Carbon Capture Journal

CCUS in Asia

CCUS landscape in Asia-Pacific

Research in Korea: recycling CO2 and waste materials into commercially viable products

Developing a CCUS value chain in Indonesia

Nov / Dec 2023 Issue 96

Porthos project launched in Netherlands

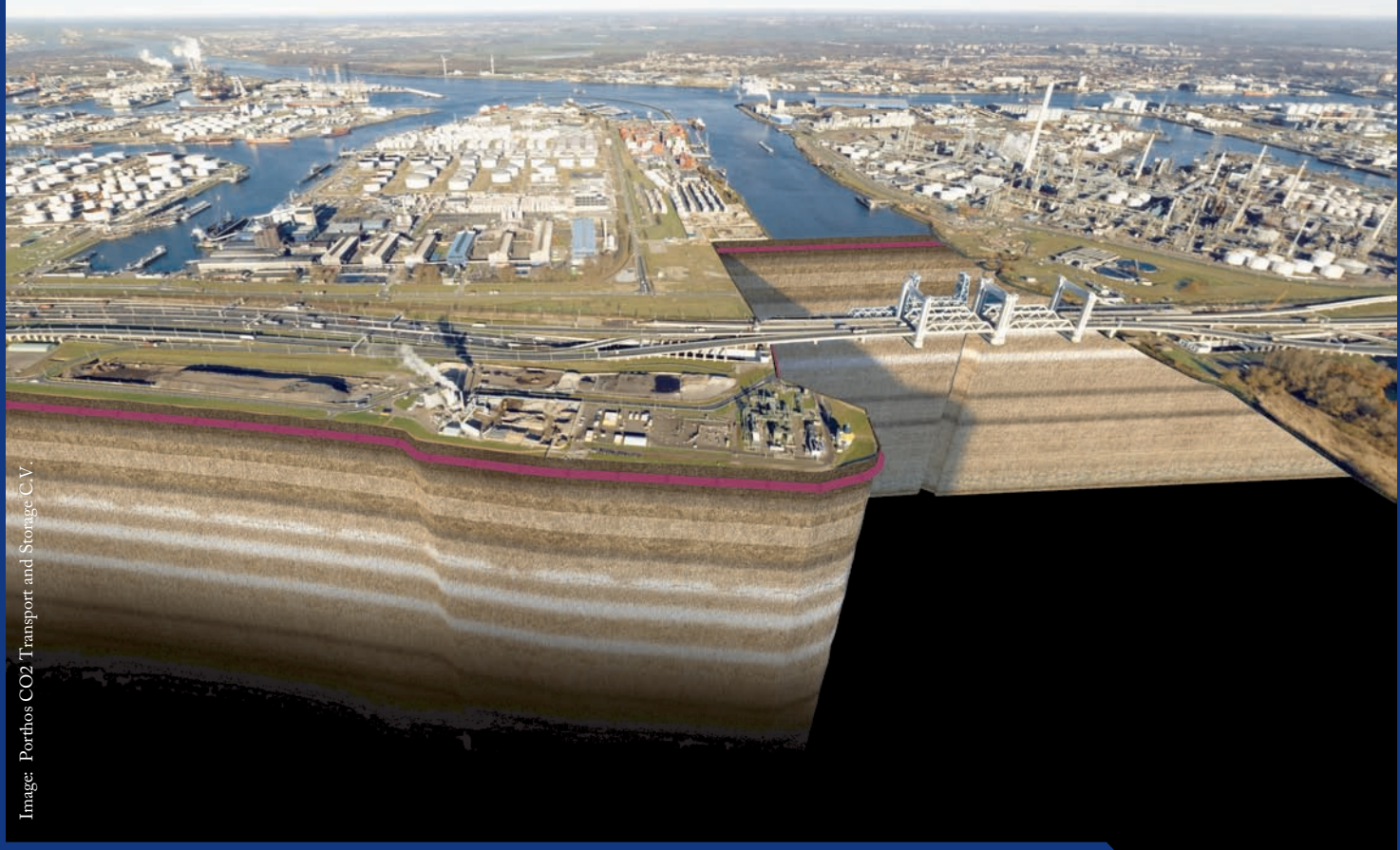

Image: Porthos CO2 Transport and Storage C.V.

The convergence of biotechnology and carbon capture

How CCS emerging technologies can empower decarbonisation

Leak detection's role in the integration of CCUS with hydrogen production

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Senior Consultant, **OGMP 2.0**

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Environment Engineer, Project Manager, **Amber Grid**

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Nov / Dec 2023 Issue 96

Carbon Capture Journal
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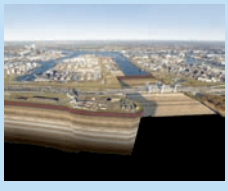


Front cover: Porthos has taken a final investment decision. It plans to store about 2.5 Mton per year for 15 years. In 2024 construction will begin in Rotterdam, with the Porthos system expected to be operational by 2026 (pg. 11)

Back cover: Porthos has partnered with TAQA Energy, the present operator of the P18 gas fields, for injection and storage of the CO2

Carbon capture journal (Print) ISSN 1757-1995
Carbon capture journal (Online) ISSN 1757-2509

Leaders - CCUS in Asia

Projects and policy

Capture and utilisation

Transport and storage

CCUS landscape in Asia-Pacific

More than 50% of global CCUS by 2050 could take place in Asia-Pacific (APAC). This staggering statistic, provided in a March 2023 McKinsey report[1], is one of many (quantitative) reasons why it is critical to consider the progress and potential made individually and jointly among countries in the region. By Priya Prasad & Ingvild Ombudstvedt.

Hard-to-abate sectors – including cement, iron, steel, and petrochemicals – are foundational to providing the resources for economic development in Asia. CCUS is recognised as part of the suite of options for these sectors to decarbonise, and for countries in the region to meet near and longer term climate pledges.

This article will provide an overview of the current state and potential of CCUS legal and regulatory framework development in select countries in the region and describe potential drivers for CCUS deployment amongst the countries.

There is currently no one-size-fits-all approach taken by countries in the region, who have either amended existing frameworks to allow for parts of the CCUS value chain to take place in country, or who have promulgated new frameworks.

Australia addresses CCUS matters across federal (Commonwealth), state, and local (territory) levels through several petroleum and greenhouse-gas related regulations.

Japan meanwhile does not have a comprehensive framework to regulate CCUS, existing laws governing activities at sea are relevant and have been used to deploy their first demonstration project. Japan is currently working on a CCS specific framework, implying that future projects may face more predictable and transparent criteria.

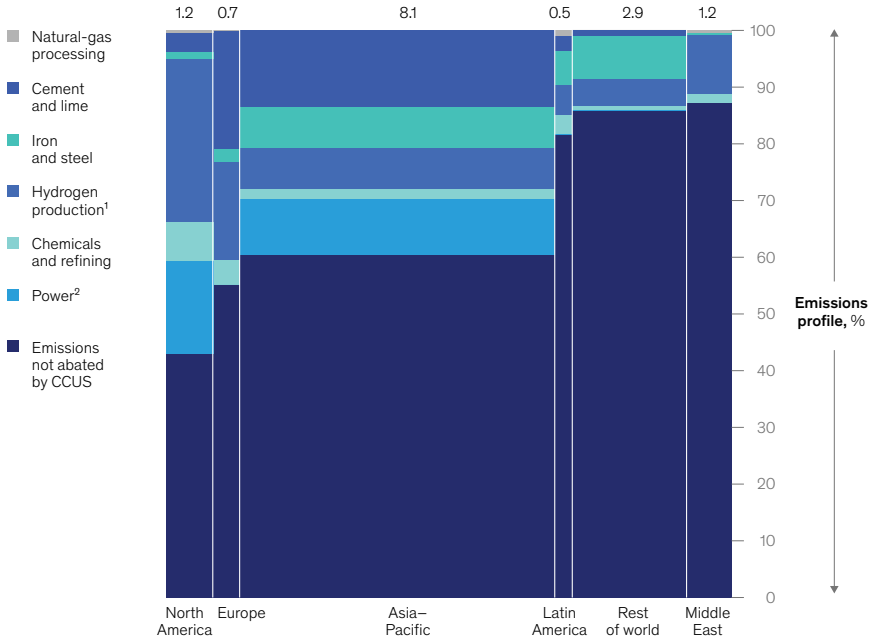
India also has no CCUS-specific legal or regulatory framework. However, the Ministry of Petroleum and Natural Gas released a 2030 roadmap for CCUS in 2022 and identified the need for a framework for safe and secure geological storage as part of the country's medium term (3-10 year) plan.

Malaysia likewise does not have a CCUS-specific law and current projects are subject to existing framework. In 2023, Malaysia introduced tax incentives to boost the CCUS industry. The country's National Energy Transition Roadmap, published by the Ministry of Economy, highlights CCUS as one of 6 energy transition levers for Malaysia. The roadmap also acknowledges that the development of a CCUS regulatory framework is a necessary step for broader deployment.

In March 2023, Indonesia launched new rules for CCUS to help support upstream oil and gas business activities and help decarbonise the extraction industry, through safe and secure storage of carbon dioxide. The Government of Indonesia has since announced the country's plans to issue a presidential regulation to address CCUS in other sectors.

Asia–Pacific could account for 55 percent of global carbon capture, utilization, and storage by 2050.

Global emissions profile and carbon capture, utilization, and storage (CCUS) uptake by 2050, gigatons of CO_2



[1]Hydrogen production, excluding H_2 for ammonia, methanol, and refineries.
[2]Power figures represent the average value across power scenarios (high and low carbon capture, utilization, and storage uptake).
Source: "Global Energy Perspective 2022," McKinsey, April 26, 2022; Energy Insights by McKinsey

McKinsey & Company

More than 50% of global CCUS by 2050 could take place in Asia-Pacific (APAC) according to a McKinsey report (Source: Unlocking Asia–Pacific's vast carbon-capture potential Feb 2023)

1. https://www.mckinsey.com/featured-insights/sustainable-inclusive-growth/chart-of-the-day/corralling-carbon

International collaboration

In addition to announcements, roadmaps, and draft regulations around CCUS, many nations in the region have also signaled their interest in learning and sharing technical and regulatory best practices by participating in international forums. As an illustrative example, over a decade ago the International Organization for Standardization (ISO) established a committee for CCUS standards and technical reports – ISO/TC265.

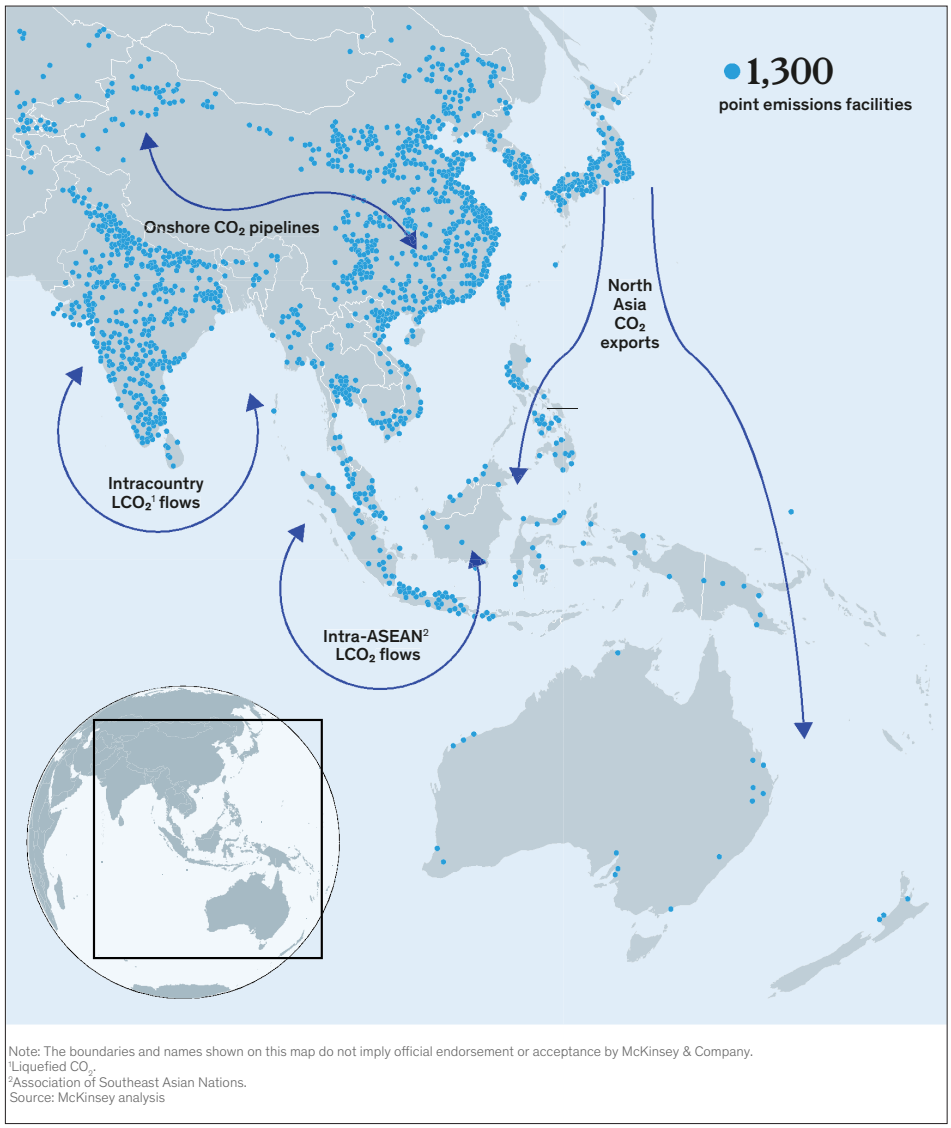
The Asia-Pacific region is well represented, both in membership and leadership on ISO's committee. Australia, China, India, Indonesia, Japan, South Korea, Malaysia, and Singapore are Participating members (along with a total of 18 other countries). Sri Lanka and Thailand are Observing members (along with a total of 15 other countries).

Countries in the region also have Working Group leads in the ISO committee, such as Japan (who leads the Working Group on the capture of carbon dioxide), and a now-dormant group led by China on the quantification and verification of carbon dioxide that is captured, transported, and stored. Some countries in the region have also adopted standards published by ISO/TC265 to their own regulations – such as Japan, who have adopted the standard covering geological storage (ISO 27914).

Looking beyond country borders, sound regulatory frameworks can also address cross-border issues, such as transport of carbon dioxide across international lines.

The London Protocol ("Protocol") is one of the most comprehensive international legal instruments on protection of the marine environment. While the Protocol initially prohibited both offshore storage and export of carbon dioxide for such purposes, as this was regarded as "dumping", an amendment in 2006 permitted storage, and a subsequent amendment in 2009 enabled such export if the countries concerned entered into an arrangement or agreement.

While this 2009 amendment has not entered into force awaiting sufficient ratification, the Contracting Parties have adopted a resolution on the provisional application of the amendment. This is a very helpful development in facilitating the transfer of carbon dioxide across borders. Australia, Japan, Philippines and South Korea are Contracting Parties to the Protocol.



The potential pan-Asia CO2 carbon capture and underground storage network could include more than 20 carbon capture and underground storage hubs (Source: Unlocking Asia–Pacific's vast carbon-capture potential Feb 2023)

Several countries in the region with no pre-existing frameworks for carbon dioxide storage are considering acceding to the London Protocol and using the provisions of the Protocol as building blocks for national frameworks.

This approach may be well-reasoned for several reasons, one of which is the comprehensive guidance documents published by the Contracting Parties through the International Maritime Organization (IMO) to assist in interpretation and implementation of the Protocol into national frameworks, as well as the availability of assistance, both through IMO and the other Contracting Parties in the implementation and the compliance process.

Therefore, the Protocol serves both as inspiration and a building block to save time and energy in the implementation process.

Another reason is the cross-border element. Several countries in the APAC region either have great potential for establishing a storage hub, and to receive CO2 volumes from other countries. Yet others depend on their neighbors to provide storage capacity for them.

Timor-Leste has abundant storage capacity on their continental shelf in depleted oil and gas reservoirs and relatively modest domestic CO2 emissions, which would allow for this capacity to be sold to their neighbors, such as Australia. Similarly, Malaysia and Indonesia have excess storage capacity available, and their location in the region may provide easy access for countries (such as Japan), who has indicated they may depend on export of CO2 to reach their emission reduction targets.

As both Australia and Japan, potential ex-

porters of CO2, are each Contracting Parties to the London Protocol, the countries receiving their CO2 for offshore storage need to have a framework in place that is equivalent or better than the Protocol for the exporting country to comply with their Protocol obligations.

Thus, either acceding to the Protocol or at the very least building a CCS framework on the London Protocol baseline would not just serve the importing country in terms of IMO assistance and guidance but also help unlock the domestic potential to establish a cross-border storage hub.

National and international regulation

The urgency of addressing CCUS in national strategies, and regulating these activities to enable the industry is not lost on the region. Greenhouse gas emissions, and reduction and removal of these, is a global issue, one which has up till now been championed by a handful of countries.

However, the APAC region is host to a lot heavy industry, which is not only dependent on reducing its emissions for the nations to fulfil their pledges under the Paris Agreement; they depend on reducing their emissions to be able to compete on the global market for the sales for goods and thus maintenance of existing jobs and revenue streams.

Some of the measures recently implemented by other regions and countries to fight climate change, will impact the APAC region. One of these measures is the EU Carbon Border Adjustment Mechanism (CBAM), which is going to impose a CO2 price on imports of certain goods from countries without a carbon pricing scheme in place, or which have had the CO2 removed or reduced from their production lines.

Thus, implementing a policy and legal framework for CCUS and potentially also a CO2 tax or crediting scheme becomes an urgent focus area for many countries, to ensure that the steel, cement, and other products being produced may still compete on the European market.

An example of a country in the APAC region with a lot of export of products to the EU that are covered under CBAM and with no current CO2 credit or tax regime or legal framework for CCS, is Vietnam. However, Vietnam also has a lot of potential storage capacity, which may both serve the need for storage space to enable a reduced carbon footprint of domestic products as well as provide amble opportunities for job creation and new revenue streams in terms of selling storage capacity and services to its neighboring countries and industries.

A robust CCUS framework will also require a sophisticated and reliable system for measuring, reporting and verifying that the CO2 captured, transported, utilized or stored is accounted for. This system will also help countries exporting certain emissions-intensive goods under CBAM comply with reporting requirements at the EU border.

Even for countries not involved with exporting relevant goods into EU pursuant to CBAM, there is an increased focus (voluntary, and in a growing number of cases mandatory) for reporting carbon intensity of goods and processes to help an entity publicly report its greenhouse gas emissions.

For companies in the West that have such reporting requirements and that conduct operations or receive raw materials from the APAC region, there will be a increasing request for a estimated (or if possible, measured) quantity of the carbon intensity of the operation or raw material as part of a global reporting roll-up.

How quickly the countries in the APAC region can implement dedicated frameworks for CCUS to take up the competition with the early-movers and tap into the extensive resources and potential in the region, will depend on several factors. Whether the countries have pre-existing extractive industries such as oil and gas, is one such factor.

It can be observed that countries with pre-existing oil and gas activities also have permitting frameworks that may be mirrored or repurposed for CCUS, and that the regulators in said countries are accustomed to interacting with operators and regulating and overseeing activities in the sub-surface. In a sense, the tertiary recovery of oil and gas in such countries can be seen as a 'proof of concept' to assess technical capability and viability of a more permanent storage.

As such, a part of the regulatory process to develop a national framework for CCUS should be a regulatory mapping of existing domestic regulatory models and frameworks that may either be amended or re-purposed to facilitate for these new activities. However, as an important starting point, the country ideally would address the national policies and strategies for CCUS and formulate a sound reasoning and purpose of national CCUS activities.

Whether the activities are desired to enable continued production of oil and gas, steel, cement, aluminum and fertilizers, or if CCUS is all about developing storage capacity to create new jobs and revenue streams, may affect not just the wording of the frameworks, but for example which governmental entity or agency who is put in charge of regulating and overseeing the activities – most commonly, the competing interests for leading the domestic CCUS effort is between the energy ministry or the environmental ministry.

Also, investigating own national resources and bottlenecks is an important aspect of the initial strategy and policy development, as extensive understanding of these aspects will be a driving-force being cross-border collaboration and potential for new value chains.

Summary

The APAC region has incentives for CCUS growth: real progress on framework development, general harmonization and coordination already present in the region, natural sources and sinks proximate and hub and clusters appearing.

However, the region also has some challenges: compliance with EU/U.S. carbon intensity report and carbon tax schemes and managing growing population and emissions natural to a developing region while continuing to reach milestones from national climate pledges.

With countries in APAC working together collectively to leverage these incentives and overcome these obstacles, the region will not simply be one to watch as CCUS projects and frameworks get underway, but one that can and will likely be a leader for other emerging regions for global deployment of this technology.

More information

Priya G. Prasad is a Senior Attorney in the Office of the General Counsel of the U.S. Department of Commerce.

Ingvild Ombudstvedt is a Norwegian lawyer and economist and the owner of the law firm IOM Law.

cldp.doc.gov

GE Vernova partners with bp, CARBONCO on CCUS in Indonesia

Under an MoU the partners will jointly carry out a feasibility study to develop a CCUS value chain and joint solutions to decarbonise gas power plants in Indonesia.

It builds on an announcement made in October 2022, by GE and CARBONCO to jointly explore a roadmap for the integration of CCUS technology with gas-fired power plants in Asia and the Oceania regions, powered by GE Vernova power technology. Both parties have since identified and developed tangible opportunities based on economic viability and project feasibility.

"GE Vernova continues to play a crucial role in supporting the advancement of the region's energy goals, working alongside global and local players such as CARBONCO, bp, PLN Nusantara and Jawa 1," said Ramesh Singaram, Asia President & CEO of GE Vernova's Gas Power business.

"We are especially focused on further developing crucial breakthrough energy technologies such as carbon capture, and are pleased that this collaboration will pave the way for a robust value chain that will help address carbon emissions reduction in the power sector and support climate change commitments in Indonesia."

Under the agreement, PLN Nusantara, Jawa 1, CARBONCO, bp and GE Vernova will collaborate to address the entire CCUS value chain, from the implementation of carbon capture technology in gas-fired power plants to the transportation of CO2 to import and export terminals as well as the sequestration of captured CO2 at the Tangguh field in Teluk Bintuni, Papua Barat, Indonesia. The study endeavors to achieve a deeper understanding of the development of a CCUS value chain for Indonesia as the hub for the region.

GE Vernova will build on its experience in advanced technology and controls to integrate combined cycle power plants with CARBONCO's CCUS technology. With proven expertise in gas combined cycle plant engineering, operability, and plant integration with carbon capture plants, GE Vernova will lead integration with the goal of ensuring dispatchability, lower carbon intensity, high flexibility and reliability, and lower capital cost.

CARBONCO will deploy its technological capabilities and experience in CCUS that is backed by more than 20 years of experience executing a variety of global decarbonisation projects. In addition, CARBONCO has successfully completed FEED and detailed engineering designs for the carbon capture of 3,000 tons per day scale.

The LNG plant at Tangguh in Teluk Bintuni, Papua Barat, Indonesia

Dr. Sang Min Lee, CEO of CARBONCO sais, "The top priority of CARBONCO's business agenda is to alleviate climate change in the world. Being a global player, CARBONCO is working tirelessly to transition the region's power industry towards cleaner energy more efficiently and effectively."

"Working alongside global and local players such as GE Vernova, bp, PLN Nusantara and Jawa1 is vital to ensure our business is on the right track. We are confident that today's agreement will further accelerate our big movement, and CARBONCO and GE will continue to assess the global marketplace for tangible projects with the right integration model."

The Tangguh CCUS project carried out by bp is the most advanced CCUS project in Indonesia with a development plan that has received approval from the Government of Indonesia in 2021, for ongoing FEED work and planned project sanction in the near future. Holding ca 1.8 GtCO2 in ultimate storage capacity, Tangguh is well-positioned and has tremendous potential to become the country's first CCS hub for domestic and international emitters.

For the initial phase at Tangguh, bp plans to inject 30+ million tons of CO2 back into the reservoir to help recover additional gas production through Enhanced Gas Recovery (EGR). This will be the first large scale CCUS project with EGR in the world.

Kathy Wu, BP Regional President Asia Pacific, Gas & Low Carbon Energy, commented, "As an energy company who has been a long time strategic partner for Indonesia and being the most advanced CCUS hub project in the country, we aim to play an active role in supporting Indonesia to achieve its Net Zero target. Together with PLN Nusantara, Jawa 1, GE and CARBONCO, we will pave the way for the decarbonization of Indonesia's power plants with potential CO2 injection in Tangguh."

In a move to be a leader in the global energy transition, GE Vernova will spin-off in 2024 into an independent company that will focus on accelerating the path to more reliable, affordable, and sustainable energy.

More information

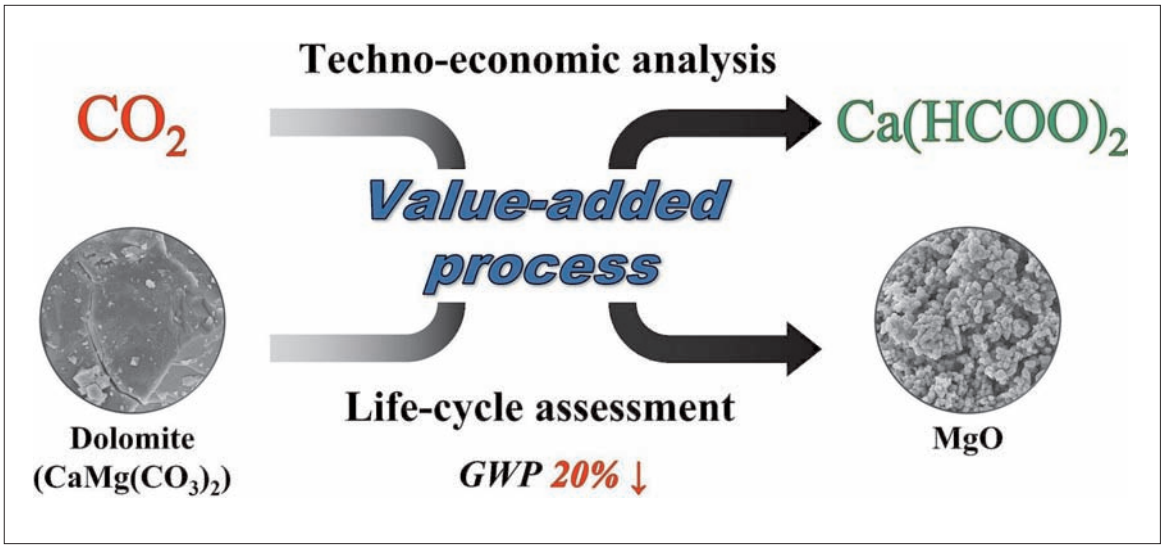
www.gevernova.com

www.bp.com

Researchers recycle CO2 into commercially viable products

A team of researchers from Chung-Ang University in Korea are conducting research on CCU processes that use waste materials or abundant natural resources as raw materials to ensure their economic feasibility.

The capture of emitted carbon dioxide and its chemical conversion into useful commercial products is one way to limit global warming and mitigate its effects. Scientists are now looking into carbon capture and utilisation (CCU) technology as a promising approach to expanding CO2 storage and conversion at a low cost.



The researchers estimated that this process could reduce global warming potential by 20% when compared to traditional calcium formate production methods

Global CCU research, however, is largely limited to only about 20 conversion compounds. Given the variety of CO2 emission sources, it is critical to have a wider range of chemical compounds, which necessitates delving deeper into processes that can convert CO2 even at low concentrations.

The team at Chung-Ang, led by Professor Sungho Yoon and Associate Professor Chul-Jin Lee, recently published a study where they discuss the use of industrial CO2 and dolomite—a common and abundant sedimentary rock that is a rich source of calcium and magnesium—for the production of two commercially viable products: calcium formate and magnesium oxide.

"There is a growing interest in utilising CO2 to produce valuable products that can help mitigate climate change while creating economic benefits. By combining CO2 hydrogenation and cation exchange reaction, a process for simultaneous metal oxide purification and high-value formate production has been developed," remarks Prof. Yoon.

In their study, the researchers used a catalyst (Ru/bpyTN-30-CTF) to add hydrogen to CO2, which resulted in the production of two value-added products, calcium formate and magnesium oxide. Calcium formate, a cement additive, de-icing agent, and animal feed additive, is also used in leather tanning.

Magnesium oxide, in contrast, is extensively used in the construction and pharmaceutical industries. The process was not only viable but also extremely rapid, yielding the products in just 5 minutes at room temperature. Moreover, the researchers estimated that this process could reduce global warming potential by 20% when compared to traditional calcium formate production methods.

The team also evaluated if their method could potentially replace the current production approaches by checking its environmental impact and economic feasibility. "Based on the results, we can say that our method offers an eco-friendly CO2 conversion alternative that could replace the conventional approaches, potentially contributing to the reduction of industrial CO2 emissions," Prof. Yoon explains.

Although converting CO2 into meaningful products sounds promising, these processes are not always easy to scale up. Most of the CCU technologies have not been commercialized owing to their low economic feasibility compared to the prevailing commercial processes.

"We need to combine CCU processes with waste material recycling to make them both environmentally and economically beneficial. This may contribute to achieving a net-zero emissions goal in the future," concludes Dr. Lee.

The paper “Kinetic conversion of magnesium and calcium ions of dolomite into useful value-added products using CO2” is published in Chemical Engineering Journal.

More information

neweng.cau.ac.kr

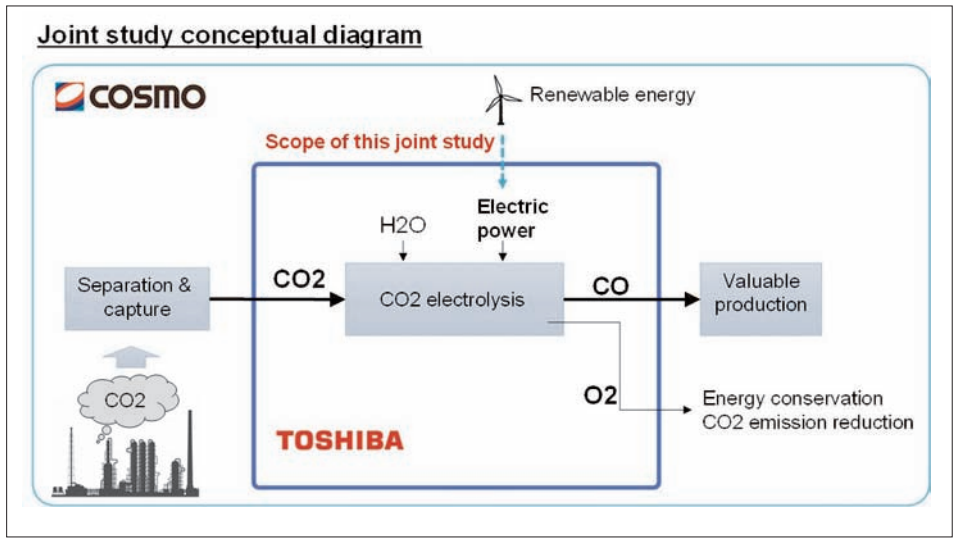
doi.org/10.1016/j.cej.2023.143684

Toshiba and Cosmo Energy study CO2 conversion via electrolysis

The companies will conduct a joint study toward the realisation of carbon capture and utilisation (CCU) that converts CO2 into valuable chemicals through electrolysis.

In this joint study, Toshiba Energy Systems & Solutions will provide a CO2 electrolysis technology that electrolyses CO2 to produce carbon monoxide (CO) at a high conversion rate. CO is attracting attention as a useful substance for the realisation of CCU as it can serve as a raw material for alcohols such as methanol and ethanol, which are key substances that can be used in chemical products and energy applications, as well as synthetic fuels, by making it react with hydrogen.

The Cosmo Energy Group aims to use Toshiba ESS's CO2 electrolysis technology to produce a valuable feedstock derived from CO2 emitted from its refineries and other facilities. In terms of the electricity used in electrolysis of CO2 generated from refineries, the Group will consider using electricity derived from renewable energy supplied by one of its own group companies.

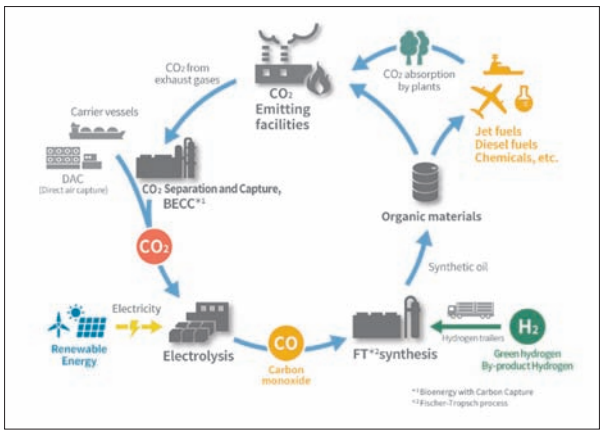


The study will determine the feasibility of converting CO2 from Cosmo's industrial facilities into valuable feedstock chemicals using Toshiba's electrolysis technology

In addition, the two companies will also consider using oxygen produced as a byproduct of CO2 electrolysis to contribute to energy conservation and reduction of CO2 emissions at refineries.

The Cosmo Energy Group announced its 2050 Carbon Net Zero Declaration and is accelerating decarbonisation-related initiatives under its Vision 2030 and Seventh Consolidated Medium-Term Management Plan Oil & New ~Next Stage~. This project is one of a number of concrete measures that the Group is taking to "strengthen competitiveness of the Oil Business and pursue low carbonisation" as set forth in Vision 2030.

It is being carried out with the goal of solving societal challenges and achieving sustainable corporate development toward the realisation of the Group's management vision of achieving "harmony and symbiosis between our planet, man and society."



Toshiba's Power to Chemicals (P2C) technology

Toshiba's efforts for a sustainable society

Toshiba Group's "Environmental Future Vision 2050" sets the goal of contributing to the realisation of a sustainable society through environmental management that creates enriched value and ensures harmony with the earth.

This project will serve as part of the Group's "response to climate change" and "response to the circular economy," and is an initiative involving the capture and utilisation of CO2 emitted from power plants and facilities.

Based on this vision, Toshiba ESS will contribute to the realisation of a sustainable society by providing environmentally friendly products and services, reducing the environmental impact and risks associated with its business activities, and undertaking environmental activities that are rooted in local communities and society.

The Circular Economy concept turns CO2 into a valuable resource through Power to Chemicals (P2C) technology (see left).

When the emitted CO2 is decomposed by the electric power of renewable energy and combined with hydrogen, it can be recycled again.

More information

www.toshiba.com

www.cosmo-energy.co.jp

Asia news

JERA undertakes joint study on CCS Indonesia power plants

www.jera.co.jp

JERA, JGC Holdings, and the Indonesian State Electricity Company will conduct the study into Carbon capture at its thermal power plants in Indonesia.

The government of Indonesia has established the goal of achieving carbon neutrality by 2060, so decarbonisation of the electricity sector, which accounts for about 40% of the country's CO2 emissions, is an important issue.

The MOU stipulates that the three companies will consider the introduction of CCS at the Indramayu Coal-Fired Power Plant and the Tambak Lorok Gas-Fired Power Plant, both owned by PLN subsidiaries, studying their potential as CCS projects by evaluating technical issues and business feasibility, investigating legal regulations, and identifying issues.

JERA has overall responsibility for the joint study and will conduct market research related to CCS projects, evaluate feasibility, and research the legal system, while JGC will consider CCS storage technologies and estimate costs. PLN will provide data related to the power plants where the introduction of CCS is being considered and coordinate with related local organizations.

JERA has been working to support Indonesia's energy transition, carrying out studies and providing other support aimed at drawing up a decarbonisation roadmap for the country's power sector. The JGC Group is working toward the commercialisation of CCS in Indonesia, Malaysia, Thailand, and other countries in Southeast Asia.

DNV and AL Group cooperate on CCS feasibility study

www.dnv.com/maritime

The companies will assess the feasibility of onboard carbon capture on containerships and bulk carriers.

Classification society DNV has entered into a Joint Development Project (JDP) with AL Group and its Singapore company Asiatic Lloyd Maritime LLP to explore the feasibility of CCS on board AL's 7,100TEU containership and Kamsarmax bulk carrier newbuildings.

Under the JDP, DNV will cooperate with AL on a techno economic study of CCS on board the vessels using DNVs FuelPath to assess the economic potential of the different fuel and technology strategies. The model will reflect a range of fuel and CO2 price scenarios and future decarbonisation requirements, aligned with AL's own net zero ambitions.

DNV published new guidelines for the safe installation of onboard carbon capture and storage (OCCS) system on board ships earlier this month. This comes amid growing pressure on the shipping industry to develop effective technologies to reduce emissions by 2030.

MOL and Cosmo Oil study ocean transport for CCS value chain

www.mol.co.jp
www.cosmo-energy.co.jp

MOL and Cosmo Oil will collaborate on the establishment of a CCS value chain consisting of separation, capture, transport, injection and storage of CO2 emitted from Cosmo Oil's refineries.

The agreement follows a successful engineering and design study between the companies demonstrating the technical feasibility and commercial readiness of CO2 capture technology offshore.

MOL, PETRONAS and MISC to develop CO2 carrier fleet

www.petronas.com
www.miscgroup.com

The companies will establish a joint venture to invest in the development and monetisation of Liquefied Carbon Dioxide (LCO2) carriers for CCS projects.

In February 2022, MOL concluded an MoU with PETRONAS, and in June 2023, obtained Approval in Principle (AiP) for the design of an LCO2 carrier and floating storage and offloading (FSO), and has been developing business related to the marine transport of liquefied CO2.

MISC recently became a partner in this collaboration and will cooperate with MOL in the study of development of various transport methods, mainly LCO2 carriers, as well as the optimal business model through a shipowner JV with the aim of establishing the way toward a flexible approach to various transport needs in the future.

SBM Offshore and MHI partner on offshore CO2 capture

www.mhi.com
www.sbmoffshore.com

The companies will offer a CO2 capture solution for Floating Production Storage and Offloading vessels (FPSO) as they are producing oil and gas from offshore reservoirs.

The agreement follows a successful engineering and design study between the companies demonstrating the technical feasibility and commercial readiness of CO2 capture technology offshore.

The CO2 capture solution will apply MHI's proprietary "Advanced KM CDR Process™" technology, jointly developed with The Kansai Electric Power Co., Inc. The technology enables significant greenhouse gas emissions reductions from FPSOs by capturing CO2 from onboard gas turbines.

It is estimated that the CO2 capture technology can reduce CO2 emissions from overall FPSO operations by up to 70%. The solution is being developed as part of SBM Offshore's emissionZERO® program and is based on a combination of MHI's proprietary CO2 capture technology and SBM Offshore's Fast4ward® principles.

MISC recently became a partner in this collaboration and will cooperate with MOL in the study of development of various transport methods, mainly LCO2 carriers, as well as the optimal business model through a shipowner JV with the aim of establishing the way toward a flexible approach to various transport needs in the future.

Through further collaboration with PETRONAS CCS Ventures and MISC, MOL will contribute to build a CCS value chain , contributing to the development of a carbon-neutral society it said.

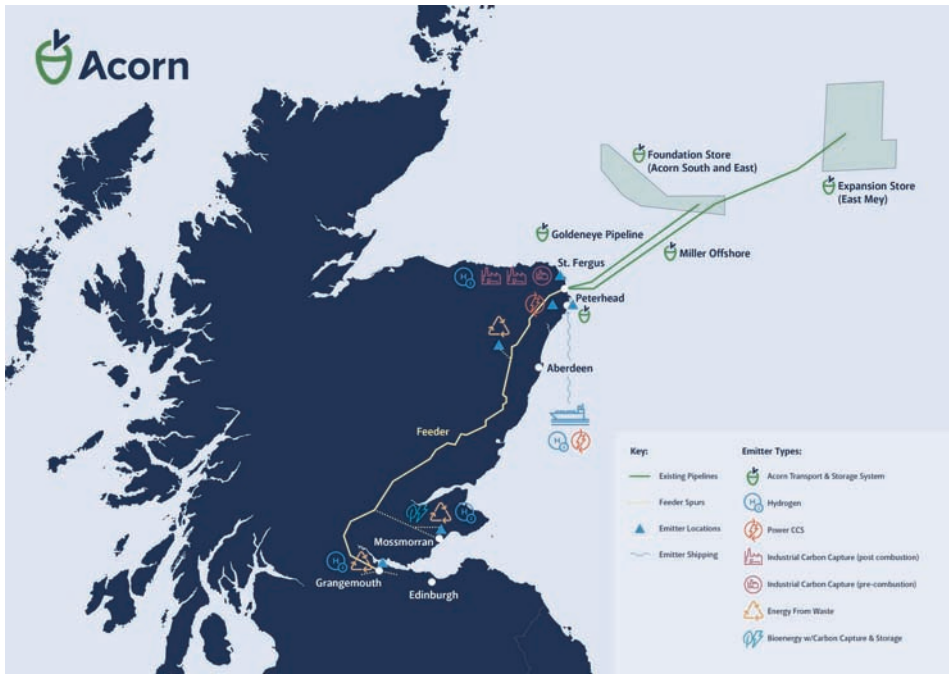
Innovating for impact: advancing CCUS technologies

Now is the time to make CCUS part of our essential infrastructure, however the suitability of existing infrastructure, impact of long-term exposure to CO2, and cost of monitoring is a concern.
By Iain Martin, Technology Manager, Net Zero Technology Centre.

Recent announcements from the UK government outlined £20bn of funding support to accelerate the essential infrastructure development for widespread CCUS, and two further projects making up the cluster sequencing with Track-2 funding, including the Scottish cluster, Acorn CCS.

In 2021 the Committee for Climate Change identified CCS as an essential component of the 'balanced pathway' to meeting the UK's Net Zero goals. It is a necessity if the UK is to meet its target to deliver 30 million tonnes per annum (equivalent to 12 million cars off the road) of CO2 storage by 2030 and net zero by 2050.

Carbon capture and storage is a proven technology with a global capacity of approximately 40MT from industrial CCS projects. CCUS forms a key vector to decarbonise industry areas where emissions are hard to abate, can't be electrified, or use alternative renewable energy sources. The process of capturing carbon is also a critical enabler for Green Enterprises using CO2 as a feedstock, for example, synthetic fuels, and supporting the creation of new industries and jobs.



The Acorn Project and Scottish Cluster connections will provide the CO2 storage capacity

Scotland, the source of storage

The Acorn CCS project is Scotland's system for the transport and storage of industrial CO2 emissions using legacy oil and gas infrastructure to carry captured CO2 emissions from the major industrial zones to permanent storage 2.5km deep under the North Sea.

The geology, infrastructure, and proximity of offshore assets to major industrial hubs in the North Sea means the UK is uniquely placed to provide a carbon storage service to both the UK's industrial and power sectors, boasting an estimated 78Gt of potential CO2 storage offshore the UK. This capacity also allows for imported CO2, placing the UK as a world leader in CO2 storage.

However, the suitability of existing infrastructure, impact of long-term exposure to CO2, and cost of monitoring is a concern.

Tackling the corrosion challenge

During combustion and industrial processes, water is produced alongside the CO2 and other gas impurities which can lead to the formation of carbonic acid.

The acid and impurities pose a huge corrosion risk which can lead to CO2 leaks and pipeline failures. This is forecast to cost the sector £1.7 billion by 2050, and there is concern over the environmental impact of a major CO2 leak.

Accurate qualification of water and other impurities in multi-component CO2 flow is a critical challenge that needs to be solved for the CCS industry to scale. However, if de-risked could result in large cost savings in the build out of transportation and storage networks.

CO2 conformance and containment

A comprehensive measurement, monitoring, and verification (MMV) plan is essential for any proposed CO2 storage site to demonstrate the CO2 is stored safely and that there are no impacts to the surrounding environment.

However, the high cost of monitoring long after CO2 injection has stopped will make many potential stores uneconomical. Innovation in this area could reduce the costs of monitoring by up to 50% making long term storage of CO2 economically viable.

Legacy wells are a major risk to safe storage as they potentially provide a leak path to surface for the stored CO2. Current assessment methods only provide a qualitative assessment of their condition based on human judgement. A quantitative approach would allow industry to understand both short and long term leakage risks from wells during operational and post operation phases. This will allow operators to plan injectivity strategies, mmv activities and provide assurance to regulators on the safe and containment of CO2 within the storage complex.

Away from wells, there are a range of technologies available to monitor underground CO2 storage. However, they face reliability, repeatability, and precision challenges. Those that meet the requirements are usually subject to high deployment costs. Therefore to solve this challenge, cost effective and techniques need to be developed and deployed at speed.

Scaling the solution

While CCS is a proven technology, scaling it is a new challenge. Technology development and innovation will help to overcome challenges such as the high costs involved, the impact of impurities in the CO2 stream, and the monitoring of stored CO2.

Through our Open Innovation Programme we are supporting the development of technologies, working with academia, technology start-ups, and tier 1 service companies, that will address these challenges. Examples of these include a first of its kind innovative sensor to accurately measure moisture content in the CO2 stream; an alternative material that is resistant to corrosion and can withstand cold temperatures for piping liquefied cold CO2 for shipping; and a low cost, permanent, adaptive monitoring system to monitor CO2 plume development using surface deployed distributed acoustic sensing (S-DAS).

This idea offers a radical approach to monitoring CCS sites with a move away from 4D seismic monitoring which focuses on full field monitoring to a plume centric and 'health monitoring' system.

The North Sea Transition Authority's (NSTA) first ever UK CCS licencing round resulted in 21 new CCS licences in depleted oil and gas reservoirs and saline aquifers being awarded, which could potentially store up to 10% of total UK greenhouse gas emissions.

It is emerging technologies, like the ones mentioned above, that will play an important role in developing the build out and safe operation of the new CO2 storage networks.

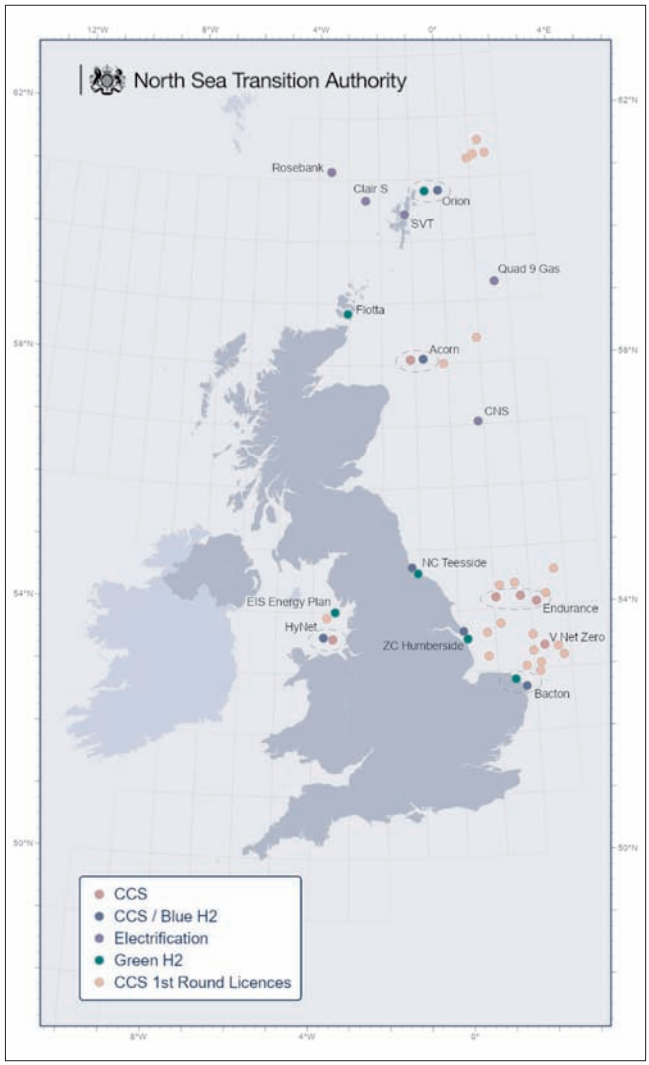
Unlocking the U

While much of the focus is on storage, we must not forget about the 'U' in CCUS. Utilisation of CO2 in the production of chemicals, building materials, surfactants, synthetic fuels could provide an outlet for captured CO2 while storage sites are brought online creating new industries and jobs.

At NZTC we're progressing the development of utilisation technology, leveraging work we've done on alternative fuels, energy hubs and hydrogen production.

We're building strategic partnerships and consortiums to deliver strategic projects and connecting industrial emitters who lie outside of the main industrial clusters.

We want to develop Offshore UK as a pan European CO2 storage hub, looking at common infrastructure, transportation options, route optimisation, landing points and infrastructure requirements.



The NSTA launched the UK's first carbon storage licensing round on 14 June 2022, inviting applications for a number of areas across the UKCS including the Northern North Sea, Central North Sea, East Irish Sea and Southern North Sea. On 18 May 2023 the NSTA offered for award 20 carbon storage licences at offshore sites

It is a really exciting time for CCUS and the UK can undoubtedly position itself as a global leader, delivering decarbonisation at scale without deindustrialisation, creating a sustainable and cleaner future.

More information

www.netzerotc.com

Porthos: first CO2 storage project in the Netherlands launched

The Porthos infrastructure requires an investment of €1.3 billion. With the final investment decision reached, Porthos will now award contracts required to realise the project.

Porthos has taken a final investment decision to develop the first major CO2 transport and storage system in the Netherlands. In 2024 construction will begin in Rotterdam, with the Porthos system expected to be operational by 2026.

Porthos is a joint venture of EBN, Gasunie, and the Port of Rotterdam Authority. Porthos will provide transport and storage services to several companies in the port of Rotterdam, including Air Liquide, Air Products, ExxonMobil, and Shell. These companies will invest in their own capture installations to supply CO2 to Porthos.

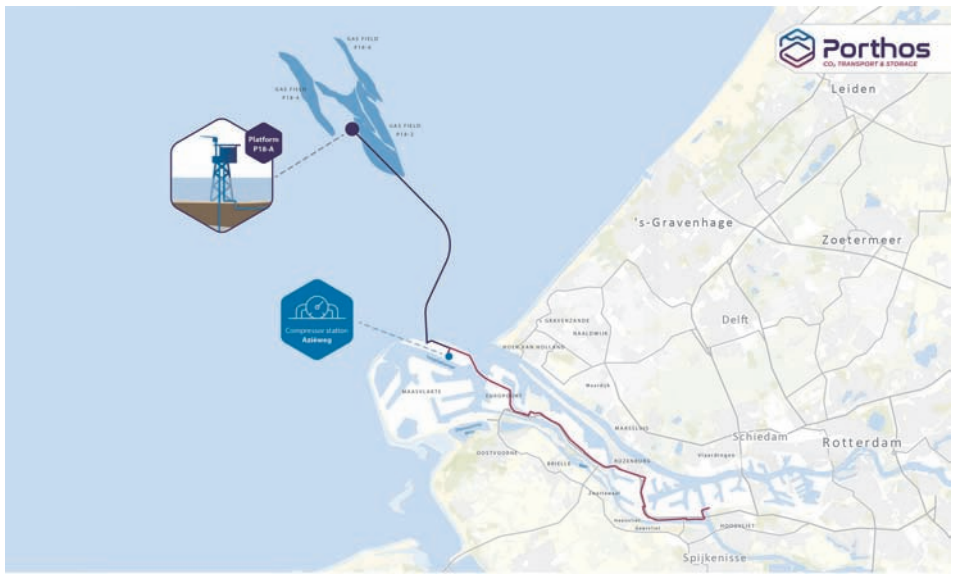
Porthos will transport the CO2 through the port of Rotterdam to depleted gas fields in the North Sea, approximately 20 km off the coast, where it will be permanently stored at a depth of 3 to 4 km under the seabed. Porthos plans to store about 2.5 Mton per year for 15 years, totalling around 37 Mton. The onshore transport system under construction allows for future CO2 storage projects.

Hans Meeuwsen, Porthos director, said, "CO2 storage is crucial if we want to achieve the climate goals in the Netherlands. This investment decision is an important starting point for future developments in CO2 storage in the Netherlands."

CCS is an important pillar of the Dutch government's climate policy. Thanks to Porthos, the Rotterdam port industry will soon emit about 10% less CO2. At the same time, the industry is working on the transition to processes based on renewable energy and raw materials.

To realise the project, Porthos has partnered with TAQA Energy, the present operator of the P18 gas fields, and specialised contractors and suppliers such as Denys N.V., Allseas, LMR Drilling GmbH, Mannesmann Grossrohr GmbH, Corinth Pipeworks, Equans, Ensco Offshore, Van der Ven and Bonatti. Together, under Porthos' direction, they will deliver the required infrastructure.

The European Union recognised Porthos as an important project in meeting climate targets, declaring Porthos a Project of Common Interest and awarded €102 million in subsidy.



Porthos plans to store about 2.5 Mton per year for 15 years in depleted gas fields (Image: Porthos)

The Clean Air Task Force has published a factsheet, which explores how the project will work and why projects such as Porthos are critical for both the Netherlands and the EU to achieve their climate goals.

"This is the first storage project in the EU to take a final investment decision so it's an exciting breakthrough, but we have to make sure this isn't where the CO2 storage momentum ends." said Codie Rossi, Policy Associate, Carbon Capture at Clean Air Task Force. "Policymakers and business leaders need to expedite the development of more storage sites, across Europe, to unlock further emissions reductions."

Choosing suppliers

MAN Energy Solutions has won the contract for delivery of three integrally-geared compressor trains (IGC) which will be used to compress the CO2 before transport and injection.

MAN Energy Solutions' scope of work covers the delivery of three RG 28-6 type compressor trains with an order for two additional units intended at a later stage. The compressor trains will be located at a station on Maasvlakte.

Allseas will construct subsea CO2 pipeline for Porthos. Starting 2025, the work includes installation, burial and commissioning of a 16-inch CCS pipeline connecting a compressor station on the Maasvlakte with the P18-A platform approximately 20 kilometres offshore.

Pipelay will be executed by Allseas' dynamically positioned S-lay vessel Lorelay, with construction support from Oceanic. The vessels can position precisely and safely in the busy waters around Rotterdam, the busiest and largest port in Europe.

More information

www.porthosco2.nl

www.catf.us

Update on CCS in the Netherlands

An update on carbon capture projects in the Netherlands, including Porthos, Aramis and Twence, government strategy and research projects, were presented at the CATO (CO2 capture, transport and storage) community gathering in Rijswijk, Netherlands on Sept 26. By Karl Jeffery.

The Dutch Porthos project, expected to be the first full scale CCS project in the Netherlands, has now overcome the final permitting barriers to its final investment decision (FID) we heard at the CATO (CO2 capture, transport and storage) community gathering in Rijswijk, Netherlands on Sept 26.

The final barrier to FID was the need for a positive ruling from the Netherlands Council of State against an appeal against Porthos made by an environmental organisation in Nov 2021. The grounds of that appeal were that Porthos should not be allowed to proceed due to nitrogen emissions from road vehicles in constructing the project. The Council made its positive ruling in August 2023.

The project team has proved that it is possible to safely decommission an offshore gas well, a step which was required before government approval was granted.

In the Netherlands, carbon capture is calculated to be more cost effective than all other CO2 mitigation schemes, in terms of emissions avoided per euro of subsidy, said Sytze Ferwerda, public affairs advisor with Porthos. This includes investing in wind, heat pumps and solar.

Aramis

The work of Porthos will be continued with the next expected Dutch project, Aramis, which will carry CO2 from emitters across Northwest Europe.

It aims to connect Northwest Germany, France, and Belgium into the Netherlands, and perhaps connections further afield if CO2 can be transported by train. There will also be an import terminal for CO2 by tanker.

It will have a pipeline with capacity of 22 mtpa, and connect to three different offshore storage sites, explained Karel Kersten, public advisor with Aramis.

Operations are expected to start in 2028, or 2029 if there are some environmental appeals, Mr Kersten said. Initial capacity will be minimum 7.5 mtpa. This means Aramis and Porthos will be storing a minimum of 10 mtpa, so nearly reaching the Dutch national target of 11.5 mtpa of CCS by 2030 (see next section).

Aramis will shortly begin its Front-end Engineering and Design (FEED) phase.

While Porthos and Aramis are separate projects, Aramis builds on Porthos, seeking to meet growing demand. "If you saw how fast Porthos sold out its 2.5 mtpa, the lesson is, 'do it ten times bigger, and do it twice,'" Mr Kersten said.

Dutch government

The Netherlands has a goal of reducing emissions by twenty-three million tonnes a year (mtpa) by 2030, and using CCS to achieve half of that goal, said Pim van Loon, CCS Programme Manager with the Dutch Ministry of Economic Affairs and Climate. "I think that is a realistic and ambitious target and we will make it."

The Netherlands has made Euro 45m available for pre-FEED studies of future projects.

Work has begun to plan a CO2 and decarbonised hydrogen pipeline between Ludwigshafen and Cologne in Germany to Rotterdam, known as the "Delta Rhine Corridor," so the CO2 project can spread across Northern Europe, he said.

The Dutch government is not setting any restrictions on what CO2 sources can be used in publicly funded CCS projects. So it is still possible to use it on power generation and blue hydrogen (fossil fuel gas) projects, he said.

The Netherlands sector of the North Sea is thought to have capacity for 1600m tonnes of CO2. The Netherlands has recently signed a MOU with the Belgian government to reconfirm both countries are happy for CO2 to be transported between the two countries.

One audience member asked whether the Netherlands public was prepared to accept some of its storage space being used to store CO2 from other countries. "In every Dutch person there hides a business man," said Mr Kersten from Aramis. "If you say, 'it's Dutch storage but Germans will pay for it,' it relieves a bit of pressure."

However, most of the CO2 sources being planned are currently Dutch. "We are not flooded by foreign CO2," said Mr van Loon.

Twence

The second full scale carbon capture and utilisation project in the Netherlands, at the Twence waste to energy plant in the East of the country, is scheduled to be operational by the end of 2023.

It follows the first full scale CCU project, AVR, which has been capturing 60,000 tonnes per year for use by greenhouses since 2019.

Twence will capture 100k tonnes a year of CO2. The CO2 will not be stored, but piped to industrial greenhouses, where it becomes a fertiliser, and replaces CO2 generated specifically for that purpose by burning gas.

Construction started in May 2022, and the carbon capture system was installed in early 2023. The largest components are three columns: the CO2 absorber system, the desorber for separating the solvent from CO2, and a cooler, said Ronald de Vries, projects manager at Twence. These columns were delivered to the site by road and canal.

The cooler is there to cool flue gas after flowing through the capture process. It is heated in the capture process and needs to be cooled to the same temperature as the rest of the flue gas, before venting. Only a third of the flue gas emitted by the site is processed by the facility, due to limitations in how much CO2 can be utilised.

The CO2 is also used to make 'dry ice,' frozen

CO2 used for cooling and theatre smoke machines. The project team seek to further reduce the level of impurities in the CO2 to bring it to 'food grade quality' so it could be used for soft drinks. "We are almost near it," Mr de Vries said.

The project could be developed further if it had a connection with a CO2 sequestration system, but this would need further government funding, he said. "it is really a challenge to make a project bankable."

Where the waste is of biogenic origin, such as paper, storing the CO2 from its combustion can be classified as a CO2 'removal', since the whole process including growing the paper to make the tree removes CO2 from the atmosphere. This can increase the value of the project, because companies seeking to make their own emissions net zero through offsets may buy carbon credits in it.

The energy requirement is 1 MW of thermal energy per tonne captured, he said.

Mr de Vries says he is happy Twence chose to be a 'first mover' in CCS, because contracts and pricing could be agreed before the breakout of war in Ukraine and subsequent inflation.

The capture and process equipment was provided by Aker Carbon Capture, as a standardised, modularised system, so one design can be used an unlimited number of times,

"We are a Scandinavian company. Scandinavian companies are known for building little boxes, [such as] Lego. That is in essence what we are doing with modularisation, said Pim van Keep, sales director Netherlands with Aker Carbon Capture.

Aker is currently making the third generation of its standard "Just Catch 100" unit, which processes 100,000 tonnes a year. Each generation has a smaller footprint and uses less energy, he said.

There are five similar installations going to projects in Denmark, including one for a negative emissions project, he said.

Government subsidies

The Netherlands has several funding opportunities for carbon capture projects, explained Martijn van de Sande, CCS co-ordinator with Dutch enterprise funding agency Rijksdienst voor Ondernemend Nederland (RVO).

There is up to Euro 2m available for feasibility studies, desk study work done prior to pilot or demonstration projects. These desk study projects can last maximum 1 year, and grants are available up to April 2024.

Then, up to Euro 500k is available for research and development projects, which can run up to 4 years. The next opening is in Spring 2024.

Up to Euro 15m is available for pilots and demonstration plants, under a scheme called Demonstrating Energy Innovation (DEI+). Projects can run for 4 years. Another scheme is MOOI (English translation - Mission-driven Research, Development and Innovation), for research among a larger group of companies, set to open in Spring 2024.

The set-up is still being discussed, but previously such schemes had a maximum budget of Euro 4m.

Further information about Dutch subsidies is online (Dutch language) at rvo.nl/tse and rvo.nl/subsidies-financiering.

Research projects

The C4U project (www.c4u-project.eu) is developing a high temperature solvent for capture, which could be used for example in steel making.

The idea is that if the whole process takes place at high temperatures, then high temperature steam could be used to displace CO2 from the solvent, explained Jurriaan Boon, process technology scientist at Dutch research centre TNO.

The Initiate Project (www.initiate-project.eu) seeks to make ammonia from blast furnace gas, using a Sorption Enhanced Water Gas Shift (SWGS) process. The aim is to build a plant producing 50ktpa of urea, a fertilizer normally made from ammonia.

The project runs from November 2020 to November 2025, and has Euro 21.3m EU funding.

There are seventy people at TNO working on a project to improve processes for CO2 capture, explained Peter van Os, senior project manager at TNO. Areas of research include managing and monitoring emissions, finding ways to better manage solvents, developing shipboard carbon capture systems, developing mobile carbon capture systems, and developing capture clusters.

Experimentation is being done with different levels of capture (such as 90, 95, and 98 per cent), and using solvents of different ages (500 hours, 5000 hours and >10,000 hours), and understanding different types of emissions, such as aerosols (liquid droplets).

In one facility, the emissions were found to suddenly jump to 750mg per cubic metre of gas, after a systems change, which is too high to be permissible, he said.

The project team have a mobile CO2 capture plant, which can handle 3 to 5 m3 per hour of flue gas, with 25 kg per hour solvent flow. This can be used to try out new solvents.

TNO is involved in two shipboard carbon capture projects. One is EverLoNG, (https://everlongccus.eu/) testing out a mid-sized capture system with a prototype installed on an LNG fuelled gas tanker chartered to TotalEnergies.

The other project is "REMARCCABLE," with a 25m high CCS system installed on the Stena Impero tanker. Project partners include the Global Centre for Maritime Decarbonisation, the Oil and Gas Climate Initiative (OGCI), Stena Bulk, Alfa Laval, ABS, Deltamarin Ltd, TNO, Lloyd's Register and Seatrium. It is claimed to be "the world's first project aimed to demonstrate end-to-end shipboard carbon capture at scale."

In the area of CO2 transport and storage, studies are taking place to better understand the challenges, such as possible large pressure drops, and a corresponding drop in temperature, as gas expands into a storage facility, said Filip Neele, senior scientist CCS at TNO.

A research project aims to build digital models of the reservoir, geomechanics, geophysics, wellbore, and facility networks, to better understand the impact of this. The project starts in 2023 and runs for 3 years.

A further project, RETURN (www.return-act.eu) seeks to better understand the process that happens in a reservoir or bottom of the well, if cold CO2 enters a reservoir and starts warming up. There could be a risk of hydrates forming close to the well.

More information

co2-cato.org

Accelerating CCS clusters development could deliver an extra £32BN for UK

New research commissioned by Drax Group shows that cluster development could be worth hundreds of thousands of jobs and tens of billions of pounds to the UK's economy by 2050, with the North of England set to benefit most.

A new independent research report, "UK Cluster potential – how the UK can lead the world in Carbon Capture and Storage" by Development Economics, finds that if the UK Government accelerates and expands the development of CCS Clusters across the country it could generate an extra £32bn of gross value added (GVA) for the economy from 2050 onward and nearly 500,000 additional jobs.

Richard Gwilliam, UK BECCS Programme Director at Drax Group, said, "Carbon capture and removals can be a catalyst for growth, stronger energy security, increasing employment and reaching Net Zero in the UK. This research demonstrates that if the UK puts its foot on the accelerator and expands the rollout of CCS Clusters across the country, a unique prize worth tens of billions of pounds to the economy and hundreds of thousands of jobs is within reach."

"At Drax, we want to play our part in ensuring the UK becomes a global leader in CCS and that is why we are working towards installing two bioenergy with carbon capture and storage (BECCS) units at Drax Power Station. This would see us become a key part of a Humber-based carbon capture cluster and we are currently working on routes to deployment through the Track 1 Expansion and Track 2 processes."

The research, commissioned by Drax Group, demonstrates that in the most optimistic scenario the UK Government could enhance our energy security, turbo-charge economic growth across the country and cement the UK's position as a world-leader in carbon capture and removals technology.

The report says that this scenario could be delivered through policy changes which can unlock investment and clarify how CCS Clusters are developed. These include:

• Finalising CCS business and financial models;

• Confirming the role of the UK ETS scheme and voluntary carbon markets in supporting investment in CCS;

• Providing a near-term incentive for prospective storage operators to appraise storage locations building on recent North Sea Transition Authority licencing rounds.

The North of England would be the region to benefit most with £22bn added to the economy per year from 2050 onward and 330,000 additional jobs.

The report also explores the economic impacts of two additional scenarios, one where the UK delivers on current CCS policy commitments and another where it does not.

If the UK does fulfil its ambitions, it will be worth an additional £23bn per year from 2050 and an additional 310,000 jobs.

"This research demonstrates the significant opportunity for the UK to be a global leader in carbon capture and storage and the importance of CCS for key industries which provides jobs, growth and opportunity across the UK," said Steve Lucas, Director at Development Economics.

"With ambition, clarity, and the necessary support from Government – following the key suggestions outlined in the report's roadmap – there is a significant prize to be won for the UK economy and environment."

However, in its recent progress report the Climate Change Committee warned that the rollout of CCS is already behind schedule and Development Economics' research shows that if this trend continues and the UK fails to deliver on its CCS policy commitments, the economic effects could be severe.

This includes the loss of 136,000 jobs and £9bn GVA per year from 2050 from heavy-emitting companies, which will have no other route to decarbonise and therefore could move their operations abroad to countries with better resourced and more CCS clusters.

The report argues that the combination of additional support delivered in the most optimistic scenario, the country's past hydrocarbon expertise and £15bn from the investment community for the energy transition, would put the UK on the map as a world-leader in CCS.

It also demonstrates that the Humber, with existing plans to become the world's first carbon negative region and 80% of the UK's licensed CO2 storage, could become a global model for regional cluster development. The research shows that with increased ambition the Humber could benefit from an additional 42,000 jobs and £3.4bn GVA per year by 2050.

Drax plans plan to invest billions in its BECCS plans at North Yorkshire's Drax Power Station to develop two units which could remove 8Mt of carbon from the atmosphere per year while continuing to provide renewable baseload power to the UK grid.

This will ensure the station continues to generate secure renewable electricity into the future while delivering up to 10,000 high-skilled jobs in the Humber at the project's peak and playing a critical role in delivering carbon removals so the UK can meet its binding engineered greenhouse gas removal target.

Drax says it is currently exploring the roles the Track-1 Expansion and Track-2 CCS cluster sequencing can play in supporting the transition to BECCS at the Selby site. Power-BECCS remains eligible to participate in either process.

More information

www.drax.com

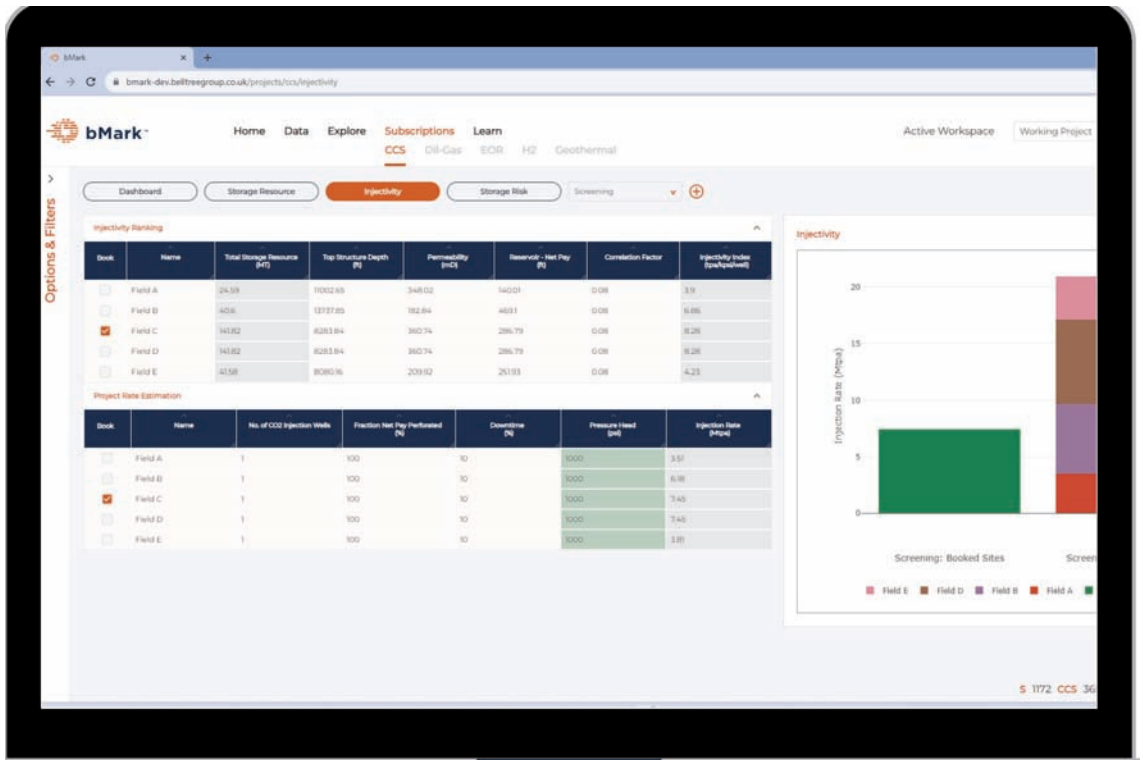
How CCS emerging technologies can empower decarbonisation

There is a market opportunity in bridging the gap between traditional oil & gas and a carbon neutral energy model. Belltree's bMark™>CCS software is a comprehensive tool for converting conventional oil and gas portfolios into future CO2 storage investments, benchmarking suitable storage sites and managing risk and collaboration. By Peter Clark, Belltree.

The Net-Zero Energy Transition describes the global process of decarbonising the energy supply and consumption chain so as to reduce greenhouse gas emissions and mitigate negative climate change impacts.

The transition presents both threats and opportunities to historical business models in the oil & gas industry.

Despite the advantages of traditional oil and gas, there are notable disadvantages. First, the world's increasing energy demands have led to a 50% rise in consumption since 2000, with growth expected to persist.



bMark™>CCS allows CCS projects to be designed, benchmarked, risked and booked, all in one place

Second, while oil and gas currently account for approximately 55% of global energy consumption, their reliance raises concerns over sustainability and climate change.

How therefore do we adapt to the Net-Zero Energy Transition?

In the context of the Net-Zero Energy Transition, adapting to the changing energy landscape requires a shift from the traditional oil & gas business model to a mixed Carbon Neutral Energy model.

This transition presents a knowledge gap that needs to be addressed, as professionals in the energy sector must understand and navigate the opportunities and challenges associated with different energy systems and the use of both new and existing infrastructure.

Bridging this knowledge gap will require the ability to define the opportunities available across multiple Energy systems using both new and existing infrastructure. Hence, there is a market opportunity for new software products providing data, analytics and workflows across this new mixed Carbon Neutral environment.

Carbon Capture & Storage offers one of the most cost-effective solution to decarbonise heavy emitting industries and is a key technology to enable the Net Zero transition. To incentivise markets to reduce carbon emissions it is widely agreed that a price on carbon, via a carbon tax or similar mechanism, will be required.

As carbon is priced, operators and national regulators will increasingly begin to value assets not only based on hydrocarbon production & reserves but also emerging technologies in Geothermal, CCS, Wind/Solar electrification and Hydrogen generation.

Similarly, commercial carbon storage projects are beginning to emerge in the USA. This growth in emerging technologies is leading to a future energy landscape that is greener but more complex and diverse than today.

Overcoming the challenge of storage sites: unlocking the potential of carbon capture business

Another key challenge is the search for suitable storage sites, which involves careful geological assessments, regulatory considerations, and stakeholder engagement to ensure the safe and effective storage of captured carbon dioxide. Overcoming this challenge is crucial for the widespread deployment of carbon capture technologies and the mitigation of greenhouse gas emissions.

There are technologies already available in the market that can help ease these issues to manage storage projects and discover storage sites, such as Lens by Wood Mackenzie and bMark™>CCS by Belltree, which additionally provide insights on CO2 emitters and transport corridors.

Using analogue data to identify storage sites

The knowledge accumulated in the upstream oil and gas industry plays a crucial role in interpreting geological data and identifying parameters for potential carbon storage sites. Global analogues provide extensive insights into the assessment of any new site suitability, including the suitability of mature & shut-in hydrocarbon fields, as well as saline aquifers for CO2 storage.

Whilst the number of implemented and planned CCS projects is growing year on year, providing a valuable and growing source of analogue data from which to benchmark new projects, the overall number of executed projects remains relatively small. Therefore, screening software that allows users to integrate this information with the much larger accumulated knowledge of the subsurface generated from decades of oil & gas exploration and development is crucial.

bMark™ facilitates this by integrating a detailed front-end CCS project screening workflows directly with its global technical database, which includes 50,000+ oil & gas fields and 15,000+ large industrial emissions sites

Geological insights play a pivotal role in assessing the design and development of CO2 storage projects, indicating the potential mass stored per unit volume of rock, the porosity, and injection rates to build the storage system and evaluate long term performance. Porosity, referring to the spaces between the grains of rock in the underground formation, is a critical factor in selecting a site with the capacity to accept and retain the CO2 in the long term.

Estimating pore space enables CO2 storage capacity predictions, therefore enabling investors to make informed decision when choosing where to store or to develop CCS projects.

Subsurface geology information is readily available in the petroleum industry, however its coverage varies regionally and on a case-by-case basis. Due to the vast volume of global data, analogues can be used where information is spare. For instance, seal parametrics, which are less well constrained than those of the underlying reservoirs, can be estimated from depositional environments- a more regionally consistent parameter (see Gibson-Poole et al, 2009; Root, 2007).

Lagoonal seals, for example, are thicker than deltaic seals by several orders, and so might be better suited for Geological Carbon Storage (GCS) projects (Cirium, 2022). Similar assumptions are linked to sedimentary basins worldwide to estimate CO2 storage capacities. In this way, analogues can allow parameters relevant to CCS to be backfilled for site selection, presenting a great economic advantage over systems where the same breadth of data is lacking.

As the number of CCS projects increases, these parameters will contribute to a framework for multiparameter benchmarking, allowing an enhanced understanding of the suitability of a site for CCS. Using depth constraints alone, the bMark™ database contains 16,462 candidate fields for deep carbon storage. Among these, 504 fields already involve some form of gas injection, while 40 explicitly use CO2-enhanced oil recovery (CO2-EOR).

Scale-up CCUS projects

bMark™ serves as a valuable tool for building a comprehensive CCS portfolio through access to global subsurface data on potential storage sites. Through bMark™, users can identify and assess suitable projects worldwide for CO2 storage investments.

Using global analogue benchmarking techniques, uncovers best practices from around the world, and provides access to valuable global geological insights and analytics.

"There is a market opportunity for new software products providing data, analytics and workflows across the new mixed Carbon Neutral environment" - Peter Clark, Belltree

Additionally, the digital workspace provided within bMark™ helps manage CO2 storage projects at scale, enabling teams to collaborate and share data in real-time, mitigate risks, validate assumptions and assess resources.

Understanding the critical issues related to geological storage sites

One of the major concerns in using depleted reservoirs to store CO2 is leakage. To achieve 99% retention over 100-year timescales, leakage rates of less than 0.1% must be maintained.

bMark™ is designed to provide a comprehensive solution for risk management. With its advanced risk assessment tools and SRMS Classification Workflow, it empowers teams to create a detailed risk profile, in which storage resources are adapted to project specifications, enabling teams for the identification, assessment, and management of risks at every stage of the project.

bMark™>CCS offers subscribers a first-to-market software solution allowing Carbon Capture & Storage projects to be designed, benchmarked, risked and booked, all within an intuitive platform.

More information

belltreegroup.co.uk

ABB and Pace CCS – digital tools for CCS operations

Managing a CCS operation is a complex activity, which coupled with the investment required to successfully integrate it into new or existing operations, has hampered adoption to date. A combined solution from ABB and Pace CCS could make it easier. By Karl Jeffery.

According to the International Energy Agency (IEA), planned CCS facilities are growing rapidly on a global scale, yet they still represent only around 20 percent of what is required for the world to reach net zero by 2050.

A lack of operational and design experience is a major hurdle to mainstream adoption with companies reluctant to invest without clear knowledge of how things will work on the ground, at every stage of the process.

One of the problems which delayed startup of Australia's Gorgon CCS project by two years related to corrosion risk, says Matt Healey, managing director of global engineering company specialising in CCS projects, Pace CCS. "Similarly, Canada's Quest CCS project had issues with salt precipitation in the reservoir."

This is a simplified telling of some of the problems encountered by CCS projects. However, it illustrates how critical it is to be able to fully model and monitor a carbon capture and storage system from design stage, testing scenarios to deliver proof of concept to give customers both peace of mind that the system design is fit for purpose and shows how they can smoothly transition into CCS operations.

In other industries such as oil and gas simulation like this is commonplace. In a relatively new industry like carbon capture, the same approach is necessary, but it is more complex in the sense that CCS operations must work at full capacity, being online constantly, 24/7.

"The key to any successful CCS project is availability ensuring the CCS network is always operable" says Healey.

Taking all this into account ABB and Pace CCS, have joined forces to make the capture, transportation, and storage of industrial emissions more accessible, making it easier for industry to implement CCS infrastructure and in doing so lowering the CAPEX and operational investment required to enter the market.

"Together, we have developed digital twin technology that provides a virtual replica of a real, physical CCS process or facility," said Nigel Greatorex, Global Industry Manager for CCS at ABB Energy Industries. "The digital twin models the full value chain of a CCS system, something existing software cannot do."

Managing the complete value chain

The major sources of global CO2 emissions are transportation, agriculture, commercial and residential buildings, heavy industry, and power generation. The CCS value chain therefore begins with the capture of CO2 from either these large sources – which generally use fossil fuels or biomass for fuel – or directly from the atmosphere.

At a design level, the biggest cost in CCS is capture. Captured CO2 contains impurities which adds risk. These impurities must be separated, purified, and then compressed before being transported for reuse or injected into reservoirs for storage. The digital twin considers the impurities and as a result can monitor and reduce the amount of power needed to pressurize and heat the CO2.

Greatorex says, "When we model CO2 flows, we need a series of process models (to model out how equipment will operate), flow assurance models (to model out how the CO2 will flow through a pipeline) and reservoir models (to model how CO2 will behave when injected into a reservoir)."

"The modelling process breaks down the pipeline into tiny parts, as with finite element analysis, Healey continues. "It evaluates what temperature and pressure CO2 will have in that section, and so what phase it will be in (gas, dense phase or two phases), and how it will flow.

This is important because energy is not always easy to get to on a CCS network. There is not always a source of power at the point of injection or the midpoint of a pipeline or even excess power at the capture source. By deploying a digital twin, operators can be sure the plant is not over-compressing or overheating, resulting in significant OPEX savings."

Ensuring 24/7 availability of the CCS network is key to project success says Matt Healey, managing director of Pace CCS

Collaborating to offer a solution for industry

The partnership formed between ABB and Pace CCS addresses all the above.

Pace CCS are the experts in designing CCS networks, while ABB are the experts in operational excellence.

"With our digital twin solution, we harness the expertise from both our organizations, providing a consistent approach from design through to operations, providing operators

with the confidence they can achieve the required high availability allowing CCS investments to proceed," says Nigel Greatorex.

"The solution not only maps out various scenarios in the design phase, but when in operation it will react to incidents in real time. Furthermore, we plan to add ABB Ability™ OPTIMAX® into the mix which will deliver an energy management system which can forecast and manage power consumption."

Not done there. The collaboration continues to grow with Canada based Computer Modelling Group (CMG) recently added into the mix. Specialists in subsurface modelling their addition will ensure a complete end-to end solution is on offer, with the above ground digital twin mirrored by one that models the subsurface, tracking the carbon dioxide as it is injected underground.

As a result, ABB and its partners Pace CCS and CMG, will be able to deliver software solutions for all the stages of a CCS project, from design through to operations and maintenance.

More information

new.abb.com

paceccs.com

UK CCS project update - report from Offshore Europe in Aberdeen

An update on UK CCS projects was provided during the Offshore Europe event in Aberdeen in September in a panel session "Delivering on the UK's CCS potential" – Northern Endurance, HyNet, Acorn, and new projects proposed in Bristol and Morecambe. By Karl Jeffery.

We heard updates from Northern Endurance, HyNet, Acorn, and new projects proposed in Bristol and Morecambe. We also heard the UK government's perspective.

Alex Milward, director for Carbon Capture Utilisation and Storage with the UK government Department for Energy Security and Net Zero (DESNZ) was keen to provide reassurance that the government will not withdraw its funding from CCS projects, as it did in late 2015.

Enormous financial capital, 'career capital' and 'sweat equity' has been put into getting the UK CCS sector to where it is now, he said.

For this reason, along with the UK government's £20bn commitment, "We remain hugely confident we will do it this time. Investors can invest with a bit more confidence."

There is a much more diverse range of users in the program this time, including hydrogen, he said. There is a Swiss Army Knife of benefits. "This makes it much more enduring."

The government has built a large, capable and growing [CCS] team. That is a different perspective to what we've had before," he said.

Mr Milward is asked to make trips to Asia "every week", to explain how the UK does it. "The world's eyes are on the UK. The collaboration between the public and private sector is leading the world."

CCS is now supported by multiple departments of the UK government.

"We're incredibly confident we'll get the first tracks away," he said. However, "I won't be happy until 10 years [time], looking back in the rear view mirror."

Mr Milward shared some advice about how industry can work better with government. Industry requests are often interpreted by government ears as, "give me the money and get out of the way."

The conversation goes down better in government circles if it emphasises national growth, taking advantage of some of the UK's biggest competencies, which are seen as being in engineering, innovation and professional services.

"People typically back a growth project over a 'protect and hold' project," he said.

The conversation goes down better with government if there is emphasis on something the UK can export to other countries, including CO2 storage services and skills.

There is some scepticism in the government about funding requests which promise to create jobs, because they often seem to overpromise, he said.

"If we add up every business case [we receive] for jobs, we'd have 150 million jobs," he said.

Northern Endurance Partnership

The Northern Endurance Partnership (NEP) CCS project is about to issue engineering, procurement and construction (EPC) contracts to build the facility, as of September 2023.

The initial phase will include five injection wells and a monitoring well. The project team are currently doing "soundings" in the market to determine if it may be possible to finance a second project.

NEP is the UK's carbon capture project for the East Coast, combining Teesside and Humber. The update was provided by Ben Kek, deputy general manager.

The project is aiming to store 23 million tonnes per year ultimately, with 10 mtpa by 2030. By comparison, the current world storage capacity is 40 mtpa, he calculates.

One challenge with the project is determining an injection rate which is high enough to keep costs low, but low enough to satisfy regulators that it will be safe. NEP may start with a more 'conservative' injection rate and then slowly increase it as there is confidence in the safety of the storage, he said.

Mr Kek said that the previous day he participated in a "UK China Climate Dialogue" hosted by Chatham House, where some Chi-

nese delegates had observed that the UK may be particularly good at projects which involve complex integration, such as this one, he said.

HyNet

At the HyNet CCS project in Northwest England, FEED (front end engineering design) is completed, and the EPC packages are "under evaluation".

The transport and storage activities of HyNet are operated by energy company ENI. The update was provided by Martin Currie, Energy Transition Manager, Eni UK, and director of Liverpool Bay CCS Ltd, an ENI subsidiary.

The Final Investment Decision (FID) is expected in 2024. This can only be made when all the licenses and permits are in place. "This process is not necessarily an easy one, but we're making good progress," he said. "Everyone is learning."

The most complex aspect of the project is not the "technical stuff" but more bringing all the components together, including pipelines and other infrastructure, he said.

The emitters include two energy from waste sites, two cement manufacturers, and a low carbon hydrogen facility.

An application has been made to connect the onshore pipeline to the offshore pipeline.

The project team is aiming to assess risks "quantitatively" (presented as numbers). This is very helpful to insurers, he said. "The CCS developer should be able to assume more risk as experience grows."

ENI is keen to develop another CCS project in Eastern England, connecting to the Bacton plant near Great Yarmouth, and using the Hewitt gas field, which has a pipeline connection.

Acorn

The Acorn Project in Northeast Scotland had its UK government funding confirmed in July 2023, as part of "Track 2".

An update was provided by John McLaughlin, EVP CO2 Storage Europe with Storegga, operator of the Acorn CCUS Project.

The project seeks to store up to 20 mtpa by 2030. As well as taking emissions from the Peterhead gas power station, the project would import CO2, with CO2 tankers discharging cargo at the nearby Peterhead port, which could handle 12 million tonnes a year.

The gas power station is a few miles from St Fergus gas terminal, which takes in 35 per cent of the UK's gas production, and processes it to put into pipelines to supply the country. It has a pipeline going offshore called Goldeneye, could be used to send CO2.

Delegates heard an update on "Delivering on the UK's CCS potential" at the Offshore Europe event in Aberdeen

The project team anticipate that they have potential access to 240m tonnes of storage resources, and much of this is within 50 km from an existing pipeline.

Storegga shareholders include Macquarie, Government of Singapore Investment Corporation (GIC), Mitsui, Snam and M&G. Shell is the technical developer.

Asked about the biggest technology challenge, Mr McLaughlin said it could be understanding about the condition of aging assets. "I'm learning about fractures," he said.

Morecambe / Spirit Energy

Spirit Energy, an energy producer with operations in the UK and Netherlands, is interested in turning its gas production in Morecambe Bay, off Northwest England, into a CCS project, after the gas fields cease production towards the end of the 2020s.

The gas field, planned to become a CO2 storage facility, is 30km offshore, beneath 30m of water, and 1km deep. CO2 storage capacity is estimated at 1 gigatonnes, said Neil McCulloch, CEO, Spirit Energy.

The geology is well characterised from the years of gas production, with a proven seal, he said.

In terms of the source of CO2, Spirit Energy is in discussion with CO2 emitters in South Wales, the Peak District and the South coast of England, and it could also be used by companies in Ireland.

Bristol

7CO2 is a project to set up a carbon capture hub at Avonmouth Dock, near Bristol, Southwest England. It is led by Paul Davies, a former partner with PricewaterhouseCoopers and former CCS advisor with Viridor.

The project is planned to initially handle 2m tonnes a year of emissions including from a power plant and an energy from waste plant. There is a disused pipeline to the port which could be utilised, he said.

The "7" in the name is a pun on the name of the river Severn, which flows out to the sea from Bristol, turning into the Bristol Channel which runs south of Wales.

There are many large emitting companies on the south Wales coast,

including an energy from waste plant in Cardiff, and steelmaking in South Wales. All of the industrial plants have rail connections to Bristol, which could carry CO2 in tankers.

Mr Davies anticipates that 7CO2 could be developed initially as a small hub but then developed, adding in connections to CO2 storage sites, shipping and rail.

It is seeking to put a bid together for the second stage of the UK CCS funding competition, together with emitting companies in the region.

More information

www.offshore-europe.co.uk

World Energy Outlook: phenomenal rise of clean energy gives hope

While major shifts underway today are set to result in a considerably different global energy system by the end of this decade, much stronger policies are needed for 1.5 °C says the flagship report from the International Energy Agency.

The latest edition of the World Energy Outlook describes an energy system in 2030 in which clean technologies play a significantly greater role than today.

If countries deliver on their national energy and climate pledges on time and in full, clean energy progress would move even faster. However, even stronger measures would still be needed to keep alive the goal of limiting global warming to 1.5 °C.

The WEO-2023 proposes a global strategy for getting the world on track by 2030 including an end to new approvals of unabated coal-fired power plants.

CCUS progress in the scenarios

The report looked at several scenarios. The Stated Policies Scenario (STEPS) provides an outlook based on the latest policy settings, including energy, climate and related industrial policies. The Announced Pledges Scenario (APS) assumes all national energy and climate targets made by governments are met in full and on time. Much additional progress is still required to meet the objectives of the Net Zero Emissions by 2050 (NZE) Scenario which limits global warming to 1.5 °C.

For the first time in a decade, multiple CCUS projects are in construction around the world, says the report. Total investment in projects reached a record USD 3 billion in 2022. The outlook for CCUS is for continued growth. Momentum is fuelled by activity in North America, where more generous tax credits and new grant funding programmes are the driving forces behind announcements of over 100 projects across the CCUS value chain since January 2022.

The global project pipeline now represents over 400 Mt CO2 capture capacity vying to be online by 2030. In the United States, where a fixed amount of funding is available per tonne of CO2 safely stored, many of the projects focus on capturing CO2 from bioethanol and hydrogen production, since these are among the cheapest options. Notable progress also is being made elsewhere, with investment in large-scale projects in Canada and China, and key regulatory advances in Canada, Denmark, Indonesia, Japan and Malaysia.

Current policies, however, are wholly insufficient to support the outcomes that match government net zero emissions pledges. In the STEPS, CCUS deployment grows nearly threefold from the 40 Mt CO2 captured in 2022 to 115 Mt CO2 in 2030, three-quarters of which is in North America and Asia Pacific. This increase is dwarfed by the projections in the APS, which sees CCUS increase more than tenfold in the period to 2030.

The APS also projects more regional diversity, with the share of captured CO2 in Europe rising to above 15% of the global total, over half of it in the European Union. The requirements of the NZE Scenario are even more ambitious, as more countries and sectors adopt best available technologies to mitigate emissions from industrial plants and to meet global demand for low emissions hydrogen. In the NZE Scenario, around 1 Gt CO2 is captured in 2030, including 265 Mt CO2 from bioenergy and direct air capture, almost 90% of which is geologically stored.

Reaching the levels of CCUS projected in the APS and NZE Scenario requires strong policy support, including measures to facilitate strategic investment in infrastructure. For example, the total length of existing CO2 pipelines is 9 500 kilometres (km), which needs to increase to between 100 000 and 600 000 km in order to facilitate the storage of 5.5 Gt CO2 and utilisation of a further 0.6 Gt CO2 in the NZE Scenario by 2050 (IEA, 2023f). The high end of this range is a similar order of magnitude to the more than 1 million km of natural gas transmission pipelines that have come online over the past century.

Enabling such a huge scale-up, and a parallel investment in seaborne CO2 transport, requires new businesses that offer commercial CO2 transport and storage services. There are signs that these are emerging in some regions, exemplified by the development of the Northern Lights CO2 storage resource in Norway, where there are now agreements that could lead to CO2 being transported to the site from facilities in Denmark, Netherlands, Norway and United Kingdom.

The European Commission has proposed that oil and gas producers take legal responsibility for ensuring the development of European CO2 storage resources, initially targeting 50 Mt CO2/year of capacity by 2030. Policy developments of this type have the potential to accelerate progress.

Industry comment

Prateek Bumb, CTO of Carbon Clean, commented, "today's IEA report outlines the role of clean technology needed by 2030. I agree that the clean energy transition is no longer a question of if, but how soon. Innovators, entrepreneurs, corporates, and financiers have got us to a point where we can seriously start to speak about technology's role in facilitating the energy transition. "

"All of this will be vain however if industry doesn't receive the support needed to have a meaningful impact. Carbon capture is critical, but we must move faster to reach the required one gigatonne capture capacity by 2030."

"Governments have a key role to play in providing policy support that enables a collaborative environment between financiers, hard-to-abate operators, and clean tech companies. We're moving in the right direction, but the planet cannot afford complacency."

More information

www.iea.org

www.carbonclean.com

Analysis of CO2 sources and demand for CO2-derived products

The report from the Industrial Energy Transition and Decarbonization (IETD) Consortium (formerly the CO2CC Program) offers a resource to gauge the extent to which CCU is meeting its potential and the key technological and commercial progress being made towards improving the outcomes.

This recent report, published in July 2023, aims to cover the landscape for CO2 emissions available for capture, CO2 conversion technologies and the market for CO2 capture and utilisation (CCU).

CCU has been primarily driven by necessity where CO2 must be removed, for example, to meet pipeline specifications, and by cost. However, its use is now expanding to various industries such as cement, iron and steel, refineries, petrochemicals, and power generation where the driver is decarbonisation as opposed to necessity.

In addition, bioenergy with CCS (BECCS) presents an opportunity to accelerate movement towards net zero by taking CO2 out from the atmosphere via plant growth.

Technology for CO2 conversion is also making strides with the scale up of e-fuels production including methanol, methane and Fischer-Tropsch (FT) products providing a means to operate CCU processes at scale.

Policy instruments in different regions are supportive of the launch of a CCU economy and longer-term the reduction in energy costs, improvements in advanced materials, CO2 conversion technologies, investor appetite and infrastructure developments all bode well for a future with large scale CCU.

An immense effort has already been made to develop and improve CCUS technologies. The total CO2 captured will reach 279 million tons/yr (Mtpy) if all currently announced projects are implemented. However, the potential volume of capturable emissions is far greater.

The report sets out to cover the landscape for CO2 emissions available for capture (Section 2), CO2 conversion technologies (Section 3) and the market for CO2 capture and utilisation (Section 4).

It draws in information from recent public domain sources, as well as the authors' experience and judgment.

In Section 2 on CO2 sources, information on the total CO2 emitted from each sector is based on published figures and best estimates.

Section 3 on CO2 conversion technologies is an expert review of recent literature and the key areas of scientific advancement in the CO2 utilisation sector.

The market for CO2 in Section 4 is based on announced projects which are operational, in construction or in the planning phase.

In summary the report provides:

- Examination on the total CO2 emitted from each sector
- Insights on the key areas of scientific advancement in the CO2 utilisation sector
- Markets for CO2 based on announced projects which are operational, in construction or in the planning phase.

Key takeaways from the report

- If carbon capture is to be scaled up to the extent required for net zero, it will require an order of magnitude increase in carbon capture capability. However, there are still a number of challenges including financing options, funding, costs, supply chain for equipment, talent pool, public awareness and acceptance, regulation and permitting, and operational experience with large integrated CCU systems. Many of these issues are common across the world while some are unique to specific geographies.
- China is a significant market which has no specific roadmap on this front, while India is the fastest growing producer building new facilities which will be operational for the longest into the future. These will need to adopt low carbon technologies and be retrofitted with carbon capture in many cases.
- The clear emerging trend is the progressive shift of the research from applications driven by the use of CO2 to reduce GHG emissions (and thus assessed from this perspective) to a set of new possibilities where the use of CO2 is an opportunity to directly use renewable energy or an alternative carbon source, to progressively substitute the use of fossil fuels.
- There is a paradigm change in assessing the technologies for CO2 utilisation and their role in the future scenario. Thus, research mainly focuses on technologies such as photo- electro- and plasma catalysis, emerging bio-enzymatic routes, and the possibilities offered by combining novel hybrid technologies. Thermocatalysis, the core technology of past research and for most pilot units, is progressively losing relevance towards these emerging technologies.
- The use of CO2 to produce chemicals is reaching an interesting juncture. Incentivized through both emission reduction and through access to potentially low-cost carbon-containing feedstock, there is a strong potential for the commercial adoption of new process routes, based on CO2 feedstock, and an acceleration in use of already commercial technologies.
- The total projected CO2 demand based on the preceding analysis reaches 350 million tons in 2030, 120 million tons higher than the 2020 figure, representing a CAGR of 4.3 percent. Of this 120 million tons additional demand, 84 million is from energy and chemical demand (including EOR, algae and cement carbonation).

More information

More information about this report and other deliverables of the IETD Consortium can be found at:

www.catalystgrp.com/tcg-resources/member-programs/industrial-energy-transition-and-decarbonization-ietd-consortium/

Projects and policy news

ADNOC and Occidental advance DAC project in UAE

www.adnoc.ae
www.oxy.com

The companies will undertake a joint preliminary engineering study for the construction of the first megaton-scale direct air capture (DAC) facility outside the United States.

The agreement is the first project to reach the technical feasibility stage since the two companies signed a strategic collaboration agreement, in 2023, to explore CCUS projects in the UAE and the US.

The study will assess the proposed one million tonnes per annum (mtpa) DAC facility to be connected to ADNOC's carbon dioxide infrastructure for injection and permanent storage into saline reservoirs. ADNOC is in the testing phase of the world's first full sequestered CO2 injection well in a carbonate saline aquifer in Abu Dhabi.

Musabbeh Al Kaabi, Executive Director for Low Carbon Solutions and International Growth at ADNOC, said, "Today's announcement represents continued positive momentum in our partnership with Occidental to significantly scale up promising carbon management technologies. This joint investment in the proposed first megaton direct air capture facility in the region exemplifies ADNOC's commitment to leverage partnerships and promising technology to accelerate our decarbonization journey on the way to net zero by 2045."

In August, ADNOC and Occidental signed a strategic collaboration agreement to evaluate potential investment opportunities in CO2 capture and storage hubs in the UAE and US and to incorporate climate technologies in energy projects such as emissions-free power and sustainable fuels.

Holding oil and gas producers accountable

www.bellona.org

Call to support Article 18 of the Net-Zero Industry Act introducing a mandatory, individual contribution of oil and gas producers to the Union-wide target for available CO2 injection capacity.

On October 30, 2023, alongside several NGOs, Bellona sent a letter to the Deputy Permanent Representatives of EU Member States and the officials responsible for the Net-Zero Industry Act.

It urged support for Article 18 within the Net-Zero Industry Act, which proposes a mandatory, individual contribution from oil and gas producers to the Union-wide CO2 injection capacity target, based on their production share.

The letter stressed the importance of holding the oil and gas sector accountable for their emissions and emphasised the significance of Extended Producer Responsibility principles. It recognised that the market has failed to provide CO2 injection capacity in the EU and supported the idea of requiring contributions from oil and gas producers to relieve pressure on public finances.

The organisations urged EU Member States to ensure industry compliance and introduce penalties for non-compliance. The letter also criticised the oil and gas sector for hindering progress in carbon capture and storage, expressing concern about attempts to weaken or delete Article 18.

It called for the EU to make the sector pay for their contribution to addressing emissions and ensuring CO2 injection capacity.

UK CCS behind schedule and lacks clarity says report

www.ccsassociation.org

A CCUS Delivery Plan update from the Carbon Capture and Storage Association says up to a third of projects considering move overseas to more supportive administrations.

Accelerating deployment of carbon capture and storage in the UK could secure around £40 billion of inward investment by 2030, says the report, but government support for CCS projects is behind schedule and there isn't enough clarity on how the £20 billion will be allocated.

As many as one in three projects are considering relocating overseas to countries backing the technology more vigorously, the report warns.

The CCSA's updated Delivery Plan has examined the pipeline of potential projects across the United Kingdom to identify the economic opportunities available and threats to successful deployment.

Since the plan was last updated in March 2022, the number of CCS projects planned for the UK has grown from 55 projects to over 90 – with enough schemes now in the pipeline to capture around 94 million tonnes of CO2 per year – up 29% from 73 million tonnes last year, equivalent to more than a quarter of total UK emissions.

The projects would protect thousands of jobs in existing industries which currently emit lots of CO2, such as cement and steel and other manufacturing, and create many more in new green economy sectors, whilst making a huge contribution to meeting the UK's 2050 net zero target.

IEA publishes first Net Zero Roadmap update

www.iea.org

The report concludes that the necessary CCUS capacity to reach the NZE Scenario by 2030 is not out of reach but the industry now needs to prove it can deliver.

An update of the IEA's landmark Net Zero Roadmap shows greater ambition and implementation, supported by stronger international cooperation, will be critical to reach climate goals. The new Roadmap sets out a global pathway to keep the 1.5 °C goal in reach.

"Keeping alive the goal of limiting global warming to 1.5 °C requires the world to come together quickly. The good news is we know what we need to do – and how to do it. Our 2023 Net Zero Roadmap, based on the latest data and analysis, shows a path forward," said IEA Executive Director Fatih Birol. "But we also have a very clear message: Strong international cooperation is crucial to success. Governments need to separate climate from geopolitics, given the scale of the challenge at hand."

If CCUS is to make progress in line with the NZE Scenario, the industry needs to prove CCUS that can operate at scale, the report says. Governments should develop effective support packages to help with operating as well as capital costs and find realistic ways of managing the long-term liabilities associated with CO2 storage.

The convergence of biotechnology and carbon capture

Processes evolved by biological organisms over millenia are being adapted to industrial applications to capture CO2 or convert carbon to valuable chemicals. By Stephen B. Harrison, sbh4 consulting.

Learning the lessons of biological evolution and nature has served mankind well for decades. The discovery of the antibiotic effects of the bacterium penicillin led to the development of modern antibiotics. Biotechnology is now instrumental in bringing new medicines to market to save lives.

Biotechnology can also guide the development of energy efficient means to capture CO2 and convert carbon to chemical intermediates such as ethanol. Ethanol can be used to make synthetic aviation fuel (SAF) and other valuable chemicals.

Seawater can be pumped into a lagoon filled with algae. Nutrients in the seawater are absorbed by the algae as they grow. They simultaneously absorb CO2 from the air in a form of direct air capture of CO2.

Enzymatic enhancement of HPC CO2 capture

Hot potassium carbonate (HPC) is a long-established CO2 capture technology. The HPC process was developed in the 1950s and was modified by two engineers: Benson and Field. It subsequently became known as the Benfield Process. In this form, it is now licensed by Honeywell UOP.

The UOP Benfield ACT-1 activator can be added to the potassium carbonate solvent to improve the CO2 absorption rate and increase the CO2 loading. It can reduce the solvent recirculation rate and thereby result in less energy required to heat up and regenerate the solvent in the stripping column. ACT-1 is a proprietary organic additive which is incorporated into the potassium bicarbonate at between 1 and 3%.

Biotechnology has also recently been applied to catalyse CO2 absorption in the HPC process through the use of Carbonic Anhydrase (CA). CA is an enzyme which plays an essential role in humans and many animals. Its function is to remove CO2, which is a byproduct of respiration.

Respiration is the mechanism by which animals convert oxygen that they breathe and food that they eat to energy. It is like an internal combustion reaction, and like combustion it produces CO2. However, the CO2 must be broken down to avoid dramatic pH changes and CA supports that by catalysing the reaction of CO2 with water to form bicarbonate and hydrogen ions: $CO_2 + H_2O \rightarrow HCO_3^- + H^+$.

A proprietary CA enzyme known as 1T1 is used by CO2 Solutions by Saipem on industrial CO2 capture systems. The molecular structure of the 1T1 enzyme has been engineered to maximise its catalytic efficacy to promote the absorption of CO2 into the potassium carbonate solution and whilst also allowing low-cost manufacture of the enzyme. Novozymes, part of the Danish biotechnology giant Novo Nordisk has entered into an agreement with Saipem to manufacture the enzymes.

Algae to capture CO2

Photosynthesis is the conversion of CO2 to higher hydrocarbons with the release of oxygen in the presence of light. Plants use this bioreaction to generate starches that they use to create leaves, branches trunks and roots.

Algae use the same reaction to grow their cell mass, however unlike trees and plants their entire function is dedicated to photosynthesis and they do not expend energy growing physical structures. The implication is that per acre of land, they are much more efficient at capturing CO2 than a forest.

Various types of algae are used in cosmetics and as a meat substitute in vegan and vegetarian foods. The use of pure CO2 gas to accelerate the growth of algae in these commercial utilisation applications has been common for several years. However, a new generation of algae technologies is turning to CO2 capture as their business model.

The Danish startup ALGIECEL has targeted capture of biogenic CO2 as biogas is upgraded to biomethane from anaerobic biogas reactors. Their vision is to utilise the captured CO2 to cultivate algae which will be rich in omega-3 oils. These can be used as nutritional supplements for humans, livestock and farmed fish.

The ALGIECEL PhotoBioReactor (PBR) is a containerised unit designed to match the

scale of biogas production on many of Europe's 18,000 biogas reactors. Light for the photosynthesis is provided by energy efficient LEDs to ensure 24-hour operation at maximum CO2 capture and conversion yields.

The British startup Brilliant Planet has also developed a CO2 capture process that relies on algae. However, their intent is not to utilise the products derived from the algae. Instead their vision is 1000-year sequestration.

The Brilliant Planet concept is ideally located next to nutrient-rich seawater in a desert location. Seawater is pumped into a lagoon filled with algae. Nutrients in the seawater are absorbed by the algae as they grow. They simultaneously absorb CO2 from the air in a form of direct air capture of CO2.

CO2 capture is also achieved through a second mechanism. The algae consume bicarbonate ions from the seawater. These ions have been created naturally during absorption of atmospheric CO2. As the lagoon water is released back into the sea, it re-absorbs CO2 from the atmosphere. This is also a natural form of direct air capture of CO2.

The algae are harvested, dried and buried under sand in the desert. The dry, salty algae are acidic and cannot biodegrade in the desert sands. This guarantees that the captured CO2 is permanently sequestered.

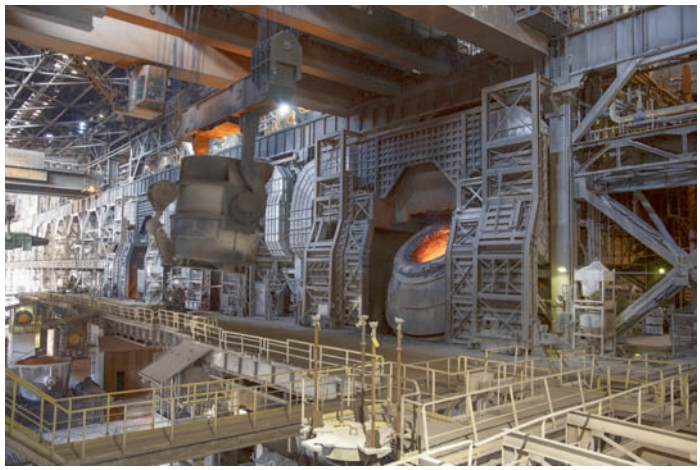
Bio-fermentation of captured carbon to ethanol

Trees and plants absorb CO2 as they photosynthesise. They use the carbon to build carbohydrates, starches, and lignin to build their leaves and structure. Bacteria can also consume CO2 and carbon monoxide (CO) to produce valuable chemicals such as ethanol.

LanzaTech utilises anaerobic acetobacter bacteria in a fermenter to convert CO rich feed gases, such as syngas, to ethanol and a range of biochemicals. Subsequently, the complimentary LanzaJet process can be used to convert the bioethanol to synthetic aviation fuel (SAF) in their proprietary 'Ethanol to Jet' or ETJ process.

The ideal feedstocks for the LanzaTech fermenter are CO-rich. CO2 rich streams can potentially be utilised in combination with hydrogen. But a high CO content in the feed to the bioreactor, or fermenter, reduces the green hydrogen feed requirement. Syngas derived from waste or biomass gasification is generally CO-rich and is a good feedstock for the LanzaTech process.

Iron and steel making also yields CO-rich flue gases which are ideal feedstocks to the LanzaTech process. Blast furnace gas (BFG) contains 20% CO and converter gas (also known as basic oxygen furnace gas or BOFG) contains 60% CO.



Basic oxygen blast furnace gas which is rich in CO can be used in the LanzaTech process to produce valuable bioethanol

At present, the energy rich converter gas (LHV 3 kWh/Nm3) is often utilised on the iron and steel making facility for heat or power generation on a gas engine. Alternatively, it is flared. Blast furnace gas has a lower energy value due to the lean CO concentration and higher CO2 content (LHV 0.9 kWh/Nm3). It can also be always utilised on the facility or is sent to the flare. Utilisation of the BFG in the LanzaTech process can generate valuable bioethanol.

LanzaTech's process was demonstrated at pilot-scale in 2008 using flue gases from the BlueScope Steel mill in Glenbrook, NZ. Since then, LanzaTech has successfully deployed its technology at two 300 tonne per annum demonstration facilities at Baosteel Shanghai and Shougang Steel Caofeidian in China. These LanzaTech fermenters are fed with a range of iron and steel making off gases including BOFG, BFG, and coke oven gas (COG).

Carbon recycling to SAF improves the life cycle analysis

The term CCT or 'Carbon Capture and Transformation' has been used to describe the LanzaTech fermentation process. Whilst it is highly effective at transforming carbon monoxide to ethanol, the LanzaTech process has more in common with carbon utilisation than CO2 sequestration.

LanzaTech operates the Freedom Pines Biorefinery in Soperton, Georgia which uses bio fermenters to generate ethanol and other chemicals. The LanzaJet ethanol to jet SAF production process will soon also be implemented at that location to utilise captured carbon to make fuels that can substitute aviation kerosene, a fossil fuel distilled from crude oil.

The LanzaTech bioreactor utilises CO2 and hydrogen, or CO from syngas to grow bacterial biomass in the main fermenter. Some gases are emitted from this fermenter. This biomass from the main fermenter is subsequently converted to biomethane in a separate anaerobic sludge digester. This energy-rich biomethane is used to fully combust the main fermenter off gases to CO2. This CO2 is then be emitted to the air.

Despite these CO2 emissions, Life Cycle Analysis (LCA) of the LanzaTech process shows that the holistic CO2 emissions reduction is primarily due to the substitution of fossil fuels with fuels derived from ethanol recovered from the fermentation broth.

Also integral to the LanzaTech LCA is consideration of whether the feedstock, such as iron and steel making flue gases are flared, or utilised. If they are flared, their recovery and conversion to ethanol is a significant environmental benefit. However, if they are utilised to make heat and power, they already avoid the use of fossil fuels and the overall CO2 reduction in the LCA is reduced.

More information

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Engineers develop an efficient process to make fuel from CO2

The approach developed by scientists at MIT and Harvard directly converts CO2 into formate, a solid fuel that can be stored indefinitely and could be used to heat homes or power industries.

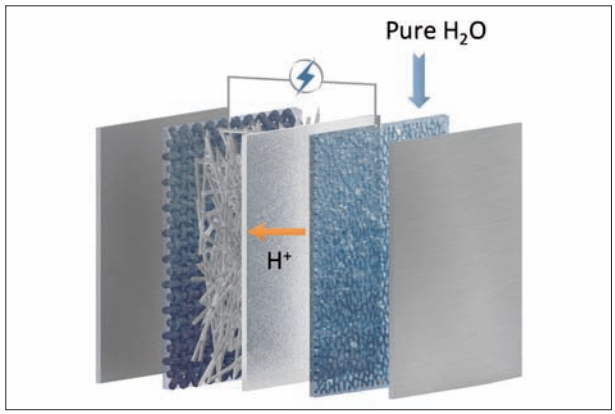
The search is on worldwide to find ways to extract carbon dioxide from the air or from power plant exhaust and then make it into something useful. One of the more promising ideas is to make it into a stable fuel that can replace fossil fuels in some applications. But most such conversion processes have had problems with low carbon efficiency, or they produce fuels that can be hard to handle, toxic, or flammable.

Researchers at MIT and Harvard University have developed an efficient process that can convert carbon dioxide into formate, a liquid or solid material that can be used like hydrogen or methanol to power a fuel cell and generate electricity. Potassium or sodium formate, already produced at industrial scales and commonly used as a de-icer for roads and sidewalks, is nontoxic, nonflammable, easy to store and transport, and can remain stable in ordinary steel tanks to be used months, or even years, after its production.

The new process, developed by MIT doctoral students Zhen Zhang, Zhichu Ren, and Alexander H. Quinn; Harvard University doctoral student Dawei Xi; and MIT Professor Ju Li, is published in an open-access paper in Cell Reports Physical Science. The whole process — including capture and electrochemical conversion of the gas to a solid formate powder, which is then used in a fuel cell to produce electricity — was demonstrated at a small, laboratory scale. However, the researchers expect it to be scalable so that it could provide emissions-free heat and power to individual homes and even be used in industrial or grid-scale applications.

Other approaches to converting carbon dioxide into fuel, Li explains, usually involve a two-stage process: First the gas is chemically captured and turned into a solid form as calcium carbonate, then later that material is heated to drive off the carbon dioxide and convert it to a fuel feedstock such as carbon monoxide. That second step has very low efficiency, typically converting less than 20 percent of the gaseous carbon dioxide into the desired product, Li says.

By contrast, the new process achieves a conversion of well over 90 percent and eliminates the need for the inefficient heating step by first converting the carbon dioxide into an intermediate form, liquid metal bicarbonate. That liquid is then electrochemically converted into liquid potassium or sodium formate in an electrolyzer that uses low-carbon electricity, e.g. nuclear, wind, or solar power. The highly concentrated liquid potassium or sodium formate solution produced can then be dried, for example by solar evaporation, to produce a solid powder that is highly stable and can be stored in ordinary steel tanks for up to years or even decades, Li says.



An electrolzyer configuration with a bicarbonate cathode, intermediate buffer layer, cation exchange membrane and a water anode. Image: Shuhan Miao, Harvard Graduate School of Design

Several steps of optimization developed by the team made all the difference in changing an inefficient chemical-conversion process into a practical solution, says Li, who holds joint appointments in the departments of Nuclear Science and Engineering and of Materials Science and Engineering.

The process of carbon capture and conversion involves first an alkaline solution-based capture that concentrates carbon dioxide, either from concentrated streams such as from power plant emissions or from very low-concentration sources, even open air, into the form of a liquid metal-bicarbonate solution. Then, through the use of a cation-exchange membrane electrolyzer, this bicarbonate is electrochemically converted into solid formate crystals with a carbon efficiency of greater than 96 percent, as confirmed in the team's lab-scale experiments.

These crystals have an indefinite shelf life, remaining so stable that they could be stored for years, or even decades, with little or no loss. By comparison, even the best available practical hydrogen storage tanks allow the gas to leak out at a rate of about 1 percent per day, precluding any uses that would require year-long storage, Li says. Methanol, another widely explored alternative for converting carbon dioxide into a fuel usable in fuel cells, is a toxic substance that cannot easily be adapted to use in situations where leakage could pose a health hazard. Formate, on the other hand, is widely used and considered benign, according to national safety standards.

Several improvements account for the greatly improved efficiency of this process. First, a careful design of the membrane materials and their configuration overcomes a problem that previous attempts at such a system have encountered, where a buildup of certain chemical byproducts changes the pH, causing the system to steadily lose efficiency over time. "Traditionally, it is difficult to achieve long-term, stable, continuous conversion of the feedstocks," Zhang says.

"The key to our system is to achieve a pH balance for steady-state conversion."

More information

li.mit.edu

doi.org/10.1016/j.xcrp.2023.101662

Copper-based catalysts efficiently turn carbon dioxide into methane

Rice University materials scientist Pulickel Ajayan and collaborators have developed a way to efficiently react CO2 with hydrogen forming methane.

According to the study published in Advanced Materials, the method relies on electrolysis and catalysts developed by grafting isolated copper atoms on two-dimensional polymer templates.

"Electricity-driven carbon dioxide conversion can produce a large array of industrial fuels and feedstocks via different pathways," said Soumyabrata Roy, a research scientist in the Ajayan lab and the study's lead author. "However, carbon dioxide-to-methane conversion involves an eight-step pathway that raises significant challenges for selective and energy-efficient methane production.

"Overcoming such issues can help close the artificial carbon cycle at meaningful scales, and the development of efficient and affordable catalysts is a key step toward achieving this goal."

The polymer templates, which were made of alternating carbon and nitrogen atoms, have tiny pores where copper atoms can fit at varying distances from one another. The catalysts assemble at room temperature in water with the copper atoms displacing the host metal ions in the polymer templates.

When tested in a reactor, the catalysts enabled the reduction of carbon dioxide to methane in one half of the cell, while oxygen was produced from water in the other half.

"We found that modulating the distances between the copper atoms lowered the energy needed for key reaction steps, thereby speeding up the chemical conversion," Roy said. "This cooperative action of nearby copper atoms helped produce methane at a very high rate of selectivity and efficiency."

The catalysts developed by Roy and collaborators yielded one of the most rapid and efficient electrolysis-based conversions of carbon dioxide to methane known so far, helping advance the conversion process both in terms of fundamental scientific insight and performance level.

"If system-level energy and carbon conversion efficiencies can be addressed, inexpensive and efficient materials like these will help catalyze the industrial translation of electrochemical carbon dioxide reduction technology," said Jingjie Wu, an associate professor of chemical and environmental engineering at the University of Cincinnati.

Ajayan, Rice's Benjamin M. and Mary Greenwood Anderson Professor of Engineering and chair of the Department of Materials Science and NanoEngineering, added that the "design and development of novel catalysts are central to the energy and sustainability challenges we face."

"Single-atom dispersed catalysts present an exciting approach in this effort," Ajayan said.

Wu and Chandra Veer Singh, a professor of materials science and engineering at the University of Toronto, were key contributors to the study.

Soumyabrata Roy is a Rice University postdoctoral research associate in materials science and nanoengineering and the study's lead author. (Photo by Gustavo Raskosky/Rice University)

More information

Read the paper:

DOI: 10.1002/adma.202300713

msne.rice.edu

Better conversion of CO2 and biofuel waste into valuable products

A University of Alberta researcher has developed better ways to convert carbon dioxide and glycerol, a leftover of biodiesel production, into value-added materials with wide-ranging uses.

The pair of procedures, which will be tested on a larger scale for their commercial viability, represent a step forward in sustainability, says Yanet Rodriguez Herrero, who conducted the work to earn a PhD in bioresource technology and food engineering from the Faculty of Agricultural, Life & Environmental Sciences.

"We've broken a barrier in terms of improving difficult conversion processes and making them more efficient."

Though CO2 is a major contributor to climate change, it also has potential to be converted into methanol, a highly valuable chemical that can be used in several industrial applications including automotive, electronic, clothing, adhesives, paints and coatings, packaging, solvents, pharmaceuticals and agricultural chemicals.

Methanol also holds promise as a method of transporting and storing hydrogen in liquid form.

But one of the major barriers to successfully converting CO2 into methanol is the water formed as a byproduct during the hydrogenation process, which deactivates a catalyst needed for the transformation.

Using nanotechnology, Herrero successfully developed a process in the lab to prepare a stable catalyst that has the ability to repel water so it works well at low pressure and temperature, making the conversion less energy-intensive and more economically efficient.

Once the process can be successfully scaled up for use by industry, it could mean direct utilization of large amounts of CO2 that has been captured and stored, along with its potential for liquid hydrogen storage, says Aman Ullah, a professor in the Faculty of Agricultural, Life & Environmental Sciences who supervised Herrero's work.

"The conversion of CO2 into various value-added products would be a more logical idea to reduce emissions, with huge benefits for the chemical industry."

The new process also "opens the door" for improving other catalytic chemical conversion processes that are deactivated by water, such as ammonia synthesis, Herrero notes.

"It is difficult to find catalytic supports that are thermally stable and water repellent. In achieving that, our process could be very useful to manufacturing other products such as ammonia and catalytic converters," she says, adding that a patent application is underway for the new process.

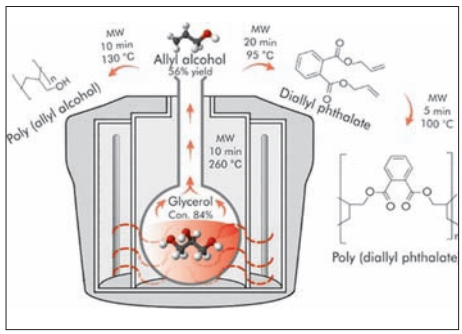
Similarly, glycerol — a thick, colourless and odourless liquid — holds potential to be used in the food, pharmaceutical and cosmetics industries, but not in its crude form. Glycerol is the main byproduct left behind from manufacturing biodiesel and compounds called oleochemicals derived from vegetable and animal oil and fat. But it is expensive to purify, making it too costly for large-scale industrial use.

To help overcome that challenge, Herrero developed a patented process to convert the crude glycerol into monomers. The chemicals are important in creating polymers — synthetic substances with a wide range of uses, such as making biopolymers for the consolidation of fluid fine tailings (FFT). Slow consolidation of FFT has been identified as the major challenge for the oilsands industry toward sustainable reclamation.

The biopolymers created through Herrero's process proved more effective in consolidating tailings and improving water recovery compared to PAM, a polymer currently being tested by the resource industry, the research showed.

The conversion process can also help the biodiesel industry address an emerging question, as production ramps up, of how to make use of the glycerol, Ullah notes.

"The industry is facing the dilemma, on the one hand, of how to meet a growing demand for biofuels, while also managing excessive crude glycerol so it doesn't pose a threat to the environment."



Glycerol is expensive to purify, making it too costly for large-scale industrial use. To help overcome that challenge, Herrero developed a patented process to convert the crude glycerol into monomers.

During the course of their research, Herrero and Ullah also investigated sustainability as an additional aspect of the conversion process.

By comparing the use of a microwave heating process with conventional heating sources such as hotplates, they showed that using microwave technology was more than 16 times less energy-intensive than conventional heating sources. The process is currently being used by an Edmonton-based biorefining company to produce chemicals more efficiently using lipids and waste glycerol.

Collectively, all of the research results show promising benefits to the energy, hydrogen, biofuel, food and chemical industries, Ullah says.

"By potentially offering sustainable alternatives for creating value-added products, our processes provide a win-win situation economically and environmentally."

The research was funded by the Natural Sciences and Engineering Research Council of Canada and Alberta Innovates, and in-kind support from SBI BioEnergy Inc.

More information

www.ualberta.ca

Capture & utilisation news

BASF pioneers MOFs for commercial carbon capture with Svante

www.catalysts.basf.com
www.svanteinc.com

BASF is the first company to produce metal-organic frameworks (MOFs) on a production scale of several hundred tons per year.

MOFs are highly crystalline structures with nanometer-sized pores and a large surface area. This structure offers a high capacity for the storage of carbon dioxide, the dehumidification of air for room climate control, and the adsorption of the greenhouse gas methane. BASF has developed expertise on the scale-up and production of MOFs, can tailor MOFs to customers' needs and specifications, and today has the capacity to produce customized MOFs for various applications and industries.

A first project has now been successfully completed for Canadian carbon capture and removal solutions provider Svante Technologies Inc. An interdisciplinary BASF team of researchers and engineers worked collaboratively on the scale-up by converting the Svante lab recipe into a safe plant procedure for large scale production. The MOFs produced will be used as solid sorbents for carbon capture projects. The collaboration with Svante will help to significantly reduce carbon emissions in various industrial sectors including hydrogen, pulp and paper, cement, steel, aluminum and chemicals.

Leilac and Heirloom to use electric kilns for DAC

www.leilac.com

The companies have signed licence and collaboration agreements to deploy renewably-powered electric kilns at future Heirloom Direct Air Capture (DAC) facilities.

Heirloom will employ Leilac's electric kiln technology to heat limestone to produce high purity CO2, which will go for permanent storage, and calcium oxide, which is looped through Heirloom's process to remove CO2 from the atmosphere.

Following the signing of a memorandum of understanding in February 2023, Leilac and Heirloom have progressed the integration of Leilac's electric calcination and CO2 capture technology into Heirloom's DAC plants through an extensive research and development campaign.

This work is informing the design of new commercial DAC facilities. Applying Leilac's technology to Heirloom's DAC process enables the DAC industry to use many years of technology investment and development from Leilac and its parent company Calix, the European Union and partners across the cement and lime industries.

With double the current combined capture capacity of all DAC facilities globally, Leilac's pilot plant is the largest operating carbon capture facility for cement in the world, outside China. A Leilac demonstration plant, with a designed capture capacity of 100,000 tonnes of CO2 per year, is due for construction in 2024.

Aker Carbon Capture wins contract with major European power producer

www.akercarboncapture.com

The pre-FEED contract is to implement carbon capture at a portfolio of power plants in mainland Europe reaching up to 14 million tonnes CO2 per year combined.

The pre-FEED will assess the optimal CO2 capture and compression, as well as the heat recovery potential and heat integration solutions for the applicable plants. This will reduce the total heating and cooling demands related to capturing and conditioning the CO2.

Aker Carbon Capture aims to deliver its bespoke Big Catch concept, which is fully integrated into the plants, including both advanced heat integration, and downstream integration enabling low energy consumption by making it possible to reuse energy along the value chain.

"This award underlines the industry's continued interest and trust in Aker Carbon Capture's expertise and capability to deliver world-leading configurable carbon capture plants, as we are doing in Norway, the Netherlands, and Denmark. Carbon capture and storage is critical to achieve the European Union's climate goals. We welcome the opportunity to support the delivery of clean electricity to European households and to contribute to the decarbonization of industry," said Jon Christopher Knudsen, Chief Commercial Officer at Aker Carbon Capture.

Aker Carbon Capture is developing a full-scale Big Catch facility with CO2 capture, conditioning, compression, heat integration, intermediate storage and loading for the Brevik cement plant in Norway. Brevik CCS will be the first industrial scale carbon capture plant at a cement factory anywhere in the world and will capture 400,000 tonnes of CO2 per year.

FuelCell Energy & Oando agree low carbon hydrogen and energy project in Africa

www.fuelcellenergy.com

The companies signed a memorandum of understanding to collaborate on the development of a 5 to 15-Megawatt (MW) power plant with potential carbon capture.

In addition to FuelCell Energy's fuel cell and electrolyzer technology, the agreement also includes the potential for the use of FuelCell Energy's carbon capture and sequestration technologies. Unlike other carbon capture technologies that require power to capture carbon dioxide, FuelCell Energy's platforms can produce power while simultaneously capturing carbon dioxide.

The signing of this MOU is an integral part of OCEL's drive to strengthen electricity access in African markets via low-carbon renewable energy sources starting in its home country, Nigeria. Today, Nigeria relies heavily on generators to support power generation at a local and commercial level. Specifically, around 84% of urban households use back-up power supply systems such as diesel/gasoline generators and/or solar-based systems, while about 86% of the companies in Nigeria own or share a generator. These fossil fuel generators create noise, particulate pollutants and are substantial contributors to greenhouse gas emissions.

Leak detection's role in the integration of CCUS with hydrogen production

The integration of CCUS with hydrogen production is being increasingly explored as an option for reducing large scale greenhouse emissions in the oil and gas industries[1], but it's important to consider the role pipeline leak detection will play and the challenges it will need to overcome as hydrogen is introduced. By Daniel Short, Senior VP Commercial, Atmos International.

Low carbon hydrogen can be produced from the process of capturing natural gas emissions during CCUS[2] and shows promise as a low-cost pathway for low-carbon production.[3]

As well as providing cost benefits, hydrogen production via CCUS is expected to decrease in cost over time and reduce emissions from existing hydrogen production, which currently averages more than 800 megatons of CO2 emissions annually.[3]

As hydrogen's integration with CCUS gains momentum, it's important to consider the role leak detection will play in hydrogen production, especially given that pipelines are key to CCUS fluid transportation.

However, it's first important to consider the challenges that will face leak detection in these pipeline scenarios.

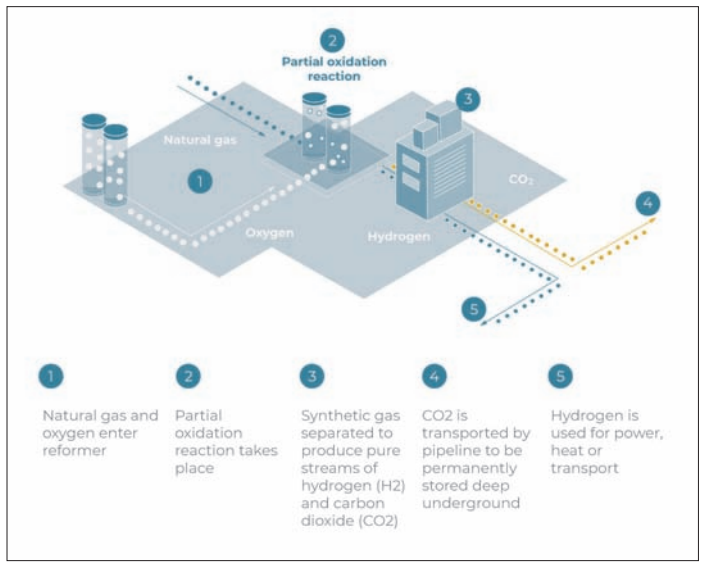


Figure 1: Example of hydrogen production via carbon capture, utilisation and storage

Considering existing pipeline infrastructure

Whether using existing pipelines that are repurposed or specially constructed networks, it's vital to have leak detection on pipelines integrating hydrogen with CCUS.

Hydrogen embrittlement can occur when it is introduced to pipelines, causing the interior wall of the pipeline to degrade and resulting in leaks.

On aging pipeline infrastructure, defects in the pipe wall are more common too. The small molecular make-up of hydrogen means leakage can occur more easily on aging gas pipelines, causing an increase in pipeline incidents, such as leaks and ruptures.

With CCUS becoming an important way for the global energy sector to help mitigate climate change, there will be a direct correlation with the number of existing pipelines being required for CCUS and hydrogen production, so examining existing infrastructure should be a core consideration.

Ambitions to build over 50 new carbon capture facilities by 2030 means that leak detection should also be factored into the planning of new CCUS pipeline projects as they emerge.[4] Installing leak detection on new infrastructure is more cost effective and sets a standard for efficient CCUS operations.

Capacity constraints

With discussions around existing pipeline in-

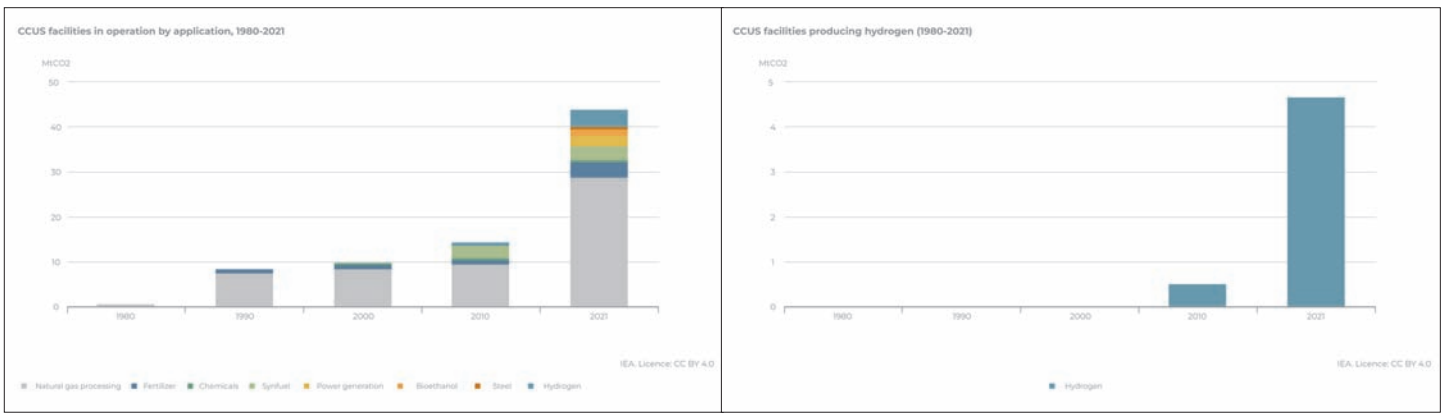


Figure 2: Operational CCUS sites (1980-2021), with a focus on the increase in hydrogen production via CCUS in the second graph

frastructure being used to facilitate the introduction of hydrogen to CCUS,[3] pipeline operators need to fully understand their network's capacity constraints.

Demand pressure requirements is one of the key areas operators should consider as hydrogen is introduced to pipelines because every pipeline has a maximum daily quantity as well as minimum and maximum pressure constraints. Exceeding these limits can threaten the integrity of the pipeline and lead to leakage, pipeline simulators such as Atmos SIM can be used to model hydrogen blends. When used offline, simulation can help pipeline companies understand whether network reinforcement is required.

When hydrogen is introduced to a pipeline, the maximum capacity is reduced as the concentration of hydrogen increases. Figure 3 shows an example of capacity reduction as 10%, 25% and 50% hydrogen is introduced in a natural gas network.

Atmos SIM makes this task easier by separating by demand groups. Once the minimum pressure constraint is violated, the demand is reduced to maintain pressure. The point this happens is deemed as maximum capacity.

Consequences of a hydrogen leak

While pipelines remain the safest means of transporting any fluid, there are still concerns that hydrogen can permeate metal and leak through the pipeline. Paired with the high possibility of hydrogen production taking place in existing pipeline infrastructure, leakage should be a core consideration of pipeline operators integrating hydrogen production with CCUS.

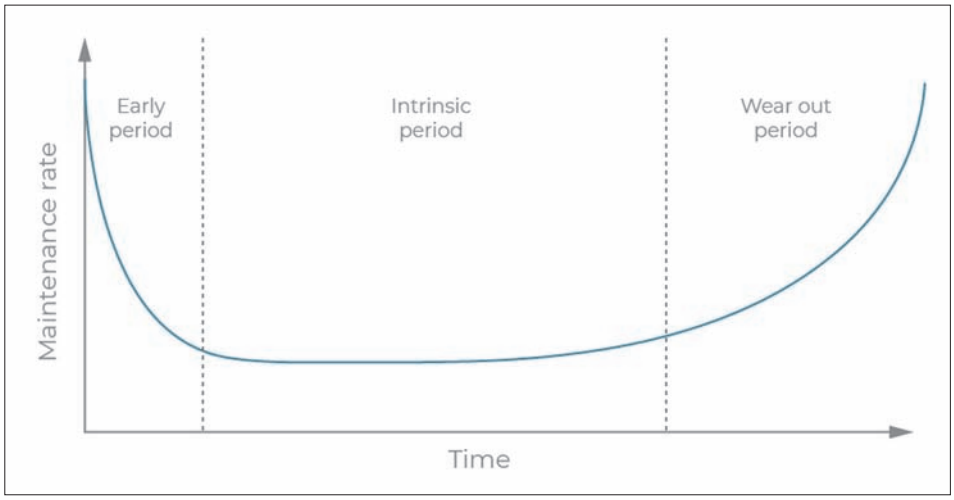


Figure 3: A visualization of the bathtub curve, as used to define the reliability of a product

When hydrogen is released into the atmosphere, it automatically becomes flammable at a range of between 4% and 75% in the air which is a wider range than in other fuels.5 As previously mentioned, the molecular makeup of hydrogen means it can disperse quickly into an open environment. It's almost invisible to the naked eye in daylight and partially visible at night, so external methods of leak detection such as line walks, drones and helicopter patrols will not be a suitable method of leak detection.

Leak detection is vital in the integration of CCUS with hydrogen production

Software solutions like Atmos SIM use a hydraulic model and statistical analysis algorithm to detect leaks reliably and accurately.

Similarly, Atmos Pipe can be finely tuned to meet the sensitivity requirements to detect a hydrogen leak on large complex pipelines. This is important, since many larger scale CCUS projects complete the storage step of the CCUS process at an offshore subsea location. When used offshore, Atmos Pipe is configured to take account of both the hydraulic profile of the pipeline and the seawater outside the pipeline.

Alternatively, the multi method Atmos Wave Flow may be used which includes both a volume balance and a negative pressure wave (NPW) algorithm.

To learn more about how Atmos is equipped to provide vital leak detection support during the integration of CCUS with hydrogen production, visit our website.

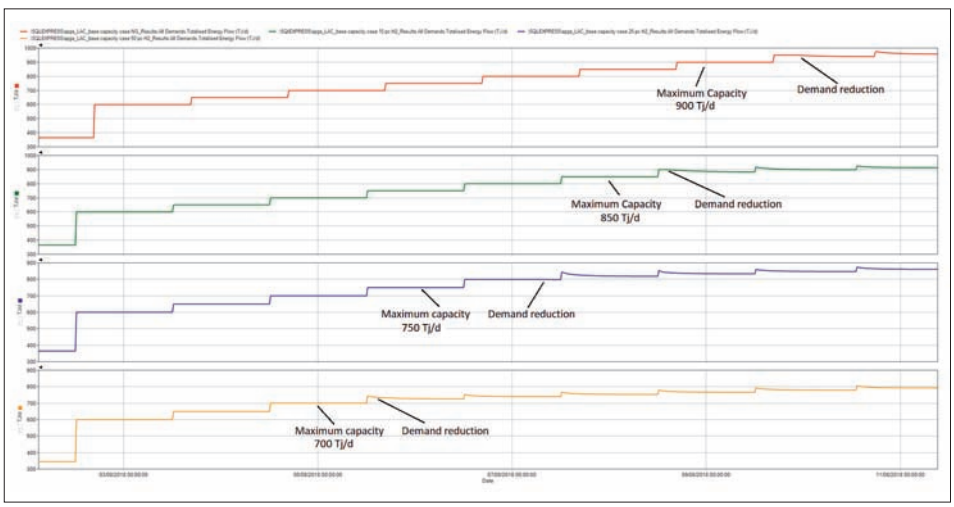


Figure 4: Hydrogen blend maximum capacity calculated by Atmos SIM (red 0%, green 10%, blue 25% and orange 50%)

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More information

www.atmosi.com

Neustark opens first commercial site for CO2 storage

The Swiss climate-tech company has joined forces with Berlin-based construction and recycling company Heim to open the first commercial site for permanent CO2 storage in Germany.

Located in Berlin, the site has the capacity to permanently store over 1,000 tons of CO2 per year, captured at biogas plants. Since the CO2 stored is biogenic, the neustark process removes emissions from the atmosphere, thus creating crucial negative emissions.

Neustark and its partners now have twelve storage sites in operation in Switzerland and Germany, all of which were launched in the last 10 months. They have a cumulative annual capacity of around 5,000 tons of CO2.

"Carbon removal is – next to massive emission reductions – indispensable to reach out net-zero targets, as the IPCC states," said Johannes Tiefenthaler, founder and co-CEO of neustark.

And that's exactly what we do at neustark, we literally remove CO2 from the air by storing it in demolition concrete. Now also in Germany, which is a huge step for neustark, but more importantly for the whole CO2 removal industry."

With over one billion tons per year, demolition concrete is the world's largest waste stream. Neustark has developed a technology and a value chain that transforms this waste stream into a "sink" for CO2 emissions.

After capturing CO2 from biogas plants and transporting it to nearby storage sites, the CO2 is injected into the granules of demolition concrete during its usual recycling process. Neustark's technology triggers a mineralization process that converts the CO2 into limestone, binding it to the pores and surface of the granules. The CO2 is permanently stored in the demolition concrete and thus removed from the atmosphere.

The carbonated demolition concrete granulate can subsequently be used by recyclers for road construction or for the production of recycled concrete.

The CO2 that neustark stores in the Berlin site mainly stems from partner MVV's biowaste fermentation plant in Dresden. Since 2021, the CO2 produced during the extraction of biomethane has been captured and liquefied there. Parts of the biogenic CO2 will continue to be used in internal processes.

Neustark's CO2 storage site in Berlin has the capacity to store 1,000 tons of CO2 per year captured from biogas plants

The Munich-based biomethane trading company Landwärme manages the excess volume of around 1,000 tons of CO2 per year. Neustark, in turn, transports the CO2 to the storage site at Heim and removes it there.

A final but important step of the value chain: neustark provides carbon removal in the form of climate certificates to companies with ambitious climate targets. Complementing their own reduction measures, companies purchase CDR certificates to remove their hard-to-abate emissions, which helps them achieve their net-zero targets. Neustark's carbon removal clients include Microsoft and UBS.

Pursuing an ambitious pathway to remove one million tons of CO2 in 2030 and every year beyond that, neustark is currently rapidly scaling up in Europe. In addition to the 12 sites commissioned to date, fifteen further projects are currently under construction in Germany, Switzerland, France, and Austria.

Neustark recently signed a landmark agreement with building solutions giant Holcim. Holcim has committed to rolling out neustark's CO2 storage technology at its recycling sites worldwide. Together, neustark and Holcim will be storing a significant part of neustark's goal – removing 1 million tons of CO2 in 2030 – at their sites in the next years, generating a huge carbon removal impact.

"To achieve the greatest possible CO2 removal impact, neustark builds on partnerships with an increasing number of local and global building materials recyclers. The first storage site in Germany at Heim and the deal with Holcim are two major milestones in our still young company history," says Valentin Gutknecht, founder and co-CEO of neustark.

Over the next few years, neustark aims to launch thousands of CO2 storage sites across the world, working hand-in-hand with a wide range of recycling partners.

More information

www.neustark.com

NETL oversees work to protect caprock integrity at carbon storage sites

A groundbreaking experiment completed with NETL oversight is expected to generate important insights about the behaviour of faults and other seismic activity when CO2 is injected into geologic formations.

Completed at the Mont Terri Underground Research Laboratory in Switzerland, the experiment involved injecting water mixed with CO2 into a subsurface fault for approximately five hours. The injection caused a controlled CO2-induced fault slip to determine its impact on the caprock that prevents CO2 leakage.

"The work completed in Switzerland by NETL partners at the Lawrence Berkeley National Laboratory and Rice University marked the first time a mixture of CO2 and water was injected into a fault," said James Gardiner, a federal project manager and a member of the NETL Carbon Transport and Storage team.

"This project is important because it will help us understand how CO2 may affect fault activation in caprocks," Gardiner said.

Carbon storage reservoirs are layers of porous rock underneath a layer of impermeable rock that acts as a seal. The caprock prevents injected CO2 from returning to the surface or migrating to aquifers that provide drinking water.

Researchers collected several terabytes of novel geophysical field data during the injection. The data will provide significant observations about fault slip and strain related to CO2 injection and the effect that CO2-induced fault activation has on storage reservoir caprocks.

The project, titled "Changes in Seal Integrity Induced by CO2 Injection and Leakage in a Hydromechanically Reactivated Fault," is designed to assess and mitigate potential risks caused by induced seismicity, which could occur due to fault slips.

Analysis of the data generated by the injection of the CO2-water solution will help researchers better understand fault slip processes, provide new insights into the leakage potential of complex fault zones and help the NETL Carbon Storage Program attain a rate of 99% CO2 storage permanence.

NETL-supported research to protect caprock integrity in carbon storage sites was completed at the Mont Terri Underground Research Laboratory in Switzerland

Other insights to be attained from the experiment include an enhanced understanding about the changes in water chemistry and fault mineralogy that may occur along a potential leakage pathway. In addition, research findings will assist in the development of a new fiber optic chemical sensing system to monitor CO2 within reservoirs and the injection wellbore.

"The project is helping us better understand important subsurface behaviors to ensure that the CO2 we store underground remains safely and securely sequestered in the subsurface," Gardiner said.

The experiment was conducted at a depth of approximately 1,200 feet below the surface at the Mont Terri Underground Research Laboratory. The lab's major objectives are to investigate and analyze the hydrogeological, geochemical and rock mechanical properties of formations containing clay.

NETL is a U.S. Department of Energy national laboratory that drives innovation and delivers technological solutions for an environmentally sustainable and prosperous energy future.

The Mont Terri Project is an international research project for the hydrogeological, geochemical and geotechnical characterisation of a clay formation (Opalinus Clay).

More information

netl.doe.gov

www.mont-terri.ch

Transport and storage news

DNV launches guidelines for onboard CO2 capture

www.dnv.com

DNV has published new guidelines for the safe installation of onboard carbon capture and storage (OCCS) system on board ship.

DNV's new guidelines are designed to be used by stakeholders across the value chain, including ship designers, builders, OCCS system manufacturers, and ship owners, and apply to both newbuilds and retrofits. They cover all aspects for safe installation, including exhaust pre-treatment, absorption with the use of chemicals/amines, after-treatment systems, liquefaction processes, CO2 storage, and transfer systems.

"Our new guidelines for onboard OCCS systems aim to support the industry as it faces strict requirements for emissions reduction. A focus on safety is crucial for new technology and must be prioritised as the industry looks to adopt sustainable fuels and CCS installations," said Chara Georgopoulou Head of Maritime R&D and Advisory Greece, Senior Research Engineer II, Onboard CCS Manager.

While the guidelines are based on DNV classification requirements additional technical or other requirements may be imposed by relevant flag-state administrations. There are currently no statutory regulations addressing the possible safety implications of using OCCS systems on board ships. The guidelines also cover alternative solutions for carbon capture, including physical absorption and cryogenic methods.

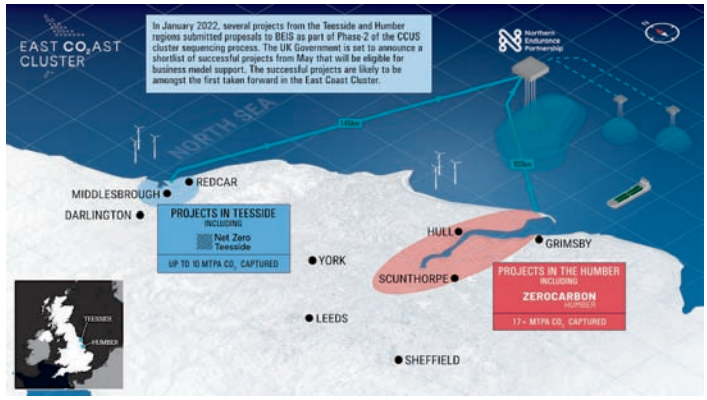
Seismic monitoring report makes carbon storage sites easier to identify

www.nstauthority.co.uk

A detailed report released by the NSTA looking at the latest technology available to North Sea explorers could play a significant role in supporting the energy transition.

The Seismic Imaging within the UKCS Energy Transition environment report published by the North Sea Transition Authority examines the vital and growing role that technology can play in studying the seabed and assessing potential uses of different areas of the North Sea.

The work is of particular importance now as 21 carbon storage licences have recently been awarded and the NSTA estimates that up to 100 carbon storage licences in total will be needed in the near future to meet sequestration targets, and the continuing development of offshore wind.



Jo Bagguley, NSTA Head of Pre-Licensing & Storage, said, "The North Sea is vital to the energy transition. There is potential for up to £200 billion of private sector investment in the UKCS by 2030, and that will drive UK energy security and the path to net zero."

Lloyd's Register approval for ERMA FIRST carbon capture

www.ermafirst.com

The post combustion CCS system absorbs CO2 from a vessel's exhaust gas that is heated to capture CO2 and then liquefied and stored cryogenically onboard.

Lloyd's Register (LR) has awarded Approval in Principle (AiP) to ERMA FIRST for its amine absorption-based CCS system that uses absorption technology to mix CO2 flue gases with a proprietary amine solvent, which is then heated to produce a chemical reaction which reverses the absorption and separates the CO2 from the solvent. The CO2 from this process is then liquified and stored under cryogenic conditions onboard with the solvent ready to use in the same process again, creating a regenerative loop for CCS.

With the ability to capture a significant amount of CO2 from exhaust emissions, ship owners and operators will be able to meet and exceed the IMO's strengthened emission reduction targets, whilst increasing their vessels' lifecycle.

LR's AiP, as part of the Risk-Based Certification process, has enabled the technology to achieve this important milestone and allows ERMA FIRST to proceed with onboard pilot testing of the application, whilst LR continues to support its industry partners in de-risking their maritime assets.

Crown Estate awards lease to bp for Endurance CCS

www.thecrownestate.co.uk

The Crown Estate has awarded a landmark Agreement for Lease for what could become one of the world's largest carbon capture and storage projects.

The agreement will allow bp, as lead operator, to further progress its planned 'Endurance' CCS project, a reservoir in the rock deep below the North Sea which would be used to store hard-to-abate carbon emissions captured from carbon-intensive heavy industry in Teesside and Humberside. The scale of the project means it has the potential to substantially decarbonise the UK's industrial emissions, significantly supporting UK Government ambitions to capture and store 20–30 MtCO2 per year by 2030.

The announcement is a significant milestone in the maturation of CCS, a technology dubbed by the Climate Change Committee as a 'necessity not an option' if the UK is to meet its 2050 net zero target.

Endurance forms part of the Northern Endurance Partnership's (NEP) East Coast Cluster, which in October 2021 was selected as one of the first clusters in phase-1 of the UK Government's CCS cluster sequencing process. The cluster also benefits from a licence awarded by the North Sea Transmission Authority (NSTA), with whom The Crown Estate collaborates closely in seeking to shape the CCS industry for the benefit of the nation. Recognising that investing in CCS is a long-term commitment with the potential to deliver benefits that will be felt over generations, the Agreement for Lease allows for construction, CO2 injection, as well as monitoring and decommissioning.

Image: TAQA