Carbon Capture Journal

CCUS in Australasia

Northern Territory CCUS hub

New Zealand CCUS Framework

COSMIC – a costing model for integrated CCUS

May / June 2025 Issue 105

Where energies make tomorrow

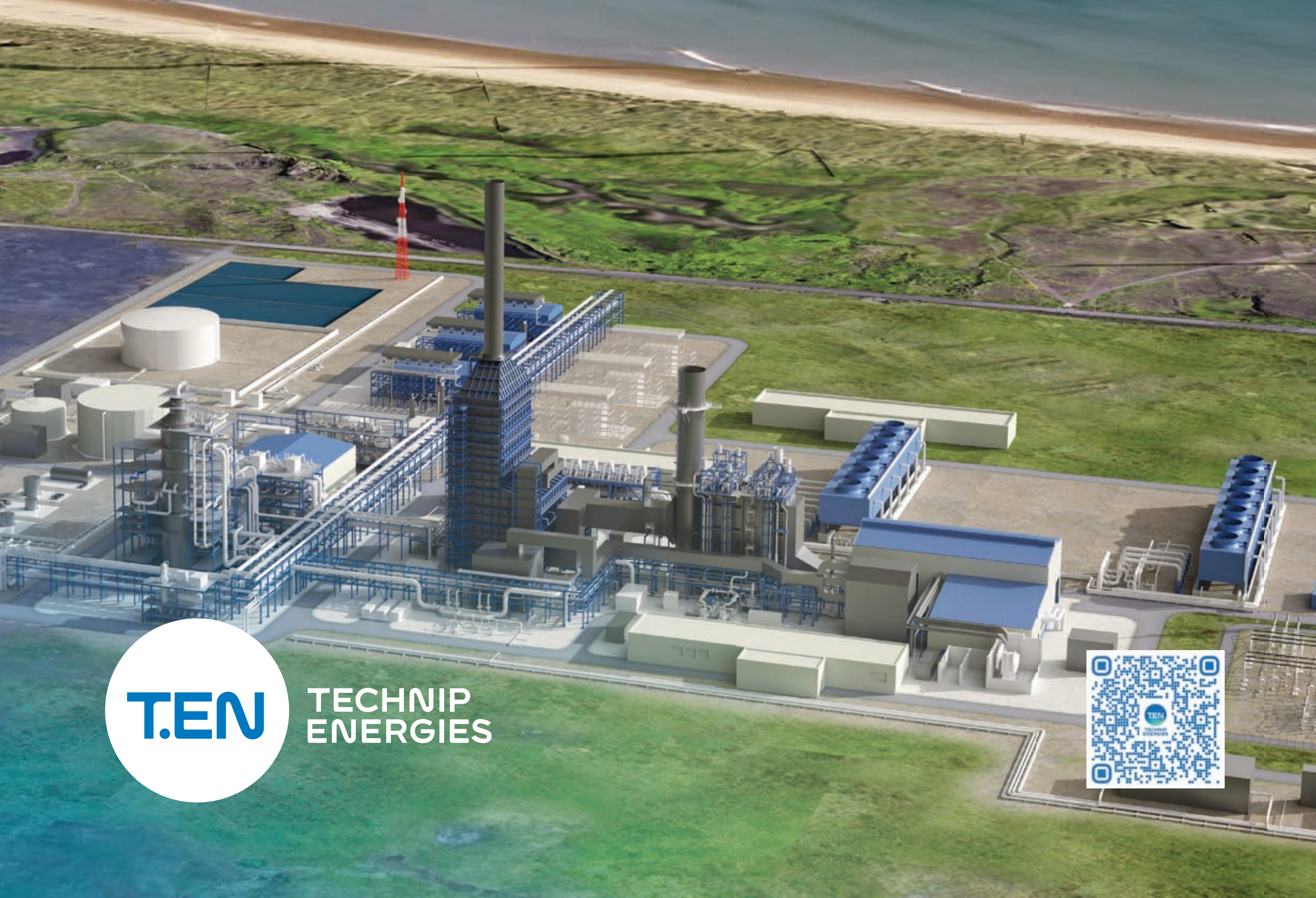
Deploying carbon capture for Net Zero Teesside Power

Technip Energies, leader of a consortium with GE Vernova and local construction partner Balfour Beatty, supported by Shell Catalysts & Technologies, is executing the world's first commercial scale, gas-fired power station **with carbon capture and storage in the UK.**

1+ MILLION
EQUIVALENT TO THE NUMBER OF UK HOMES POWERED ANNUALLY

UP TO 2 MTPA
OF CO_2 TO BE CAPTURED AND STORED

3,000+
JOBS TO BE CREATED AND SUPPORTED DURING CONSTRUCTION



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Back cover: Eni has reached financial close with the UK Government's Department of Energy Security and Net Zero (DESNZ) for the Liverpool Bay CCS project, which is part of the HyNet industrial Cluster. The financial close allows the Liverpool Bay CCS project to move into the construction phase (pg. 14)

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Leaders - CCUS in Australia and New Zealand

Projects and policy

Capture and utilisation

Transport and storage

Identifying a future vision for a Northern Territory CCUS hub

CSIRO has been working with stakeholders to build a common understanding and vision of how a Carbon Capture Utilisation and Storage Hub could be developed in the NT.

CSIRO has worked with the Northern Territory Government and industry to develop the low emissions hub concept which could involve co-location of existing and potential new industries at the Northern Territory Government's proposed Middle Arm Sustainable Development Precinct in Darwin Harbour.

CSIRO scientist and project lead, Dr Andrew Ross, said CCUS was one of several critical pathways for the Northern Territory to reach net zero emissions by 2050.

CSIRO has published a series of reports exploring the technical and economic feasibility of the concept to support carbon management and economic growth goals in the NT.

The first report of the Northern Territory Low Emission Carbon Capture Storage and Utilisation (CCUS) Hub Business Case project identifies the vision of an NT CCUS hub and establishes a shared understanding across government and industry representatives of how a NT CCUS Hub could be developed.

The report represents one of a series of reports which explore 3 broad topic areas:

• Macro-economic drivers, Northern Territory and regional emissions, low emission product markets, identification of key learnings from other low emissions hubs being developed globally (Reports 0-4).

• CCUS hub technical definition and technical risk reduction studies, including detailed studies on the infrastructure requirements for a CCUS hub, renewable power requirements, cross-sector coupling opportunities and roadmapping for CO2 utilisation for existing and potential future industries (Reports 5-9).

• A business case to develop an appreciation of the scale of investment required to develop a Low Emissions Hub and the economic returns from doing so. This will lead to suggested business models and routes of execution (Reports 10-12).

Key facts about the project

CSIRO is working to identify decarbonisation and transition pathways for existing and potential future industries that may be established in a Low Emissions Hub in the Darwin region of the NT.

It is working collaboratively with the NT Government and industry on the business case project to assess the viability of a large-scale low-emission CCUS Hub on the Middle Arm of Darwin Harbour.

The project is also investigating other decarbonisation opportunities as well as CCUS including sector coupling and renewable electrification.

Task 0 of the project was designed to elicit from stakeholders a collaborative common Vision of Success, including value drivers and opportunity statements for a CCUS hub, which could be used to guide further activities within the project and provide a common frame for further development.

The common CCUS hub vision has identified a pathway between 2025 and 2040 for capture and storage of CO2 from existing and future industries, growing CO2 storage from 5 million tonnes per annum to over 25 million tonnes per annum.

The low-emission opportunity in the Northern Territory

The Northern Territory's abundant natural gas, solar resources, and CO2 storage potential, along with its proximity to international markets, make it a key player in energy exports and decarbonisation in Australia and the region.

The NT Government has adopted a 2050 net-zero emissions target and is seeking ways to rapidly decarbonise existing energy supplies and attract future zero-emission industries.

Capital city Darwin, a gateway to South-East Asia and the location of globally significant liquid natural gas (LNG) export and industrial activity, is the proposed site for a large-scale Low Emission CCUS Hub. Led by CSIRO, a collaboration is underway on a business case project assessing the Hub's viability on the Middle Arm Peninsula.

If realised, the NT CCUS Hub could be one of the world's largest multi-user, multi-access hubs. One of the aims of the business case project is to identify transition pathways for industry in the region by sharing knowledge and experience that will help improve the likelihood of success. By taking a collaborative and regional view, an accelerated and sustainable industry transition can be explored.

The vision setting process

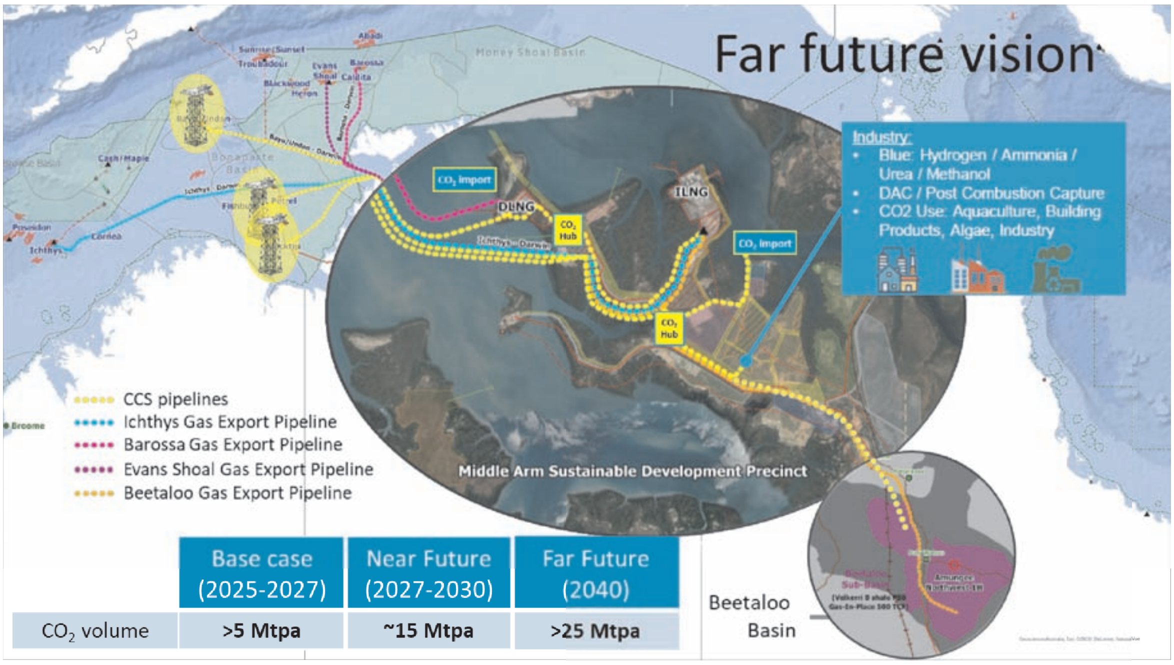
A clear, well developed business case supported by detailed reports and techno-economic models has guided investment decisions and facilitated the development of CCUS projects worldwide.

An important part of developing a business case for the NT CCUS Hub is collaboration with industry and government to understand their needs, drivers and strategic directions; this ensures that CSIRO's research delivery is informed and relevant.

Industry and government stakeholders have extensive practical knowledge of technology implementation and policy and regulatory frameworks. Incorporating these perspectives helps provide an understanding of the steps required for CCUS Hub realisation.

The process of engaging with stakeholders to develop a vision for the NT CCUS Hub was divided into several sequential activities to gradually build understanding and inputs – first at an individual organisation level and then collectively.

Following a kick-off meeting with all stakeholders, individual framing workshops were then held with each of the collaboration partners to frame their vision of the Hub and identify their individual drivers.



Collaborative Hub Future Phase (2040)

The outcomes of these individual workshops were used to prepare a draft collaborative Low Emissions Hub vision, outcomes and schematics, and these were presented to a collaborative stakeholder workshop. Feedback and inputs were sought, and from here the collaborative stakeholder vision was identified and finalised.

A shared vision for the NT CCUS Hub

The stakeholder inputs gathered throughout the process allowed the identification of a collaborative common Vision of Success, including value drivers and opportunity statements.

They also enabled the collaborative development of a 'technical definition basis' and a reference case for a CCUS Hub that comprises base, near-future and far-future cases.

These cases identify a pathway between 2025 and 2040 for capture and storage of CO2 from existing and future industries, growing CO2 storage from 5 million tonnes per annum to over 25 million tonnes per annum.

This future vision has been used to understand the steps required for CCUS Hub realisation; has identified a number of knowledge gaps and information requirements that need further investigation and analysis; and has provided valuable context for CSIRO's research delivery within the CCUS business case project.

Summary and next steps

The work undertaken in this Task 00 of the CSIRO-led CCUS Business Case project provides a valuable understanding of possible visions for the development of a large-scale CCUS Hub predominantly located in the Middle Arm of Darwin Harbour.

The collaborative approach with inputs from government and industry stakeholders has leveraged extensive expertise and many decades of experience in the development and execution of major infrastructure and industry projects. This has allowed an understanding of the potential options available for the development of CCUS associated with a CCUS hub.

The collaborative stakeholder organisations have been weighted toward the LNG industry and it is important that throughout the CCUS Business Case project a wider range of stakeholders are engaged, be that Northern Territory utilities, renewable energy proponents, and other industrial sector proponents. These organisations will enable further calibration and nuance the CCUS Hub vision identified therein.

The collaborative Vison of Success, Value Drivers and Opportunity Statements are useful in that they align the collaborative stakeholders to a common set of understandings that collectively can be pursued, be that individually, in parallel or together.

Whilst the reference cases are scenarios only and reflect the collaborative vision of the participant group at the time of their creation, they provide a 'technical definition basis' which is being used to inform the rest of the CCUS Business Case project tasks.

This 'technical definition basis' will evolve over time as understanding and knowledge are updated. Finally, the knowledge gaps and information requirements identified help identify needs from technical studies within the CCUS Business Case project.

More information

Read all the reports at:

www.csiro.au

COSMIC – A Costing Model for Integrated Carbon Capture and Storage

CO2CRC has recently released an innovative software product which calculates the costs of CCUS projects. The product, known as COSMIC, (Costing Model for Integrated Carbon Capture and Storage) was developed as a direct response to the demands of the growing CCS industry.

COSMIC accurately assesses costs and optimises infrastructure, a critical requirement for large-scale projects. CO2CRC's COSMIC model provides a flexible and adaptable approach to CCS costing and economic analysis. Further, it offers an optimised and reliable costing assessment by dividing CCS hubs into individual and shared facilities, leveraging mass and energy balance calculations and utilising an extensive industry database.

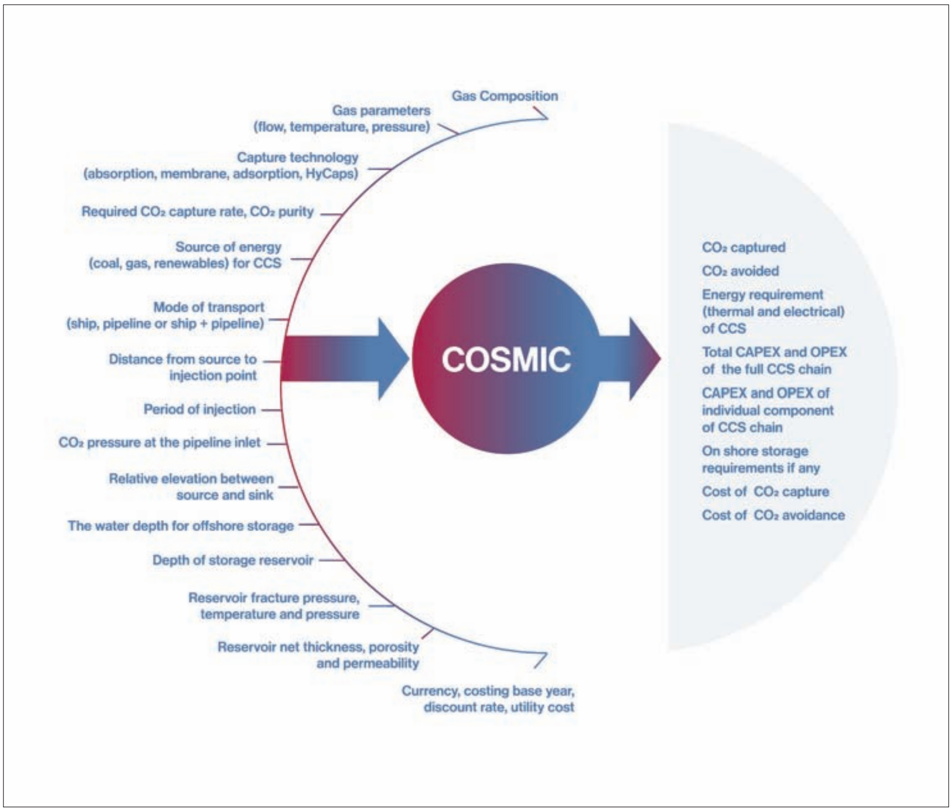
Ultimately, COSMIC serves as an important and useful tool for industries, investors, and policymakers, thereby helping to accelerate the deployment of cost-effective CCS hubs.

In recent years, the cost of carbon dioxide capture has decreased gradually due to various advancements in technology. This decrease, coupled with the urgent need to reduce industrial CO2 emissions, has led to the emergence, planned and actual, of carbon capture and storage (CCS) hubs.

These hubs can potentially play a critical role in reducing emissions from industrial zones by providing shared infrastructure for multiple emitters, making CCS more cost-effective and accessible. By optimising capture, transportation and storage operations, CCS hubs lower the economic and technical barriers associated with individual CCS projects.

Unlike conventional CCS systems, where a single entity is responsible for capturing, transporting, and storing CO2, CCS hubs introduce a more complex business model. The operation and maintenance of shared infrastructure may be managed by an independent third party rather than the individual emitters.

This structural difference creates unique economic and financial considerations that require specialised cost and business models. Existing CCS cost models often overlook the complexities of shared infrastructure. These limitations make it challenging for stakeholders—such as investors, policymakers, and industrial emitters—to accurately assess the financial viability and scalability of CCS projects'.



'COSMIC' stands for 'Costing Model for Integrated Carbon Capture and Storage', and is software used to calculate the costs of your CCUS project

CO2CRC developed COSMIC (Costing Model for Integrated Carbon Capture and Storage), an economic modelling package designed to provide cost estimates for standalone CCS projects and CCS hubs. COSMIC addresses the limitations of traditional costing approaches to support financial predictability and strategic planning to fast-track CCS development.

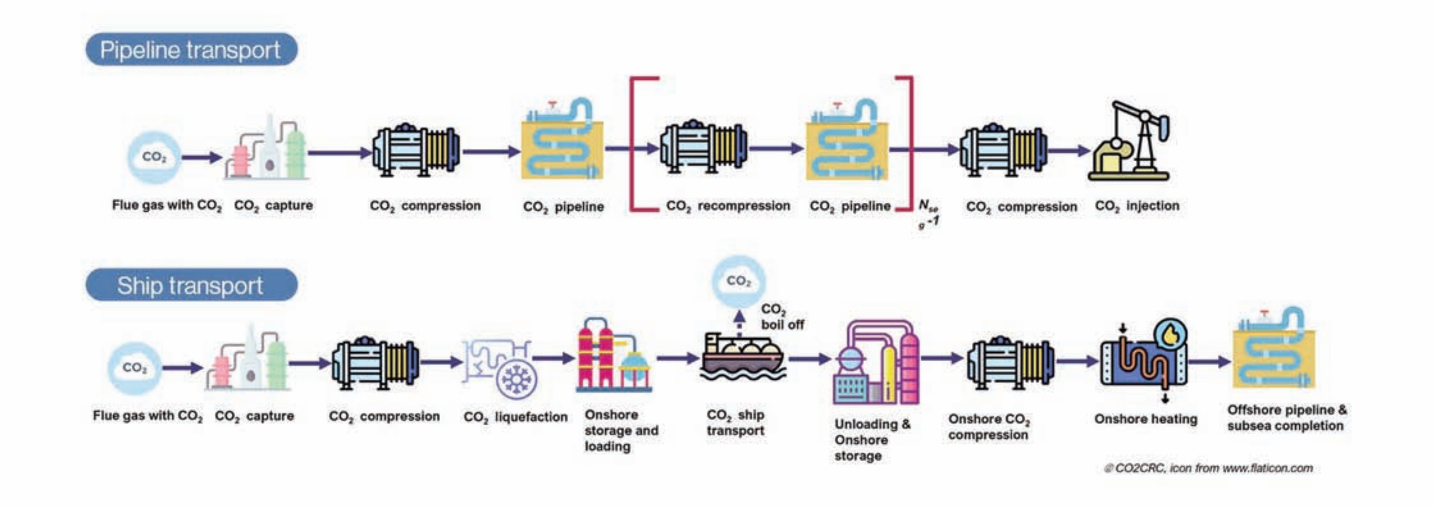
COSMIC Methodology

The COSMIC model divides a CCS hub into two primary sections to streamline cost estimation and economic analysis.

By distinctly categorising individual and shared infrastructure, COSMIC ensures that costs are accurately allocated between emitters and third-party operators. This differentiation is crucial for assessing financial responsibility and optimising investment strategies.

Cost Breakdown in CCS Projects

CO2 capture represents the largest expense amongst the various cost components in the



Examples of COSMIC applications

CCS chain. The economic feasibility of CCS projects depends heavily on reducing capture costs, as these significantly impact the total cost structure. While transportation and storage (T&S) costs have traditionally been estimated at around \$10 per tonne of CO2, as suggested in the IPCC Fifth Assessment Report, more recent studies indicate that transport costs can range between €12–30 per tonne, according to the Zero Emission Platform.

Thanks to continuous improvements in CO2 capture technologies, including process intensification and integration, capture costs are expected to fall below \$40 per tonne. Since CCS hubs aim to reduce transport and storage costs through economies of scale and shared infrastructure, estimating these costs based on site-specific factors becomes increasingly important (rather than relying on broad industry averages).

How COSMIC Improves CCS Cost Estimation

Unlike some traditional costing models that use fixed assumptions, COSMIC offers a more dynamic and flexible approach to estimating CCS costs. The model calculates costs for each component of the CCS chain separately, providing insights into capture, transport, and storage expenses.

By leveraging site-specific data, COSMIC optimises CCS hub design, helping stakeholders determine the best location for CO2 collection based on the proximity of various emitters and storage sites.

The model employs mass and energy balances to determine the type and size of equipment required for each stage of the CCS process. It utilises a combination of:

• Published literature and industry data

• CO2CRC's proprietary costing database

• Engineering scaling laws and Lang factors

This comprehensive methodology ensures that cost estimates remain realistic, data-driven, and adaptable to different project scenarios.

In addition to estimating costs, COSMIC can calculate other relevant outputs, such as the mass of CO2 captured versus CO2 avoided, which helps assess the overall environmental impact of a CCS project.

The Role of COSMIC in CCS Hub Optimisation

One of COSMIC's key advantages is its ability to optimise CCS hub design based on real-world constraints. The model determines the most cost-effective configuration for CO2 capture, transportation and storage by analysing geographic, economic and technological factors. This helps CCS developers and policymakers make informed decisions about:

• The ideal location for CO2 gathering stations

• The most efficient pipeline routes

• The best storage sites based on proximity and capacity

• The financial feasibility of different business models (e.g., public-private partnerships vs. third-party operation models)

Through these optimisations, COSMIC can enhance the assessment of the economic viability of CCS hubs, ensuring that projects are both financially and environmentally sustainable.

Conclusion

As the demand for CCS solutions grows, accurately assessing costs and optimising infrastructure will be critical for large-scale deployment. CO2CRC's COSMIC model provides a flexible and adaptable approach to CCS costing and economic analysis. COSMIC can offer an optimised and reliable costing assessment by dividing CCS hubs into individual and shared facilities, leveraging mass and energy balance calculations and utilising an extensive industry database.

Ultimately, COSMIC serves as an important and useful tool for industries, investors, and policymakers, helping to accelerate the deployment of cost-effective CCS hubs.

More information

CO2Tech is a fully owned subsidiary of CO2CRC

https://co2tech.com.au/ccus-costing-software/

The New Zealand government plans to regulate carbon capture technologies – but who will be the regulating agency?

Newly released documents add more detail to the government's plans for a regulatory framework to enable CCS. But they show indecision on two key matters – the legal framework and the agency that would be in charge. By Barry Barton, Professor of Law, University of Waikato.

The plan relates primarily to conventional carbon capture and storage technologies, which remove carbon dioxide from an industrial gas flow and dispose of it deep underground.

It also covers some methods of carbon dioxide removal, an emerging but as yet commercially untested suite of technologies such as enhanced rock weathering, bio-energy capture and direct air capture.

The latter technologies are not predicated on fossil fuel consumption and could operate in many different situations.

Neither kind of carbon removal is a simple answer to the climate challenge and the priority remains on cutting emissions. But we need to have regulatory frameworks in place for both reduction and removal technologies of all kinds, and soon.

Earning credits from emissions trading

Both types of technologies will benefit from the government's decision to allow companies to get credits in the New Zealand Emissions Trading Scheme (ETS) for the disposal of carbon dioxide from any source. Credits will not be tied to any one technology, according to the released policy discussion documents.

It's also a positive development that an operator can get credits as a separate removal activity, not merely as a reduction of an existing emissions liability (although official advice was initially against separate credits). This allows for diversity in the players and the systems for removals.

The government has decided it will assume liability for any carbon dioxide leaks from geological storage, but only after verification that

Implementation of CCUS is estimated to reduce New Zealand's net CO2 emissions by 4.65 megatonnes over the next two Emission Reduction Plan periods (2026-30 and 2031-35) according the the Government fluids in the subsurface are behaving as expected after closure, and no sooner than 15 years after closure.

Leaks this long after injection are unlikely, but we nevertheless need strong regulation, financial assurance to guarantee remedial action and clear liability rules.

The government also states ETS credits will only be available for removals that can be recognised internationally against New Zealand's commitments to cut emissions. This would apply only to geological storage but not deep-ocean deposition or rock weathering.

But that's not quite right. The general international rules already allow the inclusion in a national greenhouse gas inventory of removals from any process. Detailed methodologies for carbon dioxide removal are likely to become available within the next few years.

With change underway, New Zealand's new regime should allow a wide range of removal methods to receive credits.

A new regulatory regime

The documents acknowledge that New Zealand needs a broader regulatory regime, beyond the ETS, to cover the entire process of carbon dioxide removal. The suitability of a disposal site must be verified, a detailed geological characterisation is required and the project design and operation need to be approved.

Approval is also required for closure and post-closure plans, and systematic monitoring. Monitoring is everything; it must be accurate and verifiable but also cost effective. The operator will have to pay for monitoring for decades after site closure.

In agreeing on these features, the government is following the examples of many countries overseas, including Australia, Canada, the UK and the EU.

However, it is intriguing that the government hasn't decided where this new regime should sit in the statute book, and who should manage it. Much of the apparently relevant text in the documents has been redacted.

Given that carbon dioxide would be stored underground, the Crown Minerals Act is one possibility. But this legislation is all about extraction, not disposal. Although the New Zealand petroleum and minerals unit at the Ministry for Business, Innovation and Employment has expertise in regulating subsurface operations, it focuses largely on oil and gas, not on innovative climate projects.

The Resource Management Act certainly provides a regulatory approval regime, but it is awaiting reform and would need much more than the currently proposed changes to deal with carbon capture and storage or removal properly. So would legislation covering activities within New Zealand's exclusive economic zone.

Indeed each act would require a whole new part to be added, with its own principles and procedures. There is a lot to be said for a standalone new act, in a form that would fit with the emerging Natural Environment Act that will replace the Resource Management Act.

The new legislation and regulation regime could be administered by the Environmental Protection Authority, which is already involved in Resource Management Act call-ins and fast-track approvals, the legislation covering the exclusive economic zone and the ETS.

One can only guess there might be tensions between contending factions in government. What we should ask for is a legislative and institutional arrangement that allows carbon capture and storage or removal technologies to evolve and grow without being a mere offshoot of the oil and gas industry or any other existing sector.

As part of our efforts to reduce emissions, we must make sure all kinds of removal technologies are available that truly suit New Zealand.

About the author

Barry Barton is part of the project "Derisking Carbon Dioxide Removal at Megatonne Scale in Aotearoa" which is funded by the MBIE's Endeavour Fund. In the past, he has received funding from MBIE and the gas industry for research on CCS legal issues. He is a director of the Environmental Defence Society.

More information

This article originally appeared in The Conversation

https://theconversation.com

www.waikato.ac.nz

Bonaparte CCS Joint Venture progresses to pre-FEED

The project has received "robust appraisal results" and has now commenced preliminary front-end engineering design (pre-FEED) work to support development of the Bonaparte CCS Project, located in the Bonaparte Basin, approximately 260 kilometres offshore Darwin, Australia.

The Bonaparte CCS Joint Venture was formed in 2022 to appraise the awarded greenhouse gas storage assessment acreage (title G-7-AP).

The decision to progress the project into pre-FEED follows the successful completion of both the selection of engineering concept and a comprehensive appraisal program, which included ~1,800 square kilometres of new three-dimensional seismic surveying and two carbon dioxide (CO2) storage appraisal wells.

The appraisal program confirmed the presence of a high-quality saline aquifer reservoir in the Bonaparte Basin together with thick sealing formations considered suitable for safe and permanent long-term carbon storage.

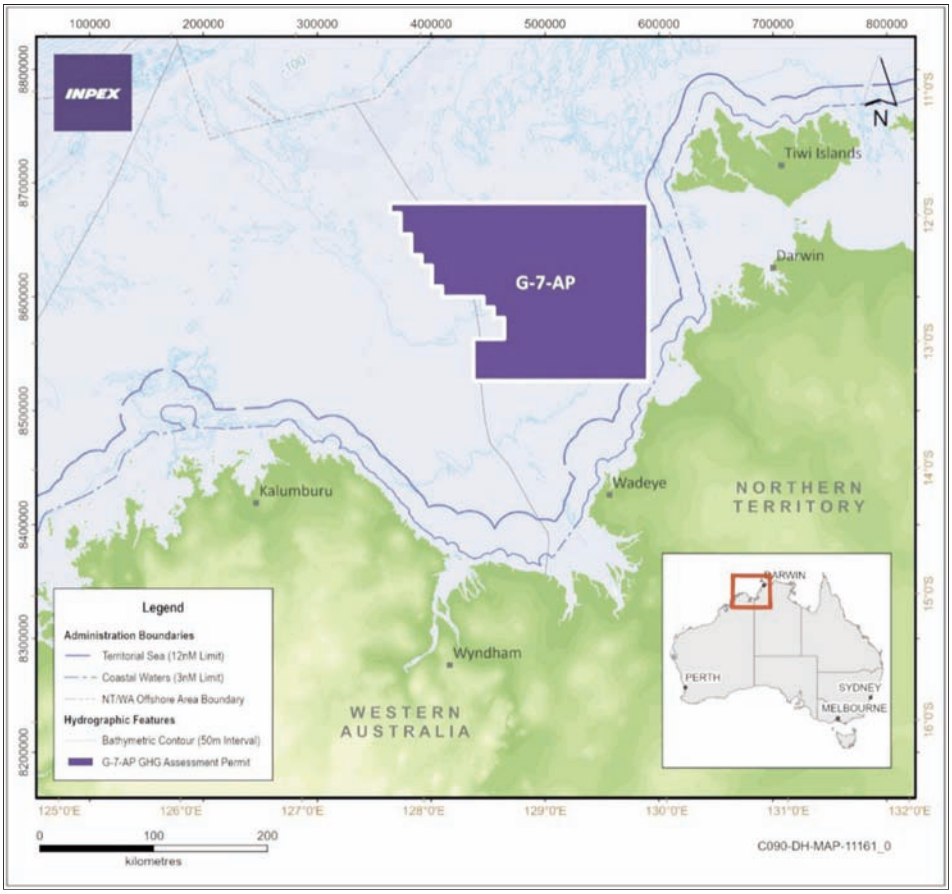
INPEX Managing Director and Country Chair Australia Tetsu Murayama said achieving the Bonaparte CCS pre-FEED milestone is an important step towards a lower carbon future.

"The Bonaparte CCS appraisal results are outstanding and have exceeded our expectations. The G-7-AP acreage is proving up to be one of the most promising CO2 storage sites globally.

"Bonaparte CCS Joint Venture intends to transport and store CO2 safely and permanently offshore northern Australia in the Bonaparte Basin, which has a potential carbon storage capacity of more than 10 million tonnes per annum, with Ichthys Joint Venture expected to be the anchor customer.

"With a plan to commence CO2 injection around 2030, the proposed Bonaparte CCS project could substantially contribute to decarbonising northern Australia and potentially the wider Indo-Pacific region," Mr Murayama said.

The Bonaparte CCS Assessment Joint Venture is now conducting detailed analysis of the reservoir appraisal data, to support a Declaration of Identified GHG Storage Formation application in advance of obtaining a greenhouse gas injection licence.



The Bonaparte CO2 appraisal area offshore Australia

CO2 Imports

Bonaparte CCS has the potential to provide significant CO2 sequestration opportunities for overseas industrial emitters and help companies and countries meet their global net zero ambitions.

Bonaparte CCS can be an enabler for the development of the full CCS value chain, from regional emitters across a range of industries, CO2 capture, aggregation, liquefaction, loading, shipping, receiving in Darwin, pumping/heating, transportation, and offshore geological storage.

First CO2 injection at Bonaparte CCS is targeted around 2030.

More information

www.inpex.com.au

Australia and New Zealand news

New Zealand releases CCUS Framework to support businesses

www.mbie.govt.nz

The Government has made decisions on the key elements of a CCUS framework, designed to enable carbon capture and storage in New Zealand, with legislation expected to be introduced this year.

The framework will enable businesses to benefit from storing carbon underground, which will support New Zealand's businesses to continue operating while reducing net carbon emissions, Energy and Climate Change Minister Simon Watts says

"Economic growth is a key focus for this Government, and we want the energy sector to be the engine for our economy – driving electrification and unlocking economic growth," Mr Watts said.

"The Government is committed to removing regulatory barriers to enable the supply of abundant, affordable energy to power our homes and businesses – and to reduce net carbon emissions."

"Under our CCUS framework, businesses that capture and store CO2 will be rewarded through the Emissions Trading Scheme (ETS), our Government's key tool to reducing net emissions. This will help reduce emissions obligations for New Zealand businesses as we progress towards a low-emissions economy."

"By making these decisions, we are aligning New Zealand with other countries that are successfully utilising CCUS to drive economic growth and attract investment. Our framework not only supports innovation but also provides a pathway for businesses to remain competitive while reducing net emissions.

"Ensuring safe and effective storage of CO2 is critically important. That's why our framework will require any CCUS project to undertake a thorough assessment of storage site suitability and proposed operations, followed by ongoing monitoring.

"CCUS is gaining momentum internationally as a way to reduce net emissions and support economic growth. In New Zealand, this innovative approach has significant untapped potential of capturing CO2 emissions that would not otherwise benefit Kiwis to create valuable products and materials.

"Our Government's second emissions reduction plan, which was released at the end of last year, highlighted carbon capture and storage as a key tool to meeting the second and third emissions budgets."

Halliburton to develop offshore CO2 storage with Incapture

https://incapture.com.au

www.halliburton.com

GHG Assessment Permit G-15-AP Operator InCapture and joint venture partners SK earthon Australia and Carbon CQ have awarded Halliburton Australia the full scope of the G-15-AP CCS Declaration of Storage Project.

The companies signed a MOU with Halliburton to progress towards the ambitious goal of launching a commercial scale CCS project within G-15-AP by the end of this decade.

Halliburton offers the G-15-AP project world-leading experience in identifying, maturing, and delivering CO2 storage projects at scale.

Working with technical teams from the collaboration, Halliburton will assess and appraise potential storage solutions from across the G-15-AP area and progress high-graded opportunities through major regulatory processes.

Julia Davies, Managing Director of InCapture, said, "The signing of the MOU with Halliburton plays a pivotal role in the development of a world-class CCS site over the G-15-AP area, which aims to help deliver safe, secure and effective storage options for domestic and international emitters, at pace".

Additionally, Halliburton will contribute to the overall success of the CCS project by providing strategic insights and robust support throughout its development.

Chiyoda awarded feasibility study for carbon supply chain in Australia

www.chiyodacorp.com

www.pilotenergy.com.au

A joint study being led by Pilot Energy aims to develop a carbon supply chain to assist with capturing and storing up to approximately 700,000 tonnes per annum of carbon dioxide.

The CO2 will come from emissions associated with the South32 Worsley Alumina Operations. The captured carbon dioxide will be delivered to Pilot's planned storage site for the Cliff Head Carbon Storage Project.

For this Feasibility Study, Chiyoda will be responsible for the onshore facility scope, while Knutsen NYK Carbon Carriers AS (KNCC), a liquid CO2 marine transportation provider, will be responsible for the marine transportation scope

The project forms part of the integrated Mid West Clean Energy Project, and is a carbon storage to clean ammonia export project, involving brownfield re-development using Pilot's Cliff Head oil infrastructure and facilities.

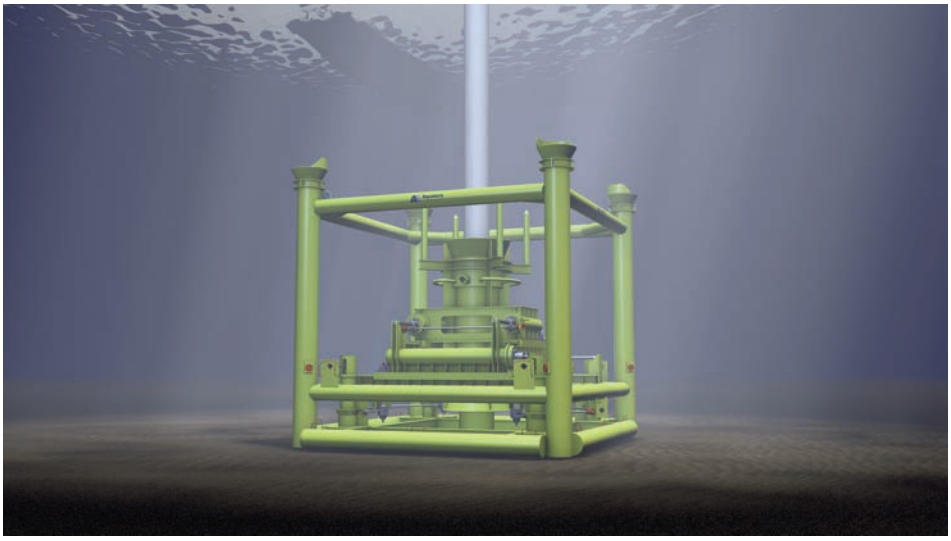
The project was recently recognized by the International Energy Agency Greenhouse Gas R&D Programme (IEAGHG) in its report 'Managing the transition of depleted oil and gas fields to CO2 storage."

How APAC is balancing unmatched growth and complexity with the energy transition

For those operating in APAC, success means balancing growth with decarbonisation, while adapting, innovating, and working with the unique conditions of each country on the ground and across borders. By Stewart Maxwell, Technical Director at Aquaterra Energy.

In the Asia-Pacific (APAC) region, rapid population growth, industrial expansion, and economic development have propelled energy demand to unprecedented levels, with the region projected to maintain a 50% share of global primary energy demand until 2050. But this growth is accompanied by a parallel challenge. Namely, how to meet surging demand while staying committed to decarbonisation, with APAC also accounting for an expected 60% share of global carbon emissions until mid-century.

Matching the region's growth is also its complexity, with huge variance in infrastructure, resources, and policy priorities between nations. Each country has unique challenges shaped by their geography, industrial structure, and regulatory landscape. This means there can' t be a one size fits all approach. For example, while Indonesia is pursuing geothermal expansion, hydrogen development, and carbon capture, Vietnam has led the way on the rapid adoption of solar and wind energy.



Advanced well intervention technologies, like Aquaterra Energy's Recoverable Abandonment Frame are pioneering cost-effective solutions

Tapping into new resources

To meet rapidly growing demand, energy production across APAC is expanding. Oil and gas continues to play a crucial role, with LNG demand surging, particularly in China, India, and Southeast Asia, driving new investments in exploration and infrastructure. Over the next decade, APAC is expected to invest $3.3 trillion in power generation, with fossil fuels maintaining a significant share.

At the same time, APAC's easily accessible fossil fuel reserves are depleting, forcing the industry to turn to smaller, more complex resources. This demands a departure from traditional methods, embracing flexible and modular technologies like conductor-supported platforms, advanced drilling systems, and enhanced riser designs that enable these previously untapped resources to be made technically and economically viable.

Take the shallow waters of Bohai Bay in the Gulf of China, an area comparable to the North Sea in scale and significance. As China's first offshore oil-producing area, with predominantly shallow depths, conventional infrastructure like semi-submersibles are impractical for developments in the field.

Instead, modular solutions such as the Sea Swift platform, which can be installed directly from jack-up rigs, offer an efficient and safe alternative. By reducing the need for heavy-lift vessels, these platforms lower costs and improve project timelines while maintaining rigorous safety standards.

In markets like China and Japan, other technologies such as subsea drilling from jack-up rigs are also gaining traction for this same reason. Although proven in other regions, they represent a new frontier for these countries, offering both operational efficiency and the potential to tap into previously economically infeasible fields, while reducing environmental impact.

CCS will facilitate APAC's journey

However, with emissions rising 151% since 2000, the need for decarbonisation is also clear. Carbon capture and storage (CCS) is emerging as a critical piece of this puzzle, not only addressing emissions from existing assets, but also shaping the long-term viability of offshore energy. But, while momentum is building, each region must navigate its own regulatory and commercial realities, requiring tailored approaches.

With around 200 offshore fields in Southeast Asia expected to cease production by 2030, these could present an opportunity for repurposing as CCS, or even hydrogen, storage facilities.

Malaysia is already taking steps in this direction. Petronas has identified vast storage potential in depleted gas reservoirs offshore Peninsular Malaysia and Sarawak, with over 46 trillion cubic feet available. To advance these opportunities, ExxonMobil and Petronas are working together to assess CO2 storage sites and establish viable commercial frameworks.

Similarly, Indonesia has vast offshore storage potential and the country has approved CCS projects involving bp, INPEX, and Repsol, signalling its readiness while also forging international relationships to accelerate deployment.

However, scaling up CCS presents several technical challenges, not least being ensuring the integrity of legacy well formations to prevent CO_2 leakage. Advanced well intervention technologies, like Aquaterra Energy's Recoverable Abandonment Frame are pioneering cost-effective solutions to support the efficient re-entry of these wells, to establish an environmental and pressure-retaining barrier, ensuring safe re-abandonment and readiness for their long-term viability for carbon storage.

Equally important is ensuring that once CO2 is stored, it remains securely in place, particularly in a region which is known for being geologically active. Cutting-edge monitoring technologies can provide continuous, remote oversight of storage sites post-injection, detecting potential leaks or seismic activity throughout the lifecycle of a project. These innovations offer comprehensive, long-term assurances that stored carbon remains contained.

By leveraging these technologies, operators across APAC can not only reduce costs but also accelerate offshore CCS development. With greater confidence in carbon security, countries such as Indonesia and Malaysia can transform depleted oil and gas formations and saline aquifers into reliable CCS storage sites, driving the region toward a low-carbon future.

Empowering regional development

The APAC region's diversity extends beyond geography to include unique regulatory environments and priorities. A unifying theme, however, is the growing emphasis on local content. For instance, Indonesia has introduced an update to PTK 007 which outlines how local companies are to be given preferential treatment during procurement activities, while in China, local sourcing is critical, even if not explicitly legislated.

Foreign companies navigating these markets must do more than introduce advanced technologies; they must invest in local partnerships, transfer knowledge, and build regional capabilities. By aligning global expertise with local insights, they can empower local content to propel APAC's low-carbon future. This ensures solutions that are not only technically innovative but also culturally and economically resonant. Such an approach strengthens trust and positions international companies as key contributors to both regional progress and national aspirations.

A collaborative future

APAC's offshore energy journey is fundamentally a collaborative endeavour. As the region's energy demand continues to surge, its leaders face the dual challenge of meeting immediate needs while laying the groundwork for sustainable growth that meets global climate goals. Through technologies like reduced steel platforms and offshore CCS, the region is bridging operational challenges with its decarbonisation goals. At the same time, prioritising local partnerships will underscore the importance of shared progress.

This balancing act – between growth and sustainability, global expertise and local insight – defines APAC's energy transformation. By embracing innovation and collaboration, the region is charting a course that not only addresses its energy demands but also sets a global benchmark for sustainable development.

More information

https://aquaterraenergy.com

Putting the U in CCUS: Overview of emerging pathways in carbon utilisation

A report from the Oxford Institute for Energy Studies looks at the role that CCU plays in the larger carbon management landscape and looks at what may lie ahead, including opportunities and challenges.

The paper intends to provide a broad-based overview of CCU, as well as a deeper dive that will incorporate scalability, market dynamics and enabling regulatory frameworks for emerging technologies.

Unlike CCS, carbon utilisation offers a series of pathways for direct and indirect conversion of CO2 into useful products that can displace fossil fuel-based alternatives and retain – or potentially increase - the economic value of those products. The emergence – and increasing relevance – of CCU pathways can help strengthen the business cases for CCUS hubs and engage emerging economies in the wider CCUS discussion, says the report.

The viable pathways further highlight the need for integrated planning and coordination of CCUS technology development, deployment and operations. Research and development work is likely to occur in parallel and is currently concentrated in OECD countries, but it is also important to note that some of the most significant markets for CO2 utilisation may be in BRICS and other emerging economies.

Breaking down borders and building CCUS bridges across Europe

At the tail end of 2023, Xodus released its much-anticipated whitepaper charting the likely path for the development of Europe's carbon capture, utilisation and storage (CCUS) industry. By Olivier Mette, Global Advisory Director, Xodus.

Among a raft of findings, Forecasting the North Sea CCUS infrastructure to 2050 predicted a reversal of decades of fossil fuel production, with the volume of carbon dioxide being stored beneath the North Sea expected to match the scale of natural gas currently extracted from it by 2050.

Developed in partnership with Subsea7, the report also evaluated the cost efficiency and timing of prospective CCUS projects across Europe.

In conducting the research Xodus assessed 560 potential CO2 storage sites, mapping them against existing infrastructure and projected emissions flows. With around 100 reservoirs, 7,500 kilometres of new pipeline, and dozens of onshore CO2 capture and gathering hubs needed to deliver abatement at the scale require, one fact became evident - the North Sea will become the key carbon sink for the continent.

Our whitepaper was designed to act as a decision-making tool for investors, developers and policymakers, helping them to navigate one of the most ambitious components of the energy transition.

A first look at Europe's CCUS future

But projections are just one piece of the puzzle. Taking this a step further meant giving emitters, regulators and investors the ability to visualise how Europe's CCUS industry will actually work in practice.

Building on our 2023 research, Xodus worked with the CCSA to create an online interactive dashboard based on economic modelling of the transport and storage of CO2 in Europe (EU-EEA-UK).

For too long, CCUS decision-making has been hindered by a lack of accessible, consolidated data on the economics of CO2 transport and storage.

This new dashboard changes that, bridging the gap between modelling and infrastructure and allowing users to measure the costs of transporting carbon to any region in Europe. In doing so it shines a light on the actual economics of the numerous different CCUS clusters that are currently being progressed, meaning evidence replaces prediction.

At the same time, storage operators can drill down into where the demand for their services is located. Policymakers stand to benefit as well, using the dashboard's insights to craft regulatory frameworks that drive market efficiency and ensure equitable access to storage infrastructure.

Collectively, this free-to-use tool, developed by an integrated team over the course of 18 months, gives us a first look at how Europe's CCUS market will evolve, where the key clusters will be located and what the most sensible economic options are.

Far from being static, Xodus has an ambition to evolve the dashboard as the industry matures. As CCUS infrastructure develops and costs fluctuate, we aim to update the platform and continue engagement with the CCSA to ensure it remains a relevant, accurate and indispensable resource for the sector.

A fast-growing hive of CCUS activity

A few years ago, such a tool would have seemed unworkable, but such has been the recent maturation of Europe's CCUS sector, we are now able to paint a picture of the future with more certainty.

There are a growing number of large-scale projects dotted around the continent that are progressing from planning to implementation. These initiatives underline strong commitment from various governments to meeting decarbonisation targets, as well as the industry's drive to create the infrastructure needed for a functioning, cross-border carbon management market.

In the UK, momentum is building around major industrial clusters. Having taken FID at the end of 2024, the Net Zero Teesside Power project, backed by BP, Equinor, and TotalEnergies, is on track to become the country's first large-scale gas-fired power station equipped with carbon capture technology, targeting operations in 2028 and the capture of 2 million tonnes of CO2 annually.

Meanwhile, the HyNet and East Coast Clusters have seen eight projects under their umbrella progress to government-supported negotiations, including power generation, industrial capture, hydrogen production and waste-to-energy schemes.

Across the North Sea, Norway remains a frontrunner. The Northern Lights project, part of the wider Longship initiative, is set to become Europe's first commercial CO2 storage facility, initially storing CO2 shipped from industrial sources like Heidelberg Materials' cement plant in Brevik.

In neighbouring Denmark, Project Greensand - led by INEOS - plans to inject captured CO2 into depleted oil fields by late 2025 or early 2026, starting with 400,000 tonnes per year and scaling up to 8 million tonnes by 2030.

The Netherlands has launched its flagship Porthos project, which broke ground in 2023. With a €1.3 billion investment, Porthos will transport CO2 from Rotterdam's industrial hub to a depleted gas field beneath the North Sea. Shell and other partners aim to store over 1 million tonnes of CO2 per year, creating a critical piece of the Netherlands' industrial decarbonisation puzzle.

At a broader level, EU-funded programmes such as STRATEGY CCUS are driving roadmap development in regions traditionally underrepresented in the CCUS landscape, including southern and eastern Europe.

These efforts are helping to lay the foundations for a truly integrated and equitable European CCUS network - ensuring that carbon-intensive industries across the continent have access to reliable, cost-effective carbon management solutions.

The case for building a Europe wide CCUS industry

Indeed, it is the development of a cross-border Europe-wide CO2 storage market that will unlock efficient, accessible and cost-effective carbon storage for industrial emitters.

The European Commission has established a technical framework allowing European Union (EU) and European Economic Area (EEA) countries to store captured CO2 within the EEA. But despite the technical feasibility of transporting CO2 across jurisdictions, policy obstacles mean it is currently impractical.

A key challenge is that CO2 captured in the EU/EEA but stored outside its borders - such as in the UK - is not currently recognised under the EU Emissions Trading System (ETS) as permanently stored. This forces emitters to surrender allowances as if the carbon were not stored, effectively paying twice. As a result, EU/EEA countries can't take advantage of the UK's significant and cost-effective storage capacity in the Southern North Sea.

Research carried out by Xodus in tandem with the Carbon Capture and Storage Association (CCSA) and detailed in the report Accelerating a Europe-wide CO2 Storage Market, highlighted the strategic advantages of granting EU Member States and the UK access to North Sea storage provided cross-border CO2 transport and storage are supported by policy.

The Southern North Sea, long central to the UK's oil and gas industry, offers extensive, high-quality CO2 storage potential. Its proximity to mainland Europe makes it one of the most cost-effective and strategically located options available. Tapping into these sites could significantly lower costs for EU emitters, while UK projects would benefit from economies of scale and improved infrastructure resilience.

Access to European CO2 volumes could also make large-scale UK CCUS investments financially viable, especially in less industrialised areas. This cross-border collaboration would accelerate industrial decarbonisation, stimulate private investment and support economic growth through job creation and supply chain development across the region.

Coordinated, practical steps must be taken to lay the legal and regulatory foundations for a seamless, cross-border CCUS market that can support climate goals and strengthen international cooperation - Olivier Mette, Global Advisory Director, Xodus

In addition to helping emitters reduce costs, countries that provide CO2 storage services stand to gain broader economic advantages. By monetising their storage capacity, they can generate new revenue streams, while the growth of the CCUS industry is poised to create jobs, not only in project development but also across the wider supply chain, stimulating economic activity in industrial regions.

We need actions, not aspirations

Providing a route for industrial clusters to tackle their emissions is essential to future-proofing industries, protecting jobs and delivering long-term growth. This cannot be achieved without CCUS at scale.

While the CCUS sector has weathered the economic storms of recent years better than other facets of the energy industry, it hasn't all been plain sailing. High costs remain an issue, something exacerbated by complex regulatory frameworks and the need for enhanced and new infrastructure.

The UK and EU need to be committed to enabling cross-border CO2 storage, which requires mutual recognition of safe, permanent storage to ensure emitters are exempt from surrendering allowances under their respective Emissions Trading Schemes.

To support this, Xodus and the CCSA included four main recommended actions in our report. Firstly, for mutual recognition of CCS regulatory regimes to be established, with shared criteria, a governance body, dispute resolution, emissions safeguards, and CO2 transport data sharing. EU and UK laws (e.g., ETS directives and regulations) should also be updated to recognize and accommodate CO2 storage outside EU/EEA borders.

Both jurisdictions must consider a range of other legislative changes to facilitate cross-border CO2 transport and storage, including establishing comprehensive arrangements for monitoring, developing consistent technical standards and clarifying liability frameworks.

Finally, actions under the London Protocol are essential. Member States, the UK, and EEA countries must notify the International Maritime Organisation (IMO) of their intention to provisionally apply the amendment to Article 6 of the Protocol, if they have not already done so.

In short, unlocking the full potential of cross-border CO2 storage requires both the UK and EU to move beyond political commitments. Coordinated, practical steps must be taken to lay the legal and regulatory foundations for a seamless, cross-border CCUS market that can support climate goals and strengthen international cooperation. The benefits are there to be reaped, but it won't happen by accident.

More information

www.xodusgroup.com

UK Liverpool Bay CCS project gets green light

Eni has reached financial close with the UK Government's Department of Energy Security and Net Zero (DESNZ) for the Liverpool Bay CCS project, which is part of the HyNet industrial Cluster.

The financial close allows the Liverpool Bay CCS project to move into the construction phase, unlocking key investments in supply chain contracts, the majority of which will be spent locally.

The project will support the UK's industrial competitiveness for the long term, by safeguarding existing industrial employment and creating new production chains and jobs – which, in the construction phase alone, are estimated to be about 2,000 people.

This significant milestone follows the UK Government's funding allocation of £21.7 billion to be invested over a 25-year period across the first two CCS Clusters in the country. The decision demonstrates the UK's commitment to prioritising the development of the CCS sector as a key lever in its decarbonisation and industrial strategy, the Government said.

Eni's Point of Ayr terminal in North Wales would form part of the carbon capture project in Liverpool Bay

The UK Secretary of State for Energy Security and Net Zero, Ed Miliband, commented, "Today we keep our promise to launch a whole new clean energy industry for our country - carbon capture and storage - to deliver thousands of highly skilled jobs and revitalise our industrial communities."

"This investment from our partnership with Eni is government working together with industry to kickstart growth and back engineers, welders and electricians through our mission to become a clean energy superpower. We are making the UK energy secure so we can protect families and businesses and drive jobs through our Plan for Change."

The Liverpool Bay CCS project will operate as the backbone of the HyNet Cluster to transport carbon dioxide from capture plants across the North West of England and North Wales through new and repurposed infrastructure to safe and permanent storage in Eni's depleted natural gas reservoirs, located under the seabed in Liverpool Bay.

The project itself foresees the efficient repurposing of part of the offshore platforms as well as 149km of onshore and offshore pipelines, and the construction of 35km of new pipelines to connect industrial emitters to the Liverpool Bay CCS network.

HyNet is one of the world's most advanced CCS Clusters that will significantly contribute to the reduction of emissions from a wide range of industries across the North West of England and North Wales. This includes companies involved in cement manufacturing, energy from waste plants, low-carbon hydrogen production, as well as additional industrial players who will connect to Eni's infrastructure.

With a storage capacity of 4.5 million tonnes of CO_2 per year in the first phase, and the potential to increase to 10 million tonnes of CO_2 per year in the 2030s, Eni's CO_2 T&S system will make a significant contribution towards achieving the UK's CCS ambitions.

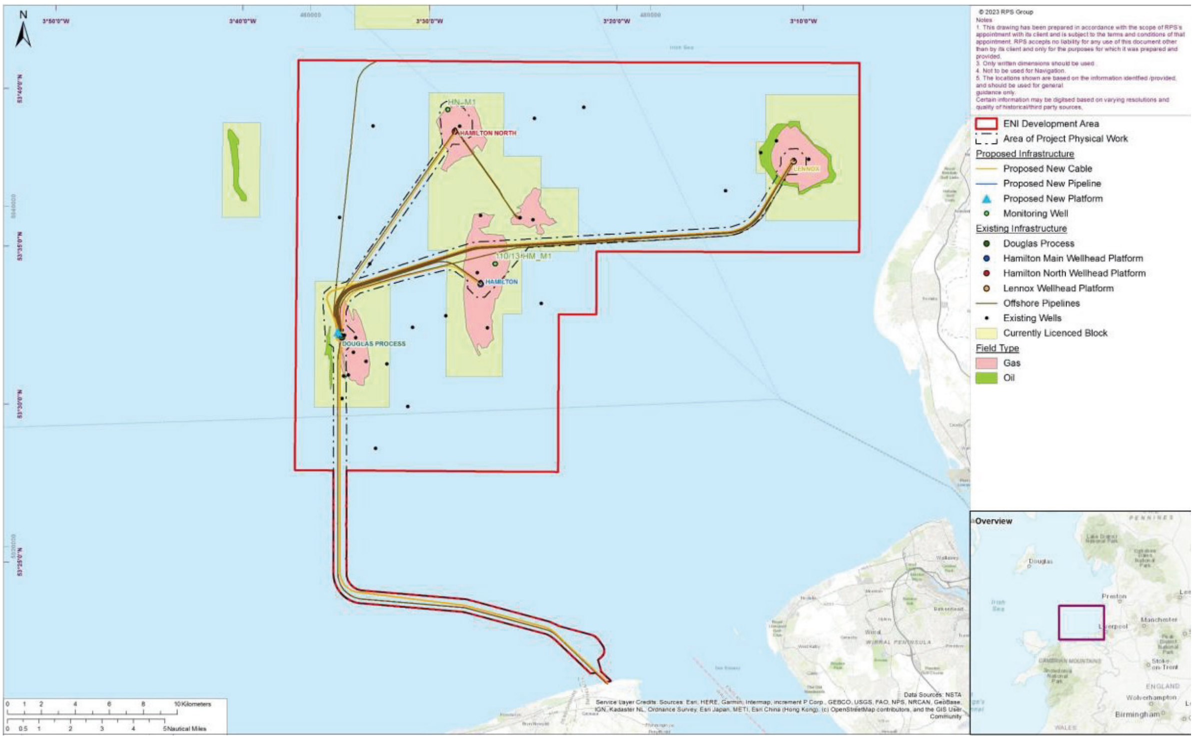
Construction of the project is expected to commence this year, ready for planned start-up in 2028, in line with industrial emitters in the HyNet Cluster.

Eni believes that CCS will play a crucial role in the energy transition and can become an important strategic activity to support the company's decarbonisation ambitions.

Eni CEO Claudio Descalzi said, "The strategic agreement with the UK Government paves the way for the industrial-scale development of CCS, a sector in which the United Kingdom reaffirms its leadership thanks to the promotion of a regulatory framework that aims to strengthen the development of CCS and make it fully competitive in the market."

"Eni has established itself as a leading operator in the UK thanks to its key role in CO_2 transport and storage activities as the leader of the HyNet Consortium, which will become one of the first low-carbon clusters in the world."

"CCS will play a crucial role in tackling the decarbonisation challenge by safely eliminating CO_2 emissions from industries that currently do not have equally efficient and effective solutions. Eni confirms its position at the forefront in the creation of this new, highly sustainable business linked to the energy transition."



Configuration of pipeline and storage sites for the Liverpool Bay CCS Project (Image: Eni)

Responding to the announcement, the Carbon Capture & Storage Association (CCSA) said the landmark agreement ensures critical infrastructure will now be in place to safeguard jobs, attract investment, and revitalise industry in the North West of England and North Wales, helping transform one of the UK's most energy-intensive industrial regions into one of the world's first low-carbon industrial clusters.

Olivia Powis, CEO of the CCSA said, "This is a pivotal moment for the North West. Eni's Liverpool Bay CCS project in HyNet is a huge step forward for the CCUS industry and demonstrates the UK's global leadership in industrial decarbonisation."

"It will protect vital industries and provide product security, create and protect skilled local jobs, and position the region at the forefront of the low-carbon economy. The focus can shift to delivery – getting spades in the ground, connecting industry, and capturing CO_2."

"Capitalising on this well-earned momentum is equally essential. This means advancing the next CCUS clusters and projects and providing a route to market for further projects across the UK. These steps will unlock the full growth potential of deploying CCUS at scale, including the potential for 50,000 jobs centred in our declining industrial heartlands."

"At the same time, it will enhance energy security, drive progress toward net zero targets, and be the central backbone to the UK's Industrial Strategy."

Offshore Energies UK (OEUK) also welcomed the news. Commenting on the announcement, OEUK Chief Executive David Whitehouse said, "We welcome the progressaion of the Liverpool Bay project - a landmark moment for the UK's carbon capture and storage sector. Eni's leadership as transportation and storage operator showcases how our existing offshore expertise is being deployed to deliver climate solutions."

"Today's announcement means that both Track-1 clusters (Hynet & East Coast) will commence construction this year. A firm commitment is also needed to support the crucial Track-2 Acorn and Viking clusters, which are vital to establish a robust CCS sector, as well as other CCS clusters that can be developed in a similar timeframe."

"As we set out in an independent report published yesterday, a self-sustaining CCS industry is achievable by the 2030s - but only if all four clusters move ahead to gain momentum, reduce costs and incorporate learnings. We look forward to continued collaboration across industry and government to accelerate the delivery of this critical infrastructure across the UK."

Evero Energy, a leading company in waste-wood-to-energy and bioenergy with carbon capture and storage (BECCS) operating within this region responded. Elliot Renton, CEO of Evero Energy, said, "This is a big moment for the UK's industrial future. The North West has powered the economy for generations, and today's Hynet FID provides a clear route to delivering high-quality negative emissions while staying competitive in a world that needs to rapidly decarbonise."

"Evero has been part of this region's story since 2015. Our InBECCS project sits adjacent to the confirmed pipeline, making it a natural fit for the cluster. We're working towards our own FID in 2026, with plans to be operational from 2029, delivering over 200,000 tonnes of carbon removals every year."

"This will be the UK's first Greenhouse Gas Removals (GGR) project - cutting emissions and driving clean growth. With the expertise, infrastructure and momentum in place, Britain has everything it needs to achieve its net zero ambitions."

More information

https://hynethub.co.uk

www.ccsassociation.org

CCSA calls for sustained momentum on UK CCUS clusters

The Carbon Capture & Storage Association (CCSA) has underscored the urgent need for clear government direction to advance the next phase of CCUS projects, following the publication of its report, 'Driving Cost Reductions and Value for Money in CCUS'.

The report highlights how collaboration between Government and industry can reduce costs, mitigate risks, and deliver economic value across the CCUS supply chain. It proposes a roadmap to transition the sector from early-stage public support to a self-sustaining, market-driven industry critical to achieving the UK's net zero targets and creating and protecting thousands of jobs.

The CCSA stresses the importance of delivering existing projects—including Track-1 (initial clusters), Track-2 (next-phase clusters), Track-1 Expansion, and other mature clusters aiming to deliver along similar timescales—to unlock billions in private investment, revitalise industrial regions, and position the UK as a global CCUS leader. Success hinges on urgent government support for near-term clusters while laying the groundwork for long-term market stability.

The report identifies critical challenges and opportunities: :

• Evolve existing business models to ensure continuity, adapt to changing conditions, and strategically allocate support—enabling a market-led CCUS sector while maintaining necessary public backing.

• Improved market integration between capture projects and end markets.

• Support for innovation, including low-carbon product standards and Greenhouse Gas Removal (GGR) frameworks.

• Greater risk accepted by the private sector in return for appropriate financial returns to ease reliance on public funding for CO2 transport and storage.

• More certainty around funding timelines and streamlined planning and permitting processes.

Mark Sommerfeld, UK Director of the CCSA, said, "The UK's CCUS industry is at a critical juncture. The successful delivery of the current project pipeline is essential, with government support urgently needed for Track-2, Track-1 Expansion, and other mature clusters operating on similar timelines."

"While the industry is actively collaborating with Government to establish the sector, it is equally important to lay the foundations for a self-sustaining future CCUS market. Achieving this will unlock cost reductions, lower investment risk and deliver long-term economic and environmental benefits for the UK."

"To realise the full potential of the sector, we need long-term policy certainty, robust funding frameworks and a clear government strategy to build a thriving, competitive, and market-driven CCUS industry. This report is a blueprint for collaboration, and we look forward to working with all stakeholders to shape the future of CCUS in the UK."

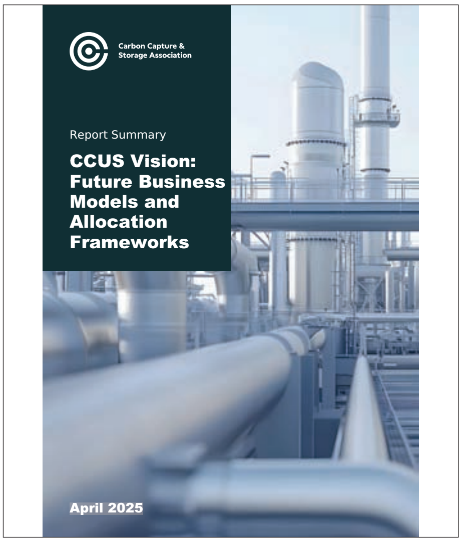
To ensure CCUS evolves into a sustainable, market-led sector, the report makes a number of recommendations, including:

• Clarifying the role of Government in long-term CCUS policy, regulation, and funding—moving toward reduced subsidies as markets mature.

• Improving value chain economics by strengthening carbon pricing, developing low-carbon product standards, and leveraging carbon dioxide removal market signals, with effective regulation where appropriate.

• Increasing pace and scale of delivery for CO2 transport and storage through more flexible, commercially-led models—including non-pipeline options, cross-border storage and reduced regulatory barriers for expansion.

Chris Thackeray, Director and Global CCS Lead, Baringa, and CCSA Board Member, said, "The UK has positioned itself as a global leader in CCUS policy and is set to deliver some of the first major privately financed



CCS clusters. We now have an opportunity to maintain this momentum with increased pace of delivery at the scale required to achieve climate mitigation and exploit this incredible industrial opportunity for the UK. We now need a sharp focus on how future projects are economically incentivised. Close collaboration between industry and government will continue to be essential."

"We should develop allocation models that build on the lessons from the initial projects and drive the transition to a self-sustaining industry, with a well thought through market transition that reduces the subsidy burden on government whilst maintaining an investible proposition."

"Acting now will bring more long-term certainty for investors, reduce costs, and secure jobs across the UK's industrial heartlands and exploit our massive offshore storage potential — giving them a clear route to market and a sustainable future."

More information

www.ccsassociation.org

Arup report offers blueprint for a successful UK CCS market

Research by global engineering and sustainable development consultancy Arup commissioned by OEUK shows that in the right conditions the UK's CCS sector can rapidly become a viable international business.

The sector is currently reliant on government support but the pathfinding report, commissioned by Offshore Energies UK (OEUK), outlines nine key steps for the creation of a commercial framework which will provide a springboard for a self-sustaining CCS industry in the UK.

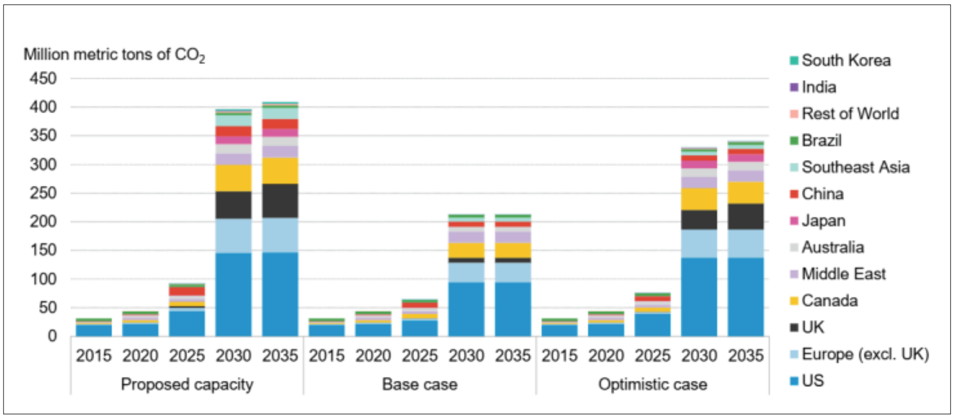
Enrique Cornejo, OEUK's Head of Energy Policy, said, "The UK's CCUS sector has marked an important milestone with the East Coast Cluster reaching financial investment decision and the granting of the first CO2 storage permit for the Endurance carbon storage site in the North Sea."

"We want to see a self-sustaining CCS market within the next decade for gas-fired power, cement, waste to energy and hydrogen production. This depends on cost reductions by better collaboration and use of technology, and the development of a pan-European carbon market with the UK at its core."

"To unlock this self-sustaining future we are looking for government to announce a clear funding envelope for Track-2 carbon capture clusters, Acorn in northern Scotland and Viking on Humberside, which are due to be operational by 2030, and a pathway for those projects that sit outside of the current process."

More than 120 of OEUK's 400-plus member organisations are already active in the UK's CCS sector, demonstrating the strong transferability of skills and capabilities from the oil and gas industry to CCS.

The Arup report titled 'Carbon Capture & Storage in the UK: Accelerating towards the merchant model' outlines nine steps to unleash a commercially self-sustaining CCS industry in the UK and underlines the need for the UK to accelerate development of the so-called Track-1 projects, the East Coast Cluster carbon storage scheme which will decarbonise heavy industries in Teesside and Humberside, and the Hynet CCS scheme which will perform the same function on Merseyside.



Annual carbon capture capacity forecast, by market and commissioning year (including EOR), BloombergNEF 2024

It also calls on the government to make a full commitment to the Track-2 plans for two further carbon capture clusters, Acorn in northern Scotland and Viking on Humberside, which are due to be operational by 2030.

Once these projects are up and running the UK will offer a sustainable international carbon capture and storage market with revenue generated from the sale of carbon capture, storage and transportation services to industrial emitters.

Further revenue will be generated by European Union or UK carbon emissions trading schemes, and by trades in carbon as a by-product of hydrogen production, cement production and other energy intensive industrial processes.

Among the other key areas identified by the report for the development of a carbon trading market, are network interconnectivity, technological advances and reducing the cost of CCS within the value chain of finished products.

The UK must capture and store 20-30 million tonnes of carbon dioxide per annum by 2030 and 40- 50 million tonnes per annum by 2035, to meet government net zero commitments.

The UK Continental Shelf is a globally important producer of oil and gas and has huge potential to safely store industrial emissions in depleted oil and gas fields and saline aquifers.

The UK can therefore play a major role in helping European nations store carbon emissions and meet its own net zero targets while promoting energy security, protecting industrial activity and prolonging the value of North Sea infrastructure.

Robert Hines, Senior CCS Consultant at Arup, said, "CCS has an important role to play in decarbonising hard to abate sectors by 2050. The UK has the foundations to become a major carbon storage provider, drawing from the skills of its oil and gas industry and geological resources that have the potential to provide vast amounts of storage."

"A self-sustaining commercial market is what everyone is aiming for and this report highlights viable routes to get there."

More information

www.arup.com

https://oeuk.org.uk

Projects and policy news

Stockholm Exergi takes final Investment decision on world's first large-scale BECCS project

www.capsoltechnologies.com
www.stockholmexergi.se

The project will deploy Capsol Technologies' carbon capture solution to permanently remove 800,000 tonnes of CO2 annually from 2028 and is backed by offtake agreements with Microsoft and Frontier Group.

Stockholm Exergi's project has received EUR 180 million from the EU Innovation Fund, as well as long-term offtake commitments from Microsoft (3.33 million tonnes) and Frontier Group (USD ~50 million), which includes Meta, Stripe, Alphabet, Shopify and McKinsey.

"This breakthrough is the result of Stockholm Exergi's pioneering efforts, strong market momentum for carbon removals, government support, and our cost-efficient, energy-smart technology," said Wendy Lam, CEO of Capsol Technologies.

"It sets a global precedent for BECCS deployment and further strengthens confidence in Capsol's technology."

Capsol's end-of-pipe solution, CapsolEoP®, can deliver 20–60% lower levelised capture costs compared to amine-based technologies, enabled by integrated heat recovery and generation, the company said.

The technology is particularly attractive for energy-from-waste and biomass plants with limited excess heat and is delivered as a standalone unit using the proven Hot Potassium Carbonate (HPC) solvent.

Capsol currently has biomass and EfW projects with a mature pipeline potential of 7.8 million tonnes of CO2, translating into EUR 80–115 million in potential license revenues based on a target of EUR 10–15 per tonne.

"With the first FID for a large-scale project using our technology now in place, we expect this to accelerate commercial traction and derisk adoption across industries," said Lam.

Stockholm Exergi's decision highlights the scalability of BECCS and Capsol's growing role in enabling carbon-negative projects globally.

The CCS facility at Filbornaverket in Helsingborg is estimated to cost approximately SEK 3 billion and will capture 200,000 tonnes of carbon dioxide annually

Unique CCS project approved in Helsingborg, Sweden

www.oresundskraft.se

The City Council of Helsingborg, Sweden, has voted with a clear majority to move forward with a CCS facility at the Filbornaverket combined heat and power plant.

The initiative combines climate policy with a technological solution that will become one of the first of its kind in Sweden and Europe. Öresundskraft is also Sweden's first municipally owned energy company to secure an investment decision for a CCS project.

The goal is for the facility to be operational by 2028, making it one of the first full-scale CCS installations in Sweden and Europe linked to a combined heat and power plant.

Stefan Håkansson, CEO of Öresundskraft, said, "This project makes it possible both to prevent large volumes of carbon dioxide from being released into the atmosphere and to remove CO2 that is already there actively. It is a crucial step in helping Helsingborg achieve net-zero emissions by 2030. With strong national and international support from the EU and the Swedish Energy Agency, we are taking a major step toward realizing a solution that strengthens Helsingborg's climate efforts and paves the way for other cities in Sweden and Europe."

The project is already advanced and has received significant national and international support. The EU Innovation Fund and Sweden's Industriklivet initiative have awarded the project approximately EUR 54 million and EUR 3 million, respectively – a clear recognition of its potential and credibility.

Öresundskraft is currently in advanced discussions with storage operators and transport companies and is in the final stages of selecting a construction contractor. Market interest is strong, and agreements for the future purchase of negative emissions certificates have already been signed with companies, including Wihlborgs and Helsingborgshem.

Without CCS, extensive and costly reconstructions would be necessary when emission allowances are phased out in 2039, likely leading to higher district heating costs for customers. With CCS, Helsingborg secures a competitive and sustainable district heating system for the future.

The project's next phase will focus on more detailed analyses, contracting suppliers, and updating the profitability assessment to secure the feasibility further. In early 2026, the Helsingborg City Council is expected to make the final decision to commence construction and move the project into full implementation.

Converting CO2 into fuel – with the help of battery waste

A nanocatalyst has been produced at TU Wien based on spent batteries and aluminium foil residues, converting CO2 into valuable methane.

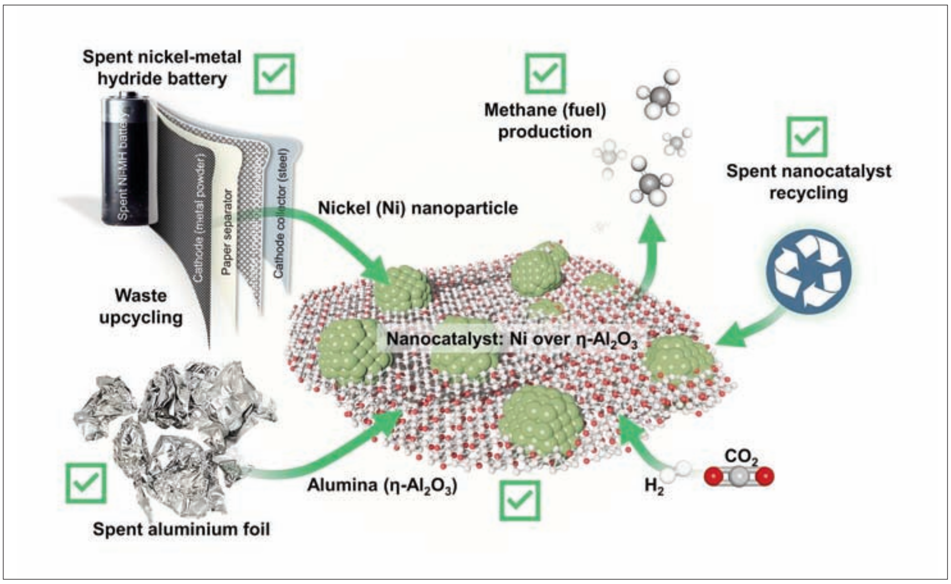
Battery waste is a serious environmental problem: it contains substances that pose a threat to both human health and ecosystems. At the same time, however, they also contain valuable materials such as nickel, which we need – for example, for the production of new batteries. Better recycling methods for batteries are therefore urgently required.

At TU Wien, it has now been possible to develop a process that can be used to recover nickel from spent nickel-metal hydride batteries. But that's not all: from this battery waste and used aluminium foil, such as that used in the kitchen, it was possible to produce a nanocatalyst that converts CO2 into valuable methane. In this way, one can reduce the waste problem on the one hand and at the same time obtain a climate-neutral fuel.

"Modern batteries, such as nickel-metal hydride (Ni-MH) and lithium-ion batteries, consist of different components, which makes recycling and recovery processes technologically challenging," said Prof. Günther Rupprechter from the Institute of Materials Chemistry at TU Wien, head of the research project. "Improper disposal can lead to chemical leaks, fires, and pollution."

The recovery of nickel from spent Ni-MH batteries is also highly important economically: In the EU, waste batteries and scrap from battery production could provide around 16% of the nickel needed by 2030, which is enough to equip 1.3 to 2.4 million electric vehicles (EVs) annually.

Despite this potential, current recycling capacity in the EU and the UK is only about one-tenth of what is needed by 2030. Investments in recycling infrastructure are therefore necessary.



Transforming battery/aluminium waste into nanocatalysts for methane (fuel) production and recycling spent nanocatalysts into catalyst precursors

Upcycling: From waste recycling to CO2 capture

"Recycling is an important step, but even greater impact can be achieved by upcycling nickel into catalysts capable of producing fuels," said Dr. Qaisar Maqbool, first author of the study.

The team extracted nickel from used Ni-MH batteries and recovered alumina from used aluminium foil. These materials were then converted into a high-performance nanocatalyst in an environmentally friendly way – using green chemistry methods.

"Our nanocatalyst consists of 92-96% aluminium oxide and 4-8% nickel, which is optimal for converting the greenhouse gas CO2 together with hydrogen into methane," explained Günther Rupprechter. The process requires neither high pressure nor high temperatures, the catalyst works at atmospheric pressure and an easily achievable temperature of 250°C.

This provides a method for converting CO2 into a valuable fuel in a climate-neutral way: Methane plays an important role as an energy source in industry, for example. "Now we want to investigate how this process can be scaled up for technological applications," said Prof. Günther Rupprechter. "We believe that this approach can transform sustainable fuel production. Our approach shows a solution to the climate problem – and in a way that also helps to solve a pressing waste problem."

Many catalysts deactivate over time – because the catalyst changes structurally at some point or becomes less effective due to the accumulation of coke (carbon). Such a deactivation was not detected in the study. Nevertheless, it was important to the team to think in closed cycles and to consider how the catalyst itself can also be recycled.

"To close the sustainability loop, you can recycle the spent catalysts back into their original precursors to be reused," said Dr. Qaisar Maqbool. This ensures that the entire process remains environmentally friendly, and the amount of waste is minimized

More information

www.tuwien.at

Capture of carbon dioxide without gas separation – a game-changer?

Costly gas separation can be avoided with chemical-looping combustion, and the scaling-up of the technology is now beginning. For blue hydrogen, there is even potential for negative capture costs. By Professor Anders Lyngfelt, Chalmers University of Technology, Sweden.

A key challenge with carbon capture and storage is the high cost and energy demand of gas separation. For example, when using MEA to capture CO2 from solid fuels such as biomass or coal, nearly 40% of the fuel's heat output is consumed in the separation process.

Chemical-looping combustion (CLC), however, enables CO2 capture without the need for costly gas separation. The magic bullet is the oxygen-carrier material, a metal oxide (MeO) that transfers oxygen from the air to the fuel. As a result, the combustion products — carbon dioxide and steam (CO2 + H2O) — are obtained in a separate gas stream, Fig. 1, with steam easily removed through condensation.

The system uses two interconnected fluidized bed reactors: an air reactor and a fuel reactor — between which the oxygen carrier circulates. These reactors resemble circulating fluidized-bed (CFB) boilers, Fig. 2, widely used for burning coal or biomass.

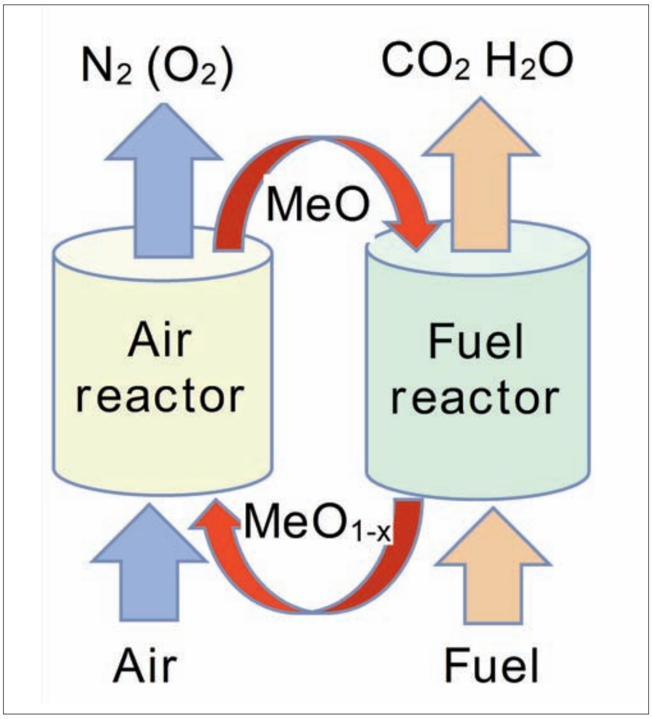


Fig. 1 - CLC principle

Fig. 2 - Circulating fluidized bed (CFB) boiler

A fluidized bed consists of a granular medium, such as sand, through which gas is blown, making it behave like a fluid. As in a CFB, gas velocities reach up to 6 m/s and the particle size is 0.1-0.3 mm. The temperature is typically 900-1000°C, but up to 1100°C is possible. Low-cost natural ores such as ilmenite and manganese ore can be used as oxygen carriers.

Does it work in practice? It does. Over 50 pilot units have demonstrated this technology, accumulating more than 12,000 h of operation. While most of this development has occurred in Europe, China is now at the forefront. In Chengdu, the world's largest CLC unit, Fig. 3, has operated successfully for over 500 h.[1] The next step is a 20 MW CLC plant with power production, planned to be operational in 2027.

Since the air reactor can be designed as a CFB, a combined CFB-CLC boiler can be built, Fig. 4, allowing for operation in both CLC and conventional CFB modes.[2] Particle circulation is achieved by collecting the downfall of solids along the air reactor walls. These are routed to the fuel reactor via an upper loop seal (yellow) and returned through a lower loop seal (green). These fluidized loop seals act like plumbing traps, keeping the gases in the two reactors separated.

Since the air reactor doubles as a CFB, the additional cost of a CLC system is limited to the fuel reactor, Fig. 4. The fuel reactor is constructed with uncooled boiler walls, costing about €2,000/m2 . With an additional wall area of 1,500 m2, the added investment would be 3 M€, or around 0.3 M€/year.

A 200 MW CFB-CLC plant can capture 0.4 MtCO2 annually, translating to a capture cost induced by the fuel reactor of less than €1 per tonne of CO2.[2]

This dual-function design significantly reduces the financial risk of a first-of-its-kind commercial-scale CLC demonstration.

Preparing CO2 for transport involves addi-

Fig. 3 - 5 MW CLC[1]

tional costs. As with other capture technologies, compression to high pressure is required. Also, residual combustibles in the CO_2 stream must be removed, which is done through oxy-polishing — requiring some oxygen production. Even though ilmenite ore, a low-cost oxygen carrier, was used, the Chinese pilot showed a residual oxygen demand of just 3-8%.

This corresponds to a 92-97% reduction in gas separation effort compared to oxy-fuel combustion. Ilmenite is more expensive than the sand or limestone typically used in CFBs, which adds a few euros per tonne of CO2 captured.

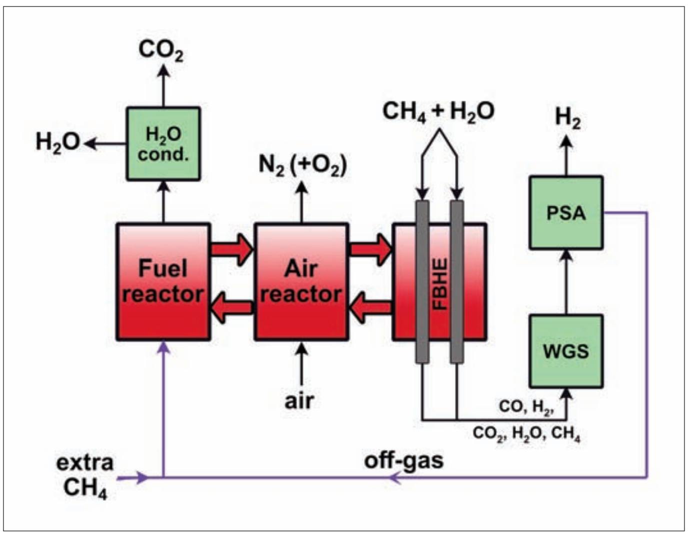


Fig. 5 - CLC-SMR

Despite these additions, the total cost of CLC is estimated at 20-30 €/tCO2 —far below competing technologies.[2] By contrast, Stockholm Exergi was recently awarded 1.8 M€ to capture 11 MtCO2 — stated to be one-third of project funding. This implies a total cost, including transport and storage, of 490 €/tonne.

CLC can also be combined with conventional steam methane reforming (SMR), Fig. 5, to produce blue hydrogen, offering important advantages.[3] In addition to inherent CO2 capture, the heat is transferred to the reformer tubes in fluidized-bed heat exchangers (FBHEs) instead of high temperature flame furnaces.

Since reformer tubes must reach around 900°C, conventional reformer furnaces operate under harsh conditions. FBHEs, by contrast, offer efficient heat transfer and allow for lower combustion temperatures.

A reduction of 250°C in the outlet gas temperature means more of the combustion heat is used for the reforming, improving energy efficiency of hydrogen production. Additionally, the more benign thermal environment allows for thinner and narrower tubes, enhancing heat transfer, leading to shorter tubes and reduced need for catalyst.

Overall, this could make it feasible to capture CO2 at a negative net cost.[3]

In conclusion, CLC could capture CO2 from combustion of solid fuels at greatly reduced cost and, in the case of blue hydrogen, capture costs could even be negative.

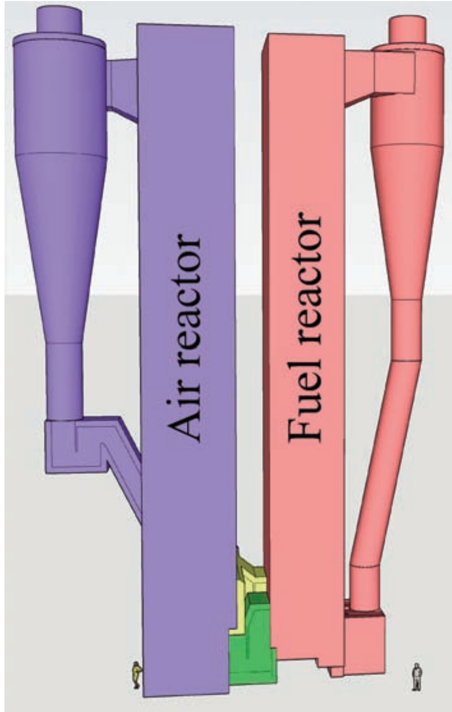


Fig. 4 - 40 m high 200 MW CFB-CLC boiler[2]

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3) Lyngfelt, A., How to Capture CO2 without the costly and Energy-demanding Gas Separation (presentation), Carbon Capture Summit Europe, June 26-27, Amsterdam 2023. www.entek.chalmers.se/lyngfelt/presentations/Amsterdam2023.pdf

More information

www.chalmers.se

Scientists crack decades-old puzzle in CO2-to-fuel conversion

Scientists in the Liquid Sunlight Alliance (LiSA) DOE Energy Innovation Hub have gained new insight into electrochemical CO2 reduction, a process by which energy from the sun can be used to convert carbon dioxide into useful products such as liquid fuels or other chemicals.

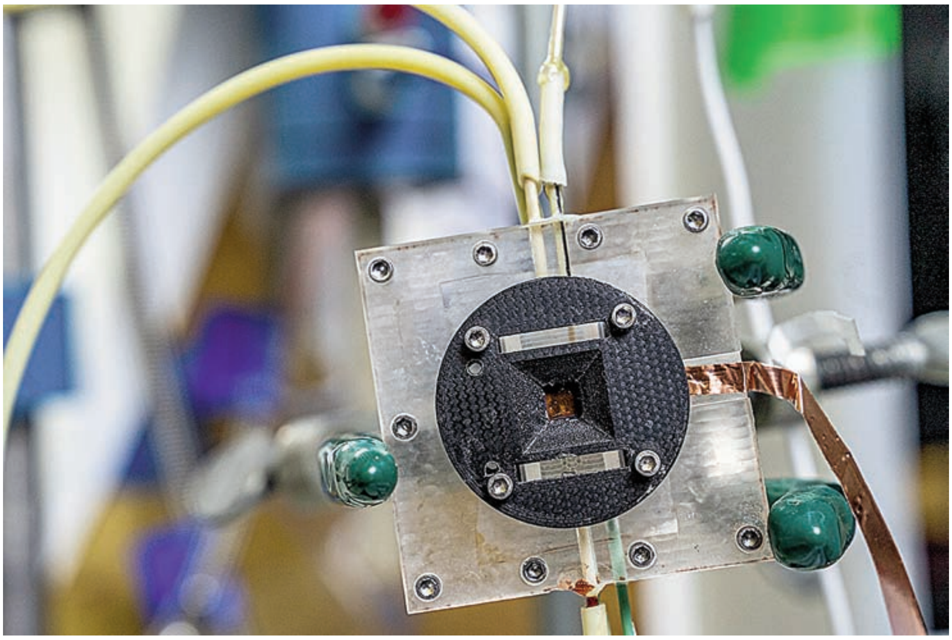
New research has revealed the fundamental mechanisms that limit the performance of copper catalysts – critical components in artificial photosynthesis that transform carbon dioxide and water into valuable fuels and chemicals.

In a study co-led by scientists at Lawrence Berkeley National Laboratory (Berkeley Lab) and SLAC National Accelerator Laboratory, researchers have used sophisticated X-ray techniques to directly observe how copper nanoparticles change during the catalytic process. By applying small-angle X-ray scattering (SAXS) – a technique traditionally used to study soft materials like polymers – to this catalyst system, the team gained unprecedented insights into catalyst degradation that has puzzled scientists for decades.

The work is part of the Liquid Sunlight Alliance (LiSA) DOE Energy Innovation Hub. Led by Caltech in close partnership with Berkeley Lab, LiSA brings together more than 100 scientists from national lab partners at SLAC and the National Renewable Energy Laboratory, and university partners at UC Irvine, UC San Diego, and the University of Oregon. Launched in 2020, this multi-institutional collaboration is developing the scientific principles needed to efficiently and selectively generate liquid fuels from sunlight, water, carbon dioxide, and nitrogen.

The CO2 electrochemical reduction reaction (CO2RR) process has intrigued scientists for decades as a promising way to make fuel and other important compounds. A big breakthrough in the 1980s identified copper as a high-performing catalyst for transforming CO2 and water into starting ingredients for liquid fuels and chemicals like ethylene and ethanol.

Subsequent studies showed that copper contains active sites where electrocatalysis takes place: electrons from the copper surface interact with carbon dioxide and water in a sequence of steps that transform them into products like ethanol fuel and ethylene for plastics. Researchers are investigating ways to tune these active sites to selectively produce specific chemicals, including ethanol, ethylene, and propanol.



Close-up of an electrochemical device custom-designed for observing CO2 reduction. Credit: Marilyn Sargent/Berkeley Lab

But copper's super-catalytic properties quickly degrade during CO2RR, diminishing its performance over time. Through the years, researchers have looked for ways to prevent this performance loss, but the chemical and physical processes that control this degradation were unclear.

With the Berkeley Lab and SLAC researchers' study – published recently in the Journal of the American Chemical Society – those processes are less mysterious thanks to an innovative application of scattering and imaging techniques that allowed the researchers to identify and observe two competing mechanisms that drive copper nanoparticles to the brink of degradation in a CO2RR catalyst: particle migration and coalescence (PMC), in which smaller particles combine into larger ones, and Ostwald ripening, where larger particles grow at the expense of smaller particles.

"Our approach allowed us to explore how the nanoscale size distribution evolves as a function of operating conditions, and to identify two different mechanisms that we can then use to guide our efforts to stabilize these systems and protect them from degradation," said Walter Drisdell, a co-corresponding author on the paper who is also a staff scientist in Berkeley Lab's Chemical Sciences Division and principal investigator with LiSA.

In this study, the researchers used a technique called small angle X-ray scattering (SAXS) at the Stanford Synchrotron Radiation Lightsource (SSRL) at SLAC to track the size and shape distributions of uniformly shaped 7-nanometer copper oxide nanoparticles under various electrical voltages in a custom-designed electrochemical cell with an aqueous electrolyte.

When running the CO2RR reaction for an hour, the researchers found that the PMC process dominates in the first 12 minutes, and then after that, Ostwald ripening takes over. Under the PMC mechanism, the nanoparticles migrate and coalesce into clusters.

When the Ostwald ripening process takes over, smaller nanoparticles dissolve and redeposit onto larger nanoparticles, the same process that can create crunchy water crystals in ice cream.

Further analyses in the current study showed that lower voltages, where reactions are slower, trigger the migration and agglomeration of the PMC process – and larger voltages speed reactions up, increasing the dissolution and redeposition process of Ostwald ripening

Separate in situ X-ray absorption spectroscopy (XAS) measurements at SSRL show that the copper-oxide nanoparticles reduce to copper metal before restructuring begins, and post-mortem imaging confirmed that the nanoparticles had migrated and formed large agglomerates. The imaging was achieved using advanced electron microscopy techniques at Berkeley Lab's Molecular Foundry.

"These results suggest various mitigation strategies to protect catalysts depending on the desired operating conditions, such as improved support materials to limit PMC, or alloying strategies and physical coatings to slow dissolution and reduce Ostwald ripening," Drisdell said.

In future studies, Drisdell and team plan to test different protection schemes, and continue working with their LiSA colleagues at Caltech to design catalytic coatings with organic molecules, and test these coatings' ability to steer CO2RR reactions into producing specific fuels and chemicals.

Scientists develop artificial leaf to convert CO2 to chemicals

Berkeley researchers have built a perovskite and copper-based device that converts carbon dioxide into C2 products – precursor chemicals of innumerable products from plastic polymers to jet fuel.

Researchers from the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) along with international collaborators have brought us one step closer to harnessing the sun's energy to convert carbon dioxide into liquid fuel and other valuable chemicals.

In a recent publication in Nature Catalysis, the researchers debut a self-contained carbon-carbon (C2) producing system that combines the catalytic power of copper with perovskite, a material used in photovoltaic solar panels.

This advance builds on over 20 years of research and brings the scientific community one step closer to replicating the productivity of a green leaf in nature. This work is part of the Liquid Sunlight Alliance (LiSA).

"Nature was our inspiration," said Peidong Yang, a senior faculty scientist in Berkeley Lab's Materials Sciences Division and UC Berkeley professor of chemistry and materials science and engineering involved in the published work.

"We had to work on the individual components first, but when we brought everything together and realized that it was successful, it was a very exciting moment."

To build a system that mimics photosynthesis, Yang and his team followed the natural processes that occur in the leaf of a plant. Each individual component of a leaf's photosynthesizing elements had to be replicated and refined. Tapping into the decades' worth of research, the scientists used lead halide perovskite photoabsorbers to imitate a leaf's light-absorbing chlorophyll. And inspired by enzymes that regulate photosynthesis in nature, they designed electrocatalysts made of copper that resemble tiny flowers.

Previous experiments have successfully replicated photosynthesis through the use of biological materials, but this work incorporated an inorganic material, copper. While the selectivity of copper is lower than biological alternatives, the inclusion of copper presents a more durable, stable, and longer-lasting option for the artificial leaf system design.

Work led by researchers in the LiSA project developed the cathode and anode components of the new device. Instruments at Berkeley Lab's Molecular Foundry allowed Yang's team to integrate the device with metal contacts. During the experiments in Yang's lab, a solar simulator mimicking a consistently bright sun was used to test the selectivity of the new device.

Prior innovations across research groups enabled an organic oxidation reaction to take place in the photoanode chamber and created C2 products in the photocathode chamber. This breakthrough created a realistic artificial-leaf architecture in a device about the size of a postage stamp – it converts CO2 into a C2 molecule using only sunlight.

The C2 chemicals produced from this device are precursor ingredients for many industries that produce valuable products in our everyday lives – from plastic polymers to fuel for larger vehicles that can't yet run off a battery, like an airplane. Building upon this fundamental research milestone, Yang is now aimed to increase the system's efficiency and expand the size of the artificial leaf to begin increasing the scalability of the solution.

More information

Learn more about the LiSA collaboration in this roundup, "Five Ways LiSA is Advancing Solar Fuels."

https://newscenter.lbl.gov/2024/08/29/five-ways-lisa-is-advancing-solar-fuels

https://foundry.lbl.gov

Scalable graphene membranes: a leap for carbon capture

Scientists at EPFL have developed a scalable method to produce porous graphene membranes that efficiently separate carbon dioxide. The breakthrough could significantly reduce the cost and footprint of carbon capture technology.

Capturing carbon dioxide from industrial emissions is crucial in the fight against climate change. But current methods, like chemical absorption, are expensive and energy-intensive. Scientists have long eyed graphene—an atom-thin, ultra-strong material—as a promising alternative for gas separation, but making large-area, efficient graphene membranes has been a challenge.

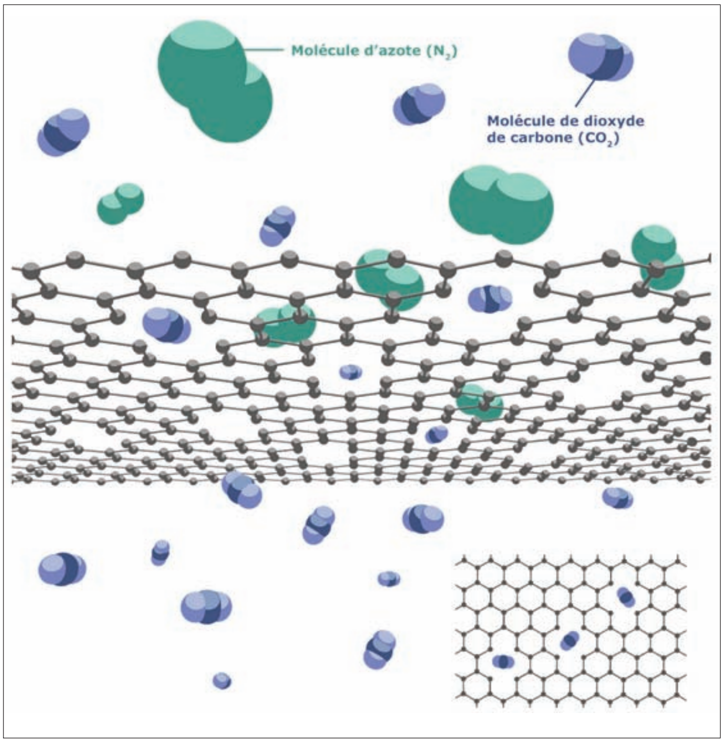
Now, a team at EPFL, led by Professor Kumar Agrawal, head of the Gaznat Chair in Advanced Separations, has developed a scalable technique to create porous graphene membranes that selectively filter CO2 from gas mixtures. Their approach slashes production costs while improving membrane quality and performance, paving the way for real-world applications in carbon capture and beyond.

Graphene membranes are excellent at separating gases because they can be engineered with pores just the right size to let CO2 through while blocking larger molecules like nitrogen. This makes them ideal for capturing CO2 emissions from power plants and industrial processes. But there's a catch: manufacturing these membranes at a meaningful scale has been difficult and costly.

Most existing methods rely on expensive copper foils to grow high-quality graphene needed for membranes and require delicate handling techniques that often introduce cracks, reducing membrane efficiency. The challenge has been to find a way to create large, high-quality graphene membranes in a cost-effective, reproducible manner.

The EPFL team tackled these challenges head-on. First, they developed a method to grow high-quality graphene on low-cost copper foils, dramatically cutting down material expenses. Then, they refined a chemical process using ozone (O3) to etch tiny pores into the graphene, allowing for highly selective CO2 filtration. Crucially, they improved how the gas interacts with the graphene, ensuring uniform pore formation over large areas—a key step toward industrial scalability.

To solve the issue of membrane fragility, the researchers also introduced a novel transfer technique. Instead of floating the delicate graphene film onto a support, which often leads to cracks, they designed a direct transfer process inside membrane module that eliminates handling issues and reduces failure rates to near zero.



A graphene membrane separating CO2 from N2. 2025 EPFL/Ivan Savicev CC-BY-SA 4.0 2025 EPFL

Using their new approach, the researchers successfully created 50 cm^2 graphene membranes—far larger than what was previously feasible—with near-perfect integrity. The membranes demonstrated exceptional CO2 selectivity and high gas permeance, meaning they efficiently let CO2 through while blocking unwanted gases.

Moreover, by optimizing the oxidation process, they were able to increase the density of CO2-selective pores, further enhancing performance. Computational simulations confirmed that improving gas flow across the membrane played a crucial role in achieving these results.

Traditional CO2 capture technologies rely on energy-intensive chemical processes, making them complex and expensive for widespread use. Graphene membranes, on the other hand, require no heat input, and operate using simple pressure-driven filtration, significantly reducing energy consumption.

Beyond carbon capture, this method could be applied to other gas separation needs, including hydrogen purification and oxygen production. With its scalable production process and cost-effective materials, EPFL's innovation brings graphene membranes one step closer to commercial viability.

More information

www.epfl.ch

Yale chemists discover a new method for reducing carbon dioxide

In a new study, Yale chemists describe an unusual method for converting carbon dioxide into the industrial compound formate, which is used primarily in preservatives and pesticides.

The world's demand for alternative fuels and sustainable chemical products has prompted many scientists to look in the same direction for answers: converting carbon dioxide (CO2) into carbon monoxide (CO).

But the labs of Yale chemists Nilay Hazari and James Mayer have a different chemical destination in mind. In a new study, they and their collaborators present a new method for transforming CO2 into a chemical compound known as formate, which may be a potential source of more complex materials.

The finding opens a new pathway for chemical discoveries, they say, and widens the possibilities for addressing environmental problems by transforming greenhouse gases into useful products. The new study appears online March 7 in the journal Chem.

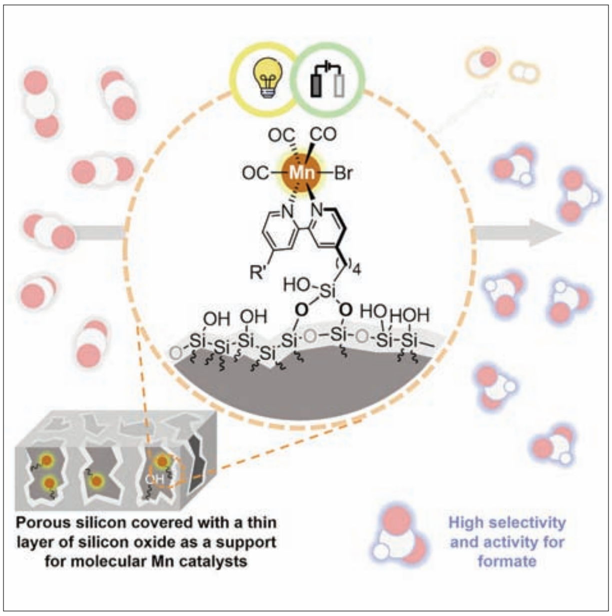
"Most of our fuels and commodity chemicals are currently derived from fossil fuels," said Hazari, the John Randolph Huffman Professor of Chemistry, and chair of chemistry, in Yale's Faculty of Arts and Sciences (FAS). "Their combustion contributes to global warming and their extraction can be environmentally damaging. Therefore, there is a pressing need to explore alternative chemical feedstocks."

Hazari, who is also a member of the Yale Center for Natural Carbon Capture, and Mayer, the Charlotte Fitch Roberts Professor of Chemistry in FAS, are co-corresponding authors of the study. They are also part of the Center for Hybrid Approaches in Solar Energy to Liquid Fuels (CHASE), a federally funded solar energy research hub based at the University of North Carolina-Chapel Hill.

The challenges for transforming CO2 into usable products — on an industrial scale — are formidable. Such processes require new catalysts that work under milder conditions (less extreme temperatures and pressures) and exhibit higher productivity and stability than currently available catalysts.

For the new study, the research team focused on a relatively under-explored type of catalytic system called an immobilized molecular catalyst. This is a system featuring a molecular catalyst that is attached to a solid support material.

The researchers developed molecular manganese catalysts that were attached to semiconducting, thermally oxidized porous silicon. When exposed to light, the silicon absorbs the light and transfers electrons to the manganese catalyst, which then converts CO2 to formate.



Yale chemists have developed a novel method for converting carbon dioxide (left) into the industrial compound formate (right)

"Formate is a very appealing product, as it is a potential stepping-stone to materials used industrially in very large quantities," Mayer said. "Our work here opens the door to the use of readily available porous silicon as a support for molecular catalysts, in part because it establishes that the presence of a thin oxide layer improves catalyst selectivity and stability."

The researchers had previously worked with hydride terminated porous silicon, said Eleanor Stewart-Jones, a graduate student in chemistry at Yale and co-lead author of the study.

"There's a rich literature studying the modification of porous silicon surfaces," she said. "Knowing that these surface modifications can be used to tune catalysis will hopefully be impactful for future hybrid catalysts using porous silicon."

The researchers also noted that the discovery may have applications for catalysts that work with other chemical feedstocks, beyond CO2

The study's other co-lead authors are Xiaofan Jia of Yale and former Yale researcher Young Hyun Hong, now of Sogang University in the Republic of Korea.

Co-authors from Yale are Abhishek Kumar, Justin Wedal, Jose Alvarez-Hernandez, Albert Gang, Noah Gibson, Madison Houck, Brandon Mercado, Hannah Nedzbala, Nicole Piekut, and.Christine Quist. Additional co-authors are Carrie Donley from the University of North Carolina at Chapel Hill and Sungho Jeon, Jongbeom Kim, Hyeongjun Koh, Eric Stach, and Yihui Zhang of the University of Pennsylvania.

CHASE, an Energy Innovation Hub funded by the U.S. Department of Energy's Office of Science, supported the research, along with the Yale Center for Natural Carbon Capture.

More information

https://chem.yale.edu

Safe and efficient carbon capture with amine solvents

When capturing CO2 from industrial sources, a capture agent is used, most often amine solvents. A new report from SINTEF provides guidelines on how industry can choose the right solvent technology.

When capturing CO2 from industrial sources, a capture agent is used, most often amine solvents. A new report provides guidelines on how industry can choose the right solvent technology.

When CO2 is captured from flue gases released from industrial sources, a substance that binds CO2 is used. The most used substance today are amine solvents. This technology is, for example, used at the cement factory in Brevik and will also be installed at the waste incineration plant at Klemetsrud in Oslo.

For successful implementation of carbon capture, it is crucial that the amine solvent is stable. This new report addresses various factors that affect the stability of the capture medium.

The report is made by SINTEF in collaboration with NTNU, as part of the international research collaboration on carbon capture and storage, NCCS.

Many alternatives on the market

There are many alternatives amine solutions on the market. Therefore, it is important to know whether the solvent or technology supplier has conducted the important and correct tests.

With the information package provided with this report, it will be easier to understand the various aspects of amine stability.

The report is intended to be a tool for industrial players who want to capture CO2, but also for suppliers, authorities, and other stakeholders. It provides an overview of various factors to consider so that the capture plant can be operated in the most efficient, risk-free, environmentally friendly, and economically profitable way.

"Safe and wise choices are crucial when it comes to solvent technology. Having control over what happens with the solvent in the process over time will make it easier to operate the plant efficiently and economically."

"This can involve impacts on operation, affecting the efficiency or functionality of the amines, or environmental impacts," said SINTEF researcher Vanja Buvik.

Amine solvents will be installed at the waste incineration plant at Klemetsrud in Oslo

Facing a tough environment

In the carbon capture process, CO2 is first bound at low temperature and then separated out at a high temperature. In the process, the amines should be as stable as possible, but this is not obviously easy to predict or ensure.

The conditions faced by the amines are challenging, including heating to just over 100°C when releasing the pure CO2 and exposure to various substances and conditions that can trigger reactions.

"Among other things, industrial gases contain oxygen, which also can react with the amines to form compounds that cannot capture CO2, resulting in a loss of capture capacity. Different amines also have varying tendencies to oxidise, making it crucial to determine the exact oxidation resistance of the amine you intend to use in your process, " Vanja Buvik explained, adding:

"High temperatures and the presence of certain metals can also significantly accelerate the oxidation process, but high temperatures alone can also be a direct cause of the amines breaking down. In addition to testing their resistance towards the tough process conditions, it is also important to test the stability of the amines in contact with nature:

"If the amines were to be released into the environment, it is important to know that they will not cause harm to humans or other organisms. Ideally, we want the amines to be biodegradable and not give rise to any negative effects on the environment and safety. This is important both for the local environment and for those working at the capture plant." Buvik explained.

More information

https://nccs.no/research

www.sintef.no

Capture & utilisation news

BASF and Forestal collaborate on e-methanol production

www.tklmethanol.es
www.oase.basf.com

Forestal will use BASF's proprietary OASE® technology for efficient CO_2 removal in the production of e-methanol from captured CO_2.

BASF and Forestal de Atlántico S.A. have signed an early disclosure agreement (EDA) aimed at advancing the production of e-methanol (eMeOH) through carbon capture solutions. Under this strategic partnership, BASF has been selected to share its proprietary OASE® blue technology, designed for the efficient removal of CO_2 from flue gases, for use in Forestal's pioneering Triskelion project in Galicia, Spain.

“By utilizing CO_2 captured from our production processes, we are embracing a more sustainable approach to fuel production,” stated Andrés Fuentes, CEO of Forestal del Atlántico.

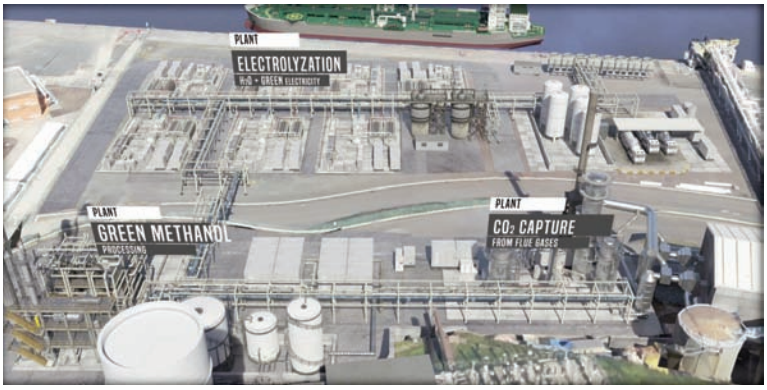
“This partnership with BASF not only enhances our capabilities but also contributes to the development of sustainable fuels, particularly in the maritime industry.”

The Triskelion project has a design capacity of 156 metric tons per day of e-methanol production. The CO_2 captured from the exhaust gases of electricity generating turbines will be transformed into e-methanol by reacting it with renewable hydrogen, highlighting an innovative approach to a more sustainable fuel production.

The EDA facilitates the essential input from BASF for the Front End Engineering Design (FEED), which will be developed by a third-party contractor hired by Forestal. This process will enable Forestal to assess the project's clarity, vision, technical feasibility and economic viability, allowing them to share the design with other contractors for competitive construction bids.

“This partnership addresses the critical need for innovative solutions in carbon capture and utilization, marking a significant stride towards reducing global emissions,” said Torsten Katz, Global Business Director, OASE Gas Treating Technologies, in BASF's Intermediates division.

“By collaborating with Forestal, we are setting the foundation for one of the first plants to produce e-methanol using our OASE technology, entering into an innovative sustainable application area for our OASE blue technology.”



BASF's proprietary OASE® blue technology, designed for the efficient removal of CO_2 from flue gases, will be used in Forestal's pioneering Triskelion project in Galicia, Spain

Aramco launches Saudi Arabia's first CO2 Direct Air Capture test unit

www.aramco.com
www.siemens-energy.com

A pilot plant capable of removing 12 tons of carbon dioxide per year has been established with Siemens Energy to assess commercial scale-up of DAC technology.

Aramco intends to use the facility as a testing platform for next-generation CO_2 capture materials in Saudi Arabia's distinct climate. It will also seek to achieve cost reductions that could help accelerate the deployment of DAC technologies in the region. Aramco and Siemens Energy intend to continue working closely together with the aim of scaling up the technology, potentially laying the foundations for large-scale DAC facilities in the future.

Ali A. Al-Meshari, Aramco Senior Vice President of Technology Oversight and Coordination, said, “Technologies that directly capture carbon dioxide from the air will likely play an important role in reducing greenhouse gas emissions moving forward, particularly in hard-to-abate sectors."

"The test facility launched by Aramco is a key step in our efforts to scale up viable DAC systems, for deployment in the Kingdom of Saudi Arabia and beyond. In addition to helping address emissions, the CO_2 extracted through this process can in turn be used to produce more sustainable chemicals and fuels.”

Such projects illustrate Aramco's strong focus on carbon capture, which represents a key pillar in the Company's ambition to achieve net-zero Scope 1 and Scope 2 greenhouse gas emissions across its assets by 2050. The Company is exploring options to capture CO_2 both at the point of emissions and directly from the atmosphere, through its circular carbon economy approach and the deployment of innovative technology solutions.

Recently Aramco and its partners, Linde and SLB, signed an agreement that paves the way for the development of a CCS hub in Jubail, Saudi Arabia. Phase one of the CCS hub will have the capacity to capture nine million tonnes of CO_2 from three Aramco gas plants and other industrial sources.

Dipeptides promising candidate for carbon dioxide capture

https://chem.utk.edu

Associate Professor Konstantinos Vogiatzis' lab at University of Tennessee at Knoxville is using computational chemistry to address excess CO_2 in the atmosphere.

CCS usually employs amine-based solvents , however this method has some limitations. The solvents used in this process are expensive, volatile, and can produce harmful byproducts that may increase cancer risks in humans.

Perenco completes UK's first CO2 injection test for CCS

The test involved the injection of CO2 into a depleted natural gas reservoir in the UK's Southern North Sea, marking a major milestone for Project Poseidon and the UK's broader decarbonisation strategy.

First UK CO2 injection test completes successfully in the Southern North Sea

Petrodec's ERDA, the first rig in the UK to have achieved an approved safety case for CO2 injection support, has now sailed away from the Leman 27H platform. This marks the end of the test which was carried out by the Project Poseidon Joint Venture, comprising Perenco UK, Carbon Catalyst Ltd, and Harbour Energy.

The Poseidon injection test delivered to plan with a total of 15 injection cycles performed into the Leman gas field, mobilising 11 CO2 offshore batch refills. The operational programme was performed in a timely and safe manner, without injection issues and, importantly, with the acquisition of an exceptional dataset.

This operation proves not only that Carbon Storage can be a reality for depleted fields of the Southern North Sea, but also that it is possible to widely reuse petroleum production infrastructure to unlock cost effective projects.

The injection test marked a successful collaboration across a number of organisations from the energy, CCS and service sectors, coordinated by Perenco UK - Petrodec - Dixstone. Perenco is hopeful that this project will strengthen confidence in the CCS industry by progressing the regulatory path and contributing to setting the technical standard for future UK CCS projects.

Armel Simondin, CEO, Perenco, commented, "This test has met our expectations, both in terms of technical execution and the quality of data gathered. These insights are instrumental as we move to the next phase of developing the Poseidon Project. The successful test highlights the role our industry can play in the UK's decarbonisation efforts. The Perenco CCS team and our joint venture partners are now fully focused on interpreting the results and converting new insights into an evidence-based development plan for Project Poseidon."

The project aims to deliver an initial injection capacity of 1.5Mtpa, rising to an ultimate capacity of 40Mtpa, commencing in 2029. The field is connected to the PUK Bacton Terminal, which will receive and process CO2 offshore.

More information

www.perenco-ccs.com

www.petrodec.eu

Better ways to do CO2 storage monitoring

For CO2 storage monitoring, 4D seismic is expensive and not technically suitable for all projects. Gravity, 2D and spot seismic, fibre optics / DAS and microseismic may be better. A UK study looked into it. By Karl Jeffery.

4D seismic, which monitors changes in the subsurface over time, has been considered by many people to be the most appropriate technology to use in monitoring CO2 stored in the subsurface.

It is normally by far the best way to get a granular picture of what is happening in a large volume of the subsurface.

But it is also expensive, with large ships doing operations for weeks with long streamers behind them, described as, in some cases, being the largest man-made moving objects on earth.

The data processing can take a lot of time. Altogether, it may be as many as 2 years between planning a survey and interpreting the data. This takes into account the time to organise and permit a survey, the time to acquire and process the data, and finally interpret the data and integrate it into reservoir models.

There are also concerns about the noise created by seismic sources, which could have a negative impact on sea life.

If the CO2 storage site has a wind farm nearby, that raises the question of whether seismic surveys are a practical monitoring method. “Our sense is that it may not always be,” says Ian Barron, one of the lead authors of a study by the CCUS Transport and Storage Task Force Monitoring Subgroup. He is a Senior Geoscientist with the North Sea Transition Authority, the regulator for offshore CO2 storage in the UK.

And seismic cannot always detect CO2 in the subsurface. It can work well in shallow aquifer stores, such as the Triassic Bunter Sandstone in the Southern North Sea. But for a depleted gas field, “it may be more difficult for the seismic to detect a change in the store,” he said.

In depleted fields, you may be able to detect CO2 movement through a time shift of the seismic signal’s arrival time at the base of the store (seismic reflections arriving at a different time, because of changes in wave velocity). But the image quality will depend on the rock physics in the individual store, he said.

You may want to use 4D seismic to monitor for possible leakage above the storage site, or to use it at the end of the injection period to get a full picture. But in this case 4D seismic is being used together with other technologies, rather than as the main technology.

As CO2 storage becomes more of a business (rather than being largely government supported, as it is in the initial stages), cost reduction will become much more important.

These are all reasons “why we don't necessarily want to rely on 4D,” he said.

“We encourage industry to get together to look at desktop feasibility studies followed by field trials” - Ian Barron, Senior Geoscientist with the North Sea Transition Authority

Some CO2 storage licensees are considering alternatives to 4D seismic, such as gravity surveys, Mr Barron said.

The Monitoring Subgroup of the CTS Taskforce authored a study looking into alternatives and how they could be brought into a Monitoring Plan. Co-authors came from Eni, CCSA, Harbour Energy, OEUK, Northern Endurance Partnership, Storegga and the Subsurface Task Force.

The study group recommended other technologies for evaluation, including measuring gravity changes, doing repeated straight line or 2D seismic surveys, fibre optic cables recording seismic on the seabed, fibre optic cables for recording seismic in wells, and microseismic - listening for very small seismic signals, perhaps generated from fractures or fluid movements in the subsurface.

The Monitoring Plan

Under UK CO2 storage regulations, CO2 storage operators must submit, at the point of applying for a storage permit, a monitoring Plan that must, among other things, enable the operator to compare the actual and modelled behaviour of injected CO2.

They should be able to detect any “significant irregularities” (something different to expected), which could evolve into a situation where there is a possibility of leakage. They must also be able to detect CO2 leakage. There must be a Corrective Measures Plan that sets out how to address any leaks or significant irregularities.

The Monitoring Plan needs to be put together for each store, based on the expected behaviour of carbon dioxide and risks associated with that behaviour. The monitoring plan needs to be updated every 5 years to keep in line with the evolving risk assessment.

The regulator (NSTA) prefers monitoring plans not to be reliant on any single technology.

Licensees are asked to present an Early Risk Assessment within 6 months of being awarded a carbon dioxide storage license, and this needs to be reviewed by 2 independent contractors.

They should consider risks relating to capacity (storage being smaller than expected), containment (CO2 leaking out) and monitorability (knowing what is going on). They should also consider whether the pressure of the CO2 may become high enough to fracture the rock above and around the storage area.

It is understood by regulators that the monitoring plan may change as knowledge of the stores increases.

There is an acceptance that CO2 behaviour in the subsurface is unlikely to happen exactly as predicted (as occurred in Norway's Sleipner store, where CO2 has been injected since 1996).

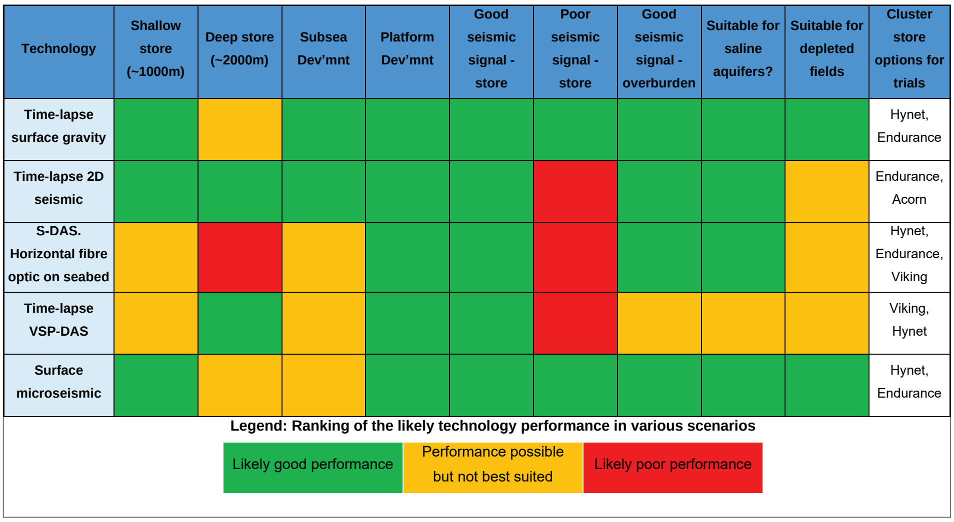
"If you have a risk which is evolving at a faster rate or slower rate [than expected] you have an opportunity to adjust the monitoring plan," Mr Barron said.

Licensees are only allowed to actually inject when they receive a storage permit from the NSTA, indicating it is satisfied there is no significant risk of leakage, harm to human health, or harm to the environment. The carbon dioxide storage license just indicates they have exclusive rights to consider CO2 storage in a certain geographical region.

The permit specifies operational limits on parameters such as injection rates and pressures, which are specified based on the information in the storage permit application.

New technologies

If technology providers would like the NSTA to be better aware of their product's capabilities, the NSTA is open to dialogue, ideally in conjunction with a licensee or with examples of successful application elsewhere. This should be part of the discussion about the technologies most suitable for monitoring a particular site, he said.



The NSTA study looked at the potential of various alternative technologies

The NSTA is keen to encourage the evaluation of new technologies. Storage Operators are required to update their Monitoring Plan every 5 years, and this could be an opportunity to discuss changes to technology, if it can be demonstrated that the proposed replacement technology provides consistent and equivalent results.

It would be beneficial for companies to share what they have found in terms of innovative monitoring technology to improve efficiency and reduce potential development times, rather than each licensee doing their own studies about every technology. Companies may agree to partner, to sharing study costs in return for input to a study design and access to the results, he suggested.

"We encourage industry to get together to look at desktop feasibility studies followed by field trials," he added.

Such shared studies may be particularly useful in the earlier stage of an application to demonstrate broadly how it could work and how long it would take to show any problem. For example, to show that a technology would be suitable for stores in a certain geological domain.

However, licensees will likely need to do more detailed work based on their proposed store when they are closer to submitting the permit application.

Study objectives

The objectives of the study were to improve understanding of the technologies which could be used on the initial UK CO2 storage projects, including how much they might help improve resolution, and reduce cost and lead time, which could be included as part of a Monitoring Plan described above.

The study was also expected to encourage more field trials of the less well understood technologies.

The study sought to encourage collaboration between companies and nurture a more open culture compared to that in the petroleum industry, where confidentiality is the norm.

Gravity

Some UK CO2 storage operators have started looking at the use of gravity changes, known as 4D or time lapse gravity.

"It has got potential to look at shallow reservoirs as well as potentially deeper reservoirs," Mr Barron said.

Gravity data can be acquired by placing a solid platform (such as concrete) on the seabed and placing a gravity sensor on it with a remotely operated subsea vehicle (ROV). There are no problems doing gravity surveys close to wind farms.

Gravity surveys can be conducted and data processed much faster than with 4D seismic, providing earlier information on store behaviour after around 6 months, Mr Barron said.

It can also be used to detect leaks in the overburden (just as 4D seismic can).

Some CO_2 licensees are looking at gravity, presenting studies they have done with contractors to show how it might be used to demonstrate CO_2 is moving in the subsurface as planned, he said.

Other seismic

Seismic surveys do not necessarily need to be repeated 3D. There has been consideration of doing repeated 2D seismic surveys (a line rather than a volume), or surveys just of a specific point in the subsurface (known as 'spot' or 1D seismic).

Time-lapse 2D has not yet been actively proposed by any company as a monitoring system but is something under discussion within the industry, Mr Barron said.

Spot seismic is being promoted by a French company called Spotlight, who are doing tests around the CO_2 injection test for the Poseidon project in the Southern North Sea.

A company might use gravity as its main tool but then use conventional time-lapse seismic on any area that it has particular concerns about, he suggested.

Fibre optics

Fibre optic cables on the seabed to record seismic data with "distributed acoustic sensing" (DAS) can work with an active source, or in a passive sense to detect natural and induced seismicity. "It is a more of an emerging technology that we'd like to see some trials of," he said.

Fibre optic cables in wells can also be used for DAS collecting a "vertical seismic profile" (VSP). This can be done "relatively quickly," Mr Barron said.

The biggest challenge might be making sure you understand the rock physics around your store, which is needed to interpret the data.

It may be used as a "triggered monitoring option" (something to use if you have concerns) as well as a "core monitoring technique".

Microseismic

The group also looked at surface microseismic, recording seismic signals at the wells, on the seabed or perhaps from the platform you are injecting from.

This could be induced seismicity, such as caused by the movement of fluids through the subsurface or fractures being created in the rock, as well as natural seismicity (such as naturally occurring earthquakes). It could be used to assess geomechanical stability and to map the source of noise to see where the plume is going.

Seabed deformation

Some licensees are proposing seabed deformation monitoring, which measures how much the seabed moves as CO_2 is injected beneath it and compares the results against models.

If part of the seabed changes more than expected in a small area, it may indicate there is 'compartmentalisation' in the reservoir, so CO_2 is not flowing as widely as was expected. This can be used to update the models and optimise the injection strategy, for example.

"All of the technologies we looked at in the study have potential, but more needs to be done to bring the technology readiness level to a point where it can demonstrably reduce reliance on 4D seismic," he said.

Monitoring well leakage

If you have old oil and gas wells penetrating the CO_2 storage site, you need to ensure that CO_2 cannot leak out through them.

A detailed assessment needs to be made for each well, categorising the leakage risk. The NSTA needs to agree with this assessment.

The risk is assessed both on the likelihood and the magnitude of the impact if any leak should happen, and what mitigation plan is in place.

Under UK oil and gas regulations, wells must be fully sealed or "abandoned" when no longer used. This sealing is done by filling the well with cement. Well experts employed by CO_2 licensees need to assess, from the abandonment reports, the quality and integrity of each abandonment.

The risk profile of a legacy well may change during a carbon storage project. The risk may be greatest when CO_2 first reaches the well. But once it can be seen that there is no leak, the risk may reduce. In some instances, the CO_2 may only reach the well several years after injection starts.

Therefore, companies may propose monitoring for signs of leakage at times of higher risk, such as with an ROV.

If a well is not properly abandoned, or its barriers cannot be verified, the only way to fix it will be to bring in a workover rig and 're-enter' the well, which may be expensive. CO_2 licensees may need to consider the impact this has on the proposed store and, depending on the number of wells and their locations, whether they want to use the site at all in this case.

Sharing data

The NSTA is supporting licensees in exploring if there are ways to reduce costs by either sharing or coordinating seismic data acquisition programmes. For example, in the UK's Southern North Sea, we may see a number of stores close together. Operators may have obligations to monitor an area beyond their storage site, in which case there can be overlap in the areas they are required to monitor. So they could potentially share monitoring data.

The government will establish a regulatory framework for retaining, reporting and disclosing CO_2 storage data, similar to what is place for petroleum licences. This may require data to be reported once a year. But it may be helpful for operators to share monitoring data earlier and more frequently to promote best practice and share lessons learned.

More information

The study can be downloaded here

www.nstauthority.co.uk/media/melld4w5/monitoringsubgroupreportfinal.pdf

This article is based on the Finding Petroleum webinar on Feb 28 2025, "Developments with New CO_2 Storage Projects". For a link to the video, see **www.findingpetroleum.com** then click on 'events' then 'past events'

First European built offshore CO2 carrier to be launched

The dedicated CO2 carrier is currently under construction at Royal Niestern Sander shipyard in the Netherlands and is a cornerstone in Greensand's mission to deliver EU's first full-scale CCS value chain.

All ship sections of the vessel have now been successfully constructed and assembled at Royal Niestern Sander shipyard in the north of the Netherlands and it is on schedule for christening and launch on May 14.

The agreement between INEOS and Wagenborg for the delivery of this new-build CO2 carrier was signed in November 2024, in the presence of HM King Willem-Alexander of the Netherlands and HM King Frederik of Denmark.

The vessel is specifically designed to transport liquefied CO2 from onshore capture sites to offshore storage in the Danish part of the North Sea. Once launched and operational, the carrier will sail regular routes from Port Esbjerg to the Nini West platform, where the CO2 will be injected for safe and permanent storage to the Nini reservoir approx. 1,800 metres beneath the seabed.

The vessel is designed to meet the highest standards for safety and environmental performance and is tailored to the specific technical requirements of CO2 transport

These geological formations have securely contained hydrocarbons for millions of years and have been thoroughly assessed and certified for safe and permanent CO2 storage.

Mads Gade, CEO INEOS Energy Europe said, "The geology in the Danish part of the North Sea is very well suited for safe and permanent storage of CO2. By fulfilling the potential for storage of CO2 deep below the subsurface in the Danish North Sea we can make a significant contribution to achieving both Danish and European climate goals. The CO2 carrier will play a pivotal role for Greensand in establishing and developing the first operational CO2 storage facility in the EU aimed at mitigating climate change".

The ship itself is designed to meet the highest standards for safety and environmental performance and is tailored to the specific technical requirements of CO2 transport, including onboard cooling and pressure systems.

With the completion of the ship's hull, the vessel enters the next phase of construction, which includes retrofitting, commissioning, testing, and sea trials.

This milestone follows a series of major developments in the Greensand project. In December 2024, INEOS and its partners Harbour Energy and Nordsøfonden made the Final Investment Decision (FID) to move ahead with full-scale CO2 storage operations in the Nini Field.

Construction has also now started on Greensand's CO2 transit terminal at Port Esbjerg and is expected to complete in Autumn.

With the plan to initiate safe sand permanent CO2 storage in the Nini Field by late 2025/early 2026, Greensand is expected to become the EU's first operational CO2 storage facility aimed at mitigating climate change. This investment decision has paved the way for expected investments exceeding 1 billion DKK across the Greensand CCS value chain to scale up storage capacity.

The dedicated carrier is central to fulfilling this ambition, enabling safe, efficient, and scalable transport of captured CO2 from across Europe to the Danish storage site.

Construction has progressed steadily with several key sections of the vessel completed and assembled. Earlier this year, the successful and safe transport of the aft ship marked another significant step forward.

Project Greensand aims to begin regular offshore CO2 injection by the end of 2025 or early 2026. The project's initial phase targets the permanent storage of 400,000 tonnes of CO2 annually, with the potential to scale up to 8 million tonnes per year by 2030.

More information

https://greensandfuture.com
www.wagenborg.com

Transport and storage news

INEOS' Project Greensand to store Swedish CO2 emissions

https://greensandfuture.com
https://oresundskraft.se

Öresundskraft Kraft & Värme AB and INEOS on behalf of Project Greensand have signed an agreement to investigate the opportunity to store up to 210,000 tonnes of CO2 annually from Sweden in Denmark.

Öresundskraft is a leading Swedish energy company providing sustainable solutions in district heating, electricity, district cooling, and energy services in the Helsingborg region and northwestern Skåne. The captured carbon dioxide is planned for safe and permanent storage in Greensand storage facility located in the Danish part of the North Sea, with the first volumes expected to be stored from 2028.

Mads Gade, CEO INEOS Energy Europe said, "The agreement with Öresundskraft marks the beginning of the next phase of Greensand—expanding the capacity to store CO2 also from other EU member states. This is a significant step toward building a truly European CCS infrastructure that enables emissions reductions across borders."

This cross-border collaboration represents a significant step toward realising the potential of CCS in the Greater Copenhagen Area and beyond. It also underlines the vital importance of international cooperation in achieving climate goals and mitigating global climate change.

Stefan Håkansson, CEO of Öresundskraft, said, "This agreement with INEOS marks an important milestone for us. We are at the forefront among our European industry peers when developing a sustainable and fully integrated CCS solution for energy recovery from waste."

"Our project has been awarded €54 million from the EU Innovation Fund and is one of Sweden's first CCS initiatives. Our goal is to offer climate-neutral district heating and achieve negative emissions. Connecting Swedish carbon capture with Danish storage infrastructure highlights the importance of international cooperation in reaching climate goals. We are proud to be working with INEOS on this."

INEOS, through the Project Greensand consortium with partners Harbour Energy and Nordsøfonden, is leading the development of one of Europe's most advanced CO2 storage sites. The latest development will play a key role in receiving CO2 from various European countries, including Sweden, for safe injection into offshore geological formations in Greensand.

Mads Weng Gade, CEO, INEOS Energy Europe, said, "Storing CO2 is essential if Europe is to reach its climate targets. This agreement with Öresundskraft demonstrates how industrial players in different countries can work together to build scalable, international CCS value chains."

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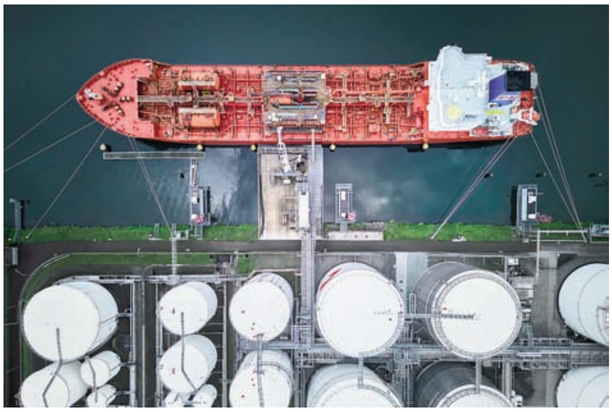


The CO2 terminal is to be built on an unused area of around 12 hectares on the Ambrian Energy site in the port of Bremen

Messer completes study for Ambrian Energy CO2 terminal in the port of Bremen

https://zecarb.messergroup.com
https://ambrian-energy.com

The aim of the study was to investigate the technical and economic feasibility of a facility for the delivery, storage and shipping of liquefied CO2.

Ambrian Energy assigned industrial gas specialist Messer with a pre-FEED study for the construction of a CO2 terminal in the port of Bremen. The planned infrastructure should make a decisive contribution to the implementation of CCS in Germany.

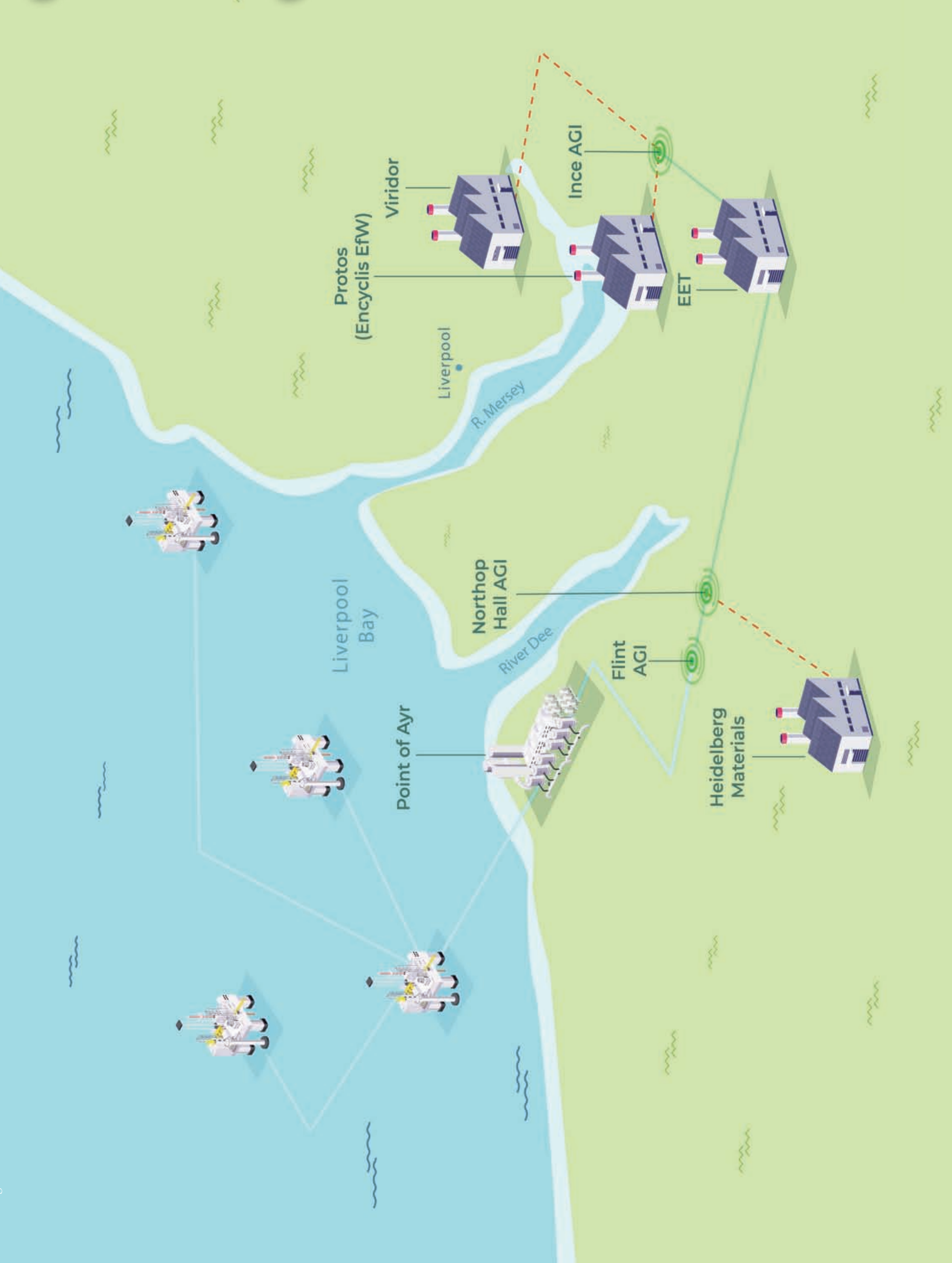
The CO2 terminal is to be built on an unused area of around 12 hectares on the Ambrian Energy site. The location offers ideal logistical conditions: An existing rail connection enables CO2 to be transported by train, while a port jetty for ships with a capacity of up to 40,000 tons ensures onward transport to geological CO2 storage facilities in the North Sea. The planned terminal capacity is initially two million tons of CO2 per year.

The scope of the pre-FEED study included the feasibility of constructing a specialized tank farm for liquefied CO2, which will have an integrated quality assurance system and a gas recovery facility. In addition, a modern unloading facility for CO2 transport by train is to be built to ensure efficient delivery of the liquefied CO2. Another key element is the ship loading facility, which will enable the safe and loss-free transportation of the CO2 to geological sinks in the North Sea.

Last year Messer launched "ZeCarb® ', a new offering in the field of 'Carbon Capture as a Service" (CCaaS). "ZeCarb® " stands for 'Zero Carbon' and helps to decarbonise industries with high CO2 emissions. Ambrian Energy has extensive expertise in the logistics of fuels. Together, the two companies are pursuing the goal of offering customers a complete value chain from CO2 recovery from industrial emitters to transportation by train and loading onto ships for CO2 sequestration.

Following the successful completion of the feasibility study, the two companies are planning a strategic partnership to jointly implement the CO2 terminal. This would create a central infrastructure that supports Germany in achieving its climate targets and contributes to the scaling of the CCS infrastructure.

Liverpool Bay CCS gets green light



HyNet CCS Cluster - Eni's Liverpool Bay CO_2 Transport and Storage project

Image: ENI