkulierenden Wirbelschicht demonstrieren, vorgestellt. Beispiele sind eine 80 MWe Anlage in Tschechien, eine 50 MWe Wirbelschicht in Ungarn und eine 30 MWe sowie 150 MWe Anlage in Finnland.

European Union is leading energy sector towards renewable energy production and circular economy. Today the drivers to invest in renewable energy are missing since most of the national incentive systems have been cancelled or minimized. Now without any incentives the firing of biomass is not feasible before a new mechanism to encourage the use of renewable fuels is in place. At the same time record low oil price is confusing the situation more. Power plants in Europe are ageing and quite many of those are firing coal only. In this uncertain situation CFB boiler is the right solution in repowering projects – almost all the projects are replacement investments because new capacity is not needed in Europe. CFB's biggest benefit is the capability to burn many kind of solid fuels – a CFB boiler can be designed to fire 100 % coal and 100 % biomass including lower cost biomass and waste based fuel. This kind of approach provides flexibility for fuel portfolio in the future until investment drivers are clear. This paper introduces several projects under construction or commissioning highlighting CFB's superiority in repowering projects – meaning replacement investment. For instance, the most recent projects are 80 MW$_e$ case in Czech Republic, 50 MW$_e$ case in Hungary and 30 MW$_e$ and 150 MW$_e$ cases in Finland. The paper introduces these projects and design features with fuel portfolio. The paper gives also same evidence that multifuel approach is not decreasing the reliability of the plant by showing actual operating data from existing CFBs firing several fuels.

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Introduction

One very efficient way to fire demanding fuels, like high ash or high moisture fuels, is fluidized bed technology. Fluidized bed technologies available are bubbling fluidized bed (BFB) and circulating fluidized bed (CFB). Valmet has been manufacturing fluidized bed boilers since the 1970s. Initially it built bubbling fluidized bed (BFB) boilers for low calorific biofuels. In the 1980s products offering was added with circulating fluidized bed (CFB) boilers for fossil fuel and biomass in any combination. Up To date over 280 fluidized bed boilers for different kind of fuels and fuel mixture have been delivered by Valmet.

Fuzzy future in solid fuel firing in EU

Renewable targets

There was a clear goal in quite many European countries to go towards renewable energy. European Union set renewable targets to individual countries and governments of those countries built different kind of incentive or taxation models to achieve those renewable targets. EU has still official 20-20-20 target in place – meaning that target is to reduce greenhouse gas emission 20 % from 1990 level, have 20 % renewable energy sources and finally have 20 % improvement in energy efficiency. And all this shall happen by 2020.

Also CO_2 trading system was established in Europe in 2005 and right now there is a 3rd trading period going on (2013-2020). EU is reporting 1.74 % reduction in CO_2 emission per each year. On the other hand total energy production has decreased and there are plenty of CO_2 allowances available due to declined economy. That has led to the situation where CO_2 per ton price is very low and this mechanism is not working as it was planned to work.

Growth in European economy is still quite low or even zero. In recent years governments have been forced to decrease or even remove incentives for renewable energy when talking about thermal power. This kind of energy policy where incentives and taxation is changing very rabidly is making the investments in thermal power production very risky. That is holding many projects back because investors don't know the right parameters in feasibility calculations. Many projects are facing delays or even cancellations making the business very slow.

Upcoming EU's legislation

The first EU level legislation change is the LCP BREF which changes flue gas emission limits for NO_x, SO_2, HCl, HF and mercury emissions to air published end of July 2017. The new legislation is pushing emission limit down causing additional investment in some cases even with fluidized bed boilers. Most likely this means that the oldest boilers are not capable to continue operation after a transition period.

One upcoming EU legislation is Heating and Cooling strategy. The biggest impact will be the decarbonizing heating and cooling segment. This segment is still using a lot of gas and oil and having distributed production. New regulation will push towards low or even zero energy buildings which means big additional cost in new buildings. In production side that may increase investments in district heating and district cooling and the use of sustainable fuels. Today district heating covers only a bit more than 10 % of European heat market.

There is still one more new topic in EU which may affect to solid fuel power plants and that is Circular Economy strategy. It is targeting towards more recycling of raw materials and also minimized landfilling. That will lead to situation where waste fuel's calorific value will be lower than today. On the other hand circular economy is also requesting higher efficiency when using raw material and this includes also waste firing. Instead of waste incineration high efficiency in heat and power production when using waste fuels will be favoured. This opens door also for new technologies such like waste gasification.

Fuel prices

Since summer 2014 crude oil price has decreased from level 100 $/barrel to level 30..35 $/barrel. In a same time frame natural gas import price has decreased from the level 10..11 $/GJ to level of 6 $/GJ.

Solid fuel prices vary a lot in different countries. Coal price without customs and taxes is quite stable – good quality coal price is in a level of 50 €/t – but local biomass price can be quite volatile based on availability of it. Biomass can be seasonal or there can be some other delivery problems related to logistics or availability. Transport distance has a big impact in biomass fuel price. Nordic countries have a long tradition to use biomass fuels in energy production. Since there are more and more biomass consumers the price has gone up or users are seeking lower cost qualities with much more technical challenges. Now in the situation where renewable incentives are smaller very few customers are investing in biomass projects with higher fuel price and more demanding fuel quality requiring more investment in boiler technology. Coal price has been quite stable except in the year 2008 when there was a huge peak because of shortage of good quality coal. Global coal demand has decreased since that time and in many countries the coal price is even declining. One trend in coal quality is inevitable – lower and lower quality must be accepted in energy production. That is not a big issue for CFB technology but for PC boiler this might be a challenge.

In this kind of uncertain situation of fuel prices and energy policies the safest investment strategy is a boiler technology which can utilize wide fuel portfolio. So the solution is CFB boiler.

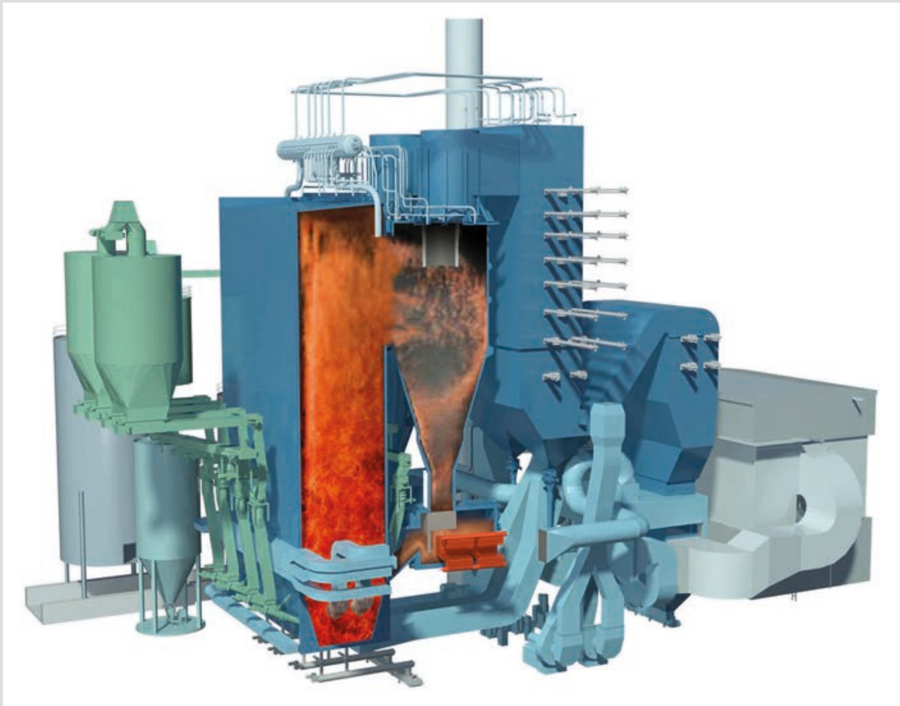

Fig. 1. CFB process overview.

What CFB technology can provide

CFB process in nutshell

CFB was originally developed to burn a variety of different kind of low grade fuels which are not suitable for PC (pulverized coal) or grate fired boilers. A large amount of inert bed material involved in the process makes it possible to have a lot of variation in fuel properties or to change fuels on-line without any remarkable disturbance in the process. Circulating solids improves heat transfer and makes it possible to burn also high calorific value fuels and still the combustion temperature stays in the level 850 to 900 °C. Low combustion temperature minimizes fouling and slagging of heat surfaces since ash melting and softening points are much higher than combustion temperature in CFB. Low temperature level makes emission control also quite easy. CFB's solids circulation provides long residence time for fuel and limestone particles meaning high combustion efficiency and low sorbent consumption. Figure 1 shows and example of a CFB boiler plant.

Excellent performance of the cyclone is a key for efficient combustion and low limestone consumption. Limestone is used for sulfur removal. Cyclone performance determines also the split in between fly ash and bed ash. Long combustion time and low combustion temperature mean that very different type of fuels can be burned in CFB boiler. For instance coal qualities with very high ash content can be burned efficiently in CFB where pulverized coal (PC) boiler is not able to do that.

Fuel flexibility and multifuel capability

In today's modern CFB boiler it is possible to fire several fuels with different characteristic either at the same time or separately. That feature makes it possible to use always fuel combination which is the most economical. Naturally there are some limitations for fuel properties. Normal ranges for those limitations are:

- Lower calorific value from biomass 6.5 MJ/kg to pet coke 32 MJ/kg
- moisture content up to 60 % in biomass
- ash content up to 65 % in waste coal
- sulfur content up to 6 to 8 % in pet coke

Examples of different fuels used in CFBs are woody biomass, recycled wood, RDF (waste), agro biomass and sludge, bituminous coal, peat, lignite, pet coke, high ash coal (ash >50 %) (Figure 2).

Usually the boiler can reach full capacity with all the design fuels but in some cases it is not feasible to design 100 % load with the worst fuel since that may increase the boiler size too much.

Easy emission control in CFBs

CFB process is working at reasonably low temperature level regardless of the fuels and that is having positive effect to primary NO_x emission and makes it possible to have very simple SO_2 control by just injecting limestone into the furnace. Primary NO_x level in CFBs is normally around 200 mg/Nm^3 and that can be reduced 60 % by ammonia injection into the cyclone inlets (SNCR). Catalyst (SCR) is not so often used in CFBs but with SCR NO_x emission can be as low as 10 % of primary NO_x.

Fig. 2. Some fuels used in CFBs – top from left: wood biomass, recycled wood, RDF (waste), agro biomass and sludge – below from left: bituminous coal, peat, lignite, pet coke, high ash coal (ash >50 %).

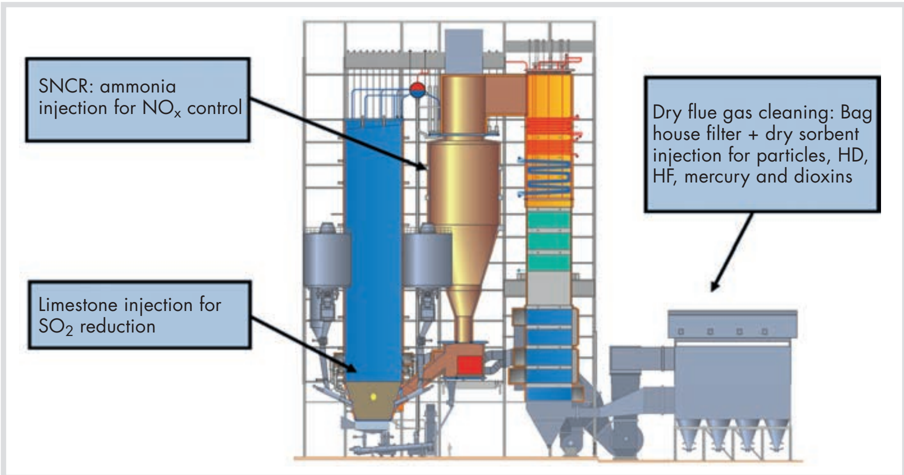

Fig. 3. Typical CFB emission control system.

Renewable fuels contain typically very low sulphur and quite often no SO_2 control is needed. With high sulphur fuels (coal, pet coke) 90 to 95 % reduction in SO_2 emission can be achieved by limestone injection. With renewable fuels chlorine content can be reasonably high – 0.1 to 1.0 %. In that case some emission control is needed for HCl. Typical method is dry flue gas cleaning integrated to bag house filter (BHF). Dry sorbent – typically calcium hydroxide ($Ca(OH)_2$) is injected into the flue gas duct before BHF. Dry flue gas cleaning takes care of acidic gases (HCl, HF and SO_2) and dioxins/furans are reduced by activated carbon injection if needed.

Generally speaking, the flue gas cleaning system consists of very similar components regardless of design fuel or fuel mixture. Limestone injection for SO_2, SNCR for NO_x control and bag house filter for particulates. Sometimes additional dry sorbent feeding prior to BHF may be needed to control rest of the acidic gas components (see Figure 3).

Project Examples

Due to reasons explained in chapter 3 most of the solid fuel firing investments are repowering cases meaning that aging capacity is replaced with new one. The target in repowing cases is typically to utilize fuels which are easily available (security) and which have affordable price to make the investment feasible. One approach is to design the boiler for several fuels so that it is possible to change the fuel in case the legislation is changing or fuel price or availability is changing drastically. Quite many of Valmet's CFB deliveries are designed for multifuel application. Sometimes the driver for multifuel decision is future provision, sometimes pure back-up fuel approach. In some cases the lowest cost fuel availability can't be secured in all condition and then the customer has selected to design the boiler for several fuel components in order to secure the operation also in the future.

Project case – SAPPI Kirkniemi, Finland

A complete multi-fuel boiler was delivered to Sappi Ltd's Kirkniemi Mill in Lohja, Finland. The startup of the plant was in summer 2015. The new boiler can flexibly use solid fuels such as bark from the mill's debarking process, other wood-based fuels and coal. This boiler is replacing old coal fired capacity with much wider fuel portfolio. Together with the mill's current biofuel boiler and Valmet's new boiler it is possible to produce biomass-based energy up to 100 %. On the other hand it is designed for 100 % coal back-up as well. The boiler plant will have a steam capacity of 88 MW_{th} (31 kg/s, 81 bar, 520 °C). Delivery time of the boiler was very tight – commissioning started only 15 months from contract and commercial operation started 18 months from the contract as planned. Boiler has been in commercial operation since summer 2015. Figure 4 shows the cross section and the outside view of the plant.

Different fuel mixtures were tested during hot commissioning. Mixtures from 100 % coal to coal and biomass co-firing were tested successfully. Future provision 100 % biomass (79 % forest residue, 15 % bark, 4 % fiber sludge and 2 % bio sludge) was not tested because some of the fuels are not available yet. In that design point the flue gas amount is much bigger than in other design points and therefore the maximum boiler capacity with above mentioned 100 % biomass is limited to 80 % of MCR. Otherwise that point had been oversizing the whole boiler plant.

Project case – Hamburger Hungaria Power, Dunaujvaros, Hungary

Hamburger Hungaria purchased a real multifuel boiler to their Dunaujvaros mill. This 158 MW_{th} CYMIC CFB boiler is designer to fire mill own fuels (wood waste, fiber sludge and rejects from recycled paper) with balancing fuels (coal and RDF). Design range is from 100 % coal to 14 % coal and 86 % mill own fuels. Chlorine (Cl) con-

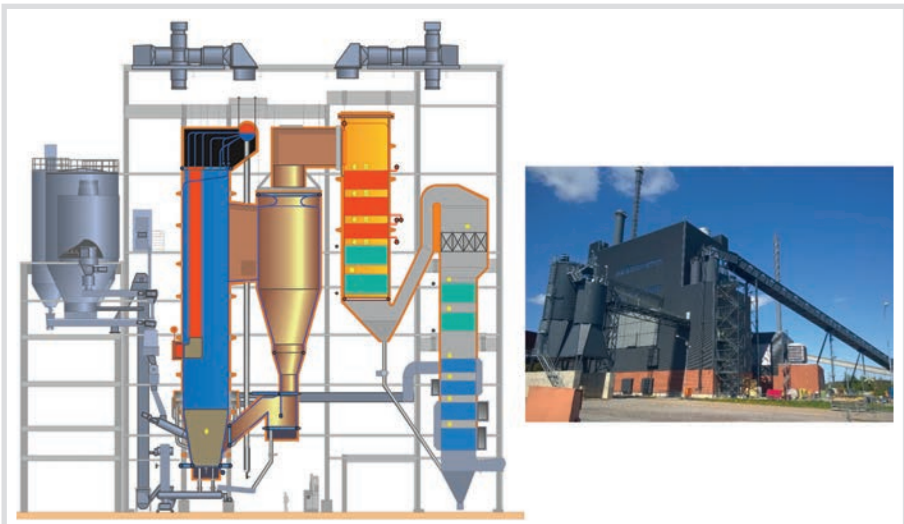

Fig. 4. Sappi Kirkniemi CFB designed for bark, forest residue, fiber sludge, bio sludge and coal.

Fig. 5. Hamburger Hungaria Power multifuel CYMIC CFB boiler designed five different design fuel.

tent in mill reject is 1.5 % and in RDF 0.7 % meaning that Cl content in fuel mixture is always in a level of 0.1 to 0.3 %. It means that high temperature corrosion mitigation was very important design basis for the boiler superheaters. Steam parameters are 520 °C and 113 bar(a). Boiler is also designed to fulfil EU's waste firing directive 2 s above 850 °C requirement as well as to fulfil waste co-firing emission limits. This projects started spring 2014 and commissioning started fall 2015 and commercial operation in March 2016.

Flue gas cleaning system in Dunaujvaros boiler consists of SNCR for NO_x control and limestone injection for SO_2 emission. Dry flue gas cleaning system is integrated to bag house filter. There is a dry sorbent feeding before BHF including calcium hydroxide ($Ca(OH)_2$) and activated carbon feeding to reduce HCl, HF, mercury and dioxins emissions. All flue gas cleaning systems are of Valmet own design (see Figure 5).

Project case – Arcelor Mittal, Ostrava, Czech Republic

ArcelorMittal Energy Ostrava s.r.o. in the Czech Republic purchased also a CFB boiler plant. ArcelorMittal Ostrava a.s. is the largest steel producer in the Czech Republic and part of the world's largest steel and mining group ArcelorMittal. The new boiler plant will supply steam to existing turbines, which produce electricity and provide process steam to the adjoining ArcelorMittal steel mill. Contract was signed in spring 2014 and hot commissioning started in March 2016 and commercial operation is scheduled to start in summer 2016. The boiler is designed for an energy-intensive industry sector, where cost-efficient energy is essential in order to ensure competitiveness in the global market. The need for sustainable power generation with a wide range of coal qualities and operation in accordance with future EU emission limits is taken into account in the boiler design. Simultaneously the mills power plant efficiency will be improved, while maintaining high availability.

The boiler plant will have a steam production of 320 t/hour (89 kg/s) and steam values are 105 bar and 520 °C which corresponds to a capacity of 80 MW_e. The new unit will replace four old pulverized coal fired boilers. New boiler is located in existing mill area in quite limited space – see Figure 6.

Design coal calorific values varies from 20 to MJ/kg (LHV). The thermal efficiency of the boiler is over 92 % with coal, even when the ash content of the coal is high - up to 26 %. Heat contained in the bed ash is recovered and utilized in the boiler furnace. This is done by means of special bed ash coolers, in which the ash is cooled by combustion air. Emission control is done by SNCR for NO_x control, limestone injection for SO_2 and BHF for particulates.

Project case – TSE, Naantali, Finland

Turun Seudun Energiantuotanto (TSE) is repowering a 50 years old coal fired power plant in Naantali, Finland, by building a new power plant block based on CFB technology. The scope of delivery is a CFB boiler island. This is a long lead project – contract was made in April 2014 and the commercial operation started in 2017. Production capacity of new power plant will be 142 MW_e electricity and 244 MW_{th} heat and annual production 900 GWh electricity and 1,650 GWh heat.

This new boiler will replace old coal fired capacity and it will also have 100 % coal firing capacity. On the other hand this boiler is a real multifuel boiler since the design fuel mixture includes also wood based biomass (0 to 75 %), agro based biomass (0 to 15 %), peat (0 to 95 %) and RDF (0 to 5 %) (Figure 7). 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 utilizing the CFB's biggest benefit: fuel flexibility. Construction of this boiler was started in February 2016 and start-up will be during year 2017.

Steam cycle values are quite high leading to high plant efficiency. Boiler is equipped with reheater. Steam flow is 144/130 kg/s (HP/RH), steam pressure 164/44 bar and steam temperature 555/555 °C. Some of the design fuels, such like agro biomass and RDF, contain quite high amount of chlorine (0.2 to 0.4 %) meaning that there is a risk for high temperature corrosion in both superheater and reheater. In order to mitigate this potential risk both finishing superheater and finishing reheater are located inside bed material in cyclone loop seals. Bed material is protecting heat surface against corrosive gases.

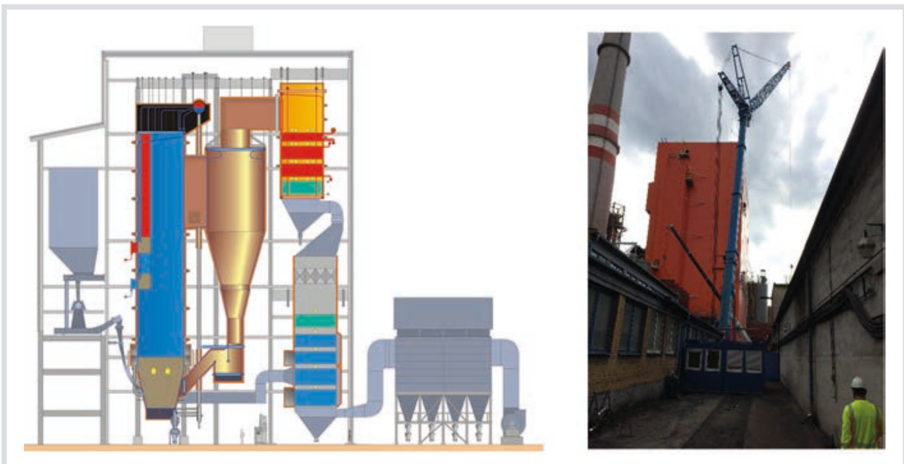

Fig. 6. Arcelor Mittal Ostrava new CFB boiler replacing four old PC boilers.

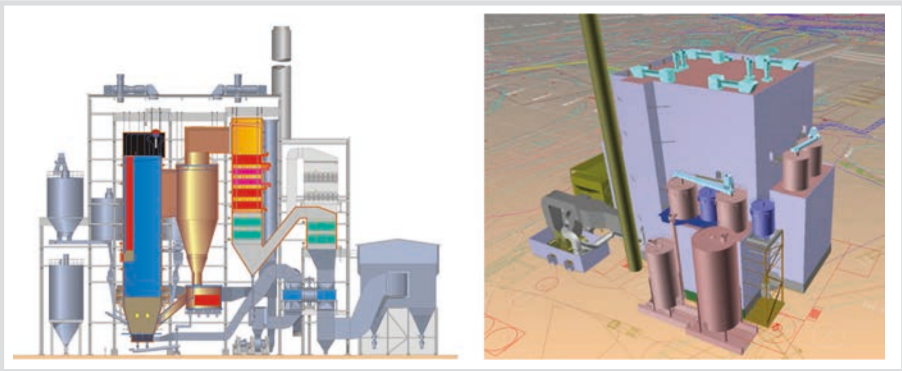

Fig. 7. TSE multifuel CFB for five design fuels: coal, wood biomass, agro biomass, peat and RDF.

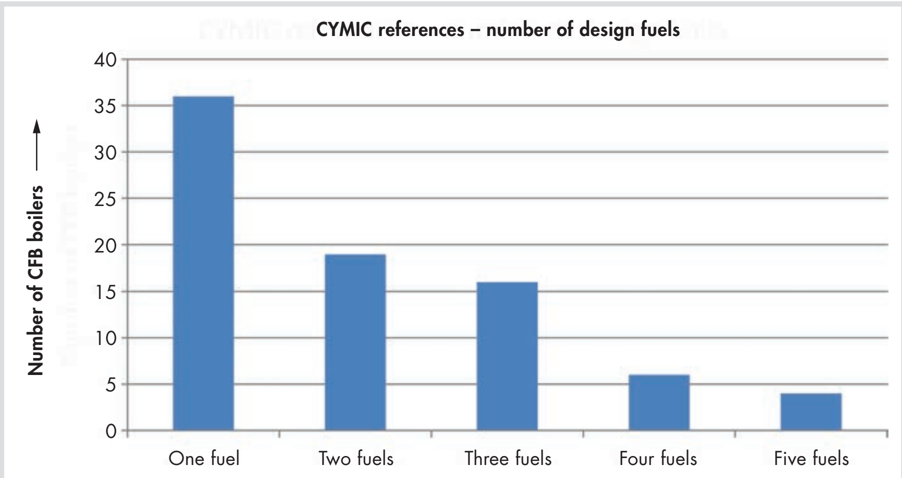

Fig. 8. Number of design fuels in CYMIC CFB deliveries (start-up fuel is not counted).

Tab. 1. Boiler reliability of five multifuel CFB boilers. Reliability is calculated of requested operation time – given numbers are annual averages of record period.

		Alholmen	Pori	Kuopio	Ostroleka	Langerbrugge
Size of unit	MW_e	260	65	50	50	40
Number of design fuels	pcs	4	4	3	4	4
Record period	years	4	6	3	4	4
Scheduled outage	h/a	736	430	1542	270	399
Boiler unavailability	h/a	72	13	6	137	59
Operation	h/a	7952	8317	7047	8353	8302
Boiler reliability of requested time	%	99.1	99.8	99.9	98.3	99.34

Flue gas cleaning system in TSE boiler consists of SNCR for NO_x control, limestone injection for SO_2 and BHF for particulates. On top of that there are space reservations for slip catalyst and dry sorbent feeding system prior to BHF. This is a preparation for tighter emission limits in the future.

Multifuel approach – not a new thing

In early days of CFB history most of the CFB boilers were designed for one fuel, mainly low grade coal. During last twenty years quite many of CFB deliveries have been for several fuel: two, three, four and today even for five different fuels excluding start-up fuel. This is how plant owners prepare for future without knowing exactly future legislation and regulation. See the number of design fuels in CYMIC CFB deliveries in Figure 8.

Multifuel boiler design is not decreasing boiler reliability. It can be even in an opposite way. By looking numbers in Table 1 it looks like multifuel approach might improve plant reliability due to several fuel sources and partly also due to redundant fuel feeding equipment.

Summary

Energy sector in European Union area is under transition. Incentive systems for thermal power using sustainable fuels are decreasing or there are no such left. At the same time oil and gas prices are record low and electricity price is also very low due to surplus wind power capacity. That is putting many thermal power investments on hold.

European solid fuel power plants are ageing and repowering investments are needed. For these projects CFB is an ideal solution since it can be designed to fire several different kind of fuels. CFB can burn different kind of solid fuels at the same time or separately. Fuels may be so demanding that any other combustion technology can't handle those. At the moment coal price is probably the most stable of all the solid fuels and one option is to design a CFB to burn coal at the beginning and selecting into fuel portfolio some local fuels which might be available and more reasonably priced in the future. Evidently biomass as a part of renewable package will come back and have a big role after playing rules are clear. Even then coal can be a back-up fuel which is stabilizing availability problems of the other fuels.

Real project examples introduced in this paper shows clearly that many plant owners have already utilized CFB's fuel flexibility successfully. They have been able to maximize their profits when fuel prices have changed or secured operation when some fuel was not available. Also changes in taxation or incentives have put fuel portfolio in different position but owners have managed thanks to multifuel design. l