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First Movers Coalition launches major expansion at Davos

The First Movers Coalition, a public-private partnership to clean up the most carbon-intensive industry sectors has expanded to more than 50 corporate members including Alphabet and Microsoft.

Led by the World Economic Forum and the US Government, the First Movers Coalition targets sectors including aluminium, aviation, chemicals, concrete, shipping, steel, and trucking, which are responsible for 30% of global emissions – a proportion expected to rise to over 50% by mid-century without urgent progress on clean technology innovation.

For these sectors to decarbonize at the speed needed to keep the planet on a 1.5-degree pathway, they require low-carbon technologies that are not yet competitive with current carbon-intensive solutions but must reach commercial scale by 2030 to achieve net-zero emissions globally by 2050.

To jump-start the market, the coalition's members commit to purchasing – out of their total industrial materials and long-distance transport spending – a percentage from suppliers using near-zero or zero-carbon solutions, despite the premium cost.

If enough global companies commit a certain percentage of their future purchasing to clean technologies in this decade, this will create a market tipping point that will accelerate their affordability and drive long-term, net-zero transformation across industrial value chains.

US Special Presidential Envoy for Climate John Kerry said, "The purchasing commitments made by the First Movers Coalition represent the highest-leverage climate action that companies can take because creating the early markets to scale advanced technologies materially reduces the whole world's emissions – not just any company's own footprint."

"With today's expansion, the coalition has achieved scale across the world's leading companies and support from committed governments around the world to tackle the hardest challenge of the climate crisis: reducing the emissions from the sectors where we don't yet have the toolkit to replace unabated fossil fuels and swiftly reach net-zero emissions."

The First Movers Coalition launched a major expansion across three dimensions:

1. New corporate members

Global technology giants Alphabet and Microsoft, along with AES, Aveva, Ball Corporation, BHP, Consolidated Contractors Company, Ecolab, Enel, EY, FedEx, Ford Motor Company, HeidelbergCement, Mitsui O.S.K. Lines, National Grid, Novelis, PWC, Schneider Electric, Swiss Re and Vestas are new members. With this expansion, coalition membership exceeds 50 companies, with a collective market value of about $8.5 trillion – or more than 10% of the Fortune Global 2000.

2. New government members

In addition to the US Government, the coalition welcomes India, Japan and Sweden to the Steering Board, as well as Denmark, Italy, Norway, Singapore and the United Kingdom as government partners. These government partners will invite companies from their countries to join the coalition and will pursue public policies to commercialize the green technologies corporate members commit to purchasing.

3. New sector commitments

The coalition is launching two new sectors: carbon dioxide removal and aluminium, which join the four existing sectoral pledges (aviation, shipping, steel and trucking) launched at COP26.

Carbon dioxide removal

Alphabet, Microsoft and Salesforce have collectively committed $500 million to carbon dioxide removal (CDR). Microsoft will further serve as an expert partner by sharing lessons from its carbon removal auctions.

Boston Consulting Group (also the First Movers Coalition Knowledge Partner) commits to removing 100,000 tonnes of carbon.

Three additional companies have each committed to 50,000 tonnes or $25 million of carbon removal: AES, Mitsui O.S.K. Lines and Swiss Re.

All members must deliver on their commitments by 2030 and demonstrate that the carbon can be stored for more than 1,000 years.

Members' carbon removal purchases will be supported by implementation partners, including Breakthrough Catalyst, Carbon Direct, Frontier and South Pole.

Aluminium

Ball Corporation, Ford Motor Company, Novelis, Trafigura and Volvo Group are founding members of the coalition's new aluminium sector, committing to have near-zero carbon emission from 10% of their primary aluminium purchases by 2030. This can only be achieved by producers who use advanced technologies that are not yet commercially available.

Explainer: Harnessing value chains to reduce the green premium of innovative technologies

The majority of decarbonization required across the seven so-called "hard-to-abate sectors" (aluminium, aviation, chemicals, concrete, shipping, trucking and steel) – as well as the negative emissions needed for net-zero through carbon dioxide removal – cannot be achieved by the incremental efficiency gains offered by existing materials and technology solutions.

More information

www.weforum.org/first-movers-coalition

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Front cover: Tata Chemicals Europe's Carbon Capture Plant in Cheshire in the UK will capture 40,000 tonnes of CO2 for use in the manufacture of net zero sodium bicarbonate (pg. 27)

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Leaders - CCUS in Australia

Projects and policy

Capture and utilisation

Transport and storage

Outcomes of the Otway Stage 3 project

CO2CRC's Otway Stage 3 project has evolved a range of simpler, less costly, less invasive and more frequent novel CO2 storage monitoring methods from a bench top design to a full field demonstration.

The Otway Stage 3 Project was conceived in 2012 with the primary objective to develop a monitoring and validation capability that was cost-effective, high resolution, on-demand and non-invasive. The Stage 3 project aims to evolve a range of novel monitoring methods from a bench top design to a full field demonstration, all informed by our member's stated need for simpler, less costly, less invasive yet more frequent monitoring.

The main objective was realised and demonstrated through the application of the monitoring modalities of downhole seismic and pressure tomography, with other techniques such as pressure inversion, earth tides analysis and passive seismic acquisition also demonstrating value.

Through field validation at the Otway International Test Centre (OITC) – Owned and operated by CO2CRC, these various techniques were conducted:

• Demonstrated accuracy through a clear agreement with the conventional monitoring technique of 4D seismic and unmatched turnaround times with new downhole seismic images available every two days and pressure tomography results available within two weeks of any survey.

• Demonstrated higher than expected sensitivity with downhole seismic detecting 300 tonnes of injected gas and pressure tomography detecting the plume at the first survey with ~5,000 tonnes of gas injected.

• Demonstrated a capability of remote operation with downhole seismic operating continuously and independently throughout the operational period (including pre injection) for 18 months and pressure tomography operations requiring only the intervention of a single site operator to perform the surveys. The entire operation was conducted during covid lockdowns with minimal site access allowed.

• Confirmed the possibility to scale up to an industrial application – through a more detailed understanding of the technologies gained during the field test, workflows have been developed to customise the technologies to industrial sites.

These techniques are risk focused to provide an early warning for industrial CCS projects but are not applicable in all cases and will need to be confirmed as suitable for the site, the project objectives, and the regulatory and operator requirements.

During the demonstration of these techniques many additional lessons were learned and findings were made such as the ability to remotely acquire a 4D seismic survey, that pressure tomography was able to be performed without the need of stopping the gas injection, that automated processing of seismic data was possible, that earth tides proved to be a viable means to passively identify a plume approaching a monitoring well, that high definition fibre optics can be safely run and installed outside of casing without compromising well integrity, that suspending pressure gauges and fibre optics inside a well provide an accurate and cost effective means of acquiring monitoring data – and many more.

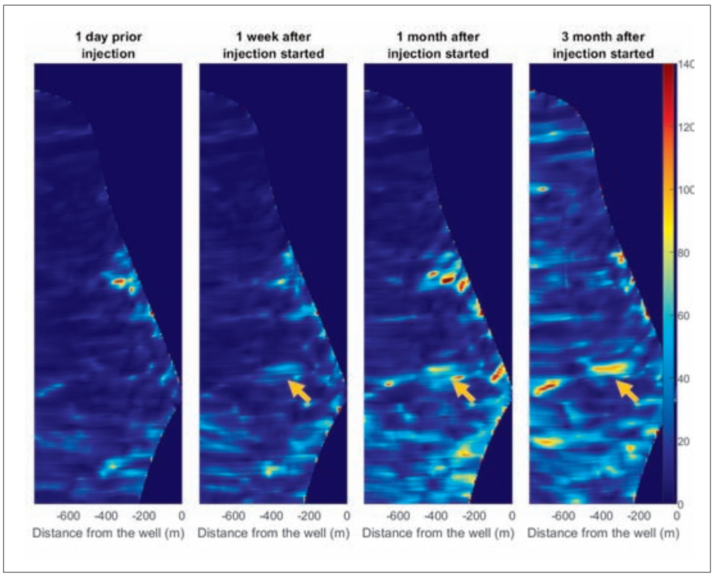

Figure 1 - Processed SOV/DAS images of the plume at stated times

Stage 3 scientific Outcomes and industry applications

The Otway Stage 3 Project achieved final investment decision in May 2019 and after 18 months of drilling and completions work, construction, commissioning and site characterisation the injection operations commenced on the 2nd December, 2020. As planned, with three separate intervals of injection and continuous monitoring activities performed, the program concluded at the end of April 2021, having safely sequestered 15,050 tonnes of buttress gas in the Paaratte saline aquifer, 1600m below ground.

With this, the CO2CRC Otway Project Stage 3 achieved its objectives: it has demonstrated the feasibility of risk-motivated monitoring methods that are spatially specific, return results quickly, and are unobtrusive at the surface. This was achieved during the pandemic and border closures, which prompted the full development of effective remote operations and data processing, especially for seismic data.

This summary is not an exhaustive list of techniques trialled and demonstrated for the Stage 3 Project, but it does describe some of the most promising techniques: namely, – downhole seismic monitoring, pressure tomography and earth tides monitoring – as effective and low-cost monitoring options for commercial CCS projects.

Downhole seismic monitoring

The downhole seismic technique, a time-lapse Vertical Seismic Profile (VSP) approach using permanent sources and in-well fibre optics – the Surface Orbital Vibrator (SOV)/Distributed Antenna Sensing (DAS) system – was utilized to track the propagation of the Stage 3 plume on a day-by-day basis. The Stage 3 project was the first successful deployment of any comparable system and provided continuous, on-demand monitoring of the plume. Critical to the success of the technique was the successful deployment of the fibres cemented securely outside of the casing.

The ability to perforate the injection and monitoring wells without damaging this fibre was demonstrated on all the wells using an oriented gun system. Nevertheless, a back up fibre was deployed inside of the casing on a deviated monitoring well and suspended from the wellhead. This style of deployment not only facilitated deployment and retrieval, but also provided an analogue for the repurposing of legacy wells in operating or depleted fields.

First gas was detected after only 2 days of injection with less than 300 tonnes of gas injected. The system was sensitive enough to detect changes in the legacy Stage 2C plume as the new Stage 3 plume intersected and merged with it, and ultimately identified movement in the far east edge of the plume.

A key outcome of the field test was to, for the first time, to completely automate the in well seismic data acquisition and processing. To date, more than a petabyte of data has been acquired and analysed. Prior to this, seismic data generated at the OITC was manually acquired in its raw format on hard disc (typically hundreds of terabytes) and transported (via postal mail or hand carry) to offsite processing facilities.

This processing then required months of time to produce the subsurface images. In contrast, the SOV/DAS system automated onsite processing of the data which meant that only 1GB /day was sent offsite (via commercial NBN) for final processing and quality checks with final images produced every 2nd day.

Our confidence in the results of the SOV/DAS plume have been justified with the overlay of the 4D surface seismic results which show clear agreement between the two methods.

The SOV/DAS system was tuned to the Stage 3 injection operation to validate the technologies and system application. The analysis of the data has provided key insights into the applicability of the technique for industrial applications and general approaches for composition, data logistics and analysis approaches can be generalized and applied to different projects after the necessary customization steps.

The downhole seismic system can be scaled up spatially, but this would involve more wells or deeper wells to widen the illumination and retain the density of transects – providing a greater definition of the plume with less interpolation required. Alternatively, well counts can be kept constant, at the price of sparser transect information and more dependence on interpolation and smoothing. For geometrical reasons – based on monitoring well trajectories, downhole seismic is best suited to locating the plume more precisely along transects close to monitoring wells so locating these monitoring wells in line with key site and operational risks, is important.

4D DAS VSP was successfully deployed to verify SOV/DAS and pressure tomography (PT) findings. 4D VSP is a relatively standard tool in reservoir monitoring, however the use of multiple deviated wells allowed us to understand the level of uncertainties arising from the acquisition geometry.

Due to COVID restrictions we had to modify the acquisition strategy and align with the necessity of predominantly remote operation with most of the professional crew (observers and geophysicists) operating the acquisition equipment remotely. This was only possible as the site was designed specifically for unmanned operation (in DAS/SOV) mode with all the required data logistics and computing facilities in place. This is (while unplanned) one of the most critical learning experiences directly applicable to most (if not all) seismic monitoring operations.

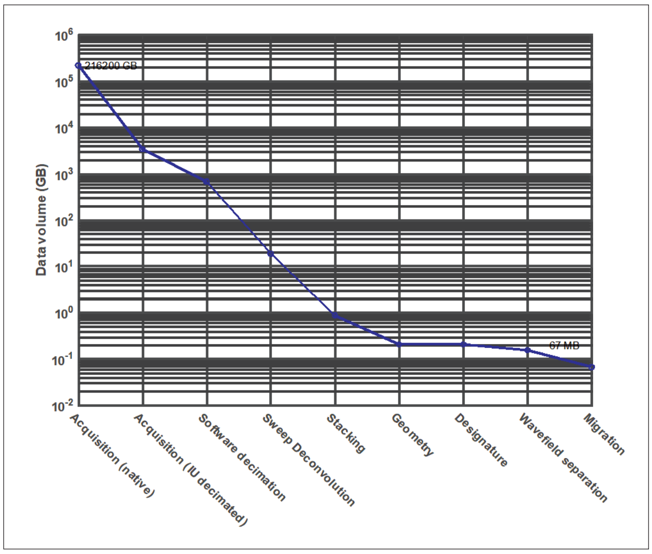

Figure 2 – Data processing steps showing raw data size to final migrated image files

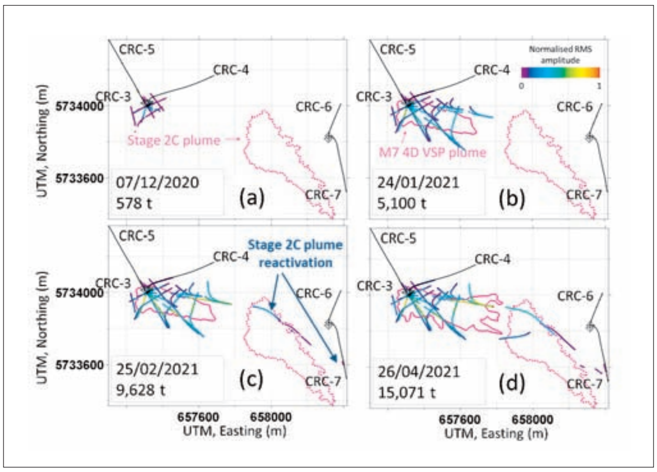

Figure 3 – Evolution of the CO2 plume during various stages of the injection

Pressure Tomography

Stage 3 successfully demonstrated plume detection and location using pressure tomography over three separate monitoring surveys. These were conducted at fixed points in the injection operation which were preselected specifically to test the technique at various plume extents, however, the surveys could have easily been applied at any point on an "on-demand" basis.

The core of the modality is pressure monitoring and for Stage 3, downhole pressure gauges were used in monitoring wells in an innovation suspension style deployment, which facilitates efficient retraction and redeployment in the event of reliability issues and provides an analogue for the re-purposing of legacy wells in existing fields.

Each survey clearly showed the growth and migration of the plume at each stage and corroborated well with the final 4D surface seismic surveys used as the benchmark for comparison. Each survey was able to be operated with minimal operator involvement and the results showing the plume image were available within weeks of each survey completion.

Subsequently, further work has been completed in understanding areas not previously investigated. Firstly, we rigorously analysed the uncertainty in the saturation inversions, providing realistic confidence estimates based on the combined experimental, post-processing and model uncertainty. We compare the results to those from seismic imaging, namely offset-VSP and 4D VSP. Generally, good agreement is found between the different monitoring modalities.

After the uncertainty quantification, efforts were made to explore the industrial scaling of pressure tomography. We use the controlling non-dimensional scaling factors to discuss conceptually the scale up of the system and well configurations that are possible. Using the available data, it's possible to demonstrate reduced well (a single cross-well pair) monitoring at the Otway site, and key considerations therein. This can then be scaled up to simulate larger injections – e.g., 1Mtpa CO2 injection simulations – at the Otway site, and a monitoring approach to capture the large-scale migration.

Earth Tides Monitoring

Of the feasibility trials for possible monitoring techniques included in the Stage 3 technical objectives, earth tides monitoring made it through the various stage gates to final field implementation. The acquisition and analysis of changes in the earth tides response at the reservoir level, has delivered low cost, opportunistic data to understand plume migration in the subsurface.

The Stage 3 investigations developed numerical models to provide useful nomograms linking the change in response in earth tide measurements with the size and distance from the plume centre. While still approximate, such tools provide useful, early and cost-effective information to help understand plume migration in the subsurface and provide an early warning in the event of the plume nearing an "at risk" area.

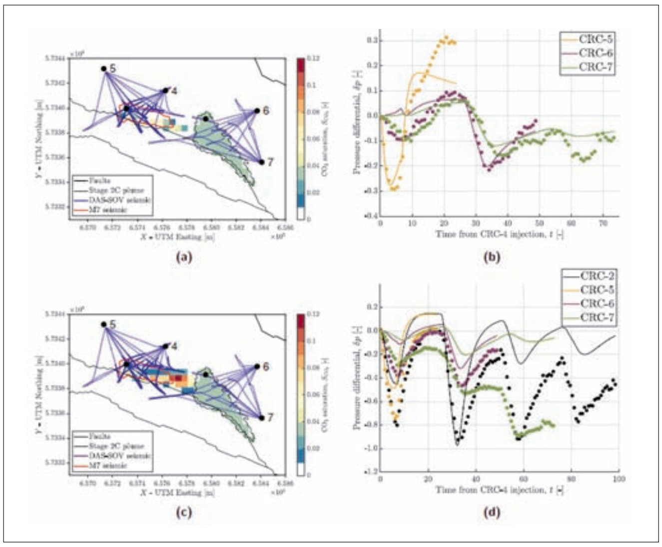

Figure 4 – Overlay of PTI inverted saturation results with seismic results – rows from top to bottom are PTI surveys 4, 5 and 6 respectively

Earth tides are the cyclic pressure perturbations imposed on the subsurface through the movement of the moon across the earth's surface. They can be easily and accurately measured using downhole gauges and can be modelled effectively to remove them as "noise" from conventional subsurface pressure data. However, a detailed analysis has shown a strong reaction in these induced pressure cycles from the passage of the Stage 3 plume.

There were strong responses of the earth tides' amplitudes and phases to the creation and propagation of the plume. Simple analytical estimates of the size of these effects are possible and give useful indications of the size and proximity of the plume. Full numerical models, coupling geomechanical and fluid flow effects, predict pressure variations that are similar to the observations.

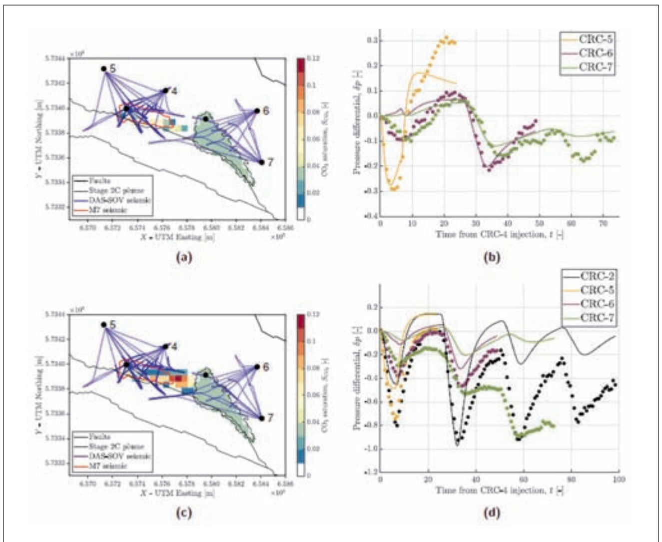

Figure 5 - Earth tide nomograms linking plume size and distance from the monitoring well

Conclusion

In conclusion, the Otway Stage 3 Project was conceived in 2012 to test and validate innovative monitoring techniques that provided operators with cost effective and reliable information that would be acceptable to both the regulators and the communities in which CCS operations were conducted.

In April 2021, after years of planning, modelling and design, a significant site upgrade and 15,000 tonnes of CO2 injected into the Paaratte saline aquifer, the project has concluded and has achieved all its objectives.

The Stage 3 project has evolved a range of novel monitoring methods from a bench top design to a full field demonstration, all informed by our member's stated need for simpler, less costly, less invasive yet more frequent monitoring. There have been significant developments of techniques to make this possible, especially implementing "remote seismic" and the complex novel methods to invert pressure data to produce images.

While the methods have been demonstrated across relatively small spatial distances and with multiple monitoring wells in an onshore environment, the analysis of the experiment shows how to evaluate the scale-up to different situations that will be of industrial relevance. Importantly, the field demonstration at the OITC has matured many of the underlying monitoring technologies – such as suspended pressure gauges and the fibres installed behind casing – to a degree that operators can now adopt them directly into their own operations with confidence in their reliability and the information they will provide.

More information

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CSIRO: demonstrating amine-based Direct Air Capture technology

This article provides an overview of an amine-based liquid absorption system for CO2 capture directly from the ambient air (DAC) that we developed at CSIRO, named the Ambient CO2 Harvester (ACOHA).

By Ali Kiani and Paul Feron, CSIRO Energy.

Amine-based capture technology is dominant for CO2 capture from flue gases, and here we show that it is also very suitable for DAC with a dedicated process design and further optimisation. The development of this technology was based on an approach that considered the ways in which the cost of DAC could be reduced. Following this early but important work, we investigated the suitability of different absorbents and gas-liquid contacting devices for DAC and evaluated ways to reduce energy requirement in such a system.

Cost reduction approach

First, we estimated the costs for a benchmark process which was based on using a standard MEA solution (5 M or 30 wt.%) as the absorption liquid to capture the ambient CO2 at a unit scale of ~2300 tonne/annum. Figure 1 shows a basic process design for the amine-based DAC. A standard stainless-steel packed column was considered as the absorber and heat was used to regenerate the absorption liquid.

Further information about the benchmark process design can be found in Kiani et al., 2021 [1]. The overall cost estimated for the benchmark process was high at around $1452/tCO2. Two immediate modifications were applied to reduce the cost:

• Replacement of MEA by amino acid salts that have negligible vapour pressure. This results in significant cost saving since it leads to elimination of a large wash column section that is otherwise needed on top of the absorber to recover amine vapour.

• Replacement of the expensive stainless steel packed column by an inexpensive "off the shelf" cooling tower for absorbing CO2.

These two modifications reduce the overall cost of capture by around 60% to around $557/tCO2, which is in line with the costs reported elsewhere [2].

Further operational cost reduction can be achieved through operation at lower liquid to gas ratios (L/G) and the reduction of gas-side pressure drop in the cooling tower compared to the conventional packed column. There are also plenty of opportunities for energy integration and process optimisation in this system due to the low temperature of the regeneration process.

For example, the energy required for regeneration of the absorption liquid can be entirely provided from utilisation processes that release heat, locally available waste heat, compression of the CO2 product, or a synergetic combination of these options.

The described pathways for reducing the cost of the ACOHA technology were examined through a series of laboratory and modelling activities. These targeted the absorbent selection, the gas/liquid contactors and the minimisation of energy requirements.

Selection of suitable absorbent

In order to identify the most suitable absorbents for our amine-based

DAC, a range of experimental activities such as thermal and oxidative stability assessment and CO2 mass transfer measurement was conducted on a select number of amino acid salts solutions.

The results showed that, in comparison with MEA, almost all the amino acid salts tested had higher oxidative stability. However, AAP1 was the only amino acid salt that posed high thermal stability. The results also suggested that the mass transfer rate of CO2 into AAP1 was lower than MEA, which was mainly due to a lower concentration of AAP1 used. Table 1 lists all the amino acid salts investigated.

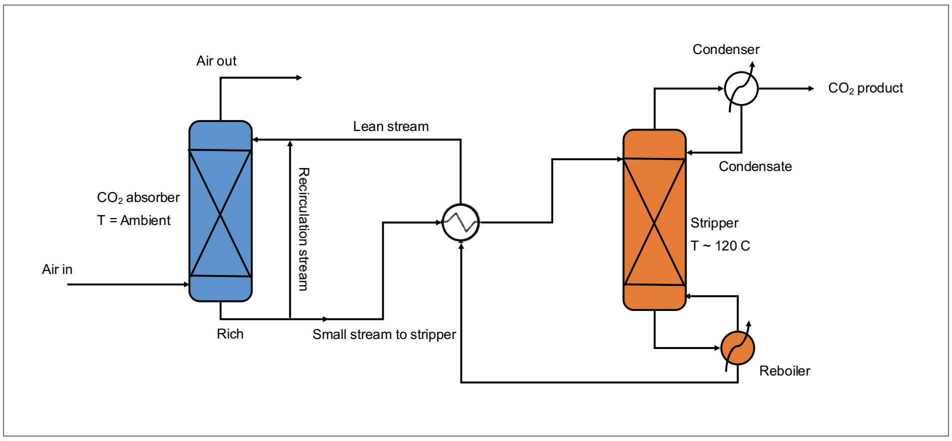

Figure 1: A simple process diagram of the amine-based DAC system

Gas-liquid contactors

We tested an aqueous solution of AAP1 in various gas-liquid contacting devices (packed column, rotating liquid sheet contactor [3], and cooling tower) for absorbing the ambient CO2 from the atmosphere. While the cooling tower gave lower overall mass transfer rates than other contactors tested and the benchmark design (Figure 2), it had much lower gas side pressure drop and enabled the operation at lower liquid to gas ratios (L/G).

Amino acid salt	Amine type	Thermal degradation	Oxidative degradation	Mass transfer rate compared to MEA
AAP1	Primary amine	Negligible	Negligible	Slower
AAP2	Primary amine	Severe	Negligible	Slower
AAP3	Primary amine	Severe	Moderate	Slower
AAS1	Secondary amine	Severe	Moderate	Faster
AAS2	Secondary-cyclic amine	Severe	Moderate	Faster
AAPD	Di-amino-acid	Severe	Severe	Slower
MEA	Conventional amine	Negligible	Severe	-

Table 1: Amino acid salts investigated in thermal and oxidative degradation studies

This would result in saving significant amount of energy that is normally required to pump gas and liquid in the system. It should be noted that the mass transfer rates obtained in the cooling tower are expected to become higher if liquid distribution is optimised in the cooling tower.

Energy requirement

The total energy required in our DAC system can be categorised as first, energy required for moving the air and liquid, and second, the energy required for regeneration of the absorption liquid.

The energy required to move the air and circulate the absorption liquid around the absorber are main contributors to the total electrical energy required. We showed in the laboratory that pressure drop per surface area can be at least half in the cooling tower contactor compared to the standard packed column. This will reduce the electrical energy that is required to move the air into the absorber by a factor of two.

We also showed that by using intermittent liquid flow, the liquid-to-gas ratio can be reduced by a factor of 10, and still reasonably high mass transfer performance can be achieved. This would result in 10-fold reduction in electricity consumption of the recirculation pumps.

Thermal energy required to regenerate the absorption liquid can be reduced through integrating DAC with processes that release

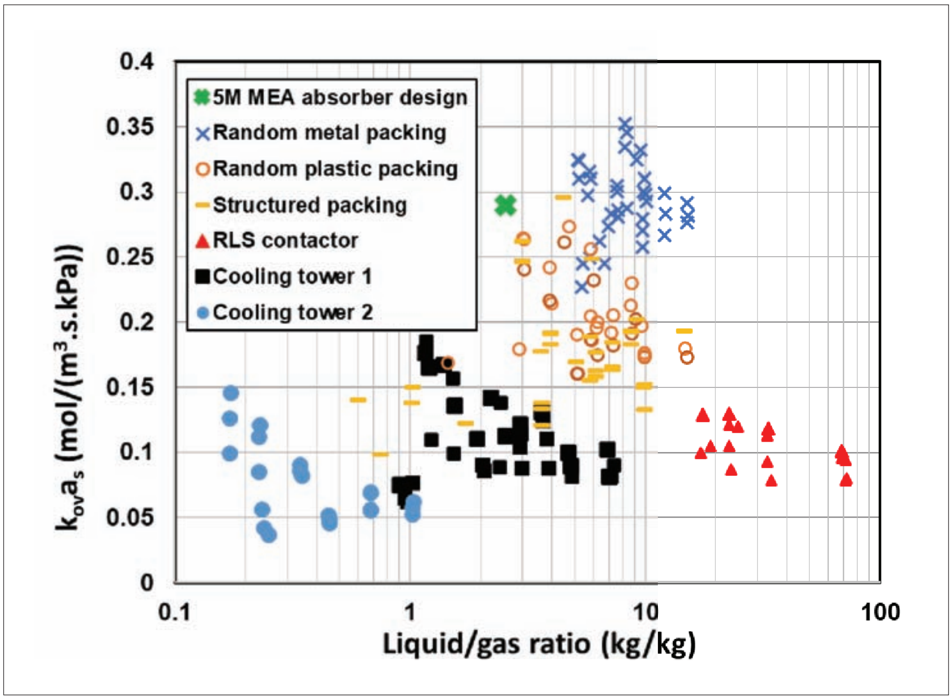

Figure 2: Overall CO2 mass transfer coefficients obtained in various gas-liquid contacting devices

heat such as methanation, or waste heat from industrial processes, or heat released from compression of the CO2 product. Our simulation showed that the heat released and available from a methanation process would cover around 55% of the heat required for regeneration of the absorption liquid in DAC.

Item	Benchmark	Use of amino acid salts	+cooling tower	+methanation	+vapour recompression
Total electricity (MWh/tCO_2)	1.452	1.03	0.31	0.31	0.34
Total heat required (GJ/tCO_2)	10.7	10.7	10.7	4.8	0

Table 2: Reduction of electrical and thermal energy requirements for the amine-based DAC

Our modelling also indicated that by compressing the CO2/H2O vapor leaving the desorber top from 2.0 bar to 2.4 bar, the heat recovery from the resulting vapour stream can cover the remaining amount of heat required for the regeneration process. This would be at the expense of a relatively low electricity consumption of around 0.03 MWh/tCO2 for the compression process.

Table 2 indicates the electrical and heat requirements of the amine-based DAC at various stages of its development.

With these reductions in energy requirement, the overall cost can be reduced from \$557/tCO2 to around \$319/tCO2. By scaling up such a technology to capture 1 Mt-CO2 per annum, the cost would be reduced to around \$69/tCO2 as a result of the economies of scale. Figure 3 illustrates a summary of the steps considered to reduce the overall cost of our DAC system [4].

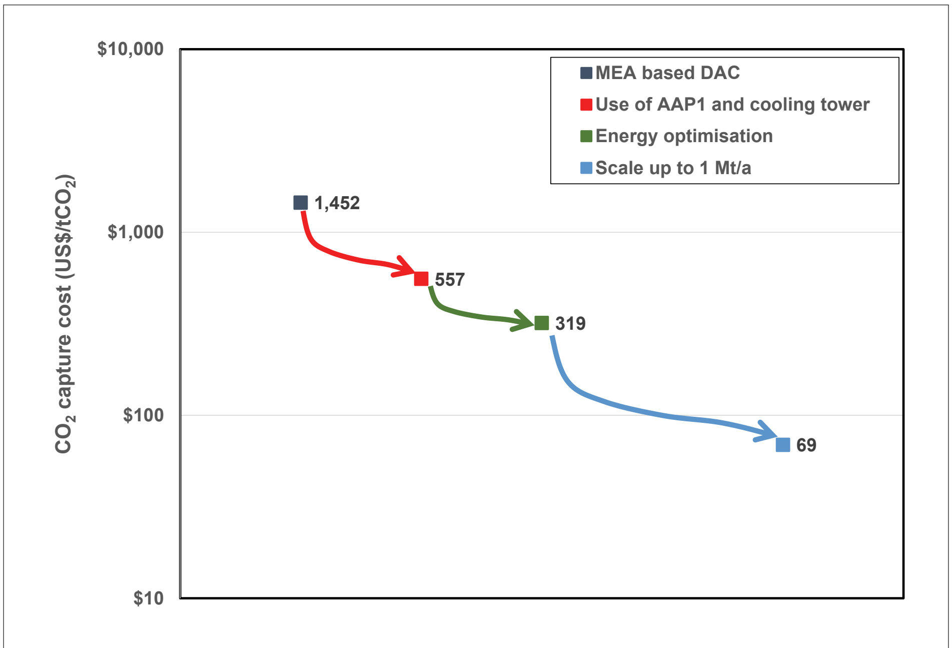

Figure 3: The technological steps considered to reduce the overall cost of the amine-based DAC

What's next...

Our techno-economic evaluation has shown that amine-based liquid CO2 capture technology has great potential to enable low-cost Direct Air Capture. We demonstrated the Ambient CO2 Harvester technology at a scale of 4 t/a CO2 capture and also carried out further underpinning experimental and process modelling work. In our next development stage, we are aiming to demonstrate the technology at a larger scale of at least 100 t/a capture.

Validation of the technology robustness through duration testing at this scale is an important part of the development of amine-based CO2-capture technology. In parallel a program of engineering and applied research will be conducted, aiming to further optimise the gas-liquid contactors for DAC application and minimise the energy required in such systems.

Acknowledgement

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Xodus eyes a global opportunity for CCS

CCS is a hot topic for Australia's oil and gas industry. As the nation continues to navigate the energy transition, it is expected to become increasingly important. This article originally appeared on the APPEA website - www.appea.com.au

It has been recognized by groups such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and International Energy Agency (IEA) as an important technology to help achieve a net-zero future, and Australia, with its natural advantages in geology and infrastructure, is in a prime place to emerge as a global leader in the development of CCS hubs.

That's why it's important to ensure experts are on hand to help navigate a smooth transition. Global energy consultancy Xodus works within several energy sectors, from offshore wind and oil and gas to hydrogen and marine energy, to deliver a responsible energy future.

Simon Allison, Xodus's Asia Pacific Regional Director, possesses more than 20 years of experience in the energy industry and has been working with oil and gas clients on multiple CCS projects in Western Australia and the Northern Territory.

He explains that Xodus has completed multiple technical studies for onshore and offshore CCS projects, providing a wealth of material for clients in the crucial early stages of development planning.

"We know just how important CCS is to Australia's story in reaching net zero," says Simon.

"The environmental impact assessment of CCS activities can be a challenge, given the increasing focus from regulators and stakeholders.

"But by implementing innovative and effective methods and working within integrated teams, we can navigate this challenge and provide timely outcomes and certainty.

The scope of this work is extensive, including identification, vendor engagement, and evaluation of technologies. This process helps clients to simplify some of the complexities around securing greenhouse gas (GHG) storage offshore consenting regimes, navigating the important work of ensuring petroleum title permits and GHG storage activities can co-exist with other non-petroleum activities.

"We know just how important CCS is to Australia's story in reaching net zero" - Simon Allison, Xodus's Asia Pacific Regional Director

In addition, Xodus advises clients on securing acreage releases, and how best to repurpose existing infrastructure for CCS hubs. It's a collaboration that lasts from initial assessment and selection through to FEED and delivery phases, providing troubleshooting and testing during commissioning and operation.

"Process and equipment technology selection is a key area for CCS projects to ensure the optimisation of an integrated CCS process system to meet performance and energy usage objectives," Simon explains.

"Xodus personnel provide value to operators in the early phase of development understanding the application and integration within the overall process system to achieve optimum results."

In October 2021, the Northern Territory Government and industry members (including Xodus) signed a collaboration agreement with CSIRO to develop the business case for a CCS hub at Middle Arm.

Dr Andrew Ross, a principal research scientist at CSIRO leading this work at, has been researching the contractual, fiscal and collaboration methods to establish large-scale CCS hub development both in Europe and Australia.

He explains that "CCS is a proven technology that has been successfully deployed for decades and it has been demonstrated that CO2 can be stored safely. If you look at future emissions reduction models, including the IEA's, they all have a CCS component," Andrew says.

"One of the requirements for low emission hub developments is a clear and cogent business case for their development, which are quite often delivered in partnership between industry, government, and an independently operated intermediary, in this case CSIRO."

Simon adds that collaborating with independent research bodies such as CSIRO isn't just beneficial for expediting CCS development, but crucial to the long-term success of CCS as a method of reaching current Australian net-zero policies.

"A good analogy might be, 'A problem shared is a problem halved'," he says.

"While collaboration in Australia's oil and gas industry has lacked historically, attitudes are different today, particularly regarding CCS. The competitive advantage afforded by CCS hubs really allow the efficiencies of scale necessary to turn projects into a reality to come to the fore."

More information

www.xodusgroup.com

www.csiro.au

Australia news

Marubeni and J-POWER fund Glencore CCS project in Australia

www.glencore.com.au
www.marubeni.com
www.jpower.co.jp

The companies will each fund A$10 million in Glencore's CTSCo Carbon Capture and Storage Project in Queensland.

Glencore's CTSCo Project aims to demonstrate carbon capture and storage technology. It focuses on capturing CO2 from the Millmerran coal-fired power station and permanently storing it deep underground in a dedicated storage site 100km from the power station. CTSCo has the potential to store significant volumes of CO2 to reduce existing and future sources of industrial emissions.

This could improve energy security for the national electricity market, maintain and grow jobs in regional Queensland and enable future industries including hydrogen production, while also contributing to Australian and Queensland Government climate and emission reduction goals. A comprehensive Environmental Impact Statement for the Project is currently in progress, working towards the commencement of CO2 injection in 2025.

"We are happy to be able to participate in the first CCS project in Australia to capture CO2 from a coal-fired power plant," said Jun Horie, Group CEO of Marubeni's Materials Group.

"CCS is an important technology in enabling a carbon neutral economy worldwide, not to mention Japan. We hope to bring back what we learn from this project to contribute to the industry's emission reduction goals."

"Promoting CCS projects will be critical technology to achieve net-zero-emissions not only for the power sector but various sectors," said Hiroyasu Sugiyama, Executive Vice President of J-POWER.

"We are glad to be a member of this project.We believe that the practical application of CCS and the technology will contribute to decarbonization in Australia and all over the world as well."

Both Marubeni and J-POWER are long term joint venture partners in Glencore's mining operations in Australia.

"We are delighted to welcome Marubeni and J-POWER as important funders in our CTSCo Project," said Earl Melamed, Head of Glencore's Global Coal Assets.

"CTSCo is one of the most advanced onshore CCS projects in Australia and has the potential to store significant volumes of CO2 from a number of industries while playing an important role in deploying this critical emission reduction technology and bringing down its costs."

"Marubeni and J-POWER are long-term investors in the Australian resources sector and their involvement in our project further highlights the potential for CCS to materially reduce emissions in Queensland."

CTSCo is a Glencore wholly owned company backed by Glencore funding. Other key project funding participants include Low Emission Technology Australia and the Australian Government.

Calix and Boral receive funding to develop cement carbon capture project

www.calix.global
www.boral.com

Boral will receive $30m in funding from the Australian Government's Carbon Capture, Use and Storage (CCUS) Hubs and Technologies Program to develop the project with Calix at its cement and lime facilities in the NSW Southern Highlands, targeting 100,000 tonnes per year of CO2.

The project will help accelerate Calix's LEILAC technology through development of both cement and lime deployment options, as well as alternative fuels and renewable energy use.

Since 2019, Calix's LEILAC technology has been piloted with leading cement and lime companies in Europe and recently attracted US-based impact investment fund Carbon Direct to invest directly into the LEILAC technology to accelerate global development and deployment.

The Project, in the NSW Southern Highlands aims to:

• Develop CO2 capture capability for Boral's cement and lime facilities,

• Assess alternative energy sources such as renewable energy and alternative fuels, to further reduce CO2

Options for utilisation of the CO2 from the project will also be assessed which, when combined with alternative fuels or renewable energy to power the technology, are targeted to create truly zero emissions lime and cement.

The project will be developed in three phases:

• The initial feasibility assessment phase will focus on a Basis of Design (BOD), commercial agreements and assessment including CO2 use option

• Phase two will concentrate on Front End Engineering and Design (FEED) leading to a final investment decision (FID)

• Phase 3 will involve detailed Engineering, Procurement and Construction (EPC) leading to commissioning and operation.

The project objectives are aligned with the Government's Technology Roadmap to reach net zero emissions by 2050 and to lower the cost of Carbon Capture, Use and Storage to less than $20/tonne.

This funding will now support Boral and Calix in finalising key commercial terms and commencing design. If the initial feasibility phase, which is expected to take about twelve months, is successful, a full FEED study will follow leading to an FID, followed by an EPC and operational phase.

"This is game changing technology for our industry and will play a critical role in supporting customers' sustainability targets, said Boral CEO Darren Schultz.

"Together, Boral and Calix have access to the required infrastructure, technology and operational expertise required to deliver this project and lead the way in reducing emissions across the industry.

"By modernising Australia's cement industry, we are enabling the growth of lower carbon construction materials, which are essential to jobs and local economies"

Nuada: A Step-Change for Commercial Carbon Capture

Carbon capture will be vital for a green economy but current technologies have stifled progress. Dr Conor Hamill, Co-CEO at MOF Technologies explains why a novel system called Nuada is poised to revolutionise the way industry manages its emissions.

The exact route to net zero may still be up for debate but carbon capture (CC) will be central to any realistic plan. Some believe it discourages the use of greener fuels, yet the most recent data from renewable energy forum REN21 leaves the situation beyond doubt. In 2019, coal, oil and gas still accounted for 80.2% of the total energy mix, representing a drop of 0.1% from 2009.[1]

Emissions, however, will not just be down to power generation but also other industries like cement where clinker-based production cannot be changed easily without significant disruption to global supply.

It's clear current demand cannot be met without some continuation of current practices, not least because a drastic, unmanaged transition would be far too damaging. Indeed, the main draw for CC is its feasibility, providing businesses in hard-to-abate sectors with a practical means to cut carbon while also maintaining a level of output needed for growth.

The potential savings are also impressive. The International Energy Agency, for example, estimates that CC projects could help reduce global carbon emissions by almost a fifth and lower the cost of tackling the climate crisis by 70%.[2] Savings of that kind are often based on long-term projections but game-changing technology like that offered by Nuada is helping to cut the timescales.

Commercial Hurdles

Some of the most recognisable names in heavy industry have started to take note of CC. Mining giant Rio Tinto announced

plans to deploy the technology at an aluminium smelt in Iceland, while the UK government signed off two multi-billion-pound schemes backed by several oil majors in the north of England.[3]

Arguably the most important development, however, comes from the Global Cement and Concrete Association, which has pledged to build 10 industrial-scale CC projects by 2030.[4] This is a significant moment as the cement industry accounts for roughly 8% of the world's carbon emissions.

These initiatives are welcomed, though the fact they're only just being rolled out hints at the difficulties around current approaches to CC. Critics argue these problems are just another convenient excuse for companies unwilling to change their operating models in any meaningful way. But that idea is misplaced. Even the Global CC Institute acknowledges the greatest challenge to wider deployment is a lack of commercial incentives.[5]

Part of this is down to the industry's unfamiliarity with CC. While the technology is proven in principle, its application has been very limited, leaving businesses with few use cases to justify investment. The perceived risk is only made worse by current capturing practices that mainly rely on amine solvent treatment.

This method is decades-old and has proven itself to be highly effective in some areas, but its benefits are ultimately undermined by a cripplingly high energy penalty. Studies have found it can take as much as 3.4 GJ/ton of CO2 removed – a huge portion of a facility's total output.[6]

1. https://www.edie.net/news/10/Report--Global-fossil-fuel-use-not-yet-in-decline--despite-renewable-energy-pledges
2. https://www.theguardian.com/environment/2020/sep/24/what-is-carbon-capture-usage-and-storage-and-can-it-trap-emissions
3. https://www.ft.com/content/cc107ae2-e81f-49b7-8fbe-13e2b61465aa
4. https://fortune.com/2021/12/12/carbon-capture-usage-storage-technology-profitable-net-zero-emissions/
5. https://www.globalccsinstitute.com/news-media/insights/carbon-capture-and-storage-challenges-enablers-and-opportunities-for-deployment/
6. https://ieaghg.org/docs/General_Docs/Reports/2008-3.pdfns

This is a stumbling block that few organisations have been able to overcome, especially in competitive markets where the margins are already fine. Beyond this, amine scrubbing is also held back by a large infrastructure footprint and high capital outlay needed at each facility. This not only drives up the overall cost but also makes it harder to convince decision-makers that CC is a worthwhile exercise.

A Revolution for CC

In some ways these issues are immaterial. First, there's increased scrutiny on the carbon tax credits scheme that will make it harder for businesses to delay action on emissions, not to mention other legislative pressure from governments in every major market.[7] Secondly, there's a now a far better method for CC that circumvents the use of amine and slashes the amount of energy needed to process the gas from flue streams by up to 80%.

This ultra-efficient system, called Nuada, has been developed by the team behind MOF Technologies and is poised to revolutionise the CC market. Its unparalleled performance is driven by vacuum pressure swing adsorption technology coupled with a MOF-based filter that has been specifically designed to capture and remove CO2.

MOFs, or metal-organic frameworks, are highly engineered filters that use bespoke chemistry to target, capture and remove specific gases like CO2. It's this selectivity combined with an ability to release with minimal energy input that gives Nuada such promise – not least for key industrial processes where cost-effective CC is now sorely needed.

Deployment is another area where Nuada is set to positively disrupt the current CC market. Unlike traditional approaches, this new system is modular, meaning it can be easily connected to a facility's waste gas line without extensive redesign or installation work.

These units can then be scaled up or down according to demand, giving businesses a non-invasive and far more cost-effective means of CC. The benefits of this system are profound with some projections showing up to $1 billion saved over the course of a plant's lifetime – and that's before taking the carbon tax into account.

If commercial incentives are the main barrier to CC then Nuada's system represents a real step-change for virtually any industry looking to capture CO2.

The energy savings make the cost of each project far more enticing for investors, while also allowing businesses to continue production without falling foul of emissions targets. Use of this MOF-based solution also makes the process of isolating CO2 more straightforward, allowing what's stored to be sold on to secondary markets for a profit.

This final point is important because cheap, abundant access to usable CO2 has been lacking, but it's also the crucial first step needed to unlock other parts of the CCU value chain.

The benefits of [the Nuada] system are profound with some projections showing up to $1 billion saved over the course of a plant's lifetime - Dr Conor Hamill, Co-CEO at MOF Technologies

Given that Nuada can offer capture costs as low as $16 per ton of CO2, it's not unreasonable to predict a period of significant progress once it becomes a staple across heavy industry.

More information

For more information, please contact Dr Conor Hamill, Co-CEO at MOF Technologies or visit:

www.moftechnologies.com/nuada

7. *https://www.ft.com/content/1f05530a-a823-488d-963b-31b42f7f56ed*

Flexible transportation solutions for CO2 to storage key to speed up deployment

As part of Bellona Europa's Campaign #TenTTuesday, Anne-Mette Jørgensen, Carbon Collector's external affairs manager, talks about the role and importance of multiple transportation modalities on the path to net-zero by 2050.

Why is CCS an important solution for Carbon Collectors?

"As we see it, we of course need to reduce fossil fuel use in general, but CCS technology is crucial for reducing emissions now. Especially for industries that currently do not have any other viable technologies available to reduce their emissions. Also on the longer term, some industries will remain dependent on CCS to bring their emissions down to zero. Moreover, CCS infrastructure is needed to achieve negative emissions.

With experience in the oil and gas sector and offshore logistics, they saw CCS as a sector where they could really make a difference. With the aim of getting the full CCS chain up and running fast, we now focus on flexible solutions to transport and store CO2 using shipping in particular.

Why are you so focused on flexibility in transport, why do you see this as crucial?

"Well, maybe it is good to first explain how our solution for CO2 transport and storage works and what makes it so flexible. We work with a push-tug barge combination where we pick up the CO2 at the place where the emitters capture it. We use our barges as intermediate storage and, when the barge is full, transport the CO2 directly to an offshore storage location. This means we reduce the need for all kinds of fixed infrastructure and provide a full-service solution for emitters who don't see CCS as their core business. That helps to act faster and to avoid any issues with potential lock-ins or stranded assets that you might face when using only pipelines. Just to make it clear: we do need pipelines, especially for very large emitters who are likely to continue emitting stabile amounts of CO2 for many years. But different solutions work for different cases.

Secondly, by using flexible transport solutions, storage sites that otherwise might have been too small or too complex for pipelines can be developed. This can help increase the total CO2 storage potential in Europe.

Finally, the solutions we provide are tailor made and easily scalable. For inland emitters, we use a combination of transport modalities such as rail, truck and inland and offshore barges to provide a viable solution for different cases. A fleet of barges and other transport modalities can easily be scaled to fit the amount of CO2 from an emitter and CO2 from small emitters can be aggregated underway to a storage location. So we believe that the flexibility we provide can help speed up the process of developing the full CCS-chain and that in the end larger amounts of CO2 can be safely stored underground."

What do you see as the main barriers facing the large-scale deployment of CCS on industrial emissions in Europe today, in particular for multiple transport modalities such as ship, rail, truck and barge?

"Here I would like to highlight three main issues. The first and biggest challenge is the development of storage locations. Serious plans for carbon capture have been growing over the last few years, but the number of available storage sites is lagging behind. There is a need to develop sufficient storage sites fast, so that captured carbon can be safely and permanently stored. This is where my earlier point comes into play: flexible transport solutions enable faster development of storage sites and development of a larger total capacity for CO2 storage.

Secondly, plans for CO2 transport and storage tend to overly focus on fixed centralised infrastructure rather than multimodal solutions. This results in limitations. It is crucial that governments start facilitating interfaces between different transport modalities, between flexible and fixed solutions to ensure an optimised system, and that they create a level playing field for different types of solutions. Here it is important to not only enable development through financing, subsidies or permits, it is also a matter of sending the right market signals. If governments focus on specific transport modalities in their communication this may affect the solutions being investigated by emitters and storage owners. By focusing solely on fixed infrastructure, without considering the important role of multimodal alternatives, we lose out on a great opportunity to reduce industrial emissions now.

The third challenge is of course the arrangements on cross-border transport and storage. There is still some hesitance, for example in the Netherlands, towards accepting CO2 from other countries. From my perspective I don't think it matters for the climate where the CO2 comes from, but it needs to be stored safely and many countries don't have available storage sites themselves. We believe that CO2 should be allowed to be transported freely across the EU, like any other product, provided it is properly disposed of. "

How can EU legislation play a role in addressing these barriers and challenges?

"Currently, as only pipelines and storage are recognised as PCIs under the TEN-E, this does not contribute to facilitating a level playing field between fixed and flexible transport solutions of CO2 to storage. While pipelines have an important role to play, it is a transport solution that can only transport from one fixed location to another fixed location. This can create a monopoly situation if not regulated properly.

By focusing on fixed infrastructure in all cases, you run the risk of stranded assets and lock-ins when large investments are made in new pipelines. You also face an opportunity cost for smaller storage sites not being developed and for smaller emitters not being connected as the significant up-front investments in a pipeline make the transport costs per ton of captured CO2 very high. Here, multiple transport modalities can be the solution. We therefore strongly support that multiple transport modalities such as ship, rail, barge and truck are included in the TEN-T regulation."

More information

www.bellona.org

www.carboncollecters.nl

DNV: Hydrogen at risk of being the great missed opportunity

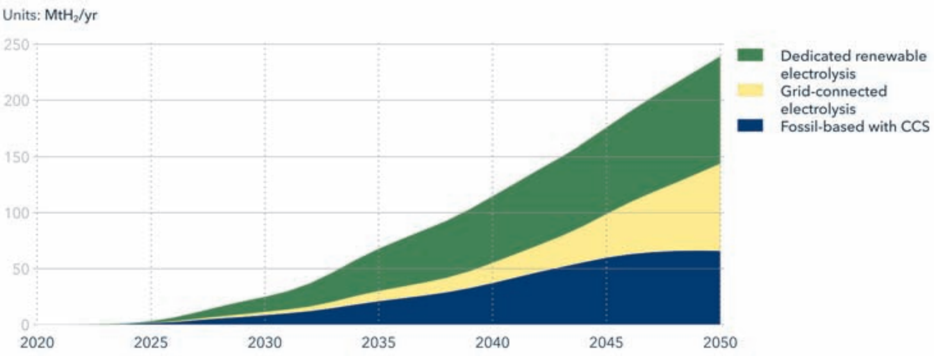
Hydrogen has a crucial role in decarbonizing the world's energy system, but uptake will be too slow. Governments need to make urgent, significant policy interventions, according to a new report by DNV.

In Hydrogen Forecast to 2050, DNV predicts the amount of hydrogen in the energy mix will be only 0.5% in 2030 and 5% in 2050. However, to meet the targets of the Paris Agreement, hydrogen uptake would need to triple to meet 15% of energy demand by mid-century.

"Hydrogen is essential to decarbonize sectors that cannot be electrified, like aviation, maritime, and high-heat manufacturing and should therefore be prioritized for these sectors," said Remi Eriksen, Group President and CEO of DNV. "Policies do not match hydrogen's importance. They will also need to support the scaling of renewable energy generation and carbon capture and storage as crucial elements in producing low-carbon hydrogen."

FIGURE 2

Global production of hydrogen and its derivatives for energy purposes by production route



According to Hydrogen Forecast to 2050, electricity-based green hydrogen – produced by splitting hydrogen from water using electrolysers – will be the dominant form of production by the middle of the century, accounting for 72% of output. This will require a surplus of renewable energy, to power an electrolyser capacity of 3,100 gigawatts. This is more than twice the total installed generation capacity of solar and wind today.

Blue hydrogen – produced from natural gas with emissions captured – has a greater role to play in the shorter term (around 30% of total production in 2030), but its competitiveness will reduce as renewable energy capacity increases and prices drop.

Global spend on producing hydrogen for energy purposes from now until 2050 will be USD 6.8tn, with an additional USD 180bn spent on hydrogen pipelines and USD 530bn on building and operating ammonia terminals, according to DNV's forecasts.

Cost considerations will lead to more than 50% of hydrogen pipelines globally being repurposed from natural gas pipelines, as the cost to repurpose pipelines is expected to be just 10-35% of new construction costs. Hydrogen will be transported by pipelines up to medium distances within and between countries, but not between continents. Global hydrogen trade will also be limited by the high cost of liquefying hydrogen for ship transport and the low energy density of hydrogen. The hydrogen derivative ammonia, which is more stable and can be more readily transported by ship, will be traded globally.

Early uptake of hydrogen will be led by hard-to-abate, high-heat manufacturing processes such as iron and steel production which currently use coal and natural gas. Hydrogen derivatives, such as ammonia and methanol, are key to decarbonizing heavy transport like shipping and aviation, but these fuels won't scale until the 2030s according to DNV's forecasts.

Hydrogen will not see uptake in passenger vehicles, and only limited uptake in power generation. Hydrogen for heating of buildings will not scale globally, but will see early uptake in some regions that already have extensive gas infrastructure.

"Scaling hydrogen value chains will require managing safety risk and public acceptance, as well as employing policies to make hydrogen projects competitive and bankable. We need to plan at the level of energy systems, enabling societies to embrace the urgent decarbonization opportunities presented by hydrogen," added Eriksen.

The uptake of hydrogen will differ significantly by region, heavily influenced by policy. Europe is the forerunner with hydrogen set to take 11% of the energy mix by 2050, as enabling policies both kickstart the scaling of hydrogen production and stimulate end-use. OECD Pacific (hydrogen 8% of energy mix in 2050) and North America (7%) regions also have strategies, targets, and funding pushing the supply-side, but have lower carbon-prices and less concrete targets and policies.

Greater China (6%) follows on, recently providing more clarity on funding and hydrogen prospects towards 2035, coupled with an expanding national emissions trading scheme. These four regions will together consume two-thirds of global hydrogen demand for energy purposes by 2050.

More information

Read the full report:

www.dnv.com

IEA: G7 members can lead the world in reducing emissions from heavy industry

A new IEA report lays out recommendations to speed up technology development and overcome high costs of drastically reducing emissions from steel and cement production.

G7 economies are well placed to be first movers on driving down carbon dioxide emissions from heavy industry, setting out a path for the rest of the world for this essential part of the transition to clean energy systems, according to a new report from the International Energy Agency.

The report, Achieving Net Zero Heavy Industry Sectors in G7 Members, was requested by Germany under its 2022 Presidency of the G7 to inform policy makers, industrial leaders and other decision makers ahead of this month's G7 Climate, Energy and Environment Ministers' Meeting in Berlin and beyond. The report lays out a series of recommendations for G7 economies to advance the transition towards near zero emission steel and cement production, building on the IEA's landmark report last year, Net Zero by 2050: A Roadmap for the Global Energy Sector.

G7 members – Canada, France, Germany, Italy, Japan, the United Kingdom, the United States plus the European Union – account for around 40% of the global economy, 30% of energy demand and 25% of energy system CO_2 emissions. Meanwhile, heavy industry's direct CO_2 emissions amount to around 6 billion tonnes per year, more than one-sixth of total CO_2 emissions from the global energy system. Producers of steel and cement in particular face unique challenges to drastically reduce their emissions footprint. The G7's economic heft, technology leadership and international alliances present it with a special role in leading the way and inspiring successful energy transitions in these crucial sectors, the new report says.

"There is no way to reach net zero without dramatic reductions in emissions from heavy industry, and G7 economies have both a responsibility and an opportunity to take a leadership role in driving that forward," said IEA Executive Director Fatih Birol. "Emissions from heavy industry are among the most stubborn, making it essential that countries with significant financial and technolog-

Recommendations for the G7

• Develop ambitious long-term sustainable transition plans for industry, backed by policy

By no later than the mid-2020s, G7 members should develop or update national industry sector roadmaps and plans in collaboration with industry stakeholders, providing a robust signal on the direction and pace of travel by developing clear targets and milestones

• Finance a portfolio of demonstration projects for near zero emission industrial production technologies

Within the next one to two years, G7 members should take decisions on funding for innovation and mitigating investment risks of demonstrating critical technologies.

• Develop finance mechanisms to support deployment of near zero emission industrial technologies and associated infrastructure

Over the next three years, G7 members should formulate finance strategies for the deployment of near zero emission technologies at new and existing domestic industrial plants.

• Create differentiated markets for near zero emission material production

G7 members should develop policies ideally within the next three to four years that create demand for near zero emission materials production,

• Explore a non-binding intergovernmental international industry decarbonisation alliance in support of the industry transition

G7 members should consider forming an international industry decarbonisation alliance in 2022.

• Establish a cement sectoral Breakthrough at COP27

This should be done using existing frameworks and secretariats, avoiding the potential for duplication and the need for additional layers of co-ordination.

• Consolidate existing work on measurement standards, ensure their fitness for purpose, and avoid the development of duplicate standards and protocols

G7 members should agree on a common set of measurement standards and reporting frameworks to use for evaluating the emissions intensity of production for each material.

• Adopt stable, absolute and ambitious thresholds for near zero emission material production that take account of sector-specific nuances

The G7 should recognise the definitions proposed herein as a starting point this year, and establish processes to develop and extend them as needed.

• Value interim steps taken to substantially lower emissions intensity, without compromising the stringency of the thresholds for near zero emission production

The IEA proposes a continuous scale of evaluation of "low emission production".

• Extend the reach of work on definitions down existing supply chains, and into new ones

More work is needed to ensure continuity between definitions of near zero emission production – the focus of the report – and near zero emission products and projects.

ical resources use them to scale up practical solutions in a coordinated way. This new report sets out realistic and actionable steps for G7 members that can provide a catalyst for the global progress that is urgently needed.

"To achieve our goal to limit the global temperature rise to 1.5 degrees, we have to decarbonise our industries. This decade is key to set the tracks to climate neutrality. Especially in sectors where emissions are high but hard-to-abate like steel and cement, we have to fundamentally shift production methods.," said Robert Habeck, Germany's Federal Minister for Economic Affairs and Cmate Action.

"The IEA report Achieving Net Zero Heavy Industry Sectors in G7 Members shows us pathways and advances our understanding of the tools and definitions we need. It brings us a big step further to jointly create an international economic and political environment that incentivises investments in green and low carbon production facilities. We want the G7 to be a pioneer in this process."

Heavy industry is responsible for more than 15% of coal use and about 10% of oil and gas use in G7 members. This makes the net zero transition in heavy industry an important pillar for reducing the reliance on fossil fuels in the G7 in the wake of Russia's invasion of Ukraine. However, many of the technologies for significantly reducing emissions from heavy industry are still at large prototype or demonstration stage, and competitive international markets for heavy industrial products often result in profit margins that are too thin to cover the higher up-front costs of integrating low emission processes.

The new IEA report sets out a toolbox that G7 members can draw upon and recommends that they set out ambitious long-term energy transition targets for heavy industry while supporting demonstration and early commercial projects through targeted finance and other risks mitigation measures. These supply-side efforts would also leverage essential private investment, it says.

On the demand side, the report recommends using carbon contracts for difference, public procurement rules, mandates, quotas and other related measures to create differentiated markets for steel and cement production with near zero emissions, which at least in the immediate future will be more expensive than materials made using legacy processes.

Importantly, the report also calls for G7 governments to adopt stable, absolute and ambitious thresholds for material production with near zero emissions. It proposes definitions and relevant thresholds for the G7 to adopt as a starting point that are compatible with a global pathway to net zero emissions by 2050.

G7 members should work with industry to establish agreed-upon thresholds, definitions and measurement standards for what constitutes steel and cement production with near zero emissions, according to the report. This is essential for establishing policy and production guidelines.

Given the urgency of the transition, the report says that G7 economies need to set mechanisms to recognise the use of interim technologies that substantially reduce emissions but do not go far enough to be considered near zero emissions.

More information

Read the full report:

www.iea.org

Developments with ACT

The ACT (Accelerating CCS Technologies) program to fund research and innovation projects in CCU and CCUS is currently in its third round of project funding, said Dr Ragnhild Rønneberg, coordinator of ACT, at the Research Council of Norway.

ACT currently has involvement of 16 funding agencies. These are based in the Alberta province in Canada, Denmark, France, Germany, Greece, India, Italy, the Netherlands, Norway, the Nordic Region, Romania, Spain, Switzerland, Turkey, UK, and USA.

It is also supported by the European Commission under the Horizon 2020 programme for research and innovation.

The first ACT Call for project proposals was published in 2016. The funding agencies ware from 9 countries, and resulted in eight projects with Eur 36m from ACT, of which Eur 12m was from the European Commission (EC). These projects were completed 2020.

The second ACT Call was published 2018. The funding agencies were from 11 countries and 12 projects were funded, ending autumn 2022/winter 2023. The budget for the call was Eur 31m, without EC co-funding.

The third ACT Call was published in 2020. The funding agencies are from 16 regions/countries. 13 projects were funded, ending 2024/2025. The budget for the call was Eur 32m, without EC co-funding.

Results of the ACT programme have to be in line with the EU's "Strategic Energy Technology" (SET) plan and the global "Mission Innovation" research and innovation targets, and pave the way for large scale CCU/CCUS deployment.

There was an ACT knowledge sharing workshop in Rotterdam on June 9, the day after the main CCS conference.

"The ACT project is more than the sum of national efforts', Dr Rønneberg said at the Rotterdam conference. "ACT established collaboration between partners in Europe and across the Atlantic and to India. Without ACT [they] would not have found each other that easily."

More information

Details about the calls are available here:

www.act-ccs.eu

Update on CCS in Rotterdam - report from the Cato CCS Forum

We heard an update on Rotterdam's PORTHOS CCS project, further plans for CCS in the Netherlands, Port of Rotterdam's hydrogen imports, challenges for Dutch industry, and how policy is evolving, at a conference in Rotterdam on June 8-9. By Karl Jeffery

The Final Investment Decision for the Netherlands PORTHOS CCS project should be made in 2022, leading to operation in 2024 to 2025, said Nico de Meester, external relations manager for the PORTHOS project.

He was speaking at a CCUS forum in Rotterdam on June 8-9, organised jointly by CATO; the Dutch national R&D programme for CO2 capture, transport and storage; the Norwegian Embassy for the Netherlands; the Dutch Ministry of Economic Affairs and Climate Policy; and ERANET-ACT, an international R&I funding program for Accelerating CCS Technologies.

PORTHOS is a partnership between the Port of Rotterdam Authority, energy network operator Gasunie, and state-owned exploration and production company EBN.

The initial phase of PORTHOS will have capacity to store 2.5 MT / year. The total capacity of the initial storage site is 37 MT, so enough for 15 years of full capacity operation.

The CCUS forum in Rotterdam on June 8-9 was held onboard the SS Rotterdam

The investment in the transport and storage infrastructure is Eur 450 - 500m. The clients will pay their own costs of capture, separating CO2 from their other gases. "You can get a business case with these numbers," he said.

The full capacity of the initial storage site has already been sold to four clients: Air Liquide, Air Products, ExxonMobil and Shell.

Offshore, the project will re-purpose the existing platform and extraction pipelines. This system will be adapted to inject CO2 in the depleted gas fields.

Most of the CO2 projects connected to PORTHOS will be generating blue hydrogen, he said. Shell is also planning to connect a biofuel plant to PORTHOS.

On the question of whether government funding should focus on blue or green hydrogen, Mr de Meester said that so much volume of hydrogen will be needed, funding of one type would not reduce the need for another. "Developing blue hydrogen will not prevent further development of green hydrogen," he said.

To expand the project, "we need more offshore storage fields," he said.

Another storage project under development in the same offshore region is ARAMIS (https://www.aramis-ccs.com/) a cooperation between TotalEnergies, Shell, Energie Beheer Nederland (EBN) and Nederlandse Gasunie. It uses a number of depleted gas fields, which combined have more than 400 Mt of storage capacity.

This project includes CO2 transport by pipeline, barge or coaster ship from inland to a CO2 collection hub on the Maasvlaakte in the Port of Rotterdam. The project expects to initially transport approximately 5m tonnes a year of CO_2 to the storage locations, being increased gradually to 20m tonnes.

The project team are "looking at 2026-2027" to have it operational, added a representative from Shell in the conference audience.

Port of Rotterdam

Allard Castelein, President and CEO of the Port of Rotterdam, described the Port's decarbonisation strategy as having four pillars.

First, energy efficiency and infrastructure, which means CCS, making use of residual heat, and having a shared stream infrastructure for industrial facilities, rather than them all generating steam individually.

Second, a 'new energy system', which means moving to hydrogen. The Port's modelling shows a need for 18m tonnes of hydrogen to be imported every year from sources outside Europe in 2050. Current projects of both local production and imports add up to 4.6 m tonnes in 2030.

Third, new raw materials and fuels systems.

Fourth, decarbonising transportation.

The port is part of the "Getting to Zero Coalition," which wants maritime trade to have an opportunity to be fully decarbonised by 2030, he said.

The CO2 and hydrogen infrastructure can continue into the hinterland. Mr Castelein said he was "going to Germany tomorrow" to discuss plans with a private industrial consortium to receive hydrogen via Rotterdam, and then send CO2 back for sequestration.

When asked about the biggest obstacles, Mr Castelein said it was the regulatory hurdles and demands for more studies. For example, at the time of the event, there was a hold-up to PORTHOS due to concerns that it may lead to more emissions of nitrogen compounds during the construction phase which could damage biodiversity.

"You need 'exchange money' to move things forward," he said, implying that to make progress, there needs to be some manoeuvring room, rather than stopping a project when there is a small risk of any negative impact. "If we fall back and get hampered by analyses, we will miss the targets we have set out for ourselves," he said.

Yara Netherlands

Michael Schlaug, managing director of fertiliser manufacturer Yara Netherlands, explained the challenges he faces, maintaining commercial competitiveness while decarbonising. He also faces demands from some environmentalists that hydrogen should come from renewable sources rather than CCS – and some people saying that ammonia-based fertiliser should not be used at all.

Yara comes under pressure as the largest single gas consumer in the Netherlands, he said. This makes it the 5th largest emitter in the country. Its ammonia production emits 2.2 mtpa (million tonnes per annum) CO2, and together with other production facilities, it emits 3.3 mtpa CO2.

In its "climate roadmap" to 2030, it envisages reducing CO2 emissions by modifications and efficiencies (0.4 to 0.6 mtpa), using CCS (0.8 mtpa) and using green hydrogen (0.1 mtpa), totalling 1.3 to 1.5 mtpa reduction to the emissions from ammonia production.

The company calculates that if it were to convert all its operations to green (renewably sourced) hydrogen, it would require 2.2GW of renewable electricity. By comparison, the entire Netherlands has 7.8 GW of wind power and 14.2 GW of solar (2021 numbers) – and this power is only generated when it is windy or sunny.

This indicates why CCS is necessary to obtain decarbonised hydrogen, he said. "The business case on green hydrogen doesn't work for us, we have to wait for costs to come down. We need CCS as a first step to decarbonize."

The company does however have a project to explore making its own green hydrogen, with a 100 MW electrolyser.

On the other hand, the company envisages that there could be new markets for clean (decarbonised) ammonia. While farmers may not pay more for fertiliser made without CO2 emissions, the maritime industry might do.

Mr Schlaug sees that ammonia could be a better choice for decarbonised maritime fuel than hydrogen, since it has a higher energy density. "We believe it can be used for larger shipping vessels," he said. "If only a small proportion of ships are converted, that is a massive business opportunity."

Yara envisages that its annual production will be 700 ktpa (thousand tonnes per annum) blue ammonia by 2025, and 70 ktpa green ammonia from 2025.

Yara has not yet identified a CO2 sequestration partner. It is not part of PORTHOS, currently the only CCS project in Rotterdam under development. "We can't do this on our own," he said. "We are not the party that puts the CO2 in the ground. I need someone to take it. We are ready as of 2025."

Decarbonisation is essential in being able to continue operating the facility, because the costs of emitting CO2 are rising – the Netherlands has both a CO2 charge and a requirement to buy ETS certificates. But Yara exports 50 per cent of its production outside the EU, so it needs to be competitive with producers outside the EU.

Until now, it has survived by achieving higher efficiencies and reliability compared to plants outside the EU, to compensate for the higher costs of EU operations. It has also faced the difficulty of gas prices being higher in Western Europe than in the US, where there are other fertiliser manufacturers it competes with.

The extra cost of decarbonised fertiliser is unlikely to be paid for by farmers, he said. "It is essential for us to create a market where there is a value for green or blue products."

"Fertilizer is required, the Ukraine crisis shows it. There will be a food crisis – I hope it will be a small one."

Mr Schlaug said that production had been reduced over March to April, due to high gas prices in Rotterdam (after the Ukraine invasion) making it more expensive to produce. But in May the fertiliser prices increased, making it possible to operate. "For time being we are at 90 per cent [capacity]," he said.

Mr Schlaug was asked about concerns raised by some NGOs, that there should not be so much production of fertiliser if it involves emissions.

He replied that Yara has no intention of providing more fertiliser than farmers need. If they use too much fertiliser it can find its way into waterways and pollute. But if you use too little, you end up with less food.

One audience member from an energy consultancy noted that renewable energy is not going to be unlimited for several decades. Until it is unlimited, it would make sense to only use it where most value can be taken from it. Using to make hydrogen with an electrolyser at 60-70 per cent efficiency "seems pretty stupid", when there are ways to use it at 100 per cent efficiency. "That is an argument for blue hydrogen," the audience member opined.

Dutch government

Joëlle Rekers, policy co-ordinator on CCS with the Dutch government, said that developing CCS policy felt like "building an aeroplane while flying", with people seeking to develop projects while the policy has not yet been fully formulated.

The Dutch government sought to find a consensus between all interested parties, from oil and gas companies to environmental groups, based on the facts, she said.

As part of this discussion, the government presented estimates of the mitigation potential of various mitigation methods in million tonnes CO2 a year by 2030. CCS was by far the highest, with a low estimate of 11 and a high of 21 mtpa.

Improving process efficiency was second best, estimated to save 7.9 mtpa. Biomass boilers were estimated to save 7.4 mtpa. Recycling was estimated to save only 2.2 mtpa. reducing CCS process emissions was estimated to save between 1 and 2 mtpa. Estimates of mitigation potential from electrification - switching fossil to wind energy and then making green hydrogen, somehow turned out to be negative, at -1.2 mtpa.

The government has supported the PORTHOS project with the aim for it to be a 'market maker', providing services to store people's CO2, she said.

One audience member asked about Netherlands' mix of incentive measures, with both a CO2 tax and an emissions trading scheme, so companies effectively pay to emit twice. Another audience member asked whether the government would consider imposing a 'carbon take-back obligation' on oil and gas producers, where they would be required to sequester CO2 to balance the hydrocarbons they produce or buy certificates from another company which does this.

While Ms Rekers did not address the questions directly, she said "it is a broad topic. It is what we are thinking about every day. I don't know all the answers. What the best mix is – it is difficult."

Also, the Dutch government does not have any 'top down' master plan for CO2 infrastructure, because it needs to be demand driven. "Industry has to make the choice – do we implement CCS or a different technology?" she said.

Tom Berendsen, a member of the European Parliament for the Netherlands, and a member of its Committee on Industry, Research and Energy, noted that "the challenge for your sector is to show why CCS will play a role, when we want to get rid of Russian gas as quickly as possible."

Hans Vijlbrief, Dutch State Secretary for Extractive Industries, noted that his party, "Democrats 66", has not always liked CCS. "We changed, because we think its so important to have all technologies. Sustainable energy policy is not one of exclusion," he said.

European Commission perspective

There was a lively discussion at the Forum

Krzysztof (Chris) Bolesta, CO2 capture, Use and Storage Policy Lead at the European Commission, noted that the commission had first tried to do a "big moon landing" with CCS in 2007 – a major expansion of the technology. In his reading, "we had a big crash because there was no business case back then".

Carbon capture was initially seen as a way to decarbonise coal power production, but then people saw that coal power could be replaced by renewable energy. "It proved to be the wrong kind of CCS," he said.

Now, CCS is seen to be a method of decarbonising heavy industry. "We have a new dawn for CCS now. I believe this is a different situation of the technology- a reset button."

"I think the European parliament is slowly turning to CCS as a solution," he said. "Even green NGOs now realize it is part of the solution."

The Emission Trading Scheme "is starting to kick in" and pushing industry to do more.

"We are constantly modelling what the future could look like," he said. But CCS is expected to be continued to be required for the 'hard to abate' sectors.

So far, we have seen that creating CO2 storage sites takes more time than expected, including for permitting, he said.

Some EU funding for decarbonisation has not been available for CO2 infrastructure projects, he said. Now, there are a number of different innovation funds, which could potentially give money for CCS and CCU, with the next round of winning projects to be announced in July.

He stressed that there is a need to get an understanding of what CO2 infrastructure is needed Europe-wide. "We need to see a European level vision," he said.

Mr Bolesta was asked about the EU's commitment to make 50 per cent of the hydrogen industry 'green' (renewably sourced) by 2030, and whether this puts CCS projects at risk.

Mr Bolesta replied that the Russian invasion of Ukraine is causing a re-think. "It is something we didn't expect, and our modelling didn't factor."

Jan Brouwer

Jan Brouwer, former program director of CATO, died in July 2021, after an illness of five years, at the age of 62, delegates heard.

"Jan was a very respected colleague, inspirer, mentor and friend for many of us. We will remember his wisdom, warmth, creativity, sense of humour and more," said Jan Hopman, director of CATO, opening the conference.

During his illness, Mr Brouwer continued at Dutch research centre TNO, and established the Rijswijk Center for Sustainable Geo-Energy, which is currently operational, and being used in a large number of geo-energy projects including for CCUS, Mr Hopman said.

More information

Presentations from the event are available on the CATO website – **www.co2-cato.org** under news / events / June 2022 CCUS conference

Why environmental groups changed their CCS position

Environmental groups / NGOs are more supportive of CCS than they have been before, but not completely supportive, and not including Greenpeace. A discussion at a Rotterdam event explored what is going on.

"Of all decarbonization options for industry, CCS has been doubted a lot," said Michelle Prins, from environmental group (Non-Governmental Organisation) Natuur & Milieu. "For every reason to do CCS you can think of a reason not to."

She was speaking at the CATO / Dutch government / Norwegian Embassy / ACT forum in Rotterdam on July 8-9.

"The main concern is about lock in or no phase out of fossil fuels," she said. But additionally, "It is energy intensive. The capture rates are not 100 per cent. (It may lead to) delaying investment in renewable technologies. [There are] concerns about safety and ecology."

But overall, Natuur & Milieu supports CCS, on the basis that keeping carbon out of the atmosphere is the ultimate objective, and it wants to support technologies which achieve this.

The various pro and anti arguments for CCS were carefully mapped out, as part of a government driven process to try to get agreement between organisations in the Netherlands in 2019, she said.

Discussions between all interested parties, including the government, NGOs, and big emitters, ended up with a consensus that CCS is needed. Aiming to reach consensus is "how we do it in the Netherlands," she said.

As part of this consensus building process, a number of conditions on government funding were agreed. There should be sufficient funding left over for other technology (such as renewables); CCS is only funded by government where "no alternatives exist"; after 2035 no more grants are to be issued for CCS unless they involve negative emissions; and from 2030 the maximum subsidy will be for 9.7 mtpa CO_2.

Some people have argued that CO_2 utilisation should be prioritised over CO_2 sequestration, on the basis that carbon is being reused, but Ms Prins believes that avoiding emissions to atmosphere should be the overall goal, not avoiding CO_2 sequestration.

The discussion considered a requirement for CCS investors to also invest in renewables, but this was rejected, she said. But it would still be a good idea to always consider renewable investment. "NGOs are blamed for dismissing options, I ask you [as CCS companies] not to dismiss options," she said.

Remco de Boer, an energy transition consultant and researcher, moderating the discussion, challenged Ms Prins about her organisation's organised opposition to CCS in 2017.

Ms Prins denied that Natuur & Milieu had been in opposition to CCS itself in 2017 but said it had been in opposition to public subsidy of it.

"No, that is not correct," Mr Boer said.

"We made some mistakes in that campaign, I will admit that" Ms Prins said. "We had a campaign against public funding. It was not against CCS, the intention was not."

Mr Boer also asked Ms Prins why her organisation was still guarded in its public support for CCS, given that it had participated in a process which aimed to create a consensual outcome, and Natuur & Milieu had signed up to the agreement. "We had real concerns about fossil fuel lock in," she replied.

When asked what the biggest challenges were with CCS, Ms Prins replied that it was to "do the projects right and show good results in CO_2 reduction".

Bellona perspective

Jonas Helseth, director of NGO Bellona Europe, noted that the past ten years have been a "lost decade" in CCS. The plans put together by the Zero Emission Partnership back in 2013 look very similar to the plans being put into action today. "We are 10 years behind schedule," he said. "Everyone seems to be way too comfortable."

Mr Helseth had criticism for the plans of Tata Steel to power its operations on green hydrogen rather than blue, noting that it would require more renewable energy than the entire 2020 Dutch wind production.

If the renewable electricity is not available, it would give Tata an excuse to continue using gas for power, he said. "Are we looking at a steel industry which is going to do nothing for 10 years? We don't have a plan."

Event moderator Remco de Boer put it to Mr Helseth that Tata had originally planned to use hydrogen from CCS – but switched to green hydrogen under pressure from environmental groups. Should Bellona be criticising other environmental groups for their pressure resulting in Tata having an unachievable plan?

Mr Helseth required that the problem was more that the discussion was based on opinions rather than numbers. "I followed the debate in [the Dutch] parliament. There were no numbers in the debate, it was just a debate about concepts," he said.

Mr Helseth added that environmental groups are still guarded in their support for CCS because it is "not something we should love", given that it still involves fossil fuels. "It is something we should deal with."

Bellona is uneasy about cement and steel manufacturers leaving the job of CO_2 sequestration to the "oil and gas industry", given that it distrusts this industry, he said.

Mr Helseth was scathing about plans some companies are making to utilise CO_2 to make new materials, given that the process would require large amounts of hydrogen made from renewable electricity. The amount of renewable power needed makes it unrealistic.

"I hate the term CCUS," he said. "CCU [utilisation] can be really interesting, but [you have to look at the accounting to see if it is climate relevant."

Mr Helseth noted that the Dutch are not as concerned as they should be about emissions from cement manufacturing. This may be because there is no cement manufacturing within the country itself. But it still needs cement, including for building low emission passive houses, and there is cement manufacturing very close to the Dutch border. "As a society we have a common responsibility for this," he said.

Tom Mikunda, representing the Dutch government, said that NGOs are taken very seriously in Dutch policy discussions. "Some NGOs we have frequent dialogue with, constructive dialogue," he said.

But "Greenpeace in the Netherlands are openly against any form of CCS," he said. "It is hard to have a dialogue then, about how you should approach it, e.g., for financing, if someone is completely against it."

While Greenpeace participated in the climate discussions and influenced them, it did not sign the final climate agreement, he said.

Bellona's Mr Helseth noted that Greenpeace's concern about CCS came down to distrust of companies. For example, that coal companies may be using CCS as a 'fig leaf' to say that people don't need to worry about the climate impact of coal.

Update on CCS in Norway - report from the Cato CCS Forum continued

At the Rotterdam CCS conference, delegates heard an update about perspectives on CCS within the Norway government, and how the Northern Lights project is developing, with speakers including the government's State Secretary for Petroleum and Energy.

The Longship project, the Norwegian Government's full-scale carbon capture and storage project. should complete its first development phase in mid 2024, said Amund Vik, State Secretary in the Norwegian Ministry of Petroleum and Energy.

There should be a decision on what is included in the second stage of the project over 2022 to 2023.

Asked about the perspective of Norwegian environmental groups, Mr Vik noted that they had not all taken the same line. Bellona is positive about CCS, but "others" are less positive, he said.

But everybody agrees that the carbon emissions problem needs solving, and CCS is a way to do that. "I think in general the Norwegian public supports CCS. We're in a period where we can actually make CCS happen."

Norway's business plan involves accepting CO2 from other countries and offering a storage facility. One challenge to this has been that the 2009-amendment to the London Protocol, allowing export of CO2 for storage in sub-seabed geological formations, has not formally entered into force.

However, since 2019/in the meantime, provisional application of this amendment is allowed in advance of its ratification.

Mr. Vik is keen to see this amendment formally enter into force and encourage Parties to ratify it, he said. Pursuant to the London Protocol, the countries concerned need to enter into an agreement or arrangement in order to export the CO2 for offshore storage.

When asked what the biggest challenges in CCS implementation were, he replied that it is to achieve "scale and pace".

We're in a period where we can actually make CCS happen" - Amund Vik, State Secretary in the Norwegian Ministry of Petroleum and Energy

Richard Wouters, from Dutch environmental thinktank Wetenschappelijk Bureau GroenLinks, suggested that Norway should state its 'end date' for CO2 production. But Mr Vik declined. "For us, I think it is important to produce [hydrocarbons]," he said.

"Product volumes will be necessary to manage the transition in Europe. And also, to make blue hydrogen, which I think is going to be very important." However, "We are strengthening the climate risk assessment."

In April 2022, Equinor announced that it had been awarded 'operatorships' to develop two CO2 storage sites, Smeaheia in the North Sea and Polaris in the Barents Sea. Equinor plans for Smeaheia to handle 20m tonnes CO2 a year.

The Barents Sea project is intended to connect to a blue ammonia production facility in Hammerfest, in Norway's far North, using Barents Sea natural gas. The first stage is to store 2m tonnes CO2 a year.

Northern Lights

Northern Lights is a component of Longship, developing and operating CO_2 transport and storage facilities. It had its final investment decision to go ahead in December 2020.

Martijn Smit, director of business development at Norway's Northern Lights project, and formerly country manager for Netherlands and Suriname with Equinor, gave an update.

The facilities are under construction. The receiving terminal is the most visible part, but wells are being drilled and the pipeline will be laid early 2023. Mr Smit showed a photo of the receiving terminal where the jetty and visitor centre is almost complete. The Carbon Capture Journal believes this makes it the first large scale CCS project associated with onshore heavy industry to break physical ground in Europe.

Phase one of the project will be completed mid-2024 with a capacity of up to 1.5 million tonnes of CO_2 per year. 800,000 tonnes CO_2 a year will come from Norway's Longship capture projects, if both of Norway's initial capture projects are developed.

The storage facility is available to any company needing CO_2 sequestration services, he said, with 700,000 tonnes a year available at this initial stage of the project. The receiving terminal will be built from the outset to accommodate higher volumes than the 1.5 mtpa of phase 1.

Phase two of the project has an ambition to expand capacity by a further 3.5 mtpa to a total of 5 mtpa, depending on market demand. The front-end engineering and design (FEED) of Phase 2 should be completed in Oct-Nov 2022, with a final investment decision planned in Q4 2022 or Q1 2023 subject to amongst others customer commitments, leading to 5-7m tonnes a year being stored from early 2026.

The market demand is significant and Northern Lights is in dialogue with customers representing up to 32 mtpa CO_2 by 2030. Storage capacity will be a challenge – this is the bottleneck at the moment, he said.

The project is receiving state support, which helped break the 'chicken and egg' problem. Otherwise, nobody would have wanted to plan to store CO_2 without a facility available, and no-one would have wanted to build CO_2 storage without a customer, he said. Public funding helps a great deal, but "the risks are [still] significant."

The CO_2 receiving terminal for Northern Lights will be located at the premises of Energiparken industrial area in the municipality of Øygarden in Western Norway

There has also been "huge interest" in using the site for negative emissions projects (either bio-energy CCS, or direct air capture). "That is a new business generated on the back of a storage site," he said.

When asked about public perception, Mr Smit replied that CO_2 sequestration is seen differently in Norway compared to the Netherlands. In the Netherlands CCS is seen as a temporary solution until all necessary energy can be obtained from renewable sources; while in Norway, CO_2 storage is seen as a new business opportunity. Much energy consumed within the country is already green (from large hydroelectric power generation).

For the project to be successful, it needs to demonstrate that it is reliable and safe, affordable and profitable, marketable, and acceptable in the political and public dimensions. "It is not enough that the public accepts CCS as such," he said.

The ETS price is currently around Eur 80 a tonne in Europe. The cost for capture, transport and storage respectively is still higher than this, so even at a Eur 80 tonne carbon price [cost to emit to atmosphere], it is still cheaper for them to emit. Government support will therefore be needed in this initial phase, until the ETS price goes up and cost is coming down.

The growing ETS price is a great help in making a business case. But for now, "many emitters receive ETS allowances for free," he said.

Paal Frisvold, who has a role of "EU Climate Pact Ambassador" with the European Commission and is described as a "Norwegian organisational leader" on Wikipedia, noted that the tankers being built to transport CO_2 from Norwegian capture sites to the jetty for sequestration in the Northern Lights project, are being built in China.

This is not good news for a project supported by the Norwegian government, he said. "That was not part of the deal. We must make CCS a European endeavour."

Mr Frisvold's second concern was the high cost of CO_2 storage in Norway. He said he had found out through private channels that Equinor is actually asking German industry to pay Eur 50 / tonne to store CO_2.

Eur 50 "is too much - a prohibitive price if you are going to decarbonize the German energy sector," Mr Frisvold said. While the cost of CO_2 capture has reduced to Eur 20 a tonne, "We don't see the same develop in transport and storage."

The Norwegian government should itself set the pricing and leave industry with the challenge of delivering storage for that price, similarly to how it sets the pricing for garbage disposal services, he suggested.

More information

Presentations from the event are available on the CATO website – **www.co2-cato.org** under news / events / June 2022 CCUS conference

Update on CCS in the UK

The Offshore Energies UK annual industry conference in Aberdeen on May 24 reviewed developments with CCS in the UK, covering both policy and projects. By Karl Jeffery

While the end state with CCS is easy to define, working out how to get there is much more difficult, said Alex Milward, director of CCS at UK overnment's Department for Business, Energy & Industrial Strategy (BEIS).

Mr Milward's motivation for getting involved in CCS is that he sees it as a way for the good things in life to continue. "I'm here because I want to fly and drive, guilt free, as we used to be able to do."

CCS is of particular interest for Mr Milward, because he sees that the renewables sector in the UK is progressing well, but in CCS there is a "classic economic market failure which needs bridging."

The market failure is that the cost of capturing and storing CO2 is still higher than the cost of emitting it – but if the government simply imposed costs on emissions, it would put its own industries at a competitive disadvantage compared to other countries.

Mr Milward noted that everywhere in the world which has a carbon price, we are seeing the price go up. "But the whole world does not have a CO2 price, That's one of the dilemmas for government." CCS means a "cost on taxpayers which may not be borne in other countries. Judging that pace is a fine art."

Mr Milward was the overseer of the process of assessing which UK cluster projects received financing under the first phase, with the winning clusters being HyNet in Northwest England, and the East Coast Cluster, covering Humber and Teesside.

A third contender, Scotland's Acorn project, did not receive financing. There has been some scepticism that the funding decision may have been politically motivated, since the UK's governing conservative party has little chance of winning seats in Scotland but won many seats in Northern England for the first time in the last election, which it seeks to hold on to.

Mr Milward sought to put this scepticism to rest. The criteria for choosing the winners was agreed in advance, and the candidates were put through a thorough assessment process against these criteria. "It was a non politically interfered process, I can assure you of that," he said.

The UK CCS funding decision making is "the most complex program I've ever worked on," he said. "The sequencing job was really difficult (choosing who gets government funding first) which is exactly what you want." It implies that there were good options to choose from.

Talking in general about government funding, it seeks to be on the 'leading edge', not the 'bleeding edge', he said. In Mr Milward's definition, the 'bleeding edge' is where money can easily bleed away. One example of this is if the UK took a position well in advance of other countries.

"(People) from industry tell me they are looking forward to the day government gets out of the way [of CCS]. Rest assured that's also our ambition. The aim is building a comprehensive, self sustaining CO2 market," he said.

The UK clusters have a mix of regulators. The North Sea Transition Authority (formerly Oil and Gas UK) will have a role in ensuring efficiency. It could have stuck with its former name, but counting CO2 as a gas being regulated, he joked.

The Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) will have an important role.

Once a CO2 emitter is connected to a pipeline, the system needs to be regulated like a utility, to avoid the storage company abusing its monopoly power – which brings in OFGEN, the Office of Gas and Electricity Markets.

The UK has published all its plans and CCUS investor roadmap on its website. "I talk to other countries [they say] its incredible how far ahead the UK is," he said.

Mr Milward was asked about how suppliers should best make use of the opportunities in the UK's CCS industry. He replied that getting CCS experience may be most important. "You're going to invite someone who's done it before, that's the same all over the world," he said.

"The aim is building a comprehensive, self sustaining CO2 market" – Alex Milward, director of CCS at UK Government's Department for Business, Energy & Industrial Strategy (BEIS)

Mr Milward said he expected the costs of CCS to go down after the first project, because this is what normally happens. The size of the first allocation of money to UK wind farms seemed high just one year later. Another analogy is Roger Bannister being the first to run a mile in 4 minutes. While it was a great achievement, many other people managed to do it soon after, he said.

Wood Mackenzie research

Mhairidh Evans, Head of CCUS Research with energy research firm Wood Mackenzie, said that her organisation forecasts £23bn will be spent in new upstream developments up to 2030 in the UK, and £14bn on decommissioning. Spending on upstream electrification will be £5bn, offshore wind spending £60bn, CCUS £37bn, and hydrogen production £37bn.

It counts 44 CCUS projects "in the pipeline" in the UK. Wood Mackenzie has been analysing how the UK compares with other parts of the world as having the ingredients of a successful CCUS market.

One factor is having capturable CO2 emissions, ideally in a cluster. Here the UK may be less attractive for CCS than China, India, US or South East Asia, which have plenty of emissions to capture. In the UK, emissions are on a downward trajectory.

But for storage, the UK scores very well, with plenty of space to store CO2 which is not too far offshore. Putting this together, it means the UK may have opportunities storing CO2 from other countries.

Wood Mackenzie thinks the UK's government position is good compared to other countries' governments, with clarity of ambition, very specific targets and funding streams.

"People ask, 'how can we replicate the UK model'. It's not perfect but up there with the best," she said.

The industry position in the UK is also good, but the costs of development are bad compared to other countries. "Carbon capture is a high-cost technology, bringing down technology costs makes this easier to solve," she said.

The UK has the third biggest CCS project pipeline in the world after the US and Canada, she said.

"The UK government's ambition is high. Company ambition is even higher. 20-30 mtpa is already in our opinion an ambitious target. But this is a good problem to have."

The best way to get new projects moving would be some completed, successful projects, she said. "CCS has a stuttering track record. Confidence in technology will go a long way. That's first on the to-do list."

Ms Evans was asked how she thinks the costs of CCS will change. "Capture costs is generally the biggest part of the cost," she replied. "Post combustion capture is a relatively immature technology. But there's lots of R+D to get after that."

ENI and Liverpool Bay

Martin Currie, energy transition manager with oil and gas operator ENI, gave an update on CO2 storage in the Liverpool Bay in Northwest England, a component of the HyNet CO2 storage cluster.

ENI is repurposing existing gas production assets for this project. Three gas fields will be used simultaneously for storage – they are called Hamilton North, Hamilton East and Hamilton. The storage is 10-20 miles offshore.

ENI received a CO2 license in October 2020, the fourth to be awarded in the UK (CS004).

ENI has oil and gas production operations in Liverpool Bay, and off the Norfolk Coast (Hewitt) on the other side of the country.

ENI plans to do decommissioning and construction at the same time, removing assets it doesn't need while it builds new ones. This helps save costs.

It has 19 Memoranda of Understanding with companies interested in storing CO2.

"There's demand from sites in South Wales, Midlands, Thames Estuary, peak District" he said. "We've got our own ideas on shipping CO2, also road and rail is feasible."

When asked what the biggest challenge is when repurposing assets, Mr Currie said that it was ensuring that the repurposed asset will be able to operate long enough to make a new project worthwhile – and having room for expansion.

Not everything is suitable for re-use – on one platform, ENI plans to remove the entire topsides and putting a new one on, he said.

East Coast cluster

Luke Warren, H2 and CCUS adviser with BP and former chief executive of the Carbon Capture and Storage Association, presented developments with the East Coast cluster, which covers the Teesside and Humber industrial regions.

The project will provide blue hydrogen production, net zero power generation, and green hydrogen, as well as CCS.

Transport and storage is provided by the Northern Endurance Partnership, involving BP, National Grid, Equinor, Shell and Total.

The storage will be in the Endurance field, a deep saline formation, and the largest saline aquifer in the Southern North Sea. There is confidence in saline aquifer storage, since Sleipner, which has been successfully storing CO2 since 1996 offshore Norway, also uses a saline aquifer.

There is capacity for 1bn tonnes storage in the Southern North Sea "when we build out," Mr Warren said.

CO2 capture and onshore gathering is provided by the Net Zero Teesside CO2 gathering network, comprising several industrial, power and hydrogen businesses. "Both Humber and Teesside have very diverse emitters including bioenergy," Mr Warren said.

In April, Costain was awarded the onshore FEED contract, to design the onshore CO2 gathering pipeline and the new grid connection for the gas power-station.

Another project is Net Zero Teesside Power, which bids to become the world's first commercial scale gas fired power station with CCS, providing low carbon flexible power. The Front-End Engineering Design (FEED) contract was awarded to Technip Energies and GE Gas Power in Dec 2021.

A £1bn investment in hydrogen is planned.

Mr Warren was asked if there may be objections from the public to CO2 pipelines near their homes. "The reality is we're going to learn much more about this," he replied.

Many members of the public say they prefer something which feels more natural to them, which means renewables. "But once time is taken to explain [reasons for CCS] the level of support starts to rise."

"Independent organisations like the Committee for Climate Change have an important role in showing how CCS fits with climate change."

Shell and Acorn

Simon Roddy, Senior Vice President of UK

By 2045, the whole UK network could be "hydrogen ready" – Derek Radburn, senior hydrogen analyst, National Grid

Upstream with Shell, said that Shell took on the role as "technical developer" of the Scotland Acorn CCS project.

For Acorn, it is working with emitters in Scotland's "Central Belt", roughly speaking from Glasgow to Edinburgh. This includes industrial facilities from Exxon and INEOS.

Shell is hoping for clarity from the government soon about whether Acorn will be funded under Track 2 of its clusters program, he said.

Altogether, Shell aims to have 25m tonnes a year storage capacity by 2025. It is involved in the CCS Quest (Canada) and Gorgon (Australia), which have stored 12m tones of CO2 to date.

Update on hydrogen in the UK

"I struggle to remember a time of such possibility for all of us," said Bob Drummond, CEO of fluid transfer company Hydrasun, chairing and opening a session on hydrogen, as part of Offshore Energies UK 2022 Industry Conference in Aberdeen on May 24, 2022.

There are 359 "large scale" hydrogen projects in the world and plotting them on a map shows the epicentre is in Europe, he said. As part of that, "I believe Aberdeen can be net zero capital of Europe," he said.

National Grid

The UK's National Grid is considering the best way to transition to hydrogen as an energy carrier, and what existing assets could be used, said Derek Radburn, senior hydrogen analyst, National Grid.

National Grid is a company which runs the electricity and gas infrastructure in most of the UK.

A starting point is blending hydrogen into the natural gas pipeline system, starting with 2 per cent hydrogen, which is considered safe. Then the level of hydrogen can be gradually increased as an experiment.

National Grid is considering starting with the 2 per cent blend in 2024 to 2025, and then trying 20 per cent and over from 2025, he said.

The decision to allow blends of hydrogen to be taken into the UK gas network, expected to be made in 2023, could be a very important accelerator for the UK hydrogen industry, he said.

The yet unanswered question is whether existing gas consuming devices can work well on higher levels of hydrogen and whether there will be any impact on the infrastructure, such as higher levels of leaks.

National Grid will research how hydrogen interacts with pipelines and equipment, at DNV's Spadeadam Research and Testing facility in Cumbria, Northern England, where it is building a new high pressure hydrogen research centre.

It has been building and commissioning the centre since Jul 21 for completion in Nov 22; then it will run the first tests over Dec 22 to June 23, including at 2 per cent and 20 per cent hydrogen / natural gas blends, and 100 per cent hydrogen. In the second phase of development there will be a 1km loop of pipeline and a compressor. "We'll know which assets work with hydrogen and which don't," he said.

It may be possible for customers who cannot use high levels of hydrogen to 'deblend' at their site, removing hydrogen from the blended stream.

Separately, National Grid has a plan called Project Union to develop a hydrogen 'backbone' network in the UK in the 2030s, repurposing around 25 per cent of current gas transmission pipelines to 100 per cent hydrogen.

This would give much better access to hydrogen across the country, enable system resilience if there were multiple routes for hydrogen to get from supplier to consumer, and allow hydrogen markets to develop. It would provide more "optionality" for future decision making.

By 2045, the whole UK network could be "hydrogen ready".

In terms of customers for hydrogen, Mr Radburn says he sees it being used initially by industrial and power sectors. But it would be used by all gas consumers if the blending starts.

Kellas Midstream

Kellas Midstream has plans to provide 1 GW of blue hydrogen made from gas coming into Teesside, connected to CO2 sequestration, in the "H2NorthEast" project, part of the East Coast CCS Cluster.

Kellas Midstream owns gas transportation and processing infrastructure in the Central and Southern North Sea. This includes the system

"Success in Teesside will depend on the level of collaboration between companies, and support from government" – Guy Appleton, Finance & Growth Director, Kellas Midstream

which connects the Central North Sea to Teesside, which brings in 25 per cent of the UK's total gas production.

Kellas' network also connects the Southern North Sea to the Bacton terminal in Norfolk and to Easington terminal in East Yorkshire.

The first phase of the hydrogen project will supply 355 MW hydrogen to individual customers, planned to be 'upscaled' to 1 GW by 2030. This will be 10 per cent of the UK target for hydrogen capacity. £750m will be invested in the project, said Guy Appleton, Finance & Growth Director, Kellas Midstream.

"If you asked me 2-3 years ago, would I be working on a project like this, I didn't see this. The opportunity is unprecedented," he said.

But success in Teesside will depend on the level of collaboration between companies, and support from government, he said.

NZTC

The Net Zero Technology Centre (NZTC) is a research centre funded by the UK and Scottish government. Since being launched in 2017 as the Oil and Gas Technology Centre, it has co-invested £232m together with industry, with £66.9m co-invested over Apr 2021-March 2022.

Looking at hydrogen in the EU, Craig Hodge, Project Engineer - Hydrogen and Energy System Integration with NTZC, noted that Germany, France and the Netherlands expect their own hydrogen production to be insufficient for their needs. So they forecast a big need to import. These imports could come from Scotland.

But there will be competing sources for low carbon hydrogen, for example hydrogen generated from solar electricity + electrolysis in North Africa.

Mr Hodge was asked if oil and gas skills are transferrable to working with hydrogen. "I think all skills are transferrable," he replied. "I'm a mechanical and electrical engineer. I started in oil and gas and moved to hydrogen."

To accelerate the UK's hydrogen industry, it is important that all forms of low carbon hydrogen are accepted, rather than people saying only green (from renewable electricity) is acceptable, he said. "Green will be the end goal but [we should do] whatever we can do quickest [meanwhile]."

BP Hydrogen Energy

Oliver Taylor, CEO of BP Aberdeen Hydrogen Energy Ltd, said that his company has a project to develop green hydrogen in Aberdeen.

In the first phase of the Aberdeen project, running to 2024, it will develop a 2.1MW electrolyser to make green hydrogen. In the second phase, 2025-30, it will have electrolyser units of above 10MW. In the third phase, it will look at district heating and selling decarbonised fuels to the maritime sector.

The project is part of BP's "decarbonizing cities" program. It has similar projects with the cities of Valencia (Spain) and Houston.

To accelerate the UK's hydrogen industry, it is important that all forms of low carbon hydrogen are accepted - Craig Hodge, Project Engineer - Hydrogen and Energy System Integration with NTZC

One of the biggest factors for success is alignment of interests – such as how BP's interests are aligned with those of Aberdeen City Council, he said.

More information

oeuk.org.uk

Ørsted to capture and store 400,000 tonnes of carbon in 2025

From 2025, Ørsted will be capturing and storing 400,000 tonnes of carbon a year. The capture potential is based on Ørsted's newest straw- and wood chip-fired combined heat and power (CHP) plants.

Ørsted is planning to establish carbon capture at its wood chip-fired Asnæs Power Station in Kalundborg on western Zealand and at the Avedøre Power Station's straw-fired boiler in the Greater Copenhagen area. The technology and logistics for handling and storing carbon from the two CHP plants are in place, and if financial support is obtained from the current tender for carbon capture and storage, Ørsted can be ready to capture and store 400,000 tonnes of carbon as early as 2025, which is also the objective of the political agreement on CCS.

"With carbon capture at the Asnæs and Avedøre CHP plants, we'll be able to capture 400,000 tonnes of carbon from 2025, which can be stored in the North Sea. This will contribute significantly to realising the politically decided climate target for 2025," said Ole Thomsen, Senior Vice President, Ørsted.

Establishing carbon hubs

The two CHP plants boast the best possible infrastructure, as they are linked to the grid and the district heating system and have their own harbours. Thus, they can act as hubs for the handling and shipping of both carbon and green fuels. Ørsted's CHP plants will not only serve as hubs for the capture and shipping of its own carbon, but also for shipping carbon produced by other players. In Kalundborg, Ørsted is, amongst others, in dialogue with Kalundborg Refinery about the possibility of capturing carbon from the oil refinery and piping it to Asnæs Power Station, before sailing it away for storage.

"Our carbon capture plans are based on our newest CHP plants which will be in operation for many years to come, and which run on sustainable straw and wood chips. The CHP plants are uniquely placed, as they have access to all the components which are needed for either capturing and shipping carbon or for using the carbon to produce green fuels, which can then be shipped from the CHP plants' own harbours. And it's already become evident how other companies with captured carbon can use our hubs as well. Kalundborg Refinery is the first potential partner, but there are several other players with carbon emissions where we also see a potential for collaboration," said Ole Thomsen.

"The entire supply chain is already in place, so the first volumes can be shipped and stored from 2025," he added.

Niels Bech, Director for Business Development at Kalundborg Refinery, said, "The potential CCS partnership with Ørsted fits well with Kalundborg Refinery's ambitions for a green transition. With this project we will be able to reduce our CO2-emissions significantly already in 2025, and we look forward to collaborating on CCS and thereby contributing to this technology being developed on a commercial scale for the benefit of Danish companies and the climate."

Asnæs Power Station and Kalundborg Refinery will focus on carbon capture and storage, while the straw-fired boiler at Avedøre Power Station has been designated for capturing and delivering some of the carbon to the initial phases of the Power-to-X project 'Green Fuels for Denmark' where the ambition is to develop green fuels for the shipping and aviation industries.

Consequently, the straw-fired boiler at Avedøre Power Station will be able to deliver carbon for storage and for Power-to-X and to function as a hub for other players with carbon emissions in the Greater Copenhagen area.

The straw-fired boiler at Avedøre Power Station has been designated for capturing and delivering some of the carbon to the initial phases of the Power-to-X project 'Green Fuels for Denmark'

Switching to primarily Danish biomass

Ørsted's carbon capture plans are concentrated on the newest CHP plants with many years of operation left. They are fuelled by sustainable straw and wood chips. Ørsted estimates that, in future, it will be possible to meet the need for sustainable biomass for the company's CHP plants from straw and wood chips primarily from Denmark and neighbouring countries in the Baltic region.

Therefore, Ørsted has decided to reduce the use of imported wood chips from 2030, as the existing wood chip-fired boilers reach the end of their service lives, and the process of increasing the proportion of Danish wood chips at the wood chip-fired power stations has already been initiated. From the mid-2030s, Ørsted expects to primarily use Danish biomass as fuel for its boilers.

Biomass consumption in Denmark will decrease in line with the increasing electrification of heat generation. According to the Danish Energy Agency, Denmark will, however, continue to need a certain amount of sustainable biomass – in combination with heat pumps, electric boilers, and Power-to-X plants – to maintain the high level of reliability of supply that Danes are accustomed to. Therefore, it is necessary to maintain a supply chain of sustainable wood chips and straw.

"Our forecasts show that we'll basically be able to meet our needs for biomass with straw and wood chips from Denmark and, to some extent, from neighbouring countries in the Baltic region, as our wood chip-fired CHP plants reach the end of their service lives."

"We'll still only source certified wood chips from production forests that supply materials for the wood and furniture industries because we need to ensure that our demand for Danish wood chips doesn't result in less untouched forest in Denmark or have a negative impact on forest biodiversity," said Ole Thomsen.

Until the wood chip-fired CHP plants reach the end of their service lives, Ørsted will continue to only use certified wood chips that are produced from sawdust and other wood residues from sustainably managed forests.

"Foreign wood pellets and wood chips are still a good and climate-friendly energy source when coming from certified sustainably managed forests. However, it makes a lot of sense to primarily use biomass from areas which are closer to home and thus get as close as possible to the supply chains to reduce the need for transport," concluded Ole Thomsen.

More information

www.orsted.com

Projects and policy news

Tata Chemicals opens UK's first large-scale CCS plant

www.tatachemicalseurope.com

Tata Chemicals Europe has officially opened the UK's first industrial scale carbon capture and usage plant, signalling a key milestone in the race to meet the UK's net zero targets.

Tata Chemicals Europe's Carbon Capture Plant in the UK will capture 40,000 tonnes of CO2 for use in the manufacture of net zero sodium bicarbonate

The £20 million investment has been completed by Northwich-based Tata Chemicals Europe, one of Europe's leading producers of sodium carbonate, salt and sodium bicarbonate. The plant captures 40,000 tonnes of carbon dioxide each year and reduces TCE's carbon emissions by more than 10%.

The project will help unlock the future of carbon capture as it demonstrates the viability of the technology to remove carbon dioxide from power plant emissions and to use it in high end manufacturing applications.

Speaking about the opening of the plant, Secretary of State for Business and Energy, Kwasi Kwarteng said, "This cutting-edge plant, backed by £4.2 million government funding, demonstrates how carbon capture is attracting new private capital into the UK and is boosting new innovation in green technologies.

"We are determined to make the UK a world-leader in carbon capture, which will help us reduce emissions and be a key part of the future of British industry."

In a world-first, carbon dioxide captured from energy generation emissions is being purified to food and pharmaceutical grade and used as a raw material in the manufacture of sodium bicarbonate which will be known as Ecokarb®. This unique and innovative process is patented in the UK with further patents pending in key territories around the world.

Ecokarb® will be exported to over 60 countries around the world. Much of the sodium bicarbonate exported will be used in haemodialysis to treat people living with kidney disease.

The carbon capture plant, which was supported with a £4.2m grant through the UK Department of Business, Energy and Industrial Strategy's Energy Innovation Programme, marks a major step towards sustainable manufacturing which will see TCE make net zero sodium bicarbonate and one of the lowest carbon footprint sodium carbonate products in the world. These are used to make essential everyday items like glass, washing detergents, pharmaceutical products, food, animal feed and in water purification.

Martin Ashcroft, Managing Director of Tata Chemicals Europe, said, "The completion of the carbon capture and utilisation plant enables us to reduce our carbon emissions, whilst securing our supply of high purity carbon dioxide, a critical raw material, helping us to grow the export of our pharmaceutical grade products across the world.

"With the support of our parent company, Tata Chemicals, and BEIS, we have been able to deliver this hugely innovative project, enabling our UK operations to take a major step in our carbon emissions reduction journey. Since 2000 we've reduced our carbon intensity by 50% and have a clear roadmap to reduce this by 80% by 2030."

Neptune Energy, ExxonMobil, Rosewood and EBN to cooperate on L10 CCS

www.neptuneenergy.com

The companies have signed a cooperation agreement to progress the L10 large-scale offshore carbon capture and storage project in the Dutch North Sea.

The agreement brings together the technical and commercial capabilities necessary to create a robust carbon storage offering for industrial customers in the Dutch sector. It intends to take the L10 carbon capture and storage development to the concept select stage in 2022 and to have the project FEED-ready by the end of the year, followed by the submission of a storage licence application.

Exploratory discussions with industrial emitters from various sectors are continuing, ahead of the upcoming round for applications for SDE++ funding from Dutch authorities.

Neptune Energy's Managing Director in the Netherlands, Lex de Groot, said, "CCS is crucial for achieving the Dutch climate goals for 2030. This Cooperation Agreement is a significant step in the development of the Neptune-operated L10 project which supports our strategy to go beyond net zero and store more carbon than is emitted from our operations, scope 1, and sold products, scope 3, by 2030."

"After the successful feasibility study, we can now combine our knowledge in the field of CCS with these parties. This next important step will enable us to jointly develop one of the largest CCS facilities in the North Sea."

"The reuse of our existing infrastructure means that, together, we can help achieve the climate goals, but also ensure this part of the energy transition becomes cleaner, cheaper and faster."

This stage of the L10 carbon capture and storage project has the potential to store 4-5 million tonnes of CO_2 annually for industrial customers within depleted gas fields around the Neptune-operated L10-A, B and E areas. It represents the first stage in the potential development of the greater L10 area as a large-volume CO_2 storage reservoir.

ExxonMobil, CNOOC and Shell to pursue carbon capture and storage hub in China

www.exxonmobil.com

The companies have jointly signed an MoU with Guangdong Provincial Development & Reform Commission to evaluate the potential for a world-scale carbon capture and storage project to reduce greenhouse gas emissions at the Dayawan Petrochemical Industrial Park.

In addition to assessing the commercial opportunity for carbon capture and storage in one of China's largest industrial areas, the companies will also evaluate the carbon policy systems in China and propose policies for consideration that would support the deployment of carbon capture and storage in Dayawan Petrochemical Industrial Park.

Initial assessments of the project indicate the potential to capture up to 10 million metric tons of CO_2 per year from Dayawan's industrial sector, supporting China's ambition of carbon neutrality by 2060. The project could also serve as a model for the chemical industry as one of the first petrochemical projects to be decarbonized.

"Collaboration with government and industry is an important part of unlocking future carbon capture and storage opportunities, with the potential for large-scale reductions of emissions from vital sectors of the global economy," said Dan Ammann, president of ExxonMobil Low Carbon Solutions.

"Well-designed government policies will help accelerate the broad deployment of lower-emissions technologies in support of society's net-zero ambitions."

While renewable technologies are important to help reach society's net-zero objectives, carbon capture and storage is a safe, proven and consistent technology that can enable some of the highest-emitting sectors such as manufacturing, power generation, refining, petrochemical, steel, and cement industries to reduce their emissions. The prospect of bringing together public and private entities to utilize carbon capture and storage collectively to reduce industrial emissions offers tremendous opportunity.

ExxonMobil is also pursuing strategic investments in biofuels and hydrogen to bring those lower-emissions energy technologies to scale for hard-to-decarbonize sectors of the global economy, by leveraging the skills, knowledge and scale of the business. The company has more than 30 years of experience capturing CO_2 and has cumulatively captured more human-made CO_2 than any other company. It has an equity share of about one-fifth of the world's carbon capture and storage capacity at about 9 million metric tons per year.

UK Government invests in CCUS, publishes knowledge deliverables

www.gov.uk

New UK government funding will support industry to reduce its reliance on fossil fuels and slash carbon emissions.

Over £31 million in new government funding will support industry to reduce its reliance on fossil fuels and slash carbon emissions, helping it to become greener and cutting energy bills.

Over £5.5 million is being invested to develop technologies that support industry to cut back use of high carbon fuels and switch to cleaner power sources, such as hydrogen, electrification or fuel from biomass and waste products.

The funding will be awarded to winners of Phase 1 of the Industrial Fuel Switching competition with the cash supporting projects that will replace natural gas with hydrogen in industrial processes, and design heat pumps for use in manufacturing sites.

In addition, winners from the first stage of the Carbon Capture Usage and Storage (CCUS) Innovation 2.0 competition will receive a share of over £12 million for projects aiming to advance next-generation CCUS technology to deploy at-scale by 2030. The second call of the competition, with up to £7.3 million available was also launched. Read a list of winners for CCUS Call 1. Projects can apply for funding under Call 2.

The funding builds on previous government support to help industry become greener, such as the £505 million BEIS Energy Innovation Programme, which included £100 million for industrial decarbonisation and CCUS, as well as the £315m Industrial Energy Transformation Fund, which supports the development of technologies to help industry with high energy use to transition to a low carbon future.

Some of the projects receiving funding include:

• British Steel in Scunthorpe will receive £161,050 for a study into switching its manufacturing processes from natural gas to green hydrogen

• Ingenza in Edinburgh will receive £443,632 to develop a new type of CO_2 conversion technology, capturing carbon from industry and turning it into a versatile chemical that can be used across a variety of chemical, pharmaceutical, agricultural and household product sectors

Also published is a report with the findings of a review carried about by AECOM and the University of Sheffield analysing next generation carbon capture technology. A particular focus of the review was the opportunity to deploy next generation carbon capture technology on UK industrial, waste and power sites between 2030 and 2035.

The outputs and learnings from the predecessor programme, CCUS Innovation 1.0, 'Key Knowledge Deliverables' are also available, demonstrating the UK government's commitment to sharing lessons learnt from previous CCUS projects, to help accelerate the development of carbon capture internationally.

These include reports from:

• HyNet CCUS

• Tigre Technologies

• 8 Rivers Capital

• Northern Endurance Partnership

• Acorn CCUS

• C-Capture

• University of Sheffield

When the second and final tranche of KKDs are published soon they will provide over 4600 pages of learning and outcomes from these innovation projects to the wider international CCUS community.

Low-cost battery-like device absorbs CO2 emissions while it charges

Researchers at Cambridge University have developed a low-cost device that can selectively capture carbon dioxide gas while it charges.

The supercapacitor device, which is similar to a rechargeable battery, is the size of a two-pence coin, and is made in part from sustainable materials including coconut shells and seawater. When the device discharges, the CO2 can be released in a controlled way and collected to be reused or disposed of responsibly.

Designed by researchers from the University of Cambridge, the supercapacitor could help power carbon capture and storage technologies at much lower cost. Around 35 billion tonnes of CO2 are released into the atmosphere per year and solutions are urgently needed to eliminate these emissions and address the climate crisis. The most advanced carbon capture technologies currently require large amounts of energy and are expensive.

The supercapacitor consists of two electrodes of positive and negative charge. In work led by Trevor Binford while completing his Master's degree at Cambridge, the team tried alternating from a negative to a positive voltage to extend the charging time from previous experiments. This improved the supercapacitor's ability to capture carbon.

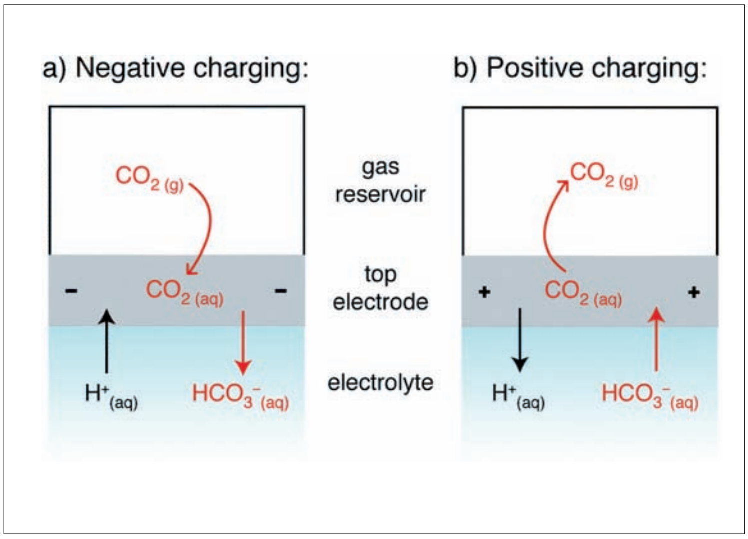
"We found that that by slowly alternating the current between the plates we can capture double the amount of CO2 than before," said Dr Alexander Forse from Cambridge's Yusuf Hamied Department of Chemistry, who led the research.

"The charging-discharging process of our supercapacitor potentially uses less energy than the amine heating process used in industry now," said Forse. "Our next questions will involve investigating the precise mechanisms of CO2 capture and improving them. Then it will be a question of scaling up."

A supercapacitor is similar to a rechargeable battery but the main difference is in how the two devices store charge. A battery uses chemical reactions to store and release charge, whereas a supercapacitor does not rely on chemical reactions. Instead, it relies on the movement of electrons between electrodes, so it takes longer to degrade and has a longer lifespan.

"The trade-off is that supercapacitors can't store as much charge as batteries, but for something like carbon capture we would prioritise durability," said co-author Grace Mapstone.

"The best part is that the materials used to make supercapacitors are cheap and abundant. The electrodes are made of carbon, which comes from waste coconut shells.



Schematic showing the proposed mechanism for the movement of CO2 and ions with charging. The direction of movement of CO2 gas observed experimentally is depicted in Fig. 3 (by curved red arrows), along with the expected movement of CO2-derived ions based on charge balancing arguments (straight arrows).

"We want to use materials that are inert, that don't harm environments, and that we need to dispose of less frequently. For example, the CO2 dissolves into a water-based electrolyte which is basically seawater."

However, this supercapacitor does not absorb CO2 spontaneously: it must be charging to draw in CO2. When the electrodes become charged, the negative plate draws in the CO2 gas, while ignoring other emissions, such as oxygen, nitrogen and water, which don't contribute to climate change. Using this method, the supercapacitor both captures carbon and stores energy.

Co-author Dr Israel Temprano contributed to the project by developing a gas analysis technique for the device. The technique uses a pressure sensor that responds to changes in gas adsorption in the electrochemical device. The results from Temprano's contribution help narrow down the precise mechanism at play inside the supercapacitor when CO2 is absorbed and released. Understanding these mechanisms, the possible losses, and the routes of degradation are all essential before the supercapacitor can be scaled up.

"This field of research is very new so the precise mechanism working inside the supercapacitor still isn't known," said Temprano.

The research was funded by a Future Leaders Fellowship to Dr Forse, a UK Research and Innovation scheme developing the next wave of world-class research and innovation.

More information
www.ch.cam.ac.uk/group/forse

Textile filter testing shows promise for Carbon Capture

North Carolina State University researchers found they could filter carbon dioxide from air and gas mixtures at promising rates using a proposed new textile-based filter that combines cotton fabric and an enzyme called carbonic anhydrase.

The findings from initial laboratory testing represent a step forward in the development of a possible new carbon capture technology that could reduce carbon dioxide emissions from biomass, coal or natural gas power plants. And while the filter would need to be scaled up in size significantly, the researchers think their design would make that step easier compared with other proposed solutions.

"With this technology, we want to stop carbon dioxide emissions at the source, and power plants are the main source of carbon dioxide emissions right now," said the study's lead author Jialong Shen, postdoctoral research scholar at NC State. "We think the main advantage of our method compared to similarly targeted research is that our method could be easily scaled up using traditional textile manufacturing facilities."

The centerpiece of the research team's design for a proposed textile-based chemical filter is the naturally occurring enzyme carbonic anhydrase, which can speed a reaction in which carbon dioxide and water will turn into bicarbonate, a compound in baking soda. The enzyme plays an important role in the human body; it helps transport carbon dioxide so it can be exhaled.

"We borrowed this wonderful enzyme in our process to speed up the carbon dioxide uptake in an aqueous solution," Shen said. To create the filter, researchers attached the enzyme to a two-layer cotton fabric by dunking the fabric in a solution containing a material called chitosan, which acts like a glue. The chitosan physically traps the enzyme, causing it to stick to the fabric.

The researchers then ran a series of experiments to see how well their filter would separate carbon dioxide from an air mixture of carbon dioxide and nitrogen, simulating levels emitted by power plants. They rolled the fabric into a spiral so that it can be shoved into a tube. They pushed the gas through the tube, along with a water-based solution. As the carbon dioxide reacted with the water in the solution and the enzyme, it turned into bicarbonate and dripped down the filter and the tube. Then, they captured the bicarbonate solution and routed it out.

When they pushed air through the filter at a rate of 4 liters per minute, they could pull out 52.3% of carbon dioxide with a single-stacked filter, and 81.7% with a double-stacked filter. While the findings are promising, they need to test the filter against the faster air flow rates that are used in commercial power plants.

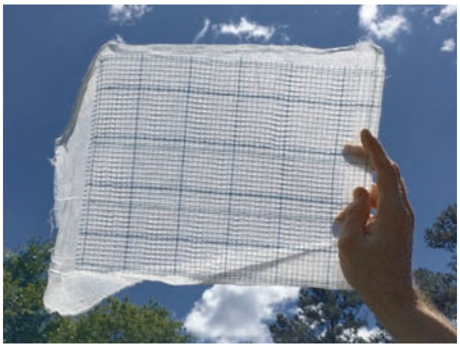
For comparison, a full-scale operation would need to process more than 10 million liters of flue gas per minute. The researchers are working with collaborators to test at a bigger scale and to compare their technology to other comparable technologies under study.

"It's a story still in progress, but we got some really exciting initial results," said study co-author Sonja Salmon, associate professor of textile engineering, chemistry and science at NC State. "We've made very significant progress."

In addition to testing the filters' carbon capture rates, they also tested how well the filter would work after five cycles of washing, drying and storing. They found it could maintain a high level of performance. "The enzyme can be maintained at a lower temperature for a very long time and it's going to be durable," Shen said. "The fabric provides physical support and structure for it, while providing a large surface area for it to react with the carbon dioxide."

Capturing the carbon dioxide is just one part of the process – they also are working on the problem of how to recycle the liquid after it exits the filter, as well as the process of turning the bicarbonate back into carbon dioxide so it can be stored and disposed of, or used for other commercial purposes.

"We want to regenerate the water solution we use with the filter so we can use it over and over," Salmon said. "That side of the process needs more work, to make the regeneration energy of the solvent as low as possible."



A new design for a filter could help remove carbon dioxide from flue gas emissions and air. Credit: Sonja Salmon

The researchers say new technologies for carbon capture are needed that would require less energy than existing commercialized carbon capture technologies, some of which are used only to filter carbon dioxide and release it back into the atmosphere. They hope their carbon capture system could help drive down the cost to help boost adoption.

"There are a lot of different ways to capture carbon dioxide," Shen said. "The current standard in the commercial setting uses a reaction that is so fast, so robust, and that binds the carbon dioxide so well, that you can't easily get the carbon dioxide out. You have to use very high temperatures, which means a lot of energy consumption. That makes your process more expensive."

The study, "Carbonic Anhydrase Immobilized on Textile Structured Packing Using Chitosan Entrapment for CO2 Capture" was published online in ACS Sustainable Chemistry & Engineering.

More information

pubs.acs.org

www.ncsu.edu

Spongy material captures carbon dioxide in cavities

Cornell led researchers are using porous, sponge-like materials that can trap carbon dioxide in their cavities while allowing other gases such as nitrogen to pass through.

One promising strategy for helping tackle the growing climate crisis is the development of materials that can capture the carbon dioxide released by a range of industrial facilities.

A big hitch is the sheer volume of material that would be required to make an impact, and the equally high price tag that would come with manufacturing it. On top of that, many of the leading contenders for carbon capture degrade quickly from oxidation.

An international collaboration led by Phillip Milner, assistant professor of chemical and chemical biology in the College of Arts and Sciences, is using porous, sponge-like materials that can trap carbon dioxide in their cavities while allowing other gases such as nitrogen to pass through.

The materials are made from sugar and low-cost alkali metal salts, so they would be inexpensive enough for large-scale deployment, and they could be particularly effective for limiting the environmental damage of coal-fired power plants.

The team's paper, "Carbon Dioxide Capture at Nucleophilic Hydroxide Sites in Oxidation-Resistant Cyclodextrin-Based Metal-Organic Frameworks," published May 17 in Angewandte Chemie, a publication of the German Chemical Society. The lead author is doctoral student Mary Zick.

For the last 100 years, the leading method for carbon capture in chemistry has been a process known as amine scrubbing. Amines are organic, ammonia-derived compounds that contain nitrogen. In an aqueous solution, they are able to selectively remove carbon dioxide from gas mixtures. However, oxygen degrades them every time they're cycled, which means that more and more of the material would need to be produced, thus driving up the cost.

Rather than trying to figure out how to overcome the oxidation problem in amines, Milner's lab has been experimenting with a different family of materials and designing them specifically for carbon-dioxide capture.

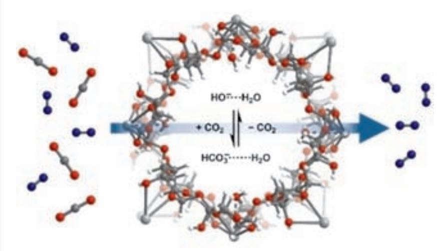
The new project focuses on sponge-like materials containing hydroxide sites in their pores. Typically, solutions of hydroxide salts reversibly react with carbon dioxide and form bicarbonate salts, such as baking soda, trapping the carbon dioxide. But in order to regenerate the hydroxide salt, the material needs to be heated up to 500 to 800 degrees Celsius – no easy feat, and not a cheap one, either.

Zick found that by incorporating bundles of sugar molecules called cyclodextrins as a starter and boiling them with alkali metal salts in water, she could create a sponge-like material that is riddled with cavities in which carbon dioxide binds strongly, but other gases such as nitrogen pass easily through.

"We expose the material to mixtures of carbon dioxide and nitrogen and see if they can absorb the carbon dioxide and ignore the nitrogen, which is the major component of air and emission streams," Milner said. "The underlying chemistry is really the same as what happens with hydroxide solutions in water. But by doing it in these sponge-like materials, you gain a lot of advantages. The carbon-dioxide capture is very fast, it can have a very high capacity and it may be very stable to oxygen."

The reversible reactions allow for carbon-dioxide release at relatively low temperatures, about 80 to 120 degrees Celsius. And the material's tunability makes it useful for an array of applications, from drug delivery to catalysis to gas storage, in addition to separations.

"Coal emissions are still the No. 1 anthropogenic contributor to carbon-dioxide emissions in the world," Milner said. "What's nice about this work is that Mary not only found a material that's useful for carbon-dioxide capture from coal flue gas, but she outlined the structure-property relationships that will allow us to design materials for other applications, like capturing CO2 from natural gas fired power plants, as well as maybe even from air, which is one of the really big challenges of our time."



Due to its low cost and performance under realistic conditions, KHCO3 CD-MOF is a promising new platform for CCS

An additional bonus of the project is the instrumentation that Zick custom-built to analyze if a gas mixture could be separated in a solid material – a capability that wasn't previously available at the university. Now Milner's group is using the modular apparatus to test samples from other Cornell researchers.

"We've got people coming out of the woodwork to do these experiments," Milner said. "We have a little hub now. If somebody brings us some material, in a week or two Mary can tell you if it's promising for carbon-dioxide capture."

Co-authors include Suzi Pugh and Alexander Forse of the University of Cambridge; and Jung-Hoon Lee of the Korea Institute of Science and Technology.

The research was supported by the U.S. Department of Energy. The researchers made use of the Cornell Center for Materials Research, which is supported by the National Science Foundation's MRSEC program.

More information

www.cornell.edu

Imperial researchers win BEIS funding for new modelling approach

The research received almost £1m for a new modelling approach aimed at reducing the risks and costs of storing CO2 underground.

The backing comes from the UK Government's Department for Business, Energy & Industrial Strategy's (BEIS) £20 million CCUS Innovation 2.0 programme, which is aimed at accelerating the deployment of next-generation carbon capture, utilisation and storage (CCUS) technology in the UK so that it can deploy at scale by 2030.

The researchers' approach, known as StrataTrapper, was developed by Imperial College London and the University of Cambridge in collaboration with industry partners OpenGoSim, BP, Drax Power, and Storegga.

Based on fluid dynamics research, StrataTrapper is software designed to help industry reduce the risks and costs associated with CO2 storage. CO2 storage is a vital component of CCUS – a technology that removes carbon from the atmosphere and could help industry transition to net zero greenhouse gas emissions by 2050. CCUS can be costly and includes risks like unexpected rates of plume migration, and the CO2 approaching potential leakage pathways.

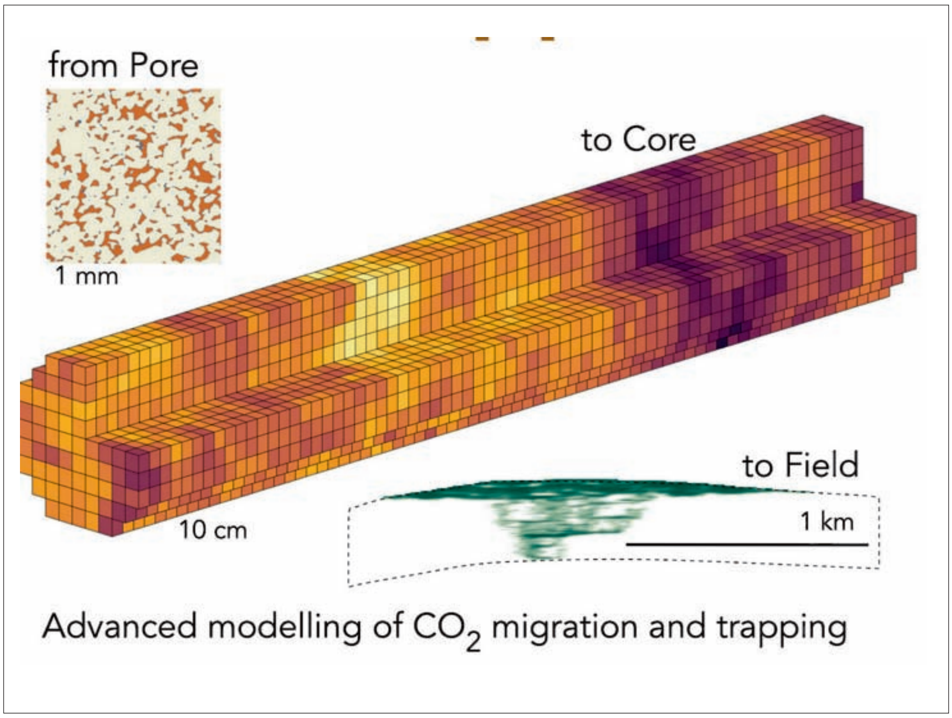


Image showing advanced modelling of CO2 migration and trapping. Image: Samuel Krevor

When carbon is sequestered underground, it is injected into reservoirs and its behaviour can be studied – a field of research known as geological fluid dynamics. Imperial's Dr Samuel Krevor and Professor Ann Muggeridge, together with Cambridge academics, have translated their research on the fluid dynamics of carbon in these reservoirs into innovative software tools that characterise and model how carbon behaves underground. These software tools can be used by industry to reduce the risks, like carbon leakage, and costs associated with CO2 storage.

Principal Investigator on the project Dr Krevor said, "Simulating how injected CO2 plumes behave in reservoirs is central to successfully engineering and managing CO2 storage. The direction and speed of carbon flow determine how efficient the storage is and can identify weaknesses that might cause leaks.

"We will incorporate our software tools into a commercial and opensource software platform that can be used by industry, while staying accessible to the academic community."

Thanks to the funding, StrataTrapper will be commercialised through incorporation into the CO2 reservoir simulation platform OpenGoSim and will also be made open-source. The researchers will demonstrate the applicability of these tools to the Endurance CO2 storage site in the southern North Sea, and the East Mey Site in the central and northern North Sea.

Co-investigator Professor Jerome Neufeld from the University of Cambridge said: "This collaboration between industry and academia will enable the rapid deployment of our advanced modelling tools to storage sites in the UK and internationally, and lead to better understanding of the subsurface flow of CO2."

The result of the work will be the validation and commercialisation of the StrataTrapper reservoir simulation tools for the rapid screening, risking, project design, and management of CO2 storage.

Energy and Climate Change Minister Greg Hands said: "As we accelerate the UK's energy independence by boosting clean, homegrown, affordable energy, it's crucial that our industries reduce their reliance on fossil fuels.

"This investment will help them to not only cut emissions, but also save money on energy bills, on top of supporting jobs by encouraging green innovation across in the UK.

More information

www.imperial.ac.uk

Transport and storage news

Bids invited in UK's first-ever carbon storage licensing round

www.nstauthority.co.uk

The North Sea Transition Authority (NSTA) has launched the UK's first-ever carbon storage licensing round with a diverse portfolio of 13 sites available across the UK Continental Shelf.

The new carbon storage areas, alongside the six licences which have been issued previously, could have the ability to make a significant contribution towards the aim of storing 20-30 million tonnes of carbon dioxide by 2030.

The areas being offered for licensing are off the coast of Aberdeen, Teesside, Liverpool and Lincolnshire in the Southern North Sea, Central North Sea, Northern North Sea, and East Irish Sea and are made up of a mixture of saline aquifers and depleted oil and gas field storage opportunities.

This round is envisaged to be the first of many as it is estimated that as many as 100 CO2 stores could be required in order to meet the net zero by 2050 target.

The NSTA said it has launched this carbon storage licensing round in response to unprecedented levels of interest from companies eager to enter the market. The areas on offer have a combination of attributes such as the right geological conditions, proximity to existing infrastructure which may be able to be re-purposed, and links to industrial clusters which are looking to carbon storage to help meet their decarbonisation goals.

The level of interest already expressed suggests there will be strong competition meaning that prospective licensees will need to produce high-quality bids to win licences.

In choosing suitable areas to make available for licensing, the NSTA fully considered issues including co-location with offshore wind – whether there are any known challenges and mitigations around existing or future offshore wind developments – environmental issues, potential overlaps with existing or future petroleum licences, and other activities to ensure key technologies can all be taken forward.

There are currently six carbon storage licences on the UK Continental Shelf which could meet up to one-fifth of storage needs, if they reach their maximum potential of up to 40 million tonnes per annum (MTPA) injection rates by the mid-2030s. Whilst the capacity estimates of the areas offered in this round carry some uncertainty at this stage, they offer the potential to make a very significant contribution to decarbonisation of the UK.

The application window is open for 90 days, closing on 13 September, and will be evaluated by the NSTA on technical and financial criteria.

It is expected that any new licences will be awarded in early 2023. The size and scale of the licensed stores mean that they are likely to proceed at different paces, but first injection of CO2 could come as early as four to six years after the licence award.

The Government's Ten-Point Plan, published in November 2020, supported the establishment of carbon capture, usage and storage in four clusters - in areas such as the North East, the Humber, North West, Scotland and Wales – encouraging private sector investment.

CCS is a developing industry and requires close co-operation between many organisations. The NSTA, The Crown Estate and Crown Estate Scotland have recently published a joint statement explaining how they intend to work together and the NSTA has, separately, agreed a Memorandum of Understanding with Ofgem, which will act as the economic regulator for the transportation and storage of carbon dioxide.

ABS, Daewoo Shipbuilding and GasLog to develop onboard CO2 capture

www.eagle.org
www.gaslogltd.com

The three companies have committed to work together to develop an onboard CO2 capture and storage system (OCCS) by signing a joint development project (JDP) at the Posidonia International Shipping Exhibition.

This emissions reduction technology returns CO2 from the exhaust gas back to the ship for storage by the process of absorption, regeneration and separation. The stored CO2, as a form of byproduct, can then be safely offloaded to shoreside facilities after entering port.

The three companies will collaborate on the design of an optimal OCCS for an LNG carrier to be built by DSME and verify the system through various risk analysis and tests before installation and operation. At the same time the project will seek to obtain ABS approval in principle (AIP) for the OCCS system.

OCCS joint development is intended to be complete by the first quarter of 2023. ABS will guide the rules and regulations for OCCS development and provide technical advice and support. In particular, ABS will conduct a series of risk assessments and supervise the assessment procedure for the final AIP for this technology.

DSME received an order for four LNG carriers from GasLog last year. These vessels are scheduled to be delivered sequentially from the first half of 2024. The actual installation of OCCS on the LNG carrier is targeted to coincide with construction. GasLog will undertake the technical requirements for the installation and operation of OCCS. They will also provide valuable ship management know-how necessary for OCCS design evaluation.

"Carbon capture onboard is going to be a critical technology in the industry's push for net zero. We are proud to be able to use our insight into OCCS to support these industry leaders with this landmark project, which promises to materially advance the adoption of this technology at sea," said John McDonald, ABS Executive Vice President and Chief Operating Officer.

Mr. Karathanos, GasLog COO said: "Strong collaborations with industry leaders such as DSME and ABS is a key enabler to decarbonizing shipping. At GasLog we firmly believe that onboard carbon capture will become one of the main methods to reduce emissions from shipping and contribute to keeping global temperature increase to 1.5 degrees Celsius."

The ABS Whitepaper: Carbon Capture, Utilization and Storage explores the technology's potential, gives an overview of the current technology, evaluates opportunities for utilization of carbon and for its storage, as well as the vessels required to carry the liquified product.future."