Development of Post Combustion Capture Technology

IEAGHG 1st Post Combustion Capture Conference, 17th to 19th May 2011, Abu Dhabi
“To be a global leader in delivering advanced clean energy technologies, products and services.”
### Doosan Group

#### Doosan Heavy Industries & Construction

<table>
<thead>
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<th>Casting and Forging</th>
<th>Nuclear</th>
<th>Doosan Power Systems</th>
<th>Power Plant</th>
<th>Construction</th>
<th>Desalination</th>
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</table>

#### Turnover

- **Doosan Group**
  - $15 Billion
- **Doosan Heavy Industries & Construction**
  - $5 Billion*
- **Doosan Power Systems**
  - $1.3 Billion

#### Employees

- **Doosan Group**
  - 36,400
- **Doosan Heavy Industries & Construction**
  - 5,800*
- **Doosan Power Systems**
  - 6,000

*Figures exclusive of DPS data and correct to the end of the financial year for 2009.*
Doosan Power Systems – Organisation

Doosan Group

Doosan Heavy Industries & Construction

Doosan Power Systems

- Boilers
  - Doosan Babcock
- Turbines
  - Škoda Power
- Plant
- Services
  - Doosan Babcock
- Wind
Post Combustion Capture
Leading Edge Technology

Doosan Power Systems
HTC Purenergy Overview

- HTC is the CO₂ Capture technology licensee of the University of Regina, who has specialised in Carbon Capture since 1987.
- HTC’s Technology Centre is commercially aligned with Doosan, International Test Centre for CO₂ Capture, and the International Risk Assessment Centre Laboratories for solvent development, materials and process design.
- CO₂ enhanced oil recovery technical expertise commercialized through subsidiary EHR Enhanced Hydrocarbon Recovery Corp.
- Smaller scale modular capture systems for SAGD and Heavy Oil consolidated into Calgary based subsidiary HTC CO₂ System Corp.
Doosan Power Systems – HTC Purenergy

Our Goal...
To be recognised as the market leader in Post Combustion Carbon Capture technology and application, with proven product leadership to support the Core Power Island EPC product offering throughout the Doosan organisation.

An Alliance...
Global licence agreement signed in 2008 between Doosan Power Systems and HTC Purenergy
Technology transfer – up to 30 engineers and specialists from Doosan Power Systems seconded to Regina, Saskatchewan.

Future Development...
Doosan and HTC participate in collaborative research with the University of Regina – which has some of the most comprehensive carbon capture research and development facilities in the world
This enables the latest technological advancements to be provided to our Customers.
Technology Leaders

- Advanced Solvent designer (RS family) solvent providing:
  - Low cost commercially available ingredients (~$2.60/kg)
  - 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
- Patents in place for steam side plant integration

Advanced solvent, advanced process and optimised integration provide maximum customer value
Test Facilities and Demonstration Projects

Facilities & Technology create a winning edge

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

**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

**Boundary Dam, 4t/day**
- Commissioned in 1987
- Dedication 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

**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

Performance demonstrated on wide range of fuels and different plant configurations
Doosan Product Development and Commercialisation

Process Technology Status and Scale-up
Doosan Power Systems Post Combustion Capture Projects

Development Roadmap

**Target Slipstream**
- 100t/d CO₂ • 5MWₑ
- *Ferrybridge*

**Emissions Reduction Test Facilities**
- 1t/d to 5t/d CO₂

**Large Demonstration Project (s)**
- Slipstream
- ~3000t/d CO₂ • 150MWₑ

**Commercialisation Full Scale Plant**
- 10,000t/d CO₂ • 500MWₑ
- 15,000 t/d CO₂ • 800 MWₑ
Demonstration Projects - Emissions Reduction Test Facility

Emissions Reduction Test Facility (ERTF) Upgrade for PCC Solvent Scrubbing - A 160kWt combustion test facility at our R&D Centre in Renfrew, United Kingdom

- Capable of firing a very wide range of coals or natural gas.

- Originally constructed to test primary NO$_x$ reduction measures, subsequently adapted and upgraded to test secondary NO$_x$ reduction measures.

- Upgraded for oxyfuel operation as part of the OxyCoal-UK: Phase 1 project - a collaborative project sponsored by the UK government with industrial and academic participation.
**Demonstration Projects - Emissions Reduction Test Facility**

**ERTF Solvent Scrubbing Process - Equipment**

**Absorber column**
- 10” NB (DN250)
- 4-off packed bed sections (with multiple solvent feed inlet points)

**Stripper column**
- 8” NB (DN200)
- 4-off packed bed sections

**Water Wash Column**
- 8” NB (DN200)
- 1-off packed bed section

**Heat exchangers**
- Gasketed (plate and frame)

**Pumps**
- Duties met by triplex diaphragm pumps for high head - low flow duties
- Variable speed drives for efficiency and ease of control
Boundary Dam Demonstration Plant

**Technology Demonstration Plant**

- Operating since 1987
- Donated to UoR in 2000
- Upgraded 2007
- 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 then 2.4 GJ/Ton CO₂ Total Capture System equates to ~110 MWe on an 800MWe

Minimised impact to existing plant performance - Industry leading plant efficiency
Main Test Campaigns at Boundary Dam CO$_2$ Capture Demonstration Plant

<table>
<thead>
<tr>
<th>Period</th>
<th>Test Objectives</th>
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<tbody>
<tr>
<td>Sep 2002 to Nov 2002</td>
<td>Establishing the baseline operation using MEA solvent</td>
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<tr>
<td>Jun 2003 to Aug 2003</td>
<td>Optimum operation &amp; energy and utilities consumptions</td>
</tr>
<tr>
<td>Aug 2003 to Dec 2003</td>
<td>Operating at reduced reboiler pressure and temperature</td>
</tr>
<tr>
<td>Feb 2004 to Aug 2004</td>
<td>Optimum lean/rich loading approach and flooding factor</td>
</tr>
<tr>
<td>Apr 2005 to May 2006</td>
<td>Solvent performance using single and mixed amines; mass transfer data at various operating conditions; optimum operation conditions</td>
</tr>
<tr>
<td>July 2007 to Nov 2007</td>
<td>Upgrading the demonstration plant for patented configuration and plate type heat exchangers</td>
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<tr>
<td>Nov 2007 to May 2008</td>
<td>Simulated NGCC flue gas test using patented configuration and RS-2</td>
</tr>
<tr>
<td>Oct 2009 to Apr 2010</td>
<td>EGR (Exhaust Gas Recycling) trials</td>
</tr>
<tr>
<td>Sep 2010</td>
<td>Design parameters of Basin CO$_2$ capture plant</td>
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</tbody>
</table>
Scale-up Experience - Slipstream Flue Gas from Coal Power Plant

- Simulation of 136 Tonne per day CO₂ Capture Plant;
- One train & standard design configuration;
- MEA solvent, 16 wt%;
- CO₂ Concentration 12.5 vol%
- 12 Years in operation;
- Slipstream flue gas from Coal power plant.
- Absorber diameter: 2.90 m
- Stripper diameter: 2.591 m
- Solvent & rate: MEA 16 wt%, 159 m³/h
Scale-up Experience - Slipstream Flue Gas from Coal Power Plant

- Simulation of 825 Tonne per day CO2 Capture Plant;
- Two trains & standard design configuration;
- CO2 Concentration 10.8 vol%
- 32 Years in operation;
- Flue gas from Coal power plant.
- Absorber diameter: 4.420 m
- Stripper diameter: 3.810 m
- Solvent & rate: MEA 20 wt%, 437.85 m3/h
Demonstration Projects - CCPilot100+

SSE Ferrybridge CCPilot100+ 100t/day CO₂ PCC Demonstration Plant

- Post Combustion Capture Demonstration Plant using Doosan Power System’s technology
- 100 t/day slip stream on SSE’s Ferrybridge Power Station
  - Largest PCC Demonstration in the UK
- Funding by the project partners, Scottish & Southern Energy, Vattenfall, Doosan Power Systems, TSB, DECC and The Northern Way.
- Fast – track, for operation during 2011
- Two year test programme
- Lessons learned will be incorporated into future designs
- Off gas analysis - amine carryover and degradation products
- On-site amine and degradation product atmospheric sampling and analysis - University of Leeds
CCPilot100+ Project Location

[Map showing locations with images of power stations]

Pictures courtesy Google Earth
CCPilot100+ Process Layout and Key Parameters

- **Direct Contact Cooler**
- **CO₂ Absorber**
- **CO₂ Stripper Column**
- **Polishing FGD**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCC Design</td>
<td>100 metric tpd</td>
</tr>
<tr>
<td>Design CO₂ removal efficiency</td>
<td>90%</td>
</tr>
<tr>
<td>CO₂ Absorber Dimensions (i.dia x height; m)</td>
<td>2.3 x 39</td>
</tr>
<tr>
<td>Stripper Column Dimensions (i.dia x height; m)</td>
<td>1.1 x 30.5</td>
</tr>
</tbody>
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CCPilot100+ Project Execution

- Current Status - In Construction

- P&IDs
  - Stripper Column
  - Delivery

- 3D Modelling
- Simulation
- Testing Programme
- Construction
- Absorber Fabrication
Case Study – Basin Electric FEED

- Sized to capture 1.0 MM tons per year of CO₂ from Basin Electric’s Antelope Valley Power Plant
  - 3,000 tons per day
  - Treating a ~120 MW slipstream
  - Turnkey EPC Scope including: PCC plant, FGD polishing and CO₂ compression and dehydration

- Key FEED Deliverables:
  - Engineering studies to investigate the integration of the PCCC Plant within the existing AVS and DGC infrastructure
  - Proposed EPC Scope of Work, based upon the final design of the PCC Plant
  - 15% EPC CAPEX and OPEX Estimate
  - Level 2 EPC Project Schedule

- Project currently deferred by client
Basin Electric - Process Layout and Key Parameters

- **CO₂ Absorber**
- **Direct Contact Cooler**
- **Polishing FGD**
- **CO₂ Stripper Column**
- **Existing Stack**
- **Offgas Return**

**CO₂ Absorber Dimensions (dia x height; m)**: 9.5 x 14.8

**Direct Contact Cooler Dimensions (dia x height; m)**: 11.8 x 53.3

**PCC Design Gas Flow (lb/hr)**: 1,544,000 lb/hr

**Design CO₂ removal efficiency**: 90%

**Striper Column Dimensions (dia x height; m)**: 5.6 x 36.2
In Summary

- Doosan utilises process technology that was invented and developed in Canada by UoR and HTC Purenergy, Inc.
- Doosan and HTC are at the forefront of PCC technology development
- Doosan has a proven highly efficient process and product which it will guarantee
- Doosan will undertake full EPC
- Doosan have available resources and can leverage the historic experience from recent projects to achieve clients goals

Low impact, high efficiency, integrated EPC Carbon Capture Solutions
THANK YOU