Adoption of USC CFB Technology to Achieving Lower Cost Generation and Environmental Sustainability.

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Doosan returns more benefit and value to clients in India as a total solution provider integrating ‘state-of-the-art’ OEM technology and aftermarket retrofit & service with proven & professional manufacturing.
## Part of the Doosan Group

### Doosan Group

### Doosan Heavy Industries & Construction

#### Business Groups

<table>
<thead>
<tr>
<th>Casting and Forging</th>
<th>Nuclear</th>
<th>Boiler</th>
<th>Turbine</th>
<th>EPC</th>
<th>Water</th>
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</thead>
</table>

#### Turnover (2013)

<table>
<thead>
<tr>
<th>Doosan Group</th>
<th>14.4 Billion €</th>
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<tbody>
<tr>
<td>Doosan Heavy Industries &amp; Construction</td>
<td>12.8 Billion €</td>
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#### Employees (2013)

<table>
<thead>
<tr>
<th>Doosan Group</th>
<th>43,000</th>
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<tr>
<td>Doosan Heavy Industries &amp; Construction</td>
<td>7,300</td>
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References to date

- Supercritical PC boilers 52,321MWhe
- Subcritical PC boilers 123,086MWe
- Subcritical CFB 21,528MWth
- Turbines 60,000MWe
Doosan Lentjes is the global center of excellence for engineering, procurement and construction for CFB, WtE and APC having its own R&D center:

- **Top tier level CFB OEM technology**
  - References: 113 units (22 GWth, max. 280 MWe)

- **Top tier WtE OEM technology**
  - References: 77 units (9 mill t/a, max. 35 t/h)
  - Chute-to-stack or full turnkey supply solutions

- **Various FGD portfolio OEM technology**
  - References:
    - Wet FGD: 205 units (71 GWe, max. 1,000 MWe)
    - Seawater FGD: 10 units (6 GWe, max. 700 MWe)
    - CFB FGD: 87 units (13 GWe, max. 305 MWe)
    - SCR DeNOₓ
    - Fabric Filters and Electrostatic Precipitators
USC CFB Cycle primary difference from the Subcritical cycle shown is the introduction of ‘once-through’ technology.

Adopting ‘Once Through’ Posiflow vertical combustor tube technology from PC boilers for the water/steam circuit allows the USC CFB design to benefit from higher efficiency.

Design of solid loop similar to subcrit CFB boiler.
Integrated Environmental Protection resulting in lower cost generation with less APC.

- **Typical Emission Limits**
  - \( \text{SO}_2 \): 120 mg/Nm\(^3\)
  - CO: 50-250 mg/Nm\(^3\)
  - \( \text{NO}_x \): 100-300 mg/Nm\(^3\)
  - Dust: 20-50 mg/Nm\(^3\)
USC CFB More Compact Than USC PC

USC CFB is more compact than PC (with FGD)

600MW USC CFB Reference (Indonesian Sub-bituminous)
Design Footprint = 4950m

600MW USC PC Boiler (Indonesian Sub-bituminous)
Footprint = 5440m includes FGD@ 900m
(Based on Dongbu Green 2x580MW)
Where fuel switching covers a wide range from high CV world traded bituminous to low cost high ash, high moisture or high slagging coals, CFB offers capex, reliability and fuel saving advantages over PC fired units.

<table>
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<tr>
<th>Fuel Experience</th>
<th>Carbon %</th>
<th>Sulphur %</th>
<th>Ash %</th>
<th>Moisture %</th>
<th>H.V. MJ/kg</th>
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<tbody>
<tr>
<td>Biomass</td>
<td>20</td>
<td>0.03</td>
<td>2</td>
<td>40</td>
<td>15</td>
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<tr>
<td>Oil Shale</td>
<td>13.8</td>
<td>0.4</td>
<td>73.7</td>
<td>5.0</td>
<td>4.95</td>
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<tr>
<td>Anthracite Culm</td>
<td>44.8</td>
<td>0.8</td>
<td>45.1</td>
<td>15.0</td>
<td>6.85</td>
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<tr>
<td>German Brown Coal</td>
<td>27.2</td>
<td>1.7</td>
<td>7.0</td>
<td>52.8</td>
<td>9.17</td>
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<tr>
<td>Gujarat Lignite</td>
<td>43.3</td>
<td>&lt; 2.5</td>
<td>19.0</td>
<td>24.0</td>
<td>16.50</td>
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<tr>
<td>Kentucky Coal</td>
<td>63.7</td>
<td>4.0</td>
<td>12.9</td>
<td>4.7</td>
<td>20.05</td>
</tr>
<tr>
<td>Anthracite</td>
<td>59.6</td>
<td>1.8</td>
<td>25.2</td>
<td>10.0</td>
<td>20.70</td>
</tr>
<tr>
<td>Petcoke / Texas</td>
<td>82.0</td>
<td>4.5</td>
<td>2.7</td>
<td>7.3</td>
<td>31.80</td>
</tr>
</tbody>
</table>
600 MW gross is targeted for USC CFB development and Korean demonstration

Demonstration plant economic modelling by 3rd party confirmed 2 year payback advantage dominated by CFBC fuel flexibility advantage

Analysis assumed,
- 30 years operation from COD
- Financing based on Gov’t funded not project financed model. (No interest during construction, NPV calculated from COD and not from NTP)
- Similar plant efficiencies/utilisation of PC and CFB assumed
- NPV difference based on fuel savings for USC-CFB comparing USC-PC-6000kcal@97$/t vs USC-CFB-4250kcal/kg@59$/t (i.e. -15%$/Gcal basis)
- Analysis needs to be qualified for Indian market requirements/conditions

<table>
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<tr>
<th></th>
<th>NPV $m*</th>
<th>IRR* %</th>
<th>LCOE* $/MWh</th>
<th>Payback* Years</th>
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</thead>
<tbody>
<tr>
<td>USC PC</td>
<td>153</td>
<td>5.6</td>
<td>46.54</td>
<td>15</td>
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<tr>
<td>USC CFB</td>
<td>431</td>
<td>6.5</td>
<td>42.48</td>
<td>13</td>
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</table>
Doosan has been developing a USC CFB product since 2012 in response to an emerging need for fuel flexible lower cost generation.

USC CFB builds on the modular design available for Subcrit CFB from 50-300MWe.

Concept study of modular design for USC/SC units up to 600MW and over completed in 2013.

6 to 8 cyclone design foreseen dependent on output, fuel and site conditions.
Doosan development plan go-ahead given August 2014. This will comprise,

- Integration of USC PC and CFB technologies for better performance and emissions control
- Scale up of the combustor and introduction of ‘once through’ vertical furnace tube technology based on Doosan Babcock’s Posiflow design
- Value assessment of Fuel flexibility to Capex and whole life cost
Development plan will also include,

- Validation of analytical results of heat transfer and gas/solid flow pattern
- Adoption of compact design approach from 150MW class.
- Design optimization for maximized fuel flexibility value and reliability
• Modularized 2 cyclone model to be adapted to 4 cyclone model

• USC CFB requires different platform however utilizes key modules of 4 cyclone CFB
### 600MWe USC CFB Demonstration Project

<table>
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<tr>
<th>Requirement</th>
<th>Target Value</th>
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<tbody>
<tr>
<td>Unit Size (MWe gross)</td>
<td>600</td>
</tr>
<tr>
<td>Location / Cooling / Arrangement</td>
<td>Coastal / Sea Water cooled, 6 Cyclones</td>
</tr>
<tr>
<td>Fuel – Indonesian LRC – GCV (kCal/kg)</td>
<td>4250</td>
</tr>
<tr>
<td>Main Steam Temperature (°C)</td>
<td>610</td>
</tr>
<tr>
<td>Main Steam Pressure (Barg)</td>
<td>280</td>
</tr>
<tr>
<td>Reheat Steam Temperature (°C)</td>
<td>621</td>
</tr>
<tr>
<td>Boiler Thermal Efficiency (%HHV)</td>
<td>&gt;85</td>
</tr>
<tr>
<td>Boiler Availability (%)</td>
<td>&gt;90</td>
</tr>
<tr>
<td>Outlet SOx (ppm@6%O2)</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Outlet NOx (ppm@6%O2)</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Outlet Dust (ppm@6%O2)</td>
<td>&lt;15</td>
</tr>
</tbody>
</table>
## Requirement | Target Value
---|---
Unit Size (MWe gross) | 660
Location / Cooling / Arrangement | Coastal / Sea Water cooled, 6-8 Cyclones
Indonesian Coal GCV (kcal/kg) | 4250
Local Sourced Biomass GCV | 3600
Main Steam Temperature | 600°C
Main Steam Pressure (Barg) | 280
Reheat Steam Temperature | 600°C
Boiler Thermal Efficiency | >85 (%HHV)
Boiler Target Availability (%) | >90
Outlet SOx (ppm@6%O2)** | <120
Outlet NOx (ppm@6%O2)** | <100
Outlet Dust (ppm@6%O2)** | <50
Doosan Lentjes is currently scaling up its CFB boiler capability to 600MWe class for demonstration in South Korea with target steam conditions at Ultra-Supercritical levels. The plant design will couple CFB combustion design with proven supercritical boiler design.

The USC CFB concept evaluated for demonstration will operate at 'state of the art efficiency levels and fuel flexibility that delivers a better payback than USC PC, resulting in lower cost generation.

The Indian USC CFB design concept would target 660MWe unit sizes with application to coastal locations where whole life cost savings from fuel arbitrage and APC avoidance will deliver lower cost generation.

The design concept for India may also accommodate locally sourced biomass for co-firing, supporting a more environmentally sustainable power plant solution.
Thank you

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