Institution: The University of Edinburgh

Unit of Assessment: B7 – Earth Systems and Environmental Sciences

Title of case study: PUBLIC AND PRIVATE SECTOR INVESTMENT IN CARBON CAPTURE AND STORAGE TECHNOLOGIES

1. Summary of the impact

Impact: Public and private sector investment in technologies for Carbon Capture and Storage (CCS), including a major UK Government CCS Commercialisation Programme.

Significance and reach: In the 2010 Spending Review the UK government re-affirmed a £1billion commitment to CCS funding, which since 2012 has been referred to as a CCS Commercialisation Programme. [text removed for publication]. The European Commission have placed CCS pipelines into 2012 infrastructure package negotiations, with allocated funds of ~ €2.5billion.

Underpinned by: Research into the sub-surface storage of carbon, undertaken at the University of Edinburgh (1999 onwards).

2. Underpinning research

Numbered references refer to research outputs in Section 3.

Key researchers

The start and end dates of continuous employment in the School of GeoSciences, University of Edinburgh, are shown along with the most recent / current position of each researcher.

Haszeldine, Professor of Carbon Capture and Storage (1999 onwards)
Wilkinson, Lecturer (1999 onwards)
Wood, Professor of Carbonate Geoscience (2006 onwards)

Several of the research outputs described below were undertaken and published collectively by the Scottish Centre for Carbon Capture and Storage. The following researchers at the School of GeoSciences, University of Edinburgh also contributed to this work and those outputs.

Gilfillan, NERC Research Fellow (2006 onwards)
Scott, Research Associate (2011 onwards)

Research overview and context

Sub-surface storage of carbon provides one important strategy for the mitigation of climate change, through reducing the rates of industrial and power plant emissions to the atmosphere. Since 1999, Haszeldine has developed in Edinburgh one of the world's leading centres of research expertise on these issues. Work by the group has demonstrated the ability for deep geological storage of carbon around many parts of the globe, including the UK North Sea, demonstrating that it is possible to globally enact Carbon Capture and Storage (CCS) to reduce the rate of industrial and power plant emissions to the atmosphere. A £2M award from the Scottish Funding Council in 2010 established the Scottish Centre for Carbon Capture and Storage (SCCS), which has facilitated the continued delivery of CCS research in close collaboration with partners in academia and industry. The global leadership and expertise of Haszeldine is illustrated by a 2009 review article commission from *Science* evaluating the present and future development of CCS globally **[1]**.

Key research findings that underpin the subsequent impact

Research published in 2006 by Haszeldine demonstrated the ability for deep geological storage of carbon around many parts of the globe **[2]**. Following from this, a 2009 report for the Scottish Government published by SCCS provided the first comprehensive quantification of CO_2 storage potential around the UK, showing the UK to have 70 x 10^9 tonnes CO_2 storage capacity (a figure confirmed in 2012 by the Energy Technologies Institute UKSAP project at £3.5M cost) **[3]**. A second influential report, undertaken jointly with Arup for the European Commission and published

in 2010, produced the first-ever Europe-wide map of onshore and offshore CO_2 storage **[4]**.

The secure retention of buried CO_2 for CCS is vital and has been investigated by the research team from several perspectives. The interrogation of a natural CO_2 occurrence deep beneath the UK North Sea, as described in a 2009 study co-authored by Wilkinson and Haszeldine, showed that if the correct geology is chosen then storage site performance can be excellent **[5]**. In particular, a mud-rock seal in a North Sea oil field has retained natural CO_2 for 70 - 80 million years, with chemical changes due to CO_2 penetration limited to just 12m above the porous reservoir, giving high confidence in engineered storage of CO_2 for times of tens of thousands of years. This study established the potential for the UK North Sea to become a CO_2 storage hub for the entire EU. A complementary 2011 study, co-authored by Wood and Haszeldine, examined natural carbon storage sites in Italy and showed that even if engineered CO_2 stores do leak, the surface impact is very small, with associated death rates less than $36x10^{-6}$ **[6]**.

3. References to the research

Comments in bold on individual outputs give information on the quality of the underpinning research and may include the number of citations (Scopus, up to September 2013) and/or the 2012 Thomson Reuters Journal Impact Factor (JIF). The starred outputs best indicate this quality.

[1]* Peer-reviewed journal review article on global CCS development, >200 citations, JIF: 31.0
Haszeldine, R. S. (2009) 'Carbon capture and storage: how green can black be?', *Science* 325, 1647–52, DOI: 10.1126/science.1172246

[2] Peer-reviewed journal article
Haszeldine, R. S. (2006) 'Deep geological CO2 storage: principles, and prospecting for bio-energy disposal sites', *Journal of Mitigation and Adaptation Strategies for Global Change* 11, 369–93, DOI: 10.1007/s11027-005-9005-6

[3]* Scottish Government / SCCS report on opportunities for CO_2 storage in the North Sea
Opportunities for CO_2 Storage around Scotland — an integrated strategic research study (2009), published by Scottish Carbon Capture and Storage, http://tinyurl.com/B7-8-S3-4A

[4] European Commission Directorate - General Energy report on CO_2 Infrastructures
Feasibility Study for Europe-Wide CO2 Infrastructure (2010), European Commission Directorate - General Energy, prepared by Ove Arup & Partners Limited (Arup) and SCCS (Haszeldine is named as a preparer of the document on Page 2), http://tinyurl.com/B7-8-S3-4C

[5]* Peer-reviewed journal review article, >20 citations, JIF: 4.1
(Lu was an Edinburgh PhD student, 2004 - 2007)
Lu, J., Wilkinson, M., Haszeldine R. S., and Fallick A. E. (2009) 'Long-term performance of a mudrock seal in natural CO2 storage', *Geology* 37 (1), 35–8, DOI: 10.1130/G25412A.1

[6] Peer-reviewed review journal article, JIF: 9.7
(Roberts was an Edinburgh PhD student, 2009 - 2013)
Roberts, J., Wood, R. A., and Haszeldine R. S. (2011) 'Assessing the health risks of natural CO2 seeps in Italy', *PNAS*, 108 (40), 16545–48, DOI: 10.1073/pnas.1018590108

A further metric of research quality is given by the grants that have contributed to the preceding outputs, which include:

- *Science and Innovation Award for carbon capture from power plant and atmosphere* (2008 - 2013), sponsor: EPSRC (peer-reviewed), value: £4M, awarded to Haszeldine.
- *ScottishPower Academic Alliance award* (2010-2015), value: £1.8M, awarded to Haszeldine.
- *UK CO2 Storage Assessment Project (UKSAP)* (2009-2011), sponsor: Energy Technologies Institute, value of Edinburgh component: £338k, awarded to Haszeldine.

4. Details of the impact

Lettered references relate to items in Section 5.

Public and private sector investment into technologies for CCS (Primary Impact)

Pathway: SCCS research outputs, as described in Sections 2 and 3, have been directly used in national and European level policy formation. Furthermore, the research has led to Haszeldine being a recognised CCS expert and advisor, regularly consulted by decision-makers within both government and the electricity generation industry. This standing is evident in the creation of the world's first personal professorship in CCS (2009, funded by ScottishPower) and the award of an OBE (2012) for 'services to climate change technologies'. Within UK Government, Haszeldine has acted as an advisor to the UK Minister for Energy (2007 onwards) and been part of DECC Advisory Groups to the Chief Scientist and on CCS Development (both 2009 onwards). Within Scottish Government, Haszeldine has acted as advisor to the Energy Minister (2009 onwards). Haszeldine has also been involved in bringing forwards research-based policy briefing documents, such as two published in 2008 with Policy Exchange, on the topic of UK readiness for CCS implementation **[A]**.

Significance and reach:

- The UK Government re-affirmed a £1billion commitment to CCS funding in the 2010 Spending Review, as of 2012 described by the DECC Secretary of State as a 'CCS Commercialisation Programme'. The influence of both SCCS research and the expert advice given by Haszeldine in the set-up and subsequent operation of the Programme is corroborated by a statement from the then Director of the DECC CCS Office **[B]**. The specific contribution from Edinburgh research in helping DECC to secure the £1 billion of public funding is further corroborated by the text of a January 2011 speech given to the Scottish Government Energy Committee by the then Secretary of State for Energy **[C]**.
- The influence of Edinburgh research in the UK Government's wider support for CCS is evident in a speech by the Prime Minister on 28 July 2010: *'We believe we can have a technology leadership on this, developed through some of our best universities, like Edinburgh … that are doing incredible work on carbon capture and storage. That's the sort of technology we can then share, and export and invest with other countries'* **[D]**.
- The incorporation of CCS into the Scottish Government's Electricity Generation Policy Statement (June 2013) cites in its evidence base a 2012 report co-authored by SCCS **[E]**.
- The continent wide map of onshore/offshore CO_2 storage (research output [4], Section 3) is cited in the evidence base of the European Commission decision to place CCS pipelines into 2012 infrastructure package negotiations, with allocated funds of ~ €2.5billion **[F]**.
- The influence of SCCS research on the 2009 launch by ScottishPower of the Longannet CCS consortium (partners: National Grid / Shell), [text removed for publication], is corroborated by a statement from their then Head of CCS Development **[G]**. This also led to provision of CPD courses for 160 teachers and outreach programmes for 1500 members of the public.
- The influence of expert advice given by Haszeldine, during a UK-FCO Science mission to the USA, on the decision of Summit Power to enter the DECC CCS Commercialisation Programme as lead developer of the Captain Clean Energy project (April 2013) is corroborated by a statement from their CEO **[H]**. [text removed for publication].

Public engagement with, and understanding of, issues related to CCS (Secondary Impact)

Pathway, significance and reach: Haszeldine has been a leading voice in the dissemination of CCS-related information and comment, achieved through sustained dialogues over the period 2008 – July 2013 with TV, radio and the printed media. For example, Haszeldine has discussed carbon storage issues on BBC Radio 4 'Material World' (October 2010, Radio 4 has a UK reach of up to 10.98M in quarterly 2013 Radio Joint Audience Research figures), BBC 'Newsnight Scotland' (October 2011, average viewers 664k), *New Scientist* (March 2011, circulation 2.5M) and various online news pieces, one of which 'Carbon Storage? Not Under my house!' (November 2009) was carried by >150 sources in the US and Netherlands (combined circulation >90million) **[I]**.

5. Sources to corroborate the impact
Where two web-links are given, the first is the primary source and the second an archived version.

[A] Policy Exchange reports (2008) on the UK readiness for CCS implementation
I) Six Thousand Feet Under: burying the carbon problem, Haszeldine S. and Yaron G. (2008)
http://tinyurl.com/B7-8-S5-XA1 or http://tinyurl.com/B7-8-S5-A1
II) Is Britain Ready for CCS, Haszeldine S., Singh T. and Sweetman T. (2008)
http://tinyurl.com/B7-8-S5-XA2 or http://tinyurl.com/B7-8-S5-A2
Corroborates the policy-relevant communication of research outputs in such briefing documents.

[B] Factual Statement from the former Director of the Office of CCS, DECC
Provides corroboration of the value of both SCCS research and the expert advice from Haszeldine in the set-up and operation of the UK Government DECC CCS Commercialisation Programme.

[C] Minutes of the Scottish Government Energy Committee (January 2011) showing text of speech by the then UK Secretary of State for Energy
http://tinyurl.com/B7-8-S5-XC1 or http://tinyurl.com/B7-8-S5-C1 Provides corroboration that Edinburgh research helped the UK DECC to secure £1billion from the Treasury for CCS technology (Paragraphs 3-4, Col. 4568, Page 1).

[D] Text of speech by UK Prime Minister in Bangalore, 28 July 2010
http://tinyurl.com/B7-8-S5-XD or http://tinyurl.com/B7-8-S5-D Provides evidence of the value of Edinburgh CCS research and the wide support for this technology from UK government (Page 7).

[E] Scottish Government Electricity Generation Policy Statement (EGPS) 2013
http://tinyurl.com/B7-8-S5-XE1 or http://tinyurl.com/B7-8-S5-E1 Provides evidence of the influence of SCCS in ensuring CCS was incorporated into the EGPS (Page 6, Point 47). This statement followed the Scottish Enterprise / SCCS joint report on a Central North Sea CO2 Storage Hub – Enabling CCS deployment in the UK and Europe (September 2012):
http://tinyurl.com/B7-8-S5-XE3 or http://tinyurl.com/B7-8-S5-E3

[F] Proposal for a Regulation of the European Parliament and of the Council on Guidelines for Trans-European Energy Infrastructure (2011)
http://tinyurl.com/B7-8-S5-XF1 or http://tinyurl.com/B7-8-S5-F1 Provides evidence of the allocation of 'around €2.5billion to CO_2 transport infrastructure' at the bottom of page 1. Reference 1 of the Proposal is to the 2010 report Energy Infrastructure - Priorities for 2010 and Beyond:
http://tinyurl.com/B7-8-S5-XF2 or http://tinyurl.com/B7-8-S5-F2 which in turn cites the Arup/SCCS Feasibility Study research output (research output [4], Section 3).

[G] Factual Statement from the former Head of CCS Development, ScottishPower
Provides corroboration of the influence of SCCS research in the decision by ScottishPower to launch the Longannet CCS project [text removed for publication].

[H] Factual Statement from the CEO of Summit Power Group Inc. (USA)
Provides corroboration of the influence of expert advice from Haszeldine in the decision by Summit Power to launch the Captain Clean Energy CCS project into the DECC CCS Commercialisation Programme in April 2013 and [text removed for publication].

[I] Selected media coverage involving Haszeldine (2010 - 2011)
I) BBC Radio 4 'Material World' (October 2010), in which Haszeldine is one of four experts commenting on the 2010 Spending Review: http://tinyurl.com/B7-8-S5-I1 (video timing 21:10).
II) BBC 'Newsnight Scotland' (October 2011), in which Haszeldine discusses the future of CCS in the UK: http://tinyurl.com/B7-8-S5-I2 (video timing 09:25).
III) *New Scientist* Instant Expert: Carbon Capture and Storage (30th March 2011):
http://tinyurl.com/B7-8-S5-XI6 or http://tinyurl.com/B7-8-S5-I6
The quoted on-line circulation figures are from a Meltwater News search, results from which are available upon request.