Future UK Power generation in a carbon constrained world

Mike Farley

Coal Research Forum
17 April 2007
In December 2006, Doosan Heavy Industries concluded an agreement to buy 100% of the Mitsui Babcock business from Mitsui Engineering & Shipbuilding.

Doosan Heavy Industries (UK) Limited is a subsidiary of Doosan Heavy Industries & Construction, the South Korea-based engineering and construction company.

Our new name is Doosan Babcock Energy Limited.

The company remains committed to all forms of power generation, including clean coal, nuclear, gas and renewables.
How things have changed for coal in about a year

• Recognition that the world scene will continue to include massive amounts of coal generation, and coal fired power plant must be cleaned up, not substituted

• Loss of confidence in gas, and recognition that gas too needs to be cleaner.

• Replacement of coal by gas is not sufficient for climate change mitigation and has a negative impact on security of supplies

• EU and UK politicians and officials are now talking about the whole generation mix, not just about the renewables part and are recognising that renewables and energy efficiency - whilst vital - cannot do it all. Coal important in the new EU Energy Package – capture ready from 2010, CCS from 2020, 10-12 demonstrations of CCS operational by 2015

• Recognition that nuclear can make an important contribution to cutting emissions but only a very limited contribution to filling the generation gap up to 2016

• UK coal fleet, already old (21 - 46 years), is one year older and the time available to start building new power plants that can fill the generation gap is one year less and now only nine years

• Wide acceptance, evidenced by our customers’ plans, that Clean Coal can be Supercritical or Gasification.

• 38% of UK electricity is from coal (48% in winter 2007), largest source of coal is Russia
Outline

- Clean Coal Technologies
- Carbon Dioxide Capture and Storage
- Can the new plants be built in time?
- What we need from the government
New Coal-fired Power Plant - Overseas

• China
  – 30-40 GW of pulverised coal fired power plant being built each year, all 600MW plant are supercritical
  – 5 x 600MW Doosan Babcock supercritical units now operating

• India
  – 10 GW mega projects, supercritical 800MW pulverised coal
New Coal-fired Power Plant- Overseas

.....Numerous inquiries for new coal fired power plant

....Almost all are for Supercritical Steam conditions
Clean Coal Technologies available now

- Higher efficiency / lower emissions than current coal
- Lower cost electricity than gas or renewables
- Suitable for UK or imported coal
- Suitable for Carbon Capture and Storage (CCS)
- ASC PC offers Capture-Ready Retrofit options
- IGCC offers Hydrogen options
Integrated Gasification Combined Cycle (IGCC)

Integrated Gasification
Combined Cycle
250-900MW

- New technology for New-Build claimed attractive because of potential for hydrogen generation and CO₂ capture
- Total of 4 units in operation worldwide on coal and some plans for further plants
- Challenges are poor availability, high cost, lack of flexibility
- Latest designs attempt to improve availability with consequences on cost and efficiency (eg Hatfield 41%)
Carbon-Abated Clean Coal Power Plant

Advanced Supercritical Pulverised Coal Boiler /Steam Turbine 350-1000MW

• Technology of choice for vast majority of new build orders
• Best Available Technology now 46/47% efficient (290 bar/600C/610C)
• Advantages are proven Availability (>95%), Load Flexibility (20-100%) and wide fuel range (inc Biomass cofiring up to 20%)
• Matches any other coal technology for emissions, easily meets LCPD limits for 2016
• Can be built now, designed to be “capture ready” and fitted with economical CO₂ capture when CCS is possible
• Can be retrofitted to existing UK stations
• For both coal and gas, CCS will be needed if CO₂ targets are to be met
• Projects have to start soon, and before the best options for CCS are finalised and regulations in place
• To maintain a diverse portfolio much of this capacity needs to be carbon-abated Clean Coal power plant
• Likely therefore that the projects will be a mixture of CCGT (should be capture ready), Clean Coal with CCS, and Capture-ready Clean Coal
• Coal Forum Sub-Group is exploring options based on Low (5GW), Medium (10GW), and High (15GW) amounts of new/replacement Coal power plant
CO₂ Abatement from Fossil Fuels – Twin Track Approach

- 95%
- 60%
- 23%
Baseline

Possible Now 2012 2020

Increased Efficiency, Biomass cofiring etc

>> concept of “Capture-ready plant”

Tracker 1

Tracker 2

Carbon Capture and Storage (CCS)
Abatement of Carbon Dioxide by efficiency improvement

Best Available Advanced Supercritical Technology being offered now

Doosan Babcock ASC
Target AD700
46% (-23%)

Lower CO₂ emissions

Increasing Efficiency

UK fleet
38%

Older Plants
32%

Chinese fleet
38%

Meri Pori Hemweg

New Chinese Orders
42%

Older Plants
Sub Critical Boilers

30%

35%

40%

45%

50%

55%

1960 1980 2000 2020

Year

Doosan Babcock Energy
Continuous innovation of two pass boilers – proven operation

- Natural Circulation
- Once Through
- Supercritical
- Posiflow™
Doosan Babcock
Two-pass boiler

EL 250 ft
76 m

+30%

Tower
FL 327 ft
99.7 m

eg
Trimble
County
for EON
USA
• Carbon Dioxide Capture and Storage
Carbon Capture Strategies

Post-combustion capture

Pre-combustion capture

O₂/CO₂ recycle (oxyfuel) combustion capture
Comparison of Carbon capture options for Coal power plant

Net Cycle Efficiencies (%LHV)

- Amine
- Oxyfuel
- IGCC

From joint paper with Jacobs at Powergen 2006

Specific Investment costs (Euro/kw)

1400-1800 Euro/kw for New build, 800 Euro/kw for Retrofit

Cost of Electricity (Eurocents/kwh)

5 -6.2 Euro/kwh for New build, <5 Euro/kwh for retrofit
- IEA, EU projects underway
- Requires scale up (factor of 10)
- 300 MW planned by MHI
- Collaborative DTI project about to start, led by RWE
- Elsam slip stream demo underway
- New Alstom demo projects in USA on chilled Ammonia scrubbing
- Technology likely to be available for 2010 / 12 implementation
Carbon Capture by Oxyfuel firing on Pulverised Coal Plant

- Pilot scale tests by Doosan Babcock 1996
- IEA, EU projects underway
- EON 1MW rig recently announced
- Vattenfall 30MW demonstration plant announced
- Several boilermakers developing this technology for 2010/12 implementation
- Sask Power 300MW project announced
- DTI funded collaborative R&D projects in progress
- Full scale 40+ MW burner test planned by Doosan Babcock in 2007/8
Comparison of Carbon Reduction Technologies

• Oxyfuel has a similar footprint to amine scrubbing

1 x ASC BT Oxyfuel Unit:
- 2 x ASU trains
- CO₂ Compression
- Maximum Height – 68m

1 x ASC BT Amine Unit:
- 2 x SO₂ removal towers
  (reduces SO₂ from 10ppm at FGD outlet to 1 ppm at CO₂ absorber inlet)
- 2 x Fans / Blowers
- 2 x CO₂ Absorber Towers
  (12.5m Dia x 45m Height)
- 1 x CO₂ Stripper Tower (10m Dia)

ASU & CO₂ Compression 24,500m²

Amine Scrubbing & CO₂ Compression 23,825m²
# OXYCOAL- UK collaboration

## Project 407 ASC Retrofits with CO2 Capture

<table>
<thead>
<tr>
<th>Project team</th>
<th>Sponsors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doosan Babcock, Alstom, Air Products, EON, Imperial,</td>
<td>EON, SSE, Drax, SP, EDF, RWE</td>
</tr>
</tbody>
</table>

Technical Steering Committee: Doosan Babcock, Alstom, Air Products, EON, RWE, SSE, Drax, SP, EDF, Imperial,

## Phase 1 Project

### Underpinning technologies

<table>
<thead>
<tr>
<th>Project team</th>
<th>Sponsors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doosan Babcock, Imperial, Nottingham, Air Products, EON, RWE, BP</td>
<td>Doosan Babcock, SSE, Drax, SP, EDF, EON, BP</td>
</tr>
</tbody>
</table>

Technical Steering Committee: Doosan Babcock, Imperial, Nottingham, Air Products, EON, RWE, SSE, Drax, SP, EDF

## Phase 2 Project

### Development and Demonstration of Oxycoal Combustion System

<table>
<thead>
<tr>
<th>Project team</th>
<th>Sponsors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doosan Babcock, Imperial, Nottingham</td>
<td>SSE (prime), Drax, EON, SP, EDF, Dong</td>
</tr>
</tbody>
</table>

Technical Steering Committee: Doosan Babcock, Imperial, Nottingham SSE, Drax, SP, EDF, EON
The Doosan Babcock burner test facility in Renfrew will be converted to Oxycoal firing.

It will be used to demonstrate full size (40+ MW) Oxycoal combustion in a collaborative project.

Cofunding by:

- Doosan Babcock, DTI (application submitted), and SSE (prime sponsor)
- supported by a group of utilities (Drax, EON, SP, EDF and Dong)

This will be the first full-scale test of Oxyfuel firing in the world.
Advanced Supercritical Retrofits with CO₂ Capture

• Doosan Babcock are leading DTI project 407

• Project 407 is demonstrating how to retrofit ASC to existing plant, how to make the design capture ready, and how to retrofit Amine scrubbing or Oxyfuel firing

• Project is demonstrating that ASC Retrofits and ASC with Carbon capture are economic in terms of the Cost of Electricity generated

• A capture ready ASC Retrofit will be a strong candidate for DTI CAT Strategy Demonstration funding

• Partners: Doosan Babcock, Alstom, E.ON, Air Products, Imperial College

• Sponsors: E.ON, DraxPower, EDF, SSE, RWE, ScottishPower

• ASC FEED Study (ies)
Ferrybridge ASC Retrofit FEED study

To date, eight months into study
- No technical showstoppers
- ASR boiler compatible with primary structural steel members
- Turbine layout compatible with existing foundations
- Anticipated costs within target
• Technologies exist, don’t need to be invented
  – Available with full commercial guarantees for Capture - ready plant now
  – Carbon capture technologies need scale up and full size demonstration
Can the new stations be built?
UK Generation Gap by end of 2015

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Capacity (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal - closures of Opted out plants</td>
<td>8</td>
</tr>
<tr>
<td>Oil- closures of opted out plants</td>
<td>3</td>
</tr>
<tr>
<td>Magnox Nuclear- closure of last two (Oldbury and Wylfa)</td>
<td>2.3</td>
</tr>
<tr>
<td>Growth at 1% pa</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
</tr>
</tbody>
</table>

Additional 5 GW if AGRs (Hinkley B, Hunterston B, Hartlepool, and Heysham A) do not get life extension and 3.5 GW if growth in demand is 1.5% 

So gap could be 29 GW

Already too late for nuclear (first new build unlikely to be on line before 2016)

Gap too large for renewables

Build capacity is limited, so vital to start new build and retrofit NOW
22GW of new power plants need to be in operation in 9 years!

- 30% of current capacity to be built in just nine years!
- 22 average sized power plants

* Assuming an illustrative peak capacity margin of 20%
• For both coal and gas CCS will be needed if CO₂ targets are to be met
• Projects have to start soon, and before the best options for CCS are finalised and regulations in place
• To maintain a diverse portfolio much of this capacity needs to be carbon-abated Clean Coal power plant
• Likely therefore that the projects will be a mixture of CCGT (which ought be capture-ready), Clean Coal with CCS “Demonstration Plants”, and capture-ready Clean Coal
• Coal Forum Power Generation Sub-Group is exploring options based on Low (5GW), Medium (10GW), and High (15GW) amounts of new or replacement Coal power plant
• Explore options based on 50% coal / 50% gas ..., ie Medium Coal Scenario 10GW of coal to be built by 2016
**Existing UK Coal Fleet**

### Opt-Out

<table>
<thead>
<tr>
<th>Power station</th>
<th>Owning Company</th>
<th>MWe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ironbridge</td>
<td>Eon</td>
<td>972</td>
</tr>
<tr>
<td>Kingsnorth</td>
<td>Eon</td>
<td>2000</td>
</tr>
<tr>
<td>Didcot</td>
<td>RWE Npower</td>
<td>1920</td>
</tr>
<tr>
<td>Tilbury</td>
<td>RWE Npower</td>
<td>1050</td>
</tr>
<tr>
<td>Cockenzie</td>
<td>Scottish Power</td>
<td>1200</td>
</tr>
<tr>
<td>Ferrybridge (2 units)</td>
<td>SSE</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Total Opt-Out</strong></td>
<td></td>
<td>8142</td>
</tr>
</tbody>
</table>

Allowed to operate only 20000 hrs in total from 2008 and must close by end 2015. Most will close much earlier.

### Opt-In

<table>
<thead>
<tr>
<th>Power station</th>
<th>Owning Company</th>
<th>MWe</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilroot</td>
<td>AES</td>
<td>520</td>
<td>ELV</td>
</tr>
<tr>
<td>Eggborough</td>
<td>British Energy</td>
<td>2000</td>
<td>NERP</td>
</tr>
<tr>
<td>Uskmouth</td>
<td>Carron Energy</td>
<td>393</td>
<td>ELV</td>
</tr>
<tr>
<td>Drax</td>
<td>Drax Power Limited</td>
<td>3960</td>
<td>NERP</td>
</tr>
<tr>
<td>Cottam</td>
<td>EdF Energy</td>
<td>1948</td>
<td>ELV</td>
</tr>
<tr>
<td>West Burton</td>
<td>EdF Energy</td>
<td>1924</td>
<td>ELV</td>
</tr>
<tr>
<td>Ratcliffe</td>
<td>Eon</td>
<td>2000</td>
<td>ELV</td>
</tr>
<tr>
<td>Rugeley</td>
<td>International Power</td>
<td>996</td>
<td>ELV</td>
</tr>
<tr>
<td>Aberthaw</td>
<td>RWE Npower</td>
<td>1386</td>
<td>ELV</td>
</tr>
<tr>
<td>Longannet</td>
<td>Scottish Power</td>
<td>2400</td>
<td>NERP</td>
</tr>
<tr>
<td>Ferrybridge (2 units)</td>
<td>SSE</td>
<td>1000</td>
<td>ELV</td>
</tr>
<tr>
<td>Fiddlers Ferry</td>
<td>SSE</td>
<td>2000</td>
<td>ELV</td>
</tr>
<tr>
<td><strong>Total Opt In</strong></td>
<td></td>
<td>20527</td>
<td></td>
</tr>
</tbody>
</table>

Must fit additional NOx reduction by 2016.
Opportunities for Clean Coal Power Plant in UK

• New capacity

• Opted-out plant - Replacement or upgrade between 2010 and 2015
  – Advanced supercritical retrofit possible with FGD and SCR
  – Or replacement plant on the same site

• Opted-in plant
  – As a minimum additional investment in NOx reduction will be necessary by 2016, eg SCR. These projects have to start soon.
  – Advanced supercritical retrofit possible.
  – Or replacement plant on the same site

All the new/replacement plant will need to be at least “Capture ready”, and some may be fitted with carbon capture from the onset.
Replacement Coal Power Plants (10GW) by end of 2015 - possible scenario

- New-Build (or retrofit) plants with CCS incorporated
  - up to 2 GW being planned, but likely to be less unless Treasury incentives for *multiple* projects are put in place quickly
  - Ought to cover the main options for capture and storage
  - >>> best CCS options understood by 2012-2015

- “Capture-ready” New-Build or Retrofits
  - at least 8 GW
  - >>> short term CO₂ reductions, security of supplies, economic electricity and options for CCS 2012 onwards

>>> combination meets all three EWP objectives, sets a global example
### Plans for coal-fired power plant in UK

<table>
<thead>
<tr>
<th>Location</th>
<th>Size/CCT</th>
<th>Date</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New Capacity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powerfuel</td>
<td>Hatfield</td>
<td>430MW IGCC with capture</td>
<td>2011</td>
</tr>
<tr>
<td>Eon</td>
<td>Killingholme</td>
<td>450-500 MW IGCC with CCS</td>
<td>2012</td>
</tr>
<tr>
<td>Centrica</td>
<td>Teesside</td>
<td>800 MW IGCC with CCS</td>
<td>2011</td>
</tr>
<tr>
<td>Others</td>
<td>New build ASC/IGCC</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Replacement / Retrofit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSE</td>
<td>Ferrybridge</td>
<td>1 or 2 x 500MW ASC Retrofit (Capture ready)</td>
<td>2011</td>
</tr>
<tr>
<td>RWE</td>
<td>Tilbury</td>
<td>2x800 MW ASC (Capture ready)</td>
<td>2013+14</td>
</tr>
<tr>
<td>Eon</td>
<td>Kingsnorth</td>
<td>2x800 MW ASC (Capture ready)</td>
<td>2012</td>
</tr>
<tr>
<td>Others</td>
<td>Several (at least 5)!</td>
<td>ASC new/retrofit (Capture ready)</td>
<td></td>
</tr>
</tbody>
</table>

**FEED study contracted with Doosan Babcock and Siemens**
### Optimum programmes – Coal Power Plant

<table>
<thead>
<tr>
<th></th>
<th>Retrofit</th>
<th>New Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning, consents and FEED</td>
<td>1 year</td>
<td>2 - 3 years</td>
</tr>
<tr>
<td>Design and engineering</td>
<td>1 year</td>
<td>1 year</td>
</tr>
<tr>
<td>Manufacture</td>
<td>1 year</td>
<td>1 year</td>
</tr>
<tr>
<td>Construction and commissioning</td>
<td>1 year</td>
<td>2 years</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4 years</strong></td>
<td><strong>6 - 7 years</strong></td>
</tr>
</tbody>
</table>

**Consider two Scenarios**

*Scenario 1- “just in time”*

*Scenario 2- “phased build”*
Scenario 1- Just in Time

- 10 GW by 2011
- 20 GW needed in 9 years by 2016
- Further 10 GW by 2016
- 2GW

Existing capacity
Implied capacity demand
Scenario 2- Phased Build Gas and Coal

GAS 5x 2 GW = 10 GW by 2014

20 GW needed in 9 years by 2016

COAL 5 x 2 GW = 10 GW by 2016

20 GW needed in 9 years by 2016
Key specialist resources to build the new stations

Key specialist resources are

• Design and engineering in the Boiler and Turbo-generator OEMs

• Procurement of materials and performance equipment

• Construction and commissioning labour

Doosan Babcock has retained its skills through export sales of new boilers, construction of plant for others and boiler services/upgrade work in the UK

Capacity recently enhanced through link to our new parent company
Key resources maintained – Doosan Babcock

- Changshu 3 x 600 MW supercritical boilers
- Rebuild 800 MW supercritical Nikola Tesla
- Trimble County B 750 MW supercritical boiler for EON USA
- Doosan Changwon works, Korea
Issues for the industry

• Many additional European and global projects to follow those already ordered
• Many OEMs booked out to 2012
• Global capacity of manufacturers’ works is limited
• Materials supply bottlenecks define the manufacturing programme
• Limited construction capacity in any one region of the country, even with the use of EU labour
• There has not been a UK build plan against which the industry can make its plans

Are the plans for training Engineers and Construction craft workers adequate?

Key Construction labour skills for Doosan Babcock are Platers, Fitters, Welders, Pipefitters and Erectors/riggers
Construction resources depend on plant mix (Boilermaker’s portion)

- **New Build Coal (1 unit)**
- **Supercritical Retrofit Coal (1 unit)**
- **New Build Nuclear 1GW**
- **New Build CCGT 0.8GW**

Staff vs. Labour for each project over the years.
3500 men for 3 years for only the “boiler” portion! Turbine and Civils additional. Total would be about 12000.
Construction labour resource ‘Phased build’ scenario

1000 - 1500 men for 6 years for the “Boiler” portion
Turbine and Civils additional
Total 5000

- Total CCGT
- ASR Coal
- New Build Coal
- Nuclear NB
- Resource Total
Solutions

• Develop an industry plan
  – Seek standardisation within companies and between companies to avoid multiple engineering and simplify future Repair + Maintenance
  – Plan to phase projects (means accelerating some projects)
  – Stagger construction of Units at any one site (3-6 months stagger is optimum)

• Develop an Industry-wide Training Plan to build skill base

• Implement measures to simplify planning and consents, including standards for BAT

All are topics for the Power Generation subgroup of the Coal Forum
Conclusions – Doosan Babcock

• Capture - ready clean coal technology available now for New build and Retrofit

• Continue to work with customers to develop their projects
  – show benefits of standardisation (steam conditions, unit size... )
  multiple unit ordering,
  – optimum stagger of units at each site (6 months)

• Continue our underpinning R+D on clean coal and CCS

• Build up our engineering resources (in UK, India, and China...) in line with firm demand/orders

• Build up Construction resources
  – including increased apprentice intake if supported by ECITB

• Use the Coal Forum as a route towards a better basis for planning
• What do we need from the government, EU?
European Technology Partnership  ZEP - Zero Emission Fossil Fuel Power plant

SRA AND SDD launched in Brussels 13 Sept 2006

Strong support from industry for an ambitious programme of R,D and Demonstrations (10 – 12 around Europe)

Complementary actions to facilitate deployment
What are EU Objectives?

Environment:

Security of supply:
- Continued presence of coal in the future energy/electricity mix.

Lisbon Strategy:
- Business opportunities: EU leads technological development.
- EU industry exports: main coal generation markets are in third countries.

Operational objectives:
Until 2010: new plants with BAT + capture-ready.
By 2015: construction of a series of demo. plants with efficient conversion of coal or natural gas and CCS.
After 2020: ZEP is the technology of choice.
UK Coal Forum

• “The Government will convene a coal forum to bring together coal-fired generators, coal producers and suppliers, power plant suppliers, trade unions, small businesses and other parties in order to help them to find solutions to secure the long-term future of coal-fired power generation and UK coal production”

• Announced in the DTI Energy Review report 2006

• Four meetings held, chaired by Sir John Collins, attended by the Energy Minister Lord Truscott

• Sub groups established on Planning, Infrastructure, Power generation and Future markets, looking at what is needed for Low, Medium, or High Coal scenarios
Messages to the Government ahead of the 2007 Energy White Paper

• We need recognition that it is already a major challenge to fill the generation gap!
  – Never forget that if plants are not built the lights will go out
  – Phasing of build essential, “just in time” not feasible
• EWP must be absolutely clear that new/replacement coal and gas power plants are necessary
  – Statement of Need for fossil fuel power plant (coal and gas), FGD and SCR retrofits and CCS facilities
  – Unnecessary planning and consent hurdles to coal power plant must be avoided
  – Adopt EU policy on fossil power plants - capture ready from 2010, CCS from 2020, 10-12 demonstrations of CCS operational by 2015
• Kick- start multiple CCS demonstration projects and re-establish confidence in long term support for R+D
• Look at implications of low coal, medium coal and high coal scenarios on demand for coal (UK and imported)
• Ensure training agencies, universities and Trade Unions recognise new build coal and gas power plant (and CCS) in their forward planning
“We remain committed to development and global implementation of carbon-abated Clean Coal Technologies as rapidly as the market allows”

Thank you for your attention

mfarley@doosanbabcock.com