CARBON CAPTURE AND STORAGE: a role for the geosphere in mitigating climate change

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The rocks beneath our feet contain abundant evidence of past changes in our climate. This geological record does not make comfortable reading. But the geosphere is not just a repository of information about the past. Long-term underground sequestration of CO_2 could make a significant contribution towards the reductions in global carbon emissions which are necessary if we are to avoid the likelihood of dangerous anthropogenic climate change. Indeed, it is hard to see how these reductions can be achieved without rapid and widespread deployment of carbon capture and storage (CCS).

The present day is not the first time in Earth's history that large amounts of carbon have been injected into our atmosphere at rates comparable to those now resulting from human activity. This has happened half a dozen times over the last 500 million years, most recently 55 million years ago, when a rapid release of carbon – possibly from destabilisation of methane hydrates on the sea floor – triggered a period of abrupt warming known as the Palaeocene-Eocene Thermal Maximum. At that time, temperatures rose by about 6° C globally and by 10-20° C at the poles. Sea levels rose, the oceans became more acidic and less oxygenated, and widespread extinction of species resulted. It took the Earth system in the order of 100,000 years to recover. It is increasingly evident that the outcome was broadly similar on each occasion that such rapid carbon injections have occurred.

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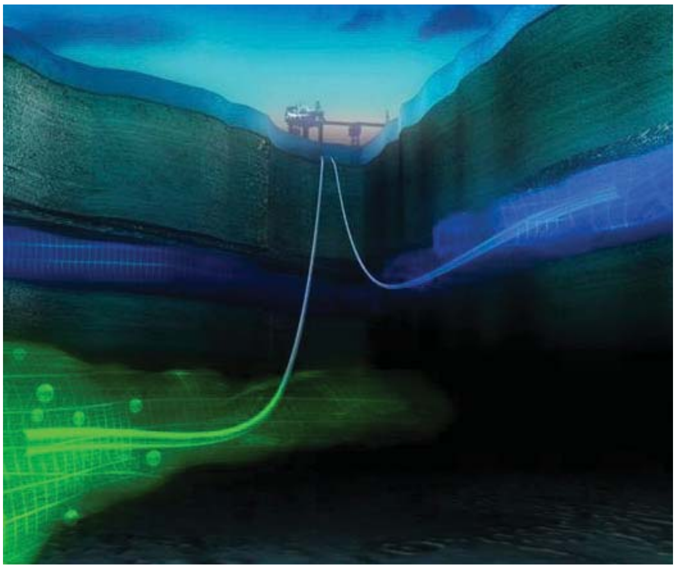
The more recent geological record can also tell us a great deal about the complex feedbacks and lags which operate in the Earth system, and about what our world was like when the atmospheric CO_2 level was last at 400 parts per million for a sustained period – that is, the annual average level reached again during 2014. Temperatures were 2-3° C higher than today, and sea level rose by up to 20m in places. Sea level takes a few hundred years to reach equilibrium in response to atmospheric CO_2 and temperature, which may explain why present day sea levels have not yet increased to such an extent. (See the Geological Society's 2010 Climate Change Statement and 2013 addendum at http://www.geolsoc.org.uk/climaterecord for further information.)



'Image courtesy of Statoil ASA'

This geological evidence, entirely independent of present day atmospheric measurements and climate modelling, should help to dispel any lingering doubt about the urgency of drastically reducing our CO_2 emissions.

The House of Commons Energy and Climate Change (ECC) Committee's May 2014 report on CCS highlights the difficulty of achieving the required emissions reductions without rapid and widespread implementation of CCS. We will continue to depend on fossil fuels for decades to come, not least to complement the intermittency of most renewable energy sources and the lack of flexibility of nuclear plant (which cannot be fired up and shut down rapidly). Consequently, UK Government places considerable reliance on CCS in its plans to decarbonise our electricity system. Furthermore, as the ECC Committee points out, CCS is the only large-scale mitigation option currently available to make significant reductions in emissions from industrial sectors such as cement, iron and steel, chemicals and refining. Such change will be necessary if we are to bring carbon emissions down to the required levels – decarbonising the electricity system will not be enough.

Despite Government's stated

commitment to CCS, progress in delivering this, including the competition to award funds to support full-chain commercial-scale demonstration projects, has been very slow. The ECC's report concludes that 'this delay has called into question the credibility of Government CCS policy and has resulted in a lost decade for this vital fledgling industry'.

CCS is still sometimes referred to as an unproven technology. This is quite misleading. Although no full-chain commercial-scale CCS project (from capturing CO_2 produced from the burning of fossil fuels or other industrial applications, to transporting it and injecting it into a suitable geological formation where it will be held securely in the long-term) is yet operational, several such projects are in advanced stages of development worldwide, many smaller demonstration projects are already operational, and each element of the chain is well tested. CCS is not a distant prospect – it is already happening.

... huge potential to reduce future carbon emissions ...

In April 2014, the Geological Society hosted the third in a series of conferences on CCS held jointly with the American Association of Petroleum Geologists. Speakers and delegates from a range of geoscience specialisms and from across academia and industry were unanimous in concluding that geological storage of carbon in depleted oil and gas reservoirs and other 'conventional' geological settings is a low-risk technology in which we can have a high level of confidence, with huge potential to reduce future carbon emissions.

The fact that a structural or stratigraphic 'trap', where a porous rock is overlain by an impermeable 'cap rock', has kept relatively buoyant oil or gas in place for millions of years (until we drilled into it to extract the hydrocarbons) is a good indication that CO_2 can be held securely in such a formation. This is borne out by field demonstrations, for example in the Sleipner field in the North Sea, where 11 million tonnes of CO_2 has been injected since 1996. Subsequent monitoring shows this has so far been contained in the reservoir.

Sleipner gas field. Image credit: Bair175, Wikimedia Commons

Sleipner is by no means unusual in terms of its storage potential – there is significant potential economic advantage to the UK in developing a CCS industry, and our North Sea pore space, infrastructure and know-how is a considerable asset.

As with many technologies, the fact that CCS can be shown to work does not mean that there is no need for further research – nor should the continuation of that research be taken as grounds for lack of confidence in the technology. Research into improved capture technologies and the storage potential of various 'unconventional' geological settings, should proceed in tandem with implementation in well-understood and low-risk sites, to reap the dividends of 'learning through doing', in order to bring down costs, improve efficiency and underpin public trust and confidence.

While depleted hydrocarbons reservoirs and closed saline aquifers (which are geologically similar, but do not host oil or gas) offer significant storage opportunities, this potential could be much greater still if promising research into novel CO_2 trapping mechanisms in a range of 'unconventional' geological settings bears fruit. Examples are migration-assisted trapping in open saline aquifers, and mineral trapping in mafic rocks (those with high magnesium and iron content, such as basalt, which are very widespread). (See the Geological Society's submission to the ECC Committee's recent inquiry at http://www.geolsoc.org.uk/CCS-inquiry13 for further details.)

The science and engineering associated with CCS are not significant barriers to its implementation at large scale. The principal constraints are political and economic. If the potential of CCS is to be realised, an urgent priority is to develop storage capacity – to identify and characterise potential storage sites, and to model and test the injection of CO_2 there – at a far greater rate than at present. Generic technologies and geological research may be transferable between nations, but development of storage capacity is not. If we are to implement CCS in the UK, we cannot depend on such work being done elsewhere.

Under current market conditions and policy frameworks, the prospects of large-scale CCS becoming commercially viable are dubious.

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But this does not weigh the cost of implementing CCS against the cost of not doing so, while still meeting our future energy and other resource needs. The question for policy-makers to address should be how – not whether – to create the political and economic conditions to stimulate rapid and widespread deployment of CCS.

Further reading:

House of Commons Energy and Climate Change Committee report on CCS, May 2014: http://www.publications.parliament.uk/pa/cm201314/cmselect/cmenergy/742/742.pdf

Geological Society submission to ECC Committee CCS inquiry, September 2013: http://www.geolsoc.org.uk/CCS-inquiry13

Geological Society Climate Change Statement, November 2010 and Addendum, December 2013: http://www.geolsoc.org.uk/climaterecord

Sleipner demonstration project: http://www.bgs.ac.uk/science/CO_2/home.html