Select Committee on Science and Technology
No. 4 of Session 2005-06 21 July 2005
Evidence on:

Geoscience perspectives on Carbon Capture and Storage Technology

Professor Stuart Haszeldine ***stuart.haszeldine@ed.ac.uk***
UK Energy Research Centre www.ukerc.ac.uk www.co2storage.org.uk/

Summary
Increased CO2 emissions from economic activity are leading to climate warming and acidification of the upper ocean. Mitigating these effects raise unprecedented challenges in engineering the habitability of our planet. The potential advantages of CCS for the UK are outlined. Future sources of oil, coal, and especially the vulnerability of gas, are discussed. The benefits of deep geological CCS in EOR, depleted gasfields, and aquifers are outlined. Particular highlights are placed on problems of CO2 retention in the deep subsurface for required timescales. Government issues of: Value, Ownership, Monitoring, and Regulation or Licensing are critical inhibitors to any large–scale development of CCS. Opportunities for some middle–scale CCS onshore on the UK are outlined.

1) WHY CARBON CAPTURE AND STORAGE FOR THE UK?

All serious predictions indicate that during the next 20 years the UK, and the world, will be using more fossil fuel than in the last 20. This will produce carbon dioxide – and the UK is on course to miss its national 20% reduction targets in 2010 by 34 million tons per year, out of a total of some 500Mt/yr. Carbon Capture and Storage (CCS) offers particular advantages on an intermediate timescale, which can provide options to renewables or nuclear. Key advantages include: rapid deployment based on existing technology, flexible generation, diverse fuel sources, UK expertise and employment. CCS provides an opportunity for a solution using, or adapting, existing technology, to help the transition to a new low-carbon, economy, whilst enabling high-technology employment in the process. The UK is very well placed to develop and exploit CCS, as there is well-developed fossil fuel power industry, world-class expertise in offshore surveying, geology and engineering, combined with accessibility of the world's best-known sedimentary basins to act as storage sites.

2) CONCEPTS OF CCS

The concepts, technology and geology of CCS are explained in many publications. A short version is briefing note 238 by POST `http://www.parliament.uk/parliamentary_offices/post/pubs2005.cfm`. The most authoritative worldwide being a newly-published (September 2005) special Report by the Intergovernmental Panel on Climate Change http://www.ipcc.ch/ An impartial summary of international research information is `http://www.co2captureandstorage.info/`. A technology-based summary including CCS for the UK is published (April 2005) by the DTI Carbon Abatement Technology `http://www.dti.gov.uk/energy/coal/cfft/catstrategy.shtml` A shorter summary of CCS, combined with an assessment of UK business opportunities, is provided (September 2005) by Scottish Enterprise http://www.scottish-enterprise.com/sedotcom_home/sig/sig-energy/energy-oilandgas/energy-oilandgas-help/energy-oilandgas-research.htm#carbon_capture A summary of current UK

University research in CCS is at http://www.co2storage.org.uk/ The European Union has decided to work to a policy of maintaining atmospheric CO2 at or below 550 ppm. CCS is expected to form a strand for major research, technology and development funding in FP7.

3) WORDWIDE DRIVERS FOR CCS: CLIMATE and OCEANS

Most European, and many USA, scientists are convinced that there is a link between levels of atmospheric CO2 and world surface temperatures http://www.ipcc.ch/. It is less-well appreciated that increased CO2 leads to ocean acidification, with poorly known consequences for life in shallow seas around the UK http://www.royalsoc.ac.uk/document.asp?id=3249. The UK Government Chief scientist is well-known to hold the strong opinion that climate change is the greatest threat facing the human world. The urgency for reducing the rate and total volume of emission of CO2 is far greater than the rate at which energy use is changing.

4) WHY IS THE UK IMPORTANT?

4.1 Much of the fundamental proposal for CCS, and its evaluation in a UK context has undertaken by the British Geological Survey, during the 1990's. Most geological data ultimately derives from this research group. An independent submission is being made to the Select Committee by the BGS.

4.2 It is clear that the UK has a world-class opportunity to use CCS. From hydrocarbon exploration, we have unrivalled knowledge of our offshore geology. These are some of the worlds best-known and most accessible sediment basins, and contain both depleted oil and gas fields and deep aquifers of saline water. The pores in such sediments can hold at least 70 years production of carbon dioxide produced by all European power stations – some estimates state 500 years. Natural carbon dioxide occurrences in the UK offshore show that safe natural storage can be measured in millions of years – not just the 10,000 years required to mitigate climate or ocean acidification.

4.3 The UK has an opportunity to establish a worldwide lead in CCS technology, and in service skills such as licensing, regulation, monitoring, and project management

4.4 However, several technological problems may exist for engineered storage, and still need further assurance (see 9 below).

5) FUTURE FUEL SOURCES: COAL, GAS & OIL

5.1 One purpose of CCS is to enable continued use of fossil fuels in UK power generation. These can be coal, gas, oil, or biofuel mixtures sourced from diverse geographical and political origins. Such diversity provides a security of supply, and is not overly dependent on the fluctuations in the market for one fuel.

5.2 Evidence on an overview of coal use and power station technology will be submitted by the UKCCSC. Coal worldwide is generally regarded as having hundreds of years of reserves, with stable prices having existed until 2004 http://www.investis.com/bp_acc_ia/stat_review/htdocs/reports/report_22.html

5.3 UK oil reserves beneath the North Sea are about 50% depleted, so that extensive, and increasing, imports can be anticipated. The quantity and timescale of depletion depends partly on the price of oil, and any deferment of decommissioning is financially valuable to both industry licensees, and to the Treasury by deferment of tax relief. Enhanced Oil Recovery can assist with some deferment (see 7 below). There is active debate concerning the possible decline of world oil reserves http://www.odac-info.org/, or the security of supply for decades http://www.investis.com/bp_acc_ia/stat_review/htdocs/reports/report_5.html.

5.4 Gas supply from the southern North Sea is now well into decline, and will effectively be exhausted by 2010, with minimal possibility for enhanced production (unlike Enhanced Oil Recovery). After 2010 about 50% of current UK requirements could be met from other gas areas of the UK offshore and the remainder will be imported by pipeline from Norway and the EU, or marine tanker LNG. However in the 20 year timescale, the world resources of gas may be dominated by Russia and its Gazprom super-giant company (which already claims to hold 20% of world reserves). Russia can dominate the supply to Europe and the UK. The UK currently holds reserves of only 14 days normal gas supply, in contrast to the European average of 50 days (http://www.oilandgas.org.uk/issues/gas/ p7, p13, Appendix 2).

6) UK GOVERNMENT and RESEARCH ISSUES

In the UK there is an urgent need for a Government lead on issues such as (below) :

- EOR incentives, financial regime or reduced tax on extra oil produced;
- long term ownership of carbon dioxide;
- technological and safety standards;
- costs and EU_ETS clean power incentives similar to "conventional" renewables
- legal licensing or permitting regime for storage sites;
- novel CCS opportunities
- timescales of deployment, and public information

Many of these need further research, in UK Universities, Institutes, or Industry.

7) EOR

7.1 Some of the most promising initial developments for CCS may exploit Enhanced Oil Recovery – that can inject carbon dioxide to produce 10 percent more oil from existing fields. But this will only work with suitably engineered platforms. An extra 900 to 2,000 million barrels of UK oil production can also store 700 million tons of carbon dioxide.

7.2 A group led by BP and Scottish and Southern Energy has plans to convert natural gas into hydrogen and carbon dioxide at Peterhead power station, then pump 1.3Mt CO2/yr liquefied carbon dioxide to deep storage offshore in the Miller oilfield, which will produce an additional 40 Million barrels of oil. The hydrogen will be burned in a modified gas turbine power plant, to generate 350 MW of electricity with near-to-zero carbon emissions. This will be a world first, if running costs can be met for the 15 - 20 year timescale. There are a group of other high CO2 oilfields adjacent to Miller in the UK offshore, and formal or financial encouragement of their Operators could lead to add-on EOR via the BP CO2 pipeline.

7.3 Miller is a crucial CCS opportunity for the UK, and it is hard to over-emphasise the unique opportunity provided by the combination in sequence of: oilfield, pipeline, equipment, power station, willing companies, and timing. If this opportunity is missed, it is hard to see another such combination on the UKCS. Miller can act as a crucial full-scale demonstration of CCS suitable for EOR, as a bridge to add-on EOR in neighbouring fields, and as learning for aquifer storage.

7.4 Scottish Enterprise (2005) calculates that limiting carbon dioxide with CCS electricity will be 2 to 4 times cheaper than the current renewables obligations based on ROC.

7.5 BP, as the Operator of Miller appears to require some long-term incentive for the operating expense of CO2 use during EOR. Previous evaluations of EOR using the Forties filed, or the Gullfaks field have foundered on finance. Incentives could take the form of tax breaks on capital cost, or could also be lower tax rates on oil produced by EOR. The UK Government needs to make a commitment to enable suitable EOR.

8) LONG-TERM OWNERSHIP

A significant unknown is the long-term ownership of stored CO2. It is difficult to expect a commercial company to maintain ownership for more than a few decades into the future. Therefore the State may need to be the ultimate guarantor. It is possible (but unknown), that stored CO2 may eventually become a resource, rather than a waste product. For example CO2 could become a feedstock for chemical industries; or it may eventually prove possible to engineer bacteria which are known to feed off CO2 plus hydrogen, to feed off CO2 plus water, or CO2 plus sewage, to produce methane – which is then useful as an energy source. The UK Government needs to make a commitment on long-term ownership and long-term liability.

9) TECHNOLOGY and SAFETY of CCS in OIL and GAS FIELDS and AQUIFERS

9.1 There are many positive points in favour of CCS in geological storage. However the present writer also considers that there are several under-researched and under-solved problems. The extent to which these problems need to be solved, will depend on the Regulatory framework into which CCS is placed in the EU and UK.

9.2 Borehole Leakage is usually a key concern. The main risk for CCS leakage is through the borehole used to emplace the stored gas. After abandonment, such boreholes are usually sealed with a specialist Portland-style cement. However it is known that Carbon dioxide reacts with such oilfield cements on timescales of decades, and their effectiveness is greatly decreased. Research is underway, in several commercial organisations, to develop more durable cements. Effective cements should be feasible to develop within a few years, but do not yet appear to have been demonstrated. A possibility arises that commercial companies may develop storage sites, and store carbon dioxide below ground – but that the cement seals to boreholes last only tens of years after the company licence has terminated. If the State owns the stored gas at that time, the State may be liable for continued maintenance of the boreholes. This issue will potentially affect all pre-existing boreholes contacted by CO2 dissolved in water, not just those used to inject CO2. In a typical offshore hydrocarbon field, this may be 30 boreholes. In saline aquifer storage there may be fewer pre-existing boreholes, but their locations may be poorly known – particularly for onshore locations – and any leakage will need to be remediated by normal oilfield techniques.

9.3 Monitoring of CCS is proposed to be undertaken by oil-industry seismic reflection techniques. These are undoubtedly well-established, and can be deployed to image liquid CO2. However, such techniques need further work to enable prediction of any fracturing of the top seal to a storage site, during the increased pressures necessary for CO2 injection. It is important that seismic is realised to have fundamental limits on the resolution of thickness of rock layers in subsurface storage – typically 25m would be optimistic. This means that significant volumes of CO2 may be hard to detect – with implications for tracking leakage, and for validating volumes injected for tax credits. Most importantly, the seismic technique is not at all useful for detecting CO2 once this has dissolved in pore water filling the reservoir. Additional work is needed on adapting existing complimentary geophysical techniques, such as electrical resistivity, which are capable of detecting dissolved CO2.

9.4 Tracers of CO2 are likely to be useful for safety, and to be economically important. If a leak of CO2 is detected, the gas itself holds little information as to its origin. It may not even be possible to discern if a gas is natural, or is a leak from a storage site. This could be important for safety liability, and for validating tax credit claims. It is simple, in principle, to add exotic tracers, which can fingerprint individual batches of CO2, even if these are injected into the same disposal site. Exactly which tracers, what concentration, and how these perform, during subsurface mixing and fluid movement, is still under active research. The types of tracer may also depend on the setting – particularly the spacing between boreholes. This is because the migration speed of tracers may differ from the CO2 fluid. The UK should explicitly consider enforced fingerprinting of injected gases by means of artificially added tracers.

9.5 CO2 injection volumes predicted, are very poorly understood into depleted oil or gas fields, and especially in saline aquifers. Estimates range by factors of 10 to 100. More research is needed to predict the volume of CO2 capable of injection into anticipated types of geological sites. This will reduce the range of uncertainty, and enable improved planning of pipeline networks, or numbers and locations of storage sites needed through time.

10) COSTS

10.1 Many barriers to CCS are considered to be financial, so that industries and the EU both aim to reduce carbon dioxide capture costs to less than £20-30 per ton before 2010. Storage costs of less than £10-20 per ton CO2 may be offset by EU-ETS purchase of emission permits. The costs published from pilot CCS projects at SACS and Weyburn seem to fall in or below this £10-20 range. To enable this, CCS must be placed firmly within the EU-ETS. At present CO2 sent for geological storage is apparently not eligible within the EU-ETS scheme, or within the ROC scheme (cf sect 7.4). This does not provide fair comparability or "level playing field" with other sources of low-carbon power generation, such as "conventional" renewables of solar, wind, wave and tide, which in the UK can be given Renewable Obligation Certificates (ROC) http://www.dti.gov.uk/renewables/renew_2.2.1.htm, or even nuclear, which can receive support for technology development.

10.2 It is worth remembering that "cost" may not need to be as cheap as possible, all that is needed is a value chain which can enable industries to make a profit. For comparison, the entire offshore exploration and production of the North Sea has never been the cheapest world option for oil or gas – Saudi Arabia has been, and still is, much cheaper.

11) LICENSING and REGULATION of STORAGE

11.1 The approach to be taken by safety regulation also needs explicit clarification. There are obviously complications with OSPAR and London conventions, which need to be agreed. However for the UK, a choice of principle exists between taking a very strict "precautionary safety" style of approach as with radioactive waste, or taking a "performance and licensing" approach, as with oil and gas exploration and production.

11.2 If the "precautionary safety" approach is taken, that would imply an extremely high level of certainty in understanding the sub-surface environment for the next 10,000 years. Such evidence from a Developer of a storage site is very difficult to defend, to a legal standard – as has been amply demonstrated by radioactive waste investigations in the UK and other countries.

11.3 Alternatively, if a "performance and licensing" approach were to be taken then, at commencement of storage, a Developer would need to show their expectations and predictions for their storage site. This would be regularly Monitored (See section 9.3) during the lifetime of the licence. If prediction and observed performance were good enough, then the licence would be continued. This is a much easier, and more pragmatic, approach – and can also enable a rapid start of licensing storage sites.

11.4 A requirement must be for a Developer to undertake a fully-specified investigation of the baseline geological conditions, so that perturbations in future can be clearly identified (cf Tracers section 9.4)

12) OTHER CCS OPPORTUNITIES

12.1 Much attention is being given to large–scale CCS opportunities involving geological deep storage. In the UK, some examples are listed below of opportunities for smaller-scale and novel CCS.

12.2 Onshore local boreholes have not been much investigated. The cost of drilling and of equipment maintenance is naturally much cheaper onshore, compared to offshore. The UK also has a diverse geology, with many areas underlain by deep saline aquifers. For example, it may be possible to develop sites with individual boreholes for individual industrial sites of cement works or paper mills, or district schemes of Combined Heat and Power using fossil fuels. The UK also has a few existing small power stations fuelled from biomass. Is it possible that such enterprises could become not just carbon neutral, but "carbon negative" by capturing CO2 for local disposal with individual boreholes?

12.3 Co-firing of biomass has begun in several coal-fired power stations, as a consequence of the Renewables Obligation. If these power plants are ever retro-fitted for CCS, or co-firing is adopted in new-build coal plants, then CO2 from this biomass can be captured and stored to result in a negative emission.

12.4 Negative emissions engineering of CO2 with biomass could become much more feasible. Engineered species of poplar or willow trees are under development, and could be grown within 10 years Prof G Taylor 2005, www.ukerc.ac.uk) as energy crops on set-aside land or as forestry. Radical opportunities will need to be considered, to move towards and exceed a 60% reduction of UK CO2 emissions by 2050. Fuels of this type can link to onshore local storage (above).

12.5 Charcoal is used commercially in some parts of Japan, and by native Brazilians, to enhance soil fertility. Charcoal fixes about 50% of the carbon from wood, is very slow to degrade, and well-preserved examples are known to be 300 million years old http://www.accstrategy.org/abstracts/ogawaokimoritakahashi.html . Basically, charcoal can lock-up carbon for hundreds or thousands of years. Minimal work has been undertaken to assess a UK application, although it can be calculated that millions of tons Carbon could be sequestered into soil worldwide using this method.

13) TIMESCALE

13.1 The timescale of to commence CCS deployment can be matched to the timescale of UK CO2 targets (sect 1). Even with the Miller project (Sect 7.2), the current reductions of CO2 are likely to be much too small to meet these targets. Much more urgent assessment, and decisions are needed on several fronts. Firstly, to incentivise further EOR in the Miller area (maybe another 4Mt CO2/yr). Secondly, to convert or build new UK fossil fired generating plant. For example, UK manufacturer Mitsui Babcock states that there is potential to retro-fit CO2 capture facilities to supercritical boilers of large coal plant (0.5 Mt CO2/yr each), at costs of £120M per 600Mwe, 12 months outage time and delivering CO2 at £12/ton. The size, and timescale, of the problem means that radical step-changes are required urgently – or part-closure of fossil fuel generation may be required to meet CO2 emissions targets.

13.2 There appears to be a lack of widespread dialogue between power companies, utilities, and oil companies. Individual companies are persistently interested, but a much wider engagement is needed. There is little public information, to help form perceptions and opinions – which will be especially important for onshore projects. UKERC and associated institutions may be able to broker such issues.

14) CONCLUSION

CCS can make a major contribution to reducing CO2 emissions from fossil fuel in power generation, for the UK and worldwide. This is extremely urgent, and should not wait until 2020, because the effects of catastrophic climate change are already apparent, and the UK is not meetings its CO2 targets. A diversity of fuel options are possible with CCS. Technology for power generation CCS is available, but has not yet been joined together in a co-ordinated demonstration. Solving existing technology gaps is significant, but seems achievable. A commercial development in the North Sea, headed by BP, is likely to be the first in offshore-onshore link in the world to undertake this, and could be operational by 2009. The UK has a world-class opportunity to build on its expertise and employment in offshore engineering. The UK Government still has to provide urgent clarification and policy on : market incentives for CCS (until inclusion within EU-ETS is negotiated, and ETS caps are a tight enough to require widespread CCS), long term ownership, standards for monitoring, standards for licensing and standards for site performance during operation and after closure. Novel CCS applications can also be investigated in cheaper UK settings onshore.

Submitted to be published in Select Committee on CCS
<http://www.parliament.uk/parliamentary_committees/science_and_technology_committee/scitech210705a.cfm>

5 October 2005
stuart.haszeldine@ed.ac.uk

Stuart Haszeldine is a geologist with 20 years research experience of the offshore oil and gas industry. He is also one of a handful of UK academics with current research experience of geological disposal of radioactive waste. He is co-Director of the Scottish Centre for Carbon Capture and Storage, a co-Leader of the UKCCSC research consortium, and a member of the Future Sources of Energy theme in the UK Energy Research Centre. This Centre is funded by the UK Research Councils, and aims to provide impartial, evidence based, advice and information on UK energy issues.

Select Committee on Science and Technology
No. 4 of Session 2005-06 21 July 2005

NEW INQUIRY
Carbon Capture and Storage Technology

The Science and Technology Committee is to conduct an inquiry into carbon capture and storage (CCS) technology.

The Committee is inviting evidence on the following points:

1. The viability of CCS as a carbon abatement technology for the UK, in terms of:

* *The current state of R&D in, and deployment of, CCS technologies;*
* *Projected timescales for producing market-ready, scalable technologies;*
* *Cost;*
* *Geophysical feasibility;*
* *Other obstacles or constraints.*

2. The UK Government's role in funding CCS R&D and providing incentives for technology transfer and industrial R&D in CCS technology.

The Committee would welcome written evidence from interested organisations and individuals addressing these points. Evidence should be submitted by Friday 30 September. Oral evidence sessions will begin in November.

For further information please call Ana Ferreira, on 020 7219 2793.
Previous press notices and publications are available on our website.

Notes to editors:

** Under the terms of Standing Order No. 152 the Science and Technology Committee is empowered to examine the "expenditure, policy and administration of the Office of Science and Technology and its associated public bodies". The Committee was appointed on 19 July 2005.*

The Committee would welcome written evidence from interested organisations and individuals addressing these points. Evidence should be submitted by Friday 30 September. Oral evidence sessions will begin in November.

For further information please call Ana Ferreira, on 020 7219 2793. Previous press notices and publications are available on our website.

Guidelines for the submission of evidence

Evidence should be submitted in Word formats, and should be sent by e-mail to scitechcom@parliament.uk . The body of the e-mail must include a contact name, telephone number and postal address. The e-mail should also make clear who the submission is from.

Submissions should be as brief as possible, and certainly no more than **3,000 words**. Paragraphs should be numbered for ease of reference, and the document should include a brief executive summary. Those submitting evidence are reminded that evidence should be original work, not previously published or circulated elsewhere. Once submitted no public use should be made of it, but those wishing to publish their evidence before it is published by the Committee are invited to contact the Clerk of the Committee to obtain permission to do so. Guidance on the submission of evidence can be found at http://www.parliament.uk/commons/selcom/witguide.htm

Notes to editors:

• Under the terms of Standing Order No. 152 the Science and Technology Committee is empowered to examine the "expenditure, policy and administration of the Office of Science and Technology and its associated public bodies". The Committee was appointed on 19 July 2005.

Membership of the Committee:

Mr Phil Willis (Lib Dem, Harrogate and Knaresborough)(Chairman)
Adam Afriyie (Con, Windsor)
Mr Robert Flello (Lab, Stoke-on-Trent South)
Dr Ian Gibson (Lab, Norwich North)
Dr Evan Harris (Lib Dem, Oxford West & Abingdon)
Dr Brian Iddon (Lab, Bolton South East)
Margaret Moran (Lab, Luton South)
Mr Brooks Newmark (Con, Braintree)
Anne Snelgrove (Lab/Co-op, South Swindon)
Bob Spink (Con, Castle Point)
Dr Desmond Turner (Lab, Brighton Kemptown)