Doosan Babcock Energy

Future UK Power generation in a carbon constrained world

Mike Farley

Coal Research Forum

17 April 2007

Company update

- 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

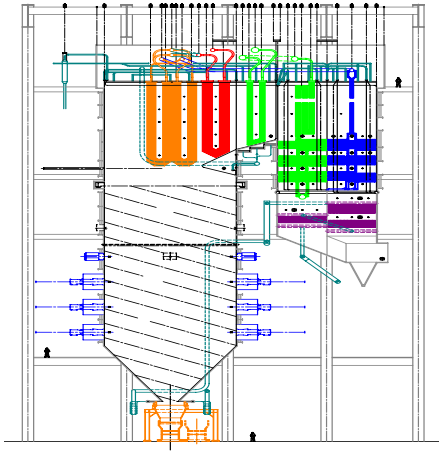
- China
  - 30-40 GW of pulverised coal fired power plant being built each year, all 600MW plant are supercritical
  - 5 x 600MW Doosan Babcock supercritical units now operating

- India
  - 10 GW mega projects, supercritical 800MW pulverised coal

New Coal-fired Power Plant- Overseas

…..Numerous inquiries for new coal fired power plant

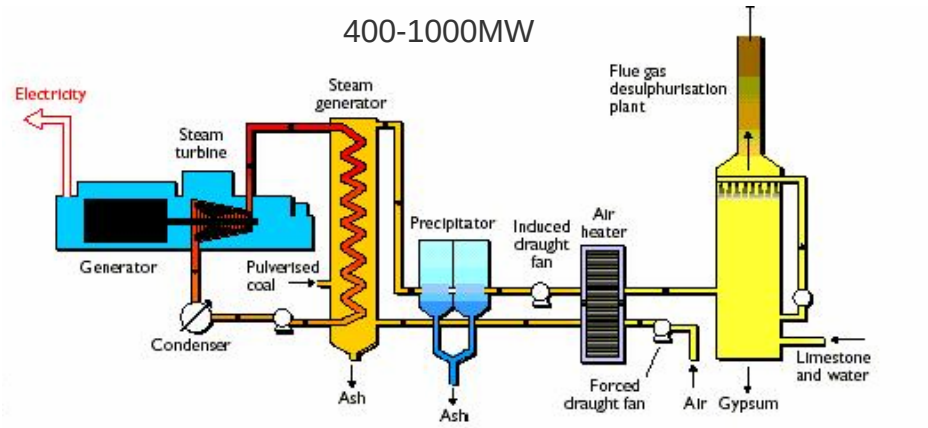
….Almost all are for Supercritical Steam conditions



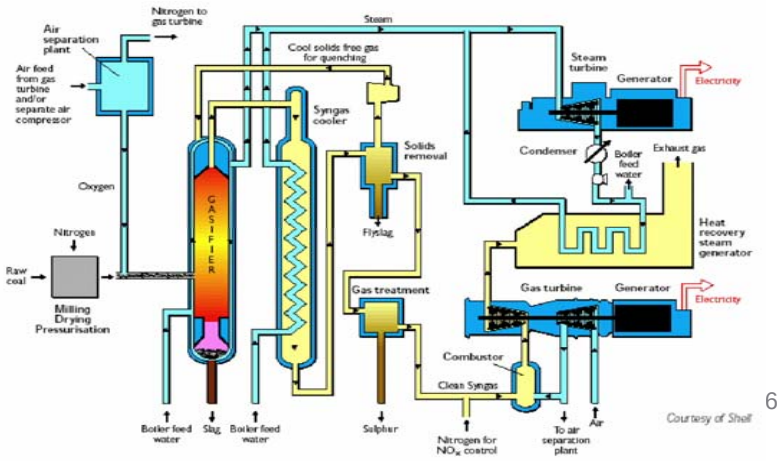
Clean Coal Technologies available now

- **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**

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



Integrated Gasification Combined Cycle
250-900MW



Courtesy of Shell

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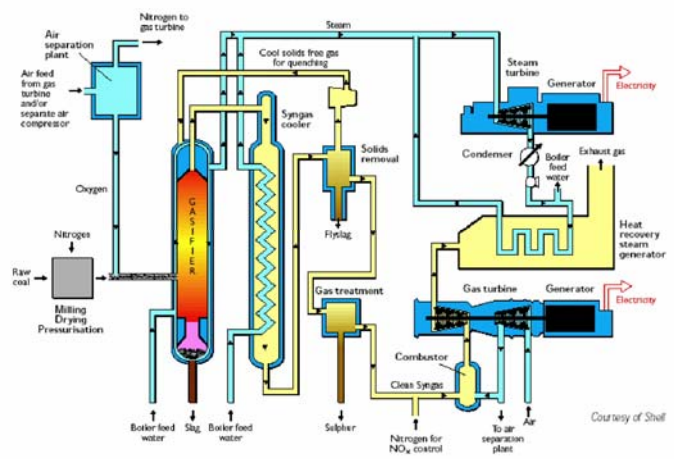
Integrated Gasification Combined Cycle (IGCC)

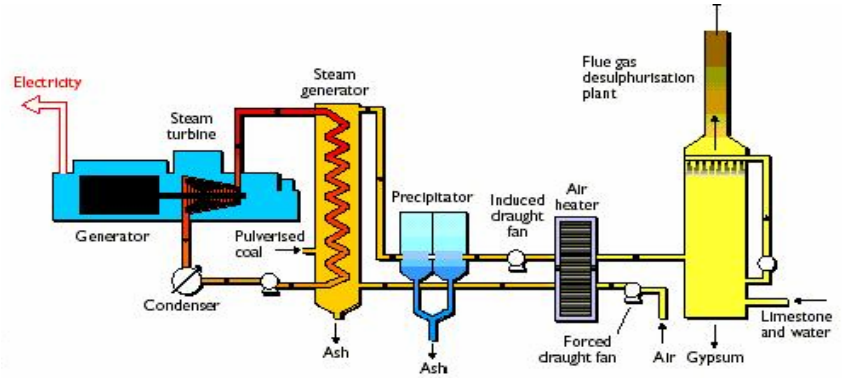
Integrated Gasification Combined Cycle 250-900MW



- **New technology for New-Build claimed attractive because of potential for hydrogen generation and CO_2 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

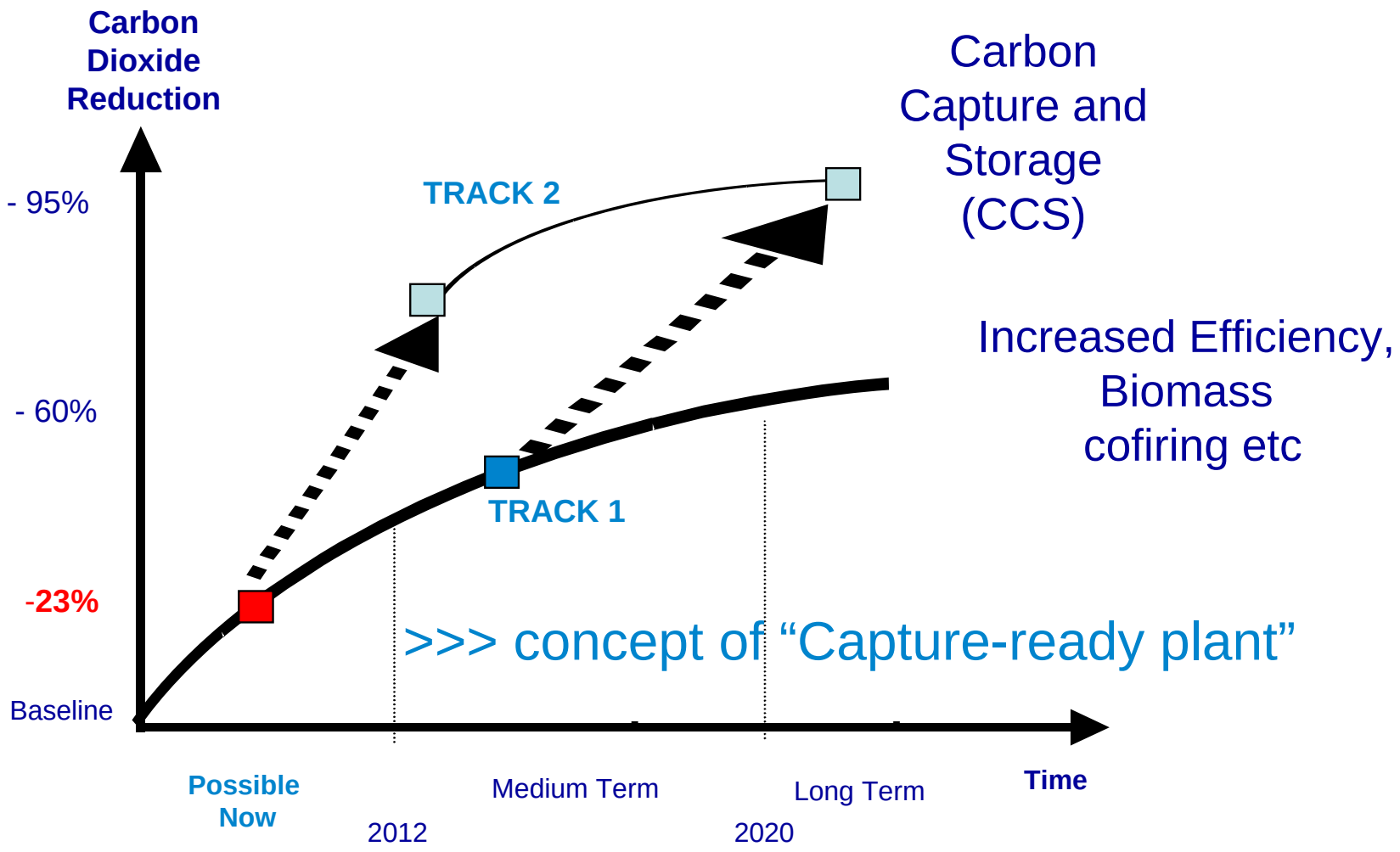


- **Technology of choice for vast majority of new build orders**
- **Best Available Technology *now 46/47% efficient (290 bar/600C/610C)***
- **Advantages are proven Availability (>95%), Load Flexibility (20-100%) and wide fuel range (inc Biomass cofiring up to 20%)**
- **Matches any other coal technology for emissions, easily meets LCPD limits for 2016**
- **Can be built now, designed to be "capture ready" and fitted with economical CO_2 capture when CCS is possible**
- **Can be retrofitted to existing UK stations**

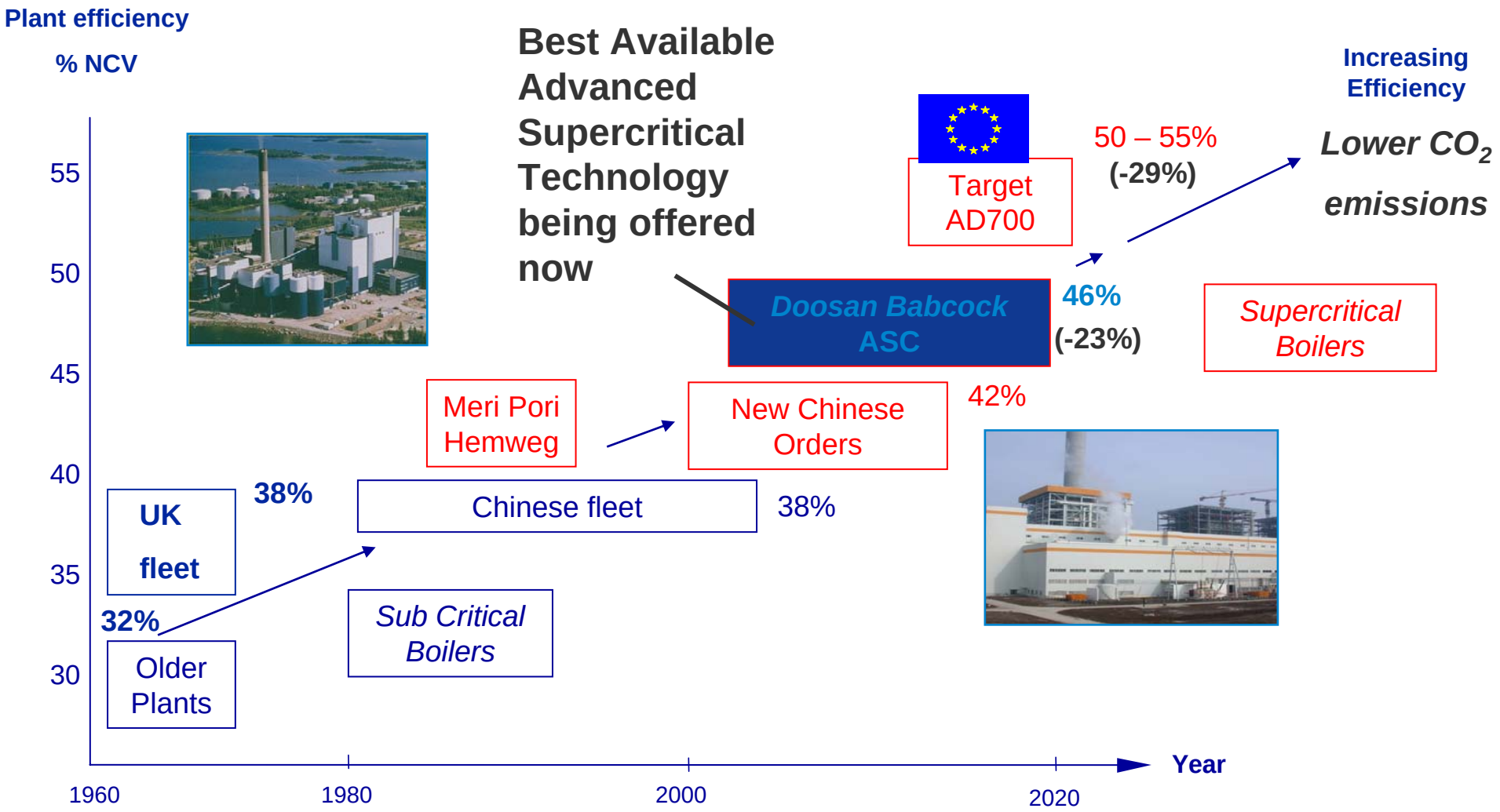
UK Scene – the way forward for Coal

- For both coal and gas, CCS will be needed if CO_2 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

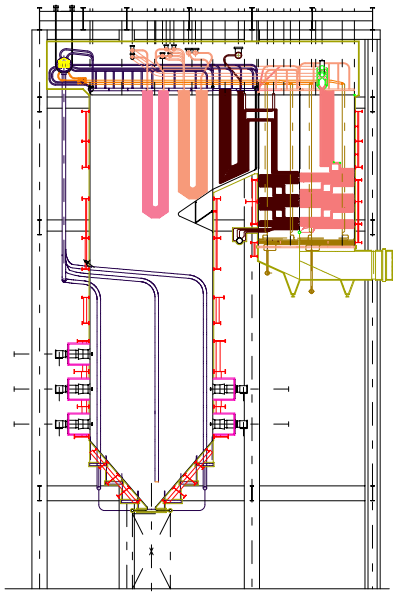
CO_2 Abatement from Fossil Fuels – Twin Track Approach



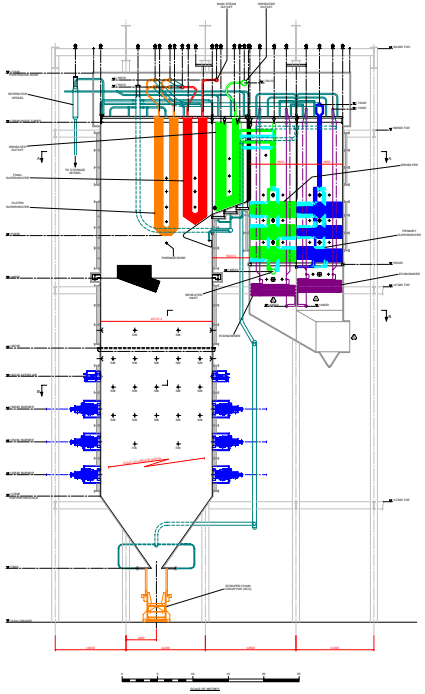
Abatement of Carbon Dioxide by efficiency improvement



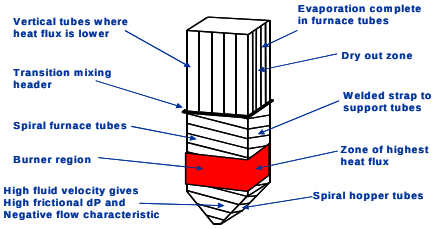
Continuous innovation of two pass boilers – proven operation



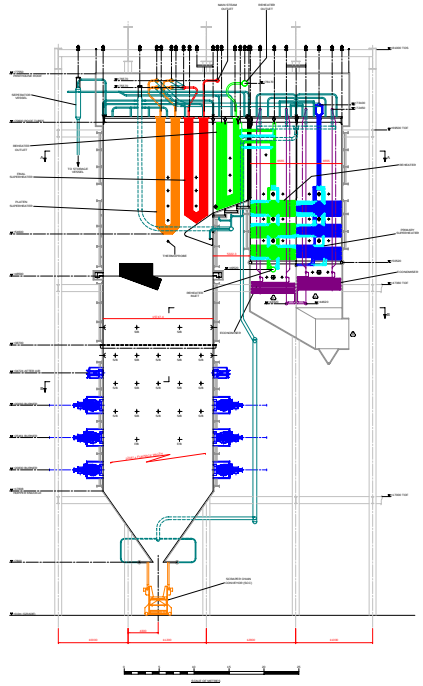
- Natural Circulation

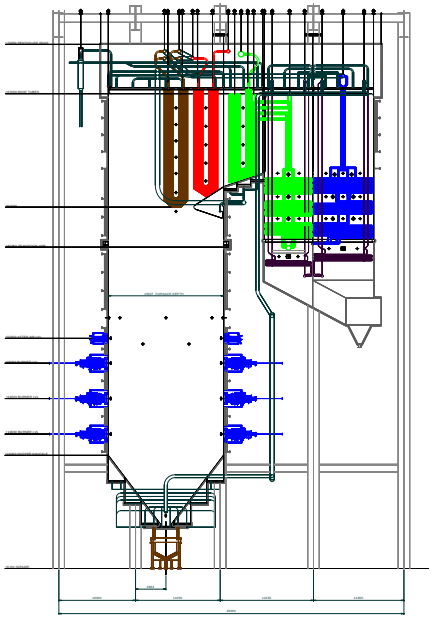


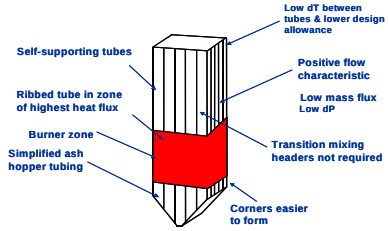
- Once Through



- Supercritical







- Posiflow™

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Boiler types

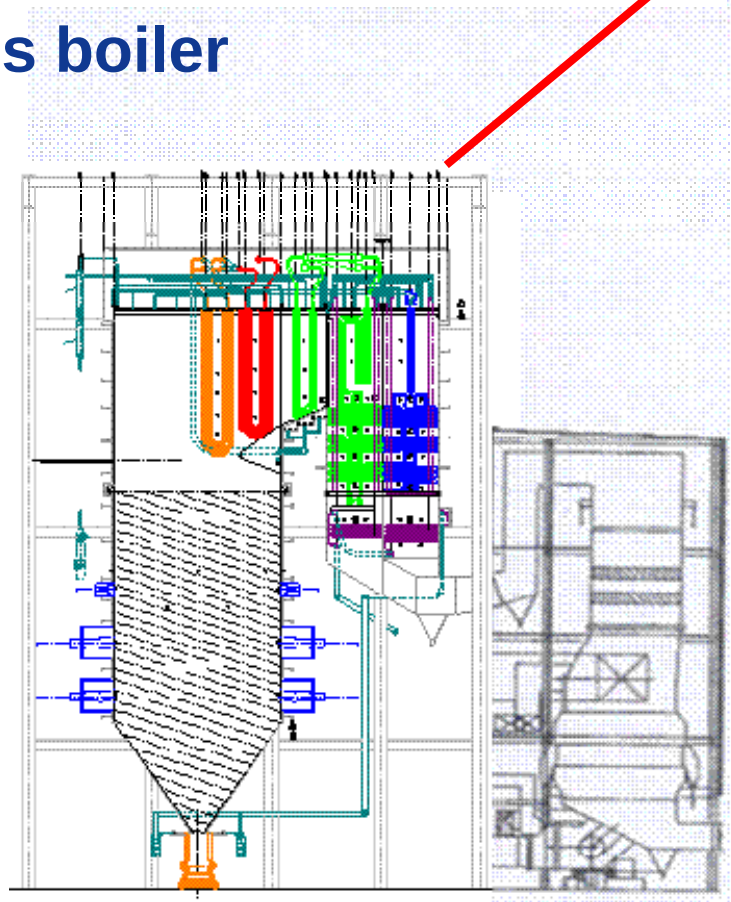
Doosan Babcock Two- pass boiler

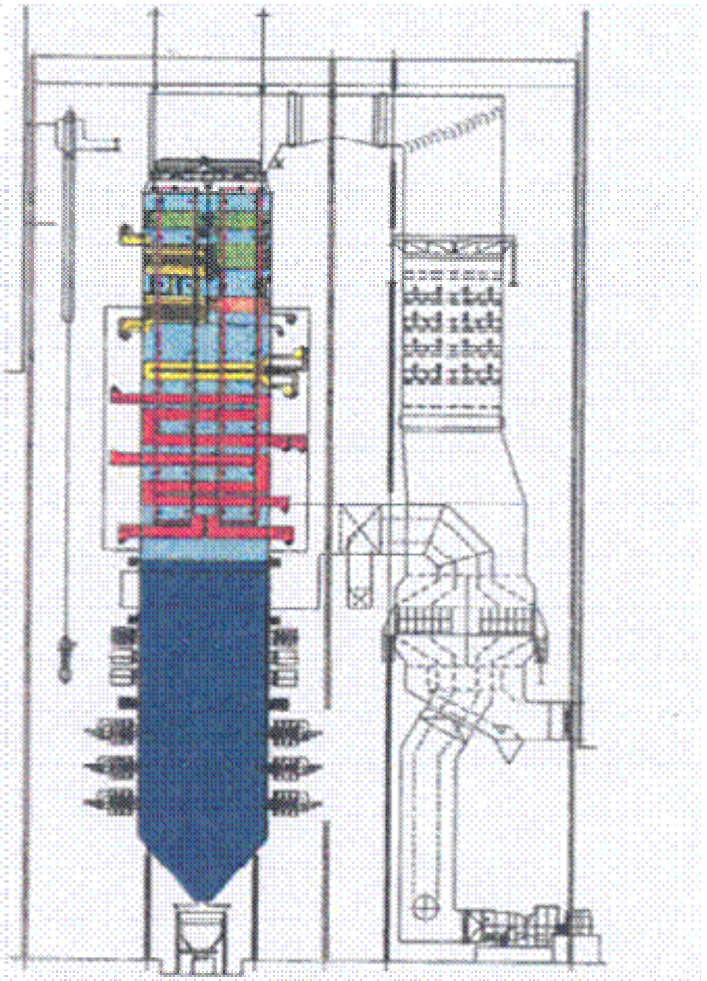
EL 250 ft
76 m

eg Trimble County for EON USA

+30%

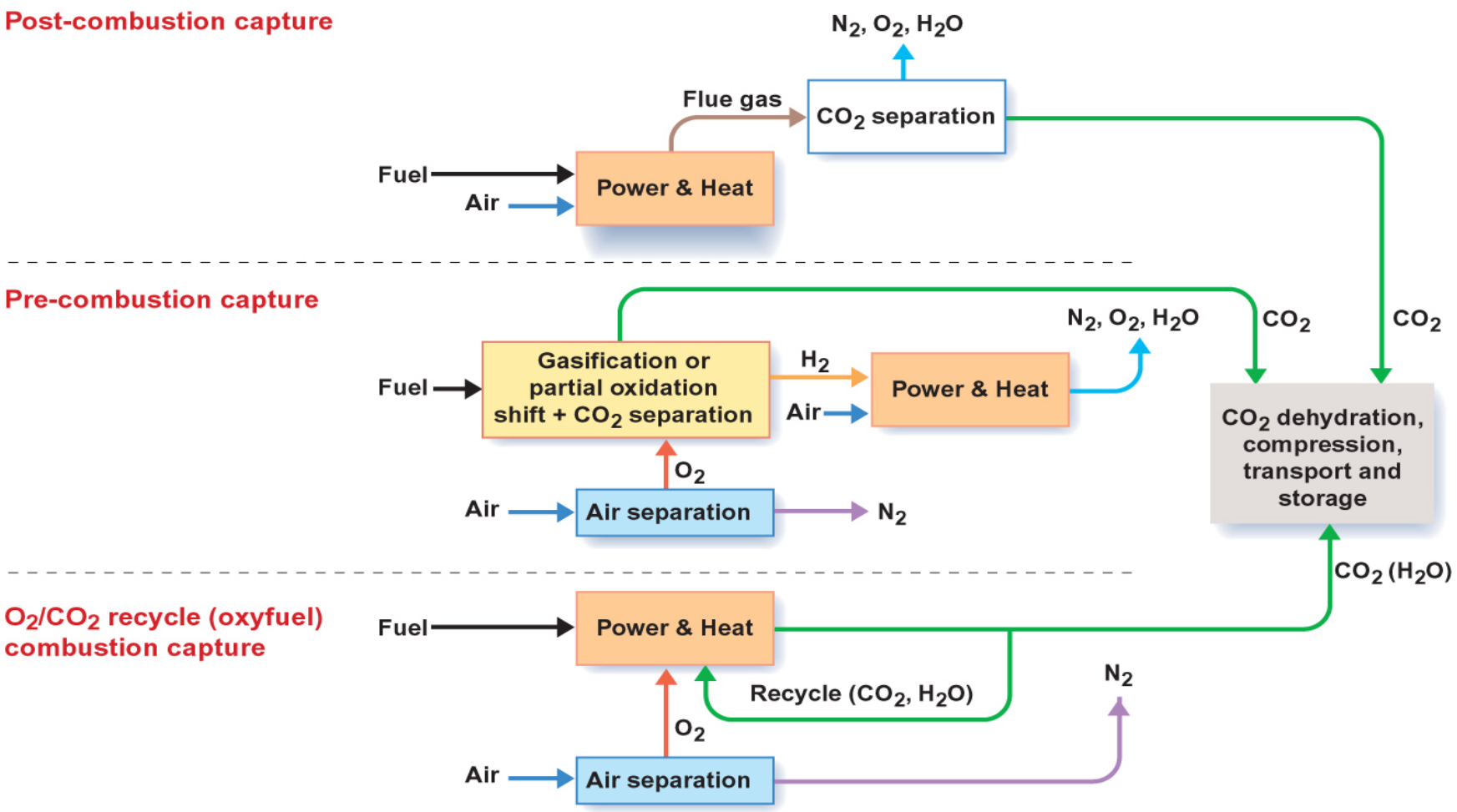
Tower
FL 327 ft
99.7 m





- **Carbon Dioxide Capture and Storage**

Carbon Capture Strategies



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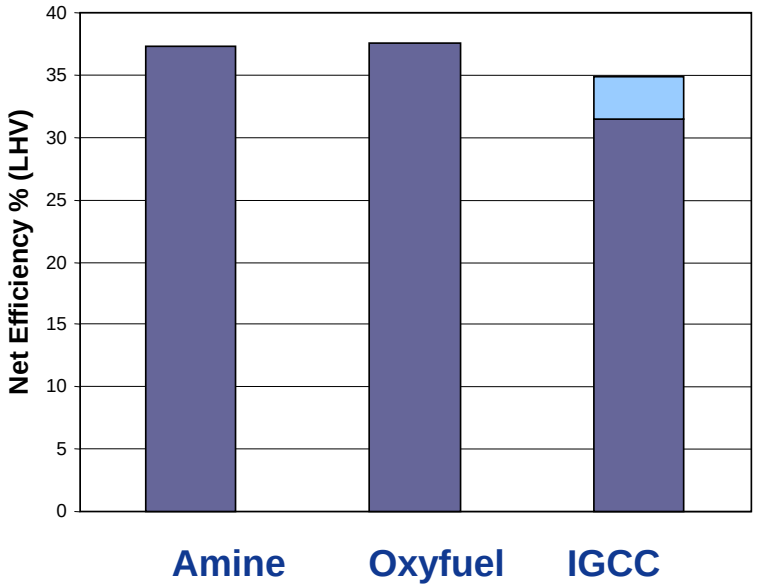
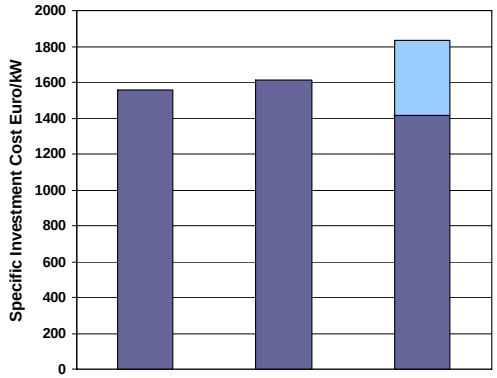
Comparison of Carbon capture options for Coal power plant

Net Cycle Efficiencies (%LHV)



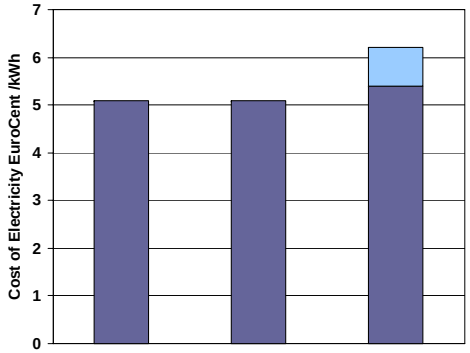
From joint paper with Jacobs at Powergen 2006

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

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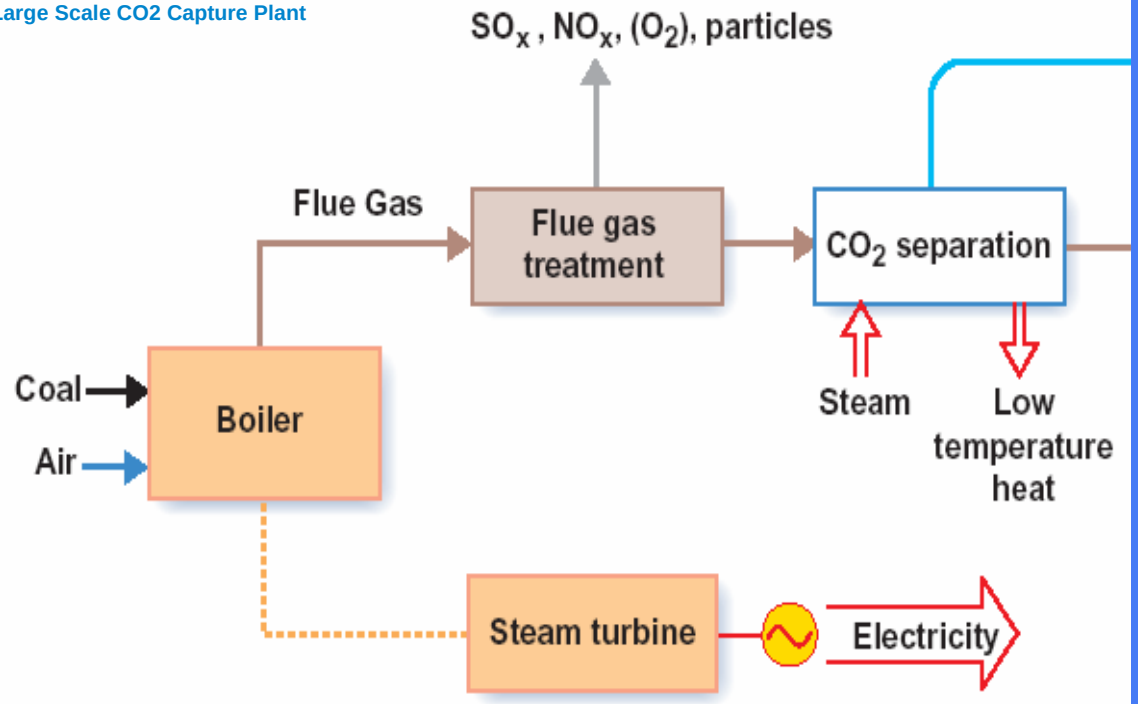
Post-combustion Carbon Capture – Flue Gas Scrubbing on Pulverised Coal Plant

Large Scale CO2 Capture Plant



- 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

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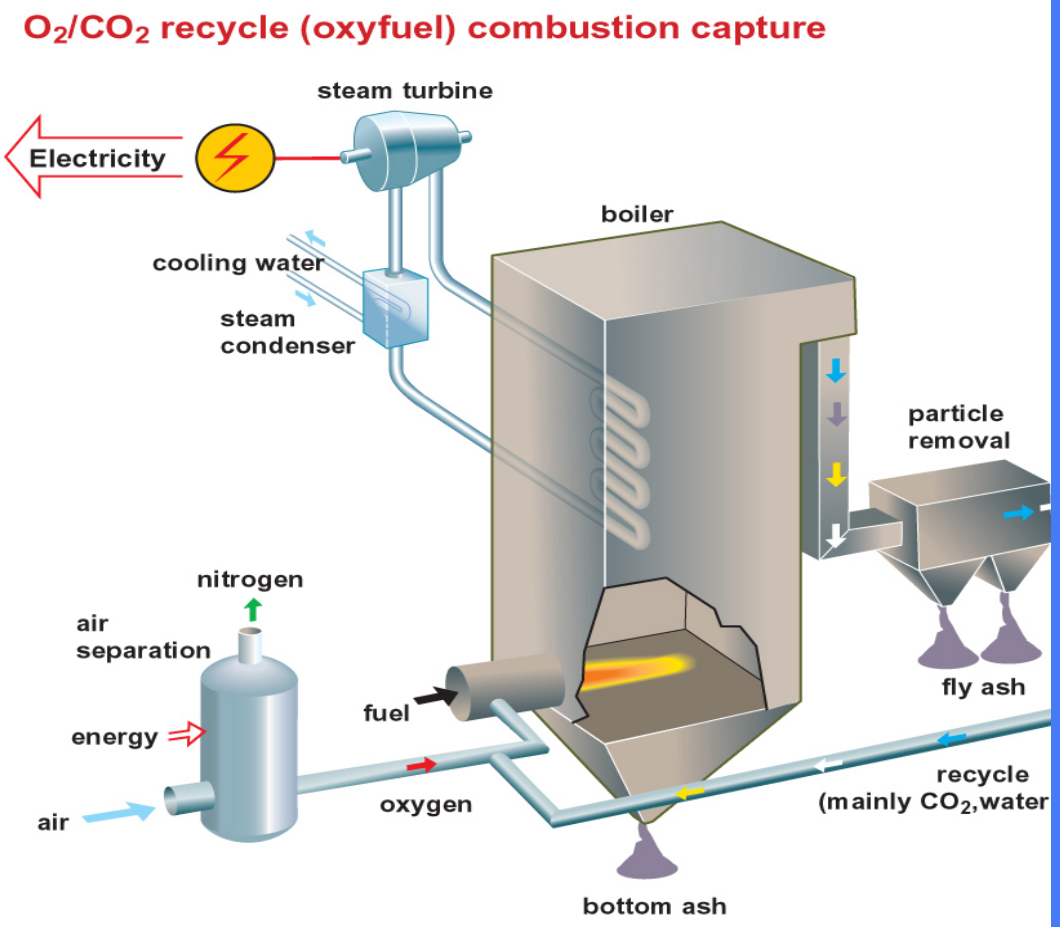
Carbon Capture by Oxyfuel firing on Pulverised Coal Plant



- 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

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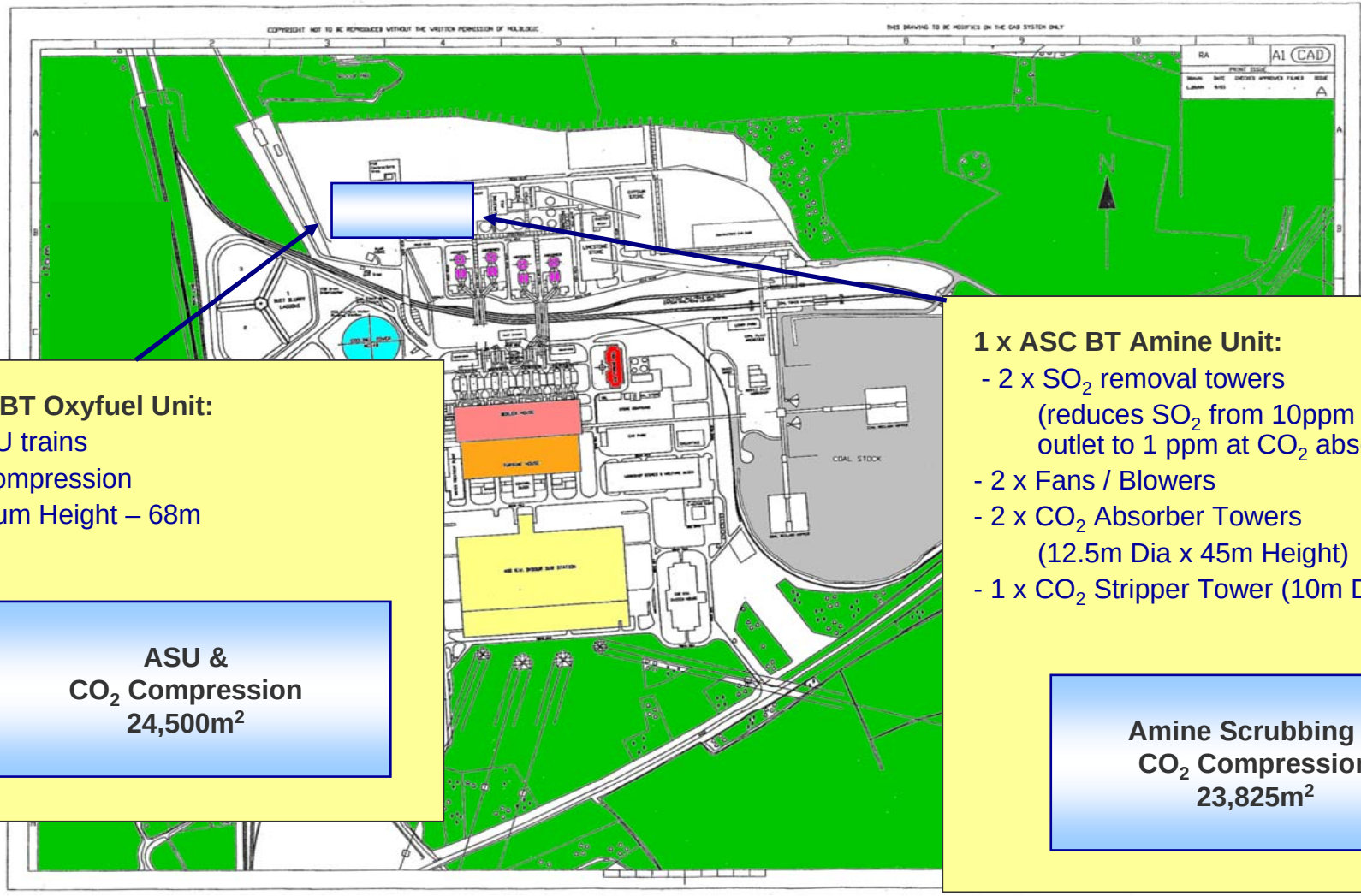
Comparison of Carbon Reduction Technologies

- Oxyfuel has a similar footprint to amine scrubbing



1 x ASC BT Oxyfuel Unit:
- 2 x ASU trains
- CO_2 Compression
- Maximum Height – 68m

ASU & CO_2 Compression 24,500m^2

1 x ASC BT Amine Unit:
- 2 x SO_2 removal towers (reduces SO_2 from 10ppm at FGD outlet to 1 ppm at CO_2 absorber inlet)
- 2 x Fans / Blowers
- 2 x CO_2 Absorber Towers (12.5m Dia x 45m Height)
- 1 x CO_2 Stripper Tower (10m Dia)

Amine Scrubbing & CO_2 Compression 23,825m^2

OXYCOAL- UK collaboration

Project 407 ASC Retrofits with CO2 Capture

Project team	Sponsors
Doosan Babcock, Alstom, Air Products, EON, Imperial,	**EON, SSE, Drax, SP, EDF, RWE**

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

Phase 1 Project

Underpinning technologies

Project team	Sponsors
Doosan Babcock, Imperial, Nottinham, Air Products, EON, RWE, BP	**Doosan Babcock, SSE, Drax, SP, EDF, EON, BP**

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

Project team	Sponsors
Doosan Babcock, Imperial, Nottingham	**SSE (prime), Drax, EON, SP, EDF,Dong**

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

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

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

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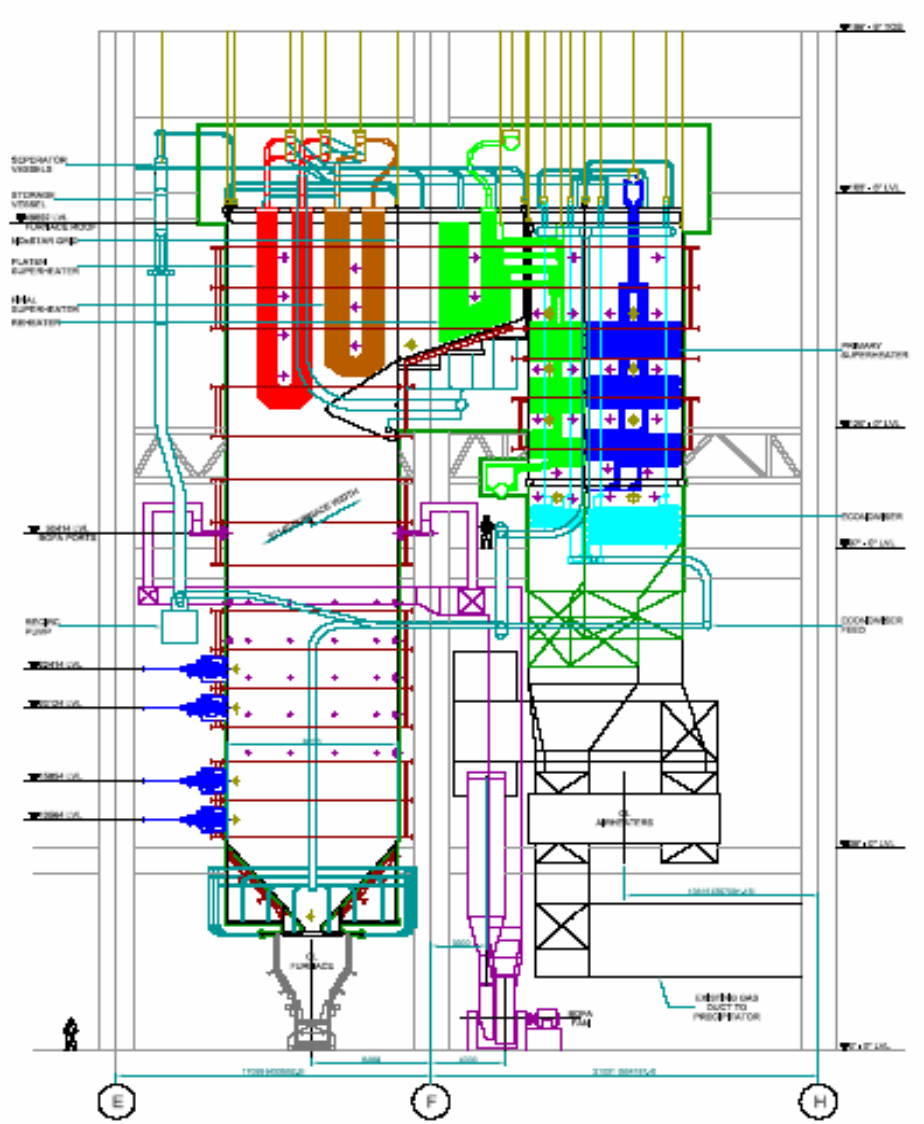
Advanced Supercritical *Retrofits* with CO_2 Capture

- 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

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Concluding Remarks – Technologies

- **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

Coal - closures of Opted out plants	8GW
Oil- closures of opted out plants	3GW
Magnox Nuclear- closure of last two (Oldbury and Wylfa)	2.3GW
Growth at 1% pa	7GW
Total	20GW

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 % ,

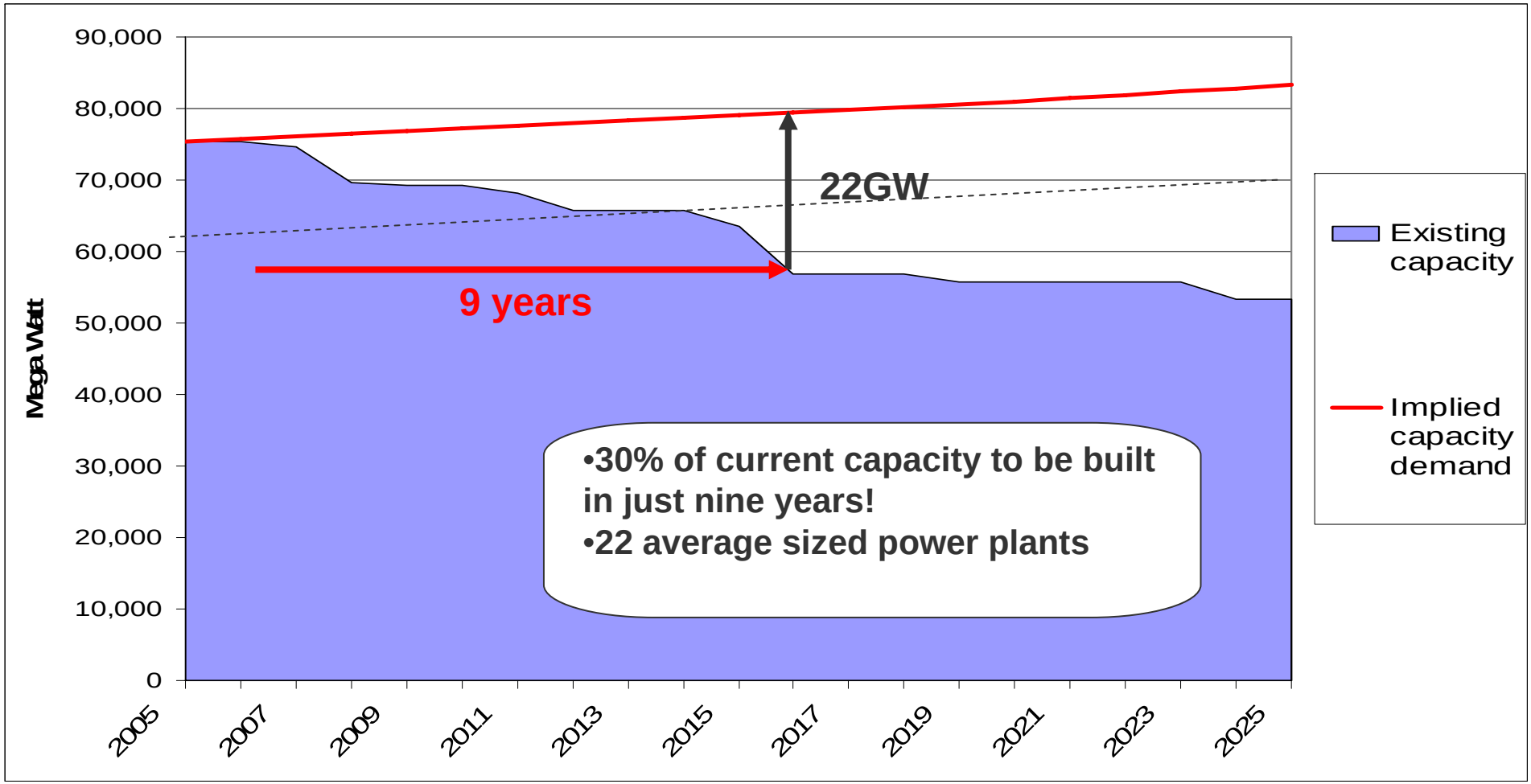
So gap could be 29 GW

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 !



* Assuming an illustrative peak capacity margin of 20%

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UK Scene – the Way Forward for Coal

- For *both* coal and gas CCS will be needed if CO_2 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

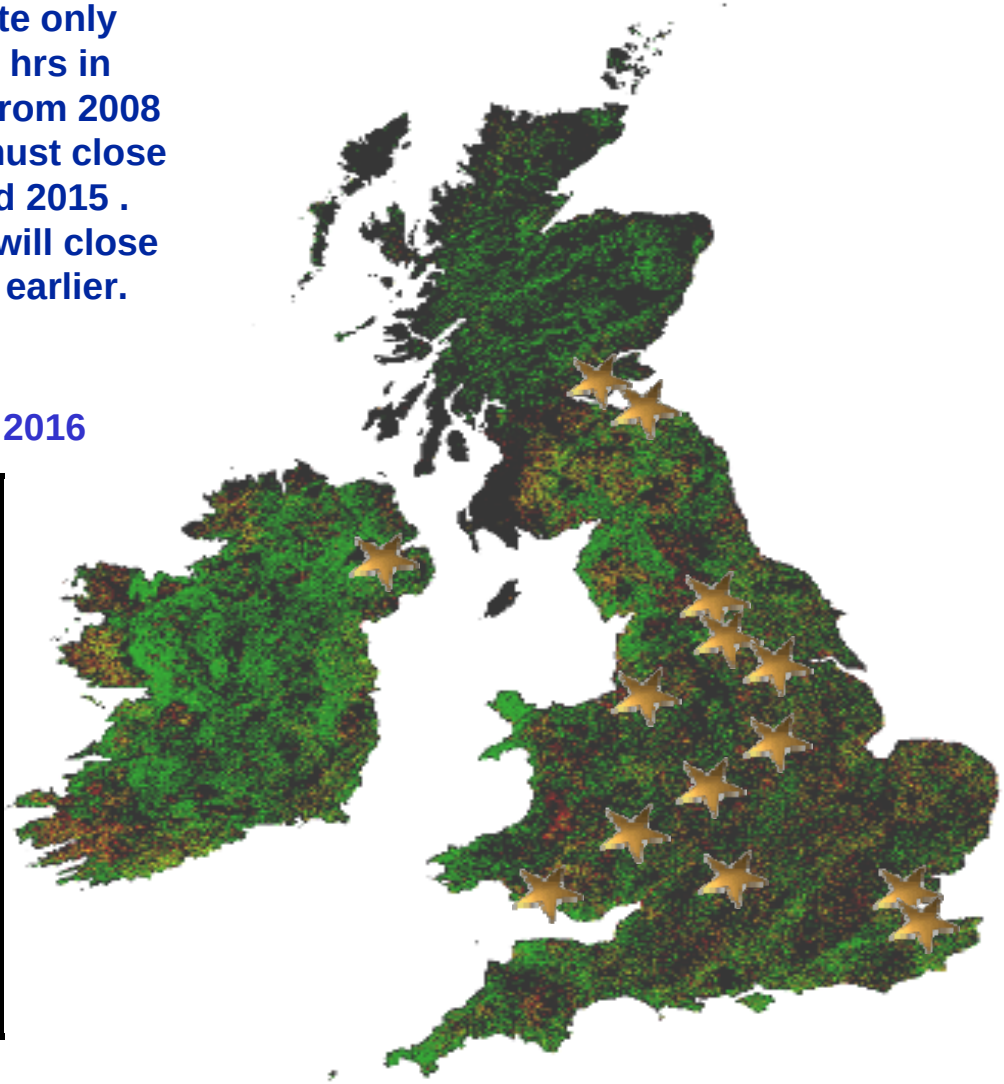
Power station	Owning Company	MWe
Ironbridge	Eon	972
Kingsnorth	Eon	2000
Didcot	RWE Npower	1920
Tilbury	RWE Npower	1050
Cockenzie	Scottish Power	1200
Ferrybridge (2 units)	SSE	1000
Total Opt-Out		**8142**

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

Opt- In

Must fit additional NOx reduction by 2016

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



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 CO_2 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

	Location	Size/CCT	Date	Status
New Capacity				
Powerfuel	Hatfield	430MW IGCC with capture	2011	Section 36 consent. FEED study starting
Eon	Killingholme	450-500 MW IGCC with CCS	2012	Internal feasibility study underway
Centrica	Teesside	800 MW IGCC with CCS	2011	FEED study started
Others		New build ASC/IGCC		
Replacement / Retrofit				
SSE	Ferrybridge	1 or 2 x 500MW ASC Retrofit (Capture ready)	2011	FEED study well advanced
RWE	Tilbury	2x800 MW ASC (Capture ready)	2013 +14	Internal feasibility study underway
Eon	Kingsnorth	2x800 MW ASC (Capture ready)	2012	Section 36 consent applied for
Others	Several (at least 5)!	ASC new/retrofit (Capture ready)		

FEED study contracted with Doosan Babcock and Siemens

Optimum programmes – Coal Power Plant

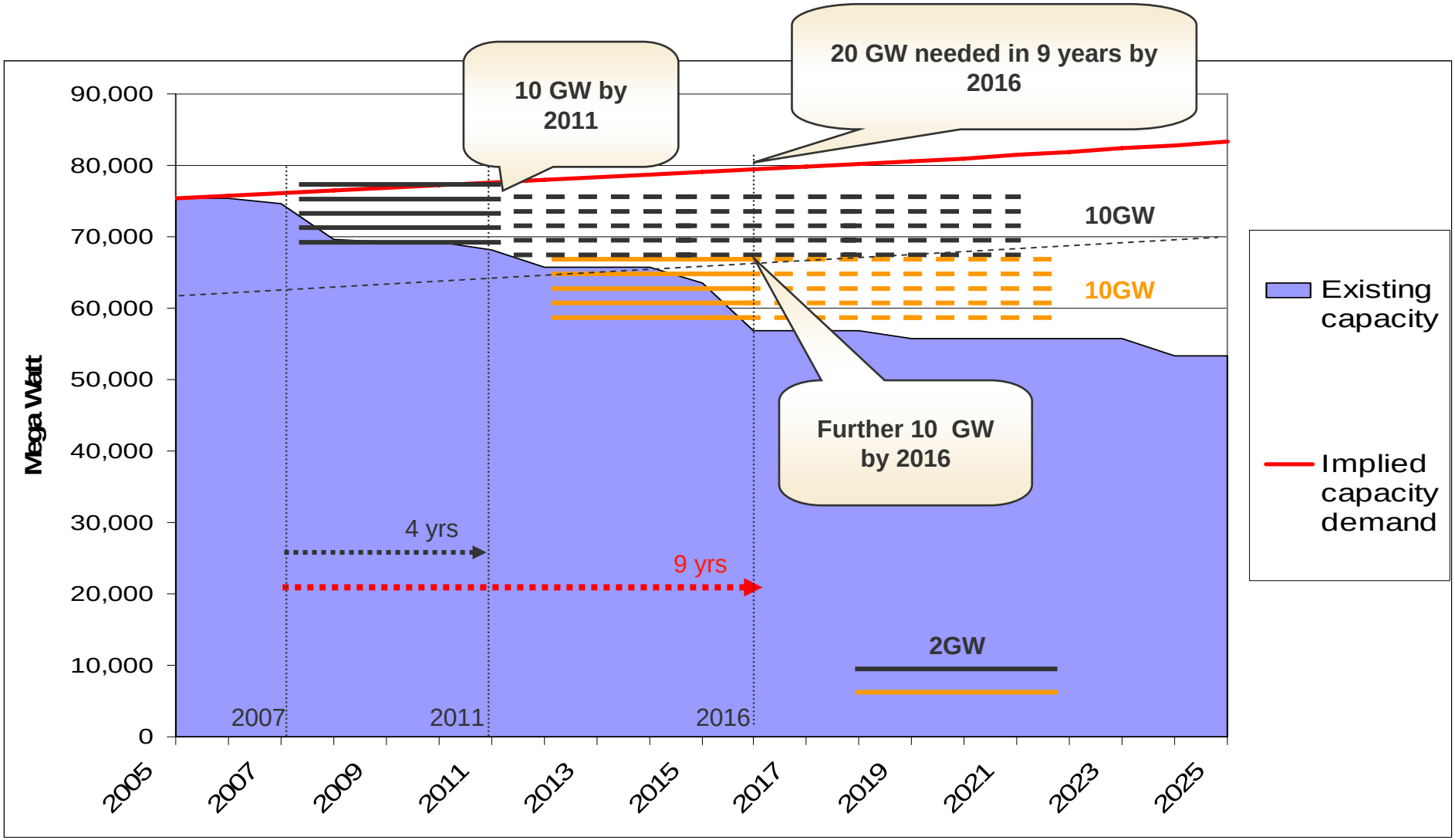
	Retrofit	New Plant
Planning , consents and FEED	1 year	2 - 3 years
Design and engineering	1 year	1 year
Manufacture	1 year	1 year
Construction and commissioning	1 year	2 years
Total	4 years	6 - 7 years

……*Consider two Scenarios*

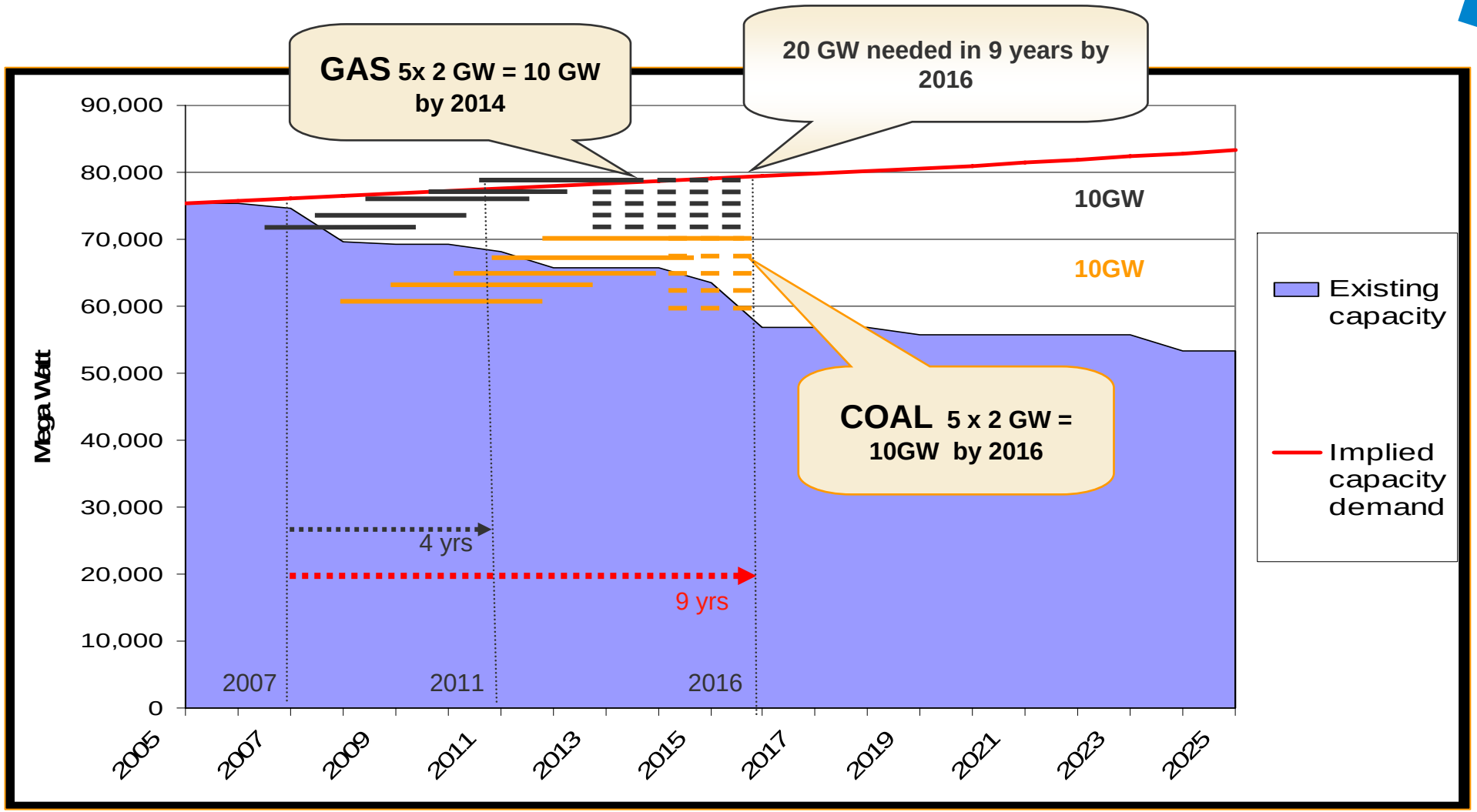
Scenario 1- "just in time"

Scenario 2- "phased build"

Scenario 1- Just in Time



Scenario 2- Phased Build Gas and Coal



Key specialist resources to build the new stations

Key specialist resources are

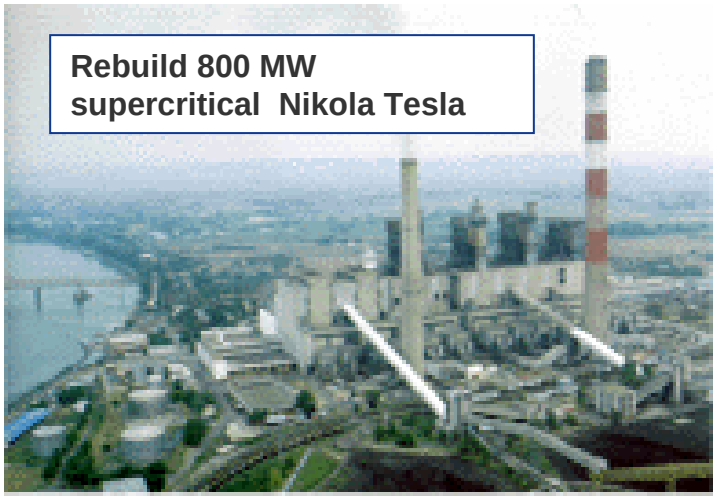
- **Design and engineering in the Boiler and Turbo-generator OEMs**
- **Procurement of materials and performance equipment**
- **Construction and commissioning labour**

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

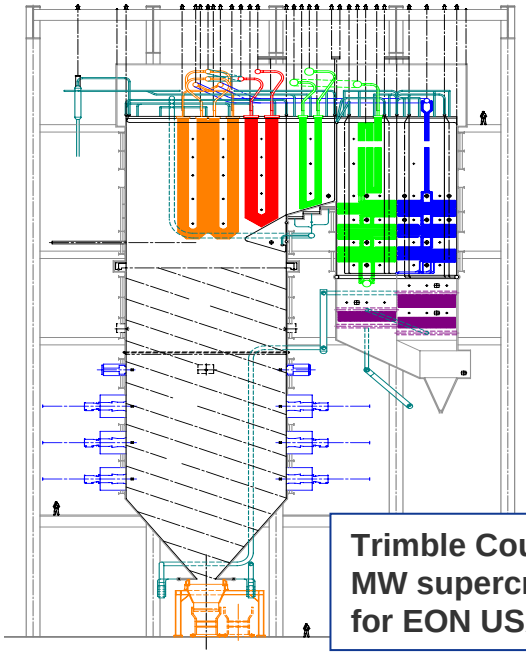
Capacity recently enhanced through link to our new parent company

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

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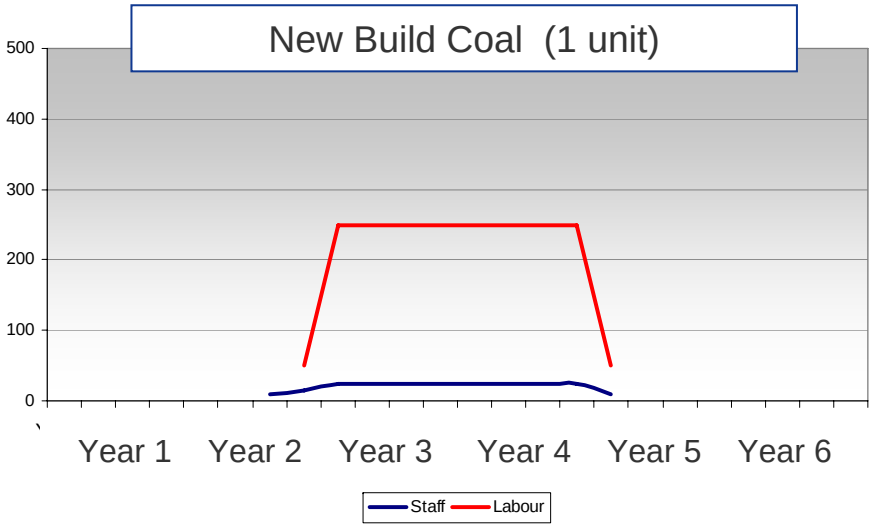
Issues for the industry

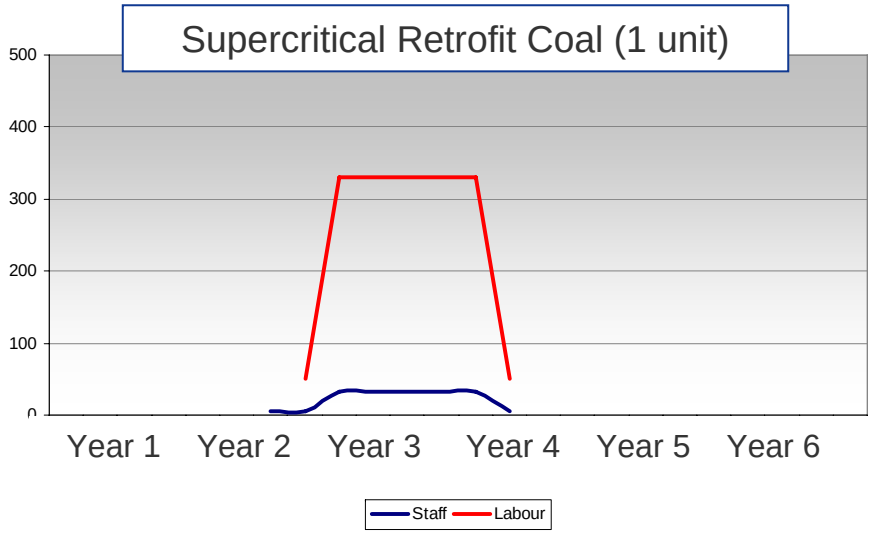
- Many additional European and global projects to follow those already ordered
- Many OEMs booked out to 2012
- Global capacity of manufacturers' works is limited
- Materials supply bottlenecks define the manufacturing programme
- Limited construction capacity in any one region of the country, even with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

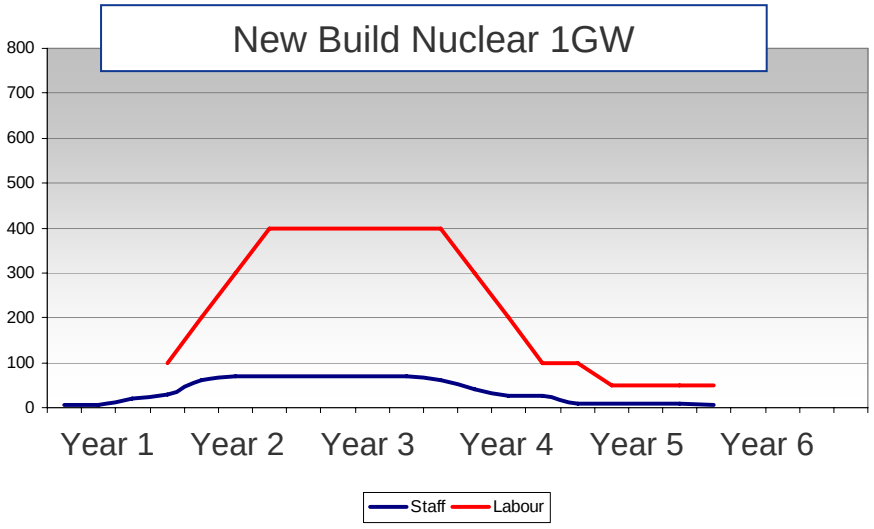
Are the plans for training Engineers and Construction craft workers adequate?

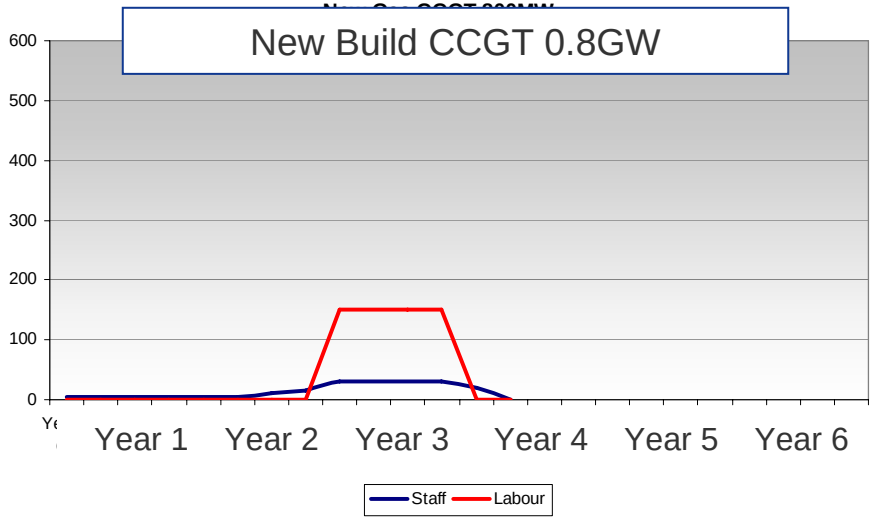
Key Construction labour skills for Doosan Babcock are Platers, Fitters, Welders, Pipefitters and Erectors/riggers

Construction resources depend on plant mix (Boilermaker's portion)









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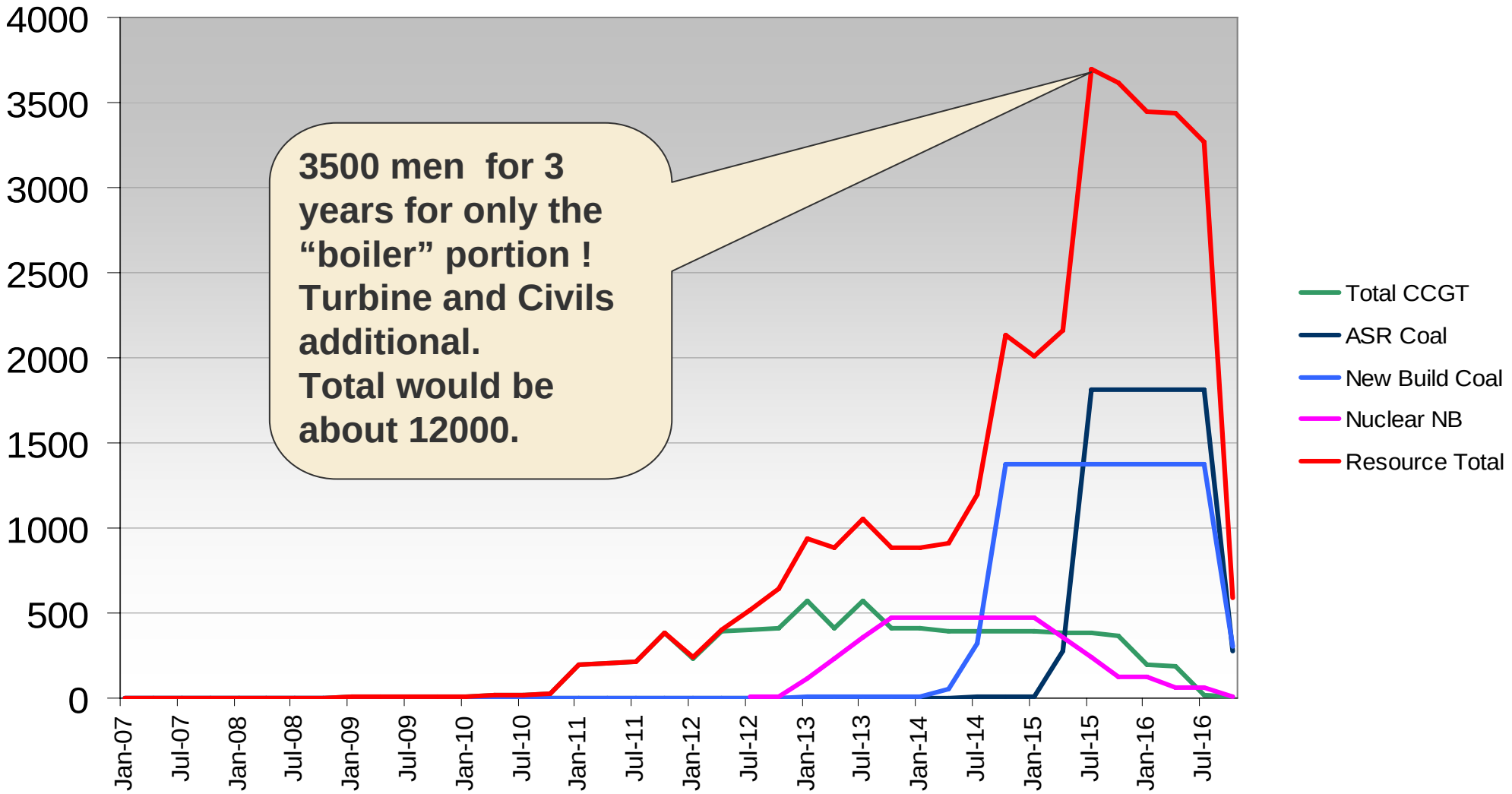
Construction labour resource for ‘Just In Time’ scenario



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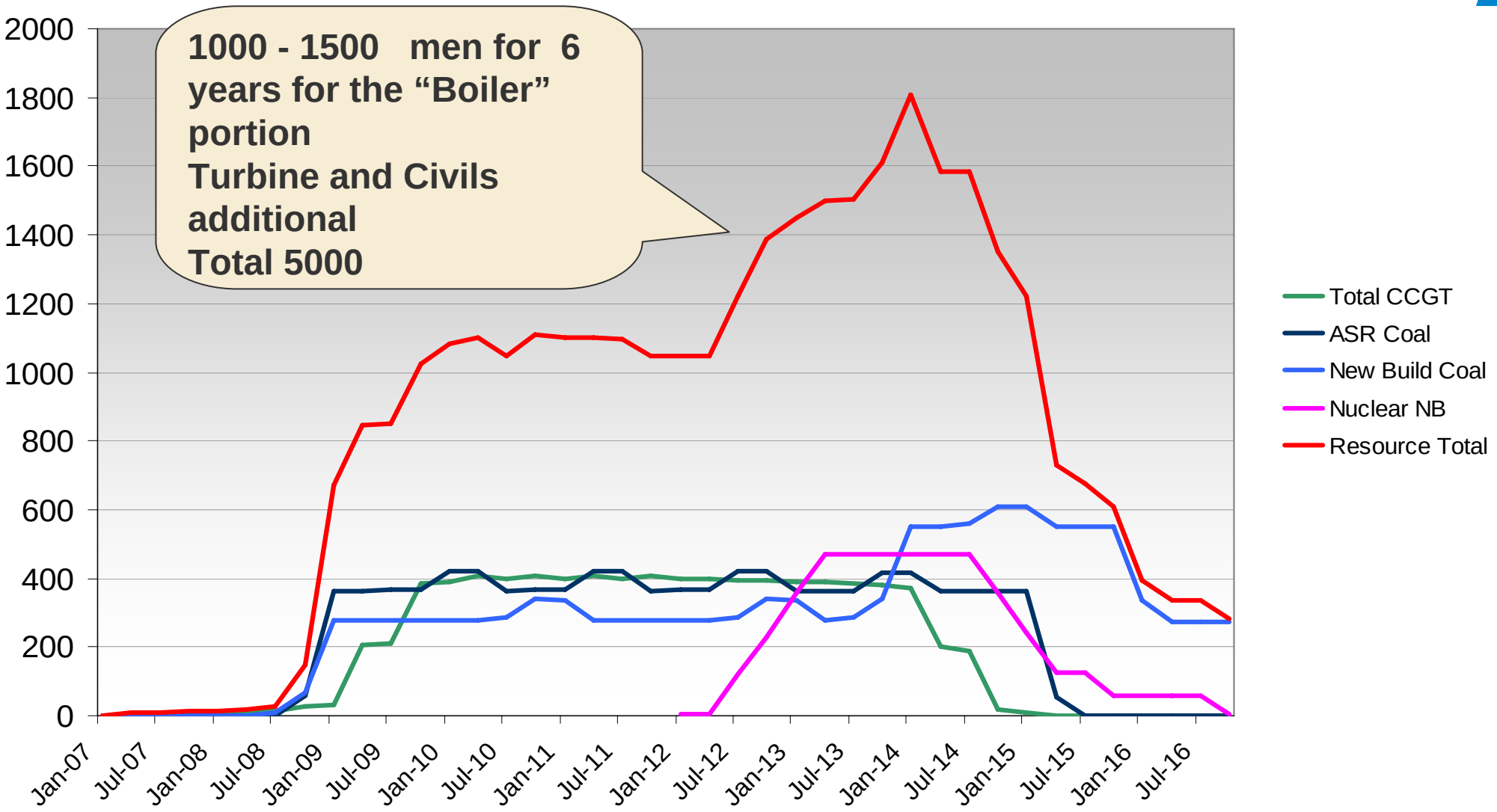
Construction labour resource ‘ Phased build’ scenario



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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

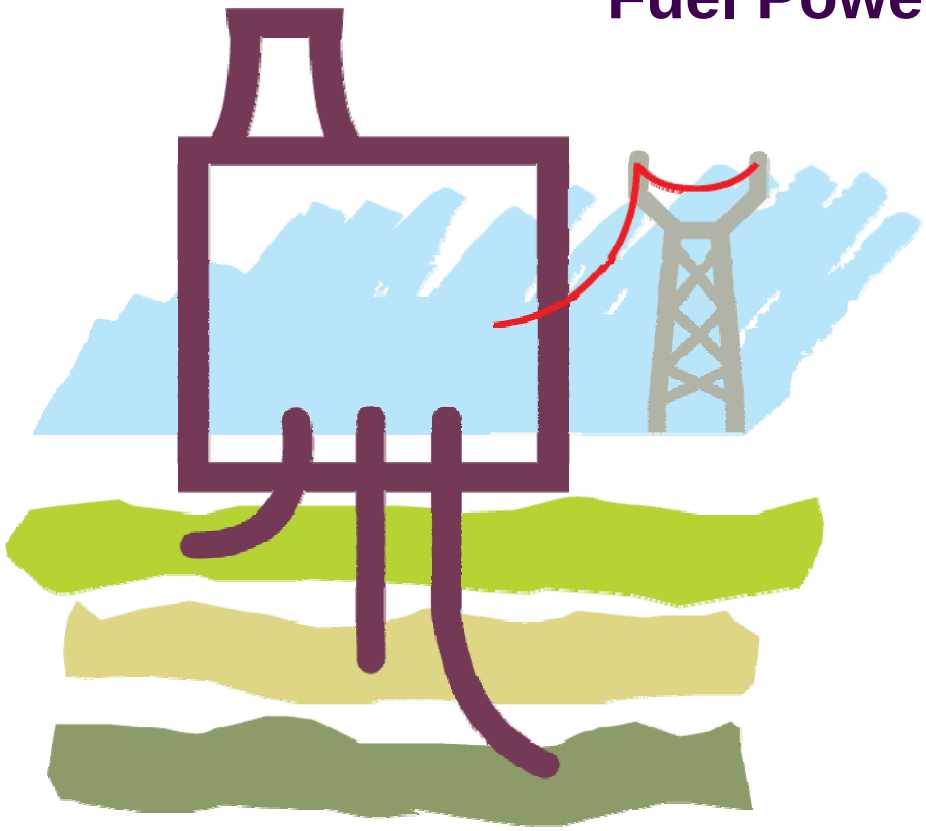
All are topics for the Power Generation subgroup of the Coal Forum

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

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What are EU Objectives?

Environment:

Limiting global warming. Meeting post-2012 objectives with coal.

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.**

By 2020: **commercial demonstration. Zero-emission power becomes viable.**

After 2020: **ZEP is the technology of choice.**

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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*

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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

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