Doosan Babcock Energy

Commercialising Carbon Capture Technology

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Carbon Capture Technology – Leading Technologies

- Post-Combustion Capture – Separation of the CO_2 from the flue gas stream following combustion and power generation utilizing a chemical scrubbing process. Doosan Babcock license process technology from HTC Purenergy in Canada

- OxyCoal Combustion – Combustion of the fuel with oxygen and recycled flue gases rather than traditional air firing to yield a high CO_2 concentration product stream that can be purified. Doosan Babcock developing their own technology.

- Pre-Combustion Capture (**Integrated Gasification Combined Cycle or IGCC)** – Turns the coal into a gas, then removes the pollutants prior to combustion giving a much lower CO_2 concentration in the flue gas. Doosan Heavy Industries developing this in Korea.

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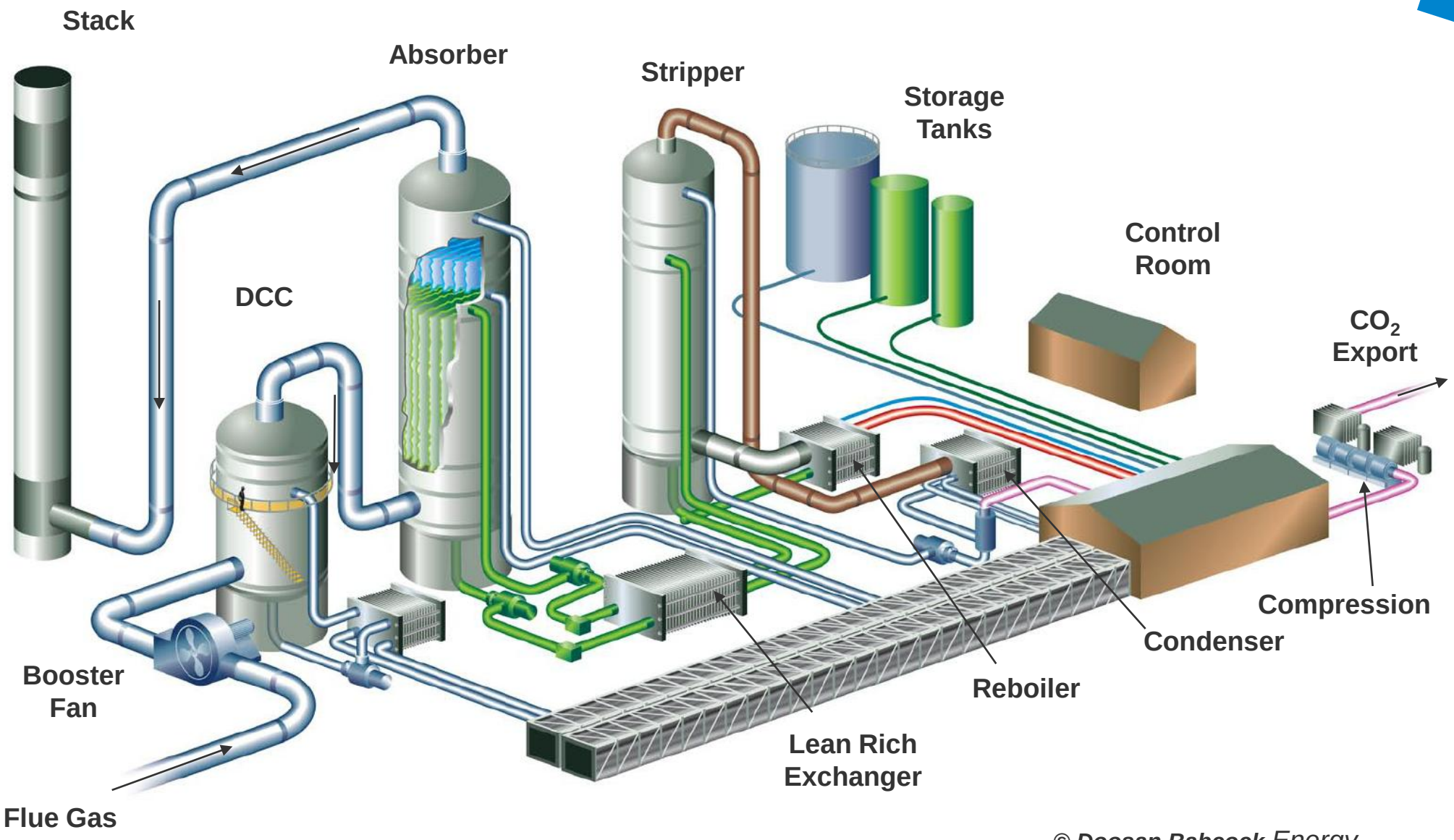
Post-Combustion Carbon Capture

Post Combustion Carbon Capture Technology



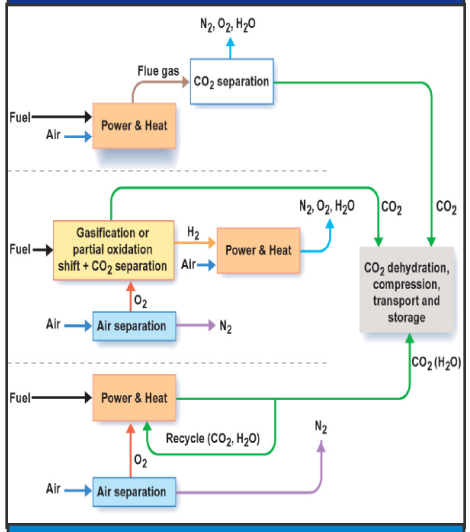
Post Combustion Capture Road Map (2007 – 2017)

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017

Technology transferred

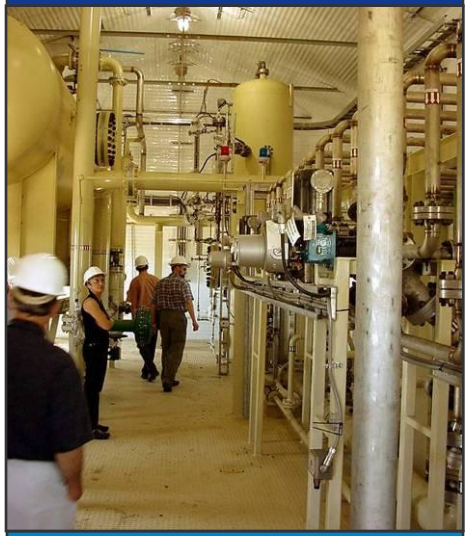
Phase 1 | 2 | Phase 3 | Phase 4

1. Acquire technology



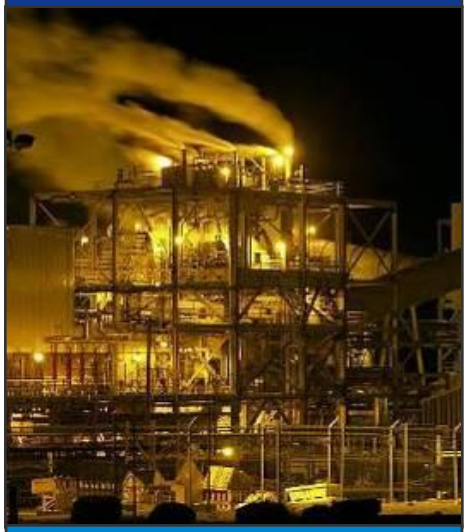
- Market evaluation
- Technology selection
- License agreements
- R&D development

2. Product & market development



- Carry out technology transfer and document processes
- Provide support to early proposals
- Develop the market proposition
- Identify DBEL and HTC opportunity pipeline

3. Demonstration & optimisation



- Secure FEED work
- Secure retrofit work
- Secure large demo projects
- Embed technology skills into organisation to support future full scale commercialisation

4. Commercialisation

- Secure commercial project as part of new build EPC
- Continue development to drive efficiency gains
- Drive down costs and increase commercialisation

Boundary Dam Testing – Solvent Verification

- Lignite Coal Flue Gas
- 3000 hour test verification*
- Process modified with TKO™ configuration
- Preliminary Results for RS™ solvent

- Low Solvent Degradation
- Steam Consumption Target 1.1 – 1.0 kg/kgCO_2

** At time of writing still to be completed (June 2009)*

PCC Commercialisation Challenges

- Design Issues:
  - Scale up (gas and liquid distribution)
  - Turndown Requirements – full scale plant must accommodate entire power plant operating range
  - Energy Supply – energy source needs to be at a suitable temperature at all operating conditions.
  - Power Plant Integration – steam supply / heat recovery options with existing turbine or other systems
  - Safety – Hazardous area classification, solvent handling
  - Environmental – disposal of waste products, control of degradation products
- Economics:
  - Achieving an optimised design (through life cost / total capture)
  - Cost of steam / cost of electricity /
  - Solvent consumption vs. SOx removal

Post-Combustion CO_2 Capture

- Advantages
  - Uses existing power plant technology
  - Can be retrofitted to existing plant or installed as new build
  - Demonstrated at small scale in other industry sectors
  - Can be designed to fire a wide range of fuels
  - Robust to changes in fuel quality
- Disadvantages
  - Energy requirement for solvent regeneration
  - Retrofit potentially requires steam turbine modification
  - Solvents degraded by O_2, SO_x, and NO_x
    - Requires flue gas treatment upstream of scrubber
  - Limited demonstration on flue gases arising from coal combustion
    - A number of projects to resolve this are planned

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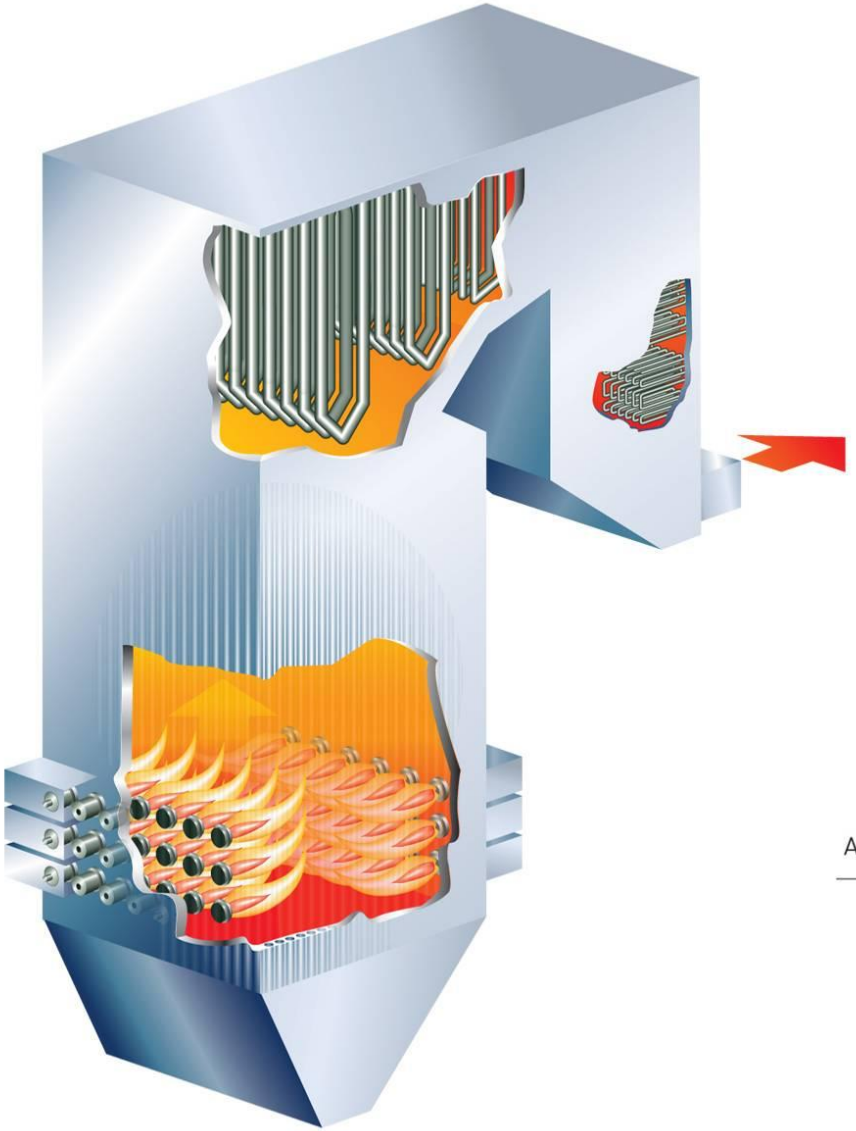
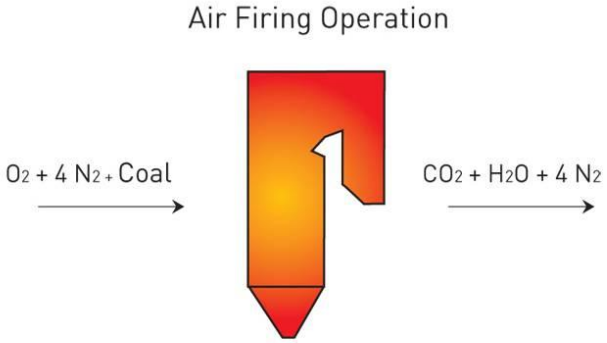
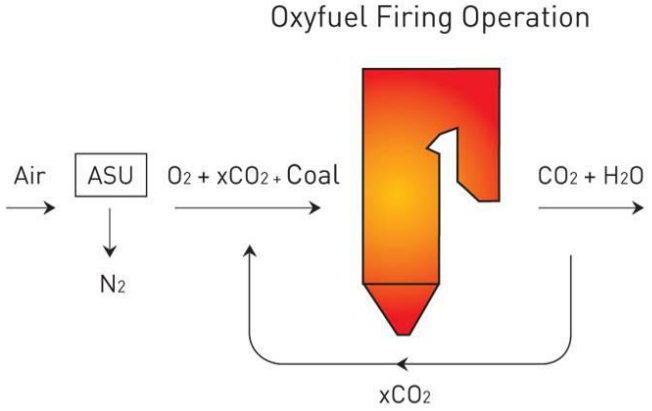
OxyCoal for Carbon Capture

Oxyfuel Technology



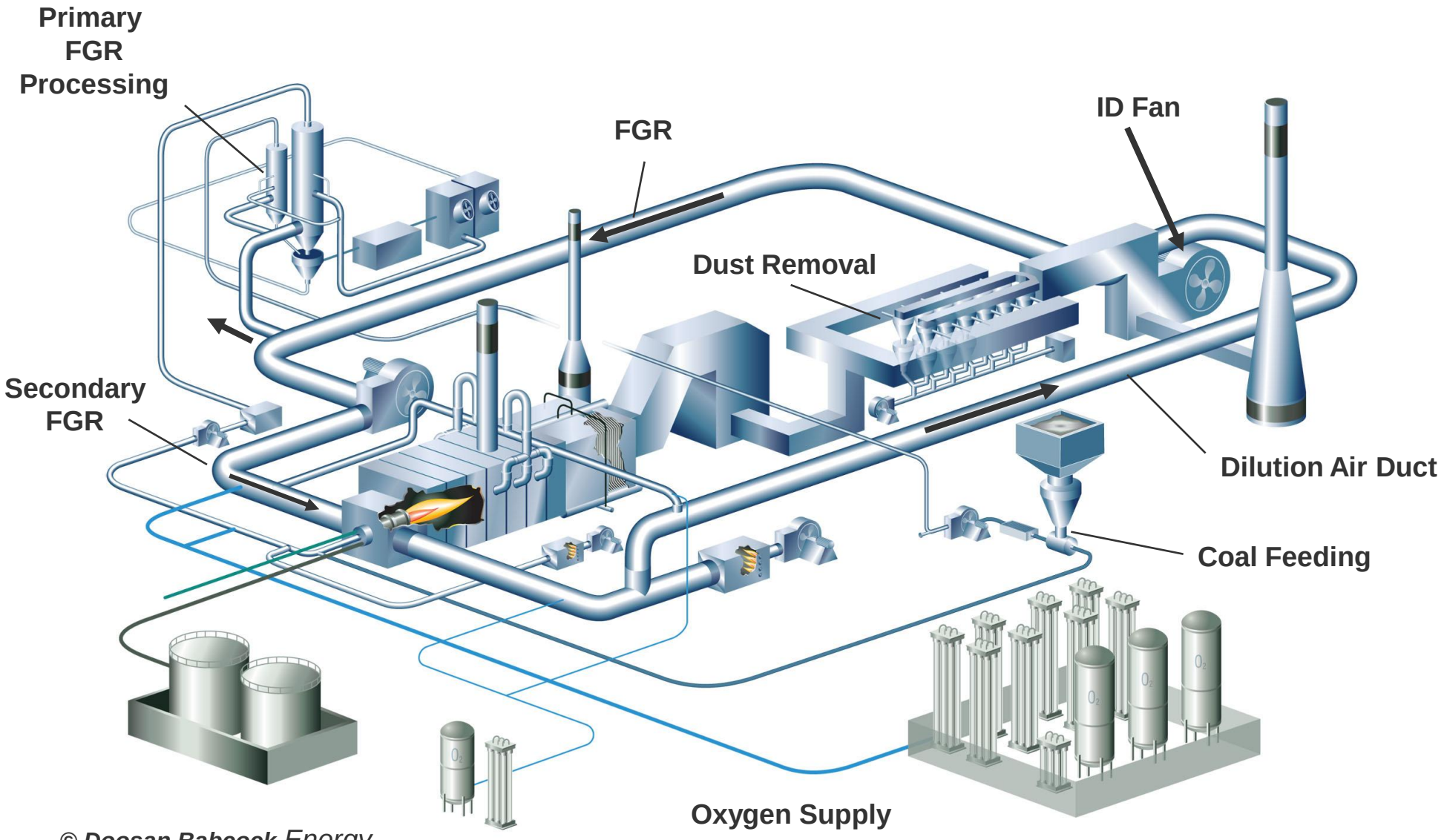




OxyCoal Combustion and CO_2 Capture

- **Other practical features of oxycoal combustion include:**
  - Retaining air firing capability for start-up
  - Use of hot, dry primary FGR for coal drying and transport
  - Addition of O_2 upstream of pulverising mills
  - Secondary FGR conditions are more flexible (e.g. moisture, O_2 level, temperature)
  - Process integration of heating and cooling loads (maximise thermal efficiency)
  - Balanced draft operation (prevent CO_2 egress)
  - Removal of SO_2 from FGR (corrosion, acid dew point), not needed for low S coals
  - Removal of dust from FGR (erosion)

MBTF – OxyCoal Firing (commissioning May 2009)



OxyCoal Development Programme

To develop a competitive oxycoal firing technology suitable for full plant application post-2010.

- A phased approach to the development and demonstration of oxyfuel technology.

• Phase 1:

– Fundamentals and Underpinning Technologies (OxyCoal-UK Phase 1, 2007 to 2009)

• Phase 2:

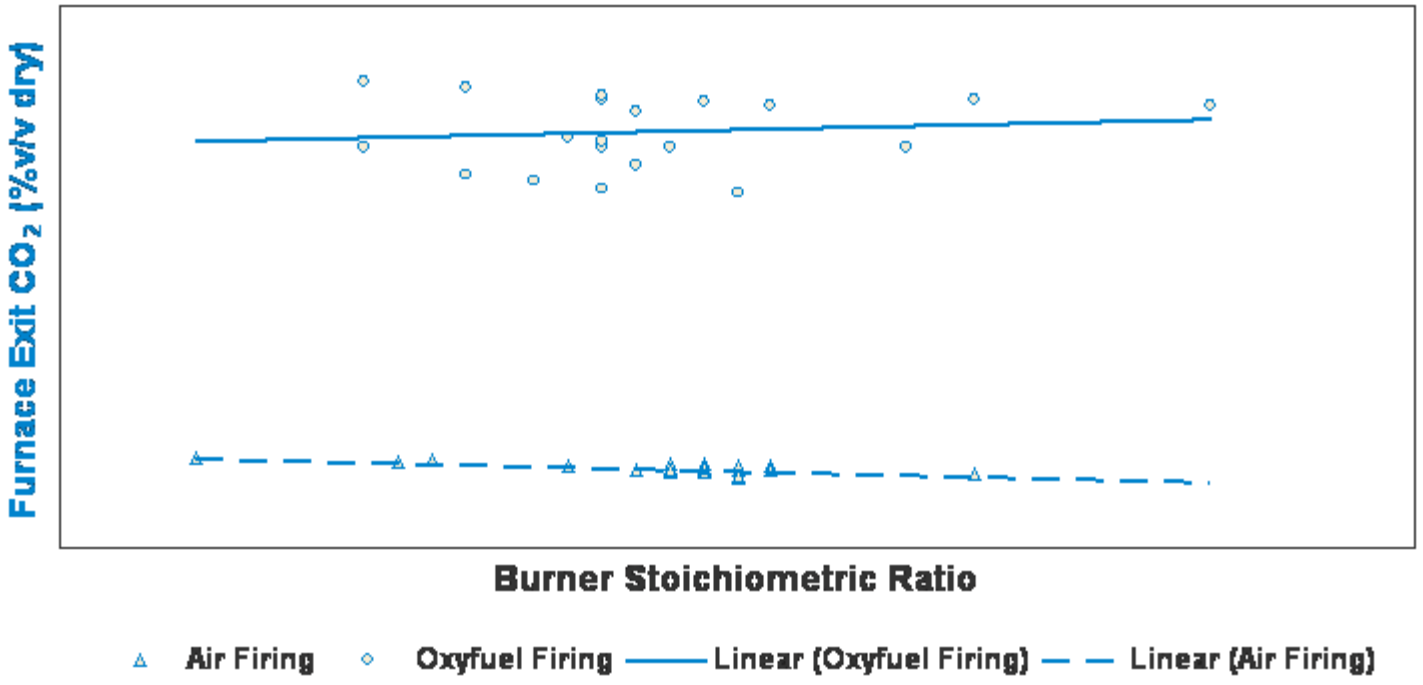
– Demonstration of an Oxycoal Combustion System (OxyCoal-UK Phase 2, 2007 to 2009)

• Phase 3:

– OxyCoal™ Reference Designs (2009 to 2010)

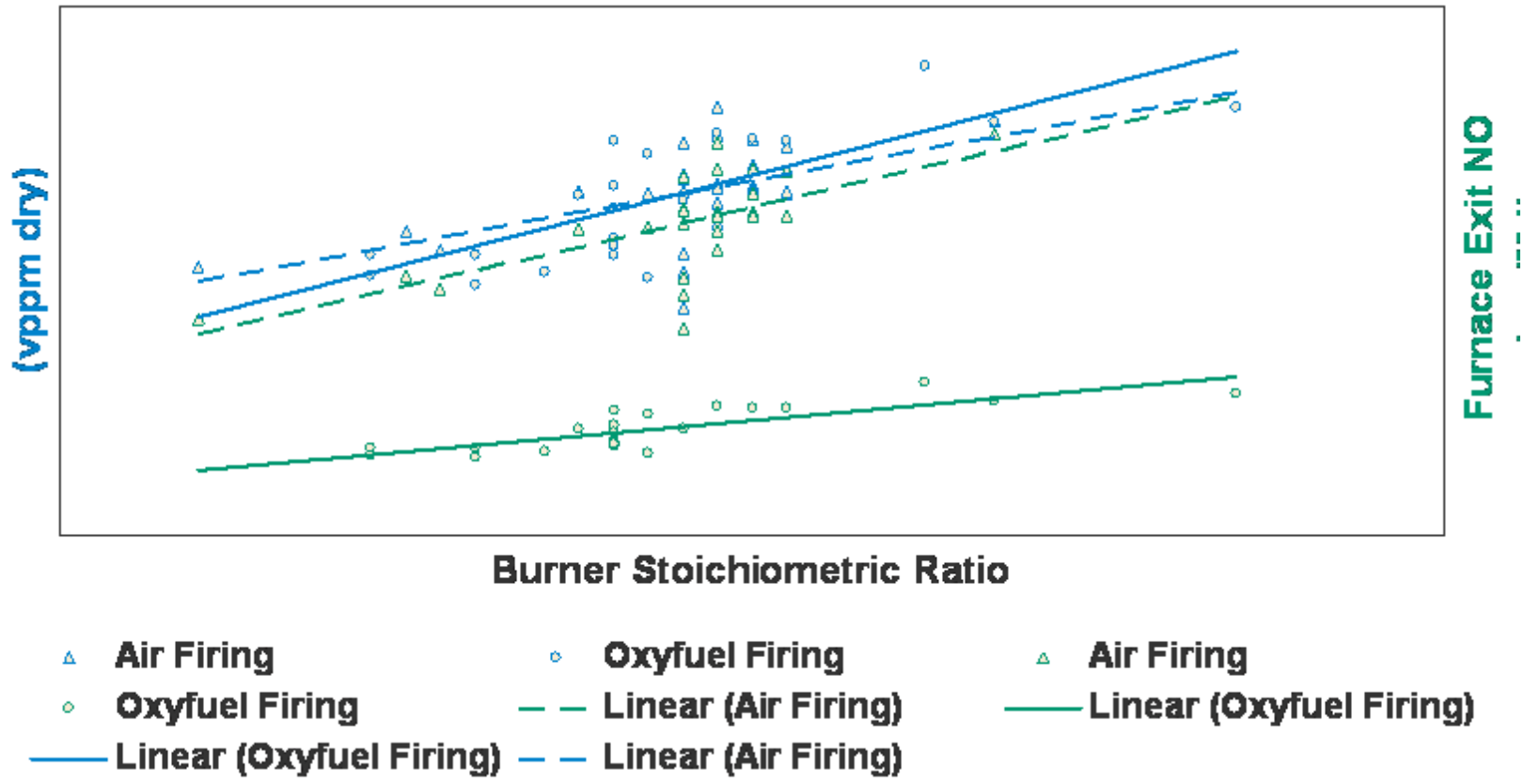
Doosan Babcock CCTF – OxyCoal Tests

Oxycoal combustion can generate a CO_2 rich flue gas typically 80%v/v dry.



Doosan Babcock CCTF – OxyCoal Tests

Oxycoal combustion reduces NO emissions by approximately 50% on a heat input basis (mg/MJ).



OxyCoal Combustion and CO_2 Capture

- Advantages
  - Relatively simple process
  - Uses existing power plant technology (well proven components)
  - Can be retrofitted to existing plant or installed as new build
  - Potential to reduce size of boiler
  - Potential to avoid requirement for FGD and/or SCR
  - Can be designed to fire a wide range of fuels
  - Robust to changes in fuel quality
- Disadvantages
  - Power consumption of Air Separation Unit
  - Full system not demonstrated at large scale

Questions

Thank you for your attention.