Carbon Capture Journal

CCUS in the UK

Project updates in the North Sea, Scotland and storage licensing

CCSA delivery plan - UK CCS sector at a 'critical juncture'

Review of 2025 and looking ahead in 2026

Jan / Feb 2026 Issue 109

Full-scale CCS for Heidelberg Padeswood in Wales

Image: Heidelberg Materials

- Vaisala: CCS technology relies on high-performance CO2 sensors
- Södra tests Svante carbon capture tech at Värö pulp mill
- First complete record of global underground CO2 storage
- Transportation: the mid-stream forgotten link in the CO2 value chain

COP30 Belém: implications for carbon management implementation

COP30 marked a pivotal moment as the United Nations Framework Convention on Climate Change (UNFCCC) process moved from political consensus toward implementation frameworks, and for the first time, negotiators acknowledged the likelihood of overshooting 1.5°C.

In a report for the Global CCS Institute, Noora Al Amer, Senior Global Advocacy Lead, said the suite of decisions, known as the Belém Political Package, advanced frameworks for carbon management technology deployment while leaving fundamental questions unresolved.

The outcomes of COP30 confirm that operational and financial frameworks for carbon management, along with other mitigation solutions, are being established within the UNFCCC's emerging implementation architecture. For carbon management technologies to access these international mechanisms, they must be rigorously integrated into national reporting.

The Nationally Determined Contribution (NDC) acts as the critical political gateway, providing the sovereign mandate for carbon management deployment and signaling national priority to investors. A preliminary assessment indicates that as of 9 December 2025, 60+ countries have integrated carbon management in their NDCs, either explicitly or via national policies.

Key outcomes and takeaways

Climate finance roadmap advances, but binding mechanisms deferred

COP30 advanced the operationalisation of the New Collective Quantified Goal (NCQG) agreed at COP29, which targets US$1.3 trillion annually by 2035 for climate action in developing countries, of which US$300 billion represents the core mobilisation goal from developed countries.

The finance architecture does not earmark funding for carbon management specifically, but the emphasis on private capital mobilisation and infrastructure investment creates pathways for CCS hubs where they align with national priorities. Project developers in developing countries could engage with national climate finance strategies to ensure carbon management is positioned within NCQG-aligned investment plans.

Article 6 carbon markets moving to implementation

The Article 6 rulebook was effectively completed at COP29 in Baku, with COP30 focused on implementation. High-integrity standards for carbon removals were maintained despite pressure from stakeholders and some governments to lower the stringency of permanence and liability requirements, aimed at reducing the financial burden to accelerate market deployment and lower the unit cost of credits under Article 6.4.

Article 6.4 provides the framework for the first UN-regulated global carbon market, replacing the Kyoto Protocol's Clean Development Mechanism (CDM). Geological storage remains eligible under the mechanism's standards on removals and permanence, creating a pathway for CCS-based credits to be used toward NDC compliance.

The finalisation on permanence standards provides clarity for project developers. Project developers can continue to track carbon methodology development by the Article 6.4 Supervisory Body, due to be finalised in 2026, and align with emerging requirements.

Just Transition Mechanism agreed

COP30 agreed to develop a Just Transition Mechanism under the UAE Just Transition Work Programme (JTWP), one of the conference's most significant institutional outcomes.

Technology Implementation Programme launched

At COP30, Parties established the Technology Implementation Programme (TIP) to strengthen the deployment of technologies identified in developing countries' NDCs, National Adaptation Plans (NAPs), and LT-LEDS. The TIP is designed to respond directly to the first global stocktake's mandate to enhance support for technology priorities in developing countries.

Transparency framework establishes accountability baseline

BTRs are standardised reports that countries submit every two years under the Paris Agreement's Enhanced Transparency Framework, detailing their greenhouse gas emissions inventories, progress toward NDCs, and climate finance flows, with the first round submitted by 31 December 2024. The first synthesis of BTRs provide the accountability architecture for tracking national climate action, including carbon management contributions.

First BTR Synthesis Report: Released ahead of COP30, the UNFCCC synthesis of 101 BTRs provides the first comprehensive picture of Paris Agreement implementation. All submitting countries reported steps toward their NDCs, with over 3,400 policies documented across sectors. This establishes the reporting infrastructure through which carbon management deployment could be monitored against national targets.

The transparency framework creates both opportunity and obligation. Projects contributing to NDC targets will require robust MRV systems aligned with BTR reporting requirements; project developers can begin this alignment now, found in the "Paris Rulebook" for transparency. Conversely, the accountability infrastructure provides a pathway for carbon management to demonstrate measurable contributions to national commitments, potentially strengthening the case for public support and private investment.

The explicit inclusion of carbon management in a growing number of NDCs provides important policy signals.

More information
www.globalccsinstitute.com

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Front cover: Heidelberg's Padeswood will be the first in Europe to deploy MHI's proprietary Advanced KM CDR Process™ to capture around 800,000 tonnes of CO2 annually from cement production (pg. 13)

Back cover: EnEarth will supply CO2 storage for Heidelberg's ANRAV project in Bulgaria (pg. 33)

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CCS expanded across regions in 2025 amid strengthened policy commitments

The CCS project pipeline continues to grow at a robust pace, with 2025 marking another year of strong momentum; 27 projects have commenced operations and another 30 have entered the construction phase since the 2024 Global Status of CCS report.

By 2030, operating CCS capacity is expected to expand significantly and across a more diverse range of industries. While natural gas processing has been the dominant CCS deployment industry since 1972, deployment in the low-carbon hydrogen and ammonia sector is anticipated to assume the top spot by 2030, with an estimated CCS capture capacity addition of more than 100 Mtpa, before potentially being overtaken by power generation and heat.

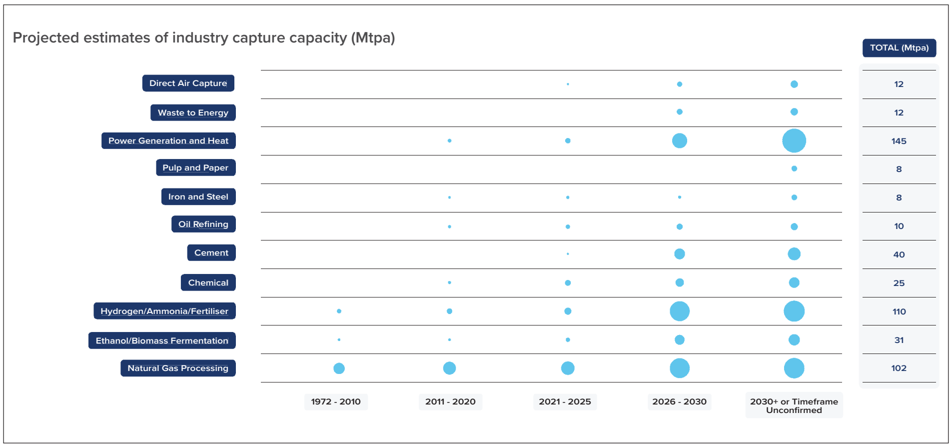
The number of CCS facilities in development has again increased substantially in the past year, driven by policy support, commercial interest, and the growing recognition of CCS as a critical climate solution.

Capture capacity continues to rise, with strong growth across all stages of development. Since 2017, total planned capture capacity has grown at a compound annual rate of over 30%, with the past year maintaining that upward trajectory.

The past 12 months have seen significant CCS-specific policy, legal and regulatory progress in many countries, and this is reflected in the increase in the number of commercial CCS projects that are now in operation, construction, and development. In several jurisdictions worldwide, it is now increasingly possible to draw a link between the timely development of national policy and regulatory foundations and the emerging pipeline of CCS projects.

The implementation of supportive policy, law and regulation continues to be a critical driver for the scale-up of CCS projects globally. Strengthened policy commitments that recognise the mitigation potential of CCS and offer pathways for financial support, coupled with enabling legal and regulatory regimes, help to shape and sustain widespread commercial deployment.

While the pace of policy and regulatory development at the regional and national level varies greatly, notable advances in the past 12 months are providing greater certainty for industry and investors.



Capture capacity continues to rise across all industries, the total operating capacity could increase to 337 Mtpa within the next five years, from 64 Mtpa today, with a potential compound annual growth rate (CAGR) of nearly 40% (Source: Global Status of CCS 2025)

The carbon management sector is entering a new phase of financial maturity in 2025, with sustained interest emerging in the CO_2 transport and storage sector. For the first time, CCS projects have secured non-recourse debt financing (Net Zero Teesside, Northern Endurance Partnership), supported by robust policy frameworks and offtake agreements. This milestone reflects growing lender confidence, aided by standardised contracts, emerging insurance solutions, and dedicated project finance structures.

Private capital is also stepping up. In May 2025, Eni partnered with Global Infrastructure Partners to co-own CCS assets in the UK, Netherlands, and Italy, signalling increased institutional investment.

Several projects have recently reached FID or financial close in Europe, highlighting the growing pipeline of bankable projects across the region – Northern Lights Phase 2 in Norway, Eni Hynet North West in the UK, and Stockholm Exergi BECCS in Sweden.

Carbon markets are evolving in parallel. The EU and UK ETS linkage agreement marks renewed regional cooperation, while Norway and Switzerland's Article 6.2 deal creates one of the first frameworks for international carbon removals.

The voluntary carbon market is also expanding rapidly, with Microsoft increasing its BECCS offtake from Stockholm Exergi to over 5 Mt, and the European Commission exploring an EU-level CDR purchasing programme to boost early demand.

However the report notes that even if all of the projects in the current pipeline become operational, we will still not meet our gigatonne-scale CO2 capture goals and every year of delay makes it harder and more costly to achieve our climate targets.

More information

www.globalccsinstitute.com/global-status-of-ccs

Looking ahead in 2026 - moving from ambition to delivery

A range of projects will reach FID in 2026 across all regions and large scale hubs will move into the operational phase, but policy and regulatory uncertainty still hampers investment. 2026 will be a pivotal year where government support will be key to accelerating deployment.

Diverging policies in the U.S., EU, and UK have shaped distinct CCUS investment climates and emission reduction pathways

	1 United States	2 European Union	3 United Kingdom
Main policies	**Federal:** • **IIJA allocated $2.5 billion for carbon storage validation and testing,** including funding for CarbonSAFE Phase III large-scale storage projects and the development of new regional carbon sequestration hubs • **$3.5 billion designated for direct air capture (DAC) hubs** supports the development of four regional DAC hubs to deploy large-scale carbon removal tech **State:** California's Low Carbon Fuel Standard; Texas's tax exemptions for CCUS infrastructure	• **EU Innovation Fund** setting aside **$1.5B for CCUS R&D and pilot projects** • **Connecting Europe Facility (CEF)** allocating **$0.5B for CO_2 transport and storage infrastructure** • **The Industrial Carbon Management Strategy and the Net-Zero Industry Act target 50 Mt CO_2 storage by 2030,** mandate oil and gas contributions, streamline CCUS permitting, and **mobilize €100B for industrial decarbonization**	• Net-zero strategy • Track-1 clusters (selected in 2021): HyNet and the East Coast Cluster; moving toward final investment decisions • Track-2 clusters (selected in 2023): Acorn project and the Viking project • CCUS Infrastructure Fund: **$1 billion fund** for clusters **contracts for difference** (CfD) for CCUS • Industrial Decarbonization Strategy • **New transport and storage licensing regime**
Subsidies offered	The Inflation Reduction Act's 45Q credits allow for **$85/ton for geological storage and $60/ton for utilization/EOR** (effective only when prevailing wage requirements are met)	**CCUS dedicated funds have been set up by various institutions, e.g., €1.5B** in the latest **Innovation Fund and €0.5B** dedicated to CO_2 transport and storage from **CEF**	**$28.5 billion** in funding: The UK government's stated ambition for the **private investment** it aims to unlock by 2030 through its comprehensive support policies (the CfDs, T&S model)
Emission abatement potential	***Up to 15% of CO_2 emissions abated in 2050 NZE scenario***	***Up to 30% of CO_2 emissions abated in 2050 NZE scenario***	***Up to 30% of CO_2 emissions abated in 2050 NZE scenario***
Carbon capture target	Reduce the cost of industrial CO_2 capture to < **$30/ton** by 2035 and develop regional storage hubs that can store at least **50M tons of CO_2 p.a.** by 2050	**50 million tons of CO_2 by 2030, 280 million by 2040, and 450 million by 2050**	**10 million tons of CO_2 annually by 2030** and up to **50 million tons by 2050**
Share of global CCUS (planned, under construction, and operational)	42%	21%	11%

Sources: Alberta, CCUS; ANU, ANU sets a new standard for high-quality carbon removal (2022); Australian government, Australian Carbon Credit Unit Scheme, Australia's Energy Commodity Resources; EY, Why carbon just became an economic fastball (2022); Journal of Cleaner Production, The impact of CCUS (2024); Canadian government, Canada's Carbon Management Strategy, 2030 Emissions Reduction Plan; IEA, CCUS Projects Explorer (2024); IEA, NZE (2021); NETL, CarbonSAFE; UK government, The Carbon Capture and Infrastructure Fund (2021); CCSA (2023).
Credit: Grace Frascati, Yosafat Partogi, Anda Wang, Michelle Priscilla, Hyae Ryung Kim, and Gernot Wagner. Share with attribution: Kim *et al.*, "Capturing Carbon" (7 November 2025).

Columbia Business School Climate Knowledge Initiative

Policy support will be key to making investment decisions but political volatility continues to be a risk - in the U.S. 45Q tax incentives remain but relies on continued political backing for carbon management infrastructure. Source: Columbia Business School Climate Knowledge Initiative "Capturing Carbon"

Key Projects Expected to Reach FID in 2026

• Aramis Project (Netherlands): A major project in the Netherlands focused on developing essential CO2 transport infrastructure and storage facilities. The project is a collaboration between EBN and Gasunie and aims to support industrial decarbonisation in the region, including potential CO2 transport from Belgium, Germany, and France.

• InBECCS Project (UK): Evero Energy's Integrated Bioenergy with Carbon Capture and Storage project in the North West. This project aims to be the UK's first Greenhouse Gas Removal (GGR) project, capturing over 200,000 tonnes of CO2 annually from a waste-wood-to-energy facility.

• Expansion of Northern Lights (Norway): The expansion of the existing Northern Lights project is among several European projects expected to reach FID around 2026 as the region scales up its carbon management infrastructure.

• US Gulf Coast Projects: Multiple projects along the US Gulf Coast, including those linked to Air Products' Louisiana Clean Energy Complex and Nucor-ExxonMobil's steel CCS initiative, are scheduled to start operations between 2026 and 2030.

• Sunda-Asri Basin CCS (Indonesia): A major project developed by Pertamina and ExxonMobil is aiming for a storage capacity of 2.9GT CO2 and first injection by 2030.

• Japan's "Advanced CCS Projects": The Japanese government has selected several projects to start operations by 2030.

• China aims to decarbonise coal facilities through CO2 capture retrofitting. The pace of regulatory and incentive development will depend on the 2026-2030 five-year plan released in March.

Challenges

Policy support will be key to success as projects are heavily dependent on government subsidies, such as the UK's £21.7 billion investment commitment and the EU's Industrial Decarbonisation Bank, planned for 2026. Progress toward FIDs remains slow, limited by permitting delays, slow infrastructure development, and inadequate regulatory or funding drivers to support project investment.

Many decisions depend on the completion of shared transport hubs such as Porthos in the Netherlands, which is due for completion in 2026.

New legislation in countries like Indonesia and Malaysia is designed to unlock revenue pathways by integrating CCUS into carbon markets.

More information

https://business.columbia.edu

www.woodmac.com

https://pemedianetwork.com

www.catf.us

Project updates: CCS in the UK Southern and Central North Sea

We heard updates and technology developments on CCS projects in UK's Southern North Sea (Project Poseidon) and Central North Sea (Humber and Teesside) at the GESGB "CCS4G Symposium 2025" December event in London. By Karl Jeffery.

In the Southern North Sea, Project Poseidon plans CO2 injection in 2029 with 1 to 5 MT per annum.

Project Poseidon is a joint venture with Perenco, Carbon Catalyst and Harbour Energy. It is one of the world's largest CO2 storage projects with almost 1 GT capacity and capacity to inject 40m tonnes a year.

The project team performed a CO2 injection test in March 2025, to check that the wells and reservoir could take CO2 at a rate of at least 1m tonnes per annum (mtpa) without leaking or seeing formation of hydrates (frozen CO2 together with water).

Marta Puig Alenya, CCS subsurface team leader, Perenco explained more, speaking at the Geoscience Energy Society of Great Britain (GESGB) "CCS4G Symposium 2025" event in London on December 10.

General concerns have been raised for many years about CO2 storage into depleted gas fields, that de-pressurisation of CO2, as it moves from a high pressure well to the low-pressure reservoir, might cool enough to freeze and block the flow lines.

Project Poseidon uses a former gas reservoir, now "ultra depleted", with pressure at 12 bar. Encouragingly the injection test did not see any leaks or hydrates form. The injection test was a requirement of the CO2 storage license. As a result, the project team received NSTA's first well test consent.

All of the 'surprises' seen during the injection test project were positive surprises, she said.

The CO2 storage area covers the same land surface area as most of London, extending from Canary Wharf to Heathrow Airport.

The storage zone is 200m thick, with a caprock above of 650m shales and salts. It is highly compartmentalised.

CO2 delivery to the field is planned to be initially shipping (such as with 5,000 tonne capacity CO2 carrier vessels), followed by pipeline.

It could deliver storage services for London, UK Southeast, continental Europe, and South Wales, she said.

The well

The project team reconfigured the well, changing the entire completion and installing a fibre optic cable.

The fibre optic cable can be used for distributed temperature sensing (DTS) and distributed acoustic sensing (DAS) for vertical seismic profile surveys. This can also be used to check for any fractures created in the rock (passive seismic).

All of the 'surprises' seen during the injection test project were positive surprises – Marta Puig Alenya, CCS subsurface team leader, Perenco

Completion equipment was supplied by Baker Hughes, Halliburton, Weatherford and Silixa. The injection package was supplied by SLB.

Pressure gauges were installed in the tubing and annulus around it. These could be used to detect the phase change when CO2 changes from liquid to gas. There were also pressure and temperature sensors in the surface equipment.

CO2 injection

The CO2 for the injection test was sourced from Air Liquide, which produces CO2 for soft drinks and beer. It was only available in wintertime, when there is less demand for carbonated drinks, she said.

For the test, CO2 was delivered by tank container (tanks the same length and height as standard box containers). 24 containers at once were loaded onto a multipurpose vessel (MPV) in a yard in the Netherlands.

10 deliveries of 24 tank containers were made roughly every 4 days, over the 43-day period of injection, so around 2,400 tank containers in total. This was 3,500 tonnes of CO2.

The containers were offloaded from the vessel to the platform before injection, rather than injecting directly from the tank containers to the well. The project team had learned from the experiences of Denmark's Project Greensand, which had done this, and had issues with weather causing outages in injection, she said.

The CO2 could be compressed and heated on the platform.

The plan was to start injection in gas phase at 40 degrees C, to try to understand the system, make sure the well was not damaged, and calibrate the system. Then the plan was to gradually increase pressure until CO2 was supercritical (when it behaves both as a liquid and a gas). Then to reduce the temperature, so CO2 could be injected as a liquid.

As it turned out, the CO2 was still in multiphase (part liquid, part gas) when injecting at 10 degrees C at the surface and at 4 degrees C at the surface. The lowest surface temperature experimented with was -12.5 degrees C.

An injection rate equivalent to 1m tonnes CO2 a year was achieved, but with CO2 still in multiphase. This was one of the most important learnings of the project, that a high injection rate can be achieved and being multiphase does not cause any problem to this, she said.

There was no clear advantage to being liquid phase only. When you know it is OK to have some gas, it is possible to have a lower temperature and pressure at the wellhead.

The well was warming up while injection was going on but cooling down when injection was stopped. The reservoir also warmed up around the well during injection.

The temperature of the reservoir at the injection point was 50 degrees C initially, dropping to 20 degrees C during injection, and dropping to 13 degrees C when injecting in gas phase.

The concern was that hydrates might form by CO2 rapidly cooling as it depressurises when entering the reservoir. But no issues were seen.

No slugs were seen, and pressure fluctuation did not trigger any hydrates. No fracturing was seen when the well was shut in and the reservoir around the well allowed to cool down.

The researchers wanted to get CO2 at a stable pressure so they could shoot seismic and see if the CO2 was observed. This is hard to achieve in multiphase. The temperature was reduced to -5 degrees, and it was still multiphase. A choke was installed downhole to reduce the pressure and enable injection in liquid phase. During this pilot, based on live observations "The programme kept changing," she said.

As part of the injection test, an experiment was made with spot seismic survey techniques to see if they revealed increase in pressure in "spots" in the subsurface.

For the seismic survey, the source were four x 250 cubic inch air guns mounted on the vessel.

Modelling has been done to show what changes might be detected with different technologies - Anna Fletcher, senior geophysicist, and Tom Martin, senior geologist, Harbour

Seismic services and equipment were provided by Spotlight and Viridien.

Humber

The Harbour Operated Viking CCS project, in the UK's Humber region, aims to store 4m tonnes a year CO2 in the early 2030s in the Southern North Sea. It has a "line of sight to 10 million tonnes CO2 a year by 2035," according to its website. Humber is the most industrialised and largest CO2-emitting region in the UK.

The first phase of storage will use the Viking South carbon storage field, the former "Victor" gas field. Here, Harbour was given CO2 storage licenses CS005 in 2021, and CS023 and CS024 in 2024.

CO2 will be collected in Immingham, and a new 55km pipeline constructed along the river Humber and south along the Coast to Theddlethorpe, where there is a former gas terminal.

There is already a 36-inch pipeline "LOGGS" (Lincolnshire Offshore Gas Gathering System) which can be re-purposed to send CO2 offshore, with a 20km spur line to be constructed going to the Viking South field.

The reservoir is Leman sandstone and the Caprock is Zechstein Group evaporites. It is 450 to 4000 feet thick above the CS005 storage, explained Tom Martin, senior geologist with Harbour Energy.

Victor has "one of the more homogenous reservoirs," with well-defined structures and a small range of uncertainties, he said. Its wells were "very good producers," up to 250bn cubic feet over their lifetimes.

For CO2 storage, the project team plan a model of the "whole hydraulic unit" so they can track plume movement.

Harbour Energy was formed from the merger of Chrysaor Holdings and Premier Oil in 2021. Chrysaor had acquired ConocoPhillips' UK oil and gas business in 2019.

Conoco Phillips was former operator of the Victor gas field, holding a license since 1964. The field was discovered in 1972, development started in 1983, with 5 wells drilled from the platform, and first gas in 1984. The field was re-developed in 1993, drilling a sidetrack to one well, and a new well to the North.

At one time this region was the "heartland of North Sea production, with over 30 platforms, 100-200 wells and a great deal of knowledge generation, Mr Martin said. Decommissioning started in 2016.

The wells all have plugs above the Leman sandstone, said Anna Fletcher, senior geophysicist, Harbour Energy.

For monitoring, the project team need to assess which risks can be detected and which technology can work.

Modelling has been done to show what changes might be detected with different technologies. It showed that CO2 in the subsurface is unlikely to cause any change to seismic amplitudes. After pressure has increased by a significant amount, after a number of years, there could be a detectable "time shift" with reflections arriving later than expected, maybe around 0.5 milliseconds, she said.

Time lapse micro gravity, measuring how much gravity changes due to the CO2 injection could be cost effective, is lower resolution than seismic, but modelling shows it could provide information sooner.

For example, after 5 years of injection, a significant gravity signal would be expected in the centre of the field, if the faults around the storage site are sealing or inhibiting flow laterally, as they are expected to do, she said.

Teesside and regional models

The Teesside and Humber CCS projects connect to an offshore area modelled by geologists which is large as the area within the M25 ring round around London, or as another comparison the size of the county of Aberdeenshire.

A "regional scale" model has been created of the region, to understand it at a wider scale than a storage model, said Carwyn Adler, CCS reservoir engineer with BP.

The Northern Endurance Partnership (NEP), a joint venture with BP, Equinor and TotalEnergies, is building onshore and offshore CCS infrastructure for the Teesside and Humber CCS projects and has licenses for much of this region. There are also CO2 storage licenses held by ENI.

The Final Investment Decision was made on Phase 1 of Northern Endurance Partnership in December 2024, for start-up in 2028, taking 4mtpa over 25 years.

The project includes the "Endurance" aquifer field, covered by the first ever UK storage license, CS001. Adjacent storage sites CS006, CS007 and CS025 are under appraisal, he said.

There are also storage sites CS020 and CS022 in the Silver Pit Basin with licenses held by ENI. The assumption is they are part of the same hydraulic unit, so CO2 injected into one site impacts another.

The area covered by the NEP regional model has 600 wells. Of these, 133 had petrophysical data and 23 had core data.

Some areas of the model have hardly any wells or data. On average there is 1 well per square kilometre, which contrasts, for example with 55 wells per square kilometre for the giant onshore Ghawar field in Saudi Arabia. "We are having to make data work quite hard."

The regional scale models can be used to understand how pressure in the subsurface may develop as CO2 is injected in multiple areas, and how much "headroom" you have for pressure to increase, he said.

By comparison, you may use larger scale storage models to model CO2 plumes and determine the best site for wells.

A "regional scale" model has been created of the region, to understand it at a wider scale than a storage model - Carwyn Adler, CCS reservoir engineer, BP

You can have geomechanical models of rock properties, covering the overburden and underburden, and possible plume migration pathways.

Well scale models can model injectivity immediately around the well, the impact of temperature on injectivity, and possible halite precipitation.

These models all run at different scales. But they can be consistent with each other and relate to each other. For example, a regional model can help you determine a suitable boundary for your storage model.

You are not likely to be able to put all of the information about CO2 storage in a single model, Mr Adler said. So, the way forward is to use multiple models and be mindful of the limitations of each of them.

Silver Pit Basin model

A regional scale model was made on the Bunter formation in the Silver Pit Basin. This covers a smaller area than the entire NEP region, but is bigger than a model for one CO2 store.

The objective of the model was to understand the capacity for injection, how pressure in the subsurface will increase, and whether there could be any formation water displacement at outcrop. The uncertainty in permeability has a big impact on all three of these, he said.

The model has horizontal cells 200m x 200m in size, and 110 vertical layers, each between 1m and 2.5m deep. This adds up to 47.8m cells, of which 33m are "active". It covers 6 geological zones.

The model includes petrophysical data, including the porosity distribution, permeability, and volume of shale. Together, this data can be used to calculate the "net to gross" of the storage site (ratio of volume of available storage space to total volume).

100 different static scenarios were generated. The dynamic performance of the reservoir will vary a great deal depending on which one you use, he said.

The facies in the model are populated using sandstone and mudstone maps.

The model can be used to choose where to place the wells. There are 31 well location options, and 6 wells may be drilled. This means 600,000 options to choose from, he said. The choice may involve avoiding stores with legacy wells or spreading injection over multiple stores to minimise pressure risk.

Studies on the model are run on a high performance computing (HPC) cluster. It takes 4-5 hours to run a simulation, which means you can start in the morning and get results by the end of the day.

A machine learning tool can tell you the probability of any cell at any depth being a certain facies.

There are complex correlations between the factors. For example, if you have a lower injection capacity, that suggests low permeability, so CO_2 is not diffusing a great distance within the reservoir, so there will be higher pressure build up in a smaller area, which can increase the possibility of outcrop displacement. In this scenario there is no interference between stores.

Conversely, a high permeability scenario means pressure diffuses broadly over the unit, and there could be interference between stores.

The model will be further calibrated as more data comes in. For example, the wells have pressure gauges fitted with them.

This should reduce the overall uncertainty in subsurface understanding, he said.

Potential water flows from the outcrop on the seabed will be monitored using "landers," which can detect tiny changes in water chemistry.

More information

For more information on the event and speakers see:

www.ges-gb.org.uk/events/ccs4g-symposium-2025/

Project updates: CCS in Scotland

We heard updates on the Acorn CCS project (NE Scotland) and plans for CCS off the Shetland Islands, at the GESGB CO2 storage forum in London on Dec 10.

In June 2025, the Acorn CCS project in Northeast Scotland was awarded enough government funding to get to the point of the Final Investment Decision (FID). £200m was provided in total for the Scottish CCS cluster, of which half is for Acorn.

The Acorn project team want to achieve FID within the current parliament, scheduled to end in 2029. Beyond that, future government funding is too unpredictable, said Catherine Witt, head of subsurface and wells with Storegga, a partner in the project. A positive FID would lead to first injection in 2030.

(Note – on December 4, 2025, Storegga announced it was selling its 30 per cent share in the Acorn project.)

The project is based around the St Fergus gas terminal, which has a pipeline connection to the nearby Peterhead gas power station, and to the Grangemouth industrial site 170 miles away. It also has two pipelines to offshore sites.

These pipelines were built to take gas from offshore to the power station and to Grangemouth, but they could be re-purposed to take CO_2 from Grangemouth and from Peterhead and send it offshore. CO_2 could also be delivered by ship to Peterhead port.

The Acorn project has 3 offshore CO_2 storage licenses.

The Captain aquifer CO_2 storage site, below 250m thick sands, has 4 wells which can be used for injection. It can receive 3 mtpa CO_2 from St Fergus, through the 20 inch "Goldeneye" pipeline.

The region is very well understood, due to its past as an oil and gas production site, known as the Goldeneye field. The legacy wells provide data, but also a possible source of risk, she said.

The planned injection pressure will not get anywhere near rock fracture pressure.

The reservoir was 100 psi when it was shut in, and pressure has been gradually building up since then.

A second storage site is known as East Mey, a saline aquifer / hydrocarbon field. It is linked to St Fergus by the 30 inch "Miller" pipeline. It has high quality Palaeocene sands, and a large number of legacy wells. The project team plan to avoid former hydrocarbon fields and target the saline aquifer area.

It has been extensively evaluated. The pressure of CO_2 in the field can be managed to ensure the plumes do not reach the legacy wells, she said.

Multiple CCS projects have been considered on the same site over the past 20 years. A BP CCS project in 2005 aimed to send the Peterhead power station emissions offshore through the Miller gas line. Shell's "Longannet" project from 2011 aimed to use the Goldeneye pipeline for emissions from Longannet Power Station. A further Shell project in 2015 aimed send the Peterhead emissions through Goldeneye pipeline. All three of these projects were cancelled due to withdrawn government funding.

The planned injection pressure will not get anywhere near rock fracture pressure - Catherine Witt, head of subsurface and wells with Storegga

In 2016, a study by the Energy Technologies Institute (ETI), led by a company called Pale Blue Dot Energy (subsequently acquired by Storegga in 2020) looked at a way to get CCS running in the region.

A 2018 study by an international association "Accelerating CCS Technologies" (ACT) identified East Mey as one of the top 5 UK CO2 storage sites. In 2019, Pale Blu Dot was awarded the CS003 storage license for "Acorn South" and "Acorn Central". In 2021, the Acorn project was given "reserve status" in the UK government's "Track 1" for government supported projects.

In 2023, Acorn was given further storage licenses, CS011 for Acorn East and CS012 for East Mey.

So, "20 years of persistence and resilience," she said.

Shetland

Oil and gas operator EnQuest has two CCS licenses Northeast of Shetland, off the North Coast of Scotland. They are both in depleted oil fields (the Magnus and Thistle fields, as well as the non-operated Tern and Eider fields).

The CO2 storage projects expect FID for phase 1 in 2030. The project team has almost completed site characterisation. There could be injection of 3 mtpa by 2033, said Dr Rahim Masoudi, chief technical lead, EnQuest & Veri Energy, at the CCS-4G London symposium.

Phase 2 of the project could mean 5 mtpa injected by the end of the 2030s, and a subsequent phase in the 2040s could mean 10 mtpa.

The field has around 70m tonne storage capacity, with 25m tonnes in phase one. For later stages, water extraction would be used to improve capacity. This will require water production wells.

EnQuest is also the operator of six oil fields located in the Northern North Sea (around the Shetland Islands), two formerly owned by Petrofac and four formerly part owned by Lundin Petroleum. It operates the Sullom Voe tanker terminal on Shetland.

The CCS license CS014 covers the Thistle and Deveron field, formerly used for oil production by EnQuest. There has been 50 per cent oil recovery from the field, and understanding is "quite good," he said.

The knowledge of connectivity between areas of the reservoir "is in good shape."

In its oil production days, production from the nearby Magnus field was improved by alternating water and gas injection, as much as 2-3 mtpa of gas. This is less than the planned CO2 injection rate of 1 mtpa, he said.

Plans for CO2 storage monitoring and verification are at early stages. It may include monitoring of containment, overburden leakage, caprock integrity, well integrity, conformance, the shape of the CO2 plume, the injection rate and storage capacity, he said.

The field has around 70m tonne storage capacity, with 25m tonnes in phase one - Dr Rahim Masoudi, chief technical lead, EnQuest & Veri Energy

Spot seismic may be used to see if pressure changes can be seen in specific "spots" of the subsurface, identified as a time shift (seismic reflections arriving at a slightly earlier time due to the increase in pressure increasing seismic velocity).

The CO2 will be trapped in capillaries and pores in the rock. CO2 will be miscible with the remaining oil in the reservoir, and soluble in the water. The remaining "mobile" CO2 is expected to gradually reduce to about 10 per cent of the CO2 injected, he said.

The project plan is to receive liquid CO2 at Sullom Voe and transfer by pipeline to the Magnus platform, 200km to the North. Sullom Voe has four deepwater jetties, one of which will be re-purposed to receive liquid CO2. There will be liquid CO2 "buffer storage" at Sullom Voe.

DNV is helping assess the carbon steel pipeline, to determine if it could be used for another 40 years. It has passed a mechanical test and will be given a pigging test to prove the condition is intact.

The project team are planning for storage costs of £40 a tonne, which should be possible since most of the necessary infrastructure is already available, he said.

EnQuest has a subsidiary company, Veri Energy, focussed on "new energy" – wind turbines, CCS, hydrogen, and e-fuels.

There is a plan to build an onshore wind farm at Sullom Voe, taking advantage of the "wind factor rate" of above 50 per cent, amongst the highest in the world. This could be up to 40MW, according to the company website.

The electricity could be used to make hydrogen and turn it into e-fuel, also using some of the captured CO2. The final investment decision is planned for mid-2027 for the hydrogen plant, and 2028 for the e-fuel plant.

More information

https://theacornproject.uk
www.enquest.com/veri-energy
www.dnv.com/focus-areas/ccs

UK news

The Carbon Removers receives £1M Scottish Enterprise grant

https://thecarbonremovers.com

www.southofscotlandenterprise.com

Ambitious plans to create a £1B company in the South of Scotland have been backed by the region's economic and community development agency.

The near-£1million investment by South of Scotland Enterprise (SOSE) is kickstarting a fundraising drive which will accelerate the expansion of the business across the UK and Europe. The Carbon Removers plans on removing one million tonnes of CO_2 per year by 2030 by expanding carbon sequestering projects.

The early investment aims to unlock a wider investment round which will continue this expansion, and ultimately lead to the South of Scotland business generating an annual revenue of £1billion by 2034/35.

Headquartered near Dumfries, The Carbon Removers actively captures carbon dioxide from biogas and the whisky industry and are now expanding into Europe. Founded by brothers Ed and Richard Nimmons, it is the only UK company granted a storage licence to permanently remove carbon from Denmark and the EU's first CO_2 storage facility.

SOSE plans to convert a loan to an equity share in The Carbon Removers, which will help the South of Scotland to continue its transition to Net Zero, particularly for the agriculture, whisky and bioenergy sectors based in the region.

Deputy First Minister Kate Forbes, said, "Carbon Capture and Storage (CCS) is of the utmost importance to Scotland's climate and economic transition to net zero – without it we couldn't reduce emissions from the hardest to abate sectors including chemicals, cement and certain aspects of power generation."

"CCS uses many of the same skills as the oil and gas industry and will continue skilled employment across the supply chain. It's great to see SOSE supporting a home grown company leading the charge both here and in Europe."

Encyclis receives planning permission for carbon capture at Rookery South

www.rookerysoutherf.co.uk

The company has confirmed planning permission for a full-scale carbon capture plant at its Rookery South Energy Recovery Facility (ERF) in Bedfordshire.

Illustrative design of proposed carbon capture plant at Rookery South ERF (Image: Encyclis)

The news follows the announcement in October that Encyclis had reached financial close, in conjunction with the Department for Energy Security and Net Zero, to build the UK's first full-scale carbon capture plant for Energy-from-Waste at Protos ERF, in Cheshire.

Rookery South ERF is set to be the second facility with carbon capture in Encyclis' core Midlands cluster of Energy-from-Waste sites in the central belt of the UK.

The facility, which recently reached the milestone of 2 million tonnes of residual waste processed since it started operating in January 2022, is already home to one of the UK's first carbon capture pilot plants in the waste sector.

The planned addition of full scale carbon capture would enable the plant to capture carbon dioxide from the residual waste combustion process. Encyclis said it is continuing to work on potential options for the transport and storage of captured CO_2.

Rookery South ERF provides capacity to safely and sustainably treat up to 657,000 tonnes per year of residual waste. The treatment process enables the facility to generate 60MWH of baseload electricity which is supplied to the National Grid, as well as recovering ash to be converted into construction aggregates and metals for recycling, in support of the transition to a circular economy.

The planned addition of carbon capture will enable the facility to decarbonise this process. Flue gases from the combustion process would be diverted to the carbon capture plant, where CO_2 molecules are stripped out and transferred away from the site for storage.

Additionally, the presence of biogenic carbon, as well as fossil carbon, in residual waste opens up the potential to deliver carbon dioxide removals, which effectively reduce the overall volume of CO_2 in the atmosphere.

Honeywell to supply automation for UK CCUS projects

www.honeywell.com

Technip Energies has selected the company to provide integrated automation and safety technologies to the Net Zero Teesside Power (NZT Power) and Northern Endurance Partnership (NEP) projects.

Honeywell's Integrated Control and Safety Systems (ICSS) will deliver a unified automation architecture that combines process control and safety functions for each projects, helping to support safe, reliable and efficient operations across both sites.

The NZT Power project is poised to be the world's first gas-fired power station equipped with carbon capture technology. Once operational, the facility will play a critical role in reducing industrial carbon emissions and accelerating the UK's transition to net zero. Up to two million tonnes of CO_2 a year will be captured from NZT Power and then transported and stored.

Similarly, the NEP project is designed to transport CO_2 from multiple carbon capture projects across the Teesside and Humber regions, collectively forming the East Coast Cluster, to offshore storage under the North Sea. Honeywell's technology will be integrated with the project's new CO_2 transportation and storage network that connects industrial emitters throughout the region.

UK CCS – licensing, moving faster, climate modelling

We heard an update about the UK CO2 storage license round, ideas on getting projects moving faster, and how climate change is already causing societal problems, at the GESGB CO2 storage forum in London. By Karl Jeffery.

The UK's North Sea Transition Authority (NSTA) announced a second carbon storage round on December 9, 2025. 14 locations are available in English and Scottish waters, including, for the first time, an area off the South Coast.

These sites are expected to provide up to 2 gigatonnes of storage capacity. Applications for the licenses close on March 24, 2026.

It follows a nomination process earlier in 2025, when companies were invited to say which storage sites they would like to be able to go for. Not all the nominated sites were included, said Nick Richardson, head of exploration and new ventures with NSTA.

He was speaking at the Geoscience Energy Society of Great Britain (GESGB) "CCS4G Symposium 2025" event in London on December 10.

NSTA has made a model of how much storage space the UK is likely to need in future and concluded that the UK is currently on track to be deficient in projects in 2040, so there is a need to build the project portfolio. This model is based on the UK's carbon budgets CB6 (Dec 2020) and CB7 (Feb 2025, covering 2038 to 2042).

One obstruction to investment is concerns about long term liability - Dr Martin Jagger, CCS consultant

Also, UK would like to offer CO2 storage space to countries in continental Europe. Discussions are ongoing about a closer relationship with the UK and EU, including on aligning emission trading systems, access to CO2 infrastructure and exemption to carbon border adjustments, he said.

The plan is to have regular CO2 storage rounds from now on. Also, in 2026, NSTA will hold a consultation on non-pipeline transport of CO2.

The consenting process for CO2 projects is very complex, Mr Richardson acknowledged, with many players involved, and different consents required at different points in time, including with onshore and offshore bodies and devolved administrations (Scottish government).

The CO2 storage industry is not unique in having a complex consenting process, many UK industries are in a similar situation, he said. The oil and gas industry may have had it comparatively easy.

The North Sea Transition Authority can act as an intermediary, helping applicants secure the necessary licenses, he said.

Moving CCS faster

For the carbon capture and storage industry to move forward faster, it would be helpful if it could provide more reliable returns to investors, said CCS consultant Dr Martin Jagger.

Many investors are satisfied by returns typically seen in the energy utility industry of around 3 per cent. But they take much lower risks.

UK would like to offer CO2 storage space to countries in continental Europe - Nick Richardson, head of exploration and new ventures, NSTA

Perhaps projects which meet certain KPIs, guaranteeing their financial viability, could be able to issue bonds, or accept and be able to renew bank loans, he suggested.

Dr Jagger worked in Shell upstream for 36 years, including a role as head of risk assessment for Shell's Goldeneye CCS project, which was cancelled when the UK withdrew funding abruptly in November 2015.

To improve credibility to investors, we could have independent verification of the amount of "net stored tonnes". Perhaps CO2 emitters could pay upfront for "readiness", for CO2 storage to be made available to them, he said.

One obstruction to investment is concerns about long term liability. The state could reduce this by accepting to take on the liability once it can be shown that the CO2 plume migration in the subsurface matches the prediction.

Many CCS projects to date are running at much less than full utilisation, some at 75 per cent, which is disappointing to investors. But perhaps the problem is more that false expectations were set at the outset, considering that few oil and gas production projects run at 100 per cent utilisation either, he said.

The oil and gas industry makes money based on barrels produced, not the utilisation rate, and perhaps the CCS industry should seek investment based on verified tonnes stored, rather than promises of injection per year, he said.

There could be better support for CCS 'explorers', such as having a structure for appraisal rounds which gradually reduce uncertainty and improve investability. In today's system, an exploration company which works on a field which later proves not to be viable will lose all their money.

Overall, the CCS industry has a problem getting projects approved for investment at a fast enough rate, he said.

The International Energy Agency set a target in May 2021 of 1.3 GT CO_2 capture a year by 2030. Today it is just 50m tonnes a year. Given the time taken to get projects developed, we can be sure this target is "dead", he said.

The Global CCS Institute (GCCSI), DNV, and Wood Mackenzie have all reported that the project pipeline could exceed 400 million tonnes per annum (mtpa) of capture capacity by 2030 if all announced projects move forward.

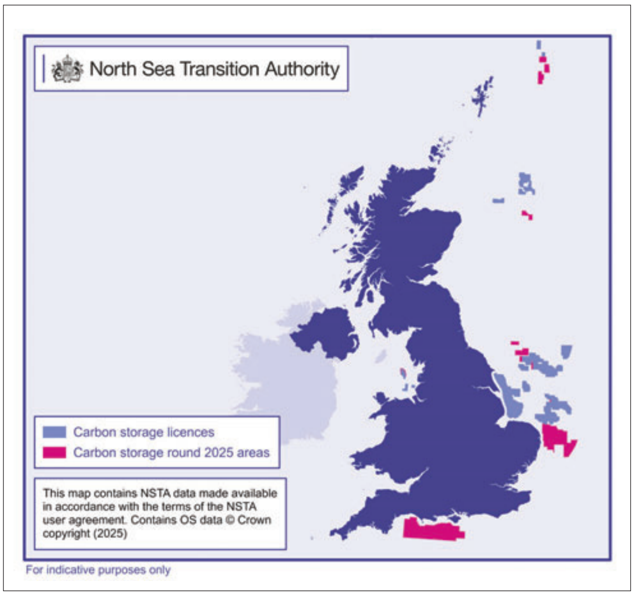
But an analysis by Thunder Said Energy found that of all currently announced projects, 14 per cent are on schedule, 50 per cent over 7 years delayed, 15 per cent providing no news flow, and 11 percent can be deemed cancelled. This suggests that by 2030 we may have more like 200 mtpa, he said.

According to the "London Register of Subsurface CO_2 Storage" from London's Imperial College, 383 MT CO_2 has been stored since 1996, including with enhanced oil recovery projects. This is just 10 days of global climate emissions.

We need more projects at a 40 mtpa scale, like potentially Project Poseidon, he said. We need to be able to get projects to a final investment decision (FID) faster. Typically, it takes 5 years today, he said.

There could be a fixed calendar for CO_2 storage license rounds, so that plans to build capture, transport and storage systems can be synchronised.

Once the UK CCS industry and government have developed a system that works, it could be published and provided to other countries as a "rule book," he said. If other countries accept the rule book, this could be good for British companies offering services in that country, because they know how to work with this system.



The UK launched a second carbon storage round in 2025

Tracking climate change

We have seen plenty of real-world impact of climate change in recent years, said Rowan Sutton, director of the Hadley Centre, the climate science division of the UK Meteorological Office.

This includes the UK June 2022 heatwave, the October 2024 Spanish floods, the January 2025 California Wildfires and November 2025 Southeast Asia flooding, he said.

The work of the Hadley Centre includes monitoring changes in climate, understanding and determining the cause of these changes, developing computer models for climate prediction / projection, providing evidence to government, and developing associated services, such as to inform risk assessments, early warning systems, and climate impact mitigation schemes.

The expert consensus is that we are currently at 1.35 degrees warming relative to pre-1850, he said. Global average temperature for 2024 was around 1.6 degrees above the pre-industrial period, but some experts say we should use the average of the last 20 years.

The relationship between global warming (temperature rise) and cumulative CO_2 emissions over the past decades looks quite linear, he said.

But it is important to recognise that the trend in extreme weather events is not linear. For example, 20mm of rain falling in an hour would be considered extreme weather. The UK saw this happening 40 times in one year, but not many times in the following year.

Hadley Centre also models the energy imbalance of the entire planet, how much energy is arriving to the planet and how much is leaving. The trend is for energy increase of 0.45 watts per m^2 per decade, he said. There is uncertainty about the role of cloud, and aerosol pollutants in this.

The climate models consider changes in oceanic currents. These are driven by density contrast, water in some parts of the world being warmer and so less dense than elsewhere, and water flows seeking to even out the density. For the Atlantic current, "there's certainty it will weaken but uncertainty about how fast," he said.

Asked how he feels when he hears Donald Trump saying climate change is a hoax, Mr Sutton replied, "it doesn't help."

"It is easy to get fatalistic [about climate] but that is not responsible action, we have to do what we can. There are forces that help and forces that hinder. We have to work with forces that help," he said, with a nod to the specialist engineers and scientists assembled in London at this year's CCS4G Symposium.

More information

www.nstauthority.co.uk

https://weather.metoffice.gov.uk

CCSA delivery plan update shows UK CCS sector at a "critical juncture"

New research from the Carbon Capture and Storage Association (CCSA) reveals that the UK now has its strongest ever pipeline of projects developing CCUS, but policy uncertainty is slowing progress, stalling projects and risking investment.

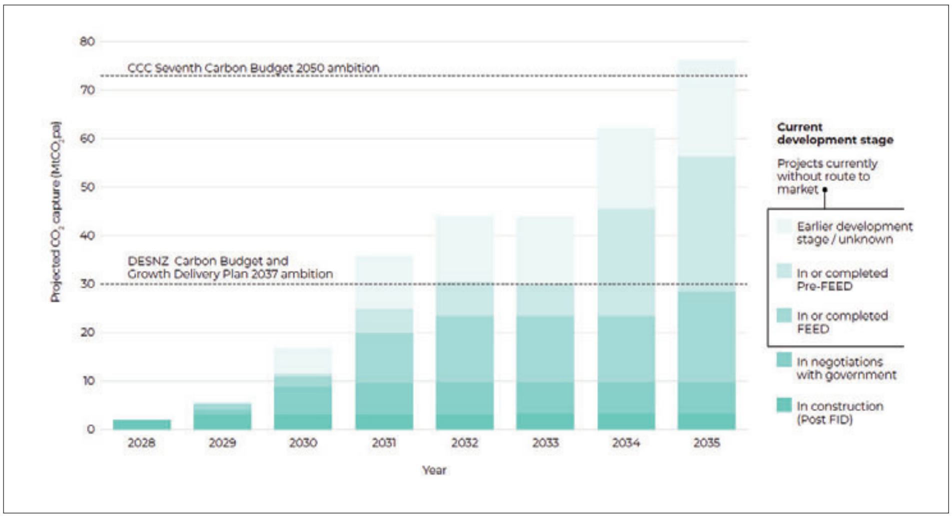
The report provides an update to the CCSA's Delivery Plan series and shows that significant momentum has been achieved. The first five major CCUS projects have now reached financial close and entered construction in Teesside and the North-West and North Wales. They are creating local jobs and protecting and future-proofing the UK's core industries including cement, energy from waste and low-carbon power.

Olivia Powis, CEO of the CCSA, said, "CCUS represents one of the UK's greatest industrial, economic and decarbonisation opportunities. This research shows the sector is primed for growth, but only if we create the conditions that allow developers to invest and deploy. With the right decisions in 2026, we can unlock billions in private investment, protect industrial jobs and secure our pathway to net zero. Without that clarity, we risk losing projects and investment to other markets."

The research highlights growing challenges. Since 2023, 27 capture projects have been cancelled or paused. Almost all remaining projects have experienced delays averaging 2 years, with 75% of developers saying they may redirect investment overseas without clearer government policy. Developers point to slow decision-making, delayed funding allocations and a lack of a route to market for projects outside government committed clusters.

Without timely action, the UK risks losing not only vital CCUS projects but also the significant economic benefits they underpin. This includes unlocking private investment in our foundation industries, enhancing energy security, delivering a predicted £94 billion boost to the UK economy, and supporting more than 50,000 jobs by 2050.

Speaking at the launch, Minister for Industry in the Department for Energy Security and Net Zero (DESNZ) Chris McDonald emphasised that CCUS will help secure the long-term future of industries such as glass and chemicals.



UK project pipeline projected operational CO2 capture capacity by year

He underlined the Government's commitment to "getting on with the job of building this new industry," which is expected to support thousands of jobs across the supply chain.

The Minister noted that construction is already underway on key projects, mentioning in particular Heidelberg Materials' Padeswood cement facility and the Protos Energy Recovery Facility (ERF) at Ellesmere Port that both reached financial close in September. Looking ahead to the next wave of deployment, the Minister confirmed that the Government is working closely with both the Acorn Project and Viking CCS to reach financial close in this parliament, and will soon identify additional projects to connect to the East Coast Cluster.

Summary of policy recommendations

The report reiterated the following key non-fiscal asks the CCSA raised with Government ahead of the 2025 Autumn Budget.

1. Deliver the actions required to progress the build-out of the East Coast Cluster and HyNet, as well as confirm the allocation of the development funding committed to Viking CCS and The Acorn Project.

2. Provide an allocation framework for government support contracts in the 2027 Spending Review and a clear nationwide route to market for CCUS deployment. This should include enabling Viking CCS, The Acorn Project, ECC Humber Expansion and MNZ | Peak Cluster to reach FID within this Parliament, and support other projects and clusters to deploy, including those using CO2 transport by ship, road, and rail.

3. Implement policies and regulations to stimulate low-carbon product, carbon removal and European-wide CO2 storage markets to enable the transition to a self-sustaining market.

More information

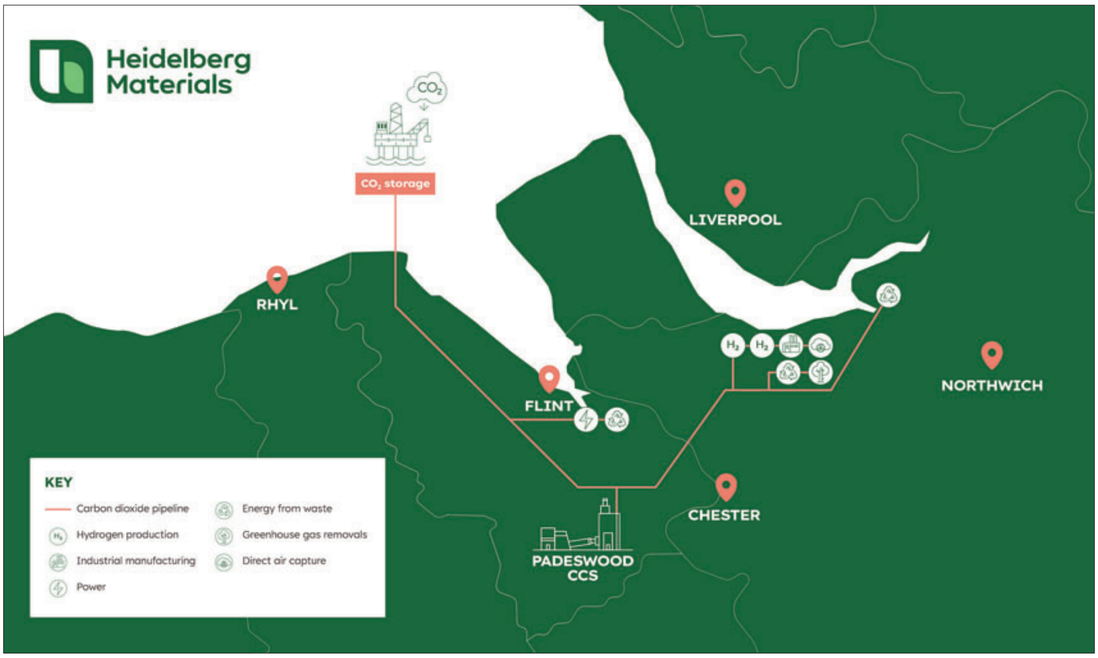
www.ccsassociation.org

MHI and Worley to deliver full-scale CCS for Heidelberg UK Padeswood

The project will be the first in Europe to deploy MHI's proprietary Advanced KM CDR Process™ to capture around 800,000 tonnes of CO2 annually from cement production operations at Heidelberg Materials' Padeswood plant in Wales.

The CO2 will be transported via pipeline for permanent storage in depleted gas fields under Liverpool Bay, as part of the HyNet North West cluster.

Tatsuto Nagayasu, Senior Vice President (CCUS) of GX (Green Transformation) Solutions at MHI, said, "We are proud to support Heidelberg Materials in realizing the UK's first full-scale carbon capture facility in the cement sector. Using our Advanced KM CDR Process™, this project will play a leading role in decarbonizing one of the most challenging industrial sectors. Together with Worley, we look forward to delivering this landmark CCS facility that will contribute to the long-term resilience of UK industry and help fulfill the country's net zero ambitions."



HyNet infrastructure for the Padeswood Cement Works in Flintshire, Wales, United Kingdom - Image courtesy of Heidelberg Materials

The news follows Heidelberg Materials' final investment decision (FID) in September 2025, made in collaboration with the UK Government under Track-1 of its CCUS cluster sequencing program. The new CCS facility is set to be operational in 2029.

MHI and Worley had been awarded a front-end engineering design (FEED) study in 2024. In the execution phase, MHI and its regional representative MHI-EMEA via its London headquarters will provide the engineering and procurement under the Advanced KM CDR Process™ for the CO2 capture technology, together with other associated plant including compressors. Worley will deliver engineering, procurement, and construction management for the balance of plant.

Cement production is responsible for around 7-8% of CO2 emissions globally. Since most of these emissions come from the chemical process (calcination), they cannot be avoided by switching to clean energy sources. This leaves CCS as the only viable option for fully decarbonized production.

Simon Willis, CEO at Heidelberg Materials UK, said, "This is the next major milestone in our plans to build the UK's first carbon capture facility at a cement works. We have established an excellent working relationship with Worley and MHI during the completion of the front-end engineering design (FEED) for our Padeswood project. This, along with their proven track record in delivering this type of complex facility, makes them the perfect partner to take our groundbreaking project to the next stage."

Chris Ashton, Chief Executive Officer of Worley, said, "This project is a landmark for industrial decarbonisation in the UK and Europe and part of the HyNet carbon capture cluster. We're proud to be working alongside Heidelberg Materials and MHI to deliver a facility that will help transform cement production and support the UK's net zero ambitions. Our role in this project reflects our ability to enable sustainable industrial solutions and leverage our global expertise in delivery for complex energy and infrastructure projects."

The Padeswood CCS project is expected to create approximately 50 new permanent jobs and secure over 200 existing roles, in addition to supporting up to 500 jobs during construction. As part of the HyNet North West cluster, the project will also contribute to building a long-term carbon management infrastructure in the UK, while enabling Heidelberg Materials to supply low-carbon cement to the construction industry.

More information

www.padeswoodccs.co.uk

www.mhi.com

Carbon capture technology relies on high-performance CO2 sensors

As the Global South's first Direct Air Capture (DAC) company, Octavia Carbon has commissioned the world's second DAC + geological storage plant. Harnessing Kenya's abundant renewable geothermal energy to capture carbon dioxide from the air for secure storage underground, Octavia has developed a scalable technology that relies on the unique performance characteristics of Vaisala's CO2 measurement sensors.

The DAC process requires energy, so for the process to deliver a net reduction in GHGs, it is necessary for the energy supply to be carbon neutral. Here, Kenya has a significant advantage – the Kenyan stretch of the Great Rift Valley offers enormous potential in geothermal energy. Tectonic plate movements around 25 million years ago, allowed water to percolate into contact with hot rocks 1-3 km beneath the surface, creating a mix of superheated, high-pressure water and steam - perfect conditions for generating geothermal energy.

Today, around 90% of Kenya's electricity is generated from renewable energy sources, of which geothermal remains the most significant source. The country's geothermal power generation plants also create waste heat, and Octavia Carbon's technology has been designed to utilize this resource. In addition, this underground volcanic geology is ideal for permanent underground CO2 storage.

Octavia Carbon site in Kenya

The success of DAC is heavily dependent on the efficiency with which it is able to remove CO2 from the air. In particular, DAC operators must maximise the difference between the flow of captured CO2 and the CO2 emissions of the capturing process. The accurate measurement of CO2 concentration is therefore critically important.

Octavia Carbon

Founded in 2022 by two innovators, Octavia Carbon now employs over 60 people on its mission to scale DAC technology down the cost curve and up the impact curve. The company's goal is to provide an effective solution for durable carbon removal, and to act as a catalyst for green industrial growth and climate justice in the Global South.

In September 2025, the Second Africa Climate Summit concluded with a clear call to position Africa, not as a victim of climate change, but as a driver of solutions in the global climate economy. Octavia Carbon was established to become one of these solutions.

Octavia offers a number of Carbon Dioxide Removal (CDR) packages which enable individuals and organisations to make philanthropic donations and/or offset their carbon emissions. In addition, organisations participating in Carbon Trading are able to purchase CDR Credits directly from Octavia.

After capturing CO2 directly from ambient air, Octavia liquifies the gas and transfers it to a partner for permanent underground geological storage.

CO2 measurement challenge

Conscious of the requirement to develop a DAC process that is as efficient as possible, Octavia's optimisation team needed to be able to take accurate inline measurements at every stage of the process. In addition, verification of Octavia's carbon capture process can only be possible with accurate reliable CO2 measurements.

Octavia staff tried and discarded several products from CO2 sensor manufacturers before adopting Vaisala's. Khamis Mwalwati Muniru, Process Optimization Lead at Octavia, explains. "Within my team, we rigorously test materials to assess their CO2 capture efficiency. This process demands precise CO2 monitoring across a broad concentration range, spanning from 0-100% vol during CO2 release phases, and to below 400 ppm during CO2 capture which necessitates exceptional measurement accuracy."

Khamis found that some sensors were able to measure accurately at some concentrations, but not all, and that reliability became an issue with some sensors. "We need to be able to accurately measure carbon dioxide levels from an ambient concentration of around 430ppm all the way up to captured CO2 at 99.99%," he says. "Vaisala's were the only sensors capable of delivering the required accuracy across such a wide range."

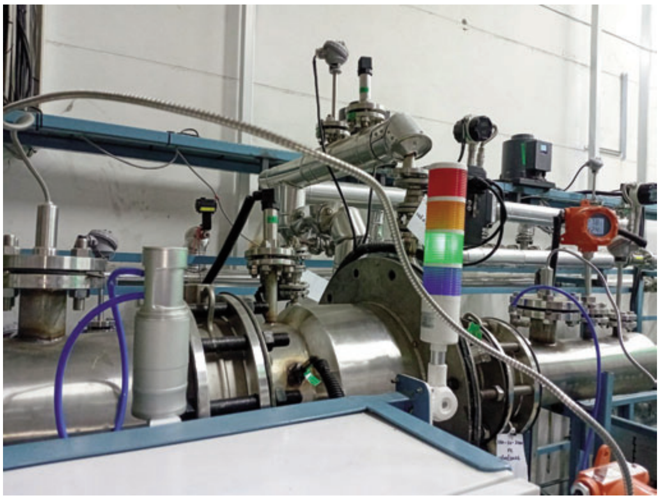
In addition to measurement accuracy, Khamis's team also required measurement stability. "Our DAC is essentially a batch process, which means that sensor measurements vary from very low to very high over a short period of time – typically around one hour. We discovered that some of the initial (now discarded) sensors lost accuracy over a single cycle, which had two important consequences. Firstly, we had to conduct frequent laborious, time-consuming recalibrations, and secondly, most importantly, we could not rely on the measurements to identify the point at which the sorbent was fully saturated."

Vaisala's solution was found to be ideal for carbon capture

Octavia's process optimization team evaluated Vaisala's GMP343 carbon dioxide probe and found it to be ideal for their application. "In addition to a wide range, we also required high accuracy below 400ppm, which was not possible with most of the sensors that we tried." Khamis explains. "So we were delighted to discover that the GMP343 could achieve this with ±3 ppm accuracy and long-term stability. Happily, this meant that we did not have to recalibrate before every test."

The GMP343 employs Vaisala's CARBOCAP® technology, a silicon-based non-dispersive infrared (NDIR) single-beam, dual-wavelength sensor with no moving parts. CARBOCAP® sensors offer high levels of stability over time because they have a micromechanical FPI filter which provides a reference measurement that compensates for any potential changes in light source intensity, as well as for contamination and dirt accumulation in the optical path. For Octavia, this stability represented an excellent ±2% of the reading per year.

In addition to the GMP343, Octavia also employs the Vaisala MGP241, which was developed specifically for carbon capture processes, delivering reliable measurements in wet and harsh conditions. Measuring inline with automatic temperature and pressure compensation, the range of the MGP241 extends from 0...100 vol-% CO2 and also employs CARBOCAP® technology for long-term stability. The MGP 241 was found to be ideal for measurements after adsorption.



Vaisala GMP343 measures ppm level CO2 at the inlet and outlet of the DAC plant with high accuracy and precision

Octavia Carbon's DAC process

There are three main phases in the process – Adsorption, Desorption and Liquefaction/Injection. Each phase requires energy, but with Kenya's easy access to renewable geothermal energy, Octavia's processes are low-cost and carbon negative.

In the first phase, ambient air (containing~ 430ppm CO2) is pulled into the DAC machine where it passes through a filter containing chemical sorbents. These chemicals selectively bind with carbon dioxide, effectively removing it from the air, until the filter material becomes fully saturated with CO2.

In the desorption phase, indirect heat under vacuum is applied to the filter material causing it to release the concentrated CO2, which is extracted. This process regenerates the filters for reuse.

In the final stage, the captured CO2 is compressed and cooled, which causes it to liquify so that it can then be transported to secure geological sites where it is injected deep underground into appropriate rock formations.

Importantly, Octavia's DAC process is completely modular and therefore scalable, so the company has ambitious growth targets. It has a target of 1,000 tons of CO2 captured annually by the first commercial-scale plant (Project Hummingbird) by 2026, and is aiming for over a million tons removed annually by 2030.

Summary

Vaisala's Product Line Manager Antti Heikkilä says: "We are delighted to be able to help Octavia Carbon with this exciting project. Our unique CO2 probes were developed specifically for challenging applications such as this. However, with 'Taking Every Measure for the Planet' as our Core Purpose, this project is a perfect example of the ways in which Vaisala's measurement technology is helping to fight climate change."

"Ultimately, the role of DAC will be dictated by the cost/tonne of CO2 captured," Khamis explains. "We are fortunate in the Rift Valley to benefit from carbon-free geothermal energy, but the scalability of our technology will depend heavily on process optimization."

Accurate and reliable CO2 measurements are essential for both the process optimization and operational teams at Octavia Carbon. Without accurate measurements, it would not be possible to select and improve sorbent performance. Similarly, accurate measurements enable effective process control, enabling operational staff, for example, to identify the exact moment of sorbent saturation.

The accurate and timely identification of the sorbent saturation point is essential for process efficiency, helping to maximise CO2 capture while minimizing costs, saving time and lowering process energy consumption.

Finally, and possibly most importantly, it is essential that Octavia Carbon's customers have full confidence in the accuracy and reliability of the CDR that they purchase. This will be underpinned by third-party accreditation, but that also entirely depends upon accurate CO2 measurements.

More information

www.octaviacarbon.com
www.vaisala.com

The sustainable carbon challenge for e-fuels

The European Federation for Transport and Environment commissioned ERM to carry out a study looking at CO2 transportation for e-fuels production in Europe.

Why do we still need to capture carbon for the future green transport system, how much is sustainable, and how should we move it around?

To achieve its net-zero target by 2050, Europe must decarbonise all of its transport sector. While direct electrification is rapidly scaling in the road sector, sectors such aviation and shipping remain harder to electrifyand continue to rely on energy-dense fuels. For these sectors, e-fuels are one of the preferred options available. But not all e-fuels are produced the same way and not all carbon sources are eligible as sustainable under EU rules.

What are the different types of e-fuels?

In the aviation sector, the flagship e-fuel is e-kerosene, often termed e-SAF, which can be blended into fossil jet fuel and used directly into existing aircraft engines. Producing e-kerosene requires large quantities of green hydrogen and a steady supply of CO2. For each ton of green hydrogen required, around 8 tonnes of CO2 are needed.

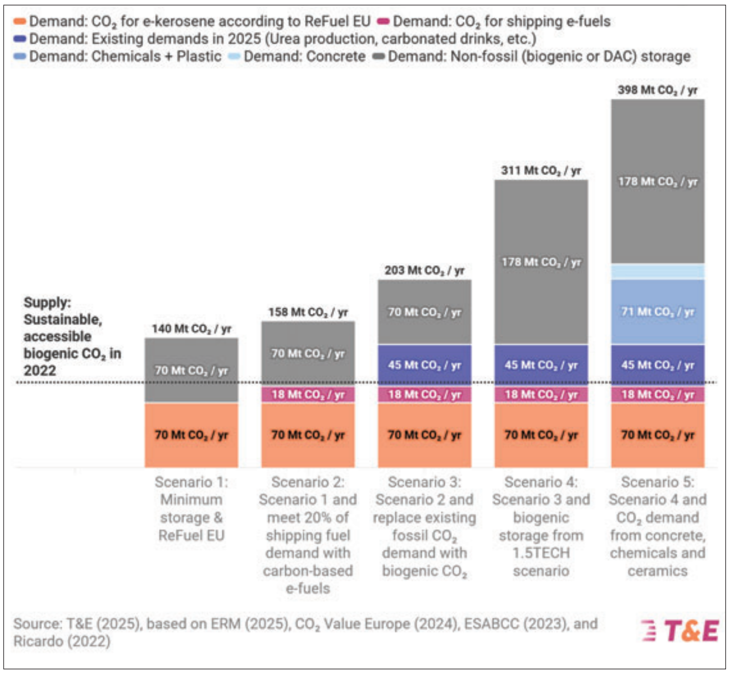
Shipping has more e-fuels options available. Two e-fuels options are e-methanol and e-ammonia. While the latter is carbon-free, e-methanol is a carbon-based fuel, like e-kerosene, requiring around 7 tonnes of CO2 per tonne of green hydrogen.

Why does the source of carbon matter?

In carbon-based fuels, the CO2 becomes embedded in the fuel molecule and is released back into the atmosphere when combusted. Unlike other CO2 utilisations, e-fuels do not store carbon temporarily. They only delay its release. The EU RFNBO rules correctly factor in this, with all fossil CO2 becoming ineligible from 2041 (with a deadline already from 2036 for carbon from fossil power generation), obliging e-fuels producers to turn towards sustainable carbon sources.

This leaves only two long-term options:

- Direct Air Capture (DAC): refers to the capture of CO2 that is directly present in the atmosphere.
- Sustainable biogenic CO2: refers to the capture of CO2 from sustainable biomass-based processes, such as pulp and paper mills.



2050 CCUS demand for biogenic CO2 exceeds current availability

In the short and mid-term, biogenic CO2 is the easiest and cheapest CO2 option. DAC will be essential in the long-term but currently the technology cannot yet supply the volumes required at economically viable cost.

What is the availability of biogenic CO2 for e-fuels in the short to medium term?

Europe has a diverse set of biogenic CO2 sources but only some are truly sustainable for e-fuel production. The ERM report commissioned by T&E identifies 92 Mt per year of sustainable and accessible biogenic CO2 in Europe in 2022. 'Sustainable' excludes bioethanol fermentation and biomass power plants that rely on unsustainable feedstocks. Sustainable sources include amongst others, pulp and paper mills, energy-from-waste, and biogas upgrading plants.

The sustainable biogenic CO2 availability in Europe is more than enough to supply first of a kind e-kerosene and e-methanol projects, which require around 300 kt per year of CO2 each.

Are e-fuels the only sector needing biogenic CO2? What other demands for CCU or CCS?

But e-fuels are not the only sector looking for biogenic CO2. The same carbon streams are being targeted by permanent carbon storage projects, especially Bioenergy with Carbon Capture and Storage (BECCS), as well as other CCU uses in chemicals, plastics and concrete.

By 2050, combined CCUS demand for biogenic CO2 could rise well beyond today's 92 Mt of sustainable, accessible supply, meaning not everyone will get the carbon they need.

With sustainable biogenic CO2 both limited and increasingly contested, T&E argues that the EU should prioritise its usage and hence, stop promoting BECCS based on burning biomass for power and instead make sure these scarce carbon resources go to sustainable uses like e-fuels production.

The chart on the previous page shows that by 2050, the total CCUS demand for biogenic CO2 ranges from 140 Mt CO2 in the minimum demand scenario to ~400 Mt CO2 per year in a high demand scenario. With the 92 Mt of sustainable, accessible biogenic CO2 in Europe, even the minimum demand case already exceeds supply.

Ultimately, DAC will need to be scaled up to meet demand for carbon utilisation and storage, and e-fuels will need to turn towards DAC to be scalable.

How to access these biogenic carbon sources?

The challenge is that e-fuel plants are not always located next to biogenic CO2 emitters.

Four transport modes are considered to transport biogenic CO2, namely pipelines, rail, trucks, and shipping.

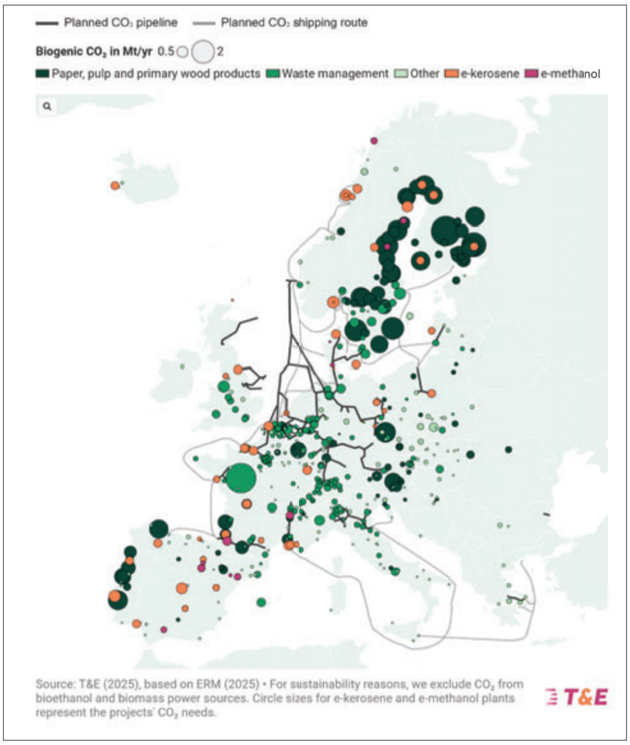
• Pipelines are the most efficient option for large, steady flows. However, planned CO2 pipelines are heavily concentrated around the North Sea, leaving major biogenic sources in Finland, Sweden, Slovakia and Central/Eastern Europe unconnected.

• Rail is a cost-effective option for the typical e-fuel plant scale, with around 300 kt per year over medium distances (around 300 km).

• Trucking can help aggregate smaller, high-purity volumes (e.g., from biogas plants) in the early years.

• Shipping may play a role for large coastal hubs

Transporting CO2 via pipeline, rail, ship or truck will be essential as the volumes of e-fuels increase. The study shows that while 60% of announced projects are within 100 km of accessible biogenic CO2, the remaining are farther away. Planning CO2 transport is crucial. With proper planning and guaranteed third-party access, this CO2 could be made accessible to e-fuel producers, helping connect large untapped volumes to future plants.



More than 60% of announced e-methanol and e-kerosene projectshave sufficient biogenic CO2 from large emitters in a 100 km radius

What is the cheapest way to transport CO2?

The study shows that there is no single preferable way to transport CO2. The most suitable option depends on the flow rate and distance from the biogenic CO2 source to the e-fuel plant.

As shown in the table below, for large, steady flows over shorter distances, pipelines are the most cost-effective solution, with transport costs below €50 per tonne of CO2. For a typical e-fuels plant handling larger volumes, a few hundred thousand tonnes per year over a few hundred kilometres, rail can be competitive, costing around 67 EUR per tonne for 300 kt over 300 km.

Transport cost per tonne of CO_2 as a function of transport distance and annual CO_2 flow rate. Cells show the cost for the cheapest transport option, which is indicated by the colour.

Cheapest transport option: Truck (liquid) Pipeline (gas) Pipeline (liquid) Rail (liquid) Ship (liquid)

Distance - Flow rate	30 kt CO_2/yr	100 kt CO_2/yr	300 kt CO_2/yr	1000 kt CO_2/yr
10 km	60 €/t	38 €/t	28 €/t	23 €/t
30 km	61 €/t	48 €/t	34 €/t	25 €/t
100 km	69 €/t	58 €/t	48 €/t	35 €/t
300 km	91 €/t	76 €/t	67 €/t	49 €/t
1000 km	147 €/t	135 €/t	94 €/t	70 €/t

Source: T&E (2025), based on ERM (2025) • Includes conditioning and assumes CO_2 is available in gas state after capture. T&E

Rail is a cost-effective CO2 transport option for medium-sized emitters over medium to long distances

Ships are the most cost-effective option for transporting CO2, but only over long distances and with a high flow rate in large coastal hubs. Overall our findings show that transporting biogenic CO2, even over longer distances, adds only less than 10% to the production cost of e-fuels.

What is the EU planning on CO2 transport and what are T&E's main policy recommendations?

In light of the 2040 climate target, the EU has started to underscore the need for CCUS to meet the EU 2050 climate objectives and hence to plan the development of competitive markets and transportation infrastructure for CO2. As part of this, the Commission is working on a new CO2 transportation infrastructure and market legislation.

This framework should map where sustainable biogenic CO2 is available and where e-fuel plants are planned, guarantee fair third-party access to pipelines and other CO2 transport modes, and create a transparent, competitive market rather than monopoly networks. Done right, this legislation can make CO2 infrastructure an enabler for e-fuels and other sustainable uses of biogenic carbon, instead of a tool that mainly locks in fossil emissions

More information

www.transportenvironment.org/articles/the-challenge-of-sourcing-sustainable-co2-for-e-fuels

Japan's CCUS capacity set to surge 30-fold by 2035

Wood Mackenzie projects 12.5 Mtpa capture capacity as industrial sectors drive deployment, but cross – border cost premium threaten timeline for government targets.

Japan's CCUS sector is entering a rapid expansion phase, with capacity projected to surge from current demonstration levels of 0.3 Mtpa to nearly 12.5 Mtpa by 2035, according to Wood Mackenzie. This 30-fold increase positions Japan at the forefront of Asia-Pacific's industrial decarbonisation efforts.

However, achieving full government targets will require accelerated development of cross-border storage partnerships. Wood Mackenzie forecasts Japan will reach its 2030 targets by 2035, with cross-border agreements requiring additional time to finalise.

Cross-border collaboration key to Japan's CCUS ambitions

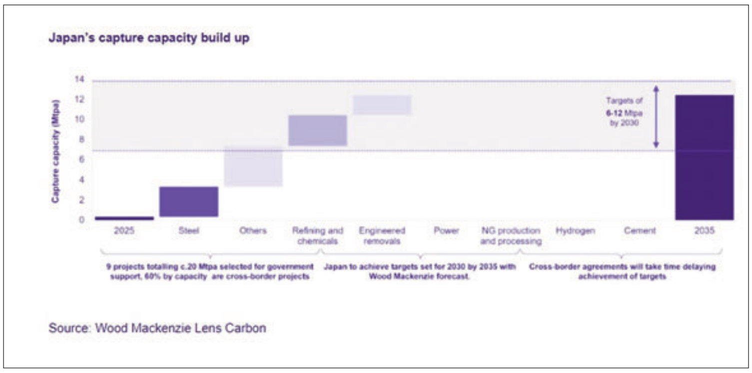
Japan's CCUS development is increasingly driven by industrial applications, particularly in hard-to-abate sectors like steel, petrochemicals. Among the nine advanced Carbon Capture and Storage (CCS) projects shortlisted by the government, totalling over 20 million tons per year (Mtpa) of potential capacity, nearly 60% of this capacity relies on international cross-border storage partnerships.

"Cross-border collaboration is not just an option, but a necessity, even though 2035," said Hetal Gandhi, Lead – CCUS, Asia Pacific at Wood Mackenzie. "While there are countries well positioned in terms of storage policy and project pipeline, costs challenges remain for cross border carbon transport. For instance, transporting captured emissions from Japan domestically versus to Australia could cost 7–9 times more.

However, early movers securing the right storage fields and partnerships could limit overall cost increases to around 15–20%. Bilateral agreements will be a critical area to watch as nations race to achieve competitive advantage."

Policy framework strengthens commercial viability

Japan now ranks second in Asia Pacific for CCUS policy readiness, trailing only Australia, according to Wood Mackenzie's Policy Readiness Index. The country scores particularly strongly on two key parameters: the quantum and specificity of CCUS targets, and access to low-cost funding.



Japan's legislated net-zero targets and robust storage regulatory regime position it alongside global leaders. The transition of Japan's GX ETS from voluntary to mandatory status, combined with fuel tax levy implementation, is creating stronger economic incentives for CCUS adoption across industrial sectors.

Cross-border transport is the next frontier

The emergence of cross-border CO2 transport represents a transformative trend, particularly relevant for Japan's island geography. Wood Mackenzie has developed a new assessment framework evaluating country readiness for cross-border CO2 transport across six parameters, from CCUS infrastructure foundations to regionally traded carbon pricing. The analysis shows Japan is well-positioned to lead this emerging market segment, with potential storage partnerships under discussion with Australia, Indonesia, and Malaysia.

However, cost challenges remain significant. Transport costs from Japan to Australia could be 7-9 times higher than domestic transport. Early-mover advantages and strategic partnerships could limit overall cost increases to 15-20%, but bilateral agreements will be critical to establishing competitive frameworks.

Gandhi added "multiple storage hubs in the Asia-Pacific region are developing capabilities specifically designed for cross-border services. Japan's early-mover positioning in bilateral agreements and strategic partnerships will be critical to securing advantaged storage access."

Investment requirements and government support

According to Wood Mackenzie, Japan will require at least USD 10 billion in government support for CCUS implementation through 2050, assuming carbon prices reach USD 69 per unit by mid-century. This support is essential given the current profitability landscape for CCUS projects globally.

Analysis of 200 CCUS projects across multiple geographies shows that even best-in-class incentives and emissions trading system (ETS) revenues often fall short of covering full project costs when considered individually. Successful project economics require "stacking" multiple support mechanisms: combining capital and operational grants, tax incentives, ETS revenues, and potential product premiums for low-carbon materials. Focus on lowering cost is also important.

"Japan's focus on high-value industrial applications and technology development will need to create pathways to commercial viability that go beyond basic carbon pricing," Gandhi concluded.

"The integration of domestic innovation with strategic cross-border partnerships will be key to optimize the value equation."

More information
www.woodmac.com/lens/carbon

Report: Role of CCUS in decarbonising India's steel sector

The study from the Climate Policy Initiative and Dastur Energy explores the potential, obstacles, and benefits of India implementing CCUS to support the steel industry's pathway to deep decarbonisation.

The steel industry is a key contributor to India's economic development and industrial growth. Policy reforms introduced in the 1990s positioned India among the top global steel producers, supported by ongoing initiatives such as the National Steel Policy and the Green Steel Taxonomy.

Projections show crude steel capacity reaching around 612 MTPA by 2050, underscoring the need for sustained investment and competitiveness improvements.

The steel sector is also the largest contributor to India's industrial emissions, the report says, therefore this sector must implement decarbonisation measures to align with the country's climate objectives and global targets.

The research employed a comprehensive analytical framework to examine techno-economics, storage and utilisation potential, and the requisite finance and policy needs.

Key takeaways

• Emission Reduction: Using a single-point capture strategy can cut down Scope 1 emissions in the blast furnace-basic oxygen furnace (BF-BOF) route by 50%, bringing emissions down from 1.95 to 1.0 tonnes of carbon dioxide (tCO2) per tonne of hot-rolled coil (tHRC).

• Targeted Capture: Single-point carbon capture in BF-BOF plants with gas conditioning (water gas shift and CO2 pressure swing adsorption) is superior, owing to improved efficiency and lower costs.

• Market Stimulation: Producing low-carbon steel and CO2-based products necessitates demand stimulation, as well as price support measures, to compete with traditional products in the market.

• Carbon Price: The carbon credit price at which a project reaches breakeven is about INR 2,099 (USD 25)/tCO2. Under such conditions, a project can demonstrate potential for maintaining financial viability in a mature carbon market.

• Storage Assurance: Significant geological storage potential, especially in deep saline aquifers, enhances the long-term viability of CCUS deployment.

• Dedicated Finance Vehicles: Specialized finance vehicles, including the proposed Carbon Capture Finance Corporation (CCFC), can de-risk projects, provide tax credits for capital expenses, and cash credits for incremental costs of operation.

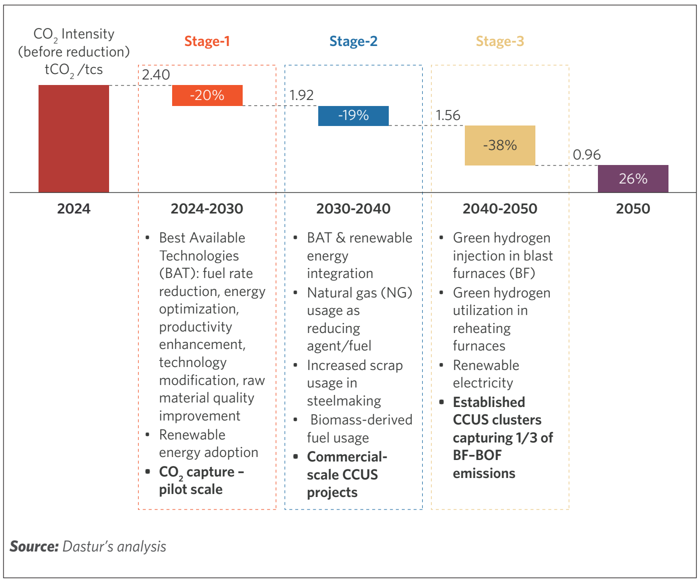
Recommendations

• Policy Certainty: To help de-risk early-stage investment, the government could deliver clear and comprehensive rules for captured CO2 ownership, long-term access and liability allocation, and a streamlined permitting process for CO2 storage.

- MRV Standards: The authority may form a requisite monitoring, reporting, and verification (MRV) framework for the monitoring of captured and stored CO2.

- Carbon Market Integration: Adopt comprehensive, progressive climate policy initiatives, such as the implementation of the Carbon Credit Trading Scheme (CCTS), which can provide an effective breakeven price and revenue stream for CCUS projects.

- Demand Creation: Develop market demand by establishing low-carbon product standards and procurement specifications to purchase green steel and captured CO2-based products.



Deployment mechanism for CCUS along with other decarbonisation

The Green Steel Public Procurement Policy could be implemented promptly to stimulate demand for green steel.

• Project Progress: Develop demonstration-scale projects in the prioritized steel clusters to collect site-specific data, verify actual operational costs, and boost investor confidence.

• Capacity Building: Support capacity building by developing standards and training programs for engineers and operators for safe operation of CO2 pipelines and injection sites.

• Concessional Finance: Increase the availability of concessional and blended finance instruments to synergize with the proposed CCFC and implement a risk-sharing mechanism to lessen the high costs related to upfront capital.

More information

www.climatepolicyinitiative.org
www.dasturenergy.com

Projects and policy news

CSIRO releases roadmap for Australian decarbonisation through CDR

www.csiro.au

CSIRO, Australia's national science agency, has released the Australian Carbon Dioxide Removal Roadmap detailing the potential for a novel CDR industry that could help the nation, and the rest of the world, reach net zero.

Achieving net-zero emissions to meet the goals of the international Paris Agreement is only possible if countries simultaneously remove carbon dioxide from the atmosphere and reduce emissions.

Australia is projected to require between 133–200 megatonnes (Mt) of CO2 removed from the atmosphere per year by 2050.

Carbon Dioxide Removal (CDR) refers to approaches that remove CO2 from the atmosphere. CDR differs from carbon capture and storage (CCS), which seeks to remove carbon before it enters the atmosphere.

The roadmap estimates the capacity and cost of a selection of novel CDR technologies and identifies the next steps required to develop and deploy them at scale in Australia.

Sweden launches billion dollar fund for BECCS projects

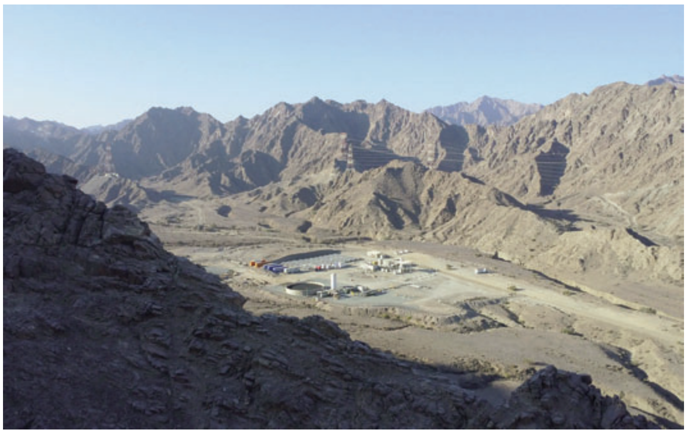
www.energimyndigheten.se

The SEK 10 billion support is aimed at operators with facilities in Sweden that can contribute to negative carbon dioxide emissions through bio-CCS.

The second call within the Swedish Energy Agency's support scheme for bio-CCS has opened with a total of SEK 10 billion (just over $1B) available for allocation.

"The state support enables the value chain for the capture, transport and storage of biogenic carbon dioxide to be built more quickly. This strengthens industrial transition and technological development in an area where Sweden has strong potential to lead," said Carl Mikael Strauss, Head of Unit at the Swedish Energy Agency.

Funds from the support scheme will be allocated through a reverse auction, where the lowest bid wins. Companies that can offer the service of capturing, transporting and geologically storing carbon dioxide from biogenic sources, while requiring the least support per tonne of stored CO2, will win the reversed auction. The support will be paid retrospectively over 15 years, once the carbon dioxide has been geologically stored.



44.01 has started injecting CO2 at its scaled-up carbon storage site in Fujairah

Holcim and 44.01 launch carbon capture and mineralisation pilot in Fujairah

www.4401.earth

www.holcim.com

It is the world's first pilot project to mineralise the CO2 captured at a cement plant in partnership with Fujairah Natural Resources Corporation (FNRC).

44.01 has started injecting CO2 at its scaled-up carbon storage site in Fujairah, UAE marking a major step towards delivering cost-effective, permanent in-situ mineralisation at scale.

44.01 has scaled up the CO2 storage capacity and capability at the site of its XPRIZE X-Factor award-winning Project Hajar. The upgraded project will provide safe, permanent local storage for CO2 from hard-to-abate industries, direct air capture (DAC) facilities and biogenic sources.

The company's single borehole has an estimated CO2 capacity of 25,000 tons per year and 44.01 intends to inject up to 20 tonnes of CO2 per day with its upgraded injection system – representing a tenfold increase from the XPRIZE winning project. The site's operations are powered 100% by renewable energy, with a biodiesel generator available as backup.

"This is an important milestone to show in-situ mineralisation can scale — and that we can deliver real solutions to customers wanting to decarbonise," said Talal Hasan, CEO of 44.01. "The project is a successful continuation of our scale-up roadmap to demonstrate our technological capability, whilst storing CO2 from a range of suppliers safely and permanently and improving costs. To meet climate goals, we need more CO2 stored safely and permanently, and scaling projects like these is how we will get there."

By increasing capacity and proving reliable field delivery, the project supports the region's net-zero goals and helps lay the groundwork for scalable, permanent carbon storage.

Blackrock takes minority stake in Eni CCUS Holdings

www.eni.com

Global Infrastructure Partners (GIP), a global infrastructure investor and a part of BlackRock, has acquired a 49.99% stake, concluding a deal first announced in August.

Eni CCUS Holding operates, through its subsidiaries, the Liverpool Bay and Bacton projects in the UK, in addition to the L10-CCS project in the Netherlands. Furthermore, the Company has the right to acquire the 50% held by Eni of Ravenna CCS project in Italy and it will be able to include other potential projects within a broader platform of CCS initiatives in the medium- to long-term.

GIP's entry, as a co-investor, confirms the effectiveness of Eni's strategy in the sector and consolidates the development plan of Eni CCUS Holding. This strategic partnership enhances the industrial potential and the value of the portfolio projects, reinforces Eni's ambition to be a leading global player in the carbon capture and storage sector, and paves the way for future growth opportunities.

Södra tests Svante carbon capture tech at Värö pulp mill

In early 2026, a pilot project for carbon capture will be launched at the Värö industrial site aiming to build knowledge around the technology and explore new business opportunities using biogenic carbon dioxide as a raw material.

The capture facility, based on technology from Canadian company Svante Technologies, will be tested in Södra's own environment at the Värö site.- Photographer: Per Pixel Petersson

By testing new technology to capture biogenic carbon dioxide in an industrial setting, Södra seeks to explore how this resource can be refined and used in new applications without increasing forest harvesting.

Södra's pulp production generates biogenic carbon dioxide, which has the potential to play an active role in future value chains. By developing technologies to use this CO2, new opportunities arise to extend the value chain and support a circular bioeconomy.

Captured carbon dioxide can be used as a raw material in sectors such as food production, water purification or chemical manufacturing, as well as in longer-lived products like construction materials or e-fuels. It can also be permanently stored, thereby enabling negative emissions. This allows Södra to create additional value from the same volume of forest raw material, while improving resource efficiency and developing new revenue streams.

"Carbon capture is a technology with the potential to generate new revenue streams and strengthen our customer offering. By capturing biogenic carbon dioxide – a currently untapped resource – we can meet the growing demand for products with a low carbon footprint and build long-term competitiveness," said Johannes Bogren, President of Södra Bioproducts.

The capture facility, based on technology from Canadian company Svante Technologies, will be tested in Södra's own environment at the Värö site. The aim is to build knowledge around the technology and evaluate opportunities for large-scale capture in the future.

"By conducting trials with carbon capture, we're building expertise based on our own conditions. It's an important step in driving innovation and developing new solutions that strengthens our competitiveness and the profitability of forest estates," said Jenny Gotthardsson, General Manager at Södra Cell Värö.

During parts of the test period, a facility from the research institute RISE will also be connected to test liquefaction of the captured carbon dioxide. This enables exploration of the entire chain – from capture to liquid carbon dioxide. The goal of the project is to evaluate both technology and business models for future investments. It also marks a step towards developing new value chains and revenue streams from the same volume of raw material.

The project is funded through Industriklivet, which is part of the EU's Recovery and Resilience Facility (RRF), under the Next Generation EU programme. Industriklivet is a government initiative managed by the Swedish Energy Agency.

More information

www.sodra.com/en/global/about-us/public-affairs/position-papers/position-on-carbon-dioxide/

DongHwa Entec demonstrates Korea's first cryogenic CCS plant

The company successfully completed a performance demonstration test of a cryogenic cooling-based CO2 capture and liquefaction plant, developed as part of a national energy technology R&D project.

The project is in collaboration with Korea Electric Power Corporation (KEPCO) and Korea Midland Power Co., Ltd. (KOMIPO). The demonstration test was conducted on November 20 under the supervision of the Korean Register (KR).

This demonstration project aimed to achieve a CO2 capture rate of 90% from flue gas, liquefied CO2 purity of 99.99%, and a daily liquefied CO2 production capacity of 1 ton. The system is characterised by the integrated operation of a membrane-based separation process and a wet amine process, optimised through organic process linkage.

A key technical highlight is the effective utilisation of waste cryogenic cooling energy. A pre-cooling process was implemented to ensure optimal membrane performance, while the recovered cooling energy was reused as the cooling source for CO2 liquefaction.

This innovative approach significantly minimised overall energy consumption across both the capture and liquefaction processes.

The nation's first CO2 capture and liquefaction demonstration achieved a 90% capture rate and 99.99% purity, plus 24-hour continuous operation

Through this demonstration, DongHwa Entec successfully showcased several core technologies, including:

• Flue gas temperature control technology to maximise membrane performance

• Moisture removal technology for flue gas streams

• Process design technology to prevent dry ice formation during CO2 liquefaction

In addition, the project achieved a meaningful increase in the localisation rate of key equipment used in the CO2 capture and liquefaction processes, further enhancing technological independence and industrial competitiveness.

Chang-Soo Kim, Executive Vice President and Head of R&D at DongHwa Entec, said, "The successful CCS demonstration proves our proprietary technology by validating CO2 capture and liquefaction performance using actual flue gas from KOMIPO's Boryeong Power Plant. This achievement clearly confirms both field applicability and commercial feasibility."

"This milestone not only enables the deployment of CO2 capture and liquefaction technology optimised for domestic power plant operating conditions, but also provides a practical solution scalable to large-scale power generation systems."

"Building on this success, DongHwa Entec plans to actively expand its technology portfolio across the entire CO2 value chain, including the development of commercial-scale CO2 capture and liquefaction facilities with a capacity of 100 tons per day, Onboard Carbon Capture and Storage (OCCS) systems, and Liquefied CO2 (LCO2) carrier Cargo Handling Systems (CHS)."

DongHwa Entec said it aims to expand the supply of its solutions to both domestic and international power generation and industrial facilities, thereby making tangible contributions to national carbon neutrality policies and energy transition strategies.

The company said it seeks to establish itself as a global leader in eco-friendly energy system technologies, aligned with the worldwide momentum toward carbon neutrality and energy transition.

More information
www.dh.co.kr/eng

Graphene membranes show promise for cheaper CO2 capture

Researchers at EPFL have modelled how a new graphene-based membrane material could cut the energy use and cost of capturing CO2 from power and industrial plants.

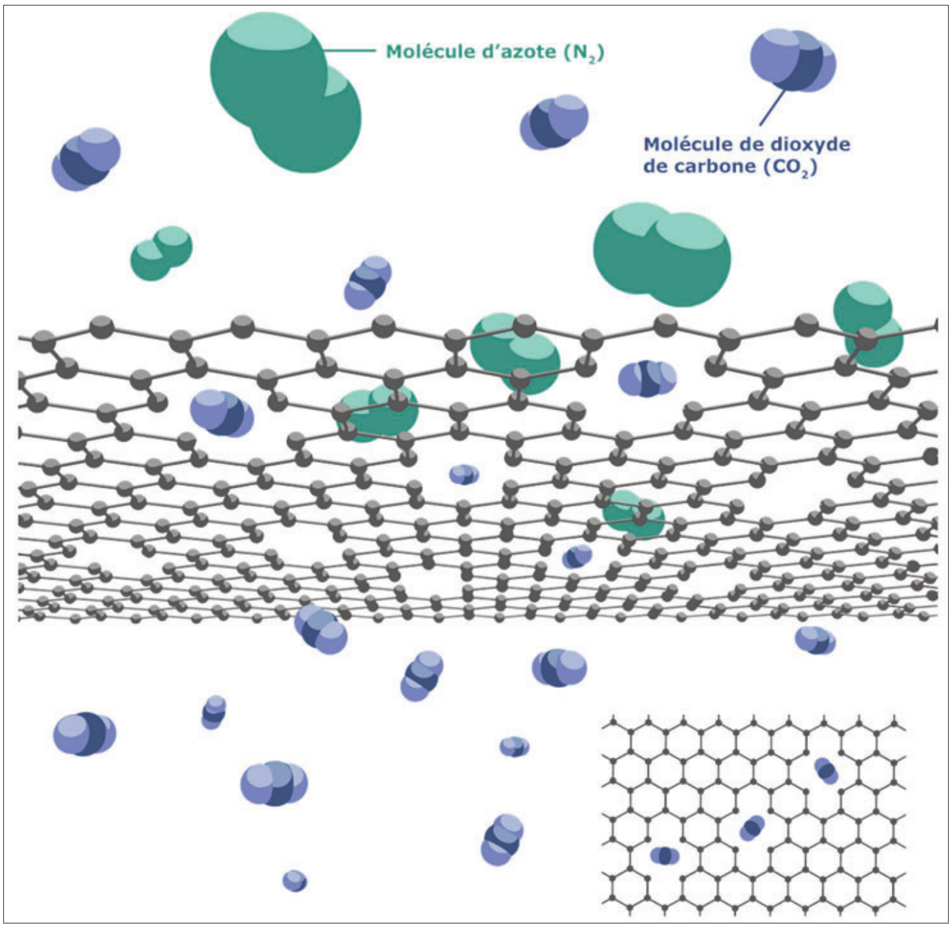
Today, most plants rely on solvent-based systems that absorb CO2, but these setups use a lot of heat, require major infrastructure, and can be costly to run.

A smaller, electricity-driven alternative is what the field calls a "membrane" system. A membrane works like an ultra-fine filter that lets certain gases slip through more easily than others, separating CO2 from the rest of the flue gas. The problem is that many membranes lose efficiency when CO2 levels are low, which is common in natural-gas plants, and this limits where they can be used.

A new study at EPFL has now analyzed how a new membrane material, pyridinic-graphene, could work at scale. This is a single-layer graphene sheet with tiny pores that favour CO2 over other gases. The researchers combined experimental performance data with modelling tools that simulate real operating conditions, such as energy use and gas flow. They also explored a wide range of cost scenarios to see how the material might behave once deployed in commercial plants.

The study was led by Marina Micari and Kumar Varoon Agrawal who holds the Gaznat Chair in Advanced Separations at EPFL. It is published in Nature Sustainability, and builds on the group's previous research in developing scalable graphene membranes.

"As we are scaling up the technology, it is important to understand the implications on reduction on energy use and cost of carbon capture in the diverse sector of carbon capture," said Agrawal. "This work address this."



An illustration of the graphene membrane separating CO2 from N2. Credit: Ivan Savicev, EPFL

Modeling shows where the membrane performs best

The team tested different graphene-based membranes, including the pyridinic-graphene membrane, under several plant setups to compare how they would perform in real conditions. For natural-gas power stations, a three-step system that starts by enriching the CO2 stream reached promising costs, roughly USD 80–100 per ton, with best cases down to USD 60–80. This is noteworthy because membranes usually struggle with such dilute flue gas.

In coal plants, where CO2 levels are higher, the membrane's strong CO2/N2 selectivity cuts energy use and brings costs into the USD 25–50 per-ton range. Cement plants have more oxygen in their flue gas, which makes selectivity trickier, but the membrane still reaches similar cost ranges and stays stable across the different scenarios tested. Across all three sectors, the membrane's high permeance keeps the required surface area small, which helps reduce the footprint of a full capture system.

The study shows that pyridinic-graphene could offer a compact and potentially cost-effective alternative to solvent-based capture once scaled. It also points to areas where the material could still improve, especially its ability to distinguish CO2 from oxygen in cement flue gas.

More information

https://actu.epfl.ch

Synthetic key enzyme enables conversion of CO2 into formic acid

A research team at the Max Planck Institute has developed an enzyme that robustly and efficiently reduces formate to formaldehyde, an important route for the sustainable conversion of CO2 into raw materials.

For a carbon-neutral bioeconomy, processes are needed that can efficiently capture CO2 and convert it into valuable products. Formic acid, or more specifically its salt, formate, is considered a promising candidate as it can be produced from CO2 using renewable electricity. It is also easy to transport, non-toxic and versatile. Research is focusing, among other things, on microorganisms that are 'fed' formic acid made from CO2 and use it to produce basic chemicals or fuels.

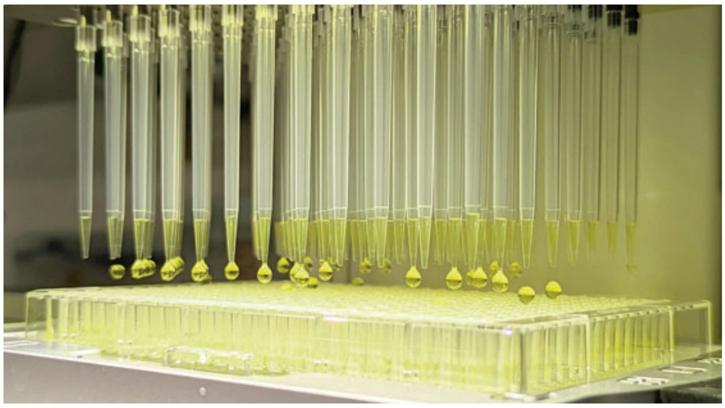
A team led by Maren Nattermann at the Max Planck Institute for Terrestrial Microbiology has developed a synthetic enzyme designed to perform the central conversion step with precision and stability in a single enzymatic process. This builds on previous research in which the team established a fully synthetic formyl phosphate pathway was established in bacteria.

Synthetic metabolic pathway

Until now, only certain bacteria have been able to utilise formic acid. Natural metabolic pathways bypass the intermediate product formaldehyde, which is an important starting point for integrating CO2 into cellular metabolism. The researchers constructed an artificial bridge in the form of a synthetic formyl phosphate metabolic pathway, which they incorporated into living E. coli bacteria.

Cooperation partner Sebastian Wenk (Project leader, University of Groningen) explained, "Our work showed that a synthetic metabolic pathway for processing formate works in living organisms — a significant step towards developing biotechnologically useful microorganisms that can use formate obtained from CO2 to produce food, fuels and materials." The formaldehyde is immediately processed by the cell and does not accumulate.

However, the connection to cellular metabolism must be robust — after all, it is competing with well-established natural metabolism that has evolved over millions of years. Until now, researchers have only been able to develop complex, fragile, multi-step enzymatic cascades that release sensitive intermediate products, such as formyl phosphate or formyl-CoA, which are prone to breaking down or entering undesirable side reactions.



High-throughput devices can dramatically accelerate research. Here, 96 samples are tested at once for the enzymatic conversion of formate to formaldehyde—recognizable by the yellow color change. © MPI f. Terrestrial Microbiology/ Franka Eiche

From a biotechnological perspective, the goal is a 'full formate diet' in which bacteria grow exclusively on formic acid, without the need for costly additives.

Tailor-made enzyme

Recently, the group achieved a decisive breakthrough with a tailor-made formate reductase enzyme that can convert formic acid to formaldehyde precisely and robustly. This enzyme, known as FAR (formate reductase), is based on a carboxylic acid reductase (CAR) found in the bacterium Mycobacteroides abscessus. This enzyme was modified through targeted mutagenesis and high-throughput screening to preferentially select small molecules such as formate.

"With FAR, we now have a single, robust enzyme that reliably reduces formate to formaldehyde — exactly where many biotechnological pathways begin," explained Nattermann. "This provides us with a missing building block for future bioconversions based directly on CO2-based raw materials."

"The most important thing is that our enzyme tolerates high concentrations of formate, whereas previous systems failed completely under these conditions,' added Philipp Wichmann, the study's first author. It is precisely this stability that makes FAR attractive for industrial processes in which formate is produced electrochemically in very high concentrations. Without the use of high-throughput methods, this result would not have been achievable in such a short time. 'After screening around 4,000 variants, we achieved a fivefold increase in formaldehyde production," said Nattermann.

FAR is now an enzyme that can be used in both living cells and cell-free systems, as well as in electrobiochemical production lines. In the future, basic chemicals, bioplastics or fuels could be produced from CO2-based formate. The researchers are already planning to combine FAR with other synthetic metabolic pathways, for example, to produce energy-rich molecules.

More information

www.mpg.de/en

Predictive "mismatch" leads to carbon capture breakthrough

Work revealing how water impacts carbon dioxide capture from air named Journal of the American Chemical Society "Editor's Choice".

When experimental results don't match scientists' predictions, it's usually assumed the predictions were wrong. But new research into materials that pull carbon dioxide directly from the air shows how such mismatches can instead be powerful clues, leading to discoveries that reshape how future materials are designed.

In a paper published Dec. 21 in the Journal of the American Chemical Society (JACS), a team led by Prof. Laura Gagliardi of the UChicago Pritzker School of Molecular Engineering (UChicago PME) and Department of Chemistry and Nobel laureate Prof. Omar Yaghi of the University of California, Berkeley outlined a new method for excluding water when using covalent organic frameworks (COFs) to build carbon capture materials.

In recognition of the scientific importance and real-world impact of this research, JACS selected the paper as its "Editor's Choice."

"Mismatches between simulations and experiments are not failures, but opportunities," said first author Hilal Daglar, who conducted the work as a postdoctoral researcher in Gagliardi's lab and is now with UL Research Institutes. "In this project, those discrepancies guided us toward residual water and subtle structural features that were not obvious at first glance."

The work came from The Center for Advanced Materials for Environmental Solutions (CAMES), which Gagliardi co-directs as part of the University of Chicago Institute for Climate & Sustainable Growth. By outlining a design strategy where researchers introduce hydrophobic pore environments to exclude retained water, the research will allow scientists to create more effective and efficient solutions for air pollution.

"We think of CAMES as a bridge between materials discovered in the lab and real-world environmental impact," said CAMES Co-Director Doug Weinberg. "Our role isn't just to support breakthrough science. It's to help ensure those breakthroughs matter beyond the lab. Hilal's work is a great example of that mission in action."

Exploring the mystery

Gagliardi has studied the power and potential of COFs and reticular chemistry for the last ten years, but COFs were thrust into the public eye this year after Gagliardi's longtime collaborator Yaghi won the 2025 Nobel Prize in Chemistry alongside Susumu Kitagawa and Richard Robson.

"These materials are known as reticular frameworks, meaning they are built from well-defined molecular building blocks that are connected through strong chemical bonds into extended crystalline networks," Gagliardi said.

"Because the connectivity is designed at the molecular level, these frameworks contain uniform, nanoscale pores, giving them exceptionally large internal surface areas that can be deliberately functionalized for specific applications."

By using those large cavities to capture and store airborne pollutants like carbon dioxide and methane, Gagliardi and her team hope to use these materials' unique properties for this major environmental issue.

Harnessing Gagliardi's theoretical modeling expertise, Daglar and Gagliardi performed complex computer simulations predicting the structure of COF-999-NH2, the precursor of COF-999, a promising material for CO2 capture from air. But there was a disconnect between their predictions and the results produced by the experimentalists on Yaghi's team.

Rather than assume failure of the computations, the theorists and experimentalists dove into this mystery together, coming up with new, unexpected insights.

"In this back and forth between experiment and theory, we started to hypothesize that there were some residual water molecules in the synthesized material, which we initially did not include in our model because the experimentalists thought that the material had been completely dehydrated," Gagliardi said.

New insights, new rule

This investigation led not only to new insights into the cause of this predictive mismatch, but a path to better, more effective carbon capture in the future. They created a simple, actionable design rule for future researchers: controlling the pore hydrophobicity during the polymerization of COF-999 avoids water retention.

"This prevents adsorption site blockage and undesired side reactions, enabling more effective carbon capture," Daglar said.

Beyond this core finding, the research also revealed previously unknown insights about COFs, including that the stacking heterogeneity, buckling and lattice contraction they were seeing were features, not bugs, intrinsic to their precursor chemical.

Gagliardi said the emergence of these important results from predictions that conflicted with experiment underscores the central role of computational modeling in enabling the research.

"To advance these discoveries, computations and simulations are indispensable," she said. "On the computer, you can try things that maybe your chemical intuition might not suggest right away. The computer can give you some useful answers that allow you to think in a different way."

More information

https://pme.uchicago.edu

TBM to provide CCU system to produce building materials in Vietnam

The companies will build a plant that produces CCU-based calcium carbonate by chemically combining CO2 from a VAPCO coal plant with steel slag supplied by Viet Hai.

TBM based in Japan has signed an MoU with Vung Ang II Thermal Power LLC (VAPCO), which operates a coal fired power plant in Ha Tinh Province, Vietnam, and Viet Hai Trading and Transportation Co., Ltd., a leading construction company in the same province.

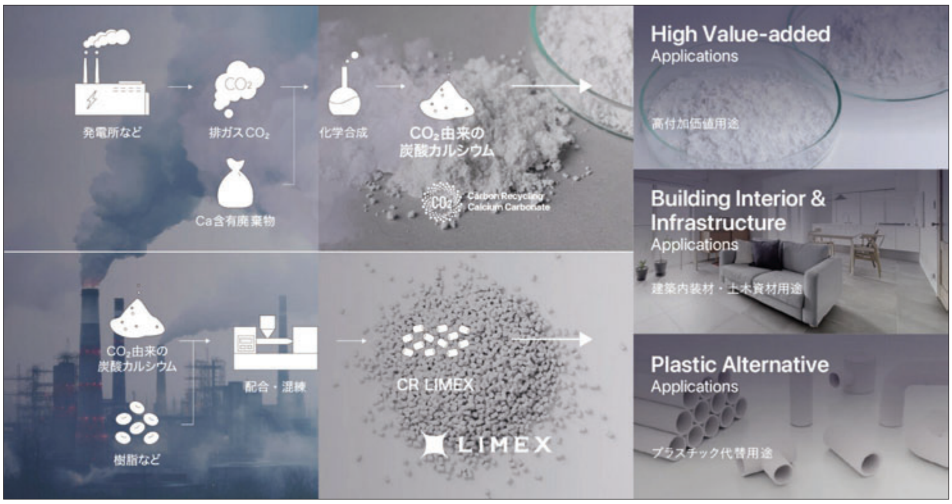
As well as calcium carbonate the companies will also manufacture "CR LIMEX" by compounding CCU Calcium Carbonate with resin and develop high value added applications for these materials.

As a next step the project will consider the construction of a CCU plant that captures and reuses approximately 160,000 tons of CO2 emitted annually from VAPCO's thermal power plants. The plant will use TBM's CCU technology to chemically synthesize approximately 400,000 tons of steel slag emitted annually from Viet Hai's steelworks with CO2, with the goal of producing approximately 210,000 tons of CCU calcium carbonate per year.

TBM will also consider the optimal method and infrastructure construction for producing CCU calcium carbonate using VAPCO's CO2 and Viet Hai's steel slag in Vietnam.

Vietnam has achieved solid economic development, recording a GDP growth rate of 7.09% in 2024, but the resulting greenhouse gas emissions have become a social issue. At COP26, the government declared its intention to achieve net-zero emissions by 2050. However, the share of coal-fired power generation in the country's electricity mix remains high at approximately 55% (as of January 2024).

Under these circumstances, in order to advance decarbonisation without compromising the stable supply of electricity essential for economic growth, there is a need for solutions that reduce CO2 emissions through technological innovation while continuing to use existing power plants as important social infrastructure.



Recycled CO2 calcium carbonate can be used as a raw material for building materials such as interior and exterior finishes. Furthermore, when blended with recycled plastics, it becomes "CR LIMEX," an alternative to petroleum petroleum-based plastics

Under TBM's CCU technology, which was introduced at the World Economic Forum Annual Meeting 2024 in Davos through the announcement of the CCU material CR LIMEX, TBM has developed a process to produce CCU Calcium Carbonate by chemically synthesizing CO2 with steel slag. CCU, which captures and reuses CO2, is positioned as one of the investment areas under the GX strategy promoted by the Japanese government.

The CCU Calcium Carbonate produced at the plant is planned to be used as construction materials in Vietnam and overseas through Viet Hai's network. In addition, the partners plan to manufacture CR LIMEX by compounding CCU Calcium Carbonate with resin.

By doing so, they aim to expand adoption in high value added applications beyond conventional calcium carbonate uses, including plastic replacement applications, interior building materials, and civil engineering materials.

The project aims to generate carbon credits by reducing CO2 emissions and by permanently storing CO2 that would otherwise be released into the atmosphere within products over the long term. In addition, the project will advance both resource circulation and carbon circulation by using steel slag, an industrial byproduct generated during iron ore melting and scrap refining.

Through these efforts, the partners will help accelerate the circular economy and carbon neutrality within the region.

Viet Hai will develop high-value-added applications for CCU calcium carbonate based on the technical and commercial information on CCU calcium carbonate provided by TBM and with TBM's support in application development.

More information
https://tb-m.com/eng

ECO2Fuel project demonstrates near-total CO_2 capture and carbon reuse

ECO2Fuel has successfully demonstrated a closed carbon loop system that combines power generation using synthetic fuel, CO_2 capture and recycling, and heat reuse.

ECO2Fuel's partner RWE Power, which oversees site-demonstration testing, has successfully demonstrated a new method of generating back-up power using environmentally friendly synthetic fuels, which will be produced electrochemically by the ECO2Fuel process that is currently being tested on a pilot scale at ECO2Fuel's partner VITO.

RWE used a stationary diesel genset with an electric output of 200 kW for this purpose. The exhaust gases produced by this engine are sent back to a carbon capture pilot plant, which uses a chemical process with amines to capture carbon dioxide.

This pilot plant at RWE's Innovation Centre at Niederaussem captures 7.2 tonnes of CO_2 per day from the exhaust gases, at a capture rate of 90% or higher. During a testing campaign, capture rates of >99.8% were achieved, at times resulting in a lower CO_2 concentration in the off-gas from the carbon capture plant than in the atmosphere.

To close the carbon cycle, the captured CO_2 can again be used as a raw material for the ECO2Fuel demonstrator, which will have a capacity of 1 MW and produce carbon-based e-fuels. These e- fuels can be further processed and reused in the engine, creating a cycle that recycles the carbon rather than releasing it into the atmosphere, thus "closing the carbon loop".

In each cycle, fossil carbon is replaced by recycled carbon and emissions from fossil feedstock are avoided. Additionally, the high-temperature exhaust gas from the engine is being studied for its potential to be reused for heating and improving overall energy efficiency.

Project Coordinator, Faria Huq, Deutsches Zentrum für Luft- und Raumfahrt e.V. – DLR, said, "The carbon-capture technology developed with ECO2Fuel converts CO_2 to sustainable synthetic gaseous and liquid e-fuels, without relying on hydrogen or critical raw materials (CRM). These e-fuels can serve as starting material for synthetic aviation and transport fuels, while the renewable energy during electrochemical CO_2 conversion can be used for different applications, for example, for backup power generation."

"By integrating CO_2 capture and waste-energy reuse, we are closing the carbon loop and advancing Europe's transition toward a circular energy system and lowering our dependency on fossil fuel-based systems for energy. Our target of achieving a system CAPEX of 400–600 €/kW will enable cost-competitive e-fuel production, supporting the EU's Green Deal, Net-Zero Industry Act, and Renewable Energy Directive goals".

In a de-fossilised energy and power supply, peak and backup power will largely be provided by batteries, which have a far better round-trip efficiency. However, batteries have a limited capacity and are not designed to run for weeks in dark, foggy winter times when solar and wind power are not available.

The ECO2Fuel technology can produce the educts for Fischer–Tropsch fuels, such as sustainable aviation fuels (or synthetic kerosene), with synthetic diesel fuel as a by-product.

"The closed carbon cycle was never intended to be a stand-alone process for peak and backup power generation, but it is an attractive add-on to e-fuel applications, although these will be mainly used in transportation sectors, such as marine and aviation, and as a feedstock for certain products in the chemical industry," explained Knut Stahl, RWE Power's project manager for ECO2Fuel. "E-fuels can be produced where renewable power is abundant, easily transported, stored in large quantities for a long time, and used when there is a severe power shortage."

"When a blackout looms, power suppliers will do anything to keep the lights on, no matter the efficiency of the power source. In the ECO2Fuel project, we have successfully demonstrated that synthetic fuels can be used for peak and backup power generation, even if they were not produced for this purpose".

In a de-fossilised world, carbon will become scarce, and captured CO_2 may become a valuable carbon source. Closing the carbon cycle by converting CO_2 and renewable power into carbonaceous fuels and back to electrical power, as demonstrated in ECO2Fuel, allows to use of carbon multiple times and replaces fossil carbon.

"The overall goal is to convert green electrons into green molecules, coupling the sectors' energy, transportation and industry," added Dr. Peter Moser, head of RWE Power's CCUS and Energy Storage research. "ECO2Fuel is part of our long- term development of carbon capture, storage and utilisation solutions in the last two decades".

They specifically looked at the effects of lower carbon dioxide and higher oxygen content in the exhaust gas and at increased nitrogen oxides (NOx) on the performance of the CO_2 capture plant, including the energy needed to regenerate the solvent, emissions, and solvent degradation.

This is important because these factors can significantly impact the efficiency, cost, and environmental footprint of CO_2 capture technologies, ultimately affecting their feasibility for large-scale implementation in industrial settings.

The advancement presented by ECO2Fuel's partners lies in the successful integration and demonstration of a closed carbon loop system. This combines e-fuel combustion, CO_2 capture and recycling, and heat reuse, contributing to the broader goal of achieving net-zero emissions in the energy, transport, and industrial sectors.

More information

Read the paper

https://dx.doi.org/10.2139/ssrn.5016150

https://eco2fuel-project.eu

Capture & utilisation news

ADM opens world's largest bioethanol carbon capture facility

www.adm.com/en-us

The company has started operations at its Columbus, Nebraska Corn Processing Complex which will use the Tallgrass CO2 transport and storage hub.

Tallgrass's Trailblazer pipeline will transport captured carbon dioxide from ADM's ethanol plant in Columbus to Tallgrass' Eastern Wyoming Sequestration Hub for permanent storage deep underground.

"ADM has been a pioneer in the CCS industry for more than a decade and this is an expansion of that expertise," said Chris Cuddy, president, North America at ADM. "CCS is an important part of our strategy to decarbonize our operations and help meet global demand for low-carbon ingredients, and we are proud to work with Tallgrass to find innovative solutions at facilities like Columbus. This is an exciting project for the industry and for the future of CCS technology."

The Trailblazer pipeline, formerly a 400-mile natural gas transmission line, runs through Wyoming, Colorado, and Nebraska, and is capable of transporting more than 10 million tons of CO2 per year. As part of the project, Tallgrass also constructed a lateral line connecting ADM's facility to the pipeline system using only voluntary easements from landowners.

The Columbus plant is expected to be part of a larger initiative to convert up to 900 million gallons of ethanol from multiple ADM sites into Sustainable Aviation Fuel and other renewable hydrocarbons, with production potentially starting in 2025-2026.

Deep Sky launches Airbus DAC technology in Canada

www.deepskyclimate.com
www.airbus.com

The modular direct air capture technology with the capacity to remove 250 tons of CO2 per year will be optimised and tested at Deep Sky Alpha in Innisfail, Alberta.

The modular hardware unit captures carbon dioxide from ambient air. Its technology is derived from Airbus (Defence and Space) life-support systems aboard the International Space Station, and was brought to market in 2023. The DAC module was delivered recently after only eight months of engineering and manufacturing.

The system inside the module employs a solid amine-based filter to capture CO2, which is then heated to release highly concentrated CO2 while returning CO2 lean air to the atmosphere. In addition to this temperature swing process, the energy system to operate the module is uniquely designed to recover the input energy and optimize energy consumption.

Technological advances in primary aluminium production, such as carbon capture and storage, will be key to achieving Hydro's sustainability goals. Pictured is Hydro's aluminium plant at Sunndal in Western Norway. Photo: Hydro

CO280 completes amine CO2 capture pilot at U.S. pulp and paper mill

www.co280.com
https://capturi.slb.com

The field pilot using SLB Capturi technology has validated the performance of liquid amine to capture biogenic CO2 from recovery boiler stack emissions at a pulp mill in the U.S. Gulf Coast.

SLB Capturi's Mobile Test Unit (MTU) was installed at the mill site in Q3 2024 where it operated for more than 4,000 hours, achieving a consistent capture rate efficiency of 95%. During the test program, the MTU met all key performance indicators including capture rate efficiency, energy consumption, solvent durability, and absorber emissions. The MTU has a rated design capacity of 3 tonnes per day (tpd).

"This critical milestone clears the way for deploying commercial-scale carbon capture and removal projects at pulp and paper mills," said Jonathan Rhone, Co-Founder and CEO of CO280.

"Our goal is to lead the world in carbon dioxide removal that sets the highest standards of permanence, quality, and affordability at scale. The success of the MTU pilot with SLB Capturi marks a critical step towards achieving that goal and delivering low-cost, low-risk CDR to our customers."

Verdox demos electrochemical carbon capture from aluminium smelting

www.verdox.com

www.hydro.com

The company has successfully completed initial testing of its all-electric carbon capture technology in collaboration with Norwegian aluminium and renewable energy company Hydro.

The trial demonstrated carbon capture directly on aluminum smelter emissions in preparation for large-scale demonstrations and potential future commercial deployment.

Primary aluminum production through electrolysis is a carbon-intensive process. However, it generates off-gas with CO2 concentrations only around 1%, making carbon capture far more challenging compared to higher-concentration streams from fossil-fuel power generation or other industrial processes. Presence of impurities in the off-gas provides additional complexity. Verdox's electrochemical approach is specifically engineered to overcome these challenges.

A two-month trial at Europe's largest primary aluminum production facility, Hydro's Sunndal plant in Norway, has confirmed Verdox's ability to capture CO2 from a 1% stream with no recorded impact from contaminants commonly present in aluminum-smelting off-gas.

First complete record of global underground CO2 storage

The first annual report by the London Register of Subsurface CO2 Storage reveals that over 383 million tonnes of carbon dioxide have been removed from the atmosphere by CCS since 1996.

This mass underground storage has mostly come about thanks to projects in the United States, China, Brazil, Australia and the Middle East, with continued growth projected in 2024-5.

The researchers behind the report say it provides unequivocal evidence that the technology is an essential tool, operating at the scale needed to tackle climate change. They say it shows that CCS isn't a concept for the future, but a proven, scalable technology operating effectively today.

Led by Imperial College London academics, the consortium1 of scientists and industrial partners includes experts from around the world at the Department of Energy Science & Engineering at Stanford, MIT Civil and Environmental Engineering, Global CCS Institute, CCSA, IEAGHG and CSIRO, Australia's national science agency.

"The central message from our report is that CCS works, demonstrating a proven capability and accelerating momentum for geologic storage of CO2," said Professor Samuel Krevor, Director of the Register from the Department of Earth Science and Engineering (ESE) at Imperial College London.

"We have found that industrial-scale carbon management is already a reality and can safely sequester CO2 deep underground. This will be a key strategy, alongside vital efforts to cut emissions, for decarbonising hard-to-abate industries and cutting the total CO2 in the atmosphere."

The report's authors say the policies underpinning the growth to date are being strengthened in places like the US and Europe. Continued or even increased growth is therefore expected over the coming decade.

"As more projects come online, costs will inevitably reduce, as already seen with other decarbonisation technologies. Industry will become more efficient with experience, and capture, transport and storage technologies will continue to develop," said Professor Krevor.

The London Register of Subsurface CO2 Storage

The London Register of Subsurface CO2 Storage is an initiative that has been set up to track the progress of CCS, starting with a single pioneering project in Norway in 1996 to what is now a global enterprise.

The Register's 2025 Annual Report tracked the annual rates of CO2 stored underground from operational projects worldwide from 1996 to 2024. It compiled public information (such as government databases on greenhouse gas reporting) and surveyed project operators in a co-ordinated effort to establish the first and most comprehensive record of CCS growth and maturation to date.

While the views on CCS are polarised among the climate science community (it is considered by some as a distraction from reducing carbon emissions, or not well developed and proven possible to rollout at sufficient scale), plans for CCS nevertheless underpin many national, international and corporate decarbonisation plans.

The new report finds that large-scale projects launched in the last decade, in the US, China, Brazil, Australia and the Middle East, have driven the average annual growth rate of CCS to 9.2%, and a record 45.2 MT were safely stored in 2023, marking a significant increase of 8.4 MT from the previous year.

Projects that are leading the charge include the Seminole San Andres Unit in the US and the Santos Basin Pre-Salt oilfield in Brazil, which injected 3.9 MT and 13.0 MT, respectively, in 2023, accounting for more than a third of all storage that year.

Although the report noted that 2024 data is still incomplete, early indications suggest continued growth, particularly in Brazil and China. Meanwhile, different nations with different geologies and industrial bases have also been able to successfully deploy CCS locally, confirming not only its feasibility but also its versatility.

Professor Krevor added: "Storage rates like these are comparable to the emissions mitigated by other renewable and decarbonisation technologies. For example, the total stored in 2023 alone amounts to the emissions avoided by all the renewable energy produced in Australia or Italy, or two thirds of the renewable energy produced by the UK, in the same year."

Limiting global warming

Today, deployment of CCS projects across the globe is at an unprecedented high, and the number of new projects is growing.

"When one project can sequester millions of tonnes of CO2 annually, it brings us a significant step forward in reducing global emissions," said Dr Xiaowei Gao, Executive Director of the Register from the Department of Earth Science and Engineering at Imperial.

However, to keep global warming below the 1.5°C pledged by the Paris Agreement, all reasonable projections suggest that the technology must scale-up to one billion tonnes of CO2 storage or more per year by 2050.

"What we are seeing in this data is that CCS project development is achieving lift-off around the world and is putting us on the track to achieve these large scales of deployment within the required timescales," said Professor Krevor.

"This depends on the maintenance and expansion of policies that enable CCS deployment; the consistent performance and expansion of these major sites around the world should provide the confidence needed for policymakers and investors to support the next wave of CCS development and for industry growth to continue."

More information

https://imperialcollegelondon.github.io/The-London-Register-of-Subsurface-CO2-Storage

Transportation: mid-stream in the CO2 value chain

Connecting CO2 emitters to geological storage sites is the forgotten link in the CCS value chain. The abbreviation CCTS (carbon capture and transportation and storage) brings the midstream link into focus. By Stephen B. Harrison, sbh4 consulting.

Road, rail and maritime logistics will experience phenomenal growth in the coming years as CCTS ramps up to support global net-zero ambitions. CO2 storage terminals must also scale up capacity to meet demand.

As CCTS infrastructure expands, investment in flexible and efficient CO2 transportation assets will be essential. Collaboration across the full value chain will be key. Civil engineering contractors, cryogenic equipment manufacturers, engineering teams and logistics providers are well positioned to participate in this opportunity.

Bulk liquid movement by rail - a cement plant capturing 1 MT CO2 per year would need one train per day with 30 waggons to transport liquefied CO2

CO2 by rail

In the absence of CO2 pipelines, inland movements of large CO2 volumes will almost certainly be by rail. However, there are very few CO2 rail tankers in service. A significant investment will be required to finance a massive build out of CO2 distribution assets.

A cement plant capturing 1 million tonnes of CO2 per year will need a supply chain capable of transporting 2,700 tonnes per day of CO2. Modern CO2 train waggons are being built to carry around 80 tonnes of CO2.

The cement plant would need one train per day with 30 waggons to transport liquefied CO2 to a port-side CO2 terminal. If the round trip from the capture location to the CO2 terminal is five days, then five trains would be required, meaning 150 rail waggons in total.

An 80-tonne liquid CO2 rail waggon, including the rolling stock and tank may cost in the order of €300,000 to build. A train with 30 waggons would therefore cost close to €10 million. To finance five trains, the rail waggon investment would be in the order of €50 million.

Annual operating costs are also incurred. The waggons must be maintained and inspected to ensure their rail worthiness. Not only the cryogenic vessel and its associated piping must be certified, but also the wheels and brakes must be validated.

Multimodal flexibility

Construction of a fixed rail tanker waggon costs less than a flat-bed waggon and a cryogenic ISO tank. Similarly, a dedicated road tanker built to carry liquid CO2 is less expensive than a flat-bed truck transporting a cryogenic ISO tank.

At first sight, the conclusion might be that fixed tankers are a better choice than ISO containers. However, this is not always the case. An ISO container can be used as static storage, can be loaded onto a truck to move to the rail terminal, then loaded onto a flatbed rail waggon. At a port it can serve once more as storage and then be loaded onto a ship.

During this multi-modal journey there are no losses of CO2 as it is transferred from one container to the next. Boil off may occur, but it can be minimised with the use of full cryogenic vacuum insulation.

An additional advantage of ISO containers is that they can be used on almost all rail gauges because they can be transferred from one flat bed waggon to another. Perhaps surprisingly, in Europe, Australia and many other geographies several track gauges exist within a continent.

Committing to dedicated CO2 waggons will minimise the capital investment. However, the flexibility of ISO tanks may reduce risk and offer an acceptable long term return.

Given the high capital investment and ongoing ownership responsibility, many rail tanker waggons for conventional liquid products, such as aviation kerosene, are owned by leasing companies. Perhaps they will, once again, underpin the railway logistics investment for CCTS.

Northern Pioneer at the Northern Lights CO2 terminal in Norway, With a capacity of between 5,000 and 7,500 tonnes of liquid CO2 such vessels would require two or three train loads. Image © Northern Lights

Canal and river networks

In northwestern Europe, barges transfer millions of tonnes of solid and liquid cargoes from the hinterland to North Sea ports. A similar network exists in the eastern United States. As CCTS ramps up, barges will also be used to move liquid CO2 from emitters to portside CO2 terminals. It is also conceivable that some types of barges may sail directly to inshore CO2 sequestration platforms.

The Rhine, in Germany, is one of the main inland waterways in Europe. Whilst it has been a major artery for transportation of coal, minerals, chemicals and fuels in the past century there are increasingly questions about its reliability.

During the rainy season, the Rhine floods making it impossible for barges to pass under bridges. In the dry season, the water level is too low for fully loaded barges to sail. These un-navigable periods are becoming more frequent and are lasting longer.

For a new cargo such as liquid CO2, with no reserve logistics infrastructure, there would be very little reserve capacity on the road or rail. Therefore, barges might be a risky choice for year-round operations on some waterways.

Ships and shoreside terminals

Nippon Gases Europe operates a fleet of three liquid CO2 tankers (Embla, Frøya and Helle) between a commercial CO2 source in Norway and offtakers in the UK and continental Europe. Each of the three ships has a capacity of around 1,800 tonnes of CO2. In total, they can transport about 300,000 tonnes of CO2 per year from Norway to the destination ports.

While these capacities have been adequately sized to support the European merchant CO2 market over the past 20 years, they are small when compared to the CO2 shipping requirements that will be required to enable CCTS.

Ships such as the Northern Pioneer which has been built for the Northern Lights CCTS scheme in Norway and INEOS's Carbon Destroyer 1 have a capacity of between 5,000 and 7,500 tonnes of liquid CO2. The implication is that two or three train loads will fill a ship. The number of ships will depend on the sailing distance and the amount of time it takes to discharge the CO2 to the geological storage site.

The port-side CO2 terminal would generally be sized with the capacity for at least two ships. That means between 10,000 and 15,000 tonnes of liquid CO2. As an example, Phase 1 of the port-side CO2 terminal at Øygarden, near Bergen in Norway serves the Northern Lights project has a storage capacity of around 10,000 tonnes of liquid CO2. This will be increased to about 10,700 in 2028 when Phase 2 is completed.

Phase 1 of the Øygarden CCTS CO2 terminal is about 5 times larger than existing CO2 terminals in the UK and continental Europe which serve the commercial CO2 supply chain. Each of those has a capacity in the order of 2,000 tonnes of CO2.

Investment for hyper scaling

Port areas may become a bottleneck for transportation of CO2 by rail to shoreside terminals. For example, there is often congestion on the rail routes into Rotterdam. Traditional refined products such as gasoline enter and leave major ports by pipeline and thereby avoid rail terminals at the ports. However, CO2 pipeline infrastructure is immature.

As the number of CO2 rail movements increases, some volumes may need to transfer to pipeline or the rail infrastructure must be redeveloped. Either way, hyper scaling is required. The investment to achieve this will be tremendous. And the business opportunities for companies financing and operating the CO2 transportation infrastructure will be transformational.

More information

https://sbh4.de/

Study finds savings potential across the onboard carbon capture value chain

The Global Centre for Maritime Decarbonisation (GCMD) has published a life cycle assessment (LCA) of the greenhouse gas emissions from Project CAPTURED, the world's first ship-to-ship offloading of onboard captured and liquefied CO2 (LCO2) with downstream utilisation, completed in June 2025.

Verified by DNV, the LCA quantifies GHG emissions and savings across the pilot's entire carbon value chain, tracing CO2 captured and liquefied on an ocean-going container vessel to ship-to-ship and ship-to-truck transfers, overland transport, and its utilisation at an industrial facility.

There, the CO2 was used as a feedstock to recycle steel slag into post-carbonated slag (PCS) and produce precipitated calcium carbonate (PCC) through carbon mineralisation, a process in which captured CO2 is chemically converted into stable carbonates.

The study found that GHG emissions savings potential rises substantially when logistics and operational inefficiencies in Project CAPTURED are addressed. CO2 utilisation can outperform permanent storage in GHG emissions savings when avoided emissions from displaced carbon are taken into account. It also raised concerns about current life cycle assessment (LCA) guidelines risking undervaluing utilisation pathways.

Professor Lynn Loo, CEO of GCMD, said, "Project CAPTURED shows that onboard carbon capture, when thoughtfully integrated with utilisation pathways, can deliver real emissions reductions today while we continue to scale up low- and zero-carbon fuels. It also highlights how we measure and account for those reductions matter.

If our frameworks continue to ignore avoided emissions and displaced carbon, we risk disincentivising investments in solutions that can meaningfully bend the emissions curve."

OCCS as a mid-term decarbonisation pathway – and why LCA matters

Onboard carbon capture and storage (OCCS) is increasingly recognised as a promising mid-term pathway to reduce emissions from vessels that continue to rely on conventional fuels.

By capturing CO2 from exhaust gases, OCCS can significantly reduce onboard fuel-combustion ("tank-to-wake") emissions. However, its true contribution to decarbonisation must be evaluated across the entire carbon value chain,.

An LCA quantifies these full-chain GHG impacts transparently and systematically, evaluating that emissions savings achieved onboard are not offset by upstream or downstream burdens.

Scenarios evaluated

The study presents a detailed LCA of the carbon value chain demonstrated in Project CAPTURED. Building on this baseline, the study also examined two hypothetical scenarios, one in which the inefficiencies associated with the first-time pilot are addressed and another in which captured CO2 is permanently sequestered in an offshore reservoir.

In the utilisation scenarios, producing PCC with captured CO2 displaces conventional carbon-intensive production methods, while the use of PCS replaces standard sintering materials in steelmaking, resulting in a reduction of emissions that would have otherwise been released ("avoided emissions").

With OCCS operating at a 10.7% capture rate, demonstrated 7.9% GHG emissions savings across the entire carbon value chain. This corresponds to 0.84 tonnes of CO2 savings realised per tonne of CO2 captured and offloaded from the vessel.

These savings were achieved despite several operational constraints, including the absence of a waste heat recovery system onboard that increased the fuel penalty, long-distance overland truck transport, as well as CO2 venting during offloading and handling.

When these inefficiencies are addressed, GHG emissions savings increase markedly to 17.8%, equivalent to approximately two tonnes of CO2 avoided per tonne of CO2 captured and offloaded from the vessel.

CO2 utilisation can avoid more GHG emissions than permanent storage

The study found that the specific CO2 mineralisation pathway in this pilot outperforms permanent storage.

At comparable capture rates of 40%, mineralising CO2 yields 34% GHG emissions savings, compared with 21% if CO2 were sequestered in an offshore reservoir. When the value chain is optimised, this gap widens further, with the total GHG emissions savings rising to 68-71% depending on whether the PCS produced is used in steel sintering or in concrete production.

This comparison reveals that CO2 utilisation by carbon mineralisation can deliver greater overall climate benefits than permanent storage when captured CO2 is durably fixed over extended periods, defined under the EU ETS as 100 years or more, and as in the case of PCC that is used in construction.

At present, the IMO's GHG accounting frameworks—including its Data Collection System, Carbon Intensity Indicator, and LCA guidelines—do not recognise or account for avoided emissions from when highly emissive conventional products are displaced by captured CO2-derived counterparts.

As a result, the environmental benefits of CO2 utilisation pathways risk being systematically underestimated in formal reporting, despite their potential to avoid more emissions across the wider value chain.

More information

https://gcformd.org/our-publications/?report-id=8863

Transport and storage news

EnEarth storage for Heidelberg ANRAV project in Bulgaria

www.enearth.earth/general-8

The company has signed a term sheet with Heidelberg Materials to act as storage operator for Heidelberg Materials' Devnya CO2 development.

Devnya CO2 is part of the wider ANRAV CCUS project launched by Heidelberg Materials, which aims to be the first full-chain CCUS project in Eastern Europe. The ANRAV project includes the capture of 800ktpa of CO2 from Heidelberg's cement plant in Devnya, situated in the wider Varna region, followed by transport and permanent onshore storage at a location close to the facility.

Nikolas Rigas, EnEarth's Head of Carbon Storage, said, "Today is an important day for EnEarth. We are taking a key step toward our aim to play a decisive role in the decarbonization of the hard-to-abate industry in the wider region of Southeastern Europe and the Eastern Mediterranean. It is very significant that a group such as Heidelberg recognizes and trusts the expertise that EnEarth is developing through its flagship CO2 storage project in Prinos."

The project has received EUR 190 MM in funding from the EU Innovation Fund, of which EUR 38 MM is designated for the storage site. Heidelberg Materials has identified the onshore storage potential and has been progressing with the legislative and stakeholder acceptance steps to develop it. Subject to entry into definitive agreements between the parties and all applicable permitting and regulatory approvals, the Project is intended to be operational before 2030.

Lithos Carbon delivers record enhanced rock weathering credits

www.lithoscarbon.com

The company has issued 5,160 registry-certified tons of carbon dioxide removal marking the largest enhanced rock weathering delivery to date.

The issuance is approximately 7x larger than any previous enhanced rock weathering carbon credit delivery generated through partnerships with North Carolina, Wisconsin, Pennsylvania, Maryland, and Michigan farmers who applied domestically-sourced and nutrient-rich basalt rockdust to their fields.

"This issuance proves that enhanced rock weathering can scale rapidly while delivering real benefits to farmers," said Mary Yap, CEO of Lithos Carbon.

Enhanced rock weathering can scale rapidly while providing additional revenue streams from carbon credits

The enhanced rock weathering process deployed by Lithos has provided multiple benefits to participating farmers, including improved soil pH management, enhanced nutrient availability, and additional revenue streams. Farmers report savings compared to traditional soil amendment applications while contributing to natural resource conservation.

Danish Energy Agency approves the first CO2 storage facility in Denmark

https://greensandfuture.com

The Danish Energy Agency has approved that the Nini West field - located about 240 kilometres northwest of Esbjerg - may now be used for geological storage of CO2.

The Danish Energy Agency has approved that the licensees behind Greensand Future may now store CO2 in the Nini West field in the Danish part of the North Sea. INEOS E&P, Harbour Energy and Nordsøfonden are behind the Greensand Future project. The permit applies to storage up to 2.4 million tonnes of CO2 for a period of 30 years. This is the first time that a permit has been granted for a CO2 storage project in Denmark.

"It is a significant milestone that we now have the first CO2 storage facility at home. It is a crucial part of the value chain for CO2 capture and storage. We only benefit the climate when CO2 is stored and away from the atmosphere. Therefore, the permit for the first CO2 storage in Denmark is a very important step on the way to establishing a market for CCS and thus creating the conditions for reaping the major climate benefits that CO2 capture and storage can contribute to this," said Peter Christian Baggesgaard Hansen, Deputy Director General of the Danish Energy Agency.

Greensand Future expects the project to be operational by mid-2026, and the permit for Greensand Future will not only be a milestone for CO2 storage in Denmark. It will also be the first full scale store operational in the EU.

Japanese insurer invests in CCS bond at Port of Rotterdam

www.dai-ichi-life-hd.com
www.portofrotterdam.com

Dai-ichi Life Insurance Company has invested JPY 4.7 billion in the bond, the world's first corporate bond with its use of proceeds exclusively allocated to CCS.

Funds raised by this bond will be allocated to Port of Rotterdam's equity investment in Porthos – the Port of Rotterdam CO2 Transport Hub and Offshore Storage project, jointly promoted by the Port of Rotterdam Authority and its partners.

Porthos will establish shared infrastructure for the collecting and transporting of CO2 emitted by companies in the port area and permanently store it in depleted gas fields beneath the North Sea. The project targets CO2 emissions from blue hydrogen production and industrial processes such as chemical and oil refining, and plans to transport and store approx. 2.5 million tonnes of CO2 annually for 15 years.

EnEarth provides storage for Heidelberg in Bulgaria

Image: Heidelberg Materials