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Carbon Capture, Usage and Storage

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Authors:

Rebecca Bell, Peter Brownsort, Hannah Chalmers,

Stuart Haszeldine, Mathieu Lucquiaud, Eric Mackay,

Philippa Parmiter, Romain Viguier

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

Carbon Capture, Usage and Storage

1 Key points

- Carbon capture and storage (CCS) is essential for the UK to meet its carbon emissions reduction targets to 2050.
- Furthermore, CCS is essential to meet the Paris Agreement goal of keeping global average temperature rise well below 2°C.
- CCS means that jobs in high-emitting industries can be retained in the UK; without CCS those industries will have to cease operation as emissions budgets tighten.
- The urgent need to deploy CCS at scale should outweigh targets for cost reduction.
- The UK is uniquely placed to develop carbon dioxide (CO_2) storage – failure to make use of the offshore geological resource could be construed as a waste of public resource.
- CO_2 usage may have a role to play in driving the development of carbon capture, but it is not a substitute for development of permanent geological storage.

2 CCUS or CCS?

Although this inquiry is asking about carbon capture, usage and storage (CCUS), the focus of our evidence is on carbon capture and storage (CCS). There is at best a minimal role for carbon capture and usage (CCU) in meeting emissions reduction targets, due to the fact that most of the uses for CO_2 merely delay, rather than prevent it reaching the atmosphere. Geological CO_2 storage, on the other hand, has been shown to be a secure and permanent way of preventing CO_2 emissions reaching the atmosphere.[1]

2.1 How essential is CCUS for the UK to meet its carbon emissions reduction targets to 2050?

2.1.1 CCS and climate change mitigation

The Committee on Climate Change has been clear that CCS is essential for the UK to meet its targets, and to meet the requirements of the Paris Agreement:

> "The Government should not plan to meet the 2050 target without CCS. A 'no CCS' pathway to even the existing 2050 target is highly challenging and likely to be much more costly to achieve. Furthermore, deeper reductions requiring the deployment of CCS will be needed to meet the aims of the Paris Agreement, whether by 2050 or subsequently."[2]

The leaked draft special report on 1.5°C from the Intergovernmental Panel on Climate Change (IPCC) stressed the urgency of climate change mitigation action:

[1] Juan Alcalde, Stephanie Flude, Mark Wilkinson, Gareth Johnson, Katriona Edlmann, Clare E. Bond, Vivian Scott, Stuart M. V. Gilfillan, Xènia Ogaya & R. Stuart Haszeldine (2018) *Estimating geological CO_2 storage security to deliver on climate mitigation.* https://www.nature.com/articles/s41467-018-04423-1

[2] Committee on Climate Change (2018), *An independent assessment of the UK's Clean Growth Strategy: From ambition to action.* https://www.theccc.org.uk/publication/independent-assessment-uks-clean-growth-strategy-ambition-action/

> "Delayed action or weak near-term policies increase mitigation challenges in the long-term and increase the risks associated with exceeding 1.5°C global warming […] Delayed action or weak near-term policies increase the severity of projected impacts and adaptation needs."[3]

2.1.2 CCS across the economy

CCS is currently the only option that would enable deep emissions reductions for many energy-intensive and process industries, such as steel, cement, chemicals and refineries. It will thereby enable innovation and the retention of high-value jobs within Europe's high-carbon manufacturing industries.

There is active consideration of converting heat networks, which supply industry and large domestic regions of the UK, to hydrogen. CCS will enable the supply of low-carbon hydrogen derived from steam methane reforming (SMR) at low cost and in sufficient volume.

When CCS is used with sustainable biomass or air capture technology, it counts as "negative emissions", which actively reduce the stock of CO_2 in the atmosphere. The leaked IPCC report makes it clear that such CO_2 removal will be required in all pathways to keep global temperature rise to 1.5°C.

The deployment of CCS at commercial scale across the whole economy has repeatedly been calculated to reduce the overall costs of decarbonisation and enable faster emissions reductions in line with scientific advice on the risks of climate change. This rate of emissions decrease is aligned with trajectories modelled to be compatible with recovery of a stable climate.

2.1.3 The UK's unique opportunity

The UK is uniquely well placed to develop CCS with its high-volume and well-understood CO_2 storage resources; an established subsurface industry, existing infrastructure that can be reused to reduce initial costs, and the right skills and experience needed to develop this new industry serving our own, and potentially European, CO_2 storage needs. Skilled offshore and subsurface jobs are at risk as the oil and gas industry reduces production: the skills and experience from the industry will be crucial in developing CCS, and the growth of a CCS industry will enable a just transition from oil and gas. Likewise, there is existing offshore infrastructure, including pipes, boreholes and subsurface geological data.

The Strategic UK CCS Storage Appraisal[4] found that the UK has offshore geological storage potential for over 78 gigatonnes of CO_2. This is an asset that very few countries have, and so gives the UK a competitive advantage over the rest of the EU in deploying CCS. Furthermore, the leasing rights to offshore subsurface CO_2 storage and leasing for pipelines on the seabed are part of the Crown Estate, so there is the potential for significant additional public revenue from development of CO_2 transport and storage.

It could be argued, therefore, that the UK Government has a responsibility to develop CO_2 storage in order to make the best use of the natural assets available to it, and should not be considering the possibility of using public money to pay another country to store the UK's captured CO_2.

A number of projects have explored and confirmed the potential for CCS projects in the UK:

[3] http://www.climatechangenews.com/2018/02/13/leaked-draft-summary-un-special-report-1-5c-climate-goal-full/
[4] Energy Technologies Institute (2016) *Strategic UK CCS Storage Appraisal.* http://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal

- Scottish Carbon Capture & Storage work on development of a Scottish CO_2 hub[5], which concludes that:
  - CO_2 storage in the Central North Sea is the best understood in Europe following decades of oil and gas activity as well as specific assessments of CO_2 storage requirements.
  - Existing pipelines can access storage sites from the Scottish mainland.
  - CO_2 utilisation for enhanced oil recovery can create significant value, extending the productive life of oilfields with a range of benefits – such as maintaining jobs and deferring decommissioning expenses for the public purse - as well as providing long-term CO_2 storage.
  - CO_2 import hubs could be developed at existing ports, some of which already handle refrigerated gases: the Firth of Forth (Scotland); Peterhead (Scotland); Teesport (England).
  - A high proportion of European emissions would be within range of this CO_2 storage system via ports such as Rotterdam, Le Havre, Antwerp and Hamburg.
  - Collection of CO_2 from industrial sources, including that already separated at European ammonia plants, could enable early stage implementation of transport and injection infrastructure.
- The ACT Acorn Project, which aims to deliver a low-cost CCS system in north-east Scotland by 2023. The project builds upon existing research, such as an appraisal of potential CO_2 storage sites and options to re-use oil and gas assets, to move the Acorn Project from proof-of-concept towards design studies.[6]
- The Caledonia Clean Energy Project, which suggests that gas-fired power generation with CCS could be developed in Grangemouth, using existing onshore and offshore pipelines to transport CO_2 to offshore storage, and that the project could be in operation by 2025.[7]
  - *Clean Air, Clean Industry, Clean Growth*[8], a report by the project, found that there are benefits to early deployment of CCS, and a significant opportunity cost of slow, or no, deployment.

2.1.4 CCUS

CO_2 usage is not likely to have a significant role in reducing emissions; however, it could have a role in creating a market for CO_2 and thus driving the deployment of CO_2 capture technology.[9][10] The Committee on Climate Change has stated that:

> "Whilst CCU could help to facilitate progress in the 2020s, the volumes of CO_2 that can be utilised as a feedstock rather than permanently sequestered appear likely to be small relative to the necessary role for CCS in the long-term."[11]

The Government's focus should therefore be on developing CO_2 transport and storage infrastructure to enable sequestration at scale.

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[5] Scottish Carbon Capture & Storage (2016) *Scottish CO_2 Hub – A unique opportunity for the United Kingdom*. http://www.sccs.org.uk/images/expertise/reports/working-papers/WP_SCCS_2016_01_Scottish_CO2_hub.pdf
[6] http://www.actacorn.eu/about-act-acorn
[7] http://www.ccsassociation.org/news-and-events/reports-and-publications/caledonia-clean-energy-project-feasibility-report/
[8] http://www.ccsassociation.org/news-and-events/reports-and-publications/clean-air-clean-industry-clean-growth/
[9] Bellona (2016) *CCU in the EU ETS: risk of CO_2 laundering preventing a permanent CO_2 solution*. http://network.bellona.org/content/uploads/sites/3/2016/10/BellonaBrief_CCU-in-the-EU-ETS-risk-of-CO2-laundering-preventing-a-permanent-CO2-solution-October-2016-2.pdf
[10] Zero Emissions Platform (2016) *ZEP Policy Brief: CCU in the EU ETS*. http://www.zeroemissionsplatform.eu/downloads/1618.html
[11] Committee on Climate Change (2018)

2.2 How should the Government set targets for cost reduction in CCUS? How could CCUS costs be usefully benchmarked?

A narrow focus on the cost of CCUS prevents discussion of the value of CCS to the UK. The Centre for Energy Policy at Strathclyde University has argued that the cost needs to be assessed against the wider economic and fiscal case.[12] The 2017 report Clean Air, Clean Industry, Clean Growth[13] explores these issues further and concludes that a CCS network based on the east coast of the UK could boost the economy by an estimated £160 billion by 2060.

The cost and value of CCS will vary from project to project: it would not be possible to come to a single useful figure for the "cost" of CCS. Carbon capture and storage is not a single technology: it is a system and will entail the development of a whole infrastructure; furthermore, each stage of the process can be done in a number of different ways, using different technologies and infrastructure.

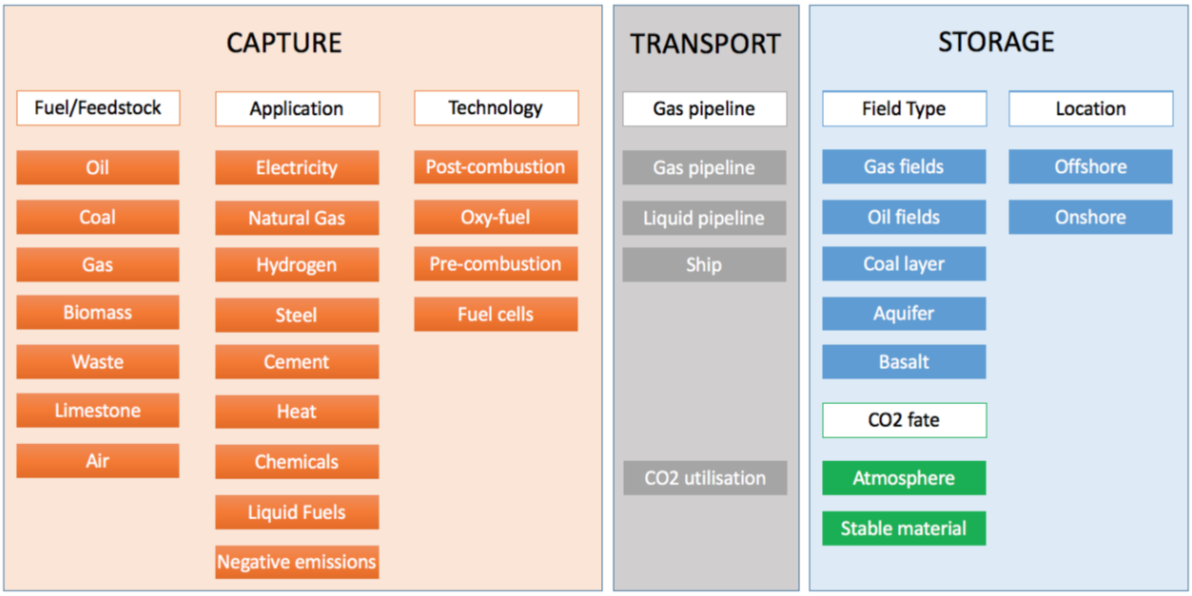

Figure 1: CO_2 capture, transport and storage options[14]

It may be useful to consider a separate benchmark for each industry or type of emissions source. How best to benchmark costs depends on whether the intention is to compare the cost of CCUS to the cost of other interventions; or to demonstrate how the costs of CCUS are changing over time.

In the tables overleaf, we explore some of the possible metrics that could be used, and some of the issues that ought to be considered when choosing a metric or group of metrics for decision-making, including identifying an appropriate counterfactual (i.e. the option that is used a baseline for comparing costs and/or CO_2 emissions). Neither of these lists are exhaustive.

[12] Karen Turner and Julia Race (2016) *Making the macroeconomic case for CCS.* https://pure.strath.ac.uk/portal/files/62682906/Turner_Race_CCJ2016_Making_the_macroeconomic_case_for_CCS.pdf
[13] http://www.ccsassociation.org/news-and-events/reports-and-publications/clean-air-clean-industry-clean-growth/
[14] Developed from https://www.sciencedirect.com/science/article/pii/S1750583612001958

Metric measured	What it tells you about	Challenges in defining/using
£ per tCO_2 abated	Cost of reducing CO_2 emissions	Value can be changed significantly depending on choice of counterfactual and the system boundaries selected
£ per unit product produced (e.g. MWh electricity or tonne H_2)	Comparison of costs within a sector	Cross-comparison between different ways of making same product needs consistent boundaries Cannot be used alone to inform cross-sector decisions
Change in whole electricity or energy system cost with or without CCS	How CCS affects electricity / energy costs	Value will depend on model structure and assumed data (typically needed for several decades into the future) and generally cannot include all technology options accurately.
Change in GDP with or without CCS	How CCS affects economic growth	CCS generally not included in whole economy models i.e. usually limited to electricity.[15]

Issue to consider	**Range of things to consider**
Defining boundaries	
Projects are developed within a system	Need to develop systems for comparison that have consistent boundaries and appropriate consideration of knock-on effects - for example, enabling infrastructure (including strengthening electricity network, new transmission line build, back-up power/storage to achieve same security of supply). How might different approaches to valuing the technical capabilities (e.g. flexibility) of CCS schemes impact on which technologies are available to the system and their likely operating patterns? Whether to separate 'whole chain CCS' into a capture component and a combined transport and storage component – or other business model?
Geographical boundaries	Costs and benefits to the UK Impacts outside the UK
Counterfactual	Very different answers can be obtained with different counterfactuals, so it is essential that any analysis includes clear identification of assumed counterfactual. For many industrial processes, CCS is the only route to decarbonisation, and its cost can only fairly be

[15] Karen Turner and Julia Race (2016)

Issue to consider	Range of things to consider
	compared to the cost of alternative ways of reducing industrial emissions – such as switching fuel, changing processes or ceasing production.
Discounting and costs	
How to price CO_2	Market price Social cost of carbon Stern review metrics?
Which discount rate to use	Social discount rate – e.g. Stern[16] or UK Government Green Book[17]? How long to model for e.g. on geological storage timescales – 10,000s of years?
CO_2 storage effectiveness	
Residual emissions	Different schemes will have different residual emissions (i.e. CO_2 that is produced when the fuel is used, but not captured by the CCS scheme). CO_2 capture rates of at least 90%-95% are achievable for several 'close to commercial' technologies, but others may have larger residual CO_2 emissions.
Permanence of CO_2 storage and abatement	How long is long enough? 5000 years vs 1000 years? (use Alcalde *et al*[18]) How much leakage is acceptable? What leakage rate is acceptable?
CO_2 storage capacity abatement capacity – total that could be stored, how much could be stored per year	Total volume of CO_2 that could be stored / abated ($MtCO_2$) Rate of CO_2 stored / abated (Mtpa)
CO_2 utilisation	
How long does it keep CO_2 out of the atmosphere?	CCU may include uses where CO_2 is stored permanently (for thousands of years, e.g. in subsurface geological storage as part of enhanced oil recovery), for long periods of time (for decades, e.g. in building materials), or for short periods (days or weeks, e.g. in food and drink applications, or in synthetic fuels)
How to measure the effectiveness of EOR?	Focus on how much CO_2 is stored that would otherwise end up in the atmosphere? Would oil produced using CO_2-enhanced EOR have been produced by another method in any case?

[16] http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf

[17] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

[18] https://www.nature.com/articles/s41467-018-04423-1

Issue to consider	**Range of things to consider**
Robust data and comparisons over sufficient timescales (sometimes several decades)	
Having enough/accurate data for modelling	Economic life for a CCS project lifecycle will typically be at least 20 years. Full valuation requires some insight into what costs might be several decades into the future: carbon price, charges for storage, etc.
Lifecycle CO_2 emissions	For full assessment, often need to consider 'cradle-to-grave' assessment for whole CCS project, from extraction of raw materials to impact on decommissioning. Particularly where data is not available, simplified scope and limits might be needed. Also, need to consider this alongside CCS system boundaries (e.g. UK inventory vs global inventory in accounting).

2.3 What would be a realistic level of cost reduction to aim for – and by when?

The CCUS Cost Challenge Task Force[19] makes clear that CCS will unlock value across the economy: by decarbonising industry, by providing services to the grid, and by enabling the large-scale production of low-carbon hydrogen.

The urgent need to deploy CCS at scale and unlock this additional value should outweigh targets for cost reduction. The UK is in a position to start deploying CCS now, and the Government should be mindful of the opportunity cost of not doing so.

Costs can be reduced through shared infrastructure, repurposing of existing infrastructure and by low cost finance – the reductions these offer outweigh the reductions that could currently be achieved by technology innovation.

2.4 If CCUS costs do not come down "sufficiently", what alternatives should the Government consider to meet the UK's climate change targets? How might the cost of these compare with CCUS?

The Committee on Climate Change and the Lord Oxburgh report[20] have been clear that any alternative to CCS would make decarbonising the economy more expensive.

It is clear that one way to bring costs down is to begin deployment so that lessons can be learned in practice and applied to subsequent CCS projects. Shell estimates that following deployment of its Quest CCS project in Canada, a subsequent project could be developed with a 30% cost reduction.[21]

[19] https://www.gov.uk/government/publications/delivering-clean-growth-ccus-cost-challenge-taskforce-report
[20] http://www.ccsassociation.org/news-and-events/reports-and-publications/parliamentary-advisory-group-on-ccs-report/
[21] http://www.jwnenergy.com/article/2016/9/shell-says-quest-ccs-project-working-better-planned/

It is also not likely that there is any alternative to CCS for industries with high emissions from their processes, or high heat demand. For industries which have no other route to decarbonisation, the Government will need to either make much deeper cuts elsewhere in the economy (which may not even be possible), or will have to allow them to close, and accept the loss of value to the UK economy, and a substantial loss of jobs.

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. Further work needs to be undertaken to understand which pipelines may be needed for carbon dioxide transport, and which may be either decommissioned or re-purposed for another use, such as electricity generation from geothermal heat, or in-situ preservation for nature conservation purposes.

2.5 Conclusion

Carbon capture and storage is essential if the world is to keep global temperature rise to a safe level. The UK is well placed to begin deployment of CCS now and achieve decarbonisation across the economy at lowest cost. The UK has a huge CO_2 storage resource, which it could be considered to have a duty to exploit. Effective cost reduction can be achieved by developing robust business models and complementary incentives/regulations that share risk appropriately and provide sufficient certainty for investors to develop a successful business case. The cost of CCS will decrease as projects are developed and learning is shared and can also be reduced through the re-use of existing infrastructure; the cost of not doing CCS is great.

3 Scottish Carbon Capture & Storage

Scottish Carbon Capture & Storage (SCCS) is a research partnership of the British Geological Survey, Heriot-Watt University, University of Aberdeen, the University of Edinburgh and the University of Strathclyde. 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.

3.1 Further information

Scottish Carbon Capture & Storage would be happy to answer any questions or provide further information. Please contact Rebecca Bell, SCCS Policy and Research Officer, on rebecca.bell@sccs.org.uk