A Proud Heritage

**Babcock**

- Count Wallenstein founds the original engineering workshop
- Emile Škoda buys the workshop
- Babcock and Wilcox established
- Babcock Power Ltd
- Babcock Energy Ltd
- Mitsui Babcock Energy Ltd
- Doosan Babcock Energy Ltd
- Škoda Energo Ltd
- Škoda Power Ltd
- Škoda Power public limited company

**Škoda Power**

- Privatisation establishment of daughter companies within Škoda a.s.
- Lentjes
## Doosan Group

### Doosan Heavy Industries & Construction

<table>
<thead>
<tr>
<th>Division</th>
<th>Turnover</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doosan Group</td>
<td>£12.7 Billion</td>
<td>38,000</td>
</tr>
<tr>
<td>Doosan Heavy Industries &amp; Construction</td>
<td>£4.2 Billion</td>
<td>19,000</td>
</tr>
<tr>
<td>Doosan Power Systems</td>
<td>£0.9 Billion</td>
<td>5,800</td>
</tr>
</tbody>
</table>
Doosan Power Systems – Products and Services

Doosan Power Systems

- Boilers & APC
  - Babcock & Lentjes

- Turbogenerators
  - Skoda Power

- Plant

- Services
  - Babcock
### Doosan Post Combustion Carbon Capture Technology Roadmap

**Oxyfuel**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>160KWt at Doosan ERTF</td>
</tr>
<tr>
<td>2008</td>
<td>ERTF Oxyfuel Conversion</td>
</tr>
<tr>
<td>2009</td>
<td>40MWt OxyCoal™ Burner at Doosan CCTF</td>
</tr>
<tr>
<td>2012/14</td>
<td>Full Power Plant Demo Expected 100-250MW</td>
</tr>
<tr>
<td>2020</td>
<td>Forecast to be fully commercialized by 2020</td>
</tr>
</tbody>
</table>

**Post Combustion Capture (PCC)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>University of Regina development of PCC</td>
</tr>
<tr>
<td>2000</td>
<td>Boundary Dam PCC donated to University for research</td>
</tr>
<tr>
<td>2003</td>
<td>UoR’s ITC completed</td>
</tr>
<tr>
<td>2008</td>
<td>Doosan invest into HTC Purenergy taking 15% &amp; exclusive rights to PCC technology</td>
</tr>
<tr>
<td>2009/10</td>
<td>ERTF converted to PCC Test Facility</td>
</tr>
<tr>
<td>2012/16</td>
<td>Antelope Valley FEED &amp; Ferrybridge Demo</td>
</tr>
<tr>
<td>2016/17</td>
<td>Large Scale Power Plant with CCS Commercial CCS Market</td>
</tr>
</tbody>
</table>

**Over 20 years of experience in carbon capture**

2011 | Carbon Capture Presentation

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Doosan Power Systems
Technology Leaders

- Global Licensee of HTC Purenergy technology developed in conjunction with the University of Regina
  - Over 20 years CCS experience
  - Laboratories for Solvent development, material and process.

- Advanced Solvent designer (RS family) solvent providing:
  - High efficiency system
  - Low degradation rates
  - Tailored to meet operating and flue gas conditions

- Scale-up validated against actual operating data from several plants as large as 800 TPD (with +/- 3% accuracy)

- Most importantly, scale-up is only achievable through a complete and thorough understanding of:
  - All physical and chemical properties (kinetics, diffusivity, etc.)
  - Operating conditions
  - Proper application of numeric modeling tools

- Patents in place for high efficiency configured to advanced solvent

Advanced solvent, advanced process and optimised integration provide maximum customer value

Optimised Process Design (TKO™)
- Heat Integration
- Reduction in Steam
Solvent Supply and Management

- Ability to optimise process to match solvent specification in-house ensures complete system optimisation and compatibility

- Online monitoring and Solvent Management

- Huntsman is our Global Strategic Partner and can provide long term aftermarket supply of optimised Solvents.

- No mandatory long term Solvent tie in, client has flexibility to meet their own needs or go to market!

Most economical and flexible approach but with infrastructure to support for the long term
Test Facilities and Demonstration Projects

Facilities & Technology create a winning edge

**ERTF, 1t/day**
- Commissioned in 2010
- Ability to test wide range of coals and other fuels
- High degree of flexibility and accuracy to test wide range of Solvents and other modifications

**Ferrybridge, 100 t/day**
- Largest PCC demonstration plant in the UK
- Long-term testing and validation of process and solvent performance
- Evaluate transient conditions and process control
- Extensive monitoring planned

**ITC 1t/day**
- Opened in 2003
- Flue gas from natural gas combustion
- Includes equipment to study corrosion, material selection, solvent degradation and kinetics

**Boundary Dam, 4t/day**
- Commissioned in 1987
- Dedicated to post-combustion capture since 2000
- Captures CO2 from flue gas emitted from lignite-fired boiler
- Upgraded in 2007 to evaluate advanced process with RS-2

Performance demonstrated on wide range of fuels and different plant configurations
Boundary Dam Demonstration Plant

Technology Demonstration Plant

- Operating since 1987
- Donated to UoR in 2000
- Upgraded 2008 (for TKO)
- Capture capabilities are 4 TPD
- Operating on lignite fuel
- Technology demonstration facility for client-specific parameters

BDPS CO₂ Capture Plant Performance

< 1.1 kg steam/1 kg CO₂ captured which equates to less than 2.4 GJ/Ton CO₂ Total Capture System equates to ~125 MWe on an 800 MWe

Minimised impact to existing plant performance – Industry leading plant efficiency
CCPilot100+ Project Location

Pictures courtesy Google Earth
Post Combustion Capture Demonstration Plant using Doosan Power System’s technology

- 100 t/day slip stream on SSE Ferrybridge Power Station
  - Largest PCC Demonstration in the UK

- Funding by the project partners, SSE, Vattenfall, Doosan Power Systems, TSB, DECC and The Northern Way

- Fast – track, operation in late 2011

- Two year test program

- Lessons learned will be incorporated into future designs.

- Academic involvement by four Universities
CCPilot100+ Process Layout and Key Parameters

- **CO₂ Absorber Dimensions (i.dia x height; m):** 2.3 x 39
- **Design CO₂ removal efficiency:** 90%
- **PCC Design:** 100 metric tpd
- **CO₂ Stripper Column Dimensions (i.dia x height; m):** 1.1 x 30.5
Absorber
CCPilot100+ Absorber and stripper columns installation at Ferrybridge
CCPilot100+ Project Execution

Absorber Fabrication

Stripper Column Delivery

Construction

Simulation

P&IDs

3D Modelling

Testing Programme

DOOSAN Power Systems
CCPilot100+ Test Programme Key Parameters

- CO₂ capture rate and product compositions
- Steam consumption at reboiler
- Amine and degradation product atmospheric emissions
- Absorber column efficiency
  - In-column CO₂ composition and temperature profiling
- Power and water consumption under differing operating regimes
- Use different process configurations to optimise thermal integration
- Solvent testing and formulation for efficiency & durability
- Performance of standard construction materials and polymers
- Comparison of performance with other pilot plant for Scale Up
### Engineering and Design Studies

**Application of the Process Technology to Real Projects**

<table>
<thead>
<tr>
<th>Project</th>
<th>Capacity</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin Electric, AVS, 3,000 t/day</td>
<td><strong>CO₂</strong> from the adjacent Dakota Gasification Company (~3.0 MTPY) is sold for Enhanced Oil Recovery</td>
<td>FEED completed November 2010</td>
</tr>
<tr>
<td>North America 3,200 t/day</td>
<td>Flue Gas Type: Coal Fired</td>
<td>450MW Supercritical boiler</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FEED based proposal; Completed January 2012</td>
</tr>
<tr>
<td>ENEL, Porto Tolle 4,100 t/day</td>
<td>Flue Gas Type: Coal fired flue gas</td>
<td>Oil boilers being converted to fire bituminous coal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FEED completed Q2 2011</td>
</tr>
<tr>
<td>SSE, Peterhead 3,300 t/day</td>
<td>Flue Gas Type: NGCC Exhaust</td>
<td>Full Flue Gas Processing of a single 230 MWe Gas Turbine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ultra Low Pressure Drop Design</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Feasibility Study Completed 2011</td>
</tr>
</tbody>
</table>