Pioneering CFB Technology
Korean Southern Power Company’s Green Power Plant in Samcheok, South Korea features four Amec Foster Wheeler advanced 550 MWe ultra supercritical CFBs.
Pioneering CFB technology

We have steadily increased unit size and integrated advanced field-proven design features into our CFB technology. Our CFBs first reached small-scale utility application in 1987 on the 110 MWe Tri-State Nucla power project in the U.S., then went on to the medium utility scale in 2001 with the 2 x 300 MWe units for the Jacksonville Energy Authority. Over the 1998-2004 period we delivered six CFB units totaling nearly 1500 MWe for the largest CFB repowering project ever in history—the Turów project in Poland.

Our success has come from a track record of satisfying clients’ reliability, environmental, and efficiency goals with innovative technology for converting economical solid fuels into valuable steam and power. Through our experience of supplying over 625 fluidized bed units to industrial and utility customers worldwide, we have steadily scaled-up and improved our technology. Over 450 of these fluidized bed steam generators have been CFB designs.

Our latest pioneering can be seen in Korean Southern Power Company’s (KOSPO) selection of our most advanced supercritical CFBs to power its Green Power Project in Samcheok, Korea. Phase I of this impressive greenfield power facility features four 550 MWe ultra supercritical CFBs at its center surrounded with renewable energy technologies like wind, solar and hydro power.
Think green

Low emissions are a key benefit of our CFB technology allowing them to meet the strictest environmental standards. Our CFBs stage the combustion process and operate at low combustion temperatures while giving the fuel long burning times, resulting in naturally low nitrogen oxide (NOx) formation and high combustion efficiency. They can also capture the fuel’s sulfur as the fuel burns by using low-cost limestone and employing selective-non-catalytic-reduction (SNCR) to achieve very low NOx and sulfur oxide (SOx) emissions in the most economical way, and in most cases, avoiding add-on pollution control equipment.

The CFB advantage is particularly highlighted in repowering projects. SOx and particulate emissions can often be cut by over 90% and NOx emissions by over 50%. Carbon dioxide emissions are often cut by 25% or more due to the dramatic improvement in boiler and plant efficiency when older equipment is replaced. For the lowest emissions, our supercritical, once-through-unit (OTU) CFB technology can reduce all these emissions another 5-10%, due to its ability to further increase overall plant efficiency.

For climate change concerns, we offer Flexi-Burn® carbon capture and storage technology for our utility CFBs. Flexi-Burn® allows the CFB to operate in either an economical air fired mode, as all plants do today, or in a carbon capture mode without requiring significant plant modifications. In the carbon capture mode, the CFB produces a carbon dioxide rich flue gas that can be stored underground. The technology will give power producers the flexibility to operate in either mode depending on regulation and market conditions.
**Fuel flexibility**

Our CFB units are capable of firing nearly all solid fuels—including waste products that otherwise would have been land-filled—while maintaining the lowest levels of emissions, and the highest equipment reliability and efficiency. Our fuel experience is unmatched as proven by our capability to design units for even the lowest-quality fuels. Our CFBs give plant owners the flexibility to source fuel from the widest base of suppliers and industries, improving their fuel supply security while taking advantage of fuels pricing and market conditions.

**Reliability**

Our simple yet advanced CFB designs can achieve the highest plant availability, proven by over 30 million hours of operational experience, even after years of operation. Preventative conditions monitoring, expert maintenance, and rapid-response repair work—all supplied by our service teams—help ensure maximum reliability—year after year.

*Note: Availability means total time plant is available to run accounting for both planned and unplanned downtime. Amec Foster Wheeler CFB values based on client supplied data reported over 2000-2008 period for units mainly located in Europe. PC values based on client supplied data over 2002-2011 period for units mainly located in Europe and reported in VGB PowerTech Report, TW103Ve, published in 2012.*
The Lagisza Power Plant in Poland features a 460 MWe Amec Foster Wheeler vertical tube supercritical CFB—state-of-the-art CFB technology successfully operating since 2009.
Utility CFBs

What started off as a solution for hard-to-burn fuels has become a mainstream boiler technology for utility power generation

Going supercritical
We have taken the next major step forward in advancing our CFB technology by offering our latest generation of supercritical once-through steam generation technology, which incorporates Siemens’ BENSON vertical-tube evaporator technology for units above 300 MWe. This allows us to offer our utility clients all of the benefits of CFB combustion technology, together with the high efficiency of supercritical steam technology.

Supercritical technology improves overall plant efficiency by 5-10% compared to conventional natural circulation steam technology, which translates directly into a 5-10% reduction in the plant’s air and ash emissions as well as its fuel and water needs for each megawatt generated. When we say a reduction in air emissions, we mean all air emissions like SOx, NOx, mercury and particulates as well as greenhouse gases, like carbon dioxide.

As with our conventional natural circulation CFBs, these highly efficient supercritical units will be equally at home with hard-to-burn fuels, as well as common utility coals. Supercritical steam technology burns less fuels and produces significantly lower levels of CO2 and other emissions for each megawatt generated. We have developed a modular design approach allowing us to offer units up to 800 MWe in steam capacity.

CFB value for utilities
Our utility customers have turned to CFBs due to the value they see in our technology: fuel flexibility, low emissions, and reliability. Many are seeing value in petroleum coke, lignite, waste coal and biomass from both an economic and environmental aspect. Our technology can reliably and cleanly burn these fuels as primary fuels or in combination with other fuels over the life of the plant, giving power generators the flexibility to alter their fuel strategies and to take advantage of fuel market opportunities and changes in environmental regulation.

**OUR UTILITY CFB FUEL EXPERIENCE**

<table>
<thead>
<tr>
<th>Primary Fuel Type</th>
<th>% of operating Amec Foster Wheeler CFB capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coals</td>
<td>74%</td>
</tr>
<tr>
<td>Oil shale</td>
<td>1%</td>
</tr>
<tr>
<td>Lignite</td>
<td>10%</td>
</tr>
<tr>
<td>Biomass</td>
<td>5%</td>
</tr>
<tr>
<td>Petcoke</td>
<td>5%</td>
</tr>
<tr>
<td>Peat</td>
<td>4%</td>
</tr>
<tr>
<td>Waste</td>
<td>1%</td>
</tr>
</tbody>
</table>

RECENT UTILITY CFB PROJECTS

**Soma Kolin Thermal Power Plant**
- Location: Soma, Turkey
- Customer: Harbin Electric International Co. Ltd.
- Start-Up Year: 2018
- Capacity: 2 x 255 MWe
- Fuel: Lignite

**Samcheok Green Power Plant**
- Location: Samcheok City, Gang Won Do, Korea
- Customer: Korean Southern Power Co., Ltd
- Start-Up Year: 2016
- Capacity: 4 x 550 MWe
- Fuel: Coal, Biomass

**Mao Khe Thermal Power Plant**
- Location: Quang Ninh Province, Vietnam
- Start-Up Year: 2012
- Capacity: 2 x 220 MWe
- Fuel: Anthracite Coal
CIRCULATING FLUIDIZED BED TECHNOLOGY

Novocherkasskaya Gres
Location: Novocherkassk, Russia
Customer: PJSC EnergoMashinostroitelny Alliance
Start-Up Year: 2016
Capacity: 330 MWe
Fuel: Anthracite & Bituminous Coal

- Integrated steam—or water-cooled solid separators for compact unit design and reduced thermal stress
- Multi-staged combustion air for reduced furnace NOx formation
- Integrated water-cooled solids return leg for compact design and low maintenance
- Final superheat and reheat surface located in INTREX™ fluidized bed heat exchanger for efficient heat transfer and protection from corrosive flue gas
- Robust ash removal and cooling system
- Low maintenance, highly effective wing-wall surface for superheat or evaporative duty
- Long-life, thin-walled cooled refractory used in lower furnace and solid separator system for low maintenance and rapid starts
- Reliable front and rear wall low maintenance gravity fuel feed system
- In-furnace start-up burners for reliable, rapid start-ups
- Proven arrow-head nozzles for reliable operation, low maintenance and excellent solids mixing

OUR LARGE-SCALE COMPACT SEPARATOR CFB DESIGN OFFERED UP TO 800 MWe UNIT SIZES

RECENT UTILITY CFB PROJECTS

Cebu Therma Visayas Energy Project
Location: Toledo, Philippines
Customer: Hyundai Engineering & Construction Co., Ltd.
Start-Up Year: 2017
Capacity: 2 x 150 MWe
Fuel: Sub-bituminous Coal

Novocherkasskaya Gres
Location: Novocherkassk, Russia
Customer: PJSC EnergoMashinostroitelny Alliance
Start-Up Year: 2016
Capacity: 330 MWe
Fuel: Anthracite & Bituminous Coal

PKE: Lagisza, Poland
Location: Bedzin, Poland
Customer: Poludniowy Koncern Energetyczny (PKE), Elektrwnia Lagisza
Start-Up Year: 2009
Capacity: 460 MWe
Fuel: Bituminous Coal
Circulating Fluidized Bed Technology

OUR MEDIUM-SCALE CYCLONE CFB DESIGN OFFERED AT A NOMINAL 300 MWe UNIT SIZE

RECENT UTILITY CFB PROJECTS

Dominion Virginia City Hybrid Energy Center
Location: St. Paul, Virginia
Customer: Shaw Group/Dominion Virginia Power
Start-Up Year: 2012
Capacity: 2 x 300 MWe
Fuel: High Ash Coal & Wood Waste

Cleco
Location: Boyce, Louisiana
Customer: Shaw Group/Cleco Power LLC
Start-Up Year: 2010
Capacity: 2 x 330 MWe
Fuel: Petroleum Coke, PRB, Lignite

Sandow
Location: Rockdale, Texas
Customer: Bechtel/TXU
Start-Up Year: 2009
Capacity: 2 x 315 MWe
Fuel: Texas Lignite

Low maintenance highly effective wing-wall surface for superheat or evaporative duty

Long-life thin-walled cooled refractory used in lower furnace, cyclones and cross-over ducts for low maintenance and rapid starts

Reliable front and rear wall low maintenance gravity fuel feed system

Economical on-demand limestone prep system

Steam- or water-cooled cyclone solid separators and cross-over ducts for low maintenance and reduced thermal stress

Efficient steam-side bypass reheat temperature control

Modular series back-pass for reduced field erection

Proven reliable solids return loop seal

Compact regenerative air heater

Proven arrow head nozzles for reliable operation, low maintenance and excellent solids mixing
A leader in industrial CFBs

Our industrial Circulating Fluidized Bed (CFB) steam generators are well known in the industry for their low emissions, reliability and long life.

Our history of developing innovative combustion technologies for industry began with our bubbling fluidized (BFB) steam generators, from which we developed our robust CFB technology for a diverse range of industrial fuels and energy needs. We are now a leading supplier of industrial CFB technology, supplying over 150 units with sizes approaching 200 MWe for industrial applications.

Proven experience
The solutions we have provided have been as diverse as our clients’ needs. The CFB we supplied to a Swedish paper mill to convert their waste bark and sludge into useful steam needed by the mill, as well as the 26 petcoke-fired steam generators we delivered to Sinopec in China, demonstrate our ability to customize units to meet clients’ needs. Our industrial boiler designs have been proven and advanced based on 40 years of operating experience.

Widest fuel experience
Multi-fuel firing is particularly important in industrial applications where utilizing on-site waste has a high value. Fuel flexibility is a key factor in unlocking the value of these waste streams since both their quality and volumes can vary on a daily basis. Our CFB technology has proven itself over the widest range of industrial fuels.

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**OUR INDUSTRIAL CFB FUEL EXPERIENCE**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>% of Operating Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coals</td>
<td>28%</td>
</tr>
<tr>
<td>Peat</td>
<td>7%</td>
</tr>
<tr>
<td>Lignite</td>
<td>1%</td>
</tr>
<tr>
<td>Biomass</td>
<td>2%</td>
</tr>
<tr>
<td>Petcoke</td>
<td>1%</td>
</tr>
<tr>
<td>Waste</td>
<td>61%</td>
</tr>
</tbody>
</table>
WE OFFER INNOVATIVE AND PROVEN DESIGN FEATURES IN OUR INDUSTRIAL CFB UNITS

RECENT INDUSTRIAL CFB PROJECTS

**Seagull Cogeneration Power Plant**
- Location: Gunsan City, South Korea
- Customer: eTEC E&C Limited
- Start-Up Year: 2016
- Capacity: 250 MWe
- Fuel: Indonesian Coal

**Yuen Foong Yu Paper**
- Location: Yangzhou Jiangsu Province
- Start-Up Year: 2013
- Capacity: 50 MWe
- Fuel: Coal & Paper Sludge

**Rio Turbo**
- Location: Santa Cruz, Argentina
- Customer: Isolux Ingenieria S.A. y Tecna Proyectos y Operaciones, S.A. (UTE)
- Start-Up Year: 2012
- Capacity: 2 x 120 MWe
- Fuel: Bituminous Coal
Highly reliable

Industry relies on high availability: day in, day out, year round. Our CFBs have a proven track record of being highly reliable.

Our CFBs have excellent load-following capabilities, enabling them to accommodate rapid swings in process steam requirements. Their wide turn-down range means that our units can adapt to temporary or seasonal changes in steam or district heat needs, operating at very low loads of nameplate capacity.

To achieve the highest reliability, we offer SmartBoiler™ to all CFB plant owners and operators. SmartBoiler™ is an intelligent operation and service support tool for monitoring, diagnosing, analyzing and optimizing steam generation and power plant operation. SmartBoiler™ combines our experience and expertise in fluidized bed combustion with advanced information technology.

Lukoil
Location: Ploiesti, Romania
Customer: LUKOIL Energy & Gas Romania s.r.l.
Start-Up Year: 2010
Capacity: 70 MWe
Fuel: Petcoke, Heavy Fuel Oil

SINOPEC Wuhan Cogeneration Plan
Location: Wuhan City, People’s Republic of China
Customer: SINOPEC Wuhan Company
Start-Up Year: 2012
Capacity: 3 x 80 MWe
Fuel: Coal & Petroleum Coke

Jiahua
Location: Jiaxing City, Zhejiang Province, People’s Republic of China
Customer: Zhejiang Jiahua Industrial Park Investment & Development Company
Start-Up Year: 2012
Capacity: 3 x 100 MWe
Fuel: Coal

Lukoil
Location: Ploiesti, Romania
Customer: LUKOIL Energy & Gas Romania s.r.l.
Start-Up Year: 2010
Capacity: 70 MWe
Fuel: Petcoke, Heavy Fuel Oil

SmartBoiler™
Combination of our experience and expertise in fluidized bed combustion with advanced information technology.

To achieve the highest reliability, we offer SmartBoiler™ to all CFB plant owners and operators. SmartBoiler™ is an intelligent operation and service support tool for monitoring, diagnosing, analyzing and optimizing steam generation and power plant operation. SmartBoiler™ combines our experience and expertise in fluidized bed combustion with advanced information technology.
Renewable energy CFBs

Biofuels and waste are two of the fuel groups ideally suited for our CFB technology.

A green technology
Concern about climate change is a key factor for developing and implementing renewable energy solutions today.

Use of biomass in power generation can contribute significantly to reducing emissions of carbon dioxide—a greenhouse gas. The fuel flexibility of our CFB technology allows them to utilize a wide range of renewable and waste fuels and fuel mixes, helping our world reach a goal of reduced greenhouse gas emissions.

Our CFBs can also divert waste headed for land-fills and instead convert this waste into valuable steam and electricity to support our growing energy needs.

Our state-of-the-art “Advanced Bio CFB” can co-fire high alkaline, quick-growing agro biomass in utility CFBs. We are currently using this technology in the world’s largest 100% biomass CFB that we supplied at the Polaniec Power Station in Poland.

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>% of Operating Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forestry and pulp and papermaking waste</td>
<td>79%</td>
</tr>
<tr>
<td>Wood processing waste</td>
<td>4%</td>
</tr>
<tr>
<td>Industrial waste and municipal refuse-derived fuel</td>
<td>11%</td>
</tr>
<tr>
<td>Agricultural waste</td>
<td>6%</td>
</tr>
</tbody>
</table>
Entire hot loop is refractory-lined to handle the most corrosive fuels while maintaining long unit life.

Coil-less back-pass in weld overlay enclosure to cool gas through most corrosive phase.

Integrated water-cooled solids separator and return leg for compact design and elimination of furnace-to-separator expansion joints.

Long-life, thin-walled cooled refractory for low maintenance and rapid starts.

Easily replaceable pendant superheaters with spring hammer cleaning system.

Vertical economizer section for compact unit design.

Bottom ash screening and recycling system to minimize bed make-up need.

Robust step-grid to handle the most difficult fuels.

Superheat surface located in INTREX™ fluidized bed heat exchanger for efficient heat transfer and protection from corrosive flue gas.

Hot cyclones capture ash for reduced economizer fouling.

OUR WASTE-TO-ENERGY CFB UNIT DESIGNED TO FIRE REFUSE-DERIVED FUEL (RDF)

RECENT RENEWABLE CFB PROJECTS

Green Energy Centre
Location: Daegu, South Korea
Customer: GS Engineering and Construction
Start-Up Year: 2016
Capacity: 23 MWe
Fuel: Waste - RDF

Dangjin 4 Biomass Power Plant
Location: Dangjin, South Korea
Customer: GS Engineering and Construction
Start-Up Year: 2015
Capacity: 105 MWe
Fuel: Biomass

Polaniec Power Station
Location: Polaniec, Poland
Customer: GDF Suez Energia
Start-Up Year: 2012
Capacity: 190 MWe
Fuel: Biomass (Wood/20% Agro Waste)
**Becoming more green**
Co-firing renewable fuels in a CFB plant originally designed for coal is an excellent, cost-effective option for helping our environment. In most cases, our operating coal-fired CFBs can co-fire biomass or waste fuels by simply adding a biomass fuel handling and feeding system, and modifying boiler operating procedures.

**Green fuels**
Biofuels include natural materials and waste produced by various industrial or other processes.

- Forest operations
  - thinnings
  - harvesting waste
  - bark
  - stumps
- Wood processing waste
  - offcuts
  - sawdust
  - demolition wood
- Pulp & papermaking waste
- Fast-growing energy crops
- Agricultural waste
- Industrial waste
- Municipal Refuse-Derived Fuel (RDF)

**Avoided CO2 Emissions**
(Ktonnes/yr)
*Based on a 150 MWe coal plant with balance fuel being biomass

<table>
<thead>
<tr>
<th>% Biomass Fired</th>
<th>100%</th>
<th>25%</th>
<th>87</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.On Värme</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location: Norrkoping, Sweden</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer: E.ON Värme Sverige AB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start-Up Year: 2010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity: 30 MWe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel: Waste RDF</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Jyvaskylen Energia Oy |      |     |    |
| Location: Keljonlahti, Finland |      |     |    |
| Customer: Jyvaskylen Energy Oy |      |     |    |
| Start-Up Year: 2010 |      |     |    |
| Capacity: 200 MWe |      |     |    |
| Fuel: Milled Peat and Biomass |      |     |    |

| KAUKAS |      |     |    |
| Location: Lappeenranta, Finland |      |     |    |
| Customer: Kaukaan Voima Oy |      |     |    |
| Start-Up Year: 2010 |      |     |    |
| Capacity: 125 MWe |      |     |    |
| Fuel: Biomass, Peat |      |     |    |
Amec Foster Wheeler’s Global Power Group offers a full range of steam generator equipment, clean air technologies, aftermarket products and services to the power, industrial, and waste-to-energy sectors. GPG’s global engineering, manufacturing, and procurement network delivers high-quality, cutting-edge products and services cost competitively, no matter where the project is located.

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PRODUCTS AND SERVICES

Steam Generators
- Circulating Fluid Bed
- Pulverized Coal
- Oil & Gas
- Solar
- Bubbling Fluid Bed
- Package
- Grate and MSW
- Waste Heat
- HRSG

Environmental Products
- Wet FGD systems
- CFB scrubbers
- Dry Sorbent Injection
- Spray Dry Absorbers
- Wet and dry ESPs
- Fabric filters
- Cartridge collectors
- Low NOx combustion and SCR retrofits

Aftermarket Services
- Engineered pressure parts
- Replacement parts
- Weld overlays
- Refractory upgrades
- Coal mill service and upgrades
- Construction Services
- Performance upgrades
- Boiler retrofits

Auxiliary Equipment
- Condensers
- Feedwater heaters
- Biomass gasifiers