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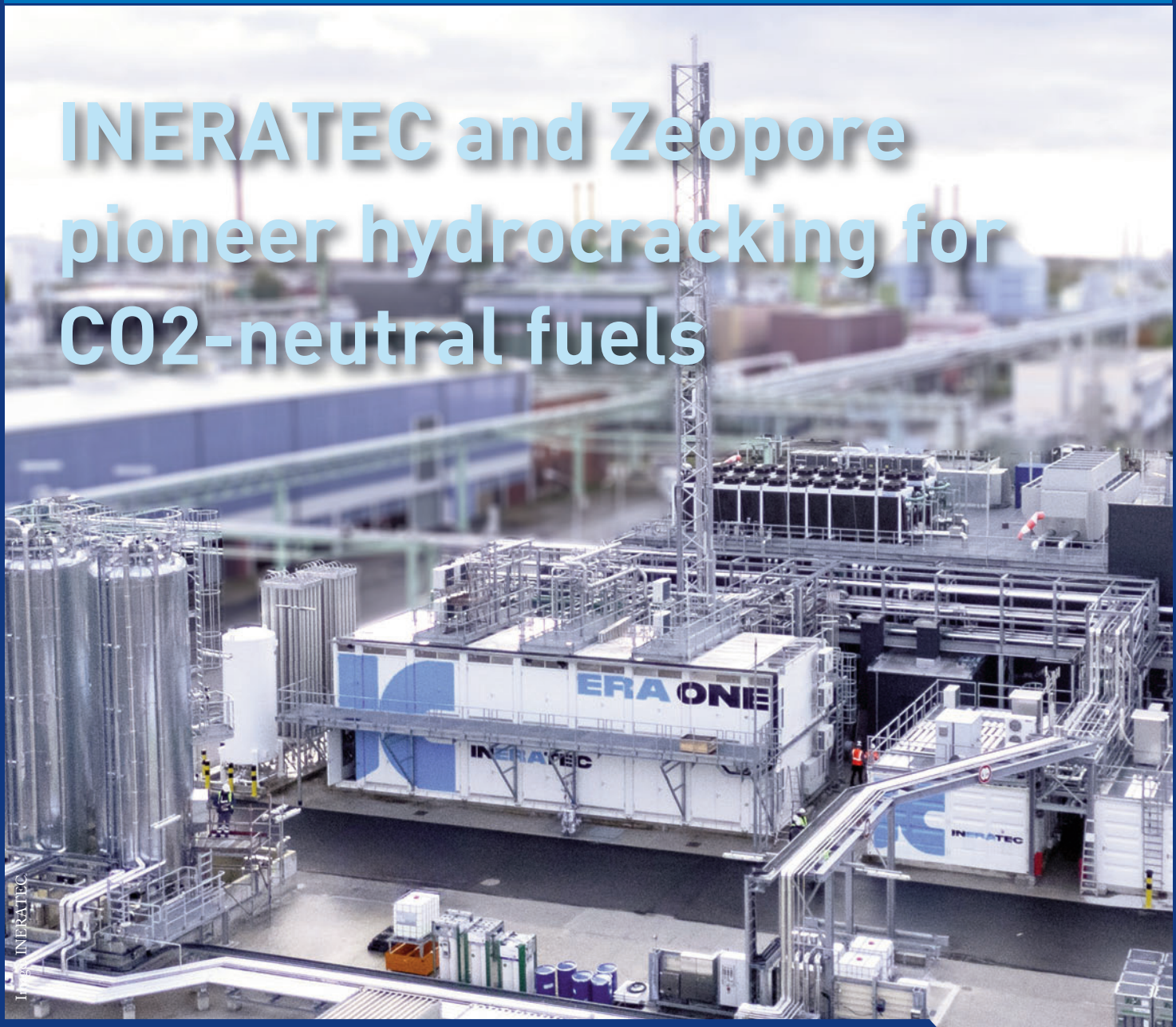
CCUS in Canada

Tax incentives in Alberta-Canada accord could spur EOR

Agreement with Oil Sands Alliance advances Pathways

Deep Sky delivers first climate credits

INERATEC and Zeopore pioneer hydrocracking for CO2-neutral fuels



- OGCI report on scaling CCS across the Asia-Pacific region
- The sweet spot for cryogenic CO2 capture
- Study confirms potential of rail transport for European CO2 hub
- Puro.earth certifies world's first permanent carbon removal from biogas

NGOs call for EU to implement penalties under the Net Zero Industry Act

The joint letter highlights that effective, proportionate, and dissuasive penalties are essential to enforce oil and gas producers' obligations to deliver the EU's 2030 CO2 storage target of 50 million tonnes of annual injection capacity.

In July Bellona Europa, Clean Air Task Force, Carbon Balance Initiative and Cement Europe, joined by a broad coalition of industry associations, infrastructure operators, carbon removal stakeholders, civil society organisations, and other actors across the CCS value chain, called on EU Member States in an open letter to rapidly implement penalty regimes required under Article 23 of the Net-Zero Industry Act (NZIA).

Now they urge Member States to publish and enforce these penalties without further delay, providing the regulatory certainty needed to unlock investment in CO2 storage infrastructure and support Europe's industrial decarbonisation and climate objectives.

The Net Zero Industry Act (NZIA) requires Member States to adopt penalties for non-compliance that are effective, proportionate and dissuasive in order to enforce the obligations placed on oil and gas producers to contribute to the deployment of 50 million tonnes of annual CO2 injection capacity across the European Union by 2030. Member States were required to publish and implement these penalties by 30 June 2026.

Introducing penalties is essential to ensuring the NZIA's enforcement framework functions as intended and remains one of the central mechanisms to reaching the Union's CO2 storage target. It is furthermore of vital importance that these penalties are sufficiently high to ensure it is more financially prudent for the obligated entities to comply with their obligations than not.

The European Commission's first progress report has already indicated that current efforts are not sufficient to deliver the EU's 2030 CO2 injection capacity target. At the same time, demand for CO2 storage services is growing rapidly among industrial sectors that depend on CCS to achieve deep decarbonisation. There is therefore a genuine and pressing need for Member States to strengthen the framework.

For industries such as cement, lime and fertiliser production, access to CO2 storage is not optional: it is a prerequisite for achieving deep decarbonisation. The Innovation Fund continues to support an increasing number of carbon capture projects, including more than 15 cement and lime plants selected for funding. These investments represent real commitments made in good faith on the expectation that the enabling framework for storage and transport will be in place.

Complementing the implementation of Article 23 with credible penalty regimes is an important part of honouring this expectation. Article 23 was introduced precisely to ensure that storage capacity develops to meet industrial demand. Its effectiveness depends not only on the obligation itself, but on the existence of credible enforcement mechanisms that provide certainty to all actors across the value chain.

We recognise that legislative and administrative processes differ across Member States, and that implementation takes time and resources.

We do not underestimate these challenges, says the letter. At the same time, the window for ensuring that the 2030 target remains achievable is narrowing, and implementing penalties sends a clear and timely signal to investors, project developers, and industrial sectors that the EU is serious about its CO2 storage objectives.

"We therefore invite all Member States that have not yet published and implemented their Article 23 penalty regimes to do so without further delay, and we stand ready to engage constructively with any Member States seeking to move this process forward."

"Together, we can ensure that Article 23 fulfils its purpose and that Europe's industrial decarbonisation ambitions are matched by the infrastructure needed to deliver them, ultimately safeguarding the EU's climate neutrality and competitiveness objectives."

Strengthening the EU ETS

Clean Air Task Force published a briefing setting out recommendations to ensure that the EU's review of the ETS reinforces the system's core function: driving deep, rapid, and sustained emissions reductions.

It highlights the need for a cautious and integrity-driven approach to integrating permanent carbon removals, alongside greater ambition and policy clarity in the inclusion of aviation and maritime emissions, as well as the expansion to municipal waste incineration and landfills. It makes the following recommendations on carbon removals:

• Integrate permanent carbon removals into the EU ETS gradually and with strong safeguards, ensuring environmental integrity is preserved and emissions reductions are not displaced.

• Prioritise high-integrity permanent removals, such as DACCS and BioCCS, and apply robust rules on MRV.

• Maintain the gross emissions cap for initial integration so that for each extra carbon removal allowance entering the EU ETS, one fewer traditional emission allowance is released at auction.

• Implement supply controls on different permanent carbon removal methods to address sustainability risks concerning biomass-based permanent carbon removals as well as manage potential fiscal impacts.

• Introduce differentiated allowances to enable a regulatory distinction between traditional emissions allowances and allowances from different permanent carbon removals methods.

More information

https://eu.bellona.org

www.catf.us

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Front cover: ERA ONE, Europe's largest commercial power-to-liquid facility located at Industriepark Frankfurt-Höchst, Germany, produces up to 2,500 tons of e-Fuels per year (pg. 13)

Back cover: Evero Energy's Ince Bioenergy with Carbon Capture and Storage (InBECCS) project is the UK's mosr advanced such project (pg. 19)

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Excluded no more: CCS incentives in Alberta-Canada accord could spur EOR

By extending the CCUS Investment Tax Credit (ITC) to Enhanced Oil Recovery (EOR) projects Canada can now simultaneously advance its environmental goals and economic interests says Will Gibson from the Alberta Energy Centre.

The federal government is following through on a key element of its energy accord with Alberta[1].

In its spring economic update, Ottawa confirmed plans[2] to extend the carbon capture, utilization and storage (CCUS) investment tax credit to projects that include enhanced oil recovery (EOR).

EOR projects were notably excluded from Ottawa's CCUS investment tax credit when it was rolled out in 2024[3].

"We were always puzzled; we were always concerned that EOR was removed from the conversation," Mark Scholz, president of the Canadian Association of Energy Contractors, told reporters[4] at the group's December state of the industry luncheon.



Enhance's Origins saline acquifer CCS project in central Alberta will manage CO2 from hard-to-abate industries, like cement, oil and gas, power generation, and petrochemicals that exist along Alberta's Edmonton-Calgary Corridor

"I mean, EOR is a game changer for the conventional business."

Enhanced oil recovery involves injecting CO2 captured from industrial sources deep underground into mature oil reservoirs to help increase production.

The CO2 helps oil flow more easily out of the porous rock, making it more efficient to extract, while the injected CO2 remains trapped underground. This process can extend the life of existing oil production while also enabling large-scale storage of greenhouse gases.

Six of Canada's eight operating commercial-scale CCUS projects involve using captured carbon for EOR.

One example is the Weyburn-Midale project, which since 2000 has safely stored CO2 equivalent to the annual emissions of more than 9.5 million cars—exceeding the total number of gasoline-powered light-duty vehicles in Ontario.

Having produced more than 600 million barrels of oil, Weyburn is one of the world's longest-running CO2 EOR projects. It still has decades of remaining potential, executives with owner Whitecap Resources said at the company's investor day in January 2026[5].

In Alberta, Enhance Energy's Clive sequestration project near Red Deer permanently stores more than 1.5 million tonnes of CO2 each year while producing oil through EOR.

The project helps reduce emissions from Alberta's large industries while making use of existing infrastructure and addressing legacy liabilities from past oil and gas operations, said Enhance Energy vice-president Candice Paton.

"The inclusion of EOR in the CCUS ITC as a permanent geological storage option for industrial CO2 allows companies like Enhance to continue having a positive impact in both emissions reductions and energy production by repurposing existing assets," she said.

Excluding enhanced oil recovery from federal investment incentives never made sense, lawyers Scott Masson and Tom Collopy of MLT Aikins' energy group wrote in an analysis prior to the Canada-Alberta agreement.

"EOR is not a novel technology in Canada.

1. https://open.alberta.ca/publications/mou-goc-goa-strengthen-energy-collaboration-build-stronger-more-competitive-sustainable-economy
2. https://budget.canada.ca/update-miseajour/2026/report-rapport/tm-mf-en.html#:~:text=Expansion%20to%20Enhanced%20Oil%20Recovery
3. https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/corporations/business-tax-credits/clean-economy-itc/carbon-capture-itc/about-ccus-itc.html
4. https://www.cbc.ca/news/canada/calgary/elizabeth-may-alberta-ottawa-mark-scholz-danielle-smith-9.7002043
5. https://app.webinar.net/prV1XVQjeOM

These facilities, such as the Boundary Dam Power Station in Estevan, Saskatchewan, demonstrate that EOR is a natural extension of CCUS operations," they wrote.

Including EOR in the investment tax credit would make the technology more financially viable for energy producers.

As a result, "Canada can simultaneously advance its environmental goals and economic interests," they wrote.

Along with existing regimes in Alberta and Saskatchewan, this will encourage more producers to consider using CO2-EOR to extend the value of mature assets, Masson told CEC.

"This significantly changes the economics of a project," he said.

"When you are looking at CCUS projects, the incentive structures required to build them are important. We're seeing a lot of projects in the CCUS space hovering around this final investment decision," Masson said.

"A lot of organizations have had problems getting projects across the line, and this change helps remove a sticking point that a lot of our clients in this space have had when it comes to CCUS."

Calgary-based Conifer Energy welcomed the expansion of Canada's CCUS framework to include EOR, saying it will help enable the long-term investment needed to advance major decarbonization infrastructure.

The company said access to the federal tax credit "materially improves" the economics of its future Alberta projects, which will permanently store CO2 while supporting jobs and generating government royalties.

More information

www.abenergycentre.ca
www.enhanceenergy.com
www.alberta.ca

Conifer welcomes "transformational" MoU for Canadian CCUS and EOR

The agreement marks a pivotal milestone in enabling a competitive, investable, and lower-emissions future for Canadian energy with the inclusion of EOR within federal CCUS incentives representing a critical policy signal for investors and project developers.

Cenovus Energy commended both governments for reaching a "pragmatic and forward-looking agreement that strengthens Canada's position as a global energy leader."

A central component of the MOU is the commitment to extend federal Investment Tax Credits (ITCs) and related policy supports to include EOR within the national CCUS framework. Conifer said it has actively engaged with stakeholders at both levels of government to advance this outcome, recognizing EOR as a proven pathway for permanent and verifiable CO2 sequestration.

By providing clarity on the treatment of EOR and reaffirming long-term carbon pricing commitments, the Government of Canada is helping unlock the large-scale, multi-decade capital planning required to advance transformational decarbonisation infrastructure.

This clarity will help attract the significant domestic and international investment necessary to support CCUS deployment, enhance energy security, and bolster Canada's economic competitiveness, said Conifer.

For Conifer, this commitment is an essential enabler for both of our CCUS-EOR projects; one at Redwater located in the Alberta Industrial Heartland and the second at Judy Creek located northwest of Whitecourt.



Conifer's operations in Alberta are both well suited to EOR

At Redwater, the scale, favourable geology, and prior CCUS-EOR pilot performance makes it an ideal candidate for large-volume, permanent sequestration and incremental oil recovery. Allowing industrial emitters to qualify for ITCs while supplying captured CO2 to EOR projects creates a level playing field and materially improves the economics around Conifer's future development.

Conifer's proposed CCUS-EOR projects at both Redwater and Judy Creek will use established technologies to permanently sequester CO2 while significantly extending the life of mature fields, generating additional royalties and supporting jobs.

Importantly, the size and characteristics of formations like Redwater mean CO2 sequestration can continue long after oil production ceases, contributing meaningfully to Alberta and Canada's long-term emissions-reduction goals.

"Today's MOU is an important step toward the modernization of Canada's CCUS policy framework. Conifer looks forward to continuing its collaboration with federal and provincial partners."

More information

www.coniferenergy.ca
www.canada.ca

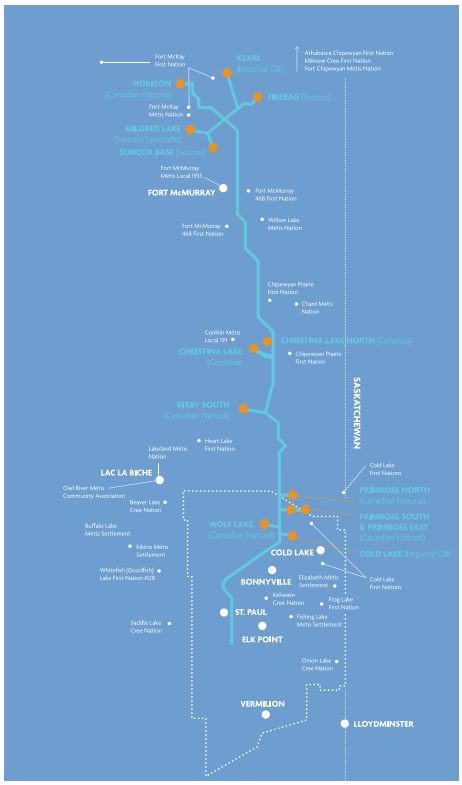
Canada signs agreement to advance Pathways CCS Project

The Governments of Alberta and Canada and the Oil Sands Alliance have signed an MoU to enable a substantial increase in oil production necessary to fill the new West Coast oil pipeline and build Pathways CCS.

This follows the recent announcement by Alberta that it had submitted an application for the proposed West Coast Oil Pipeline to the Major Projects Office.

The trilateral MOU contemplates a series of regulatory reforms and fiscal measures needed to accelerate oil sands production growth and get products to new markets, including via the proposed West Coast Oil Pipeline.

Advancing the proposed Pathways Project as outlined in the MoU is subject to execution of definitive agreements and regulatory approvals. When operational, the project will have the capacity to safely transport and store about 6 million tonnes per annum of captured CO2 by the mid-2030s from multiple oil sands facilities to a hub in the Cold Lake area for permanent underground storage.



An overview of the general location and routing for the proposed Pathways Project, which includes the CO2 transportation line, the hub distribution line and laterals. The subsurface boundary of the evaluation permit, within which CO2 injection wells would be placed, is also shown

Quick facts

Alberta has a goal of doubling its oil production to eight million barrels per day over the next 10 to 15 years.

The proposed West Coast oil pipeline was submitted to the Major Projects Office on July 2 for project of national interest listing. This pipeline will transport more than one million barrels of oil per day to Canada's west coast.

Total crude oil and equivalent production in Alberta increased from about 4.1 million barrels per day in October 2022, to a record 4.8 million barrels per day in December 2025.

Enbridge recently announced its final investment decision on the Mainline Optimization Phase 1 project, which will add capacity for an additional 250,000 barrels per day to the company's Mainline network and Flanagan South Pipeline, while South Bow announced plans for their Prairie Connector pipeline to connect with the Bridger pipeline and is expected to export 450,000 barrels per day of Alberta bitumen to the U.S. and Gulf Coast.

The proposed Pathways Project would create one of the world's largest carbon capture and storage infrastructure networks.

Alberta has invested approximately $2 billion to support carbon capture, utilization and storage-related projects and programs.

The Oil Sands Alliance represents five major oil sands producers: Canadian Natural, Cenovus, ConocoPhillips Canada, Imperial and Suncor.

Through the Alberta Carbon Trunk and Quest facilities, Alberta has already successfully captured more than 19 million tonnes of carbon dioxide.

The project has been identified as a strategic priority by Alberta and Canada and is expected to reinforce Alberta's leadership in CCUS technologies while helping maintain the competitiveness of Canada's oil sands sector.

The Alliance, which represents Canadian Natural, Cenovus Energy, ConocoPhillips Canada, Imperial and Suncor said it will also work toward the objective of additional reductions in subsequent years which may be achieved through the Pathways Project, deployment of other emission reduction technologies, or projects deploying improved production practices.

"We believe we've achieved a framework that is positive for the oil sands industry and provides a step forward to help enable production growth and to advance the Pathways Project," said Oil Sands Alliance President Kendall Dilling.

"It helps meet our shared vision to grow Canadian oil production and benefit Canadians across the country. Our members will continue to work with both the provincial and federal governments to ensure Canada is a competitive destination for energy investment."

More information

https://oilsandsalliance.ca

www.alberta.ca/alberta-carbon-capture-incentive-program

https://natural-resources.canada.ca

New Approach to Adsorbent Technology Increases Practicality of Carbon Capture Implementation



The Cat Carbon Capture Solutions CO2-TSA system reduces operating costs in multiple ways with little to no impact on engine and genset performance

From mid-to-downstream energy companies, the importance of carbon mitigation is clear. However, the capital and operating expenses often required for such initiatives challenge project economics. Overcoming these concerns requires careful evaluation of available methodologies paired with an engineering-driven, site-optimized approach that leverages existing assets.

In the United States, the 45Q tax credit offers an incentive of $85 per tonne of captured carbon. Choosing a methodology that enables operators to realize a capture cost below that figure underpins the feasibility and success of a carbon capture project.

Different Approaches, Different Trade-Offs

Companies can choose from four primary carbon capture approaches today. A**B**sorbent systems dissolve CO2 into liquid amines and then apply heat to remove the CO2. This raises regeneration energy and adds costs for continuous solvent make-up as well as related handling, monitoring and disposal. This approach is best suited for larger scale applications with concentrated CO2 streams.

Membrane systems rely on a pressure differential across selective filters, creating substantial compression costs to separate CO2. Cryogenic separation changes the phase of CO2 through extreme cooling, again driving greater operating costs. A**D**sorbent systems capture CO2 on solid sorbents through a change in temperature or pressure, eliminating the added costs of alternative methods.

The Cat® Carbon Capture Solutions Approach

Following years of rigorous research and development, Caterpillar offers a field-proven carbon capture approach for gas turbines and Cat gas reciprocating engines that significantly improves upon the adsorbent method.

Cat Carbon Capture Solutions is a proprietary CO2-temperature swing adsorption (TSA) system that replaces traditional solvents with long-life solid sorbents, eliminating the need for continuous solvent make-up while decreasing health, safety and environmental concerns.

This approach also resolves the high pressure drop normally encountered with traditional mole sieve adsorbent systems to avoid high electricity use and costs.

The CO2-TSA system reduces operating costs in multiple ways with little to no impact on engine and genset performance. It leverages waste heat present in the engine exhaust to drive the capture and regeneration process. It also incorporates a vessel design that allows for a low system parasitic load, and the longer-life sorbent delivers additional operating cost savings.

Additionally, the modular low-maintenance design mitigates solvent use as well as harmful byproducts to produce a lower total cost of ownership.

Proven in the Field, Engineered to Scale

The CO2-TSA system is operationally validated to deliver efficient carbon capture at scale at less than half the 45Q incentive. An initial North Texas pilot project captured 20 TPD on a single Cat G3606 rated at 1,875 horsepower, confirming capture performance and system integration under working site conditions.

The same architecture is also engineered to scale to support larger configurations. A four-engine G3608 site of approximately 10,000 horsepower is designed to reach 100 TPD to achieve carbon capture below $40 per tonne at a 95% capture rate. With today's carbon capture plants reaching 1,000 TPD or more, the technology can provide an even lower capture cost.

With Cat Carbon Capture Solutions, operators receive a custom-engineered scalable system specifically designed for the unique dynamics and current assets of a site. By targeting a capture cost below the 45Q incentive, that approach helps make carbon capture financially feasible and pragmatic, even as industry requirements evolve.

More information

http://cat.com/capture-carbon

Entropy commissions Phase 2 of Glacier co-generation and CCS project

The project builds on earlier phases of commercial capture systems operating since 2022 and integrates CCS on a total of 45 MW across both gas compression and power generation.

Glacier Phase 2 provides a new 15 MW co-generation installation with fully integrated carbon capture, transportation and storage for both the co-generation gas turbine and approximately 30 MW of reciprocating engines that drive compression at Advantage's Glacier Gas Plant in Saddle Hills County, Alberta.

All major construction is complete and all equipment at the facility has been commissioned. Key highlights of Glacier Phase 2 project execution and completion include:

A 15 MW Solar T130 turbine has been installed, representing a key step in delivering reliable low-carbon power from natural gas with CCS.

Electricity is being sold to Advantage under a 15-year power purchase agreement for 6 MW at a price of $85/MWh. A third-party process engineering firm has calculated the design-basis carbon intensity of the electricity at 84 kg/MWh, using a lifecycle assessment approach.

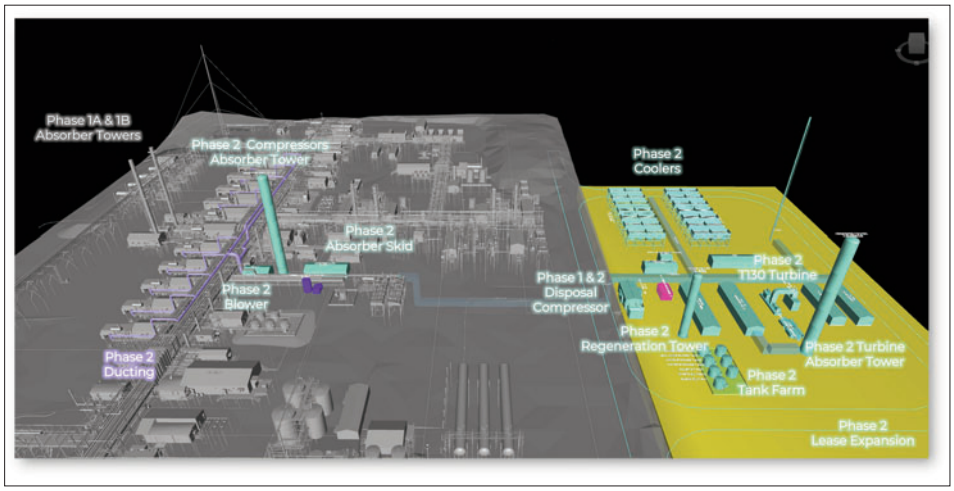
Glacier Phase 2 will materially reduce emissions from the Glacier Gas Plant while supplying low-carbon power to site operations and exporting surplus power to the Alberta Electric System Operator (AESO) grid.

All material unabated emissions sources at the Glacier Gas Plant will be captured using Entropy's industry-leading CCS technology, targeting CO2 removal rates of over 90%.

Including prior phases, total CO2 capture capacity is targeted on 45 MW from eleven gas fired engines (30 MW) plus one gas-fired power generation turbine (15 MW) for capture and sequestration of 192,000 tonnes per annum (tpa) of CO2.

Over 250,000 exposure hours were worked without a serious incident, completing extensive work at heights and executing multiple critical litis safely and successfully.

With commissioning complete, Entropy is now bringing the facility to steady-state operation and expects to publish verified performance data for Glacier Phase 2 in the coming months. That data will be measured and reported through EntropyIQ, the Corporation's real-time carbon measurement, performance and accounting system that quantifies captured CO2 from process measurements and traces every tonne from flue-stack to wellhead.



Sanjay Bishnoi, Chief Executive Officer of Entropy -"This first-of-a-kind asset will provide reliable, baseload, low-carbon power to our customer, Advantage, and sell merchant power to the AESO system. As demand for reliable, low-emission electricity grows, we believe Glacier Phase 2 will mark an important milestone for industry"

"It's great to see Entropy's success with Glacier Phase 2 operating as the first post-combustion CCS system on a gas turbine for power generation. Their technology and business model provide a low-carbon solution that is highly scalable to help meet today's growing demand for clean, firm power," said Jarad Daniels, CEO of the Global CCS Institute.

"It's encouraging to see this phase of the project online, demonstrating that CCS can support both climate goals and long-term competitiveness."

Entropy has invested more than $250 million across multiple CCS projects in Canada that are currently progressing through the NRCan and CRA review process although timelines have been significantly longer than anticipated and budgeted, with no Federal Investment Tax Credit (ITC) or Alberta Carbon Capture Utilization and Storage Investment Program (ACCIP) proceeds received to date.

Entropy said it is commited to working with the federal departments administering the CCUS ITC to improve administration; however, these delays result in increased financing costs, reduced certainty for project developers and investors, and weakened effectiveness of the incentive.

As Canada looks to advance larger-scale carbon capture projects, predictable and timely administration of the CCUS ITC program will be essential to supporting future investment decisions and atracting capital.

More information

www.entropyinc.com

Mantel Capture demonstrates its novel technology at commercial scale

Mantel Capture, a startup based on technology developed in part with support from the MIT Energy Initiative (MITEI), has raised $50 million in capital and is managing multiple demonstration projects of its carbon capture technology.

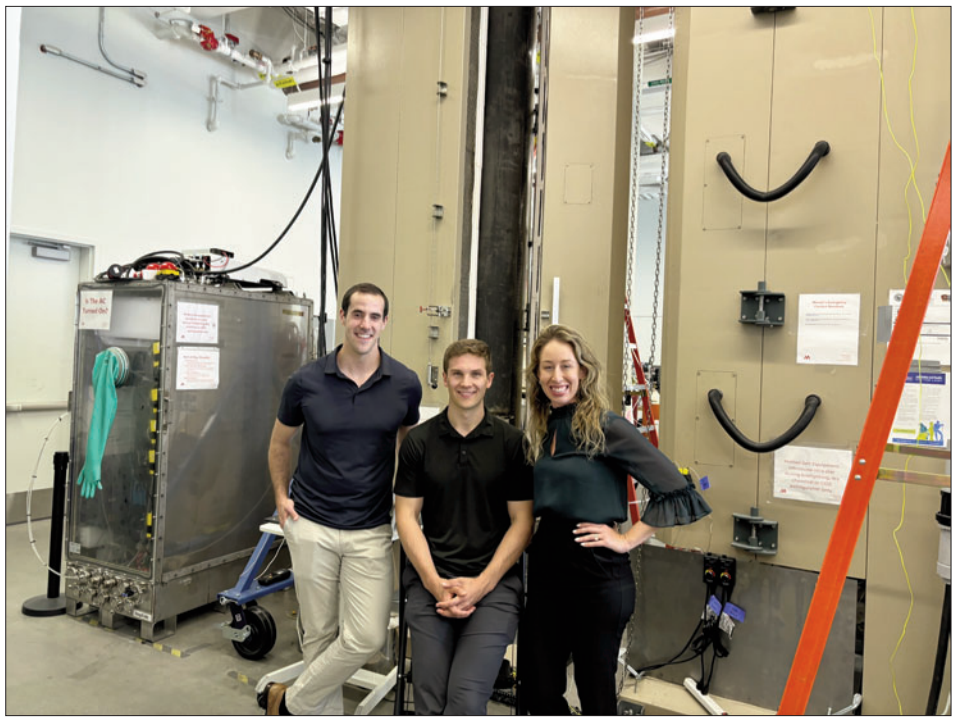
Around the world, tens of thousands of power plants, large industrial plants, and other facilities critical to the global economy pump millions of tons of climate-warming greenhouse gas emissions into the Earth's atmosphere each year. A few have systems in place that are designed to capture carbon dioxide (CO2) before it is emitted, but those systems are expensive to run and not always effective.

Even as the world transitions to cleaner and renewable energy options, these facilities will continue to rely largely on fossil fuels until zero- and low-carbon energy sources can operate at scale. In the meantime, there is a need for effective and affordable methods to capture the CO2 that the power plants and other industrial facilities produce.

Paper, packaging, and tissue company Kruger Inc. uses the technology at its pulp and paper mill in Quebec, and another commercial-scale project in Canada will integrate Mantel's capture system into an existing steam generator used to extract oil from the Canadian Oil Sands. A third opportunity will be an installation of Mantel's technology at a coal-fired power plant in West Virginia.

The U.S. Department of Energy recently awarded $18.5 million to fund the deployment of Mantel's technology at this plant. Mantel expects to capture up to 98% of the carbon emissions and also produce carbon pure enough to be sold for other products, generating a new revenue stream for the owner. Taken together, these projects test whether Mantel's technology can enable industry, including power plants, to have cleaner facilities, with no impact on reliability and little impact on cost.

While Mantel's current demonstration projects are in North America, the company's founder sees strong market potential on other continents. "We need to be deploying these carbon-capture technologies, particularly through Asia and Africa, because that's where the people are. That is where the industry is, increasingly," says Cameron Halliday SM '19, MBA '22, PhD '22, and CEO of Mantel.



Halliday and his colleagues Danielle Colson Rapson and Sean Robertson launched Mantel in 2022 to build their system to capture CO2 for all types of large industrial plants

The evolution of carbon capture

Capturing and removing CO2 from gas streams has been possible for decades, but the approaches are expensive when used on flue gas streams, in part because they consume so much energy. The hot exhaust needs to be cooled down for the sorbent material to collect the CO2 and then heated back up so the sorbent releases the CO2 and can be used again.

For decades, researchers have tried to find CO2 capture material that could work at high temperatures, but the most promising materials become less effective and need to be replaced after a few absorb-release cycles. Indeed, the sorbent now receiving the most attention shows a 70% decline in performance in just 10 absorb-release cycles.

To explain, Halliday offers an analogy: "That's like charging your phone 10 times and losing 70% of its battery power. In practice, you'd need to cycle your sorbent for thousands, tens of thousands of cycles, over 20-30 years. So that's not an economically viable commercial product."

In 2019, Halliday; his PhD thesis supervisor, T. Alan Hatton, Ralph Landau Professor of Chemical Engineering Practice, Post-Tenure; and Takuya Harada, research engineer in the Department of Chemical Engi-

neering, began to search for a sorbent that would work at high temperatures and wouldn't degrade so quickly.

Finding the right mixture: Persistence, theoretical investigation, and a bit of serendipity

Their goal was well-defined: "The interaction between the sorbent material and the CO_2 needs to be strong, so you can capture it well, but not so strong that you can't get it back off," Halliday explains. And it had to work at high temperatures, without degrading over time.

In a series of experiments with different compounds, they found that mixtures of borates (boron plus oxygen) and lithium seemed promising, but there was still some decay in performance. Furthermore, the mixtures used so much lithium that the approach was expensive.

Their breakthrough came when they added some sodium to their mixture. The resulting sorbent displayed no measurable decay—even over a thousand cycles. "We never expected to solve the problem," Halliday recalls. "We expected to reduce the problem. And this entirely eliminated the problem, to the point where we were kind of baffled."

After months of modeling and theoretical work, they figured out why. Solid sorbents degrade because, as they heat up and cool down, their structure changes, and they crack. "Our novel sorbent didn't degrade because it's inherently a liquid at high temperatures," says Halliday.

Their proprietary salt is solid at room temperature but becomes a liquid at the operating temperatures of industrial facilities such as boilers, kilns, furnaces, and gas turbines. After every capture-and-release cycle, the salt remains in liquid form.

The advent of Mantel Capture

In 2022, Halliday and his colleagues Danielle Colson Rapson and Sean Robertson, PhD '22, launched Mantel to build their system to capture CO2 for all types of large industrial plants. Rapson is now COO of Mantel, Robertson is CTO, and Hatton and Harada serve as the company's scientific advisors.



Mantel's demonstration project, D-1, is located at Kruger's Wayagamack Pulp & Paper mill in Trois Rivières, Quebec. This project is rated to capture over 2,000 tonnes of CO2 per year and generate 1 MW of steam which is fed into the mill's main steam header

The Engine, an MIT-affiliated startup incubator, led Mantel's first funding round and is still one of the startup's major investors. In addition, The Engine is home to Mantel's offices and lab space. There, Mantel built a shipping-container-sized version of their system that's been running for two years.

Here's how Mantel's carbon capture process works: The hot flue gas enters a chamber, where it flows through droplets of molten salt that enter from above through an injector that looks like a shower head. The molten salt captures the CO2 in an exothermic chemical reaction, meaning that it gives off energy, which is later recovered.

Once the CO2 is removed, the cleaned exhaust exits to the atmosphere. The energy produced throughout the capture cycle is converted into high-pressure steam, which can be used to generate electricity or be fed back into plant operations.

Meanwhile, the sorbent with the trapped CO2 passes to the desorption stage, where it's heated up by burning fuel in air, and the hot exhaust that forms is sent back through the CO2 capture system for cleanup. As the sorbent heats up, the CO2 boils out and is recovered as a high-purity product.

The CO2-free salt is now ready to recirculate through the system, and the CO2—now 99.9% pure—is ready for the company to use or to sell, providing a new revenue stream.

Interest from industry

Mantel's system is designed for all industries where steam and heat are central to operations, and it can be connected to any facility with little or no modification. And interest is high.

Mantel has more than 100 projects in their commercial pipeline, Halliday says. The targeted facilities include refineries, data centers, cement and steel plants, oil and gas companies, and others. Many of the discussions are at an early stage, involving conceptual design and feasibility studies.

Halliday's vision is that carbon capture technology will be an automatic addition to all new industrial plants. Equipment has long been used to remove sulfur dioxide and other pollutants from flue gases.

"No one thinks about that technology anymore. It's just deployed on the back of everything. It's part of how industry operates," he says. "In the future, also including carbon capture equipment should become standard practice."

More information

https://energy.mit.edu

www.mantel.com

Canada news

ERA invests nearly $51M in Alberta innovation to cut emissions

www.eralberta.ca

Emissions Reduction Alberta (ERA) is investing nearly $51 million across 16 new projects worth nearly $180 million that reduce greenhouse gas emissions while driving innovation and economic growth in Alberta.

This funding comes from the industry-funded Technology Innovation and Emissions Reduction (TIER) fund, delivered through ERA.

"This support from the Government of Alberta through Emissions Reduction Alberta marks a significant milestone for the Northern Spruce project at Mercer Peace River," said

The investment supports breakthrough technologies across carbon capture, hydrogen, methane management, critical minerals, nuclear fuel, advanced manufacturing, and resource efficiency. Together, the projects will reduce emissions, strengthen Canadian supply chains, improve industrial competitiveness, and create new opportunities to commercialize Alberta-made technologies.

Among the projects related to CCUS are:

Quantiam Technologies Inc.

ERA Funding: $3,400,000 | Project Total Value: $11,000,000

Develop technologies that convert captured carbon dioxide and clean hydrogen into low-emissions, low-cost methanol, a key feedstock for the manufacture of plastics and low-carbon fuels.

Svante Technologies Inc.

ERA Funding: $7,000,000 | Project Total Value: $25,950,000

Advance the Peace River carbon capture project using Svante's technology to capture approximately 500,000 tonnes of CO2 annually from Mercer's pulp mill.

VulcanX Energy Corp.

ERA Funding: $2,500,000 | Project Total Value: $10,000,000

Demonstrate a next-generation methane pyrolysis reactor that produces low-emission hydrogen and high-value solid carbon.

Since 2009, ERA has committed approximately $1.22 billion toward 368 projects valued at more than $11.5 billion. ERA-funded projects are estimated to deliver cumulative reductions of 28.1 million tonnes of CO2e by 2030 and 83.4 million tonnes by 2050.

Government of Quebec approves carbon storage pilot application

www.questerre.com

Questerre Energy's pilot project for carbon storage has been authorized for a term of five years and may be extended by two additional years.

The pilot will evaluate subsurface formations for long term carbon dioxide storage potential through the drilling of injection and observation wells including the use of one of Questerre's existing wells. Questerre said it believes that the future success of the energy industry depends on a balance of economics, environment, and society.

Michael Binnion, President and Chief Executive Officer of Questerre, commented, "The approval of our pilot application is the first step towards demonstrating Quebec's carbon storage potential. We are optimistic that the combination of carbon storage to reduce emissions and local gas provides a made in Quebec solution to its goals of reducing greenhouse gas emissions and strengthening its energy security."

"Much like natural gas, the Government of Quebec's Integrated Energy Resource Management Plan released last month notes that long term carbon storage is a strategic imperative to decarbonize hard to abate sectors and achieve the province's emission reduction targets. Our pilot is situated less than ten kilometres away from the Becancour industrial park and proximate to other large emitters in the province."

"Our next steps are to work with the provincial and federal Government on funding this pilot project. We are also working with the Government of Quebec on validating our pre-existing rights to explore for carbon storage that we held prior to the enactment of Bill 21." Bill 21, An Act mainly to end petroleum exploration and production and the public financing of those activities, was enacted in April 2022.

Mercer International receives funding for Peace River pulp mill upgrade

https://mercerint.com

The Government of Canada has committed C$20 million to support work including to prepare the facility for the expansion of bio-energy production and carbon capture and storage.

The support consists of a C$1 million non-repayable contribution and a C$19 million repayable contribution, with repayment scheduled to commence in 2031, subject to the terms of the contribution agreement. The funding was provided through Prairies Economic Development Canada.

"Canada did not choose this trade conflict with the United States, but we will stand up for the workers, businesses and communities under pressure," said The Honourable Eleanor Olszewski, Minister of Emergency Management and Community Resilience and Minister responsible for Prairies Economic Development Canada. "For more than 35 years, Mercer Peace River has been an anchor of northern Alberta's economy. This C$20 million investment will help the mill modernize, compete and protect the good jobs that families across the region depend on as we build a stronger, more resilient Canadian economy."

It provides capital to support MPR's broader transformation plan, designed to improve productivity and modernise the mill. This includes improvements to prepare the facility for the expansion of bio-energy production and carbon capture and storage. The funding builds on work already underway at the mill, including the carbon dioxide capture demonstration unit.

"This investment is an important step in the continued modernization of Mercer Peace River," stated Juan Carlos Bueno, President and CEO of Mercer. "It supports improvements to the mill's productivity and competitiveness and reflects the important role MPR plays within northern Alberta's forest products economy. I also want to recognize the work of our Peace River team in advancing these improvements."

Joint Thailand - Canada pilot on carbon capture in the Thai cement industry

A Mobile Carbon Capture Unit (MCCU) has been deployed in Thailand for the first time to test a technology's performance in real industrial conditions within the cement sector.

The deployment of the MCCU marks a significant step in strengthening technological readiness for carbon capture while supporting the Thailand 2050 Net Zero Cement and Concrete Roadmap.

Dr. Chana Poomee, Honourary Chairman of TCMA and President of the ASEAN Federation of Cement Manufacturers (AFCM), said that the project reflects Thailand's strong commitment to driving industry toward Net Zero through international collaboration. TCMA serves as a central platform linking industry, government, academia, and global organizations to develop practical carbon reduction solutions.

"The transition to Net Zero for hard-to-abate sectors such as cement cannot be achieved in isolation. It requires policy support from the government, as well as international collaboration in technology, finance, and knowledge transfer to accelerate real-world implementation," Dr. Chana said.

Connecting technology and investment through global collaboration

The project is funded by the Government of Canada through Environment and Climate Change Canada (ECCC), with the United Nations Industrial Development Organization (UNIDO) serving as the implementing agency. The initiative aims to develop a technology and innovation ecosystem for decarbonizing Thailand's cement and concrete industries.

Ms. Richelle Bourgouin, Deputy Minister of Trade and Export Development, Saskatchewan, Canada, noted that the collaboration highlights the power of integrating knowledge, technology, and innovation to support the transition toward a low-carbon economy.

A key outcome of the project is the deployment of the MCCU, developed by the Clean Energy Technologies Research Institute (CETRI) at the University of Regina, Canada. The unit will be tested in Thailand to evaluate its performance and applicability within the Thai cement industry.

"Saraburi Sandbox": A PPP model for accelerating low-carbon industry

Under the project, TCMA is collaborating with Chulalongkorn University to study and transfer knowledge on carbon capture technology while building human capacity. The MCCU will be rotated across cement plants operated by TCMA member companies in Saraburi province to test performance, collect technical data, and assess future investment pathways.

The "Saraburi Sandbox" serves as a Public-Private Partnership (PPP) platform, bringing together government, industry, academia, and international partners to pilot and scale carbon reduction technologies, while establishing investment models for a low-carbon economy.

Dr. Chana emphasised that deploying the MCCU in Thailand represents an important step in enhancing technological and knowledge readiness, particularly in carbon capture technologies that are essential for industries facing significant decarbonization challenges.

Preparation must begin today, as the transition to Net Zero requires time for technological development, workforce readiness, and infrastructure buildout, alongside appropriate support mechanisms. This is especially important as global carbon measures—such as carbon pricing and emissions trading systems (ETS)—become increasingly stringent.

"The success of decarbonising the cement industry depends on collaboration across all sectors to create an enabling ecosystem for investment and to accelerate the adoption of technologies at scale," Dr. Chana said.



Deploying the Mobile Test Unit in Thailand

TCMA's efforts not only reflect the Thai cement industry's commitment to translating decarbonisation plans into action, but also reinforce the importance of Thailand–Canada collaboration in advancing clean technologies and innovation in the industrial sector. This includes knowledge transfer, technology development, and expanding future investment partnerships.

This collaboration represents a key mechanism in laying the foundation for Thailand's cement industry to remain competitive in a low-carbon economy, while accelerating progress toward Net Zero 2050 and strengthening Thailand's role as a regional model for low-carbon industrial development in ASEAN.

More information

www.thaicma.or.th/en/development/cement_industry/cement_industry_and_greenhouse_gas_reduction

www.cetri.ca

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OGCI report on scaling CCS across the Asia-Pacific region

The Oil and Gas Climate Initiative (OGCI) report "CCS in the Asia-Pacific Region", prepared by the Global CCS Institute (GCCSI), examines what is needed to unlock CCS deployment across selected economies in the region.

The report assesses policy, legal and regulatory frameworks across selected economies, alongside CO2 storage opportunities and the economic implications of different development pathways. It finds that good progress is being made in many jurisdictions but further work is required to enable coordinated approaches across regions to unlock further development.

Specific provisions identified | Partial provisions identified | No specific provisions identified

CCS Project lifecycle	Australia	Brunei	Indonesia	Japan	Malaysia	South Korea	Vietnam	Singapore
Classification of CO_2	✓	✓	✓	✓	✓	✓	✓	✓
Ownership regime for sub-surface	✓	✗	✓	✗	✓	✗	✗	✗
Design standards for CCS projects	✓	✗	✓	✓	✓	✓	✗	✗
Transboundary movement of CO_2	✓	✗	✓	✗	✗	✓	✗	✗
Surface access and reclamation	✓	✗	✓	✗	✓	✗	✗	✗
Leakage provisions	✓	✗	✓	✓	✓	✓	✗	✗
Transport of CO_2	✓	✗	✓	✓	✓	✓	✗	✓
Monitoring and verification requirements	✓	✗	✓	✓	✓	✓	✗	✓
Storage and siting	✓	✗	✓	✓	✓	✓	✗	✗
Closure	✓	✗	✓	✓	✓	✓	✗	✗

Summary of key regulatory considerations for CCS projects included in legal and regulatory regimes across APAC

While some economies are advancing CCS-specific regulation, others have yet to establish the legal and permitting structures that make investment viable. The report also finds that delays in storage development will potentially carry a cost over longer time horizons, constraining available pathways to net zero and potentially increasing the price of reaching it.

The report is intended as a practical reference for policymakers, project developers, investors and others working to advance responsible CCS deployment in the region and builds on OGCI's earlier assessment of CCS hub potential in northern Egypt, also prepared by the Global CCS Institute, as part of OGCI's program of geography-specific CCS deployment analysis.

The review reveals that with the exception of Australia, Indonesia and more recently, Japan, Malaysia, and South Korea, all the jurisdictions surveyed have gaps in their existing regulatory frameworks relating to CCS. Gap analysis conducted in the report demonstrates that while existing frameworks address most of the key aspects related to CCS to some extent, the following issues remain in need of dedicated CCS-specific provisions:

- Clarification of pore space ownership
- Separate permitting pathway authorising CCS activities
- Classification of CO2
- Site characterisation requirements
- Monitoring and verification
- Risk mitigation and management
- Authorisation of site closure
- Post-closure site care and monitoring
- Long-term liability

The lack of clarity on these issues is a considerable uncertainty that may serve to deter project operators from advancing investments in CCS. Furthermore, the lack of regulation across these aspects holds implications for assuring the safety, permanence and integrity of CO2 storage operations.

Economic Analysis

An economic analysis uses the Global Economic Net Zero Optimisation model, GENZO. The model evaluates three scenarios: Low Storage Growth, Accelerated Storage Growth and Accelerated Emissions Trading. GENZO models 24 regions simultaneously and represents trade in energy, commodities and physical CO_2 for storage.

The modelling indicates that constrained storage development increases the cost of reaching net zero. It also shows that storage availability affects CO2 prices, physical CO2 transport needs and broader energy-system structure. Where domestic storage is unavailable or constrained, CO2 shipping becomes more important.

More information

www.ogci.com

INERATEC and Zeopore collaborate on hydrocracking for CO2-neutral fuels

INERATEC's proprietary process combined with Zeopore's high-performance zeolite catalysts could further increase the efficiency of CO2-neutral fuels and support the competitive scale-up of sustainable fuel and chemical production.

At the center of the collaboration is INERATEC's newly developed hydrocracking process, designed to upgrade Fischer-Tropsch waxes from power-to-liquid production into high-value, drop-in-ready fuels and chemicals. Zeopore's unique meso-zeolite catalyst technology further increases the performance of this process by enhancing catalytic selectivity, activity and lifetime.

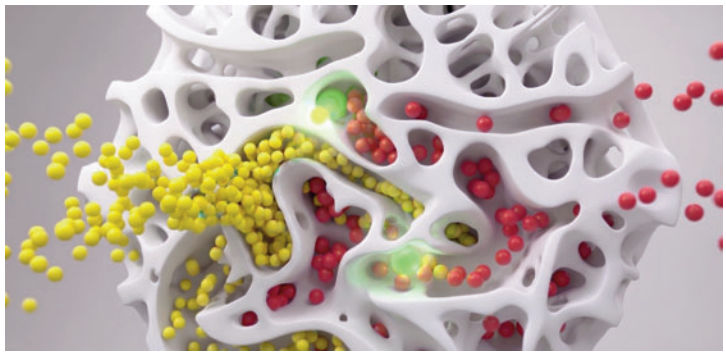
Tim Böltken, CEO of INERATEC, said, "Zeopore's catalyst technology complements INERATEC's process innovation extremely well. Catalyst performance is a key building block in creating a highly efficient and competitive hydrocracking process, and we are excited to see how strongly Zeopore's solution supports our own technology approach. Together, we are advancing a scalable path toward more efficient production of sustainable, drop-in-ready fuels and chemicals."

INERATEC's modular power-to-liquid plants cover the full value chain of sustainable fuel production — from green CO2 and hydrogen to drop-in-ready fuels and chemicals. At the core of the process, the reverse water-gas shift reaction and lower-temperature Fischer-Tropsch synthesis are coupled to convert renewable feedstocks into high-quality synthetic hydrocarbons.

By integrating microstructure technology directly into stacked reactor foils with extremely fine channels, INERATEC enables precise mass and heat exchange throughout the process. The innovative reactor design maximizes energy efficiency, dynamically adapts to fluctuating renewable power inputs, and provides a highly scalable solution for climate-neutral fuel and chemical production.

Zeopore catalysts as a key performance enabler

By integrating Zeopore's catalyst technology into its hydrocracking process, INERATEC further elevates process efficiency. The improved structure of the catalyst, containing engineered 'mesopores' serving as internal molecular pathways, enables a strongly controlled conversion of Fischer-Tropsch waxes into high-value fuels and chemicals.



The core of Zeopore's technology: the unhindered diffusion of feed molecules into the widened pore structure, followed by their selective cracking into the desired products — in this case, SAF

Combining INERATEC's proprietary hydrocracking technology and modular reactor design with Zeopore's highly performant zeolite catalysts is an important performance booster — improving efficiency, product quality and the economic competitivity of synthetic fuel production.

Performance benefits by combining Zeopore's catalyst with INERATEC's low-pressure hydrocracking include:

• Extensive catalytic testing at INERATEC facilities have successfully demonstrated that Zeopore's catalysts lift traditional diffusion and selectivity constraints in standard zeolites. As a result, the integrated process delivers measurable efficiency gains across the production chain:

• Higher carbon utilisation: improved feedstock retention helps convert a greater share of captured CO2 inputs into target fuel fractions instead of unwanted byproducts. Moreover, Zeopore's catalyst strongly reduced deactivation rates multiply the catalyst lifetime, and maintained near-complete conversion levels.

• Operational temperature: The Zeopore catalyst allows operating at significantly lower reaction temperatures, saving costly energy and lowering process severity.

• Reduced hydrogen consumption: Minimizing over-cracking reduces hydrogen consumption with double-digit percentages, directly addressing one of the most dominant cost factors in e-Fuels production.

• Lower byproduct formation: Enhanced catalytic selectivity suppresses the generation of undesired lighter gases, simplifying the downstream process, and improving overall efficiency.

• Industrial durability: Zeopore's modified zeolites have shown stability and recyclability over extended operating periods, increasing long-term plant performance and economics.

Kurt Du Mong, CEO of Zeopore, said, "Our ambition is to reduce the price premium and increase the industrialization of sustainable fuel production. Seeing our meso-zeolites add such significant value to frontrunning technologies like INERATEC's ERA ONE is incredibly rewarding. We are now ready to scale and welcome partners to join us in shaping the future of sustainable refining."

More information

www.ineratec.com

www.zeopore.com

Contribution of CCU towards climate neutrality in the EU

CO2 Value Europe revealed its updated modelling results showing that by 2050, the EU will be able to capture about 400 MtCO2 converting around half to products.

CO2 Value Europe is advocating for the creation of a circular carbon economy based on the principle of CCU. Depending on the context, these technologies can reduce or avoid greenhouse gas emissions; and, in some circumstances, generate negative emissions via Carbon Dioxide Removal (CDR) when CO2 from the air or from biogenic processes is sequestered permanently in products.

Published as a new report that is a follow-up to its first quantitative assessment published in 2024, the exercise was carried out with international industrial, technological, economic, and academic experts on CCU and related subjects to understand and quantify the potential of CCU.

Since then, data and modelling improvements have been carried out and led to an updated report that focuses on the new modelling results and adjustments. It includes:

• Modelling of additional mineralisation pathways (i.e., mineralisation of CO2 to produce supplementary cementitious materials, mineralisation of CO2 to produce carbonated concrete aggregates)

• Ex-post calculations of CO as feedstock to produce e-ethanol; CO sources considered were steel-making off-gases, biomass gasification and CO2 conversion

• Detailed modelling of CO2 from biogas upgrading

• Introduction of cost elements (CAPEX, OPEX, fuel costs)

• Configuration of the national context for the implementation of CO2 Value Europe's Vision Scenario at Member-State level (with the case-study of the Netherlands)

• Additional improvements in the model (update of EUROSTAT latest input data, improved modelling of capture in refineries, improved circularity modelling, and more)

• Various corrections (domestic aviation data, double counting of CCU fuels for energy and non-energy applications in the industry, separation of benefits in terms of emission reduction and feedstock availabilities for the chemical industry, and more)

This new report shows that the CO2 will be captured mainly from biogenic (26%), atmospheric (34%) and process emissions (20%), with around half converted into products, while the rest will be stored underground. Although CCU technologies require significant amounts of low-carbon electricity, they could produce more than half of the EU's fuel demand by 2050, reducing reliance on fossil fuels, strengthening energy sovereignty and cutting greenhouse gas emissions.

Next steps, sectoral and thematic documents as well as a detailed methodology will be published in September 2026.

The report contains the following recommendations:

1. Europe must be more systematic and consistent in including CCU in its legislations to drive down emissions: every EU legislation addressing the transition away from fossil fuels like the Circular Economy Act or the Industrial Accelerator Act must address the scale-up of alternatives like CCU.

2. Create definitions, map carbon availabilities, remove red tape: Europe has the right legislative vehicles in the pipeline to set definitions for sustainable carbon, quantify the sources and revise outdated rules (e.g. allow CO2 to be transported and utilised under MRR), mainstream net zero technologies categories under NZIA, and include CO2-based products in the CO2 market and infrastructure legislation.

3. EU policies must reward CCU to address the cost gap with conventional products: create under ETS revision (and in CBAM) a level playing field between captured carbon and virgin fossil carbon to avoid penalising cleaner alternatives; mobilise instruments to reduce that cost gaps with conventional equivalents (e.g. earmarking of ETS revenues, double-sided auctions, CCfDs, IPCEI for CCU/CCS/CDR).

4. Amending EU legislations to make them fit-for-purpose for CCU deployment: the EU must amend rules around renewable hydrogen and derivatives that have failed to deliver on upscaling solutions that reduce fossil dependency and revise the current rules disincentivising the use of unavoidable industrial CO2 to produce CCU fuels after 2041. Rules for permanent removals through CO2 mineralisation should also be expedited.

5. Create new incentives for fossil-free feedstocks for chemicals: the EU is still not incentivising the uptake of fossil-free textiles, packaging, plastics or cleaning products. Market pull mechanisms for sustainable carbon are a must to change course: the EU should swiftly implement related recommendations from the Critical Chemicals Alliance in the Industrial Accelerator Act.

6. Take stock of progress and shortcomings of current EU rules from ReFuelEU Aviation & FuelEU Maritime: EU rules should build on proposals made under the Sustainable Transport Investment Plan, the Communication AccelerateEU, both of which acknowledged the need for large scale production of sustainable aviation and maritime fuels, by maintaining targets and complementing them with additional derisking mechanisms.

7. Encourage action at national level and build synergies in EU instruments: the EU should encourage countries to take action to support CCU projects on their soil, to map their strategic dependencies on fossils, mobilise new possibilities offered by Clean Industrial State Aid Framework, adopt national strategies on CCU, and assess NECPs based on the promotion of clean techs, including CCU.

More information

https://co2value.eu

Puro.earth certifies world's first permanent carbon removal from biogas

The first validated and verified CORCs from biogas-based BECCS have been delivered by Inherit, HoopCO2 and Northern Lights JV from the VEAS wastewater treatment plant in Norway.

The CO2 Removal Certificates (CORCs) were issued to the world's first project in which biogenic CO2 released during biogas production is captured and permanently stored geologically. This also marks Puro.earth's first certification for a BECCS facility in Europe.

Kaja Voss, CEO, Inherit Carbon Solutions said, "Working with Puro.earth through this certification has given us a clear and credible pathway to bring these credits to market. This project shows just how much potential there is across the biogas supply chain for capturing and permanently storing biogenic CO2. The collaboration with HoopCO2 and Northern Lights has been strong, and we're excited about what this pilot means for scaling biogenic CO2 removal from biogas facilities more broadly."

The certification recognises Inherit's innovative and robust approach to carbon removal, ensuring the long-term sequestration of carbon by capturing biogenic CO2 released during biogas production and storing it permanently in geological formations. It also demonstrates the viability of a new approach to engineered carbon removal: by connecting existing biogas infrastructure with dedicated CO2 transport and storage, the project uniquely turns a byproduct of wastewater treatment into permanent, verifiable carbon removal – a model that can be replicated across the biogas sector globally.

Following validation and verification under Puro.earth's Geologically Stored Carbon methodology (Edition 2024), including audit by a third-party validation and verification body (VVB), the project has been issued more than 700 CO2 CORCs in the public Puro Registry, covering its first four months of operation, from February to May 2026. Ongoing monitoring, reporting and verification (MRV) will underpin frequent CORC issuances, supporting deliveries to offtakers as the project progresses and matures.

The VEAS project is a collaboration between Inherit Carbon Solutions, the project developer; HoopCO2, which operates the capture and liquefaction facility; and Northern Lights JV, which provides transport and permanent offshore storage.

From wastewater to permanent storage

The CO2 originates from the VEAS wastewater treatment plant in Slemmestad, Norway's largest, which processes wastewater from more than 800,000 residents across Oslo, Bærum and Asker. As organic material is processed in VEAS's biogas production unit, biogenic CO2 is released as a natural byproduct of the process.

Under the JV, HoopCO2 operates the capture and liquefaction facility to collect CO2 for permanent storage. The liquefied CO2 is transported by road to Northern Lights' receiving terminal in Øygarden, west of Bergen, where Inherit offloads the trucks into intermediary onshore storage. From there, Northern Lights transports the CO2 offshore by pipeline for permanent storage 2,600 metres below the seabed.

Northern Lights has stored fossil-based CO2 permanently offshore since August 2025 and is the world's first initiative to offer CO2 transport and storage as a commercial service. The VEAS project is the first instance that Northern Lights is storing biogenic CO2. It will receive up to 7,000 tonnes of CO2 per year from VEAS over the agreement period with Inherit, the starting point for future scale at the site.

As one of the first BECCS projects in the Nordics, the VEAS project offers a real-world reference point for buyers, governments and partners - proof that durable carbon removal built on existing infrastructure is not just technically feasible, but investable, operational and already being integrated into corporate climate strategies. Smaller in scale and faster to deploy than larger facilities with longer development timelines, projects like this offer a flexible, scalable pathway to durable carbon removal.



This marks the first time anywhere in the world that biogenic CO2 from biogas production has been captured and permanently stored geologically

Jan-Willem Bode, President, Puro.earth, commented, "Inherit's issuance shows what's possible when biogas infrastructure and carbon storage infrastructure are combined through one succinct process. Biogenic CO2 that would otherwise have been released is instead captured and permanently stored."

"This is exactly the kind of innovative approach to BECCS that the Puro Standard and Registry was built for. Inherit is a true pioneer in this field, and we're proud to certify the world's first project of its kind. With the scale of biogas production across Norway, the Nordics and more widely across Europe, the potential for BECCS regionally is significant."

More information

www.inheritcarbonsolutions.com
https://puro.earth
www.hoopco2.com
https://norlights.com/what-we-do

CCS regaining prominence in Germany says study from Potsdam Institute

A study by the Research Institute for Sustainability examines the reasons behind this comeback and shows that the strict limits originally envisaged for CCS were progressively relaxed throughout the political process. This increases the risk that the lifespan of fossil fuel infrastructure will be prolonged, potentially side-lining other climate protection measures.

The study published in Environmental Politics underscores the challenges of implementing and enforcing a conditional approach to CCS, particularly in the face of resistance from fossil and industrial incumbents.

It reveals the coalitional, discursive and institutional factors why even in Germany – arguably a most-likely case for a strictly limited CCS approach, given broad public skepticism toward the technology – the conditional approach failed.

"In Germany, CCS was long regarded as a political non-starter. This makes the question of how the technology returned to the centre of the climate policy debate within just a few years all the more intriguing," said lead author Tobias Haas from the Research Institute for Sustainability at the GFZ (RIFS).

In the late 2000s, an initial attempt to introduce CCS failed due to resistance from local initiatives, environmental NGOs, and low public acceptance. The technology subsequently fell out of political favour for years, although it continued to be viewed as a critical element in climate scenarios for achieving neutrality.

The political comeback was initiated by the so-called 'traffic light' coalition government (2021–2024), which revised the Carbon Dioxide Storage Act, developed a carbon management strategy, and worked on a long-term strategy for unavoidable residual emissions.

The establishment of the umbrella term 'carbon management' opened the door to many technological approaches. In addition to CCS, these include the use of captured carbon dioxide (Carbon Capture and Utilisation, CCU) as well as processes for removing CO2 from the atmosphere (Carbon Dioxide Removal, CDR).

"The concept of carbon management is politically appealing because it places CCS in a new context," explained Haas.

"The technology is no longer discussed in isolation as a controversial process, but as part of a more comprehensive management approach." This shift in perspective played a key role in the political resurgence of CCS.

How rather than whether

At the same time, the debate shifted: the argument was no longer about whether CCS should be used; instead, the focus turned to how and to what extent its use should be permitted. In the process, the conditions originally laid down for the use of the technology were gradually relaxed.

At the outset of the debate, there was still broad agreement that CCS should only be used where CO2 emissions could not be avoided for technical reasons, and that avoiding emissions must, in principle, take precedence.

In 2025, the current federal government passed an amendment to the Carbon Dioxide Storage Act. While this continues to place the emphasis on storage beneath the seabed, the original restrictions on its use were further relaxed. The law only excludes coal-fired power plants from using CCS—plants that are already scheduled for decommissioning by 2038.

At the same time, the federal government is planning additional power plant capacity of 12 gigawatts, which is to become climate-neutral by 2045 using 'technology-neutral' approaches. In the authors' view, this could also facilitate the use of CCS in new gas-fired power plants and thus prolong dependency on fossil fuels.

A clear definition of 'hard-to-abate emissions' is needed

The study identifies three reasons why the originally envisaged strict limits on the use of CCS could not be enforced: environmental organisations held differing positions, which weakened their collective political clout. At the same time, the public debate increasingly lost sight of the fact that many supporters were only willing to allow CCS under strict conditions. Finally, the conditions were further watered down during a protracted political decision-making process.

The authors therefore recommend that the use of CCS be contingent upon clearly defined conditions. Central to this is a binding definition of which emissions are truly 'hard-to-abate.' "Otherwise, there is a risk that more and more emissions will subsequently be classified as unavoidable and that the use of CCS will be gradually expanded," said Haas.

The role of CCS is therefore not merely a technical or economic matter, but a political decision regarding the path Germany wishes to take towards climate neutrality. The debate surrounding CCS exemplifies the risk of relying, in order to achieve climate targets, on technologies that have yet to make a tangible contribution to climate protection and where it is unclear whether they will 'deliver' on a large scale in the future.

Haas, T., Brad, A., Schneider, E., Hüttenhain, Z., & Koinzer, J. (2026). The renaissance of carbon capture and storage in Germany and the politics of conditionality. Environmental Politics

More information

www.rifs-potsdam.de

Study finds CCS could help curb emissions from AI

When out-of-state storage options are included, the researchers found that more than 90% of data center-related carbon dioxide emissions could potentially be mitigated through CCS.

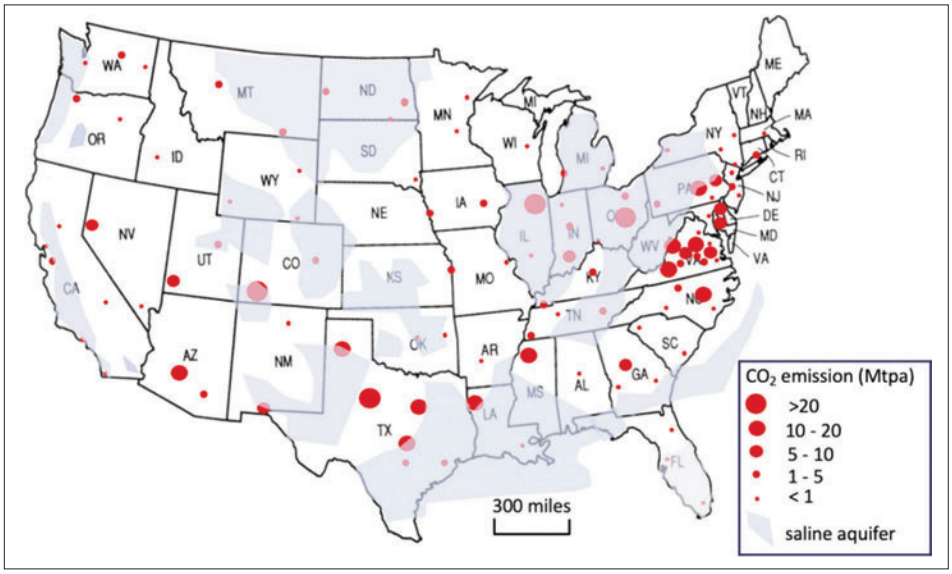
As artificial intelligence accelerates demand for computing power across the U.S., a new study co-authored by Hon Chung Lau, adjunct professor in the Department of Chemical and Biomolecular Engineering at Rice University and founder of Low Carbon Energies LLC, has found that carbon capture and storage could play a major role in limiting the climate impact of data centers.

Published in Energy & Fuels, the study estimates that U.S. data center power capacity could grow from 40 gigawatts in 2025 to 169 gigawatts by 2030 — a more than fourfold increase in just five years. Without new strategies to manage emissions, the carbon dioxide produced by fossil fuel power plants supplying electricity to data centers could rise from about 90 million metric tons per year in 2025 to more than 404 million metric tons per year by 2030.

"Data centers are becoming one of the defining energy challenges of the AI era," said Lau. "The question is not only whether we can build enough computing infrastructure, but whether we can power it in a way that is reliable, affordable and compatible with decarbonisation goals."

The study, conducted by Lau and Steve C. Tsai, an energy transition consultant at Low Carbon Energies LLC, analyzed publicly available data on announced U.S. data centers, including projected power capacity, energy sources and locations. They then estimated data center-related carbon emissions based on each state's electricity mix and examined whether those emissions could be captured and stored underground in saline aquifers.

Their findings point to rapid growth in states including Texas, Virginia, Pennsylvania, Ohio, Arizona, Colorado, Utah and Illinois. They estimated that Texas alone would need to add approximately 25 gigawatts of power capacity by 2030 to meet projected data center demand.



Location of saline aquifers relative to locations of Data Centre-related CO2 emission. It can be seen that many emission locations reside within or near a saline aquifer

Because data centers require highly reliable, around-the-clock electricity, Lau and Tsai found that natural gas combined cycle power plants equipped with carbon capture and storage may offer one of the most practical near-term pathways for providing low-carbon power. Natural gas is abundant in the U.S., gas-fired plants emit less carbon dioxide than coal-fired plants and many major data center growth areas are located near underground saline aquifers that could be used for long-term carbon storage.

The study found that 34 states have enough saline aquifer storage capacity to store more than 100 years of projected data center-related carbon dioxide emissions beyond 2030. In 2025, those aquifers could store an estimated 59 million metric tons of data center-related carbon dioxide, or about 66% of the sector's emissions. By 2030, that number could grow to 299 million metric tons, or about 74% of projected data center-related emissions.

"This does not mean carbon capture is the only solution," Lau said. "But it does show that the geology exists to make a meaningful impact, especially in states where data center growth is strongest."

The authors noted that their estimates are conservative because they included only data centers with publicly announced power requirements. In addition, they also assumed that when companies did not specify a power source, electricity would come from the state grid and that each state's energy mix would remain constant through 2030.

Even with those limitations, Lau said the results offer a useful state-by-state framework for balancing digital infrastructure growth with climate goals. "The AI economy will require enormous amounts of energy," Lau said. "Our study helps identify where that demand is growing, where emissions are likely to rise and where carbon storage could help."

More information

www.rice.edu

CCSA calls for government action to unlock greenhouse gas removals

By acting now, Government can unlock billions of pounds of private investment, reduce the long-term cost of tackling climate change and position the UK as a global leader in carbon removals.

Senior leaders from across the CCUS sector gathered at the House of Lords alongside Lord Whitehead, Minister for Energy Security and Net Zero, to celebrate the progress of the UK's CCUS industry.

As the UK experiences its third heatwave of the year, it is another reminder of the need to accelerate climate action. The event also marked the launch of the CCSA's new Position Paper on accelerating the deployment of greenhouse gas removals – which are essential if we are to address the rising temperatures.

Projects across the North West, North Wales and Teesside are now in construction, with more than £4 billion of supply chain contracts already awarded, supporting and creating around 5,000 construction jobs. The first CCUS clusters have also met the industry's voluntary commitment to source at least 50% of goods, services and labour from UK suppliers, demonstrating the sector's contribution to British businesses and skilled employment.

Speaking at the event, the Minister reiterated his support for the technology and the commitments the Government has already made, highlighting the vital role of CCUS and greenhouse gas removals in decarbonising industry, strengthening energy security and driving long-term economic growth. He also welcomed continued collaboration between Government and industry as deployment accelerates.

Olivia Powis, CEO of the CCSA, said, "The UK has built real momentum in CCUS, with projects under construction and a world-class CO2 transport and storage industry taking shape. We now have a once-in-a-generation opportunity to build on that foundation and establish the UK as a global leader in greenhouse gas removals."

Building on industry momentum, the CCSA launched 'Capturing the Greenhouse Gas Removal (GGR) opportunity' – setting out how the UK can establish itself as a global leader in greenhouse gas removals. The Position Paper highlights the UK's unique strengths, including world-leading CO2 storage capacity, a rapidly expanding CCUS industry, internationally recognised engineering expertise and deep capital markets.

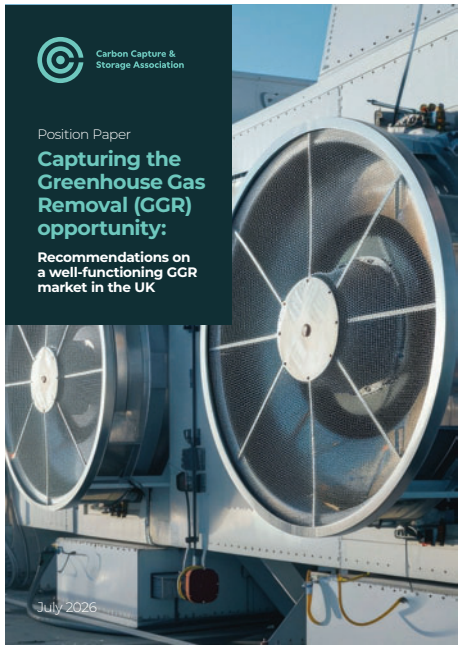
Analysis by AFRY finds that a strong UK greenhouse gas removals market could cut public support costs by £1 billion a year in the 2030s and more than £3 billion a year by 2050. As more businesses buy GGR credits, private demand would help fund new removal projects and reduce the need for long-term government support, significantly lowering the cost of delivering the GGRs needed to meet the UK's climate ambitions. Taken together, this could cumulatively save taxpayers up to £35 billion by 2050.

Greenhouse gas removals will be essential to achieving the UK's climate targets. The Climate Change Committee (CCC) estimates that the UK will require up to 35.8 million tonnes of carbon dioxide (MtCO2) of removals each year by 2050 – equivalent to removing the emissions of around 16 million cars annually.

The CCSA estimates that the current pipeline of UK projects, if provided a route to market, could deliver 18.2 MtCO2 of removals every year by 2035 – equivalent to taking around 8 million cars' worth of emissions out of the atmosphere annually – provided the right policy and investment framework is established.

However, the Paper warns that delays to policy development, transport and storage infrastructure, and long-term market incentives risk slowing deployment and weakening investor confidence at a critical stage of market development.

To unlock the sector's full potential, the CCSA is calling on Government to provide stronger long-term demand signals through sectoral mandates (such as in aviation), incentives for corporate buyers, the creation of a UK buyers' club for removals, and the timely integration of GGRs into the UK Emissions Trading Scheme by 2029.



Without action, the Paper warns, the UK risks losing its first-mover advantage as international competition intensifies. By acting now, Government can unlock billions of pounds of private investment, reduce the long-term cost of tackling climate change and position the UK as a global leader in carbon removals.

Despoina Tsimprikidou, Senior Policy Officer at the CCSA and author of the Position Paper, said, "The opportunity is significant. Greenhouse gas removals are essential to meet climate targets while attracting billions of pounds of investment, create skilled jobs and strengthen the UK's industrial competitiveness."

"What we need now is a clear, long-term policy framework that enables a well-functioning GGR market, gives investors and businesses confidence to scale, and reduces the cost for government and taxpayers."

More information

www.ccsassociation.org/resources

Projects and policy news

Switzerland's first cross-border integrated commercial BECCS value chain

www.airfixcarbon.com
www.co2-energie.ch

Airfix, CO2 Energie AG and South Pole have begun commercial operations at Switzerland's flagship BECCS project in Niederwil as CO2 is delivered for permanent storage in North Sea.

The first ISOtainers filled with liquefied biogenic CO2 have left the Regionalwerke AG Baden (RWB) biomethane plant and arrived in Denmark for permanent geological storage at Project Greensand in the North Sea.

This marks the transition from years of development into active, daily execution, establishing Switzerland's first operational, cross-border, commercial-scale, multimodal Bioenergy with Carbon Capture and Storage (BECCS) value chain.

"BECCS Niederwil proves that complex multimodal logistics and cross-border regulatory boundaries are no longer barriers to carbon removal," said Jonas Lötscher, MD at Airfix.

"By active integration across capture, rail, maritime shipping and subsea injection, we have built an operational framework that can be replicated by small- and medium-sized biogenic emitters across the entire continent."

Operating at Switzerland's largest biomethane facility in Niederwil, the project captures biogenic CO2 generated during the anaerobic digestion of local agricultural and food waste. Up to 4,300 tonnes of biogenic CO2 will be captured and liquefied on site each year.

Evero submits planning application for flagship InBECCS project

www.evero.energy

The Ince Bioenergy with Carbon Capture and Storage (InBECCS) project is a Track-1 project within the HyNet industrial cluster in North West England.

InBECCS is the UK's most advanced BECCS facility under the Government's Greenhouse Gas Removals (GGR) business model. With operations targeted from 2030, InBECCS is expected to play an important role in the UK's negative emissions infrastructure.

Neil Bennett, Chief Commercial Officer at Evero Energy, said, "Submitting this planning application marks a major milestone for Evero and for the UK's carbon removals sector. InBECCS demonstrates how waste wood management and carbon capture can work together to deliver meaningful climate impact while supporting UK industry."

Ince Bio Power currently generates energy from waste wood, diverting domestically sourced Category C material, which has no other use apart from landfill, and repurposing it into low-carbon power. By installing carbon capture technology, InBECCS is expected to capture up to 250,000 tonnes of CO2 annually, permanently removing these emissions from the atmosphere while contributing to homegrown baseload energy.

Located within the HyNet cluster, the UK's most advanced carbon capture cluster, the project was selected as a priority under the Government's Track-1 expansion process in 2025. It will benefit from shared carbon transport and storage infrastructure, enabling the safe and permanent sequestration of captured CO2 beneath the Irish Sea.

Project Tundra moves ahead with Reliant as CCUS operations partner

https://minnkota.com
www.reliantccs.com

Minnkota Power Cooperative is continuing the project under an updated joint development structure that brings the experienced carbon capture developer into a larger role.

Under the revised structure, Reliant Carbon Capture & Storage will assume responsibility for the development, ownership and operation of the carbon capture facility planned at the coal-based Milton R. Young Station near Center, North Dakota.

Project Tundra is designed to capture up to 5 million tons of CO2 emissions annually from the Young Station.

"The updated development structure and emerging CO2 utilisation opportunities strengthen the long-term potential of Project Tundra," said Mac McLennan, Minnkota president and CEO.

"The addition of carbon capture technologies at the Young Station would help preserve the value of the facility while delivering economic and environmental benefits, supporting North Dakota's energy economy and maintaining reliable, affordable electricity for our members."

Reliant, the exclusive channel partner for Baker Hughes' Chart cryogenic carbon capture technology at U.S. coal-fired power plants, pairs that equipment with its proprietary approach to carbon capture project development. Because the majority of the capture system can be manufactured offsite and assembled at the plant location, the design is expected to materially improve operational efficiency and reduce construction risks.

Minnkota will maintain responsibility for CO2 storage activities, including management of its permitted geologic storage facilities and ongoing engagement with project landowners.

In addition to carbon storage, Minnkota and Reliant are pursuing opportunities to utilize captured CO2 for enhanced oil recovery (EOR) operations in North Dakota.

Achieving systemic bankability of CCS in Poland

www.catf.us

A report from the Clean Air Task Force aims to understand why Poland has not deployed any large-scale CCS facilities and what it will take to change that.

CCS technologies present one of many vital opportunities to address hard-to-abate emissions and advance competitive industrial decarbonisation in Poland. Yet the country has not deployed a single large-scale CCS facility.

Drawing on the systemic bankability framework developed by Clean Air Task Force and Princeton's Andlinger Center for Energy and the Environment, the report applies nine conditions for commercial-scale technology deployment to Poland's CCS sector. Systemic bankability exists when technology costs have fallen, project risks are manageable, financing is available on commercial terms, and enough projects have been built that private capital can flow repeatedly and at scale.

The sweet spot for cryogenic CO2 capture

Optimising the capture element, without due consideration of the total cost of the full value chain, results in pushing expenses down the chain and increasing the cost of the end-to-end system. By Stephen B. Harrison, sbh4.

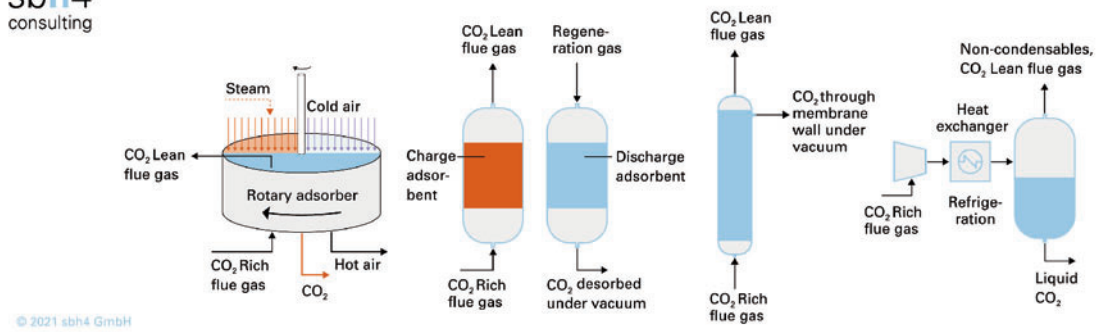
Unit operations must support system boundary conditions

Consider the case that a liquid solvent-based CO2 capture system, such as a twin-tower amine process, is used upstream of a CO2 liquefier to condition the CO2 for transportation by rail and ship to an offshore geological storage facility.

Imagine that the given boundary conditions are an overall CO2 capture rate of >90% from the emissions source to geological storage and that the liquid CO2 must comply with the Northern Lights CO2 purity specifications.

Carbon Capture technologies – Adsorption based & others

sbh4 consulting



	TSA – temperature swing adsorption and desorption	VSA – vacuum swing adsorption and desorption	Selective membrane separation	Cryogenic CO_2 liquefaction
Separation principle	Adsorption	Adsorption	Membrane	Physical (phase separation)
Specific energy demand	1.5 GJ/t_{CO2} (mostly waste heat)	1.7 GJ/t_{CO2} (mostly power)	1.20 GJ/t_{CO2} (mostly power)	n.a. (mostly power)
Typical temperature	40-60°C	<40°C	30-50°C	-50°C
Typical pressure	Ambient	Cycling between moderate pressure and vacuum	Moderate pressure flue gas, CO_2 under vacuum	20-50 bar_g
Typical CO_2 removal	90% (target)	<90%	<80%	>99% (with CO_2 feed >50%)
Typical CO_2 purity	95% (target)	<95%	95%	>99% (with CO_2 feed >50%)
Typically combined with	Standalone	Cryogenic Liquefaction	Amine wash, Cryogenic Liquefaction	VSA, Membrane (eg Cryocap)
Typical plant size (tonnes per year CO_2 removal)	200 – 2,000,000	1,000 – 500,000	10,000 – 1,000,000	>100,000
Technology maturity level	Pilot / Commercial, eg Husky Energy SK, Lafarge Holcim Cement, BC	Demonstration / Commercial, eg Air Products Port Arthur SMRs, USA	Demonstration / Commercial	Demonstration / Commercial, eg Air Liquide Cryocap at Port-Jérôme SMR, France

If the amine-based CO2 capture system were optimized in isolation, it would capture just over 90% of the flue gas CO2. This minimises the size of the absorption tower to reduce capex, and minimises the reboiler energy to reduce opex.



Optimising CO2 capture to Northern Lights CO2 storage specification requires a holistic approach. Image: ©Torstein Lund Eik, Equinor

The amine system would typically yield CO2 of around 99% purity with nitrogen as the main impurity. This would then be fed to the CO2 liquefier. In the liquefier, the incondensable nitrogen must be vented from the system. As it is released, it carries with it an amount of CO2 according to the vapour / liquid equilibrium of these two gases. Typically, the vent contains 50% to 60% CO2, in addition to nitrogen which must be purged.

The implication is that the overall capture rate is less than 90% due to the CO2 loss with the purge gas. The end-to-end system no longer meets the given constraints defined in the boundary conditions.

To achieve the >90% rate, it will be necessary to increase the rate in the amine absorption towers, increasing both the energy requirement and the equipment size. Optimising the end to end value chain is essential to avoid one process winning, at the expense of another.

Avoiding a zero-sum game

In the case above, it may be decided that the amine system should be replaced with a pressure / vacuum swing adsorption process using a solid zeolite sorbent to capture the CO2. This technique is generally able to produce CO2 of a purity of 95% cost-effectively, with nitrogen being the balance. Whilst the CO2 capture rate might be high, at 98%, the CO2 purity may be low.

However, substituting one technology for another, without consideration of full value chain implications is perilous.

The motivation for substituting the amine-based system for the VPSA unit may be sound, for example to reduce the capex or opex of the CO2 capture aspect of the process. However, the knock on effect is negative consequence to the operation of the CO2 liquefier.



Chart's Cryogenic Carbon Capture process (CCC) exploits the gas to solid deposition phase change that is unique to CO2. Image: ©Chart Inc

The electrical energy input required to liquefy CO2 of 99% purity from the amine system is lower than that required to liquefy CO2 of 95% purity from the VPSA. This is because the compressors must do un-productive work to handle additional inert nitrogen gas.

Also, the compressor discharge pressure is increased due to the presence of a higher amount of incondensable nitrogen. This also increases the energy requirement.

The net result could to be that the savings achieved by implementing the VPSA system are negated by the increased capex and opex in the liquefier compressor.

A holistic approach to optimisation

To optimize the CO2 capture technology, it makes sense to consider the requirement at the end of the CCTU/S value chain. What is the required purity of CO2? What is the required temperature and pressure condition?

If the goal is to compress supercritical CO2 into a geological storage site, and CO2 transmission is by pipeline, the CO2 capture technology can be selected to produce CO2 gas (rather than liquid) which can be compressed.

On the other hand, if the end-game is utilisation of the CO2 in an e-methanol or Fischer Tropsch e-fuels production process, and liquid CO2 will be transported by rail, there is a requirement to produce liquid CO2 at the capture location, or at a CO2 transfer terminal, where liquid CO2 can be loaded onto the train.

Cryogenic CO2 capture to the fore

If CO2 is required as a gas for transmission in a pipeline, expending additional energy required to liquefy CO2 is wasteful. On the other hand, if liquid CO2 is the requirement, the energy for liquefaction must be consumed at some point in the value chain. In this case, it makes sense to integrate CO2 capture with CO2 liquefaction. This is the essence of cryogenic CO2 capture.

The physical property of CO2 that makes cryogenic CO2 capture technically feasible is that CO2 liquefies at a much higher temperature than nitrogen and oxygen which are major components in post-combustion flue gases.

Cryogenic CO2 capture processes cool the entire flue gas stream to the point where the CO2 forms a liquid or solid, but the other components remain as gases. Several critical aspects influence the operability and energy efficiency of this process.

1) Moisture must be removed from the flue gas using a drying process, prior to cooling the flue gas below 0 °C. This is prevent water forming ice, which would block the process.

2) Nitrogen and oxygen in the flue gas are cooled along with the CO2. This serves no benefit at the outlet of the process, so the cold energy must be recovered from these gases. This is achieved using a heat exchanger to cool the incoming flue gas against the cold oxygen and nitrogen exiting the process.

3) CO2 forms a solid directly from the gas under certain temperature and pressure conditions. If solid CO2 accumulates, it will block the process. The transition of CO2 from gas to liquid must be carefully managed through appropriate process control and respect of CO2's unique phase diagram.

Several pioneers have overcome the issues associated with cryogenic CO2 capture.

SES and CCC

Sustainable Energy Solutions (SES), founded in 2008 by Dr. Larry Baxter and based in Orem, Utah. In 2020, Chart Industries acquired SES as part of their drive to focus their business towards the energy transition. Chart has since become an acquisition target for Baker Hughes.

Chart's Cryogenic Carbon Capture process (CCC) exploits the gas to solid deposition phase change that is unique to CO2. The entire flue gas stream is cooled to around -120 °C which causes deposition of CO2 as solid particles. After the solid CO2 particles are formed, they are converted into liquid CO2 through carefully controlled temperature and pressure changes.



The Ortloff process owned by Honeywell yields very pure CO2 and operates in a manner which prevents solid CO2 formation. Image: ©Honeywell UOP

During cooling of the flue gas, condensable pollutants such as oxides of sulphur (SO2) and nitrogen (NOx) are liquefied before CO2 deposits as a solid. These liquids can be separated from the flue gas. Any traces of these pollutants that flow through into the liquid CO2 are solidified and can be removed by filters.

The simultaneous removal of pollutants is a feature of CCC aligns it well with greenfield projects, because it eliminates the need for additional SO2 and NOx removal equipment.

A 1 tonne per day containerised CCC pilot plant has been used to process cement making and power plant flue gases. A 30 tonne per day demonstration plant at Central Plains Cement Company in Sugar Creek, Missouri has also been commissioned.

CarbonCloud from Revcoo

Founded in 2021 by Hugo Lucas and based in Lyon, France, Revcoo's CarbonCloud is exactly that. Cryogenic liquid nitrogen is sprayed into the pre-cooled flue gas. As the CO2 in the flue gas is cooled by the liquid nitrogen, it solidifies. The solid CO2 particles are separated from other gases in a cyclone. The solid CO2 is then warmed to yield liquid CO2.

To create the liquid nitrogen, mechanical energy is required for the liquefier compressor. This is generally provided from electrically powered motors. To maximize the energy efficiency of the process and minimize the amount of electricity required for the nitrogen liquefier, the cold flue gas leaving the cyclone pre-cools the warm incoming flue gas before it enters the CarbonCloud chamber.

Additionally, cold energy is released from the solid CO2 as it converts to liquid. This cold energy provide additional cooling for the flue gas entering the CarbonCloud.

A CarbonCloud pilot plant capable of removing 2 tonnes per day of CO2 was installed at the Eiffage lime kiln in France in 2024. Lime making releases unavoidable geogenic CO2 as limestone is converted to lime. Similar to cement, the geogenic CO2 emissions from lime making can only be decarbonized with the use of CO2 capture.

Building on natural gas processing

Cryogenic technologies for CO2 removal from natural gas have been implemented for many years. The Ortloff CO2 Fractionation / Dual Refrigerant Fractionation (DRCF) process (owned and licensed by Honeywell UOP) is ideal to liquefy and capture very high concentrations of CO2 (between 30 and 80%).

It yields very pure CO2 and operates in a manner which prevents solid CO2 formation. On the other hand, due to the vapour liquid equilibrium of the CO2 and the incondensable gases, around 15 to 20% CO2 remains in the flue gas. Where partial CO2 capture is appropriate, this is acceptable. To achieve capture rate of >90%, a polishing technology such as an amine solvent system must be used after the DRCF process.

Chart's CCC is fundamentally similar to the CryoCell process, developed in Australia by Cool Energy Ltd to remove CO2 from natural gas. ExxonMobil's Controlled Freeze Zone (CFZ) is another gas processing technology that relies on formation of solid CO2 followed by desublimation of CO2 to the liquid phase. The main difference is that CCC and CarbonCloud are optimised to remove CO2 from flue gases, not from a methane-rich natural gas stream.

More information

https://sbh4.de

Nuada and Idex partner on CO2 capture project in France

Following several successful demonstrations at pilot sites, Nuada is taking a further step forward with Idex by rolling out its process on an industrial scale.

The companies will deploy one of Europe's first industrial units for the capture and utilisation of biogenic CO2. Installed at the Kogeban biomass cogeneration plant, operated by Idex in the Hauts-de-France region, the unit is based on porous materials (MOFs) capable of filtering and trapping CO2 from flue gases.

Conor Hamill, Co-Chief Executive Officer of Nuada, said, "Following several successful demonstrations at various industrial sites, the industrial deployment of our Adspire® technology marks a decisive milestone for Nuada. Together with Idex, we will demonstrate that it is possible to capture biogenic CO2 under conditions that are viable from both a technical and economic perspective."

"Designed to be replicated at other industrial sites in France and across Europe, our technology paves the way for a more efficient decarbonisation of residual emissions."



The facility will be able to capture up to 10,000 tonnes of biogenic CO2 per year, paving the way for the roll-out of this solution at other industrial sites

Powered solely by electricity, it reduces the energy requirements of the capture process whilst eliminating the environmental risks associated with the use of chemical solvents. Compact and autonomously operated, the unit can be integrated into existing energy plants without interfering with their heat and electricity production.

Ultimately, the facility will be able to capture up to 10,000 tonnes of biogenic CO2 per year, paving the way for the roll-out of this solution at other industrial sites.

Beyond capture, the project aims to establish a new local value chain centred on two outlets for this naturally occurring CO2.

Once captured at the Kogeban site, the CO2 will be purified and liquefied to achieve a quality standard compatible with most industrial uses, particularly in the food and beverage sector. It will thus be used locally by regional manufacturers, replacing fossil-derived CO2.

Another portion of the captured CO2 will be stored in deep geological formations to prevent it from returning to the atmosphere. By removing carbon from the atmosphere that was originally absorbed by trees, this process generates so-called 'negative' emissions, a key driver for global carbon neutrality.

The project is supported by the Region's main institutional and economic stakeholders, notably the Somme Prefecture, Nord France Invest, the Communauté de Communes de l'Est de la Somme and Nesle Town Hall. It will contribute to local economic growth by creating direct skilled jobs in engineering and operations, as well as indirect jobs generated during the construction phase.

Thomas Le Beux, Chief Executive of the Idex Group, said, "The energy transition requires us to utilise every available means. Whilst our priority remains energy conservation, efficiency and the development of local, low-carbon energy sources, certain emissions call for new solutions."

"With Nuada at our Kogeban site, we are creating a genuine value chain around biogenic CO2, combining capture, local utilisation and storage. As a mission-driven company, we have a responsibility to develop innovative, replicable and value-creating solutions to accelerate the decarbonisation of territories."

More information

www.idex.fr

www.nuadaco2.com

CI4C consortium launches *catch4climate* pure oxyfuel CO2 capture facility

The goal of the project is to create the technical prerequisites for the large-scale deployment of CO2 capture technologies in the cement industry.

After seven years of intensive planning, development, and implementation the world's first of its kind research and development facility applying the pure oxyfuel process designed by thyssenkrupp Polysius has been inaugurated. The facility is intended to demonstrate how CO2 emissions from cement production can be captured energy- and cost-efficiently.

The four European cement manufacturers Buzzi SpA/Dyckerhoff GmbH, Heidelberg Materials AG, SCHWENK Zement GmbH & Co. KG, and Vicat S.A. founded the research company CI4C back in 2019 to jointly realise the "catch4climate" project. With investments of more than €120 million, a dedicated rotary kiln line with a clinker production capacity of 450 metric tons per day was built at the Mergelstetten cement plant.

The facility is the first to use the so-called pure oxyfuel process for CO2 capture and is dedicated exclusively to research and development. The project was implemented without the use of public funding.

"The start of operations marks a special milestone for everyone involved. When companies tackle shared challenges together within the framework of antitrust-approved cooperation, such forward-looking achievements become possible."

"Through 'catch4climate,' we are generating valuable insights for the future of CO2 capture in the cement industry and creating significant potential to advance climate protection," said Jürgen Thormann, Technical Managing Director of CI4C.

Around 200 guests from politics, industry, associations, academia, and the media, as well as representatives of the four shareholder companies, attended the official inauguration. Among the guests was Baden-Württemberg's Minister for the Environment, Thekla Walker. The event program included expert presentations and discussions on the challenges and opportunities of industrial transformation.



Two weeks after inauguration and following the operation of the kiln in oxyfuel mode with 100% oxygen supply, the project team achieved the first capture of high-purity CO2 as dry ice in the downstream Carbon Purification Unit (CPU)

Pure Oxyfuel Process field test

In conventional combustion processes, air is typically used as the source of oxygen. The pure oxyfuel process replaces the air with pure oxygen. This creates a highly concentrated CO2 stream, making the capture of carbon dioxide considerably easier. In the long term, the process is intended to provide the foundation for efficiently capturing CO2 and subsequently storing it or reusing it as a feedstock for other industrial processes.

In doing so, it aims to make a significant contribution to reducing process-related CO2 emissions, which are unavoidably generated during cement production. The knowledge gained will help further develop CO2 capture technologies and create the foundation for their broader deployment across the European cement industry.

In the weeks leading up to the opening ceremony, the project team had already achieved important milestones: at the end of May 2026, clinker was successfully produced for the first time. In mid-June, the first supply of oxygen to the facility took place. At the same time, the objectives of the first operating campaign were fully achieved — an important step on the way to the upcoming test phases.

Two weeks after the inauguration the team successfully demonstrated the functionality of CO2 capture under oxyfuel conditions. The achievement marks an important step in the further development of the Pure Oxyfuel process. At the same time, the result marks the completion of the second test campaign and provides valuable insights for the continued research and development of CO2 capture technologies in the cement industry.

More information

https://catch4climate.com/en

Cardinal Glass to install carbon capture at its float glass facility in Winlock

The system is expected to capture approximately 130,000 metric tons of CO2 per year and is designed to remove up to 95% of CO2 from targeted float glass manufacturing process streams.

Cardinal has issued purchase orders and paid deposits for critical and long-lead project items with operations planned for the first quarter of 2029. The project follows Cardinal's feasibility, design and engineering work with K2-CO2 of Padova, Italy.

"Cardinal has always approached environmental performance as an engineering discipline, not simply as an aspiration," said Kelly Busch, President of Cardinal FG.

"With the feasibility, design and engineering phases now complete, we are moving toward installation of this carbon capture system at our Winlock facility. This is an important milestone for Cardinal, for our customers, and for the future of lower-carbon float glass manufacturing worldwide."



Cardinal FG's float glass facility in Winlock, Washington, site of Cardinal's planned carbon capture installation. System operations are planned for Q1 2029. Image: Courtesy of Cardinal Glass Industries

Float glass manufacturing requires continuous, high-temperature furnace operations. The process produces CO2 from the energy used to melt glass and from glassmaking raw materials. The Winlock system is being developed to address both sources within targeted process streams.

Cardinal is working with K2-CO2 to integrate the capture system into the operating float glass facility. Cardinal and K2-CO2 will use the controls and measurement instruments needed to monitor system performance. The project is not currently receiving government funding.

Cardinal is exploring potential future markets for the captured CO2

Cardinal and K2-CO2 have also patented a system that enables the use of additional gases from the resulting flue gas. The work adapts carbon capture technology to the technical requirements of float glass production.

"This program builds on years of work between Cardinal and K2-CO2 to evaluate, engineer and adapt carbon capture technology for float glass manufacturing," said Alessandro Monteforte, CEO of K2-CO2.

"The Winlock installation will be an important demonstration of how carbon capture can be integrated into one of the most demanding industrial manufacturing environments."

Once the system is operating and its performance has been demonstrated, the expected reduction in embodied carbon in Cardinal glass can help customers offer products that support architects pursuing lower-embodied-carbon project requirements.

"This is not a one-time announcement; it is part of a broader roadmap," said Bowie Neumayer, President of Cardinal Glass Industries.

"The Winlock project gives us a defined first installation, a concrete operations target and the opportunity to generate the performance data needed to evaluate future deployment across additional float glass lines."

Winlock is Cardinal's first installation of this technology. It hopes to use what it learns there to support future deployment at other Cardinal float glass facilities.

More information

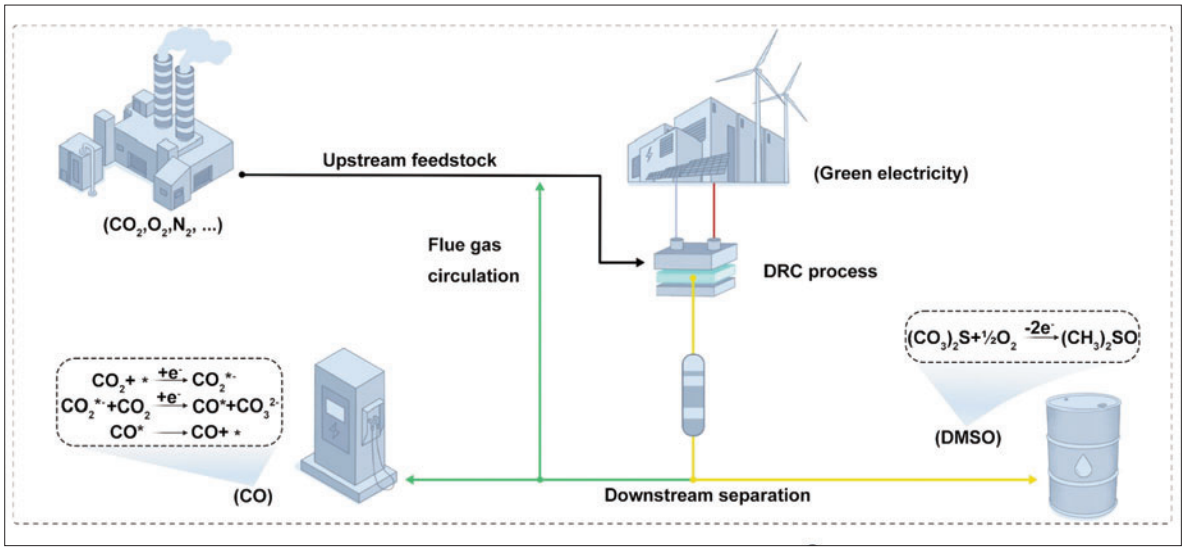
www.cardinalcorp.com

www.k2-co2.com

An organic liquid for CO2 to CO conversion without separation

The breakthrough, published in Nature Communications, overcomes one of the biggest challenges facing carbon capture technologies: the complex mix of gases found in industrial flue, a major source of global CO2 emissions.

A team led by the Université de Montpellier and Adelaide University has developed a system that uses a special organic liquid to efficiently convert CO2 from industrial emissions into carbon monoxide (CO), a key building block used to manufacture fuels and chemicals.



Schematic of the idealized process flow for the DRC of oxygen-rich flue gas streams powered by green electricity

Industrial flue gases typically contain only small amounts of CO2 alongside large quantities of nitrogen and oxygen.

These impurities have long hindered efforts to convert captured carbon into useful products because they trigger competing chemical reactions that reduce efficiency.

Most existing carbon capture technologies require CO2 to be separated and purified before it can be converted into useful products, making the process both costly and energy intensive.

Adelaide University Chemical Engineering Dean, Professor Yan Jiao, said the team has developed an organic solvent mixture that weakens hydrogen bonding, suppressing unwanted side reactions, while favouring CO2 conversion.

"Our work shows it is possible to use CO2 directly from industrial exhaust streams without extensive purification, making carbon utilisation much more practical and potentially more economical," Prof Jiao said.

"This could help heavy industries such as steel, alumina refining, cement, chemicals, and energy production move toward cleaner and more circular production."

Using a simulated industrial flue gas containing 15% CO2 and 8% oxygen, the researchers achieved almost 100% conversion selectivity to carbon monoxide.

The process consumed 30.7 gigajoules of energy per tonne of CO produced, placing it among the most competitive direct carbon capture and conversion approaches reported to date.

The technology also demonstrated strong durability, operating continuously for more than 100 hours while maintaining high performance.

To explore its renewable energy potential, the team coupled the system with a high-efficiency solar cell. The integrated setup achieved a solar-to-fuel efficiency of approximately 5.5%, comparable to many systems that rely on purified CO2 feedstocks.

Dr Damien Voiry from the Université de Montpellier said the findings highlight a promising pathway for transforming industrial emissions into valuable products while reducing the need for energy-intensive carbon capture infrastructure.

"We found that controlling hydrogen-bond interactions is the key to suppressing unwanted reactions and enabling highly selective carbon dioxide conversion," Dr Voiry said.

"This opens a new direction for carbon utilisation technologies and could help accelerate the transition towards sustainable fuel and chemical production powered by renewable energy."

More information

www.umontpellier.fr
https://adelaide.edu.au

Veolia trials C-Capture non-amine CO2 capture at Sheffield research facility

The trial tested a novel non-amine solvent originally discovered by researchers at the University of Leeds, and is currently capturing up to one tonne of carbon dioxide per day from the Sheffield facility's flue gas.

In a UK first, Veolia and Sheffield City Council in partnership with clean technology company C-Capture, trialled the technology at the Sheffield Energy Recovery Facility (ERF).

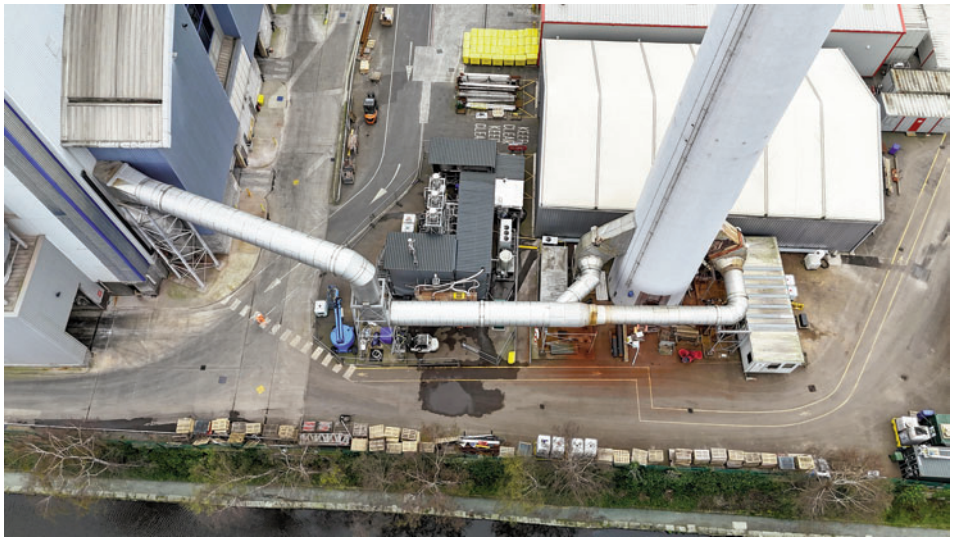
The captured CO2 will initially be released as part of the testing process, allowing engineers to assess performance, safety and efficiency of the technology. At this stage, the objective is to validate how effectively the system captures CO2 and how efficiently the solvent can be regenerated for repeated use.

The two-year trial aims to demonstrate the economic viability of scaling the technology to capture, store and utilise carbon from the waste management facility.

Greg Searle, Commercial Director, C-Capture, said, "Successfully operating our technology at the Sheffield site is a major milestone. It demonstrates not only the scalability of our non-amine approach, but also its real-world advantages in energy efficiency, cost, and safety—particularly for challenging applications like energy-from-waste facilities. Veolia has been an excellent and progressive host, providing the ideal environment to demonstrate our technology."

This demonstration project represents an important step in assessing the role that carbon capture technologies can play in decarbonising hard-to-abate emissions. It is intended as a complementary solution alongside waste prevention, increased recycling, eco-design and other measures to reduce fossil carbon entering the waste stream, rather than as a standalone answer to climate change, and forms part of the Veolia Group's wider research and development into a range of carbon capture techniques.

While the initial results are promising, this pilot also reflects the current stage of carbon capture technologies. Their large-scale deployment will depend on the availability of supporting infrastructure, appropriate regulatory frameworks, viable business models and continued public investment.



The objective is to validate how effectively the system captures CO2 and how efficiently the solvent can be regenerated for repeated use

The CCS industry is experiencing significant investment. The UK government has committed up to £21.7 billion in funding over 25 years to support the development of CCS, which it projects could add £5 billion annually to the UK economy by 2050. This funding is predominantly focused around designated carbon clusters, and given that over half of emissions occur outside of clusters this presents a missed opportunity to support dispersed industrial assets across the country that could benefit from carbon capture and utilisation technologies.

Donald Macphail, Chief Operating Officer - Treatment, Veolia UK said, "Carbon capture is one of the tools available to help decarbonise residual emissions where they cannot yet be avoided. However, achieving net zero also requires continued progress in waste prevention, recycling and circular economy solutions to reduce emissions at source. Technologies such as this are designed to complement - not replace - those priorities."

For businesses, particularly those with high energy use or hard-to-abate emissions, the trial highlights the potential for scalable, lower-cost decarbonisation solutions that can be integrated into operational sites. The modular nature of the technology means it could be deployed across a wide range of industrial facilities without fundamentally changing their existing operations.

Over time, technologies like this could help businesses to reduce exposure to carbon pricing, future-proof assets against tightening climate regulations, and unlock new commercial opportunities through the reuse of captured carbon in low-carbon fuels and materials.

More information

www.veolia.co.uk

https://c-capture.co.uk

Capture & utilisation news

Mitico and Bangchak complete carbon capture demo in Thailand

www.mitico.tech

The project was designed to evaluate Mitico's point source carbon capture technology under real operating conditions in a refinery and to explore how carbon capture can be integrated into existing industrial processes in a cost-effective and scalable way.

The system successfully captured 99% of the CO2 from varying flue gas composition for 400 h. This successful first step provides valuable operational insights and lays the groundwork for future collaboration opportunities in the region. the company said further updates on technical findings and future collaboration opportunities will be shared as development progresses.

"As industries across Southeast Asia seek pathways to reduce emissions while remaining competitive, practical carbon capture solutions are becoming increasingly important. The Mitico-Bangchak collaboration reflects a shared commitment to exploring technologies that can help address climate challenges while supporting continued economic development," said Clement Cid, PhD, CEO, Mitico.

"This demonstration allowed us to validate key aspects of our technology in a real-world environment and strengthened our confidence that affordable carbon capture can play a meaningful role in industrial decarbonization."

The project also highlighted the growing interest among industrial operators in technologies that can reduce emissions without requiring major changes to existing infrastructure. Initial findings indicate that carbon capture can be deployed as part of a broader strategy to support energy transition goals while maintaining operational efficiency.

A novel catalyst to transform CO2 into synthetic plastics

www.chem.colostate.edu

Researchers at Colorado State University have developed a process to transform naturally occurring and highly stable carbon dioxide into recyclable, high-performance materials that could replace today's plastics in many situations.

Their catalytic process, described in the journal Nature, is another step toward a circular economy that reduces plastic waste and supports environmental sustainability.

The paper describes a closed-loop platform for producing a class of new materials from inexpensive carbon dioxide. The process uses a chemical reaction to combine carbon dioxide with a reactive molecule called bicycloalkane. An organic catalyst initiates this reaction to form new chemical bonds in the product structure.

This results in durable and customizable synthetic plastics that are highly stable, meaning they can withstand stress from heat or attack from chemicals. The new material also features sought-after characteristics, such as high mechanical strength and flexibility. Crucially, the foundational building blocks of these new plastics can be recovered through recycling after their end use, as well.

Prof Chen said researchers have been searching for a way to unlock the potential of carbon dioxide for this purpose because it is naturally occurring, odorless, nonflammable, abundant and inexpensive.

"There are existing processes utilizing carbon dioxide for polymer synthesis dating back to the 1960s. The challenge has been to maximize incorporation of inactive carbon dioxide into plastic products and produce the eco-friendlier polyesters that are recyclable and degradable," he said. "Our approach unlocks the potential for carbon dioxide as a renewable and inexpensive resource to produce recyclable polyesters that also exhibit performance-advantaged and beneficial end-of-life properties."

Purem by Eberspaecher presents Direct Air Capture device

www.eberspaecher.com

At the Hydrogen Technology World Expo in Hamburg the company showcased its expanded portfolio including a DAC concept for removing CO2 straight from ambient air.

The company presented technologies spanning the entire hydrogen and CO2 value-added chain, delivering sustainable energy solutions and driving global decarbonisation forward.

Its DAC system removes CO2 from the atmosphere, thereby generating negative emissions. Ambient air flows through a reactor lined with solid sorption media that bind the carbon dioxide molecules. Once saturated, the media is heated, releasing the carbon dioxide, which is then collected in gaseous form. It can then either be stored or reused as a raw material.

It also introduced a interactive digital dashboard, which lets visitors assess the efficiency and cost of future DAC plants by selecting a location and sorbent material.

MHI extends compact CO2 capture system to larger size

www.mhi.com

www.wsew.jp

Its CO2MPACT™ compact CO2 capture system has been expanded with a new model capable of capturing up to 450,000 tonnes of CO2 per year to cover a broader range of customer needs.

Mitsubishi Heavy Industries (MHI) introduced new additions to its lineup at at CCUS EXPO that are larger than earlier models, while still following CO2MPACT™ Full-Module's mass-produced full-module concept based on the standard design.

While earlier models were capable of capturing up to 70,000 tons of CO2 per year, the new model offers a capture capacity of up to 450,000 tons per year while being designed to handle a wide range of flue gas sources (CO2 concentrations). Additionally, since the module ratio has been increased to over 90%, the efficiency of on-site work has been improved and the workload has been reduced, which traditionally accounts for a significant portion of plant construction.

As a result, the new model can shorten delivery times by approximately six to twelve months compared with conventional construction methods. The module enables delivery with a trailer on public roads and by train. This will make it possible to meet a broader range of customer needs.

Tatsuto Nagayasu, Head of CCUS, Plants & Infrastructure Systems gave a keynote speech at the EXPO on "Establishment of CCUS Value Chain by MHI"

Japanese consortium backs direct ocean capture trial on seawater

Hitachi, Mitsui O.S.K. Lines and Japan Airlines will conduct Japan's first pilot test to separate and capture CO2 dissolved in seawater on Kume Island in Okinawa.

In this pilot test, the three companies aim to confirm the applicability of DOC technology using seawater from around Kume Island, and obtain foundational data on operational challenges and environmental impacts for deployment along Japan's coast. Specifically, the test will use containerised pilot equipment installed on land on Kume Island, taking in seawater to separate CO2.

Based on the knowledge gained from this project, the three companies will explore potential applications and expansion of DOC technology, including local use of captured CO2, as well as promotional and environmental education initiatives, to contribute to the creation of a new ocean-based value concept known as the Blue Economy.

Background of the Pilot Test

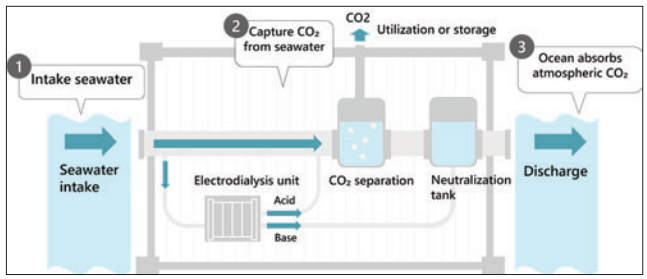
In "hard-to-abate" sectors such as shipping and aviation, where electrification alone is difficult and emissions are hard to reduce, offsetting emissions has become a key challenge alongside corporate reduction efforts.

As demand continues to grow, expectations are rising for CO2 removal technologies as a key means to address this, driving the need to establish technologies that directly remove CO2 through engineered approaches. Establishing a domestic ecosystem is also becoming increasingly important from the perspective of curbing the future cost of procuring carbon credits from overseas.

The three companies have invested in Captura Corp., a U.S.-based DOC technology developer and have been jointly exploring a domestic pilot test toward the deployment of Captura's technology in Japan by combining the expertise of each company.

The companies position this pilot test as a first step toward building an island-based, domestically self-sufficient carbon economy in which the recovered CO2 is ultimately used as a feedstock for synthetic fuels such as E-SAF.

Seawater naturally absorbs carbon until it reaches equilibrium with CO2 concentrations in the atmosphere. Artificially extracting and removing CO2 from seawater disrupts this balance, prompting the ocean to absorb more CO2 from the atmosphere to make up for the deficit. By repeating this cycle, atmospheric CO2 concentrations can be effectively lowered via the ocean.



Conceptual illustration of Direct Ocean Capture (DOC)

The concentration of CO2 in seawater is approximately 100 to 150 times higher than in the atmosphere. DOC is widely expected to be a promising climate change solution capable of capturing CO2 at lower costs and with lower energy consumption.

Roles of the Three Companies

Hitachi: Under its management plan, "Inspire 2027," the Hitachi Group has established its sustainability strategy, PLEDGES, and is leading this initiative. Using analytical instruments and characterisation methods from Hitachi High-Tech Corporation, Hitachi will measure and record operating status and water quality/environmental data (e.g., Dissolved Inorganic Carbon (DIC) and pH in seawater).

By analyzing this data and implementing 'Physical AI' that directly feeds insights back into actual plant operations, Hitachi aims to identify and control operating conditions that deliver higher energy efficiency. Furthermore, by recording and verifying data on the amount of CO2 captured and the electricity consumed, it will contribute to building an MRV data platform for generating highly trustworthy carbon credits.

Hitachi Industrial Products, Ltd. will advance studies toward developing and supplying the core equipment required for commercial plants. Through One Hitachi, the Hitachi Group aims to establish an intelligent DOC model originating in Japan.

MOL: The MOL Group positions its environmental strategy as a key initiative under its group management plan "BLUE ACTION 2035" advancing decarbonisation initiatives as an ocean-based social infrastructure company. In this pilot test, MOL will use the local foundation established through a partnership agreement with Kumejima Town, Okinawa Prefecture, to build cooperative relationships with local stakeholders and prepare the pilot environment.

JAL: As part of its Green Transformation (GX) strategy under the "JAL Group Management Vision 2035" the JAL Group has identified carbon dioxide removal (CDR) technologies as a key initiative. In this pilot test, together with Japan Transocean Air Co., Ltd. and Ryukyu Air Commuter Co., Ltd., both of which operate flights to Kumejima, the JAL Group will use regional partnerships to lead promotional activities and raise awareness of DOC technology both within and outside the industry.

More information

www.hitachi.com
www.mol.co.jp/en
www.jal.com

KAIST and MIT turn CO2 to rock for permanent marine storage

The technology converts carbon dioxide dissolved in seawater into calcium carbonate, preventing it from returning to the atmosphere and enabling permanent storage.

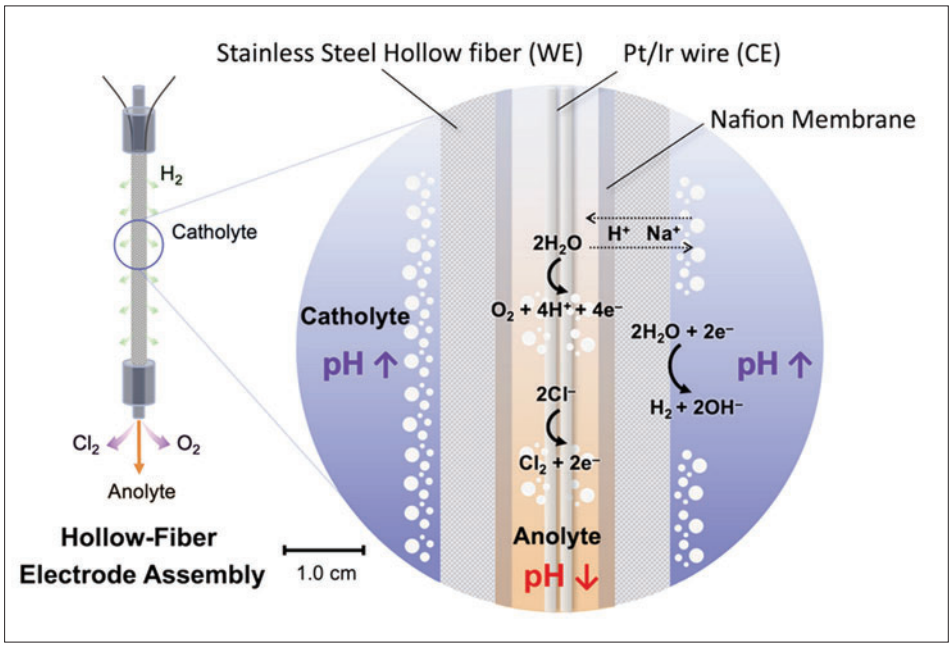
A research team led by Professor Dong-Yeun Koh from the Department of Chemical and Biomolecular Engineering, in collaboration with Professor T. Alan Hatton's group at the Massachusetts Institute of Technology (MIT), has developed an electrochemical dissolved ocean carbon removal (e-DOC) technology that converts carbon dioxide dissolved in seawater into calcium carbonate (CaCO3), a stable mineral form, enabling virtually permanent carbon storage.

The ocean is the planet's largest carbon reservoir, absorbing about 30% of the carbon dioxide emitted by human activity. Just as water naturally refills a large container when some is removed, removing carbon dioxide from seawater enables the ocean to absorb more carbon dioxide from the atmosphere.

The research team developed a technology that converts dissolved inorganic carbon (DIC), the carbon species dissolved in seawater, into a mineral form that does not return to the atmosphere. Once stored in this form, the carbon is effectively prevented from returning to the air, allowing the ocean to continue absorbing new carbon dioxide. Such technologies are gaining attention as key carbon dioxide removal (CDR) solutions for responding to climate change.

However, conventional technologies have faced a major challenge: mineral scaling. Much like limescale building up inside a kettle, minerals such as calcium carbonate adhere to electrode surfaces and clog the system. As operation continues, performance declines, requiring frequent cleaning or replacement of components and increasing both energy consumption and maintenance costs.

To overcome this issue, the research team developed a hollow fiber electrode assembly (HFEA), a device composed of bundled hollow, thread-like electrodes. In this structure, minerals form outside the electrode surface rather than directly on it, while hydrogen bubbles naturally generated during the reaction act like a brush, continuously cleaning the electrode surface and preventing mineral buildup.



Schematic Illustration of the Electrochemical Reactions in the hollow fiber electrode assembly (HFEA), a device composed of bundled hollow, thread-like electrodes

In experiments using Jeju lava seawater, the team successfully operated the device continuously and stably for more than 120 hours. The system removed 80–90% of dissolved inorganic carbon from seawater and reduced electricity consumption by up to 54% compared with existing technologies. In addition, the process simultaneously produced high-purity hydrogen (H2) and magnesium hydroxide (Mg(OH)2), a material used in eco-friendly products and industrial applications, further improving its economic potential.

The device can be produced in a compact, modular form, making it suitable for installation on ships, offshore plants, and other marine industrial facilities. The research team expects the technology to be scaled up into large-scale marine carbon removal systems that can contribute to achieving carbon neutrality and responding to climate change.

Professor Dong-Yeun Koh said, "This technology converts carbon dioxide dissolved in seawater into a mineral form that does not return to the atmosphere, nabling permanent storage and helping the ocean continuously absorb new carbon dioxide," adding, "We expect this work to accelerate the commercialization of marine carbon removal technologies and contribute to the realization of a carbon-neutral society."

This study was co-led by KAIST Ph.D. candidate Inhwan Park of the Department of Chemical and Biomolecular Engineering and Dr. Young Hun Lee of MIT, who received his Ph.D. from KAIST in 2023 and is currently affiliated with the Department of Chemical Engineering at MIT, as co-first authors.

More information

www.kaist.ac.kr/en
https://hattongroup.mit.edu
https://onlinelibrary.wiley.com

Study confirms potential of rail transport for European CO2 hub

Rail-based CO2 logistics to the Wilhelmshaven terminal are technically and operationally feasible, offering industrial companies a realistic perspective of decarbonisation from the late 2020s onwards.

How can captured CO2 emissions from industry be transported efficiently and safely to storage sites? This question was at the heart of a comprehensive study conducted by DB Cargo together with HES International, developer of the CO2nnectNow export terminal at Wilhelmshaven, Harbour Energy, a leading developer of CO2 stores in Europe, and DB InfraGO between mid-2025 and early 2026.

Industries such as cement and lime production, thermal waste-to-energy, and others face the challenge that process-related CO2 emissions cannot be entirely avoided. CCS is therefore regarded as a key component in achieving European climate targets. The study demonstrates how captured and liquefied CO2 can be transported by rail from the emitters to a central hub, the planned CO2nnectNow export terminal in Wilhelmshaven, from where it can be shipped onwards to offshore storage facilities in the North Sea.

Commissioned by the supporters of the CO2 export terminal, DB Cargo and DB InfraGO examined both the capacity of the German rail network and emitter-specific logistics concepts for eleven industrial companies. The analysis covered main lines and junctions as well as individual site conditions and potential bottlenecks.

The findings highlight the considerable transport potential: by 2030, around 11 trains per day in each direction could already operate between the emitters and the Wilhelmshaven terminal, increasing to up to 17 trains by 2033. This demonstrates not only the technical feasibility but also the scalability of rail transport for increasing volumes of CO2. For decentralised industrial sites in particular, rail can provide a long-term link to storage sites.

Torsten Lüders, Head of the Liquids & Bulk Business Unit at DB Cargo, sees the company playing a key role in the future: "We see ourselves as a European full-supply provider for CO2 logistics – from planning and equipment to safe execution. Our experience in handling sensitive goods and our European network make us a strong partner for CO2 transport and CCUS projects."

Safety, efficiency and sustainability in focus

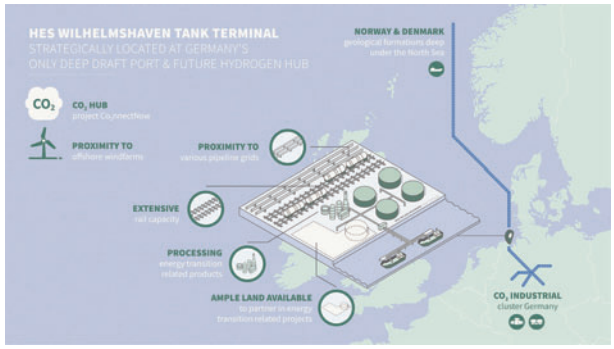
CO2 transport will take place in specially insulated tank wagons designed for cryogenically liquefied CO2. The use of dual-mode locomotives is intended to ensure the efficiency of time-critical CO2 transports. In addition, the use of Hydrotreated Vegetable Oil (HVO) on non-electrified routes can further enhance the sustainability of rail logistics.

Daniel Röder, Head of Operations at DB Cargo BTT, said: "Our established processes and the expertise of DB Cargo BTT as experienced dangerous goods specialist within the DB Cargo group ensure safety, reliability and sustainability along the entire transport cha

Wilhelmshaven as a CO2 hub

HES International is developing its existing operational Wilhelmshaven terminal into a CO2 hub under the name "CO2nnectNow". There, CO2 delivered by rail will be temporarily stored and subsequently transported by ship to various offshore storage facilities including one of Harbour Energy's CO2 storage locations. The clear division of responsibilities – terminal expansion and operation by HES, and the development of suitable storage sites by Harbour Energy – helps to develop a robust CO2 value chain and creates planning certainty for industrial companies.

Otto Waterlander, director New Energies at HES International, said, "Our Wilhelmshaven terminal is very well positioned to become one of Germany's first CO2 export hubs, because it can make use of existing rail infrastructure onsite and capacity at its existing jetty's where ships can berth from 2030 onwards.



EcoLog Terminal Amsterdam is the world's first commercial-scale liquid hydrogen import and liquid CO2 export facility

Expanding cooperation further

The study marks an important milestone, but it is only the beginning. In the coming years, the concepts are to be further refined and translated into market-ready solutions. Discussions with emitters and partners are already underway. At the same time, the regulatory framework for CO2 transport and storage continues to evolve.

The results clearly show that rail can play a central role in future CO2 transport – flexible, scalable and rapidly implementable. Moving forward, DB Cargo sees rail as part of a multimodal transport chain. With its hazardous goods expertise, its Europe-wide network and its holistic approach, DB Cargo is positioning itself as a reliable innovation partner for industrial transformation and a climate-friendly future of CO2 logistics.

More information

www.dbcargo.com/rail-de-en

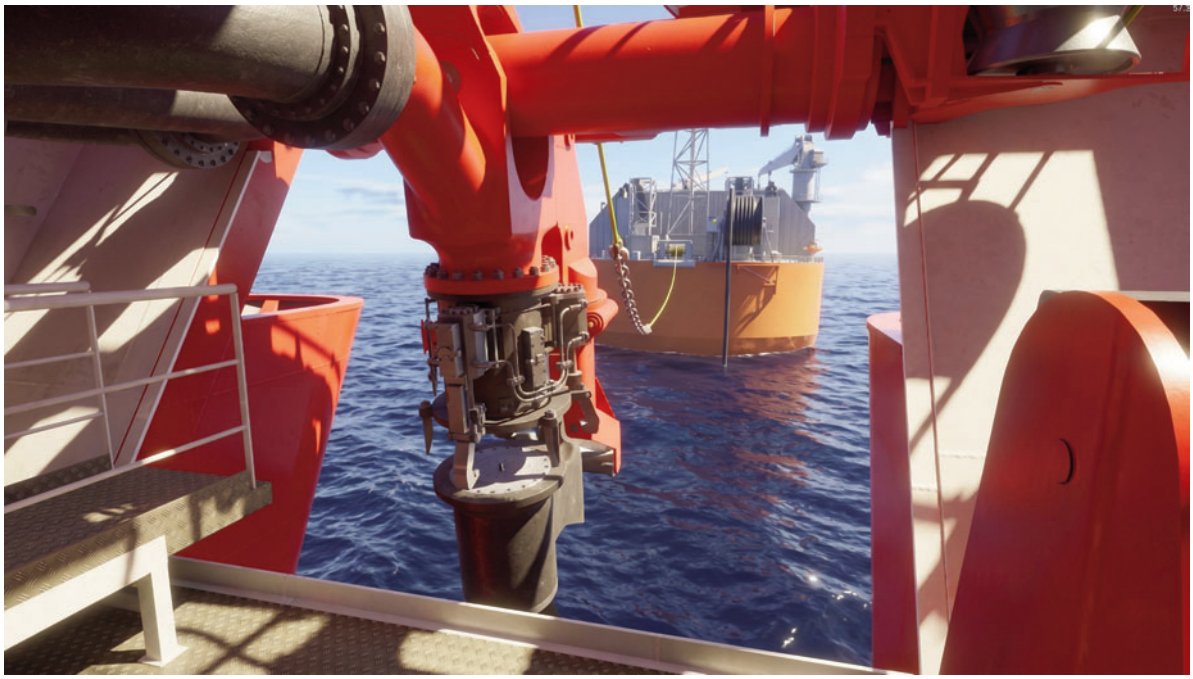
www.hesinternational.eu

MacGregor advances direct ship-to-well LCO2 transfer

MacGregor has developed a new Liquid Carbon Dioxide Bow Transfer System (BTS) to enable safe, reliable ship-to-well and ship-to-rig transfer of LCO2 across a wide range of operating conditions.

The system connects capture plants directly to offshore injection units, removing the need for the costly intermediate onshore storage and conditioning facilities that current standards often require.

The BTS builds on MacGregor's Bow Loading System (BLS), which has served the oil and gas sector reliably since the 1970s. Around 79% of the new system draws on field-proven technology, with the remainder comprising targeted modifications and newly engineered components designed specifically to handle the highly volatile properties of LCO2.



BTS connection phase view inside LCO2 carrier – the system is designed to support safe, uninterrupted handling in heavy sea states with wave heights of five to six metres

Seal materials for the system have been tested with research organisation SINTEF under rapid gas decompression and LCO2 conditions, maintaining integrity through repeated pressure cycles and temperatures as low as -57°C, the threshold below which CO2 can no longer exist in a liquid state. The system is designed to support safe, uninterrupted handling in heavy sea states with wave heights of five to six metres, and to seal against water ingress at depths of up to 150 metres.

"Our robust new design solves the challenges of securing reliable and safe connection, transfer, and disconnection in all seasons, even in severe weather, without delays or interruptions," said Øyvind Solli, Development Programs Manager, MacGregor. "This ensures zero disruption across the value chain, directly supporting the business case for CCS projects."

MacGregor's hardware is designed as the foundation for four distinct system architectures, spanning low- and medium-pressure (30–60 bar) and high-pressure (300 bar) direct reservoir injection via seabed swivels or disconnectable turrets — giving operators flexibility to match the system to their specific field requirements.

MacGregor joined the EU-funded COREu research and innovation consortium in early 2025 and is engaged in an ongoing technology qualification process with DNV.

COREu aims to accelerate the transition to a low-carbon future by demonstrating key technologies for the entire CCS value chain in Southern Europe and supporting the development of CCS routes linking emitters with storage sites in Central Eastern Europe.

The company has completed the planning phase of this process — comprising a qualification basis, technology assessment, threat assessment and qualification plan — with prototype testing and demonstration expected in mid-2027.

"At this stage, we have successfully identified all risks associated with our equipment and its application for LCO2 transfer," said Solli. "DNV has formally acknowledged these findings, and together, we have established a framework for managing and mitigating the identified risks, including the specific methods required to provide the evidence for final verification."

More information

www.macgregor.com

https://coreu.eu

Transport and storage news

LR: Applying Onboard Carbon Capture and Storage to Ships

https://maritime.lr.org/l/941163/2026-08-03/d84wq

A report from Lloyd's Register explores whether onboard carbon capture and storage (oCCS) offers a viable pathway for existing vessels through an assessment of technology, economics and regulation.

The report from Lloyd's Register's Retrofit Research Programme explores whether oCCS could provide a new pathway to reduce emissions from ships that will continue operating on carbon-based fuels for years to come. Can onboard carbon capture bridge the gap to maritime net zero?

The report covers the current status of oCCS technology – from commercially deployed amine systems to emerging technologies such as cryogenic capture, membrane separation and mineralisation including real-world deployment experience from pioneering projects including Eastern Pacific Shipping's Pacific Cobalt, Solvang's Clipper Eris pilot and Project CAPTURED.

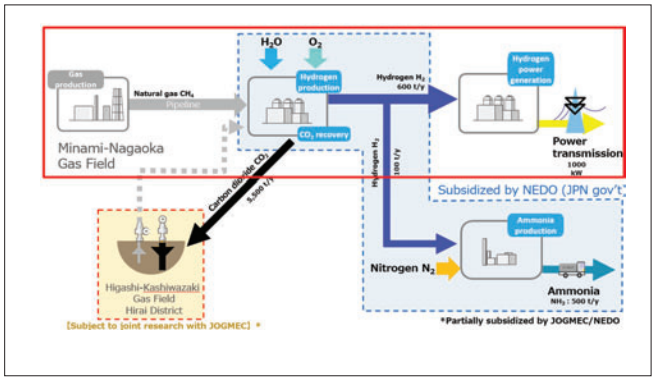
oCCS is no longer a theoretical concept. Commercial installations are already operating, pilot projects are generating valuable operational data, and the supporting carbon value chain is beginning to emerge. Yet significant technical, regulatory and commercial questions remain. The report distils complex industry developments and provides a balanced, practical assessment of where onboard carbon capture could fit into shipping's energy transition journey.

INPEX begins CO2 injection at Kashiwazaki Hydrogen Park

www.inpex.com

The CO2 is generated as a by-product of hydrogen production and injected into a subsurface reservoir in the Hirai area of the Higashi-Kashiwazaki Gas Field, where gas production has already ceased.

The operation is part of its Integrated Blue Hydrogen and Ammonia Production and Utilization Demonstration Project being conducted in Kashiwazaki City, Niigata Prefecture. The Demonstration Project is the first in Japan to integrate the entire hydrogen and ammonia value chain, from production through utilisation, involving hydrogen and ammonia as clean energy sources that do not emit CO2 during use.



INPEX's Demonstration Project is a locally integrated project based in Niigata Prefecture, where INPEX has conducted operations for many years

The commencement of CO2 injection will enable the project to reduce CO2 emissions by capturing and storing CO2 generated during hydrogen production. The feedstock gas used in the project is domestically produced natural gas from the Minami-Nagaoka Gas Field operated by INPEX in Niigata Prefecture.

In the Demonstration Project, CO2 generated from the hydrogen production facility is separated and captured using HiPACT®, a high-pressure CO2 capture technology jointly developed by JGC Global Co., Ltd. And BASF. A key feature of the technology is its ability to capture CO2 under high-pressure conditions, which is expected to reduce energy consumption and costs required for the entire CO2 capture and injection process compared with conventional technologies.

Contract signed with JOGMEC for Mizushima Cluster project

www.jfe-steel.co.jp

www.jogmec.go.jp

The project is based on a new public solicitation launched by JOGMEC to promote cost reductions in CCS projects with maritime transport by forming industrial clusters and enabling the shared use of CO2 liquefaction, temporary storage and shipping facilities.

Sumitomo Corporation, Asahi Kasei Corporation, ENEOS Corporation, JFE Steel Corporation, Mitsubishi Gas Chemical Company, Inc. and Mitsubishi Chemical Corporation have been selected by the Japan Organization for Metals and Energy Security (JOGMEC) to conduct a commissioned design work for CO2 separation, capture, liquefaction, temporary storage, and shipping facilities for 'Ship-Based Advanced CCS'.

The proposal submitted by the six companies focuses on the Mizushima industrial area in Kurashiki City, Okayama Prefecture and the companies have entered into a service agreement with JOGMEC to carry out the project.

Mizushima is home to one of Japan's largest industrial complexes, where major steel, chemical, automotive and energy industries are concentrated. Because several large-scale CO2 emitters that are difficult to decarbonise through electrification or the use of renewable energy alone are located within the industrial complex, CCS is regarded as a key solution for advancing the green transformation of the Mizushima Industrial Complex.

Taking advantage of the industrial complex's layout, the six companies will proceed with design and feasibility studies aimed at establishing a CCS value chain that enables the shared use of liquefaction, temporary storage and shipping facilities for captured CO2. Through this initiative, they aim to reduce costs by sharing facilities and to establish a model for advancing decarbonisation not on an individual company basis, but across the entire industrial complex.

The Mizushima Cluster is expected to ship approximately 3.43 million tons of liquefied CO2 annually. This would represent the largest shipping volume among the clusters currently under development in Japan, positioning the Mizushima Cluster as a key hub for advancing the commercial deployment of CCS nationwide.

Image: Evero Energy



Evero submits planning for inBECCS project