Carbon Capture Journal

# CCUS in EMEA

Gassnova knowledge sharing summit: moving from ambition to delivery

CCS as a system in Norway, Netherlands, Denmark

CO2 as a raw material

July / Aug 2026 Issue 112

# 1 million CORCs retired in Puro Registry

**1 million retirements of CO2 Removal Certificates (CORCs) in the Puro Registry reflects strong and growing demand as buyers move from initial CDR purchases to ongoing procurement.**

Each CORC is a third-party verified, registry-tracked instrument representing one tonne of CO2 permanently removed from the atmosphere, with full lifecycle traceability from issuance to retirement. CORCs were designed for durable CDR with permanence over 100+ years, and in many cases, 1000+ years.

Jan-Willem Bode, President, Puro.earth, commented, "One million retirements is not just a number – it is evidence that the market is working as it should. Buyers are not just purchasing credits and waiting to retire them. They are retiring them quickly, replenishing demand, and signalling to suppliers that further investment in carbon removal capacity is commercially justified. The trend in time-to-retirement tells that story clearly: what once took over a year now takes days. That is the hallmark of a maturing asset class."

CORCs meet the due diligence requirements of corporate sustainability frameworks, banks, institutional investors and infrastructure funds to demonstrate high integrity carbon removal. As an asset class, they help to unlock project debt and equity financing for project developers building facilities and operations to remove CO2 durably.

The milestone marks a structural shift in the voluntary carbon removal market: demand is growing, buyers are procuring with increasing speed and confidence, and retirements are following issuance in days rather than months. It confirms that buyers are not holding CORCs, they are actively claiming the carbon removal attributes, demonstrating that the CDR market is being used for its intended purpose: delivering verified, permanent CDR against real climate commitments.

## Demand signals continue to strengthen

Puro Registry data shows retirements grew 140% in 2024 and a further 112% in 2025, and that the average time from issuance to retirement has fallen from 510 days in 2019 to just 7 days in 2026.

Both trends demonstrate that buyers have moved from initial purchases to systematic, repeatable procurement retiring credits quickly because they trust the instrument and have integrated CDR into their climate frameworks.

Each retirement also sends a near-term demand signal to suppliers, justifying continued investment in removal capacity and accelerating the growth of the next cohort of supply.

Buyer intent is increasingly being expressed ahead of issuance. The average time to primary trade – when a CORC is purchased - has fallen from 115 days in 2024 to just 7 days in 2026, reflecting a market in which forward agreements to deliver CORCs are being fulfilled, and that buyers are becoming more confident in their procurement via advance agreements to secure supply.

Finally, more and more buyers are coming to the market to purchase CORCs. Puro Registry data shows that between 2020 and 2025 there has been a 4.7x increase in the number of beneficiaries – the ultimate end buyers of CORCs that own the environmental attributes of the instrument. Over 650 beneficiaries have retired CORCs over this time.

While some of these companies are repeat buyers, data shows that the buyer base is also expanding with new companies coming to the market. The number of new unique companies retiring CORCs grew more than threefold, from 42 in 2020 to 138 in 2025.

Puro.earth data from 1 January – 10 June 2026 shows there have been 350 CORC transactions, from 53 projects across 20 countries.

Retirements span proven and emerging CDR pathways, led by Biochar and Geologically Stored Carbon:

- Biochar: 489,280 CORCs (48.1%)
- Geologically Stored Carbon: 338,598 CORCs (33.3%)
- Carbonated Materials: 40,343 CORCs (4%)
- Terrestrial Storage of Biomass: 6,624 CORCs (0.7%)
- Enhanced Rock Weathering: 3,034 CORCs (0.3%)
- Other pathways: 139,408 CORCs (13.7%)

With Puro.earth representing approximately 76% of retired CDR credits, it is clear that CDR is becoming a multi-pathway market, with retirements distributed across both proven and emerging CDR methods.

## Frontier approves Puro.earth's Enhanced Rock Weathering methodology

Frontier, an advance market commitment to buy $1.8B of permanent carbon removal between 2022 and 2040, has approved the 2025 methodology for use by its suppliers. It is the second Puro.earth methodology to earn Frontier's approval, following its 2024 approval of the Geologically Stored Carbon methodology.

The ERW 2025 methodology brought a significant update to Puro.earth's approach to certifying ERW projects, and was developed in collaboration with experts from academia, industry, and the non-profit sector.

Key updates included more detailed quantification approaches - requiring suppliers to combine two independent measurement methods for greater reliability - alongside clearer sampling requirements, refined accounting for carbon losses, and a new framework for managing measurement uncertainty.

The approval follows Frontier's approval of Puro.earth's Geologically Stored Carbon methodology in 2024, subject to two conditions: for direct air capture (DAC) projects, suppliers must also comply with Frontier's clean energy procurement principles; for BECCS projects, approval currently applies only to projects with minimal net new biomass use.

### More information

**www.puro.earth**

**https://frontierclimate.com**

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

**Editor**
**Keith Forward**
editor@carboncapturejournal.com

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

**Subscriptions**
subs@carboncapturejournal.com

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

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*Back cover: A performance verification conducted by DNV has confirmed Carbon Ridge's centrifugal onboard carbon capture system can reach CO2 capture rates of as high as 98%. In its first maritime deployment, the test was set up to capture and treat a part of the emissions stream generated by a LR2 product tanker owned by Scorpio Tankers (pg. 33)*

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## Leaders - CCUS in EMEA



## Projects and policy



## Capture and utilisation



## Transport and storage

# Gassnova knowledge sharing summit: from why to how

**Knowledge Sharing 2026 reinforced the importance of collaboration and knowledge sharing to move CCS and CDR from ambition to delivery. A clear takeaway from this year's summit was the shift from "why" to "how" — from justification to execution.**

Technology is no longer the primary constraint. Instead, challenges related to value chain integration, access to transport and storage, standardisation, and credible monitoring, reporting and verification (MRV) are increasingly decisive. Projects perform best when CCS and CDR are approached as integrated value chains, with clear ownership and strong coordination from an early stage.

## Status of CCS and CDR internationally

1. Knowledge sharing is a core enabler for scale. Scaling depends on systematically generating and openly sharing lessons from real projects, with Longship framed as a key European learning platform.

2. Longship shows end-to-end CCS is operational – and the next step should be more market-based. Public risk-taking was necessary for the first chain; future expansion should rely on market-driven investment and stronger commercial incentives, based on a firmer /more reliable climate policy framework that can deliver the need investments for the climate neutrality goal.

3. Bankability – not technology – is the binding constraint for most projects. Finance is increasingly comfortable with CCS as an asset class, but requires stable policy, bankable revenue stacks, and explicit downside-risk mitigation (value chain + infrastructure).

4. Different national policy models can deliver, but contexts differ. Norway (state-backed demonstration + incentives), UK (detailed business models), Canada (progressive policy stack incl. investment tax credits) were presented as distinct pathways that produced projects.

5. CDR is increasingly intertwined with CCS infrastructure build-out. The panel argued that CDR cashflows (voluntary markets + subsidies) can unlock storage infrastructure, and that scaling to 2030 requires demand liquidity, value on carbon, and mechanisms that manage "double burden" risks.

## What will drive progress going forward?

Key takeaways:

1. Treat CCS/CDR as a whole value chain, not separate assets Value chains fail at interfaces: misaligned assumptions across capture, conditioning, transport, storage and regulation propagate cost and delay. The strongest lesson was to assign clear interface ownership early and coordinate decisions across actors, not sequentially.

2. Secure the maturity needed before execution: FEED quality and change control decide project delivery outcomes CCS projects are often large and complex. Execution risk is strongly caused by lack of project maturity and late changes. The summit repeatedly highlighted minimum maturity requirements, early operational readiness, and disciplined change control as core levers to protect schedule, cost and commissioning performance.

3. Transport and storage access is a gating factor – design for hubs and optionality where this can contribute to cost reductions Across the European project pipeline, progress depends on access to transport and storage and the ability to connect to shared infrastructure. Flexible concepts (including shipping-based solutions) and hub approaches were repeatedly framed as practical enablers for scale and resilience.

4. Standardise where possible; tailor wherenecessary (CO2 quality, interfaces, risk processes). Cost and risk are amplified by fragmented specifications and bespoke requirements. A clear message was to converge on fit-for-purpose standards for CO2 specifications and to align mitigation responsibilities across the chain—especially where mixed sources and hub solutions increase complexity.

5. MRV must be credible, interoperable, and workable across real value chains. There is no single harmonised MRV framework today. The summit highlighted practical challenges that must be solved to scale: mixed CO2 streams (incl. biogenic fractions), nonpipeline transport, and the need for MRV approaches that work across storage types and emerging "green product" value chains.

6. Bankability is possible when conditions are right – revenue certainty and insurability unlock capital. Projects become investable when downside risk is managed and cash flow is stable. Key enablers discussed long-term revenue structures, regulatory clarity, and insurance solutions that can price risk even with limited loss history. These are underpinned by better data, clearer regulatory definitions, and more standardised risk management practices.

7. Real plant operation and open learning drive cost reduction faster than lab progress alone. The summit emphasised that real plant operation reveals the constraints that matter (flue gas variability, integration, emissions control, energy use). Knowledge sharing and learnings from projects in operation matter for upcoming projects to reduce cost and risk. In addition are stepwise scale-up, demonstration and comparable test campaigns, plus nonproprietary knowledge sharing, still crucial for each project to succeed on the way towards full scale operation.

8. Storage scale-up requires phased development, operational data, and monitoring optimisation. Storage maturity grows through operations: models must be validated and updated with injection and monitoring data.

Monitoring strategies should evolve from "learn fast" (early, high information) to "optimise cost" (later, fit-for-purpose). Scale will come from multiple reservoirs and hub-based systems, not one blueprint.

9. CDR needs the same delivery discipline—plus demand and market architecture. Technology-based removals remain a small share today, and meaningful scale requires rapid growth supported by infrastructure, standardisation, streamlined MRV/permitting and durable demand. Early markets are concentrated; scaling depends on predictable frameworks that broaden buyers and volumes. Government action (e.g. procurement) and policy drivers will play a larger role going forward.

## Longship experience sharing: Insights across the full project lifecycle

Longship was established to demonstrate full-chain CCS and enable learning. The objective is to show that large-scale CCS is technically feasible and safe, and to generate technical, regulatory and commercial learning that can reduce cost and risk in future projects.

Gassnovas role in Longship has been to be a project integrator and to follow up the industrial projects through state aid agreements. In the development of Longship, Gassnova early identified the whole-chain risk as a major investment barrier.

This led to splitting the CCS chain in two, capture and transport & storage and Gassnova taking on an integrator role, including facilitating for a common design basis, coordination of schedules and decision gates, and structuring requirements and cooperation on experience sharing.

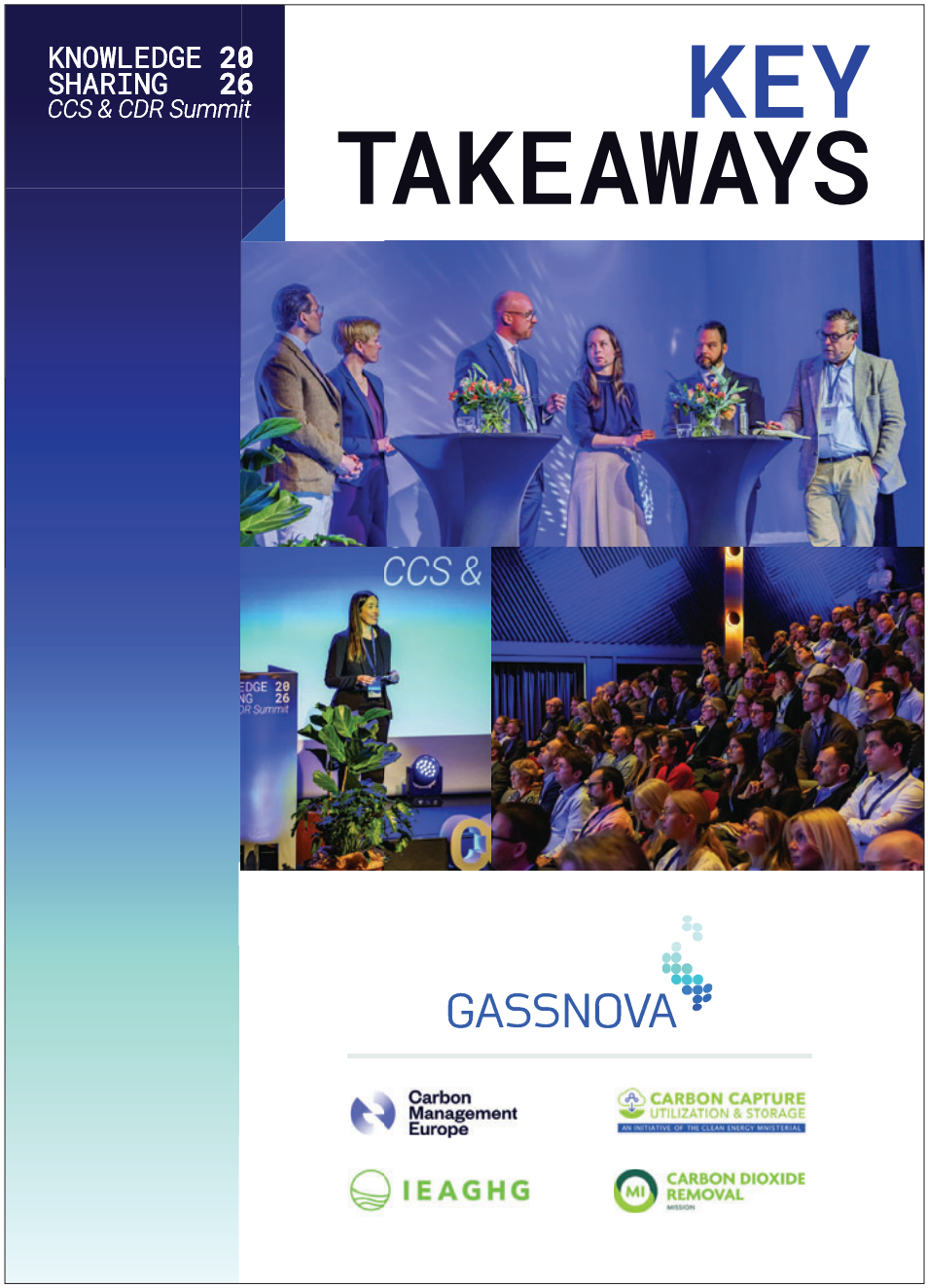
The industrial actors retained responsibility for their own project execution. Gassnova has been following up the industrial project development, and are now following up the state aid agreements for construction and operation.

Integration into existing industrial plants is technically demanding. Experience from Brevik CCS and Oslo CCS shows that limited space, complex interfaces with existing processes, energy integration and continued operation significantly increase execution risk.

FEED maturity and scope discipline are decisive. Experience from Brevik CCS and Oslo CCS shows that a mature FEED and strict control of scope changes are critical for contract negotiations, execution, cost control and schedule.

Interfaces dominate risk during commissioning and startup. Northern Lights' experience shows that many technical and schedule challenges materialize late, when capture, transport and storage systems are tested together and handed over to operations.

The presentations showed that successful CCS delivery depends on early technical maturity, disciplined scope and interface management, and deliberate integration across capture, transport and storage. Longship demonstrates that full–chain CCS can be realized at industrial scale, while experience from Brevik CCS, Oslo CCS and Northern Lights provides concrete and transferable lessons on how and where risks materialize during execution and startup.




*The meeting showed that investment decisions now are less constrained by technology and more by issues like integration of value chains, bankability, fit-for-purpose standards, credible and aligned MRV.*

### More information

**https://gassnova.no**

# CCS as a system in Norway, Netherlands, Denmark

**Speakers involved in CCS projects in Norway, Netherlands and Denmark shared perspectives on challenges with getting CCS to work as a system and how to overcome them, speaking at the Edinburgh OEUK North Sea CCS & Hydrogen summit. By Karl Jeffery.**

## Northern Lights Norway

Norway's Northern Lights CO2 storage project shows that technology is working, but there are questions about how to expand beyond phase 2, said Gjermund Stakland, Asset Manager CCS with Equinor.

He was speaking at the Edinburgh Offshore Energies UK "North Sea CCS & Hydrogen Summit 2026" in June.

Before starting the Northern Lights project, there had been predictions that storage demand would increase in a straight line, with a queue of companies wanting to use it. Reality has turned out differently. "So, it has been a journey," he said.

The first phase of Northern Lights, storing 1.5m tonnes a year (mtpa) CO2, has CAPEX and OPEX for a limited period 80 per cent funded by the Norwegian government. Injection started in Autumn 2025.

Last year the final investment decision was made on phase 2, taking storage up to 6 mtpa. This was after signing a commercial agreement with Stockholm Exergi to transport and store up to 0.9m tonnes of biogenic CO2 annually for 15 years.

*There is no shortage of CO2 storage capacity to expand further – Gjermund Stakland, Asset Manager CCS with Equinor*

There are also storage agreements for phase 2 with Yara Sluiskil, Ørsted, Heidelberg Materials, and Celsio.

There is no shortage of CO2 storage capacity to expand further. And the project has 4 CO2 vessels delivered and 4 more under construction, providing operational flexibility.

But emitters may also choose to store in other countries, so it is not clear what size CO2 pipeline would be best. "There's a risk of waiting for a perfect design," he said.

It would be great to do a project on a really big scale, but then it is much harder to make a strong investment case initially, leading to delays, he said. "We have to take it step by step."

*"Rotterdam is set to be the CO2 hub of Northwest Europe" - Alexander Vink, Commercial Director CCS Gasunie (Photos courtesy Offshore Energies UK)*

## Netherlands

The first CCS project in the Netherlands, Porthos, plans to store 2.5m tonnes CO2 a year for 15 years, so 37.5m tonnes in total.

The backbone pipeline through the Dutch industrial area Maasvlakte was built to carry 10 mtpa. It is so large construction of some sections involved lifting 7 pipelines to put this pipeline underneath, said Alexander Vink, Commercial Director CCS with energy network operator Gasunie, one of the three state owners.

The next Dutch project, Aramis, will be built to store 22m tonnes CO2 a year, initially with a compressor which can handle 10m tonnes a year.

It expects to handle CO2 volumes from Germany and the Antwerp industrial cluster, since Belgium and Germany do not have much North Sea area to store CO2 themselves.

"Rotterdam is set to be the CO2 hub of Northwest Europe," Mr Vink said.

"We think connecting to the UK will be the next step. We need you; you might need us," he said. If this happens, Gasunie would like the UK to build the UK part of the network.

Pipeline projects should be seen like highways, with access provided to every emitter, he said, and government taking a role in ensuring this. There have been problems with one company seeking to block access to a competitor company.

Another challenge is managing the risks if the pipeline is not utilised fully. If an emitter company would pay a penalty for not utilising the pipeline to the contracted amount, that would discourage companies from being first movers.

And for now, the capture and storage costs are around Euro 200, while the carbon price is Euro 80. No-one doubts that infrastructure will be used once it is built, but "getting there is hard".

One unpleasant surprise has been one Dutch individual who has tried to block CO2 storage projects by legal methods. "He has done that successfully. That really felt harsh."

In the Netherlands, every contract for carbon capture and storage is bespoke, and every change involves a re-negotiation. "It is a very complex way to build a system," said Joost Hooghiem, Director CCS, Energie Beheer Nederland (EBN), the state energy company of the Netherlands, also an owner of PORTHOS.


*No-one doubts that infrastructure will be used once it is built, but "getting there is hard" - Joost Hooghiem, Director CCS, Energie Beheer Nederland (EBN)*

"We need a flexible regulatory framework that recognisees this is not a mature market," he said.

"We need financial support, particularly for underutilisation risks. We need to reward first movers, not penalise them."

It helps that EBN is able to enter projects with lower returns than private companies can, with private companies typically expecting returns on storage projects in double figures, due to the perceived risk.

From a Dutch perspective, government bodies in UK and Norway appear to be taking a more active role compared to the Netherlands, stepping in as an "aggregator", helping to build a trusted community, not just companies transacting, he said.

This helps encourage companies to be a first mover, which is otherwise "not necessarily attractive."


*Project Greensand now has a dedicated CO2 transport vessel, Carbon Destroyer 1 - Kurt Jager Lykke, Head of Business Denmark with INEOS Energy*

## Project Greensand, Denmark

Project Greensand, storing CO2 in the Danish North Sea, expects operational injection to start in mid to late July 2026, with CO2 from biogas facilities. The project is funded under the EU Innovation Fund.

It ran a pilot program for CO2 injection in Spring 2023. The CO2 was captured from the INEOS Oxide plant in Antwerp, Belgium. It was compressed, put into tank containers and shipped 500km, across European borders, explained Kurt Jager Lykke, Head of Business Denmark with INEOS Energy.

The CO2 tankers were carried offshore on the deck of multipurpose offshore vessel Aurora Storm.

Project Greensand now has a dedicated CO2 transport vessel, Carbon Destroyer 1, built in the Netherlands by Wagenborg.

## More information

**www.equinor.com**
**www.gasunie.nl**
**www.ebn.nl**
**www.porthosco2.nl**
**www.aramis-ccs.com**
**https://greensandfuture.com**

# Captured carbon dioxide could become a Swedish industry of the future

**Researchers at Stockholm University are working together with RISE Research Institutes of Sweden and other institutions and companies to develop more efficient solutions for capturing carbon dioxide, using it as a resource and storing it long-term.**

Today's carbon capture technology is expensive and energy-intensive.

"Today's technology has not been developed specifically for carbon capture. That means there is still a great deal left to do," said Niklas Hedin, Professor of Materials Chemistry at Stockholm University.

Plastics, textiles, pharmaceuticals, chemicals and fuels all contain carbon. Today, a large share of these carbon atoms comes from fossil raw materials such as oil, natural gas and coal.

They are extracted from the ground, used once and, in many cases, released into the atmosphere as carbon dioxide. To slow climate change, society needs to stop emitting fossil carbon into the atmosphere. At the same time, new solutions are needed to make use of carbon that is already in circulation.

"We need to recirculate carbon instead of releasing it, and also achieve negative emissions through permanent storage of carbon dioxide in various forms," said Sara Bargi, project manager at RISE, Research Institutes of Sweden.

This is the starting point for an initiative to further develop CCUS technology: solutions for capturing carbon dioxide, using it as a resource and storing it long-term.

## Sweden has strong potential

Sweden has large amounts of biogenic carbon dioxide, meaning carbon dioxide that comes from biological material rather than fossil raw materials. It is generated, for example, in the forest industry, the pulp and paper industry, and in biofuelled heating and combined heat and power plants. Instead of being released into the atmosphere, it could be captured and used as a raw material or stored long-term to create negative emissions.

"Our combined heat and power plants and pulp mills that burn biomass currently emit carbon dioxide that comes from biomass with relatively short cycles. This is a resource that ought to be put to use and create value both for them and for other associated companies," said Niklas Hedin.

The researchers argue that Sweden's combination of biogenic carbon dioxide flows, industrial environments and strong research gives the country good opportunities to take a leading role in the field and, in the long term, become an international hub for carbon dioxide use and a strategic supplier of carbon dioxide for long-term storage.

## Today's technology is too expensive

There are already projects that capture and use or store carbon dioxide. But the technology is still too expensive and energy-intensive to be used at the scale required.

"Many companies say that the technology is mature but too expensive. We would rather say that it is not mature, precisely because it is too expensive and requires too much energy," said Sara Bargi. An important part of the research is therefore to develop new processes that can reduce both costs and energy needs.

At Stockholm University, research is underway into new ways of capturing carbon dioxide more energy-efficiently. One example is processes in which carbon dioxide causes a liquid to separate into two phases, so that only the part containing the carbon dioxide needs to be heated. According to the researchers' calculations, this could significantly reduce energy use.

## More than a technical issue

Carbon capture is not only a technical issue. For the technology to have an impact, functioning regulations, new business models, life cycle analyses, transport solutions and legitimacy in society are also needed.

The research spans several areas. At Stockholm University, this includes research on policy issues, justice and moral-philosophical perspectives on the technology. This may involve how costs and risks should be distributed, how future generations are affected and how society should weigh different climate measures against one another.

"A lot of this takes place in a political and civic context. In addition to capital, citizens also need to be comfortable with the methodology itself," said Niklas Hedin.

## Carbon capture pilot plant

RISE's mobile CO2 capture pilot (a complete 20-foot container system) enables testing of novel capture solvents under industrial fluegas conditions. Designed for Bioenergy with Carbon Capture applications, the pilot addresses one of the sector's greatest challenges: reducing the high energy demand and cost of commercial CO2 capture.

By bridging the gap between laboratory research and industrial deployment, the facility delivers critical performance data to support technology scale-up and commercialization. The pilot directly contributes to Horizon Europe's climate ambitions for a net-zero energy system by demonstrating BECCS and CCUS technologies at TRL 5–7.

The CO2 capture facility is designed for testing a broad range of solvents. including amines, hot potassium carbonate (HPC) and advanced solvents (eutectic mixtures, ionic liquids).

### More information

**www.su.se**

**www.ri.se**

# Carbon dioxide to become a raw material for the chemistry of the future

**Could the medicines, plastics and chemicals of the future be made from carbon dioxide rather than oil? That is the vision behind the new research centre ACCELERATE, in which researchers from Stockholm University and KTH Royal Institute of Technology play a key role.**

At a time when the climate issue is putting pressure on industry, researchers are looking for new ways to move away from dependence on fossil fuels for raw materials. At KTH, chemists, engineers and sustainability experts are gathering in a new research centre where one of the goals is to turn carbon dioxide into a raw material in the materials and chemicals of the future.

With the new research centre ACCELERATE whose aim is to accelerate the transition and scale-up of bioCO2 usage, the researchers are taking the first steps towards a chemistry where carbon dioxide can go from emissions to raw materials. The initiative is funded by the Swedish Foundation for Strategic Research and brings together researchers from several universities.

The background is society's continued dependence on fossil raw materials and the fact that the chemical industry accounts for about five to six percent of global greenhouse gas emissions. Factors that make a transition necessary, but technically and financially challenging.

“Almost everything around us is made of fossil molecules, from paint and pharmaceuticals to glasses and clothes. The challenge is to stop using them," said Christophe Duwig, professor at KTH and director of the centre.

## Alternative carbon sources

The ambition of ACCELERATE is to replace fossil raw materials with alternative carbon sources, where carbon dioxide plays a central role. Today, the use of CO2 as a raw material is severely underdeveloped compared to biomass and waste.

"We want to develop new ways of making chemicals from CO2. It's about capture, transformation and putting everything together into a sustainable process," said Christophe Duwig.

The centre focuses on developing techniques to capture biogenic carbon dioxide and convert it into high-value products, such as polymers, solvents and pharmaceutical building blocks. The goal is to be able to produce products with a significantly lower climate footprint compared to today's fossil-based products.

"There is a particular potential in using biogenic carbon dioxide. By combining the combustion of biomass with the capture and use of carbon dioxide, production can in some cases have very low emissions," said Christophe Duwig.

The work spans several scientific disciplines where technology, chemistry, techno-economic analysis and sustainability analysis are developed in parallel. To determine whether the solutions really reduce climate impact, Hanna Steinum, doctoral student in sustainability studies at KTH, conducts prospective life cycle analyses.

"We are looking at the entire value chain and trying to understand what it would look like if the technology were scaled up to an industrial level, and what effects this would have in a long-term perspective." The method means that future scenarios for the project are analysed already at the research stage.

"It's complex, but important for us to be able to make the right decisions early in the development. The research is formed in close interaction between different disciplines. My work is directly affected by what my research colleagues come up with. This makes the project very dynamic," said Hanna Steinum.

The work on the chemical transformation is led by Belén Martín-Matute, Professor of Organic Chemistry at Stockholm University, who is developing catalysts to convert the stable carbon dioxide molecule into complex organic substances.

"Carbon dioxide is a very stable molecule, so it takes a lot of energy to convert it. With catalysis, we can lower the energy requirement and make the process possible. The big challenge is to create complex molecules where all the carbon comes from CO2. We are not there yet, but that is where we want to go," said Belén Martín-Matute.

The project is carried out in close collaboration with industry and also includes economic and political perspectives. Today, fossil raw materials are still cheaper, which slows down development. "It's a systemic issue. We must change both technology, economics and politics at the same time."

ACCELERATE's ambition is also to strengthen Sweden's position in the area. By bringing together research, industry and education, the centre will contribute to building a new generation of chemists and engineers – and lay the foundation for a more sustainable chemical industry.

"This is a marathon. We build knowledge that the next generation will take forward. In ten or twenty years, we want to see a new chemical industry that is not dependent on fossil raw materials. But the road to get there is long.”

“Society is heavily dependent on fossil molecules, almost like oil. Breaking this requires cooperation on many different levels. This centre is a piece of the puzzle in that endeavour," concluded Christophe Duwig.

ACCELERATE’s goal is to develop technology to convert carbon dioxide into chemicals, materials and pharmaceutical components, thereby replacing fossil raw materials and reducing climate impact. The centre is part of SSF's ongoing investment in multidisciplinary research centres (MRCs).

## More information

**https://www.kth.se/accelerate**

# EU will miss CCUS target by 35% despite ongoing projects

**The EU is on course to fall short of its legally mandated carbon capture and storage target by at least 17.5 million tonnes per annum, according to Wood Mackenzie's latest analysis, even if every project in advanced development proceeds as planned.**

The finding comes from an independent study commissioned by ExxonMobil, OMV Petrom, Shell and TotalEnergies. This is the second Wood Mackenzie report for the four companies. Where the October 2025 study focused on storage feasibility, this analysis examines capture, transport and storage as a connected system.

Wood Mackenzie's analysis measures storage capacity that is fully operational by end 2030, the standard against which the Net Zero Industry Act injection target is assessed. On that basis, the EU faces a position 35% below the 50 million tonnes per annum threshold, and the gap widens further once project delays and shortfalls across the broader capture and transport value chain are factored in.

"The issues with meeting the NZIA target reflect the challenges of developing a functioning large-scale, cross-border CCS ecosystem from a standing start," the report said.

The NZIA was designed to break the classic chicken-and-egg deadlock in CCS by mandating storage capacity ahead of confirmed demand. The analysis finds this has produced a different problem where there is an inconsistent approach across the sectors. No single element of the value chain can advance without progress across the others.

Less than 6% of targeted NZIA storage capacity is operational or under construction and reaching 50 mtpa would require a five-fold increase in storage final investment decisions between 2026 and 2028, against a base of just 4 mtpa of EU capture capacity that has taken FID and is contractually linked to EU storage.

"Storage developers across Europe are not failing to act, they are being asked to commit capital to projects without the contracted volumes or transport connections that any rational investment decision requires," said Lisa Gillespie, Director, Energy Consulting at Wood Mackenzie.

## Key details

Projected shortfall: At least 17.5mtpa, placing the EU 35% below the 50mtpa NZIA target

Storage progress: Less than 6% of targeted NZIA storage capacity is operational or under construction

FID requirement: A five-fold increase in storage FIDs required between 2026 and 2028

Bankable capture: Only 4 mtpa of EU capture capacity is post-FID and contractually linked to EU storage

Stranded risk: 11 mtpa of capture capacity assessed as potentially stranded, concentrated primarily in France and Germany

Delays: Average EU storage project delay of 1.5 years; Porthos commissioning now expected second half of 2027, three years behind original schedule

Antwerp@C: Over 730 million euros in EU funding received; no FID reached across associated projects

"The policy has mandated one part of an integrated system while leaving the others to develop at their own pace and through different frameworks. That is the core of the problem. Resolving it requires policy design that addresses the full value chain, not just the storage end of it."

## Four barriers, one system

Value-chain fragmentation leads the list. The hub-based model splits ownership across multiple parties and no component can advance without guarantees from the others. The EU policy framework treats capture, transport and storage as discrete activities rather than interdependent parts of a single system.

The second barrier is insufficient capture supply. The EU capture pipeline totals 36.5 mtpa and planned storage capacity stands at 32.5 mtpa, both short of target. Of the 26 mtpa lacking a confirmed storage solution, 11 mtpa is assessed as potentially stranded, with no proximity to planned pipeline or existing CO2 infrastructure.

Persistent delay is the third factor. Average overruns across EU storage projects stand at 1.5 years and the trend is worsening.

The fourth barrier is capture economics. Wood Mackenzie's modelling shows the EU Emissions Trading System price will remain below the levelised cost of CCS for projects approaching FID. The ETS delivers avoided compliance cost rather than concrete revenue, and prices carry both price and political risk.

The report also identifies a mismatch in how obligations and public funding are distributed. NZIA obligations are based on oil and gas production rather than industrial emissions. Some obligated countries have no pre-2031 storage capacity in development and limited EU Innovation Funding.

Sweden and Spain received substantial EU Innovation Funding despite holding neither NZIA obligations nor pre-2031 storage capacity. Capture and transport developers face limited regulatory pressure to meet NZIA milestones. Storage operators face legal obligations without the contracted volumes or infrastructure commitments the investment case requires.

## More information

www.woodmac.com

# Turning food waste into carbon captors

**Researchers at ETH Zurich have developed a new method that efficiently binds carbon dioxide and releases it again using only a small amount of energy. The starting materials are provided by waste products from dairy and soy processing.**

In a study published in the journal PNAS, researchers present a promising new approach to DAC. A group led by materials scientist Raffaele Mezzenga, a professor at the Department of Health Sciences and Technology of ETH Zurich, uses whey and by-products from tofu production for CO2 absorption.

Dairy and tofu production generate large quantities of protein-containing solutions, only a small part of which is reprocessed in food production – the remainder goes to waste. From this waste, the researchers isolate proteins that they use to form long, threadlike chains known as amyloid fibrils. They then load these fibrils with potassium hydroxide and process them into beads with a diameter of between half and one centimetre. "The resulting material is like a sponge that can absorb large quantities of CO2 via the potassium hydroxide," Mezzenga explained.

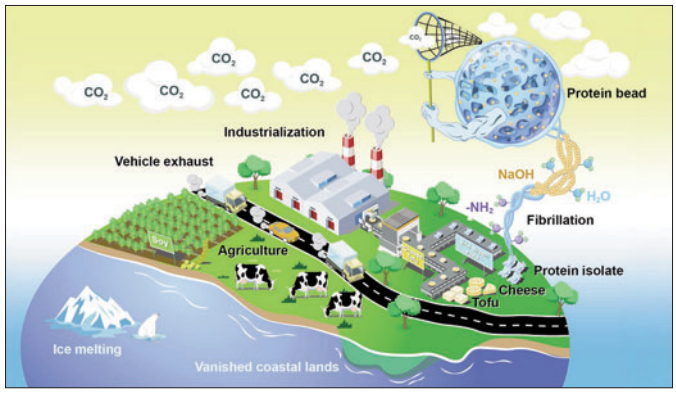
When the porous beads are exposed to ambient air, the potassium hydroxide reacts with CO2 to form hydrogen carbonate, a salt of carbonic acid. This process removes the CO2 from the air. "In our tests with ambient air, we were able to extract 97?milligrams of CO2 with one gram of material," said Zhou Dong, a postdoc in Mezzenga's group and lead author of the study.

This is a very high rate, he says, and 10 to 50 percent greater than the capacity of conventional DAC methods. Dong assumes that, with one kilogram of protein beads, it would theoretically be possible to bind and isolate 100 grams of CO2 per process cycle.

## Technique for a circular economy

Conventional DAC methods generally use heat and negative pressure to release the carbon dioxide from the absorption material again. This is necessary in order to then store the CO2 or convert it into other materials, thereby removing it from the atmosphere on a long-term basis. However, this process requires a great deal of energy, which is why DAC generally only makes sense nowadays – in terms of both energy and economics – where large amounts of renewable energy are available.

This is another area in which the researchers in Mezzenga's team are taking a different approach: in order to release the carbon dioxide from the protein beads again, the beads are alternately sprayed with a mild acid and base for around 10?minutes at room temperature. This breaks the chemical bonds so that the CO2 can be isolated.




*The new direct air capture method: food waste from cheese and tofu production is processed into small beads that can capture CO2 (Image: Mezzenga Lab / ETH Zurich)*

The acid, base and beads can then be reused. "The synthetic materials that are used to capture CO2 today decompose quickly," said Dong. "By contrast, our protein beads remain stable for a long time." In the lab, the researchers tested 30 cycles of CO2 adsorption and release without observing significant losses of efficiency.

Mezzenga assumes that the material would nevertheless need to be replaced after a few thousand cycles due to a decrease in adsorption capacity. However, the protein beads could then be used as fertiliser in agriculture or converted into biofuel, the researcher explains. The beads are made up entirely of organic material, he says, and are readily degradable – meaning that the system could therefore become part of a circular economy.

"The materials we use for this process are non-toxic and are food-grade," Mezzenga points out. In a life cycle analysis, the researchers show that their method generates less environmental pollution across the entire life cycle than other DAC methods.

## Expected to be cheaper than other capture methods

Further tests are needed to reveal whether the technology is scalable for practical use and the high CO2-absorption capacity will remain intact on a larger scale. For the recently published study, the researchers tested the method in a controlled laboratory environment with a few grams of protein beads, binding and isolating around 50 grams of CO2.

Mezzenga is optimistic. He has been working with amyloid fibrils for nearly 20 years and is well acquainted with the material. In the past, he has used it to develop biodegradable alternatives to plastics as well as techniques for water purification. "We're confident that the technology is scalable," he said. According to Mezzenga, the spray system used to separate the CO2 from the protein beads is geared towards existing techniques that are already used in industry. Postdoc Zhou Dong will now further examine the question of scalability.

Although the researchers are yet to make an exact calculation of the costs per captured tonne of CO2, Mezzenga expects them to be significantly lower than with conventional DAC. "Our technology is cheaper and more sustainable because it requires little energy and is based on a widely available waste product," he said. "That could be a game changer for the future of removing CO2 from the air."

## More information

**https://ethz.ch/en.html**

# Poland opens new chapter by expanding areas eligible for onshore CO2 storage

**The Polish government has adopted long-awaited legislation significantly expanding the areas where onshore geological storage of carbon dioxide can take place, marking a major milestone for the development of CCS in one of Europe's most emissions-intensive economies.**

The change is expected to facilitate the identification and development of suitable storage sites closer to industrial emitters, and compliance with Article 23 of the Net Zero Industry Act (NZIA) obligating the Polish oil and gas sector to establish CO2 injection capacity.

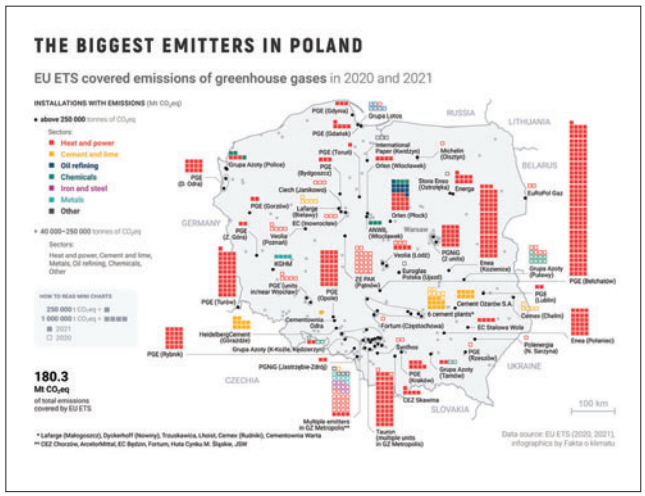
## Building momentum for industrial carbon management in Poland

The legislative change follows years of work by industry, researchers and civil society organisations advocating for a more enabling framework for CCS deployment. Bellona Europa has for a long time actively supported these efforts and participated in discussions aimed at modernising the country's legal framework for industrial carbon management, including through its membership in the CCUS Poland association.

The organisation played a key role in building awareness of the importance of geological CO2 storage and in advocating for reforms that align Poland with European carbon management and NZIA objectives. Earlier, with the CCS4CEE project, Bellona and its partners initiated regional discussions and activities on the long-term deployment of CCS in Poland and other countries in Central and Eastern Europe. We are proud that these combined efforts are now leading to tangible results.

"This is an important step towards creating the conditions necessary for deploying CCS at scale in Poland. By expanding the areas available for geological storage, the government has addressed one of the key barriers to investment. The challenge now is to build the broader ecosystem that will allow projects to move from concept to reality," said Michał Wendołowski, Head of Net Zero Industry.

The reform comes at a time when Poland is increasingly exploring CCS as part of its long-term climate and industrial strategy. Several projects are under development, while industrial stakeholders have highlighted the need for domestic storage capacity to complement cross-border solutions and avoid reliance on more costly export routes.




*Poland's largest CO2 emitters - Bellona/CCS4CEE*

## Towards a well-functioning CO2 infrastructure and market

Looking ahead, further policy work will be essential to translate this legal change into operational projects. Through the CCUS Poland association, Bellona Europa is also supporting the development of Poland's forthcoming CCUS Strategy, which is expected to provide a long-term vision for the sector, as well as dedicated national CCS legislation governing CO2 transport and storage infrastructure.

These frameworks will signal high-level policy support and will be critical for regulatory certainty. Equally important will be the creation of a fair and transparent regime for third-party access to transport networks and storage sites, to prevent market concentration and ensure fair competition.

At the same time, Poland will need to establish appropriate financial support mechanisms to de-risk and enable first-mover projects and overcome the high upfront costs associated with CCS infrastructure.

These national efforts should be closely aligned with the European Commission's forthcoming legislative proposal on $CO_2$ transportation infrastructure and markets, expected in the third quarter of 2026.

(See Bellona's position: https://network.bellona.org/content/uploads/sites/6/2026/03/Position-Paper-CO2-markets-and-infrastructure-regulation.pdf). A coherent framework between Polish and EU regulation will be essential to facilitate cross-border $CO_2$ flows, provide investor confidence and support the emergence of an integrated European carbon management market.

Bellona Europa said the decision represents an important milestone rather than the end of the journey. With the expansion of onshore storage opportunities now in place, the focus should turn to meeting the NZIA CO2 injection target by 2030, developing the transport infrastructure, market rules and financial frameworks needed to make CCS a practical and scalable decarbonisation solution for Polish industry.

### More information

**www.bellona.org**
**https://ccuspoland.org**
**https://eu.bellona.org/project/ccs4cee**

# EMEA news

## BioCirc opens world's largest biogas-based CCS plant in Vesthimmerland

**https://biocirc.com**

**It is the first of five CCS plants in the company's overall CCS roll-out and marks the beginning of BioCirc's BECCS platform with CO2 capture and storage and carbon credits.**

BioCirc is planning to implement CCS at five out of its eight biogas plants. BioCirc said its ambition is to create an economically accessible green transition and thus contribute to a more secure and sustainable future.

"The inauguration of Vesthimmerland CCS facility marks the first, important step in BioCirc's overall BECCS rollout," said Bertel Maigaard, CEO of BioCirc. "The plant is the first of five, and when all plants are in operation, BioCirc will contribute with the capture and permanent storage of CO2 from biogas on a large scale."

Using multiple value streams from biogas operations, BioCirc said it can extend cost-effective CO2 displacement with permanent negative CO2 emissions and a scalable approach that simultaneously supports sectors such as agriculture, shipping and heavy land transport, which are difficult to transition.

## Holcim launches carbon capture test platform in industry first

**www.holcim.com**

**Holcim has opened the sector's first industrial-scale carbon capture test platform in Martres-Tolosane, France to enable field testing and validation of advanced technologies alongside valued third-party partners.**

Developed by Holcim R&D teams in Switzerland and France, CaptureLab enables Holcim, as well as manufacturers, startups and researchers, to test breakthrough carbon capture technologies and adapt them to cement manufacturing.

For CaptureLab's launch, Holcim is operating the platform while the first pilot project is being conducted by Air Liquide, a leader in gases, technologies, and services for industry and healthcare.

CaptureLab will allow Holcim's partners to test and validate current or next-generation technologies - such as cryogenic treatment, chemical absorption, physical adsorption, membrane separation, or biological processes - in real-world conditions and at scale.

The 2,500m2 platform is capable of analyzing and processing real-world emissions - predominantly nitrogen, oxygen, CO2, water and trace impurities - from the cement industry. Its plug-and-play architecture accommodates different carbon capture systems that can be easily connected to Holcim's Martres-Tolosane plant.

Ram Muthu, Head of Group Operational Excellence, said, "With CaptureLab, Holcim has built a unique facility to test and scale the most advanced carbon capture technologies through an agile, open innovation model with our valued partners. Validated technologies will be used at Holcim's own sites, advancing our industry-shaping decarbonisation roadmap and contributing to the production of near-zero cement."

## KAUST and Aramco convert CO2 into jet fuel-range hydrocarbons at record efficiency

**https://discovery.kaust.edu.sa**

**Researchers at King Abdullah University of Science and Technology (KAUST), in collaboration with Aramco, have achieved the highest reported efficiency in converting carbon dioxide into jet fuel-range hydrocarbons, advancing the development of sustainable aviation fuel (SAF).**

A study, published in ChemCatalysis, describes a catalyst that converts carbon dioxide into long-chain hydrocarbons in the range of aviation fuel. The system achieved the highest reported yield for converting CO2 into jet fuel-range hydrocarbons for producing these heavier fuel molecules. Around 75% of the liquid product falls within the range required for jet fuel. The catalyst also operated continuously for more than 1,000 hours under reaction conditions, a critical aspect for industrial implementation.

"This work demonstrates how data-driven methods can accelerate catalyst discovery," said Jorge Gascon, Professor of Chemical Engineering at KAUST. "By combining machine learning with high throughput experimentation, we were able to reach performance levels not previously reported for direct CO2 conversion."

Further scale-up, techno-economic evaluation, and certification processes will be required before commercial deployment. The findings, however, establish a new performance benchmark for direct CO2 conversion and contribute to ongoing efforts to develop lower-carbon fuel pathways for hard-to-abate sectors.

## NG Nordic demonstrates carbon capture at hazardous waste facility in Denmark

**www.ngnordic.com**

**https://capturi.slb.com**

**The demonstration using SLB Capturi technology marks the first time carbon capture has been implemented at a hazardous waste incineration plant, setting a new benchmark for the sector.**

Hazardous waste incineration is recognised as a hard-to-abate activity due to the high-temperature combustion processes, variable flue gas composition, and elevated levels of contaminants. Despite these challenges, the carbon capture technology applied at the Nyborg facility delivered strong performance across key parameters, including energy efficiency, carbon capture rates up to 95%, and emissions control.

The successful demonstration shows that carbon capture can be a viable and effective solution for significantly reducing CO2 emissions from essential hazardous waste treatment operations. The project provides a valuable blueprint for how carbon capture can be deployed within the hazardous waste industry, supporting a viable technical transition towards lower-carbon operations.

"This pilot project has provided valuable insight into how carbon capture technology performs in one of the most demanding waste treatment environments," said Katrine Magnussen, Senior Manager, Business Development, NG Nordic. "Successfully testing the technology at a hazardous waste facility and achieving strong technical results is an important milestone in itself and contributes valuable knowledge for the sector."

# UK CCS – evolving from projects to a system - report from OEUK

**To evolve UK CCS from a set of projects to a system, we may need UK-EU pipelines, balancing storage and emission, a focus on resilience, risk share agreements, government investment, maritime transport, insurance. By Karl Jeffery.**

The UK already has 100 potential CCUS projects. The first three reached financial close in 2025. But only the first 5 projects have access to storage, and sufficient government subsidy, to give a firm route to market.

To move forward, we need UK CCS to evolve from being a set of separate projects, as it is now, to a system. Speakers at the Edinburgh Offshore Energies UK "North Sea CCS & Hydrogen Summit 2026" in June discussed how to get there.

There is progress. Projects are increasingly seeing ways to cover their costs with a "merchant model", rather than being dependent on subsidy, particularly when they involve taking CO2 from the EU, said Mark Sommerfeld, UK Director, CCSA.

This is because the EU has increasing regulatory demands for purchase of low carbon products through mandates and standards, such as for steel and transport fuel. One pathway for making these low carbon products involves CCS.

To give UK investors more confidence in a market from the EU, it would help if there was more cross-EU discussion happening, he said. Also, politicians showing a willingness to resolve the regulatory barriers, such as allowing transfer of waste products across national borders and connecting UK and EU carbon regulatory schemes.

*Speakers on the panel "Pioneering Projects in CCS" at the Edinburgh OEUK summit. From left to right: Matt Browell-Hook, Spirit Energy, Kurt Jager Lykke, INEOS Energy (Project Greensand), Gjermund Stakland, Equinor (Northern Lights), Rich Denny, Northern Endurance Partnership, Alessandro Barberis, ENI CCUS Holding, Alexander Vink, Gasunie. (Photos courtesy Offshore Energies UK)*

*Mark Sommerfeld, UK Director, CCSA*

And UK CCS companies cannot yet be sure projects will get public acceptance. "It is a live discussion, it is going to take time," he said. "We should not pretend the public [even] knows what CCUS is." And as the public learn about it, "we should not pretend they will support it."

## Achieving resilience

DNV did a study of what a "resilient and interconnected" CCS network would look like, looking at economic, regulatory, technical and operational resilience.

Such resilience could be defined as the "ability for the system to adapt so it can remain viable," said Gwen Jackson-Johns, senior consultant, DNV. "Resilience must be designed in, it doesn't just emerge."

To achieve resilience, you need systems with a strong backbone, redundancy and flexibility, she said.

"Infrastructure developed on a project-by-project basis doesn't automatically create a system."

Designing a resilient system requires addressing misalignments at the early stage but also accepting that systems may not be completely efficient in the early stage.

For example, DNV's modelling found that total UK store injection capacity will be greater than what is required for capture until 2040. But it is also important that there is more store injection capacity than capture requirements, she said. Emitters need to know storage is available so they have confidence investing in capture equipment and infrastructure.

It would improve resilience if emitters had multiple storage sites available to them. Systems should also have the capacity to expand and adapt to future needs.

Stable policy helps with resilience, allowing investor confidence to build over time, she said.

Another issue to balance is supply and demand of low carbon hydrogen, created with gas with carbon capture. The planned projects in the North Sea indicate a potential surplus of supply initially, she said. But there could later be high demand for hydrogen from Germany and central Europe.

German and central Europe customers may also be able to buy low carbon hydrogen, and ammonia derived from it, from sources outside Europe, delivered by ship. So UK supply will need to be competitive with this.

DNV's modelling finds that hydrogen industry will only be economic when it reaches a big scale, and by around 2050. The systems are capital intensive, with high levels of uncertainty.

*"Infrastructure developed on a project-by-project basis doesn't automatically create a system" – Gwen Jackson-Johns, senior consultant, DNV*

For resilience, it would help if hydrogen has flexible routing options, she said.

## Planning offshore space

With limited offshore space, plans need to be made now to ensure everyone's activities can continue, said Professor John Underhill, University Director for Energy Transition, Aberdeen University.

*Professor John Underhill, University Director for Energy Transition, Aberdeen University*

Users of offshore space include oil and gas and mining in the subsurface; cables and fishing affecting the seabed; shipping, aquaculture and wind farms using the water, and protected areas; the commercial and military use of the airspace.

Much of the space has already been allocated to something, limiting the options.

The subsurface activities can only happen where there is suitable geology, such as oil and gas resources, and this should be given primacy, he said.

There has already been one complex overlap, between an area the Endurance CCS project wanted to expand into, and an area planned for part of the Hornsea wind farm. This was resolved with a financial settlement between BP and Ørsted Energy.

Some overlaps are possible, for example fishing and oil and gas can use the same waters. But wind farms may send fish away.

Professor Underhill has drawn a map of all the potential demands on different areas of offshore waters. In some places, there are 8 different potential demands on the same piece of sea. "It's a very complicated picture, we've got to get this right," he said.

The whole North Sea needs to be managed holistically. It would be best done with a unified licensing regime determining which use of each area is in the best national interest, he said.


*Adrian Topham, Senior Technology Manager - CCUS & Hydrogen, The Crown Estate*

The Crown Estate, a UK body which owns and manages UK land for the benefit of the UK, has organised an "Offshore Wind and CCUS Co-Location Forum.

This forum takes input from government and trade associations to try to map out the best location for wind, CCS and oil and gas, explained Adrian Topham, Senior Technology Manager - CCUS & Hydrogen, The Crown Estate.

It seeks to understand the procedures and processes of each sector and try to map out how co-location challenges should be resolved.

The biggest risks come from different project timelines, when one group wants the location now, but another may need it in the future. The overlap may not be clear, he said.

There are also multiple bodies involved in leasing, licensing and consenting, and it can be unclear what their roles are.

"Most co-location challenges are manageable if identified early," he said. So, the work has the greatest value before projects get locked in.

## Appropriate risk sharing

If any of the links in a carbon capture, transport and storage project are not operating, the whole system cannot work, and all parties incur costs. But the operator of every link cannot carry everybody's costs if this happens.

For example, if the shipping service is not available, the emitter is not able to capture their CO2 and loses out on subsidies or pays carbon prices. But the shipping company would probably not be able to cover the costs of this.

Ideally you want individual members to carry the risks of their own part of the system, but not the entire system, said Alistair Black, Partner with law firm Norton Rose Fulbright.

Another challenge relating to risk sharing is that emitters and stores need to make a final investment decision at the same time. Emitters cannot commit to investing in capture equipment without knowing there is storage available, and storage companies cannot invest without knowing they will have CO2.

In the UK, the government developed systems to separate the risks.

"The structure is incredibly supportive. But government effectively controls pricing and government picks winners," Mr Black said.

*Alistair Black, Partner with law firm Norton Rose Fulbright*

*Eddie McAvinchey, Scotland Director, UK National Wealth Fund*

Companies would prefer a "completely liberalised market underpinned by commercial revenues, where stores compete on pricing."

If there are transport options other than pipelines (rail or shipping) the network's geographical reach can be extended, and there are different ways to allocate the risk. So, this is a "stepping stone to a deregulated market."

Normally, with rail and maritime transport, the cargo is owned by the company which is hiring the rail and maritime services, and the cargo owner carries some of the risk during transport. Similarly, with CO2 transport, the CO2 is owned by the emitter during the transport stages, and the emitter carries some of the risk.

## Targeted government investment

The UK National Wealth Fund is a UK government investment organisation with £27.8bn of capital. It seeks to make targeted investments where there is a strong business case, there are benefits to the country of making the investment, and the project cannot be financed purely with private investment, explained Eddie McAvinchey, Scotland Director of the fund.

It seeks to make investments alongside private investors, who are reassured by having government investment beside them. It aims for private investment to be three times as much as the government investment, so generating £100bn investment in the UK economy from the state's £27.8bn.

Its goal is that this will create 200,000 new jobs and save 15m tonnes of CO2 from being emitted.

The fund has decided to prioritise capital intensive products and assets, which may struggle to get private investment. The priority areas are ports, CCUS, hydrogen, batteries, the EV supply chain, and green steel. Second in priority are investment in the power grid, energy storage, nuclear and transport infrastructure. It also seeks to invest in parts of the country which get less private investment.

It has already invested in the Peak Cluster CCS project in return for a shareholding. Otherwise, this would have been seen by private investors to be too risky.

## Need for maritime transport

Energy consultancy Xodus has done a study of how maritime transport of CO2 in Europe might work. It predicts that Europe could be transporting 32m tonnes per annum (mtpa) by ship by 2030, requiring 22 tankers.

This could grow to 32 mtpa and 30 tankers by 2035, 53 mtpa and 48 tankers by 2040, 66 mtpa and 59 tankers by 2045, and 79 mtpa and 65 tankers by 2050.

It sees that the Port of Rotterdam is very well placed to gather and export emissions.

Availability of maritime CO2 transport would help the UK move from having a "bunch of projects" to a CCS industry, said James McAreavey, Global Head of CCUS, Xodus. It would make it possible for the many emitters who are far from pipelines to send their CO2 to stores.

## Insurer's perspective

Availability of commercial insurance is an important component in CCS being able to operate as a system, free of government control.

Each section of a CCS chain needs specific insurance products. You also need insurance for the financing, delivery of parts, and offshore construction.

"When we break CCS down, there's lots of things the insurance industry is well versed in," said Joseph Dutton, Energy Innovation Lead, AXIS Insurance. "And if we can do oil and gas and nuclear, we can do CO2."

AXIS Insurance is the largest insurer of renewable energy systems in the London market and also insures CCS projects and marine cargo.

Oil and gas companies do not typically see insurance as something strategic, just something which is necessary, such as to cover their risks that a stray vessel in a storm damages the platforms, he said. Some CCS insurance will be like this.

But carbon capture companies may additionally want to cover their risks of business interruption due to failure of another party, or leakage, he said.

The consequences of a loss of well control in CO2 injection are not as big as a loss of well control in hydrocarbon production, he said.

It complicates insurance that there is no clear definition of what a 'leak' is, since small amounts of CO2 are expected to be released to the environment in normal operations.

We are likely to see CCS risk put into "pools", as we see on nuclear operations, to spread the risk between multiple parties, he said.


*"if we can do oil and gas and nuclear, we can do CO2" - Joseph Dutton, Energy Innovation Lead, AXIS Insurance*

## Regulator's perspective

As the UK regulator, the North Sea Transition Authority (NSTA) can't grant a CO2 storage permit until "all the bits of the jigsaw are ready," said Alistair Macfarlane, Head of UK Carbon Transportation & Storage, NSTA.

There are unlikely to be many more permits granted before the next UK parliament elections, due by mid-2029.

It helps that there are many individuals within government building communication channels with industry, Mr Macfarlane said. Getting projects working requires "a huge amount of effort and co-ordination."

Where legislation is not working as regulators expect, it may need to be changed, he said.

## ENI perspective

ENI's CCS project in Bacton, on the East coast of England, aims to inject 10 mtpa in the 2030s, with injection starting in 2031, said Alessandro Barberis, managing director Bacton CCS Ltd and Eni Tellus CCS Ltd.

It could attract CO2 emissions from the East and Southwest England, including energy from waste projects. It could take CO2 from Europe, and provide storage for the Bacton hydrogen production project, he said.

ENI CCUS Holding Ltd is a subsidiary of ENI established in 2024. It has 3 UK projects, Liverpool Bay, Bacton and Tellus. It also operates the L-10 CCS project in the Netherlands. It may acquire 50 per cent of Ravenna CCS in Italy, a project operated by ENI and gas transmission operator Snam.

Investment company Blackrock took a 49.99 per cent shareholding in ENI CCUS Holding in December 2025, demonstrating that CCUS is investor friendly.


*Bacton does not have government support, "despite our effects to put a proposition in place for a heavy carbonised area, South of England" - Alessandro Barberis, managing director Bacton CCS and Eni Tellus CCS*

The Liverpool Bay project has both regulatory and market support. But Bacton does not have government support, "despite our effects to put a proposition in place for a heavy carbonised area, South of England."

"We need [government] support in place for emitters," he said. For example, a contract for difference scheme on the carbon price, providing government compensation if the carbon price drops below a level which makes CCS worthwhile.

If there was to be a CO2 pipeline from the EU to the UK, it is not clear what size pipe would be best. It could be smaller because the initial requirement is low, or bigger because big volumes are expected in future. "We need to take a decision; the decision can be wrong," he said.

### More information

**www.spirit-energy.com**
**https://greensandfuture.com**
**https://norlights.com**
**www.axiscapital.com**
**www.liverpoolbay-ts.co.uk**

# Rich Denny and Northern Endurance

**Rich Denny of the Northern Endurance Partnership provided an update on the UK's biggest CCS project, explained how his background in both oil and government helps manage it, and how he deals with LinkedIn trolls. By Karl Jeffery.**

Northern Endurance Partnership is a company developing CO2 transport and storage infrastructure connecting to Teesside and the Humber industrial regions in the UK. It is owned by BP, Equinor and TotalEnergies.

The Northern Endurance Partnership aims to build new industry on the site of the former steelworks in Redcar, North Yorkshire. So, it will be "re-industrialising" the region and creating and supporting 3,000 jobs, said Rich Denny, Managing Director, Northern Endurance Partnership.

The first phase of the project, connecting to Teesside, aims to be onstream storing CO2 in late 2028 or early 2029. "We are on cost and schedule target," he said.

It has one of the world's largest jack-up rigs drilling the first appraisal wells offshore, gathering core from the Bunter sandstone.

£1.5bn worth of contracts have been offered to UK suppliers, through 230 subcontracts. The construction will contain 50 per cent UK content.

There is development funding in place to build the second leg of the system, connecting to the Humber industrial region with an 85km pipeline offshore, and further pipeline onshore.

BP is both a shareholder and the main service provider to the project, so Northern Endurance is a "small company managing a super major."

The project shows that once government and business is aligned, including banks and insurers, with a common agenda and a sense of purpose, things can move extremely quickly, despite the enormous levels of complexity, he said.

Northern Endurance has a large amount of UK government funding and is independently accountable to parliament.

A big challenge is ensuring that the project can grow further and at pace without government subsidy. This requires carbon prices to be "predictably higher", or other regulatory drivers. Ideally, markets would pay a premium on products produced with low carbon, giving CCS more of a business case, he said.

The decarbonisation industry in the region needs to grow as fast as other industrial facilities are declining, so that skilled workers do not lose their jobs or move away, and infrastructure is not decommissioned before it can be used for decarbonisation projects, he said.

*The Edinburgh Offshore Energies UK "North Sea CCS & Hydrogen Summit 2026"*

The CCS industry is a century behind the oil and gas industry in maturity, and there's a lot of learning which needs to take place. Momentum needs to be maintained. We do not want more of the "stop-start" of UK CCS projects over the past 2 decades.

The Northern Endurance project team has put a lot of emphasis on supporting the region. It has provided scholarships to 140 students in local colleges and has 30 apprentices.

The North of England has a strong background in the oil and gas industry, with people from the region working in the industry around the world. "This is an opportunity for people to come back to the region and mentor," he said. "The pride they have in something new in the region is really tangible."

For people with expertise in project management, The Northern Endurance Partnership is "just "another project", he said.

But it needs project managers who are comfortable working with ambiguity, because for a new type of project like this, you don't have all the answers when you need them. You need people who are motivated by curiosity and can work to achieve the underlying intent of the project, "rather than get stuck in dogma," he said.

## Career

Mr Denny's advice for young people is to "find out what your sense of purpose is." He only realised what he really wanted to do when he was 50 years old, which is a bit late. "I wish I'd figured it out a few decades earlier," he said.

After graduating in manufacturing engineering at Cambridge in 1991, Mr Denny had job offers from Shell and Andersen Consulting (now Accenture) and chose Shell. At the time, many people were choosing careers in management consulting or marketing, he said.

"I couldn't get too fired up about it. I liked the idea of doing something that creates something."

Initially working in Shell in a commercial role, he moved in 1994 to be a production technologist at Nederlandse Aardolie Maatschappij, a Shell joint venture. He also worked for Al Furat Petroleum Company (Syria), for Shell in Nigeria, and then as Shell's vice president upstream and country chair for Norway.

"I spent 28 years in Shell largely trying to build stuff," he said. "My time in Norway gave me a taste for CCS."

In 2021 he joined the British civil service as major projects lead, CCUS and hydrogen, in the Infrastructure and Projects Authority (IPA), with an aim to make the UK's third attempt in building a CCS industry a success. The IPA sits between the UK treasury and environmental / energy departments, as an independent advisor.

## Industry and government

Having a background both in industry and government, he can see how CCS projects need collaboration between industry and government to work. The needs of industry and government are complex and different.

For government, what is most important is project affordability, value for money, a pathway to scaling up, and reducing storage cost per tonne, he said. But government also needs to demonstrate a project offers value for money for the taxpayer. This can be done by running a competition and giving funding to the winner.

Industry should push back on government attempts to size a project smaller to reduce initial costs, because it makes it harder to build on. That is "penny wise, pound foolish", he said, saving money today but losing much more tomorrow.

## Meeting the opposition

Mr Denny told a story of when he was playing golf with a golf partner he had just met, a few weeks before the conference (May 2026). The golf partner asked partway through the round what Mr Denny did for a living.

When Mr Denny explained he was a civil servant who had been working on net zero projects for four years, his golf partner responded aggressively, saying he would not have agreed to play golf if he had known. "It showed just how polarised this world is," Mr Denny said. "These extreme positions are not helpful."

"This is not a net zero world," he said. "Transition is a period of decades, where we learn to live alongside each other. You do it at a pace where the transition is sustainable."

Mr Denny also has a "LinkedIn troll" who would always leave negative comments on his posts. He invited this person to his office for an hour for a discussion. Although this person had a different view ideologically, Mr Denny was able to identify some factual misunderstandings.

"It definitely helped," he said. "I did the same with a Just Stop Oil campaigner."

### More information

**https://northernendurancepartnership.co.uk**

# NEP finds strong potential for new carbon storage site in Southern North Sea

**Initial analysis indicates the prospective BC39 aquifer storage site has suitable properties to safely and securely store millions of tons of CO2.**

In the first of two exploration and appraisal wells planned for 2026, NEP has reported positive preliminary results from its C43/30-2 well, including around 500 metres of strong sealing rock above the 250-metre Bunter sandstone BC39 storage site. Early analysis indicates this structure could safely store millions of tons of CO2 over the coming decades.

The outcome shows that additional storage exists in the same highly secure geological setting as the Endurance store which will be used to help decarbonise the Humber region. An extensive dataset has been collected, which will be used by NEP and its UK and international partners to complete detailed technical studies to further appraise the BC39 store.

Rich Denny, Managing Director of Northern Endurance Partnership, said, "These early results are a highly encouraging step forward for the UK's carbon capture and storage ambitions. The success of the C43/30-2 well demonstrates both the quality of the Southern North Sea as a storage resource and the strength of collaboration between partners across the project."

"By delivering this programme, we are not only progressing a potential expansion option beyond Endurance but also building critical evidence to support the development of scalable carbon storage solutions for the Humber and Teesside. This is exactly the kind of progress needed to underpin industrial decarbonisation and long-term energy transition goals. This work forms part of our broader commitments to Ofgem, ensuring we continue to develop reliable, future-ready infrastructure that supports the UK's transition to net zero."

*Core sample taken from well C43/30-2*

The successful result from C43/30-2 marks one of the first dedicated saline aquifer appraisal programmes in the UK. The data and operational experience gained will help shape future carbon storage developments, particularly as saline aquifers are expected to represent a significant share of the UK's overall CO2 storage resource.

# Harmonised standards for a CCS system

**All participants in a connected CCS system must agree on a CO2 standard, such as maximum impurities. You don't need the same standard for every system. And standards should not be too complex. By Karl Jeffery.**

Standards in CCS don't need to be gold plated, they only need to be good enough, said Jørg Aarnes, Manager CCS and Hydrogen, Offshore Norge, a trade association for offshore energy and supplier companies.

CCS is a very young industry, and we don't have insight into future needs, he said. We may need to change the standards in future.

Different CO2 systems require different specifications of CO2. And CCS projects so far contain different mixes of systems, he said. CCS networks have different combinations of land terminals, pipelines, ships, direct injection from a vessel, floating storage and injection units.

Higher technical requirements have an impact on costs and so can impact achieving commercial objectives, he said.

There is a complex interplay between standards and regulations, with some emitters asking for standards to be embedded in regulations, but transport and storage companies saying it is too early to know what these standards should be, he said.

Standards should not "control a project", said Ivan Gutierrez, CEO of OGC Energy, a consultancy on materials, corrosion, and asset integrity.

"If we make standards too rigid, too early, we risk making standards which only work for one type of project."

Today's CCS standards are largely based on oil and gas industry experience, which may not be relevant to CCS, he said.

The most complex risks with carbon capture and storage projects sit at interfaces, such as between capture and compression, and between offloading and injection. As CO2 passes through the system, it needs to be ready for the next stage.

A fixed parts per million (ppm) impurity limit is the wrong approach. It would be better to focus on the specific risks of each project. Each party needs to do a risk assessment and determine what the responsibilities of each party are.


*Harmonised standards panel: Ivan Gutierrez, OGC Energy; Craig McKay, Wood; Eva Leinwather, Energy Institute*

We should not expect to see a universal standard for minimum levels of impurities in CO2, because different carbon capture systems have different tolerance levels.

"A specification for short US pipeline will be different to a long offshore pipeline," he said.

We need a standardised methodology for how to reach an answer. For example, it would be useful to have a standard of what analysis is needed when old infrastructure is being re-purposed to be used for carbon capture, he said.

Standards should also define what needs to be demonstrated by various parties, what assumptions need to be tested, and where the responsibility for meeting them sits, he said.

There could be agreed contingency plans related to not meeting a standard, such as what to do with temporarily off-specification CO2.

Carbon capture projects around the world face the same issues. If the UK could develop a useful framework for standards it could be used around the world. "The North Sea should export a trusted way to make CCS decisions."

## Wood Group

Wood Group recently completed a joint industry project to write industry guidelines for setting the CO2 specification for a CCUS chain, explained Craig McKay, Energy Transition Lead EMEA, Wood.

The project sought to understand the impact of impurities on CO2 systems, including looking at how they impact thermodynamics (such as behaviour when compressed or cooled), safety issues, leaks, and pipeline transport.

The project team found 1.5m different data points about behaviour of CO2 with over 30 impurities, from a range of studies already

published. Models were created for behaviours of "binaries," CO2 with one impurity.

Further research is needed about thermodynamic behaviour, reaction chemistry and corrosion, he said.

Wood Group is often asked by its clients for advice about the right specification, and it needs to emphasise that its advice is "based on current understanding of where industry is at," Mr McKay said.

In one example, a transport and storage company asked an emitter to meet the standard which is used on Norway's Northern Lights project, based on what is required to reduce corrosion of pipelines. The emitter replied that meeting that specification would mean excessive cost.

The transport and storage company also had the option of using more expensive stainless steel pipe to reduce their corrosion risk. There is not yet enough information to know what the best choice is overall.

Another issue is how fast gas can flow through the pipe. Wood suggests clients take a limit of 3-4 metres per second, based on the risk there may be solids in the flow which can damage the pipe. But then clients say that meeting this velocity limit means they need 5 wells rather than 3. "It requires a lot more assessment and testing," he said.

## Energy Institute

The Energy Institute, a chartered professional body, is developing guidance for harmonising CCS practises, said Eva Leinwather, Technical Manager CCUS, Energy Institute.

This guidance goes alongside other technical guidance documents produced by the Institute, including in process safety engineering and flow assurance.

The guidance is not prescriptive and follows a risk-based approach, she said.

Whether something is a hazard depends on the context. For example, the risk of impurities in a CO2 stream is different in different places.

There also needs to be room for innovation. "There is risk of over specifying."

"Harmonisation" is not necessarily about everybody doing things in the same way, and often flexibility is essential, she said. It can be iterative, updating practises with experience. The knowledge base is evolving, such as on which impurities cause corrosion, she said.

### More information

**https://ogcenergy.com/ccs**
**www.woodgroup.com**
**www.energyinst.org**

# A hydrogen system with CCS

**A low carbon hydrogen system could be developed alongside the UK CCS system. People involved in projects in from Bacton, Teesside, Shetland and the Netherlands explained how it could work.**

Bacton, a complex of gas processing terminals in Norfolk on the UK East Coast, could become a major hydrogen hub, if the gas is reformed to hydrogen for onshore consumption, and CO2 sent to storage offshore. Surplus hydrogen can also be stored in the subsurface.

Bacton receives 30 per cent of the UK's gas production through multiple pipelines.

A political advantage of a low carbon hydrogen industry is that the link between the UK's electricity price and gas price could be broken, said Richard Sheppard, Bacton BH2 Director, Summit Energy Evolution Limited.

Rather than pay the market rate for gas whenever renewables are unable to meet total demand, electricity generation could be made from low carbon hydrogen from storage.

Converting gas to hydrogen, capturing the CO2 and burning hydrogen to make power is known as pre-combustion capture. This has many advantages compared to post combustion capture (burning gas to make power and separating CO2 from the exhaust gas).

With pre-combustion capture, you have CO2 which is high pressure, high concentration and "relatively pure". With post-combustion capture, CO2 is low pressure and low concentration and can be contaminated if there as incomplete combustion.

Hydrogen is needed in a net zero era because the UK is unlikely to ever be able to supply its peak energy requirement from renewables, because demand for heating is so high at winter, he said. Gas is used for 70 per cent of UK heating of homes, business and industrial.

To illustrate, the maximum UK gas consumption peaks at 4,000 GwH/day, or 166 GW average over the day in winter. By comparison, UK's peak wind generation capacity is 40 GW and peak solar capacity is 15 GW.

*Richard Sheppard, Bacton BH2 Director*

## Teesside

H2NorthEast is a low carbon hydrogen production plant project on Teesside from gas transmission company Kellas Midstream and power company SSE Thermal. Front end engineering and design (FEED) was completed in 2025, said Gary Humber, Business Development and Strategy Director at Kellas Midstream.

Phase 1 is to build 355 MW of hydrogen production capacity, using gas from the Central North Sea, with CO2 delivered to the Northern Endurance CO2 storage system.

There are MOUs with potential users of the hydrogen agreed, and there can be potential to serve more customers. Ideally, it should grow into a single integrated hydrogen distribution system.

The UK government is running a competition to determine which UK emitting projects will be able to connect to Northern Endurance, and a final investment decision on H2NorthEast will depend on this, he said. Applications closed in April 2026; the winners were not announced as of June 2026.

To move forward, investors need clear signals for demand of CCS enabled hydrogen as part of the energy mix, as well as market structure and government support mechanisms, he said.

## Veri Energy

Veri Energy, a subsidiary of oil and gas operator EnQuest, has a project to produce e-methanol via hydrogen from wind power and biogenic CO2 in Shetland, UK.

The pre-FEED studies began in April 2025. FEED is expected to begin in Q4 of 2026. It is expecting a final investment decision in 2028, leading to first production in 2030 of 30,000 tonnes per annum (tpa). It is now welcoming discussions with customers.

E-methanol production could be increased to 90,000tpa by 2032 as part of a second phase of the project. Further wind developments are planned on Shetland, both onshore and offshore.

Veri believes it will be able to produce e-methanol at a similar landed UK cost to countries such as China and India, says Gavin Templeton, CEO of Veri Energy. And UK and EU customers may prefer to work with a local supplier, for logistical reasons.

The Veri team are exploring if its e-methanol can be used as a feedstock for producing Sustainable Aviation Fuel (SAF), possibly in Grangemouth, Scotland.

Export of the e-methanol could be made by the deep sea Sullom Voe tanker terminal in Shetland. This terminal exported 1.5m barrels a day of locally produced oil at its peak in 2001. Today it is just 40,000 barrels of oil per day.

EnQuest is operator of the Sullom Voe Terminal and has a number of production assets in the surrounding Northern North Sea.

E-methanol is produced from hydrogen and carbon dioxide and must be produced with very little net carbon emission to the atmosphere. Veri's e-methanol will meet the EU Renewable Fuels of Non-Biological Origin (RFNBO) standard for carbon intensity. Veri Energy produces the hydrogen from electrolysing water using electricity from wind.

Shetland has one of the best wind resources in Europe making it an ideal location for producing e-fuels. Onshore wind capacity factors on Shetland are around 52 per cent. This compares to a UK offshore average of 40 per cent.

Veri is planning to procure the power via a private wire from an onshore wind farm adjacent to the Sullom Voe Terminal, currently in development.

A private wire arrangement involves the direct supply of electricity from a generation source to an end-user via dedicated infrastructure, bypassing the public grid.

This structure typically avoids transmission and distribution network charges, as well as certain grid-related levies, resulting in lower and more predictable power costs.

For the biogenic carbon dioxide, Veri has a memorandum of understanding with a Scottish company called Carbon Removers, which is collecting CO2 from whisky distillation in North Scotland. The CO2 can be delivered to Shetland by tank container. There will certainly be enough biogenic CO2 available this way for the first phase of the project, Mr Templeton says.

Veri Energy's plans will enable the existing skilled workforce and Shetland supply chain to transition from oil and gas into new low-carbon activities, supporting the energy transition.

As plans develop, Veri will continue working with Sullom Voe Terminal owner EnQuest to identify optimal locations that complement existing operations, including ongoing decommissioning.

The project team are looking at opportunities to expand production to other sites where there are high levels of wind. One possibility is Flotta, on the neighbouring Orkney Islands, where there is an active oil terminal. It is in discussion with other potential suppliers of biogenic CO2.

*Gavin Templeton, CEO of Veri Energy*

Separately, Veri Energy plans to operate its own CO2 storage, using the large, depleted gas fields around the terminal, with CO2 delivered to Sullom Voe by tanker.

In future, the e-methanol production could be connected with the CO2 storage projects, by storing biogenic CO2 in the subsurface, or using captured CO2. The CO2 storage project is running to a different timeline, planning capture sometime after 2032.

## Hydrogen Netherlands

In the Netherlands, state energy company EBN is keen to support development of a low carbon hydrogen market. There is already a large grey hydrogen market in Europe.

Moving directly from grey to green is challenging because of the cost increase. "The only way is grey to blue," said Joost Hooghiem, Director CCS, Energie Beheer Nederland (EBN), the state energy company of the Netherlands. "That's where CCS and hydrogen go hand in hand."

Much European gas comes from Norway, and much CO2 storage is likely to be done in Norway. It would make sense to reform gas to hydrogen and CO2 in Norway and only transport hydrogen to the Netherlands, rather than bring gas to the Netherlands, do the reforming there, and send CO2 all the way back to Norway, he said.

### More information

**www.summit-evolution.com**
**www.kellasmidstream.com**
**https://verienergy.com**

# Projects and policy news

## Tencent announces winners of CarbonX 2.0

**https://carbonxprogram.com**

**The winners will receive a share of nearly US$30 million in catalytic funding, supported by technical resources, expert networks, and opportunities to pilot and scale their solutions for real-world impact.**

CarbonX 2.0 received 660 applications from 54 countries and regions across six continents. A cohort of 50 finalists was identified, before 16 winners were selected to receive the funding and resources needed to scale their solutions from pilot to real-world deployment.

Ten of the 16 teams span four critical technology areas:

• Carbon Dioxide Removal (CDR) – technologies that remove CO2 directly from the atmosphere, with pilots in Kenya

• CCUS for Steel – solutions to reduce emissions in one of the hardest-to-abate industrial sectors, with pilots in Serbia and China

• Carbon Utilization (CCU / CarbonXmade) – converting captured CO2 into useful materials and products

• Long-Duration Energy Storage (LDES) – enabling stable, 24/7 renewable energy systems, with pilots in the Maldives

Six additional teams were selected to receive tailored support, including Measurement, Reporting and Verification (MRV), carbon-credit procurement commitments, and green-premium subsidy mechanisms.

From using geothermal energy to capture CO2 and creating sustainable plastics from captured CO2 emissions, the 16 winning teams ranged from the US, UK, EU, China and Kenya.

## CCSA launches the European CCUS National Associations Forum

**www.ccsassociation.org**

**The informal European Forum designed to enhance cooperation, knowledge-sharing, and alignment among representatives of European and national CCUS stakeholders.**

The Carbon Capture and Storage Association (CCSA) said momentum behind CCUS is increasing as is the need for coordinated action to support the deployment of CCUS technologies in Europe.

As countries confirm their climate ambitions and industries invest in decarbonisation, national CCUS associations are playing a critical role in shaping CCUS policy, supporting project development, and helping to shape policy, support market development and address barrier to deployment.

The new Forum will enable these organisations to work more closely together, share best practice, and help inform an effective policy and regulatory framework for CCUS in Europe's net-zero transition. It will also support dialogue in countries where CCUS National Associations have not yet been established.

"Together, these organisations represent a broad cross-section of the European CCUS value chain and are committed to continued cooperation and timely CCUS deployment across Europe," said the CCSA.

## OGCI report explores carbon accounting and reporting

**www.ogci.com**

**The Oil and Gas Climate Initiative (OGCI) report explores how carbon capture and storage and engineered carbon removals are reported and accounted for across national inventories, corporate reporting and carbon markets.**

As CCS and engineered removals move from pilots toward larger, more complex projects, value chains are becoming increasingly complex. With different organizations involved across capture, transport and storage, sometimes across more than one jurisdiction, it can be challenging to establish how emissions reductions and removals are measured, attributed and claimed.

The report, "Carbon accounting and reporting for carbon capture and storage and engineered carbon removals" finds that many current frameworks provide a starting point, but do not always provide clear answers for more complex project structures.

The report provides a detailed overview of:

• How CCS and engineered removals are treated in national greenhouse gas inventories

• Corporate accounting and reporting considerations for CCS and engineered carbon removal activities

• How these activities are being integrated into compliance and voluntary carbon markets

• Practical challenges linked to ownership, Scope 3 reporting, cross-border projects and long-term storage monitoring

• Opportunities for further harmonization across national, corporate, project and product-level reporting frameworks

The report concludes that in order to support deployment of CCS and ECR projects, there is a need to further understand how accounting and reporting of these activities are impacted and interact across the various levels of reporting.

## GCCA and GCCSI partner on CCS for global cement industry

**www.gccassociation.org**

**The Global Cement and Concrete Association (GCCA) and the Global CCS Institute have established a framework to advance the development and scale-up of CCS across the global cement and concrete sector.**

The GCCA, whose members operate in nearly every country and account for a significant share of global cement production, and the GCCSI will work to accelerate industrial decarbonisation through shared outreach, thought leadership, capacity building and stakeholder engagement to support CCS as a key mitigation option for the cement industry.

"Cement producers around the world are working to reduce emissions while continuing to supply a material that is essential to building resilient and safe infrastructure, and CCS will be an important part of that effort," said Jarad Daniels, CEO of the Global CCS Institute. "Through this partnership, we aim to support the industry by sharing expertise, fostering dialogue, and creating the conditions needed for CCS projects to succeed."

The parties will first convene a high-level roundtable bringing together industry leaders and key stakeholders to enhance collaboration and accelerate progress on shared priorities and initiatives.

# The critical role of gas chromatography in CCUS success

**Process gas chromatography is one of the most consistent tools supporting the safe, compliant and optimal operation of processes using carbon capture, utilization, and storage (CCUS). By Valmet.**

Carbon capture initiatives are typically presented with a focus on new and emerging technologies, large scale capital projects, and ambitious decarbonization goals. Behind each successful CCUS project however, there exists a much less visible, but equally important, foundation upon which those projects depend: precise chemical composition measurement of gas streams.

For the power generation, cement, steel, refining, chemical, and hydrogen production sectors, CCUS represents a primary method to reduce emissions associated with processes that have been traditionally difficult or impossible to decarbonise.

Each of these sectors generates a large volume and continuous flow of CO2 gases, creating ideal conditions for capturing these gases before they enter the atmosphere. As regulatory standards continue to be implemented at a rapid pace and companies increase their commitment to addressing climate change, CCUS is rapidly evolving from a forward-looking concept to a necessity for operations.

While the strategic and regulatory case for CCUS is increasingly well established, its successful implementation ultimately depends on precise process monitoring and control.

However, the performance, reliability, and cost-effectiveness of such technology is largely dependent upon an accurate description of the gas streams involved. As such, process gas chromatography continues to be one of the primary tools used in industrial processes for ensuring that CCUS systems are operating reliably, meeting all applicable regulatory requirements, and achieving the best possible performance.

## Process Gas Chromatography

A process GC is an analytical tool used to continuously measure the chemical make-up of a gas stream flowing through industrial equipment. One of the most significant advantages of using gas chromatography is the ability to analyze a complex gas mixture and split it into individual components during a single measurement.

Understanding the chemical composition of a gas is important for several reasons. It is important for maintaining the quality of products, optimizing operating parameters, protecting people who are working near the process area, and compliance with regulations.

The analyzer works by sampling a small amount of gas from a pipeline or process stream and injecting it into a flow of carrier gas. This mixture then moves through a column filled with a stationary phase material. Each component interacts with the stationary phase differently, causing it to move through the column at a distinct rate. As each separated component reaches the end of the column, it enters the detector where it is identified and quantified. The detector's signal is processed by the computer to determine the concentration of each component in the sample.

In carbon capture processes, large amounts of flue or process gases enter a capture unit. Therefore, it is imperative to be able to accurately separate and quantify the major components in the gas. However, one of the biggest obstacles in this regard is that different processing plants generate different gas mixes while operating under different pressures, temperatures and impurity levels.

For flue gas analysis from a power plant, the analyzer typically tracks CO2, O2, N2, SOx. When analyzing the gas during blue hydrogen or syngas production, it would likely follow $H_2$, CO, CH4, CO2 to ensure the CO2 removal is effective. In both industrial off-gas and chemical looping systems, there could be many additional hydrocarbons and contaminates present that need to be measured and tracked.

Because of these factors, analytical equipment needs to be versatile. However, many plants use online analyzers that detect only one compound or element, so several are needed for more complex streams.

"The strength of gas chromatography lies in its ability to measure multiple components within a gas stream simultaneously, unlike individual gas analyzers that are limited to detecting a single component at a time," says Al Kania, Business Development at Valmet, a global provider of technologies, automation, and services for process industries. Valmet's process GC, MAXUM II, has a large installed base across process industries globally.

## Accurate measurements guide decisions

Process gas chromatograph systems must deliver a level of accuracy that supports effective CCUS implementation. Reliable, high-precision measurements enable operators to accurately determine system composition, providing a dependable foundation for all downstream decisions.

With detailed compositional information, operators can effectively evaluate the performance of carbon capture processes and make informed adjustments to improve absorption and stripping efficiency.

Accurately measured process parameters provide the confidence needed by operators to make educated decisions regarding the actual chemistry of the system.

In addition, using accurate measurements of the chemical composition of the feedstock, operators can make knowledgeable decisions as to the effectiveness of the carbon capture process and identify opportunities to optimize the absorption and stripping processes.

The accurate identification and quantification of each component present in the gas stream is critical in managing amine degradation during CO2 absorption, mitigating corrosion risks through effective control of corrosive conditions, operating compressors and pipelines safely at or below their design limits, and ultimately ensure that the captured CO2 meets the specified standards of purity for transportation and storage.

Validated laboratory grade compositional data is also necessary to meet many of the reporting requirements for regulatory purposes related to carbon sequestration and to qualify for available tax incentives.

"Many reporting frameworks require validated, laboratory grade quality for process compositional data," notes Kania. "Process GCs are the established analytical method capable of meeting these requirements."

## Guarding against analytical drift

Although advanced analyzers like gas chromatographs are sophisticated, small measurement inaccuracies can lead to higher operational expenses or cause the control system to make unnecessary adjustments to the process.

This gradual shift in accuracy – known as analytical drift – is caused by variables such as temperature, detector deterioration, contaminants, and electronic stability issues. Analytical drift may occur even when the analyzer is regularly calibrated.

"If an instrument experiences analytical drift, it may report $CO_2$ concentrations that are either higher or lower than actual values. This can lead the system to incorrectly adjust absorber or regeneration conditions, resulting in increased energy consumption or reduced capture efficiency," says Kania.

Accurate gas chromatography (GC) readings play an important role in minimizing operational and safety-related risks from hydrogen sulfide (H2S) breakthroughs and oxygen (O2) ingress.

By maintaining their accuracy and reliability, GC instruments provide timely and reliable information on changes to the gas mixture so operators can take actions before the situation escalates.

## GC design and construction

The design and construction of the process GC is also a factor in controlling drift. Industrial-grade products like the MAXUM II are designed to operate across a temperature range of -20 °C to 100 °C and should be rated for use in corrosive and potentially explosive atmospheres where hazardous gases may be present

Kania says the MAXUM II also utilizes real-time diagnostics to predict component wear, drift, or failure before it disrupts operations.

Another factor that can affect measurement accuracy are the changes that occur in gas composition when a pilot-scale operation transitions to full-scale production.

"At the pilot stage, the gas composition may appear consistent. Once the process is scaled up, small variations in temperature, reaction efficiency, or material flow can cause the gas composition to drift over time," says Kania.

If these changes are not detected promptly, the plant may continue producing gas that falls outside the required purity specifications. This is where the advantages of real-time monitoring far outweigh periodic sampling and analysis in a laboratory.

"Instead of waiting hours for laboratory results, inline analyzers allow operators to observe changes in gas composition as they occur," says Kania.

## Advancing CCUS initiatives

According to Kania, processors producing significant amounts of CO2 are regularly approached by major energy companies which develop and operate CCSU projects, often in partnership with specialized technology providers.

Carbon capture systems come in several types and are typically installed on industrial exhaust streams to remove CO2 before it is emitted, often as modular units that can be retrofitted onto existing plants.

For facilities like steel mills, cement plants, and pulp and paper mills, the most widely deployed technology is amine-based chemical absorption systems installed on flue gas streams. In this approach the exhaust gas is passed through a large absorber tower containing a liquid solvent that chemically binds with carbon dioxide.

Most industrial-scale facilities such as steel mills, cement plants, and pulp and paper plants deploy chemical absorption systems that use amine solvents to remove CO2 from their flue gas streams. The process works by passing the flue gas through an absorber tower that has a liquid solvent in it which reacts with carbon dioxide to form a compound.

The amines react specifically with CO2 while allowing nitrogen, oxygen, and all other gases to be removed from the absorber. The CO2 rich liquid is then heated in a regeneration column, releasing the CO2 into a compressed gas stream. The solvent is then recirculated to the top of the absorber.

Another type of gas purification for removing CO2 is physical absorption, also known as solvent absorption. In this method the gas being purified is contacted with a solvent that will absorb the CO2.

Various other carbon capture methods separate CO2 by using different mechanisms to improve efficiency and purity.

Given the diverse process configurations, projects often prioritize the flexibility of a single instrument platform.

"With configurable detectors, one analyzer can perform a wide range of analytical measurements across multiple points in the CCUS value chain, minimizing the need for separate instruments and reducing long-term maintenance demands," explains Kania, adding that the MAXUM II can be configured for a range of applications, including flue gas analysis, CO2 removal in hydrogen and syngas production, industrial off-gas treatment, CO2 purity verification before transport, and monitoring during reinjection and at the wellhead.

## A foundational tool for CCUS

Today, CCUS has evolved from an ambitious concept into an actual engineering solution to meet ambitious decarbonization goals.

As processers continue to increase their CCUS investments, measuring, validating, and controlling the gas streams will become increasingly important for both operational efficiency as well as regulatory reporting requirements, verification of stored CO2 and integrity of long-term storage.

In environments characterized by extremely high concentrations of CO2, trace contaminants, and the need for uninterrupted operation, process gas chromatography is a foundational technology that enables the precise, continuous monitoring of complex gas streams.

### More information

**www.valmet.com**

# Australia opens the world's first carbon refinery MYRTLE

**MCi Carbon has officially opened Myrtle, the world's first fully-integrated multi-purpose carbon refinery, which converts CO2 and low value feedstocks into valuable raw materials.**

The technology has the potential to reduce net emissions in hard-to-abate industry by up to 90 per cent. Unlike conventional decarbonisation approaches, the company generates saleable products in the process, reframing industrial decarbonisation as an investment with a return, rather than a cost. The market for carbon-embedded construction materials is projected to reach USD 1 trillion per year by 2050.

With Myrtle now open on Kooragang Island in Newcastle, global industrial companies can rapidly validate MCi's platform against their own feedstock, emissions profile and commercial requirements – and generate the commercial data needed to make profitable decarbonisation an investment decision, not a compliance cost.

Marcus Dawe, Founder and CEO of MCi Carbon said, "Heavy industry now has a commercial pathway to decarbonise – and profit while doing so. By transforming CO2 and low-value mineral feedstocks into carbon-embodied materials that cement, steel, plastics, glass and construction industries already buy, MCi Carbon's mineral carbonation platform reframes decarbonisation as an investment with a return, not a cost to be managed."

"Myrtle is open. Our invitation to the leaders of hard-to-abate industry is simple: send us your CO2 profile and your feedstocks. We'll run a rapid validation and hand back the technical, product and commercial data you need to make profitable decarbonisation your next capital decision, not your next compliance problem."

MCi Carbon has received more than AUD $40 million in cumulative government funding across federal and NSW programs, including the Carbon Capture Technologies Program and the CCUS Development Fund.

The company has also raised more than AUD $40 million from global private investors, including founding investor Orica, cornerstone investor ITOCHU Corporation, Mizuho Bank, Sumitomo Mitsui Trust Bank and Mitsubishi UBE Cement Corporation from Japan, and RHI Magnesita - MCi Carbon's first global commercial customer.

## Turning diverse industrial CO2 into valuable materials

Mineral carbonation is a low-pressure, low-energy chemical process. When industrial CO2 reacts with mineral-rich feedstocks - including steel slag and waste rock - it forms stable carbonates: chemically permanent mineral compounds with no leakage risk and no monitoring liability. The CO2 is locked into those materials at the molecular level. The process is zero waste.

The MCi platform is consciously versatile. Where other decarbonisation technologies are built for a single input and output, Myrtle accepts diverse CO2 streams and a wide range of reactive mineral inputs and can produce multiple product lines from one integrated facility.

That flexibility means the platform can be configured for two distinct deployment models: installed directly on-site at an industrial facility, integrated into existing processes; or operated hub-and-spoke from a central facility serving multiple emitters across a region. Both models have export potential - MCi's technology and the materials it produces can be deployed wherever hard-to-abate industry operates, making it a globally transferable decarbonisation platform.

Orica, MCi Carbon's founding investor and industrial partner, hosts Myrtle at its Kooragang Island ammonia plant, supplying the facility's CO2 and providing a working example of the on-site integration model in action. Myrtle can transform up to 2,500 tonnes of CO2 per year into up to 10,000 tonnes of saleable material, producing several tonnes of product for every tonne of CO2 processed.

Critically, Myrtle is also the bridge to commercial scale. Before any first-of-a-kind commercial plant proceeds to a final investment decision, customers and financiers need real process data, real product performance data and a validated business case. Myrtle generates all three - with real feedstocks, at meaningful volumes, under industrial conditions. The platform is designed to scale to hundreds of thousands of tonnes of CO2 per year, with materials feeding directly into customer supply chains. The data Myrtle produces is what makes that scale-up investable.

Sophia Hamblin Wang, Co-Founder and COO of MCi Carbon, said, "Myrtle embodies everything we've been building towards. We've spent more than a decade proving that carbon dioxide doesn't have to be a problem, it can be a building block. Now we have an industrial-scale facility that can transform CO2 from industry into materials the economy already needs and buys."

## MCi Carbon's first commercial customer is targeting a plant by 2030

Myrtle is running its first commercial validation campaign with RHI Magnesita, a global leader in refractory products headquartered in Austria. The campaign is designed to build the technical, product and commercial case for a first-of-a-kind commercial plant at RHI Magnesita's Austrian site, targeted for 2030.

After a global review of decarbonisation technologies, RHI Magnesita selected MCi Carbon as its partner, investing more than USD $10 million to advance the technology toward commercial scale. First-stage capacity to produce over 200,000 tonnes of green minerals absorbing 50,000 tonnes of CO2 per year is planned, with a shared ambition to scale up in due course.

### More information

**www.mcicarbon.com**

# Sirona Technologies launches commercial-scale DAC in Norway

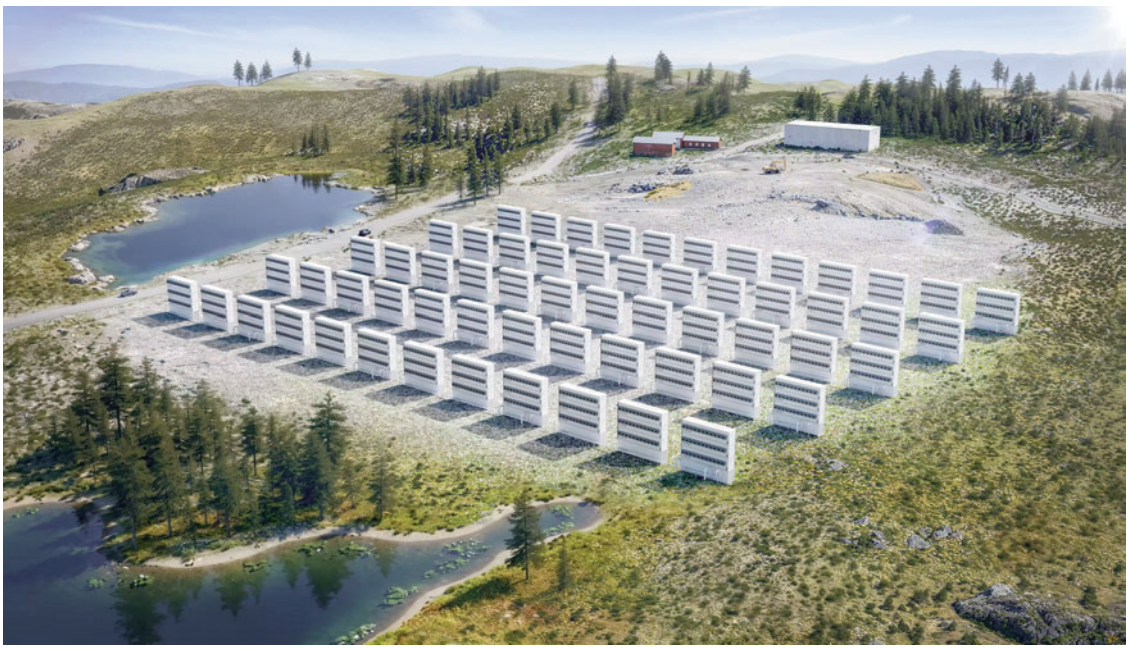
**Project Furu will be developed at Øygarden on the west coast of Norway, directly next to the Northern Lights CO2 transport and storage facility.**

Project Furu is located in Øygarden, Vestland County, in an industrial area owned by Øygarden municipality and CCB Energy. This site combines three crucial elements for DAC:

- A clean, low-cost grid. Norway's electricity mix is over 90% hydropower, with the remainder from wind and other renewables. It is among the cheapest and cleanest power on earth - the ideal energy input for DAC.

- An operational CCS storage hub next door. Northern Lights is Europe's first commercial-scale open-access CO2 storage facility, and it is already injecting today.

- A local ecosystem actively building this future. CCB Energy is developing the area of 1.4 km$^2$ to be a green industrial hub, specifically for large-scale green industry, with the explicit aim of creating synergies between co-located projects.



*Project Furu is Sirona's European flagship and one of the most strategically positioned DAC projects in the world. The modular Direct Air Capture units run on one of the cleanest and cheapest grids on earth — Norway's electricity mix is over 90% hydropower*

"Project Furu brings together everything you want in a DAC project: a clean grid, operational storage next door, the right partners, and a regulatory framework that's finally catching up with the technology. Europe is putting the incentives in place and we are putting the projects on the ground," said Thoralf Gutierrez, CEO & co-founder of Sirona Technologies.

The project is being developed in partnership with CCB Energy. CCB is also building CarbonLink, a shared aggregation infrastructure designed to bundle smaller DAC volumes and deliver them into Northern Lights' pipeline, a critical enabler for DAC projects of this size.

## A scaling roadmap from pilot to commercial

Project Furu will scale in phases, all on the same site. Phase 1 is ready to deploy with the site, permits and energy already in place. It will run on catch-and-release until CarbonLink comes online and is expected to start with a capture capacity of 10,000 t/yr in 2029, reaching +100,000 t/yr in the years after.

This phased path is designed to scale capture, storage, grid and financing in lockstep, and to start delivering high-integrity credits as the European compliance market opens up.

Project Furu launches at a pivotal moment. The European Commission has just adopted the first set of certification methodologies under the Carbon Removal Certification Framework (CRCF) for permanent removals. DACCS is on track for inclusion in the EU Emissions Trading System (EU ETS), opening the door to a true compliance market for direct air capture and storage.

And Sirona has submitted Project Furu to the EU Innovation Fund, the EU's flagship instrument for accelerating commercial-scale climate technology.

Because Norway is part of the European Economic Area, Project Furu is uniquely positioned to supply into the EU compliance carbon market once it opens to DAC, a market that is expected to be orders of magnitude larger than today's voluntary market.

## More information

**www.sirona.tech**

**www.ccbeh.com**

# Capture & utilisation news

## POLICAP mobile CO2 capture facility launched in Italy

**www.energia.polimi.it**

**A mobile pilot laboratory for CO2 capture using solvent-based technologies developed at the Politecnico di Milano has been inaugurated in Piacenza.**

POLICAP is an advanced research facility developed by the Department of Energy and funded as part of the national ECCSELLENT project. The project's laboratories are part of the European ECCSEL-ERIC network and contribute to the development of CCUS technologies.

The facility is designed to test CO2 capture via solvent absorption. In addition to using conventional, widely adopted solutions, POLICAP was also created to test new materials, components and processes that deliver improved performance from a technical, economic, energy and environmental perspective. One of its distinctive features is its mobility: the transportable design allows installation at industrial sites, enabling experiments with both synthetic gases and actual emissions streams.

The main objectives include demonstrating high capture efficiencies, conducting performance tests representative of industrial conditions, and studying scale-up and industrialisation processes, supported by advanced digital models.

## O.C.O Technology expands into Europe with CO2 to aggregates project

**https://oco.co.uk**

**https://petronor.eus**

**The Biscay Eco Aggregates plant has the capacity to recover up to 50,000 tonnes of thermal residue (APCr), capturing up to 6,000 tonnes of CO2 and producing 125,000 tonnes of Eco aggregate.**

Biscay Eco Aggregates (BEA) has begun manufacturing Eco aggregate at its facility located at the Port of Bilbao in Spain in a project co-funded by the European Commission's 2020 Innovation Fund.

The joint venture project represents a £20 million investment. Petronor holds a 75% stake, while O.C.O Technology holds the remaining 25%. The project will also create 20 new jobs at the Port of Biscay.

The Biscay plant integrates O.C.O's Accelerated Carbonation Technology (ACT), a process that permanently captures CO2 and transforms thermal residues (APCr) into high quality, sustainable aggregates, marketed in Spain as Eco aggregate.

These Eco aggregates can be used in concrete, precast construction products and a wide range of building applications, providing a low carbon alternative to traditional construction materials.

*The POLICAP mobile CO2 capture laboratory is part of the European ECCSEL-ERIC network*

At the heart of the process is the utilisation of thermal waste (APCr) that would typically go to landfill into a stable, sustainable construction resource.

During this process, industrial CO2 captured from Petronor's refinery is permanently mineralised, embedding carbon into the aggregate produced. This not only reduces emissions into the atmosphere but also decreases reliance on natural aggregate extraction, easing pressure on global resources. The mineralisation plant has the capacity to capture up to 6,000 tonnes of CO2 within its aggregate.

## Ambuja Cements and Leilac partner on commercial scale low carbon cement

**www.ambujacement.com**

**www.leilac.com**

**A commercial demonstration project will assess Leilac's carbon capture and hybrid electrification technology designed to reduce emissions, lower fuel consumption and increase the use of renewable electricity in cement manufacturing.**

Ambuja Cements, the cement and building materials company of the Adani Group, has partnered with Leilac as part of its broader decarbonisation strategy. The collaboration is expected to improve the economics of carbon capture, strengthening the business case for large-scale deployment of carbon capture and utilisation.

Karan Adani, Director, Ambuja Cements, said, "The cement industry's transition to a lower-carbon future will require bold thinking, technological innovation and collaboration across the value chain. Our partnership with Leilac reflects our commitment to evaluating next-generation technologies that can reduce process emissions while improving energy efficiency and supporting long-term sustainable growth. This initiative aligns with our vision of building world-class manufacturing operations for the future."

The commercial demonstration project at Ambuja Cements' 6.6 MTPA Sanghi plant in Sanghipuram, Kutch, will evaluate the integration of Leilac's carbon capture and hybrid electric heating technology to support lower-emission cement production through greater use of renewable electricity and the capture of unavoidable process carbon dioxide.

The technology is designed to enable a pathway where coal consumption can be reduced to zero, while allowing alternate fuels to be used flexibly.

Subject to successful demonstration, the project, positioned as the largest industrial-scale plant of its kind globally, could be scaled up by 7x to 8x to capture more than one million tonnes of carbon dioxide annually, helping establish a scalable pathway for low-carbon cement production in India and beyond.

# How innovative leak detection methods can support Carbon Capture

**In this article, PipeSense Founder and CTO Stuart Mitchell explains how the company used its expertise and track record of monitoring and detecting leaks in oil and gas pipelines to support CO2 applications and networks.**

PipeSense is a U.S.-based provider of pipeline leak detection and monitoring solutions and technologies. Established under the umbrella of pipeline construction and maintenance specialist Charps, PipeSense applies ultra-high-frequency pressure sampling and advanced machine learning to detect, pinpoint, and validate pipeline anomalies and leaks in real-time.

Working with a US operator, PipeSense proved the transferable capabilities of its technologies on a South Texas pipeline transporting dense phase and supercritical carbon dioxide (sCO2) at approximately 2,000 psi.

## Background

In midstream markets globally, there is a growing demand to consider infrastructure suitable for the transfer of supercritical carbon dioxide (sCO2). This demand stems from collaborative efforts to mitigate the effects of climate change and to support Carbon Capture and Storage (CCS) ambitions.

In the U.S. specifically, pipeline infrastructure for carbon dioxide is projected to expand up to 20 times by 2050, and CCS capacity growth of 16–80 times the current levels. Innovative applications include using CO2 as a carbon source for ethanol production and in enhanced oil recovery (EOR), followed by sequestration.

These developments underscore the need for robust midstream infrastructure that ensures environmental safety, operational reliability, and regulatory compliance – particularly in complex regions where pipeline networks are extensive.

SCO2 is defined as CO2 maintained above its critical point: a temperature of 88°F (31.1°C) and a pressure of 1,070 psi (7.39 MPa). At this point, the distinction between liquid and gas phases ceases to exist, resulting in a fluid that exhibits hybrid properties – gas-like viscosity and diffusivity combined with liquid-like density (typically 0.5–0.9 g/cm$^3$).

This state allows sCO2 to expand and fill its container while maintaining high density, making it ideal for efficient transport in pipelines. However, sCO2's density is highly tunable and sensitive to small fluctuations in pressure and temperature, which can lead to compressible behavior more pronounced than in traditional liquids or gases.

In contrast to dense phase CO2 – a broader term encompassing high-pressure, single-phase CO2 with liquid-like density but potentially below the critical temperature – sCO2 strictly requires conditions above both critical thresholds.

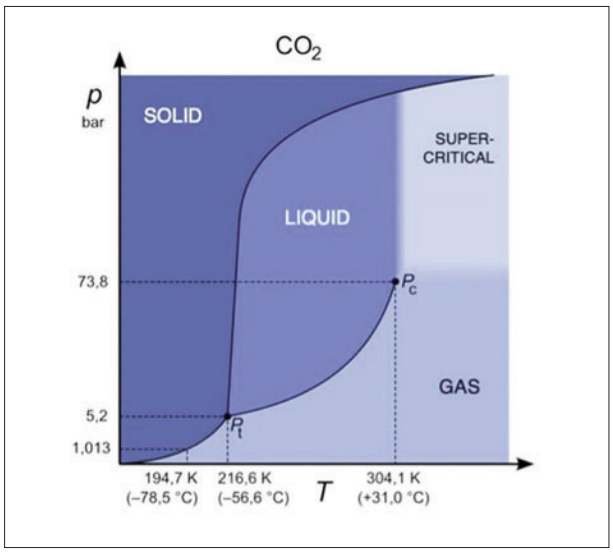



*Figure 1 - Phase Diagram of Carbon Dioxide Illustrating Critical Point*

Dense phase transport is common in pipelines to optimize mass flow, but sCO2's supercritical regime introduces additional complexities due to its proximity to the critical point, where properties like compressibility and speed of sound vary dramatically.

To make the safe and reliable flow of sCO2 possible to meet targets and demands, midstream operators must reckon with the highly specific challenges that sCO2 pipelines face, specifically when considering structural leaks.

## Leak Detection Challenges for sCO2 Pipelines

SCO2 pipelines present several challenges for pipeline leak detection – particularly more so for common advanced model-based leak detection techniques such as real-time transient modeling (RTTM), primarily due to the fluid's unique thermophysical properties and operational dynamics.

The high compressibility, variable density, and sensitivity to impurities in CO2-rich mixtures necessitate accurate equations of state (EOS) for modeling compressible flow, but commonly used models (i.e., Peng-Robinson) exhibit non-negligible errors near the critical region, potentially leading to inaccuracies in pressure and flow predictions during transients such as pump startups or demand swings.

These errors can propagate, causing false alarms when flow residuals are misinterpreted as leaks. Additionally, in multi-source CCUS networks, sudden composition changes from upstream events (e.g., plant trips) result in density variations that, if not updated in real-time due to slower composition measurement intervals compared to pressure and flow data, generate persistent positive or negative leak signals – up to 9% of flow rate in simulated cases – compromising system reliability.

While high-pressure operations (>1,700 psig) mitigate some EOS inaccuracies, the need for rapid computation (simulator time orders of magnitude faster than data collection rates) and real-time boundary data from pipeline ends further complicates implementation, as does the potential for multi-phase flow during depressurization. Instantaneous density measurements via Coriolis flowmeters can help mitigate potential errors, though density alone may not uniquely identify CO2 composition.

Other leak detection methods, such as negative pressure wave (NPW) detection, which identifies leaks via pressure drops propagating as waves, are promising but challenged by sCO2's high compressibility, which dampens leak pulses. This necessitates highly sensitive thresholds, risking false positives from operational noise. Additionally, the speed of sound (SoS) in sCO2 is highly variable – real-world changes of ±5°F and ±100 psi seen during this case study can alter SoS by around ±79 ft/s, leading to leak location inaccuracies up to ±1,935 ft over a 12-mile segment with 24.5-second wave travel times.

PipeSense's experienced team of engineers, operators, and software developers sought to address these challenges by deploying a machine learning (ML) enhanced NPW system on an operational sCO2 pipeline. By integrating high-frequency pressure sampling with AI-driven analysis, the approach can minimize false alarms while achieving high detection sensitivity.

## System Design and NPW Principles

PipeGuard, the leak detection system developed by PipeSense, employs an advanced NPW method, utilizing two sensors/Field Processing Units (FPUs) positioned at each end of the pipeline segment.

The FPUs were equipped with high-sensitivity pressure sensors sampling at rates sufficient to capture transient pulses (typically 1 kHz). The core principle involves detecting the negative pressure wave generated by a leak, which propagates at the fluid's SoS.

Traditional NPW systems use single thresholds set against background noise, but in sCO2, high levels of pressure pulse attenuation require tighter thresholds to background hydraulic noise, potentially increasing false positive rates. To mitigate this, the system incorporates multi-stage filtering:

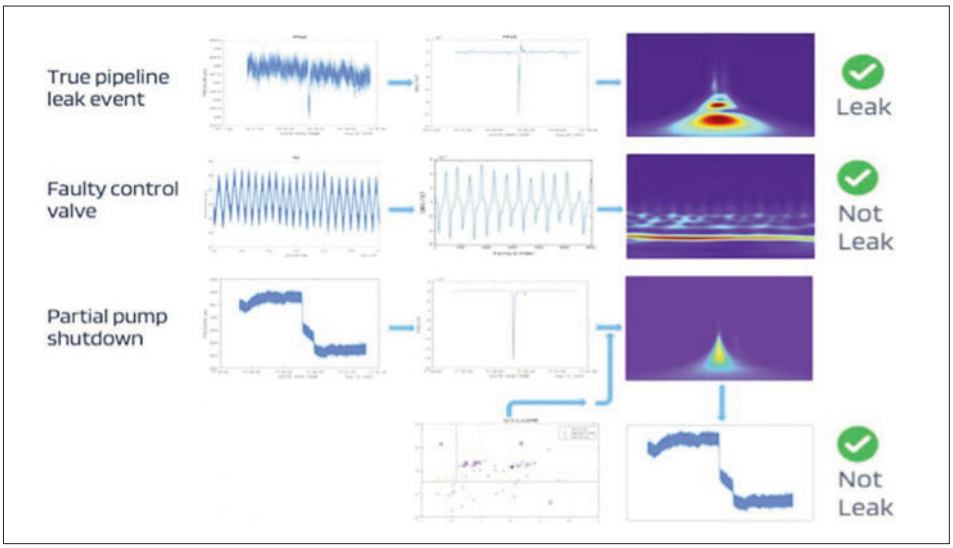



*Figure 3 - Example of Multi-Stage Filtering*

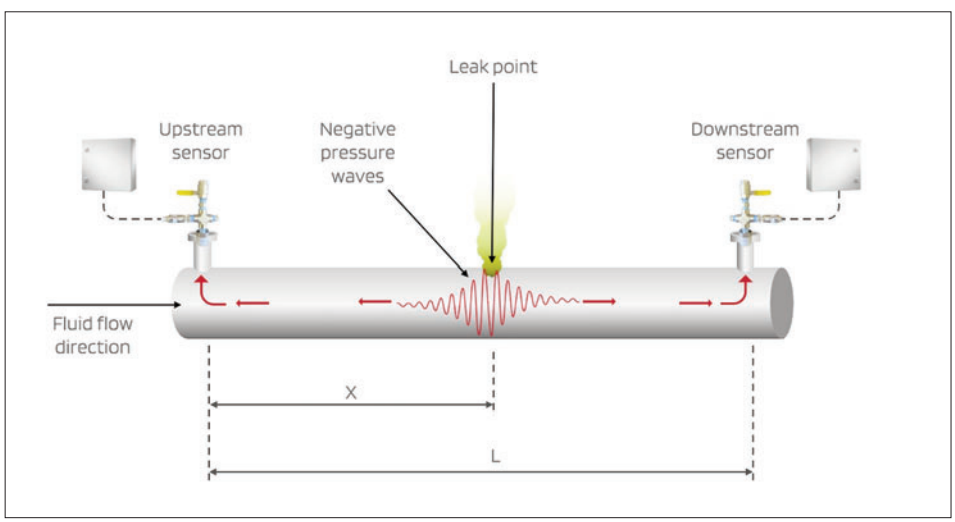



*Figure 2 - A schematic of the negative pressure wave method & equipment*

• Data Filtering and Thresholding: Initial edge-based filtering removes noise, with potential leak events being captured and transmitted by each FPU to a common remote server for further analysis.

• Initial Thresholding: Initial thresholding is set off short 1-3 second physical test releases of fluid from the pipeline at the required leak threshold size, and longer-term sampling of normal and abnormal (non-leak) operation. short 1-3 second physical test releases of fluid from the pipeline at the required leak threshold size, and longer-term sampling of normal and abnormal (non-leak) operation.

• 3D Frequency Conversion: Potential leak events from each FPU are converted to 3D spectrograms (frequency-time-amplitude) for ML classification.

• Additional Filtering Methods: For more dynamic pipeline systems that present pressure anomalies with similar filtered and frequency properties, additional filtering methods such as variable thresholding and pressure shape analysis can be employed.

The 3D spectrogram ML model is trained on a dataset of over 200,000 images, including normal pipeline operations, pressure events, anomalies, and simulated leaks. This dataset encompasses diverse fluids—crude oil, natural gas, water, liquid gas products, and dense phase / supercritical CO2—to generalize across behaviors.

Deployed filters, thresholds, and methods are adaptable based on pipeline-specific behavior,

allowing customization for sCO2's dynamic properties.

PipeGuard was built on high-speed pressure pulse detection, enhanced by AI-driven signal validation. When a leak occurs, it generates a pressure pulse that propagates upstream and downstream through the pipeline fluid (liquid or gas). PipeGuard continuously monitors these transient pressure events using distributed pressure sensors sampling at 1,000 samples per second.

## Case Study: Deployment on 12-Mile sCO2 Pipeline

In Q3 2025, the PipeGuard system was deployed on a 12-mile, 8-inch sCO2 pipeline operating at ~2,000 psi between a compressor station and client handoff. Initial calibration involved short (~2 s) releases via 3/8-inch (5% flow) and 1/4-inch (2% flow) orifice fittings at the far-end and mid-point locations. Data was then processed offline to select filtering algorithms, followed by an initial two weeks of monitoring for false positives.

Tests continued in Q4, simulating leaks at compressor-end, mid-point, and far-end, addressing issues like release manifold icing during pressure release and noise due to an unexpected loss of compression.

Upon completion of the project, the system detected leak events within 2-3 minutes and with location precision down as low as <20 ft. One false positive and zero downtime was observed over a 5-month period, with the system achieving sensitive, accurate detection and addressing key pipeline network challenges like such as speed of sound variability, unplanned compressor station shutdowns, and changes between dense and supercritical phases.

## Supporting CCS Ambitions and Infrastructure

False positives are one of the biggest operational challenges in pipeline leak detection, regardless of the product being transported. False positives reduce confidence in deployed systems and create significant operational disruption by triggering unnecessary shutdowns, pressure reductions, or emergency response procedures that impact throughput and revenue, increasing operational costs.

Alarm fatigue is a big concern, as frequent false alarms can desensitize controllers. However, for this project, the system has been false-positive-free for approaching six months.

Working on the South Texan pipeline demonstrated the efficacy of an ML-enhanced NPW system for leak detection in sCO2 pipelines and has positive implications for CCS expansion.

Due to PipeGuard only requiring pressure sensors for leak detection, deployment onto both new and existing systems is comparatively straightforward. The flexibility of sensor spacing and the ability for the system to cope with changes in speed of sound on the fly, along with being flow agnostic, allow it to be successful in CO2 leak detection.

The system's simplicity – two FPUs / pressure sensors, and flexibility in dashboard interface deployment – facilitates scaling to larger CCS networks, many of which will be required by the expected growth in CO2 pipelines.

With U.S. CO2 pipelines expected to grow dramatically over the next 25 years, this project was key to demonstrating how the PipeGuard system enhances safety and minimizes environmental risks from undetected leaks. By supporting innovative uses like $CO_2$-to-ethanol processes and EOR-sequestration, it aligns with net-zero goals.

Pressure pulse-based methods offer a superior, mass-flow-independent alternative, paving the way for reliable monitoring in expanding CCS infrastructure.

*Figure 4 - PipeSense delivered a new dynamic pressure analysis-based leak detection system to a Texan sCO2 pipeline*

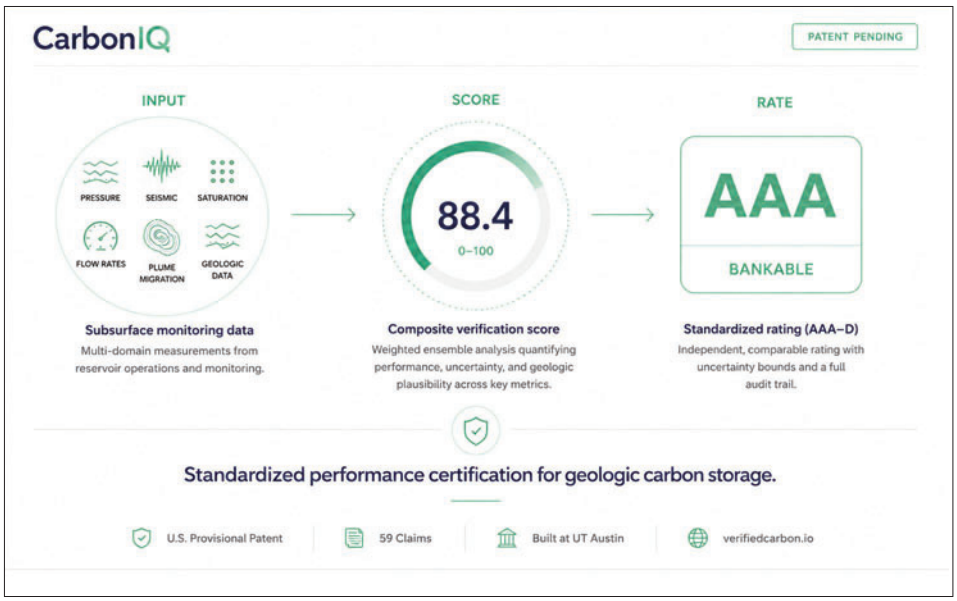
### More information

**https://pipesense.com**

# Verified Carbon files U.S. provisional patent for CarbonIQ

**The software platform is designed to verify, score, and rate geologic carbon storage projects on a standardised scale from AAA to D — the same scale capital markets already use to price every other major asset class.**

Oil trades on the NYMEX. Treasuries clear through DTCC. Corporate debt has Moody's and S&P. But carbon — the next great commodity, with hundreds of billions of dollars in committed capital flowing toward it — has nothing. No standard rating. No way for a bank to underwrite a carbon storage project the way it underwrites a pipeline. No way for a trader to compare two storage assets and price the difference. No way for an insurer to stratify containment risk across a portfolio.




Verified Carbon is a Texas-based carbon infrastructure company founded by UT Austin researchers that is trying to build that missing layer. The goal is to take carbon — today an opaque, project-by-project environmental claim — and turn it into a financial-grade asset that can be financed, insured, traded, and speculated on like any other commodity.

## Why this matters: capital cannot flow without a rating

Carbon capture and storage is scaling rapidly. The U.S. 45Q tax credit, voluntary carbon markets, and corporate net-zero commitments have unlocked enormous demand for permanent CO2 storage. But the financing layer underneath is broken.

A traditional credit rating from Moody's or S&P typically takes four to six weeks for a single new issuance. That is fast enough for the bond market because the underlying asset — a corporate balance sheet — is well understood. Carbon storage verification is different.

Today, technical due diligence on a single CO2 storage project can take months to years. Each project is reviewed bespoke. Each reviewer applies their own framework. The output is a confidential PDF, not a tradable rating.

That timeline does not just slow projects down. It blocks entire categories of capital. Banks cannot underwrite what they cannot benchmark. Insurers cannot price what they cannot stratify. Commodities desks cannot speculate on what does not have a comparable score. As a result, carbon storage today is financed almost entirely by sponsors and grants — not by the deep, liquid pools of capital that scale every other piece of infrastructure.

CarbonIQ believes it can compress that timeline from years to hours — and in doing so, open carbon storage to the same capital markets that finance oil, gas, and power.

"Carbon is becoming a commodity and it should be treated like one. If carbon markets are going to scale globally, projects need standardised ratings, independent audits, and transparent risk profiles," said Coleman White, co-inventor of CarbonIQ and co-founder of Verified Carbon.

"Traders should be able to compare projects, price risk, and speculate on carbon assets the same way markets operate in energy, debt, or commodities."

How CarbonIQ works: subsurface monitoring data is processed into a composite verification score and a standardised rating from AAA to D

## Inside the patent

The provisional patent (59 claims, four sections) covers an AI-driven system for converting raw subsurface monitoring data into a numerically defensible performance score. The platform combines ensemble reservoir modeling, statistical scoring, agentic AI orchestration, and cryptographic audit trails to evaluate the reliability, uncertainty, and geologic plausibility of CO2 storage projects — then translates those results into a standardised rating that investors, insurers, and regulators can act on.

Verification timelines that traditionally take months can be compressed to hours through automation, while every score and methodology version is committed to an immutable record for independent third-party verification.

The patent filing is titled: "CarbonIQ: A System and Method for Quantitative Verifica-

tion and Rating of Subsurface Geosystem Performance for Listing on Market Exchanges."

"Subsurface storage verification has historically been a non-unique problem. CarbonIQ introduces a quantitative and reproducible framework for ranking storage performance, uncertainty, and geologic reliability across projects," said Dr. Tip Meckel, Research Professor at the Bureau of Economic Geology, The University of Texas at Austin.

## What a standardised carbon rating opens up

If CarbonIQ becomes the standard, the implications run far beyond CCS. A rated, comparable carbon storage project becomes a financeable one — the same way a rated bond becomes a tradable one.

Project finance and lending: Banks can underwrite carbon storage projects the same way they underwrite pipelines or power plants with comparable, transparent metrics that price risk to grade.

Insurance and risk transfer: Insurers can finally stratify containment risk across portfolios using a standardised ladder, opening a new asset class for actuarial pricing.

Commodities trading and speculation: Traders can compare projects, build derivatives, and speculate on carbon storage performance the way they trade crude grades or natural gas basins.

Carbon markets: Buyers can pay premium prices for AAA-rated tons and reward project quality — transforming carbon from an opaque environmental claim into a differentiated, financial-grade asset.

Regulatory compliance: 45Q tax credit substantiation, EPA Class VI oversight, and registry integration all gain a transparent, reproducible audit trail.

## The bigger bet

Verified Carbon's thesis is that the binding constraint on scaling carbon removal is no longer technology or even policy. It is capital markets infrastructure. Without a rating system, carbon stays a project-by-project conversation between sponsors and grant-makers. With one, it becomes an asset class — financeable, insurable, tradable, and ultimately scalable to the trillions of dollars the climate transition will require.

That is the bet behind CarbonIQ. Not a better verification tool. A new market.

### More information

**https://verifiedcarbon.io**

# DNV establishes measurement framework for onboard carbon capture

**DNV has published a recommended practice (RP) providing a standardized framework for measuring and verifying the performance of onboard carbon capture and storage (OCCS) systems on ships.**

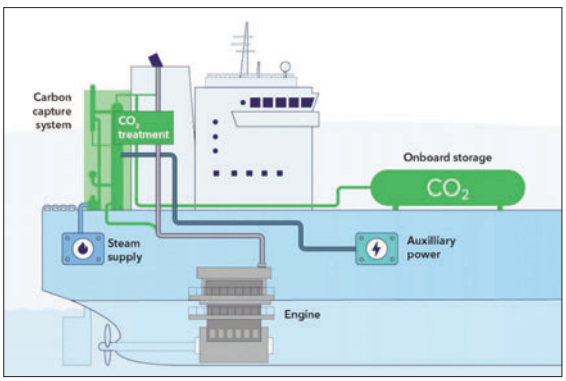
With around 90% of the operational fleet still dependent on fossil fuels according to a DNV report, onboard carbon capture is emerging as a viable pathway to reduced emissions for vessels that cannot easily or economically transition to low-GHG fuels. On the regulatory side, the International Maritime Organization (IMO) has initiated work on guidelines for OCCS, with development ongoing and expected to be completed by 2028.

"OCCS has potential as a pathway for a large part of the existing fleet, and that matters given how long many of those vessels will remain in service," said Cristina Saenz de Santa Maria, CEO Maritime at DNV.

"Our Maritime Forecast to 2050 estimates that developing CO2 offloading infrastructure at just 20 of the world's largest ports could reduce total world fleet CO2 emissions by 9%. With this recommended practice, we want to give the industry a shared technical language, and in doing so, support further development of onboard carbon capture solutions."

The DNV-RP-0698 "Performance of onboard carbon capture and storage systems" is built around mass balance principles and defines a harmonized set of performance metrics, including capture rate, captured CO2 quantity, emissions to atmosphere, and gross capture efficiency.

The framework is technology-neutral, covering pre-combustion, post-combustion, oxy-fuel and other approaches. Finally, a structured third-party verification process covers system documentation, measurement setup, performance calculations and uncertainty evaluation.




*An onboard CO2 capture and storage system (Source: DNV)*

Chara Georgopoulou Head of Maritime R&D and Advisory Greece, said, "This recommended practice provides a structured way to account for the full performance picture, not just capture volume. It enables designers, yards, OCCS manufacturers, and owners to define and verify performance in newbuild and retrofit projects, supporting alignment between stakeholders early in system design and more informed investment and deployment decisions."

### More information

**www.dnv.com/rules-standards**

# Europe needs substantial CO2 shipping and ports buildout says Xodus report

**Europe's ambitions to capture and store carbon at scale depend on transport infrastructure that is yet to be built, with a dedicated fleet of around 65 CO2 carriers and 33 ports needed by 2050, according to an industry report.**

Published by global energy consultancy Xodus, a Subsea7 company, on behalf of the Net Zero Technology Centre (NZTC) and with the support of sponsors EBN, Port of Rotterdam, Gasunie and Offshore Energies UK (OEUK), the CCUS Enabling Infrastructure Study examines the ports, ships and onshore transport needed to move captured carbon dioxide (CO2) from emitters across Europe to offshore storage sites.

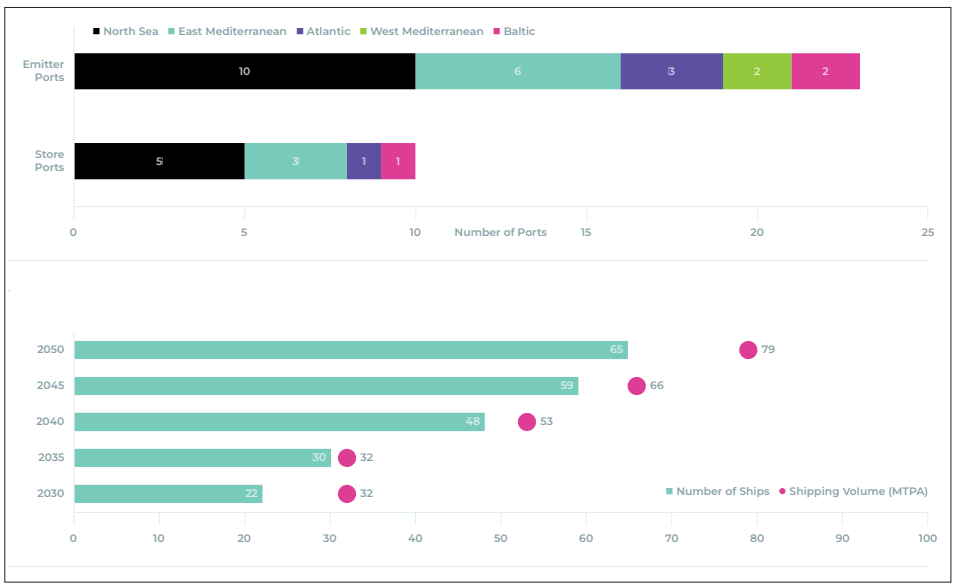
Captured emissions across Europe are forecast to grow from 70 million tonnes per annum (MTPA) in 2030 to 320 MTPA by 2050. While the shipping share of the transport market is expected to fall from 48% to 24% over that period as pipeline networks are built out, the volume of CO2 carried by ship is predicted to more than double to 79 MTPA.

The analysis screened roughly 850 operating ports across Europe down to a shortlist of around 200, identifying up to 60 that are particularly well placed to gather captured emissions and route them to offshore geological storage by 2050. Many of the likely dual-purpose 'emitter' and 'store' ports sit in heavily industrialised areas such as the Port of Rotterdam, Humberside and Liverpool Bay.

James McAreavey, Global Head of CCUS and Special Projects Lead at Xodus, said, "Most of the technology needed to move captured carbon around Europe already exists. It has been proven over decades in the liquefied petroleum gas (LPG) industry and is in CO2 service today through projects such as Northern Lights. The task now is scaling it."

"Shipping gives emitters early access to offshore storage years before onshore pipeline networks can be consented and built. If investment in ports and vessels starts now, the North Sea can set the benchmark for how the UK and Europe connect emitters to storage."

The report predicts the European CO2 transport market will evolve as a hybrid system between 2030 and 2050. Pipelines are expected to dominate high-volume, heavily industrialised corridors, while shipping provides flexibility, cross-border connections and a route to decarbonise regions where pipelines would not be competitive.




*Predicted Number of Required CO2 Shipping Ports in 2050 (top)*
*Predicted CO2 Shipping Volume and Number of Required CO2 Ships (bottom)*

Cost-based modelling consistently identifies the North Sea as Europe's primary storage sink across the period, with the UK, Dutch and wider sectors predicted to receive large-scale imports of CO2 from other regions.

Iain Martin, CCUS Technology Manager at NZTC, said, "This study reinforces the strategic importance of enabling infrastructure in scaling CCUS across Europe. As offshore storage demand grows, the North Sea is well placed to serve as the central hub of a connected, cross-border CO2 transport and storage system."

"Targeted investment in port infrastructure, shipping capacity and storage development will be essential to creating a resilient and commercially viable network. The priority now is to translate this insight into coordinated action that accelerates deployment and strengthens the UK and wider North Sea region's role in Europe's decarbonisation ambitions".

The modelling indicates a fleet of around 22 ships will be required by 2030, growing to 65 by 2050 based on an average cargo capacity of 15,000 tonnes per vessel. These would serve a network of high-throughput ports, supported by a set of regional export sites, and includes around 23 gathering and exporting CO2 from emitters, and 10 receiving it for onward transport to offshore storage.

For the journey from emitter to port, the report finds that road tankers, rail cars and river barges all offer established routes for lower-volume transport, drawing on technologies already proven in the LPG sector.

## More information

**www.netzerotc.com**

**www.xodusgroup.com**

# Transport and storage news

## Santos Moomba CCS project stores 2M tonnes CO2

**www.santos.com/moombaccs**

**Moomba CCS located in South Australia's Cooper Basin has stored over 2M of CO2e safely and permanently in just over 18 months of operation.**

The project has also received more than 1.19 million Australian Carbon Credit Units (ACCUs) for CO2e injected from project start-up to 30 September 2025. Santos said its aim is to build and operate a commercial carbon storage business for third-party emissions.

In the 2024/5 reporting period Moomba CCS stored ~ 1Mt CO2e, equivalent to approximately one-third of the total reduction in Safeguard Mechanism covered emissions versus the prior year.

Santos Managing Director and Chief Executive Officer Kevin Gallagher said the race is on to develop and deploy CCS, and Australia has unique competitive advantages – geological storage resources, a robust regulatory regime and proximity to regional emitters with large CO2 sources – to lead the way.

"Santos' acreage in the Cooper/Eromanga Basins alone has the potential for injection of up to 20 Mt of CO2 per year for up to 50 years. We stand ready to work with governments and hard to abate sectors like steel and cement to deploy this cost competitive, proven technology and deliver real decarbonisation solutions."

## Aker Solutions, Vår Energi and KNCC to develop CCS value chain in North Sea

**www.akersolutions.com**

**The companies will jointly advance the development of an integrated CO2 transportation and storage value chain on the Norwegian Continental Shelf.**

The partnership combines the strengths of three industry leaders, spanning offshore engineering, CO2 storage development and operations, and marine transportation. The MoU reflects a shared ambition to strengthen the Trudvang CO2 transportation and storage project and establish robust, flexible, and commercially attractive CO2 transport and storage solutions for European industrial customers.

The Trudvang project offers flexible transport and storage services for customer supporting the design of an unmanned CO2 injection platform and enabling direct offshore batch injection.

The concept is designed for scalability and replicability enabling initial injection volumes of approximately 2 million tonnes per annum (Mtpa), with the potential to scale to more than 20 Mtpa.

*Aquaterra's Recoverable Abandonment Frame (RAF) system can reduce the time and costs of well abandonment*

## Carbon Ridge receives DNV approval for centrifugal onboard capture

**www.carbonridge.net**

**DNV's technical evaluation of the pilot installation onboard a Scorpio Tankers vessel confirms Carbon Ridge's OCCS performance results.**

A performance verification of onboard carbon capture and storage (OCCS) has confirmed Carbon Ridge's centrifugal onboard carbon capture system can reach CO2 capture rates of as high as 98%.

This is the first maritime deployment of a centrifugal OCCS system, which during the testing was set up to capture and treat a part of the emissions stream generated by a LR2 product tanker owned by Scorpio Tankers Inc.

"For any shipowner that foresees higher prices or stricter regulations for carbon, Carbon Ridge's OCCS is an attractive solution," said Cameron Mackey, Scorpio Tankers COO.

The results were reached using data gathered over a scheduled five-month pilot period, which commenced in July 2025 at Besiktas Shipyard in Turkey, on the 109,999 dwt, 2015-built STI Spiga as the vessel undertook regular commercial operations.

DNV reviewed and validated the associated methodologies, calculations, and reported performance metrics and based on the data provided was able to corroborate peak CO2 capture rates of over 98%, with 55% of the observations falling within a range of 86–98%.

## Aquaterra Energy launches RAF system to tackle legacy well challenge for NEP

**https://aquaterraenergy.com/solutions**

**The company has inaugurated its first Recoverable Abandonment Frame (RAF) system for the Northern Endurance Partnership CCS project.**

Developed as part of Aquaterra Energy's wider legacy well re-entry and re-abandonment service, the patent pending RAF system will tackle one of offshore CCS' most complex integrity challenges by ensuring historic wells do not become weak points in future CO2 storage sites. RAF enables a vertical well re-entry tieback method that supports safe and efficient re-entry, remediation and permanent abandonment, while providing long-term assurance that intersecting legacy wells can be securely managed.

Aquaterra Energy estimates the technology could reduce abandonment costs by up to £20 million per well and cut remediation timelines by as much as 50%. By enabling legacy wells to be safely and efficiently managed, while remaining fully recoverable and reusable, the RAF system tackles a critical technical barrier to scaling offshore carbon storage at pace, not only for NEP, but for future CCS projects in mature offshore basins globally.

Rich Denny, Managing Director of NEP, said, "Aquaterra Energy's RAF system represents an innovative and unique approach to the safe re-entry and permanent abandonment of legacy wells, helping support the long-term integrity of future CO2 storage sites."

# Carbon Ridge centrifugal OCCS gains DNV approval


Image: Scorpio Tankers