Foster Wheeler CFB Technology - Enabling Fuel Flexibility for Power and CHP Generation

The European Power Generation Strategy Summit
3rd-5th December 2012, Prague, Czech Republic
Markku Kostamo
Presentation Outline

- Foster Wheeler
- Fuel flexibility, needed?
- Introduction to solid fuels available for power production
- Key advantages of Circulating Fluidized Bed (CFB) Boiler technology
- Key references
- Summary
• Established in 1884, known as Foster Wheeler since 1927.
• Foster Wheeler is a global engineering and construction contractor and power equipment supplier, with a reputation for delivering technically advanced, reliable facilities and equipment with world-class quality and safety.
• Traded on NASDAQ National Market in New York.

**Key figures, 2011**

- Employees
  - Approx. 12,000
- Order backlog
  - USD 3.6 billion
- New orders booked
  - USD 4.3 billion
- Operating revenues
  - USD 4.5 billion
- Consolidated EBITDA
  - USD 283 million
Foster Wheeler AG, Business Groups

The Global Engineering & Construction (E&C) Group
Designs and constructs leading-edge processing facilities for the upstream oil & gas, liquefied natural gas (LNG), gas-to-liquids, refining, chemicals and petrochemicals, power, environmental, pharmaceutical, biotechnology and healthcare industries.

The Global Power Group
Has world-leading expertise in combustion technology, and designs, manufactures, supplies and erects steam generating, flue gas cleaning and auxiliary equipment for power stations and industrial markets worldwide. The group also provides a range of environmental products and aftermarket parts and services.
Fuel flexibility, needed?

- Fuel Flexibility offers high added value:
  - Possibility to optimize plant economy with most economical and available solid fuels
  - Large potential for fuel cost savings over the life of plant

- Ability to fire and co-fire carbon neutral solid fuels. Biomass has an important role in reducing the environmental effects (CO$_2$) of energy production

- Biomass fuel market has changed to global and makes possible large scale power generation of biomass

  CFB is IDEAL TECHNOLOGY for large scale power generation for broad range of coals/lignites, biomass alone or in co-firing
Introduction to solid fuels available for power production
We have a Wide Fuel Experience on Our CFB Technology

And:
- Waste Coal
  - Bituminous Gob
  - Anthracite Culm
- Agricultural Waste
  - Rice Husks
  - Bagasse Pith
  - Oat Hulls
- Peat
- Tire Derived Fuel
- Refuse Derived Fuel
- Refinery Bottoms
- Oil
- Natural Gas
CFB Technology opens the door to Fuel Flexibility and Carbon Neutral Fuels

- **PC Fuel Range**
  - ANTRACITE COAL
  - BITUMINOUS COAL
  - BROWN COAL, LIGNITE
  - PETROLEUM COKE

- **Heating Value, MJ/kg**
  - PEAT
  - WASTE COAL
  - BARK

- **Burning Difficulty**
  - POLYOLEFIN PLASTICS (PE, PP, PC..)
  - COLORED OR PRINTED PLASTICS, CLEAN
  - COLORED OR PRINTED MIXED PLASTICS
  - CHIP BOARD
  - PLY WOOD
  - WOOD BIOMASS
  - DEMOLITION WOOD
  - BIO & FIBER SLUDGE
  - DEINKING SLUDGE
  - OIL SHALE
  - PETROLUM COKE
  - COAL
  - BITUMINOUS COAL
  - BROWN COAL, LIGNITE
  - PETROLEUM COKE

- **CFB Fuel Range**
  - RDF
  - RDF
  - WOOD & PLASTICS
  - PAPER & WOOD
  - RDF
  - CONSUMER REF II - III
  - MIXED PLASTICS
  - REF PEIETS
  - WOOD & PLASTICS
  - RDF
  - PETROLUM COKE
  - COAL
  - BITUMINOUS COAL
  - BROWN COAL, LIGNITE
  - PETROLEUM COKE

- **Fuel Flexibility and Carbon Neutral Fuels**
  - PC Range
  - CFB Range

- **Range**
  - 0 - 5 - 10 - 20 - 35
Key advantages of CFB technology
CFB Combustion Concept

Bed material exiting furnace is separated
In solids separator and returned back to furnace

Moderate combustion temperature
(850-900 C) enables:
SOx removal in furnace with limestone injection
Low thermal NOx formation

Part of heat surfaces can be located to
solids return flow enabling effective heat transfer
In corrosion-free environment (INTREX SH/RH)

Bed material (sand, fuel ash, limestone)
in furnace is fluidized with primary air
Fuel is fed to bed in lower part of furnace
Key Advantages of CFB Firing

- **Fuel flexibility is a special advantage**
  - Wide range for coals and lignites
  - Mixes of wood, agro, waste, etc
  - Mixes of biomass fuels, coals and lignites
  - Hard-to-Burn fuels (petcoke, refinery by-products etc)

- **High availability & competitive price**

- **Longer boiler life and improved reliability due to low and even combustion temperature**

- **Excellent emission performance. Meets the requirements of IE Directive with Lower Capital Cost due to avoided back-end FGD equipment and need for SCR**
Key References
Industrial, Multifuel CHP 36 MWe, 100 % bio / 80 % coal
Stora Enso Kvarnsveden AB, Borlänge, Sweden

CFB 130 MWth, 44.9 kg/s, 40(80) bar, 490(520) °C

FUEL DATA

<table>
<thead>
<tr>
<th></th>
<th>Bark</th>
<th>Sludge</th>
<th>Ext. Wood</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur</td>
<td>0.05%</td>
<td>0.7%</td>
<td>0.06%</td>
<td>0.3-0.8%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.4%</td>
<td>1.3%</td>
<td>0.6%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Moisture</td>
<td>60.0%</td>
<td>65%</td>
<td>65%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Ash</td>
<td>4.0%</td>
<td>15%</td>
<td>8.0%</td>
<td>12.5%</td>
</tr>
<tr>
<td>LHV</td>
<td>5.9 MJ/kg</td>
<td>4.3 MJ/kg</td>
<td>4.9 MJ/kg</td>
<td>23.5 MJ/kg</td>
</tr>
</tbody>
</table>

DESIGN PERFORMANCE, (O₂ 6% in dry gases)

<table>
<thead>
<tr>
<th></th>
<th>Bark + Sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flue Gas Exit Temperature</td>
<td>135 °C</td>
</tr>
<tr>
<td>Boiler Efficiency</td>
<td>89.5%</td>
</tr>
<tr>
<td>Emissions</td>
<td></td>
</tr>
<tr>
<td>- NOₓ</td>
<td>50 mg/MJ</td>
</tr>
<tr>
<td>- SO₂</td>
<td>50 mg/MJ</td>
</tr>
<tr>
<td>- CO</td>
<td>180 mg/MJ</td>
</tr>
<tr>
<td>Particulate Matter (dry)</td>
<td>30 mg/Nm³</td>
</tr>
</tbody>
</table>

COMMERCIAL OPERATION 2005
Municipal, Multifuel CHP 200MWₑ, Jyväskylä, Finland

• **Customer:** Jyväskylän Energia Oy  
  – Owned 100 % by Jyväskylä city

• **Combined heat and power plant (CHP)**

• **Project - Investment drivers**
  • Decrease oil consumption on DH production
  • Increase local electricity production 212 MWₑ-gross
  • Increase DH production capacity 200MW (+ 188MWₑ in CHP-mode)

• **Commercial Operation April 2010**
Municipal CHP 200MW<sub>e</sub> Jyväskylä, Finland
Cofiring of Peat, Clean Biomass and Coal

CFB 200 MW<sub>e</sub>, 160/143 kg/s, 164/40.5 bar(a), 560/560°C

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Peat</th>
<th>Wood Chips</th>
<th>Bituminous coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>[%]&lt;sub&gt;ar&lt;/sub&gt;</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Ash</td>
<td>[%]&lt;sub&gt;dry&lt;/sub&gt;</td>
<td>5.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>[%]&lt;sub&gt;dry&lt;/sub&gt;</td>
<td>1.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Sulfur</td>
<td>[%]&lt;sub&gt;dry&lt;/sub&gt;</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Chlorine</td>
<td>[ppm]&lt;sub&gt;dry&lt;/sub&gt;</td>
<td>&lt; 500</td>
<td>&lt; 200</td>
</tr>
<tr>
<td>LHV</td>
<td>[MJ/kg]&lt;sub&gt;ar&lt;/sub&gt;</td>
<td>8.3</td>
<td>7.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance</th>
<th>Peat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flue gas T&lt;sub&gt;exit&lt;/sub&gt; [°C]</td>
<td>90</td>
</tr>
<tr>
<td>Boiler efficiency [%]</td>
<td>94.1</td>
</tr>
<tr>
<td>NOx [mg/m³n]</td>
<td>150</td>
</tr>
<tr>
<td>SO₂ [mg/m³n]</td>
<td>200</td>
</tr>
<tr>
<td>CO [mg/m³n]</td>
<td>200</td>
</tr>
<tr>
<td>Dust [mg/m³n]</td>
<td>30</td>
</tr>
</tbody>
</table>
Industrial CHP 125MW<sub>e</sub> Kaukas, Finland
CFB for Clean Biomass and Peat

- **Owner:** Kaukas Kaukaan Voima Oy
  - Owned by Lappeenrannan Energia Oy (46%) and Pohjolan Voima Oy (54%).
- **Located at** UPM-Kyymmene paper mill site in Lappeenranta, Finland
- **Combined heat and power plant (CHP)**

- **Project - Investment drivers:**
  - More effective utilization of paper mill by-products
  - Replacing gas with cheaper biomass fuel for Lappeenranta City’s electricity and district heat production (earlier 100% gas)
  - Commercial Operation February 2010
Industrial CHP 125 MWe, Kaukas, Finland
CFB for Clean Biomass and Peat

CFB 125 MW\textsubscript{e-net}, 110 MW\textsubscript{DH}, 149 kg/s, 115 bar(a), 550 °C

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Biomass</th>
<th>Peat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture [%]\textsubscript{ar}</td>
<td>48</td>
<td>50</td>
</tr>
<tr>
<td>Ash [%]\textsubscript{dry}</td>
<td>2.5</td>
<td>5</td>
</tr>
<tr>
<td>Nitrogen [%]\textsubscript{dry}</td>
<td>0.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Sulfur [%]\textsubscript{dry}</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>LHV [MJ/kg]\textsubscript{ar}</td>
<td>9.2</td>
<td>8.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Flue gas (T_{\text{exit}}) [°C]</td>
<td>149</td>
</tr>
<tr>
<td>Boiler efficiency [%]</td>
<td>91</td>
</tr>
<tr>
<td>NO(_x) [mg/m(^3)n]</td>
<td>150</td>
</tr>
<tr>
<td>SO(_2) [mg/m(^3)n]</td>
<td>200</td>
</tr>
<tr>
<td>CO [mg/m(^3)n]</td>
<td>200</td>
</tr>
<tr>
<td>Dust [mg/m(^3)n]</td>
<td>20</td>
</tr>
</tbody>
</table>

“The Power Plant was the World’s largest user of solid biomass fuels in 2010!”
GDF Suez 205MW\textsubscript{e} Power Plant, Polaniec, Poland

CFB for Biomass with 20%-w Agro

- World’s Largest pure solids Biomass Fired Power Plant
  - 80% wood chips & 20% Agro

- 447MW\textsubscript{th}, 535/535\textdegree{}C, 127/20 bar(a)

- Re-powering from Coal to Biomass

- Customer: GFD Suez Energia Polska S.A

- Contract Award 2/2010

- Commercial operation 11/2012 (six weeks before schedule)
GDF Suez 205 MWe Power Plant, Polaniec, Poland
Advanced Bio CFB Concept for 20%-w Agro

CFB 205MWₑ, 447 MWₑ, 535/535°C, 127/20 bar(a)

| Fuel | 80% Wood Chips &
|      | 20% AGRO (Straw, Sunflower,
<table>
<thead>
<tr>
<th></th>
<th>dry fruits, Palm kernel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>[%]₀ᵃʳ</td>
</tr>
<tr>
<td>Ash</td>
<td>[%]₀ᵈʸ</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>[%]₀ᵈʸ</td>
</tr>
<tr>
<td>Sulfur</td>
<td>[%]₀ᵈʸ</td>
</tr>
<tr>
<td>LHV</td>
<td>[MJ/kg]₀ᵃʳ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emissions</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NOₓ</td>
<td>[mg/m³ⁿ]</td>
<td>150</td>
</tr>
<tr>
<td>SO₂</td>
<td>[mg/m³ⁿ]</td>
<td>150</td>
</tr>
<tr>
<td>CO</td>
<td>[mg/m³ⁿ]</td>
<td>50</td>
</tr>
<tr>
<td>Dust</td>
<td>[mg/m³ⁿ]</td>
<td>20</td>
</tr>
</tbody>
</table>
Multifuel CHP Igelsta (Söderenergi AB, Södertälje), Sweden
CFB for Waste and Clean Biomass

CFB 240 MW_{th}, 73 MW_{e-net}, 209 MW_{DH}, 92 kg/s, 90 bar, 540°C

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>Mix 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass [%]_{LHV}</td>
<td>75</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Rec.wood [%]_{LHV}</td>
<td>0</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>REF pellets [%]_{LHV}</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moisture [%]_{ar}</td>
<td>44.3</td>
<td>35.6</td>
<td>50.0</td>
</tr>
<tr>
<td>Ash [%]_{dry}</td>
<td>6.5</td>
<td>4.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Nitrogen [%]_{dry}</td>
<td>0.6</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Sulfur [%]_{dry}</td>
<td>0.09</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>Chlorine [ppm]_{dry}</td>
<td>1200</td>
<td>800</td>
<td>200</td>
</tr>
<tr>
<td>LHV [MJ/kg]_{ar}</td>
<td>9.7</td>
<td>11.0</td>
<td>8.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emissions</th>
<th>6%O₂, dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx [mg/MJ]</td>
<td>35*</td>
</tr>
<tr>
<td>SO₂ [mg/m³]</td>
<td>75</td>
</tr>
<tr>
<td>CO [mg/m³]</td>
<td>50*</td>
</tr>
<tr>
<td>Dust [mg/m³]</td>
<td>10</td>
</tr>
<tr>
<td>NH₃ ppm</td>
<td>10</td>
</tr>
<tr>
<td>TOC [mg/m³]</td>
<td>10</td>
</tr>
<tr>
<td>HCl / HF [mg/m³]</td>
<td>10 / 1</td>
</tr>
<tr>
<td>Cd+Tl / Hg / HMs [mg/m³]</td>
<td>0.05 / 0.05 / 0.5</td>
</tr>
<tr>
<td>PCDD+F [ng/m³]</td>
<td>0.1</td>
</tr>
</tbody>
</table>

*) only at 100% load with Mix 1, 2, and 3
Coal firing and Biomass & coal co-firing with Super-Critical Steam Parameters in CFB’s up to scale $800\text{MW}_e$
Impact of efficiency improvement and biomass co-firing on CO₂ reduction
Samcheok 4 x 550 MW$_e$ Power Plant
Coal & Biomass Co-Fired Supercritical CFB Project

• 4 x 550 MW$_e$ supercritical OTU – CFB to feed 2 x 1100MW$_e$ Turbines
  – 437/356 kg/s, 25.6/5.4 MPa, 603/603 °C
  – Efficiency 42.4% (net)
• Fuel flexibility:
  • Lignite/Sub-bituminous coal
  • max. 5% share of wood pellets
• End client: KOSPO, Korean Southern Power Co. Ltd
• Foster Wheeler scope: Basic design of boiler plant and delivery of hot loop pressure parts etc.

• Contract Signed (NTP): June 2011
• Commercial operation: 2015
CFB Co-Combustion of Biomass and Coal up to scale 800MWₑ

- CFB Technology with:
  - Sub-Critical steam parameters available up to scale 600MWₑ with 100% coal and 100% Biomass firing
  - Super-Critical Steam parameters available up to ~600MWₑ scale in coal firing with 50% solid biomass share
  - Super-Critical Steam parameters available up to ~800MWₑ scale in coal firing with 20% biomass share
Fuel flexibility has an important role in reducing the costs and environmental effects of energy production both in pure biomass plants and in coal and biomass co-combustion.

CFB technology is an ideal Technology to be used for large scale power generation with broad range of solid fuels.

CFB Technology with coal and co-firing of biomass available up to 800MW_e scale and with pure biomass firing up to 600 MW_e scale.
FW is the Leading Global Supplier of CFB Technology

- 403 Units Sold
  - 23,087 MWe Subcritical Units in Operation
  - 460 MWe Supercritical Unit in Operation
  - 5 Supercritical Units in Construction
    - 4 x 550 MWe + 1 x 330 MWe
- Units in Service Over 30 Years
- Total Fleet logged over 30 Million Hours of Operation
- Widest Fuel Experience in Industry
- High Availability Demonstrated

Offering Unit Sizes to 800 MWe

Source: FW/McCoy Database 042512, CFB Boiler Type. All sizes. Excludes domestic orders provided by domestic suppliers in China, India, and Japan. Other includes suppliers with less than 2% of the market share. Market share based on GWe.

Total: 26.6 GWe, 259 Units
INTEGRITY
ACCOUNTABILITY
HIGH PERFORMANCE
VALUING PEOPLE
TEAMWORK

OUR CORE VALUES
DEFINE THE STANDARDS
OF BEHAVIOR FOR
EVERY EMPLOYEE IN
FOSTER WHEELER

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