The Value Proposition for CFB Power Plants in Indonesia and Broader Asia

Robert Giglio
SVP Strategic BD
Sumitomo FW
Hampton, New Jersey, USA

Presented at:
PowerGen Asia
Jakarta, Indonesia
September 18 – 20, 2018

The Value Proposition for CFB Power Plants in Indonesia and Broader Asia

Robert Giglio
SVP of Strategic Business Development
Sumitomo FW

Abstract

All over the world, power producers are experiencing increasing pressure to generate low-cost clean power. Many are turning to low quality solid fuels and a wide range of carbon neutral biomass and waste fuels available either indigenously or from imports. This challenge is complicated by the steady ratcheting down of plant emissions.

The use of circulating fluidized bed (CFB) technology has steadily increased in large scale power generation principally because of the technology's inherent ability to burn a very wide range of fuels, such as low-quality coals and lignites as well as opportunity fuels like petcoke, waste coal washings, biomass and peat.

CFB is the only technology proven to fire these fuels fully or in unlimited combinations while maintaining high plant reliability and low plant maintenance. Its ability to fully fire or co-fire biomass and other carbon neutral waste fuels offers power producers a low risk and affordable path to carbon reduction.

A key value point for the CFB boiler is its inherently low air emissions which translates into big savings in power plant life cycle cost when compared to conventional pulverized coal (PC) boilers. Because of these benefits, CFB power plants can achieved levels of reliability, fuel security, and environmental performance well beyond PC power plants.

This paper will compare CFB to PC boiler technology from aspects of plant reliability, fuel and operational flexibility, environmental performance, capital, O&M and life cycle cost. Case studies of operating CFB plants will be reviewed to illustrate the value points and benefits realized by specific plant owners. The comparison and case studies will be tailored for market pricing and fuels commonly available in Indonesia and neighboring countries.

CFB's Strong Growth in the Utility Power Sector

Circulating Fluidized Bed (CFB) combustion technology has been around for over 40 years. Over the last 10 years its use in large utility power plants has grown strongly. It has now reached sizes and efficiency levels never imagined; drawing attention from utility power companies around the world.

Figure 1. Lagisza CFB Power Plant located in Bedzin, Poland

Figure 1 shows the longest running supercritical CFB power plant operating in the world today, located at Tauron's Lagisza power plant in Bedzin, Poland which has been successfully running since 2009. At the heart of the plant is a single 460 MWe supercritical SFW CFB featuring many unique first-of-a-kind design features and a very impressive net plant LHV efficiency of 43.3%. Its most profound feature is that this plant meets its permitted stack emissions without SCR or FGD equipment, saving Tauron over $45 million in its construction cost.

An even more impressive example is the 2,200 MWe Green Power Plant operating since 2016 in Samcheok, South Korea, shown in figure 2. The Samcheok plant has four larger 550 MWe SFW CFBs utilizing ultra-supercritical steam conditions (257 barg, 603/603°C). The Samcheok plant meets even tighter stack emissions (50 ppm for both SOX and NOx) without using FGD equipment, saving Korea's Southern Power Company (KOSPO) over $100 million in construction cost. These CFBs are now the most advanced units operating in the world today.

Figure 2. The 2,200 MWe Advanced Green Power CFB Plant in Samcheok, South Korea

The Transition of CFB technology from Industrial to Utility Application

CFB boilers were originally developed as a solution for industrial facilities with a need for steam and power combined with sources of unwanted by-products, such as: waste bark, wood, plastic, cardboard, paper, and sludge's. Over the last 20 years, SFW has broadened the CFB's fuels range and unit size so much that many power companies took notice and saw the CFB as a solution to produce low cost power from low quality fuels such as brown coals, lignites, and waste coals, as well as, high-energy, hard-to-burn fuels like anthracite and petcoke.

Conventional PC boilers have trouble accepting these off-spec fuels due to their narrow fuel specs typically calling for heating values above 5500 kcal/kg, ash and moisture levels below 35%, and volatility's above 20%. To cope with fuels outside of this range, designers developed specialized PC designs, such as, tower designs for lignites and brown coal, and arched fired designs for anthracites and petcoke.

Figure 3 shows the limited fuel experience of PC compared to CFB boiler technology. CFB designs are adjusted over the entire range of fuels shown in figure3, but compared to the three small circles for different PC boiler, a much larger circle can be centered on a broader range of fuels for a single CFB design. SFW CFB's have fired the worst and best coals, lignites, biomasses and waste fuels with heating values ranging from 900 to 8500 kcal/kg, ash and moisture levels as high as 60%, and volatilities down to 5%.

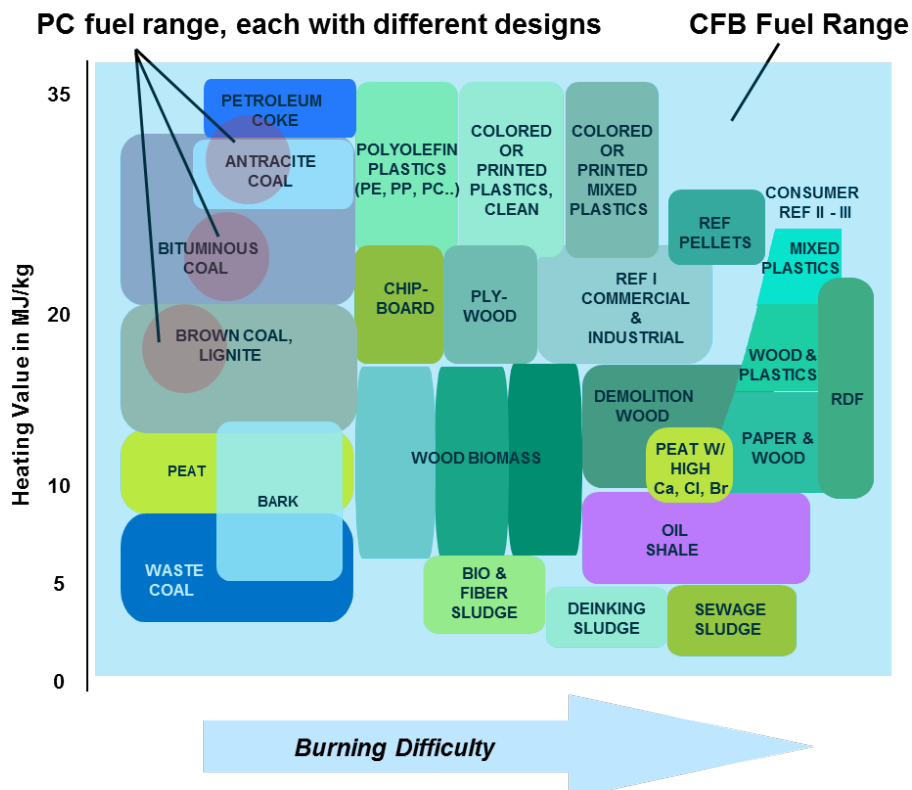


Figure 3. Fuel experience of SHI FW CFBs vs. PC

Meeting a Market Need

CFB's fuel flexibility can provide an economical and low risk approach to carbon reduction. Biomass and waste fuels are considered carbon neutral in most countries. Carbon emissions can be greatly reduced by co-firing them in larger coal power plants,. The CFB offers power generators the flexibility to find the right balance between power reliability, affordability and carbon emissions. The beauty of the CFB solution is that this balance can be continually adjusted over the life of the CFB plant.

As shown in figure 4, a coal fired CFB power plant co-firing 20% biomass can reduce its carbon dioxide emission to below the 750 g/kwh standard set by the OECD for obtaining export credit financing for coal power plants. Further, by combining more efficient ultra-supercritical steam conditions with increasing shares of biomass, carbon emissions for a coal power plant can be reduced by over 50% as shown in figure 4.

Co-firing coal and biomass in the same power plant allows the plant to be built at a large scale, lowing the cost of power generation. Further, the plant's CO2 emissions can meet the OECD standard and rely on coal as a guaranteed fall back for energy production and operating cost, during those times when biomass supplies are limited by local weather or market conditions. All these factors make the co-fired plant much more "bankable" than either a small biomass or large coal power plant.

We are seeing fully fired and co-fired biomass power, co-gen and CHP plants growing in many countries, such as, Japan, South Korea, United Kingdom, India, Poland and China driven by these benefits.

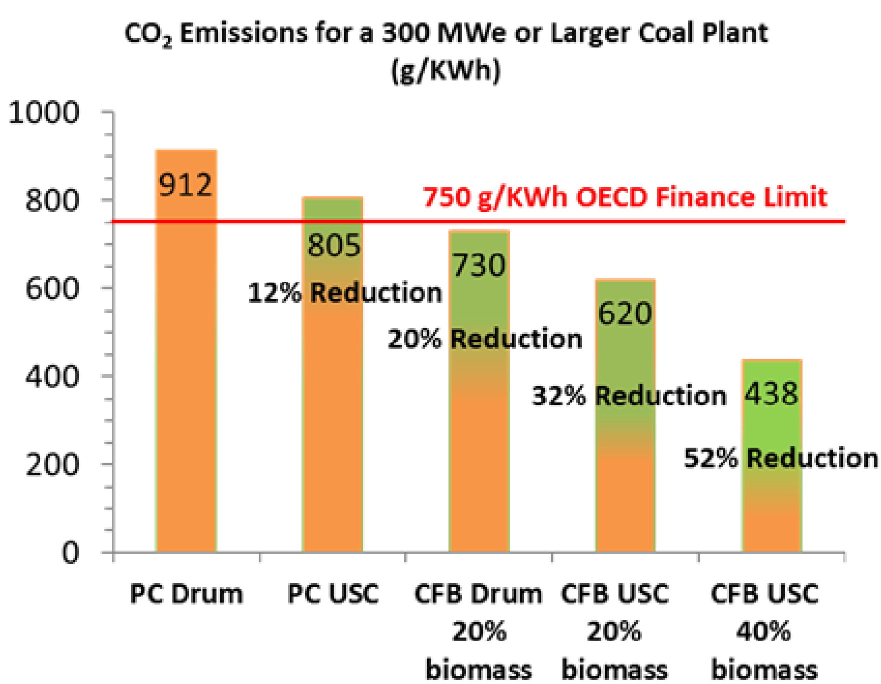


Figure 4. CO2 emissions from a large coal power plant firing a 5000 kcal/kg Indonesian sub-bit coal with a LHV net plant efficiency of 38% for sub-critical plant design and 43% for ultra-super-critical plant design.

Another important trend we are seeing in the international steam coal market is the explosion of coal exports from Indonesia. Since 2005, Indonesian steam coal exports have grown faster than coal exports from all other countries combined, nearly quadrupling to over 400 million metric tons over the last 13 years (see figure 5) and projections show Indonesia maintaining its dominant position in the world's global coal market over the long term.

The primary driver for the ballooning of Indonesian coal trading is simple economics. Even after accounting for the difference in heating value, on a comparative energy basis, Indonesian coals offer 15-40% discounts as compared to premium coals (see figure 6), which goes right to the bottom line of a power plant's balance sheet. Since fuel makes up 75%-85% of the operating cost of a large power plant, the economic benefits of using low quality fuels are tough to ignore.

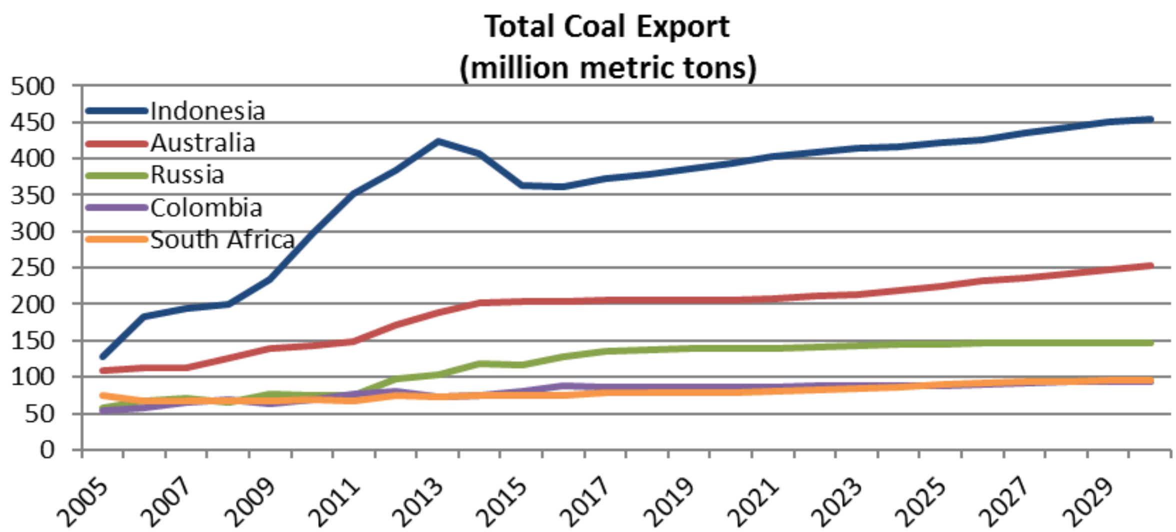


Figure 5. Global coal exports. Source: IHS

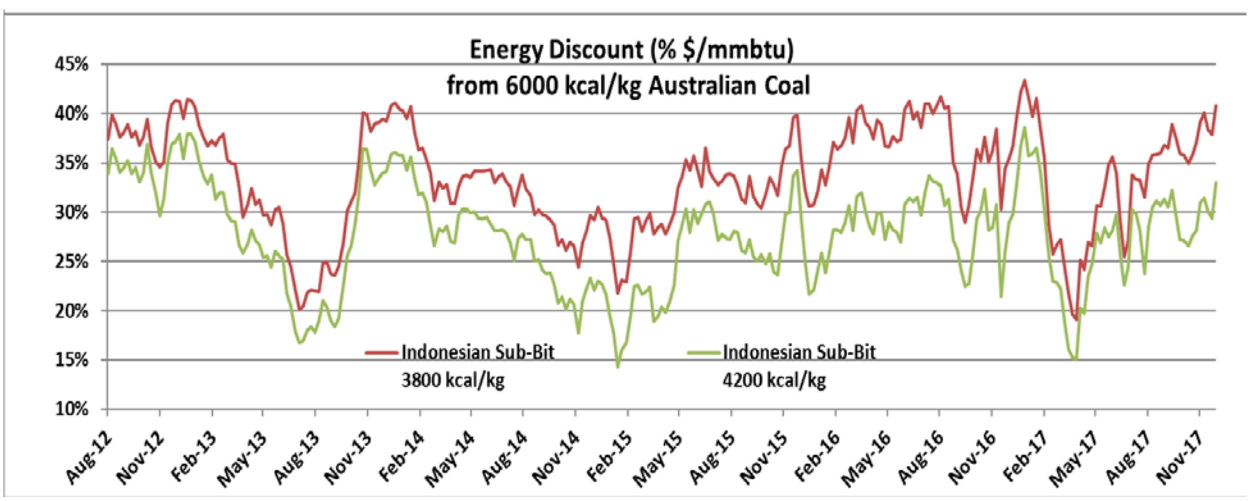


Figure 6. Historic energy discount of low quality Indonesian sub-bituminous coals compared to 6000 kcal/kg premium steam coals. Source: SHI FW & IHS

But, there is a downside to these highly discounted coals, which is a steady decline in heating value; a trend expected to continue well into the future, as shown in figure 7. Typically, as coal mines mature, mining operations move to lower quality coal seams. To save cost and reduce growing mountains of coal washeries, mining companies are increasingly selling higher ash and moisture fuels to the market at very attractive discounts, instead of increasing coal washing to maintain heating value.

About 50% of Indonesian coal exports consists of high-moisture, sub-bituminous coals with gross-as-received (GAR) higher heating values ranging between 3900-4200 kcal/kg. Further, the best quality Indonesian coal reserves are expected to produce coals with average heating values no greater than 5200 kcal/kg (with economical washing levels). These heating values are well below the 6000 kcal/kg benchmark used in the international steam coal market for the last 50 years.

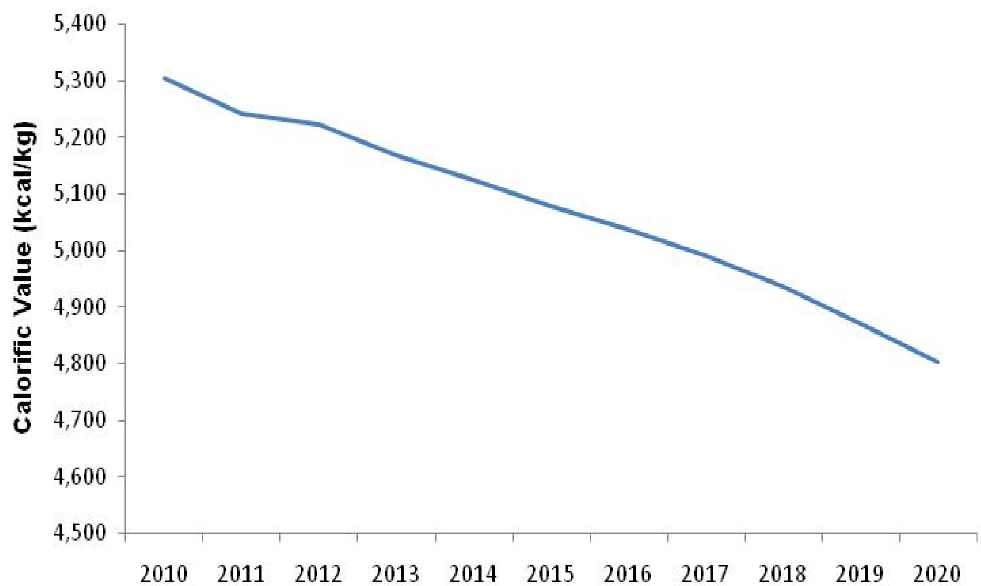


Figure 7. Average Gross Heating Value of Indonesian coal exports. Source: Marketing, Sales and Logistics Analyst, Banpu PCL

Driven by economics and energy security, we are also seeing a growing use of low quality fuels in several domestic power markets, as well. For example, 38% of Turkey's solid fuel power capacity is fueled by low quality Turkish lignites, while in Germany and the US this number grows to 45% and 49% respectively for use of domestic lignites and waste coals. Today, nearly all new-build coal projects in Turkey are planning to utilize Turkish lignite.

In addition to Turkey, use of low rank coals, lignites and petcokes for power production are growing in India, China, Vietnam, Indonesia, Philippines, Thailand, and South Africa driven by better economics, lower fuel price volatility and improved energy security.

This trend is not expected to change anytime soon. Instead it looks to be a permanent shift toward a more flexible solid fuel market, where buyers and sellers will trade fuel quality for price, very similar to many other commodity and finished good markets. These expanding low quality solid fuel markets across the globe have dramatically increased the value of fuel flexibility for large scale power plants and have been the primary driver behind the large CFB power plants coming on-line over the last 10 years.

Money Matters

Fuel flexibility can add up to huge operating cost savings over the life of a power plant. Figure 8 shows the savings in plant operating cost that can be realized for a 600 MWe coal plant by buying discounted lower quality fuels. Whereas, a power plant with a narrow fuel spec would be competitively disadvantage by a higher average fuel cost, limiting its dispatch and financial return.

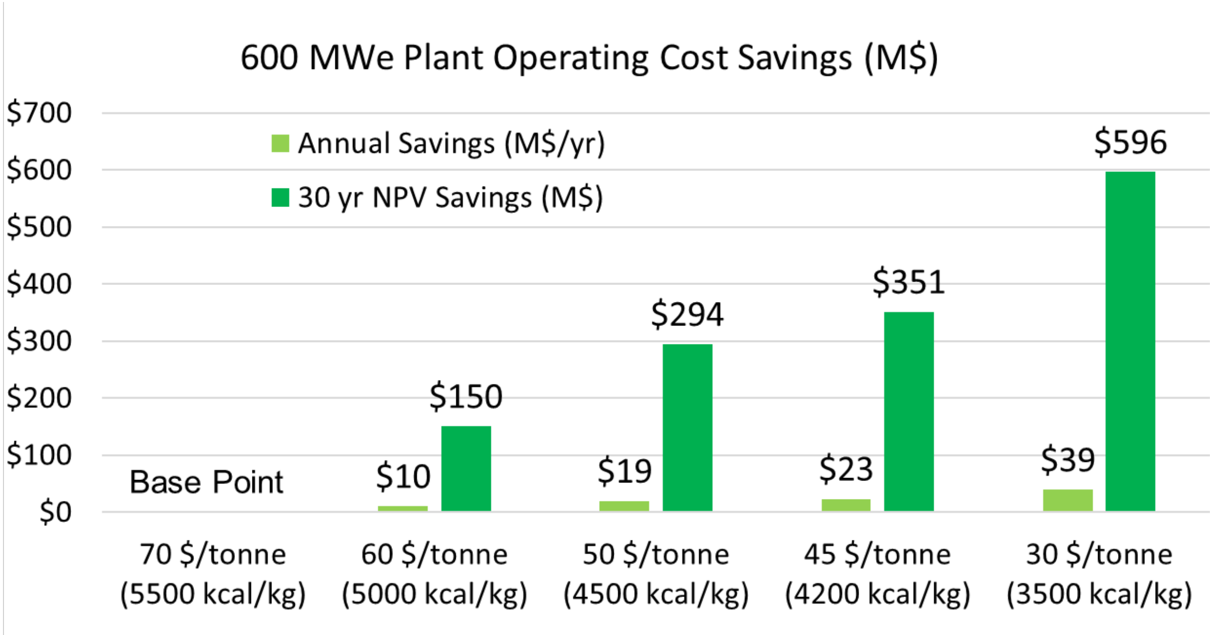


Figure 8. Plant operating cost saving for 600 MWe supercritical coal plant with 90% annual capacity factor firing 70 $/tonne (5500 kcal/kg) coal as base fuel. NPV based on 5% discount rate

When shopping for discount fuels, plant owners must also balance the downside risk of reduced plant output, more plant downtime and higher plant maintenance cost. PC plants can fire fuels beyond their design range, but are impacted the most from these downside factors. Figure 9 shows the loss in plant income as plant capacity or utilization factor is impacted by these factors.

With SFW CFB technology, this trade-off is avoided or minimized. Plants with SFW CFBs have demonstrated plant availabilities well above conventional PC boilers over a wider fuel range. Figure 10 shows the results from a study comparing average availabilities for PC plant fleets in North America, Europe and Asia compared to plants utilizing SFW CFBs.

As shown by figure 10, the plants with SFW CFBs have about a 3 - 5% higher average availability than the PC plants. This higher availability difference was maintained for even brown coals and lignites which can translate to over a $100 million NPV gain in net income over the life of a 600 MWe power plant, as shown in figure 9.

In addition to fuel flexibility, the CFB also provides emission flexibility. It can achieve low air emissions without post combustion SCR NOx and FGD SOx controls saving significant plant construction, operating and maintenance cost over life of the power plant. This flexibility is important since emission regulations are continually tightening in nearly all countries.

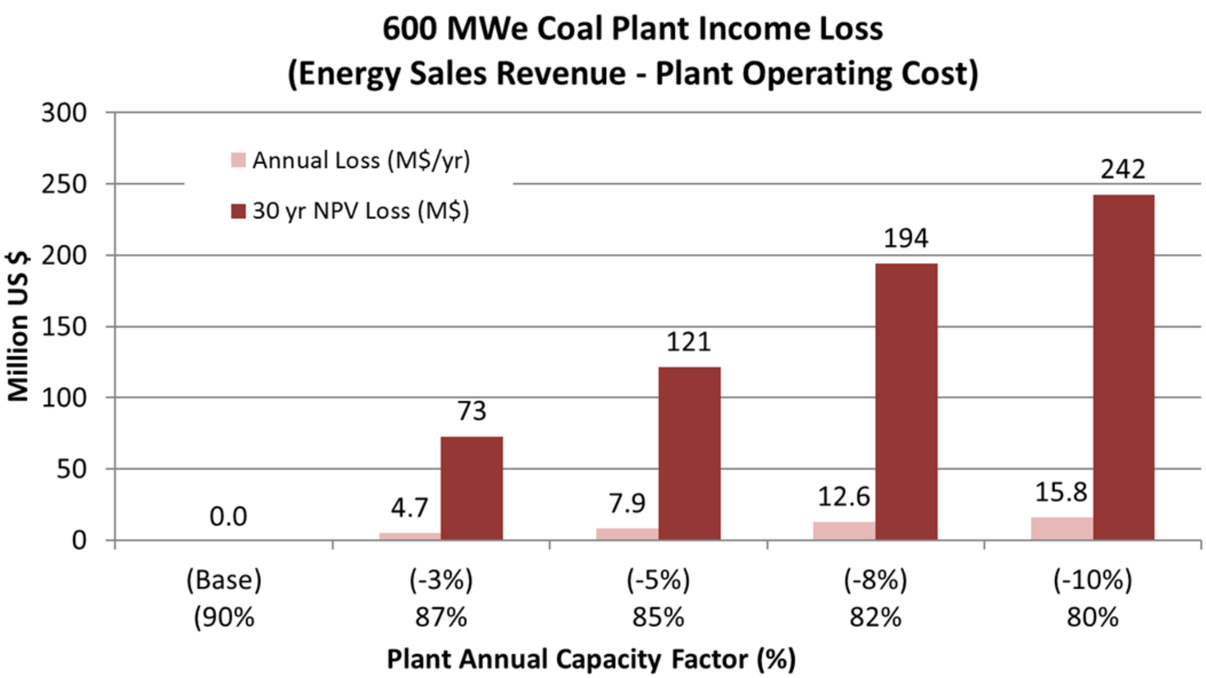


Figure 9. Impact of loss in plant capacity or utilization factor on plant net income for 600 MWe USC coal plant firing 4200 kcal/kg Indonesian coal at 45 $/tonne, selling power at 60 $/MWh. Plant Capacity Factor = Actual annual electricity produced by plant/ possible maximum (net MWe x 8760 hrs). NPV based on 5% discount rate.

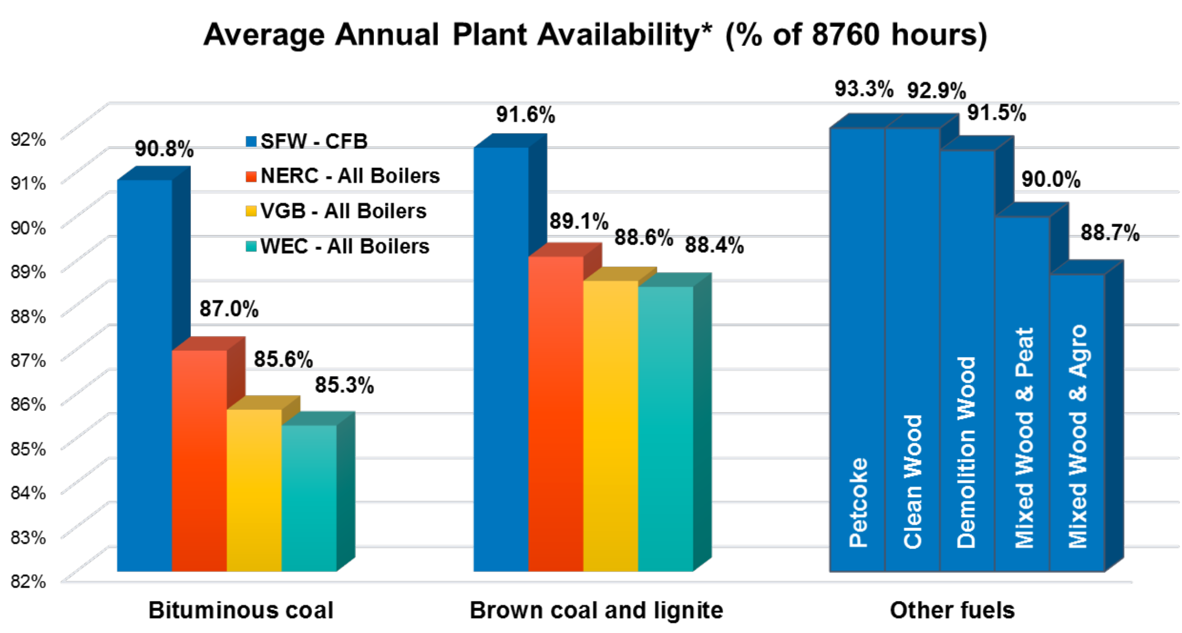
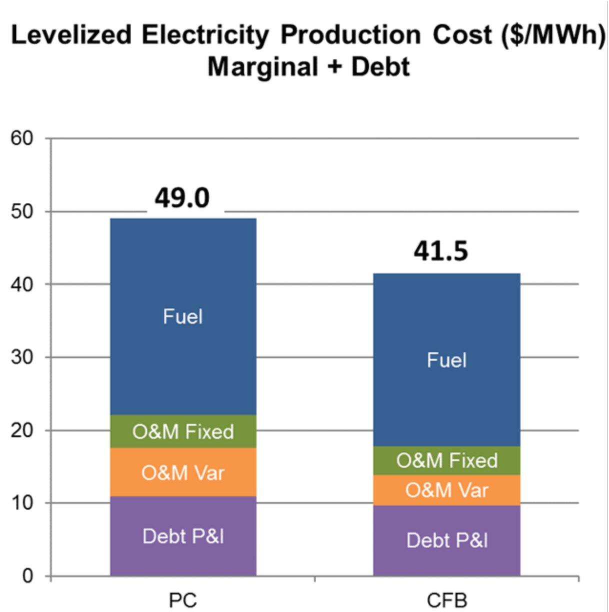


Figure 10. Results from Reliability study of PC vs. CFB Power Plants. Plant Availability means total time plant is available to run accounting for both planned and unplanned downtime.

Using reasonable assumptions for fuel, plant O&M and power cost, Table 1 adds up nearly a $600M higher net present value which a 600 MWe CFB plant can deliver in fuel flexibility, plant reliability, capital and operating cost savings as compared to a PC plant. As shown in figure 11, this NPV value translates into a 18% lower levelized electricity production cost (LCOE) and nearly a 7-point increase in project internal rate of return when selling the power at a fixed 60 $/MWh.

CFB Benefit over PC	Annual Savings (M$/yr)	NPV (M$)
Broader fuel flexibility	23	351
Higher plant reliability	4.7	73
No FGD	3.6	92
No SCR	1.6	43
No mills, burners, less boiler maintenance	1.5	29
Total Value	34.4	588

Table 1. Value comparison of 600 MWe CFB vs. PC plant. NPV based on 30-year term and 5% DR.



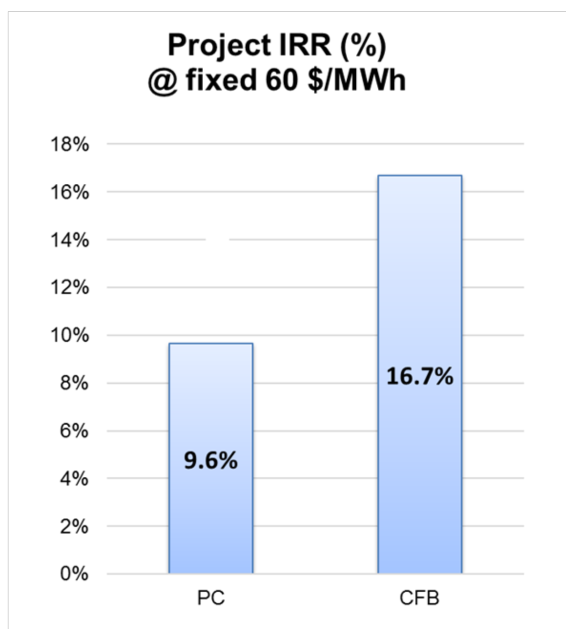


Figure 11. Results from plant proforma analysis based on 600 MWe plant firing 70/45 $/tonne 5500/4200 kcal/kg Indonesian coal, 60 $/MWh levelized wholesale power tariff, 90%/87% CFB/PC plant capacity factor, 1500/1383 $/KWe PC/CFB plant EPC cost, 200/200/30 mg/Nm3 SOx/NOx/PM stack emission limit, 30%/70% Equity/Debt ratio, 6.0%/12yr commercial financing.

CFB's High Reliability and Fuel Flexibility comes from its Unique Combustion Process

The CFB's reliability and fuel flexibility is rooted in its unique flameless, low-temperature combustion process. As shown in figure 12, unlike conventional pulverized coal (PC) or oil/gas boilers, instead of an open flame, circulating solids are used to achieve high combustion and heat transfer efficiency to burn a wide range of fuels. The fuel's ash does not melt or soften which allows the CFB to avoid the fouling and corrosion problems encountered in conventional boilers.

From an environmental aspect, the low temperature CFB combustion process minimizes NOx formation and allows limestone to be fed directly into the furnace to capture SOx as the fuel burns. In most cases, a SCR and FGD are not needed for NOx and SOx control, dramatically reducing the plant's construction, operating cost and water consumption while improving plant reliability and efficiency.

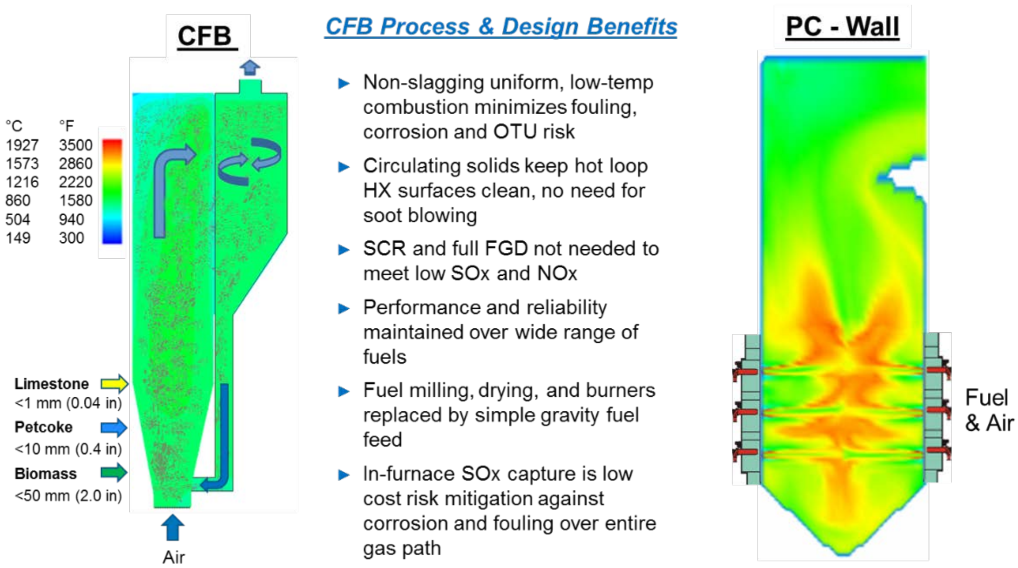


Figure 12. Comparison of PC vs. CFB combustion process

Furnace Size vs. Fuel Quality

Since the fuel's ash doesn't soften or melt in a CFB, the size of the furnace doesn't grow as much as PC boilers when firing lower quality fuels. As can be seen in figure 13, to control fouling, slagging and corrosion, PC furnace height increases by 45% and its footprint increases by over 60% when firing low quality fuels like high sodium lignite. Whereas, the CFB boiler height increases by only 8% and its footprint increases by only 20%. This results in a smaller and lower cost CFB boiler as compared to the PC boiler for lower quality fuels.

Further, unlike a PC, a CFB doesn't need soot blowers to control the build-up of deposits and slag in the furnace since the circulating solids keep the furnace walls, panels and steam coils clean for the most efficient heat transfer.

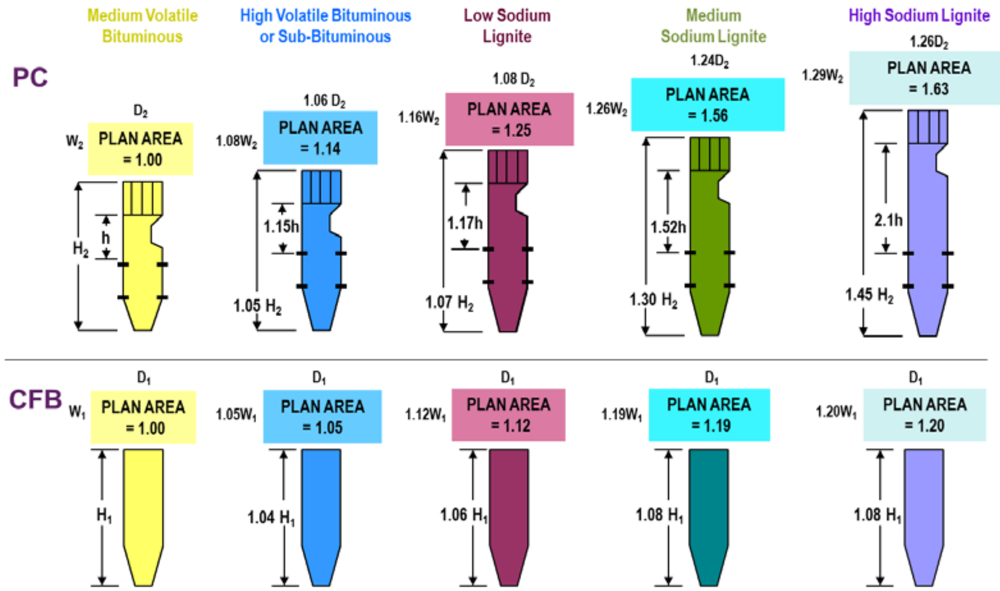
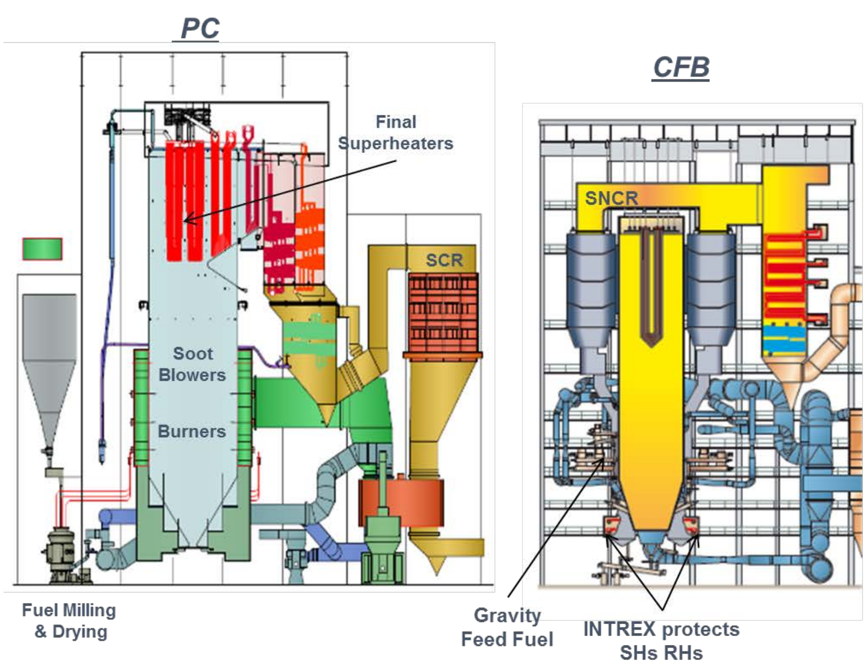


Figure 13. PC vs. CFB - Impact on furnace size as fuel quality degrades

Superheater and Reheater Design Considerations

Another very important feature of the CFB involves the final superheat and reheat steam coils. These coils operate at the highest metal temperatures in the boiler making them the most vulnerable to corrosion and fouling attack. This vulnerability increases significantly for supercritical boilers with high steam temperatures.

-



CFB Design Benefits

- Fuel milling, drying, and burners replaced by simple gravity fuel feed system
- No furnace soot blowers needed, circulating solids keep HX surfaces clean
- High temp superheat coils protected by INTREX
- In-furnace SOx capture minimizes corrosion and fouling over entire gas path
- No FGD or SCR catalyst needed for low SOx and NOx

Figure 14. PC vs. CFB boiler design feature comparison

In a PC or oil/gas boiler, these coils are hung from the furnace ceiling and are directly exposed to the slagging ash and corrosive gases (sodium and potassium chlorides) in the hot furnace flue gas. To cope with this undesirable situation, boiler designers use costly high-grade alloys and recommend a high level of cleaning and maintenance for these coils.

As shown in figure 14, this design weakness is avoided in SFW's CFBs by submerging these coils in hot solids, fluidized by clean air in heat exchanger compartments called INTREXs, protecting them from the corrosive flue gas. The bubbling hot solids efficiently conduct their heat to the steam contained in the coils and since the solids never melt or soften, fouling and corrosion of these coils are minimal. Further, due to the high heat transfer rate of the solids (via conduction heat transfer), the final superheat and reheat coil sizes are 4-5 times smaller than the pendent and convective coils in PCs saving more capital and operating cost.

<u>Fuel Delievery System</u>

One last important design feature is the fuel delivery system to the boiler. A PC boiler requires coal pulverizes to grind the coal to a powder which is then pneumatically transported and distributed in coal pipes to many burners. For low quality, high ash fuels, like brown coals and lignites, the initial cost, maintenance and power consumption of the fuel pulverizers increase dramatically while the reliability of the entire fuel delivery system declines.

For a CFB, these issues are avoided since pulverizers are not needed. The fuel is only coarsly crushed by primary crushers in the fuel yard, once in the boiler island fuel silos, the fuel is fed to the CFB via a simple gravity feed system. Figure 15 shows a typical fuel feed system for an SFW CFB.

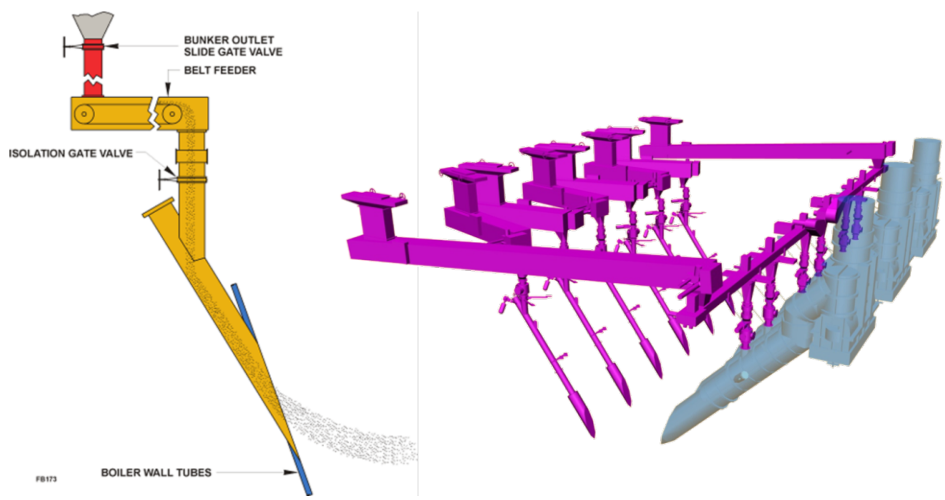


Figure 15.Typical fuel feed system for Amec Foster Wheeler CFBs.

Important Points to Remember

The traditional fixed 6000 kcal/kg global steam coal market has moved to a more flexible "price vs. quality" market dramatically increasing the value of fuel flexibility for large scale power plants and has been the primary driver behind the large Circulating Fluidized Bed (CFB) power plants coming on-line over the last 10 years.

Pulverized coal (PC) power plants with tight coal specifications will have a limited ability to capitalize on the growing supply of discounted coals, domestic lignites, and carbon neutral biomasses to reduce both power generation cost and carbon emissions. These plants will have a choice to stay within the premium steam coal market or venture into the broader market and trade fuel price discounts for lower plant output, reduced reliability and higher plant maintenance cost.

This is not to say that new PC boiler power plants can't be designed to burn these low rank fuels, because they can. The point for consideration is that once a PC is designed for a specific low rank or hard-to-burn fuel, it cannot burn other fuels without negatively impacting plant performance, reliability and maintenance.

However, power plants utilizing CFB boiler technology allows power generators to fully capitalize on fuel cost savings and reduced carbon emissions by accessing the full range of discount coals, lignites, biomasses and waste fuels (even for ultra-supercritical designs) with little impact to plant performance, maintenance and reliability.

For countries with domestic low rank coals, lignites, waste coals or hard-to-burn fuels, like anthracite and petcoke, the CFB opens the door to affordable and secure power over the long term while lessening the risk of future carbon regulation due to the CFB's ability to utilize biomass and other carbon neutral fuels.