Doosan Babcock Energy

Ambitions for near zero emissions fossil fuel power plant - based on supercritical PC

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CRF 22 April 2009

Company update

Nuclear

Thermal

Turbine & Generator

Desalination

Casting & Forging

Construction

- Doosan Babcock Energy Limited is a subsidiary of Doosan Heavy Industries and Construction of South Korea, part of the Doosan Group, and a market leader in gas, coal, nuclear power generation and desalination . Orders in 2007 totalled 7 Bn USD
- Doosan remains committed to all forms of power generation, including clean coal, nuclear, gas and renewables
- Doosan offers Pre and Post combustion and Oxyfuel carbon capture technologies
- Doosan Babcock Energy has been designated the Doosan global Centre of Excellence and R+D Centre for Boilers (including Clean coal and Carbon dioxide capture)
- Doosan Babcock Energy's sales territory is Europe, Americas, Southern Africa and China, but its boiler technology is used globally, including recent orders In India and Thailand

Context of Presentation

- Why do current energy policies need reappraisal ?
- Current policy aspirations (EU and UK) have put a very high priority on climate change and could be said to have taken a cavalier view on security of supplies and energy costs
- More careful balance is needed to ensure sufficient priority is given to:
    - lower cost low-Carbon options,
    - security of supplies, and
    - technologies that will be exportable on a large scale and which would achieve a major impact globally
- Why Coal and Gas need CCS?

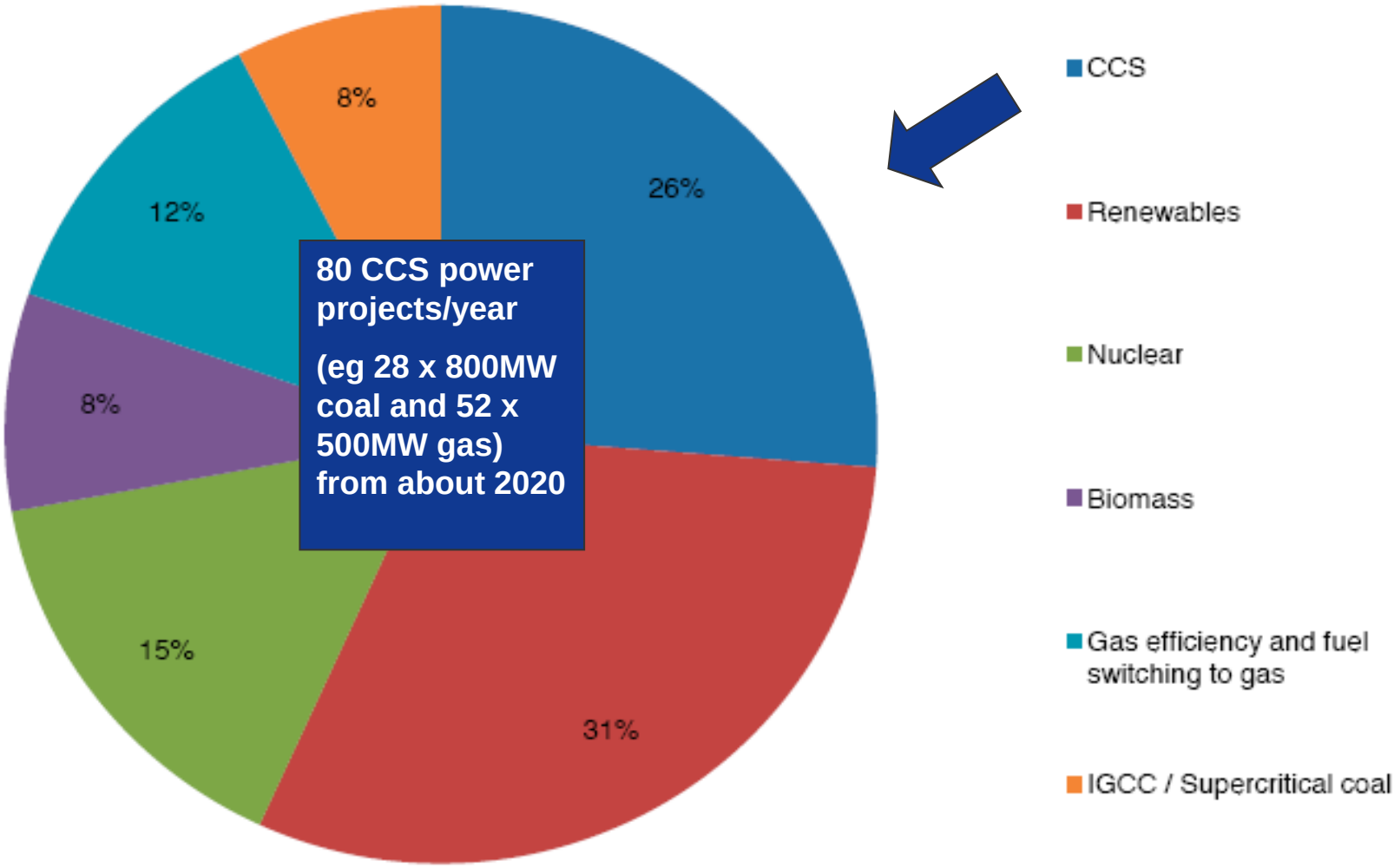
Why coal for electricity generation?

- Globally
  - According to the IEA by 2030 world demand for electricity will double with 4800GW of new power plant needed
  - Huge dependence (>70%) for power in countries like China, India , USA but also in South Africa, South America, South East Asia, and Europe

- UK
  - Flexible fossil power needed to provide power on demand and balance the intermittency of renewables
  - Coal power important to avoid over-dependence on imported gas

- Coal with CCS and use of waste heat can be near-zero emissions
- Coal with CCS is comparable in cost to other low carbon options

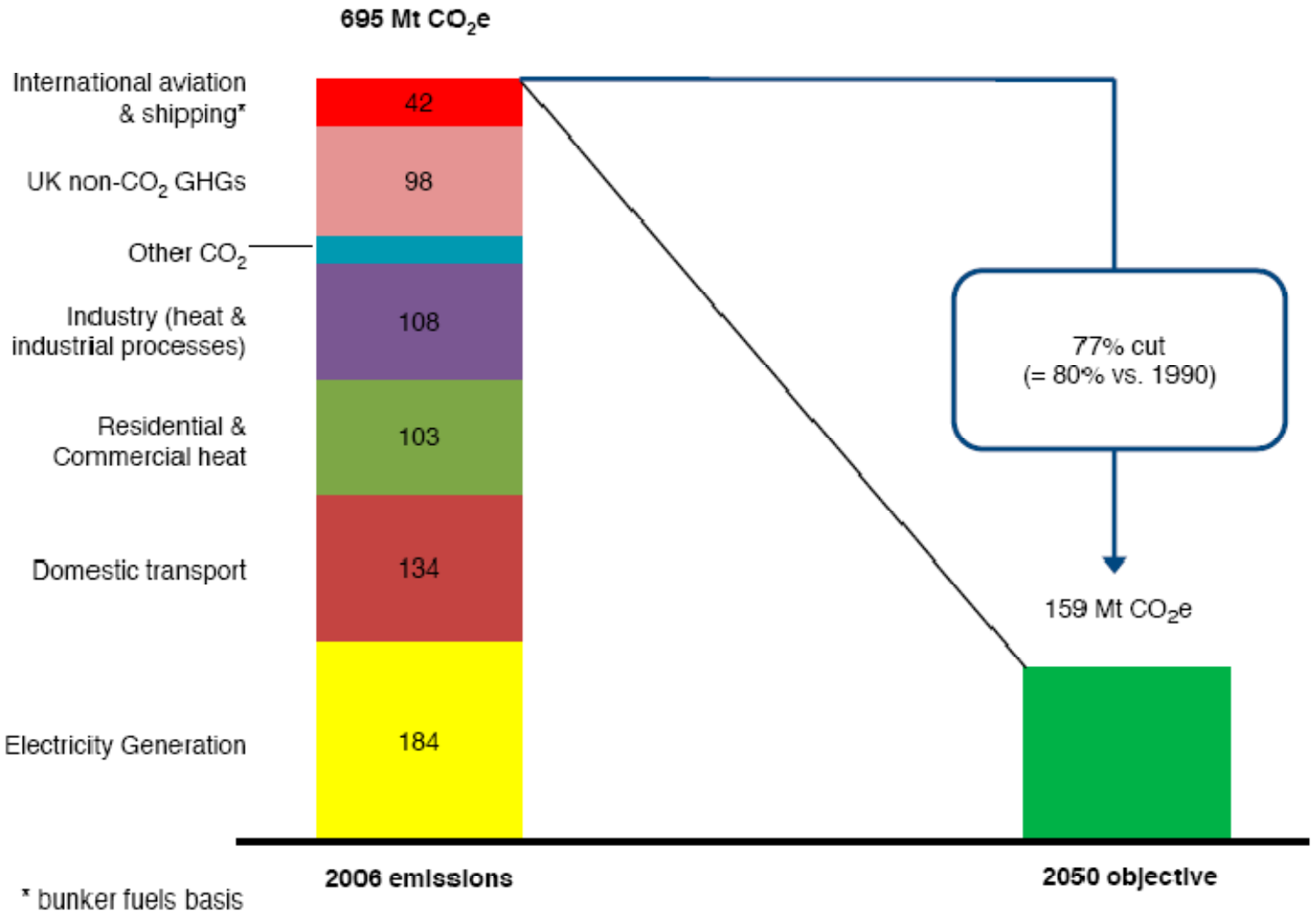
Global power generation abatement in 2050 (IEA BLUE Map scenario)



Power sector abatement: 18.3 $GtCO_2$

Page 71, Figure 2.23

The scale of the challenge for target emissions reductions (UKCCC)



Source: UK National Atmospheric Emissions Inventory (2008).

UK CCC Page 38, Figure 2.1

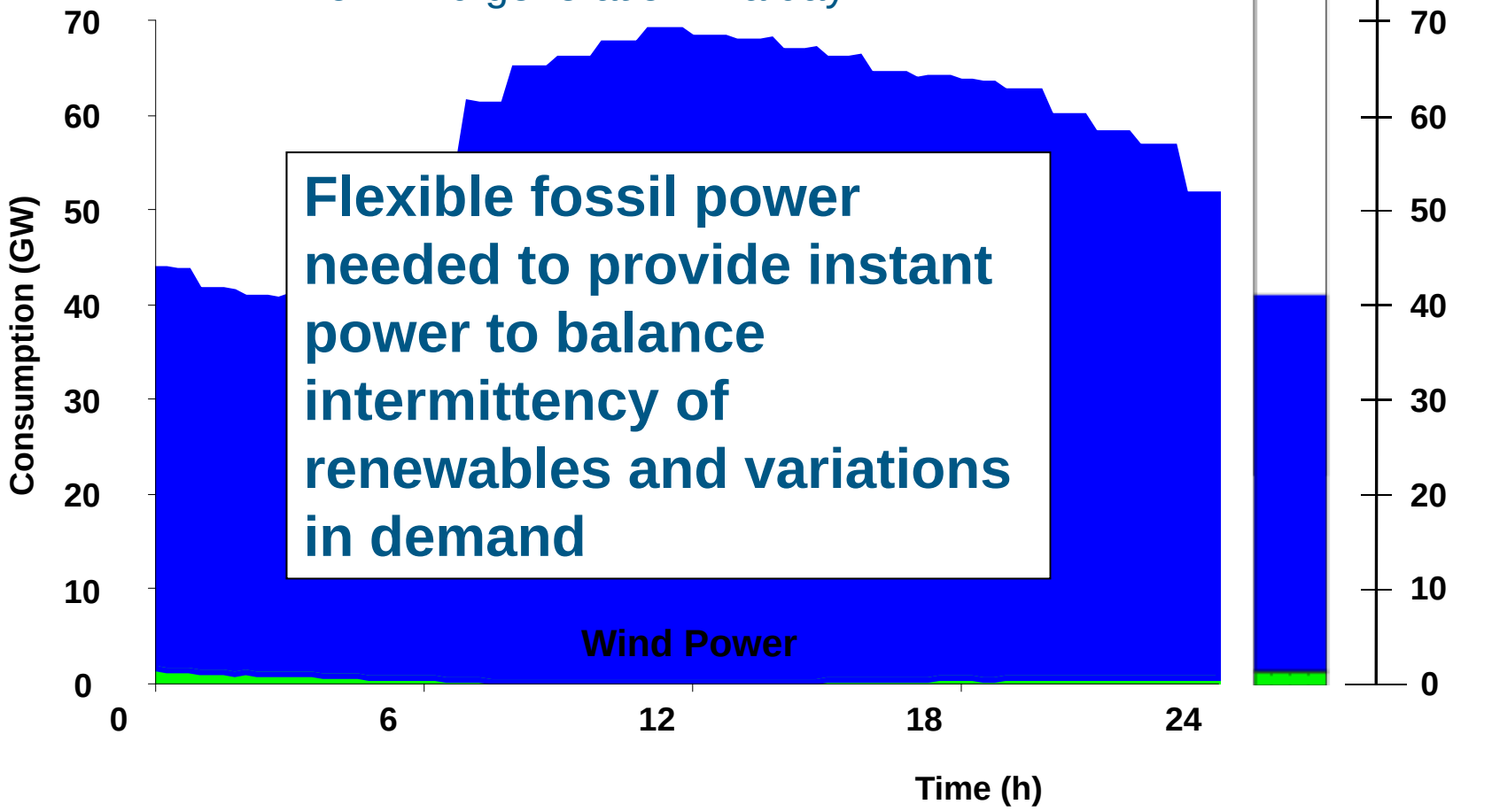
Flexible fossil power needed to provide instant power to balance intermittency of renewables and variations in demand

Germany,

June 11th, 2007

Worst case scenario

for Wind generation in a day



Flexible fossil power needed to provide instant power to balance intermittency of renewables and variations in demand

Sources: VdN, UCTE

Coal + CCS is a lower cost low-carbon option

- Recent evidence to the House of Commons Select Committee on Environmental Audit Committee by EON UK, a major developer of windfarms (onshore and offshore), gas-fired power stations and the proposer of the Kingsnorth clean coal project, quoted the following relative costs-of-electricity generation (£/MWh):

£/MWh		Excluding cost of Carbon Allowances	Including Cost of Carbon Allowances €20/te	Including Cost of Carbon Allowances €40/te
CCGT (gas)		44.3	51.8	59.3
Coal		41.7	56.4	70.8
Coal + CCS		67.7	69.2	70.7
Coal + CCS less expensive than WIND!				
Onshore Wind		75.0	75.0	75.0
Offshore Wind		107.0	107.0	107.0

But more expensive than unabated gas!

Coal Forum - Scenarios for UK

If all of the coal and nuclear stations which are scheduled to close by 2016 are replaced by gas CCGT's then ….

- **75% dependence (GW) on gas for power generation during a cold still spell in winter (cf 36% now)**
- **54% of generation (TWh) from gas, 17% from renewables in 2016**

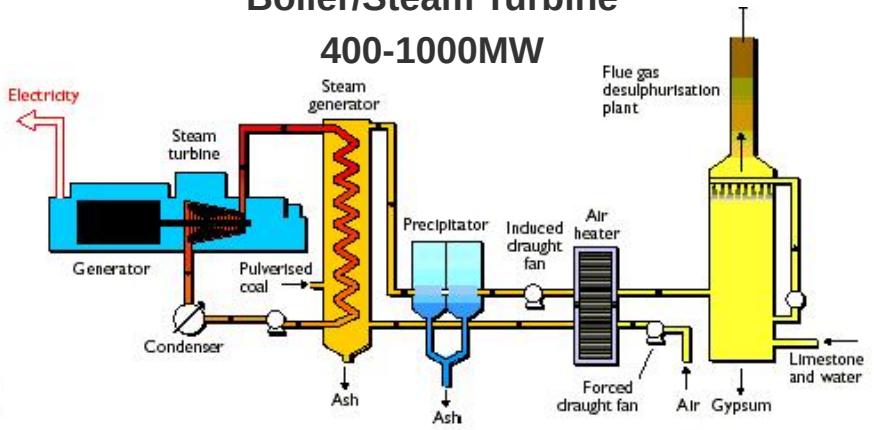
Need clean coal to avoid further overdependence on imported gas for heating and power generation

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) - 90% capture
- ASC Pulverised Coal offers Capture-Ready Retrofit options
- IGCC offers Hydrogen options
- 95% of current orders are for Pulverised Coal

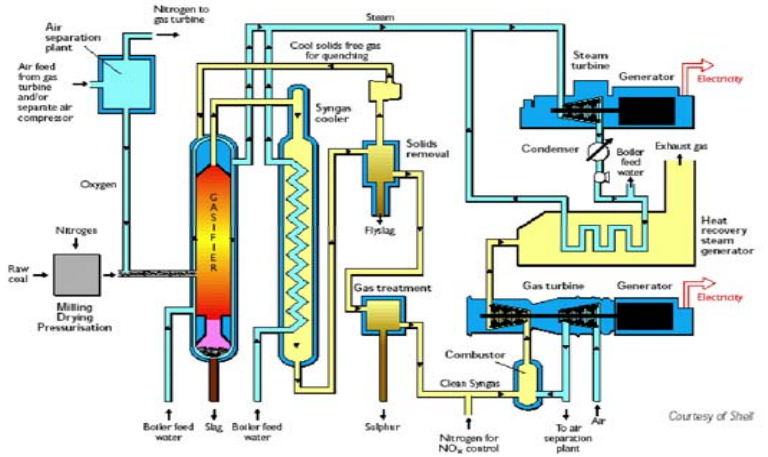
Advanced Supercritical Pulverised Coal Boiler/Steam Turbine

400-1000MW



Integrated Gasification Combined Cycle

250-900MW



Courtesy of Shell

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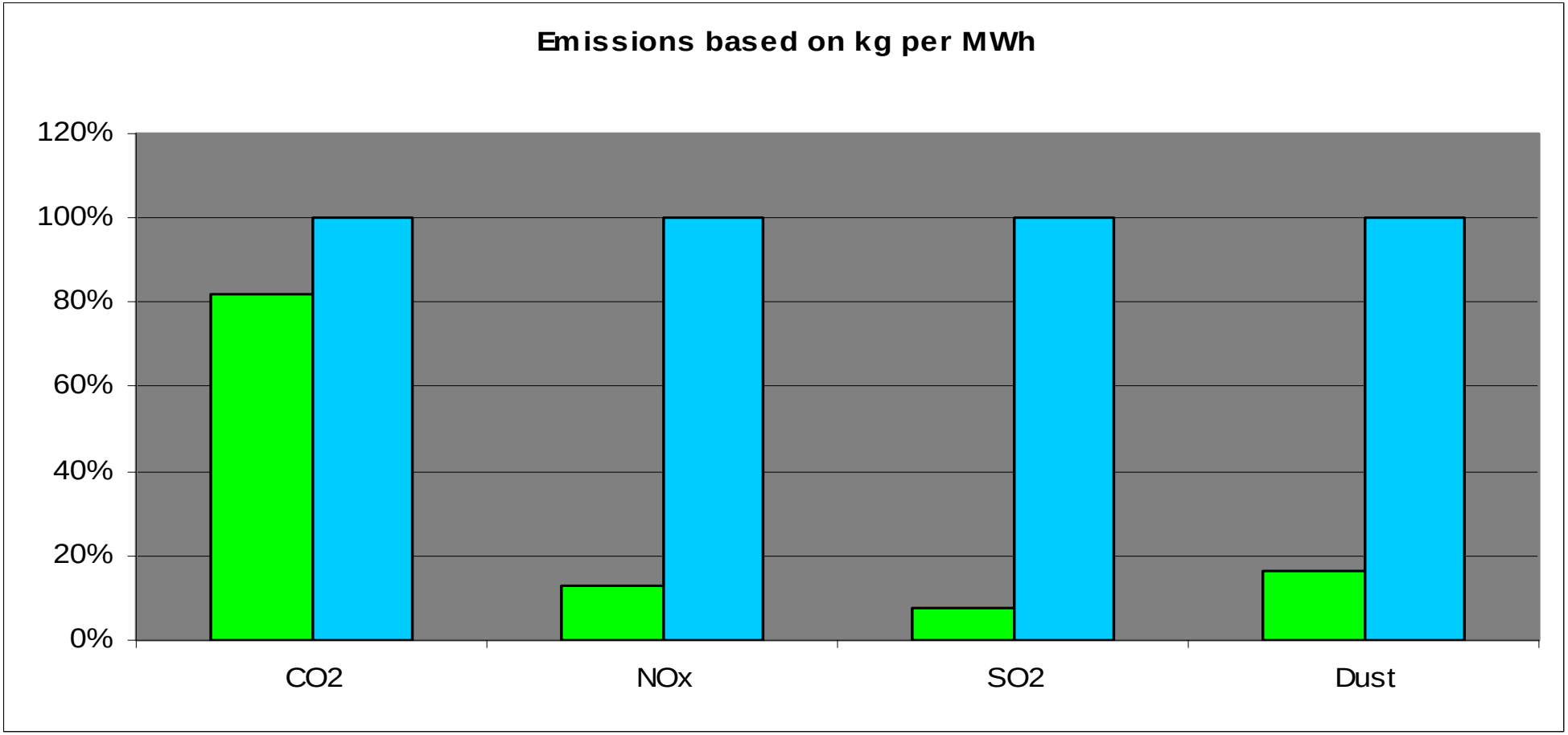
Emissions reduction of new clean coal power plants vs existing

NO_x, SO_x and dust reduced by more than 80%

CO_2 reduced by 20% now, and 90% when full CCS fitted



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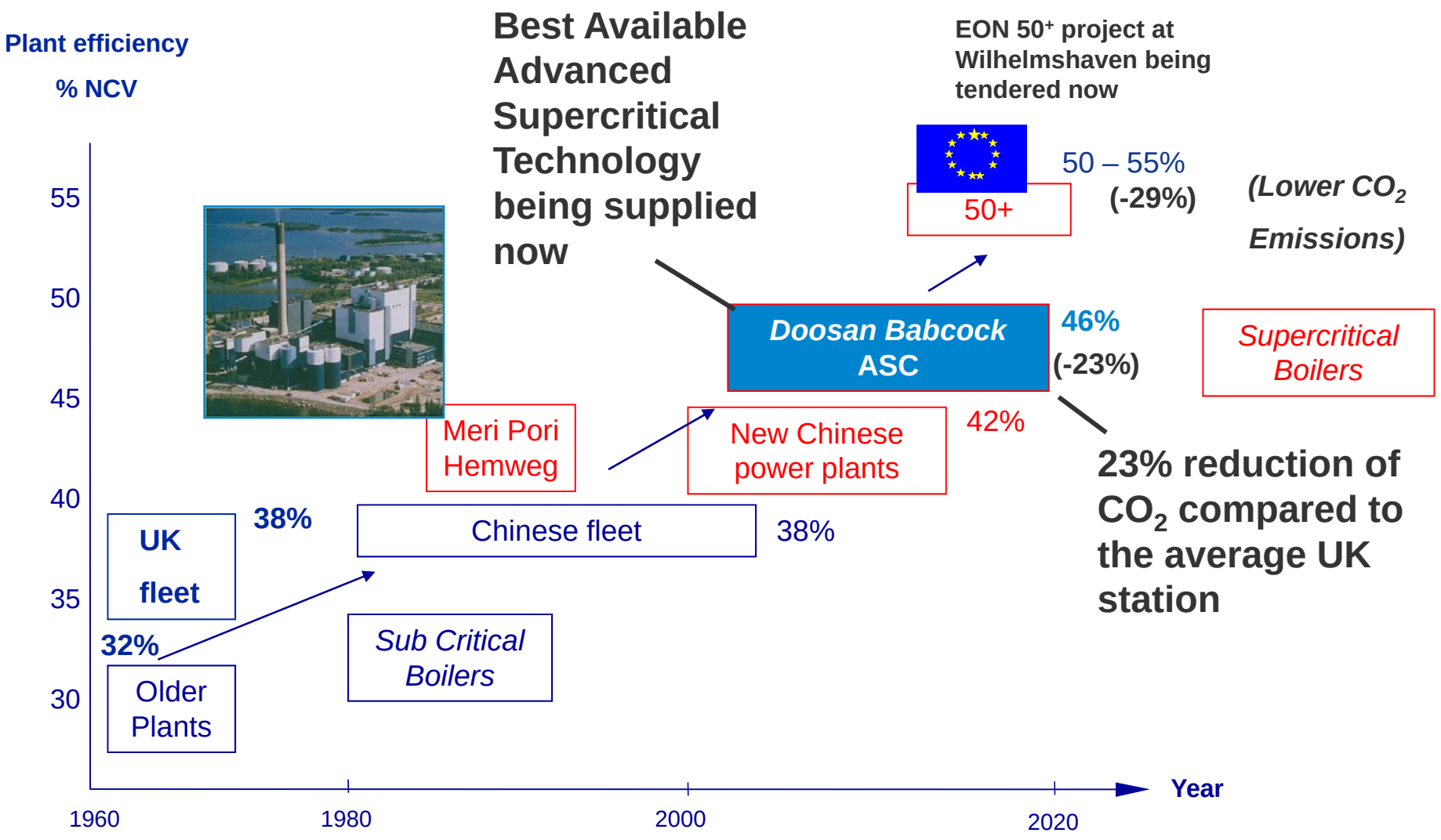
Abatement of CO_2 by efficiency improvement of Pulverised Coal Plant



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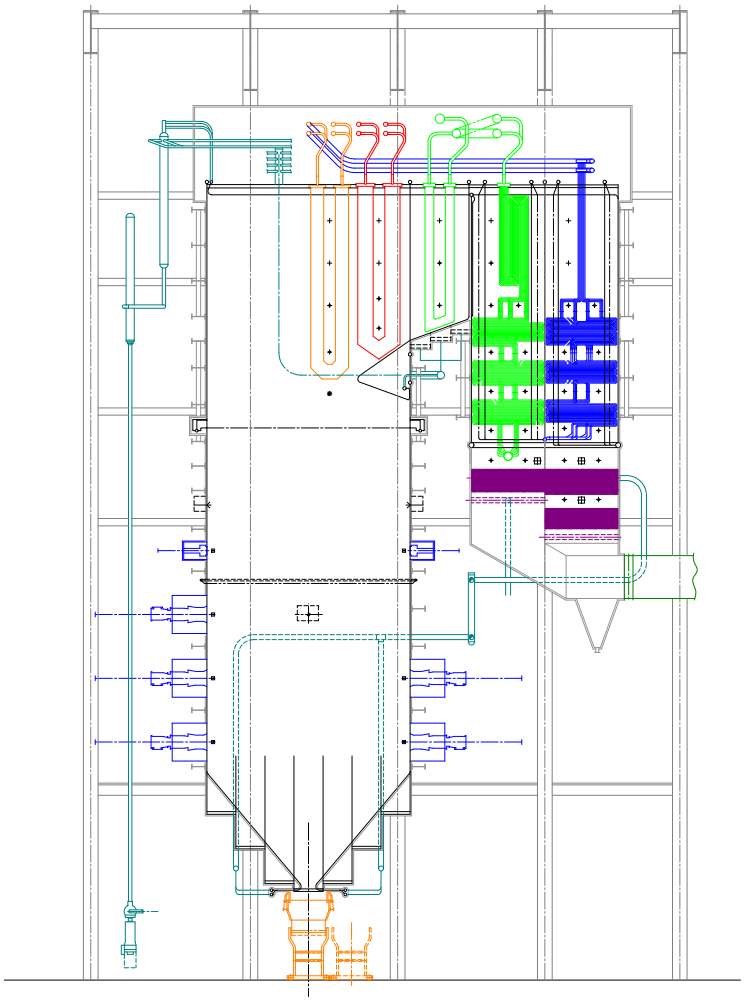
800MW 46 % efficiency advanced supercritical boiler



Main Steam	**281bar**
	602.45°C
Reheat Steam	**605 °C**

Ordered in Germany

Suitable for UK (eg for Kingsnorth, Tilbury, Longannet)

Can be designed capture ready

Suitable for new build or retrofit

Pressure drop (bar)	
HP	**27**
RH	**2.4**
SCR inlet NOx (worst coal)	**<450mg/Nm^3**
SCR outlet NOx (all coals)	**200mg/Nm^3**
CO at econ outlet	**<200mg/Nm^3**

Near Zero Emissions Power plant – CO_2 capture options

Three options:

- **Post Combustion Capture (PCC) –**
  - **Amine or Ammonia scrubbing**
  - **Oxyfuel firing**
- **Precombustion – IGCC**

Numerous studies show these are similar in resulting efficiency and cost of electricity and competitive amongst low carbon technologies

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

Scale up of Post Combustion Capture for Coal power plants

HTC	Searles Valley Minerals	2009	50MW	Coal
	CSIRO - Huaneng Beijing	2009	175MW	Coal
Alstom	AEP Oklahoma	2011	233MW	Coal
Alstom	NRG WA Parish	2012	125MW	Coal
(HTC)	Sask Power	2011		Coal
HTC	EPCOR Genese	2010		Coal
HTC & EESTech	Loy Yang	-	60MW	CBM

Target is "Commercialised by 2020"

More than 6 industrial scale demonstrations 60-250MW planned, for operation

2009 -2012

300 - 400 MWe UK Competition demonstration

2014-

UK project is a major step up, 2x 800MW commercial units would be a step too far

More than 5 pilot scale demonstrations in the 10 – 30MW range for operation by

2008 - 2012

Many R+D scale pilot plants using power station flue gases in operation

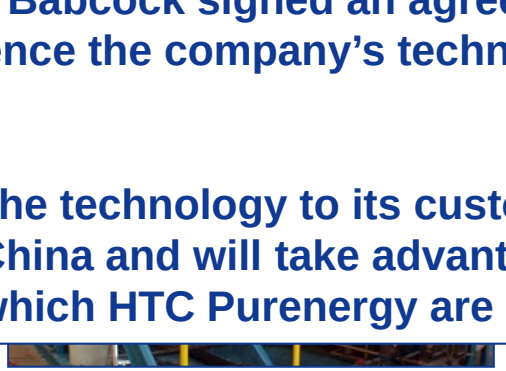
Powerspan	Basin Electric Beulah, ND	2012	120MW slipstream	Coal
MHI	E.ON Germany	2010	6-25 MW	Coal
Fluor	E.ON Wilhelmshaven	2010		Coal
Cansolv	E.ON Heyden	end 2009	10MW approx	Coal
Alstom	Karlshamn	2008	5MWe	Oil/gas
	EON/Electrabel/HitachiEuro	2009?		Coal

Alstom	We Energies	Mar-08	1.7MW	Coal
MHI	Matsushima		0.5MW	Coal
Various	CASTOR Dong	2006	1MW	Coal
ITC	Boundary Dam	2005	0.25MW	Coal
BASF	RWE Niederaussem	mid 2010	0.33MW	Coal
?	RWE Aberthaw	2010	1MW	Coal

Doosan Babcock partnership with HTC Purenergy

In September 2008, Doosan Babcock signed an agreement with HTC Purenergy of Canada to licence the company's technology for post-combustion capture of CO_2.

Doosan Babcock will offer the technology to its customer base in the UK, Europe, the Americas and China and will take advantage of the series of demonstration projects in which HTC Purenergy are involved



ITC - Natural Gas flue gas capture Centre

Coal flue gas demonstration - Test Facilities at Boundary Dam

CCS1000 Modular Design

Absorption Column, 14 ft-6 in ID x high 119 ft

Stripper Column, 12 ft-6 in ID x 77 ft high

2008 Demonstration at SV Minerals - 50MW, includes new solvent (RS1), new packing material strategy, steam reduction

HTC PURENERGY
CARBON CLEAN SOLUTIONS

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Carbon Capture by Oxyfuel firing on Pulverised Coal Plant

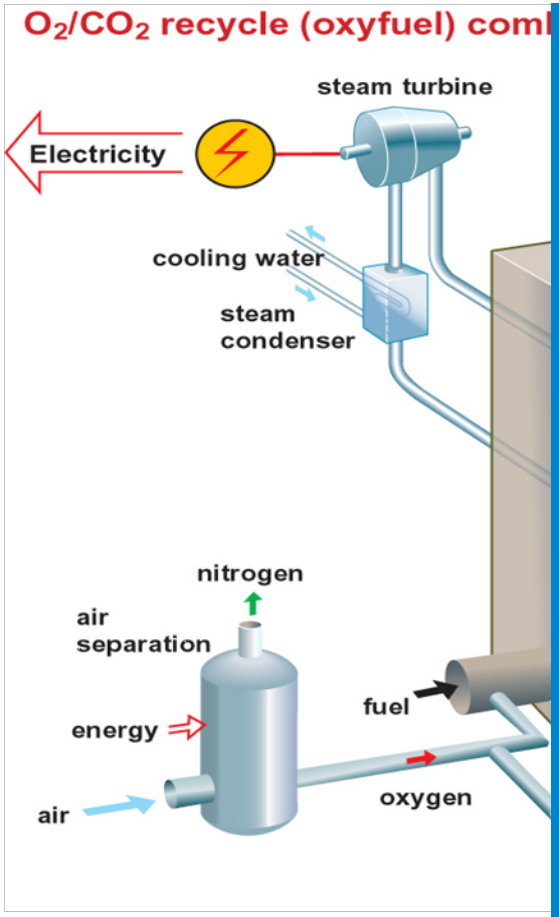
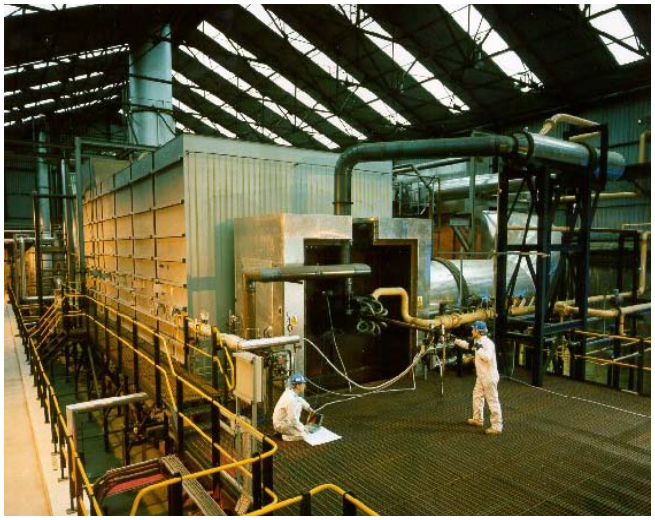


Figure courtesy of Vattenfall

- Pilot scale tests by Doosan Babcock Energy 1996
- EON 1MW rig now operational, confirmed DBE results
- DTI funded collaborative R&D projects in progress (Doosan Babcock Energy, SSE, SP, EON, RWE, Air Products …)
- Full scale 40 MW burner test by Doosan Babcock in 2009
- Vattenfall 30MW demonstration plant being inaugurated in Sept 2008 , and similar projects at Lacq and Callide
- Several boilermakers developing this technology for 2012 implementation

OxyCoal 2 - Demonstration of OxyCoal™ combustion system

- £7.4M project
- Convert Doosan Babcock's full-scale burner test facility to oxyfuel firing
    - Oxygen supply
    - Flue gas recycle system (fans, ducts, cooler, heater, etc.)
    - Instrumentation
- Design and build full-scale utility OxyCoal™ burner (40MW)
    - Derived from air-firing experience, CFD modelling and Oxyfuel R+D
- Demonstrate a full-scale utility OxyCoal™ burner
    - Flame stability, combustion efficiency, emissions, flame shape, and heat transfer characteristics as function of %CO_2 recycle and excess oxygen
    - Start-up, shut down, transition from air to oxyfuel, load change



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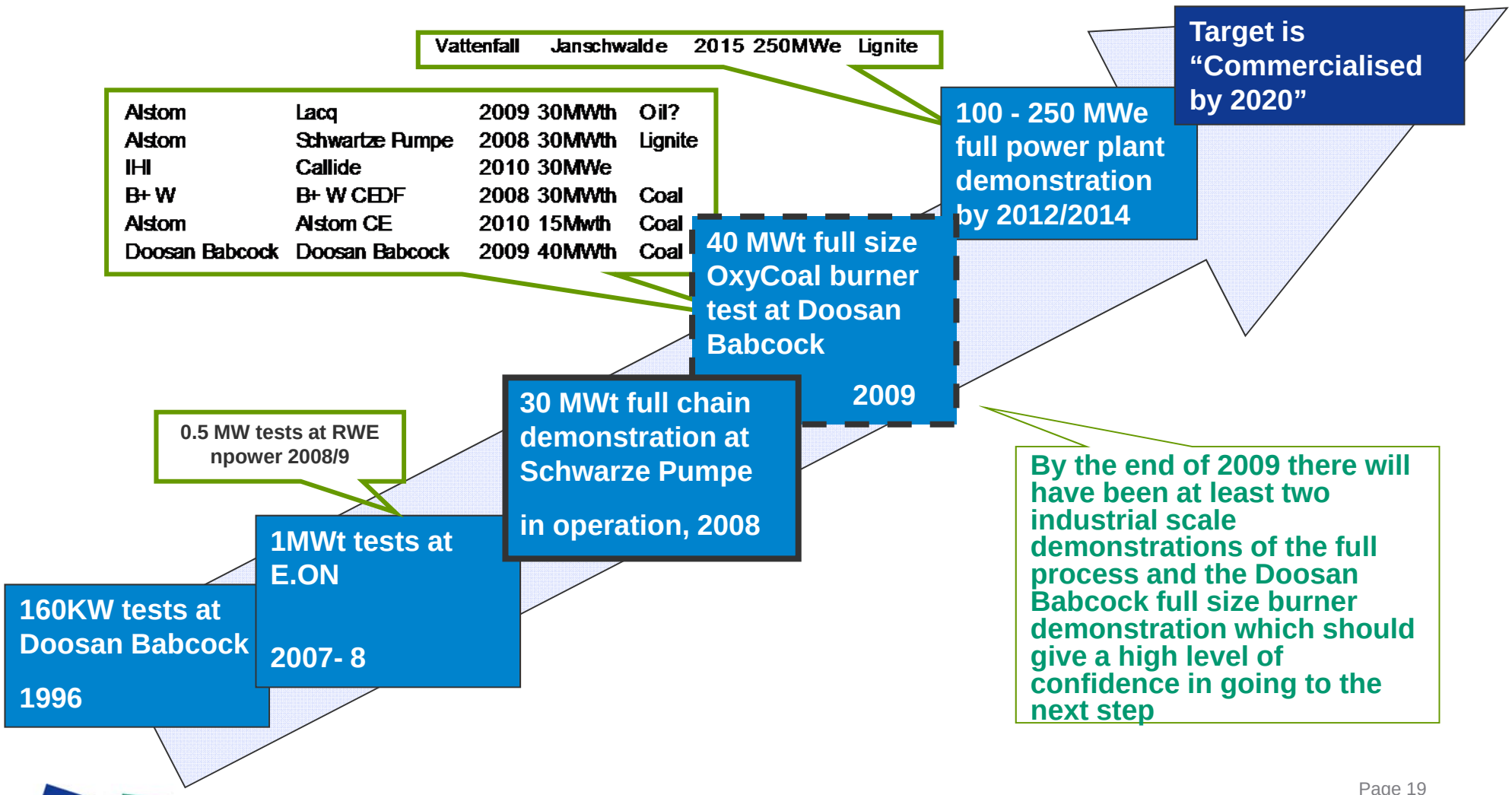
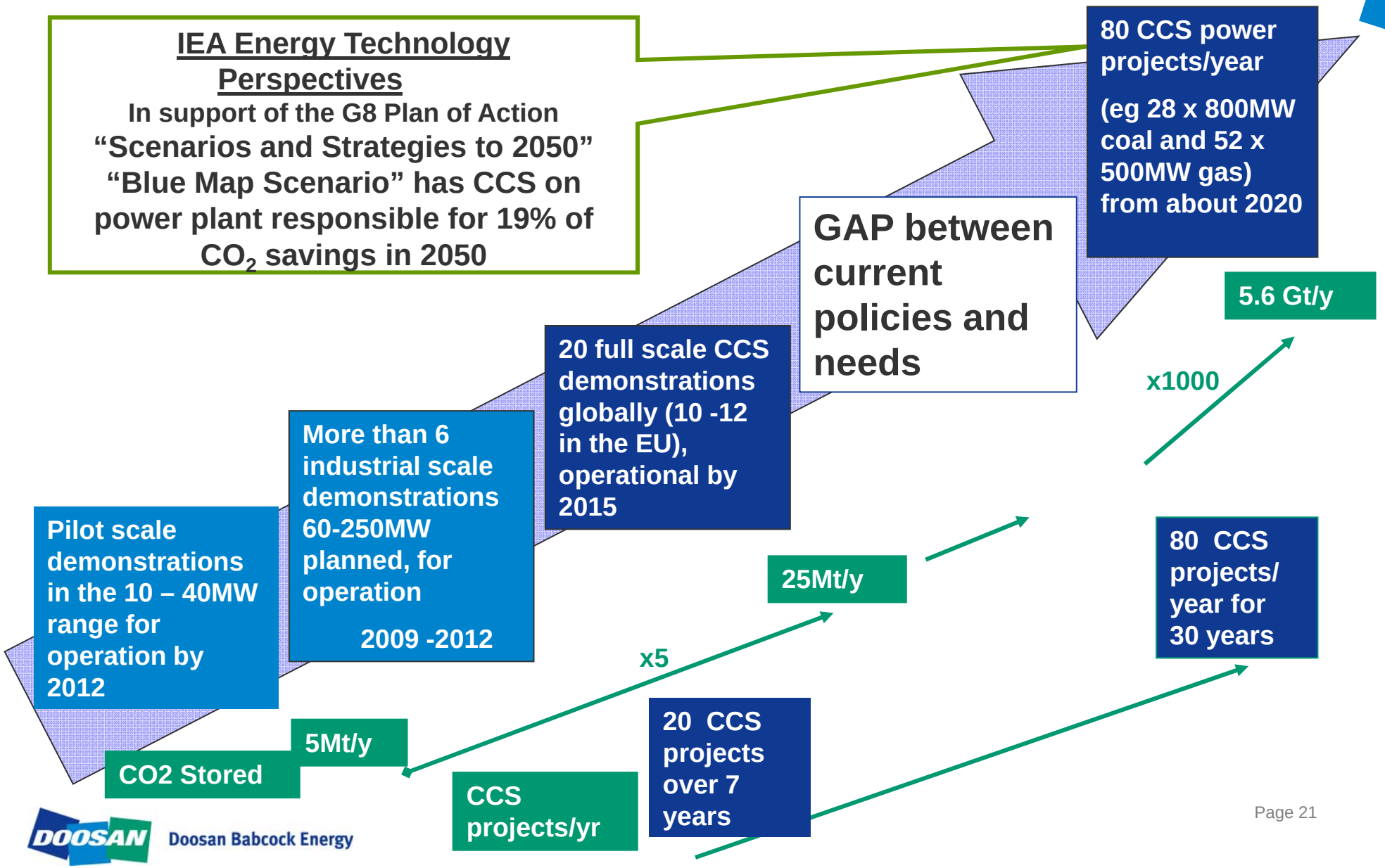
Scale up of Oxyfuel firing for coal power plants



Scale- up of CCS capacity needed to commercialise CCS on power plant by 2020



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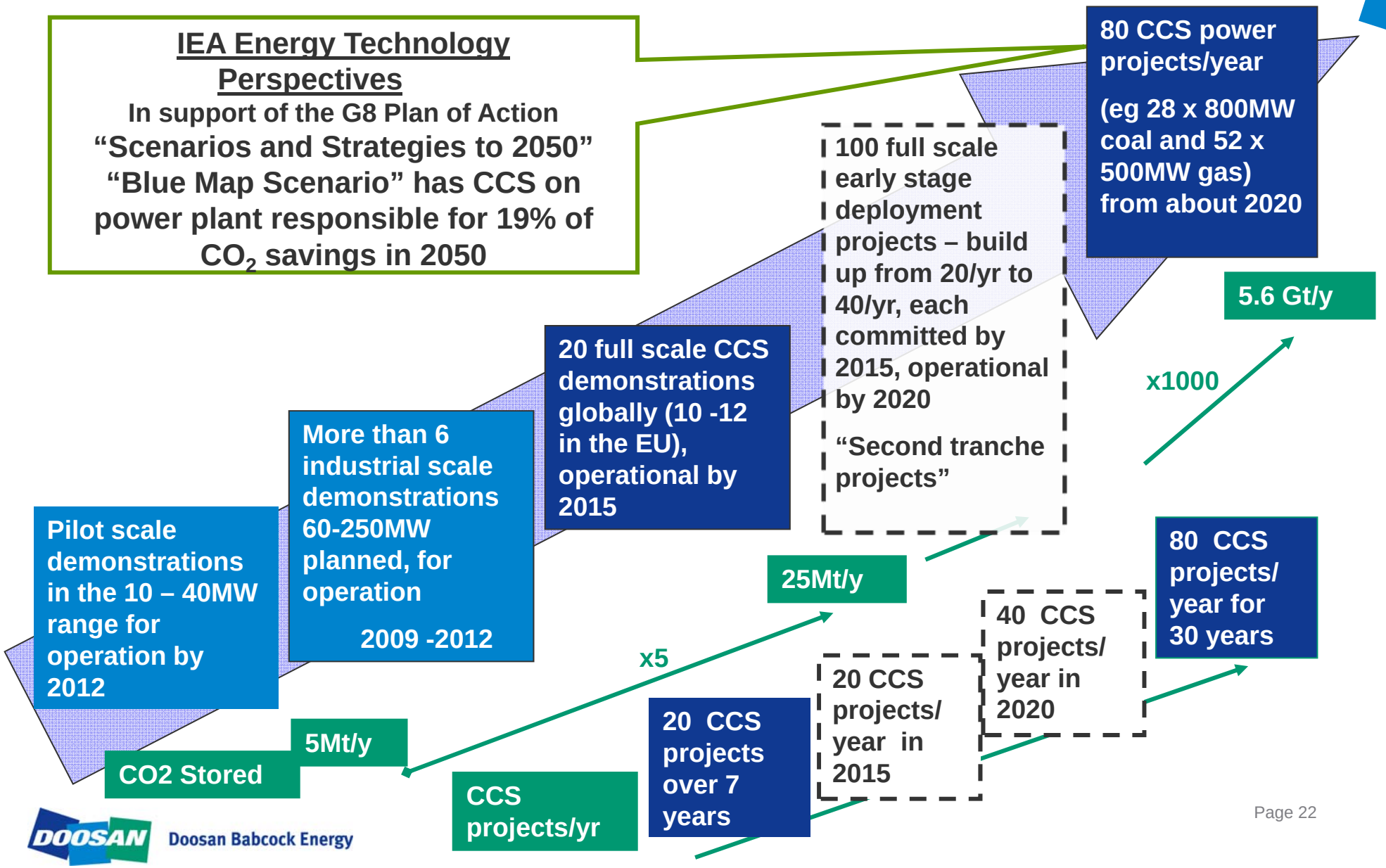
Scale- up of CCS capacity needed to commercialise CCS on power plant by 202

IEA Energy Technology Perspectives

In support of the G8 Plan of Action

"Scenarios and Strategies to 2050"

"Blue Map Scenario" has CCS on power plant responsible for 19% of CO_2 savings in 2050



Why Carbon Capture Ready as well as multiple CCS Demonstrations ?

80 CCS power projects/year

(eg 28 x 800MW coal and 52 x 500MW gas) from about 2020

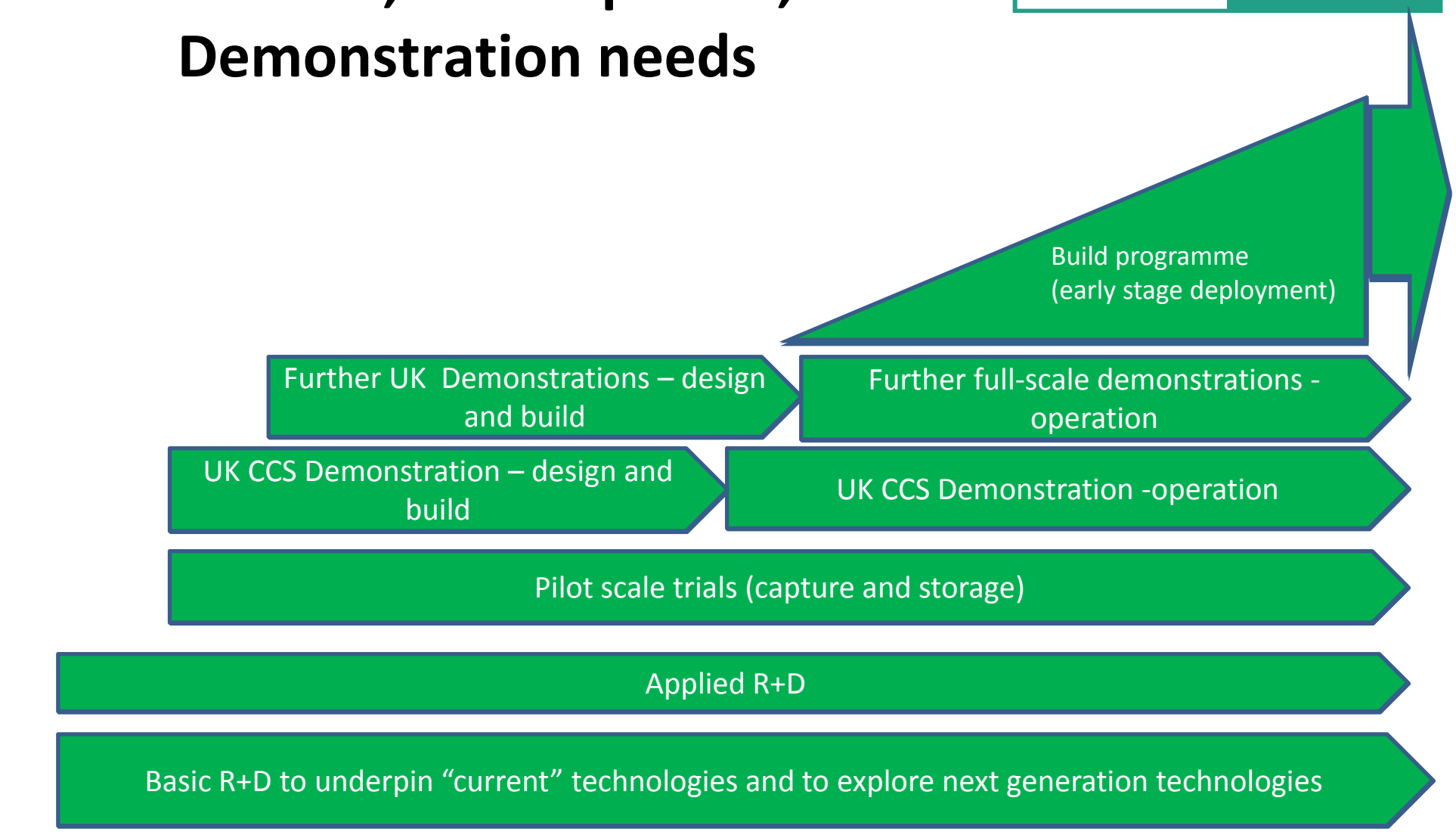
- **Timing and scale of introduction of CCS is restricted by the pace of**
  - **pilot/demonstration projects**
  - **introduction of regulations and**
  - **market conditions/incentives …dependent on the carbon price under the ETS**
- **“Capture ready (CCR)” is therefore very important since new power plants are needed in UK and globally on a scale larger and on a timescale faster than it is feasible to adopt CCS**
- **We conclude that we need *both* CCR and multiple CCS demonstrations**
- **We can set an excellent global example by building power plants capture ready and in parallel accelerating the demonstration of CCS**

Future R+D

- Support by DTI, BERR, TSB , and the Research Councils has laid a good foundation and we have now the opportunity to build on this
- Need targeted research as above but also require underpinning R+D in cross cutting areas such as coal science, modelling, environmental impact etc
- R+D in Universities also has an important role in creating the skilled people which industry needs for the future and specialist laboratory facilities – EPSRC Doctorate Training initiatives welcome
- EPSRC/EON Strategic Partnership - Call for University proposals, very timely (deadline 6 Nov) and appropriately targeted
- TSB (June) call for proposals in this topic area –will encourage involvement of the Research community in what will be industry- led projects
- Need properly coordinated support for CCS Research and Development, underpinning demonstration projects, bringing together the activities of the Research Councils, Technology Strategy Board, Carbon Trust, Energy Technology Institute and Environmental Transformation Fund
- APGTF is publishing its recommendations following January 2009 Workshop

Research, Development, Demonstration needs

APG TF



UK CCS Demonstration projects needed

APG TF

Carbon dioxide capture (coal) **•Post-combustion**	**600°C coal power plant with Post combustion capture, operating in the UK by 2014**
•Oxyfuel	**Full-scale 100-250MWe oxyfuel CCS demonstration by 2015**
•Pre-combustion	**A 4-800MW_e UK IGCC demonstration based on UK OEM capability by 2016**
Carbon dioxide capture (gas)	**State of the art gas fired power plant with post combustion capture operating in the UK by 2017** Demonstration of high efficiency gas turbine working on very high H_2 content fuel (international collaboration) Demonstration of pre-combustion capture with a natural gas combined cycle power plant (possibly retrofit)
Carbon dioxide transport	**Development of onshore transport network linked to several capture sites by 2015/17**
Carbon dioxide storage	**Multiple storage demonstrations in by 2015, including EOR, depleted gas and oil fields and saline aquifers**

UK Pilot scale projects needed

APG TF

Proven	Up to 2012	2014
Post combustion capture		
0.25-2 MW scale	Pilot scale demos at 1-20 MWe scale	Full scale power plant, at least 300MWe
Oxyfuel capture		
0.1 to 1MWscale	Demo of full size single burner(40MWth)	Full scale power plant,eg 100 -250MWe
	Demo of CO2 purification	
Pre-Combustion		
		Full scale power plant, at least 300MWe
CO2 storage in Saline acquifers		
1 million T/Yr into a very large aquifer with limited monitoring	CO2 development store with extensive monitoring to better understand interaction of CO2 with sub-surface structures. Single well. Near shore site preferred Injection around 100,00T/Yr	Further R&D using development store with multiple wells and extensive monitoring. Injection around 1million T/Yr
CO2 Stored in Depleted Gas Fields		
Limited test injection of CO2 currently underway, but limited information available	Test injection of around 100,000 T/Yr, from tanker With extensive monitoring	Increased injection of around 1 million T/Yr either from tanker or pipeline

Applied R+D

Basic R+D to underpin “current” technologies and to explore next generation technologies

APG TF

- Document covers
  - detailed needs
  - priorities
- Focus on
  - **Power plant** : focus on cost and increasing efficiency, biomass cofiring
  - **Capture technologies**: focus on cost, efficiency penalty, waste heat utilisation
  - **Storage**: focus on security, monitoring and verification
  - **Transport**: focus on logistics and transport network
  - **Whole system**: focus on risks, transient capability
  - **Advanced and novel capture technologies**
  - **Underpinning technology support**

Implications for Policy

- **Consenting process to require all large combustion plant/fossil fuel power plant emitting more than 1Mt CO_2/yr to be built capture-and-storage-ready**
- **Seek international agreement to make "certified" CCR mandatory for both coal and gas**

- **UK CCS regulations in place by 2010**

- **Three coal and one gas large scale CCS demonstration projects in UK, operational by 2015 (an appropriate share to meet EU, G8 and IEA objectives and maintain a leadership position for UK industry) funded from EU 300M EUAs and auction revenues**

- **Development of incentives by 2010 to support a second tranche of CCS projects (to be committed by 2015 and operational by 2020)**

- **Development of a strategy to implement CCS on all CCR plants (coal and gas) on fast- track timescales**
  - **eg enabling legislation for an EPS of 150g/kwh for all plants (new and CCR) emitting above a tonnage threshold**

- **Develop an overall electricity system plan, to define optimum combination of wind, nuclear, gas + CCS, coal + CCS**

STOP PRESS – Budget 2009

- Carbon budgets – CO_2 down by 34% by 2020
- £435M for energy saving measures
- £525M support via Renewables Obligation for offshore wind
- Coal, oil and gas will continue to be important, so CCS vital
  - UK determined to lead
  - *New funding mechanism to support between 2 and 4 CCS projects*

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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