UK Energy Research Centre

insight

An energy briefing paper

Carbon Capture and Storage
Analysing uncertainty



Executive summary

- Carbon capture and storage (CCS) could be a key technology to tackle climate change
- However, there are many economic, political, financial and technological uncertainties that hamper its development and deployment
- Comprehensive government policy support is needed to reduce these uncertainties sufficiently to enable further progress
- It is not necessary to resolve all uncertainties in order to make CCS financeable in the UK
- The UK CCS commercialisation programme needs to make rapid progress, with firm commitments to build several demonstration projects as soon as possible

Introduction

Carbon capture and storage (CCS) is seen as a key technology to tackle climate change. The principal idea of CCS is simple – to remove carbon from the flue gases arising from burning fuels for electricity generation or industrial applications and to store it in geological formations to prevent it entering the atmosphere and contributing to climate change [see text box 1: How it works].

But there are many economic, political, financial and technological uncertainties that hamper the development and deployment of CCS. The challenge is to assess these and develop strategies to deal with them, and to find the best ways to encourage innovation to improve the technology, ensure its reliability, and make it financially viable.

Why CCS?

CCS is often considered by policy makers to be a crucial technology for the long-term of abatement of carbon emissions. Large-scale integrated demonstration systems are being considered around the world, including in the UK. CCS shows great promise for reducing CO_2 emissions related to power generation; potentially 90% or more of the carbon emitted by burning coal in a power plant could be removed using existing technology (see text box 1: How it works).

Electricity generation from fossil fuels is a significant contributor to CO_2 emissions, and the use of fossil fuels for electricity generation is predicted to continue for a long time. The UK government sees CCS as a key part of its strategy to reduce carbon emissions by 80% by 2050, while continuing to use coal and gas in power generation.

Understanding uncertainty

However, there remain significant uncertainties around CCS, related to technical, economic, political and financial aspects, as well as public acceptance. This creates challenges for all concerned about climate change mitigation. What is certain is that CCS will need government support to form part of the mitigation mix. We need robust evidence and analytical capacity to inform the decisions not only of government but of businesses, in relation to investment in climate change mitigation.

This highlights the need for a framework for analysing and assessing uncertainties for CCS.

Major challenges exist for both CCS analysts and practitioners in relation to identifying and assessing the current uncertainties and understanding how they can be reduced, managed or adapted to, and finding ways to encourage the innovative thinking needed to improve CCS technology. These uncertainties and their effects, along with suggested methods for assessing and mitigating them, are outlined in Table 1.

History lessons

In the UKERC Research Project Carbon Capture and Storage: Realising the potential? (see Further Reading) the authors drew on experience of previous technologies that are analogous to CCS in some way, considering historical case studies that dealt with the range of uncertainties related to CCS listed in Table 1. This case study evidence was used to develop a number of pathways for CCS deployment in the UK to 2030. The case studies, listed in Table 2 and summarised at http://www.ukerc.ac.uk/support/ES_RP_SystemsCCS, demonstrate that many of the uncertainties were reduced sufficiently for progress to be made. In some cases they were resolved entirely. This points towards a way forward for evaluating low-carbon technologies in general, and CCS policy in particular.

The way forward

While it is tempting to focus efforts and resources on one variant of CCS technology, the lessons learned from the historical case studies suggest that the best way forward for CCS is to keep the options open. The extent of current uncertainties means that it is too soon for government and industry to close down on a particular option for CCS technology. It is also too early to mandate CCS on all existing fossil fuel plants.

In the meantime, it remains important for the government to carry out further analysis and to support CCS demonstration projects. Recognising that it is possible to learn as much from the 'failures' as from the 'successes', it's important to ensure that scarce funding is not dedicated to a single project but shared by a small number of integrated projects. Although future liabilities related to the storage of CO_2 are difficult to predict, a clear framework can be put together for dealing with them, as can arrangements for sharing liabilities between the public and private sectors.

But perhaps the most important lesson overall is to recognise that when it comes to making decisions about the possible future development of CCS and the form this might take, a framework for decision making that takes into account social, economic and technical issues related to CCS is essential. And all in all, it's best to view the race to deploy CCS as a marathon – rather than a sprint.

Further reading
Watson, Jim (editor) et al., Carbon Capture and Storage: Realising the potential? UKERC Research Project Final Report.

Text box 1: How it works

Carbon capture and storage principally consists of three operations: capturing carbon at the power plant or industrial application; transporting it to appropriate storage sites; and storing it underground. The process involves a number of different technologies and industries. These range from equipment suppliers that produce equipment to capture CO_2 to utility companies or industrial players which need to integrate the capture equipment onto their site; pipeline network operators to transport the captured CO_2; and oil and gas companies with offshore expertise who might take charge of the injection into oil and gas fields.

Capturing carbon

Carbon capture technology is already used on a small scale for enhanced oil recovery, and other potential applications also exist in industry. Processes already exist to extract carbon from point sources such as power stations at the pre- or post-combustion stages.

In pre-combustion processes, carbon is removed from the fuel before it is burned. To do this, the fuel is gasified and the carbon dioxide chemically separated out. In post-combustion processes, the carbon is removed from the flue gas after the fossil fuel has been burned. This can be done using a number of different chemical solvents. In addition, carbon can be extracted by burning fossil fuels in almost pure oxygen rather than air, in a process known as oxyfuel combustion. This produces almost pure carbon dioxide and water vapour from which the carbon can be relatively easily be removed.

Transport and storage

Once captured, the carbon can be transported via pipelines to storage locations. There are a number of different carbon storage options being explored, including injecting CO_2 into saline aquifers, or into depleted oil and gas fields. To promote public acceptability, the current focus for storage options centres on the potential of offshore storage sites.

Table 2: Analogues from the past

Uncertainty addressed	Historical analogue case study*
1. Variety of pathways	The French Nuclear Programme, 1950s-1980s
2. Safe storage	The management of radioactive waste in the UK, 1956-2011
3. Scaling up and speed of development and deployment	The UK 'Dash for Gas', 1987-2000 Flue Gas Desulphurisation in the USA, 1960s-2009
4. Integration of CCS systems	Natural Gas Network in the UK, 1960-2010
5. Economic and financial viability	Flue Gas Desulphurisation in the USA, 1960s-2009 Investments in landfill in the UK, 2001-2011
6. Policy, politics and regulation	Flue Gas Desulphurisation in the UK, 1980s to 2009
7. Public acceptance	Natural gas infrastructure development in the UK, 2000-11

The case studies are available at: http://www.ukerc.ac.uk/support/ES_RP_SystemsCCS

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Table 1: Uncertainties and recommended actions

Key uncertainties	Recommended actions
1. Variety of pathways The diversity of technological options represents an uncertainty for investors and policy makers. Early selection might accelerate development, but risks locking in weak technologies.	– The UK CCS demonstration programme should support a limited number of different technologies and fuels to enable learning about their relative merits (government).
2. Safe storage There is uncertainty as to whether geological storage of CO_2 will prove safe over long time periods, and about how the associated risks can be reliably assessed and managed.	– Potential storage sites should be characterised in detail (storage site operators; government). – An appropriate regime for CO_2 storage liabilities is required that strikes a balance between the public and private sectors (government; storage site operators).
3. Scaling up and speed of development and deployment There is uncertainty about whether and how fast CCS technologies can be scaled up and developed to maturity.	– Scaling up does not only require an increase in size of individual components, but also their integration and some technology transfer from other applications (CCS equipment suppliers). – Government should be prepared for technical problems and cost increases that might accompany scaling up and early deployment. Support programmes should be regularly evaluated (government). – Targeted public R&D support and knowledge sharing can help to address scaling up challenges (government, CCS equipment suppliers).
4. Integration of CCS systems It is unclear how CCS systems will be integrated. Integration is a technical challenge, as well as an issue of organisation and governance.	– The deployment of CCS should take into account the potential for regional and international pipeline networks (CCS project developers; government; pipeline companies). – The social and organisational challenges of CCS system integration require appropriate business models, risk sharing arrangements, and the integration of different areas of expertise (CCS project consortia; government).
5. Economic and financial viability The future costs and financial risks of implementing CCS are very uncertain. The economic and financial uncertainty is heavily dependent on policy.	– Several full scale demonstration projects should be supported by public funds, and their costs published (government, developers). – Financial support for CCS should include long-term contracts to reduce risks and encourage performance (government).
6. Policy, politics and regulation CCS development is strongly influenced by uncertainties about political support, as well as the choice and design of policies and regulations.	– A regulatory approach is unlikely to be sufficient to support CCS deployment. It is too early to mandate CCS on existing fossil plants, though this should be kept under review (government). – Substantial analytical and other capabilities are required within government to understand the impacts of policy implementation, and to negotiate with industry (government). – Some flexibility is needed in the implementation of regulations and funding programmes, but this should be underpinned by a clear commitment to CCS deployment (government).
7. Public acceptance Public acceptance may be crucial to CCS development, but is uncertain. Attitudes to CCS are shaped in social interaction.	– There should be fair, transparent processes for the siting of CCS plants, CO_2 transport infrastructure and storage reservoirs (government; prospective storage operators, independent bodies).