Carbon Capture Journal

CCUS in the U.S.

Carbon Capture Coalition 2025 Federal Policy Blueprint

New storage play types - research and experience

RepAir Pelican DAC hub project in Louisiana

Mar / Apr 2025 Issue 104

Ørsted's full-scale CCS project progresses

Image: Ørsted

Implications of declining clinker demand for CCS projects

From waste to wealth: multi-billion-dollar carbon removals market

Solar-powered CO_2 capture from air to make sustainable fuel

Xodus dashboard provides EU CO_2 transportation costs

Report: carbon capture possible without subsidy billions

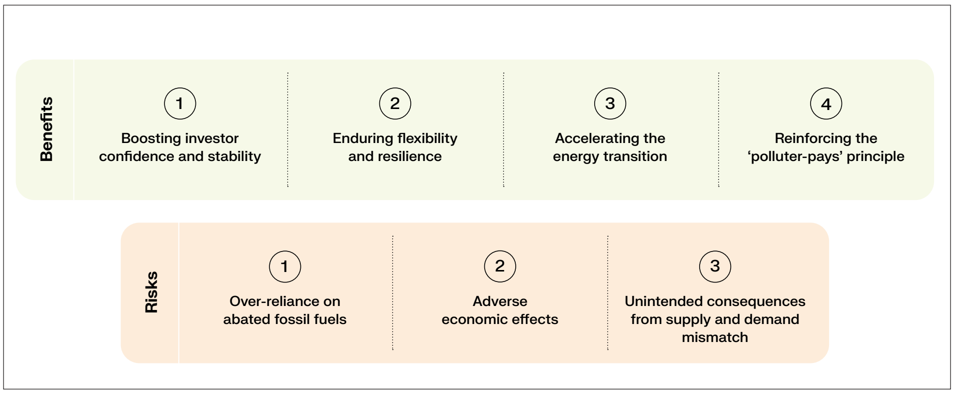
Oxford Net Zero and Carbon Balance researchers reveal the risks of the current UK CCS policy mix and explore how a carbon storage mandate on fossil fuel producers could help the UK meet its climate targets while protecting public finances.

The report addresses a critical challenge in UK climate policy: how to develop essential carbon storage infrastructure while protecting public finances. The report, authored by researchers at Oxford Net Zero and the Carbon Balance Initiative, responds to a direct call from the government to examine long-term policy mechanisms for carbon storage deployment and the Carbon Takeback Obligation (CTBO).

Meeting the UK's legally binding net zero target requires a rapid and significant reduction in fossil fuel use, alongside permanent geological CO2 storage of any residual CO2 production by 2050. This makes developing a robust and financially sustainable carbon capture and storage (CCS) industry essential for meeting climate targets. In 2024, the UK government committed £21.7 billion to kick-start CCS development. It has ambitions to store 50 megatonnes of CO2 annually by the mid-2030s – equivalent to the emissions from all UK power stations today. Reaching these targets will require billions in additional investment beyond current public funding commitments.

The research, developed through extensive consultation with over 20 senior stakeholders across government, academia, industry, and civil society, in collaboration with the Carbon Capture and Storage Association (CCSA), finds that current plans to rely primarily on the UK Emissions Trading Scheme to scale CCS from the 2030s are unlikely to attract sufficient private investment in carbon storage, potentially jeopardising our net zero targets and prolonging the CCS industry reliance on government subsidies beyond current funding commitments.

The authors explore an alternative policy scenario: requiring fossil fuel suppliers to permanently store a rising percentage of their CO2 emissions – such as through a Carbon Takeback Obligation. This approach could create a self-sustaining storage market while gradually reducing dependence on public funding. The authors find that storage mandates could be particularly effective if combined with complementary demand management measures such as carbon pricing.



Overview of Benefits and Risks: 'Base-Case'+ Scenario. The 'Base Case+' scenario combines a marketwide ETS and CfD revenue support for CO2 capture sites with an upstream CTBO on all fossil fuel producers and importers to drive CCS deployment

"The new Labour government faces tough choices about public spending across many sectors," said Mirte Boot, UK Director of Carbon Balance and report author. "Our research shows that, with the right policy design, the government could create a clear investment case for CCS and GGR without pushing the costs for CO2 clean-up onto taxpayers," added Ingrid Sundvor, report author and Executive Director of Carbon Balance.

The authors caution that careful policy design and further research are needed, particularly to address the potential impacts and implementation challenges of any storage mandate on UK industrial competitiveness, energy security, consumer costs, and the risk of carbon leakage. The authors emphasise any carbon storage mandate would need to align with a trajectory of fossil fuel phase-out and a broader energy transition.

"The fossil fuel industry has the resources to deliver the storage capacity we need," said Professor Myles Allen, report author and Oxford Net Zero Principal Investigator. "Making this a condition of their continued operation provides a practical pathway to net zero. Further policy development on this is urgently needed."

Professor Stuart Haszeldine from the University of Edinburgh, who reviewed the report, added "The world heated ever-faster in 2024 – we are losing the climate fight. Commercial carbon storage has started, but models show it will need to develop 100 times faster to protect net zero. But without change, these grant-funded projects may be the last. The Government must look at a supply-side obligation that integrates the cost of CO2 storage into wholesale fossil fuel prices."

More information

Read the full report at:

https://netzeroclimate.org

www.carbon-balance.earth

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

Editor
Keith Forward
editor@carboncapturejournal.com

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

Subscriptions
subs@carboncapturejournal.com

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

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Front cover: Ørsted will capture 150,000 tonnes of biogenic carbon per year from the straw-fired unit at Avedøre Power Station as part of the Ørsted Kalundborg CO2 Hub Project (pg. 21)

Back cover: SAMSUNG E&A will optimise a Carbon Clean carbon capture module for a MODEC FPSO vessel as a pilot (pg. 32)

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Leaders - CCUS in the U.S.

Projects and policy

Capture and utilisation

Transport and storage

New CO2 storage play types - research and experience from the U.S.

We normally think of only two CO2 storage "play types" – the aquifer and depleted oil and gas field. But a better understanding of how CO2 flow can be restricted in the subsurface leads to two more play types, said Dr. Alexander P. Bump. report by Karl Jeffery.

There are more possible CO2 storage "play types" when we consider areas of subsurface which will allow pressure to dissipate quicker or will encourage horizontal flow.

Dr. Alexander P. Bump, Research Associate Professor at the Bureau of Economic Geology at The University of Texas at Austin explained more, speaking at the Geoscience Energy Society of Great Britain (GESGB) CCS for Geoscientists (CCS4G) event in London on December 17.

One "play type" is where we know we can contain a large plume without increase in pressure over a wide area because the reservoir has high permeability. The other "play type" is where there are multiple changes in grain size going vertically which will encourage CO2 to flow horizontally.

Dr Bump said he had come to CCS with a background in petroleum exploration, thinking that he should know how it works. The answer, he said, is "sort of". While an understanding of resources, traps and seals is indeed helpful in CO2 storage, there are many differences, he said.

A key difference is that CO2 storage has a different goal to petroleum exploration – keeping something permanently in the ground, rather than getting it out.

Also, CO2 storage projects have very marginal economics, with small price increases making a project unviable, he said.

Another difference is that CO2 storage only works in a certain depth "window" governed by pressure. CO2 is injected in supercritical form (where it behaves partly like a liquid, without requiring cooling), which normally means depths of above 800m. But there is no need to consider very great depths because of the higher compression costs which would be involved. Hydrocarbons in contrast can be produced from a much wider range of depths.

"Play based exploration" approach

Oil and gas explorers look for the best "plays", seeking an opportunity which does well on multiple factors, such as reservoir quality, seal and pressure.

A similar approach could be used when seeking CO2 storage sites, where you seek storage sites with the lowest cost, from considering multiple factors.

The biggest cost factors are likely to be how many wells are required to inject a certain volume of CO2.

Dr Bump has drawn a map of the Gulf Coast showing which areas CO2 storage could be done with minimal costs, low costs or moderate costs. Much of the area is coloured green, indicating minimal costs. "We have widespread quality storage," he said.

The question with CO2 storage is not 'could it work', but 'how many wells would it take,' he said. "We could make it work wherever we want."

Companies might be better off using "good enough" storage very close to where the CO2 is being emitted, rather than seeking "perfect" storage thousands of miles away, where high CO2 transport costs would be incurred, he said.

Old wells

A bigger potential problem than geology might be the legacy wells, or as he put it, "1.1m 'holes' in the subsurface geology."

These could create risks of CO2 leakage, if they are not sealed properly.

To get a US CO2 storage permit, you need to identify all the legacy wells in the region of

"Pressure space, not pore space, is the key subsurface commodity" - Dr. Alexander P. Bump, Research Associate Professor at the Bureau of Economic Geology at The University of Texas at Austin

your proposed storage and determine if they are safe or what is required to make them safe.

Or to express in more detail, one of the steps in the Class VI well application process is determining the "Area of Review" (AoR). CO2 injection will increase subsurface pressure over a large area, and it is important to ensure there are no legacy well leakage risks in this region.

It is worth noting that of the 100 CO2 storage projects on the Gulf Coast, not one is in an old oil and gas field, he said.

Propagating pressure

When seeking to understand what happens in the subsurface during injection, the biggest concern is not necessarily about the CO2 plume itself, but the increased pressure around it, as the CO2 displaces other fluids in the subsurface. These fluids could find their way into old wells which are not sealed properly, or cause fractures.

"Pressure space, not pore space, is the key subsurface commodity," he said.

The higher the available pore volume for CO2 in the subsurface, the smaller the volume of subsurface seeing a high increase in pressure, because there is more volume available close to the CO2 plume to absorb the pressure.

How CO2 flows

The University of Texas has been researching how CO2 flows through a reservoir. While it might be expected to always flow upwards from the injection point due to buoyancy, experiments show that it will also seek the easiest path through a reservoir. This means that if there are layers of medium and coarse-grained sand, it will stay in the most porous and permeable coarse-grained sand layer.

"With the first reduction in grain size, it says, 'I'm going laterally,'" he said.

An experiment was done with physical models to compare CO2 flow through the same volume of sand all of the same grain size, and the other with sand of mixed grain sizes.

The time for CO2 to break through at the top was 6.5 minutes with the same grain size, and 55 hours with mixed grain sizes.

In other models, the CO2 is lost out of the side, it never goes vertically to the surface.

It indicates that it may be possible to immobilise industrial volumes of CO2 in a reservoir even without any seal.

In the Gulf Coast, occasionally there is oil and gas produced from sands which are not covered by seals.

A system of sands with multiple layers with different grain sizes provides continuous barriers.

This could be a classic "nightmare reservoir" if the goal is oil and gas production, but if the goal is sequestration it can be wonderful, he said.

Asked whether regulators would be satisfied with CO2 storage without a seal, Dr Bump replied that some individuals from regulators are quietly saying, "we're open to the idea."

They say, "show us that it works. Push your models to failure – find out what it takes to make these seals fail".

ExxonMobil's research

Jenny Joyce, senior principal geoscience at ExxonMobil explained how CO2 storage research is being done at many different 'scales' – from how CO2 enters pores, to how plumes interacts with faults and develop in a reservoir, and how to monitor CO2 in storage.

Companies are building more realistic heterogenous models to study it and gathering more monitoring data.

Pore scale research looks at the wettability of pores, their preference to be in contact with one fluid rather than another. It found that pores which are "water wet" can hold CO2. But further studies are being done, using NMR (Nuclear Magnetic Resonance) technology, molecular simulations, and studying fluid flow in core samples.

Jenny Joyce, senior principal geoscience at ExxonMobil

Research is being done to see if high salinity brine can migrate up faults. Faults are often surfaces and can be a migration pathway for hydrocarbons.

A digital model was created with 1.6mtpa CO2 being injected into an aquifer over 10 years, with an inspection well 1.5 miles away from the fault, to see what would happen over the next 1000 years.

The study aimed to find out if the pressure increase in the aquifer would push brine into the fault.

The model suggested that the CO2 would not reach the fault over the 10-year period, but brine (displaced from the aquifer by the CO2) would reach the fault. However, it would not percolate up the fault and would not reach a modelled hypothetical drinking water aquifer close to the surface.

Understanding the impact of permeability can be much harder than stratigraphy, she said. Studies are being made into how the migration of the CO2 plume is affected by pressure, temperature and salinity.

In her models the best reservoir is "deep, cold and fresh", she said. "Deep" is because pressure increases with depth, and at higher pressure CO2 is denser and more compressed, so has lower buoyancy and viscosity contrast with brine. "Cold" is because CO2 is denser in colder temperatures. "Fresh" (meaning low salinity, like fresh water) is good because water with less salt allows more CO2 to be dissolved in it, thus keeping the CO2 plume smaller.

Ms Joyce also discussed developments in CO2 monitoring technologies. 4D seismic might be the best, but it can be very expensive, to the point where its use can make a CO2 storage project not financially viable, she said.

Another possibility is monitoring for "ground heave" using satellite radar data. The ground movement from CO2 storage will be tiny, such as 38mm movement over 80 years of injection, but this can be detected by InSAR satellite radar data.

Digital reservoir models

ExxonMobil is also researching ways to better characterise the heterogeneity of a reservoir with digital models, she said. "We always have an incomplete picture of the subsurface."

If you start by building a geological model with known features such as channels and fields, it might "look right", but it can be very hard to match with your data.

If you start by building a probabilistic model, you can make a model which matches the data, but it doesn't look like geology.

Another possibility is to use AI. Ms Joyce talked about machine learning frameworks called "generative adversarial networks" (GAN), where new data can be generated with the same characteristics as a training set. For example, it can be used to generate images of a human face which can look very realistic.

Applied to geology, it can build a geological model which "looks right" as geology, and also matches the available data. It needs to be trained on many 3D geological models, such as where an analysis has been made of a rock outcrop, or how fluids flow in the subsurface.

More information

More about the event at:

www.ges-gb.org.uk

Carbon Capture Coalition publishes 2025 Federal Policy Blueprint

The blueprint is a consensus-based roadmap of essential, common-sense policy, regulatory, and implementation recommendations for the 119th Congress and the new administration to support the rapid, responsible scale up of carbon management technologies nationwide.

The Carbon Capture Coalition is the national voice for carbon management technologies, working to enact and implement the necessary supportive domestic policy framework to enable the economy-wide, commercial-scale deployment of carbon management technologies. It is a nonpartisan collaboration of more than 100 companies, unions, conservation organisations, and environmental policy organisations.

"Since 2019, before the beginning of each Congress, Coalition members have successfully worked together on a consensus basis to develop a set of policy recommendations for carbon management technology deployment," explained Carbon Capture Coalition Executive Director Jessie Stolark.

"As a consensus-based organisation focused on achieving durable, effective policies for the scale up of carbon management, our broad, diverse membership stands behind this resource as an essential policy roadmap because they helped to develop it. These recommendations, if enacted, will spur continued deployment of carbon management technologies to reach commercial scale in the next decade," Stolark continued.

Carbon management policy has been a rare bright spot in energy and environment policy in the US over the past decade, garnering support from Republicans and Democrats alike. Supportive policies, including the 45Q tax credit, have been included in some of Congress's most significant legislative achievements. However, inflation and other

Title	Year Enacted	Main Carbon Management Provisions
Inflation Reduction Act (IRA)	2022	Contained crucial enhancements to the foundational section 45Q tax credit, including increased credit values, a direct pay mechanism, extension of the commence construction window and reduced capture thresholds.
Creating Helpful Incentives to Produce Semiconductors Act (CHIPS and Science Act)	2022	Created authorizations for several relevant carbon management programs.
Infrastructure Investment and Jobs Act of 2021 (IIJA)	2021	Appropriated $12.1 billion for large-scale demonstration and commercial deployment of carbon management technologies.
Utilizing Significant Emissions with Innovative Technologies Act (USE IT Act)	2020	Made carbon transport and storage infrastructure eligible for the permitting review process created under Title 41 of the Fixing America's Surface Transportation Act (FAST-41). Directed Council of Environmental Quality to address federal permitting of carbon management, including creation of two permitting task forces.
Furthering carbon capture, Utilization, Technology, Underground storage, and Reduced Emissions (FUTURE Act)	2018	Restructured and significantly expanded the 45Q tax credit, increasing credit levels, extending the commence-construction deadline, and making 45Q accessible to a wider variety of technologies, including heavy industry, carbon reuse, and DAC.

Existing supportive framework for carbon management

2025 FEDERAL POLICY RECOMMENDATIONS

Ensuring Investment Certainty

1. Adjust 45Q for inflation starting immediately.
2. Secure the diversity of carbon management projects needed.
3. Achieve increased commercial deployment and reduce regulatory barriers to reused carbon.
4. Ensure direct pay mechanisms work as intended.
5. Implement the full range of enhancements to the 45Q tax credit.

Transport and Storage Infrastructure

1. Improve the efficiency of our permitting system.
2. Create an optional federal siting authority pathway for CO_2 pipelines.
3. Enact further commonsense safety measures for CO_2 pipeline operators.
4. Ensure Class VI program provides regulatory certainty to project developers.
5. Clarify regulations for geologic storage of CO_2 on federal lands and the Outer Continental Shelf (OCS).
6. Retool the Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA) program to increase its appeal to investors.

Market Development

1. Collect data on the emissions intensity of domestically produced goods.
2. Explore trade mechanisms and how they can help the US capitalize on its carbon advantage.
3. Establish standards to expand the use of carbon marketplaces.
4. Support procurement efforts for carbon management technologies.

Next-Generation Technology Development

1. Implement carbon storage provisions from the IIJA.
2. Provide targeted support for crucial technologies to achieve commercial liftoff.
3. Create a technical assistance program for carbon reuse project developers to engage with communities.
4. Provide adequate funding through appropriations for next-generation carbon management technologies.

economic factors have created headwinds for deploying these technologies. These economic pressures necessitate additional policies to ensure these technologies can continue contributing to America's economy while supporting energy and environmental goals.

"Despite impressive progress over a few short years, the sectors that make up the carbon management value chain face significant headwinds to maturing and deploying nationwide. Without enhancements to the existing policy framework, we risk not only the commercialization of projects already in the pipeline but the broader deployment of these technologies across sectors," said Stolark. "These policies mark the beginning, not the end, of the efforts to build the portfolio of necessary federal policies for the economywide deployment of carbon management technologies," Stolark added.

Recent federal and private sector investment has helped spur the announcement of more than 270 carbon management projects nationwide. The Coalition's blueprint contains a set of recommendations for the 119th Congress, including addressing growing inflationary pressures, improving permitting systems across the value chain, expanding markets, and investing in innovative, next-generation carbon management technologies to help ensure these projects and this industry come to fruition.

The suite of recommendations is designed to help safeguard the US's global position, meet growing energy demand, and drive economic growth and stability in energy regions across the country.

"This blueprint offers a pragmatic roadmap to ensure America's leadership position in carbon management technology deployment. Congress and the administration now have the opportunity to solidify and grow the role of American leadership in developing and deploying these technologies so they can scale economywide throughout the remainder of this decade and beyond," Stolark concluded.

Conclusion

Carbon management technologies, which include capturing carbon from power generation facilities and heavy industrial sites as well as directly from the atmosphere, paired with carbon reuse, transport, and storage, are crucial tools for balancing the increasing need for affordable, reliable energy that drives the American economy with the global imperative to reduce carbon emissions. Together, they are an enabling technology platform for the production of cleaner energy and materials and are important in the effort to continue growing our economy and providing Americans with family-sustaining jobs.

The Coalition's 2025 Federal Policy Blueprint draws on the consensus of its more than 100 members spanning companies, labor unions, and conservation and environmental nonprofits to outline a necessary federal policy and regulatory agenda for the nationwide deployment of carbon management technologies.

These recommendations are needed to close the growing deployment gap for carbon management technologies domestically and retain the United States' global leadership in the development and commercial deployment of these technologies. Congress and the administration now have the imperative to ensure that the more than 270 publicly announced carbon capture, direct air capture, CO2 transport, and storage projects move toward construction by addressing gaps in the available policy framework.

More information

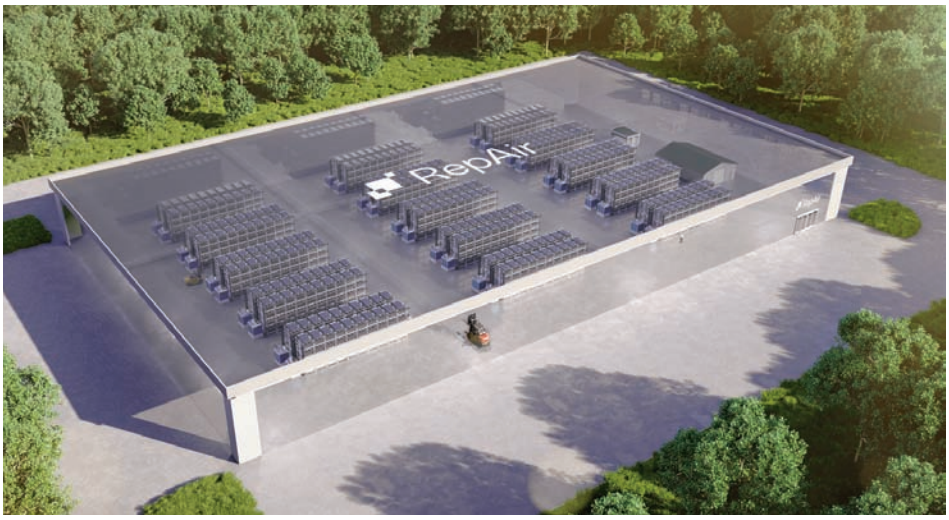
Read the full blueprint at:

https://carboncapturecoalition.org

RepAir Carbon reaches agreement for Pelican DAC hub project in Louisiana

A commercial agreement was signed with Shell US Gas and Power and Mitsubishi to act as a key technology provider for the Gulf Coast Carbon Removal DAC Hub (Pelican), a project to evaluate the feasibility of building a direct air capture facility in Louisiana.

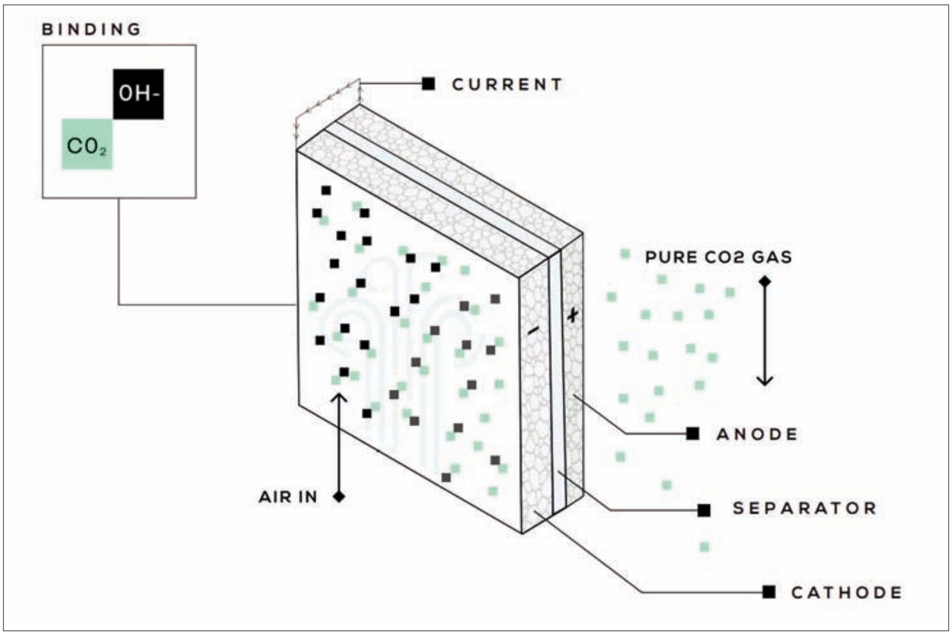
Under the agreement, Shell and Mitsubishi Corporation will provide RepAir with up to $3 million in development funding, contingent upon delivery of project milestones, to accelerate engineering and manufacturing capabilities for RepAir's proprietary electrochemical DAC technology, to be piloted within Pelican.



A RepAir DAC facility

Pelican is an early-engineering study that evaluates what is required to deploy DAC technologies at commercial scale, starting with an initial capacity of CO2 removal and scaling to higher capacity with time. The study has received grant funding from the US Department of Energy's DAC hub program, aligned with the US Department of Energy goal to establish large-scale carbon removal infrastructure. The partners share an ambition to assess potential for RepAir's technology and future scaling.

"This project is another milestone in scaling next-generation carbon removal technology," said Amir Shiner, CEO of RepAir Carbon. "Through this agreement with two global energy leaders, we're accelerating our transition to commercial-scale manufacturing. This will establish us as a key equipment supplier in an ambitious carbon removal project targeting hundreds of kilotons of annual capture capacity by 2030, in a market expected to reach hundreds of millions in value. The timing is significant, as we see major carbon management projects advancing globally, demonstrating growing market confidence in technological solutions for decarbonization."



How the RepAir technology works

Pelican's location in the U.S. Gulf Coast region allows access to extensive CO2 storage capacity, and established infrastructure. The location's humidity levels are optimal for the performance of RepAir's technology.

RepAir said its technology represents a fundamental advance in carbon capture, consuming just 600 kilowatt-hours of electricity per ton of CO2 removed - 70% less energy than conventional methods. The system operates without liquids or solvents at ambient temperature, making it ideal for mass manufacturing and deployment.

More information
www.repair-carbon.com

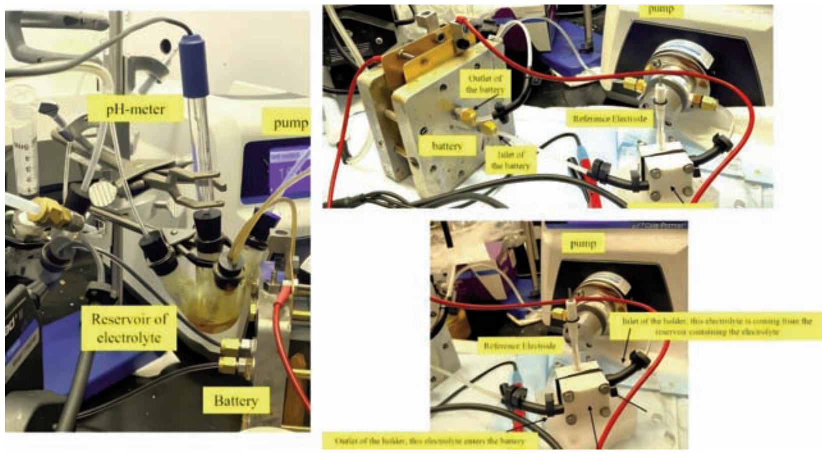
Harvard scientists pioneer quinone carbon capture

Researchers from the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) have developed carbon capture systems that use molecules called quinones, dissolved in water, as their capturing compounds.

Existing carbon capture technologies, such as amine scrubbing, are hard to deploy because they require significant energy to operate and involve corrosive compounds.

A new study in Nature Chemical Engineering provides critical insights into the mechanisms of carbon capture in these safer, gentler, water-based electrochemical systems, paving the way for their further refinement.

Led by former Harvard postdoctoral fellow Kiana Amini, now an assistant professor at University of British Columbia, the study outlines the detailed chemistry of how an aqueous, quinone-mediated carbon capture system works, showcasing the interplay of two types of electrochemistry that contribute to the system's performance.



Quinone-mediated electrochemical carbon capture experimental setup

The study's senior author is Michael J. Aziz, the Gene and Tracy Sykes Professor of Materials and Energy Technologies at SEAS. Aziz' lab previously invented a redox flow battery technology that uses similar quinone chemistry to store energy for commercial and grid applications.

Quinones are abundant, small organic molecules found in both crude oil and rhubarb that can convert, trap, and release CO_2 from the atmosphere many times over. Through lab experiments, the Harvard team knew that quinones trap carbon in two distinct ways. These two processes happen simultaneously, but the researchers have been unsure of each one's contributions to overall carbon capture – as if their experimental electrochemical device were a black box.

"If we are serious about developing this system to be the best it can be, we need to know the mechanisms that are contributing to the capture, and the amounts … we had never measured the individual contributions of these mechanisms," Amini said.

One of the ways dissolved quinones trap carbon is a form of direct capture, in which quinones receive an electrical charge and undergo a reduction reaction that gives them affinity to CO_2. The process allows quinones to attach to the CO_2 molecules, resulting in chemical complexes called quinone-CO_2 adducts.

The other way is a form of indirect capture in which the quinones are charged and consume protons,which increases the solution's pH. This allows CO_2 to react with the now-alkaline medium to form bicarbonate or carbonate compounds.

The researchers devised two real-time experimental methods for quantifying each mechanism. In the first, they used reference electrodes to measure voltage signature differences between the quinones and resulting quinone-CO_2 adducts.

In the second, they used fluorescence microscopy to distinguish between oxidized, reduced, and adduct chemicals and quantified their concentrations at very fast time resolutions. This was possible because they discovered that the compounds involved in quinone-mediated carbon capture have unique fluorescence signatures.

"These methods allow us to measure contributions of each mechanism during operation," Amini said. "By doing so, we can design systems that are tailored to specific mechanisms and chemical species."

The research advances understanding of aqueous quinone-based carbon capture systems and provides tools for tailoring designs to different industrial applications. While challenges remain, such as oxygen sensitivity that can hinder performance, these findings open new avenues for investigation.

The research was supported by the National Science Foundation and the U.S. Department of Energy.

More information
https://seas.harvard.edu

LLNL supports CO2 storage in California's delta

A project to develop a regional CO2 storage hub in California's Sacramento-San Joaquin Delta in California has received U.S. Government funding.

The U.S. Department of Energy's Office of Fossil Energy and Carbon Management (FECM) has awarded $6 million to Lawrence Livermore National Laboratory (LLNL) researchers, as part of a $45.2 million award to a team led by Pelican Renewables LLC, to develop a regional CO2 storage hub in California's Sacramento-San Joaquin Delta in California.

The funding came through FECM'sCarbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative, which aims to reduce technical risk, uncertainty and the cost of commercial-scale geologic CO2 storage projects. The project was one of nine selected for CarbonSAFE Phase III funding, which is reserved for those projects that have passed feasibility criteria and are ready for site characterization and permitting.

The Class VI injection wells and related infrastructure will be located on Rindge Tract, an island in the Delta 7 miles from the Port of Stockton

The Pelican Carbon Sequestration Project begins at the Port of Stockton, where the company's ethanol facility with existing carbon capture technology is located. From here, the CO2 will be transported by barge to two Class VI injection wells for permanent geologic sequestration on Rindge Tract, an island in the Delta seven miles from the Port of Stockton.

"Decades of research, including research done by LLNL, indicate that the Delta region of the Sacramento Basin is highly suitable for geologic CO2 storage and that CO2 storage is a critical technology to addressing climate change," said Briana Schmidt, the principal investigator (PI) and group leader of LLNL's Energy & Carbon Management Group. "This award is a huge step toward building one of the first commercial scale CO2 storage projects in California."

LLNL has established itself as a world-leading research institute on CDR, both through basic and applied scientific research to develop these technologies and assessing how state and national climate goals can be met by applying these technologies, including through a series of recent reports: Getting to Neutral; Carbon Negative by 2030; Permitting Carbon Capture & Storage Projects in California; Sharing the Benefits; and Roads to Removal.

LLNL's role on the project includes geologic and reservoir modeling using LLNL's GEOS simulator, which is necessary for the EPA Class VI permit that ensures the CO2 will be safely stored underground permanently.

"The research team here has spent years studying the behavior of CO2 in the subsurface and how best to optimize a storage system for safety and performance. It is so exciting to see this work pay off in real projects," said Joshua White, LLNL's Atmospheric, Earth and Energy Division leader, who has led several of the modeling studies supporting Pelican Renewables' permit application.

LLNL's other role on the project, led by Kim Mayfield, staff scientist in the Energy & Carbon Management group at LLNL, is supporting the Stockton non-profit, Restore the Delta (RTD), in their role as the project's Community Benefits Plan (CBP) lead.

"CBPs are still relatively new," Mayfield said. "They are best led by a community organization that is local to the project, but non-profits in under-resourced areas, like Stockton, do not necessarily have expertise on staff to carry out large new projects like CarbonSAFE alone; this is where the Lab comes in."

LLNL will assist RTD in the design and construction of a publicly-accessible, near-surface monitoring network for the project, which will give visitors to the site the chance to collect their own soil and porewater chemistry data to verify the absence of CO2 leakage themselves.

"The level of trust necessary to work collaboratively on this CarbonSAFE's CBP did not happen overnight," Mayfield said. "However; it was built over several years through projects like the DOE FECM Communities Local Energy Action Program (LEAP) pilot, the DOE Office of Technology Transition-funded Umbrella Monitoring, Reporting, and Verification project, and the DOE Office of Science-funded San Joaquin Valley Climate Resilience Center, all of which involve community engaged research in the Delta, Stockton and RTD on the topic of carbon management."

More information

www.llnl.gov

U.S. news

DOE invests $101M to establish CCUS test centres

www.energy.gov

Five projects will help establish test centres to cost-effectively research and evaluate technologies to capture and convert carbon dioxide into products from utility and industrial sources or remove carbon dioxide from the atmosphere.

The five projects will support the development of CO2 capture, removal, and conversion test centres for cement manufacturing facilities and power plants.

"Carbon management technologies such as carbon capture can significantly reduce emissions from fossil energy use and key industrial processes, like cement production," said Brad Crabtree, Assistant Secretary of Fossil Energy and Carbon Management. "By investing in test centers, we are helping reduce barriers to commercial scale deployment of carbon capture, conversion, and removal technologies that will ultimately help reduce pollution and create jobs."

Establishing test centres of various sizes that use varying feedstocks from different industries can help establish and improve the efficacy and performance of carbon capture technologies. Each of these projects will enable economical and environmentally sustainable carbon management:

The Board of Trustees of the University of Illinois (Urbana, Illinois) plans to develop the conceptual design, business, technical and managerial structures for a test center to evaluate and accelerate carbon capture, removal, and conversion technologies in the cement industry.

Holcim US (Chicago, Illinois) plans to establish a domestic Cement Carbon Management Innovation Center at its Hagerstown Cement Facility in Maryland and explore the feasibility of the testing center location, ownership structure, business model and technology partners.

Southern Company Services, Inc. (Birmingham, Alabama) intends to maintain and operate the National Carbon Capture Center, a comprehensive test facility capable of evaluating CO2 capture, removal, and conversion technologies under electric generating plant operating conditions.

University of North Dakota Energy & Environmental Research Center (Grand Forks, North Dakota) plans to enhance its existing CO2 capture, removal and conversion test center to rapidly and cost-effectively test more technologies under relevant power plant operating conditions.

University of Wyoming (Laramie, Wyoming) plans to expand the existing Wyoming Integrated Test Center's capabilities to accommodate a wider range of carbon management technologies, simulating emissions from natural gas and industrial facilities.

Project funding is subject to appropriations. DOE's National Energy Technology Laboratory (NETL), under the purview of FECM, will manage the selected projects.

Baker Hughes and Frontier partner on CCS projects

www.bakerhughes.com

https://frontierccus.com

Frontier's SCS Hub, spanning nearly 100,000 acres in Wyoming, will provide open-access CO2 storage for industrial emitters and ethanol producers using its CO2-by-rail strategy

Baker Hughes will provide key CCS and power generation technologies, including CO2 compression, well design, and its industrial NovaLT™ gas turbines to support power solutions for data centers and industrial customers.

"Baker Hughes is committed to delivering innovative solutions that support increasing energy demand, in part driven by the rapid adoption of AI, while ensuring we continue to enable the decarbonization of the industry," said Lorenzo Simonelli, chairman and CEO of Baker Hughes. "Working with Frontier Infrastructure represents a significant opportunity to demonstrate how Baker Hughes' portfolio is uniquely positioned to support CCUS projects for lower-carbon industrial and energy development."

Frontier is leading the development of the Sweetwater Carbon Storage Hub, one of the largest open-source carbon sequestration assets in the country. Spanning nearly 100,000 acres in Wyoming, the hub is designed to support industrial emitters across the region and ethanol facilities across the Midwest using its CO2-by-rail strategy. Frontier currently holds three Class VI permits and has commenced drilling activities on its first wells with first injection commencing year-end 2025.

As part of the agreement, Baker Hughes will provide technology solutions to support the development of the SCS Hub and future infrastructure projects. Using its key technologies for well design, CO2 compression, and long-term monitoring, Baker Hughes will help optimise project execution, allowing Frontier to move forward with greater efficiency and financial certainty.

Frontier is also expanding its infrastructure footprint with the development of 256 megawatts (MW) of gas-fired generation, designed to meet the increasing power demands across Wyoming, the broader Mountain West, and Texas — particularly driven by the rapid expansion of data centers and industrial operations. Baker Hughes' industrial NovaLT™ gas turbines will be deployed to support power generation, ensuring efficient and flexible energy delivery for Frontier.

"With energy demand rising across the country, industrial customers need scalable, low-carbon solutions, and Frontier's expanded infrastructure will deliver exactly that," said Robby Rockey, president and co-CEO of Frontier Infrastructure. "By integrating gas-fired energy with the potential for permanent carbon storage, we are creating a direct, reliable power solution tailored to evolving industrial needs. Baker Hughes' leadership in turbine technology, drilling services, and CCS innovation makes them an ideal partner in executing this vision."

EPA gives West Virginia primacy over carbon storage

www.epa.gov

The EPA signed a final rule approving the State's request to regulate the injection of CO2 into deep rock formations.

By granting the State primacy for Class VI Wells under the Safe Drinking Water Act, EPA recognises that West Virginia is best positioned to protect underground sources of drinking water while bolstering energy independence and dominance. This marks the fourth time a state has received primacy for Class VI wells since 2018.

From waste to wealth: The multi-billion-dollar carbon removals market

As the pressure mounts for businesses to decarbonise, the carbon market is expected to grow rapidly in the next five years – and with it, the investment opportunity for engineered carbon removals. By Elliot Renton, Chief Financial Officer, Evero Energy.

Just last year there was a 65% year-on-year increase in the number of businesses setting climate targets validated by the Science Based Targets initiative. With many more businesses expected to rely on carbon removals to achieve net zero, forecasts suggest the carbon removal market could grow to $1.2 trillion by 2050, according to McKinsey.

More striking still, those forecasts predict that the value of the carbon removals portion of the market could match or even outstrip that of carbon offsets in the next five years. This is because carbon removals result in a direct decrease in atmospheric carbon, while offsets only avoid further emissions. Early adopters like Google have abandoned carbon offsets, and switched their investment into removals.

Buying carbon removals is increasingly attractive to those companies in 'hard to abate' industries such as data centres, shipping and aviation in which it is often costly or technically difficult to decarbonise operations. Notably, Microsoft and Airbus are two of the largest offtakers of carbon removals globally buying into projects such as bioenergy carbon capture and storage (BECCS) and direct air capture.

Evero's carbon capture and storage (BECCS) projects are capable of capturing over 400,000 tonnes of carbon annually

Setting up carbon credits for success

Understanding the transformative potential of carbon credits and the need for greater transparency and regulation within the market to attract investors and participants, this year's COP29 delegates agreed how carbon credits should be created, traded and registered. From next year, businesses will be able to offer carbon credits backed by the credibility of an internationally agreed standard.

Separately, the UK government intends to offer revenue support to spur market growth by extending the Contract for Difference (CfD) scheme to incorporate greenhouse gas removals. This would create investor certainty using the same pioneering scheme that has successfully brought forward over 9GW in renewable generation with a further 20GW under construction or in planning. While the business model is currently in detailed design, the government has already confirmed that CfD contract durations will be for 15-year terms.

Taken together, these actions are helping to derisk investment in carbon removals so that large-scale projects such as bioenergy carbon capture and storage (BECCS) can be constructed to meet demand.

Carbon capture and storage is progressing at pace

Carbon capture and storage involves the capture of CO2 emissions from industrial processes, such as steel and cement production, or from power generation such as waste to energy (including bioenergy), and fossil fuels. This CO2 is then transported from where it was produced and stored deep underground. In some cases, it can also be used as a feedstock for producing materials used to carbonate drinks, or processed into a chemical or sustainable fuel, to name just a few.

It is often mistakenly believed that carbon capture technologies are new or there is little expertise in the field. Oil companies have been capturing carbon and injecting it into oil reservoirs to improve production yields for around half a century. With a vast amount of existing expertise and capability to tap into from a catalogue of previous studies, for an experienced team, delivering a CCS project is not any more complicated or higher risk than any other infrastructure asset. Indeed, there are already 45 commercial facilities operating globally and the UK has over 90 CCS projects in the pipeline.

CCS will play a critical role in tackling climate change, creating jobs and boosting economic growth. This has led the UK government to make big commitments to the technology this year; in October £21.7 billion in funding over 25 years was committed to make the UK an early leader in CCS and hydrogen. This was followed in December with contracts signed to begin construction of the UK's first CCUS scheme in Teesside, the East Coast Cluster. The UK's second most advanced scheme, of which Evero's first CCS plant will connect to – Hynet in Cheshire – is expected to follow in its footsteps in early 2025.

Carbon reductions versus carbon removals

As more CCS projects come forward, there will be an important distinction to be made between those that only offset carbon and those that remove it. When applied to a fossil fuel plant, CCS simply stops carbon from being emitted into the atmosphere – in other words a carbon offset. However, when applied to a waste wood to energy plant (also known as BECCS) it permanently removes carbon from the atmosphere. This is because as a tree grows it removes carbon dioxide from the atmosphere, when it is burned to generate electricity the CCS plant captures the embedded carbon from the flue gas; once the carbon is stripped from the flue gas and stored it creates a carbon removal.

The choice of fuel source is important too. Wherever possible, waste wood should always be reused or recycled to maximise its monetary value and reduce its carbon and ecological footprint before being burnt to generate electricity. The life of a kitchen cupboard is a prime example. Typically made from plyboard or MDF, kitchen cabinets are made from recycled materials which are too brittle to be processed again. With over a million kitchens replaced every year in the UK, hundreds of thousands of tonnes of waste wood are created that has no other value or use to society.

While previously this waste wood would have been landfilled, as the UK moves to eliminate almost all biodegradable waste from landfill by 2028, finding sustainable methods of disposal has become increasingly important. This has led to the construction of several waste wood to energy plants (also sometimes referred to as bioenergy plants) that use the waste wood as a fuel source to produce renewable electricity. As an example, across its portfolio of assets, Evero Energy diverts around 380,000 tonnes of locally sourced waste wood from landfill to generate renewable electricity for over 125,000 homes annually.

With stable, high quality cash flows underpinned by government subsidies, long-term power purchase agreements and fuel contracts, it is an infrastructure asset that performs well. And it also makes these plants ideal candidates for installing carbon capture and storage onto, with the sale of carbon removals credits poised to unlock a substantial new revenue stream.

Indeed, the UK already has several such sites investigating or in the pre-FEED or FEED stages of applying CCS.

Many more opportunities to be explored

While accessing the carbon removals market is a sizeable opportunity alone, it is the tip of a much larger iceberg of potential. In the future, waste wood could be turned into sustainable fuel for ships transporting food and goods into the country or to fuel the plane you take on holiday.

New use cases for CO2 and waste wood are being developed all the time. Just before Christmas, German scientists announced that they had developed a biotechnological process that converts waste wood into biohydrogen which could be used to power local industry. Meanwhile e-methanol can already be produced by blending CO2 and hydrogen.

Altogether applying CCS to waste wood to energy represents a multifaceted opportunity that is well supported by the UK government and by market dynamics. Applying CCS to existing successful infrastructure assets is low risk, and opens the door to a multitude of future opportunities.

More information

https://evero.energy

Evero Energy achieves record quarter in waste wood energy generation

Evero's sustainable-waste-wood-to-energy plants exported 113,000 MWh (91% capacity) of clean electricity to the national grid and local industrial partners in the final quarter of 2024.

The company's Ince, Mersey and Lisahally waste wood biomass plants achieved consistently high availability and generation hours. In particular, Ince saw a 13% improvement in availability during Q4 2024.

Evero's waste wood plants use only grade C wood, which is wood that can no longer be reused or recycled, saving it from going to landfill. The wood is sourced locally to its plants to minimise the carbon footprint generated from transportation.

Evero is accelerating its plans for BECCS - its two BECCS projects, which have passed the UK government's Track 1 deliverability assessment, have the potential to capture over 400,000 tonnes of carbon annually, reinforcing the role of waste-wood-to-energy as a key tool in achieving negative emissions and delivering the UK's clean power by 2030 action plan.

Mark Roberts, Head of Engineering at Evero, said, "This record quarter demonstrates the immediate and long-term benefits of waste-wood-to-energy assets. Not only are we increasing power output today, but by advancing BECCS, we're proud to support the UK's net zero ambitions and contribute to the essential greenhouse gas removals needed."

Implications of declining clinker demand for carbon capture projects

The cement industry faces unprecedented changes over the next 25 years in the course of a transition to a decarbonised future. By Ian Riley, World Cement Association CEO. www.worldcementassociation.org

In collaboration with CNBM, Sinoma is conducting a demonstration project that utilizes CO_2 from kiln exhaust gases and carbide sludge to produce precipitated calcium carbonate (PCC), with an industrial feasibility study targeting a production capacity of 50,000 to 100,000 tons annually

The cement industry is responsible for 7% of global GHG emissions. These emissions come from two main sources: emissions from fuels burned to generate the 1450C temperatures required for clinker production, and the emissions as limestone breaks down into CaO and CO2 in that clinker process. Clinker is the main component of cement and in traditional Portland Cement can be up to 95%.

GHG emissions from fuel have been reduced through improvements in energy efficiency and by substituting lower carbon fuel for coal. In Europe especially a considerable amount of biogenic fuel is now used as this has zero net carbon emissions. The trend everywhere is to use more waste derived, often biogenic fuel.

How the Cement Industry has been Reducing Emissions

The main lever to reduce emissions from limestone is to use less clinker in cement. Blended cements have typically been formulated with 70% clinker and 30% of other materials, mainly supplementary cementitious materials (SCMs) such as blast furnace slag or fly ash from coal fired power generation. However, these materials are not available everywhere and their supply is declining. More recently there has been great interest in using calcined clays as an SCM as clays are abundant and widely distributed around the globe. It is possible to reduce the portion of clinker in cement to 50% with calcined clay and limestone.

Potential new Cement Technologies

Many companies are exploring and developing non-clinker binder systems, mainly based on geopolymer concretes with steel slag, mine tailings and other industrial byproducts. These are likely to be accepted initially for non-structural and sub-surface applications. These applications which typically use C30 or standard grade concrete and have low risk/loss in the case of failure are estimated to amount to more than 50% of all concrete used.

While geopolymer concrete is not new, it is now very close to achieving 3 pre-conditions for rapid growth: comparable cost to conventional cement, supply scalability and adherence to standards.

Several ClimateTech companies are exploring how to make cement with zero or close to zero emissions. Some of these are developing a completely new process that will produce the same products without any emissions. Others believe this would require too much capital investment in new plants and are working on the pre-treatment of limestone to remove the CO2 without atmospheric emissions.

Another approach is to produce a clinker with a different composition, lower emissions but similar properties to conventional clinker. It will require more time before the industrial feasibility of these novel approaches can be confidently assessed.

Effect on Cement and Clinker Demand

The cement industry faces unprecedented changes over the next 25 years in the course of a transition to a decarbonised future.

Everyone in the cement industry is aware of the ever-increasing pressure to reduce carbon emissions. Over the last 30 years the industry has cut per ton emissions by about 25%. However, our customers – primarily real estate and infrastructure developers – are also under pressure to cut the carbon footprint of their projects, often at a rate that is faster than the cement industry can satisfy. This will lead them to take actions that will reduce the demand for conventional cement.

There have been several well publicised high-rise buildings that have used timber to replace concrete and steel. No doubt we will see more of this in the future. However, limitations in the supply of sustainable timber mean this will not replace a significant portion of concrete.

There is considerable waste in the concrete supply chain, where cement is ultimately being put to use. In ready mixed concrete supply this involves over-ordering and dumping or returning excess concrete. In addition to the reduction of wastage, there is considerable potential to reduce binder demand with greater use of admixtures and the addition of novel materials such as graphene and carbon nanotubes.

Current design practices have been based on cost considerations. As engineers and architects take into account the embodied carbon, there will be reductions in the amount of concrete used to achieve specific objectives.

Global cement demand in 2050 is likely to be around 20% lower than today at around 3bn tpa mainly due to a large drop in construction demand in China and increased efficiency in building design and concrete supply.

Implications for CCS requirements

Demand for clinker, the key ingredient contributing to carbon emissions, will decline at an even steeper rate, down to roughly half of current levels by 2050 at 1.5bn tpa. Today, the only solution we have for capturing the emissions from limestone from this residual clinker production is CCUS. At 1.5bn tpa clinker demand, limestone emissions would be about 800 million tpa.

As I noted above, it will be some time before the industrial feasibility of the novel approaches to producing clinker can be confidently assessed. In the meantime, the only option to reduce residual carbon emissions (mainly from limestone) is CCUS. It is expensive and energy intensive. Projects involve a range of parties, making for complex coordination. Furthermore, CCUS projects have technical, planning, logistics and counterparty risks. They consequently take a long time and often suffer delays. However, we do not yet have another feasible way of getting to net zero. With time, new low carbon ways of making cement may be developed and could offer solutions that are significantly less expensive than CCUS.

As noted above, the potential market for CCUS in the cement industry is 800 million tpa CO2 emissions. Of this, approximately 100 mtpa is in the developed economies of N America, Europe and NE Asia. Most of the projects in other regions are likely to be commissioned in the period from 2040-2060 or even later.

So, what does this mean for projects in the period 2025 – 2040? According to Global Cement 41 projects with capture capacities above 250,000 tpa of CO2 at cement plants have been announced. Of these, 35 projects have announced target completion dates between 2025 and 2035 and 6 projects have no completion date announced. Final investment decisions have only been announced on a handful of projects. With the exception of 1 project in India for which no date has been announced, the other 40 projects are all in developed economies with 32 in Europe, 4 in USA, and 2 each in Canada and Japan. The CO2 capture capacity of these projects totals just over 40 million tpa. If projects continue at the 2030-2032 rates, we would project a total of 70-80 million tpa of capture plants installed by 2040.

Conclusion

Current emissions from cement plants worldwide are 2.5 billion tpa, which appears a very large opportunity for providers of CCUS solutions. Due to the emergence of new cement and concrete technologies and efficiencies in use of concrete, these emissions will fall in line with clinker demand to around 1.5 billion tpa in 2050. Since there are lower cost approaches for abating the 40% of emissions that come from fuel, the potential CCUS requirement is around 800m tpa.

Looking forward to the period from 2025 to 2040, the market for CCUS will be almost entirely in developed countries and could amount to a cumulative installed capacity of 80m tpa by 2040. Today CCS projects still have considerable technical, planning, logistics and counterparty risks which may lead to delays. Longer term, new low carbon cement technologies may offer solutions that are significantly less expensive than CCUS.

UK Government's latest funding round

Ian Riley, CEO of the World Cement Association, shares his thoughts on the UK Government's latest funding round under the Industrial Energy Transformation Fund (IETF) which supports the advancement of low-carbon technologies.

Ian Riley said, "The Industrial Energy Transformation Fund's latest funding round is a significant step forward in fostering low-carbon innovation across industries. By supporting transformative technologies such as large-scale carbon capture, the IETF is enabling businesses to contribute meaningfully to the UK's net-zero goals."

"The urgency to decarbonise the cement industry cannot be overstated. Contributing 8% of all global CO2 emissions, the sector requires immediate action, particularly as 2024 marked the first year global warming surpassed the 1.5°C threshold. Hanson Cement's CCS project exemplifies the decisive measures needed to tackle this crisis and demonstrates how carbon capture technology can be effectively deployed to mitigate emissions. As the only currently viable and scalable solution to decarbonising cement production, CCS offers the most likely pathway to significantly reducing the industry's carbon footprint."

"As outlined in the World Cement Association's latest white paper, global demand for cement and clinker is projected to decline sharply by 2050. However, the sector remains one of the largest industrial emitters of CO2, and the scale of emissions from remaining production necessitates the swift adoption of technologies like CCS, greater use of alternative fuels, and adoption of low-carbon binders for concrete. These measures are not merely about meeting demand more sustainably but are essential for mitigating the substantial emissions footprint that persists even as production slows. Industry collaboration and robust policy support will be critical in accelerating the transition to a decarbonised future."

'Substantial green prize' lies ahead for UK as it decarbonises economy says DNV

To address lagging emissions reductions, the UK must accelerate large-scale electrification in heating and transport, alongside scaling CCS and hydrogen infrastructure.

The UK's energy transition will deliver a cleaner, more efficient, and less expensive energy system, according to DNV's 2025 UK Energy Transition Outlook (ETO) report.

DNV assessed the UK's trajectory against key government targets: Clean Power 2030, 2035 Nationally Determined Contribution (NDC) and the net zero by 2050 goal. While the UK will fall short—missing net zero by 18%—DNV's analysis shows substantial progress in decarbonisation. By 2050, emissions are projected to drop 82% from 1990 levels, amounting to remaining annual emissions of 145 million tons of CO2 equivalent (MtCO2e).

The short-term Clean Power 2030 target sets an ambition to decarbonise the electricity system by decade's end, but DNV forecasts that unabated gas will still generate 12% of UK electricity in 2030. Full decarbonisation is expected by 2035.

Renewables will see strong growth, with solar, onshore wind, and offshore wind capacity nearly doubling to 90 GW by 2030. However, this remains 45 GW short of government targets to double onshore wind, triple solar, and quadruple offshore wind.

Under the new NDC, the UK has committed to reducing economy-wide greenhouse gas emissions by 81% by 2035, compared to 1990 levels. DNV's projections suggest it will reach only 68%, requiring steeper reductions to meet its pledge.

Hari Vamadevan, executive vice president and regional director, UK & Ireland, Energy Systems at DNV, said, "Despite economic and geopolitical challenges, the UK's trajectory remains positive. A substantial green prize for our economy – cleaner and more affordable energy-, is there for the taking if we can grasp it. We must act swiftly to ensure we make decisive moves along the correct path."

Decarbonisation is cost-effective: by 2050, household energy costs for consumers will drop nearly 40% from 2021 levels. Energy demand will shrink by 25%, even as electricity consumption more than doubles, requiring 180 GW of new generation capacity. This decoupling of energy demand and GDP highlights continual energy-efficiency improvements across the economy.

Major UK industrial cluster annual emissions accounted for in the UK Emissions Trading Scheme. Source: NAEI 2019 data

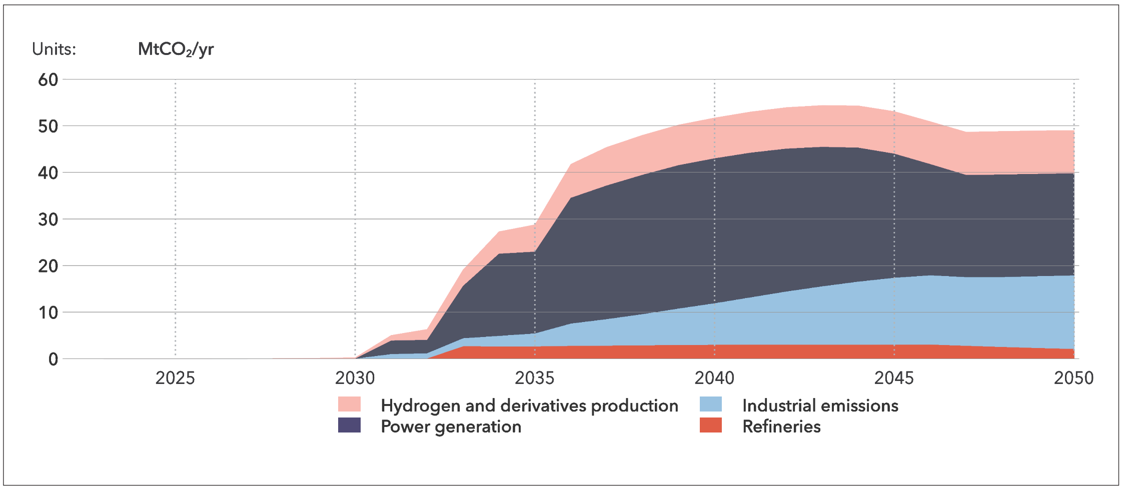
Low carbon sources are expected to surpass fossil fuels in the supply mix, with the latter falling from 75% of primary energy today to 34% by 2050. However, oil and gas will remain dominant across the next decade, with significant amounts still required to balance energy demand and ensure security of supply.

CCUS in the report

Clear and defined business models are needed for Greenhouse Gas removals (GGR) and Power BECCS to incentivise uptake of the technologies and development of the projects, says the report. Some global GGR and Power BECCS projects are seeking funding through the voluntary carbon market and projects in the UK are seeking similar routes for project capital / security.

GGRs can play an important role in offsetting CO2 emissions, particularly in hard to-abate areas such as aviation and manufacturing. The Net Zero Strategy, the UK Climate Change Committee, the IEA and the IPCC all agree that we need engineered GGRs if we are to meet the ambition of limiting average global warming to below 1.5°C.

The overall vision of the UK Government is



UK carbon capture and storage capacity

that CCUS will go through three phases: first, achieving the ambition of capturing 20–30 MtCO2/yr by 2030; second, a transition involving the emergence of a competitive commercial market; third, a self- sustaining CCUS market becoming a reality.

DNV's CCS forecast

DNV's forecast indicates that UK carbon capture capacity will reach 5 MtCO2/yr by 2030, significantly short of the UK target of 20-30 Mt by that year. However, beyond 2030 we see a steep increase in capture capacity reaching 42 MtCO2/yr by 2035 and peaking at 54 MtCO2/yr in the mid 2040s.

Initially, the majority of carbon capture will be associated with power generation and a smaller proportion with blue hydrogen production, focusing on the current large emitters. However, as production of hydrogen through electrolysis increases, this will displace CCS-enabled hydrogen production. Longer term electrolytic hydrogen replacement of natural gas for power generation will also displace CO2 capture rates from mid to late 2040's.

DNV forecasts that biogenic CCS has a significant increase between 2030-35 and maintains a strong position over time with approx. 14Mt CO2/ yr throughout the 2040s. The need for engineered greenhouse gas removals and a high carbon price is predicted to sustain this demand. Cheaper forms of electricity generation are predicted to reduce biogenic CO2 captured, but the carbon dioxide removals market could support the additional cost.

The availability of sufficient transportation, injection and storage capacity is critical to meet these values, but DNV believes that should not be a major constraint in that time frame, considering the large potential for CO2 storage in UKCS and the existing offshore infra structure available for re-use. The main constraint will be the design, build and commissioning of the necessary number and scale of capture projects.

Confidence in the short to medium term outlook for CCS in the UK has decreased due to the delays in the first projects reaching FID and uncertainty on the status of the next CCS clusters. Key reasons for missing the 2030 targets are the slower-than-expected development of the Track 1 clusters (and associated projects), as the majority have yet to take FID (as of December 2024); and the expectation that only in the early 2030s will carbon prices start to approach the cost of CCS, so that uptake accelerates and deployment at scale begins.

The initial clusters and projects passing through FID and into detailed engineering design, are essential to provide industry and investors with clarity on economic models of financial support and the confidence that an initial wave of projects will be developed that can unlock the pipeline of CCS projects and the flow of capital into the market.

The role of carbon removal markets in the Energy Transition

There are two primary categories of carbon dioxide removals: nature-based and engineered solutions. Engineered solutions rely on technologies such as CCS, typically Bioenergy with Carbon Capture and Storage (BECCS) or Direct Air Capture with Carbon Storage (DACCS). The UK government aims to deploy at least 5 MtCO2/yr of engineered removals by 2030, scaling up to around 23 MtCO2/yr by 2035.

The UK ETS Authority also intends to include engineered removals within the UK ETS, aiming to incentivise investment and provide a source of demand for removals from polluting sectors, subject to robust Monitoring, Reporting, and Verification (MRV).

The UK government, in collaboration with the British Standards Institute (BSI) is also developing technology specific methodologies for engineered removals, such as BECCS and DACCS, to define the requirements around the quantification and MRV.

In addition, the UK is consulting on implementing a Carbon Border Adjustment Mechanism (CBAM), which is another critical element in this landscape. CBAM aims to ensure that importers pay the same carbon price as domestic producers under the UK ETS, thereby preventing carbon leakage and ensuring equal treatment for products made in the UK and imports from elsewhere.

This mechanism will motivate importers to decarbonise their supply chains to remain competitive. Furthermore, the UK's CBAM is designed to align with similar measures being implemented by the EU, promoting a cohesive approach to carbon pricing across Europe.

The evolving landscape of carbon markets presents both challenges and opportunities, however the UK can lead the way in creating a credible and effective carbon market.

More information

www.dnv.com

Strategies for enhancing the economic viability of carbon capture projects

In this paper, the authors argue that successful project structuring is key to enhancing the economic viability of carbon capture projects. By Louis-Jean Germain, Salekh Kharov.

Do you know that, for carbon capture (CC) projects, only 20% of announced capacity for 2030 have reached final investment decision as of 2024?

The main difficulty for project developers is ensuring the economic viability of CC projects. The challenge is to control CAPEX and OPEX from the early design phase, or FEED 'Front-End Engineering Design'), through the EPC phase ('Engineering, Procurement and Construction'), and into start-up and operation. If CAPEX and OPEX increase excessively, the project is at risk and may be deemed economically unviable or even cancelled.

These cost increases can be due to factors such as higher-than-expected prices for EPC and construction contractors, multiple design changes during the EPC phase and operation, lower CO2 capture volumes, and higher-than-expected electricity consumption during operation.

Are you aware that the primary threat to the economic viability of CC projects is the uncertainty caused by technology risk?

Excluding CO2 storage and distribution, Carbon capture projects, within its own battery limits, still need to overcome major technical challenges particularly when scaling up or dealing with complex applications like capturing carbon from cement factories or other hard-to-abate processes. Currently, only pilot plants and few plants are operational, and most of technology remains untested large-scale with no performance track record. All the current CC projects are first-of-a kind in term design and construction.

Most of the companies interested in implementing carbon capture are industrial focusing primarily on their own plants, to address environmental challenges and policies. These major companies are not structured to drive project developments independently and remain dependent on technology providers and contractors.

Through a paper published over two issues of the Journal (the present issue and the following one), the Authors argue that successful project structuring is key to enhancing the economic viability of CC projects.

Successful project structuring considers: (1) early involvement of the contractors, licensors and vendors to uplift risks mitigation and strengthen project cost estimate, and (2) a contracting structure allowing allocation of risk to the entities best placed to manage them, maximizing the chances of success.

The authors will outline solutions to implement successful project structures to mitigate the technology risk. The aim is enhancing the economic viability of CC Projects. They will address project development strategy in this first part of the paper, then, present three contractual project structures in the second part of the paper (next issue of the journal).

1. Project development strategy

The first part of this paper proposes a project development structure to mitigate the technology risk inherent to carbon capture projects. The main difficulties faced by developer can be summarised as followed:

• First-of-a-kind type of projects leads to general lack of experience among engineering forms and EPC Contractors.

• Lack of proven technologies and process at large scale reduces flexibility of project's design and execution schedule, leading to uncertainties in estimating project cost (CAPEX).

• Lack of experience in Operation and Maintenance ('O&M') of plants and equipment significantly increases risk of failing to meet targeted performance at the start of production, leading to uncertainties in estimating operational cost (OPEX).

• Lack of technical regulatory environment further complicates plant permitting process, generating delays and additional costs.

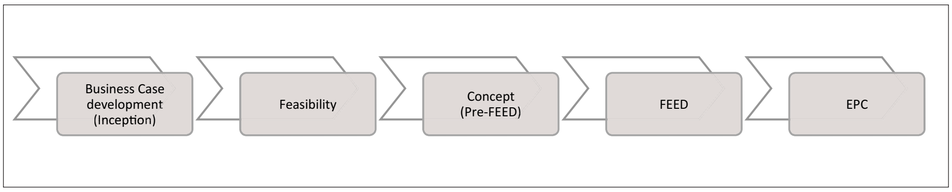
This section will address early engagement of vendors and contractors within the project execution, from a Front-End Loading (FEL) approach. This strategy combines with the three contractual schemes addressed in the second part of the paper.

Front-End Loading methodology

The FEL involves developing sufficient strategic information at the early stage of the project to support assessment and response to risk, and decision-making to maximize the success of the project. The FEL defines key stages of project development from the inception to EPC execution phase, with formal decision gate review conducted at the end of each stage.

Standard FEL approach

In the technologically well-established markets, like oil & gas or power generation, prior to the FEED stage, the interaction with licensors and vendors are limited to mere information exchange; EPC contractor and O&M



Front-End Loading stages

contractors are not consulted at all. Generally, the contractor in charge of the FEED is replaced by another EPC contactor with stronger execution and construction track record towards the end of FEED and prior to EPC. The purpose is to:

• Introduce another layer of optimization through competitive EPC tendering.

• Reinforce design consistency control through the process of FEED endorsement by this new EPC contractor.

• Reinforce execution certainty; as opposed to contractors specialised for FEED, EPC Contractors usually have an established supply chain, manpower availability, stronger market presence (ability to negotiate equipment and subcontracts prices) and possess construction and commissioning expertise. They are less averse to construction risk.

Difficulties with FEL standard approach for carbon capture projects

However, in the context of carbon capture projects, late engagement and changes of EPC contractors (prior to EPC) brings the following disadvantages:

• Late engagement of EPC contractor prevents achieving the accurate and reliable estimate of the project cost (CAPEX) prior to EPC, as contractors specialised for FEED generally do not possess the necessary competence and are less incentivized by the developer to delivering it.

• Due to the lack of experience in carbon capture projects, EPC contractors typically do not feel comfortable with a simple short-term endorsement of the FEED. They require more time for its assessment prior to commitment and introduce major contingencies into their bidding price and schedule, and propose large deviations to reduce their liabilities and risk level.

• Licensors and vendors, being engaged earlier than EPC contractors typically have direct contracts with the developer thus complicating optimisation and problems solving between EPC contractor, licensors and vendors.

The standard FEL approach for carbon capture project increases the risk of budget increase, delays and possible failure to agree a contract with an EPC contractor. This threat the economic viability of the project.

Recommended alternative FEL strategy

The authors recommend carbon capture project developers the following alternative FEL strategy:

• Engage early and keep the same contractor through all the stages of the project (FEED and EPC). The contractor should be already involved from the business case development stage to lay the sound technical ground for any further developments.

• If the selected contractor for FEED lacks project execution capacities (specifically in procurement, construction and commissioning), reinforce the contractor through partnering with experienced EPC or construction contractor. Early involvement during FEED of experienced construction contractor is highly recommended to improve the constructability of the design, which reduce the CAPEX, and maintain speed to market by avoiding handover period between the two contractors.

• Engage main licensors and vendors by the end of the feasibility study (step 2 of above Chart) to actively participate in concept design and be contractually tied directly to the EPC contractor to maximise coordination and cooperation during the design phase of the project. It may happen the contractor for the FEED is also the licensor of the technology.

• Engage an O&M specialized contractor during the FEED stage to ensure the design solutions are operationally adequate, facilitating project permitting approval and reducing OPEX.

• In case a same EPC contractor is rolled up from FEED to EPC, an open book tendering may be implemented. The contractor will have to submit its proposal for the EPC sustained by price from subcontractors and vendor on an open book basis. This method enhances the control of CAPEX.

Conclusion and mitigations

In summary, the FEL alternative approach suggested for carbon capture projects considers the early involvement of contractors and vendors, alike implementing the project as an EPC right from the start.

One potential drawback is that the pre-EPC cost of the project might be higher due to those early engagements. However, the authors suggest that this cost should be seen as an investment by developers to control the CAPEX and OPEX of their projects.

Another drawback of this FEL alternative approach (“merged FEED and EPC” execution) is that parties may tend to overlook inconsistencies by transferring resolutions of those during the following stages of the project. To avoid that issue, it is essential to set a proper project governance structure considering:

• Distinct FEED and EPC development teams, and introduce endorsement process between them through specific split of responsibilities and reporting lines, and

• Project Steering Committee, composed of representatives from the developer, the contractors and vendors, to act as key decisions taking entity, arbitrating between the FEED and EPC development teams.

The second part of this paper, which will be published in the July/Aug issue of the Journal, proposes three schemes for contractual project structures. The purpose is to mitigate the technology risk inherent to carbon capture projects by proposing efficient allocation of risk between developer, EPC contractor, licensor and vendors. The three schemes combine with the project development strategy addressed in the first part of the paper.

The solutions introduced in this paper need to be meticulously evaluated and tailored to the unique specifics of your projects. By doing so, and leveraging expertise in developing project structuring and supporting the successful execution of projects, you will maximize your chances of enhancing the economic viability of your carbon capture project.

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More information

Louis-Jean Germain, LLM, Meng, FCIArb, Founder and Managing Partner at Joyan Consulting
linkedin.com/in/louisjeangermain

Salek Kharov, Independent Consultant

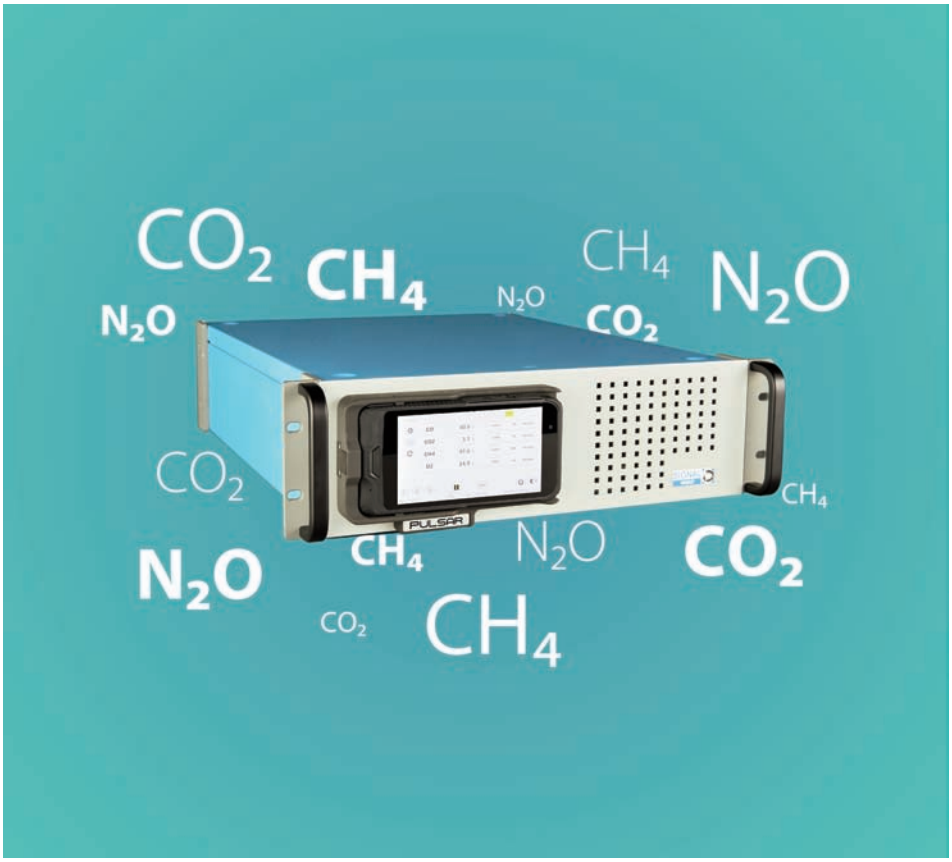
Carbon capture relies on accurate greenhouse gas monitoring

As the world urgently seeks ways to decarbonise, James Clements from Signal Group explains how gas analysis will perform a vital role – particularly in carbon capture, and not just for CO2 but for all of the important greenhouse gases.

The climate crisis is forcing nations to urgently find ways to lower their greenhouse gas (GHG) emissions, and carbon capture is likely to be one of the key technologies in enabling this goal. This, in turn, is prompting a demand for GHG analysers to help assess capture technologies and to verify that GHG reduction claims are valid.

There are many forms that CCS can take, however, with all of these options, as the saying goes: 'you can't manage what you don't monitor' so the measurement of GHGs such as carbon dioxide, methane and nitrous oxide will be essential.

It is important to acknowledge that carbon capture may not be the silver bullet that solves the climate crisis. Firstly, it has yet to be implemented on a large scale, secondly, even if it is successful, it will only partially lower GHG emissions, and thirdly many environmental groups are unhappy with reliance on carbon capture because it risks extending the use of fossil fuels. Nevertheless, given the climate emergency, enormous investments in carbon capture are either underway or planned.



Signal Group Ltd develops and manufactures gas analysers for the professional testing of VOCs, vehicle and engine emissions, tobacco smoke, impurities in special gases, power plant emissions, catalyst efficiency, and boiler/burner combustion emissions

According to the Global CCS Institute, in its Global Status Report 2024, over the previous 12 months, the number of CCS facilities in operation globally had risen to 50, while the total number of facilities in the development pipeline has surged 60% to 628. At the same time, the carbon capture capacity of facilities under construction increased by 57%.

The UK is one of the countries leading the growth in carbon capture capacity. In October, for example, the UK government announced £21.7 billion of funding for carbon capture projects over 25 years. The announcement is in line with the UK's ambition to store 20 to 30 million tons of CO2 per year by 2030 by using CCS technology.

Many other countries are also legislating for and investing in decarbonisation strategies including carbon capture. The EU for example has set a target of 50 Mtpa CO2 injection capacity by 2030, introduced by the Net-Zero Industry Act, which came into force in June 2024.

In the USA the DOE has awarded or is negotiating awards for over US$2.2 billion from the 2021 Bipartisan Infrastructure Law (BIL) to advance carbon management projects.

231 Class VI CO2 injection well permit applications are being evaluated for 88 projects across 18 US states and one tribal nation under the US EPA's Underground Injection Control (UIC) program.

At Signal Group, our main involvement with carbon capture has been with combustion processes involving fossil fuels or waste derived from fossil fuels. To-date these projects have largely been in the pilot stage, as researchers and process operators seek to refine and prove the technology before investing in a full-scale facility. For example, Signal analysers are being utilised at a pilot carbon capture unit at a natural gas combustion plant in southern Arkansas, USA.

The company Aqualung Carbon Capture is trialling its novel carbon capture technology on a generic gas-fired boiler, and approached Signal for help with its requirement to continuously check for non-combusted hydrocarbons in the boiler's emissions.

Explaining the advantages of Aqualung's membrane technology, Jonathan Garbett says: "Traditional carbon capture techniques such as absorption with amines are relatively expensive, with a requirement for amine, heat and a steady stream, so they are only used commercially in larger applications. In contrast, our patented membrane technology requires less power and works well on smaller, de-centralised plants."

Signal's gas analysis system included an S4 SOLAR heated FID VOC analyser with a heated line and model 346 front-end filter. In most countries, FID (flame ionisation detection) is the standard reference method for the measurement of total hydrocarbons, and the sampling handling system is designed to ensure that the sample being delivered to the analyser is truly representative of the emissions, with no possibility of condensation in the sample line, or the analyser.

Choosing a GHG analyser

In the example above a Signal analyser is being used to detect incomplete combustion; not just for safety reasons, but also because fossil fuels are inevitably an important part of the transition to a decarbonised economy, so it is vital that where they are used, they are utilised as efficiently as possible.

In order to be able to check and verify carbon capture it is necessary to measure GHGs both before and after the capture process. Consequently, it is preferable to deploy analysers that are able to take samples from two different locations concurrently, and frequently it will also be necessary to be able to continuously measure more than one GHG.

S4 PULSAR gas analysers employ Gas Filter Correlation technology to measure only the gas, or gases, of interest, with negligible interference from other gases. The optical bench is enclosed in a heated chamber which means that an external chiller is not necessary for non-condensing samples.

By using two sample cells of different lengths, in series, it is possible to select a low-range and a high-range. This is important for applications such as carbon capture where high levels exist before capture, and very low levels after. A parallel twin optical bench version is also available for applications requiring the measurement of two different gases or two ranges of the same gas running continuously.

In addition to their remote connectivity software (S4i), Signal's S4 analysers also feature a rugged, detachable tablet which serves as a control screen, and connects wirelessly to the analyser via an inbuilt 802.11 wifi that can connect up to 50 metres away. This provides users with the enhanced ability to view live data from a different (safer or more convenient) location, and even manage data logging, alarms and calibration.

At the moment, many carbon capture projects are still at the pilot stage, and GHG analysis is performing a vital role within them, helping to evaluate and verify carbon capture techniques. As full-scale projects are implemented, gas analysis will play an even more important role, demonstrating not just that carbon has been captured, but also how much.

This function will be critically important in carbon markets. In addition, where captured CO2 is sold or transferred for utilisation, the accurate measurement of CO2 concentration will be required.

COP29 moved towards the establishment of a global carbon market

A significant outcome from COP29 in Baku was agreement on the remaining sections of Article 6 of the Paris Agreement, to enable the development of a global carbon market. Article 6 details how participants can pursue voluntary cooperation to reach their climate targets – with the Paris Agreement Crediting Mechanism identifying and encouraging opportunities for verifiable emission reductions.

Following protracted negotiations in Baku, developed nations also agreed to help channel at least $300bn a year into developing countries by 2035 to support their efforts to deal with climate change. This finance will be used for adaptation, mitigation, renewable energy, agriculture, loss and damage, and debt restructuring. Of these measures, mitigation (reducing emissions and enhancing sinks) will help drive the growth in carbon capture.

Here at Signal Group, we very much welcome initiatives to accelerate GHG emissions reductions. Some carbon credit projects do not involve the direct measurement of GHG gases – wind farms and forest conservation for example.

However, it is important to note the word 'verifiable' in carbon trading texts, and this is where our GHG analysers will play a critically important role, because, where GHGs are emitted, it is only possible to claim GHG emissions reductions (by carbon capture for example) if they are measured, and one of the most important ways to do this is with an accurate, reliable gas analyser.

Further measurements will be necessary if the captured carbon is stored or utilised (CCS or CCUS).

Signal's S4 PULSAR analyser employs NDIR technology to measure a range of critically important gases including GHGs such as carbon dioxide, nitrous oxide and methane. The S4 PULSAR is an extractive gas analyser, capable of drawing samples from both before and after carbon capture, so that effective GHG emissions reduction can be demonstrated.

To generate carbon credits, a project's emission reductions need to be measured and quantified. This involves calculating how much CO2 (or equivalent GHGs) has been avoided or removed compared to the baseline.

The calculation depends on the specifics of the project and involves standard methodologies set by certifying bodies. It is important to note that although the term 'carbon credits' is applicable, it is actually a term that applies to all GHGs – hence the mention of 'or equivalent GHGs'.

With the ability to measure a range of GHGs, the S4 PULSAR uses reference method gas analysis for important gases such as methane and nitrous oxide. Why are they important? Well, methane is about 25 times more powerful as a GHG than carbon dioxide, and nitrous oxide is 300 times more powerful!

Summary

The successful achievement of global net zero targets will depend on an enormous array of factors. However, accurate, reliable, verifiable data will be essential if the data produced by organisations and countries are to be trusted.

More information

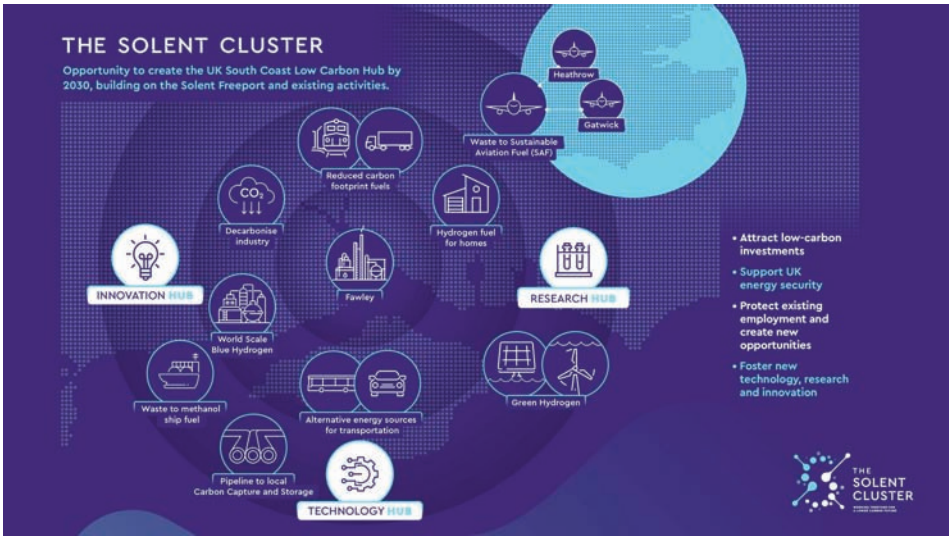
www.signal-group.com

The Solent Cluster launches landmark report on industrial decarbonisation

The report addresses key barriers and opportunities, models business actions, and examines public perceptions surrounding industrial decarbonisation in the UK.

The Solent Local Industrial Decarbonisation Plan (LIDP) Transitioning Pathways report, the result of a year-long collaboration with industry and academic partners, delves into the pathways for decarbonising industry in the Solent region.

"The transition to a lower carbon economy has the potential to drive local economic growth and skilled jobs in our local communities at the same time as benefitting the wider UK," said Stu Baker, Executive Director of The Solent Cluster. "As one of the largest industrial regions in the country, it is vital we decarbonise industry here and our collaborative work over the past year has shown both the challenge ahead of us, and the ambition we have to achieve this."



"The LIDP report perfectly articulates the scale of the task ahead and the actions needed – notably around policy support, investment, local collaboration and skills development. It also highlights the enormous potential that exists in the Solent's innovation and collaboration ecosystem which could see the wider South of England become a leading area for low carbon investment."

The report was unveiled at a networking event at Southampton Football Club, where delegates heard from a range of international and national speakers: Jörgen Sandström from the World Economic Forum, Will Lochhead from the Department of Energy Security and Net Zero, Will France from ERM, and Mark Sommerfeld from the Carbon Capture and Storage Association. The event also included an in-depth panel discussion with project partners.

The Local Industrial Decarbonisation Plan project was funded through a successful bid to the Government's Local Industrial Decarbonisation Plan competition, run in partnership with Innovate UK (IUK), with contributions from project partners. The Solent Local Industrial Decarbonisation Project has been supported by key partners: Ada Mode, ExxonMobil, SSE Energy Solutions, Veolia UK, GEO Specialty Chemicals, University of Southampton, Enoflex, and StandardAero.

The role of carbon capture is particularly critical, says he report, with major industries such as petrochemical production and energy from waste facilities lacking alternative opportunities to reduce emissions.

In fact, CCS has the potential to be the single most-effective abatement lever for reducing industrial emissions in the Solent region. The decarbonisation scenario modelling in the report suggests that CCS could cumulatively reduce emissions in the region by around 60 $MtCO_2$ by 2050, should large-scale storage be available by 2030, with capacity to store around ~3 .5 $MtCO_2$/yr.

CO_2 storage in the Solent region could also lead to wider opportunities to unlock decarbonisation elsewhere in the UK. Limited geological formations for CO_2 sequestration are available locally to industrial regions elsewhere in the UK, such as South Wales and south-east England. Currently, emissions-intensive industries in these geographies may seek to ship CO_2 into the Solent for sub-sea injection and storage.

Should infrastructure be developed for CCS in the English Channel, the Solent region could also become a key location for CO_2 removals using BECCS. Biogenic CO_2 from energy recovery facilities represents a key opportunity and other CO_2 sources could also potentially be used, such as dedicated energy crops.

Major sites in the Solent region, such as petrochemicals and energy recovery facilities, have no realistic means of decarbonising without the use of carbon capture and, in the absence of CO_2 transport and storage infrastructure, over 3.8 $MtCO_2e$ may remain in annual industrial emissions by 2050.

However the business case for such projects remains challenging without government policy support – as seen, for example, through the recent halting of ExxonMobil's CO_2 transport and storage project plans for the English Channel. Clarity around future government policy would provide further certainty and reduce risk for these projects to progress.

More information

www.thesolentcluster.com

Ørsted's full-scale CCS project progresses with key components

Absorbers, desorbers, and direct contact coolers supplied by SLB Capturi have now successfully been lifted into place at Asnæs Power Station and Avedøre Power Station, marking an important milestone for the 'Ørsted Kalundborg CO2 Hub'.

Ørsted has taken the next big step towards the realisation of Denmark's first full-scale CCS project with the installation of five sets of absorbers, desorbers, and direct contact coolers, which together constitute the key components of SLB Capturi's Just Catch™ standardised, modular carbon capture plant.

Three sets have been lifted into place at Asnæs Power Station, two sets at Avedøre Power Station.

Ole Thomsen, Senior Vice President and Head of Bioenergy at Ørsted, said, "By establishing a full CCS value chain, the 'Ørsted Kalundborg CO2 Hub' marks the beginning of the Danish CCS adventure. Therefore, I'm proud to see the construction taking shape, as the key components are lifted into place."

"It's a key milestone that we've been working towards since beginning the construction. The absorbers, desorbers, and direct contact coolers are essential components that enable the facility to capture and store CO2. With those in place, we've taken a great leap forward towards realisation of our project."

Work has now started on installing internals and piping for the key components, connecting them to the rest of the power stations. The project is expected to be operational in early 2026.

Additionally, Ørsted has received CO2 tanks where the captured carbon dioxide will be stored intermediately until it is shipped to the Northern Lights storage reservoir in the Norwegian part of the North Sea once the project is operational.

The 'Ørsted Kalundborg CO2 Hub', which was awarded a 20-year contract by the Danish Energy Agency in May 2023, will capture 430,000 tonnes of biogenic CO2 annually from the two combined heat and power plants. The carbon dioxide will initially be transported by lorry to Asnæs Power Station until a potential shared pipeline infrastructure across Zealand has been established.

The sets are comprised of three components that each performs a key role in capturing carbon dioxide:

1. Direct contact cooler (DCC):

Cools the flue gas by spraying water directly into it. Removes impurities and reduces the temperature, which improves the efficiency of the carbon capture.

2. Absorber:

Removes carbon dioxide from the flue gas by passing it through a liquid that chemically binds the carbon dioxide. The carbon dioxide-rich liquid is then sent to the desorber for further processing.

3. Desorber:

Heats the carbon dioxide-rich liquid to release the carbon dioxide gas. The released carbon dioxide is collected and compressed for storage or further use.

Each carbon capture unit will be able to capture 12,5 tonnes of carbon dioxide per hour.

Carbon removals are certified by an independent third party under the VERRA standard and Microsoft has already agreed to purchase 3.67 million tonnes of certified carbon removal. .

Key facts about the project

The 'Ørsted Kalundborg CO2 Hub' project aims to capture and store 430,000 tonnes of carbon dioxide annually from early 2026, equivalent to the annual carbon emissions from approximately 200,000 petrol-powered cars.

Ørsted is responsible for the full CCS value chain.

Ørsted will capture 150,000 tonnes of biogenic carbon per year from the straw-fired unit at Avedøre Power Station. The carbon dioxide will initially be transported by lorry to Asnæs Power Station until a potential shared pipeline infrastructure across Zealand has been established.

The straw-fired unit at Avedøre Power Station converts locally sourced straw into electricity and district heating. The straw used is a by-product of agriculture.

Ørsted will capture 280,000 tonnes of biogenic carbon per year from the wood chip-fired unit at Asnæs Power Station, which will also function as a carbon dioxide hub, handling and shipping biogenic carbon from both the Avedøre and Asnæs power stations to the Northern Lights storage reservoir in the Norwegian part of the North Sea.

The wood chip-fired unit at Asnæs Power Station converts wood chips into electricity, district heating, and process steam for the local industry. The wood chips come from sustainably managed production forests and consist of surplus wood from forest management and sawmills.

More information

www.orsted.com

Projects and policy news

enfinium announces next phase of UK carbon capture deployment

www.enfinium.com

Kanadevia Inova will deploy a capture pilot plant at Parc Adfer in Wales while Nuada will pilot its technology at the Ferrybridge-1 facility in West Yorkshire.

enfinium has announced the next phase of its CCS pilot programme, advancing its commitment to deliver CCS across its facilities. One of the projects, located at enfinium's Parc Adfer facility in Flintshire, North Wales, will be the only active carbon capture pilot in Wales and the first pilot deployed in the wider HyNet industrial cluster.

Mike Maudsley, CEO of enfinium, said, "To achieve net zero, the UK needs to produce carbon removals at scale. Energy from waste will play a critical role in delivering the millions of tonnes of durable carbon removals that are necessary for the UK to achieve net zero."

"By supporting the development of carbon capture technologies, we are advancing innovation in the UK while building our own understanding as we progress with our plans to deploy CCS across our six UK facilities."

In April 2025, enfinium will relocate the CCS pilot plant currently at its Ferrybridge 1 facility in West Yorkshire to Parc Adfer. The pilot plant will be installed and operated by Kanadevia Inova, a leading global clean technology company. The Parc Adfer facility is a candidate for grant support through the UK Government's Track-1 HyNet Expansion programme and could accelerate economic growth and decarbonisation in North Wales subject to a positive decision from the Government in the coming months.

A new pilot plant will subsequently be installed at Ferrybridge by Nuada, a British technology company scaling an innovative metal-organic framework (MOF) technology that captures carbon dioxide from point sources through a vacuum swing process. This innovation has the potential to deliver significant efficiencies when deployed at a commercial scale.

Both pilot projects will run for at least six months and form part of enfinium's broader ambition to deploy CCS across its six UK facilities, underpinned by investment to help achieve net zero emissions.

enfinium will relocate the CCS pilot plant currently at its Ferrybridge 1 facility to Parc Adfer in Wales while a new Nuada pilot testing MOFs will be installed

Xodus appointed to one of Japan's first large-scale CCS projects

www.xodusgroup.com

Global energy consultancy Xodus has secured a contract to support the development of an advanced carbon capture and storage hub in Japan.

Xodus will design the pipeline and cable geotechnical surveys for the Offshore Western Kyushu CCS project. The project will enable significant carbon emissions reduction across key industrial sectors in Japan, to support the country's ambition to achieve carbon neutrality by 2050.

It is targeting the capture and storage of approximately 1.7 million tons of CO2 per year from ENEOS's oil refineries and J-POWER's thermal power plants located in the Setouchi and Kyushu regions. The captured emissions will be transported via ship and pipeline to saline aquifers off Japan's south-western island of Kyushu for permanent storage.

Saline aquifers off the coast of Western Kyushu have been identified as potential candidates for primary CO2 storage sites. The initiative seeks to develop a full-scale CCS value chain by 2030, encompassing CO2 separation, capture, transport, and storage.

Having worked across energy projects in Japan for many years, Xodus now has a full-time presence in Japan and is committed to supporting the rollout of the sector, the company said.

Clean Industrial Deal sends strong signal to EU industries but clarity needed

www.ccsassociation.org

The Carbon Capture and Storage Association (CCSA) welcomed the publication of the Clean Industrial Deal and its support for CCUS but said clarity on implementation was needed.

The CCSA said it particularly welcomed the positive signals sent to the CCUS industry, responding to the clear messages the CCSA set out in its open letter to the Commission in November – echoed by 30 MEPs – urging it to include CCUS in the scope of the Clean Industrial Deal.

"We support the Commission's commitment to rolling-out the creation of a market for captured carbon – with the Industrial Carbon Management Strategy (ICMS) building the case for permanent carbon removals and their potential to decarbonise hard-to-abate sectors," said the CCSA. "It is also reassuring to see the continued commitment to the review of the ETS Directive in 2026."

"However more clarity on the ICMS implementation is needed to make sure the EU leads on CCUS and realises its ambitions."

Solar-powered CO_2 capture from air to make sustainable fuel

Researchers from Cambridge have developed a reactor that pulls carbon dioxide directly from the air and converts it into sustainable fuel, using sunlight as the power source.

The University of Cambridge researchers say their solar-powered reactor could be used to make fuel to power cars and planes, or the many chemicals and pharmaceuticals products we rely on. It could also be used to generate fuel in remote or off-grid locations.

Unlike most carbon capture technologies, the reactor does not require fossil-fuel-based power, or the transport and storage of carbon dioxide, but instead converts atmospheric CO_2 into something useful using sunlight. The results are reported in the journal Nature Energy.

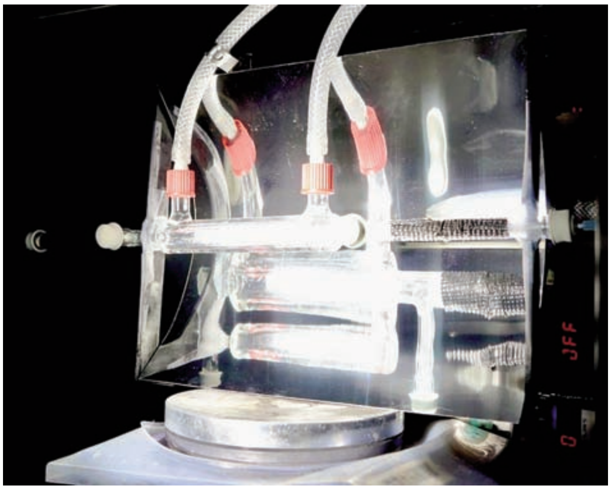
CCS is energy-intensive and there are concerns about the long-term safety of storing pressurised CO_2 deep underground, although safety studies are currently being carried out.

“Aside from the expense and the energy intensity, CCS provides an excuse to carry on burning fossil fuels, which is what caused the climate crisis in the first place,” said Professor Erwin Reisner, who led the research. “CCS is also a non-circular process, since the pressurised CO_2 is, at best, stored underground indefinitely, where it’s of no use to anyone.”

“What if instead of pumping the carbon dioxide underground, we made something useful from it?” said first author Dr Sayan Kar from Cambridge’s Yusuf Hamied Department of Chemistry. “CO_2 is a harmful greenhouse gas, but it can also be turned into useful chemicals without contributing to global warming.”

The focus of Reisner’s research group is the development of devices that convert waste, water and air into practical fuels and chemicals. These devices take their inspiration from photosynthesis: the process by which plants convert sunlight into food. The devices don’t use any outside power: no cables, no batteries – all they need is the power of the sun.

The team’s newest system takes CO_2 directly from the air and converts it into syngas: a key intermediate in the production of many chemicals and pharmaceuticals. The researchers say their approach, which does not require any transportation or storage, is much easier to scale up than earlier solar-powered devices.



Researchers have developed a reactor that pulls carbon dioxide directly from the air and converts it into sustainable fuel, using sunlight as the power source. Image: Sayan Kar - University of Cambridge

The device, a solar-powered flow reactor, uses specialised filters to grab CO_2 from the air at night, like how a sponge soaks up water. When the sun comes out, the sunlight heats up the captured CO_2, absorbing infrared radiation and a semiconductor powder absorbs the ultraviolet radiation to start a chemical reaction that converts the captured CO_2 into solar syngas. A mirror on the reactor concentrates the sunlight, making the process more efficient.

The researchers are currently working on converting the solar syngas into liquid fuels, which could be used to power cars, planes and more – without adding more CO_2 to the atmosphere.

“If we made these devices at scale, they could solve two problems at once: removing CO_2 from the atmosphere and creating a clean alternative to fossil fuels,” said Kar. “CO_2 is seen as a harmful waste product, but it is also an opportunity.”

The researchers say that a particularly promising opportunity is in the chemical and pharmaceutical sector, where syngas can be converted into many of the products we rely on every day, without contributing to climate change. They are building a larger scale version of the reactor and hope to begin tests in the spring.

If scaled up, the researchers say their reactor could be used in a decentralised way, so that individuals could theoretically generate their own fuel, which would be useful in remote or off-grid locations.

“Instead of continuing to dig up and burn fossil fuels to produce the products we have come to rely on, we can get all the CO_2 we need directly from the air and reuse it,” said Reisner. “We can build a circular, sustainable economy – if we have the political will to do it.”

The technology is being commercialised with the support of Cambridge Enterprise, the University’s commercialisation arm. The research was supported in part by UK Research and Innovation (UKRI), the European Research Council, the Royal Academy of Engineering, and the Cambridge Trust. Erwin Reisner is a Fellow of St John’s College, Cambridge.

More information

www-reisner.ch.cam.ac.uk

Filtration: the key to successful CCUS

Colm Joy, Chief Technical Officer at Cleanova, explores filtration's crucial role in guaranteeing the quality of captured carbon dioxide for industrial reuse and explains how system developers can engage more effectively with filtration experts to derive optimal return on investment

Techniques for separating carbon dioxide (CO2) from gas streams are well-established, but the sustainability imperative is driving innovation in carbon capture, utilisation and storage (CCUS) – particularly in utilisation. It makes practical, environmental and economic sense to reuse captured CO2 in applications such as food and chemical production, refrigeration, fire suppression and renewable fuels – but the gas quality has to be right.

CCUS encompasses a suite of technologies designed to capture CO_2 emissions from point sources such as power plants and industrial facilities, prevent their release into the atmosphere, and either store the CO_2 underground or repurpose it for industrial use. These processes hold the potential to significantly reduce CO_2 emissions and mitigate the effects of climate change. Filtration equipment plays a vital role in all stages of the CCUS process, from initial capture to compression, transportation, and storage or reuse.

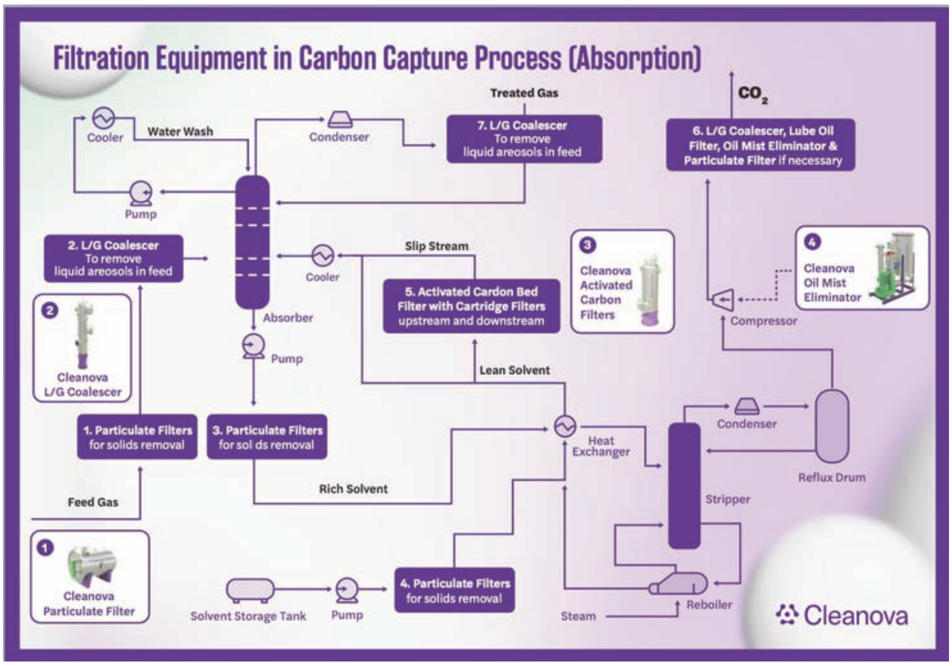


Figure 1: Filtration equipment in the absorption carbon capture process

The case for utilisation

Capturing carbon dioxide as part of an industrial process is not new. Various capture technologies already exist, including the use of solvents and membranes. These tried and trusted techniques are being adapted to improve efficiency and reduce costs in carbon capture and storage applications.

The practical challenges of permanent CO_2 storage are considerable. Identifying and assessing potential storage sites can be time-consuming and expensive. Where appropriate geological sites are identified, they may need to be adapted and monitored to prevent leakage. Transportation distances are also a factor. Building, monitoring and maintaining the necessary infrastructure adds significant costs1. Clearly, storage is not necessarily the most economical solution.

Utilisation can be a better option. There are established markets for CO2 and new applications, such as the generation of eFuels, are emerging. Applying circular economy principles and reusing CO2 in other industrial processes creates a value stream rather than a financial burden and supports wider sustainability objectives2. Whichever outcome is desired, the quality of the captured CO_2 is critical for success.

Filtration during capture

CCUS projects primarily focus on capturing CO_2 emissions from point sources, where it is more cost-effective to capture the gas directly from concentrated exhaust streams rather than from the ambient air. Correctly applied, filtration maintains carbon capture system efficiency and delivers the CO2 to downstream processes with minimal contamination.

1. Post-combustion filtration

Chemical absorption is the most mature technology for post-combustion capture, where solvents such as amines are used to selectively absorb CO_2 from the flue gas. This process is commonly employed in power plants, cement production, and other industries that burn hydrocarbons to produce energy. The CO_2-laden solvent is heated to release the captured CO_2, which is then compressed for transportation or storage.

Filtration protects the solvent from impurities in the flue gas that can cause fouling, foaming, and solvent degradation, which result in a lower per unit CO2 capture rate and exhausted CO2 escaping into the atmosphere. Residual organics and hydrocarbon removal via activated carbon filtration is equally important. Any contamination reaching the top of the absorber column will directly impact the quality of the CO2 and may lead to inefficient CO2 capture.

Figure 1 illustrates the primary points where filtration should be applied in a solvent absorption system.

2. Pre-combustion capture

Pre-combustion capture is a method by which CO_2 is separated from the fuel before combustion occurs. This technique is commonly used in integrated gasification combined cycle (IGCC) plants, where fossil fuels are converted into syngas (a mixture of carbon monoxide, hydrogen, and CO_2). Following a process known as the phase shift reaction, the CO_2 is separated to allow the hydrogen to be used as a clean fuel.

Filtration is required to remove impurities such as sulfur compounds, particulates and moisture from the syngas before CO_2 separation. Membrane technologies, pressure swing adsorption (PSA), and solid sorbents are often used for CO_2 removal in pre-combustion systems.

3. Oxy-combustion capture

Oxy-combustion involves burning fossil fuels in an environment of pure oxygen (O_2) instead of air. This reduces the presence of nitrogen in the flue gas, leaving primarily CO_2 and water vapour as combustion byproducts. The water vapour can be easily condensed, leaving a highly concentrated stream of CO_2.

The key component of an oxy-combustion system is the air separation unit (ASU), which generates the pure oxygen required. Filters are essential for removing impurities from the incoming air to protect the ASU and ensure efficient oxygen production.

4. Direct air capture

Direct air capture (DAC) is a non-combustion form of carbon capture and enables CO2 removal directly from atmospheric air. Solid DAC relies on sorbent materials with an affinity towards CO2 and uses a cycle system of adsorption and desorption. Liquid DAC uses solvents in a process based on absorption and regeneration loops.

Although a relatively new technique, the similarities between DAC and conventional carbon capture methods facilitate the transfer of existing filtration technologies into DAC processes for filtering the incoming air, maintaining solvent purity, and removing residual liquids before the air is released back into the atmosphere.

'Supercritical' filtration

Captured CO_2 is dehydrated and compressed to high pressure for transport and storage. This is known as the 'Supercritical' or 'Dense Phase' state. Undesired contaminants such as water, lube oil, oxygen and hydrogen sulphide (H_2S) present in the CO_2 can threaten pipeline integrity. H_2S and oxygen are corrosive and trace water can react with CO_2 to form corrosive byproducts and hydrates that cause pipeline blockages.

Solid corrosion products and pipe scale can also be carried downstream, fouling critical equipment such as control valves, metering stations, and high-pressure injection pumps. This increases maintenance costs and can involve equipment replacement or unscheduled downtime. Solid contaminants can also plug permeable storage reservoir pore structures, requiring increased energy for CO_2 injection and limiting the amount of available reservoir storage capacity.

In selecting filters and separators for dense phase CO_2 applications, substantial care must be taken over which materials are used, how filter sizing is performed, and the correct filtration rating. To protect reservoirs, the filter rating must be selected based on the reservoir permeability and approximate pore diameter. Figure 2 illustrates where filtration should be applied during the supercritical phase.

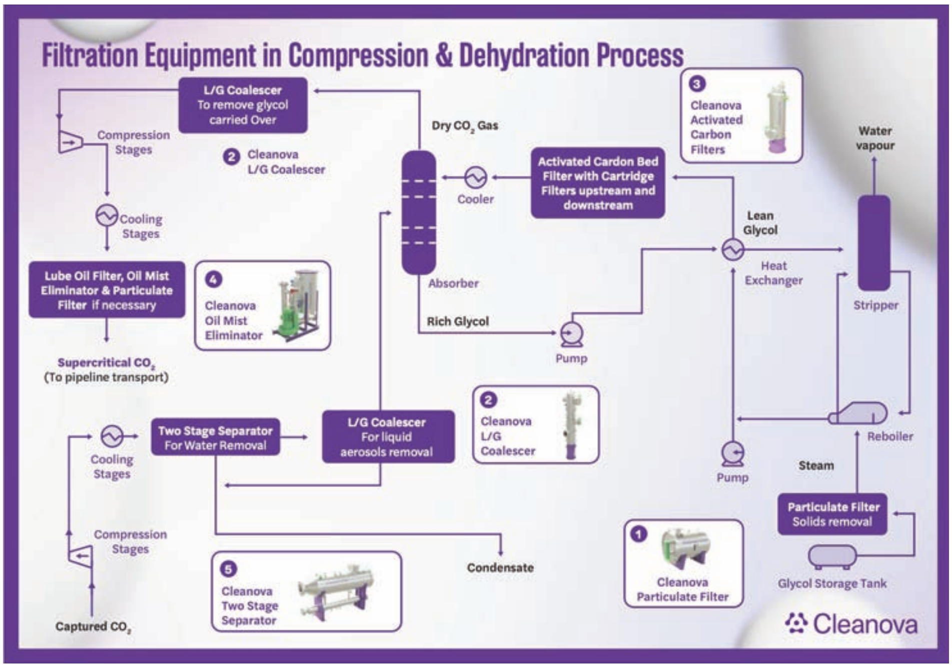


Figure 2: Filtration equipment in the CO2 compression and dehydration process

Getting filtration right

No 'standard' design for CCUS exists and each application will have unique process challenges. This makes it difficult to identify the best filtration solution. Cleanova.C-CLEAN3 provides a solution. This innovative approach recognises that each process has unique parameters and each customer has specific needs and desired outcomes.

It provides tailored filtration solutions designed for each carbon capture process, based on the chosen method, load quantities, type of contaminants, CO2 concentration, pressure and temperature. The aim is to collaborate with CCUS operators from the earliest concept stages, because considering filtration requirements from the outset, and within the context of the entire system design and business model, will yield the best results.

Driving down costs, optimising uptime, and delivering high-quality products are common aims in any industrial application. The correct application of filtration in CCUS systems contributes at every level and is critical to achieving global decarbonisation.

More information

This article is based on the whitepaper "Carbon capture, utilisation and storage: a filtration perspective", which can be downloaded here:

www.cleanova.com/ccuswhitepaper

SLB Capturi and Aker Solutions to deliver CO2 capture for Hafslund Celsio

They will deliver a carbon capture solution at its waste-to-energy facility in Klemetsrud, Oslo as part of the Longship project.

The contract includes delivery of a carbon capture plant, liquefaction system, temporary storage, and a loading facility at the waste incineration site. It also includes an intermediate CO2 storage and ship loading system at Oslo harbor, from where the CO2 will be transported to the Northern Lights permanent storage facility on the Norwegian continental shelf.

The waste-to-energy plant at Klemetsrud is the largest carbon emitter in Oslo and is responsible for 19% of the capital's fossil carbon emissions.

When operational, the carbon capture plant is expected to capture 350,000 metric tons of CO2 annually.

The project had previously been paused in 2023 due to fears of large cost overruns.

Hafslund Celsio has decided to proceed with the CCS project at its waste-to-energy plant in Oslo

"We are pleased to have Aker Solutions and SLB Capturi collaborating with us on this significant industrial project," stated Martin S. Lundby, chief executive officer at Hafslund Celsio.

"Working with reputable partners who possess extensive experience in carbon capture and storage from the Longship project provides us with security and strength. Our partners bring valuable expertise from large industrial developments both in Norway and internationally. Together, we will construct a carbon capture solution that is expected to be operational by third quarter 2029."

The engineering, procurement, construction, installation and commissioning (EPCIC) award follows a cost reduction phase for Hafslund Celsio's project, which identified opportunities for efficiencies, including layout optimization.

The project will now be delivered based on SLB Capturi's modularized Just Catch™ 400 unit. The space-efficient Just Catch design has been fundamental to enabling a viable, cost-effective solution by reducing onsite footprint, installation, and outfitting work.

"Standardization and modularization play a key role in shifting the economics of carbon capture projects," said Egil Fagerland, chief executive officer, SLB Capturi.

"We are extremely proud of our collaboration with Hafslund Celsio and Aker Solutions to align our Just Catch plant design with the techno-economic requirements of this project to help make it a reality. We look forward to delivering this flagship project as a successful blueprint for industrial decarbonization projects in Norway and across the globe."

Hafslund Celsio's project is the second carbon capture plant in Longship, where SLB Capturi is already delivering the carbon capture plant at Heidelberg Materials' cement facility in Brevik in collaboration with Aker Solutions.

"Today marks a significant milestone for Aker Solutions and the CCS industry in Norway. We are proud to be part of this key project and look forward to contributing with our effective project execution, based on three decades of experience in the CCS market," said Kjetel Digre, CEO for Aker Solutions.

"This project is a testament to important public and private collaboration to build an industrial value chain for carbon capture and storage. The project will also significantly contribute to reducing emissions and will create value for both industry and society."

The project will start in the first quarter of 2025 and is expected to be completed by 2029.

More information

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

University of Cincinnati develops efficient DAC system

Chemical engineers in UC's College of Engineering and Applied Science are developing a more efficient carbon capture system that can capture CO2 directly from the atmosphere.

University of Cincinnati Professor Joo-Youp Lee said the Golden Fleece of carbon capture draws carbon dioxide directly from the atmosphere, which is much, much harder than capturing from point sources.

"The concentrations of carbon dioxide in the atmosphere are so low," he said. "It would be like trying to remove a handful of red ping-pong balls from a football stadium full of white ones."

He is a professor of chemical engineering in UC's College of Engineering and Applied Science.

But Lee and his students have developed a promising system of removing carbon dioxide at about 420 parts per million from the air. And with his process called direct air capture, it can be deployed virtually anywhere.

Power plants and transportation are responsible for about 53% of all carbon dioxide emissions. The remaining emissions are generated by industry, commercial and residential buildings, agriculture and other human activities.

"Although industrial decarbonisation efforts are underway, it's really hard to implement carbon capture in the remaining sectors," Lee said.

The system Lee developed in his lab uses electricity to separate carbon dioxide. But he is advancing his system by using hot water instead of electricity or steam, making it more energy efficient than other carbon-capture systems. And it's robust enough to last for thousands of cycles.

To test his system, Lee built a benchtop model about the length of a pool noodle. Air from outside the building is pumped through a canister. Lee said they can't use indoor air because it typically contains more carbon dioxide from the people using the building.

Inside the canister, the air whooshes through a honeycomb-like block wrapped with carbon fiber that Lee's lab had custom manufactured. The individual cells of the block are coated with a special adsorbent material that Lee's team designed to capture carbon dioxide. Gauges on the air intake and exit measure the amount of carbon dioxide in the air. When the readings on the outlet of the block begin to climb, Lee's students know it's time to heat the structure to remove the trapped carbon dioxide with a vacuum pump and begin the process again.

UC doctoral student James Akinjide holds up a honeycombed block covered in an adsorbent that captures carbon from air. Photo/Andrew Higley/UC Marketing + Brand

UC researchers have been able to repeat the process more than 2,000 times without seeing any decline in efficiency or degradation of the materials. But Lee said he thinks 10,000 cycles is within reach. This efficiency would make the system more economically appealing,

Lee's team scaled up the project in one of UC's high-bay engineering labs, where students work on engines and other big industrial projects. Here, Lee maintains a climate-controlled environmental chamber where he can do larger-scale experiments of his concept.

They built a person-sized canister that again draws air from outside the building. But in this sealed room they can control temperature, humidity and wind speed. And they use larger honeycombed blocks the size of a loaf of bread.

"I think it's a great project. We're doing some real applications that can help the environment," UC postdoctoral fellow Soumitra Payra said.

Payra is optimistic that this technology will be pulling carbon dioxide out of the atmosphere at scale soon.

With the promise of his demonstration system, Lee is hoping the U.S. Department of Energy will continue to support his plans to develop an industrial-size prototype.

"Our technology has proven to reduce the heat required for the desorption by 50%. That's a really big improvement," he said. "By using half of the energy, we can separate out carbon dioxide more efficiently. And we can make the cycle longer and longer."

Projects like this could be funded through carbon credit systems like the Regional Greenhouse Gas Initiative, which indirectly pays for energy efficiency programs in 11 states.

Lee said these systems could be instrumental in addressing climate change as demand for electricity is expected to surge in years to come.

"Big tech companies like Google, Microsoft and Amazon are supporting this type of research. They will need a lot of energy to run their data centers," he said. "In the carbon tax credit market, the more electricity you use, the more carbon dioxide you emit. So they're buying carbon tax credits, which support the development of these carbon-capture technologies."

Lee's research is supported through the U.S. Department of Energy National Energy Technology Laboratory.

More information

www.uc.edu

Capture & utilisation news

Bright Renewables to build CO2 liquefaction plant in Austria

www.bright-renewables.com
www.biomassehof.at/energiewerk-ilg

The company will build a carbon capture and CO2 liquefaction system for EnergieWerk Ilg's wood-fired power plant in Dornbirn, Austria.

CO2 from the waste gas will be captured and liquefied for a wide range of industrial uses. The system is to be commissioned at the end of July 2025 and is expected to reduce the plant's CO2 emissions by c. 80%.

EnergieWerk Ilg GmbH, an energy company and producer of biochar, operates a wood-fired heat and power plant that incorporates CHP (Combined Heat and Power) to generate green electricity and heat. The plant emits 2,500 Nm3 of flue gas per hour, part of which is CO2. Bright Renewables' modular built carbon capture system CarboPac-C will capture and liquefy 600kg/hr of this CO2.

The process will generate 3.7 kilotons per year of high-purity, food-grade bioCO2, which can be sold to the food and beverage industry, replacing CO2 from fossil sources. BioCO2 is a valuable end-product that can be used across industries for many applications. The CO2-neutral carbonic acid for the beverage industry actively contributes to climate protection. Another goal is use in building materials where CO2 can be stored permanently and represents a carbon sink.

The CO2 capture project makes it possible to separate biogenic CO2 from the flue gases of the biomass heat and power plant. Bright Renewables uses both amine-based carbon capture technology and Vacuum Swing Adsorption (VSA) technology to separate CO2 from flue gas. Both technologies are applicable for the addition of CO2 liquefaction technology and both technologies have a high yield of gaseous CO2. In this Austrian project, amine-based technology is applied.

The carbon capture system and CO2 liquefier will be installed on the roof of EnergieWerk Ilg's existing facility, reducing its footprint and the use of (costly) land. Julia Ilg of EnergieWerk Ilg GmbH, said, "Sustainability is at the core of what we do. This carbon capture and CO2 liquefaction plant will help us to reduce our annual greenhouse gas emissions by an estimated 4,000 tons of fossil CO2. This is a major step towards our goal to operate in an ecologically and economically sustainable manner so that we can protect nature while securing a future worth living for future generations."

CO2 from EnergieWerk Ilg's wood-fired power plant in Dornbirn, Austria will be captured and liquefied to generate high purity food grade CO2

Because of Bright's sustainability ambitions, carbon dioxide is used as a refrigerant during the CO2 liquefaction process, replacing traditional synthetic refrigerants such as Freon or Ammonia. CO2 is a natural refrigerant that is environmentally friendly and safe. This technology enhances the liquefaction efficiency, reducing operational expenses and increasing bioCO2 production capabilities. The use of CO2 optimises energy consumption, making it a more sustainable and cost-effective solution.

NeoCarbon and Carbonaide partner to store DAC CO2 in concrete

www.neocarbon.tech
www.carbonaide.com

The companies have announced the successful mineralisation of the first batch of concrete cured with ~1 kg CO2 captured from NeoCarbon's pilot Direct Air Capture (DAC) blended with other biogenic CO2.

The collaboration will see an increase in the share of DAC CO2 used in the mineralisation process, in addition to CO2 captured from biogas and waste-to-energy plants. DAC has a more flexible implementation and a modular unit that can be located anywhere - eliminating the liquefaction and transportation costs, as well as saving a lot of time in refilling the CO2 tank.

NeoCarbon's CEO, René Haas, commented, "The first shipment of captured CO2 represents a significant step in our mission to decarbonize the cement and concrete industry. Our work with Carbonaide is transforming how the construction sector views CO2—turning it from a challenge into an opportunity. We are proud to be at the forefront of this innovation, and are very excited to scale up the capture and storage capacities in the years ahead."

The process not only results in around 50% lower footprint, but can also transform concrete into a carbon-negative material if low-carbon binders are used instead of cement. In the upcoming years, NeoCarbon and Carbonaide aim to increase the storage capacity to thousands of tonnes from 2026 onwards.

The cement and concrete industries account for approximately 8% of global CO2 emissions, primarily due to the energy-intensive clinker-burning process and the release of CO2 during the chemical reactions involved in cement production. With demand for infrastructure and construction rising, finding effective solutions to reduce emissions in this vital sector is more critical than ever.

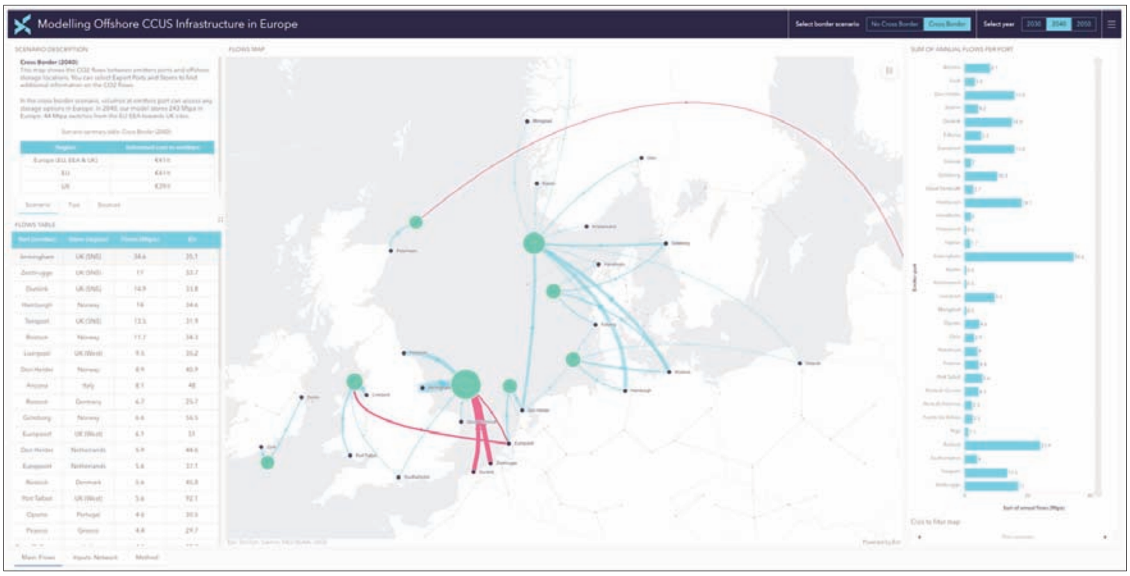
NeoCarbon's first paying customer pilot has successfully demonstrated how DAC technology can be implemented in real-world industrial environments. The fully operational DAC unit at the pilot site captures CO2 from the atmosphere using waste heat, ensuring a highly energy-efficient process. This marks a key milestone in optimising DAC technology for broader industrial application.

The CO2 captured by NeoCarbon is now being used by Carbonaide to mineralise and permanently store the CO2 in pavement products. They are on track to start generating high-quality carbon removal credits in 2025, helping companies reach Net-Zero.

Xodus dashboard provides EU CO2 transportation costs

A new online interactive dashboard that allows users to measure the costs of transporting carbon to any region in Europe has been launched.

Developed by global energy consultancy Xodus, in partnership with the Carbon Capture Storage Association (CCSA), the tool will help industry to interact with and analyse the economics of different CCUS options.



Modelling offshore CCUS infrastructure in Europe

The dashboard captures economic modelling of the transport and storage of CO2 in Europe (EU-EEA-UK) meaning emitters can now assess the cost of transferring their CO2 to any offshore storage site in Europe.

At the same time, storage operators will be able to visualise where the demand for their services is located, while policymakers can use the information to define regulatory solutions that support optimisation of infrastructure access

Developed by an integrated team including advisory experts, energy development specialists and geospatial consultants over the course of 18 months, there is an ambition to add to the dashboard to ensure that it remains live and accurate as the sector matures and costs change.

Olivia Powis, CCSA CEO, said, “A Europe-wide CO2 market is within reach and it is essential that industry and policymakers have economic modelling, as it can provide important insights into feasibility, risk management, and financial planning for projects and clusters."

“As our report into accelerating a Europe-wide CO2 storage market found, there is an exciting opportunity to cut CO2 storage costs by 20% across Europe and save billions annually if the EU and UK break down policy barriers and make cross-border CO2 storage happen."

“The future of CCUS in Europe, as well as effective climate action, hinges on deploying CCUS across Europe and this dashboard will be a helpful tool in achieving this.”

The launch of the free to use dashboard follows the publication of the CCSA report ‘Accelerating a Europe-wide CO2 storage market’, which is based on modelling and analysis by Xodus.

Released at the end of 2024, the study found that storage costs could be cut by 20% and billions saved annually if the EU and UK are able to break down barriers to CO2 transport.

The dashboard also builds on Xodus’ ‘Forecasting the North Sea CCUS infrastructure to 2050’ study, which was published in 2023 and found that 100 North Sea storage sites will be needed to meet 2050 CCUS demand.

James Monnington, Global Geospatial Director at Xodus, said, “Xodus has long recognised the importance of adopting integrated, spatial thinking to model and solve real-world problems, championing the use of advanced techniques to provide a holistic perspective and communicate results in an accessible and engaging form."

“We have developed this tool to allow users to interrogate the summary-level model outputs, query input data and deep-dive into the underlying methodology that will underpin Europe’s CO2 storage market."

“It will help emitters, storage operators and policymakers determine the solutions that make the most sense economically and technically and we look forward to seeing the real-world outputs that arise from it.”

More information

www.xodusgroup.com

www.ccsassociation.org

CO2 storage - finding the best locations

A "Common Risk Segment" (CSR) mapping approach could identify which places in the world are lowest risk for CO2 storage based on multiple factors. Catherine Horseman-Wilson of Wood Mackenzie presented a study. Report by Karl Jeffery.

When looking for a CO2 storage site to invest in, you might ideally want storage which has been 'risked' by regulators, in a region with a national CCUS target, a carbon price, government support, possibility of international CO2 transport, and a regulatory framework for CO2 injection.

Catherine Horseman-Wilson, Senior Research Manager EMEA CCUS, Wood Mackenzie, examined these factors for different possible CO2 storage sites around the world, to see which places work out best taking multiple techno-economic factors into account.

She was speaking at the Geoscience Energy Society of Great Britain (GESGB) CCS for Geoscientists (CCS4G) event in London on December 17.

This is a 'CO2 storage' version of the 'Common Risk Segment mapping' activity commonly undertaken in hydrocarbon exploration, to find the lowest risk places to explore based on multiple factors. Most of the factors have more to do with government policy than to the subsurface itself, she said.

For availability of storage space, we can start by saying that nearly everywhere in the world has possible reservoirs, because everywhere in the world has rock. There are many areas with water, oil or gas production from subsurface reservoirs.

But very few countries have thoroughly studied these for CO2 storage so far. 83 per cent of the storage capacity in the world which has been "risked" (analysed for suitability for CO2 storage) to date is in just 10 countries, she said. Biggest to smallest, these are US, Canada, UK, China, Australia, India, Norway, Netherlands, Saudi Arabia, Indonesia.

US, UK and Canada combined have 55 per cent of the "risked" global capture capacity today. However Wood Mackenzie studies suggest this will decline to 40 per cent by 2035, as other countries develop storage sites, she said.

Another big enabler is whether countries have a national CCUS target. The biggest targets are in Europe and also Saudi Arabia, she said.

Carbon pricing is a big factor which will make CO2 storage viable. The highest prices are currently in Europe and Canada. But there are many different schemes around the world. The average price for the world, weighted by how much each region emits, is only $25 a tonne CO2.

The most advanced government funding is in US, Canada and UK, where support is provided to the "full chain" of capture and storage. But there are particularly interesting funding projects in Brazil, Germany, Australia, Sweden, Saudi Arabia, she said.

The EU Innovation Fund has granted Euro 3.2bn to CCUS projects since 2021, and there is Euro 4.2bn available in the 2024 "call for large scale projects". Consequently, there is growing activity in the Mediterranean, such as with Italy, Spain and Greece.

Another area to consider is whether CO2 can be transported between countries by ship. Historically, this is prohibited under the London Protocol which covers dumping of waste, unless two countries explicitly agree otherwise. However, 12 countries so far have now made such agreements, including Belgium, Denmark, France, Malaysia, Netherlands, Norway, Sweden, Australia.

Another factor is whether the country has a regulatory framework for offering CO2 storage licenses and permits to inject. This is available in the UK, US, Norway, much of the EU and Australia.

Many eyes will be on Denmark during 2025, because it has offered onshore licenses, which could enable a much reduced CO2 storage cost, she said.

While CO2 storage licensing is growing in general, there have been some noises in the market that Norway may slow down licensing in 2025 and focus more on appraisal projects, she said.

Putting all of these risk factors together, the countries with the lowest risks turn out to be the UK, US, Canada and France, she said.

Catherine Horseman-Wilson, Senior Research Manager EMEA CCUS, Wood Mackenzie

Ms Horseman-Wilson was asked by an audience member whether some governments are "shooting themselves in the foot" by setting unachievable targets. This person cited Denmark's target timelines which don't tie up with its CCUS financing plans, UK's target to store 20-30 million tons per year of CO2 by 2030, and targets in Japan.

"We need to be careful about managing expectations," she replied. "In UK, if we don't hit targets, people will say, 'I'm not getting bang for my buck'".

Projects typically start with small injection rates, "especially aquifers where there's a lot of unknowns." For example, Project Greensand in Denmark is starting at just 400k tonnes a year, although it aims to ultimately store 8m tonnes a year.

More information

www.ges-gb.org.uk

Storing CO2 underground in Switzerland

Researchers at ETH Zurich have investigated whether CO2 can be permanently stored underground in the Swiss Alps by compiling all criteria for the first time.

To achieve its net zero climate target by 2050, Switzerland must press forward with the energy transition – whether in electricity, heating or mobility. The permanent storage of CO2 is another important challenge. In particular, Switzerland must find a permanent solution for emissions that are difficult or impossible to avoid, such as those produced by waste incinerators.

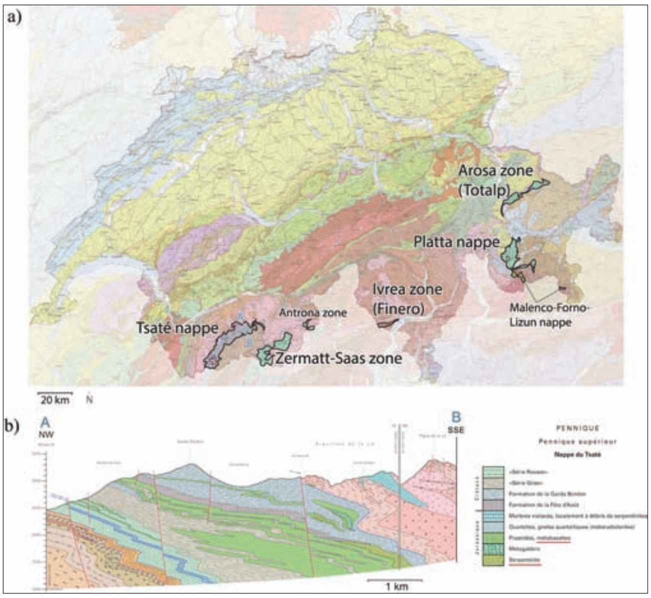
Researchers at ETH Zurich have conducted the first ever study to investigate whether CO2 can be permanently stored underground in Switzerland in the form of carbonate rock, and what criteria would need to be met for this to happen. They present their findings in a study recently published in the Swiss Journal of Geosciences.

Initially ETH researchers wanted to find out whether there are any zones in Switzerland where CO2 can be permanently stored in the rocky underground. Permanent storage of CO2 underground requires that the rock be rich in calcium, magnesium and iron, while at the same time containing as little silicon dioxide as possible. Potential candidates include basalt, peridotite and serpentinite.

For ideal storage capacity, the rock in the subsurface must also be of a certain volume and located at a depth of at least 350 metres in order for the pressure to be high enough to keep the CO2 in the water. An optimal temperature of between 90 and 185 degrees Celsius, plus the age, alteration condition, porosity and permeability of the rock all play an important role as well.

“These are some of the criteria that have to be met before an area can even be considered as a reservoir,” said Adrian Martin, whose master’s thesis forms the basis for this study"

Thanushika Gunatilake, a former postdoc with Stefan Wiemer, a professor in the Department of Earth and Planetary Sciences and head of the Swiss Seismological Service, also worked on the study. She is now an assistant professor at the Vrije Universiteit Amsterdam and emphasises that this nationwide search for suitable rock types is the first of its kind in Switzerland. Martin has not only analysed numerous scientific studies; he has also examined geological maps area by area and identified those locations that meet the criteria and could therefore be suitable for in-situ CO2 mineralisation. These areas include the Zermatt-Saas zone and the Tsaté nappe in Valais, as well as the Arosa zone in Graubünden.



The areas identified by Martin are not currently suitable for permanent underground storage of CO2. “Although we do have suitable rock types in Switzerland, we face major technical challenges,” says Martin. The geological structure is very complex due to the heavily folded rock strata and tectonic faults. At the Tsaté nappe in Valais, the layers in suitable rocks in areas such as the one between Gouille and Mont des Ritses can have a thickness of over 500 metres, while at Les Diablons thickness is only around 150 metres.

Other factors compound the issue: the rocks in the Zermatt-Saas zone, for example, were transformed in the past by high pressures and temperatures and now already contain many carbonate minerals, indicating that natural CO2 absorption (i.e. previous mineralisation) has already occurred. Furthermore, the Zermatt rocks are packed very close together underground and contain few open cavities or cracks, into which the CO2 could penetrate.

Additionally, the volume of water required for in-situ mineralisation is enormous – close to 25 tonnes of water would be needed to store one tonne of CO2. Martin adds: “On top of that, there are economic and societal hurdles: Who will bear the costs? How do you overcome the scepticism of local residents who are concerned about water pollution, for example? What would be the legal regulations?”

The researchers concluded that permanent storage of CO2 through in-situ mineralisation in Switzerland is not feasible in the short term and appears unsuitable in the long term. They therefore recommend investigating alternative storage methods. Gunatilake has recently published another study, this time focussing on storing CO2 in saline aquifers. For this project, researchers used numerical simulations to analyse data from the area around Triemli in Zurich. They succeeded in injecting CO2 into the geological unit, the lower Muschelkalk, to a depth of over 2,000 metres without water. “This method of CO2 storage is promising,” emphasises Gunatilake.

There are also projects that successfully demonstrate permanent storage of CO2 underground. “One example is the DemoUpCARMA project, where CO2 from Switzerland was transported to Iceland where it is now stored underground in the form of carbonate rock,” said Martin.

It is important to raise public awareness of the issue and to dispel myths and rumours. “Many people think we’re creating a bubble underground and that it could even explode at some point,” explained Martin. “But the risk to the public from underground CO2 storage is minimal and the methods are scientifically well proven.”

More information

https://ethz.ch/en.html

Samsung E&A to optimise Carbon Clean CO2 capture tech for MODEC FPSO

MODEC has entered into a FEED contract with SAMSUNG E&A for an offshore carbon capture pilot project on a Floating, Production, Storage and Offloading vessel, selecting Carbon Clean's modular CycloneCC technology.

The study envisages the installation of a carbon capture module on a MODEC Floating, Production, Storage and Offloading (FPSO) vessel as a pilot, and it will be a first-of-a-kind deployment of CycloneCC in an onboard carbon capture setting.

Koichi Matsumiya, Chief Technical Officer, MODEC, said, "MODEC is proactively pursuing two targets through our R&D activities. One is to provide a stable energy supply to society with minimum GHG emission, and another is to prepare for new floater solutions to bridge the society with alternative energies from oil and gas."

"We believe that the carbon capture technology proposed by Carbon Clean will be the key to achieve both of our targets. We will make our best efforts to progress the readiness level of this technology by utilising our experience at offshore and would like to materialise this technology at offshore in the shortest possible timeframe."

The modular CycloneCC carbon capture technology is well suited to offshore maritime use due to its small footprint and enhanced performance under vessel motions

Carbon Clean will provide FEED support to SAMSUNG E&A, including equipment supply of the rotating packed bed (RPB) technology at the heart of CycloneCC and process design package (PDP) licensing for the unit. SAMSUNG E&A will perform detailed engineering to optimise CycloneCC for the offshore environment and FPSO's boundary conditions.

CycloneCC is well suited to an offshore maritime environment, as the unit footprint is up to 50% smaller than conventional solutions, with its largest equipment sizes reduced by a factor of 10. The recently launched CycloneCC C1 series delivers a height reduction of 70% compared to column-based technologies. The RPBs will achieve enhanced capture performance under vessel motions compared to columns, making CycloneCC ideal for offshore operations.

Aniruddha Sharma, Chair and CEO, Carbon Clean, said, "We're proud to deliver this groundbreaking, first-of-a-kind project with industry leaders SAMSUNG E&A and MODEC. Onboard carbon capture is essential for decarbonising offshore oil and gas operations."

"Our highly modular CycloneCC technology is 10x smaller than conventional solutions, making it ideal for confined spaces, including floating vessels and maritime settings. Its replicable, scalable design makes it logistically and commercially viable to be deployed across a fleet at a fraction of the cost of traditional amine systems."

The carbon capture project is in line with MODEC's decarbonisation strategy outlined in its Vision 2034 plan, specifically the goal of reducing CO2 emissions in its FPSO operations. Once successful, the next stage may include the installation of a commercial, scaled-up CycloneCC unit on MODEC's FPSO fleet.

Samsung E&A and Carbon Clean also recently partnered with Aramco to deploy CycloneCC at a gas turbine project in Suadi Arabia where very low concentration CO2 streams will be captured.

More information

www.modec.com

www.samsungena.com

www.carbonclean.com

Transport and storage news

ORLEN and Equinor to collaborate on CCS technology

www.orlen.pl
www.equinor.com

Under the agreement, ORLEN and Equinor will jointly identify potential CO2 storage sites, considering both land-based locations and areas within the Polish section of the Baltic Sea.

In the next step, the partners will assess the feasibility of joint projects based on the identified storage locations in Poland.

"Our collaboration with Equinor marks a major milestone in advancing the ORLEN Group's strategic goals. We are joining forces with an experienced and driven partner to develop unique know-how in the CCS technology. Building on this knowledge, we aim to establish a new, forward-looking business area that will boost our decarbonisation potential. At the same time, the initiative has the potential to serve as a catalyst giving rise to an entire ecosystem of businesses that could grow, create value, and generate new jobs. This is how we fulfil our role as the energy transition leader," said Wieslaw Prugar, Member of the ORLEN Management Board, Upstream.

As part of its new strategy, ORLEN has committed to achieving an annual carbon capture, transport, and storage capacity of 4 million tonnes by 2035. A portion of this capacity would be allocated to advancing the ORLEN Group's net zero goal, mainly for its petrochemical and refining assets, while the remainder would be offered as a service to other firms.

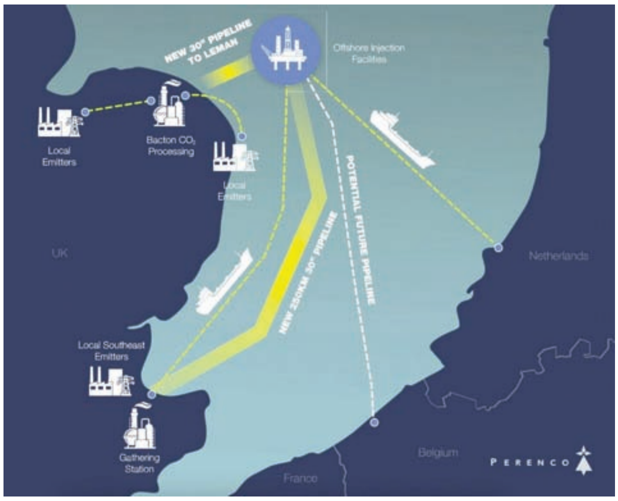
ORLEN's plans for CCS, and its resulting collaboration with the Norwegian partner, reflect the Company's ambitious decarbonisation goals and align with new European regulations. In June 2024, the EU's Net-Zero Industry Act (NZIA) came into force, aimed at enhancing the competitive strength of European companies in zero-emission technologies and improving access to such solutions.

Among other provisions, NZIA sets specific targets for CCS capacity development, mandating that the EU achieve an annual CO2 injection capacity of 50 million tonnes by 2030. The responsibility for meeting this target falls on companies engaged in oil and gas extraction within the EU, including ORLEN.

Carbon Catalyst begins CO2 injection at Poseidon

www.carboncatalyst.co.uk
www.perenco-ccs.com

This is the first of its kind in UK waters and following a successful injection test the project will move to FID in 2027 and first commercial storage in 2029.



Perenco's partner Carbon Catalyst has begun injecting CO2 into a depleted gas field in a UK first

The Poseidon injection test uses Petrodec's Erda rig, specially equipped for the injection of CO2 into the H compartment of the Perenco-operated Leman depleted gas field in the UK Southern North Sea. This operation follows the successful recompletion of the H27 well in August 2024.

It is anticipated that Poseidon will target an initial annual injection capacity of 1.5 million tonnes of CO2, scaling up to an ultimate annual injection rate of 40 million tonnes. Given this, and the potential 1 billion tonnes storage capacity, Poseidon is set to become one of the largest Carbon Capture & Storage projects in Northwest Europe.

Nick Terrell, Executive Director at Carbon Catalyst, commented, "CCL is delighted to announce the start of CO2 injection at Poseidon. This project has the potential to play a very significant role in decarbonising both the UK and Continental European economies. As such, reaching this milestone is an extremely positive step in derisking the project and advancing it towards commercial viability."

Stryde to supply seismic nodes for Danish CarbonCuts project

https://strydefurther.com
www.s3seismic.com

Stryde has secured a major contract to supply 42,000 autonomous nodes to Smart Seismic Solutions (S^3) for the Danish onshore CO2 storage project.

The nodes will be deployed on a 3D high-density seismic survey for the CarbonCuts CO2 Storage Project, a high-profile initiative aimed at identifying optimal onshore subsurface storage solutions for CO2 sequestration.

The seismic survey will be crucial in advancing Denmark's ambitious goal of achieving net-zero emissions by 2045, using advanced seismic technology to map geological formations with unprecedented accuracy, ultimately helping to ensure safe and effective onshore CO2 storage.

With geological CO2 storage now a globally recognised, proven, and safe technology to tackle the climate crisis, and CO2 storage on land being significantly more affordable than offshore options, onshore CO2 storage is becoming increasingly accessible for a wider range of emitters to manage their emissions responsibly.

"The CarbonCuts Project is a cornerstone in Denmark's journey toward a greener future, and we are proud to contribute. The Rødby structure, an elongated anticlinal dome with a four-way closure that formed during the Mesozoic Era over a Zechstein salt pillow, is a fascinating target for this high-density seismic survey," said Patrick Robert, CEO at S^3.

"The dense deployment of STRYDE nodes provides exceptional clarity of the subsurface, enabling stakeholders to identify geological structures suitable for carbon storage with greater precision. This significantly reduces risks and enhances the reliability of long-term CO2 sequestration solutions."

Samsung E&A optimises Carbon Clean CO2 capture tech for MODEC FPSO

Image: MODEC