Carbon Capture & Storage: An Interdisciplinary Review

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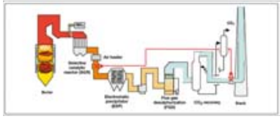
CO_2 Capture
How does it work?

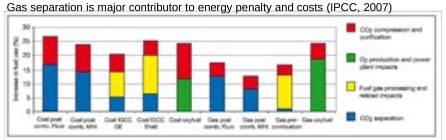
- High performing, economical gas separation technologies required to bring down costs
- Capture method is dependent on generation type, desired end product and process conditions

Typical amine-based capture system for a pulverised coal power plant. (IPCC, 2005)



- **Liquid solvent** absorption is currently the most developed and widely used method, particularly for post-combustion capture
- **Solid adsorbents** are promising but require further development before widespread applicability
- **Membrane technologies** are most suitable for pre-combustion processes which yield highly concentrated CO_2 streams
- **Cryogenic distillation** is currently too costly to be considered a viable CO_2 separation technology on a large scale

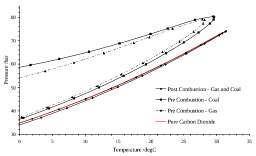
Gas separation is major contributor to energy penalty and costs (IPCC, 2007)



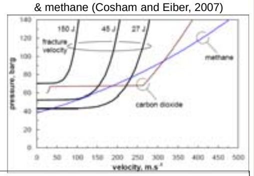
CO_2 Transport
From source to sink

- **Options:** preferably by pipeline (onshore/offshore) - most economical and technologically advanced
- **Experience:** offshore transport of anthropogenic CO_2 not currently practised, extensive onshore experience with natural CO_2 for EOR in USA

Effect of capture impurities on phase behaviour (Race, 2010)



Depressurisation characteristics of CO_2 & methane (Cosham and Eiber, 2007)

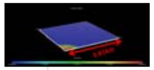


Schematic of network design for CCS in Yorkshire and Humberside (Yorkshire Forward, 2009)

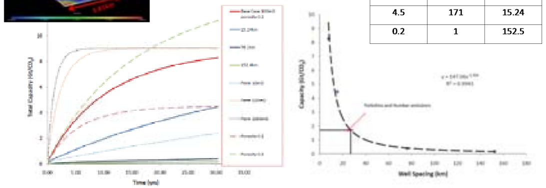
- **New concepts:** impurities in post-capture CO_2 stream can cause corrosion and adversely affect fluid physical properties
- **Safety:** potential for propagating fractures in CO_2 pipelines cannot be modelled by experience in natural gas pipeline due to different depressurisation rates
- **Economics:** transport of CO_2 is cheaper if part of a pipeline network but this needs to be incentivised by governments
- **Regulation:** decisions to be made on pipeline impurity levels and safe distances between pipelines and population centres

CO_2 Storage
Where is it going?

- Reservoir modelling to determine capacity of Bunter Sandstone saline aquifer in the southern North Sea
- Capacity of 14.25GtCO_2 based on available pore space with 'fracture pressure' a limiting factor



Capacity ($GtCO_2$)	No. Wells	Spacing (km)
8.3	687	7.62
4.5	171	15.24
0.2	1	152.5



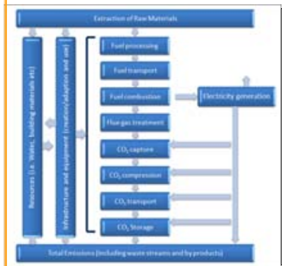
- Projected emissions capture from Yorkshire and Humber CCS scheme **over 30yrs - 1.7GtCO_2**
- Relationship derived from modelling suggests well spacing of 26.9km or **56 injection wells required within aquifer**
- Based on a well cost **of between £30 million and £122 million** this indicates a storage cost of **£1.00 to £4.29/tCO_2**

CCS and CO_2 Mitigation

Global CO_2 emissions are set to **increase by over 100%** by 2050
CCS predicted to provide **20% of required mitigation** by 2050
Without CCS, mitigation costs could be up to **70% higher**

International Energy Association (2008) projections, compared to 2005 baseline

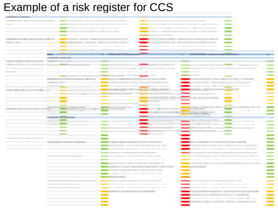
Environmental Impacts
What is the risk?



Life-cycle
- Additional energy required for capture, storage, transport, infrastructure, materials extraction and fuel processing
- Increased by-products, wastes and emissions of pollutants
- Additional fossil fuel use contributes to acidification, eutrophication and the depletion of natural resources

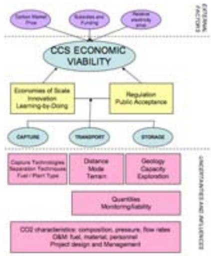
Risk assessment
- Amine emissions, pipeline failure and storage failure are the most likely causes of environmental damage.
- Higher risks are attached to the areas where more commercial experience is needed
- A risk register can be used to assess risks

Example of a risk register for CCS



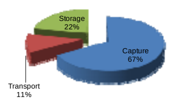
Economics
How much?

Influences on CCS Economic Viability

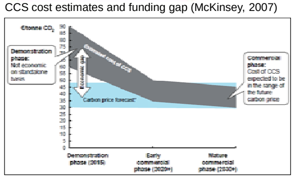


- **Estimated project costs**
  - Demonstration £m 22.5 - 77.7
  - Commercial £m 15.8 - 47.3
- **Current carbon price** is £12/tCO_2
- **Projected prices of carbon**
  - 2020: £34/tCO_2
  - 2030: £78/tCO_2
  - 2050: £170/tCO_2

Relative costs in the CCS chain (McKinsey, 2007)

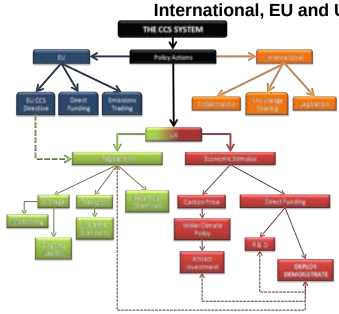


CCS cost estimates and funding gap (McKinsey, 2007)



- Success or failure of CCS will be driven by its long-term financial viability in mitigating climate change
- Dependent on a strong carbon price and demonstration stage funding policies
- Must be compared against other mitigation technologies and energy pathways to assess its viability
- Lack of commercial deployment makes cost estimates uncertain

The Role of Policy
International, EU and UK



International:
- 100 planned projects
- Global CCS Institute, Canberra
- Near Zero Emission Coal project between UK and China
- Amendments to legislation including the London Convention and OSPAR Convention

EU:
- CCS Directive 2009 – legislative framework for CO_2 storage
- CCS included in EU Emissions Trading Scheme 2009
- Auction of 3M carbon credits to fund 10-12 demonstration projects

UK:
- New coal plants must demonstrate CCS and all new combustion plants must be built capture ready
- Regulations for storage and transport will be in place by 2011
- CCS fuel levy to raise up to £9.5bn for 4 demonstration plants

Conclusions

CCS is a complex endeavour involving carbon capture, transport, storage, environmental impacts, economics and policy. Successful implementation will require a coordinated approach from all stakeholders. Many physical processes involved in CCS have been proven to be feasible, yet the main challenges relate to scaling up of these processes as well as their integration into a complete commercial system. A number of possible environmental impacts of widespread CCS implementation can be identified and care will need to be taken in assessing and mitigating these. Economically, CCS is not self-supporting in the demonstration phase and financial stimulus will be required for initial deployment. Yorkshire and Humber is a prime area for commercial CCS due to a high concentration of point sources and the storage space available in the North Sea.

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