Prospects for Carbon Capture and Storage

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A Rorschach Test: What is CCS?

Geosequestration is one option for trapping CO2 emissions from gas or power plants. But not everyone agrees – *ABC (Australia)*

Recycled geological structures to reduce CO2 – *Independent (S. Africa)*

Carbon dioxide storage holds limited promise: Approach could halve industrial emissions by 2050 – *Nature*
No Potential for CCS?

Potential for the future?

**Wind** Pros: windmills have been a feature of our landscape for centuries; they provide a clean and renewable source of power. Cons: wind farms can be expensive to commission and maintain; piping the electricity to the national grid poses technical problems.

**Biomass** Pros: produced from fermented and refined organic matter such as sugarcane and oilseed rape, which consume as much carbon dioxide during growth as they produce during combustion; uniquely offers a renewable alternative to liquid transport fuels, with which it can be blended. Cons: needs a lot of space.

**Nuclear fusion** Pros: has the potential of producing vast amounts of energy; perpetual, cheap and relatively hassle-free, with minimal waste. Cons: fusion technology has a long way to go and at the moment is prohibitively expensive.

**Geothermal** Pros: in the right places, provides a clean, safe and stable source of power. Cons: effective use depends on the right geological conditions and there are few sites around the world capable of producing power at a competitive cost; it is not strictly renewable – over time, heat-producing sites will cool as more energy is extracted.

**Combined heat and power** Pros: reduces emissions, waste and cost by transferring the production of electricity to the point of use; well established among larger businesses and public-sector organisations. Cons: it still burns fossil fuel, giving it a limited appeal for the long term.

**Hydrogen** Pros: efficient, versatile and completely clean—the only emission being pure water; huge potential for transport. Cons: does not occur naturally in a usable form.

What Difference Does a Year Make?

The case for carbon capture

Whether we like it or not, the world is going to burn a lot of coal and gas. UK industry can lead the way in carbon capture and storage, but government must be prepared to act quickly, too.

SIMON SHACKLEY and JON GIBBINS report

14. We will work to accelerate the development and commercialization of Carbon Capture and Storage technology by:

(a) endorsing the objectives and activities of the Carbon Sequestration Leadership Forum (CSLF), and encouraging the Forum to work with broader civil society and to address the barriers to the public acceptability of CCS technology;

(b) inviting the IEA to work with the CSLF to hold a workshop on short-term opportunities for CCS in the fossil fuel sector, including from Enhanced Oil Recovery and CO2 removal from natural gas production;

(c) inviting the IEA to work with the CSLF to study definitions, costs, and scope for ‘capture ready’ plant and consider economic incentives;

(d) collaborating with key developing countries to research options for geological CO2 storage; and

(e) working with industry and with national and international research programmes and partnerships to explore the potential of CCS technologies, including with developing countries.
IPCC Special Report - presented at COP/MOP1
Global profile of large point sources

Table S.1. Profile by process or industrial activity of worldwide large stationary CO\textsubscript{2} sources with emissions of more than 0.1 million tonnes of CO\textsubscript{2} (MtCO\textsubscript{2}) per year.

<table>
<thead>
<tr>
<th>Process</th>
<th>No. of sources</th>
<th>Emissions (MtCO\textsubscript{2}/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fossil Fuels</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power (coal, gas, oil and others)</td>
<td>4,942</td>
<td>10,539</td>
</tr>
<tr>
<td>Cement production</td>
<td>1,175</td>
<td>932</td>
</tr>
<tr>
<td>Refineries</td>
<td>638</td>
<td>798</td>
</tr>
<tr>
<td>Iron and steel industry</td>
<td>269</td>
<td>646</td>
</tr>
<tr>
<td>Petrochemical industry</td>
<td>470</td>
<td>379</td>
</tr>
<tr>
<td>Oil and gas processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other sources</td>
<td>90</td>
<td>33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7,887</td>
<td>13,466</td>
</tr>
</tbody>
</table>

**Biomass**

<table>
<thead>
<tr>
<th>Process</th>
<th>No. of sources</th>
<th>Emissions (MtCO\textsubscript{2}/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioethanol and bioenergy</td>
<td>303</td>
<td>91</td>
</tr>
</tbody>
</table>

Distribution of sources

Figure S.6a. Global distribution of large stationary sources of CO₂ (Based on a compilation of publicly available information on global emission sources, IEA GHG 2002)
Mapping prospective storage sites

**Figure S.6b.** Prospective areas in sedimentary basins where suitable saline formations, oil or gas fields, or coal beds may be found. Locations for storage in coal beds are only partly included. Prospectivity is a qualitative assessment of the likelihood that a suitable storage location is present in a given area based on the available information. This figure should be taken as a guide only, because it is based on partial data, the quality of which may vary from region to region, and which may change over time and with new information (Figure 2.4) (Courtesy of Geoscience Australia).
Storage Options

Source:
IPCC SRCCS,
Figure S.4
Maturity of system components

<table>
<thead>
<tr>
<th>CCS component</th>
<th>CCS technology</th>
<th>Research phase</th>
<th>Economics phase</th>
<th>Economically feasible under specific conditions</th>
<th>Mature market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture</td>
<td>Post combustion</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre combustion</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oxyfuel combustion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Industrial separation (natural gas processing, ammonia production)</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>Pipeline</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shipping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geological storage</td>
<td>Enhanced Oil Recovery (EOR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gas or oil fields</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Saline formations</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enhanced Coal Bed Methane recovery (ECBM)</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ocean storage</td>
<td>Direct injection (dissolution type)</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direct injection (lake type)</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mineral carbonation</td>
<td>Natural silicate minerals</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waste materials</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Industrial uses of CO₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: IPCC SRCCS, Table S.2
### Projected costs

<table>
<thead>
<tr>
<th>Power plant system</th>
<th>Natural Gas Combined Cycle (US$/kWh)</th>
<th>Pulverized Coal (US$/kWh)</th>
<th>Integrated Gasification Combined Cycle (US$/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without capture (reference plant)</td>
<td>0.03 - 0.05</td>
<td>0.04 - 0.05</td>
<td>0.04 - 0.06</td>
</tr>
<tr>
<td>With capture and geological storage</td>
<td>0.04 - 0.08</td>
<td>0.06 - 0.10</td>
<td>0.05 - 0.09</td>
</tr>
<tr>
<td>With capture and EOR(^1)</td>
<td>0.04 - 0.07</td>
<td>0.05 - 0.08</td>
<td>0.04 - 0.07</td>
</tr>
</tbody>
</table>

**Source:** IPCC SRCCS, Table S.3
CCS as Part of Portfolios to Address Global Warming

Source: IPCC SRCCS, Figure S.7
• It is indisputable that—in the absence of CCS—fossil fuel consumption in countries such as China and India will have a profound and potentially catastrophic impact on global atmospheric CO2 levels, eclipsing any reductions made by the UK and others.

• The UK’s geological expertise through the hydrocarbon industry and British Geological Survey is recognised to be amongst the best in the world. This expertise should be leveraged to facilitate and promote UK demonstrations of CCS and, ultimately, uptake of CCS internationally.

• Most of the component technologies of CCS are not novel: the key outstanding requirement is to integrate them within full-scale demonstration projects involving different elements of the technology and operating under different conditions (including offshore).
• We are encouraged by the number of companies considering investing in UK CCS demonstration projects. Industry evidently believes that CCS technology is sufficiently advanced to proceed with full scale demonstrations. What is needed now to complement this positive response from industry is a commensurate effort from the Government.

• Government can play an essential role in ‘pump priming’ the initial demonstration projects. In order to do this effectively, Government support in the order of hundreds of millions of pounds needs to be forthcoming over the next five years.

• We acknowledge the need for Government support during the early stages of technology development. Ultimately, however, a market-based mechanism that puts a price on carbon is the best way to incentivise industry to invest in CCS and other carbon abatement technologies.

Source: Science and Technology Committee, Meeting UK Energy and Climate Needs: The Role of Carbon Capture and Storage
Carbon capture and storage: A consultation on barriers to commercial deployment
An important contribution to the Government’s energy policy objectives could be made by carbon abatement technologies (CATs) which enable fossil fuels to be used with substantially reduced CO2 emissions. The most radical CAT option is carbon capture and storage (CCS).

This consultation invites answers to questions that aim to establish the extent to which there are barriers to commercial deployment and whether and how these could be addressed. Specifically, the consultation aims to build understanding on: the current state and future development of CCS technologies and the likely costs attached to deploying them commercially; the potential carbon savings available from CCS; the barriers which currently exist to further development and commercial deployment; and whether there is a case for Government
## Announced Prospects (>300 MW)

<table>
<thead>
<tr>
<th>Company/ Project Name</th>
<th>Fuel</th>
<th>Plant output/cost</th>
<th>Capture technology</th>
<th>Commissioning date*</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP DF1 Peterhead UK</td>
<td>Natural gas</td>
<td>350 MW</td>
<td>Autothermal reformer, Precomb’n</td>
<td>2010</td>
</tr>
<tr>
<td>BP DF2 Carson, Calif</td>
<td>Petcoke</td>
<td>500 MW ($1bn)</td>
<td>Gasifier+shift</td>
<td>2011</td>
</tr>
<tr>
<td>Statoil/Shell Draugen Norw</td>
<td>Natural gas</td>
<td>860 MW</td>
<td>Post-combustion Amine</td>
<td>2011</td>
</tr>
<tr>
<td>Hatfield UK</td>
<td>Bituminous coal</td>
<td>~500 MW (£800m)</td>
<td>IGCC + precombustion</td>
<td>2011</td>
</tr>
<tr>
<td>SaskPower Sask Canada</td>
<td>Lignite coal</td>
<td>300 MW</td>
<td>Post-combustion or oxyfuel (TBD Q3 06)</td>
<td>2012</td>
</tr>
<tr>
<td>E.ON Lincolnshire UK</td>
<td>Bituminous coal (+pet?)</td>
<td>450 MW</td>
<td>IGCC + precombustion?</td>
<td>2012</td>
</tr>
<tr>
<td>Stanwell Qld Australia</td>
<td>Bituminous coal</td>
<td>N/A</td>
<td>IGCC + precombustion</td>
<td>2012</td>
</tr>
<tr>
<td>RWE Germany</td>
<td>Coal</td>
<td>450 MW (€1B)</td>
<td>(Shell gasifier)</td>
<td>2014</td>
</tr>
<tr>
<td>RWE Tilbury UK</td>
<td>Bituminous coal</td>
<td>~500 MW (£800m)</td>
<td>PC (supercritical retrofit) + post-combustion</td>
<td>2016 (w/), supercritical retrofit earlier?</td>
</tr>
</tbody>
</table>
Projects on Social and Political Aspects of CCS

- AGS
- CCP/CCP2
- Manchester/Tyndall
- UKCCSC
- CATO
- CSIRO
- CMU/SFU/Calgary
- DOE Regional partnerships
- ACCSEPT
- C2S2RN
Respondents Who Have Heard or Read of Listed Technologies in Past Year
Can CCS Reduce These Environmental Concerns?

**US**

- Global warming
- Ozone depletion
- Smog
- Acid rain
- Water pollution
- Toxic waste
- Resource depletion

**UK**

- Global warming
- Ozone depletion
- Smog
- Acid rain
- Water pollution
- Toxic waste
- Resource depletion

**Sweden**

- Global warming
- Ozone depletion
- Smog
- Acid rain
- Water pollution
- Toxic waste
- Resource depletion

**Japan**

- Global warming
- Ozone depletion
- Smog
- Acid rain
- Water pollution
- Toxic waste
- Resource depletion
Can CCS Reduce These Environmental Concerns?

US Responses

- Global warming
- Ozone depletion
- Smog
- Acid rain
- Water pollution
- Toxic waste
- Resource depletion*

0% 25% 50% 75% 100%

- Can reduce
- Does not reduce
- Not sure
For respondents who have heard of CCS:
Can CCS Reduce These Environmental Concerns?

- Global warming
- Ozone depletion
- Smog
- Acid rain
- Water pollution
- Toxic waste
- Resource depletion*

**US Responses (heard of CCS)**

- Can reduce
- Does not reduce
- Not sure

0% 25% 50% 75% 100%
Can CCS Reduce These Environmental Concerns?

- Global warming
- Ozone depletion
- Smog
- Acid rain
- Water pollution
- Toxic waste
- Resource depletion

* Resource Depletion not included in the US Survey
For respondents who have heard of CCS:

**Can CCS Reduce These Environmental Concerns?**

![Bar chart showing UK responses to the question of whether CCS can reduce various environmental concerns. The categories include Global warming, Ozone depletion, Smog, Acid rain, Water pollution, Toxic waste, and Resource depletion. The chart indicates varying percentages of respondents who believe CCS can reduce, does not reduce, or are unsure of the reduction potential for each concern.](chart.png)
Hopes and Fears?


  
  > “Nuclear plants are expensive and if you're looking at the energy mix, then at the moment I think you'll probably get more value from investment in clean coal.” – Elliot Morley, MP

- MP's clean coal energy solution: Unmined coal in Wales could be the answer to Britain's energy crisis – *BBC News*, Oct 12, 2005
  
  > It seems like absolutely amazing science fiction... but it's already being done in Algeria and elsewhere, and highly productively
  - Huw Irranca-Davies, MP
Despite the critics, massive geo-sequestration projects are already underway in Australia… Is burying hundreds of tonnes of carbon dioxide underground a novel way to reduce greenhouse gas emissions or a large-scale attempt at sweeping them under the rug?

If you enjoyed this feature, you might like...

Pipe Dream (Geosequestration) (09/09/2004)

Geosequestration won't rock world (04/08/2004)

Renewable energy would reduce our dependence on coal

Image: iStockPhoto

Workers at a power plant

Image: Reuters
Cautionary Tales

- Industry and CCS advocates explicitly trying to avoid fate of nuclear power by engaging stakeholders
- National energy context frames debate over CCS
- Lumpy nature of projects – Having DF1 equivalent to CO2 reductions from all UK wind is both good and bad
- Dependent on ETS price but likely insufficient in near-term
- Rationale for HMG support on grounds of energy security, climate leadership, and postponing decommissioning of North Sea infrastructure, BUT great reluctance to pick winners, be seen as subsidising energy industry and opening public purse to ‘unproven’ technology