Future Power Generation Options: Coal

British Flame - Cardiff
June 2008

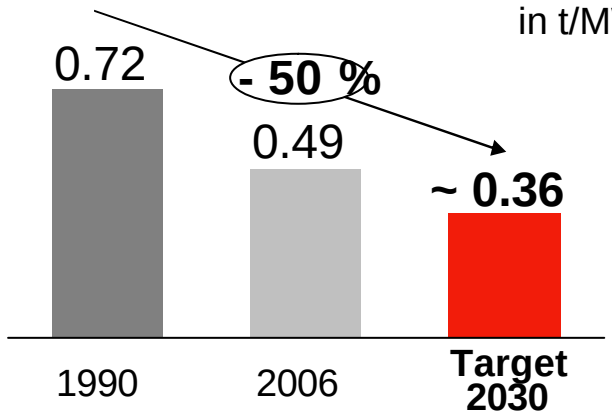
Contents

E.ON is committed to reducing its specific CO_2 emissions by 50% from 1990 levels by 2030.

"*We are going to be pushing every technical possibility to make electricity from coal-fired plants CO_2-free. If CO_2 capture is technically possible and economically feasible no new coal-fired power plant should be built from 2020 on without CCS*"

Wulf Bernotat, E.ON CEO, 4th April 2008, Madrid.

E.ON's specific CO_2 emissions



- 50% reduction of CO_2 emissions compared to 1990 baseline.
- Reduction of CO_2 emissions down to 0.36 t/MWh by 2030.

In addition, E.ON is

- Expanding Renewables rapidly, with the aim of 24% by 2030.
- Supporting nuclear power, including new nuclear power plants.

http://www.eon.com/en/investoren/news-show-news.do?id=8527

A range of technologies are needed to reduce CO_2

Renewables

- Wind
- Hydro
- Biomass
- Marine

Better Fuel use

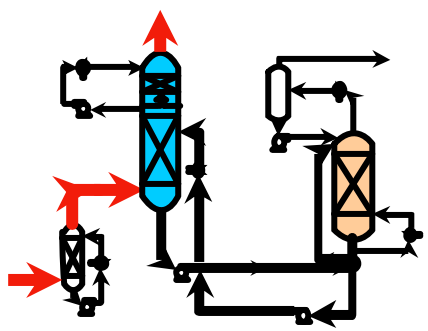
- Enhanced Efficiency
- CHP
- Micro-CHP

Demand Reduction

- Energy Efficiency
- Insulation
- Smart Metering

New Large Scale Generation Technologies

- Nuclear
- Carbon Capture and Storage



Our leading scenarios all show a role for CCS after 2020.

The Case for Carbon Capture and Storage

1 CO_2 Reductions

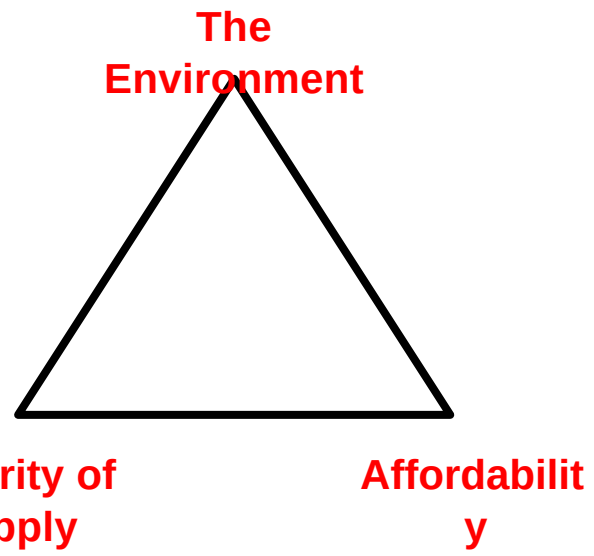
- Reduces fossil fuel plant emissions by 90%
- Applicable to coal based economies such as India and China which are driving world emissions growth.

2 Security of Energy Supply

- Coal based CCS gives security of energy supply, coal can be stored & freely traded
- Coal+CCS allows the continued burning of coal in a carbon constrained world
- Only option for a non-gas, fossil fuelled future

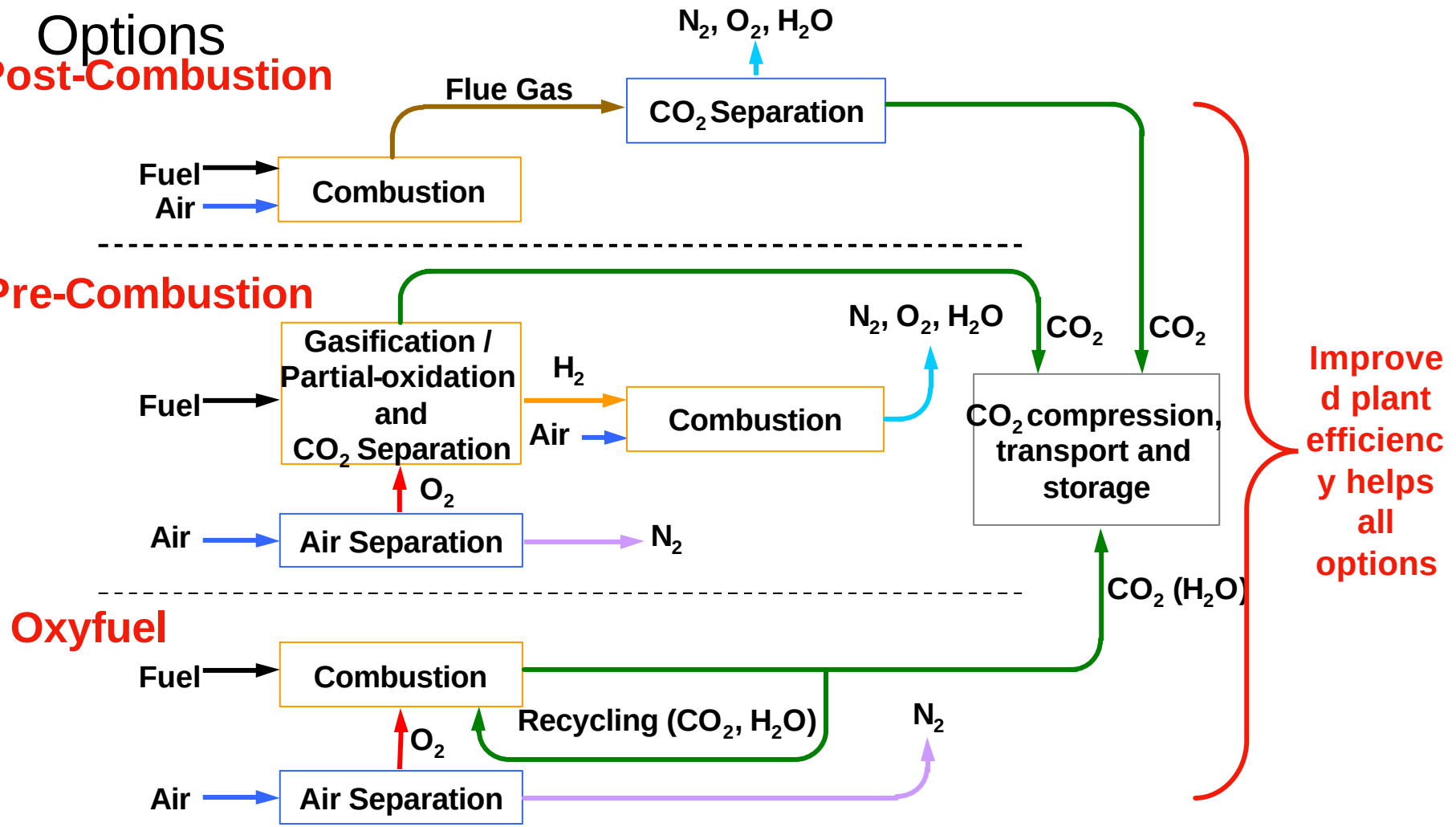
3 Affordability

- CCS carries a cost penalty over unabated plant
- Cost competitive form of carbon abatement

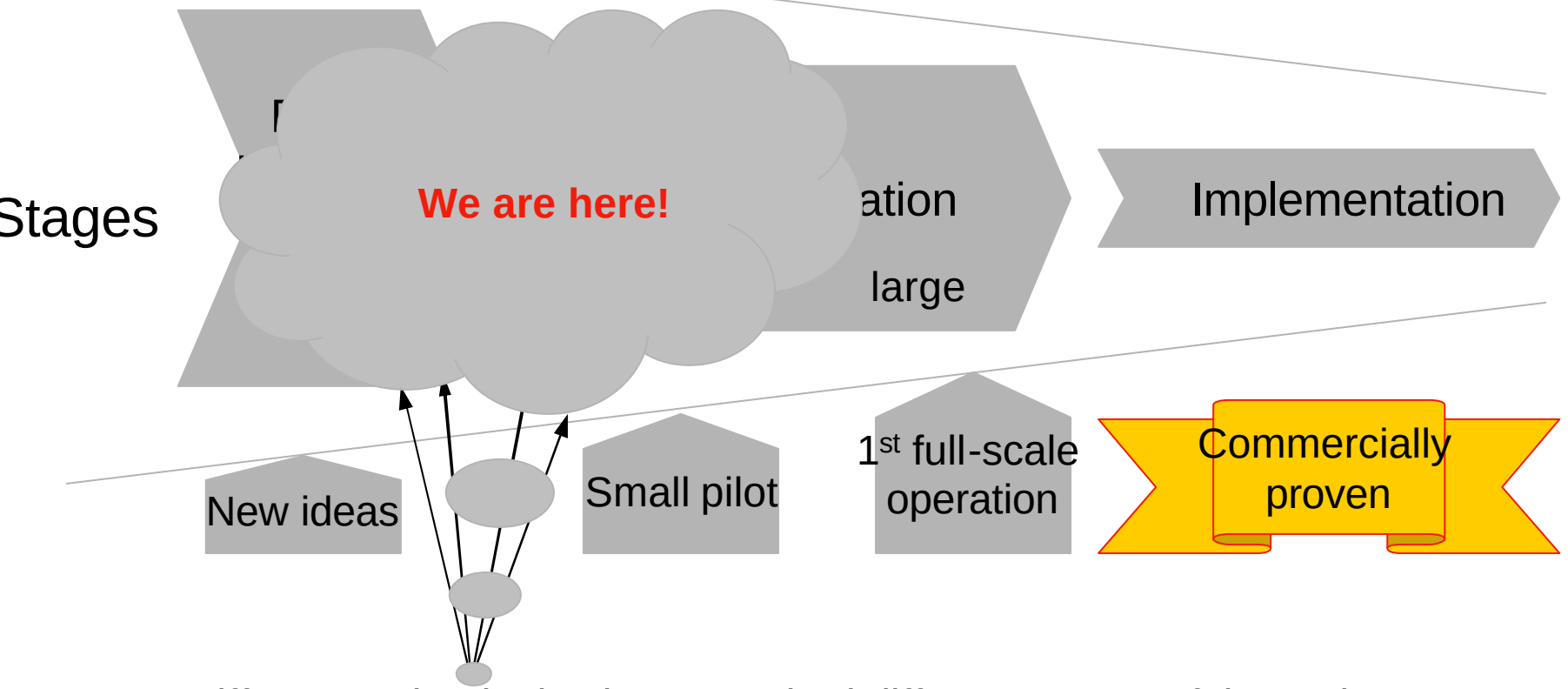


CCS is vital to solve the Global Trilemma

Technology Options



Technology Development Pathway



- Different technologies have reached different stages of the pathway
- None yet at full scale operation
- The long term winner is not at all clear

E.ON's approach – back as many options as possible!

Technology

- Oxyfuel
- Pre-combustion
- Post-combustion

Scale

- Small R&D projects
- Test rigs
- Pilot / small scale demonstrations
- Large scale demonstrations

Associated factors

- Looking at transport and storage options
- Plant efficiency!

Pre Combustion Capture projects (IGCC)

FutureGen

- Public-private partnership to build a 275 MW IGCC plant with CCS
- Preferred site selected in Mattoon, Illinois
- Pre-FEED has commenced, concluding circa Q3/Q4 2008
- Multiple site and CO_2 sink options still being considered.
- All sinks are onshore saline aquifer formations
- Single unit IGCC with CCS, net output estimated at 370 MW

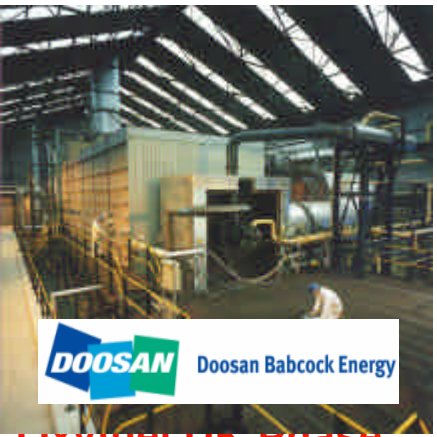
Killingholme, E.ON UK

- Pre-FEED study completed Sept 07
- Highly promising net efficiency of circa 36-37%
- 90% CO_2 capture is achievable
- Ideal storage sites identified in depleted gas fields in SNS
- Work suspended due to lac

COORIVA

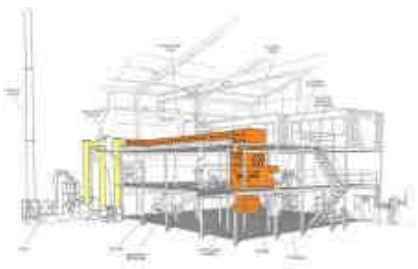
- E.ON is involved in the EU-funded COORIVA FP6 project
- Looking at solutions for the development of an IGCC power plant demo project
- CO_2 capture, “State of the art IGCC full scale technology”, H_2 turbine, coal gasification and gas treatment

Oxyfuel Combustion Projects



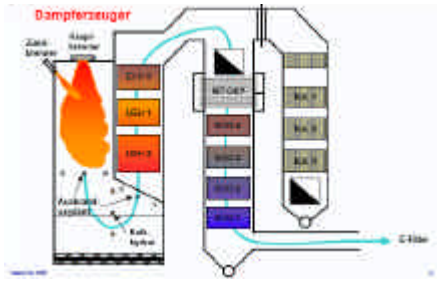
Oxyfuel UK Phase II

- Innovative 40MW$_{th}$ oxycoal Doosan Babcock burner test rig
- Operational 2008/9
- E.ON will have access to tests and significant budget to monitor



1 MWt test facility

- 1 MW$_{th}$ E.ON test rig at Ratcliffe, UK will underpin the large scale testing by studying deposition and corrosion
- Built under ACECOGS partnership



ALSTOM e·on

ADECOS

- Development of components for an coal/lignite fired power plant with O_2/CO_2 atmosphere (burner, CO_2 capture, preparation pilot plant)

Oxycoal Aachen

- Component development for a coal fired power plant with O_2/CO_2 atmosphere (high temperature membrane for air separation, burner, turbo components)

Post Combustion Capture Projects – Small Scale

CASTOR/CESAR

- EU consortium testing at an existing coal fired plant (1t CO_2/h)
- Testing different solvents, maintenance and material costs

CATO

- Testing at existing coal fired plant
- Solvent tests, membrane contactors
- Starts operation mid 2008

Chilled ammonia

- ALSTOM & E.ON pilot plant in Karlshamn, Sweden
- 7,5 MW_{th} scale on an oil-fuelled boiler
- Simulation of CCGT.
- Starts operation mid 2008

POSTCAP

- Siemens & E.ON in Germany
- Solvent development and testing.
- Operation at <1 MW scale by end 2009

Post Combustion Capture - Larger scale

Large scale post-combustion capture entry into UK Government CCS Competition

- The planned supercritical unit at Kingsnorth, combined with UK Government funding gives a unique opportunity to demonstrate CCS on a high efficiency modern plant at nearer commercial scale

The Government Rules Require

- 300MW$_e$ amine scrubber fitted to a new supercritical coal-fired unit by 2019
- Capturing circa 2Mt/y CO_2 and transporting offshore for storage in the North Sea
- Competition negotiations and plan submissions during 2008 and early 2009.
- Full chain of capture, transport and storage should be demonstrated by end 2014

In addition…

>30 MW$_e$ amine test facility

- A commitment to build a >30MWe facility in Germany ~2014
- To test second generation capture technology at scale
- With view to commercial implementation circa 2020

Not forgetting improved efficiency

We are aiming for a Quantum Leap Using New Materials

Location	**Wilhelmshaven,GER**
Efficiency	50 %
Capacity	> 500 MW_{el}
Investment	> 1000 Mio. €
Start of operation	2014

- "Ca
- post
- ture pilot under investigation

in 2007 — 2010 — 201

Preliminary planning
Search for location

Material developmen
Request for proposal

Construction
Start of operation

Feasibility Study into possible CCS project at Killingholme

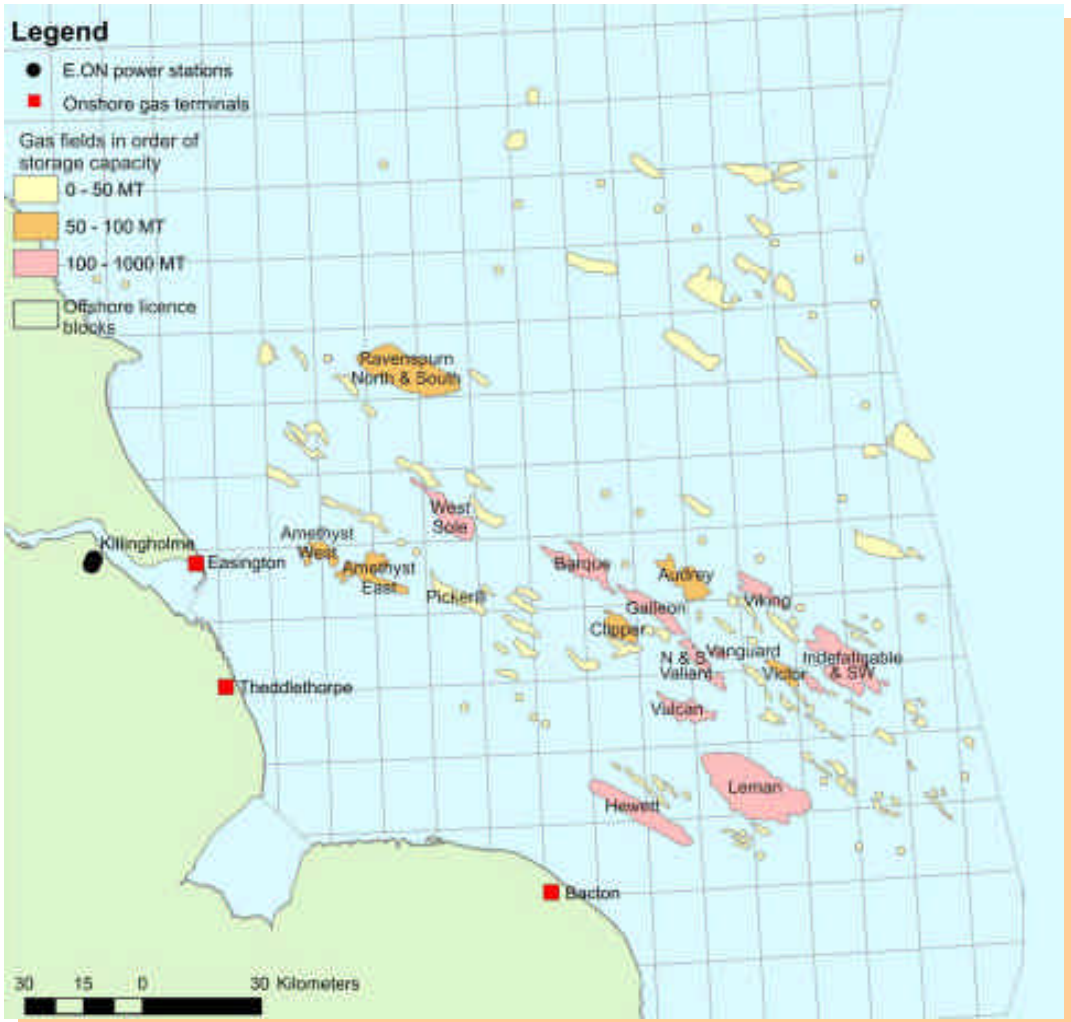
Overview

- Based on a single F class GT IGCC+CCS fuelled on coal
- Built on or close to the existing Killingholme site
- Multiple CO_2 storage options identified in the Southern North Sea (SNS)

Multiple $C0_2$ storage sites identified in the SNS

CO_2 storage

- Killingholme is well positioned for CO_2 evacuation from Easington and Theddlethorpe
- The vast majority of gas fields in the SNS are capable of storing CO_2
- The SNS is capable of storing 2.8Bt of CO_2, Killingholme would produce 2.5Mt of CO_2 pa.



Killingholme Study Results

Pre-FEED conclusions:

- IGCC plant is technically feasible; individual units being proven on existing applications
- Unit size ~370-380 MWe – but single module is very expensive, three are preferred.
- 90% CO_2 capture is achievable
- Various ideas to improve reliability and reduce cost were identified – with scope for future improvement
- High efficiency plant with potential as intermediate step towards hydrogen economy
- Adequate number of competing equipment vendors
- Technology well suited for Killingholme site with potential for additional scale up

Killingholme Study Results

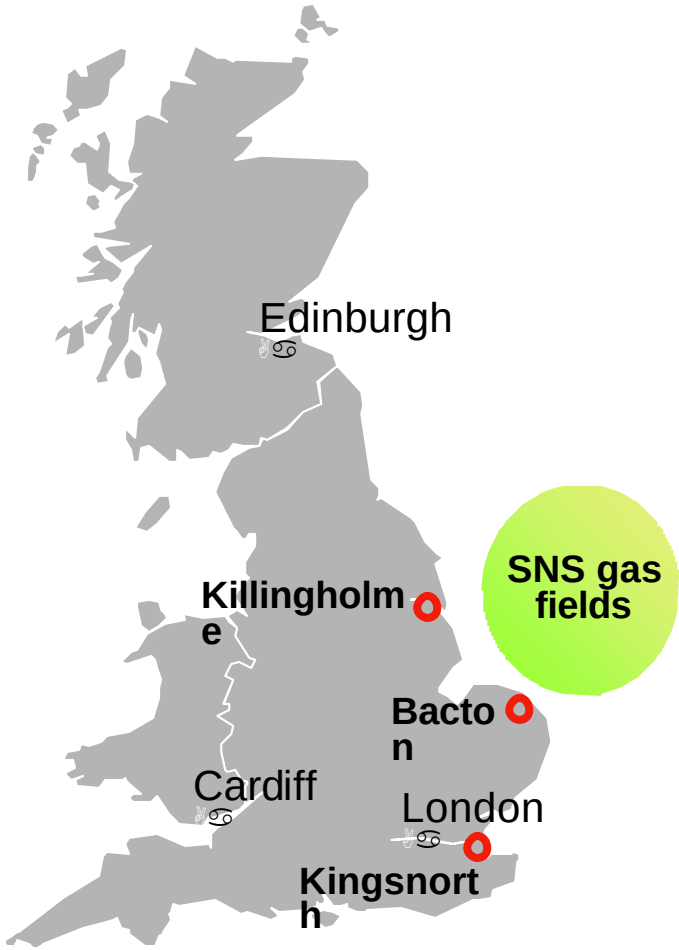
Comparison with Supercritical + amine scrubbing:

- IGCC is more efficient with capture
- But IGCC is also more expensive and less reliable
- Overall economics are too similar to choose a winner

The UK Government decision to fund post-combustion only, led to work on Killingholme being stopped

Kingsnorth – Competition Entry

- New 1.6 GW coal station (two 800 MW units) on the River Medway, Kent, due for operation in 2013 – consent decision awaited from UK Govt.
- Use of Killingholme site would push up base power plant costs
- Main difficulties at Kingsnorth are on-site space, and getting to the CO_2 sink



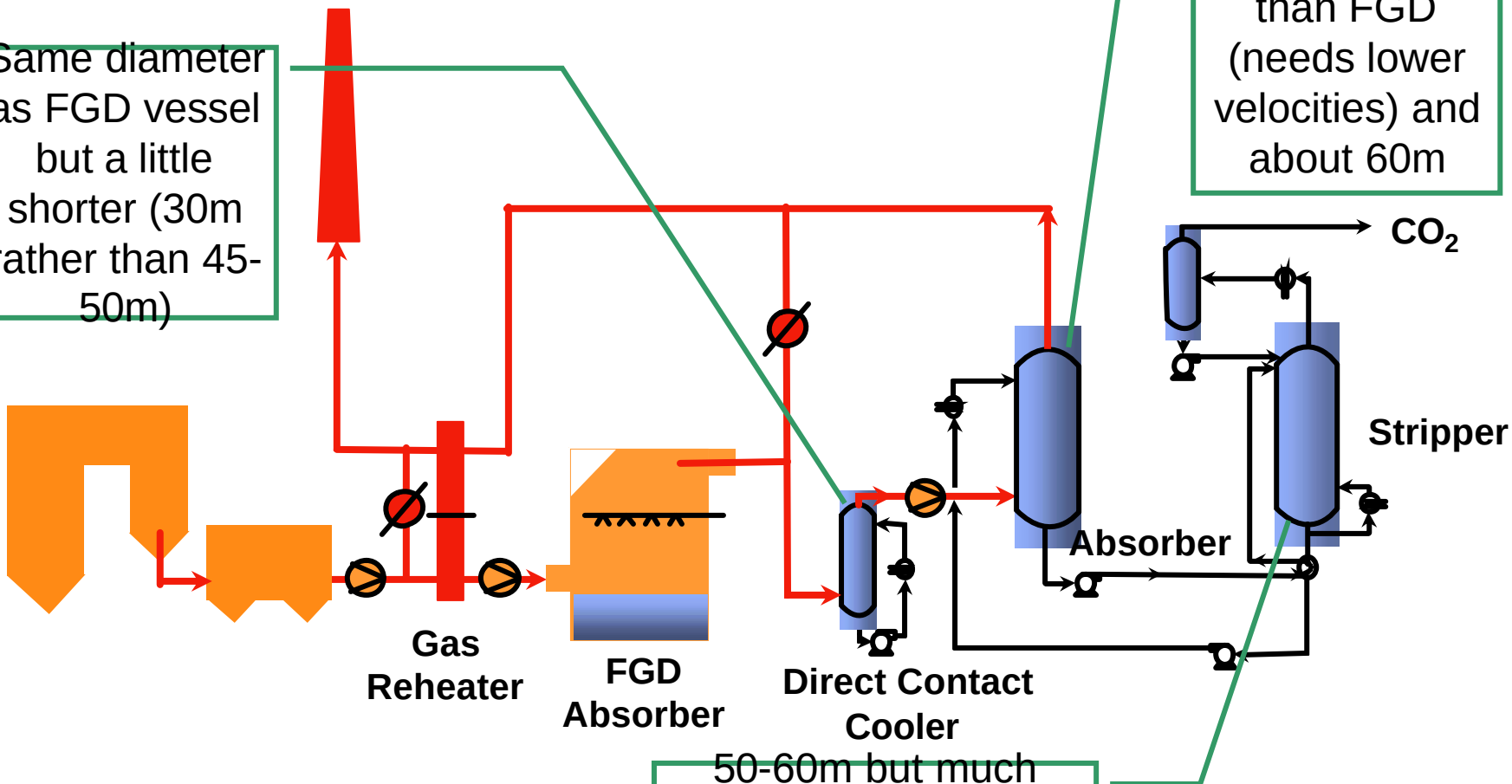
CCS on Kingsnorth

- A 300-400 MW scrubber would take ~50% of the flue gas from one unit with 90% CO_2 capture.
- Chilled ammonia and advanced amines are not seen as ready for full scale demonstration yet, so conventional amines are most likely to be used – but will be kept under review
- Fluor and MHI are technology market leaders for conventional amines and are supporting our bid
- The plant is anticipated to capture about 2 Mt/y CO_2
- Pipeline transport of CO_2 to a gas-field off Bacton for geological storage – we are working with Penspen on pipelines and Tullow to deliver the storage
- Over sizing of the infra-structure will be considered, but is at our risk

What does Amine Scrubbing look like?

Same diameter as FGD vessel but a little shorter (30m rather than 45-50m)

Larger diameter than FGD (needs lower velocities) and about 60m



50-60m but much narrower than absorbers

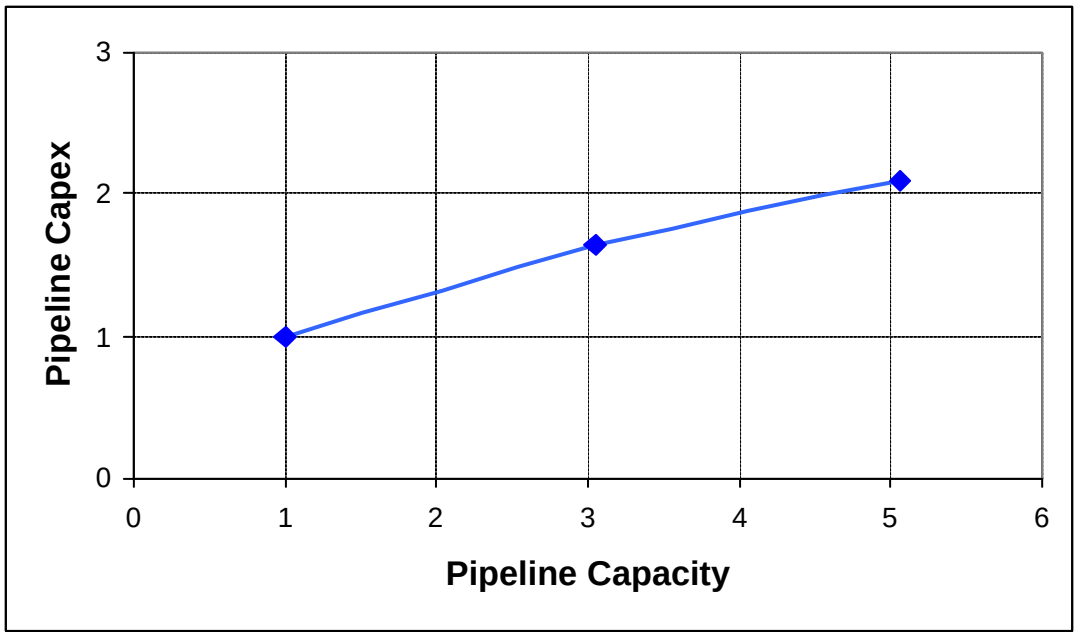
Kingsnorth Animation

Challenges of Commercial Scale CCS Demonstration

	Pre-combustion	Oxyfuel	Post-combustion
3-400 MW Scale	400 MWe OK but an expensive plant	400MW – high technology risk & still not full scale	Partial capture on 800+ unit OK if politically acceptable, but hard to consent unabated plant – UK has no suitable existing plant
Capture-ready	CCS affects GT sizing unless efficiency hit is taken up front	OK in principle, but technology needs development	Good

Challenges of Commercial Scale CCS Demonstration

- Transport and storage benefits strongly from economies of scale



Challenges of Commercial Scale CCS Demonstration

Who Pays?

- Commercial cost estimates are €30-40/t of CO_2
- EU ETS uncertainty means prices >€40/t are likely to be needed
- Initial demonstrations will cost more – maybe €60-80/t – higher if smaller scale – of order €1billion per commercial scale project
- EU wants 10-12 demonstrations by 2015, but has offered no money
- Companies are willing, but need a credible return on investment
- UK Government has offered to pay for:
  - Demonstration only, no scale-up (no additional pipeline capacity)
  - Up to 100%
- Norwegian Government has publicly backed one CCGT demonstration
- **We need more!**

Practical Challenges

- The need to select the technology when there isn't a clear winner…
- …and therefore design a plant that is "future-proof"
- Unclear how we get a CO_2 injection permit
- Regulation is evolving – so decisions are likely to be slow and any agreed solution (e.g. monitoring and verification) may be revised later
- Storage in the Southern North Sea re-using gas infra-structure still isn't legal
- Any large construction project has local planning and environmental requirements to meet
- It takes a "consortium" – our pre-qualification questionnaire involved seven companies – with attendant management issues: project control, decision making, risk allocation etc
- If you need a new unabated coal plant for the demonstration – expect public opposition unless a firm commitment to full CCS can be given!

In Summary

- We need CCS as one of a package of measures to deliver a low carbon future – with affordability and security of supply
- E.ON is committed to the development of CCS at senior level
- And has R&D programmes in place across the technologies and across the size range
- We are keen to see conventional CCS demonstrated at commercial scale, and accelerate the development of 2nd generation technologies
- And also improve the efficiency of the base plant – an important step to improve the competitiveness of CCS

But …

- Substantial practical challenges remain
- The financial framework to allow CCS investment at scale by industry is urgently needed to deliver CCS.