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Building a Zero-Carbon Economy: SCCS evidence

SCCS evidence to the Committee on Climate Change

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Authors:

Rebecca Bell, Policy & Research Officer,

Dr Peter Brownsort, Scientific Research Officer,

Scottish Carbon Capture & Storage

Scottish Carbon Capture & Storage
Edinburgh Centre for Carbon Innovation
High School Yards, Infirmary Street, Edinburgh, EH1 1LZ
Telephone +44 (0)131 651 4647 www.sccs.org.uk

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Introduction

Scottish Carbon Capture & Storage (SCCS) is a research partnership of the British Geological Survey (BGS), Heriot-Watt University, University of Aberdeen, the University of Edinburgh and the University of Strathclyde with associate member the University of St Andrews. SCCS researchers are engaged in innovative applied research and joint projects with industry and government to support the development and commercialisation of carbon capture and storage as a climate change mitigation technology.

SCCS is pleased to submit evidence to the Committee on Climate Change on how carbon capture and storage, carbon dioxide utilisation, and negative emissions technologies can contribute to building a zero-carbon economy.

Question 4: International collaboration

Beyond setting and meeting its own targets, how can the UK best support efforts to cut emissions elsewhere in the world through international collaboration? What efforts are effective currently?

The UK is well placed to develop an industry storing CO_2 for other countries in its North Sea geology: we have significant storage which is uniquely well characterised, and uniquely accessible. SCCS's working paper on a Scottish CO_2 Hub[1] explores this for Scotland, although the findings could be applicable for the UK more widely.

Evidence on the UK's CO_2 storage capacity includes:

- Opportunities for CO_2 Storage Around Scotland: An integrated strategic research study[2]
- Progressing Scotland's CO_2 Storage Opportunities[3]
- CO_2 Aquifer Storage Site Evaluation and Monitoring (CASSEM)[4]
- Strategic UK CCS Storage Appraisal[5]
- CO_2 Multistore Joint Industry Project[6]
- Central North Sea – CO_2 Storage Hub[7]

The Strategic UK CCS Appraisal, funded by the UK Government, identified more that 1000 million tonnes of CO_2 storage available by 2030[8]. The UK has probably the best organised global system for CO_2 storage appraisal, and a transparent and accessible database usable by governments and

[1] http://www.sccs.org.uk/images/expertise/reports/working-papers/WP_SCCS_2016_01_Scottish_CO2_hub.pdf
[2] http://www.sccs.org.uk/images/expertise/reports/opportunities-for-co2/CO2-JointStudy-Full.pdf
[3] http://www.sccs.org.uk/images/expertise/reports/progressing-scotlands-co2/ProgressingScotlandCO2Opps.pdf
[4] http://www.sccs.org.uk/images/expertise/reports/cassem/CASSEM_Comp-12_12_11.pdf
[5] https://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal
[6] http://www.sccs.org.uk/expertise/reports/co2multistore-joint-industry-project ;
[7] https://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal
[8] https://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal

commercial developers – www.co2stored.co.uk (the output of the CO2MultiStore project) – developed by UK universities, with BGS and ETI, and now operated by BGS; this is combined with explicit regulation on CO_2 storage leasing and licensing – this may be able to form the core of an international standard[9].

To achieve net zero greenhouse gas emissions, verifiable storage of CO_2 at large scale will be needed for many decades – this is a resource that few countries have. Norway – the only other country in Europe whose CO_2 storage potential is comparable to the UK's – has already announced its intention to provide a CO_2 storage service for other countries[10].

Development of technology, standards and legal frameworks necessary for international transport of CO_2 and its storage offshore, for example transport by ship, can help build an international market in CO_2 storage services. Collaboration with countries such as Norway and the Netherlands in the near term to develop common equipment and standards can allow these to be transferred to other regions, such as South East Asia, where overseas transport and offshore storage of CO_2 may help reduce emissions. Once established, having common standards will allow a resilient and competitive CO_2 storage market to develop, keeping costs to a minimum[11]. The necessary legal frameworks will include the ratification of the second amendment to the London Protocol[12], which would allow transboundary CO_2 transport[13].

It is clear that emissions trading schemes have not produced any storage of CO_2; it is also clear that even in its revised form, the EU Emissions Trading Scheme is extremely unlikely to produce a price high enough to encourage CO_2 storage. SCCS proposes that certificates of storage are simple, low cost and reliable methods of achieving CO_2 storage[14].

Question 6: Hard-to-reduce sectors

Previous CCC analysis has identified aviation, agriculture and industry as sectors where it will be particularly hard to reduce emissions to close to zero, potentially alongside some hard-to-treat-buildings. Through both low-carbon technologies and behaviour change, how can emissions be reduced to close to zero in these sectors? What risks are there that broader technological developments or social trends act to increase emissions that are hard to eliminate?

The Intergovernmental Panel on Climate Change (IPCC) found that emissions from industry in 2050 need to be 75-95% lower than in 2010, and that this would need to be achieved with a range of technologies and practices, including CCUS. The IPCC found that "In industry, emissions reductions by energy and process efficiency by themselves are insufficient for limiting warming to 1.5°C with no or limited overshoot (*high confidence*)."[15] This implies that the approach proposed by the UK and Scottish Governments to industrial emissions reduction will be insufficient:

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[9] Haszeldine, R & Ghaleigh, NS (2018) *Geological Factors for Legislation to Enable and Regulate Storage of Carbon Dioxide in the Deep Subsurface*, in Carbon capture and storage – emerging legal and regulatory issues. 2nd ed. Hart Publishing.
[10] https://www.designnews.com/materials-assembly/norway-opening-business-carbon-capture/174448485959225
[11] http://www.sccs.org.uk/images/expertise/reports/working-papers/WP_SCCS_2016_01_Scottish_CO2_hub.pdf. Brownsort, P (2015) *Ship Transport of CO_2 for Enhanced Oil Recovery* – Literature Survey available at http://www.sccs.org.uk/images/expertise/misc/SCCS-CO2-EOR-JIP-Shipping.pdf
[12] The London Protocol (1996) replaces the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters (the "London Convention")
[13] http://www.imo.org/en/OurWork/Environment/LCLP/EmergingIssues/Documents/LCLP%20and%20climate%20change.pdf
[14] Working Paper SCCS WP 2015-04, *Certificates for CCS at reduced public cost: securing the UK's energy and climate future*. Available at: http://www.sccs.org.uk/images/expertise/reports/working-papers/wp-2015-04.pdf
[15] Intergovernmental Panel on Climate Change (2018) *Special Report on Global Warming of 1.5°C. Summary for policymakers*, page 21 http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

- "As part of the Industrial Strategy, the government will establish an Industrial Energy Transformation Fund, backed by up to £315 million of investment, to support businesses with high energy use to transition to a low carbon future and to cut their bills **through increased energy efficiency**."[16] (our emphasis)
- "We aim to improve industrial and commercial energy productivity by at least 30% by 2032, through a combination of fuel diversity, energy efficiency improvements and heat recovery."[17]

Carbon capture and storage is currently the only option for decarbonising industries that have CO_2 process emissions, or a high heat demand that can only be met by fossil fuels. SCCS research in Scotland has shown the potential for development of a CCS cluster in Scotland based on shared CO_2 transport and storage infrastructure using existing on- and off-shore gas pipelines, repurposed for CO_2 transport.

> "Approximately 80% of large point-source CO_2 emissions in Scotland are within 40 km of the Feeder 10 pipeline. Thirteen selected emitters are evaluated for potential CO_2 capture volume, estimated capture project cost and cost of connection. Scenarios for sequential deployment show that Feeder 10 has capacity through known expansion potential for developments allowing capture volumes rising from 2 to 8 Mt yr−1 CO_2 "[18]

As well as capture from large point sources, the technology for capturing CO_2 from smaller sources is well established globally. Where CO_2 volumes are smaller, transport methods other than pipelines may be more practical, and have lower absolute costs. Road, rail and ship are all established methods for transporting CO_2 and may be used for collection for transfer to storage or to a bulk transport system (pipeline or ship). Many opportunities for negative CO_2 emissions are likely to be at smaller scales[19].

Summit Power found that over 70% of the benefit of CCS is associated with industry and negative emissions. It also found that, over the period to 2060, around 1.5Gt of CO_2 could be captured and stored in a CCS network based around clusters of major industry and power generation in Scotland, Teesside, the Humber region and the South East.[20]

CCS has a key role to play in enabling bulk production of hydrogen (through steam methane reforming, with the CO_2 resulting from the process captured and stored), as recognised in the CCC's recent report on *Hydrogen in a low-carbon economy*[21]. That report makes it clear that hydrogen has particular value for decarbonising some hard-to-treat sectors, including heat in building and industry, and heavy transport. It is also clear that at the scale likely to be required, production of hydrogen by steam methane reforming with CCS will be the most cost-effective low-carbon route.

Although 90% is often given as the capture rate for CO_2, higher (and lower) rates of capture are possible. Although evidence on costs is currently limited, IEAGHG has commissioned a study on this, which we understand to be in progress; work has also been done on the potential value of varying the

[16] UK budget 2018 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/752202/Budget_2018_red_web.pdf
[17] Scottish Government website: https://www.gov.scot/policies/energy-efficiency/industrial-energy-efficiency/
[18] Brownsort, PA, Scott, V & Haszeldine, RS (2016), 'Reducing costs of carbon capture and storage by shared reuse of existing pipeline—Case study of a CO2 capture cluster for industry and power in Scotland' *International Journal of Greenhouse Gas Control*, vol. 52, pp. 130-138. DOI: 10.1016/j.ijggc.2016.06.004
[19] SCCS Working Paper WP SCCS 2018-08, *Negative Emission Technology in Scotland: carbon capture and storage for biogenic CO_2 emissions*, available at http://www.sccs.org.uk/images/expertise/reports/working-papers/WP_SCCS_2018_08_Negative_Emission_Technology_in_Scotland.pdf
[20] Summit Power (2017) *Clean Air – Clean Industry – Clean Growth: How carbon capture will boost the UK economy*, available at http://www.ccsassociation.org/news-and-events/reports-and-publications/clean-air-clean-industry-clean-growth/
[21] https://www.theccc.org.uk/publication/hydrogen-in-a-low-carbon-economy/

CO_2 capture level at CCS post-combustion power plants[22]. A review of the options for industrial decarbonisation can be found in the recent report, An Industry's Guide to Climate Action[23].

SCCS has undertaken work on large-scale storage of hydrogen. If the UK moves to a mixed energy system with electricity and hydrogen as vectors, then multiple terawatt hours of storage will be needed for security of supply. The UK possesses storage capacity for several months of hydrogen supply (research in process): candidate storage can be identified and quantified onshore and offshore[24,25].

Question 7: Greenhouse gas removals

Not all sources of emissions can be reduced to zero. How far can greenhouse gas removal from the atmosphere, in the UK or internationally, be used to offset any remaining emissions, both prior to 2050 and beyond?

We know that geological CO_2 storage is exceptionally secure.[26] It is required for many of the options available to the UK for achieving 'negative emissions', including bioenergy with CCS and direct air capture[27].

SCCS has carried out a review of the existing sources of biogenic CO_2 emissions in Scotland, which could be captured and stored once CO_2 transport and storage infrastructure is in place, delivering negative emissions.[28] The methodology for this review could be replicated across the rest of the UK, to provide an estimate of the immediate opportunity for greenhouse gas removal in UK.

The review found that approximately 3.6 Mt-CO_2/yr is emitted in Scotland from biogas, biomass combustion and the fermentation industry for alcohol production. Some 60% – 2.1 Mt-CO_2/yr – is emitted at 29 larger sites of a scale where CO_2 capture would be practical. This work confirms a view that there is a sizeable potential to achieve negative CO_2 emissions in Scotland through the use of CCS technology on existing biogenic CO_2 emissions in energy and industrial sectors, and this would also be the case for new developments in these sectors. The review makes the following recommendations:

- Improve consistency and coverage of reporting of biogenic CO_2 emissions to allow better quantification of the opportunity for negative emissions.
- Consider incentives and/or policies specifically to encourage capture of biogenic CO_2 emissions.
- Support early project development to demonstrate CO_2 capture from biogenic sources at appropriate scales (smaller than previous CO_2 capture proposals).

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[22] Errey, O, Chalmers, H, Lucquiaud, M & Gibbins, J (2014) *Valuing responsive operation of post-combustion CCS power plants in low carbon electricity markets.* https://www.sciencedirect.com/science/article/pii/S1876610214025995
[23] Bellona (2018) *An Industry's Guide to Climate Action* available at http://bellona.org/publication/an-industrys-guide-to-climate-change
[24] Heinemann, N, Booth, MG, Haszeldine, R, Wilkinson, M, Scafidi, J & Edlmann, K (2018), Hydrogen Storage in porous geological formations – Onshore play opportunities in the Midland Valley (Scotland, UK). International journal of hydrogen energy. DOI: https://doi.org/10.1016/j.ijhydene.2018.09.149
[25] Mignard, D, Wilkinson, M & Amid, A (2016) *Seasonal Storage of Hydrogen in a Depleted Natural Gas Reservoir.* In: International journal of hydrogen energy. 41, 12, p 5549-5558. Available at: https://www.sciencedirect.com/science/article/pii/S036031991531781X
[26] Alcalde, J, Flude, S, Wilkinson, M, Johnson, G, Edlmann, J, Bond, C, Scott, V, Gilfillan, S, Ogaya, X & Haszeldine, R (2018) Estimating geological CO_2 storage security to deliver on climate mitigation. Available at: https://www.nature.com/articles/s41467-018-04423-1
[27] Smith, P, Haszeldine, RS, & Smith, SM (2016) *Preliminary assessment of the potential for, and limitations to, terrestrial negative emission technologies in the UK.* In Environmental Science: Processes and Impacts. 18, 11, p 1400-1405.
[28] http://www.sccs.org.uk/images/expertise/reports/working-papers/WP_SCCS_2018_08_Negative_Emission_Technology_in_Scotland.pdf

- Initiate and/or support further work to define better the options for smaller-scale CO_2 transport modes, both technically and commercially, including the integration of such modes with trunk transport of CO_2.
- Maintain support for existing proposals that aim towards development of CO_2 transport and storage infrastructure in Scotland; such infrastructure is clearly a pre-requisite for achieving significant negative CO_2 emissions.

See also *The potential for implementation of Negative Emission Technologies in Scotland*[29], which found that Scotland is exceptionally well suited to using land-based negative emissions technologies (NETs) and has the potential to abate 90-100% of emissions in this way.

Question 10: policy

Including the role for government policy, how can the required changes be delivered to meet a net-zero target (or tightened 2050 targets) in the UK?

Government support for carbon capture and storage is crucial. The CCUS Cost Challenge Taskforce made a series of recommendations, including supporting the development of at least two CCUS clusters. The Government's response to this report acknowledges this recommendation (which echoes the recommendations of the Oxburgh report):

> "We will examine in detail the scope of the opportunity for maximising economies of scale by developing a shared carbon dioxide infrastructure network in an industrial centre, and will report by the end of 2019."[30]

However, this approach does not appear to address the urgency and scale of CCS deployment that is needed to achieve deep decarbonisation in the UK; in addition, the Government has not committed funding beyond a small amount (£20 million) for a carbon capture and utilisation (CCU) demonstration programme. There appears to be a disconnect between the timescales of existing projects (e.g. the Acorn Project[31] is pretty to enter pre-FEED in April 2019) and development of policies that would support wider CCUS deployment; in addition, there appears to be a disconnect between government (BEIS) ambition on CCUS, and allocated funding from Treasury.

There are a number of reasons why additional, funded action to support CCS is needed urgently:

- The CCUS Cost Challenge taskforce found that deployment at scale in the 2030s requires at least two CCUS clusters to be operational from the mid 2020s, and project development timescales mean that investment decisions for these need to be taken in the early 2020s at the latest.[32]
- Project development costs can be significantly reduced by re-purposing existing gas pipelines for CO_2 transport – the ACT Acorn project found that reusing the Atlantic and Cromarty pipeline for CO_2 transport would reduce project costs by almost £100m against constructing a

[29] Alcalde, J, Smith, P, Haszeldine, RS & Bond, C (2018) *The potential for implementation of Negative Emission Technologies in Scotland*. In: International Journal of Greenhouse Gas Control. Volume 76, September 2018, p 85-91. Available at: https://www.sciencedirect.com/science/article/pii/S1750583617310794
[30] https://www.gov.uk/government/publications/the-uk-carbon-capture-usage-and-storage-ccus-deployment-pathway-an-action-plan
[31] https://pale-blu.com/acorn/
[32] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/727040/CCUS_Cost_Challenge_Taskforce_Report.pdf

new pipeline[33]. However, the window for taking advantage of this opportunity is small, and decisions must be taken on whether and how to preserve pipelines that are at risk of decommissioning.

- The use of hydrogen for heating would require changes to the Gas Safety Management Regulations (to allow the blending of greater than 0.1% hydrogen in the natural gas mix) and the Control of Thermal Energy Regulations (to allow customers to be charged by energy density rather than gas volume). In order for gas networks to allocate funding for hydrogen blending and conversion in the 2021-26 spending period, this would need to be settled in 2019.[34]

The *Maximising Economic Recovery UK Strategy*[35] states that "before commencing the planning of decommissioning of any infrastructure in relevant UK waters, owners of such infrastructure must ensure that all viable options for their continued use have been suitably explored, including those which are not directly relevant to the recovery of petroleum such as the transport and storage of carbon dioxide". Anecdotal evidence suggests that this requirement is being interpreted in a way which allows the decommissioning of pipelines that have been identified as being suitable for CO_2 transport – by projects such as ACT Acorn and the Caledonia Clean Energy Project - but which do not have a firm project plan attached to them.

It is clear from informal discussions with OGA and BEIS that neither party feels they have responsibility for this aspect of decommissioning planning, so urgent action is needed to close this gap to ensure that infrastructure is retained and maintained, and CCS projects are not lost due to poor regulation.

We recommend a strategic approach to decommissioning which includes a strategic assessment of the oil and gas assets in the UKCS and their suitability for reuse – for CCS, but also for other potential uses such as renewable energy or nature conservation. There are immediate cost-cutting options available through the reuse of existing infrastructure, but only if near-term decommissioning of pipelines is replaced by their preservation for future use.

CO_2-enhanced oil recovery (CO_2-EOR) is a use of CO_2 that could enable the development of CO_2 storage and create a market for captured CO_2. SCCS research suggests that CO_2-EOR can produce low carbon intensity crude oil from a mature basin and could store more CO_2 than is released from the production, transport, refining and final combustion of oil, if it is managed to maximise CO_2 injection.[36]

The CO_2-EOR Joint Industry Project[37] was established to undertake a collaborative programme of work to develop an understanding of EOR, focusing on areas of work to address issues of major importance to project developers, including economics; stakeholder perceptions; EOR performance; CO_2 management and environmental impacts; legal issues; and CO_2 supply.

Potential sites for CO_2-EOR are identified in:

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[33] ACT Acorn (2018), *Infrastructure Re-use* https://actacorn.eu/sites/default/files/ACT%20Acorn%20Infrastructure%20Re-use%20Report%201.0.pdf Other deliverables from this project may also be of use to the CCC, and are available at: https://actacorn.eu/downloads

[34] For more information see SCCS Working Papers WP SCCS 2018-09 (*Evidence to BEIS Committee Inquiry: CCUS – Supplementary RAB business models, gas networks, transport pipe re-use and decommissioning*) and WP SCCS 2018-10 (*Requested evidence to BEIS Committee Inquiry: CCUS – gas standards, hydrogen and GSMR)* both available at http://www.sccs.org.uk/expertise/reports/working-papers

[35] Available at https://www.ogauthority.co.uk/news-publications/publications/2016/maximising-economic-recovery-of-uk-petroleum-the-mer-uk-strategy/

[36] https://www.sciencedirect.com/science/article/pii/S1750583618301154

[37] http://www.sccs.org.uk/expertise/reports/co2eor-joint-industry-project

- Energy Research Partnership (2015), Prospects for CO_2-EOR in the UKCS[38]
- Pershad et al (2012) Economic impacts of CO_2 enhanced oil recovery for Scotland[39]

Production of oil from a North Sea oil field typically leaves 55% of the oil underground.[40] Enhanced oil recovery from existing fields is therefore crucial to the UK's strategy to maximise economic recovery. The OGA has produced an *Enhanced Oil Recovery Strategy*[41] which characterises CO_2-EOR as a 'future opportunity' and includes an action to "Develop a CO_2 EOR strategy and five-year plan". SCCS considers that the need to develop CO_2-EOR should be treated with greater urgency, since deployment of CO_2-EOR has been shown to lead to the development of CO_2 storage, with the end result that more CO_2 can be stored than is released though the production, transport, refining and combustion of the produced crude.[42] However, email correspondence between SCCS staff and the OGA suggests that the OGA takes the opposite view, and may not now produce a CO_2-EOR strategy at all:

> "The OGA will review its overall EOR strategy through 2018 and will undertake an Industry EOR workshop late 2018. Pending the outcome of that workshop a decision will be made to move forward on a CO2 specific strategy, which, if at all, would be completed late 2019."[43]

Question 13: Devolved administrations

What differences in circumstances between England, Wales, Scotland and Northern Ireland should be reflected in the Committee's advice on long-term targets for the Devolved Administrations?

Scotland is significantly more dependent on the offshore oil and gas industry than the rest of the UK.[44] This should not affect the Committee's advice, but it does mean that policies to achieve emissions reductions will need to be implemented with more care for a just transition. SCCS has produced a briefing on the role of CCS in a just transition, submitted as a supplementary paper to this response, and would be happy to discuss this issue further with the CCC.

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[38] http://erpuk.org/wp-content/uploads/2015/10/ERP_CO2-EOR-Report-Oct-2015.pdf

[39] Pershad, H., Durusut, E., Alan, C., Black, D., Mackay, E. J., & Olden, P. (2012). *Economic Impacts of CO2-Enhanced Oil Recovery for Scotland: Final report*. Glasgow: Scottish Enterprise.

[40] SCCS (2015) *CO_2 Storage and Enhanced Oil Recovery in the North Sea: Securing a low-carbon future for the UK*. Available at http://www.sccs.org.uk/images/expertise/reports/co2-eor-jip/SCCS-CO2-EOR-JIP-Report-SUMMARY.pdf

[41] Available at https://www.ogauthority.co.uk/news-publications/publications/2016/enhanced-oil-recovery-strategy/

[42] Stewart R.J., Johnson G., Heinemann N., Wilkinson M., Haszeldine RS, *Low Carbon oil production: Enhanced oil recovery with CO_2 from North Sea residual oil zone*. Available at https://www.sciencedirect.com/science/article/pii/S1750583618301154#!

[43] Email from OGA, 29/05/2018

[44] Scotland has approximately 8% of the UK population, but is home to 39% of the UK's oil and gas workers – figures from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2017 and https://www.sdi.co.uk/business-in-scotland/key-sectors/oil-and-gas