



Doosan Babcock Energy

CO₂ Capture - Ready : Technical and policy issues

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EPRG Cambridge Dec 7 2007

Company update



Nuclear



Thermal



**Turbine &
Generator**



Desalination



Casting & Forging



Construction

- Our new name is Doosan Babcock Energy Limited,
- We are now a subsidiary of Doosan Heavy Industries and Construction of South Korea, part of the Doosan Group – the oldest and one of the top 10 conglomerates in Korea
- Doosan Heavy is a market leader in gas, coal, nuclear power generation and desalination . Orders in 2007 to date total 5 Bn USD
- Doosan Babcock Energy remains committed to all forms of power generation, including clean coal, nuclear, gas and renewables
- Doosan Babcock Energy will be the Doosan global Centre of Excellence and global R+D Centre for Boilers (including Clean coal and Carbon dioxide capture)
- Doosan Babcock Energy's territory is Europe, USA, Soth Africa and China

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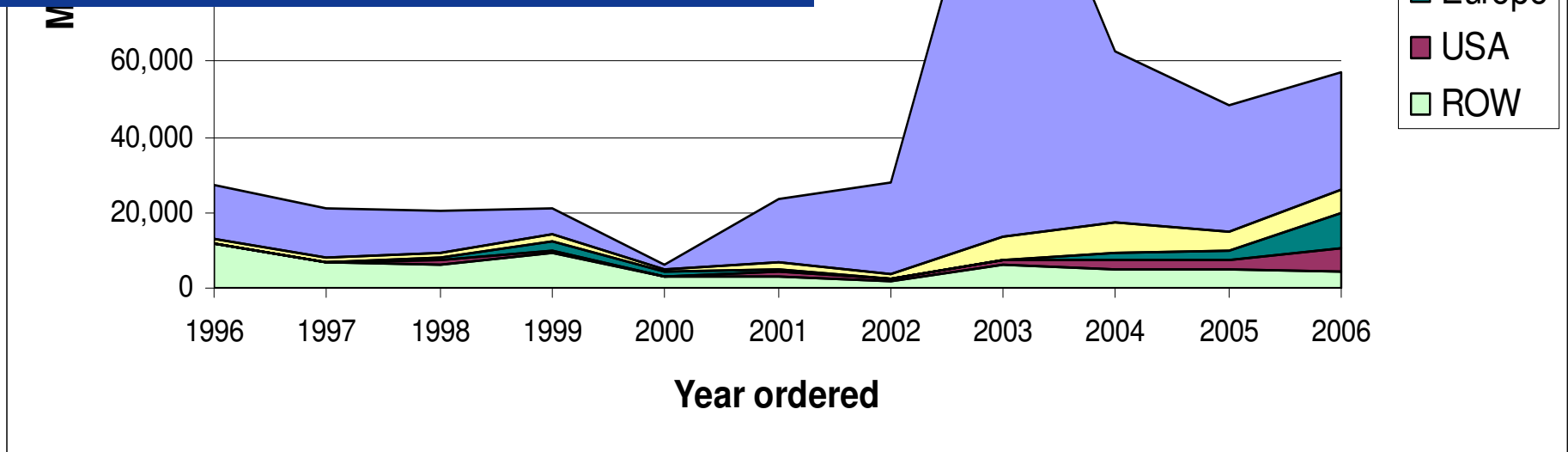
- Doosan Babcock
- **Capture ready power plant**
 - Technologies and their validation
 - Retrofit study project (DTI 407)
 - Definition (IEA, EPPSA)
 - Policies
 - EU policies on fossil fuel power plant, CCS
 - UK policies

How things have changed for coal and gas

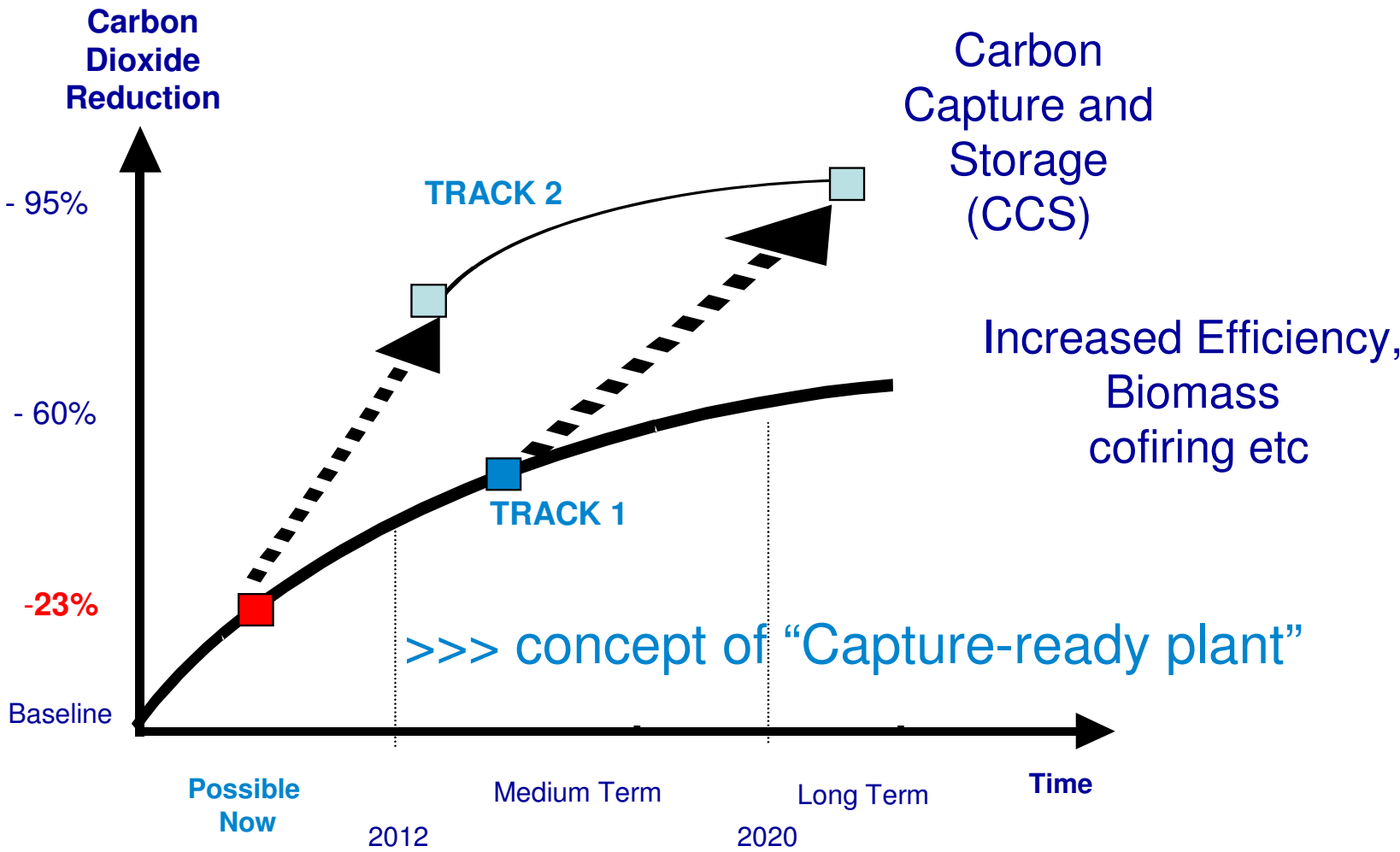
- **Recognition that the world scene will continue to include massive amounts of coal generation, and coal fired power plant must be cleaned up, not substituted**
- **Loss of confidence in gas, and recognition that gas too needs to be much cleaner to achieve climate change targets**
- **EU and UK politicians 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.**
- **Wide recognition of the need for new coal power plants around Europe, USA and Africa as well as China, India etc**
- **Wide acceptance, evidenced by our customers' plans, that Clean Coal can be Supercritical or Gasification and that plants can be designed to be "Capture Ready"**
- **Almost all plants now call for EU standards on emissions**
- **Understanding that to meet CO₂ reduction targets CCS will be needed not only on new build plant (coal and gas) but also on the large numbers of coal fired plant currently being built since these plants are likely to be in operation for 40- 50 years**
- **Recognition that plants need to be built capture ready as soon as possible to avoid carbon lock-in**

New Build Coal Power Plant Orders (>200MW)

- Coal fired power plants planned around Europe
 - Germany – 21GW hard coal and 3.8 GW lignite by 2014
 - UK – 10.6GW by 2016
 - Poland – 8GW needed
 - Italy, Belgium, Holland, Spain....



CO₂ Abatement from Fossil Fuels – Twin Track Approach



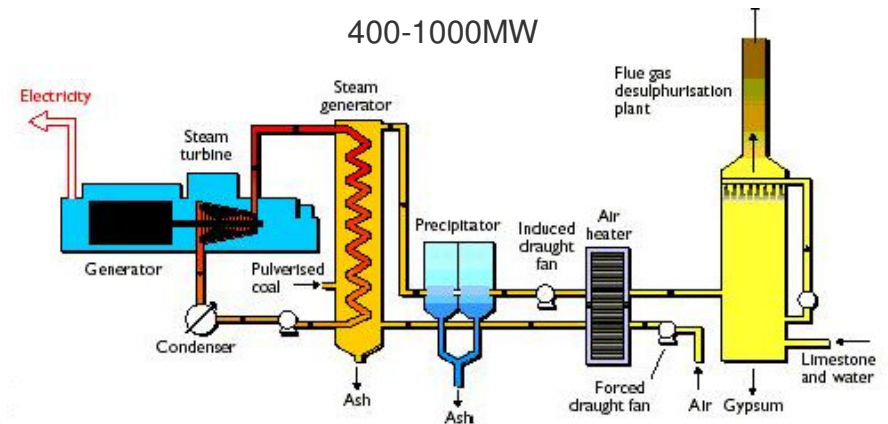
Capture ready clean coal power plant

- **Doosan Babcock Energy has recognised that CO₂ reduction targets will need CCS as well as efficiency improvement**
- **Efficiency improvement is of great benefit both for its own sake and as a precursor to CCS but ultimately on its own will not be enough**
- **Capture ready is very important in the context of the New Build power plants which are needed now on a scale larger and on a timescale faster than it is feasible to adopt CCS**

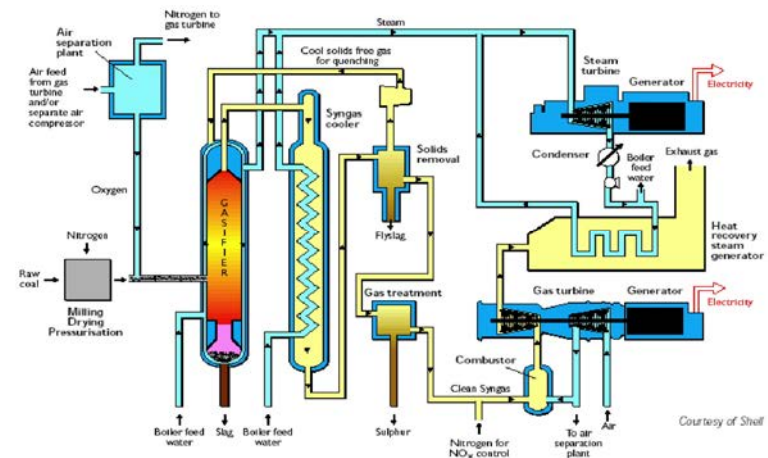
Clean Coal Technologies available now

- Higher efficiency / lower emissions than current coal, better than LCPD standards
- 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 and is especially suitable for Petcoke

Advanced Supercritical Pulverised Coal
Boiler/Steam Turbine
400-1000MW

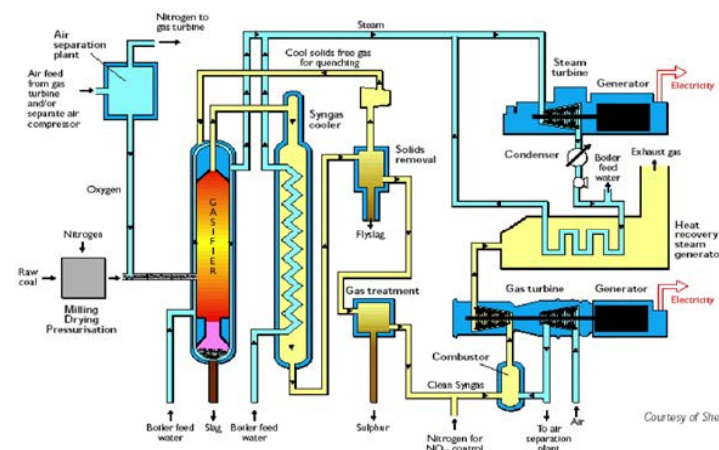


Integrated Gasification Combined Cycle
250-900MW



Integrated Gasification Combined Cycle (IGCC)

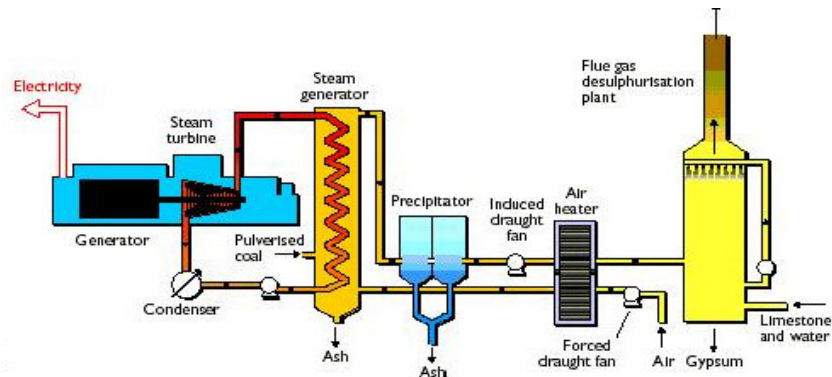
Integrated Gasification Combined Cycle 250-900MW



- 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%)
- IGCC projects are being developed in UK, Europe and USA, some with CCS, but few are certain to go ahead
- Main challenge for CCS is the GT (has to fire natural gas, syn gas and hydrogen in turn)

Carbon-Abated Clean Coal Power Plant

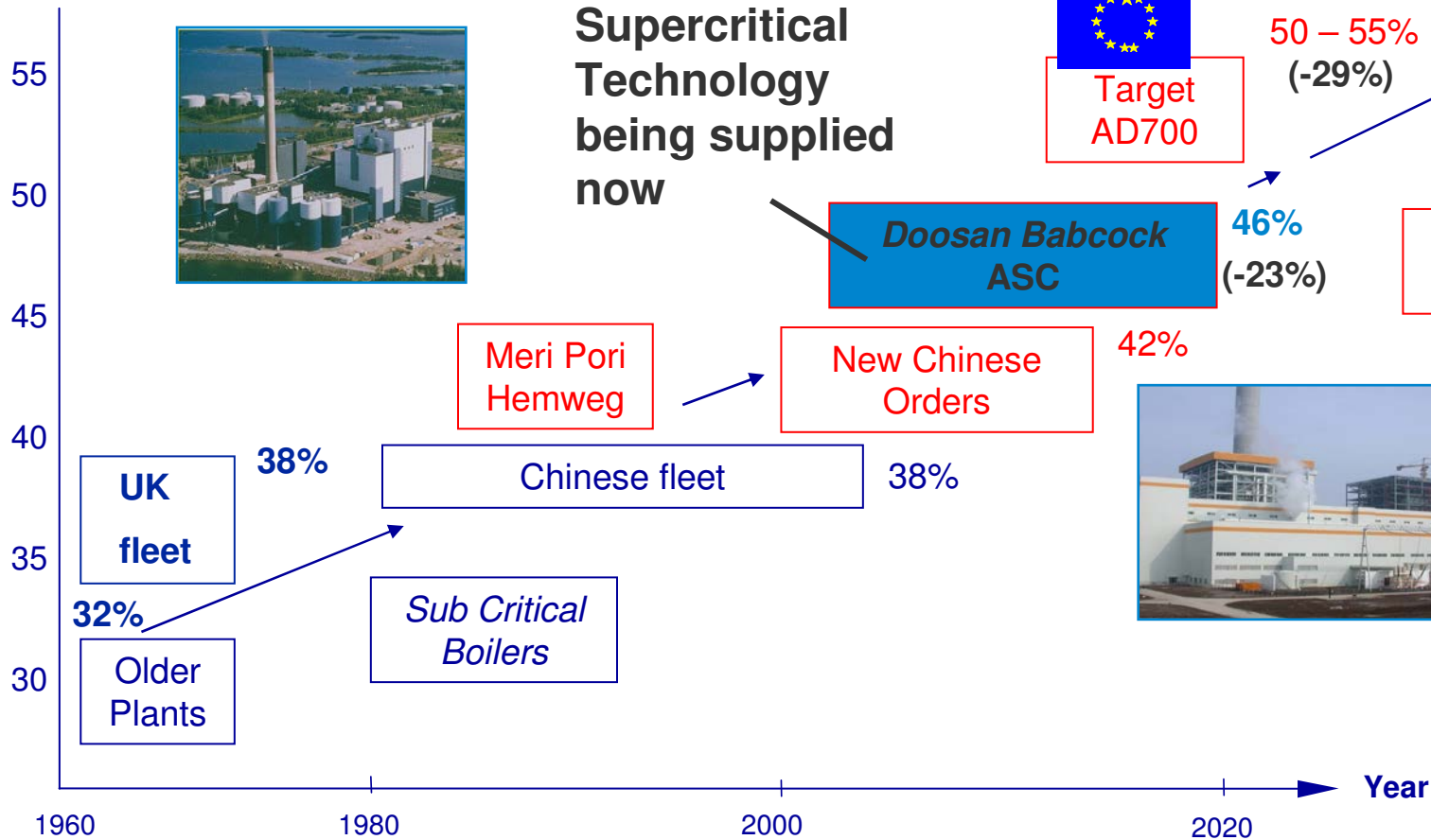
Advanced Supercritical Pulverised Coal Boiler /Steam Turbine 350-1000MW



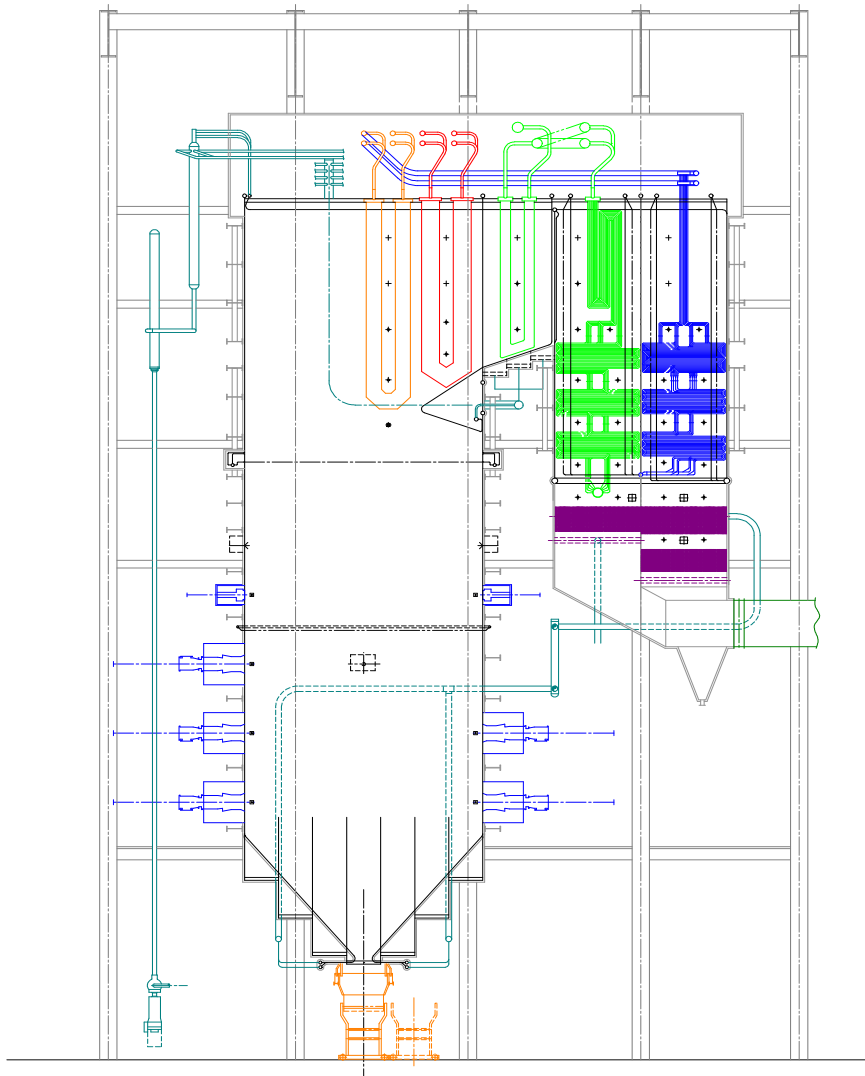
- Best Available Technology *now 46/47% efficient (290 bar/600C/610C)*
- Advantages are proven Availability (>95%), Load Flexibility (20-100%) and wide fuel range (inc Biomass cofiring up to 20%)
- Matches any other coal technology for emissions, easily meets LCPD limits for 2016
- Can be built now, designed to be “capture ready” and fitted with economical CO₂ capture when CCS is possible
- Can be retrofitted to existing UK stations
- Technology of choice for vast majority of new build orders

Abatement of CO₂ by efficiency improvement of Pulverised Coal Plant

Plant efficiency
% NCV



Capture ready 2x 800MW 46 % efficiency two pass boiler



Main Steam

281bar

602.45 °C

Reheat Steam

605 °C

International traded Bituminous Coal with 3 specified guarantee coals plus 100% oil firing

Boiler E

Ordered in Germany

O₂ at econ

Suitable for UK

Boiler HP steam flow

578.65 kg/s

Pressure drop (bar)

HP

27

RH

2.4

SCR inlet NOx (worst coal)

<450mg/Nm³

SCR outlet NOx (all coals)

200mg/Nm³

CO at econ outlet

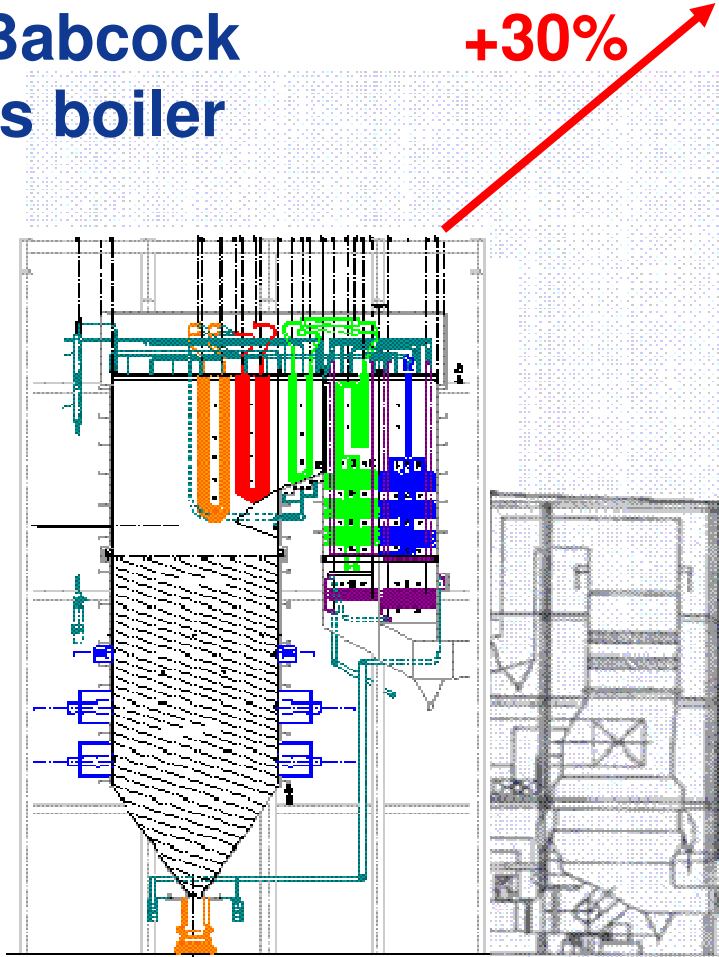
<200mg/Nm³

Boiler types

Doosan Babcock Two-pass boiler

EL 250 ft
76 m

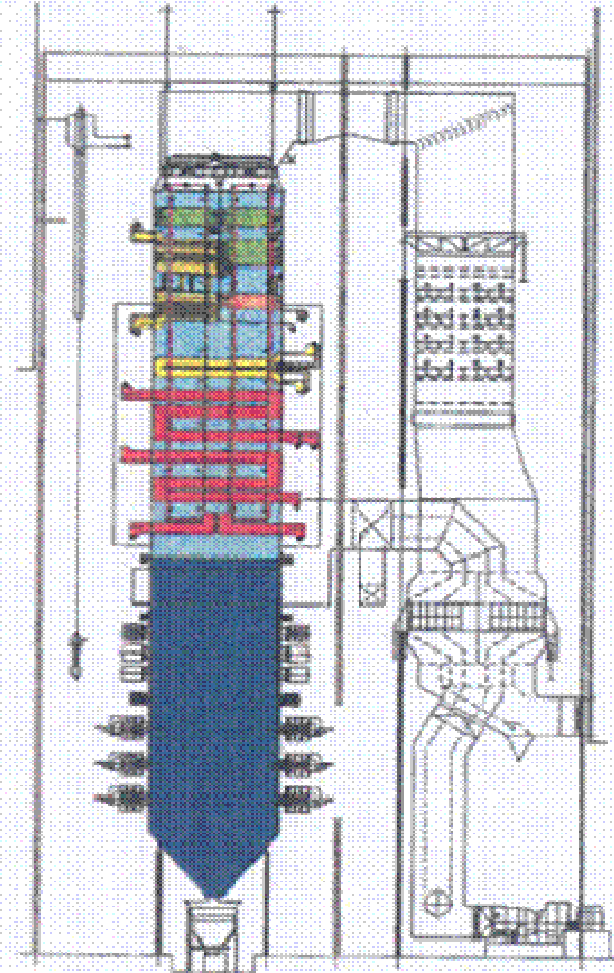
eg
Trimble
County
for EON
USA



+30%

Competitor's Tower boiler

FL 327 ft
99.7 m



Comparison of Carbon capture options for Coal power plant

Three options:

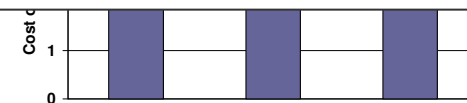
Post Combustion Capture – Amine or Ammonia scrubbing

Oxyfuel firing

Precombustion – IGCC

Numerous studies show these are similar in resulting efficiency and cost of electricity.

No clear winner but PCC and Oxyfuel needed for retrofit to plants currently being built around the world (including China and India)

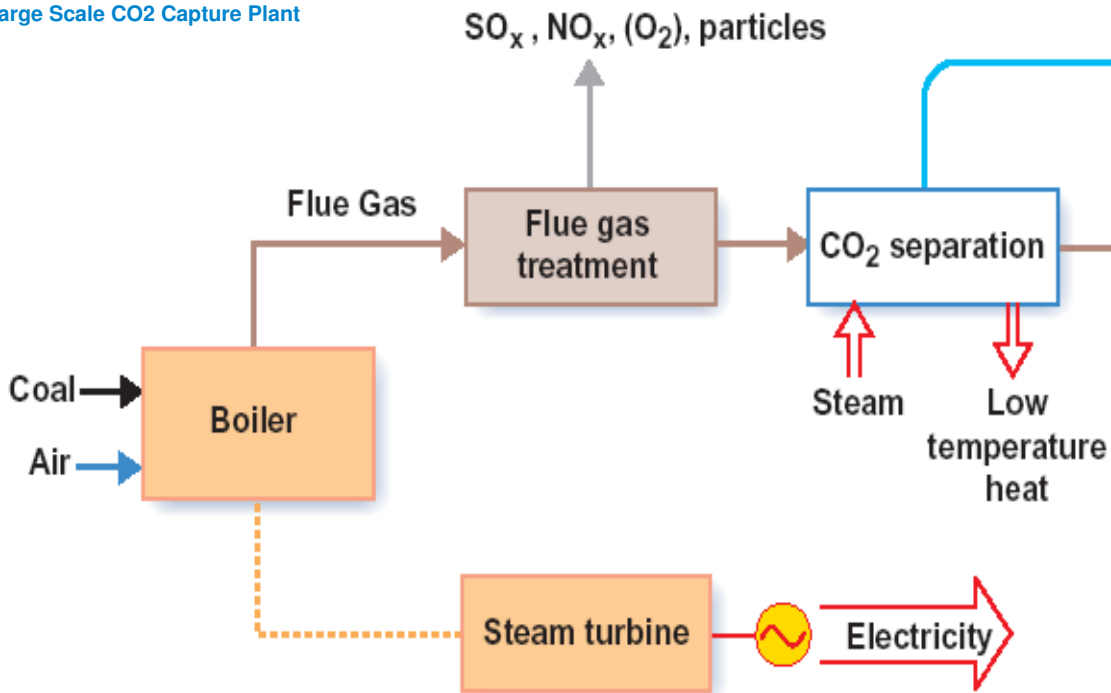


Amine Oxyfuel IGCC

Post-combustion Carbon Capture – Flue Gas Scrubbing on Pulverised Coal Plant



Large Scale CO2 Capture Plant



- IEA studies complete
- Elsam slip stream demo on Amine scrubbing underway
- New Alstom demo projects on chilled Ammonia scrubbing
- Collaborative UK DTI project about to start, led by RWE Npower
- Requires scale up (factor of 10)
- Several 100MW demos planned
- Need larger demonstrations as a step towards large power plant

Capture ready for Post Combustion Capture

- **Space for Scrubber close to boiler/FGD**
- **Space for CO₂ compression**
- **Steam source for Reboiler**
- **Control of NO_x (NO₂), SO_x into PCC plant**

Carbon Capture by Oxyfuel firing on Pulverised Coal Plant

O₂/CO₂ recycle (oxyfuel) comp

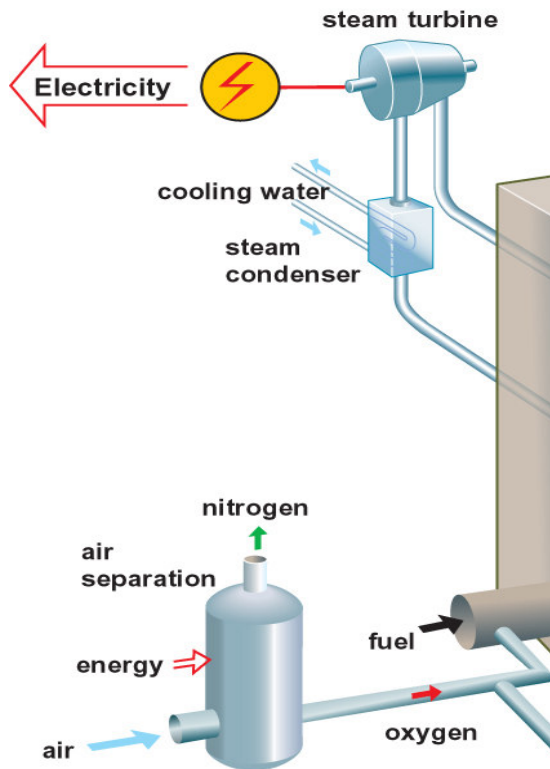


Figure courtesy of Vattenfall

- Pilot scale tests by Doosan Babcock Energy 1996
- IEA studies completed
- EU project ENCAP underway
- EON 1MW rig now operational, confirmed DBE results
- DTI funded collaborative R&D projects in progress (Doosan Babcock Energy, EON, RWE, Air Products ...)
- Vattenfall 30MW demonstration plant being built , and similar projects at Lacq and Callide
- Full scale 40 MW burner test planned by Doosan Babcock in 2008/9
- Several boilermakers developing this technology for 2012 implementation
- Intermediate scale demo needed in Europe (say 200MW)

Doosan Babcock burner test facility to be converted to Oxycoal firing

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

£7M project co-funded 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



Capture Ready for Oxyfuel

- **Space for Air Separation Unit**
- **Space for CO₂ cleaning and compression**
- **Space for CO₂ recycle ducts**
- **(FGD may be needed for some coals)**

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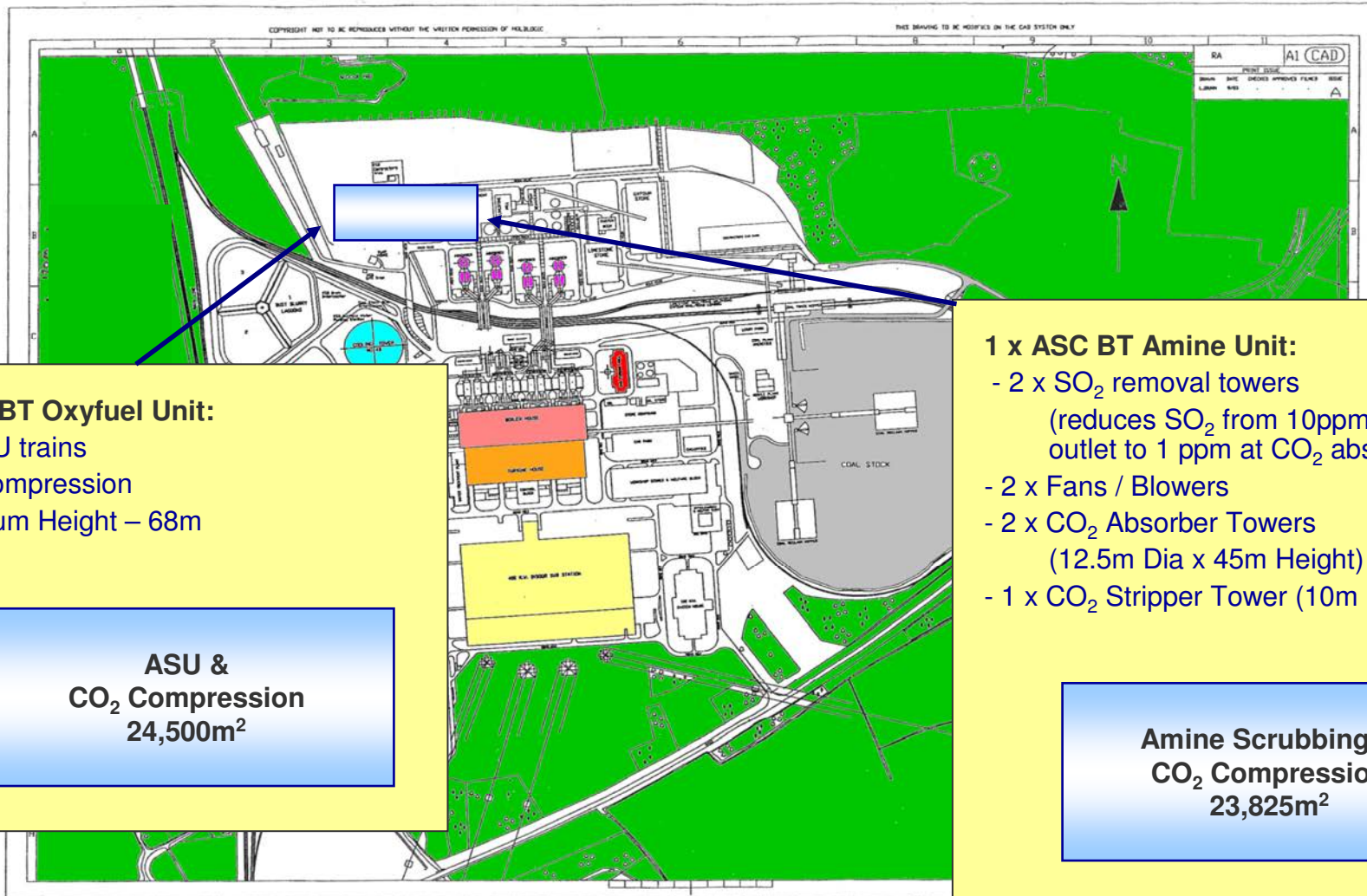
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DTI Project 407 : Retrofit of Advanced Supercritical Boiler/Steam Turbine and CO₂ Capture to UK Coal Fired Power Plants

- Retrofit of carbon abated clean coal technologies is a practical solution with no technical or physical show stoppers being identified in the course of the project.**
- ASC boiler/turbine technology is available now with the appropriate guarantees for retrofitting to coal-fired power plant to improve efficiency, reduce fuel costs and reduce CO₂ emissions.**
- The work undertaken has:-**
 - (i) Demonstrated technical feasibility of ASC Retrofit capture-ready plant to UK power plants with compliance to LCPD new plant emission standards.**
 - (ii) Demonstrated technically feasible to retrofit CCS technologies of Amine Scrubbing or Oxyfuel Combustion to an existing coal-fired power plant. However, in most UK power plants there is insufficient space (and insufficient cooling capacity) as required for the application of carbon capture equipment to all units of the power plant.**
 - (iii) Demonstrated that ASC Retrofits and ASC Retrofits with CO₂ Capture (subject to carbon tax / future CO₂ prices) are economically viable in terms of the Cost of Electricity generated.**
- When CO₂ capture and storage becomes economic or mandatory the retrofit routes studied are likely to be amongst the best and most economic options for existing PF power generation plant. The project consortium members are well positioned to exploit the opportunities world-wide.**

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

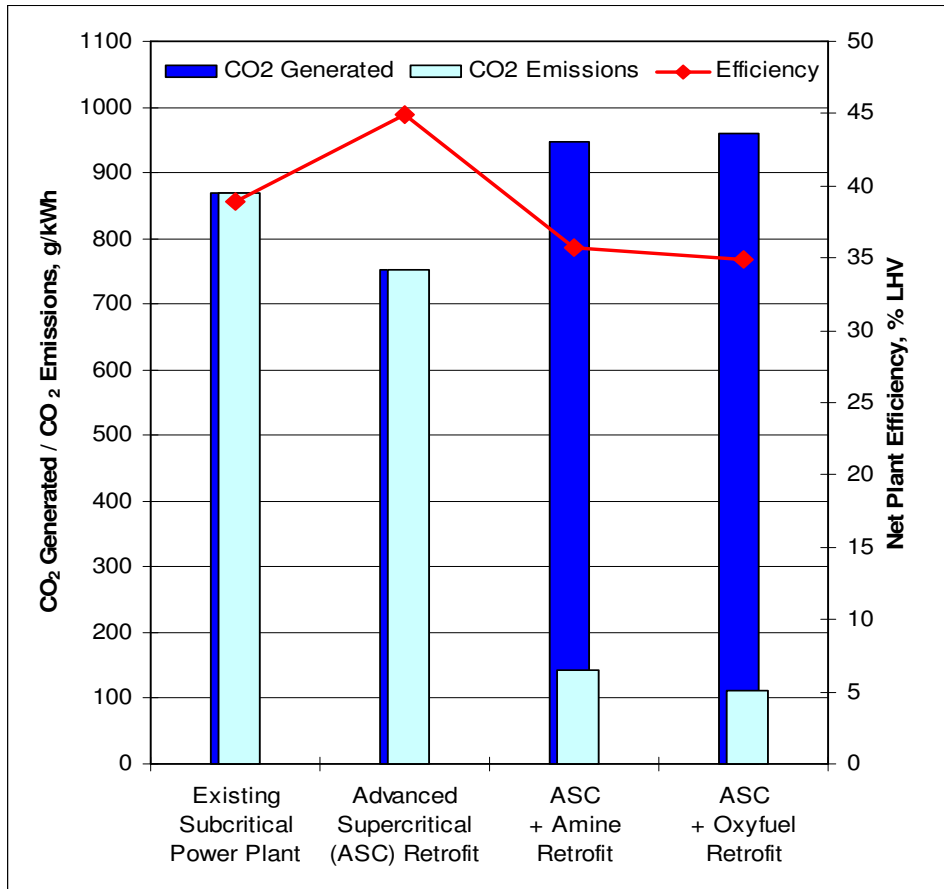
**ASU &
CO₂ Compression
24,500m²**

1 x ASC BT Amine Unit:

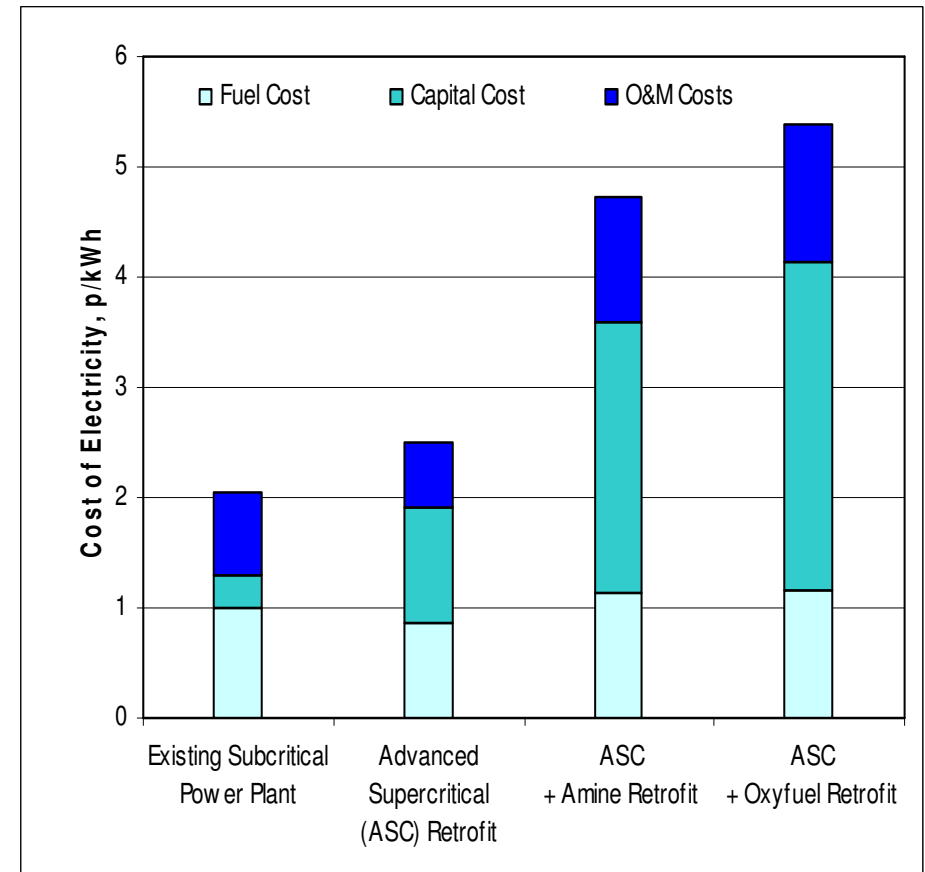
- 2 x SO₂ removal towers
(reduces SO₂ from 10ppm at FGD outlet to 1 ppm at CO₂ absorber inlet)
- 2 x Fans / Blowers
- 2 x CO₂ Absorber Towers
(12.5m Dia x 45m Height)
- 1 x CO₂ Stripper Tower (10m Dia)

**Amine Scrubbing &
CO₂ Compression
23,825m²**

ASC BT Retrofit & CO₂ Capture : Overall Plant Performance



Retrofit Plant Performance



Cost of Electricity

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Capture Ready Definition

- **Definition (IEA)**

- Space for a technically feasible capture option
- Design of plant must not preclude the capture option
- Feasible CO₂ pipeline route to a storage area
- (ref IEA GHG Programme Report 2007- 4 CO₂ capture ready power plants)

- Further guidance published by EPPSA

- **Regulation**

- Avoid being over prescriptive, technologies are evolving

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EU Policies on Coal and CCS

- **EU energy policy must balance the competing requirements of security, environment and competitiveness (Moscow - Kyoto – Lisbon)**
- **EU Energy Package (Jan 2007) recognised the importance of coal in the EU energy mix because of its cost and security of supply advantages but ...**
- **It also recognised that to meet the long term targets (eg 60 % by 2050) for CO₂ reduction , CCS will be necessary on coal and gas plant**
- **The European Commission proposed**
 - **All plants consented from 2010 onwards should be capture ready**
 - **CCS should be mandatory from 2020**
 - **10 to 12 CCS power plants should be operational by 2015 in order to demonstrate the technology**
- **The Spring Council of Ministers endorsed these recommendations and the Commission is now working hard on**
 - **Regulations to control CCS**
 - **How to accommodate CCS in the ETS**
 - **How to support the demonstration projects**
 - **EU (with ETP ZEP) is developing the concept of a Flagship Programme of 10 – 12 projects**
- **Further package on 23 January 2008**

EU Policies on Coal and CCS – further package

- **Communication: Strategic Energy Technology Plan** (published 22.11.2007)
 - CCS included in key technical challenges for next ten years to meet 2020 targets
- **Communication: Supporting Early Demonstration of Sustainable Power generation from Fossil Fuels** (expected 23 January 2007)
 - Considers options for funding/incentives
- **Proposed Directive: Regulation of CCS** (expected 23 January 2007)
 - CO₂ captured and stored will be credited as not emitted under the Emissions Trading Scheme
 - Options considered included the possibility of making CCS (for both new build and the installed base) mandatory, but that this was decided against on cost grounds
 - All new plants must be capture ready from the entry into force of the Directive (and an assessment made of the technical feasibility of retrofitting)
 - “1. The transition to low-carbon power generation requires that new investments in fossil fuel power generation are made in such a way as to facilitate substantial reductions in emissions. To this end, this Directive amends Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants to require that all combustion plants, for which the original construction license or the original operating licence is granted after the entry into force of this Directive, have suitable space on the installation site for the equipment necessary to capture and compress CO₂ and that the availability of suitable storage sites and the technical feasibility of CCS retrofit have been assessed.
 - 2. On the basis of the experience gained with CCS and in the light of developments in the international context, the Commission may make further legislative proposals by 31 December 2015.”

CCS – UK policies

- **Capture-ready recognised in 2007 EWP**
- **Consultation on Capture-ready expected early 2008**
- **Section 36 consents – several CCGT plants - have specified that plant must be capable of having CCS added**
- **EON announced that all future coal fired plants will be capture ready**
- **UK plants will be capture ready**

Dr Paul Golby EON CEO in Energy World Nov 2007:

“Our Kingsnorth project will be built capture ready – ready to have the kit fitted to the units once the technology is proven”

UK power plant plans- coal

	Location	Size/Technology	Status
New Capacity			
Powerfuel	Hatfield	2 x 430MW IGCC with Capture	Section 36 consent. FEED study starting
E.ON	Killingholme	450-500MW IGCC with CCS	Internal feasibility study underway
Centrica	Teesside	800 MW IGCC with CCS	FEED study started
Conocco	Immingham	IGCC/CHP/petcoke	Study
RWE npower	Blyth	New build ASC (Capture ready) 3x800 MW	Scoping Report submitted 11/05/07
Replacement / Retrofit			
SSE	Ferrybridge	1 or 2 x 500MW ASC Retrofit (Capture Ready)	FEED study well advanced
RWE npower	Tilbury	1600MW ASC (Capture Ready)	Scoping Report submitted 13/3/07
E.ON	Kingsnorth	2 x 800MW ASC (Capture Ready)	Section 36 applied for 11/12/06
Scottish Power	Longannet and Cockerzie	ASC retrofit (capture ready), up to 3390MW	Feasibility study announced 17/05/07

UK power plant plans- coal

	Location	Size/Technology	Status
New Capacity			
Powerfuel	Hatfield	2 x 430MW IGCC with Capture	Section 36 consent. FEED study starting

Government CCS Competition

Government plans:

- Call for proposals in November 2007
- Focus on Advanced supercritical pulverised coal and Post combustion capture (including Oxyfuel)
- Will announce winners by early 2009
- Want to see first CCS Demonstration operating by 2014

E.ON	Kingsnorth	2 x 800MW ASC (Capture Ready)	Section 36 applied for 11/12/06
Scottish Power	Longannet and Cockerzie	ASC retrofit (capture ready), up to 3390MW	Feasibility study announced 17/05/07

Plans for Gas- Fired Power Plants

Name	Owner	MW	Section 36	Operation	Status	
Langage	Centrica	890	Approved	2008/09	Under construction	
Immingham	Conocco	+450	Approved	2009		
Marchwood	SSE/ESB	840	Approved	2009	Under construction	2180
Grain	E.ON	1275	Approved	2010	Under construction	
Staythorpe	RWE npower	1650	Approved	2010	Starting 2008	
Uskmouth	Severn Power	800	<i>Approved /CR 28/08/2007</i>	2010	Site works started	3725
Pembroke	RWE npower	2000	Applied	? 2011		
Drakelow	E.ON	1220	<i>Approved /CR 16/10/2007</i>			
West Burton	EDF	1270	<i>Approved/CR 30/10/2007</i>			
Sutton Bridge	EDF	1260				
Partington	Bridestones	380	Approved			
Barking	Barking power	470				6600

Most recent consents include a capture ready condition

BERR Energy Markets Outlook October 2007

Name	Owner	MW	Section 36	Operation	Status	
Langage	Centrica	890	Approved	2008/09	Under construction	
Immingham	Conocco	+450	Approved	2009		

Gas: 12 GW of CCGTs started or planned !!!

Coal: Only 1.6 GW (Kingsnorth) has reached the tender stage

Both: Latest Section 36 consents require plant to be designed to be capture ready

CCS: Government announced competition and that it will consider the possibility of making CCS compulsory for all new fossil power plants

Conclusions

- **Capture - ready clean coal technology available now for New build and Retrofit**
- **Technologies continue to develop so need to avoid being overly prescriptive in the definition**
- **Project developers have to recognise the requirement and take account of it, particularly in respect of the space needed**

Doosan Babcock are committed to development and global implementation of cleaner power plants - clean coal, clean gas, nuclear and renewables as rapidly as the market allows”

Thank you for your attention

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