Achieving a low-carbon society: CCS expertise and opportunity in the UK

SCCS Conference 2015 Report

Credits and disclaimers

THIS report is based on outputs from the SCCS Conference 2015, held in Edinburgh on 28 October. It also presents findings from a number of key references and reports. This document is intended as a guide for politicians, policy makers and opinion shapers across Scotland and the UK. It describes the UK's unique array of expertise and opportunity in Carbon Capture and Storage (CCS) within the context of delivering a fully low-carbon society in line with climate change actions and ambitions.

Any recommendations are the sole responsibility of SCCS and should not be attributed to individual conference speakers or participants. More details about the event at:

http://www.sccs.org.uk/events/sccs-conference-2015

About SCCS and our partners

Scottish Carbon Capture & Storage (SCCS) is an independent research partnership of British Geological Survey, Heriot-Watt University, the University of Aberdeen, the University of Edinburgh and the University of Strathclyde. It is the largest CCS research group in the UK and provides a single point of coordination for all aspects of CCS research, from capture engineering and geoscience to public engagement, policy and economics. SCCS is funded by the Scottish Funding Council with contributions from the European Regional Development Fund, the Natural Environment Research Council, BGS, Heriot-Watt University and the University of Edinburgh. www.sccs.org.uk

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Contents

1. OVERVIEW

THE outcome of the Paris climate talks in late 2015 was hailed as a "turning point" for international action on climate change, with 195 countries agreeing to limit the increase in average global temperatures to 1.5°C by the end of this century. It is an ambitious and necessary goal, but is it achievable? An increasing emphasis on clean, renewable energy is essential, as are more efficient ways of using energy. However, the best of intentions will hit an insurmountable roadblock if we continue to burn fossil fuels without deploying Carbon Capture and Storage (CCS).

CCS is a chain of proven technologies that can take us all the way to a zero-carbon future. For many economies that will be reliant on fossil fuels for several decades, CCS can support a gradual phasing in of renewable energy. CCS remains the only path to deep cuts in carbon emissions from products such as cement, steel and fertiliser – even whisky – and will effectively decarbonise power and heat generation. Deployed on gas or sustainable biomass power, it can plug the gaps in the intermittency of power supply from renewables. And there are many studies that show that the UK and its assets are best placed to deliver CCS for the whole of Europe.

Although CCS is already operating in other parts of the world, this climate change technology has had a tough time making progress in the UK. The latest blow came in the last quarter of 2015, within days of the Paris talks. Two major UK CCS projects were poised to begin construction after completing front-end engineering and design (FEED) studies. Without warning, anticipated funding from the UK Government's £1 billion CCS Commercialisation Competition was withdrawn before these studies had been submitted. The Peterhead CCS Project, set to become the world's first CCS project on gas power, and White Rose, which would demonstrate oxyfuel with CCS technology on coal power, have had little choice but to consider closure.

In the aftermath of the COP21 climate deal, and with the UK's own climate change advisers restating the importance of the technology in meeting the UK's Fifth Carbon Budget, the case for CCS remains as cogent as ever. In the UK, we have access to an immense CO_2 storage asset beneath the North Sea, which could contain a century of Europe's carbon emissions. Added to that is an impressive track record of world-leading research and development (R&D), decades of oil and gas industry knowledge and skills and an infrastructure facing decommissioning that can be repurposed to put carbon back below ground.

The progress and potential of CCS in the UK is much more than a government competition. This report describes why we need to get one of the most obvious and effective climate change tools back on track and highlights the strengths of and opportunities for the UK – and Scotland, in particular.

SCCS Conference 2015 at the Royal College of Physicians Edinburgh.
Photo: Will Robb Photography

2. THE CONTEXT

Climate change and CCS

THE impact of global warming is already hitting home with increasingly frequent episodes of extreme weather, rising sea levels and ocean acidification affecting habitats and communities worldwide. Countries are preparing adaptation plans but they must also combat the greenhouse gas emissions (GHG) that are stoking the problem. However, this has to be balanced with every nation's need for energy security, economic competitiveness and a range of other issues relating to our carbon-intensive lives.

The Paris climate talks in late 2015 marked a shift in attitude and commitment, with 195 countries signing up to a binding treaty that includes a trajectory for carbon emissions reductions from 2020. However, it is clear that the reductions proposed by individual countries (in the form of intended nationally determined contributions or INDCs) and submitted before the talks will fall far short of what is needed.

The Conference of the Parties noted with concern that "the estimated aggregate GHG levels resulting from the intended nationally determined contributions in 2025 and 2030 do not fall within least-cost 2°C scenarios, and that much greater emission reduction efforts than those associated with the INDCs will be required in the period after 2025 and 2030 in order to hold the temperature rise to below 2°C or 1.5°C above pre-industrial levels".

"Climate concerns must be balanced with ensuring energy security and increasing the competitiveness of our economy, especially in heavy industry. One of the answers to this challenge lies in developing technologies, such as CCS or Carbon Capture Utilisation and Storage (CCUS)."

Jerzy Buzek MEP, European Parliament

Jerzy Buzek MEP, addressing SCCS conference delegates by video a month before COP21, underlined the opportunity for European Union (EU) states to develop and deploy innovative technologies, such as CCS, and share them with other regions that will continue to depend on fossil fuels for decades. He argued that, with the Treaty of Lisbon – the legal basis of the EU – allowing Member States to choose their own energy mix with least environmental cost, CCS offered an important solution well into the future.

The Intergovernmental Panel on Climate Change (IPCC) highlights the role of CCS, alongside energy efficiency measures, renewable energy and nuclear energy, in any future energy scenario: "At the global level, scenarios reaching 450ppm CO_2 are also characterised by more rapid improvements of energy efficiency, a tripling to nearly a quadrupling of the share of zero- and low-carbon energy supply from renewables, nuclear energy and fossil energy with carbon dioxide capture and storage (CCS), or bioenergy with CCS (BECCS) by the year 2050".

Photo: Ciara O'Connor

According to the IPCC, the use of CCS could even result in overall negative emissions, with the proviso that biomass feedstock is sourced sustainably: "…BECCS offers the prospect of energy supply with large-scale net negative emissions, which plays an important role in many low-stabilisation scenarios"[1].

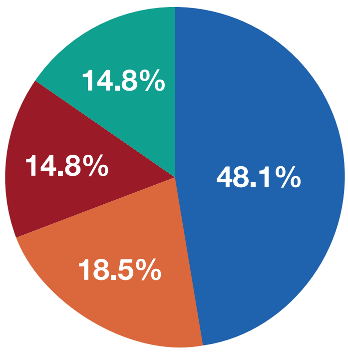
According to analysis by the International Energy Agency (IEA)[2], CCS "could deliver 13% of the cumulative emissions reductions needed by 2050 to limit the global increase in temperature to 2°C ... [by capturing] around 6 billion tonnes of CO_2 emissions per year in 2050, nearly triple India's energy sector emissions today".

CCS is integral to the IEA's scenario in which the global temperature rise is kept within 2˚C: "Fossil fuels will remain a major feature of the global energy mix and will account for around 40% of primary energy use in 2050. Coal use in power generation falls to around one-third of current levels, with 95% of coal-fired generators equipped with CCS. Forty percent of gas-fired power generation will also need to be equipped with CCS in 2050".

CONFERENCE POLL

The role of CCS in curbing global emissions is recognised. What now?

- Demonstrate CCS works at regional scale
- Step up international R&D and industry collaboration
- Invest in infrastructure now to deliver savings later
- Engage with key political and societal opinion shapers on need for CCS



1 *Summary for Policymakers, In: Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*
2 http://www.iea.org/publications/freepublications/publication/CarbonCaptureandStorageThesolutionfordeepemissionsreductions.pdf

Climate targets and CCS ambition

The United Kingdom

THE United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol in 1997. This international treaty set the scene for nations to commit to emission reductions that would collectively begin to rein in global warming. The UK signed up and followed through with a commitment to "urgent collective action" on climate change, beginning with its Climate Change Act 2008.

The legislative framework leading from the Act includes:

- A target for reducing GHG emissions by at least 80% in 2050 from 1990 levels
- Legally binding carbon budgets covering five-year periods
- The formation of the UK Committee on Climate Change (CCC) to provide independent advice to government on emissions targets and how best to achieve them.

Carbon budgets describe the most cost-effective route to decarbonisation for all sectors, including industry and power, over five-year segments, with the first four budgets running until 2027. In its advice to the government on the fifth budget[3], which will be legislated for in 2016, the Committee includes CCS and offshore wind in the low-carbon portfolio of its central scenario, "given their long-term importance and the role of UK deployment in driving down costs".

In addition, the Committee stated: "Given the importance of CCS in meeting the 2050 target, CCS must make significant progress by 2030. This requires continuing deployment in the power sector over the period to 2030, in order to provide anchor loads for CO_2 infrastructures and reduce risk for projects in both power and industry".

Until late 2015, the UK Government had made what appeared to be a firm commitment to CCS delivery through its £1 billion CCS Commercialisation Competition. It had already provided the Peterhead and White Rose CCS projects with around £100 million towards the cost of FEED studies. Both projects were ready to begin construction had competition funding not been withdrawn.

3 https://www.theccc.org.uk/publication/the-fifth-carbon-budget-the-next-step-towards-a-low-carbon-economy/

Scotland

SCOTLAND'S transition to a low-carbon economy is framed by the 2009 Climate Change (Scotland) Act. The Act and resulting legislation sets an interim target for reducing Scotland's GHG emissions by 42% for 2020, and an overall target of achieving an 80% reduction by 2050.

Two subsequent Scottish Government reports describe proposals for making "significant progress towards decarbonisation", with the latest covering the period 2013–2027[4]. This report restates an intention to "demonstrate CCS at commercial scale in Scotland by 2020 with full retrofit across conventional power stations thereafter by 2025–30".

The Scottish Government recognises the role of CCS on fossil fuel power generation in smoothing intermittent electricity supply from renewable energy sources. It also acknowledges its value in decarbonising industry, while taking full advantage of Scotland's regional assets – namely, North Sea CO_2 storage capacity, the offshore/subsurface industries, and R&D expertise.

"CCS is the only technology hat has the potential to reduce large-scale emissions from energy-intensive industries."

John Ireland, Scottish Government

The government has thrown its weight behind three phases of attempts to deploy large-scale CCS in Scotland – including the Peterhead DF1, Longannet, Hunterston and second Peterhead projects. In early 2015, the Scottish and UK Governments provided pre-FEED funding to Summit Power's Caledonia Clean Energy Project to be located at Grangemouth. This work is ongoing. However, the withdrawal of the CCS Commercialisation Competition funding is a serious blow to Scotland's plans for developing a homegrown CCS industry within an innovative low-carbon economy.

4 *Low Carbon Scotland: Meeting the emissions reduction targets 2013–2027*, The Second Report on Proposals and Policies, Scottish Government, 2013. http://www.gov.scot/Resource/0042/00426134.pdf

Scotland's CCS opportunities

The CCS industry in the UK has now seen three attempts to demonstrate the technology at commercial scale beaten back due to lack of government support. Regardless, CCS remains an essential part of the UK's future energy policy – the problem right now is one of missed opportunity and the true cost of delaying its deployment will be substantial (see The Cost of Delay, page 11).

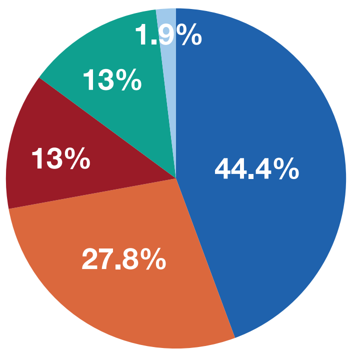
1. The Peterhead CCS Project, with UK Government support, would have been the world's first large-scale CCS project on gas power, establishing the first onshore plant and offshore infrastructure in Scotland that could potentially serve the rest of Europe.

2. The Caledonia Clean Energy Project could bring CCS to industry in central Scotland, using existing pipeline infrastructure and North Sea CO_2 storage to create an inspirational industrial low-carbon zone.

CONFERENCE POLL

What should industry prioritise to deliver large-scale CCS?

- Access to infrastructure and storage
- Commitment to stable feed-in tariffs
- Societal backing
- Capital expenditure grants
- Other (CCS Certificates, i.e. polluter pays)



3. THE COST OF DELAY

THE UK Government stated that its decision to withdraw CCS Commercialisation Competition funding was based on cost as the Treasury set out its plan to take the economy from deficit to surplus. However, it is UK taxpayers and businesses who will carry the burden of this flawed argument when the true cost of delaying progress on CCS – an essential climate change technology – hits home.

- The IPCC has highlighted the economic impact of ignoring CCS as part of decarbonisation strategies worldwide. It estimates that the cost of achieving 450 ppm of CO_2 by 2100 – the scenario whereby global warming is kept to within 2°C – will be 138% higher without CCS[5].

- Across the spectrum of future UK energy scenarios, CCS "offers enormous potential", according to the Energy Technologies Institute (ETI)[6]. Its analysis suggests that missing out on the technology would at least double the cost of delivering the UK's climate change targets from around 1% of GDP (Gross Domestic Product) to 2%. In other words, the Net Present Value (NPV) to 2050 of CCS in the UK's energy system is more than £200 billion.

- In its advice to the UK Government on the Fifth Carbon Budget[3], the CCC urges a strategic approach to commercialising key technologies, such as CCS, which are not yet fully mature. The period to 2032, it suggests, will be vital to the development of CCS, "which has the potential to almost halve the cost of meeting the UK's 2050 target".

- According to the ETI and others, CCS must be at the heart of any national strategy to meet carbon targets cost-effectively as it enables flexible, low-carbon electricity generation alongside renewable energy and also cuts emissions from industrial processes[6].

- CCS would be particularly effective in a mixed energy portfolio that includes increasing quantities of wind and nuclear power, providing a readily dispatched back-up energy supply to mitigate against the intermittent nature of wind power and inflexibility of nuclear[7].

- In the UK, the technology can deliver "least-cost, secure energy in association with green growth". Analysis shows that CCS can deliver a 15% reduction in the wholesale price of electricity, or an £82 reduction in household electricity bills per year by 2030[8]. Modelling suggests that the reduction in the wholesale price of electricity is greatest with the full deployment of CCS across the power and industrial sectors.

5 *IPCC (2014) Fifth Assessment Report – Synthesis Report*
6 *Strategy: Targets, technologies, infrastructure and investments – preparing the UK for the energy transition*, Coleman, Haslett, Energy Technologies Institute, 2015
7 *A UK Vision for Carbon Capture and Storage*, Orion Innovations, 2013
8 *The Economic Benefits of Carbon Capture and Storage in the UK*, CCSA and TUC, 2014

- The continued use of fossil fuels for existing energy production, transport and generation infrastructure could be enabled through the deployment of CCS. It delays the retirement of valuable assets and avoids increases in production costs[7].

- CCS will create a significant number of jobs. A conservative project-based assessment gives an estimate of total annual employment of 30,000 by 2030 with 20 GW installed capacity, or between 15 and 25 projects[7]. With the right support, the UK could achieve this capacity.

- Each power sector project could deliver £150 million per annum GVA benefit (Gross Value Added, or the value of goods and services in an area or sector) during construction, and £200 million GVA per annum in operation. Deploying CCS in the UK will allow UK-based companies to gain a 10% share in a global market estimated to be worth over £100 billion a year from 2020[7].

- Industrial CCS can play a significant role in safeguarding 160,000 direct jobs and 800,000 indirect jobs as well as combined GVA of over £14 billion contained within the UK's energy intensive industries[7].

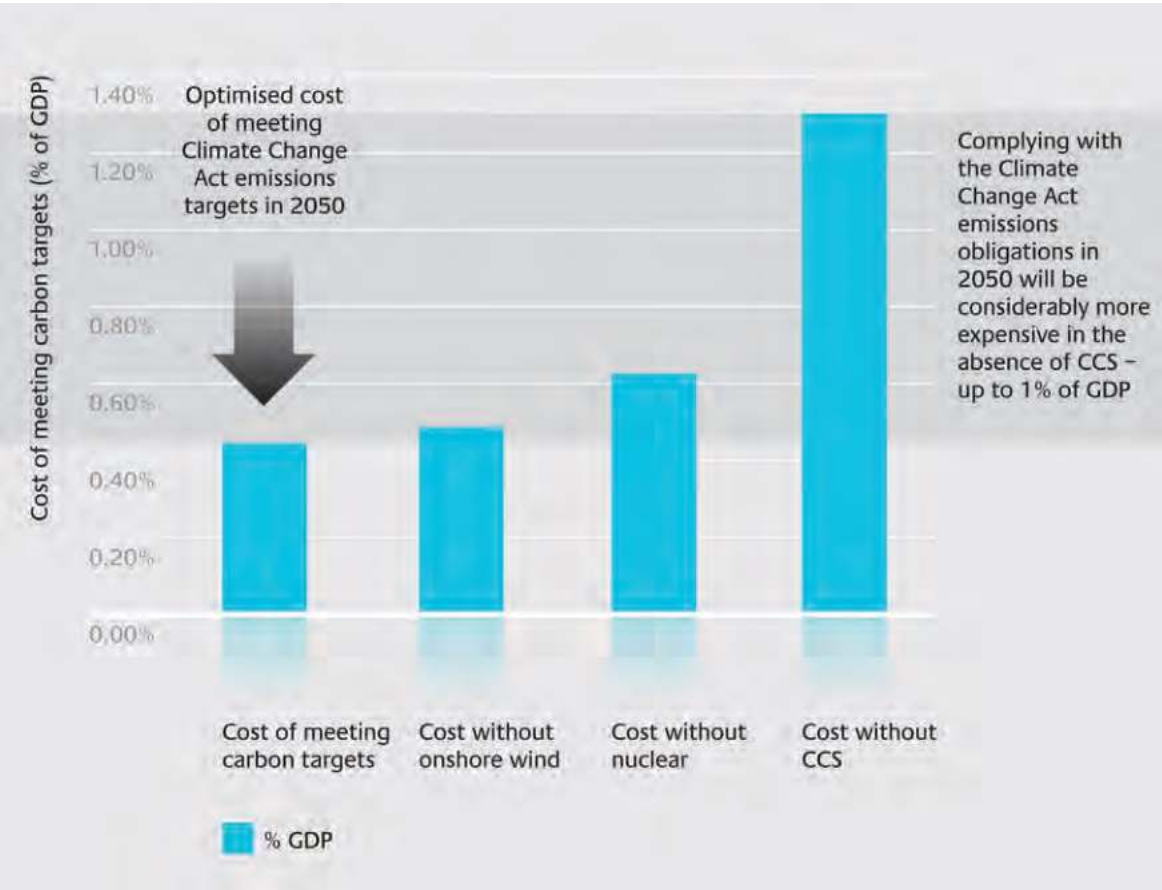


Figure 1: The annual cost of meeting carbon targets in 2050. Source: *Carbon Capture and Storage: Mobilising private sector finance for CCS in the UK*, Ecofin, ETI, 2014

Carbon penalties

With the right choices in low-carbon technologies, the extra cost of meeting the UK's carbon emissions targets could be as little as 0.6% of GDP. A failure to develop CCS could double that cost, which will need to be met by industries and consumers in the future[9].

Without a national CCS infrastructure, the cost of reaching UK climate change targets will double from a minimum of around £30 billion per year in 2050. Each five years of delay in implementing CCS until 2030 will add the equivalent of £4 billion per annum to the total cost of achieving a compliant UK energy system[10].

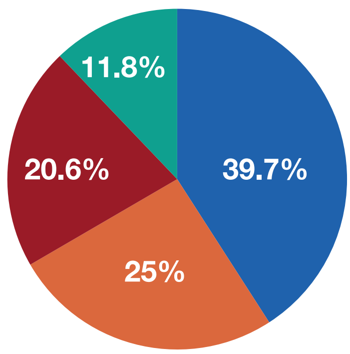
If the UK fails to achieve its emissions targets, there are penalties stemming from European legislation[11]. If a Member State's report for a given year shows it has not achieved its annual targets, it must take corrective action. Any shortfall in emission reductions will have to be achieved in the next year, multiplied by a factor of 1.08.

Any failure to get back on track with 2020 emissions targets results in a temporary suspension of the Member State's eligibility to transfer any emission allowances or other emission rights to another Member State. The European Commission can also launch an infringement procedure against the Member State concerned.

CONFERENCE POLL

What will deliver the biggest push for large-scale CCS across Europe?

- Financial incentives that reward CCS
- CCS Certificates (i.e. polluter pays)
- Building a public interest case for CCS
- Global climate agreement at COP21



9 *Carbon Capture and Storage: Mobilising private sector finance for CCS in the UK*, Ecofin, ETI, 2014
10 *Carbon Capture and Storage: Potential for CCS in the UK*, ETI, 2014
11 *Questions and Answers on Annual Emission Allocations*, European Commission, 2013, http://ec.europa.eu/clima/policies/effort/framework/faq_en.htm

4. OPPORTUNITY

North Sea potential

THE geology deep beneath the North Sea has an immense capacity for storing CO_2 captured from large emitters, such as power plant and industry. Extensive research by SCCS and others suggests that the UK Continental Shelf (UKCS) could account for 35% of the EU's storage capacity, and most of this is off the coast of Scotland[12].

Economist, Dieter Helm, told SCCS conference delegates that the North Sea presented the best opportunity for rolling out a CCS industry, which provides the only realistic route to continued fossil fuel use alongside climate goals. While capture and transport technology can be imported, this storage asset is geographically fixed. It presents the UK with a huge opportunity to develop a CCS industry that serves a domestic market and the rest of Europe. Just one of the North Sea storage sites identified – the Captain Sandstone – could store current emissions from the UK's gas power sector for the next 100 years.

Figure 2: Potential CO_2 storage sites beneath the North Sea include the Captain Sandstone, which is one of the best understood offshore sites due to decades of oil and gas sector operations. Source: British Geological Survey

12 *Progressing Scotland's CO_2 Storage Opportunities*, SCCS, 2011

The UK and the North Sea basin have a unique set of assets and opportunities:

- Existing infrastructure, from on and offshore pipelines to platforms and port facilities
- Realistic opportunities for early-phase CCS developments, including power projects and industrial CCS clusters
- Options for transporting CO_2 by ship, providing high flexibility and low capital risk
- The potential for CO_2-enhanced oil recovery (CO_2-EOR) to boost oil production from mature fields while aiding the rapid development of a CCS network.

The legacy of oil and gas production, together with significant CCS appraisal work, means the Central North Sea (CNS) is exceptionally well understood. It provides the opportunity, using existing infrastructure and shipping, to transport CO_2 and develop early-stage, high-volume storage. SCCS analysis of the situation suggests the following:

- The CO_2 storage asset beneath the CNS 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, which can be converted for CO_2 transport, can access storage sites from the Scottish mainland.
- Existing production platforms in the CNS can be converted to CO_2 injection as fields become depleted.
- CO_2 import hubs could be developed at existing ports with gas-handling facilities: the Firth of Forth (Scotland); Peterhead (Scotland); Teesport (England).
- Deep-water ports along Scotland's eastern coast, which have been the subject of CO_2 import feasibility studies, can receive CO_2 from geographically dispersed sources that require ship transport.
- A high proportion of European carbon emissions would be within cost-effective 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 role of CO_2-enhanced oil recovery

A recent study by the Energy Research Partnership has concluded that developing enhanced oil recovery using CO_2 (CO_2-EOR) could extend the life of oilfields on the UKCS for up to 15 years, delivering extra domestic oil revenues and jobs while delaying decommissioning[13]. At the same time it could provide low-cost CO_2 storage.

Findings from a recent SCCS joint industry project were presented at conference by Chris Bryceland from Scottish Enterprise, one of the project partners[14]. The multidisciplinary study suggests that:

"[CCS is] a core technology, it matters and it would be ludicrous not to try and see whether it works and see what the cost and policy framework might look like. It would be irresponsible not to try a big CCS project in the North Sea."

Dieter Helm, University of Oxford

- A synergy between CO_2-EOR and CCS could be the driver for developing both technologies in the UKCS.
- This approach to using and storing CO_2 could provide the most cost-effective way to accelerate an energy transition between 2018 and 2030 to adhere to the UK CCC's decarbonisation pathways.
- CO_2-EOR could bring significant benefits to the UK economy, including extending the producing life of the North Sea, reducing imports of oil, maintaining employment and giving rise to additional taxation revenues[15].
- Through accelerated CCS deployment, more CO_2 would be abated more quickly than by any other route, even when emissions from any additional oil produced are accounted for.
- A business demand for CO_2 would be created, which would drive the sequential construction of CO_2 capture projects and enable cheaper low-carbon electricity.
- CCS by this route, with secure CO_2 storage already proven, would develop more rapidly and protect the onshore UK economy and industry from increasing carbon prices.
- Public subsidy of the cost of a low-carbon transition would be greatly reduced, and the development of CO_2-EOR could give a national return of up to 7.2 times investment, which is a much higher return than that offered by rival energy opportunities, such as offshore wind.

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13 *Prospects for CO_2-EOR in the UKCS*, Richard Heap, Energy Research Partnership, 2015
14 *CO_2 storage and Enhanced Oil Recovery in the North Sea: Securing a low-carbon future for the UK*, SCCS, 2015
15 The oil market price is obviously a major driver of CO_2-EOR in the North Sea, with techno-economic evaluation by the JIP suggesting that an oil price of over 60 GBP per barrel is necessary (SCCS, 2015, p28)

“Can CO_2-EOR accelerate CO_2 storage in the UK? Yes, but fiscal incentive is needed to develop the CCS industry...”

Chris Bryceland, Scottish Enterprise

- A CO_2-EOR pathway could provide sufficient capacity to meet current projections of the amount of CO_2 that will need to be stored. For example, the ETI envisages an optimal injection rate of 60 million tonnes of CO_2 by 2030. The CCC’s “core decarbonisation scenario” of the Fourth Carbon Budget envisages 52 million tonnes a year of CO_2 being stored by 2030. Both scenarios can be met by a UK CO_2-EOR market, which develops commercial CCS projects every year from 2019 to 2030.

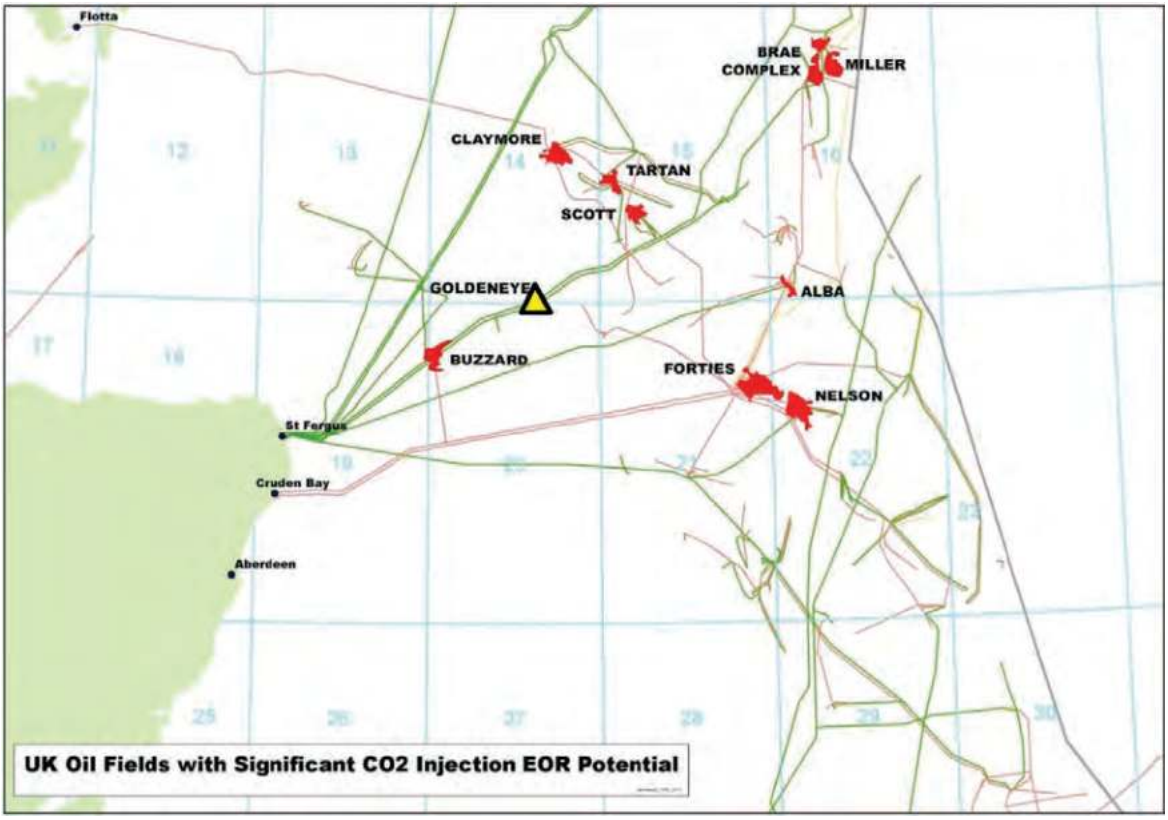


Figure 3: Map showing offshore oilfields in the Central North Sea, which are considered to be particularly suitable, technically and economically, for CO_2-EOR. Source: McCormack et al, 2014

Power players

DELEGATES and speakers at the SCCS conference represented decades of international CCS expertise, learning and research and included developers behind the UK's most promising commercial schemes. Despite the recent withdrawal of funding for CCS by the UK Government, these schemes continue to hold the door open to a secure, effective and potentially profitable CCS industry. With the right support the projects can be put back on track.

Peterhead CCS Project

Shortly before the conference, Shell was finalising its Peterhead project FEED study for submission to the UK Government. It had also just successfully launched its Quest CCS project at an oil sands venture in Canada, which will store 25 million tonnes of CO_2 over 25 years. Ten years of experience and learning derived from developing full-chain projects was shared with conference delegates by Bill Spence of Shell UK.

Over the decade, Shell has been building competence in CO_2 storage, capture technology, CCS on gas-fired power and heavy oil refining, and even CO_2 utilisation. The company fully recognises that this will ensure it is "competitively advantaged in a world that needs more energy but less CO_2".

In Shell's experience, it has proved more effective to work collaboratively on projects and R&D activities rather than go it alone. It has also learned, through its Barendrecht project in the Netherlands, that public engagement is essential to the success of any project – this includes clear messaging, conveying community benefits and addressing safety concerns. This work will be beneficial to future projects. The Peterhead project remains one of the obvious routes to kickstarting large-scale CCS in the UK and North Sea basin. But stakeholders must quickly find a way to restart the scheme before essential infrastructure is decommissioned.

Demonstrating value

- The Peterhead CCS Project would retrofit capture technology to gas-fired power plant. The UK Government has stated its intention to end unabated coal power and switch to new gas capacity. Gas combustion still has a carbon penalty, however, which CCS would help to mitigate. This crucial technology can be tested and demonstrated at Peterhead.

- Existing infrastructure, including gas pipelines and the Goldeneye gas platform, could be redeployed by the project thereby achieving significant savings for start-up costs.

- Peterhead would utilise one of the most studied, secure CO_2 storage sites beneath the North Sea, unlocking further storage capacity for follow-on projects and demonstrating the full-chain to future CCS investors and the wider public.

Caledonia Clean Energy

Summit Power has been developing clean energy projects for over 25 years, including solar and wind, and has shifted its focus in recent years to CCS. Its plans include the Caledonia Clean Energy Project, a 570 MW coal gasification plant with CCS at Grangemouth in Scotland, which has secured Scottish and UK Government funding for a feasibility study. This work is ongoing. Project manager, Stephen Kerr, described the benefits of Caledonia at the SCCS conference:

"Around 73% of Scotland's emissions are within 10km of an available pipeline, and almost 90% of industrial emissions are within easy reach. But there needs to be an alignment of decision-making and certain interdependencies, such as CO_2 transport and storage, in order to build an effective business case for the Caledonia project."

Stephen Kerr, Summit Power

Summit will bring learning and cost-reduction benefits from its Texas Clean Energy Project in the US, which could begin construction this year. Both projects will utilise integrated gasification combined cycle (IGCC) technology, with Caledonia producing 570 MW of low-carbon electricity from coal for 1 million homes.

As with Peterhead, the Caledonia project would reuse existing pipeline systems – including the onshore Feeder 10 gas pipeline – to link one of Scotland's key industrial zones to permanent CO_2 storage beneath the North Sea. Subsequent project phases will provide opportunities to build on the work involved in the first phase, particularly in terms of collaboration and knowledge sharing.

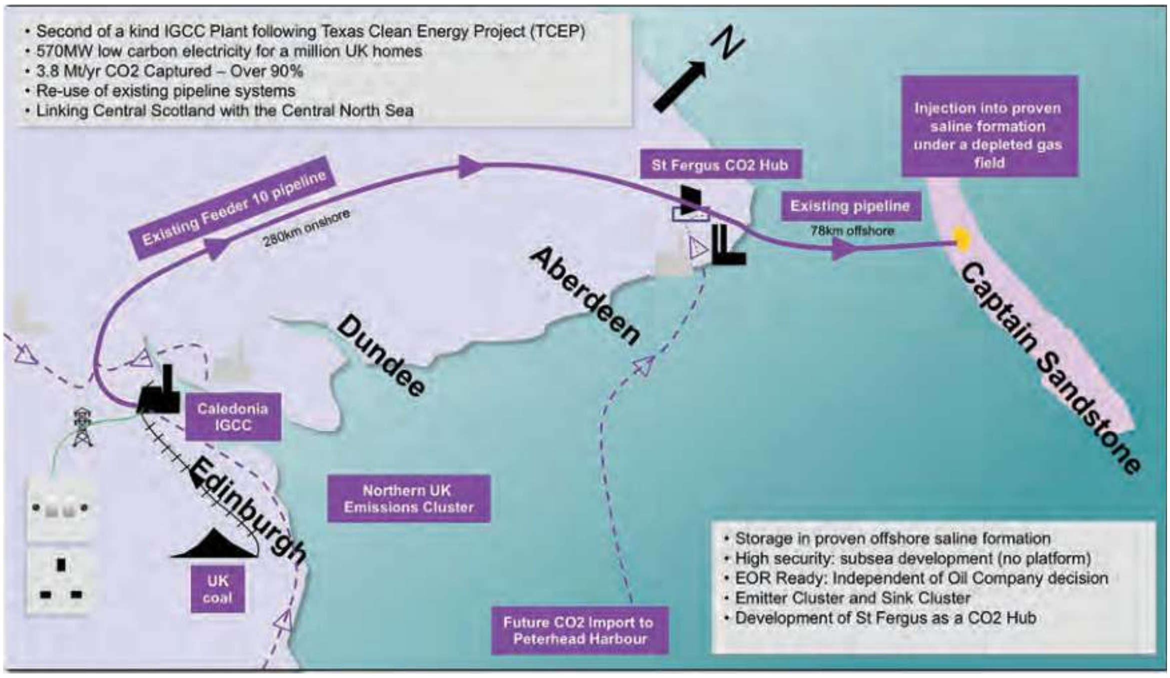


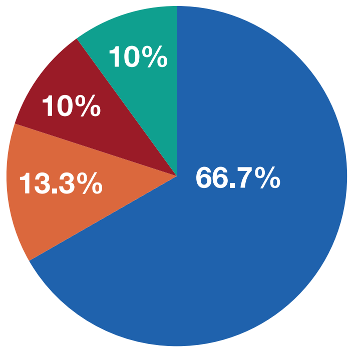
Figure 4: The Caledonia Clean Energy Project's CO_2 chain would utilise existing infrastructure to access storage sites within the Captain Sandstone in the Central North Sea. Source: Summit Power

Caledonia would capture and store around 3.8 million tonnes of CO_2 a year, and could form the basis of a northern UK emissions cluster, with high potential for key industries to share infrastructure if policy and finance were in place. Overall, Caledonia would be able to provide low-carbon baseload electricity efficiently, which reduces the overall cost of energy generation. If the Grangemouth opportunity is fully developed, through several envisaged phases, it could ultimately provide 1500 MW of ultra low-carbon power and lead to 10 million tonnes a year of CO_2 being stored.

CONFERENCE POLL

What has been the most valuable lesson for the CCS community to date?

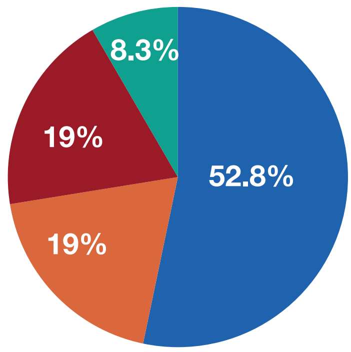
- Long-term and consistent government support is essential
- No business case, no CCS industry
- Cluster approach is only viable route to large-scale CCS
- Societal support is crucial for delivering CCS



CONFERENCE POLL

What is the best way to nurture industry involvement and investment in CCS?

- Supportive long-term policy and finance mechanisms
- Public finance for infrastructure development
- A focus on CO_2-EOR
- Incentivising CCS R&D



Industrial CCS clusters

In its advice on the UK's Fifth Carbon Budget, the CCC recognises the role of "clustering" in providing the iron, steel and chemicals sectors with access to CCS technology. It is already widely accepted that CCS is the only option for significantly decarbonising industrial processes worldwide.

Work undertaken by the Global CCS Institute[16], with a particular focus on Europe, demonstrates the value of a collaborative cluster approach to the economic survival of industrial sectors and regions across Europe. The study concludes: "Many emissions-intensive industries are located in tight geographical clusters that can leverage CCS infrastructure. A clear developing theme in the CCS conversation, especially in Europe, is concerned with the development of CCS hubs and clusters."

Teesside

The Teesside Collective is a cluster of leading industries in the north east of England, which has responded to the climate challenge by developing the case for an industrial CCS hub in the north east of England. It believes Teesside's process industries, which contribute £26 billion to the UK economy, can be "future-proofed" from the rising cost of emitting CO_2 by the deployment of CCS, and will retain a competitive edge internationally as a result.

Mark Lewis, of North East Process Industries Cluster, described to delegates some key findings from the Collective's recently published *Blueprint for Industrial CCS in the UK*, a government-funded study[17]:

- Large numbers of direct and indirect employees would benefit from industry clusters, with an estimated doubling of average GVA per person for those working in the chemicals sector.
- Clusters would produce a consistent trade surplus for the UK and ensure Teesside's process industries continue to contribute to the UK economy.
- CCS would insulate key UK industries from uncertainties over future carbon prices, and also enable them to contribute to meeting UK-wide 2050 emission targets.
- Teesside would become a magnet for inward investment from international firms seeking to reduce their exposure to future increases in the carbon price.
- Clustering can protect investors in CCS from individual company failures and lead to a decrease in infrastructure costs.
- Findings from Teesside can serve as a template for similar networks elsewhere, based around exportable expertise in industrial CCS.

16 *The Global Status of CCS, 2015, Special Report: The role of CCS hubs and clusters in Europe*, GCCSI, 2015
17 *Blueprint for Industrial CCS in the UK*, Teesside Collective, 2015

Adequate and timely investment is obviously key to delivering industrial CCS, and the Teesside Collective has identified two possible approaches to this:

- Emitter driven, with a subsidy paid to the capture operators, who then pay a fee for transport and storage (T&S)
- T&S driven, with subsidy paid to T&S operator to provide capacity, which they pass upstream to the capture operators.

Both approaches require development as the impact on cost to customers is a significant issue that could result in so-called “carbon leakage”, with buyers seeking cheaper products in countries with unequal emission costs and regulations.

An East Coast Network?

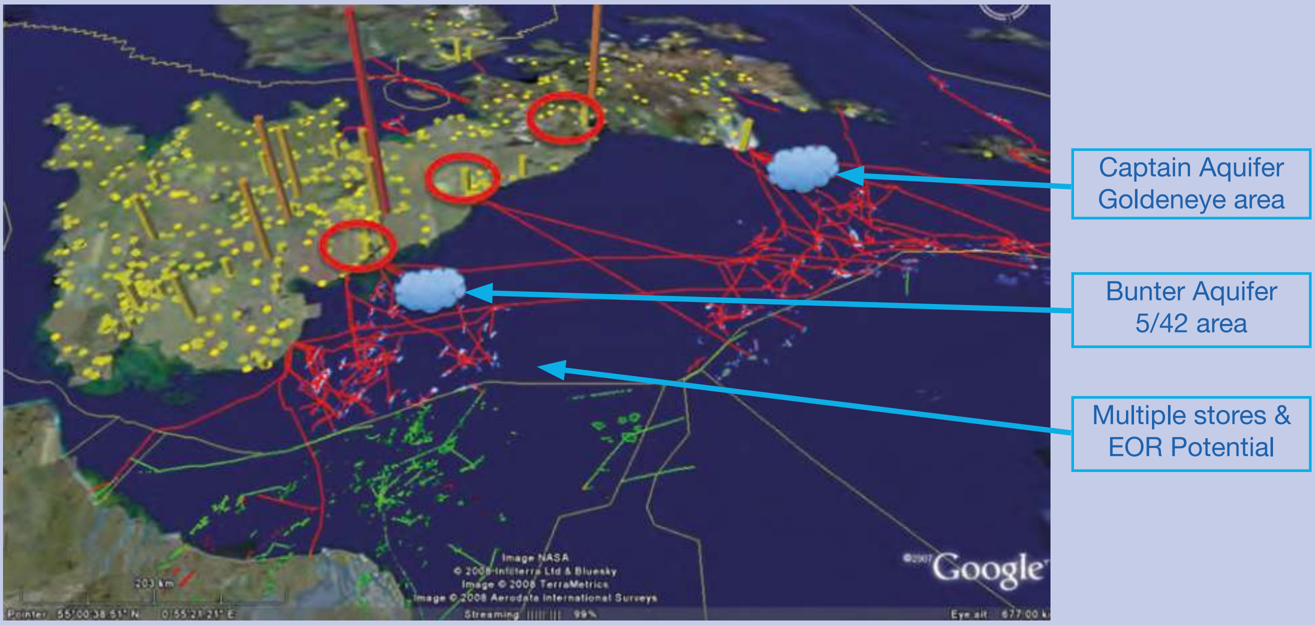


Figure 5: The Teesside Collective’s study suggests that the proximity of east coast industrial clusters to well-characterised CO_2 storage offshore presents one of the world’s best opportunities to develop an industrial CCS network. Source: Mark Lewis, NEPIC

Focus on steel

Dave Robson, Steel industry

The steel industry illustrates how technology developers must deal creatively with global environmental and economical challenges. A strong and healthy steel industry is a source of economic activity but, unfortunately, is also a high source of CO_2 emission.

CCS is the only serious option to decarbonise the industry but steel cannot do it alone; it must be done alongside other industries. The steel industry in the UK has experienced problems resulting from other factors, such as globalisation, which are outwith its control. But CCS can bring a degree of certainty on the cost of CO_2. With CCS, the UK has an opportunity to become the place where low-carbon steel is produced; this could turn into a major advantage in a global low-carbon economy.

Focus on cement

The use of CO_2 to create useful products, such as building materials – known as CO_2 utilisation – often sits at the periphery of CCS debate, yet industries such as cement production could benefit from being part of industrial CCS clusters.

Michel Gimenez, of LafargeHolcim, explained further. Cement production accounts for about 5% of global man-made CO_2 emissions. With demand continuing to increase worldwide, emissions reduction is an urgent task for the industry. It favours CO_2 utilisation and important developments, such as low-carbon products derived from mineral carbonation, could bring a significant reduction in emissions.

The challenge lies in the cost of CO_2 supply if a plant could not produce enough of its own. The current cost is around €50 to €75 per tonne for the high-grade CO_2 required by CCS and other applications, such as enhanced oil recovery. The cement industry needs comparatively smaller quantities of low-cost, low-grade CO_2 for utilisation to be economically viable.

The best model, according to Gimenez, is to use partial CO_2 utilisation, which differs from the usual full-chain CCS approach. For this to work, the cement industry would need access to local, cheap sources of CO_2, which an industrial cluster could well provide.

One third of CO_2 emissions from a cement plant derive from fuel combustion and two thirds from the calcination process itself. Photo: LafargeHolcim 2015

From clusters to systems – building a European CCS sector

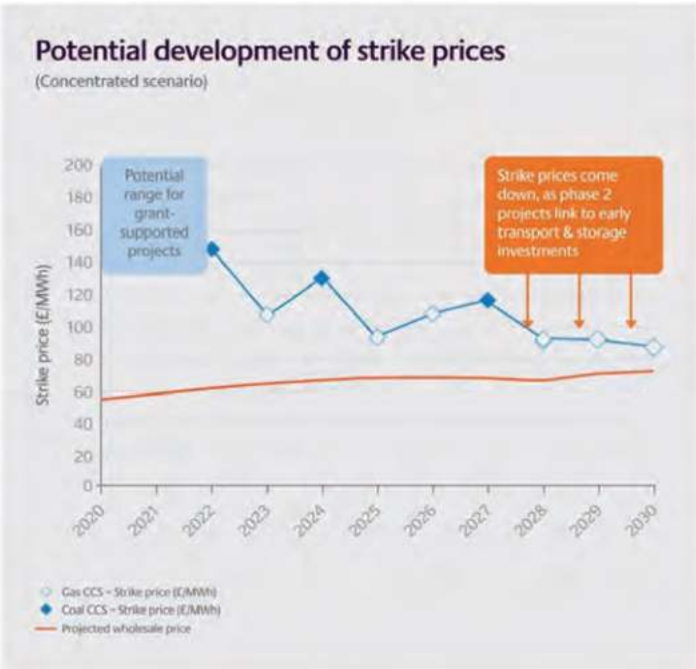
The delivery of CCS for the UK's power and industry sectors could provide the knowledge and impetus needed to begin the roll-out of clusters and networks across Europe. Andrew Green of the ETI drew on analysis from a recent institute report[18] to describe this wider role:

- CCS would bring value to energy systems across the EU. Benefits would include low-carbon electricity from fossil fuels (important in a transitional capacity), negative emissions from CCS with biomass, and allowing fossil fuel use in industry where no alternatives exist.

- Benefits derived from a cluster/network approach include reduced costs from sharing T&S infrastructure; learning from earlier projects; shared risk resulting in reduced capital cost; and more flexibility in a T&S system better able to absorb variable CO_2 supply.

energy technologies institute

Benefits of clustering



Substantial cost savings driven by:

- Sharing of infrastructure
- 'Learning by doing' – improved engineering and project delivery
- Reduced investor risk = reduced cost of capital

Improved flexibility of the transport & storage system

- Improved ability to absorb variability in CO_2 supply
- Multiple stores/injection sites – reduce risk of failure

Figure 6: The ETI's modelling work shows how electricity strike prices (£/MWh) can start to reduce as the benefits of a cluster/network approach accrue. Source: ETI, 2015

18 *CCS Sector Development Scenarios in the UK*, Element Energy and Pöyry for Energy Technologies Institute, 2015

- According to the ETI, each cluster should ideally start with an anchor project of sufficient scale to justify investment in infrastructure and to provide secure volumes of CO_2 to allow consistent operation of the storage site. This would then open up other opportunities, such as smaller power projects, industrial CCS, CO_2-EOR, etc.

- The most cost-effective delivery of CCS would then be through developing key clusters linked to comprehensive T&S systems, stemming from initial anchor projects (see Figure 7 below).

SCCS has also studied the potential role of a Scotland-based CO_2 hub, which utilises existing infrastructure and other assets, in providing a stepwise and affordable route to a CCS industry for both the UK and the rest of Europe[19].

An evolving process

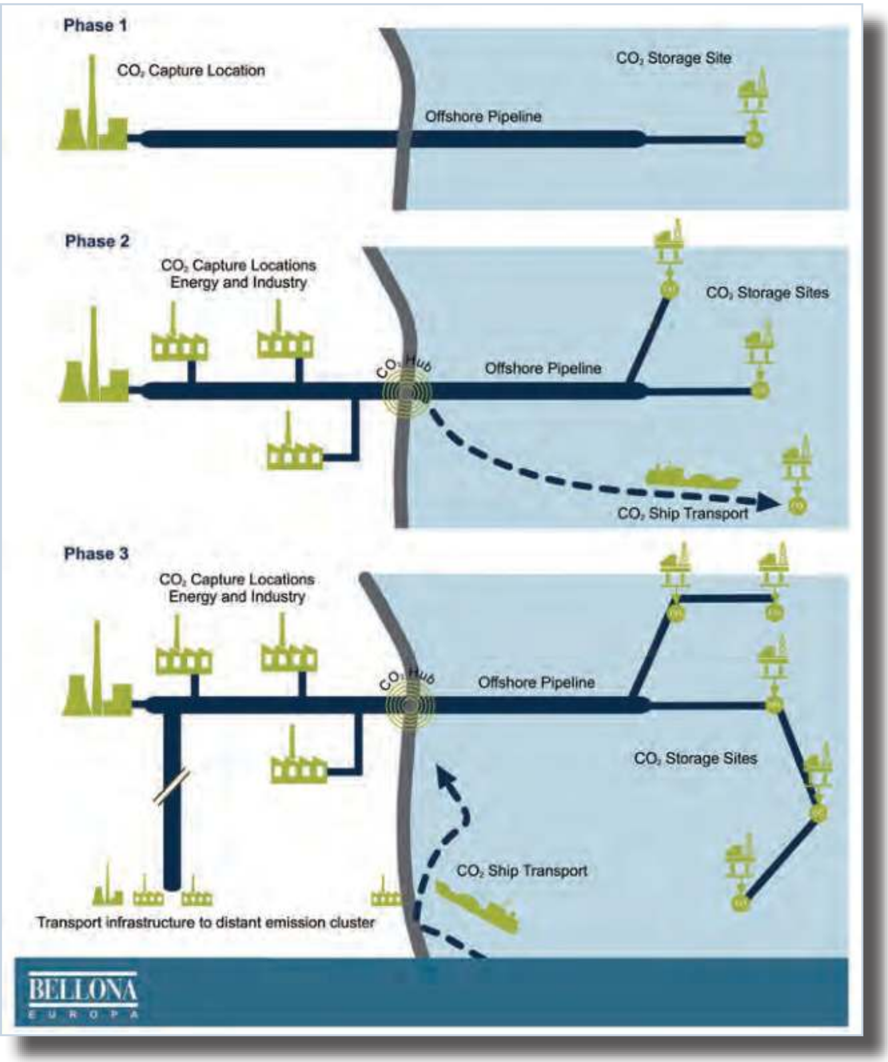


Figure 7: Research published by ZEP suggests that commercial CCS should evolve through three key phases, from a single source project through to a hub serving neighbouring countries, and making full use of CO_2 shipping as well as pipelines. Source: *An executable plan for enabling CCS in Europe*, ZEP/Bellona, 2015

19 *Scottish CO_2 Hub – A unique opportunity for the United Kingdom*, SCCS, 2016

R&D in the UK

THE UK's science and engineering research community has been described as "punching well above its weight" within an international arena[20]. British scientists continue to innovate, enhance and take the lead on the technologies that will be crucial to a successful transition to a low-carbon future. This R&D expertise is a fundamental part of the UK's CCS offering and is exportable to other countries. If the industry's development is not supported in the UK there is a significant risk of "brain drain" to countries where large-scale CCS is already making progress, such as North America, Australia and China.

This expertise has been built up over many years of R&D in the UK, with the support of tens of millions of pounds of largely public research funding. There continues to be a significant level of CCS research in the UK with funding already committed for several years to come. Loss of government support for CCS deployment means the return value from this R&D funding may accrue in other parts of the world with little benefit to the UK economy.

The SCCS conference highlighted the breadth of R&D under way within Scotland and between Scottish research institutes and other partners (including industry) in the UK and abroad. Representatives from across Scotland presented overviews of the research activity and expertise within the SCCS partnership. These pages provide a snapshot of that work. Conference R&D presentations and posters can be downloaded at:

http://www.sccs.org.uk/events/sccs-conference-2015

Emerging carbon capture technologies

Full-chain CCS begins with the capture of CO_2 from large emitters pre or post-combustion, and technologies differ depending on fuel type and the combustion method. Researchers within the SCCS partnership are seeking solutions to a number of challenges, such as reducing the energy penalty of capture technology; the regeneration of capture materials; and reductions in overall capture costs. Other SCCS research activities focusing on power plant flexibility and solvent research were also presented at the conference.

Key SCCS collaborative projects in this emerging field, presented by Stefano Brandani (University of Edinburgh), include:

- The development of amine-impregnated silicas for capture
- Adsorption materials and processes for gas power (novel and experimental)
- Post-combustion CO_2 capture using metal-organic frameworks (MOFs)
- Hydrogen production from integrated gasification combined cycle (IGCC) power with carbon capture
- MOF-based mixed-matrix membranes for CO_2 capture.

20 *Inside Science*, BBC, 4 December 2015

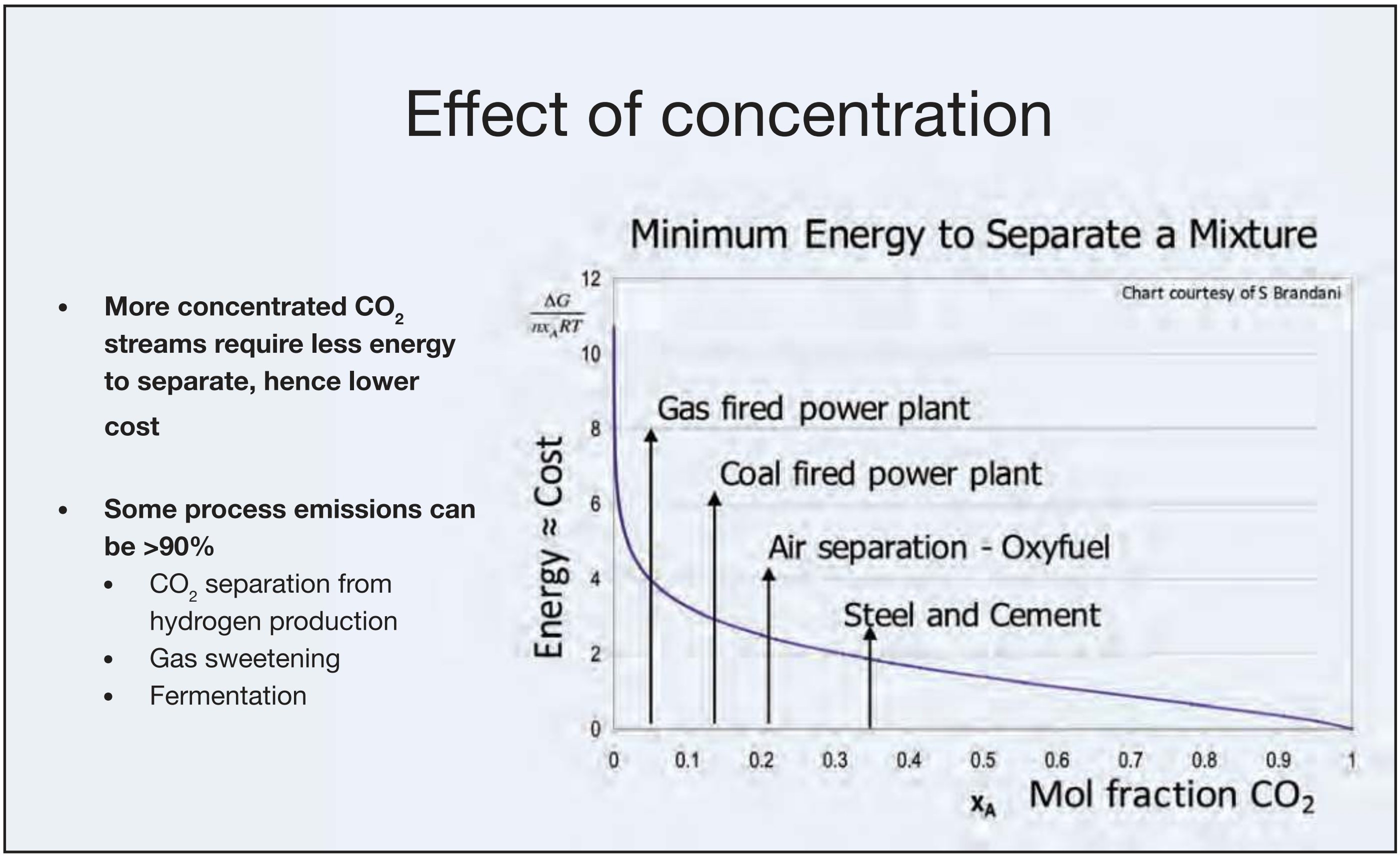


Figure 8: Having a range of different technology developments is important to address varied industry requirements. For example, not all capture is the same, and this chart shows that more energy is needed for capture from more dilute CO_2 emissions. It also illustrates that CO_2 capture from steel and cement production is cheaper than from gas power plant. Source: Stefano Brandani

CO_2 transport: delivering on the challenges

The transport of CO_2 after capture is an essential part of the CCS chain but is the least studied. While there is wide international experience of CO_2 pipelines, there is limited appreciation of shipping as a method of CO_2 transport, which would enable early-phase projects where pipeline infrastructure is not yet in place.

Key SCCS research in this area, presented by Julia Race (University of Strathclyde), seeks to address the following challenges for CO_2 transport:

- Flexible transport network simulation and design
- Risk assessment and safety methodologies
- Onshore and offshore leak detection and CO_2 dispersion modelling
- Detection, monitoring and measurement equipment
- Material selection and testing and the effects of impurities in CO_2 flow
- Development of large-scale shipping solutions.

CO_2 storage: the fate of CO_2 in CCS

The secure and permanent storage of CO_2 worldwide depends on the availability of reliable, accessible and well-understood geological storage sites, either on or offshore. In the US, over the last 40 years, more than 100 CO_2-EOR projects have shown how oil and gas reservoirs can safely store the injected gas in liquid form. In Norway and Algeria, CO_2 has been routinely injected and geologically stored as part of natural gas production. Elsewhere, there is more limited experience of CO_2 storage, and SCCS continues to conduct and support such appraisal work. Key areas of SCCS research, presented by Eric Mackay (Heriot-Watt University), include:

- Appraisal of geological CO_2 storage sites beneath the UK North Sea, including reservoir modelling
- Unlocking CO_2 storage potential through study of multi-user storage sites (CO_2MultiStore JIP)
- Geochemistry and geomechanics
- Injectivity, capacity and security of storage
- CO_2-EOR and the link to CCS (CO_2-EOR JIP)
- Measurement and monitoring, regulation and environmental impact
- Public perception.

Environment and society: putting CCS in context

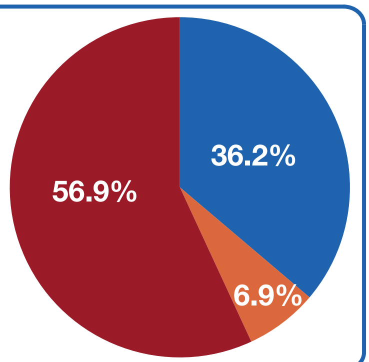
The delivery of a CCS industry in the UK and Europe hinges on engagement with a spectrum of existing and potential stakeholders, and there have already been good – and bad – examples of differing approaches (see also International learning, page 32). Research into public perception and acceptance of CCS has focused on debating and addressing public concerns, such as risk and uncertainty; building citizen and stakeholder support; and assessing the position of CCS within a social, political and economic context. Research in this area, presented by Leslie Mabon (Robert Gordon Institute), has been an intrinsic part of several projects looking at risk, impact and mitigation, including the following:

- Mitigation and remediation of CO_2 leakage
- CO_2 fingerprinting as means of managing storage sites
- Nature and probability of CO_2 leakage and quantifying marine impact potential
- Modelling and monitoring techniques for sub-seabed CO_2 storage
- CCS and CO_2-EOR.

CONFERENCE POLL

What should the R&D community prioritise to help deliver large-scale CCS?

- Technology gaps and cost reduction for first-wave projects
- Looking ahead 10-20 years to follow-on project needs
- Both of the above



Joint Industry Projects

“Results from the CO_2MultiStore project show that, by using more than one injection site in a single sandstone, operators can store greater volumes of CO_2 compared to using a single injection site, so increasing Europe’s capacity to reduce greenhouse gas emissions.”

Maxine Akhurst, British Geological Survey

Strategic projects between the research community and industry partners have yielded results, which are crucial for developing a viable CCS industry in the UK and worldwide. Within the SCCS partnership, joint industry projects have focused on, for example, work to identify a domestic pathway to CCS through rigorous assessment of the UK’s sizeable offshore storage asset; and an extensive study aimed at addressing issues of importance to project developers looking to link North Sea CO_2-EOR with CCS projects onshore (see page 16).

The CO_2MultiStore project[21] recently published findings from an innovative study into multi-user storage sites. The work focused on a North Sea case study – the Captain Sandstone – and results predict that the secure and permanent storage of CO_2 within a single geological storage formation can be optimised by injecting at more than one point simultaneously.

These findings could help to unlock an immense CO_2 storage resource underlying all sectors of the North Sea and will inform the work of those managing and operating this natural asset. The cutting-edge research methods deployed will also reduce the effort and resources needed to characterise other extensive storage sandstones suitable for CO_2 storage worldwide.

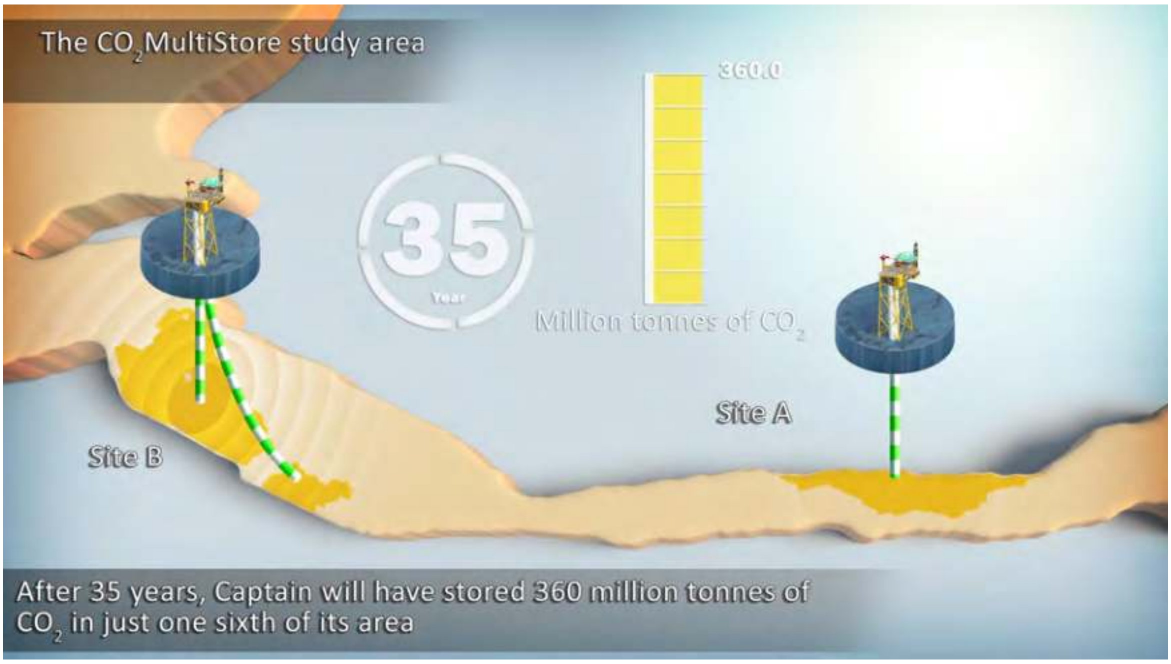


Figure 9: Results from the CO_2MultiStore project show that, by using more than one injection site simultaneously in a single sandstone formation, operators can securely store greater volumes of CO_2, and increase Europe’s capacity to reduce greenhouse gas emissions. Source: CO_2MultiStore animation, CO_2MultiStore/SCCS

21 *Optimising CO_2 storage in geological formations; a case study offshore Scotland*, SCCS, 2015

Engaging with the global community on climate change

Prior to the COP21 climate talks, SCCS coordinated an open letter to the UNFCCC Executive Secretary, Christiana Figueres, from 43 geoscientists and engineers, representing CO_2 storage expertise from 14 countries. The letter – supported by an online body of evidence – sought to reassure the UNFCCC that the geological storage of CO_2 for CCS "is secure and safe".

In response, the Executive Secretary stated: "As we work with governments towards the adoption of a global climate agreement to curb carbon emissions in the upcoming Conference of the Parties in Paris, it is clear that the full use of all safe and cost-effective technologies, including CCS, will be encouraged by the climate agreement as one of the many solutions needed to manage the global risk of climate change, to avoid damaging impacts on the environment, and to re-establish the ecological balance."

Katherine Romanak of The University of Texas at Austin, one of the 43 letter signatories, who was also involved in CCS side events at the Paris climate talks in November 2015. Photo: Ciara O'Connor

Dear Ms Figueres,

The geological storage of CO_2 for carbon capture and storage is secure and safe

As geoscientists and engineers representing decades of scientific research worldwide we would like to reassure the United Nations Framework Convention on Climate Change (UNFCCC) that the geological storage of carbon dioxide (CO_2) with relevance to carbon capture and storage (CCS) is safe, secure and effective, and we have considerable evidence to show this.

Extensive research gives us very high confidence that CO_2 storage in appropriately selected sites is secure over geological timescales and leakage is very unlikely. The residual risk of leakage can be managed by well-understood procedures and presents very low risk of harm to the climate, environment or human health.

The knowledge and techniques required to select secure storage sites are well established, being built upon decades of experience in hydrocarbon exploration and production. A global capacity of suitable CO_2 storage sites has been estimated at several trillion tonnes. There is also extensive experience of CO_2 injection and storage in a variety of situations and locations around the world. We can state the following with very high confidence:

> ***Natural CO_2 reservoirs have securely held billions of tonnes of CO_2 underground for millions of years.*** *These provide an understanding of CO_2 storage processes and inform the selection of rock formations for secure storage as part of full-chain CCS.*
>
> ***Stored CO_2 is securely contained by physical and chemical processes that increase storage security with time.*** *Injected CO_2, held within the storage site by multiple layers of impermeable rocks, is trapped in isolated pockets, dissolves in fluids in the rock and may eventually react with the rock to make new minerals.*
>
> ***Millions of tonnes of CO_2 have been injected and stored since 1972 in storage pilots and demonstrations, enhanced oil recovery and other industry practices.*** *Accumulated experience of CO_2 injection worldwide has led to the development of routine best practices for the operation and closure of CO_2 storage sites, and provides direct evidence of engineered storage security.*
>
> ***CO_2 injected into underground rocks can be monitored to confirm its containment. A variety of monitoring methods has been developed and demonstrated.*** *In the very unlikely event of poor site selection, these techniques are able to identify unexpected CO_2 migration before leakage to the surface can occur.*
>
> ***Leakage of CO_2 from geological storage presents a very low risk to climate, environment and human health.*** *Research results show that the impacts of any CO_2 leakage on land or at the seabed will be localised and very unlikely to cause significant harm to ecosystems and communities. Should CO_2 move towards the surface, interventions can be made to control, minimise and prevent leakage.*

Tackling CO_2 emissions from power generation and key industries is critical to delivering climate change mitigation in line with the UNFCCC's objectives. The IPCC finds, with high confidence, that attempting to limit global warming to below 2^oC without CCS is unachievable.

Full-chain CCS, which integrates CO_2 capture, transport and storage technologies, is already being demonstrated at a growing number of facilities. The security of properly selected and regulated storage sites presents no barrier to its further deployment and enables its important contribution to climate change mitigation. We urge you to reflect this position in the content and outcome of your forthcoming talks in Paris this December.

For a full list of signatories, supporting evidence and the UNFCCC's reply, go to:
http://www.sccs.org.uk/cop21-open-letter

International learning

DESPITE a lack of progress on CCS in the UK, other countries have seen full-chain projects either start operating or begin construction. The Global CCS Institute's status report for 2015 listed 15 operational projects – on gas production, power and industry – which together captured around 28 million tonnes of CO_2 last year[22]. These are significant achievements and policy makers and potential project developers can learn from this combined international experience of CCS in action.

Reducing the cost

SaskPower's Boundary Dam facility in Saskatchewan, Canada, is the first project across the line for full-chain CCS on coal-fired power. The project experienced some operational issues, as would be expected in any first-of-a-kind demonstration project, and there is already important learning to be shared[23]:

- Follow-on project costs can be significantly reduced due to enhanced understanding, operational experience and the need for fewer risk-mitigating contingencies. First-of-a-kind projects tend to be over-engineered in order to ensure necessary outputs, with follow-on projects not needing the same level of specification.

- Operating experience allows the respective value of different risk-mitigating equipment to be judged, helping to identify redundant elements and reducing capital costs as a result.

- With engineering experience from the first scheme, SaskPower believes costs can be reduced by 30% for the next project.

- Key stakeholders had adequate time to consider technology choices before final decisions were taken, thereby increasing confidence in the project.

Inside the Boundary Dam CCS facility.
Photo courtesy of SaskPower

22 *The Global Status of CCS 2015*, Summary Report, GCCSI, 2015
23 *Integrated CCS Project at SaskPower's Boundary Dam Power Station*, IEAGHG, 2015

- The project team chose to retrofit an existing power plant rather than build new in order to retain the value of previous investment. Capture technology costs will be met over 30 years by selling useful by-products, including carbon dioxide, sulphuric acid and fly ash.

Supportive financial and regulatory regimes

The Quest CCS project, a joint venture by Shell, Chevron and Marathon at an oil sands operation in Alberta, Canada, had strong financial commitment from both the federal and provincial governments. A rigorous regulatory framework was also put in place to guide developers and ensure the safe operation of CCS technology in the province. The introduction of a new carbon tax on large emissions also played a part.

As part of funding agreements[24], the partners are now sharing knowledge and experience to help other CCS developers build large-scale projects more rapidly and efficiently[25].

Although many aspects of CCS are covered by Alberta's existing oil and gas regulations, various funding and regulatory acts were passed by the province to enable Quest to be built[26]. These included:

- Carbon Capture and Storage Funding Act, which created the $2 billion CCS funding programme to enable large-scale CCS projects in Alberta.

- Carbon Capture and Storage Funding Regulation, which authorised spending for the Regulatory Framework Assessment as well as for education and research.

- Carbon Capture and Storage Statutes Amendment Act 2010 (Bill 24), which addressed two key barriers – long-term liability for CO_2 stored underground and pore space access[27].

- Regulatory Framework Assessment, which ensures CCS is conducted in the safest and most environmentally responsible way possible.

R&D frameworks to support commercialisation

In 2003, the US Department of Energy began to roll out its Regional Carbon Sequestration Partnerships to support the development of large-scale CO_2 storage technology, infrastructure and regulations[28]. Arguably the most effective R&D programme for the geological storage of CO_2, it has led to significant new findings and technologies. The safe storage to date of 8 million tonnes of CO_2 is testament to this public and private sector effort.

24 http://www.energy.alberta.ca/CCS_FA_Quest_-_consolidated_-_02_21_14.pdf
25 http://www.shell.ca/en/aboutshell/our-business-tpkg/upstream/oil-sands/quest.html
26 More details at http://www.energy.alberta.ca/CCS/3840.asp
27 The companies injecting CO_2 may have a shorter lifespan than the storage. This Act allows the Government of Alberta to assume long-term liability for storage sites once the sites have been properly closed and the operators have demonstrated through long-term monitoring that the stored CO_2 is stable.
28 http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research/regional-partnerships

The seven partnerships, launched in three phases, involve around 400 organisations, 43 US states and four Canadian provinces. They seek to encourage and support local partnering to help select the best storage sites and technology solutions. The first phase covered storage site characterisation, the second phase dealt with validation and the third phase (2008–2018+) was concerned with development[29].

The second phase of the initiative led to 11 onshore storage projects and the production of a number of "best practice" manuals, which will be of value to future project developers and storage operators.

Public Engagement

The value of involving local communities and other stakeholders in the development of any new technology cannot be underestimated. Some CCS projects have shared analysis of their own experiences in public engagement, including the CO2CRC Otway Project in Australia. A case study published in 2010 has continuing relevance to other project developers and includes the following insights[30].

Public engagement initiatives, such as Shell's Geological Journey at Peterhead in Scotland (above), have been effective in explaining CCS technology to local communities. Source: Shell/GCCSI/CO_2Degrees/GeoBus

Successful communication and engagement strategies included:

- Early proactive engagement with stakeholders to build trust and form working relationships, creating two-way dialogue.

29 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3084463/
30 *Case Study of the CO2CRC Otway Project*, CSIRO, 2010

- Social research in the community to establish baseline understanding of CCS.
- Face-to-face informal meetings with key landholders and stakeholders held at convenient times to allow discussion of key concerns, such as compensation and access to land.
- Appointment of a local former schoolteacher as a liaison officer to establish communication channels and build trust between developer and community.
- The establishment of a community reference group, which was considered a key strategy for communicating concerns from community to developer.

International collaboration

The delivery of CCS at national and regional level is at the heart of global action on climate change, and requires international community efforts in order to be successfully achieved. A number of initiatives seek to harness global expertise through collaboration and sharing of knowledge, including the EU-funded CO_2Geonet "network of excellence".

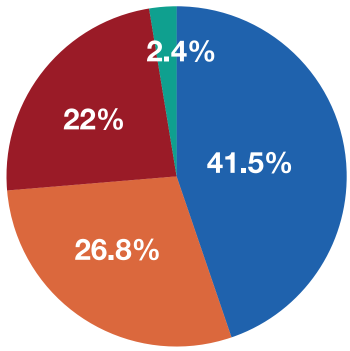
The network was set up under the European Commission's 6th Framework Programme to coordinate action on CO_2 geological storage[31]. It represents 26 partners from 19 European countries and connects more than 300 experts. Since 2004 it has promoted joint research on CO_2 storage, provided scientific advice, supported training and helped to raise the profile of CCS at international events, including the Paris COP21 climate talks.

CO_2GeoNet also has an important role in raising awareness about geological storage, and has provided clear, unbiased scientific information to the public, policy makers, regional authorities, and other stakeholders worldwide. The network's members also continue to encourage dialogue on essential issues.

CONFERENCE POLL

How do we encourage reluctant EU Member States to deliver CCS?

- Address public and stakeholder scepticism towards CCS
- Facilitate knowledge exchange between Member States' power and industry sectors
- Commercialise regional clusters
- Maintain ongoing communication with MEPs



31 http://www.co2geonet.com/Home.aspx?section=1

5. DELIVERING CCS

Progress on supportive mechanisms

THE first large-scale CCS projects in the UK and Europe will only achieve traction with the right supportive frameworks and mechanisms in place. Some progress has been made, lessons have been learned but more support is needed.

The EU's Roadmap 2050[32] includes CCS in three of its five decarbonisation scenarios. In 2014, the European Parliament adopted a resolution on "developing and applying" CCS technology in the EU, recommending that the European Commission:

- Ensure CCS makes a significant contribution to 2050 emissions reduction targets
- Prepare guidelines for Member States on measures to incentivise CCS deployment
- Promote the production of a European Atlas on Europe's CO_2 storage potential
- Revise the current guidelines and provide clarity on the EU's CCS Directive.

Jerzy Buzek MEP, chair of the parliament's Committee on Industry, Research and Energy, suggested to the SCCS conference that fears over the high cost of CCS technology and uncertainty over returns on investment could be tackled through legal and policy changes and the provision of financial support – a cost outlay that would "bring fast returns and a technology that would serve Europe for many years".

In 2007, the EU expressed its ambition to have CCS commercially available by 2020. Krzysztof Bolesta of Poland's Ministry of the Environment gave his analysis of actions and their impact since then:

- Regulation: The CCS Directive was meant to be "enabling" but it became too complex for both Member States and industry. Nations were to make their own decision on permitting CO_2 storage, but few did so as a result of public concerns and other issues.
- Finance: Two EU mechanisms – the EEPR[33] and NER300[34] – tried to support too many projects and were overly prescriptive on the technologies that it considered should be supported.
- Knowledge sharing: A communication "platform" was initially successful, particularly around public engagement, but interest tailed off as demonstration projects were abandoned across Europe.

32 The EU's *Roadmap 2050 A Practical Guide To A Prosperous, Low-Carbon Europe*, published in April 2010, discussed the feasibility and challenges of realising an 80% GHG reduction objective for Europe, and included decarbonisation pathways. http://www.roadmap2050.eu/project/roadmap-2050

33 European Energy Programme for Recovery (EEPR), http://ec.europa.eu/energy/eepr/projects/

34 New Entrants Reserve scheme (NER300), established to kickstart the demonstration of CCS and renewable energy technologies on a commercial scale within the EU. It has been succeeded by NER400

"The EU over-regulated the CCS demonstration phase, but industrial decarbonisation is the the big opportunity for CCS; we need to retain jobs and output."

Krzysztof Bolesta, Polish Ministry of the Environment

- Infrastructure: CO_2 transport has been made part of the EU's energy infrastructure programme and, while not utilised yet, this remains a crucial enabler for CCS.

- Research: Large investment in CCS R&D has been made through EU research programmes and will continue through, for example, the current Horizon 2020 programme[35].

In Poland, initial enthusiasm for CCS was hit by concerns over cost, regulatory complexity, public opposition and a lack of serious industry buy-in. Across the EU, CCS has also been hindered by the financial crisis, a collapse in the EU carbon price and, argued Bolesta, overly ambitious ideas for full-chain CCS. An overarching issue was a lack of "serious political buy-in" from the majority of Member States, industry and the wider public.

Enabling CCS across Europe

A number of steps are described below that would strengthen existing mechanisms for supporting CCS and a low-carbon energy transition and address any remaining gaps.

The European Union

Engaging Member States: The EU should focus its work on nations actively showing support for CCS and avoid forcing projects on unwilling Member States. All states should be encouraged to develop robust national climate plans to 2050.

Industrial CCS in Energy Union[36]: Europe has missed the opportunity to export CCS technologies, but CCS on industrial plant remains a crucial opportunity for retaining jobs and addressing emissions targets to 2030 and beyond.

A cluster approach: The creation of regional industrial clusters, with access to CCS opportunities and infrastructure, should be fostered by encouraging collaboration between industrial sectors.

Flexible funding: A new innovation fund for first-phase and follow-on projects should be established based on the EU Emissions Trading Scheme (EU-ETS) but avoiding the problems of the original, overly prescriptive NER300 fund.

Storage options: As yet, CO_2 storage options have been insufficiently verified or developed. This could be prioritised through R&D and funded by the Horizon 2020 programme.

Transport options: The EU's Projects of Common Interest (PCIs) can play a crucial role in kickstarting and delivering essential CO_2 transport infrastructure.

35 Horizon 2020: An €80 billion research and innovation programme of funding available over seven years (2014 to 2020) aimed at securing Europe's global competitiveness.
36 http://ec.europa.eu/priorities/energy-union/

Scotland and the UK

Natural gas in the energy mix: If UK Government policy continues to support gas-fired power as part of its low-carbon trajectory then CCS deployment will be essential in order to meet future emissions targets.

Demonstrating CCS: The delivery of CCS on gas power will depend on demonstrating the technology. The Peterhead CCS Project could still begin construction if funding is forthcoming, but the decommissioning of North Sea infrastructure means the door is closing on its intended CO_2 storage site – the Goldeneye reservoir.

Strategic planning: Any new gas build will need to fully consider access and proximity to viable CO_2 storage as well as transport networks.

Pipeline development: The Feeder 10 high-pressure gas pipeline, which runs within kilometres of Scotland's main industrial emissions, should be developed as part of the infrastructure needed to enable industrial CCS.

In the zone: The creation of an East Scotland Low Carbon Zone would provide industrial emitters with access to CO_2 transport and storage facilities and create a production hub of high quality and low-carbon products future-proofed against a rising carbon price.

Cross-border collaboration: Scotland should play a key role in encouraging regional cooperation in order to develop CCS clusters, transportation facilities and CO_2 storage assets.

Industrial CCS: The UK Government should develop funding mechanisms for industrial CCS as a top-up to the Carbon Price. The Teesside Collective suggests two approaches (see Industrial CCS clusters, page 21), with subsidies passing up or down the CCS chain.

Facilitating storage: As The Crown Estate's leasing responsibilities devolve to Scotland, they could be used to encourage and enable CCS by facilitating the development of CO_2 storage.

The way forward

THE historic pledge made by 195 nations at the Paris COP21 climate talks, to keep global warming to less than 2°C, will only be as good as the actions countries now take to ensure its delivery. The UK Committee on Climate Change has since described what the agreement means for domestic climate policy, including energy, industry and transport, suggesting that the UK Government must be prepared to do more, not less, in order to reduce carbon emissions.

"Huge potential exists within the UK and Scotland, from an exceptional North Sea CO_2 storage asset to an enviable R&D community with its amassed knowledge."

Stuart Haszeldine, SCCS

Current emissions in the UK must decrease by at least 2% year-on-year from now until 2050. The CCC also notes that more ambitious action on emissions will be needed across the European Union. For that, CCS is essential and an urgent plan is needed for the delivery of clean power and a competitive, decarbonised industrial sector by 2030 and beyond.

This report lays out the potential that exists within the UK and Scotland – from an exceptional North Sea CO_2 storage asset, oil and gas sector infrastructure and workforce expertise to an enviable R&D community with its amassed knowledge, and CCS projects poised to deliver decarbonisation from power and industry – if support from government and investors is forthcoming. This investment of both effort and funding will benefit everyone, now and for the future, and must not be derailed by short-term fiscal decisions.

The UK is uniquely well-positioned to develop and benefit from CCS, but windows of opportunity are closing fast. As North Sea decommissioning proceeds apace, we will lose the infrastructure that can help deliver CCS. We risk a brain drain of expertise to countries where CCS is already being delivered. Project developers will take their enthusiasm elsewhere, while investors will look to other low-carbon opportunities. Additionally, we lose the opportunity for CO_2-EOR in the North Sea, which analysis suggests could deliver a seven times return on national investment while establishing a CO_2 storage network.

In light of recent and unexpected developments for CCS in the UK, there must be a reset of objectives and ambitions to get the industry back on track and capable of delivering deep emissions cuts for industry and power across the UK and the rest of Europe. We recommend a concerted effort by industry, government and academia on the following areas:

A Scottish CO_2 Hub

The development of a Scottish CO_2 Hub can unlock the potential for CCS in the UK and Europe by providing early access, for CO_2 captured in the North Sea region, to extensive and well-characterised storage in the Central North Sea at low financial risk. Such a hub would be uniquely important as the downstream component of a Europe-wide CCS system, supporting collection-and-dispatch hubs envisaged for mainland Europe, Scandinavia and England. By re-using existing on- and offshore transport and storage infrastructure and, potentially, using returns from CO_2 utilisation in CO_2-EOR, a Scottish hub can be created economically and rapidly. In the shorter term, the use of shipping for transporting CO_2 from emitter zones to North Sea storage sites would provide a flexible solution, with low capital investment, for eastern England and Europe. The system could be expanded sequentially, on a project-by-project basis.

Delivering industrial CCS

The UK Government should develop funding mechanisms for industrial CCS to top up the Carbon Price. The Teesside Collective has suggested two approaches, with subsidies passing up or down the CCS chain. The creation of an East Scotland Low Carbon Zone would provide industrial emitters with access to CO_2 transport and storage facilities and create a production hub of high-quality and low-carbon products future-proofed against a rising carbon price.

The existing Feeder 10 high-pressure gas pipeline, which runs within kilometres of Scotland's main industrial emitters, should be developed as part of the infrastructure to enable industrial CCS. This approach would allow for phased expansion of CO_2 flow as import volumes from European and other UK CO_2 clusters become available.

Natural gas in the energy mix

If UK Government policy continues to support gas-fired power as part of its low-carbon trajectory then CCS will be essential to meeting future climate targets. This is especially important as it is unclear whether new nuclear capacity will form a large enough component of power generation from 2025 onwards. It will then become more challenging to make progress on emissions reduction. If gas is expected to deliver a sizeable proportion of electricity demand, existing and future power plants must be genuinely CCS-ready. So the siting of any new gas plant will need to be assessed alongside the viability and cost of pipeline and/or shipping connections to suitable CO_2 storage sites.

The delivery of CCS on gas power will depend on demonstrating the technology, which the Peterhead CCS Project can still deliver if funding is forthcoming. However, the decommissioning of North Sea infrastructure means the door is closing on its intended CO_2 storage site – the Goldeneye reservoir – and available pipeline connections. If, as the government stated last November, the CCS Competition "cannot proceed on its current basis" then alternative financing mechanisms should be designed in its place.

Clarity on cost

A more accurate reflection of the cost of CCS comes about when capture costs are separated from transport and storage costs – this "unbundling" is routinely done for waste from nuclear power or the renting of pipeline for methane distribution. At present, the first CCS projects are expected to bear the cost of infrastructure, despite the fact that follow-on projects would benefit from this development. This is unfair as well as misleading. The true cost of deploying CCS is less than it seems, particularly when any delay is likely to increase the burden on UK taxpayers in the future. Benefits and savings could certainly be maximised by combining gas power, industry and CO_2-EOR along the UK's east coast. And we must never lose sight of the overall prize: a clear pathway to a zero carbon future for Scotland and the rest of the UK as part of international efforts to contain global warming.

Professor Stuart Haszeldine,
SCCS Director

The SCCS Conference wrapped up with a wide-ranging discussion between panellists and delegates.The panel, from left: Stephen Kerr (Summit Power), Emrah Durusut (Element Energy), Bill Spence (Shell) and Luke Warren (CCSA).
Photo: Will Robb Photography

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SCCS is a research partnership of British Geological Survey, Heriot-Watt University, University of Aberdeen, the University of Edinburgh and the University of Strathclyde. Our researchers are engaged in high-level CCS research as well as joint projects with industry with the aim of supporting the development and eventual commercialisation of CCS in the UK andabroad.