Carbon Capture Journal

CCS in the UK

Three scenarios for building a UK CCS sector to 2030

Low Carbon Scotland: Decarbonising industry and energy

Mar / Apr 2015

Issue 44

Catalysing North Sea action: A CCS Future for Europe

- 2015: a defining year for CCS in the EU?
- CCS deployment in the U.S. and Californian regulatory uncertainties
- Microcapsule material for energy-efficient carbon capture
- Effectiveness of geological CO2 storage questioned in two studies

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Front cover: Shell's Goldeneye platform in the North Sea. Up to 10 million tonnes of CO2 from Shell and SSE's Peterhead project in Scotland could be stored in the depleted Goldeneye gas reservoir. North Sea infrastructure would be crucial in developing a UK and European CCS sector (Image: ©Shell)

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Leaders - CCS in the United Kingdom

Projects and policy

Capture and utilisation

Transport and storage

How to build a 10GW CCS Sector in the UK by 2030?

ETI commissioned Element Energy and Pöyry to explore ambitious but deliverable scenarios for building the UK CCS sector to 2030. The aim was to extend previous modelling studies by analysing real geographies and dependencies, plausible potential projects, existing and potential power generation and industrial sources of CO2, realistic decision timelines and project economics. Over a period of six months, and with significant input from many stakeholders, the project has developed three realistic sector scenarios to 2030.

By George Day, Energy Technologies Institute and Emrah Durusut, Element Energy

The potential for CCS

Over the past few years the ETI has emphasised the central importance of CCS to the UK's low carbon transition. Our energy system modelling shows how CCS can save tens of billions of pounds (something like 1% of GDP) from the annual costs of low carbon energy by the 2040s: a huge potential saving by any standards. Apart from its role in power generation, CCS can capture industrial emissions, support low carbon gasification applications and deliver 'negative emissions' in combination with bio-energy.

Our work on the UK's storage resource has shown that we have more than enough geological storage capacity to meet our needs. And our work on CCS infrastructure has shown how we can build a relatively simple but integrated network to transport and store up to 100 million tonnes of CO2 every year[1].

Key conclusions

• Developing a 10 GW scale CCS sector by 2030 is feasible and affordable through a number of different pathways, based on co-ordinated cluster / hub development

• Early phase 2 projects can achieve strike prices at or below £100 per MWh by 2025, with potential further cost reductions by 2030, by making use of the stores and transport infrastructure developed under the commercialisation programme

• A 10 GW scale CCS sector would be affordable in terms of the demand on levy control framework funds (an annual support cost of around £1.1 to £1.3 billion by 2025) and efficient in terms of cost per tonne of CO2 reduction.

• This scale of CCS deployment could capture and store around 50 million tonnes of CO2 emissions per annum from power and industry by 2030, enabling CCS to develop in the 2030s to the optimal scale suggested by longer term analysis of the UK energy system.

• This outcome can be delivered by creating a supportive policy environment with early action on critical issues to bring forward timely investment.

Why do sector scenarios?

Progress in implementing CCS on the ground has been slow, and sceptics continue to suggest that the UK might be better served by waiting for others to develop CCS technology. We wanted to explore how action could be taken 'on the ground', building on the first 2 projects (expected at Peterhead and White Rose) to develop a large scale CCS sector by 2030.

Our modelling of the UK's energy transition points clearly to the importance of achieving large scale deployment of CCS by 2030. Failure to develop CCS will mean the need for very difficult and challenging choices in the late 2020s about infrastructure and other technologies in heat and transport to meet carbon targets. (We explore this in more detail in our recently published insight report 'Targets, technologies, infrastructure and investments – preparing the UK for the energy transition'2).

In the middle of 2014 we decided to do further work to test whether, and how, the UK could build a CCS sector of significant scale (approx. 10 GW) by 2030. Prior to this work our analysis has been based to a large degree on modelling approaches, so the aim has been to explore and understand real world challenges to getting a critical mass of capacity on the ground. To do this we created and explored alternative scenarios for building a 10 GW scale CCS sector by 2030, taking account of real geographies and dependencies, plausible potential projects, existing and potential power generation and industrial sources of CO2, realistic decision timelines and project economics.

ETI employed Element Energy and Poyry to create and analyse the scenarios, in terms of economics, geography and timelines. We also put together a steering group with representatives from the Crown Estate (Ward Goldthorpe), the Carbon Capture and Storage Association (Luke Warren) as well as the expert chair from DECC's Office of Carbon Capture and Storage, Patrick Dixon to critique and challenge the work.

1. ETI evidence submitted to Environment and Climate Change Committee inquiry on CCS;
A picture of CO2 storage in the UK: learnings from the ETI's UKSAP and derived projects;
Optimising the location of CCS in the UK;
Potential for CCS in the UK.

This work is now nearing completion, after a number of iterations and robust steering group meetings, as well as a lively stakeholder workshop in autumn 2014. The process has crystallised important insights and challenges which we are keen to share more broadly, with the full report to be launched later in March.

What did we find?

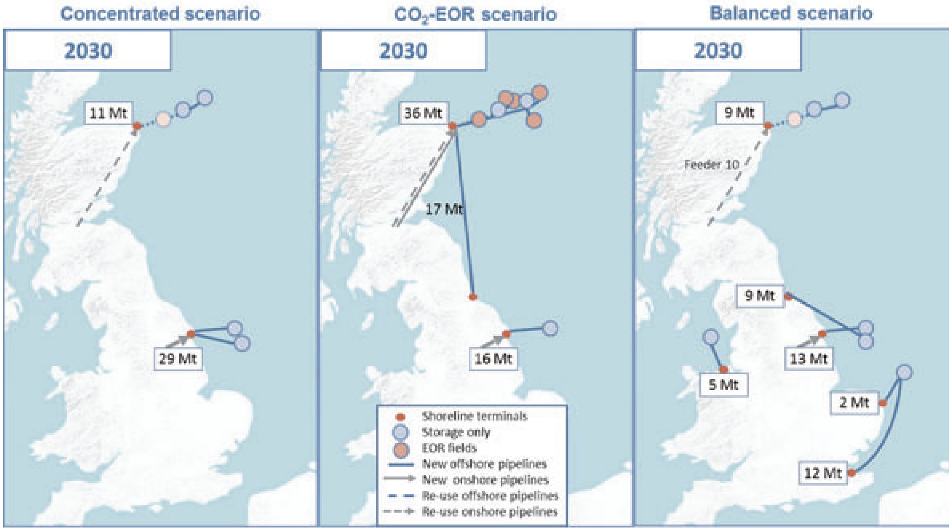
The project has reached some very clear conclusions (see box opposite), most notably that delivering a 10 GW scale CCS sector by 2030 can be done. This conclusion is at the same time comforting and also very challenging: it is comforting that large scale CCS by 2030 remains both 'do-able' despite delays to date, and affordable in terms of support needs via feed in tariffs; but very challenging in terms of the scale of effort and the step change in the rate of progress needed.

A key challenge will be enabling early final investment decisions by around three further ('phase 2') projects before the first two projects (expected at Peterhead and White Rose) are operational.

Why 10 GW?

Enabling CCS to realise its long term potential and play a key role in UK decarbonisation will require developing around 10 GW of capacity by 2030. This level of ambition is consistent with DECC's EMR delivery Plan (which included up to 13 GW of CCS by 2030), and with the Committee on Climate Change's (CCC) scenarios for curbing power sector emissions to 50g CO2/kWh by 2030. Delaying development of this level of capacity beyond 2030 would expose the UK to substantial cost and deployment risks in meeting carbon budgets.

If delay were to permanently stunt the growth of CCS in the UK, then ETI's analysis points to a substantial increase in the economic burden of meeting carbon targets, arising from the need to deploy higher cost technologies to cut emissions, particularly in heat and transport.



CCS sector scenarios

Table: Summary of CCS sector scenarios

Scenario	Costs	Strike prices	Benefits / issues
Concentrated Concentrated around first 2 projects; dominant role for gas CCS with SNS storage.	£14 bn CfD cost to 2030 £2.1 bn per annum in 2030 £22 bn capex spend	Early Phase 2 projects < £100/MWh by 2025 < £90/MWh in 2030 for new gas-fired plants	Fast cost reduction, but limited optionality or deferred costs to 2030s.
EOR-led Wood report-style push; market pull for CO2 for EOR supported by e.g. tax incentives.	£14 bn CfD cost to 2030 £2.2 bn pa in 2030 £27 bn capex	Both coal and gas plants < £90/MWh in 2030 Assumes £20/t CO2 price to EOR	North Sea jobs & revenues Oil & gas production cuts net costs to society. Oil price risk exposure
Balanced Multiple regional clusters, fuels and capture technologies.	£18 bn CfD cost to 2030, £3.2 bn per annum in 2030 £31 bn capex	New coal and gas-fired plants < £100 in 2030 as 3rd gen of plants developed	Greater optionality for 2030s roll out Store & technology diversity = risk reduction

Notes: The Committee on Climate Change (CCC) projections suggest that total annual LCF spend could be around £10 bn per annum by 2030 (CCC projections in Energy prices and bills – impacts of meeting carbon budgets, Dec 2014)

Historical experience suggests that stimulating a robust project development pipeline will be important to deployment and realising cost reductions in practice. So delay in building the sector will increase the risk that CCS fails to deliver a significant contribution to either power sector or broader decarbonisation, in turn creating broader risks of higher costs, heavy reliance on other technologies or failure to meet carbon budgets

A shorter 5 or 10 year delay in developing the CCS sector would still be likely to increase costs and risks across the UK energy system. Containing the cost impacts of a 5 year delay would require both rapid (and risky) 'catch up' development of CCS during the 2030s and accelerated early uptake of a range of other low carbon technologies during the 2020s to fill the gap left by CCS.(e.g. rapid replacement of domestic gas heating).

More realistically, if broad strategy remains focused on early decarbonisation of the power sector, delay to CCS would lead to greater reliance on nuclear and offshore wind. Even with successful unit cost reductions, our modelling suggests this would increase system risk and costs both before and after 2030.

What do the scenarios look like?

The analysis is based on three ambitious but deliverable scenarios for the UK CCS sector to 2030. These scenarios are not predictions or strategies, rather they are tools to identify challenges and actions needed in the context of realistic geographies, dependencies and timelines for decisions and projects.

We are not recommending a particular scenario – indeed the development path that the CCS sector takes in practice could mix elements of all three scenarios presented. However the issues and actions identified through this analysis can inform policy makers and industry participants alike.

The scenarios are summarised in the graphic and table below and show three distinct and plausible pathways to developing a circa 10 GW capacity CCS sector by 2030.

So what do we need to do to deliver 10 GW by 2030?

It's clear that delivering 10 GW of CCS capacity on the ground by 2030 will be enormously challenging and that significant steps will be needed to bring forward the volume of investment needed. In practice a host of complexities will need to be addressed – many of which are no doubt being addressed by DECC and the developers of the commercialisation programme projects.

However, beyond this the scenarios show we will need a robust pipeline of projects, with a supportive environment for large scale investment. Based on the scenario analysis the box summarises the top 4 requirements.

Four key requirements to build the CCS sector

1. Both Commercialisation Programme projects are needed - to develop vital transport and storage infrastructure which unlock later unit cost reductions and strategic build out options. Failure to open up two CCS hubs would constrain options and increase risks of failure later.

2. Early investment is needed to appraise and expand the promising 5/42 and Captain aquifer stores and appraise further sites. The long lead times for developing storage sites, and the need for clarity to underpin investment decisions, means that immediate investment to expand capacity is needed. This could be either tax payer funded or by strengthening incentives for private investment.

3. Enable early investment decisions by phase 2 projects by awarding a further 3 appropriately designed CfDs by 2020. All three scenarios depend on enabling at least three early 'phase 2' projects to reach FID by 2020, in effect requiring the award of three further power sector CfDs ahead of commissioning of the Commercialisation Programme projects.

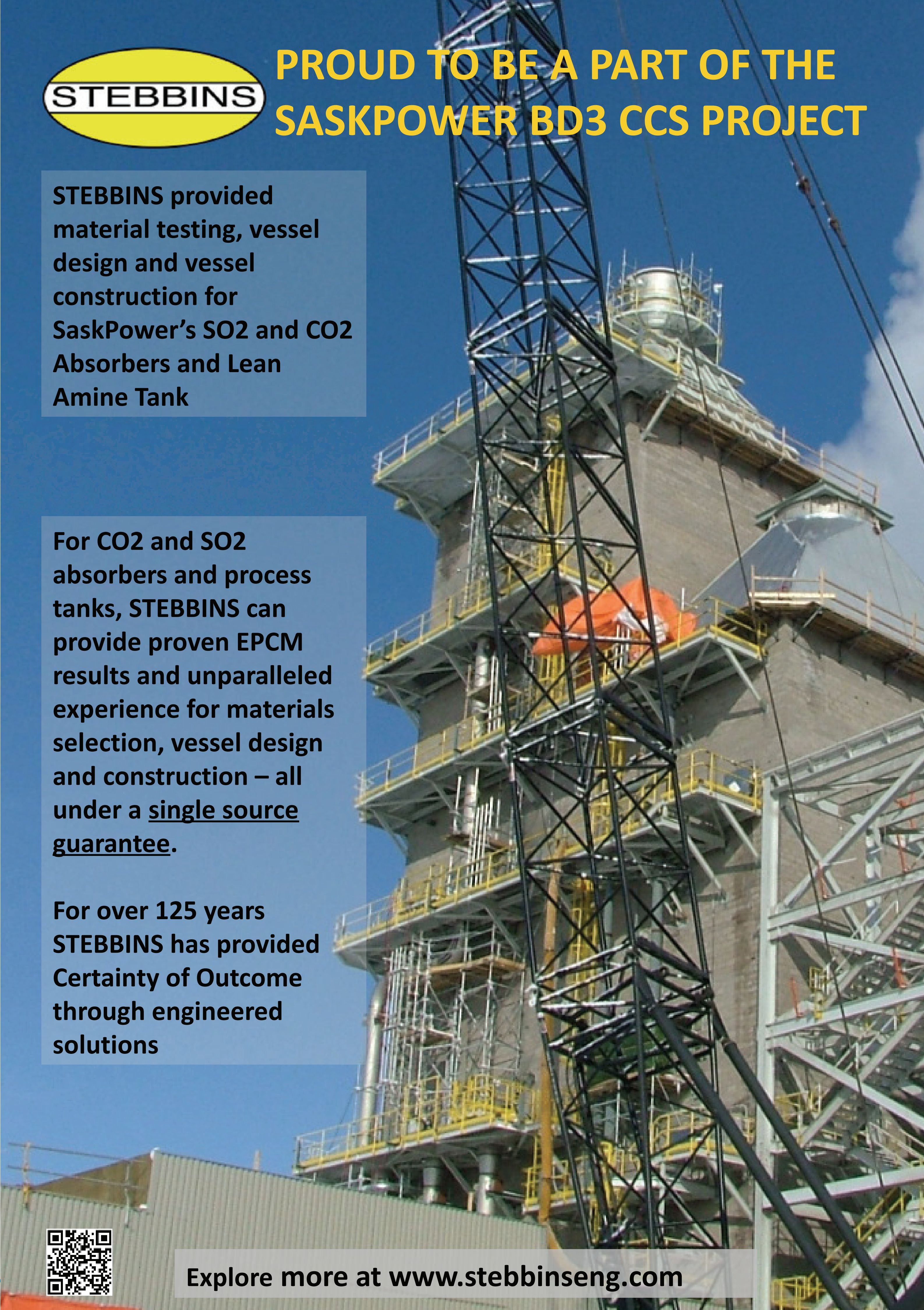
4. Stimulate a robust project development pipeline by delivering clear signals to investors and project developers about the scale and strength of policy (levy control framework support) commitment to developing CCS:

More information

The final report of this project will be published on the ETI website in March, including detailed descriptions of the scenarios, timelines for capture and storage development, CO2 flows, investment requirements, strike prices, T&S costs and CfD costs in each scenario.

Anyone interested in this project is welcome to contact Emrah Durusut (emrah.durusut@element-energy.co.uk) or George Day (george.day@eti.co.uk).

For details of all the ETI's CCS projects, visit **www.eti.co.uk**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Low Carbon Scotland: The role of CCS to decarbonise industry and energy

CCS has a key role to play for both industrial and power emissions reductions and Scotland is well placed to establish CCS infrastructure to enable the development of low carbon industry.

By Sam Gomersall, Ideas Spark: Pale Blue Dot Energy

It is well understood that a key part of the process of CO2 emissions reductions is to decarbonise industrial emissions, in addition to reducing emissions from thermal power generation. CCS has a key role to play and Scotland is well placed to establish CCS infrastructure and create new opportunities from hydrogen as an energy intermediary. These would complement and balance the drive for other renewables and deliver the vision of a Low Carbon Scotland.

Regional context

There is huge opportunity for Scotland to promote and develop CCS. Stimulating CCS on industrial emissions is fundamental to retaining and attracting high carbon industry, critical to employment and wealth creation. Decarbonsing thermal power generation is essential to meet carbon emissions reduction targets.

The UK Continental Shelf, offshore North East Scotland, offers an internationally significant location for CO2 storage in terms of potential storage capacity and the number of potential storage sites (Ref 1). In addition significant potential exists for Enhanced Oil Recovery (EOR), which has the potential to support the further evolution of infrastructure for CCS and create new CO2 storage options.

86% of Scotland's CO2 energy & industrial emissions come from electricity generation, refineries / gas processing and chemical plants, representing point sources from which CO2 could be captured to reduce atmospheric emissions. 88% of Scotland's energy and industrial emissions are within 20km of existing pipeline infrastructure which could export CO2 for storage deep below the North Sea (Ref 2).

The Scottish regional emphasis is intended to support and complement other regional UK CCS initiatives such as Teesside and Yorkshire whilst developing aspects which are specific to Scotland.

Forth Valley emissions cluster

The Forth Valley in Central Scotland represents the largest concentration of emissions in Scotland, with 59% of Scotland's energy and industrial emissions in this area. These include Longannet coal fired power station and Ineos refinery / chemical plants at Grangemouth.

The possible future Captain Clean Energy Project, a coal based power station with CCS, may be built at Grangemouth, with CO2 export via an existing pipeline, 'Feeder 10', to St Fergus in NE Scotland. Additional emissions in Fife, Tayside and Aberdeenshire are within a short distance of 'Feeder 10', providing a considerable opportunity for emissions reductions. The corridor includes the Shell/SSE Peterhead CCS project, with potential to be the first CCS project in the UK and the first demonstration of CCS on gas.

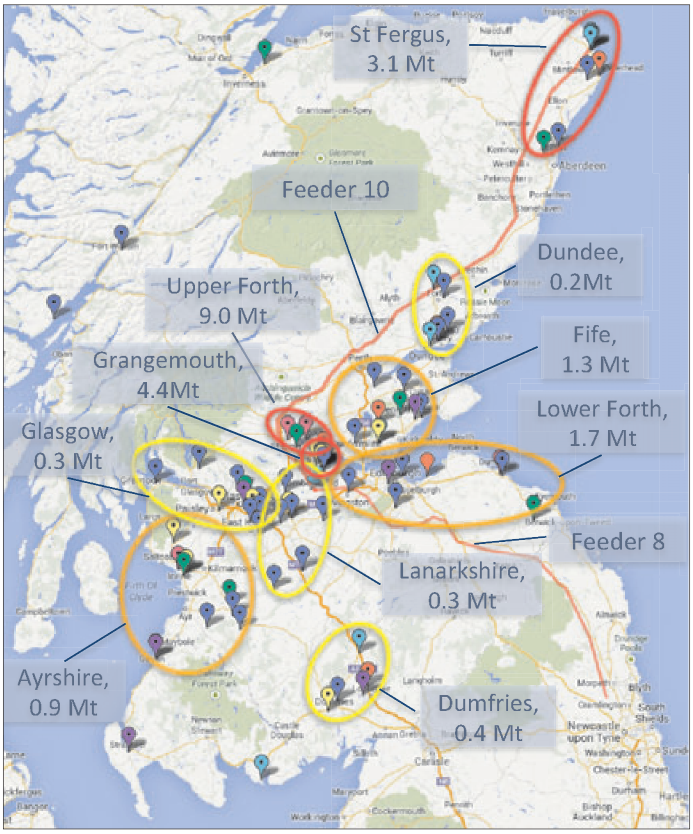


Figure 1 - Schematic of Feeder 10 route connecting Central Scotland to St Fergus showing major CO2 (Source: Scottish Carbon Capture and Storage, 'Industrial CO2 Source Clusters in Scotland')

Feeder 10

Scotland has the potential to significantly decarbonise its energy and industrial facilities by creating a CCS hub in the upper Forth Valley and converting the existing pipeline, Feeder 10, to CO2 service, creating a low carbon energy corridor across Scotland. Feeder 10 is one of four existing pipelines carrying natural gas from St Fergus on the North East coast down to Central Scotland (Figure 1).

As N Sea gas production has declined, there is surplus capacity in the four feeders. In 2010 National Grid completed a Front End Engineering Design (FEED) into the conversion of Feeder 10 to enable CO2 transport from Central Scotland to St Fergus. The design study demonstrated that the pipeline was suitable for CO2 transport. The use of the existing pipeline provides the opportunity to significantly reduce infrastructure cost and accelerate availability.

Offshore from St Fergus a number of existing subsea pipelines also exist some of which are no longer in use for hydrocarbon production and can be converted into CO2 service. Central Scotland is already connected to suitable offshore storage sites by existing pipelines which are available for use.

Hydrogen

Hydrogen, created from a variety of low carbon means, provides the way to balance thermal and renewable power generation and opens up a new vector in the energy mix. Surplus renewables can be used to generate hydrogen, which can be subsequently converted back to electricity by fuel cells or gas turbines. Potential exists to generate Hydrogen or Synthetic Natural Gas (SNG) by gasifying coal.

This is a proven technology used to generate town gas in the time before natural gas was used in the UK. If applied now, it would include CCS, in order to avoid CO2 emissions. CCS therefore opens up the potential for hydrogen or SNG from coal, which could be introduced to the gas grid as an alternative to natural gas, with a lower carbon footprint and enhanced energy security benefits.

In this way the potential exists for linking the electricity network with the gas grid by generating hydrogen from surplus renewables and using the storage and transport capacity of the gas grid to balance renewable electrical generation, as a critical part of the energy transition (Figure 2).

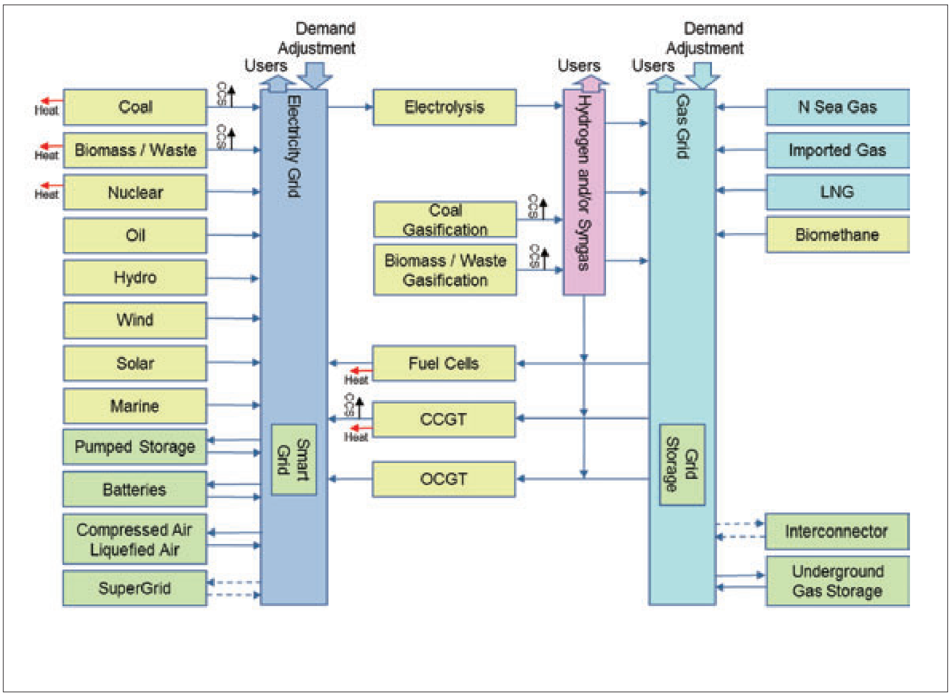


Figure 2 - Schematic showing a future energy system with hydrogen intermediary and connected gas and electricity grids

Opportunities

Further work is now required to develop implementation plans to convert Feeder 10, creating an early regional CO2 infrastructure and to ensure industrial emitters are aware of the opportunity this creates. Current gas grid specification limits on Hydrogen limit the amount that can be injected in the UK, but just as in other countries, this needs to be evaluated and adjusted.

Commercial mechanisms to encourage CCS on industrial emissions and stimulate energy storage projects need to be developed, building on work already ongoing in Teesside. Collaborative institutions and associations, such as the SCCS, The Scottish Hydrogen and Fuel Cell Association and the CCSA, should be encouraged to push forward the opportunities and broaden the debate.

As a result of existing pipeline infrastructure and CO2 storage potential there is an early opportunity for Scotland to progress industrial emissions reduction and lead the energy transition.

References

1. Opportunities for CO2 Storage around Scotland SCCS April 2009

2. Industrial CO2 Source Clusters in Scotland, SCCS August 2013

More information

Sam Gomersall is Ideas Spark at Pale Blue Dot Energy, corporate development advisors in the energy business, with a specialist capability in CCS

www.pale-blu.com

Catalysing North Sea action: A CCS Future for Europe

Europe and particularly the North Sea nations should aim to develop CCS clusters by the mid 2020s through co-ordinated action to deliver economies of scale and secure long-term investor interest.

By Davey Fitch and Philippa Parmiter, Scottish Carbon Capture and Storage

Framing the options: strategic planning

In October 2014, the European Council agreed EU climate and energy targets and measures for the period 2021 to 2030, including at least a 40% reduction in EU domestic greenhouse gas emissions by 2030, relative to 1990 levels, with reductions in sectors that fall both within and outside the EU Emissions Trading System (ETS).

Under the EU2030 framework, Member States will need to develop national plans for decarbonisation. It is very likely that many will need to include CCS, in particular for industrial sources, in (or even prior to) the 2030s. This will require a high degree of regional and national planning for shared infrastructure and storage – and this planning needs to start now.

However, leaked drafts of the EU Commission's thinking on the new 'Energy Union' agenda emerged in February 2015, which relegate CCS to a topic for 'research interest' rather than 'infrastructure deployment'.

There are active projects outside the EU, demonstrating CCS components and full chain systems: Boundary Dam in Canada began operating in October 2014, and both the Kemper County and Petra Nova Carbon Capture Projects in the USA are due to start up in 2016. There is a real danger that Europe will be left behind when it comes to CCS development just as other regions of the world begin to make real progress. That would be catastrophic for Europe's recently agreed objectives on climate and energy out to 2030, as a milestone on the route to a decarbonised economy by 2050.

We must not forget that 2030 efforts aren't even the end goal – Europe has already committed to achieving overall reductions of CO2 of 80-95% by 2050. Even beyond 2050, it is accepted that CCS will prove significantly cheaper than Renewable Energy Systems as a means of achieving significant emissions cuts.

The 10 Recommendations

- Rapidly deliver a renewed New Entrants Reserve financing instrument (NER400) of the EU's Emissions Trading System to support new industrial and power generation CCS projects
- Support the creation of CO2 transport and storage infrastructure through the EU's Projects of Common Interest, including pipeline construction and CO_2 shipping
- Create capture-to-storage CCS cluster plans for Europe's industrial regions
- Provide specific funding, through the EU or Member States, to construct regional carbon capture clusters
- Reward CO_2 transport and storage with clear pricing mechanisms
- Undertake analyses to identify tariff incentive mechanisms for CCS
- Develop a CO_2-Enhanced Oil Recovery plan for the North Sea
- Encourage the research community to take lead on defining future research and development (R&D) needs for cost reduction with strategic industry input
- Ensure R&D priorities are informed by industry needs, with feedback from demonstration projects being developed worldwide
- Support existing CCS networks and bodies and their work to exchange information between industry and academia; government and regulators; and financiers and insurers

Addressing Energy Union

The application of CCS is the only way that continued use can be made of domestic European fossil fuel resources into the medium term and enable energy security in Europe while meeting emission reduction targets. Additionally, when used in combination with sustainably-sourced bioenergy, CCS has the potential to achieve a net removal of CO2 from the atmosphere with existing technology.

It is important to remember that renewable energy alone cannot clean up crucial heavy industrial emitters like cement and steel works, where CO2 is a by-product of the manufacturing processes. However, these industries will continue to be vital for the European economy for many decades to come and, indeed, supply materials essential for transition to low-carbon energy systems.

The EU-ETS has proven inadequate to secure investment in CCS projects. There is a pressing need to create a financial support mechanism to incentivise CCS in power generation by rewarding low-carbon electricity output. To date, only the UK has proposed a CCS-targeted reward in the form of the CfD feed-in tariff.

Industrial emitters currently have no business case for considering CCS. The EU-ETS is insufficient to provide incentive, and allocations to sectors at risk of carbon leakage lead to no action.

Overall, the European Commission believes that CCS is an essential part of the EU's future low carbon electricity system. It encourages Member States with high-carbon sectors to support CCS development actions." - Ilinca Balan, European Commission

The five dimensions of the Energy Union seek to deliver an integrated, secure, sustainable, accessible and affordable energy system for Europe, and we would argue that this needs to include a meaningful contribution from CCS. So how are we to progress from the current impasse, and deliver on the ambition of Energy Union with CCS at its heart?

The building blocks of a North Sea network

Delegate discussions at last October's Scottish Carbon Capture and Storage (SCCS) Conference led to a report with ten principal recommendations, released in January 2015, and available in full from the SCCS website.

The Business Case

During the Conference the following points were discussed around CCS in low-carbon electricity markets:

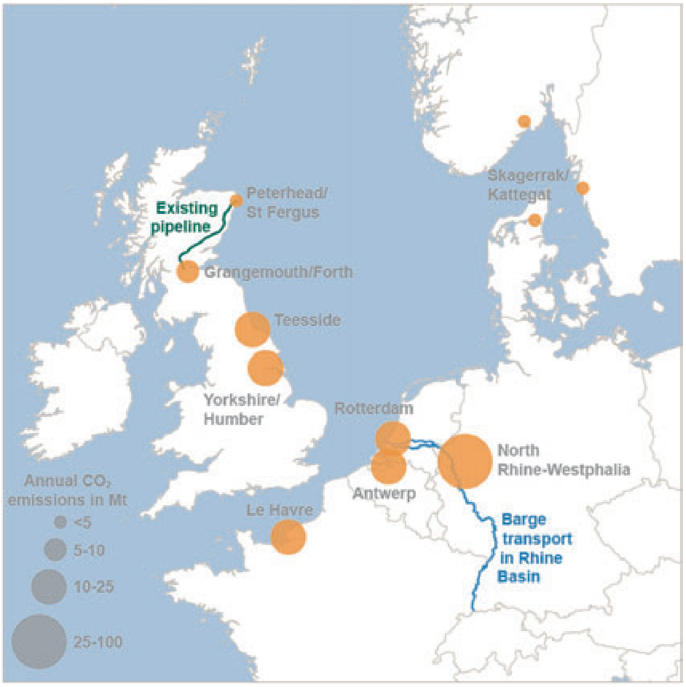
• The UK CfD is a "crucial test case that the world is watching". The value of the CfD in passing finance down-chain to develop transport and storage for additional projects must be emphasised.

• Electricity markets are being forced to change so there is value in examining how measures, such as Emissions Performance Standard or "clean" capacity markets that reward negative emissions could enable innovative entries to the market.

• A level playing field should not mean the same price for all electricity – different generation types (baseload, flexibility, using price-secure resources) have different values that must be recognised, and CCS generation is likely high value.

• The correct incentive model for CCS on power generation could attract significant investment from the financial sector, as CCS projects will be long-operating and free from risks of changes to climate policy.

However, for industrial CCS (ICCS) there are as yet few incentives and no business case. Delegates discussed opportunities and measures for encouraging ICCS, including:



Existing studies of clusters around the North Sea. Source: SCCS

• The need to secure government finance for technology demonstration projects – e.g. could a specified industrial category be part of the NER400 mechanism?

• The need to explore sectorial agreements on decarbonisation rather than waiting for a "one-fits-all" carbon price.

• Growing pressure from some end-users of industrial chemicals to reduce their lifecycle emissions; this could provide useful policy focus.

• Strategic pre-investment in CO2 transport and storage to reduce risks and costs, and allow high concentration and closely clustered industrial emissions to be gathered efficiently.

• The capture of industrial emissions as a route to provide a stable supply for CO2-EOR, as an alternative to sourcing from the power sector where demand variations could interrupt supply.

In the oil and gas sector in the North Sea both CO2 storage and CO2-EOR represent significant opportunities for the industry, but they need a specific focus:

• Incentives to delay decommissioning of offshore assets should be examined; these assets are potentially valuable for storage and EOR.

• Aggregating sufficient CO2 (at least 3-5 Mtpa for 10-20 years) to enable EOR is best achieved through using early CCS projects to seed clusters. Clusters of sources can also address issues of securing stable CO2 supply.

• Funding for transport and storage could be obtained from an earmarked percentage of tax receipts from new licences.

• The EU Commission should examine how a certificate model – requiring storage of a percentage of CO2 by fossil fuel producers – might operate.

Planning for industrial clusters and full-chain networks

The clustering of CO_2 emitters within a geographical area provides an unparalleled opportunity to share the cost of CCS development and infrastructure, and a shared route to North Sea storage. There have been several studies of CCS for emission clusters, as well as analyses of CO2 transport networks and North Sea storage, and there are a handful of European projects seeking to develop the cluster approach.

A mechanism is needed that controls pricing of, and access to, transport and storage infrastructure so that emitters and investors have a clear view of costs, including for third-party use. In addition, there should be a system for trading capacity in transport and storage infrastructure. Visible commodity price forecasts, including carbon price risks, are also recommended.

Industry needs to see that a transparent and fair pricing mechanism will exist, one that can adapt to changing demand for capacity as new partners adopt CCS or as industrial rationalisation occurs. Investors need visibility of risks and to know that they are managed appropriately.

> "When the EC set out 2030 climate and energy proposals it also made recommendations on reindustrialising Europe – with heavy emphasis on regional clusters and innovation policies. A concerted attempt to join these two objectives is a key way to build regional clusters, grassroots support and industrial-public sector cooperation for CCS." - Jude Kirton-Darling, MEP

Stuart Haszeldine OBE, Professor of Carbon Capture and Storage, University of Edinburgh, speaks at the conference which led to the SCCS report, "A CCS future for Europe: catalysing North Sea action"

Two of the recommendations advocate developing plans for the North Sea and Europe: a North Sea CO2-EOR framework plan and a CCS cluster plan for Europe.

An EOR framework should cover location, capacity and timing of potential CO2-EOR demand linked to a CCS cluster plan, which includes an acknowledgement of issues of global competitiveness and proposals for how these will be addressed. Any cluster plan should also refer to CCS cluster models already developed, for example, for Le Havre, Rotterdam and proposals under development for Teesside.

The publication of such a framework plan will give visibility of CO2 demand to emission clusters considering CCS development, allowing transport networks to be developed in a co-ordinated fashion. It will also act as an incentive for major oil company engagement by showing the potential to delay decommissioning costs and gain additional revenue from EOR. This will attract financial investment to fund infrastructure at the cluster and network levels.

The Commission should set out a clear expectation that Member States will prioritise development of CCS through capture at emission clusters with associated transport and storage networks as a way of achieving CO2 emission reduction targets within the EU 2030 framework. Specific funds should be made available for identification and development of appropriate clusters and projects.

European vision could lead to the development of regional, national and EU-wide integrated plans for CCS infrastructure development.

Driving Progress

One thing is very clear – the immediacy of the issues. Most of the actions proposed need to start now, we cannot park this for five to ten years.

Nobody is claiming that the type of co-ordinated action necessary to develop a meaningful CCS industry in Europe will be easy to achieve. However, this is precisely what Europe should strive towards to safeguard the sustainable future spelt out in the goals of Energy Union.

It should be noted that similar coordinated actions undertaken by the US Department of Energy to support CO2 storage pilots, CO2 pipeline infrastructures and CCS demonstration projects now enables CCS to form an important component of the US federal governments decarbonisation strategy.

The value of CCS cannot be underestimated: no other technology provides such significant decarbonisation options for power (secure, on-demand, concentrated, negative emissions) and industry (guarantees climate-proof future). The immediate priority is to secure final investment decisions on current demonstration project proposals in the North Sea region. With sufficient support, they could rapidly secure the linking-in of additional projects. Without this, Europe will again lose momentum and struggle to realise CCS deployment on the timescale required.

Europe's ambition, particularly the North Sea nations, should be to realise the first CCS clusters in the mid-2020s – delivering economies of scale; the potential for CO2-EOR to deliver returns on investment and augment domestic energy resources; and, crucially, to secure investor interest in the long-term.

Europe must grasp hold of CCS as a means of enabling a sustainable and competitive European economy while delivering on the continent's deep decarbonisation objectives.

More information

The full report, "A CCS future for Europe: catalysing North Sea action" can be downloaded free from:

www.sccs.org.uk

2015: a defining year for CCS in the EU?

Although Europe has struggled to find its way on carbon capture and storage in recent years, political will is greater now than it has been for some time and the private sector is ready to take up the challenge, says Theo Mitchell, Policy Manager, The Carbon Capture and Storage Association.

In the realm of policy development, Member States – with the exception of the UK and a few others – have failed to champion CCS demonstration and deployment. The European Commission had expected twelve large CCS plants to be working now, but, as we all know, we are yet to have one.

In a further blow, the much-anticipated NER300 programme managed only to award funding to one project, in what should have been the centrepiece of European CCS efforts.

But despite the frequent setbacks and a shroud of negativity, CCS remains essential to meeting carbon reduction targets. As the IPCC recently reminded us in its Fifth Assessment Report, the cost of decarbonising our global economy without CCS could be 138% more expensive than if we utilise CCS.

In its own Impact Assessment accompanying the EU2030 Communication, the Commission showed that by 2050 CCS could account for up to 15% of the EU's electricity generation. Depending on capacity factors, this could mean somewhere in the order of 170 GW of CCS installed in the power sector alone before we even consider its application to energy intensive industries.

So far the compelling case for CCS has not yielded the necessary response. In the UK alone more than £300 million has spent by Government and industry on developing projects but we still don't have an operating project. Despite this, optimism is slowly mounting in this fragile sector, and there is a growing sense amongst stakeholders that 2015 could be a defining year for CCS.

Movement in Europe

In the past, CCS has sometimes struggled to cement its place in the energy and climate discussion in Europe, but as the EU continues to transition on a number of fronts, five factors are coming together and opening up a number of opportunities for the CCS case to be revisited: the evolving EU 2030 energy and climate policy framework; the ubiquitous-but-not-yet-fully-articulated Energy Union concept; the all-encompassing CCS Directive review; a new batch of Commissioners and MEPs; and, of course, the on-going discussions on reform of the EU ETS.

European Council Conclusions

The European Council's 40% reduction target for greenhouse gas emissions under the EU 2030 framework is to be welcomed. It has been interpreted by industry as a move towards a more technology-neutral framework which recognises the importance of CCS – alongside renewables and energy efficiency – in delivering a secure future energy mix for Europe.

In another crucial development, CCS benefited from its first mention in the Conclusions for six years, as part of the creation of a new industrial innovation facility, NER400. The explicit inclusion of CCS within the context of the new NER Programme is an important step in making sure that the European power sector and energy intensive industries get the support they need to drive costs down and make the technology commercially viable.

Such support will provide a strong and long-awaited investment signal to industry but the Commission must first look at the successes and failures of the NER300 programme and ensure that lessons are learnt. For NER400 this means more flexibility, a longer-term feature, less ETS price risk, and a better balance between different technologies awarded funding. Avoiding a large funding gap between now and the monetisation of funds will also be key.

Energy Union

Creating a European Energy Union is one of President Juncker's key political priorities in seeking to deliver an integrated, secure, sustainable, accessible and affordable energy system for Europe.

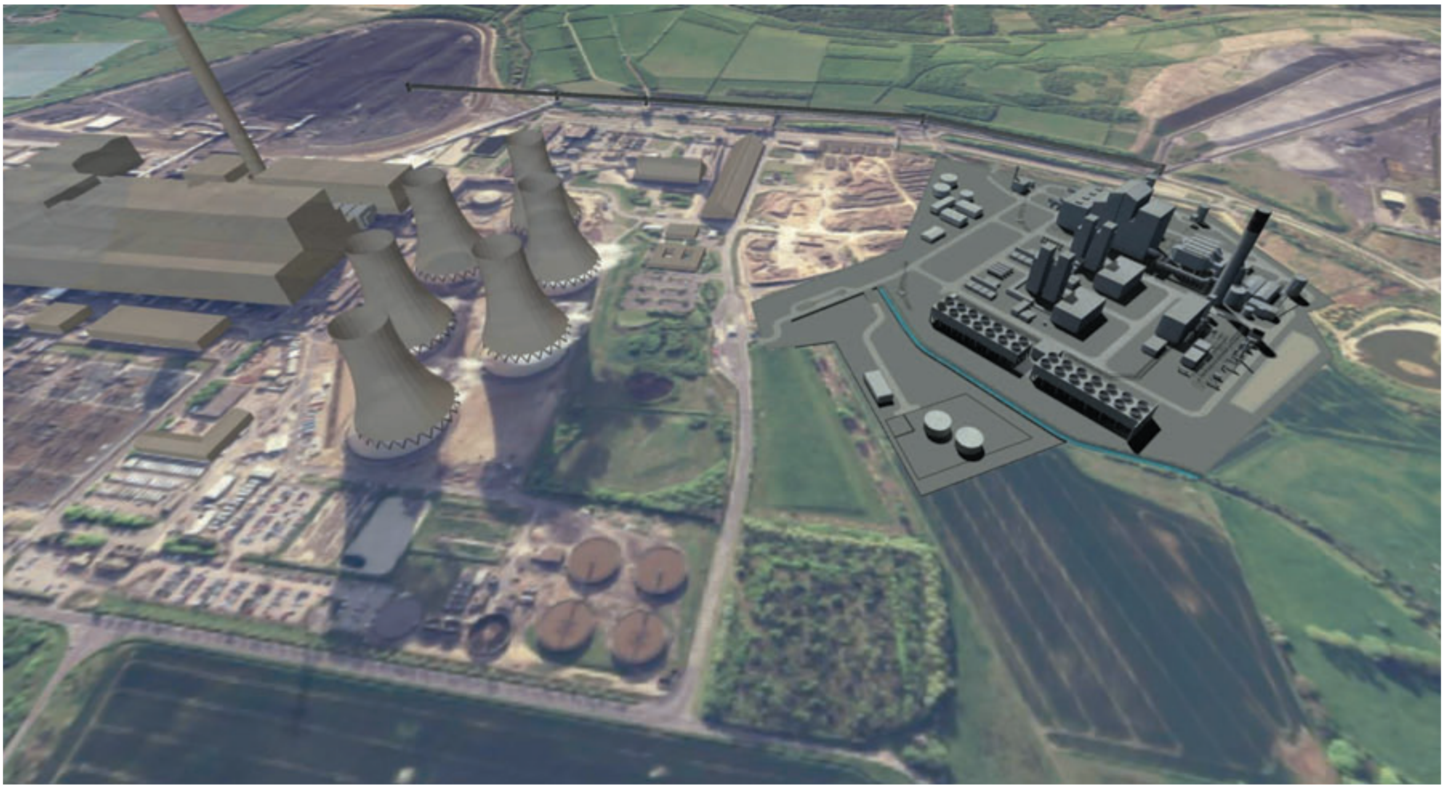
The envisaged Energy Union strategy will be structured around five mutually-reinforcing and closely interrelated pillars: security of supply, the internal energy market, energy efficiency, decarbonisation and research & investment. Although the Energy Union appears to mean different things to different people, undoubtedly, decarbonisation is a strong driving factor and should place CCS front and centre in meeting the new objectives.

CCS Directive Evaluation

Last year saw the Commission appoint consultants to evaluate the 2009 'CCS Directive' with a Final Report published in January 2015. Following a very successful and inclusive evidence gathering process, the consultants released a series of recommendations targeted at both the Commission and Member States alongside their Final Report. Conclusion: CCS remains essential to Europe's energy and industrial future and we must collectively do more to kick-start its deployment.

The consultants re-affirm the urgent need for Europe to deploy CCS, they call on Member States to look to 2050 in their energy systems analysis and, most importantly, they recommend that the Commission develops an EU-level CCS Roadmap or Strategy to support investment and deployment. Both of these are very welcome developments.

The Commission is now due to report on the Evaluation by 31st March 2015 in line with its legal obligation under the original text of the Directive. It remains uncertain which recommendations the Commission will choose to take forward but the industry view is clear: keep the Directive as it is and instead develop a supporting policy framework guided by an EU-level CCS Strategy.



The White Rose Project (right of image), developed by Capture Power, a joint venture set up by Alstom, Drax and BOC, and located on land adjacent to the existing Drax Power Station, near Selby in North Yorkshire, was the only CCS project awarded funding in the EU NER300 Second Funding Round

Institutional turnover

The incoming cohort of Commissioners and supportive MEP's has undeniably contributed to a new sense of optimism surrounding CCS in Brussels. A series of recent public statements indicate that the Commission appears to have firmly grasped the need for CCS.

Climate Action and Energy Commissioner, Miguel Arias Cañete, has recently committed to steering the implementation of key energy infrastructure projects, and the effective and efficient use of EU funding to support investments in low-carbon technologies, such as CCS. In his European Parliament hearing, Vice President for the Energy Union, Maroš Šefčovič, also emphasised the importance of CCS in ensuring that Member States meet ambitious GHG targets.

EU ETS reform

This January marks the 10th anniversary of the EU Emissions Trading System. Despite issues along the way, it has stayed with us and continues to be the bedrock of the EU policy framework in managing our carbon dioxide emissions. Few would argue that reform is not needed - the collapse in the carbon price has reduced the scale of public funding available and fundamentally undermined the medium-term business case for investment in CCS.

The various reforms being considered now offer vital redress, ranging from tackling the demand-supply imbalance as early as possible, preventing backloaded allowances from re-entering the market, disallowing the use of international offsets after 2020 and introducing full auctioning in industrial sectors post 2020.

Whatever Phase IV of the ETS ultimately looks like, it's clear that reform will secure a strong low carbon investment signal, which will undoubtedly strengthen the business case for CCS.

Final thoughts

The CCS experience in Europe shows us that timing, political will, and financing all need to come together in order to really kick-start the sector in the EU. The task for the Commission, the Parliament, European Council and Member States in 2015 is to scale-up activity on CCS so that it can be deployed at the necessary scale and at the necessary time; thereby achieving cost reductions and contributing to significant carbon dioxide reductions.

Slowly but surely, decision makers at European and national level seem to be getting it: CCS is essential. The real question therefore lies in how we integrate this realisation into our future policy framework.

Although the 'how' remains unclear, on-going discussions on climate and energy policy seem to provide the perfect platform for doing so. The opportunity is there, the political will is greater now than it has been for some time and the private sector is ready to take up the challenge.

More information

The Carbon Capture & Storage Association (CCSA) represents the interests of its members in promoting the business of capture and geological storage of carbon dioxide.

www.ccsassociation.org

ETS Reform – Where are we now?

The first two trading periods of the European Union's Emission Trading System (EU ETS) were marked by a low and volatile carbon price, which failed to incentivise investment in low-carbon technologies and sufficient cuts in CO2 emissions.

By Bellona Europa

With the aim of curing the Emission Unit Allowance (EUA) price, the European Commission (EC) submitted a reform proposal, the so-called Market Stability Reserve. Bellona views the EU ETS as a key instrument to attain the EU's climate change objectives cost-effectively and therefore calls for its comprehensive structural reform to ensure it sends a strong price signal to investors and places us on the right track to attaining a low-carbon economy.

The EC has proposed a reform in the form of a Market Stability Reserve (MSR) to be introduced as of 2021. The MSR aims to address the problem of a persistently low EUA price by adjusting the amount of allowances circulating in the system, according to pre-determined thresholds, in order to protect the EU ETS from economic fluctuations and reduce the surplus of allowances that has built up over the past years.

In its brief entitled Comprehensive ETS Reform Bellona underlines a number of design weaknesses of the envisaged MSR and expresses strong doubts over the mechanism's ability to stabilise the EUAs price. Bellona questions the very central assumption of the MSR – that a temporary reduction of the allowance surplus would raise the EUA price, due to it being in contradiction to standard economic theory and the concept of inter-temporal price smoothing. In other words, because in the long-term, temporarily removed allowances will be returned to market auctions, the overall impact on the EUA price would be minor and so will the impact of investment in low-carbon technologies.

European Parliament has its say

Discussions on the draft proposal have been ongoing in the European Parliament's Committees on the Environment, Public Health and Food Safety (ENVI) and on Industry, Research and Energy (ITRE). The amendments made by both committees indicate a significant majority in favor of an earlier start date than 2021, as initially proposed by the EC. The Council's position, which was drafted by the Latvian Presidency, however, is more ambiguous reflecting the diverging views of the EU Member States.

On the fate of backloaded allowances (those allowances that were taken out of the market a year ago), EU Member States want to bring these right back into the MSR, 'warning' that releasing them back into the market would "undermine the aim of the reserve to tackle structural supply-demand imbalances" in the ETS. These backloaded allowances do not however, face a choice of being released into the market OR brought into the MSR, they can also remain backloaded and alltogether out of the market – as they should! The latest draft compromise proposal for the position of the ITRE Committee, on the other hand, does not support placing the backloaded allowances directly into the reserve.

> Bellona is strongly concerned about these uncertainties and subsequently doubts the ability of the MSR to cure the EUAs price and ensure a well-functioning ETS

Bellona regards an earlier start date of the MSR reform and keeping backloaded allowances out of the market as crucial measures to ensure the stabilisation of the EUA price at a level, sufficiently high, to stimulate low-carbon investments and emission reductions.

Low-carbon funds and EPS

What is more, there are various amendments suggesting the use of revenues from auctioned allowances to fund low-carbon technologies, such as Carbon Capture and Storage (CCS), as well as the introduction of an Emissions Performance Standard (EPS). MEP Gunnar Hökmark of the European People's Party for instance suggested an amendment stating that "Member States should invest more in research and development of energy efficiency, CO2 reductions and carbon capture and storage as well as new generations of power production including wind, water and solar power as well as hydro energy and nuclear power. The revenues from auctions of allowances should contribute to this".

Moreover, MEPs Seb Dance, Theresa Griffin and Paul Brannen of the Socialists and Democrats Group tabled an amendment suggesting that "A stronger carbon price signal is necessary to avoid locking the EU into high carbon capital and investment. Therefore, by 31 December 2015, the Commission shall also consider whether the establishment of an EU wide Emissions Performance Standard for the power sector is necessary to support an adequate price signal to incentivise low carbon investment and where appropriate the Commission shall make a proposal to the European Parliament and to the Council for the establishment of such an EU – wide Emissions Performance Standard."

Bellona is a strong advocate for the establishment of an EU-wide EPS for CO2 from power plants and sees it as an important measure to prevent lock-in to the worst-polluting infrastructures and a catalyst for CCS deployment.

And on CCS, on which Bellona has worked for 20 years, Director at Bellona Europa Jonas Helseth argues: "CCS is indispensable in any future climate mitigation strategy."

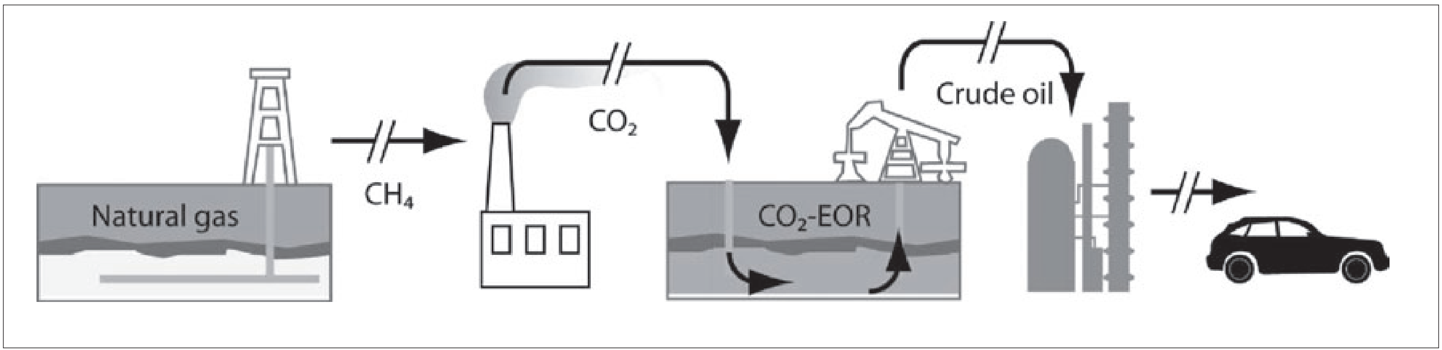
More information

Read Bellona's brief on Comprehensive ETS reform:

bellona.org/assets/sites/6/Bellona_brief_ETS.pdf

California needs to resolve regulatory uncertainties surrounding CCS

A California Council on Science and Technology paper, "Electricity from Natural Gas with CO2 Capture for Enhanced Oil Recovery" finds that regulatory uncertainties are a barrier to CCS deployment.



Components of the NG-CCS-EOR system analyzed in the paper: the natural gas supply; the CO2 supply; crude oil production via CO2-EOR; and crude oil refining

CCS is potentially important for advancing California's energy future and climate goals, but deploying the technique depends in part on resolving regulatory uncertainties, according to the latest paper in CCST's California's Energy Future - Policy series.

"Almost all solutions developed by the California's Energy Future project to meet 80% reductions in emissions by 2050 require CCS in some manner," said CCST Council Member Jane C.S. Long, Former Principal Associate Director at Large, Global Security Directorate Fellow, Center for Global Security Research Lawrence Livermore National Laboratory. "CCST commissioned this white paper to inform the discussion of how to include CCUS in the portfolio of climate options in California."

The paper tracks the carbon for projects which capture CO2 from gas-fired power plants and sells this CO2 into an enhanced oil recovery market (known as carbon capture "utilization" and storage, or CCUS). Several companies have proposed CCUS projects in California where the economics can be improved by using captured CO2 for CO2-EOR.

While many of the component technologies required for such projects are available, significant risks remain, and innovation is required to effectively integrate the technologies, organizations, and industries that comprise CCS-EOR. In theory, California's climate policies could stimulate such CCUS deployments (within a broader technology portfolio) to advance key climate policy objectives; however, the treatment of these systems under existing regulations is not yet sufficiently well resolved.

Resolving the regulatory uncertainties surrounding CCUS is important because, if successful, early CCUS projects could open the door to several potentially important low-carbon energy systems for California, such as:

- Burning biomass to make electricity and sequestering the CO2 to yield net negative emissions;

- Reforming methane to make hydrogen fuel and sequestering the resulting 2;

- Applying methods to directly capture CO2 from the air and either sequestering the CO2 or utilizing it to produce low-carbon fuels;

- Providing dispatchable low-carbon electricity

The paper addresses these regulatory uncertainties and provides a concrete basis for ongoing policy discussions by evaluating greenhouse gas emissions from a hypothetical CCUS deployment according to a plain reading of the California cap-and-trade program and the California Low Carbon Fuel Standard.

CCST's California's Energy Future - Policy (CEF-P) project is intended to help explore a policy framework that will enable the best energy technology deployment decisions for the state of California. It was initiated following the completion of the California's Energy Future project, which provided detailed analyses of the potential of different energy technologies to reduce California's emissions by 2050; the CEF-P papers focus exclusively on the implications of these technology analyses for policy.

"CCUS has been identified first as a way to develop CCS in California, but the analysis in this report indicates that significant carbon reductions are afforded by CCUS as a system," said Long. "Testing out this technology in the state would allow policy makers to understand how much they can count on sequestration and how to regulate it."

CCUS can provide large reductions in aggregate CO2 emissions and in petroleum fuel carbon intensity.

Emission accounting conforming with the CA-C&T program indicates that NG-CCS-EOR could reduce aggregate emissions from electricity generation and petroleum fuel use (including oil recovery, refining, and combustion) by roughly 40%. This reduction is computed relative to a baseline consisting of California average emissions from electricity generation and crude production and simplifying assumptions for oil refining fuel combustion emissions. This result appears to be reasonable, as the configuration modeled here effectively cuts power plant emissions by 90% from a baseline portfolio in which roughly half of emissions originate at the power plant.

Credit allocation represents a key uncertainty in the treatment of CCUS under the CA-C&T.

The current regulatory language is clear about emissions accounting for individual "covered entities"; however, CCUS requires a complex arrangement between different industries. The NG-CCS-EOR configuration modeled here includes at least four separate "covered entities": the natural gas supplier; the power plant; the crude oil producer; and the refinery. The regulation is not clear how CO2 sequestered via enhanced oil recovery should be allocated among these various entities. In theory, policy incentives should reflect physical carbon flows, reward entities responsible for achieving emissions reductions, and support efficient reporting and enforcement. It is not obvious how these goals can best be achieved in CCUS projects. This reflects the distribution of responsibilities, costs, and carbon flows among CCUS project participants (e.g., power plants capture CO2 and oil-field operators ensure its long-term sequestration).

The treatment of CI reductions from CCUS under the CA-LCFS is uncertain.

CCUS can provide large reductions in fuel CI, as noted above; however, the treatment of these reductions under the CA-LCFS depends on how and to what extent the CI benefits of CCS-EOR are recognized under the regulation. For the purpose of this analysis we assume that CCS-EOR will qualify under the regulation's "innovative methods" provisions. This is because systems like NG-CCS- EOR appear to meet a plain reading of the current regulatory requirements for these provisions: they use CO2 capture and storage; they have never been deployed before; they require innovation in technology, business, and industry integration; and they can reduce crude oil CI by more than 1 gCO2e/MJ. CCS-EOR also meets the spirit of these provisions—it provides new methods of producing crude oil that can substantially reduce the lifecycle carbon intensity of petroleum fuels.

Policy design considerations for allocating emissions benefits under the C&T program

Policy design considerations	Policy Scenario (Covered entity recognizing C&T benefit of sequestered CO2)		
	CO2 producer	**Oil producer**	**Refinery**
Reflects physical carbon flows?	Yes Reflects atmospheric emissions from the power plant.	Yes Reflects injection of CO2 into geologic formations for sequestration.	Partially Reflects that fuel carbon in crude is balanced by CO2 sequestered during production (analogous to biofuel treatment).
Aligns incentive with CO2 capture investments?	Yes	No	No
Aligns incentive with CO2 sequestration and measurement, monitoring, & reporting obligations?	No	Yes	Partially Aligns incentive with oil production, which corresponds with MRVs more closely than initial injection.
Enables consolidated reporting and enforcement under C&T and LCFS?	No	Maybe Depends on implementation of proposed amendments.	Maybe Depends on implementation of proposed amendments.

C&T and LCFS-type regulations can each incentivize CCUS and thereby advance the public interest.

The NG-CCS-EOR configuration analyzed here yields large reductions in both total emissions and in transportation fuel CI, and deployment would consequently involve installing CO2 capture, building CO2 pipeline infrastructure, and exercising MRV protocols. This is consistent with conclusions from prior analyses that identify CCUS as a potentially important step for advancing climate policy objectives.

Several high level policy questions were also identified through this analysis that warrant further consideration.

Some have recently argued that CI reductions from CCS-EOR should not be recognized or incentivized under LCFS-type policies. Emissions reductions in NG-CCS-EOR and related CCUS configurations may be viewed as occurring primarily in the electric sector, and it may therefore be inappropriate to incentivize such reductions with regulations targeting transportation fuels. There may also be concern that LCFS credits from CCS-EOR could overwhelm nascent LCFS credit markets and reduce incentives for other low carbon fuels. It has also been suggested that CO2-EOR is not itself innovative, as CO2 floods are routinely used for oil production outside California, and that it may therefore be inappropriate to include CCS- EOR under "innovative methods" provisions of the CA-LCFS.

More information

CCST is a nonpartisan, impartial, not-for-profit corporation which provide sobjective advice from California's best scientists and research institutions on policy issues involving science.

www.ccst.us

U.S. National Coal Council study on CCS deployment

The NCC study looks at speeding deployment of CCUS at commercial scale and offers recommendations to U.S. Secretary of Energy Ernest Moniz on how to advance the deployment of CCS/CCUS at commercial scale.

In response to a request by Secretary of Energy Ernest Moniz, the study, entitled "Fossil Forward – Revitalizing CCS: Bringing Scale & Speed to CCS Deployment," provides an industry assessment of the progress made by DOE and others regarding the cost, safety and technical operation of carbon capture utilization and storage (CCS/CCUS).

NCC Chair, Jeff Wallace (Vice President Fuel Services, Southern Company) noted that "In order to meet U.S. economic, energy and environmental goals, power generators are being called upon to enhance the environmental performance of fossil fueled power plants. For coal, that enhanced environmental performance requires the application of CCS/CCUS technology. NCC's Fossil Forward study addresses critical RD&D and investment needs that must be addressed to advance CCS/CCUS technologies."

Discussing the value and timeliness of the NCC study, NCC Coal Policy Committee Chair, Fred Palmer (Senior Vice President Government Affairs, Peabody Energy) commented on the valuable role coal plays in power generation and economic development both globally and in the U.S. "Cities cannot be built without coal. Increasing demand for electricity cannot be met without coal. Energy poverty cannot be eliminated without coal. CCS is the only large scale technology that can mitigate CO2 emissions from fossil fuel use for electricity generation and key industrial sectors."

In presenting the study to the membership at the January 29th meeting, NCC Study Chair, Amy Ericson (US Country President, ALSTOM) summarized the key findings and recommendations by noting that while DOE is indisputably a world leader in the development of CCS technology, the DOE CCS/CCUS program has not yet achieved critical mass. "While there have been some successes, there is a need for a substantial increase in the number of large-scale demonstration projects for both capture and storage technologies before either system approaches commercialization."

Key Recommendations

In order to achieve CCS deployment at commercial scale, policy parity for CCS with other low carbon technologies and options is required.

- Policy parity for CCS in funding, extending tax credits and other subsidies provided to renewable energy sources, will facilitate creation of a robust CCS industry in the U.S., benefiting the American people and leading to the development of the lowest cost, near zero emission energy technology. Such technology would be available for electric generation as well as all fossil fuel dependent industrial applications. The NCC recommends that DOE take a stronger position on the need for policy parity with respect to funding allocations.

Technology and funding incentives must be significantly better coordinated to be effective.

- The NCC recommends that DOE develop a plan to have a total of 5–10 GW of CCS/CCUS demonstration projects in operation in the U.S. by 2025.

- The NCC recommends that all federal incentives provided by the DOE and other federal agencies for CCS demonstration projects undergo a coordinated review for their combined adequacy and effectiveness in supporting CCS deployment. If necessary, combinations of incentives or new incentives could be utilized to achieve the desired level of demonstration projects. Examples of such incentives include feed in tariffs, tax credits, production credits, loan guarantees, and "contracts for differences". This coordinated review needs to be completed in time to achieve the installation of 5–10 GW of CCS demonstration projects by 2025.

- The NCC recommends that DOE expand its Regional Carbon Sequestration Partnership (RCSP) program to identify and certify at least one reservoir in each region that is capable of storing a minimum of 100 million tons of CO2 at a cost of less than $10/ton by 2025.

DOE program goals need far greater clarity and alignment with commercial technology and financing approaches used by industry.

- The NCC recommends that DOE and industry convene a task force to clearly define the role and objectives of individual projects in achieving broad program goals. The aim is to better understand industry technology goals and needs and to understand industry criteria for investment in CCS technologies throughout the entire development pipeline. Prioritization of projects is critical to achieving overall goals with limited budgets, consistent with the need to bring CCS technologies up to Technology Readiness Level 9 (TRL-9).

Funding for CCS RD&D is limited and must be enhanced and focused.

- The NCC recommends that DOE continue its strategy of fostering a portfolio of technologies for implementing CCS. It is important to maintain DOE's approach of "priming the pump" with early stage funding for promising concepts, but in recognition of budgetary constraints and the need to move more quickly in getting larger scale CCS projects operating, the NCC recommends that after technologies reach TRL 4, DOE cull its support to only those technologies which show a clear promise of meeting or exceeding DOE's CCS performance goals.

- The NCC recommends that DOE develop a plan for demonstrating second generation and transformational CCS technologies at a scale of 25–50 MW by 2020 and make subsequent budget requests to Congress to carry out the plan. However, these demonstrations should only move forward for technologies which have a clear advantage in cost and performance compared to first generation CCS technologies.

Public acceptance continues to be a major hurdle.

- The NCC recommends that DOE accelerate its current efforts in CCS/CCUS public engagement, education, and training activities. Outreach efforts should target counties and states with demonstration projects and regions that have potential infrastructure developments (e.g., CO2 pipelines and storage sites). Training activity should build workforce capacity across the CCS/CCUS chain and build U.S. leadership and knowhow to meet potential national and international demand.

Control of GHG emissions is an international issue in need of international initiatives.

- The NCC recommends that DOE maintain its existing CCS/CCUS international collaboration efforts including the Carbon Sequestration Leadership Forum (CSLF) and the U.S.-China Clean Energy Research Center (CERC).

- International partnerships in commerce should also be pursued. The NCC recommends that the DOE explore ways to foster CCS/CCUS demonstrations in developing nations which are rapidly increasing their CO2 emissions, such as China and India. In particular, conducting CO2 utilization and storage projects using CO2 from new and existing coal gasification projects in these countries, could be a low cost.

More information

The NCC provides advice and guidance on a continuing basis as requested by the Secretary of Energy on general policy matters relating to coal.

www.nationalcoalcouncil.org

Boundary Dam C02Degrees education awards

Students around the world taking part in the Institute-led CO2Degrees education program are getting ready for a special awards ceremony soon to commence on March 5th, 2014 in the Canadian Province of Saskatchewan, Canada. By Kirsty Anderson, Global CCS Institute

Late last year, the world's first carbon capture and storage (CCS) facility on a coal-fired power plant began operating at the Boundary Dam power station in Estevan, Saskatchewan.

Aside from the impressive technical feat of commissioning the low-carbon power plant, a great deal of community engagement work was undertaken. Boundary Dam's operator, SaskPower, teamed up with the Institute to provide interactive education sessions with local schools in the Province culminating in the SaskPower CCS Challenge.

About the Saskpower CCS Challenge

In September 2014, 100 Grade 7 students attended the SaskPower CCS Workshop where they learned about carbon dioxide (CO2), capturing CO2, and the storage or use of CO2. The workshop took place the same week as the grand opening of Boundary Dam's CCS plant. During the workshop, a two-tiered CCS Challenge was launched challenging students and groups to: create a video about the Boundary Dam project and its significance for Saskatchewan and the rest of the world, produce a video submission that creatively explained CCS and its role in sustainability.

Creating international education

The Regina students took inspiration from the fun and creative videos featuring international students that filmed experiment demonstrations to help teach students at the SaskPower CCS Workshop.

SaskPower's Boundary Dam power station

Showcasing the results

The Challenge was created by the Regina Catholic School Division with support from SaskPower. Each Challenge submission has been assessed for its: accuracy, creativity, originality, quality or effort and message and comprehension of 'big ideas'.

On the 5th March 2015, awards will be delivered to the winning students and award winning videos will be showcased on CO2degrees.com as part of the CO2Degrees Education Challenge.

More information

The article was originally published as an Insight on the Global CCS Institute website.

www.globalccsinstitute.com

Projects and policy news

DOE focusses on CCS with $560 million

energy.gov

In 2016, U.S. Fossil Energy Research and Development will continue to focus on carbon capture and storage and activities that increase the performance, efficiency, and availability of systems integrated with CCS.

The President's Financial Year 2016 budget requests $560 million for the fossil energy research and development (FER&D) portfolio. FE leads Federal research, development, and demonstration efforts on advanced carbon capture and storage (CCS) technologies to facilitate achievement of the President's climate goals. FE also conducts R&D related to prudent and sustainable development of our unconventional domestic resources.

CCS Demonstrations

FER&D manages the Clean Coal Power Initiative program along with two American Recovery and Reinvestment Act CCS demonstration programs: FutureGen 2.0 and the Industrial Carbon Capture and Storage program under the CCS Demos program.

Carbon Capture & Storage and Power Systems

The CCS and Power Systems program conducts research to reduce carbon emissions by improving the performance and efficiency of CCS technologies and of fossil energy systems integrated with CCS. The FY 2016 budget request for the program is $369.4 million. It also includes $34 million for NETL staff to conduct in-house fossil energy R&D.

Carbon Capture

The President's FY 2016 budget requests $116.6 million for carbon capture R&D. The Carbon Capture activity is focused on the development of post-combustion and pre-combustion CO_2 capture and compression technologies for new and existing coal and natural gas-fired power plants and industrial sources. Post-combustion CO_2 capture technology R&D is focused on capturing CO_2 from flue gas after the fuel has been consumed/combusted. Pre-combustion CO_2 capture is applicable to systems that capture and separate the CO_2 from mixed gas streams prior to combustion or utilization of the gas. The FY 2016 Budget Request funds a new emphasis on optimizing carbon capture on natural gas systems, funds ongoing projects, and proceeds to larger scale pilot tests of technologies on both coal and natural gas. These efforts will support the program's commitment to deliver a demonstration project that captures and stores >75 percent of the carbon emissions from a natural gas power system of at least 50 MWe capacity by 2020 using what has been determined to be the best available carbon capture technology available for demonstration at the time.

Carbon Storage

President's FY 2016 budget requests $108.8 million for carbon storage R&D. The overall goal of the Carbon Storage Program is to develop and validate technologies to ensure safe and permanent geologic storage of captured CO_2. Development and validation of these technologies is critical to ensure stakeholders have the capability to assess, monitor and mitigate storage risks for CO_2, and ensure the viability of carbon storage as an effective technology solution that can be implemented on a large-scale to mitigate carbon emissions.

Advanced Energy Systems (AES)

The President's FY 2016 budget requests $39.4 million for advanced energy systems R&D. The AES mission is to increase the availability and efficiency of fossil energy systems integrated with CO_2 capture, while maintaining the highest environmental standards at the lowest cost. The program elements focus on oxy-combustion, advanced turbines, gasification, and solid oxide fuel cells.

Cross-cutting Research

The President's FY 2016 budget requests $51.2 million for crosscutting research. The Program serves as a bridge between basic and applied research by targeting concepts that offer the potential for transformational breakthroughs and step change benefits in the way energy systems are designed, constructed, and operated. In addition, the Cross-cutting Research Program leads efforts that support University-based energy research including science and engineering education at minority colleges and universities.

Supercritical Carbon Dioxide Technology

The Supercritical Carbon Dioxide Technology's (sCO_2) $19.3 million request supports the Department's sCO_2 crosscut which is focused on technology development for supercritical carbon dioxide-based power conversion cycles. These cycles can be applied to most heat sources, including fossil, nuclear, solar and geothermal applications, while offering significant improvements in efficiency, cost, footprint, and water use. FER&D's ultimate goal is a directly-fired supercritical CO_2 fuel cycle which could also significantly reduce the costs of carbon capture and storage. The major thrusts of the crosscut are a coordinated R&D effort in high temperature technology development/component validation, and the Supercritical Transformational Electric Power Generation (STEP) initiative to design, construct and operate a 10MW pilot test bed.

FutureGen suspended after funding withdrawn

futuregenalliance.org

The U.S. Department of Energy has suspended the FutureGen clean-coal project in western Illinois because it could not meet a spending deadline.

DOE spokesman Bill Gibbons told The Associated Press the department concluded the project couldn't meet a September deadline to use its $1 billion in federal stimulus funding. Without the federal funding there isn't enough money to finish the $1.65 billion project.

Peabody Energy, a founding member of the FutureGen Alliance, called on the Obama Administration to reverse its decision to suspend development funding for FutureGen 2.0.

"It makes no sense to pull the plug on $1 billion committed to America's signature near-zero emissions power project at such a critical time for these investments in technology," said Peabody Energy Chairman and Chief Executive Officer Gregory H. Boyce. "The Administration has pledged $1 billion for advanced coal projects in China, and I urge them to support investments in the United States. We have the knowledge to advance low-carbon technologies to commercial scale and must demonstrate our leadership and our will."

EURELECTRIC calls on EU to push ahead with CCS

www.eurelectric.org

EURELECTRIC, the EU electricity trade body, has urged EU policymakers to push ahead with CCS demonstration as part of Europe's decarbonisation strategy.

Given the economic circumstances, EURELECTRIC said, CCS technology will take longer to commercialise than initially hoped, but it remains convinced that, along with other low carbon technologies and energy efficiency, CCS has an important part to play in meeting Europe's climate goals.

CCS is a key enabler of a carbon-neutral power sector. Moreover, without CCS, the cost of decarbonising the EU economy and the power sector will be far higher. This is a particular concern at a time of increasing global competition and worries about the competitiveness of the European economy. CCS can also play a major role in maintaining a diversified and secure energy mix.

In this context, EURELECTRIC welcomes the 2030 framework which provides an opportunity for a more technology neutral and cost-efficient approach than the 2020 framework. Construction of large-scale demonstration of CCS in Europe should be a priority within the EU's broader energy policy framework, as should strengthening the EU Emissions Trading System to provide a longer term incentive for CCS deployment in the EU.

To reflect and reinforce the European electricity industry's commitment to CCS, EURELECTRIC is establishing a CCS task force. This dedicated expert group will act as the power industry's voice on CCS towards policymakers and regulators and will look at the necessary policy measures to ensure that this important technology can be commercialised in Europe.

CCS vision for UK Tees Valley launched

www.teesvalleyunlimited.gov.uk

Major energy intensive industrial plants located in Teesside in the UK Tees Valley have set out their vision of transforming the area into Europe's first CCS equipped industrial zone.

Amec Foster Wheeler plc, Societe Générale and Pale Blue Dot have been appointed to support the development of this work. Amec Foster Wheeler has been undertaking engineering design and cost estimating for this project. Societe Générale will provide expert advice to ensure that the project is financially viable and competitive. Pale Blue Dot is providing expert CCS project development advice and building the business case.

Work is ongoing, but initial findings indicate the project is feasible. Retrofitting carbon capture technology to the four anchor projects' different industrial processes - steel, ammonia, hydrogen and polyethylene terephthalate production – is operationally and technically feasible. Teesside is also assessed as being well located for the transportation of the carbon to permanent storage facilities under the Central or Southern North Sea.

Tees Valley Unlimited, the Local Enterprise Partnership, has been awarded £1 million funding by the UK Department of Energy and Climate Change to develop a business case for deploying industrial CCS in the Teesside cluster and to make recommendations for a funding mechanism. This will be complete by summer 2015.

At a launch event in the House of Commons, the cluster of leading North East employers introduced their project name – Teesside Collective – and outlined the initial positive findings of engineering work undertaken by Amec Foster Wheeler.

Four energy intensive Teesside firms are involved as 'anchor projects' – BOC, Lotte Chemical UK, SSI UK and GrowHow – all of whom face stiff competition internationally and the prospect of escalating carbon permit prices in the future. National Grid, Tees Valley Unlimited (the Local Enterprise Partnership) and NEPIC (North East Process Industry Cluster) are also on the project's steering group.

UK member joins International CCS Test Centre Network

ukccsrc.ac.uk

The UK CCS Research Centre's PACT Facilities have joined the CC Test Centre Network founded by TCM Mongstad.

The Pilot-scale Advanced Capture Technology (PACT) Facilities form part of the UK Carbon Capture and Storage Research Centre (UKCCSRC) and is jointly funded by the UK Department of Energy and Climate Change (DECC) and the Engineering and Physical Sciences Research Council (EPSRC).

The purpose of PACT is to support and catalyse industrial and academic R&D, by providing open-access testing facilities. This helps accelerate the development and commercialisation of technologies for carbon capture and clean power generation. The PACT facilities bring together a comprehensive range of integrated pilot-scale and accompanying specialist research and analytical facilities, supported by leading academic expertise.

PACT bridges the gap between bench-scale R&D and large-scale industrial pilot trials, enabling users to develop and demonstrate their technologies to provide the necessary commercial confidence before committing to the significant costs of large-scale trails.

PACT's core facility – which includes a 1 tonne a day carbon capture plant – is operated and managed by the University of Sheffield, with satellite facilities at the Universities of Cranfield, Edinburgh and Nottingham; and additional expertise at Imperial College and the University of Leeds. The core and satellite facilities work alongside complementary facilities at partner universities to form the equipment pool, while partner universities also provide relevant academic input and research to form the overall expertise pool within PACT. The PACT national facilities are open access and available for use by any organisation who wishes to undertake CCS research.

The International Test Centre Network was initiated by TCM in 2012 to enable carbon capture test facilities around the world to progress the technologies that will be a key component of our clean energy future. The network aims to share knowledge that can accelerate technology commercialisation, including, for example, next-generation technologies that can sharply reduce the costs of electricity generation (and industrial products) using CO2 capture.

Other members of the Network are :

- CO2 Technology Centre Mongstad – test facility at Mongstad, Norway
- E.ON – test facility at Wilhelmshaven, Germany
- SaskPower – test facility at Shand, Saskatchewan, Canada
- Southern Company/National Carbon Capture Center – test facility at Wilsonville, Alabama, *USA*

Microcapsule material for carbon capture developed

A team of researchers has developed a novel class of materials that could enable a safer, cheaper, and more energy-efficient process for carbon capture.

www.seas.harvard.edu

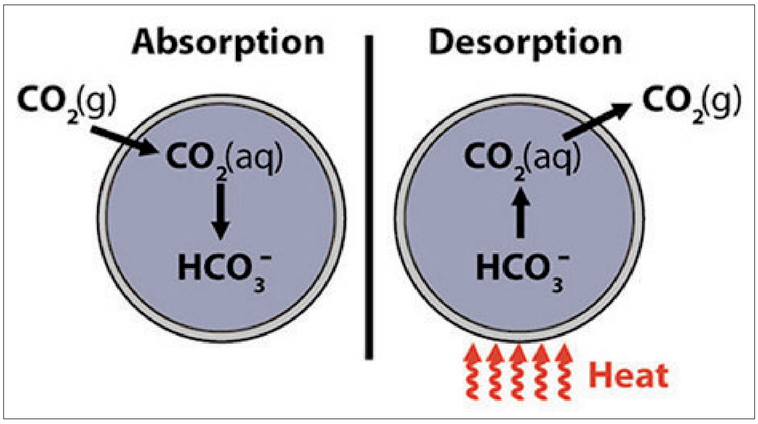
Led by scientists from Harvard University and Lawrence Livermore National Laboratory, the research employed a microfluidic assembly technique to produce microcapsules that contain liquid sorbents encased in highly permeable polymer shells. They have significant performance advantages over the carbon-absorbing materials used in current capture and sequestration technology, the research found.

The work is described in a paper published online in the journal Nature Communications.

"Microcapsules have been used in a variety of applications — for example, in pharmaceuticals, food flavoring, cosmetics, and agriculture — for controlled delivery and release, but this is one of the first demonstrations of this approach for controlled capture," said Jennifer A. Lewis, the Hansjörg Wyss Professor of Biologically Inspired Engineering at the Harvard School of Engineering and Applied Sciences (SEAS) and a co-lead author.

Current carbon-capture technology uses caustic amine-based solvents to separate CO2 from the flue gas escaping a facility's smokestacks. But these processes are expensive, result in a significant reduction in a power plant's output, and yield toxic byproducts. The new technique employs an abundant and environmentally benign sorbent: sodium carbonate, which is kitchen-grade baking soda. The microencapsulated carbon sorbents (MECS) achieve an order-of-magnitude increase in CO2 absorption rates compared to sorbents currently used in carbon capture. Another advantage is that amines break down over time, while carbonates have a virtually limitless shelf life.

"MECS provide a new way to capture carbon with fewer environmental issues," said Roger D. Aines, leader of the fuel cycle innovations program at Lawrence Livermore National Laboratory and a co-lead author. "Capturing the world's carbon emissions is a huge job. We need technology that can be applied to many kinds of carbon dioxide sources, with the public's full confidence in the safety and sustainability."



This schematic illustration shows the encapsulated liquid carbon capture process in which carbon dioxide (CO2) gas diffuses through a highly permeable silicone shell and is absorbed by a liquid carbonate core. The polymer microcapsules are then heated to release absorbed CO2 for subsequent collection.

Researchers at Lawrence Livermore and the U.S. Department of Energy's National Energy Technology Lab are now working on enhancements to the capture process to bring the technology to scale.

Aines says that the MECS-based approach could also be tailored to industrial processes like steel and cement production, which are significant greenhouse gas sources.

"These permeable silicone beads could be a 'sliced-bread' breakthrough for CO2capture — efficient, easy-to-handle, minimal waste, and cheap to make," said Stuart Haszeldine, a professor of carbon capture and storage at the University of Edinburgh, who was not involved in the research. "Durable, safe, and secure capsules containing solvents tailored to diverse applications can place CO2capture … firmly onto the cost-reduction pathway."

MECS are produced using a double-capillary device in which the flow rates of three fluids — a carbonate solution combined with a catalyst for enhanced CO2absorption, a photocurable silicone that forms the capsule shell, and an aqueous solution — can be independently controlled.

"Encapsulation allows you to combine the advantages of solid-capture media and liquid-capture media in the same platform," said Lewis. "It is also quite flexible, in that both the core and shell chemistries can be independently modified and optimized."

"This innovative gas separation platform provides large surface areas while eliminating a number of operational issues, including corrosion, evaporative losses, and fouling," said Ah-Hyung (Alissa) Park, the chair in applied climate science and associate professor of Earth and environmental engineering at Columbia University, who was not involved in the research.

Funding for the encapsulated liquid carbonates work was provided by the Innovative Materials and Processes for Advanced Carbon Capture Technology program of the U.S. Department of Energy's Advanced Research Projects Agency–Energy.

Other authors who contributed to the "Nature Communications" article include: James O. Hardin IV of Harvard; John Vericella, Sarah Baker, Joshuah Beeler-Stolaroff, Eric Duoss, James Lewicki, William Floyd, Carlos Valdez, William Smith, Joe Satcher Jr., William Bourcier and Christopher Spadaccini, all of Lawrence Livermore; and Elizabeth Glogowski of the University of Illinois at Urbana-Champaign.

Asphalt could provide CO2 capture for gas wells

The best material to capture carbon dioxide from natural gas wells may be a derivative of asphalt, according to Rice University scientists.

Rice University chemist James Tour has discovered a compound that could be made cheaply in a few steps from asphalt, the black, petroleum-based substance primarily used to build roads. The research appears in the American Chemical Society journal Applied Materials and Interfaces.

The best version of several made by the Tour lab is a powder that holds 114 percent of its weight in carbon dioxide at room temperature while letting the desired methane natural gas flow through.

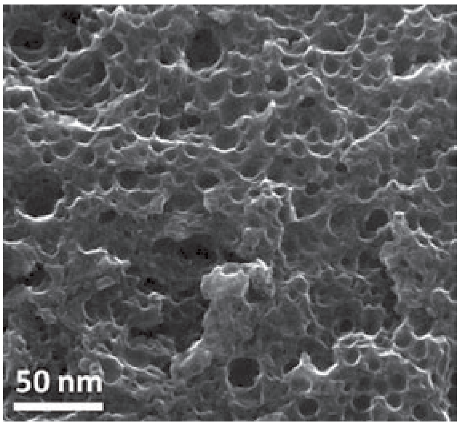
The basic compound known as asphalt-porous carbon (A-PC) captures carbon dioxide as it leaves a wellhead under pressure supplied by the rising gas itself (about 30 atmospheres, or 30 times atmospheric pressure at sea level). When the pressure is relieved, A-PC spontaneously releases the carbon dioxide, which can be piped off to storage, pumped back downhole or repurposed for such uses as enhanced oil recovery.

“This provides an ultra-inexpensive route to a high-value material for the capture of carbon dioxide from natural gas streams,” Tour said. “Not only did we increase its capacity, we lowered the price substantially,” he said they tried many grades of asphalt, some costing as little as 30 cents per pound.

Tour’s goal is to simplify the process of capturing carbon from wellheads at sea, where there’s limited room for bulky equipment. The ability of A-PC to capture and release carbon over many cycles without degrading makes it practical, he said.

The paper’s lead authors, postdoctoral associate Almaz Jalilov and graduate student Gedeng Ruan, and their Rice colleagues made A-PC by mixing asphalt with potassium hydroxide at high temperature; they turned it into a porous carbon with a lot of surface area: 2,780 square meters per gram. That material captured 93 percent of its weight in carbon dioxide. Further experiments showed processing A-PC with ammonia and then hydrogen increased its capacity to 114 percent.

Tour said the lab is continuing to tweak the material but noted that it’s already better for carbon capture than other materials in current use. Amine-based materials now used by industrial facilities like power plants to absorb carbon dioxide are expensive and corrosive and can only capture about 13 percent carbon dioxide by weight. Materials in development

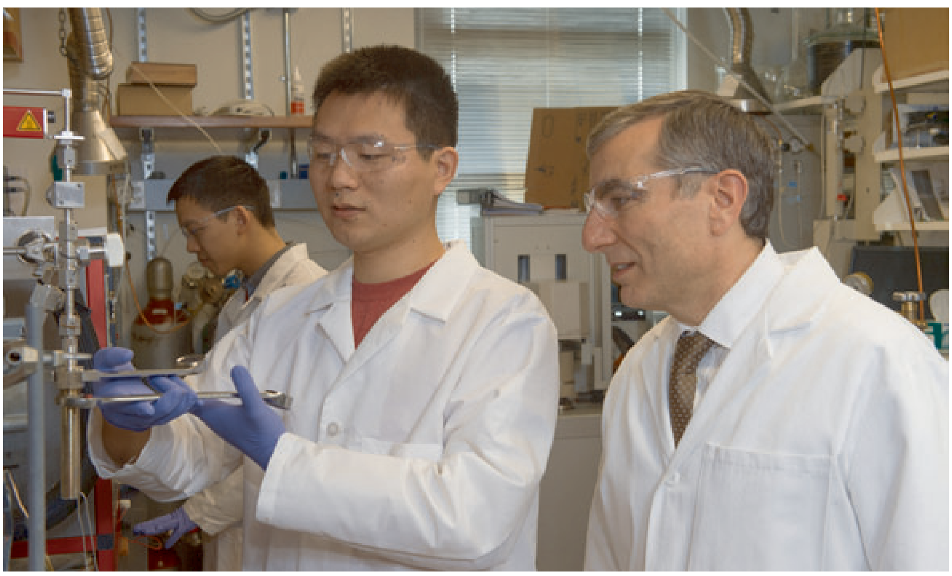


A scanning electron microscope image shows the fine pores in a carbon material created at Rice University to capture carbon dioxide from production streams at natural gas wellheads. The material sequesters carbon dioxide molecules at normal wellhead pressures and lets them go when the pressure is released. Courtesy of the Tour Group

based on metal organic frameworks are far more expensive to produce and don’t show as great a selectivity for carbon dioxide over methane, he said.

The paper’s co-authors are graduate students Chih-Chau Hwang, Desmond Schipper, Yilun Li, Huilong Fei and Errol Samuel and lab assistant Josiah Tour, all of Rice. Tour is the T.T. and W.F. Chao Chair in Chemistry as well as a professor of materials science and nanoengineering and of computer science and a member of the Richard E. Smalley Institute for Nanoscale Science and Technology.

The Apache Corp. funded the research. MI SWACO-Schlumberger and Prince Energy provided asphalt samples.



Rice researchers Gedeng Ruan, center, with chemist James Tour, right, and Yilun Li, in the background at left, prepare to test a sample of their carbon dioxide-capturing powder. Photo by Jeff Fitlow

More information

The full full paper can be dowbnloaded from: **pubs.acs.org**

Or see the chemistry home page:

chemistry.rice.edu

Capture and utilisation news

Novel carbon capture solvent begins pilot-scale testing for emissions control

www.nationalcarboncapturecenter.com

Pilot scale testing of a Linde-BASF CO2-capture technology has begun at the National Carbon Capture Center in Alabama.

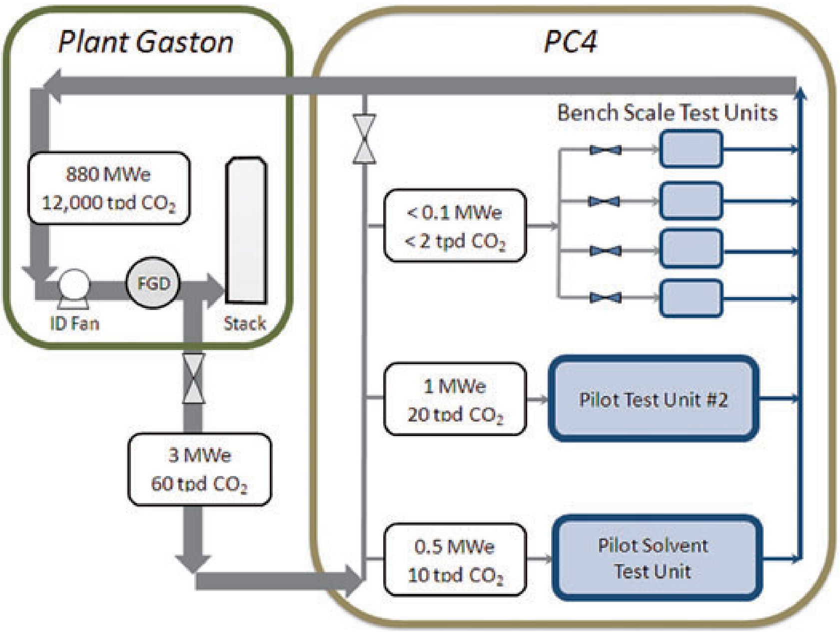
Under a cooperative agreement with the Energy Department's National Energy Technology Laboratory (NETL), Linde LLC is operating a nominal 1-megawatt-electric (MWe) pilot plant expected to capture 30 tons of CO2 per day.

Testing at the pilot plant will validate performance of the Linde-BASF CO2-capture technology on actual coal-derived flue gas. The NCCC includes a post-combustion carbon-capture facility that allows testing and integration of advanced CO2-capture technologies using flue gas from Alabama Power's Gaston power plant Unit 5—an 880 megawatt pulverized coal unit. Successful testing will be a major step toward achieving the overall Energy Department goal of 90 percent CO2 capture with 95 percent CO2 purity at a cost of $40 per metric ton of CO2 captured.

The technology being tested integrates BASF's advanced aqueous amine-based solvent (OASE® blue) and process technology with novel CO2-capture process and engineering innovations being developed by Linde. OASE® blue chemically absorbs CO2 from the flue gas at a relatively low temperature in the absorption column. The CO2-rich solvent is then transferred to a stripping column where steam is added to heat the solvent, reversing the chemical reaction and releasing high-purity CO2 for compression and pipeline transport. The CO2-lean solvent is recycled back to the absorption column for additional CO2 capture.

BASF's OASE® blue offers key benefits in comparison to monoethanolamine, a benchmark solvent employed in other applications. These benefits include increased CO2 loading, reduced regeneration steam requirements, and increased thermal and chemical stability. Process-related innovations incorporated into the pilot plant include:

• Gravity-driven interstage absorption column coolers.



The Linde-BASF CO2 capture technology will be tested at the National Carbon Capture Center using flue gas from Alabama Power's Gaston 880 MWe power plant Unit 5

• High-capacity structured packing.

• An advanced amine wash unit.

• Placement of a reduced-size flue gas blower downstream of the absorption column.

• High-pressure stripping of the captured CO2.

The planned 18-month test program consists of three phases: initial start-up and operation with flue gas and solvent recirculation, parametric testing, and long-duration testing for a minimum of 60 days. Parametric testing will evaluate the impact that key parameters—including flue gas flow rate, solvent circulation rate, and regeneration pressure—have on process performance criteria, such as the CO2 capture rate, solvent CO2 loading, solvent working capacity, pressure drop, steam demand, and outlet CO2 pressure. Long-duration testing at optimal operating conditions will evaluate steady-state performance with power plant cycling, pilot unit reliability, solvent stability, and the emissions profile.

Following pilot testing, Linde and BASF will jointly pursue opportunities for larger-scale testing, leading to full-scale commercialization in the 2025 timeframe.

CO2 Solutions' pilot plant begins construction

www.co2solutions.com

The pilot at Husky Energy's Pikes Peak South heavy oil site in Saskatchewan has begun construction.

CO2 Solutions completed the design review and detailed engineering phase for the pilot installation in collaboration with Montreal-based engineering consulting firm Seneca in 2014, now procurement of components for the pilot plant is complete and construction has commenced.

The pilot unit is being constructed in the Montreal area and will be tested on-site, prior to being skid-mounted for transport to Saskatchewan. Installation and commissioning at the site are anticipated early in the second quarter of 2015, with operation until September, 2015, representing over 2,500 hours of field operation. The project to date is on schedule and within budget.

"This project represents the final stage in the scaling up of our technology prior to CO2 Solutions entering the commercial phase of its development," said Evan Price, President and CEO of CO2 Solutions.

MIT study finds a natural impediment to the long-term sequestration of CO2

Researchers in the Department of Earth, Atmospheric and Planetary Sciences at MIT have found that once injected into the ground, less CO2 is converted to rock than previously imagined.

Christine Daniloff/MIT, based on images by Carol Schoellhammer and Giovanni Traverso

The team studied the chemical reactions between carbon dioxide and its surroundings once the gas is injected into the Earth — finding that as carbon dioxide works its way underground, only a small fraction of the gas turns to rock. The remainder of the gas stays in a more tenuous form.

"If it turns into rock, it's stable and will remain there permanently," says postdoc Yossi Cohen. "However, if it stays in its gaseous or liquid phase, it remains mobile and it can possibly return back to the atmosphere."

Cohen and Daniel Rothman, a professor of geophysics in MIT's Department of Earth, Atmospheric, and Planetary Sciences, detail the results this week in the journal Proceedings of the Royal Society A.

Current geologic carbon-sequestration techniques aim to inject carbon dioxide into the subsurface some 7,000 feet below the Earth's surface, a depth equivalent to more than five Empire State Buildings stacked end-to-end. At such depths, carbon dioxide may be stored in deep-saline aquifers: large pockets of brine that can chemically react with carbon dioxide to solidify the gas.

Cohen and Rothman sought to model the chemical reactions that take place after carbon dioxide is injected into a briny, rocky environment. When carbon dioxide is pumped into the ground, it rushes into open pockets within rock, displacing any existing fluid, such as brine.

What remains are bubbles of carbon dioxide, along with carbon dioxide dissolved in water. The dissolved carbon dioxide takes the form of bicarbonate and carbonic acid, which create an acidic environment. To precipitate, or solidify into rock, carbon dioxide requires a basic environment, such as brine.

The researchers modeled the chemical reactions between two main regions: an acidic, low-pH region with a high concentration of carbon dioxide, and a higher-pH region filled with brine, or salty water. As each carbonate species reacts differently when diffusing or flowing through water, the researchers characterized each reaction, then worked each reaction into a reactive diffusion model — a simulation of chemical reactions as carbon dioxide flows through a briny, rocky environment.

When the team analyzed the chemical reactions between regions rich in carbon dioxide and regions of brine, they found that the carbon dioxide solidifies — but only at the interface. The reaction essentially creates a solid wall at the point where carbon dioxide meets brine, keeping the bulk of the carbon dioxide from reacting with the brine.

"This can basically close the channel, and no more material can move farther into the brine, because as soon as it touches the brine, it will become solid," Cohen says. "The expectation was that most of the carbon dioxide would become solid mineral. Our work suggests that significantly less will precipitate."

Cohen and Rothman point out that their theoretical predictions require experimental study to determine the magnitude of this effect.

"Experiments would help determine the kind of rock that would minimize this clogging phenomenon," Cohen says. "There are many factors, such as the porosity and connectivity between pores in rocks, that will determine if and when carbon dioxide mineralizes. Our study reveals new features of this problem that may help identify the optimal geologic formations for long-term sequestration"

This research was funded in part by the U.S. Department of Energy.

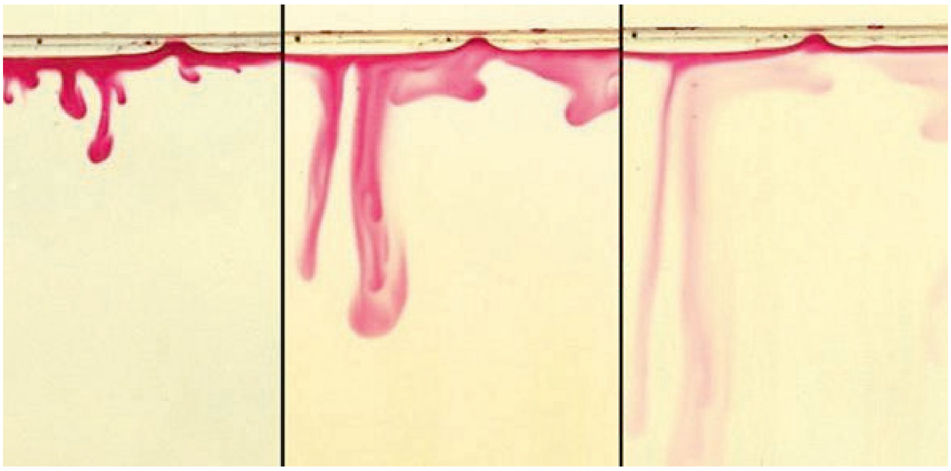
More information

eapsweb.mit.edu

Geochemical reactions may decrease effectiveness of carbon storage

Research from the University of Cambridge has shown that aquifers rich in silicate minerals may delay, or even prevent, CO2 from being carried to greater depths where it may be less likely to escape.

Geochemical reactions taking place in aquifers may lead to carbon dioxide being 'pooled' for hundreds or even thousands of years, and may force a rethink of how these underground reservoirs are used in carbon capture and storage (CCS) schemes. The results are published in the journal Nature Communications.



Evolution of the pink diffusive boundary layer formed by geochemical reactions. Image: Silvana Cardoso

Saline aquifers have been considered the safest and most efficient option for CCS schemes, where anthropogenic carbon emissions are trapped and stored underground so that they do not enter the atmosphere.

Both dissolution in the formation water and transport to depth decrease the risk of CO2 escaping: dissolution reduces the risk of potential upward leakage through fractures in the cap rock of the reservoir, while transport to greater depth increases the rate of dissolution and of potential incorporation of the CO2 into the rock minerals.

"Our research has found that CO2 may not behave as expected when stored in aquifers, challenging some of our previous assumptions about CCS schemes," said Dr Silvana Cardoso of the Department of Chemical Engineering and Biotechnology, who led the research.

It has been thought that once the CO2 is dissolved in the aquifer water, making it denser, convection streams develop and carry the mixture to deeper parts of the aquifer.

Dr Cardoso and her co-author, Jeanne Andres, a former PhD student in the same department, found that chemical reactions between the rock formations and the dissolved CO2 may delay, or even prevent, the CO2 from reaching greater depths by decreasing the strength of the convection streams.

The researchers used a combination of simple laboratory experiments and mathematical analysis to establish the basic interaction between fluid flow and chemical kinetics in a deep porous medium. Their study assessed the impact that the natural chemical reactions between the dissolved CO2 and the rock formation have on the convection streams which carry the CO2 to greater depths.

The researchers found that the behaviour of carbon dioxide depends strongly on the chemical composition of the rock formation: while the streaming of dissolved carbon dioxide persists in carbonate rocks, the chemical interactions in silicate-rich rocks may curb this transport drastically and even inhibit it altogether. For example, for a rock matrix rich in calcium feldspar, the convection streams may be completely shut off just two months after the onset of motion. After this, the carbon dioxide will be transported to depth by much slower diffusional processes.

These results challenge current views of carbon sequestration and dissolution rates in the subsurface, suggesting that pooled carbon dioxide may remain in the shallower regions of the formation for hundreds to thousands of years, while deeper regions of the reservoir can remain virtually carbon free.

"Screening of new sites will need to include not only the size and location of the reservoir, but also the mineralogy of the rock," said Cardoso. "The present study simply shows that mineralogy has a strong impact on where the CO2 ends up. Which specific mineralogy is best remains to be studied."

More information

www.ceb.cam.ac.uk

Transport and storage news

DOE and Shell Canada work on CO_2 storage tests

www.shell.ca

The Department of Energy (DOE) and Shell Canada will collaborate on field tests to validate advanced monitoring, verification, and accounting (MVA) technologies for underground storage of CO_2.

The tests will take place at Shell's Quest Carbon Capture and Storage (CCS) project in Alberta, Canada. Details of the collaboration are expected to be finalized in early 2015.

The Shell Quest team and technology developers funded by the DOE and managed by DOE's National Technology Laboratory (NETL), have been discussing opportunities to field test and validate advanced MVA technologies at the Quest CO_2 underground storage site.

The Quest project is significantly funded by the Government of Canada and the Canadian Province of Alberta. The Department of Energy is leveraging a federal investment of approximately $3 million in existing and ongoing projects in their research and development program by proposing roughly $500,000 for this collaborative effort to field test advanced MVA technologies.

MVA technologies are critical throughout the lifecycle of large-scale CCS projects such as Quest. They are needed to understand and track CO_2 movement in the storage formation and to monitor and ensure safe, permanent CO_2 injection and storage in geological formations.

The technologies under consideration would be tested alongside the state-of-the-art, comprehensive monitoring program Shell has already put in place for the project. The results from the tests are expected to provide additional information that would benefit future large-scale CCS projects around the world.

AUS $25 million for Otway project

www.co2crc.com.au

The Australian Government has granted AUS $25 million over five years to the CCS research project based in Victoria.

The Australian Government funding, which will be provided to CO2CRC under the CCS Flagships Program, will be matched by cash and in-kind contributions from CO2CRC members. This includes $10 million from the Australian coal industry's Coal21 Fund and a $5 million Victorian Government grant announced in September 2014.

Welcoming the funding announcement, CO2CRC's new chief executive officer, Tania Constable, commended the Australian Government for supporting CCS as an essential component in a portfolio of low- and zero-carbon emissions technologies required to tackle climate change.

"The wide-scale deployment of CCS is critical to reduce carbon emissions as quickly and cost effectively as possible," Ms Constable said. "This funding will allow CO2CRC to embark on a new program of research to improve CCS technologies.

"In particular, the intention is to lower the costs of developing and monitoring CO_2 storage sites, enhance regulatory capability and build community confidence in geological storage of CO_2 as a safe, permanent option for cutting emissions from fossil fuels.

"A major focus of CO2CRC's research will be on high resolution monitoring and verification of stored CO_2."

DOE Illinois project captures one million tonnes of CO_2

www.sequestration.org

The Illinois Basin-Decatur Project successfully captured and stored one million metric tons of carbon dioxide and injected it into a deep saline formation.

The project is part of the development phase of the Department's Regional Carbon Sequestration Partnerships initiative, which is helping develop and deploy CCS technologies as part of a path towards a low carbon future.

The carbon dioxide is captured from the Archer Daniels Midland Company ethanol-production facility in Decatur, Illinois, and is compressed before traveling across a mile-long pipeline and injected approximately 7,000 feet below the surface into the Mount Simon Sandstone formation.

Since beginning in November 2011, the injection test performed better than expected, sustaining pressure increases well below regulatory limits. Over the course of 100 years, the injected CO_2 is projected to remain hundreds of feet below a 300-foot thick shale formation that will act as a seal and inhibit upward migration of the CO_2.

"This milestone is an important step towards the widespread deployment of carbon capture technologies in real-world settings," said Energy Secretary Ernest Moniz. "The successful testing of these technologies and the lessons learned support a range of industries in the region, while also reducing the amount of emissions in the atmosphere and protecting the planet at the same time."

The Midwest Geological Sequestration Consortium, led by the Illinois State Geological Survey, is evaluating CCS options for the 60,000-square-mile Illinois Basin, which underlies most of Illinois, southwestern Indiana, and western Kentucky.

Canada funds CO_2 field research station

www.carbonmanagementcanada.ca

CMC Research Institutes will establish a Field Research Station (FRS) to commercialise instruments associated with CO_2 underground storage.

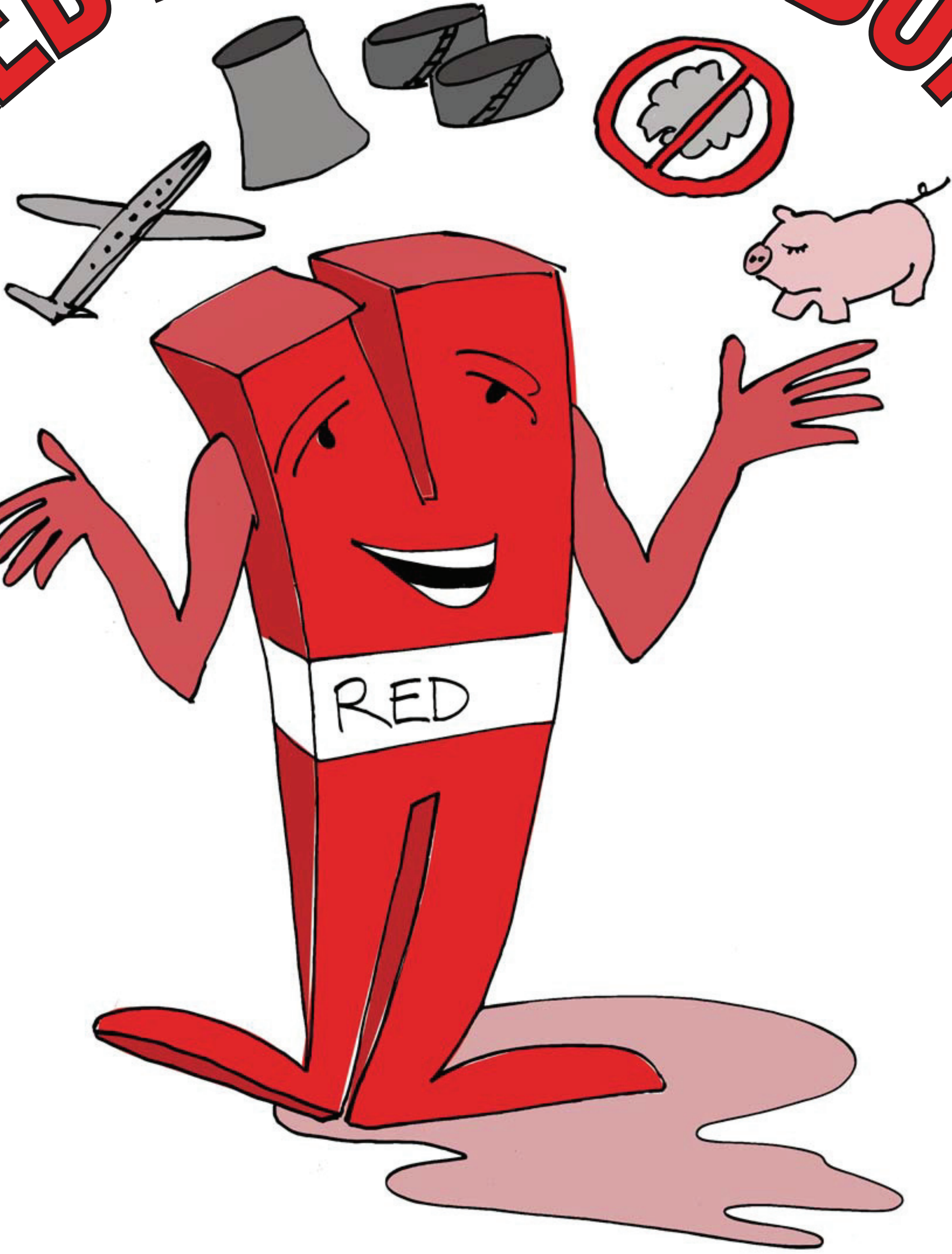
Federal funding of $4.9 million, through the Western Diversification Program (WDP), will enable CMC Research Institutes to purchase advanced equipment, construct a new well and additional infrastructure, and acquire a specialized mobile geochemistry laboratory for water and gas sampling at field sites.

The project, which is also receiving support from the University of Calgary, Schlumberger and Cenovus Energy, will help reduce Western Canadian industrial greenhouse gas emissions, particularly in the energy sector, as well as accelerate small- and medium-enterprise (SME) engagement and commercialization opportunities in international markets.

CMC Research Institutes is an independent not-for-profit organization that helps technology developers identify opportunities and create solutions for decarbonizing the fossil energy industry. The FRS will be the first of its kind with the capacity for injection at an intermediate depth, simulating release into a subcritical geological horizon.

Carbon Capture Journal

RED HYDROCARBON



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