Carbon Capture Journal

CCUS in the UK

Building on the "ten point plan"

A net zero UK Oil & Gas industry

Southampton researchers' solution for turning carbon emissions into plastics

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Review of 2020 - the Gorgon project celebrated one Mt of CO2 stored

How the US 45Q tax credit is motivating CCS

University of Wyoming begins third phase of CarbonSAFE

HeidelbergCement to install first full-scale CCS facility in a cement plan

Compact CO2 capture technologies for small to medium-scale emitters

Bellona hails 'victory' as Norway approves Longship project funding

The Norwegian parliament has formally approved the budget proposal for 2021 which includes funding for the Longship – or in Norwegian: 'Langskip' – project, which promises to be the world's first complete CO2 capture, transport and storage system based on emissions from industry and storage offshore. By Todd Allyn Flach, Bellona Europa.

While the Longship funding approval is a breakthrough for industrial CCS, it is the result of a process that began as a specific environmental campaign by Bellona over 20 years ago, which has evolved and grown to today.

Bellona's first public advocacy campaign for CCS started in 1996. At that time, it was relevant for Norwegian policy. The question was whether or not to build new natural gas power plants on the western coast of Norway. Many rejected the concept outright because it would significantly increase CO2 emissions.

Bellona's position was that if the power plant installed CCS from the start, then emissions would be small and tolerable. Unfortunately, this option was not subject to a proper public debate. The project developer rejected CCS due to its perceived technical immaturity and high cost. The center-right government resigned in March 2000 due to their general opposition to natural gas power plants.

The plans for natural gas power plants on land in Norway were later cancelled. But Bellona did not drop its campaign for CCS, instead it pivoted to focusing on how CCS can be applied to non-power plant industries with hard to abate emissions. The most prominent examples are cement, steel and chemicals. These will be needed even if all electric power production comes from renewable energy sources. Bellona's experts in Brussels explain this in their analysis from 2018.

Being the first NGO to actively advocate for aggressive CCS deployment was just the start. The urgency of the climate crisis, for those who have carefully examined it, calls out for removal of excess CO2 from the atmosphere. Bellona published its first appeal for action to achieve net negative emissions in 2008.

This pivot also inspired Bellona to expand its CCS advocacy in Brussels by adding resources to reach out to a broad range of European stakeholders aiming to reduce their CO2 emissions, as well as building a dialogue to convince technology sceptics of the necessity of CCS.

One of hardest nuts to crack has been finding capital and funding for CCS projects. Bellona's active contribution to the first attempt at the EU level culminated in the EU ETS funding mechanism called NER300. This process established the first formal mechanism of linking revenues from CO2 cap-and-trade auctions to supporting climate action projects.

The number and types of project proposals to the first call for the NER300 were impressive. Although this first attempt to kick-start full-scale CCS projects with funding support from the EU ETS did not result in new full-scale projects, it provided valuable lessons for its follow-up, the EU Innovation Fund (EU IF).

The first call for full-scale projects received proposals for 311 projects across all technology categories. We estimate that more than 150 proposals of the 311 were for various types of CCS and CCU projects. The total amount of emissions reductions estimated by all 311 proposals was 1.2 Gigatonnes CO2 over their 10-year support periods. The total amount of funding applied for from the EU IF was 21.7 billion Euros. This is 21.7 times the total framework for this call, and 2.17 times larger than the anticipated framework for the 10-year support program as it currently stands for the EU IF.

So while the Longship project may be first of its kind in operation, it will be swiftly followed by a wave of similar projects. Already it has been hinted that the Northern Lights CO2 transport and storage infrastructure (a sub-project within the Longship project) has confirmed 11 separate CO2 capture projects that have applied for EU IF funding plan to store CO2 on the Norwegian continental shelf.

So the overall success criterion laid down by the Norwegian government that the Longship project would not be the first and the last of its kind, appears to be just about guaranteed.

Longship project

The Government has laid out its plans for Longship in a white paper, which was originally scheduled to be heard by the Storting on December 10. Due to changes in the Storting's program it will now take place in early 2021. The formal approval of the plan for development/installation and operation will take place as soon as the Storting has adopted the white paper.

The overall investments for the project are estimated to be NOK 17.1 billion. The pertaining operating costs for ten years of operation are estimated to be NOK 8 billion. The total cost estimate is thereby NOK 25.1 billion. Longship receives state aid in accordance with negotiated agreements. The state's share of the costs is estimated to be NOK 16.8 billion. This means that the state covers around two thirds of the costs of the project.

Longship facilitates the production of blue hydrogen from natural gas with carbon capture and storage. This results in hydrogen with very low emissions and a major potential for value creation in Norway and for greenhouse gas emission cuts in Europe. Hydrogen also plays a key role in the EU's Green Deal.

More information

www.bellona.org

www.regjeringen.no

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Carbon Capture Journal
United House, North Road, London N7 9DP
www.carboncapturejournal.com
Tel +44 (0)208 150 5295

Editor
Keith Forward
editor@carboncapturejournal.com

Publisher
Future Energy Publishing
Karl Jeffery
jeffery@d-e-j.com

Subscriptions
subs@carboncapturejournal.com

Advertising & Sponsorship
David Jeffries
Tel +44 (0)208 150 5293
djeffries@onlymedia.co.uk

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Front cover:

The Gorgon Carbon Dioxide Injection facility is the largest dedicated geological storage operation in the world with a capacity of up to 4 Mtpa CO2 (Image courtesy of Chevron)

Back cover: Air Products' Port Arthur Carbon Cature facility has captured and stored over six Mt of CO2 (Image courtesy of Air Products and Chemicals, Inc.)

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Leaders - 2020 review and CCUS in the UK

Projects and policy

Capture and utilisation

Transport and storage

CCS capacity sees 33% increase in 2020 says Global CCS Institute report

The total capacity of carbon capture and storage facilities operating and under development has grown by 33% world-wide over the last year alone. The 2020 Global Status on CCS report also finds that there are a total of 65 commercial CCS facilities in various stages of development globally.

Global progress in CCS over the past year has been substantial a few examples illustrating the broad applications, and spread, of CCS in 2020 are:

• The Drax BECCS project commenced in the UK. The existing Drax power station has already undergone modification, transforming from coal-fired to one firing biomass. The addition of CCS will further reduce its CO2 footprint. Drax is targeting capture of four Mtpa of CO2 from one of its four power generation units. Storage will be in the North Sea oil fields, with a proposed start date of 2027. This project is part of a larger program to eventually deploy CCS on all four of its bioenergy power units by the mid-2030s.

• Enchant Energy is developing a CCS project for its coal-fired San Juan Generating Station in New Mexico, USA. Up to six Mt of CO2, captured through post-combustion capture technology per year, would be used for EOR in the Permian Basin.

• In Australia, energy company Santos announced it has commenced the FEED study for a CCS project to capture CO2 from natural gas processing at its Moomba gas plant. The project will capture and geologically store 1.7 Mt of CO2 in a nearby field, each year. Santos has claimed abatement costs of less than AUD $30 per tonne (US $22).

• Lafarge Holcim is looking at the feasibility of carbon capture on its cement plant in Colorado, US. This project, in partnership with Svante, Oxy Low Carbon Ventures and Total, would capture 0.72 Mt of CO2 per year. Using the captured CO2 for EOR, it would receive 45Q tax credits and would be the largest-scale use of Svante adsorption-based capture technology ever.

• The ZEROS project involves the development of two innovative oxyfuel combustion waste-to-energy (WtE) (power) plants in Texas, USA with a capture target of 1.5 Mt of CO2 per year. Oxyfuel combustion ensures a high concentration of CO2 in its flue gas, making carbon capture more economical than in conventional WtE plants.

• The Pouakai project, owned by 8 Rivers Capital, is a hydrogen, fertiliser, and power generation industrial complex in the Taranaki Region, New Zealand. It will use natural gas as a feedstock and CCS (approx. 1 Mtpa CO2), resulting in near-zero emissions, with ambition for operations mid-decade.

Some of the most significant industry milestones reached in the past year are:

• The Alberta Carbon Trunk Line (ACTL) commenced operation in March 2020. With a capacity of 14.6 Mt of CO2, this key infrastructure for Canadian industry transports CO2 for EOR storage in Central Alberta6. It's the world's highest capacity CO2 transport infrastructure and was developed with the future in mind. Its foundation CO2 capture facilities are the Sturgeon oil refinery and Nutrien Fertiliser plant.

Global Status on CCS highlights

The CCS facility pipeline continued to grow three years in a row, with global capture and storage capacity nearly doubling within three years and increasing by 33% since 2019. Almost 40 million tonnes of carbon dioxide are being captured annually from 26 commercial CCS facilities currently in operation.

The United States, which is already home to the highest number of operational CCS facilities, continues its lead in the global CCS league and hosts 12 of the 17 new commercial facilities added to the project pipeline in 2020. The US has some of the most advanced supportive policies for CCS of any country in the world, including the enhanced 45Q tax credit and the California Low-Carbon Fuel Standard.

2020 saw increased ambition and support for CCS in Europe as well. The Norwegian Government announced its green light for the Langskip project. Funding for CCS infrastructure was earmarked in the UK's Spring Budget, with the goal of developing several hub and clusters during the decade. Elsewhere in Europe, the first call of EU's €10 billion Innovation Fund, expected be a major source of funding for CCS projects, was launched in July, whilst the Porthos Project in Netherlands is scheduled to take a final investment decision in 2021.

In Asia Pacific, regional collaboration between countries and businesses continued to gather pace in 2020 in order to advance technical understanding and develop regulatory frameworks, with notably Australia and Japan making progress in terms of domestic policies and CCS investments.

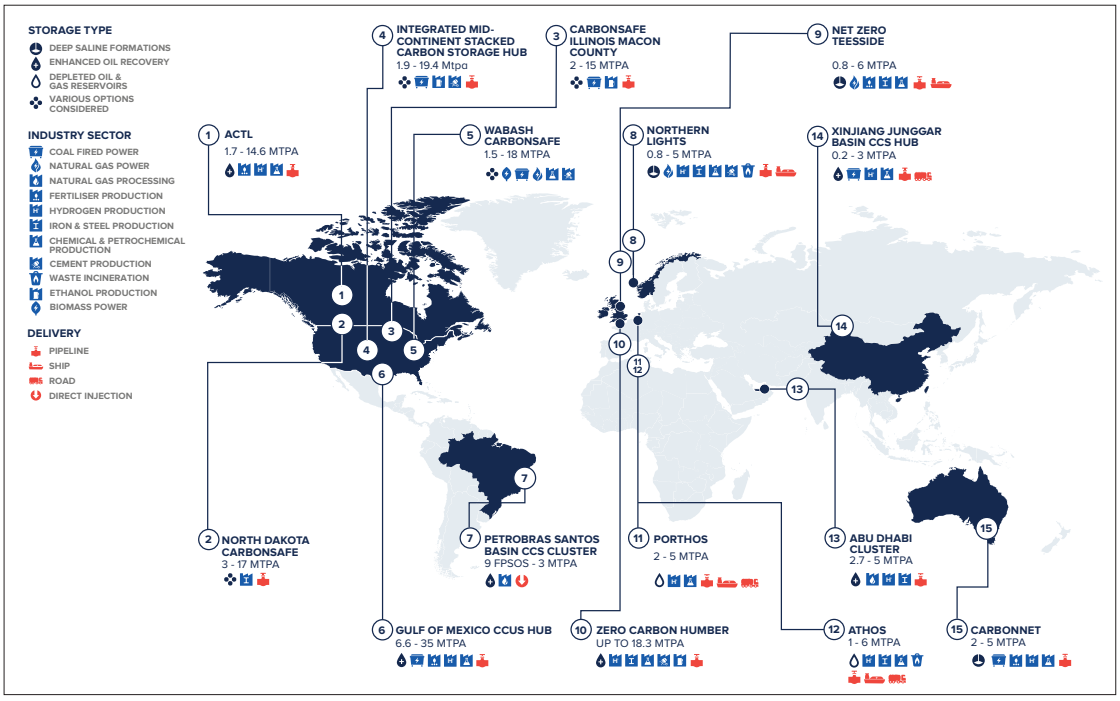
In a move that will reduce both cost and risks to government and industry, CCS hubs and clusters – the shared use of CO2 transport and storage infrastructure among companies – is predicted to support a boom in the adoption of CCS in the coming years. CCS investments in the United Kingdom are largely geared towards hubs and cluster development, and nearly all new facilities in the United States will have access to shared storage sites

• The Gorgon Carbon Dioxide Injection facility on Barrow Island, Western Australia, was commissioned in August 2019 and has been storing CO2 since. Chevron has progressively commissioned its CO2 compression trains, ramping up CO2 injection capacity. The milestone of one Mt of CO2 stored was announced in February this year. Gorgon is the largest dedicated geological storage operation in the world with a capacity of up to 4 Mtpa CO2.

• Air Products Steam Methane Reformer facility captures CO2 from two steam methane reformers located in the Valero Energy refinery at Port Arthur, Texas. It produces 500 tonnes of clean hydrogen per day. In April 2020, the US DOE published that the facility had cumulatively captured and stored over six Mt of CO2.

• Quest CCS facility captures CO2 from three steam methane reformers at the Scotford Upgrader in Alberta, Canada. It produces 900 tonnes of clean hydrogen per day. In July 2020, the facility reached five Mt of CO2 safely and permanently stored in dedicated geological storage.

• Petrobras Santos Basin Pre-Salt Oil Field CCS facility uses membranes to capture CO2 from offshore natural gas processing and reinjects it into the Lula, Sapinhoá and Lapa oil fields for EOR. Membranes have size and weight advantages which make them best suited to offshore applications. Petrobras is the largest project using membrane technology globally. The project's capacity recently increased from three to 4.6 Mt per year.



Hubs and clusters currently operating or in development (Source: Global CCS Insitute Status CCS 2020)

Hubs and clusters: moving toward more flexible CCS networks

Like most industries, CCS benefits from economies of scale. Larger scale compression, dehydration, pipeline and storage drives big reductions in cost per tonne of CO2.

Early developments in CCS adopted a point-to-point model, which tended to favour situations where a single large emitter (e.g. a power station or gas processing plant) was situated within reasonable distance of a large storage site.

Hubs aggregate, compress, dehydrate and transport CO2 streams from clusters of facilities. There are significant economies of scale to be obtained, particularly in the capital costs of compression plants (up to approximately 50 MW of power consumption), and in pipelines (up to around 10-15 Mtpa of capacity). This industrial ecosystem with multiple customers and suppliers of CCS services also helps reduce risk. The Figure above shows CCS hubs and clusters either operating, or progressing through studies, in 2019–20.

Hubs also enable better source/sink matching between carbon capture facilities and storage resources. They allow for more flexible compression operations, by allowing greater turndown (reduction in flow) than would be possible with individual compression plants at every source.

One of the most advanced hubs in development is the Northern Lights Project. In the North Sea, this Norwegian CCS hub aggregates CO2 streams, beginning with foundation sources from WtE and cement plants (combined capacity of 0.8 Mtpa of CO2). Developed by Equinor, Shell and Total, the project will compress and liquefy CO2 at source plants before transport by dedicated CO2 ship, to a storage site. The project is targeting a 2024 commissioning date.

Impact of Covid-19

While development and deployment of CCS gathered momentum in 2020, the sector is not immune to the economic downturn brought on by COVID-19. The epidemic severely impacted the global economy and entire industries significantly scaled back production. This includes the global oil sector which saw extraordinarily rapid falls in demand and price.

The Petra Nova CCS facility in Texas, US successfully captured CO2 from the NRG-owned W.A. Parish power station from when it was commissioned in early 2017. Its business model, based on using CO2 for EOR, was severely impaired by the oil price decline and, in March 2020, carbon capture operations paused. NRG indicated they should restart when economic conditions improve.

More information

The full report is available at:

www.globalccsinstitute.com

CCUS in the UK – building on the "ten point plan"

The UK CCS industry is buoyed by the government's "ten point plan" including a commitment to put £1bn into carbon capture projects and develop four clusters. Developments were reviewed at the Carbon Capture and Storage Association (CCSA) online meeting in December.
By Karl Jeffery.

On November 18 2020, UK Prime Minister Boris Johnson announced a "Ten Point Plan for a Green Industrial Revolution", including a target to capture and store 10 MT of CO2 annually by 2030, develop two carbon clusters by mid 2020s and two more by 2030, and increase the spending commitment on carbon capture to £1bn.

There was also a plan to generate 5 GW of low carbon hydrogen production by 2030, which could be either "blue" (from fossil fuel with carbon capture) or "green" (from renewables with electrolysis).

Matthew Knight, head of business development with Siemens Energy said he thought it was a great announcement, a clear signal, and a ratcheting up of ambitions.

"The history of CCS had a few false starts, we're really getting seriously into the detail now," he said. "The 10 point plan has fired a starting gun."

"Just 2 years ago, the government's goal was at least one carbon capture project by 2030. This we increased to one by the mid-2020s and another by the end. Now the plan has increased to two clusters by mid 2020s and two more by 2030."

Questions about how this will be achieved are not yet answered. Mr Knight noted that "there's not a lot of detail behind it", but more detail can be expected over early 2021.

Jonathan Briggs, chair of the Carbon Capture and Storage Association and Project Director for its Humber Zero decarbonisation project, said that the work for 2021 is to create the business models and markets, and develop the supply chain capability.

Also this year, the UK should ensure it makes best use out of its hosting of the 2021 United Nations Climate Change Conference (COP 26). It should "showcase the incredible benefits that CCUS can play internationally in helping support net zero electricity systems, low carbon, clean hydrogen, negative emissions, enabling all of us to collectively meet our goals in support of the Paris agreement," he said.

Kwasi Kwarteng, Minister of State for Energy with the UK government, said in the meeting that the £1bn investment "will not only drive technology innovation, but create jobs in areas such as Humber, Northeast England, Northwest England, Scotland, Wales."

"This support is coupled with [the UK's] geographical advantages and world leading expertise [in CCS]."

"We're focusing on developing new business models to support development of CCUS in the UK. Separate business models will help support carbon capture in industry and power, and stimulate new investment for infrastructure to transport and store the captured CO2."

"We will publish a hydrogen strategy in early 2021, with a plan for further decarbonisation and expansion of the hydrogen economy."

"If we can get the market structure right, there's no reason why we can't see faster deployment. That's what happened in the wind industry."

Mr Kwarteng was asked for his advice, as a politician, on how to get the public to better understand that net zero cannot be achieved purely with renewables, and to be convinced that it isn't greenwash.

"We mustn't confuse the public with [UK environmental campaign group] Extinction Rebellion," he replied. "The broad public doesn't know enough. The main thing is to try to explain in simple terms why it is necessary to [use CCS to] meet net zero."

"The main thing we have to do is just explain what carbon capture is. Then we can enter a debate with - I would say - purists."

"I agree there are sections of the public who think it is somehow cheating, you are somehow admitting you have to use carbon."

"My response is we can't make the perfect the enemy of the good."

Mr Kwarteng was asked about how carbon capture could be better encouraged in developing countries. "I think there's a huge opportunity. Many developing countries are still in a phase where they are on coal," he said.

"Purists again will regret that [developing countries should use carbon capture] and argue against it. [But] you have to work with what you have."

Mr Kwarteng was asked what carbon pricing system we are likely to see in the UK, with the UK leaving the EU.

"Certainly in [UK government department] BEIS, we've always favoured the Emission Trading Scheme (ETS)," he said. "If there is a UK ETS it will be linked to the EU ETS."

BEIS perspective

Declan Burke, director Clean Power Strategy & Deployment with UK government department BEIS, says that the government also sees CCS infrastructure as a "critical enabler" for renewables. Gas + CCS can provide power when there is less wind or sun. "In a balanced system it enables higher levels of renewable deployment."

The UK government likes that carbon cap-

ture can create jobs in less wealthy parts of the country.

The government also likes that the "blue" hydrogen market can make use of the UK's oil and gas expertise in a decarbonised era, he said. The government is also interested in carbon capture's potential to enable negative emissions.

"Shift in attitude" of the finance community

There has been a significant "shift in attitude" of the UK financial community in favour of carbon capture, as people realise that decarbonization cannot be done without it, said Allan Baker, global head of power with French investment bank Société Générale

"There's been a significant shift in attitude of the finance community [towards CCS]," said Allan Baker, global head of power with French investment bank Société Générale.

That is driven by the net zero targets that are being rolled out around the world, and people realising that it is not possible to reach these targets without carbon capture being part of the energy mix. "For investors, it addresses the role of CCS in energy policy."

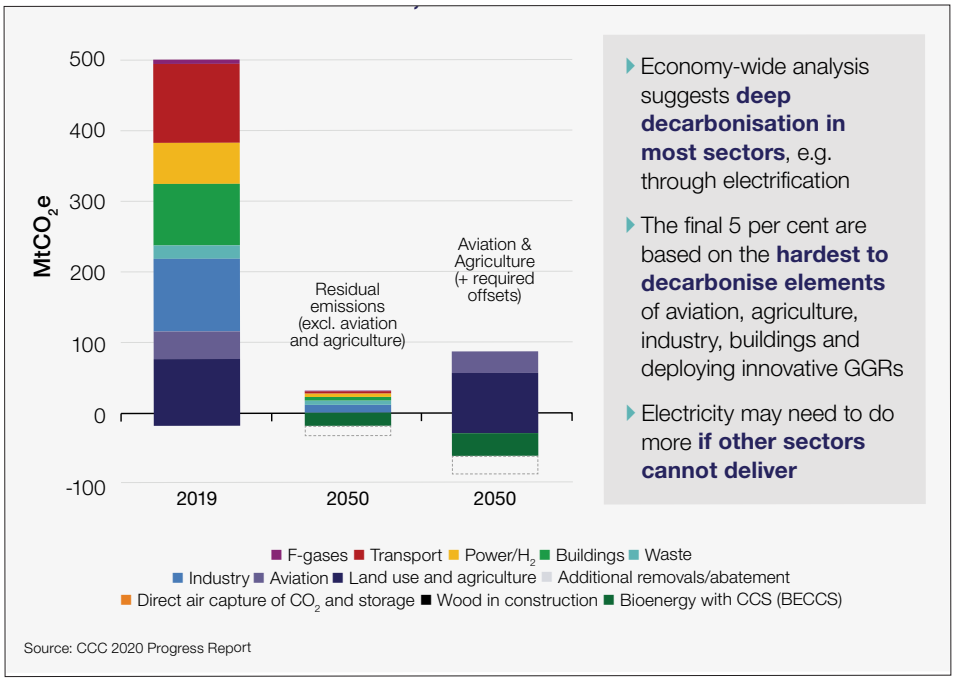
Working in carbon capture finance has been a "frustrating and lonely process," he said. For many years, there has been a perception among financial people that CCS is a "niche" or an "interesting pilot type technology."

"They didn't see the need to invest time in understanding the business."

It hasn't helped that a lot has work has gone into projects across Europe which looked like they had a good chance of going ahead, and "often those projects didn't materialise or fell away before getting to the point where banks would get involved." This reinforced the sense that carbon capture was only about pilots.

Consequently, financial people did not take the industry very seriously. "Three years ago, it was very hard getting a group of financiers together to talk about carbon capture."

"Now there are a lot more people coming forward and trying to join the debate. They look at it as a business which will need to be financed."



UK Emissions Net Zero Scenario (From Energy White Paper: Powering our Net Zero Future)

It helps when investors see CCUS being included in national and regional energy policies, such as the UK government's 10 point plan.

Investors like to see governments setting targets for carbon capture. Targets were set in the early days of offshore wind, and investors took this as evidence that it was a "serious consideration".

Another feature which has "added impetus" is the development of the idea of hydrogen in industrial decarbonisation. Previously carbon capture was mainly focussed on the power sector. Now there is a "wider decarbonisation play across the economy."

There is progress on the development of carbon capture business models. "Those models are developing in a way which is not far from other models which have been banked," he said, with a regulatory-type model for transport and storage, and contract-for-difference based model for capture.

"Those are models the finance community understands," he said. "They can point to precedent where it has been banked before."

It also helps that there are investors getting involved in carbon capture who have a long term perspective for other reasons, seeing it as a way to decarbonise their own businesses. For example, the five major oil and gas companies involved in the Net Zero Teesside project. And banks already know these companies very well.

Carbon capture projects are not as straightforward as a standard power plant. "Some of the risks are non-standard and quite difficult to allocate," he said.

Société Générale's reservoir experts see carbon capture leakage as a low probability but very high impact risk, if companies were expected to pay for any leak calculated using the Emission Trading Scheme (ETS) price at that time. So the general view is it will need some government cover in order to mobilise financing.

But also consider there have been many cases in finance where a risk is initially seen as unpalatable, but people gradually get comfortable with it, he said.

In the US, the situation is different. Projects most likely to get financed are where the CO2 is used for EOR, and the oil company also takes liability.

Mr Baker said he liked that the UK industry is looking at a number of clusters, rather than point-to-point projects. "That will enable the industry to grow from that backbone. We've got the opportunity to develop other low carbon projects, hydrogen, steel."

Financial models

Paul Davies, Chair of the CCUS Advisory Group, said he sees two financial models for carbon capture. A "project finance" model, where people invest or lend to a project based on its projected cash flows, and the "utility model" which is based on it being a regulated asset, with lower cost, longer term finance. The models attract different types of investors.

Mr Davies is a former corporate finance partner at PricewaterhouseCoopers and project financier at HSBC.

"I see a lot more of my finance colleagues showing up to [CCS] webinars and conferences. 5 years ago, I was probably the only finance person in the room at a conference."

The mood has changed since the (cancelled) White Rose project of 2015. At the time, carbon capture was considered a 'nice to have', now people see it as critical, and "an imminent opportunity rather than an opportunity in 10 years' time."

One key question is what the price of capital will be. The Thames Tideway super sewer project was able to attract capital at a price of 2.9 per cent, he said.

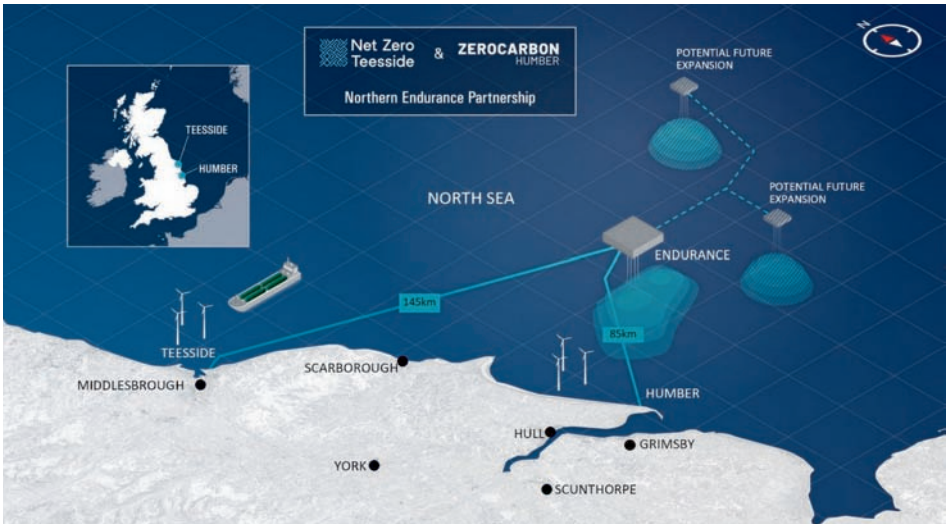
Charlotte Morgan, partner in law firm Linklaters, pointed out that the Thames Tideway had "quite an extensive government support package." This led to "very intense competition" among investors which drove down the cost of capital. Carbon capture does not look quite the same from an investor's perspective.

There may be a different level of return for investment made during the construction period, and questions about whether the return would be set through a competition, or set by a regulator. It needs to be set at a level to encourage continued investment, she said.

Teesside and Humber

Two of the likely carbon capture projects to go ahead in the UK are around the Teesside and Humber industrial areas, with CO2 from both regions going into the same offshore storage site, called "Endurance"

The Humber Estuary region has been described as the most carbon intensive region of the UK, the second most intensive in Europe, with a third of Britain's oil refining capacity, a huge steelworks and process industry.



BP, Eni, Equinor, National Grid, Shell and Total have formed the Northern Endurance Partnership to develop offshore carbon dioxide transport and storage infrastructure in the UK North Sea

In October 2020, the Zero Carbon Humber partnership submitted a £75m bid for government funding, under Phase 2 of the UK's Industrial Decarbonisation Challenge.

Members include Associated British Ports, British Steel, Centrica Storage Ltd, Drax Group, Equinor, Mitsubishi Power, National Grid Ventures, px Group, SSE Thermal, Saltend Cogeneration Company Limited, Uniper, and the University of Sheffield's Advanced Manufacturing Research Centre (AMRC).

The purpose of the bid is to "kickstart the decarbonisation of the Humber, so it can transform into a low carbon cluster by 2040," said Torbjørn Klara Fossum, Vice President Global CCS Solutions with Equinor, which plays a leading role in the project.

There are two components to the bid – a low carbon infrastructure connecting the broader area, with CO2 pipelines leading to storage, and a "blue hydrogen" production plant near the Saltend chemical plant.

This hydrogen plant project is led by Equinor, and aims to generate 600 MW of hydrogen. The hydrogen will be delivered to the Saltend Chemicals park near Hull. It will enable chemical plants in the Park to switch to hydrogen fuel. A gas power plant will also move to a 30% hydrogen 70% natural gas blend. Emissions from the Park will reduce by 900,000 tonnes CO2 per year.

The storage will be in the "Endurance" CO2 store, which will also be used for CO2 from the Net Zero Teesside project. This storage site was studied in depth for the abandoned White Rose project.

Equinor is involved in three decarbonisation "consortia" in North East England – in Humber, Teesside, and the offshore "Endurance" storage site, explained Grete Tveit, senior Vice President, Low Carbon Solutions, Equinor.

In Norway it is developing the "Northern Lights" transport and storage project with Shell and Total, part of an end-to-end project called Longship, taking CO2 from a cement plant and waste-to-power facility. It will offer CO2-storage-as-a-service to other companies, if they can deliver CO2 by ship. The Final Investment Decision was made in May 2020 and the government confirmed it will provide financial support in November 2020.

In Germany, it is evaluating hydrogen for steel making, replacing coal, at the largest steel plant in Germany, operated by ThyssenKrupp. In the Netherlands, it is looking at providing hydrogen to replace natural gas for a Vattenfall power plant.

And it also has 2 commercial CCS projects in operation in Norway, Sleiper and Snøvhit.

Equinor has learned from its experience with Norway's Northern Lights project, that building trust between project partners is very important for success.

"We are not developing only a project. We a creating a regulatory and commercial frame-

work, building a new industry. Defining a clear and common goal from industry and government and aligning on that. It is not traditional project development."

Another learning from Northern Lights is the importance of having a portfolio of customers.

"We're speaking with a lot of different industries in Europe [as potential Northern Lights customers], we learn a lot about the incentives for looking into CCS," she said. "At the moment we are in dialogue with more than 50 industries."

The emission trading scheme is just one of a range of incentives. Others are company's voluntary ambitions, customer demands for low carbon products, public procurement having a low carbon requirement. The first movers appear to be waste-to-energy, cement and refineries, she said.

Siemens perspective

Siemens has an interesting perspective on the Humber region and decarbonisation.

Matthew Knight, Head of Business Development with Siemens Energy, explained that four wind farm turbine factories were planned to be built in the UK at one point, but the only one which made it into operation was a Siemens factory in Hull (in the Humber region). "I was the face of Siemens the day we announced we would build that factory, it was the best day of my working life," he said.

"We know now the bulk of electricity [by 2050] is probably going to come from offshore wind. What we need is the things that balance that when wind is not blowing - dispatchable low carbon power. CCS gives us two ways to do that. One is creation of hydrogen. The other is you burn natural gas and capture the CO2."

Whether it is preferable to generate power from decarbonised hydrogen, or from gas with post combustion CO2 capture, depends on how long you expect the plant to be running for.

Whilst a gas turbine can be switched on and off quickly, chemical plants operate better if they are running continually, so they don't go through changes in temperature and pressure. And a post combustion CO2 capture system is a small chemical plant. So it is better to use this on a gas power station which will be continually operating.

If you only need fossil based power intermittently, you can have the gas reforming plant making hydrogen continuously, and then store the hydrogen until you need it.

The Humber region is likely to see both kinds of plants in operation by 2030. "You don't have to choose between the two," he said.

The Humber decarbonisation project will not have any particular need for new skills. It is more about traditional skills deployed in a new way. "The chemical plant is like other chemical plants," he said.

In terms of spending, generally capturing CO2 from a stream of mixed gases takes two thirds of the cost, and transport and storage one third.

Industries will have different incentives from government to capture their CO2 and add it to the infrastructure, ranging from tax breaks to regulatory settlements.

Teesside

Teesside is an important region of the UK to decarbonise, having five of the 25 top single emitters in the country, said Andy Lane, Managing Director, Net Zero Teesside, with BP.

The project will build a gas power station with carbon capture, which will be able to operate flexibly (switching on as needed).

One of the first industries to be decarbonised is an existing hydrogen plant, so it will change from making "grey" hydrogen to "blue" hydrogen.

There are a number of waste and bio-energy plants in Teesside, and others planned. If carbon capture is added to a bio-energy plant, there is a negative CO2 emission system.

Mr Lane said he believes that the discussion in the UK has now moved from "if we will have carbon capture" to "when and how will we have carbon capture".

Building the supply chain – learning from wind

To make carbon capture projects work in the UK, there will need to be a supply chain. Government money is funding much of the initial projects, and to repay the taxpayer, the government would like much of the supply chain to also be British. There may be some useful learning from the wind industry here

There could be something the CCS industry could learn from the development of the UK offshore wind industry, said Matthew Knight, head of business development with Siemens Energy. "The limited role for the local supply chain [in UK offshore wind] is a lesson that government doesn't want to repeat."

Most of the factories for building UK wind turbines are now in Denmark, since that was where the market for turbines got going first. "The supply chain invested there, it could see a pipeline of work."

The UK disadvantaged itself by going back on its construction commitments. In 2010, the then Prime Minister Gordon Brown talked about having 40 GW of offshore wind by 2030, at a time the country had under 1 GW.

"Four companies seriously considered building [UK] wind turbine factories because of that ambition," Mr Knight said.

But with the next government under David Cameron, every announcement was lower than the previous one, ending with a plan for 9 GW by 2020 if the costs could be reduced.

"Industry and government got stuck into a cycle - government said we're not going to do projects unless you get the costs down, and industry said, unless we can see a pipeline of projects, we can't invest to reduce the cost," Mr Knight said.

The problem was not only a lack of ambition, it was also that future projects were being planned one by one, so there was only ever one project in the pipeline. "For the supply chain, that makes it really hard to invest in anything - taking on an apprentice or building a factory."

The government also gave mixed messages about local content, saying they wanted local suppliers but also making clear their priority was cost reduction.

"In 2019 several companies went to great lengths to make UK supply chain investment part of their bid, but the winners in the CFD were the projects with the least local content. No account was taken of indirect and other jobs. That sent a really clear negative signal to the offshore wind industry. Government has talked about creating local jobs but when it comes to awarding contracts there's absolute-

ly no account taken of it," Mr Knight said.

"Eventually government and industry decided to move forward together

That led to the successful industry we have today." But only one of the four factories had not been cancelled – a Siemens factory in Hull.

Meanwhile, "France is paying over the odds for local supply," he said. "France was very clear, if you want to build offshore wind farms in France you have to build a factory in France to supply them."

"I don't think the UK needs to go that far," he said. Although it is legitimate under European Union state aid rules that, if a large amount of funding for an industry is coming from taxpayers, the government can require local content.

"There's a license to operate dimension - if you're spending a lot of taxpayer money to deliver something which is a public good you should be a good citizen in that region."

"Since then the [wind] industry has grown, and costs came down faster than even optimists had expected. Boris Johnson is talking about 40 GW by 2030."

When asked for advice for a supplier considering entering the UK carbon capture market, he suggested, "look for what's going to support growth of the carbon capture industry as a whole and offer your service and support to that. Don't say, 'I can supply you with bits and pieces.'"

It is possible that the capture technology itself may not be local, if other countries can do it better. But the carbon capture supply chain needs more than capture technology. "We should and must make most of UK strengths for the whole range of engineering, financing, project delivery, all the things that go into successful CCS clusters."

The UK oil and gas industry has a supply chain skilled at large scale, high value process engineering, said James Smith, co-chair of the CCUS council, and a former chairman of Shell UK. "There is a readymade supply chain that can swing into action when the signals are strong enough."

The CCUS Council is "currently kicking off a substantial workstream called supply chain excellence, getting rolling early in the new year," he said. "This is a time for ideas. At this stage in the work there isn't such thing as a crazy idea."

Getting CCS discussed at COP 26

In November 2021, the UK hosts the 2021 United Nations Climate Change Conference, also known as "COP 26". There hasn't been much discussion of CCS at past COP meetings. Can this be changed?

COP 26 is "an opportunity to galvanise the international community [around CCS]," said Luke Warren, CEO of the Carbon Capture and Storage Association.

"My observation is that so far, conversations about CCS and related technologies like hydrogen haven't yet been very prominent in conversations around COP."

Tim Dixon, General Manager of IEAGHG, said he has been attending COP meetings since 1999, and represented the CCS industry at COPs since 2005. This includes a role as an observer, part of a country delegation, and being the EU's lead negotiator on CCS.

IEAGHG is a CCS research organisation, set up by the International Energy Authority in 1991, but which exists as a separate body.

"These are incredibly important meetings, it cannot be exaggerated," he said. "The future of the planet is decided in those meetings. But it is a very complex environment to be active in, with many stakeholders."

This COP is particularly important because this is the one year in five where countries update their Nationally Determined Contributions (NDCs), the promises each country makes about how much to reduce their emissions, he said.

There were 187 NDCs submitted in the Paris COP of 2015. (COP 26 was originally planned for 2020).

"The UK government should now be encouraging countries to submit their updated and advanced NDCs this year," he said. "When I looked last, 13 had been updated, and only 1 had CCS in it - Norway."

If countries specifically include CCS as part of their plans, it gives a positive message to investors to take the technology seriously (and the opposite also applies).

Developing countries will only receive carbon funding for technologies highlighted in their NDCs. So by not including carbon capture, countries can inadvertently rule themselves out of CCS funding.

The IEA has estimated that CCUS must form 15 per cent of the world's CO2 mitigation activities if we want to get to net zero by 2070, and 25 per cent if we want to get to net zero by 2050, based on least cost modelling, Mr Dixon said.

The UK is a major donor to funding bodies, and can be influential in decisions about how the funds are allocated, Mr Dixon said.

The Green Climate Fund, a fund established by UNFCCC to support developing countries with climate change, appears to be opposed to carbon capture in terms of the applications it approves, although this has not been stated as a former policy.

He cited an example where an un-named "major developing country" applied to the GCF for a project involving CCS and "they got turned down at the first step. Initially it was because CCS was 'ineligible technology', although it says in black and white that CCS is eligible."

"Senior civil servants and ministers put their time and energy into applications and got knocked back. That country has walked away from considering CCS for the moment. That wrong decision has put the country back several years," he said.

"We've been in correspondence with the Green Climate Fund on this. GCF is supposed to be technologically neutral and not exclude any technology."

So far GCF has funded 150 projects, including reduced deforestation and planting trees, and renewable energy technologies, but no carbon capture projects. It is the world's main climate finance body, distributing $10bn a year, with objective to grow that to $100bn.

If carbon capture needs to be 15 to 25 per cent of the mitigation strategy (according to IEA's estimate, depending on when you want to reach net zero), it should receive an equivalent amount of funding. "We're just asking for technology neutrality and not bias," he said.

A more positive story on CCS comes from Trinidad and Tobago, which has its own oil and gas industry, and so access to storage.

The country's minister of environment has announced "Trinidad was ready to move into more precise studies for CCS."

Small island developing countries like Trinidad have a powerful voice within UNFCCC, he said.

"The UK has presidency of G7 next year. It can use that to encourage these other points. When the UK had presidency of G8 in 2005, we got CCS onto the political agenda for the first time. In 2005, CCS was quite new to people."

Since then CCS in China has progressed well. But CCS failed to get traction in India. "It did [get traction] with the stakeholders but it didn't at the political level, it always got stopped. There was never a clear reason why."

Now the British Geological Survey has funding to do some storage studies in India, and India has joined the EU "ACT" initiative on collaborative research.

The "carbon take-back obligation" policy idea

CCS could be incentivized simply by asking fossil fuel producers and importers to sequester an equivalent amount of carbon to the carbon in their fuels, said Myles Allen of Oxford University

The UK could accelerate its CO2 storage if it established a "carbon takeback obligation" on fossil fuel suppliers, requiring them to sequester an equivalent amount of carbon to the carbon in fuels they sell, suggested Myles Allen, Professor of Geosystem Science with the Environmental Change Institute, University of Oxford.

Mr Allen calculates that it would cost fuel suppliers £10 per tonne CO2. "It could be passed onto the consumer and no-one would even notice."

"Everyone who still uses fossil fuels is responsible for taking up some of the remaining carbon space, and therefore has a duty to help with expanding that carbon space by developing CCS," he said.

"The idea is simple. You impose an obligation on extractors and importers of fossil fuel to dispose of a rising fraction of the CO2 generated by their activities and products. A very simple regulation you impose at the point of entry of fossil carbon into an economy or region. Costs are distributed across all users of fossil fuels rather than a narrow group of them."

"The political economy would be much better than contracts for difference. You are not talking about some negotiated price between civil servants and industry, where there's always scope for [complaints] industry is getting a handout."

"We need a sustainable, long term, investable funding model which doesn't depend on either direct subsidy from the taxpayer or costs imposed on a narrow group of consumers or industries. That's what makes CCS policy unstable and open to lobbying and reversal."

CCS could be incentivized simply by asking fossil fuel producers and importers to sequester an equivalent amount of carbon to the carbon in their fuels, said Myles Allen of Oxford University

"The advantage of a carbon take back obligation is that no money is negotiated. They have to get rid of a certain amount of CO2. So market forces work very much in its favour, and political economy works very much in its favour."

The UK government may be better off "to make a less ambitious headline goal but announce a policy to get us to 10% sequestration by 2030, which if done by carbon takeback would be entirely affordable.

"Then we'd be demonstrating to the world a way of achieving net zero, rather than showing how the UK can achieve net zero in a way that's not replicable for the rest of the world."

"For industry, it would provide certainty in the amount of CO2 that will need to be disposed over time, and also provide a level playing field across fossil fuel providers."

It could be linked to financial statements, if companies were required to show they have access to storage equivalent to the carbon in their reserves of oil and gas.

"The ingenuity of the [oil and gas] industry is remarkable. If they have to get rid of CO2 to stay in this business, they'll just do it."

"You don't end up in an argument with treasury about whether you should spend money on CCS or anything else, because the treasury isn't spending any money. That way you avoid the arguments which have really held us back for the past 15-20 years."

Grete Tveit, Senior Vice President, Low Carbon Solutions, Equinor, agreed "this is a proposal that probably has a lot of merit."

"If it is designed well it provides greater certainty that emissions will be reduced, it encourages oil and gas providers to be more efficient."

It would also reward domestically produced hydrocarbons if their production and transportation means making less emissions than imported hydrocarbons.

"Actually I think the obligation to store, or at least competence to store, for a large part sits with the oil and gas industry, as we know the geology. We've been in the business for many years," she said.

"Having large industrial companies taking some kind of responsibility for this, is probably a good idea, because then you can do it safe, and you can do it in a cost efficient manner."

However, "in Norway we have had this carbon tax for many years and it has proved to be very efficient. We have the upstream activity with the lowest emissions in the world because of this."

"So if we could impose a carbon tax around the world, I think that would be as efficient. It would also cover industries like cement, and waste to power."

More information

Report from CCUS 2020: Delivering clean and sustainable growth, Dec 2-3 2020

www.ccsassociation.org

Building back better – Raising the UK's climate ambitions for 2035

The UK Climate Change Committee (CCC) has presented the first ever detailed route map for a fully decarbonised nation. A world first.

Last year, the UK became the first major economy to make Net Zero emissions law. In its new landmark 1,000-page report, the CCC sets out the path to that goal over the next three decades, including the first ever detailed assessment of the changes that will result and the key milestones that must be met.

The Sixth Carbon Budget (2033-2037) charts the decisive move to zero carbon for the UK. The CCC shows that polluting emissions must fall by almost 80% by 2035, compared to 1990 levels – a big step-up in ambition. Just 18 months ago this was the UK's 2050 goal.

To deliver this, a major investment programme across the country must be delivered, in large measure by the private sector. That investment will also be the key to the UK's economic recovery in the next decade. In many areas, this gives people real savings, as the nation uses fewer resources and adopts cleaner, more-efficient technologies, like electric cars, to replace their fossil-fuelled predecessors. The CCC finds that these savings substantially reduce the cost of Net Zero compared with previous assessments: now down to less than 1% of GDP throughout the next 30 years. This is thanks, not only to the falling cost of offshore wind but also a range of new low cost, low-carbon solutions in every sector.

Climate Change Committee Chairman, Lord Deben, said: "The Sixth Carbon Budget is a clear message to the world that the UK is open for low-carbon business. It's ambitious, realistic and affordable. This is the right carbon budget for the UK at the right time. We deliver our recommendations to Government with genuine enthusiasm, knowing that Britain's decisive zero-carbon transition brings real benefits to our people and our businesses while making the fundamental changes necessary to protect our planet."

"As we emerge from the COVID-19 pandemic, the Sixth Carbon Budget is a chance to jump-start the UK's economic recovery. Anything less would shut us out of new economic opportunities. It would also undermine our role as President of the next UN climate talks."

The CCC's message to Government is clear: the 2020s must be the decisive decade of progress and action on climate change. By the early 2030s, every new car and van, and every replacement boiler must be zero-carbon; by 2035, all UK electricity production will be zero carbon. Modern low-carbon industries will grow; producing hydrogen; capturing carbon; creating new woodlands; renovating and decarbonising the UK's 28 million homes. These provide hundreds of thousands of jobs throughout the UK.

The CCC concludes that these changes are feasible and affordable but only if they are led by decisive action from Government now. And the process must also be fair and just – the report includes important new insights into how the costs and the benefits of Net Zero can be shared more evenly. These are fundamentally desirable goals, bringing multiple wider benefits including better health, and an improved natural environment.

With bold new climate commitments from China and, soon, the US, over half of global greenhouse emissions will shortly be covered by Net Zero targets. This has brought the goals of the Paris Agreement within reach. If the CCC's recommendations are adopted by Ministers next year, the Sixth Carbon Budget will position the UK as a true global climate leader, as it prepares to host heads of state for the next major climate summit in Glasgow.

The Sixth Carbon Budget can be met through four key steps:

Take up of low-carbon solutions. People and businesses will choose to adopt low-carbon solutions, as high carbon options are progressively phased out. By the early 2030s all new cars and vans and all boiler replacements in homes and other buildings are low-carbon – largely electric. By 2040 all new trucks are low-carbon. UK industry shifts to using renewable electricity or hydrogen instead of fossil fuels, or captures its carbon emissions, storing them safely under the sea.

Expansion of low-carbon energy supplies. UK electricity production is zero carbon by 2035. Offshore wind becomes the backbone of the whole UK energy system, growing from the Prime Minister's promised 40GW in 2030 to 100GW or more by 2050. New uses for this clean electricity are found in transport, heating and industry, pushing up electricity demand by a half over the next 15 years, and doubling or even trebling demand by 2050. Low-carbon hydrogen scales-up to be almost as large, in 2050, as electricity production is today. Hydrogen is used as a shipping and transport fuel and in industry, and potentially in some buildings, as a replacement for natural gas for heating.

Reducing demand for carbon-intensive activities. The UK wastes fewer resources and reduces its reliance on high-carbon goods. Buildings lose less energy through a national programme to improve insulation across the UK. Diets change, reducing our consumption of high-carbon meat and dairy products by 20% by 2030, with further reductions in later years. There are fewer car miles travelled and demand for flights grows more slowly. These changes bring striking positive benefits for health and well-being.

Land and greenhouse gas removals. There is a transformation in agriculture and the use of farmland while maintaining the same levels of food per head produced today. By 2035, 460,000 hectares of new mixed woodland are planted to remove CO2 and deliver wider environmental benefits. 260,000 hectares of farmland shifts to producing energy crops. Woodland rises from 13% of UK land today to 15% by 2035 and 18% by 2050. Peatlands are widely restored and managed sustainably.

More information

www.theccc.org.uk

UK must accelerate and scale-up net zero action

The Net Zero All-Party Parliamentary Group (NZ APPG) has launched a powerful report and 10 Point Net Zero Action Plan that calls on the Government to urgently scale-up its decarbonisation plans.

The All-Party Group's report, "Putting Net Zero at the Heart of UK Policy," is backed by MPs and Peers from across the political spectrum as well as organisations like Centrica, WSP, Barratt Developments, Atkins, EDF, Savills, National Grid and the University of Oxford. Together, they warn that the UK is not on track to meet its net zero emissions by 2050, and that the UK risks falling behind other countries, unless Government takes urgent action to decarbonise power, transport, housing and land now.

Launching the report, Alex Sobel MP, Chair of the NZ APPG said, "The French and German governments have announced green recovery packages totalling €38 billion and €40 billion respectively. The green funding announced by our Government to date pales in comparison, and the £3.05 billion announced for energy efficiency is well short of the £9.2 billion pledged in the Conservative and Unionist Party Manifesto 2019."

The NZ APPG Decarbonisation Report - launched one year ahead of COP26 - follows a 5-month long inquiry and evidence gathering exercise. Its key recommendations are consolidated in a '10-Point Net Zero Action Plan' which sets out the urgent steps the UK needs to take now to get back on track to meet net zero.

Alex Sobel MP, Chair of the NZ APPG went on to say, "The key finding of our inquiry and this report is simple: while achieving net zero is a major challenge, it is also a major opportunity. By accelerating our decarbonisation efforts, we can create new industries, new job opportunities, and new cost savings. With the coronavirus wreaking havoc with our economy, and our competitors forging ahead, now is the time for visionary leadership and investment."

"Reaching net zero stands to create up to 260,000 new jobs in our energy sector alone. Over the next decade, we will need to install 2.8 million low-carbon heating systems in homes and 60,000 electric vehicle chargers—just two examples of shovel-ready projects that will create jobs, cut carbon, help to level-up the country and ultimately reduce costs for consumers."

"Our ambitious 10-Point Net Zero Action Plan helps char a clear course for the UK to meet its net zero targets. I urge the Government to take courage from this strong demonstration of cross-party and industry support for net zero and adopt the Action Plan in full."

Wera Hobhouse MP said, "It is encouraging to see a number of green investment announcements being made by the Government this year. But, as we heard throughout the course of our inquiry, they ultimately fall short of what is required to get us on track for net zero."

"Given the scale of the economic challenges we currently face, and with the nation going into a second Coronavirus lockdown, it is time for the Government to develop an expansive and ambitious green recovery package that focusses on green job creation."

Report findings

Two roundtable pre-sessions were held on 25 February 2020 and 24 March 2020 that brought together parliamentarians, stakeholders and academics to discuss policy and science issues on what it will mean, and what it will take, to achieve net zero, including:

Carbon capture and storage and carbon removal

• CCS is a critical technology that will offer significant economic benefits and competitive advantage to the UK if the initial investment and engineering challenges can be overcome;

• Major investment is needed now from the Government and private sector to ensure we achieve the scale, cost reductions and domestic capacity required;

• Establishment of the £800 million CCS Infrastructure Fund in the 2020 Budget is a welcome development;

• Need to develop long-term sustainable funding models for CCS and direct air capture and storage of CO2, such as a Carbon Take Back Obligation (CTBO);

• Scope for North Sea infrastructure to play a major role – potentially provides opportunities for blue hydrogen.

Net zero hydrogen

• Scope to manufacture green hydrogen from renewables, zero carbon hydrogen from nuclear, or blue hydrogen from gas with full carbon capture and storage;

• Uncertainty around the role it will play given technology and economics are still evolving, but it has significant potential;

• Could be key to decarbonising many industrial processes, heavy transport, and the gas network;

• Scope for it to provide an energy storage option and improve economics of overbuilding offshore wind capacity;

• The Government, together with Ofgem, should conduct a review as to what reforms will be necessary to ready the gas network to cope with high concentrations of hydrogen.

More information

netzeroappg.org.uk

New net zero requirement for UK oil and gas industry

A revised Strategy from the Oil & Gas Authority has been submitted for laying in the UK parliament, featuring for the first time an obligation on the oil and gas industry to support the UK's net zero target.

Oil and gas are expected to remain a vital part of the UK's energy mix for the foreseeable future, and the Strategy positions the UK Continental Shelf (UKCS) as a key enabler for the transition towards net zero carbon. The onus is on industry to step up efforts to reduce emissions from existing and new production; support carbon capture and storage projects; and help unlock clean hydrogen production.

The revised Strategy reflects the ongoing global energy transition. Oil and gas currently provide about 75% of the UK energy consumption and official government forecasts expect oil and gas to remain important to the UK's overall energy mix for the foreseeable future, including as we transition to net zero.

As long as this demand exists, managing production and maximising value from the UKCS as cleanly and efficiently as possible is necessary for security of supply, to ensure an orderly energy transition, and to reduce reliance on hydrocarbon imports. This is especially important as some imports, such as liquified natural gas (LNG) has a carbon footprint more than twice that of UK-produced gas.

The Strategy requires industry to operate in a way consistent with net zero ambitions, lowering production emissions and making serious progress on the solutions that can contribute to the UK achieving net zero. The OGA believes the industry has the skills, infrastructure and capital to help unlock net zero solutions, such as Carbon Capture and Storage (CCS) and hydrogen production.

In addition to the net zero obligation, the revised Strategy also requires industry to work in such a way that encourages collaboration with the supply chain and actively support carbon capture and storage projects. The OGA will monitor governance closely and ensure that carbon costs are considered in its regulatory decisions.

Alongside the direction set out in the Strategy, industry is also making progress in commitments to reducing production greenhouse gas emissions, and as well as stewarding towards emission reductions, the OGA will track, monitor, benchmark and report on this overall emissions reduction, and published its first benchmarking report on emissions from flaring and venting earlier this year.

The OGA said it is working with industry and government to unlock net zero opportunities at pace, and many in industry have already made real progress by taking positive action such as announcing targets for production emissions.

The OGA's analysis of Energy Integration illustrated the substantial overall net zero potential of the UKCS. Integration has the potential to make a deep and meaningful impact, with a possible 30% contribution towards the country's overall net zero target, primarily through CCS projects and through CCS plus hydrogen production. Adding offshore renewables (wind, wave and tidal) could take that up to 60% of the abatement required in 2050.

Dr Andy Samuel, OGA Chief Executive, said, "This is an important moment in the North Sea story, bringing a key sector of the economy into the overall net zero project. We have a clear vision for how to achieve this, supporting industry to reduce production emissions and to provide the infrastructure, expertise and capital to unlock game-changing carbon capture and storage and hydrogen production at scale."

"With around 30 energy transition projects already underway, this Strategy lays the foundation for that vision to become a reality, unlocking significant high value opportunities and jobs to last long into the future."

Net Zero Strategy

The OGA is embedding the net zero challenge in its own work, and supporting the industry as it rises to this challenge

Oil and gas will remain an important part of the UK energy mix for the foreseeable future, and maximising economic recovery from the United Kingdom Continental Shelf (UKCS) is vital to meet UK energy demand

The OGA is seeking views on its proposed revised strategy, which is now open for consultation

Carbon Storage Research Project

The OGA is seeking tenders from third parties with CCS project experience that aim to identify and describe risks and mitigations which must be considered as part of future carbon storage projects in the UK.

The key deliverable is a detailed checklist based on expert knowledge and evidence from analogue projects which will be used to support assessment of applications and stewardship of Carbon Storage licences.

It is envisaged that the project will begin on 1st February 2021 and must be completed by 31st March 2021. Tenders must arrive by no later than (22nd January 2021).

More information

www.ogauthority.co.uk

Southampton researchers' solution for turning carbon emissions into plastics

Scientists from the University of Southampton have invented a hybrid catalyst platform that can efficiently and sustainably convert carbon dioxide into versatile plastic materials.

The Viridi CO2 platform, created by Dr Daniel Stewart and Professor Robert Raja, has been recognised by the Royal Society of Chemistry (RSC) as a winner of its prestigious 2020 Emerging Technologies Competition.

The novel chemistry solution could be used to more effectively produce tens of millions of tonnes of plastics used annually in mattresses, clothing and building insulation, while also reducing carbon dioxide emissions.

In future, the technology could be retrofitted to the output streams of petrochemical refineries to close the carbon loop, representing a major step toward the UK's vision to bring all greenhouse gas emissions to net zero by 2050.

Viridi CO2 has emerged from Dr Stewart's doctoral research, which followed an MChem degree from Southampton's School of Chemistry. During this research he and Professor Raja invented the hybrid, heterogenous catalytic platform (PCT/GB2019/053596) capable of superior Carbon Capture Utilisation (CCU) potential compared with conventional Carbon Capture Storage (CCS) solutions.

Professor Raja's group has been developing a predictive catalyst design rationale at Southampton for the past 15 years, but this new technology represents a significant advance from the finite potential of CCS technologies while offering sustainable alternatives for the advanced manufacturing of plastics through CCU.

The award-winning approach has focussed on the production of polyurethanes. These materials, which can be tailored to be either rigid or flexible, are currently created solely from fossil fuels and are single use.

One way to improve the sustainability of these materials is to derive the starting materials, in this case the polyol, from carbon dioxide. This process produces polyols with carbonate linkages that allow the polymer to be more easily broken down at the end of its life and recycled.

There are, however, few catalysts capable of performing this transformation. Current processes suffer from using highly toxic chemicals, or require synthetically demanding and costly processes to remove the catalyst from the polymer, as is the case for homogeneous catalysts. The few heterogeneous examples available all require forcing conditions with extremely high pressures, temperatures and lengthy reaction times.

Viridi CO2's catalyst platform provides a route to polymer feedstocks that can be synthesised under more sustainable conditions with energy savings of up to 75 per cent. The innovation has been named the Energy and Environment winner of the RSC Emerging Technologies Competition, selected from over 90 proposals worldwide.

Dr Stewart, EPSRC IAA Research fellow within the School of Chemistry, says: "To have the endorsement of the Royal Society of Chemistry for the stage we're at is phenomenal, and gives us real impetus to speak with investors and stakeholders and demonstrate our enthusiasm and expertise in this area.

"Our platform is capable of maximum carbon dioxide insertion under lower temperatures, pressures and dramatically reduced timeframes. These benefits provide superior energy efficiency and high productivity leading to reduced costs. Unlike other alternatives, these catalysts can also be reused and synthesised in minutes."

The research team have filed a patent for the discovery and are participating in the SETsquared Innovation to the Commercialisation of University Research (ICURe) Programme, as they prepare to spin out the technology.

Professor Raja, Professor of Materials Chemistry and Catalysis, says, "This ground-breaking research is motivated by the lack of technologies utilising carbon dioxide as a viable synthetic feedstock, despite its low price and huge abundance.

"30 million tonnes of polyurethanes are produced globally every year yet they remain scarcely recyclable. They find use across many commercial sectors and the industry is set to grow to $70 billion by the year 2022. In the presence of uniquely designed catalysts, up to 50 per cent of the polyol feedstock mass can be replaced with carbon dioxide.

"By developing a platform-based design, we have shown that components of the catalyst can be modified, tuning the catalyst towards desired physical properties within the polymers. Having worked with multinational catalyst and petrochemical industries worldwide for over 20 years, we are optimistic the innovative and advanced characteristics of this catalyst platform can provide a significant manufacturing impetus to the UK chemical industry."

The Viridi CO2 platform was produced with research funding from the Engineering and Physical Sciences Research Council (EPSRC), with further scale-up work and commercialisation activities supported by an EPSRC Impact acceleration (IAA) award.

The team has been advised by the University's Future Worlds start-up accelerator and business mentor Chris Spackman, together with technology transfer expert Paul Wilkinson.

More information

www.viridico2.co.uk

www.southampton.ac.uk/chemistry

Compact light-weight CO2 capture technologies for small to medium-scale CO2 emitters

There is a significant challenge and opportunity for applying CO2 capture technologies to smaller emitters says a techno-economic investigation from The Catalyst Group Resources. However greater understanding is needed of the different CO2 point sources across all sectors and the different strategies needed for tackling them based on individual profiles.

While there are a smaller number of very large emitters, e.g. large-scale coal and gas-fired power plants, there are also a wide range of smaller energy plants and industrial emitters, for instance in chemicals, pulp and paper, refining and heavy industrial manufacturing. To date, the focus of carbon capture developments has been on large scale energy plants and systems developed for those emitters have varying potential for downsizing.

In terms of size, large emitters in the energy sector such as coal and gas fired power stations typically fall into the size of 1-5 GW. Associated CO2 emissions are in the order of 5-25 million tons CO2/y. Small-to-medium emitters fall approximately in the range of 50-750 MW and emit typically 1-5 million tCO2/yr. Globally these number in the order of 100,000s. These include smaller coal and gas energy plants, industrial emitters and some larger municipal plants e.g. waste to energy (WTE).

Combined Heat and Power (CHP) units located in industrial manufacturing plants also form part of those sectors profiles. In those schemes, there is potential to combine flue gas streams to go to one central capture plant. More challenging are lone CHP plants serving the needs of communities at district level, although there are a few projects in existence which are looking to do so.

Collectively industrial emitters account for around 20% of annual CO2 emissions. Even smaller point emissions in residential premises, municipal and commercial buildings account for >6% of CO2 emissions. However, there is a size limit below which capturing CO2 is not practicable and different decarbonisation approaches are employed (e.g. use of green hydrogen and carbon-neutral fuels).

A tailored solution for different industry sectors

Given the multitude of technologies evaluated, and the range of stationary emission sources discussed, the report aims to best match those sources with appropriate capture technologies:

- For dilute CO2 sources (< 20 %mol CO2) at high or low-pressure, and low-pressure sources up to 40 %mol, currently the only feasible technology that is currently available is amine absorption.
- With further development, the C-Capture process, and Inventys' VeloxoThermprocess may become viable commercial alternatives within a decade.
- For high concentration CO2 sources (≥ 30 %mol) at either high or low pressure, cryogenic capture and adsorption-based capture become viable.
- If excess refrigeration were available at a site, cryogenic capture, or physical absorption processes such as Rectisol, may become feasible alternatives based on a site-specific techno-economic analysis/FEED study.
- For oxy-fuel combustion, or oxygen generation in general, large scale O2 production (> 500 tpdO2) is currently most feasible by cryogenic distillation.
- Membrane-based technologies, and chemical looping technologies, are the furthest from commercialization.
- It is unlikely for chemical looping technologies to achieve commercialization, at least in the short-term, due to process complexity.

Unlike the energy sector, a range of industrial emission sources do not have low-emission alternatives (i.e. renewable energy) and tend to have multiple CO2 emission sources through the plant.

Downscaling of CCS for these types of emitters is a big challenge, although CO2 utilisation projects for instance for sustainable concrete production have relatively small CO2 recovery systems as part of the flowsheet. Near term, more obvious targets include sectors under pressure to reduce their carbon footprint e.g. cement and steel, oil refineries and some of the more energy intensive chemical sectors e.g. hydrogen and ammonia.

The vastly heterogenous characteristics of GHG sources across all these sectors, not just in terms of size, but also flue gas composition, accessibility and opportunities to build a surrounding CCUS infrastructure at specific site locations means a complex range of solutions are necessary.

Downsizing of CO2 capture systems designed for larger emitters can pose a big challenge. Some commercial solvent capture systems may have more scope to downscale than others.

There are various limitations to applying these methods at small-to-medium scale, namely the trade-off between capital and operating costs (CAPEX and OPEX) in the case of solvent approaches e.g. monoethanolamine (MEA). A high CAPEX translates to a higher penalty on process operating cost at small scale. Therefore, the comparatively high operating costs for MEA could not be justified when capital costs were also higher per tonne of acid gas capture.

A further possibility is to use membrane systems. Membranes have already been applied for a range of gas separations at the industrial scale, but the issues of fouling need to be overcome before they could be applied at scale for CO2 capture. Developments in commercial processes which would enable small-to-medium scale operations are discussed in the full report.

The report contains a full sectoral analysis including:

- Energy
- Iron and steel
- Cement
- Pulp and paper
- Refineries
- Ethylene production
- Ethylene oxide production
- Hydrogen production
- Ammonia production
- Natural gas processing
- Ethanol production

Technology overview

Considering the power sector is the largest CO2 emitter, the majority of research and development efforts have been directed towards this area, i.e. post-combustion capture, which involves the separation of CO2 from exhaust gases (flue gases). The advantage of post-combustion capture is that it is retrofittable to a range of processes considering its 'end-of-pipe' nature. A challenge in this area though are whether provisions have been made regarding process expansion.

The other capture technology being considered for the power sector is oxy-fuel combustion. Oxy-fuel combustion involves combustion of the fuel in an O2/CO2 atmosphere such that a CO2 rich flue gas is produced, requiring little further processing. Consequently, development around oxy-fuel combustion technologies are concerned about the economical production of O2 at large scales, as the traditional technology (cryogenic distillation) is energy intensive.

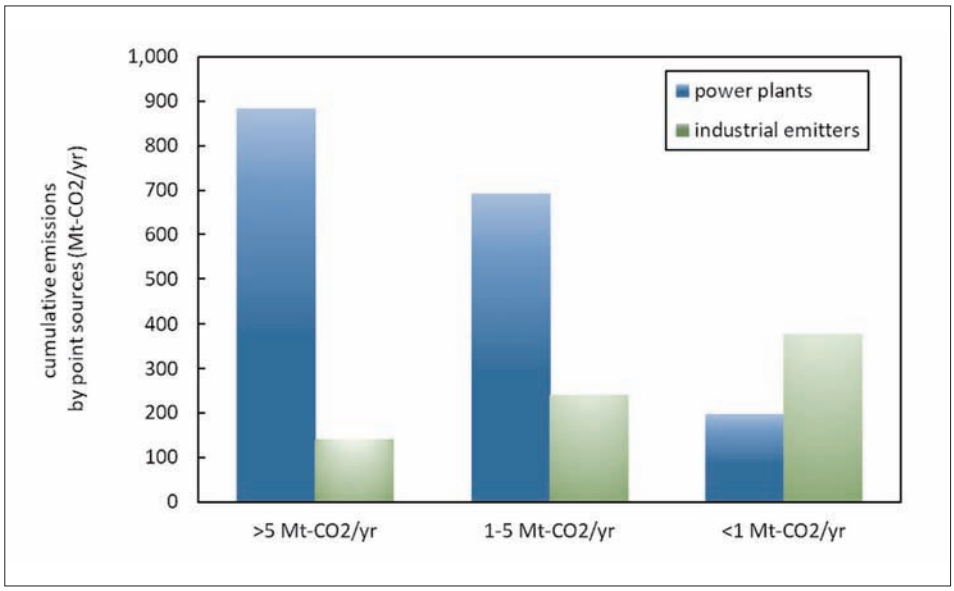


Figure 1 - US Emissions by point sources by size. Source: EPA, 2018

Regarding the heat sector, a range of alternatives are being proposed for its decarbonisation. They predominantly include green hydrogen, electrification, and carbon negative fuel sources. Green hydrogen involves producing H2 at plants with integrated CCS and distributing the produced H2 in existing natural gas networks for combustion.

Electrification would allow heat to be generated using heat pumps or direct heating using electricity produced from low-carbon electricity sources, however, the success of this is reliant on the development of local electricity grids to tolerate the increased demand. Carbon negative fuel sources such as biogas or biomass are also an alternative, as the combustion of said fuel would result in low-carbon or carbon-neutral heating.

Combined heat and power (CHP) plants in various forms contribute approximately half of global heating demand for district heating. In addition, the majority of industrial facilities have on-site CHP plants to meet their utility requirements – many thousands globally. These may present a number of CCS opportunities, however, retrofitting CCS to these plants will reduce the energy available for end-use.

The production of steel, cement, ethylene oxide, hydrogen (and ammonia), and ethanol, all have steps where the production of CO2 is unavoidable due to the process chemistry. Most of these emission sources can be considered for post-combustion capture, as the CO2 is generated from the combustion of a carbonaceous fuel with air, and in the case of clinker production in the cement process, the calcination of the lime further enriches the CO2 content in the flue gas.

In specific cases such as H2 separation from syngas in hydrogen production, where a CO2/CO/H2 separation takes place, it is considered pre-combustion capture. The term pre-combustion capture originated from the concept that H2 could be used a fuel source, the combustion of which would produce H2O. Syngas is produced by the reforming of natural gas, or gasification of other carbonaceous material (coal, oil, biomass), from which the CO2 is separated prior to combustion of the fuel.

Commercial progress

There are a range of technology alternatives for the main CO2 methods, post-combustion capture, pre-combustion capture, and oxy-fuel combustion that are at various stages of commercial development. There are some

technologies which seem promising and may become viable in the medium term if further development funding can be secured.

The C-Capture post-combustion capture process based on non-amine absorbents has advantages in terms of corrosivity, degradation, and regeneration energy. Inventys' VeloxoTherm technology has seen promising developments in making temperature swing adsorption (TSA) accessible to CO2 capture by reducing process cycle times from hours to minutes, resulting in significant process intensification.

Some technologies have shown progress; however, their future is uncertain. The Air Liquide hollow fibre membrane (HFM) cryogenic process, and the MTR Polaris process for post-combustion capture have seen reasonable development, with the MTR process being scaled up to 20 tpdCO2. The main concern about membrane processes is that CO2 product purities are low, requiring further processing for most CCUS applications inhibiting commercialisation.

Air Products' Ion Transport Membrane (ITM) process for low-cost O2 production did experience reasonable development and is the closest to commercialisation. However, due to the high process temperatures required, it is not a viable integration option for most processes which is key to minimising energy consumption. Development by Air Products appears to be discontinued.

Another CO2 capture method which has been proposed more recently is direct air capture (DAC). As the name implies, CO2 is captured from the ambient air, resulting in net negative emissions. There are three main competitors for DAC technology, Carbon Engineering, Climeworks, and Global Thermostat. Carbon Engineering proposes a chemical absorption process, and the latter two operate adsorption-based processes.

Although a range of carbon capture technologies are being proposed and have been investigated, the majority of them are still in the early stages of development. The Aker Solutions Just Catch system is an immediately viable option for post-combustion capture at scales up to 0.1 MM tCO2/yr.

Air Liquide's CryoCAP™ process, and packed-bed pressure swing adsorption (PSA) processes offered by the traditional vendors are viable options for pre-combustion capture applications. Air Liquide also offers a CryoCAP™ Steel which is an alternative post-combustion capture technology for steel and cement processes.

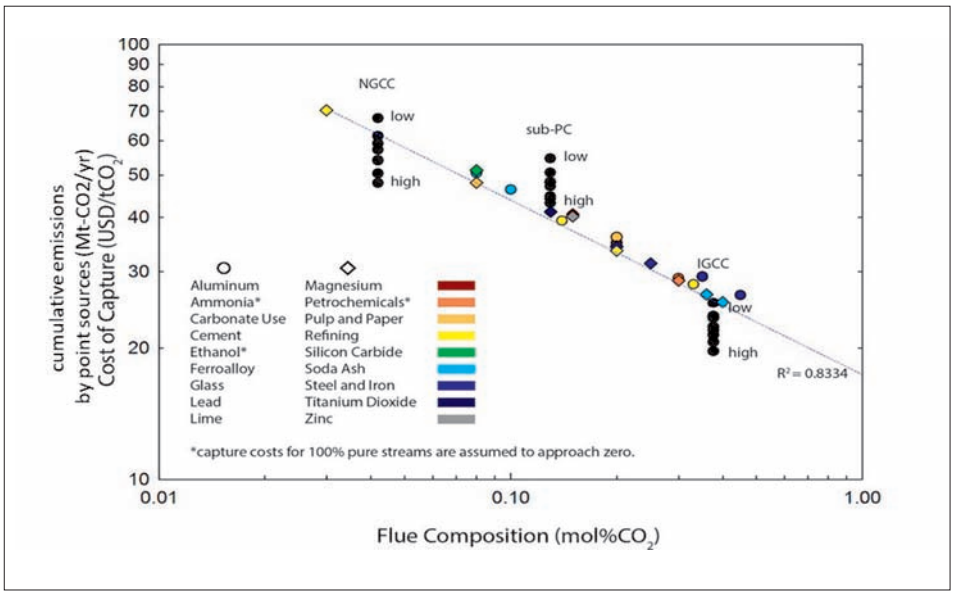


Figure 2 - Prediction of capture costs from a range of industrial sources (coloured symbols), and power generation (black circles) for low and high flow rates (Psarras et al., 2017)

Due to the costs associated with O2 production at the scales required for oxy-fuel combustion, combined with limited developments in this area, it is unlikely that oxy-fuel combustion will become a commercially viable CCUS alternative.

Chemical looping processes could be considered as still being in their infancy. There are a range of issues regarding adsorbent life, and process configurations are generally complex. In conjunction with the requirements for high-grade heat and oxygen, it is unlikely that these processes will achieve commercialisation.

Membrane-based separation processes are also unlikely to achieve commercialisation for post-combustion capture applications; however, offerings from Air Liquide and MTR may be feasible for pre-combustion capture applications. There are also a range of instances where membranes from a range of vendors are already being applied for high-pressure CO2/CH4 separations.

Although DAC has a number of concerns from an overall feasibility perspective, it does have the advantage of having high public acceptance. Although it may not be the most sound alternative from a techno-economic perspective, it may experience deployment due to this factor alone.

In the next issue

This is the second in a series of articles summarising key reports from The Catalyst Group Resources Carbon Dioxide Capture and Conversion (CO2CC) Program.

The next issue will feature "Advances in Direct Air Capture of CO2". Don't miss "Technical and Commercial Progress Towards Viable CO2 Storage" which featured in the previous issue.

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More information

More information about this and other services of the CO2CC Program can be found at:

www.catalystgrp.com/php/tcgr_co2cc.php

How the US 45Q tax credit is motivating CCS

There are around 30 CCS projects at various stages of development in the US, largely thanks to the 45Q tax credit. But there are concerns that it is too small to make projects work financially, or too difficult to work with. By Karl Jeffery.

Following the implementation of the US 45Q tax credit scheme in 2018, there are now over 30 CCS projects in various stages of development in the US, with a wide range of applications, business models and technology.

Under this scheme, you can get $35/tonne tax credit for CO2 sequestered as part of an enhanced oil recovery (EOR) project, in addition to any financial reward you get for using the CO2 in EOR. If you sequester the CO2 in a saline aquifer with no EOR, you can get $50 a tonne CO2 tax credit.

This article is based on a conference session at CCUS 2020 on Dec 3, "Beyond 45Q: Policy, projects and infrastructure for a US carbon capture market," moderated by Lee Beck, CCUS Policy Innovation Director at the US Clean Air Task Force (CATF).

All US CO2 storage projects up to now have been in enhanced oil recovery. As a result of the EOR business, the US has 5,000 miles of CO2 pipeline, carrying 70m tonnes of CO2 a year in a commercial activity.

CO2 capture in saline aquifers can be a more complex business to establish, because you need a way to de-risk the investment in the infrastructure. This is more easily done for EOR because you have a revenue stream from the improved oil production, said Jessie Stolark, Public Policy & Member Relations Manager, with the Carbon Capture Coalition.

The Coalition would like the US government to take more of a role in developing the CO2 transport infrastructure and network, so reduce the risk to investors.

The Carbon Capture Coalition is set up by the Great Plains Institute, an environmental organisation based in Minneapolis, with a mission to encourage economy wide deployment of carbon capture. It has 3 goals which are treated equally – reducing emissions, supporting domestic energy production, and supporting jobs.

Until 2018, the Coalition was focussed on getting 45Q agreed. It has now expanded its role to supporting uses of CO2 other than EOR, projects to capture carbon monoxide, and direct air capture, Ms Stolark said.

The Great Plains Institute has done some modelling on what the US CO2 network could look like, including some "near term" opportunities for CO2 capture, and identifying suitable CO2 storage locations. It drew a map covering 22 states, a vertical band through the middle of the US, "our most industrialised area of the country."

The study found ways to capture and store 300m tonnes CO2 a year. "They found if you do co-ordinated planning from the beginning, you dramatically lower cost and lower the environmental impact," she said.

In terms of the new presidency and administration, it will be interesting to see what policy is developed for supporting energy intensive industries, she said. "We haven't really figured out how to maintain those sectors domestically, without offshoring a lot of industry. We've seen commitment from Joe Biden, he's really interested in working on it."

There have been some complexities arising with 45Q, she said. Facilities are required to begin construction by 2024 to be eligible. But guidance from the US Internal Revenue Service (IRS) took 2 years to be produced, which means that the construction window has been reduced from 6 years to 4.

There is a minimum threshold of 500,000 tonnes CO2 per year, so facilities smaller than this do not qualify. This means that to invest in a carbon capture project you need to have a very high tax "equity", because the money is offered as a tax credit. So for a $50 / tonne tax credit, you would need to be paying a minimum of $25m annually in tax to qualify.

"We are arguing that thresholds should be eliminated." she said. "it does nothing to help commercialise carbon capture".

The credits could also be bigger. The amount of tax credit provided is generally high enough to justify sequestering a pure CO2 stream, such as produced from ethanol fermentation or natural gas processing, but not enough to justify the costs when the CO2 separation (or capture) process is included.

DOE perspective

Within the US government, carbon capture has strong support from both Democrats and Republicans, and support is expected to continue under Joe Biden's presidency, said Jarad Daniels, Director, Office of Strategic Planning, Analysis and Engagement at the US Department of Energy (DOE).

The Department's CCS research focus until now has been mainly on reducing costs, but now it is focussing on expanding carbon capture beyond the power sector – to industrial capture, bioenergy, and hydrogen production integrated with CCS.

It has also done work on storage research through its "carbon sequestration partnerships." This work involves analysis, development of models, and submitting applications to the US Environmental Protection Agency, requesting approval for a "Class 6 well" used for CO2 sequestration.

One regulatory possibility which would help carbon capture is if some of the US states with renewable portfolio standards could change them to low carbon standards (so CCS can be included), he said.

There may also be opportunities to combine state level incentives around emission control technologies with 45Q, he said.

Mr Daniels was asked about the Department of Energy's perspective on hydrogen. "I've been at DOE for 26 years. [Over this time] hydrogen has been in vogue, out of vogue," he said.

"Hydrogen looks like an efficient way to decarbonise some sectors, such as transportation. Most of our analysis shows there needs to be a strong blue hydrogen or fossil derived component in the near term, with [increasing] renewable derived hydrogen feeding in that system."

Occidental Petroleum and CCS

Occidental Petroleum is the "largest sequesterer of CO2 in the world," through its CO2 EOR business – which it is now using as a seed to get into saline aquifer storage

Occidental Petroleum, an international oil and gas company based in Houston, is using its experience in CO2 for enhanced oil recovery as a "seed for us getting into a broader [CO2] ecosystem," said Ryan Edwards, Low Carbon Policy Advisor with Oxy Low Carbon Ventures.

He was speaking at a conference session "Beyond 45Q: Policy, projects and infrastructure for a US carbon capture market", part of CCSA's "CCUS2020" event in late November.

Occidental has been doing CO2 EOR for 40 years, currently sequestering 20m tonnes of CO2 annually, and can claim to be the "largest sequesterer of CO2 in the world," he said. It also has an extensive CO2 pipeline infrastructure in West Texas.

"That background, experience and expertise became an opportunity to turn into a new business model."

Occidental launched Oxy Low Carbon Ventures as a subsidiary company, to invest in new CCUS technologies, develop projects, and provide consulting services to others.

It fits with Occidental's net zero target of 2050, where emissions from use of the company's oil and gas will also be 'net zero', so offset with net negative CO2 projects elsewhere. It also means that Occidental is "transitioning to being a carbon management company as well as an oil company."

Occidental has invested in Carbon Engineering, a Direct Air Capture technology company in Squamish, British Columbia; Net Power, a company developing a gas power technology which captures CO2 in a different way, in Durham, North Carolina; and Cemvita, a Houston biotech start-up which mimics photosynthesis, using CO2 as feedstock to produce industrial chemicals and polymers.

The company is involved in a number of projects linked to the US 45Q tax credit for carbon capture schemes. "There's a very big diversity in where these projects are, what industries," he said.

The list of projects includes potentially CO2 negative biofuels projects, a cement plant in Colorado, and the development of sequestration sites and hubs around the US. "Carbon capture can be a really flexible tool in reducing emissions," he said.

It is partnering with Carbon Engineering "to build the first large scale direct air capture facility in the world" in West Texas, with CO2 used for EOR, starting construction by the end of 2022, capturing up to 1m tonnes CO2 per year, "a huge scale up on where we've been before."

The carbon in the increased oil produced is about the same as the carbon in the CO2 which is injected. "One of our goals is to create carbon neutral or slightly carbon negative fuel."

A follow-on project could involve injecting CO2 from direct air capture into saline geological storage.

The company has another project with Velocys of Oxford, UK, to convert waste biomass to diesel and jet fuel, with CO2 created during the process being sequestered. "The net life cycle emissions are quite strongly negative," he said.

It also launched a development company to finance the projects.

Infrastructure

The projects being planned at the moment are about half EOR, half saline aquifers. There is no clear answer about whether better returns are available for CO2 EOR projects or saline aquifer projects, he said. CO2 EOR gives you returns from the enhanced oil recovery, saline aquifer projects attract a bigger tax credit.

The main criteria for choosing is your location. If you are near an EOR project, there is existing infrastructure and CO2 storage you can use. "You can plug in [a new project] very quickly. That's a huge advantage. Maybe some of the faster opportunities will be EOR."

Lee Beck, CCUS Policy Innovation Director at the US Clean Air Task Force (CATF), moderated the conference session at CCUS 2020 on Dec 3, "Beyond 45Q: Policy, projects and infrastructure for a US carbon capture market."

Transport and storage infrastructure "is critical to scaling up the industry to where it needs to go. The more infrastructure there is, the more projects," he said.

"Just realising economies of scale, the more CO2 you put through one pipeline, the more CO2 in one storage site, the dramatically lower costs, through scale."

It also helps build markets. "If you have one capture project connecting to one sequestration site, they are mutually dependent on each other. Once you have a connected system, many buyers, many sellers, the risks get lower, the financing cost gets lower."

It avoids the chicken and egg problem, where no-one will build storage infrastructure if they are not sure if there will be any CO2 captured, and vice versa.

"The US is in the enviable position of having extensive infrastructure in some parts of the country. This kind of connected system can already happen."

"If you look at a map of where these 30 projects have been announced so far, they are all either very close to the existing CO2 pipeline network or very close to CO2 storage."

Policy

Since 45Q is structured as a tax credit, you need to be paying tax elsewhere to use it. If it was converted into a cash grant scheme, it could be much easier to get projects financed and built, he said.

California's low carbon fuel standard is "a really important policy," he said, providing a potential revenue stream for carbon capture projects. It is an emissions trading scheme but limited to transportation fuels within California. Because of the difficulty of decarbonising transportation fuels, credits trade at $200 / tonne.

But that makes a very good incentive for driving carbon capture projects, particularly as companies can simultaneously take advantage of 45Q. It also means "you're in the ballpark of what direct air capture costs for these early projects. It is the most important policy in the world right now for direct air capture."

Improving CCS knowledge sharing

Lamberto Eldering, Business Developer Low Carbon Solutions with Equinor, explained some of the CCS knowledge sharing which has been going on in Europe over the past decade, and how useful it was. By Karl Jeffery.

There has been a lot of carbon capture knowledge sharing in Europe over the past few years, even though there are not many projects to show for it, said Lamberto Eldering, Business Developer Low Carbon Solutions with Equinor.

Today's projects "will not be able to be where they are today if not for the knowledge sharing we have seen in the last 10 years. We cannot do cost reduction if we are not sharing what we have learned."

Equinor's two CCS projects in the Norwegian Continental Shelf were themselves based on US CO2 EOR projects. "They were the grandfathers for these projects to take their investment decisions."

Norway also developed a great deal of know-how at its Technology Centre Mongstad carbon capture research centre.

In the UK, the FEED studies for both cancelled CCS projects Peterhead and White Rose are freely available on the UK government (BEIS) website. "There's tonnes of information out there to be used," he said.

A session was held at the end of the first UK CCS commercial program, where all project developers and stakeholders spent a day answering questions from an audience. "I'm confident the projects in UK are still benefitting from that day."

There have also been 8 projects around Europe developing CCS, supported by the EU Recovery Program. Each project included a knowledge sharing session.

The most useful format for knowledge sharing is "direct interactions," he said, such as "where project developers are sitting together on a table."

A few years ago, there was a meeting between project developers for Norway's Northern Lights project and the Netherlands Porthos project. "We sat together for one and a half days."

There was a commercial session, looking at business cases and how to get funding, and a technical session, talking about how to set up the storage.

It was very useful for the Porthos team to learn about the experiences in Norway, and it was useful for the Northern Lights team to "see where our project sits compared to the potential market out there."

More information

www.ccsassociation.org

Projects and policy news

HeidelbergCement to install the world's first full-scale CCS facility in a cement plant

www.heidelbergcement.com

www.akercarboncapture.com

The Brevik full-scale carbon capture and storage facility is the first in the world on a cement plant and will use Aker Carbon Capture's technology.

The Norwegian parliament has approved the investment in a full-scale carbon capture facility at the HeidelbergCement Norcem plant in Brevik, Norway. The Brevik CCS project will enable the capture of 400,000 tonnes of CO2 per year and the transportation for permanent storage, making it the first industrial-scale CCS project at a cement production plant in the world.

The Brevik CCS project will enable the capture of 400,000 tonnes of CO2 per year and the transportation for permanent storage, making it the first industrial-scale CCS project at a cement production plant in the world

Work on the new facility in Brevik is expected to begin immediately, with the goal of starting CO2 separation from the cement production process by 2024. The end result will be a 50% cut of emissions from the cement produced at the plant.

Aker Carbon Capture have signed an agreement for the engineering, procurement and construction (EPC) delivery of the CO2 capture, liquification and intermediate storage plant.

"We are delighted about the final approval of the Norwegian parliament for our breakthrough CCS project in Norway," says Dr Dominik von Achten, Chairman of the Managing Board of HeidelbergCement. "To meet national and international climate targets, CO2 separation is an important cornerstone. Our CCS project in Brevik will pave the way for our industry and other sectors."

Giv Brantenberg, General Manager HeidelbergCement Northern Europe and Chairman of the Board of Norcem says: "HeidelbergCement highly appreciates the successful cooperation with the Norwegian authorities. The Brevik CCS project clearly shows the importance of industry and public sector to find common solutions in the fight against climate change."

The Norwegian government had shortlisted Brevik for an industrial-scale CO2 capture trial at the beginning of 2018. In September 2019, a memorandum of understanding on the capture and storage of CO2 was signed by HeidelbergCement and the state-owned Norwegian energy Group Equinor. The project funding is largely supported by the Norwegian government as part of the Norwegian full-scale 'Longship' climate investment project that comprises capture, transport and storage of CO2.

HeidelbergCement has committed itself to reduce its specific net CO2 emissions per tonne of cementitious material by 30% compared to 1990 by 2025. This figure had previously only been targeted for 2030. To achieve this, the company has defined concrete CO2 reduction measures for all plants worldwide. HeidelbergCement aims to offer carbon-neutral concrete by 2050 at the latest.

Congress acts to boost CCUS in year-end spending package

carboncapturecoalition.org

The Carbon Capture Coalition said the Omnibus Spending Bill passed by Congress includes its top priorities.

The full text of the omnibus spending bill is now public. The bill includes a two-year extension of the 45Q tax credit and numerous provisions boosting carbon capture and removal research, development and demonstration, all top priorities for the Carbon Capture Coalition.

Carbon Capture Coalition Director Brad Crabtree released the following statement on the expected passage of the 2020 omnibus spending package, which includes the Energy Act of 2020 and a two-year extension of the 45Q tax credit:

"The 2020 omnibus spending package includes vitally important provisions that mark a critical next step toward a federal policy framework for economywide deployment of carbon capture and removal to put our nation on the path to achieving net-zero emissions to meet mid-century climate goals, while preserving and creating high-wage domestic energy, industrial and manufacturing jobs."

"This omnibus legislation features a sweeping update and expansion of federal research, development and demonstration programs for carbon capture, removal, use and storage through inclusion of the bipartisan Energy Act of 2020, along with enactment of a two-year extension of the 45Q tax credit, which are among the Carbon Capture Coalition's top priorities in this Congress. While the Coalition's other top priority of a direct pay option for 45Q did not make it into the final package, the measures included in the omnibus make this year-end legislation the most important accomplishment for carbon capture and removal since passage of the 2018 FUTURE Act that reformed and expanded the 45Q tax credit."

ADNOC and Total Sign Strategic Framework Agreement on CCUS

www.adnoc.ae/en

www.total.com

The agreement is to explore joint research, development and deployment partnership opportunities in the areas of CO2 emission reductions and carbon capture, utilization and storage.

Under the terms of the agreement, ADNOC and Total will jointly explore opportunities to reduce CO2 emissions, improve energy efficiency and use renewable energy for oil and gas operations. In the area of CCUS, the companies will further develop joint research into new technologies covering carbon capture, storage solutions and enhanced oil recovery projects based on CO2 usage.

The agreement was signed by His Excellency Dr. Sultan Ahmed Al Jaber, UAE Minister of Industry and Advanced Technology and ADNOC Group CEO, and Patrick Pouyanné, Chief Executive Officer of Total.

H.E. Dr. Al Jaber said, "We are pleased to strengthen our partnership and alliance with Total as we work towards a low carbon future. The agreement builds on our sustainability goal to decrease greenhouse gas (GHG) intensity by 25 percent by 2030, and reinforces ADNOC's commitment to responsible oil and gas production as we deliver on our 2030 smart growth strategy."

"We look forward to leveraging this expertise and collaborating with Total to further research and develop low carbon technologies and sustainable growth opportunities."

The potential for collaboration in CCUS by ADNOC and Total complements ADNOC's CCUS program which has seen the company establish the Al Reyadah facility, the first commercial-scale CCUS facility in the Middle East.

Currently, the facility has the capacity to capture 800,000 tonnes of CO2 annually. ADNOC plans to expand the capacity of this program six-fold by capturing CO2 from its own gas plants, with the aim of reaching 5 million tonnes of CO2 every year by 2030 – the equivalent of the annual carbon capture capacity of over 5 million acres of forest.

Patrick Pouyanné, Chairman & CEO of Total, said, "We are very pleased to start this new cooperation with ADNOC, our long-term partner in the United Arab Emirates."

"This initiative will allow the two companies to join forces in several domains such as the reduction of carbon emissions on industrial sites, improvement of the energy efficiency in operations, and the development of innovative solutions and business models towards the CCUS chain."

"This is a perfect example of Total's commitment to leverage its global presence and expertise to act towards its 2050 net-zero ambition alongside its long-standing key partners."

Total currently collaborates with ADNOC across the full value chain, from offshore and onshore exploration, development and production of oil and gas, to gas processing and liquefaction, product marketing, research and development (R&D), and National Talent development.

Construction of Climeworks' direct air capture and storage plant Orca begins

climeworks.com

The plant combines Climeworks' direct air capture technology with the underground storage of carbon dioxide provided by Carbfix on a much larger scale, capturing 4000 tons of CO2 per year.

Orca will permanently remove CO2 from the atmosphere on behalf of corporations or institutions as well as individuals. A unique subscription-based program enables anyone to join nearly 3000 who have lready signed up.

The rapid construction of Orca has just started and will take six months. Due to the modular nature of the Climeworks technology it is possible to achieve short construction times, which will be a key enabler for scaling the technology in the future.

The construction of Orca comprises two phases: phase one started in October and is expected to be completed by the end of this year. It includes the infrastructure and the foundation for the new generation of Climeworks' CO2 collectors. Phase two involves the installation of the plant and machinery in Iceland and is expected to be finalized by spring 2021.

Orca, once complete, will remove over 4000 tons of CO2 from the atmosphere every year, making it the largest direct air capture and storage plant to date. Orca is being built close to ON Power's Hellisheidi Geothermal Power Plant in Iceland, meaning that all the energy required to run the direct air capture process at Orca will come from purely renewable sources. Underground storage of CO2 is performed by Carbfix.

Carbon Clean and Veolia to develop CCUS projects in India

www.carbonclean.com

The newly established company Veolia Carbon Clean will first develop two CCUS and compressed biogas (CBG) projects in India, using Carbon Clean's patented CDRMax and MethPure technologies.

CCUS and biofuels (including CBG) are both important components of India's future green energy mix, as outlined in the Government's 2018 Sustainable Alternative Towards Affordable Transportation (SATAT) scheme. SATAT aims to produce 15 million tonnes of CBG from 5,000 plants by 2023, along with generating 50 million tonnes of bio-manure.

Through increased domestic production of biofuels, the scheme aims to help India to reduce imports, generate employment, and reduce pollution. This partnership between Veolia and Carbon Clean is an important step in the right direction.

Veolia Carbon Clean will finance, design, build and operate these projects, and will find opportunities for other projects in this country. Guillaume Dourdin, CEO Veolia India, said: "This partnership is a great opportunity to illustrate Veolia's commitment towards combating climate change in India by deploying solutions to mitigate CO2 emissions."

"Through Veolia Carbon Clean we look forward to creating resilient projects which will help companies to lower their carbon emissions in a sustainable manner and thus contribute towards reducing pollution levels in the country."

From today, the Board of Veolia Carbon Clean will consider proposals for setting up new green projects in India, including those involving CO2 capture, that comply with Investment Criteria. Interested project developers can contact the companies via: enquiry.in@veolia.com

New method to make carbon spheres developed

A fast, green and one-step method for producing porous carbon spheres which capture CO2 has been developed by Swansea University researchers. The method produces spheres that have good capacity for carbon capture, and it works effectively at a large scale.

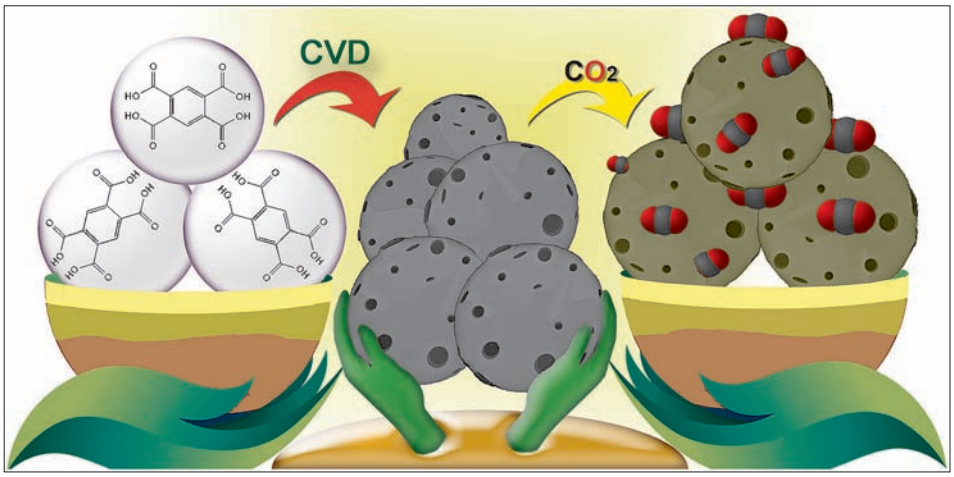
Carbon spheres range in size from nanometers to micrometers. Over the past decade they have begun to play an important role in areas such as energy storage and conversion, catalysis, gas adsorption and storage, drug and enzyme delivery, and water treatment.

They are also at the heart of carbon capture technology, which locks up carbon rather than emitting it into the atmosphere, thereby helping to tackle climate change.

The problem is that existing methods of making carbon spheres have drawbacks. They can be expensive or impractical, or they produce spheres that perform poorly in capturing carbon. Some use biomass, making them more environmentally friendly, but they require a chemical to activate them.

This is where the work of the Swansea team, based in the University's Energy Safety Research Institute, represents a major advance. It points the way towards a better, cleaner and greener way of producing carbon spheres.

The team adapted an existing method known as CVD – chemical vapour deposition. This involves using heat to apply a coating to a material. Using pyromellitic acid as both carbon and oxygen source, they applied the CVD method at different temperatures, from 600–900 °C. They then studied how efficiently the spheres were capturing CO2 at different pressures and temperatures



A new procedure can produce spheres at large scale without relying on hazardous gas and liquid feedstocks unlike other CVD methods

Findings of the research

They researchers found that:

• 800 °C was the optimum temperature for forming carbon spheres

• The ultramicropores in the spheres that were produced gave them a high carbon capture capacity at both atmospheric and lower pressures

• Specific surface area and total pore volume were influenced by the deposition temperature, leading to an appreciable change in overall carbon dioxide capture capacity

• At atmospheric pressure the highest CO2 adsorption capacities, measured in millimolars per gram, for the best carbon spheres, were around 4.0 at 0 °C and 2.9 at 25 °C.

This new approach brings several advantages over existing methods of producing carbon spheres. It is alkali-free and it doesn't need a catalyst to trigger the shaping of the spheres. It uses a cheap and safe feedstock which is readily available in the market. There is no need for solvents to purify the material. It is also a rapid and safe procedure.

Dr Saeid Khodabakhshi of the Energy Safety Research Institute at Swansea University, who led the research, said, "Carbon spheres are fast becoming vital products for a green and sustainable future. Our research shows a green and sustainable way of making them."

"We demonstrated a safe, clean and rapid way of producing the spheres. Crucially, the micropores in our spheres means they perform very well in capturing carbon. Unlike other CVD methods, our procedure can produce spheres at large scale without relying on hazardous gas and liquid feedstocks."

"Carbon spheres are also being examined for potential use in batteries and supercapacitors. So in time, they could become essential to renewable energy storage, just as they already are for carbon capture."

The research was published in the journal "Carbon".

More information

www.esri-swansea.org

www.swansea.ac.uk

Novel method of studying glassification in CO2 capture

Studying the process of glassification in post-combustion carbon capture solvents could inform the development of successful prototypes.

Researchers from ISIS Neutron and Muon Source alongside collaborators from University of Texas (El Paso), Washington State University and Pacific Northwest National Laboratory (PNNL) have studied glassification in carbon capture solvents, which causes the failure of carbon capture technologies.

This work is the first paper that focuses on glassification and how working above glass transition temperature can minimize clusters and prompt more efficient testing of carbon capture and sequestration technology.

Solvent-based technology is the most mature post-combustion carbon capture solvent technology that is undergoing testing. The advantage of using solvent-based technologies is that their formulation can be designed to reduce the amount of water used. These "water-lean" compounds exhibit unique physical and thermodynamic properties that make them more efficient. For example, by using a concentrated CO2-rich solvent, less material is heated during regeneration.

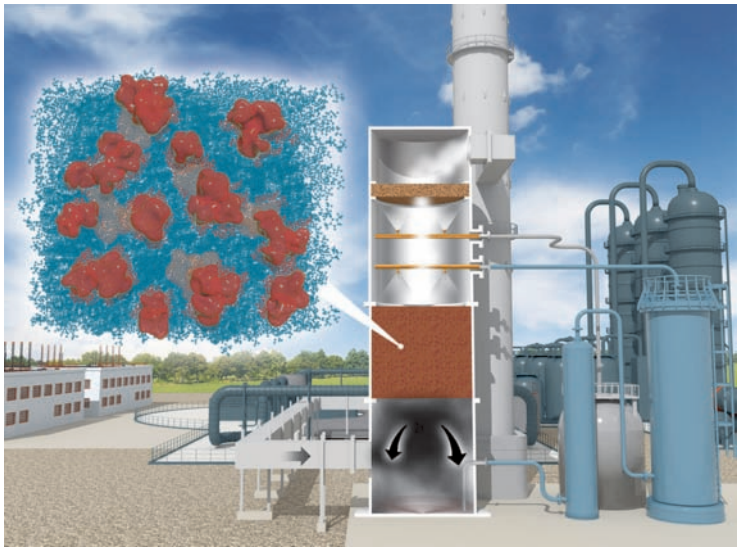
Researchers from ISIS alongside other collaborators have been studying the properties of these concentrated solvents, such as CO2-binding organic liquids (CO2BOLs). These are derived from chemicals known as alkanolguanidines.

Their recent study, chosen as a 2020 HOT article in the "Physical Chemistry and Chemical Physics"? journal?, implements new structural measurements using ISIS instruments NIMROD and Larmor, combined with computational studies, to measure changes in the CO2BOL, 1-IPADM-2-BOL.

They began with viscosity test simulations with "CO2-rich" and "CO2-lean" solvents. The same experiment was repeated with a fresh batch of 1-IPADM-2-BOL and another material with a similar chemical structure.

Based on the simulations, they found that the viscosity increases in alkanolguanidine solvents coincide with the glassy state that is driven by changes in the orientation of hydrogen bond in the solution.

To explain the structural changes that were converting the 1-IPADM-2-BOL to a glassy state, the scientists used neutron diffraction on Nimrod, combined with computer simulations, to investigate the molecular and nanoscale interactions within the water-lean solvent, and observe changes in the solvent structure as the temperature was changed. They found that the glassy state is consistent with the CO2-loaded solvent.



The formation of clusters can degrade solvent performance in post-combustion CO2 capture systems

Using Larmor to take SANS measurements to outline the behavior and properties of the solvent, they took measurements at temperatures ranging at - 5°C to 40°C. These showed the formation of large aggregates with declining temperature, and the opposite with a temperature increase.

Ultimately, they found that the heating and cooling of these clusters is reversible and temperature-dependent, much like a glass transition. They saw that the alkanolguanidine solvents, such as 1-IPADM-2-BOL, show a first-order phase transition at 40°C, which is near to the absorption temperature for post-combustion CO2 capture processes.

Although further research has to be conducted into this area, the molecular-level understanding of alkanolguanidine-based solvents is crucial in exploiting commercial operations that help lessen carbon emissions.

When asked about the impact of the work Dr David J Heldebrant, from PNNL, explains, "Climate change is a global challenge that will require multinational approaches to solve. This international collaboration between our team and the world-class scientists using cutting edge instrumentation and analytical capabilities at ISIS was paramount to making this study of the behavior of carbon capture solvents a success."

This research is based on work supported by the U.S. Department of Energy, Office of Science Basic Energy Sciences Early Career Research Program FWP 67038 in the Chemical Sciences, Geoscience, and Biosciences (CSGB) Division.

More information

www.isis.stfc.ac.uk

Capture and utilisation news

Aker Carbon Capture and MAN Energy Solutions collaborate on CCS compression

www.man-es.com/process-industry/products/compressor

www.akercarboncapture.com

The companies have signed a technology-cooperation agreement to develop energy-efficient compression solutions for CCS applications with heat recovery.

With CCS, captured CO2 is compressed before being liquefied and transported to a permanent-storage location. The two companies aim to develop carbon capture solutions that require less energy. The transfer of heat is key for CO2-capture plants' improved, overall power-consumption with MAN Energy Solutions able to recover heat from its compression systems. Hence, the steam generated will cover nearly 50% of the power demand for Aker Carbon Capture's capture plant.

The cooperation builds on MAN's experience in compressor technology, the integration of system components and their design and delivery, as well as Aker Carbon Capture's proprietary amine technology and efficient carbon-capture process design.

"We are very pleased to formalize our good relationship with MAN Energy Solutions in the form of a technology-cooperation agreement. Through this partnership, we intend to further improve the process efficiency and thereby lower the cost of carbon capture to the benefit of our clients and the environment," said Valborg Lundegaard, CEO of Aker Carbon Capture.

The technology-cooperation agreement will run for seven years and forms the basis for project deliveries to carbon-capture plants. Solutions will be applicable for large facilities, such as the Heidelberg Cement Norcem cement plant in Brevik, Norway where Aker Carbon Capture will deliver a carbon-capture plant using the company's patented and HSE-friendly CCS technology.

"Carbon capture and storage will play a major role in a decarbonized future. This technology contributes both to reducing emissions in key sectors directly, and to removing CO2 to balance unavoidable emissions, which is critical with regard to the targets of the Paris Agreement," stated Dr Uwe Lauber, CEO of MAN Energy Solutions. "As experienced forerunners in the CCS field, we will build on our well-founded knowhow and work together on new, energy-efficient, environmentally-friendly CCS-technology solutions."

Braskem studies sustainable plastic production from CO2 capture and use

www.braskem.com.br

Braskem joined the University of Illinois at Chicago (UIC) to research a development route for ethylene, a raw material used in the production of thermoplastic resins, using CO2 emitted in industrial processes.

The project is in its initial stage of development and Braskem will have the mission of combining its know-how in the commercialization of raw materials and production of polymers with the aim to scale the technology, contributing to the validation of theoretical and experimental studies, produced by the University .

"Reducing carbon emissions is a fundamental premise for combating climate change, a commitment that is part of our macro-objectives for sustainable development. The objective of the partnership with the University of Illinois in Chicago, is to evaluate the possibility of capturing and converting the CO2 emitted in our industrial operation to make it a raw material in our polymer production processes ", said Luiz Alberto Falcon, responsible for Braskem's recycling platform.

According to a study by the International Energy Agency, the global chemical industry emits approximately 1.5 billion tons of CO2 annually from the use of energy in addition to its industrial processes. Initial estimates of the technology's potential indicate that if all of this gas were converted and recovered, more than 300 million tons of chemicals or resins would be generated, such as those produced by Braskem. In addition, the use of renewable energy in the process is key to reducing the carbon footprint and improving the attractiveness of technology from an economic and environmental perspective.

According to Professor Meenesh Singh, responsible for the project at the University of Illinois at Chicago, the partnership with Braskem will contribute to the development of an integrated, sustainable and energy-efficient technology.

"Fossil fuels, such as natural gas and coal, are used extensively in industrial boilers to generate steam for the production of chemicals. More sustainable boiler operations, with greater energy efficiency and reduced carbon intensity, require continuous capture of CO2 and its recycling for chemicals such as ethylene, which has a major impact on the circular economy of manufacturing processes."

"The objective of the partnership between UIC and Braskem is to establish a completely integrated, sustainable and low-energy system, capable of continuously capturing flue gas CO2 and converting it into ethylene for the production of polyethylene. To develop the system with the necessary performance, our group at UIC will rely on the experience demonstrated in electrochemical CO2 reduction reactions and will combine it with the technology that is being patented to actively capture CO2 from flue gases," explained Professor Singh.

LanzaTech, Total and L'Oréal make plastic from captured CO2

www.lanzatech.com

LanzaTech, Total and L'Oréal have premiered the world's first sustainable packaging made from captured and recycled carbon emissions.

The conversion process takes place in three steps:

• LanzaTech captures industrial carbon emissions and converts them into ethanol using a unique biological process.

• Total, thanks to an innovative dehydration process jointly developed with IFP Axens, converts the ethanol into ethylene before polymerizing it into polyethylene that has the same technical characteristics as its fossil counterpart.

• L'Oréal uses this polyethylene to produce packaging with the same quality and properties as conventional polyethylene.

It is a technological and industrial first.

Researchers synthesize light aromatics from CO2 hydrogenation

Aromatics are usually produced from petroleum via chemical conversion processes, which are energy-intensive and accompanied by high CO2 emissions.

Using CO2 as the feedstock for sustainable production of aromatics through catalytic hydrogenation is an economically and environmentally viable approach to address the pressing challenges of energy demand and global warming.

A research team led by Assoc. Prof. Sun Jian, Prof. Ge Qingjie and Assoc. Prof. Wei Jian from the Dalian Institute of Chemical Physics (DICP) of the Chinese Academy of Sciences synthesized light aromatics from CO2 hydrogenation by precisely regulating Brønsted acid sites (BAS).

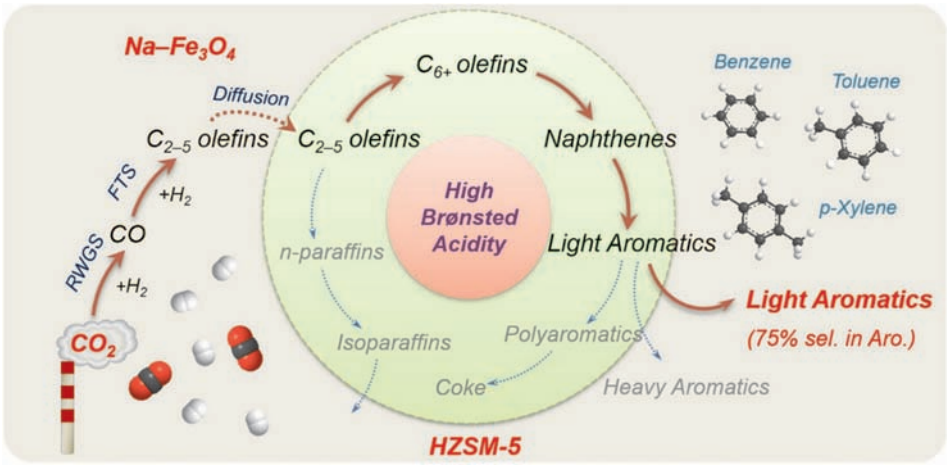
This study was published in Applied Catalysis B: Environmental on Oct. 17.

The scientists studied a series of composite catalysts comprising Fe-based component and ZSM-5 zeolites with distinct Brønsted acidities to explore the influence of BAS on the light aromatic synthesis and coke formation in CO2 hydrogenation.

They found that BAS of ZSM-5 were the main active sites for aromatization, and the increasing of Brønsted acidity significantly promoted the synthesis of aromatics, especially light aromatics. The further passivation of the external BAS of HZ(25) zeolite by silylation process could inhibit the alkylation of light aromatics and the isomerization of xylene.

The results showed that light aromatics accounted for up to 75% of aromatics, which was the highest value reported in CO2 hydrogenation, and p-xylene could make up as high as 72% of xylene. Moreover, a larger density of BAS, which promoted the formation of highly condensed, carbon-rich, and hard-to-oxidize coke, would accelerate the coke formation, degrade their physico-chemical properties, and shorten the catalyst lifetime.

This work provides a promising strategy to directly synthesize high-valued light aromatics from CO2 and H2, which is important to cope with energy and environmental



Precisely regulating Brønsted acid sites to promote the synthesis of light aromatics via CO2 hydrogenation (Image by WEI Jian and YAO Ruwei)

Transition metal for highly-efficient CO2 activation

In another project a research team led by Prof. JIANG Ling and Prof. FAN Hongjun from the Dalian Institute of Chemical Physics (DICP) of the Chinese Academy of Sciences, in collaboration with Prof. ZHAO Zhi from Hebei University of Engineering, characterized a transition metal M[A2-(O,O)C] species for highly-efficient CO2 activation.

The result was published in The Journal of Physical Chemistry Letters on Dec. 28.

Based on the recently-developed infrared photodissociation spectroscopy apparatus, the researchers synthesized and characterized an unprecedented transition metal M[η2-(O,O)C] motif with bidentate double oxygen metal-CO2 coordination in the [ZrO(CO2)n>=4]+ complexes.

The Zr[η2-(O,O)C] species yielded a CO2-radical ligand, showing high efficiency in CO2 activation. The CO2- radical and nonlinear character of these series of M[η2-(O,O)C] complexes might enable high reactivity in many important reactions such as C-C coupling and C-H activation.

There were two important prerequisites for certain metals to form this intriguing M[η2-(O,O)C] species: the metal center had high reduction capability and the oxidation state of the metal center was lower than its highest one by one.

Systematic analyses for the effects of different transition and main-group metals on the formation of M[η2-(O,O)C] complexes provided comprehensive insights into the microscopic mechanism of CO2 activation by a single metal center, offering design criteria for single-atom catalyst with isolated transition metal atoms dispersed on supports. Such advances might be integrated into the CO2-activation and -utilization technology.

More information

english.dicp.cas.cn

Transport and storage news

CO2CRC begins CO2 injection at Otway

co2crc.com.au

CO2CRC's Otway Stage 3 Project trials next generation subsurface monitoring and verification (M&V) technologies to reduce the costs for monitoring in industrial applications.

Traditional methods monitor the CO2 from the surface and can be costly due to long-term planning and their interaction with farming or marine industries. CO2CRC developed with its research partners from CSIRO and Curtin University technologies which instead provide an on-demand image of the CO2 plume in the subsurface. The monitoring techniques have a lower surface environmental footprint, can be operated and monitored remotely, are more cost-effective and come with a high level of reliability.

"Initial estimates show the technologies being tested could provide a cost saving of up to 75 percent of monitoring costs over traditional monitoring technologies," said David Byers, CEO of CO2CRC.

"CO2 injection has commenced at a rate of 140 tonnes per day and we have established good communication between the injection well and the monitoring wells and the storage reservoir is responding to CO2 injection as predicted."

"CO2 injection will pause in early Jan 2021, when around 5,000 tonnes of CO2 will have been injected. At this point we will perform our first pressure tomography measurement as well as an intermediate surface based seismic survey, allowing comparison between traditional M&V techniques and the novel technologies and methodologies deployed as part of the Otway Stage 3 Project."

"We are already seeing significant improvements in data collection and processing times. The Stage 3 technologies will enable operators to track the plume on demand, as it moves through the storage reservoir. This will allow operators to reduce the number of on-going repeat surface seismic acquisition operations and significantly reduce on-going monitoring costs."

"The M&V techniques will provide regulators and communities with ongoing confidence that CO2 injected deep underground is permanently stored within the bounds of the storage formation in large scale CCUS projects," he said

After the January pause, a further 10,000 tonnes of CO2 will be injected with additional measurements made after each 5,000 tonnes to further test the sensitivity and accuracy of the new M&V techniques. Research and analysis of data will continue into 2022.

Silixa launches fibre-optic sensing-based monitoring solution for CCS

www.silixa.com

Carina® CarbonSecure™ is a distributed acoustic sensing (DAS) based solution for continuous or on-demand monitoring of all stages of carbon capture and storage.

The new solution offers offshore and on-land operators the necessary monitoring measures for their CCS facilities with a reduced cost and environmental impact. The solution enables operators to provide the assurance to regulators and communities necessary to expand CCS adoption worldwide.

Carina CarbonSecure delivers ultra-high resolution, densely sampled acoustic data for real-time continuous and/or on-demand monitoring. Elements of the solution include microseismic monitoring and passive seismic throughout the lifetime of a CO2 storage facility. The system also includes 3D vertical seismic profiling (VSP), time-lapse seismic, well-integrity and leak detection to ensure maximum safety over the various stages of CCS development.

Carina CarbonSecure is a reservoir management tool. It can be deployed to:

• Assess the viability of geological formations for carbon storage during site characterisation.

• Monitor microseismic activity during the injection phase.

• Ensure well and storage integrity when CO2 is being injected.

• Provide 4D monitoring of the CO2 plume migration throughout the lifetime of the facility.

At the core of Carina CarbonSecure is Silixa's Carina® Sensing System, a patented, precision-engineered fibre-optic acoustic sensing system that is proven to achieve 20 dB or 100x improvement in signal-to-noise ratio compared to standard DAS systems.

Carina CarbonSecure requires minimal seismic sources on land and fewer seismic shots offshore to acquire seismic data, meaning it can significantly reduce a project's environmental impact and cost. The system can be fully automated, enabling unmanned and remote seismic surveys on demand, lowering costs further while increasing employee safety.

In addition, Carina CarbonSecure's fibre array delivers high resolution temperature data, is permanently installed and, because it has no mechanical parts, can be used without maintenance for decades in line with mandated CCS monitoring periods.

Glynn Williams, CEO at Silixa, said, "Carina CarbonSecure is new in the market, but it utilises proven technology with a significant track record throughout the hydrocarbon value chain. We have leveraged the extensive experience, R&D investment, and technical expertise within Silixa to create a low-impact solution that can secure CO2 storage facilities – and demonstrate that security – while transforming the CCS cost model. We believe it is a vital step for creating a viable global infrastructure for essential CCS."

Neptune Energy to conduct feasibility study into Dutch North Sea CO2 storage

www.neptuneenergy.com

The plans are for a large-scale offshore Carbon Capture and Storage project in the Dutch North Sea, with the potential to safely store 120-150 million tonnes of CO2.

The study will assess the feasibility of injecting between 5 and 8 million tonnes of CO2 annually into the depleted gas fields around the Neptune-operated L10-A, L10-B and L10-E areas. If the project is developed, it will be one of the largest CCS facilities in the Dutch North Sea and could meet more than 50% of the CO2 reduction being targeted by the Dutch industrial sector.

The Dutch North Sea has the potential to be-

come a 'new energy hub', given its existing infrastructure that connects offshore with onshore. It will also be home to the world's first offshore green hydrogen pilot, PosHYdon, which Neptune's Q13a platform will host.

Lex de Groot, Managing Director of Neptune Energy in the Netherlands, said, "The first step is a feasibility study to confirm that CO2 can be handled and stored safely in these depleted gas reservoirs, using our existing infrastructure. We will engage with organisations and emitters to offer safe and competitively priced CO2 storage.

"As the largest offshore gas producer in the Dutch sector of the North Sea, we are well-positioned to help the Netherlands achieve its climate goals by using existing infrastructure to enable offshore CCS and offshore green hydrogen production."

Jan Willem van Hoogstraten, CEO of Energie Beheer Nederland (EBN), added, "CCS is crucial for the Netherlands to achieve the Paris climate goals. We are already making great strides with the Porthos and Athos projects that want to store CO2 in empty gas fields off the coast of Rotterdam and IJmuiden respectively. This study by Neptune is another important step to convert the empty offshore gas fields into large-scale CO2 storage.

Project Greensand: North Sea reservoir and infrastructure certified for CO2 storage

www.maerskdrilling.com

The mission to store CO2 beneath the Danish North Sea has cleared the first major hurdle after the intended subsea reservoir was confirmed feasible for CO2 injection by independent certification body DNV GL.

The certification of feasibility issued by DNV GL concerns the Nini West reservoir operated by INEOS Oil & Gas Denmark which is leading the Project Greensand consortium, partnered by Wintershall Dea and Maersk Drilling. DNV GL confirms that the Nini West field is conceptually suitable for injecting 0.45 million tonnes CO2 per year per well for a 10-year period, and that the subsea reservoir can safely contain the CO2 in compressed form. Further, the Geological Survey of Denmark and Greenland (GEUS) acts as research partner to the project and is in the process of performing laboratory experiments of core material from the actual Nini West reservoir.

Project Greensand targets having the first well ready for injection from the Nini platform in 2025. Longer term, the ambition is to develop the capacity to store approximately 3.5 million tonnes CO2 per year before 2030. Like the majority of carbon capture and storage projects currently being developed within Europe, the establishment of a funding model is required to mature Project Greensand to a state where CO2 injection can commence.

Maersk Drilling expects that Project Greensand will provide important learnings about how offshore drilling rigs and capabilities can be used to repurpose existing oil wells for CO2 injection and handle well modifications during the injection period.

Chrysaor applies for North Sea CO2 storage licence

www.chrysaor.com

The application to store CO2 in a depleted Southern North Sea gas reservoir is in support of the V Net Zero Project, which aims to store and transport CO2 from the Immingham cluster on Humberside.

Chrysaor, a leading North Sea oil and gas independent, has submitted a Licence Application for the purpose of storing CO2, and will, in parallel, seek agreement for a Storage Lease with The Crown Estate.

The capture, compression and conditioning of the CO2 will be performed by the Humber Zero project, a coalition of industry partners including Vitol and Phillips 66. The V Net Zero project will be critical to delivering low carbon infrastructure on Humberside, the UK's most carbon intensive industrial region.

Commenting on the application, Phil Kirk, Chief Executive, Chrysaor, said, "This application is a meaningful step for V Net Zero and our ambition towards delivering the UK's first industrial scale carbon capture and storage project. We are delighted to work alongside a strong industrial coalition of leading energy companies and play a key part in the UK's net zero journey."

Jonathan Briggs, Project Director, Humber Zero, added, "Humber Zero represents a critical part of UK industry; one of Europe's most efficient power plants and a highly sophisticated refinery, providing power, fuels and components vital to the electrification of transport. Capturing and storing CO2 from this industrial complex will significantly reduce UK emissions, whilst preserving jobs and British industry. It will also provide a platform to build a hydrogen economy in an around the Humber, with a view to developing green-energy expertise and processes which can be replicated across the country and provide a meaningful contribution to net-zero targets."

Høglund and HB Hunte develop CO2 vessel tank system

www.hoglund.no

www.hb-hunte.de

This new system more than doubles current vessel cargo capacity to transport liquified CO2, representing a vital step forward in the development of maritime transport solutions for the expanding CCS market.

Høglund Marine Solutions and HB Hunte's transportation solution uses a unique bilobe tank with a capacity of 8000cbm, drawing on Cargo Handling System (CHS) and tank designs that they have previously proven in LNG, LPG and other sectors. The development of this unique solution came following a proof of concept request from gas technology experts.

The solution is readily available for use in existing tanker designs. It more than doubles the transportation capacity of liquid CO2 over current vessel capacity without the size, weight and stability concerns that would have come from a higher capacity "monolobe" design. It can be quickly adapted for LPG, giving extra flexibility to a vessel that uses them.

The tank configuration has a direct and positive impact for the use of different alternative material and reasonable fabrication processes while complying with IGC Code and conventional rule. This allowed the production of a solution which is substantially lower cost and risk than conventional very large diameter cylindrical type offering the same capacity.

Currently, the maximum capacity for transporting liquified CO2 is approximately 3600cbm, or roughly 1770 tonnes in dedicated CO2 tankers predominantly with specialist operators, Larvik shipping who have been transporting CO2 since 1988. However, as CCS chains develop, maritime transportation capacity needs to increase significantly, requiring innovation in tank design and cargo

University of Wyoming begins third phase of CarbonSAFE

The School of Energy Resource's (SER) Center for Economic Geology Research (CEGR) at the University of Wyoming has officially launched Phase 3 of the CarbonSAFE project.

Funding for Phase 3 of the project was approved in April, when SER and its partners received a $15.4 million award from the U.S. Department of Energy's (DOE) National Energy Technology Laboratory.

In addition to the $15.4 million in federal funding, project partner Basin Electric Power Cooperative is contributing $1.5 million, with UW's cost-sharing contribution at $2.4 million.

The Wyoming CarbonSAFE Project (Carbon Storage Assurance Facility Enterprise) is among 13 original carbon capture, utilization and storage (CCUS) project sites in the U.S. Funded by the DOE, the project's ultimate goal is to ensure carbon storage complexes will be ready for integrated CCUS system deployment.

With the advancement of each stage and varying success, fewer sites continued to the subsequent stages. Four of the original 13 projects have advanced to Phase 3, including sites in North Dakota, Alabama and Illinois. One new project, located in New Mexico, has joined the program.

Phase 1 of the CarbonSAFE project was an 18-month initiative that began in 2016 to assess the pre-feasibility of CCUS technology. The Basin Electric Dry Fork Station, in Campbell County, was selected as the project site. Not only is the site ideally located in the Powder River Basin, which accounts for 40 percent of U.S. coal production, but also the unique subsurface geological features in Wyoming allow for optimal potential storage zones, says Scott Quillinan, director of UW's CEGR.

Geological formations investigated included the Muddy, Lakota, Fall River (Dakota Group), Lower Sundance and Minnelusa, which are overlain by thousands of feet of impermeable rock that would ensure the permanent containment of carbon dioxide (CO_2) fluids in the storage sites.

Phase 2 of the project, in September 2018, began to assess the storage complex feasibility, with major activities including drilling a test well at the site and conducting a 3D geophysical survey. The test well was completed at a total depth of 9,873 feet, with 625 feet of core samples from nine different geological formations collected for analysis.

Following the completion of drilling, the team gathered downhole data by running sensors into the hole where team members gathered the information about the rock layers, fluids in the layers and pressure within the formations of interest.

Phase 3, last month, was pivotal for wrapping up data collection from Phase 2. Phase 3 project objectives are to finalize site characterization; complete Class 6 permitting to construct; integrate Membrane Technology and Research Inc.'s CO_2 capture assessment; and conduct National Environmental Policy Act analyses to advance toward the eventual commercialization of a large-scale -- storage of 50 million metric tons of CO_2 within a 30-year period -- CCUS project at Dry Fork Station.

If the projected success of Phase 3 comes to fruition, then the venture will advance to Phase 4 of the initiative for permitting and the construction of an actual storage complex, Quillinan says.

"Phase 3 will be the phase that tees up commercial operation at the study site, but also for other areas in Wyoming," Quillinan says. "By the completion of Phase 3, the project team will have finalized all site characterization and Class 6 permitting activities, thereby leaving the project poised to begin final commercialization actions with the consent of project partners. In so doing, the project will have commercially advanced CCUS technologies both in terms of reservoir characterization in the CO_2 storage context, and in obtaining the first Class 6 permit to construct in Wyoming so that others may follow suit."

The Environmental Protection Agency recently approved the application allowing Wyoming to have permitting authority for Class 6 wells.

By achieving primacy, Wyoming will be a haven for operators that want to take advantage of the 45Q tax credit that was extended and expanded through a bipartisan effort co-sponsored by Wyoming's U.S. Sen. John Barrasso, the Furthering Carbon Capture, Utilization, Technology, Underground Storage and Reduced Emissions (FUTURE) Act.

The tax credit incentivizes utilities and other industrial sources to build out CCUS projects, including Class 6 wells.

"Not only is Wyoming one of the test sites that is ahead of the curve in terms of the actual feasibility of CCUS technology, but we believe the ability to work directly under the guidance and regulatory oversight of the Wyoming Department of Environmental Quality makes the possibility of developing a commercial CCUS project more feasible in the state of Wyoming," Quillinan adds.

Other major participants and partners in the Wyoming CarbonSAFE project are Basin Electric Power Cooperative; Energy and Environmental Research Center; Advanced Resources International Inc.; Carbon GeoCycle Inc.; Membrane Technology and Research Inc.; Denbury Resources Inc.; UW Enhanced Oil Recovery Institute; UW College of Business; UW College of Law; Los Alamos National Laboratory; and Schlumberger.

More information

www.uwyo.edu/ser/research

netl.doe.gov/coal/carbon-storage/storage-infrastructure/carbonsafe

Carbon dioxide capture solution progressing at the Port of Gothenburg

At the Port of Gothenburg's Energy Port, various locations suitable for building a future facility for intermediate storage and liquefaction of carbon dioxide are being investigated.

What is the smartest way to transport captured carbon dioxide from facility to quayside? To discover the answer, five major energy companies in western Sweden have joined forces in the CinfraCap project. A prestudy commenced in May to determine whether a joint solution could be found for an efficient, sustainable infrastructure for captured carbon dioxide. Every aspect of this undertaking is being examined in detail, both on the drawing board and out in the port.

"Our remit was to investigate the possibility of creating an optimised logistics and intermediate storage chain, the ultimate aim being to transport up to two million tonnes of captured carbon dioxide each year from facility to quayside. To realise this ambition, a highly efficient infrastructure needs to be in place, and we are currently working flat out to produce analyses, scenarios, and estimates," said Hesam Mortazavi, project manager at the COWI consulting group.

A visit was made this week to the Energy Terminal at the Port of Gothenburg to identify a suitable location for intermediate storage and possible liquefaction of carbon dioxide.

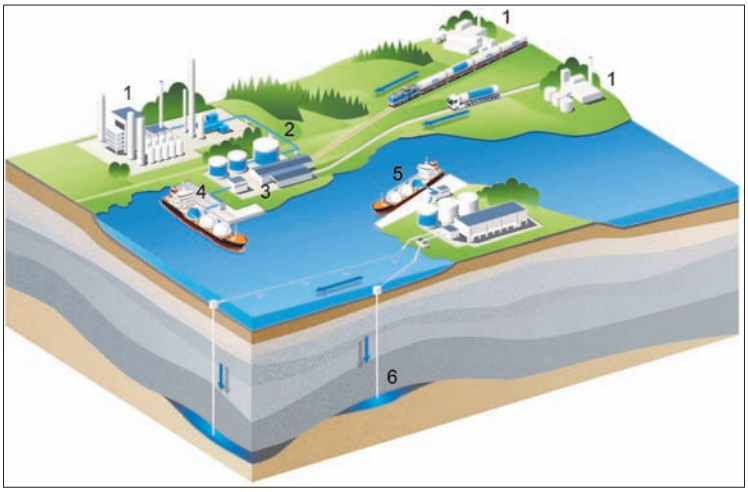
"We have found a potential site close to the quayside that could work. We have also been around the port to get an overall picture of the situation and to formulate ideas about the configuration of the new pipelines down to the quayside," said Claes Rödén, Engineering Manager at the Gothenburg Port Authority.

Financial benefit

Previous experience has shown that complex infrastructure projects in general tend to be extremely cost-intensive, and funding is frequently a crucial issue.

With this in mind, the focus during the prestudy was on the potential to optimise the cost of investment and energy consumption and determining which alternative – an individual or joint investment – would be most suitable. The CinfraCap prestudy will be completed in March 2021 and the results will then be presented.

"Regardless of the outcome, we have already acknowledged the need to recommend subsidies. As it will be a costly project to implement and maintain over time, it is vital that we have an established investment framework in place for both the facility and the pipelines, and that we take full account of future operating costs.



1. Carbon dioxide capture facilities; 2. Liquid carbon dioxide is transported through pipelines from capture plants nearby and by truck or railway from plants further away; 3. CinfraCap reception site with temporary storage at the Port of Gothenburg; 4. Liquid carbon dioxide is loaded onto a ship using loading arms; 5. Receiving terminal from where liquid carbon dioxide is unloaded and pumped into rock formations 3,000 metres below the seabed; 6. Porous rock, with impermeable rock above, where liquid carbon dioxide is returned

However, there is a commercial upside in the fact that the companies can sell emission rights and by doing so reduce their carbon emissions when they use CCS technology," said Isabella Herstad-Norin, process manager for CinfraCap at COWI.

CinfraCap stands for Carbon Infrastructure Capture. The project is focused on the transport of captured carbon and how this can be done in a climate-smart, cost-effective way.

The aim behind CinfraCap is to produce a more comprehensive picture of the logistics chain required to transport captured carbon dioxide from different industrial facilities in western Sweden – from liquefication and intermediate storage, through to distribution to ships and onward transport to the repository site.

The interface for CinfraCap will be the fence around the facility in western Sweden that captures the carbon dioxide, through to the loading arm on the vessels that transport the liquefied carbon dioxide onwards by sea.

CinfraCap will complement a number of other ongoing research and development projects, including Preem CCS, ZEROC, and Northern Lights, which is a full-scale carbon dioxide repository project being run off the west coast of Norway.

CinfraCap is a collaborative venture between Nordion Energi, Göteborg Energi, Renova, Gothenburg Port Authority, Preem, and St1.

More information

www.portofgothenburg.com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