Carbon Capture Journal

CCUS in Australia

Optimising CO2 storage utilisation - insights from Otway Stage 4

Offshore permits show growing role of CCS

Sept / Oct 2024 Issue 101

CCSA highlights pivotal role of CCUS technology in the net zero transition

The UK-based Carbon Capture and Storage Association (CCSA) has published CCUS Voices, gathering independent insights from experts across the CCUS value chain to emphasise the technology's essential role in climate mitigation.

Drawing on expertise in areas such as power and industrial decarbonisation, innovation and skills, CO2 transport and storage, carbon markets, governance, sustainability and public perception, the report sets out ambitions for the delivery of a new CCUS industry at pace across the UK and EU.

Ruth Herbert, Chief Executive of the CCSA said, “The UK CCUS industry has come a long way in recent years and is now poised ready to deploy the first two CCUS clusters. I have been encouraged by the level of innovation, insight and expertise in the industry, as well as the ambition to drive forward projects to create the low carbon economy.”

“These experts have provided their perspectives on the future opportunities that the industry can unlock, as well as what is needed to further develop the industry from both the Government and through industry lead initiatives, in order to navigate the next set of challenges and seize the global opportunities.”

The deployment of the world’s first large-scale CCUS clusters in the UK will be instrumental in achieving net zero ambitions and driving sustainable industrial growth, and will provide learnings to other countries with ambitious CCUS plans.

As CCUS transitions from concept to large-scale reality, the perspectives set out in CCUS Voices from thought leaders in industry, academia, and policy, offer an in-depth analysis of the challenges as well as the important opportunities ahead.

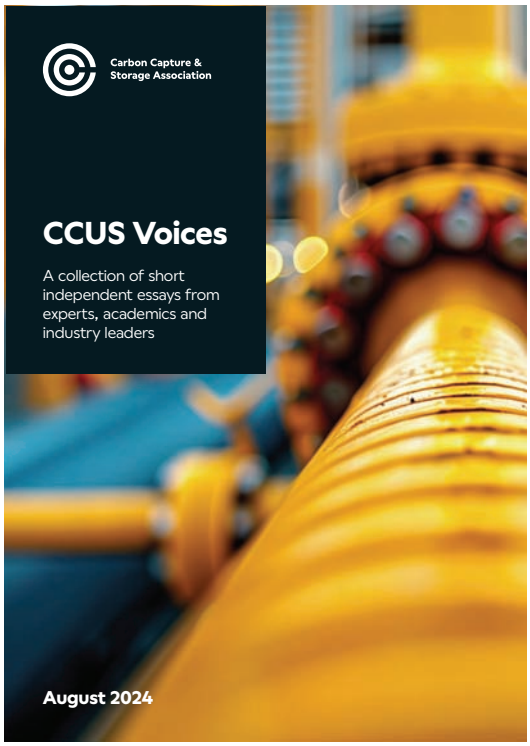
“These ‘Voices’ collectively highlight the multiple opportunities, and some of the challenges, within the CCUS landscape, both across the UK and the EU,” said Olivia Powis, UK Director, CCSA.

“They stress the need to future-proof key manufacturing and industrial sectors by using CCUS technology. They also highlight the importance of having skilled engineers, supporting women in the industry, building strong CO2 transport infrastructure and cross-border collaboration, and innovating within the supply chain.”

These experts have put forward recommendations on the immediate actions needed to advance CCUS. This includes establishing clear policy direction and expansion plans for CCUS clusters, reforming planning and permitting systems to accelerate project timelines, and implementing supportive revenue models to drive private sector investment.

Sir David King, Founder & Chair of the Global Climate Crisis Advisory Group (CCAG), concludes the report, "CCUS Voices presents crucial insights from experts at the forefront of CCUS work. It highlights vital points for the UK and other governments to consider: the lack of investible business models with a bankable revenue stream, the need for a Europewide competitive model for CO2 storage (including the UK), the necessity of reforming the planning and permitting system, and exploring the abundant deep porous rocks offering the potential to store 130 billion tons of CO2 across Europe. Globally, we could achieve a storage rate of 10-15 billion tons per annum."

"Ultimately, CCUS is not just a tool, but the linchpin for securing our planet’s future."



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More information

Read the full report at:

www.ccsassociation.org

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Back cover: Calix will demonstrate the Leilac technology at a world first renewable energy powered plant in South Australia to produce near zero emissions lime and supply captured industrial CO2 emissions to the HyGATE funded Solar Methanol 1 project (SM1) (pg. 8)

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Leaders - CCUS in Australia

Projects and policy

Capture and utilisation

Transport and storage

Optimising CO2 storage resource utilisation: insights from Otway Stage 4

Otway Stage 4's field demonstration and R&D endeavour will enhance CO2 storage technologies, improve the utilisation of storage resources, and accelerate the development of commercial CO2 storage says the team from CO2CRC in a recent paper published in the Australian Energy Producers Journal.

CO2CRC's Otway Stage 4 program aims to improve site modelling workflows and demonstrate the potential for a >20% increase in CO2 storage efficiency through innovative reservoir management techniques, and develop low-cost monitoring technologies. Further, this program will demonstrate the viability of lower-quality reservoirs for effective CO2 storage.

The program, conducted at CO2CRC's Otway International Test Centre (OITC), will involve two sequential injections of up to 10,000t of CO2-rich fluid, with the first of these commencing in October 2024,

The GeoCquest Field Validation (GFV) project, a collaboration between CO2CRC, University of Melbourne and Stanford University, is a key component of Otway Stage 4, demonstrating a new workflow for understanding fine-scale CO2 flow processes in heterogeneous reservoirs, by acquiring and analysing time lapse CO2 saturation and fluid data during the CO2 plume's migration,.

Another key area of field research, in collaboration with RITE, conducted as part of Otway Stage 4 involves the injection of CO2 microbubbles (MBs), which, due to their smaller size, lower buoyancy effect, and enhanced dissolution properties, significantly increase storage efficiency compared to standard CO2 injection.

Surfactant injection is also being explored by KIGAM (at bench-scale using the OITC's samples and datasets) to enhance CO2 storage effectiveness. By modifying interfacial tension (IFT) and wettability, surfactants are expected to improve sweep efficiency and minimise CO2 footprint. Such modifications could lead to improved injectivity, thus reducing the pressure requirement for CO2 injection and increasing the overall storage capacity.

Two innovative techniques, CO2 saturation monitoring from seismic and Distributed Strain Sensing (DSS), are also being trialled by CO2CRC, in collaboration with Curtin University and RITE respectively, in conjunction with the CO2 injections. Performance monitoring capabilities are an important component for storage optimisation, measuring effectiveness and providing on-demand information for operational decisions.

The monitoring component of the program aims to generate time-lapse, seismic-based CO2 saturation maps, providing insights into storage efficiency. DSS will use Rayleigh scattering to assess geomechanical responses to CO2 injection.

The outcomes of the Otway Stage 4 program are expected to include materially advanced reservoir management technologies, demonstrating a minimum 20% increase in CO2 storage efficiency and cost-effective monitoring solutions, which will ultimately accelerate the commercial viability and uptake of CO2 storage at scale.

SLB and Wild Desert contractors running cables down the outside of the tubing at CO2CRC's Otway International Test Centre Stage 4 injection well CRC-3 (Image: CO2CRC)

Background

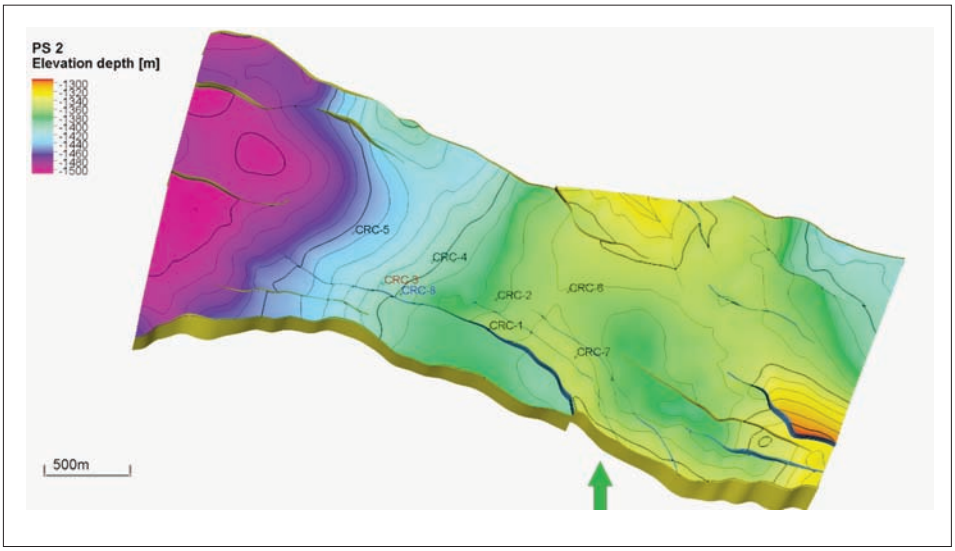
The optimised use of storage resources and accelerated commercial CO2 storage development is vital for carbon capture and storage to play an important role in reducing emissions at scale.

CO2CRC is seeking to address this challenge through an international collaboration – the Otway Stage 4 field program – that demonstrates a suite of cost-effective reservoir management techniques with the potential to improve CO2 storage capabilities, particularly in

lower-quality reservoirs, maturing them for commercial readiness.

Aiming to enhance injectivity, improve sweep, increase model resolution, and develop performance monitoring capabilities, Otway 4 will substantially improve CO2 storage resource usage, furthering economical viability for decreasing CO2 emissions to the atmosphere.

Otway Stage 4 includes acquisition and analysis of CO2 saturation and chemical data during plume migration and trapping, combined with investigation of fine-scale geological heterogeneity's role in CO2 flow dynamics, to refine modelling workflows and, ultimately, develop strategies for optimising commercial CO2 storage.



Well depths at the Otway International Test Centre (OITC)

Otway Stage 4 program summary

The Otway Stage 4 program comprises a series of applied, CO2 geological storage R&D projects to be undertaken between 2023 and 2027 at CO2CRC's Otway International Test Centre. This program will undertake two sequential injections of up to 10,000t of CO2-rich fluid to test in-field reservoir management technologies and use the resulting data and validated techniques to materially decrease the project cost and increase the viable commercial options for CO2 storage.

Otway Stage 4 activities include:

1.The GeoCquest Field Validation (GFV) project, an injection of up to 10,000 t of CO2-rich fluid and subsequent logging operation that will test a new workflow for geological and dynamic modelling that is hypothesised to better represent and understand the impact of fine-scale reservoir heterogeneity on the flow of CO2.

2. Assessing the effectiveness of CO2 microbubble (MB) injection (in-field) and surfactant injection (bench- scale) for enhancing CO2 storage efficiency against conventional injection methods.

3. Seismic monitoring to assess the efficiencies in reservoir utilisation and to derive CO2 saturations from seismic data using an on-demand permanent seismic monitoring system.

4. Demonstrating Distributed Strain Sensing (DSS) to illustrate the capability for measuring the evolution of strain in the reservoir resulting from CO2 injection operations.

Otway Stage 4 key objectives

The overarching goal of the Otway Stage 4 program is to demonstrate and develop focused reservoir management technologies to improve CO2 injection, storage, and monitoring efficiencies, thereby materially lowering costs for commercial CO2 storage projects. This program aims to address the following objectives:

• Modelling: improve modelling workflow and software solutions, with a capacity to simulate optimisation technology effectiveness, and support performance-based site operations and closure decisions.

• Optimisation: prove the potential to achieve a minimum 20% increase in CO2 storage efficiency for commercial storage and unlock poorer-quality storage systems' capacity for commercial CO2 storage.

• Monitoring: develop storage performance monitoring and verification technologies and workflows that are fit-for-purpose and low cost.

Next steps

The Otway Stage 4 Program begins with the GFV injection & monitoring operations in ~October 2024, and the microbubble injection & monitoring operations in ~December 2025.

The microbubble injection trial does not incorporate surfactant, as an attempt to limit variables in this experiment. The role of surfactants on storage efficiency will therefore be tested through laboratory and modelling.

Data stemming from the injection operations will be used for the following additional R&D:

• Accurate model representation of optimisation techniques

• Improving model-observation conformance, including incorporation of 'saturation from seismic' and strain data

• Coupling CO2 injection related thermal, hydraulic, mechanical and chemical (THMC) changes into simulation models, using new Otway 4 data, to understand the influence these processes have for safe CO2 storage operations

• Deliver commercially relevant reservoir management solutions for the emerging CO2 storage industry

The project is funded by BHP, BP, Chevron, ExxonMobil, LETA, Australian government, RITE, and KIGAM.

Watson M et al. (2024) Optimising CO2 storage resource utilisation: insights from the Otway Stage 4 field program. Australian Energy Producers Journal 64(1), 54–65. doi:10.1071/EP23217

More information

co2crc.com.au

Urgent scale-up of CCS needed to keep Australia on net-zero trajectory

BloombergNEF's New Energy Outlook: Australia report highlights the need to scale up nine key technologies including CCS in order to get on track for net zero.

The window for achieving net zero by 2050 is closing, but Australia could still achieve a carbon emissions trajectory in line with the major goal of the Paris Agreement – holding global warming to well below two degrees Celsius and avoiding the worst impacts of climate change. BloombergNEF's New Energy Outlook: Australia shows what it would take to get there.

Australia must rapidly decarbonize its power sector to stay on track, growing renewable-energy capacity by 135% before 2030, to more than 126 gigawatts. BNEF's analysis shows that Australia's energy mix will need to transform over the next decade, with all unabated coal and almost all unabated gas generation exiting the power system by 2035. Australia will rely instead on a lower-cost mix of renewables paired with flexible technologies like batteries, pumped hydro, and gas.

The report also sheds light on other important topics relating to the global low-carbon transition, including:

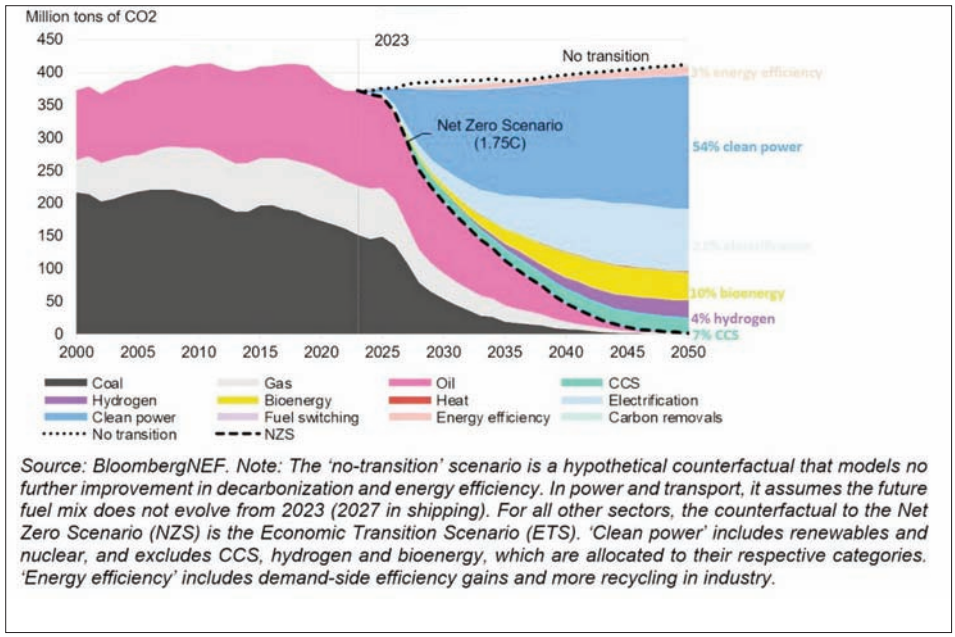
• The need to scale up nine key technologies in order to get on track for net zero: renewable power, electric vehicles, battery energy storage, nuclear energy, carbon capture and storage, hydrogen, sustainable aviation fuels, heat pumps and power networks.

• A more nuanced picture of where low-carbon hydrogen can be most impactful in the energy transition, and where electrification plainly makes more sense.

• The pace of Australia's coal retirements under a least cost, and net-zero aligned future.

• Why the estimated investment volumes are surprisingly similar under both scenarios.

"Australia's window to stay on a well-below-two-degree pathway is closing, fast" said Leonard Quong, head of BNEF in Australia. "Rapidly moving to a clean power system based on wind, solar and storage will be essential to cost-effectively reduce carbon emissions in line with our existing decarbonization targets – but the heavy lifting must be done this decade. A low-carbon power sector will also serve as a bedrock for future emissions reduction efforts in other areas of the economy in the years to come."



Source: BloombergNEF. Note: The 'no-transition' scenario is a hypothetical counterfactual that models no further improvement in decarbonization and energy efficiency. In power and transport, it assumes the future fuel mix does not evolve from 2023 (2027 in shipping). For all other sectors, the counterfactual to the Net Zero Scenario (NZS) is the Economic Transition Scenario (ETS). 'Clean power' includes renewables and nuclear, and excludes CCS, hydrogen and bioenergy, which are allocated to their respective categories. 'Energy efficiency' includes demand-side efficiency gains and more recycling in industry.

Australia's CO2 emissions reductions from fuel combustion by measures implemented, Net Zero Scenario versus no-transition scenario

The report builds and expands on the results of the New Energy Outlook 2024, presenting two updated climate scenarios, the Net Zero Scenario (NZS) and a base-case Economic Transition Scenario (ETS), designed to inform public policymaking, country climate ambition and low-carbon transition strategies of corporations and financial institutions.

The report's NZS, which is consistent with a 67% chance of holding global warming to 1.75 degrees Celsius, shows there is no room for any further carbon emissions growth in any sector if Australia is to reach net zero by mid-century. Australia's emissions from power, transport, industry and buildings sectors must have already peaked, and now begin rapidly falling depending on what technology pathways are available for them to decarbonize.

The alternative scenario, the ETS, which assumes no new policies are implemented, breaches the Paris Agreement with a global warming result of 2.6 degrees Celsius – but demonstrates how far the energy transition can go based on economical and commercially ready technologies.

Australia's current 2030 emissions reduction target is in line with BNEF's NZS energy-related emissions reductions. The NZS results imply that for Australia to remain aligned with the Paris Agreement goal, it needs to target at least 71% emission reduction from energy-related sectors by 2035 relative to its 2005 baseline for the next round of Nationally Determined Contributions.

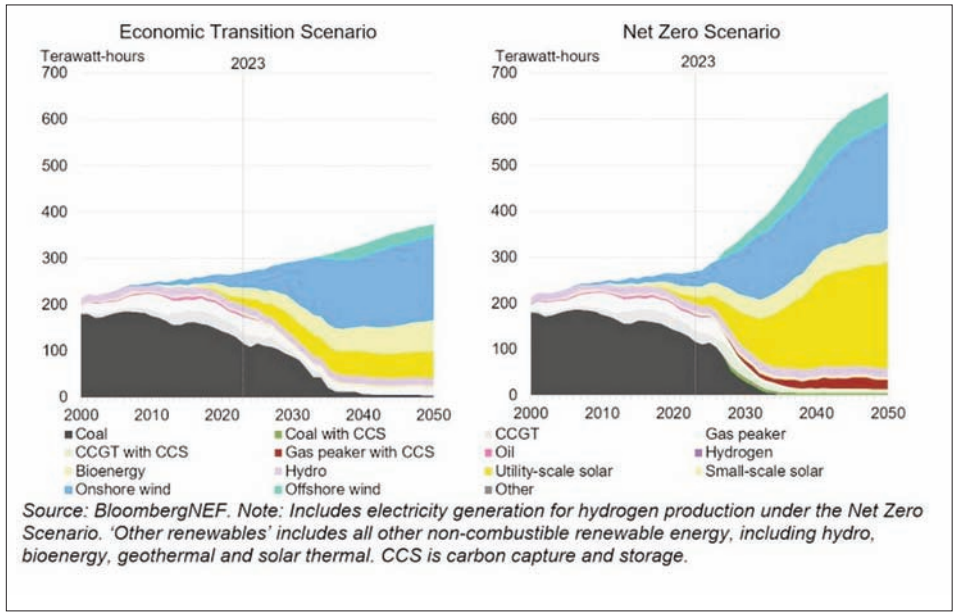
These NDCs are due for submission to the United Nations Framework Convention on Climate Change by November 2025.

In the NZS, cleaning up the power sector accounts for 54% of emissions avoided between today and 2050, compared with a no-transition scenario, in which there is no further action on decarbonization. Electrification of end-use sectors, including road transport, buildings and industry, accounts for a further 21% of further avoided emissions.

By 2050, Australia's power system grows dramatically and re-orientates entirely to clean power technologies. Wind and solar installations reach a combined 290 gigawatts by mid-century, storage, in the form of pumped hydro and batteries, increases from around 3 gigawatts today to over 59 gigawatts.

"Australia's abundance of world-leading wind and solar resources gives us an advantage in decarbonization, and combined they represent a $213 billion investment opportunity by 2050." said Tushna Antia, BNEF Australia Associate. "But getting there won't be easy and we will need flexible demand from smart electric vehicle charging and hydrogen electrolyzers, along with battery storage, flexible generators, and investment in the power network."

The solutions needed to abate the remaining quarter of emissions are among the most challenging to scale: biofuels in shipping and aviation; hydrogen in industry and transport; and carbon capture and storage in industry and power. To get to net zero by 2050, under the NZS, Australia's hydrogen consumption increases 14 times and carbon capture increases to 30 million metric tons per year.



Source: BloombergNEF. Note: Includes electricity generation for hydrogen production under the Net Zero Scenario. 'Other renewables' includes all other non-combustible renewable energy, including hydro, bioenergy, geothermal and solar thermal. CCS is carbon capture and storage.

Electricity generation by technology/fuel, Economic Transition Scenario and Net Zero Scenario

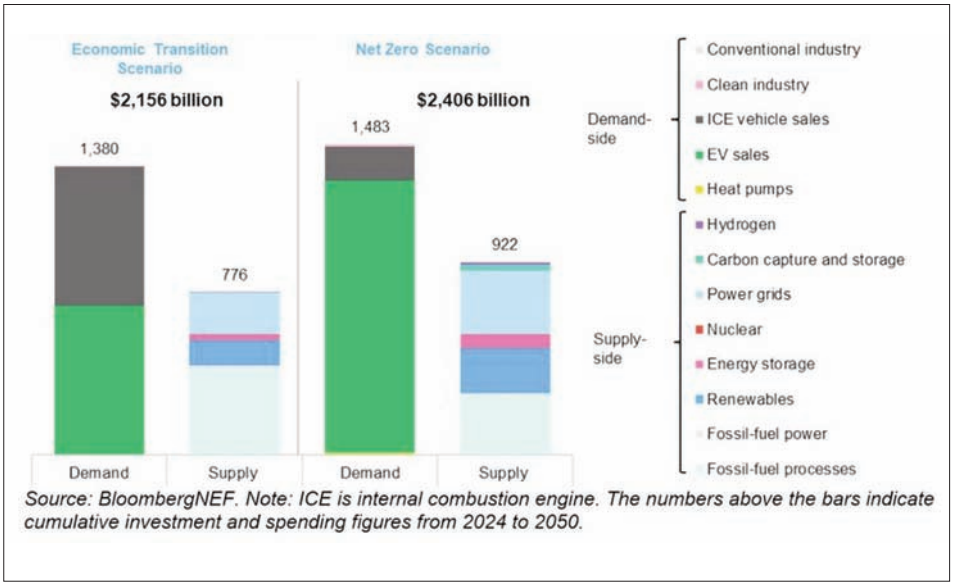
The New Energy Outlook also details a base-case ETS, in which clean-energy technologies are only deployed where they are economically cost-competitive or adopted by consumer choice, with no further policy support for clean technologies. Under the ETS, hydrogen and CCS see little new investment.

"Emerging technologies like hydrogen, biofuels and carbon capture systems will be essential for Australia to reach net zero," said Sahaj Sood, BNEF Australia Senior Associate. "While questions still remain about their reliability, acceptability, and scalability – if they aren't able to be used, emission reductions will have to come from somewhere else in the economy, and likely from more expensive solutions."

Australia's energy sector investment and spending under the Net Zero Scenario is only 12% higher over 2024-50, at $2.4 trillion, compared with the Economic Transition Scenario.

"Australia will always need to invest in its energy system, irrespective of whether it reduces its carbon emissions" said Caroline Chua, BNEF Energy Transition Specialist and lead author of the report. "The challenge of getting to net zero is going to be making sure capital flows into the right type of technologies, at the right time."

This research forms part of a series of regional and sector reports diving deeper into results from BloombergNEF's global New Energy Outlook report for Europe, China, the US, Japan, and India over the coming months.



Source: BloombergNEF. Note: ICE is internal combustion engine. The numbers above the bars indicate cumulative investment and spending figures from 2024 to 2050.

Australian energy investment and spending across 2024-2050, Economic Transition Scenario and Net Zero Scenario

More information

about.bnef.com

Growing recognition of role of CCS as offshore exploration permits issued

The announcement that the Federal Government will issue 10 new permits for carbon capture and storage exploration is another sign of the growing recognition of CCS in achieving emissions reductions targets says Dr Matthias Raab, CEO of CO2CRC.

In announcing the new permits, Federal Resources Minister Madeleine King, acknowledged "the International Energy Agency, the CSIRO, the UN Intergovernmental Panel on Climate Change and Australia's Climate Change Authority all identify that carbon capture, utilisation and storage will be needed to support the net zero transition."

However, the decision to restrict seismic on new exploration permits is baffling, says Dr Raab. Seismic is also critical for the identification of suitable CCS locations as it is for the ongoing monitoring of storage structures.

Limiting the use of seismic is like expecting modern medicine without x-rays.

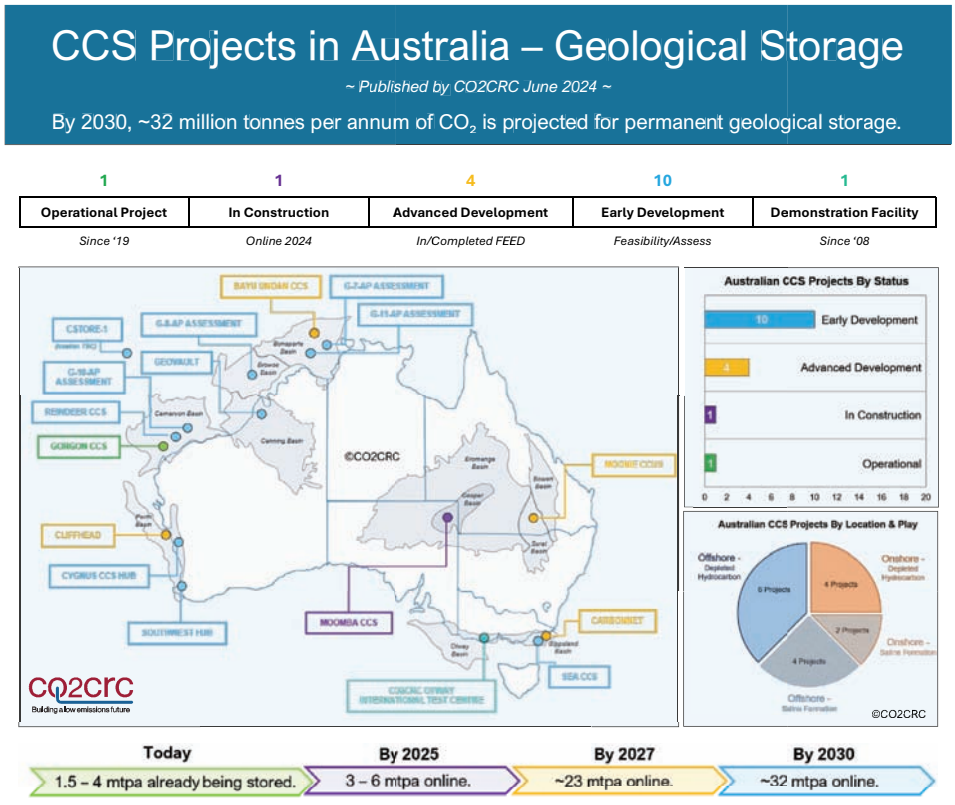
Generally, we are placing too many obstacles on the road to net zero.

Instead of restricting the use of still essential technology, we should do more to develop alternate technologies that could enable us to move beyond current practice.

CO2CRC has done significant research with Curtin University and CSIRO on how we can provide high resolution reservoir monitoring – without the necessity for conventional seismic surveys over the half century lifetime of CCS projects. The technologies have been proven onshore at the Otway International Test Centre, and further advancements are part of CO2CRC's future program. This is a much needed, yet brilliant Australian innovation originating in our home country, where so many potential CCS projects are planned.

This exceptional innovation is coming out of Australia and means regulatory process can be streamlined and interaction with the marine environment and industries reduced.

While the new permit allocation is encouraging, the fact remains that current CCS projects around Australia are moving too slowly – often due to delays in granting environmental and other regulatory approvals.



CO2CRC CCS Projects in Australia Map

Combined with delays in bringing renewable energy projects online, that means Australia's chances of meeting our 2035 and 2050 emissions goals are becoming more challenging by the day.

Industry must also do its bit to restore momentum to the Australian CCS sector.

Without offshore CCS, storage hubs and shared infrastructure, the hard-to-abate sectors won't have any chance to reduce their emissions as required under the Safeguard Mechanism.

State and Territory governments are backing regional hubs such as Darwin's Middle Arm Sustainable Development Precinct and potential hubs in Gladstone, Bell Bay, Gippsland, Newcastle, and Southwest WA.

The allocation of the new CCS permit areas should encourage State and Territory governments to strengthen their support for projects that can help lower emissions in their regions.

More information

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Calix awarded $15m grant for Leilac CCU demonstration

The Australian Government's Carbon Capture Technologies Program grant will support the construction of a world-first renewably powered demonstration plant for lime and cement CO2 capture which will supply captured industrial CO2 emissions to the HyGATE funded Solar Methanol Project.

The demo will be located in South Australia to produce near zero emissions lime and supply captured industrial CO2 emissions to the HyGATE funded Solar Methanol 1 project (SM1). Highlights of the project are:

• Calix has been awarded a $15 million grant from the Australian Government to reimburse up to 50% of the expenditure to build a commercial demonstration electric calciner for near zero emissions lime and cement in South Australia, subject to achievement of Project milestones.

• The novel, renewably powered CCU project will create two revenue streams via a near zero emissions lime product and the sale of captured CO2 for use as a chemical feedstock.

• The Leilac technology will be used to capture up to 20,000 tonnes of process CO2 emissions per annum produced unavoidably in the manufacture of cement and lime.

• Up to 15,000 tonnes of CO2 per annum will be sold to the SM1 project to produce green methanol. Additional captured CO2 may be supplied to other users in local industry.

• The SM1 project is being developed by a consortium of partners, including Vast and German energy company Mabanaft, under the Australian-German funded HyGATE initiative.

• Calix will collaborate with its partners on the operation of the electric calciner and sale of its lime products.

• A second phase of the project aims to develop a novel cement making process for near zero emissions cement.

Calix Technology Centre in Bacchus Marsh, Victoria (Image: ©Calix)

Demonstrating zero emissions lime and cement

Lime is an essential material used in the iron & steel, alumina, paper, pharmaceuticals, food, farming and chemical industries, and demand for lime in Australia is predicted to grow by 57% between 2022 and 20504. Like cement, lime is made from the processing of limestone to form quicklime (calcium oxide). When limestone is heated in this process, carbon dioxide is unavoidably released directly from the raw material.

This 'process' CO2 accounts for ~60-70% of the emissions released during the production of lime. Collectively, lime and cement account for ~8% of global greenhouse gas emissions. The 'Zero Emissions Intensity Lime and Cement Technology Built in Australia Project' (ZETA Project) will use an electric and renewably powered version of the Leilac technology to efficiently capture unavoidable process CO2 emissions and produce near zero emissions lime and cement.

In phase 1 of the Project, the Leilac technology will be used to produce ~15,000 tonnes per annum of near-zero emissions lime and capture of up to 20,000 tonnes per annum of high purity CO2. Calix will collaborate with its partners on the operation and sale of the zero emissions lime products. Up to 15,000 tonnes of CO2 per year captured by the Leilac technology will be sold to the SM1 project in Port Augusta, South Australia, with any excess captured CO2 available to be supplied to local industrial CO2 users in South Australia. The Project will also train plant operators to support future projects.

In a second phase of the Project, the ZETA program will aim to expand production to include the processing of cement raw meal to a near-zero emissions cement clinker product, with captured CO2 again supplied for use. By

incorporating cement clinkering as an additional process in the Leilac technology, the Project aims to develop a novel route to zero emissions clinker production that reduces cost, energy consumption and footprint.

Demonstrating cost-effective CCUS

The ZETA Project aims to deliver revenue from two streams: a near zero emissions lime product and supply of captured CO2 for use as a chemical feedstock. Calix's electric calcination technology also enables fast start-up and shut down, and highly flexible production rates. The ZETA Project aims to leverage this capability to match production to demand and renewable energy costs. Developing this capability is intended to support more cost-effective electric mineral processing and support future grid load-balancing applications.

The ZETA Project's multiple revenue streams, efficient electric heating and flexible operations, coupled with the support from the Australian Government's Carbon Capture Technologies Program, aim to deliver a project with positive economics despite being a first-of-a-kind demonstration.

By capturing and using unavoidable process emissions, the ZETA Project aims to demonstrate innovative pathways to decarbonise multiple hard-to-abate industries. For industries such as cement and lime, where the majority of emissions are unavoidably released directly from the raw material, cost-effective CCUS is an essential part of the sector's decarbonisation strategy. The use of captured CO2 eliminates the need for CO2 transport and storage infrastructure, and potentially provides an additional revenue source to decarbonisation projects.

The production of near-zero emissions lime is also an important enabling capability to produce green metals, particularly near-zero emissions steel and aluminium. Using captured CO2 as a feedstock to produce low-carbon fuels can also support the decarbonisation of hard-to-abate transport sectors such as aviation and shipping.

Green methanol can be synthesised from renewable energy, green hydrogen and captured industrial CO2. Methanol is a viable low-carbon alternative to diesel for the shipping industry, a pre-cursor for sustainable aviation fuel, and a versatile green hydrogen carrier.

The Solar Methanol 1 project

SM1 aims to develop a world-first methanol production demonstration plant, producing ~7,500 tonnes of methanol per year. SM1 is being developed by a consortium of members, including Vast, Mabanaft and Calix, and has been awarded funding of ~$40 million as part of the German-Australian Hydrogen Innovation and Technology Incubator (HyGATE) initiative.

The SM1 project has passed numerous milestones since it was announced, including receipt of planning consent and the formation of a Joint Development Agreement between Vast and Mabanaft.

Next steps and timelines

The ZETA Project aims to develop and demonstrate cost-effective solutions to manufacture sustainable lime, cement and future fuels, and is being developed in parallel to SM1, with the quantity and timing of CO2 supply targeted to match the demand for methanol production.

Calix CEO and Managing Director, Phil Hodgson said, "Calix is delighted to have been awarded funding under the Australian Government's Carbon Capture Technologies Program to produce near-zero emissions lime and cement. This highly innovative project aims to demonstrate solutions for several national priorities identified in the Australian Government's Future Made in Australia program."

"Calix's renewably powered technology platform can electrify mineral processing and capture unavoidable emissions to enable carbon-intensive industries like cement and lime to reach net zero. Zero emissions lime will also be an important enabling material for the development of an Australian green metals industry for green steel and aluminium."

"Additionally, by combining captured CO2 with Australian sunshine in collaboration with our partners in the SM1 project, we aim to demonstrate a low-cost decarbonisation pathway for cement and lime and a novel way to make low-carbon transport fuels."

"It is exciting to see Australian technology companies, supported by Australian Government funding, collaborating to take advantage of the unique comparative advantages Australia can have in a decarbonising global economy."

Leilac response to U.S. RFI: "Transforming Industry – Strategies for Decarbonization"

Significant policy support in the U.S. is accelerating decarbonisation efforts, including for hard-to-abate industries like cement. Leilac is highly supportive of these efforts, and welcomes the opportunity to respond to the U.S. Department of Energy's (DOE) recent Request for Information on Transforming Industry – Strategies for Decarbonization – to help identify cost-effective decarbonisation pathways.

Cement is considered a hard-to-abate industry for many reasons. Foremost is that the industry's carbon dioxide emissions are mostly process emissions – that is, CO2 released directly and unavoidably from the raw material. Coupled with the critical and irreplaceable role cement plays in almost all modern infrastructure, that cement production is expected to increase 43% in the U.S. by 2050, and that globally cement accounts for around 8% of global greenhouse gas emissions, and the hard-to-abate tag becomes easy to understand.

A combination of policy support, industry commitments, and technology innovation, however, now provide viable pathways for cement decarbonisation.

For cement, low-cost CCUS will be critical to abate unavoidable process emissions, while the use of lower carbon fuels and feedstocks, and electrification provide flexible and cost-effective pathways for the industry to reduce its emissions, retain its international competitiveness and support sustainable U.S. manufacturing.

Leilac is confident that rapidly implementing sustainable cement and lime solutions is viable globally. In the United States, we are particularly optimistic about the bipartisan support for industrial CCUS projects, including through Section 45Q of the US tax code and the Bipartisan Infrastructure Law, and we commend the US DOE for the flexible sector specific decarbonization pathways it seeks to enable.

More information

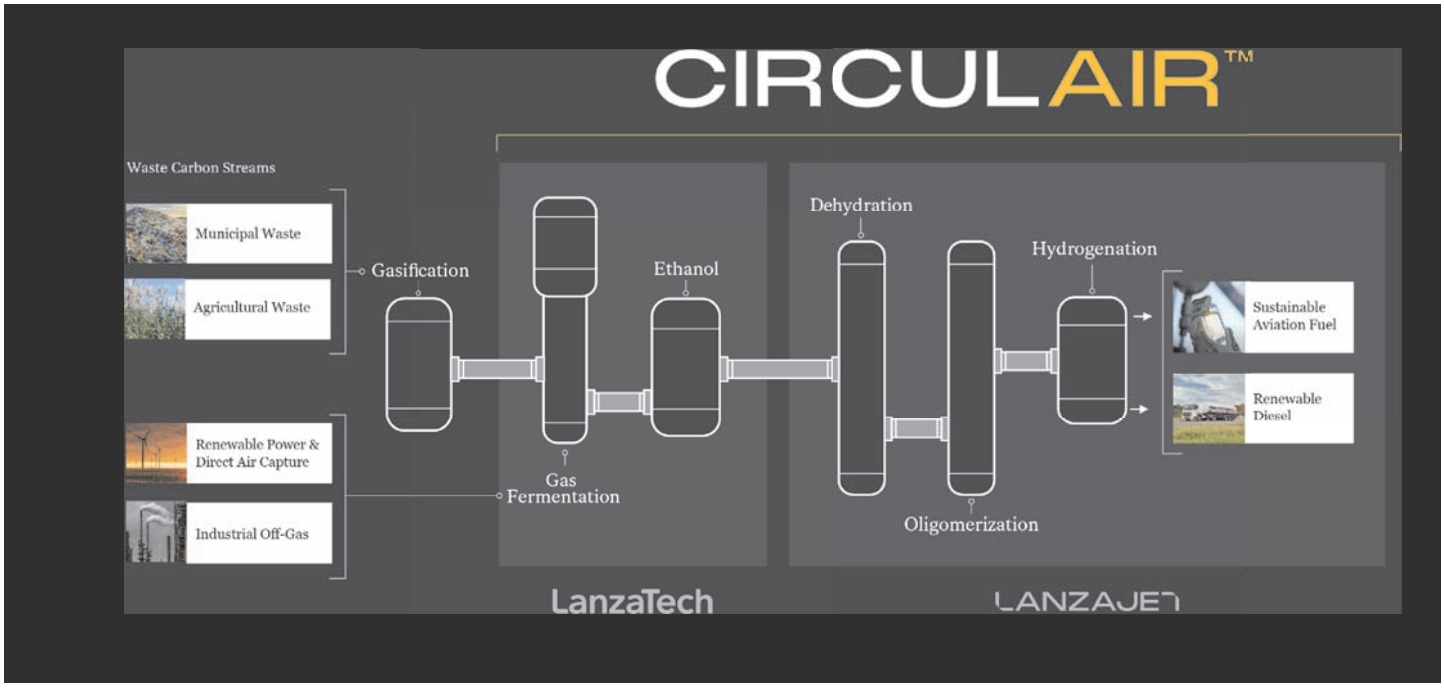
calix.global

www.leilac.com

www.energy.gov

LanzaTech and LanzaJet launch project with Wagner for sustainable jet fuel

This is the first project to be developed with CirculAir, a commercial sustainable fuels technology converting waste feedstocks into Sustainable Aviation Fuel (SAF).



The project with Australia's Wagner Sustainable Fuels will consider equipping the Brisbane SAF Refinery with CirculAir™, LanzaTech and LanzaJet's joint technology solution that converts waste carbon and renewable power into SAF.

In addition to using the LanzaTech and LanzaJet technologies, the project has received investment from The Boeing Company and the Queensland Government.

"LanzaTech and LanzaJet look forward to providing a joint commercial solution to support the work of Wagner Sustainable Fuels and advance the development of a domestic Australian SAF market," said Dr. Jennifer Holmgren, CEO of LanzaTech and Board Chair of LanzaJet.

"There is enough carbon above ground to transform the 100 billion gallons of fossil fuel-derived jet fuel consumed each year into reliable jet fuel made by recycled carbon, and the flexibility of the CirculAir technology makes it possible for this project to unlock the myriad waste-based resources required to meet that demand."

The CirculAir process first uses LanzaTech's commercial carbon recycling technology to transform waste streams, such as industrial emissions and municipal solid waste, into CarbonSmart™ ethanol, LanzaJet's Alcohol-to-Jet (ATJ) technology then converts the ethanol into SAF.

The process could help to accelerate decarbonisation of the global aviation industry by using a variety of locally sourced waste-based feedstocks to produce the SAF volumes needed to supplant fossil fuels.

"The combination of our leading SAF solution with the front-end of LanzaTech's proven and commercial carbon recycling technology makes it possible to create a domestic SAF supply in Australia using local renewable waste sources, further supporting the country's energy security, while also working to protect its natural environment," said Jimmy Samartzis, CEO of LanzaJet.

SAF is estimated to account for a 65–70% reduction of overall aviation emissions to help achieve net zero by 2050, making it a critical tool for this hard-to-abate industry. Historic supply constraints, high costs, and technical barriers have made it difficult for the industry to default to SAF as the primary fuel source. CirculAir breaks down these barriers, as the technology is able to turn a wide range of waste-based feedstocks into SAF to meet demand. Widespread adoption is projected to accelerate the production and economies of scale necessary to bring down the global cost of SAF.

"Our partnership with LanzaTech and LanzaJet will advance the Wagner SAF Refinery in Brisbane, accelerating the SAF industry in Australia and helping to decarbonize aviation by 2050," said Matt Doyle, Wagner Sustainable Fuels Chief Executive Officer. "Together, these proven technologies can help us realize Australia's first, fully integrated SAF production facility and provide a path to producing domestic fuel at scale."

More information

www.lanzatech.com

www.wagnersustainablefuels.com.au

Carbon dioxide storage in residual oil zones - results of 4 year study

Geoscience Australia, in collaboration with CSIRO, conducted a 4-year study under the Exploring for the Future Program (2020-24) to investigate the potential for carbon storage and CO2 enhanced oil recovery (CO2-EOR) in residual oil zones (ROZ) in Australia.

The study unlocked new CO2 geological storage opportunities and accelerated the deployment of CCS technologies in Australia, supporting the transition to net zero by 2050.

CO2 enhanced oil recovery involves the injection of CO2 into a near-depleted oil field or residual oil zone to help produce some of the remaining oil. Some CO2 is produced with the oil and recycled while the remaining volume of CO2 is stored in the reservoir.

Around the world, CO2-EOR projects have been injecting and storing CO2 for some 6 decades and are currently responsible for achieving much of the world's CO2 storage in geological formations. CO2-EOR projects benefit from geological knowledge of the storage site, use of existing infrastructure, and dedicated financial incentives that can be used to offset the costs of CO2 capture, transport and storage in the early days of CCS deployment.

With the appropriate settings, CO2-EOR can result in larger volumes of CO2 injected and stored than is emitted from the life cycle of any additional oil produced. CO2-EOR projects demonstrate the feasibility of large-scale sustained CO2 injection, storage and monitoring, and can pave the way to purely storage-focussed projects in the future.

Residual oil zones occur in geological reservoirs that contain potentially economic oil resources that can be produced through CO2-EOR (Figure) and, importantly, could offer large-scale geological storage capacity, with or without EOR. These rocks can occur beneath or near oil fields or in areas with no conventional oil accumulations but their occurrence and potential CO2 storage and oil resources are not yet well understood in Australia.

Aside from the primary driver of accelerating CCS deployment, there was potential for incremental oil recovery from CO2-EOR projects to contribute towards domestic energy security and liquid hydrocarbon supply for non-energy purposes.

Development of ROZ could be economically beneficial, help to address greenhouse gas emissions, and provide increased energy security through the production of new domestic oil resources.

The key objectives are:

• Increase Australia's options for geological storage opportunities.

• Understand the geological parameters and engineering approaches that define a prospective ROZ target and maximise the amount of CO2 stored through CO2-EOR.

• Understand the scale and opportunity for CO2 storage capacity and potential additional oil production through CO2-EOR in ROZ in Australia's key onshore basins by developing and testing a workflow comprising geological and petrophysical analysis and reservoir modelling.

• Understand the economics of transport and storage of CO2 in Australia to support decision-making around CCS projects, hubs and related resources.

• Identify regions that demonstrate high potential for early-mover CO2 geological storage in depleted fields and ROZ for further investment, research and development.

What was done

As part of the CO2-EOR in ROZ study Geoscience Australia:

• Completed a targeted review of the international ROZ production industry and the parameters that were most important to developing CO2-EOR in ROZ.

• Developed a geological and petrophysical workflow and used this to identify and characterise residual oil zones in key hydrocarbon-bearing onshore Australian basins.

Residual oil zones can offer a large-scale opportunity for CO2 storage, including through CO2-EOR, with potential oil production of the residual oil from the largely water-saturated reservoir (Image: Geoscience Australia)

• Completed preliminary spatially-enabled economic modelling for CO2 transport and storage in Australia. This model is being implemented in a carbon capture, utilisation and storage (CCUS) multi-criteria decision support tool to help advance the development of CCUS studies and attract investment in CCUS in Australia.

• Completed a reservoir modelling study to understand both the behaviour of CO2 in a typical Australian residual oil zone and estimate the amount of CO2 that could be stored.

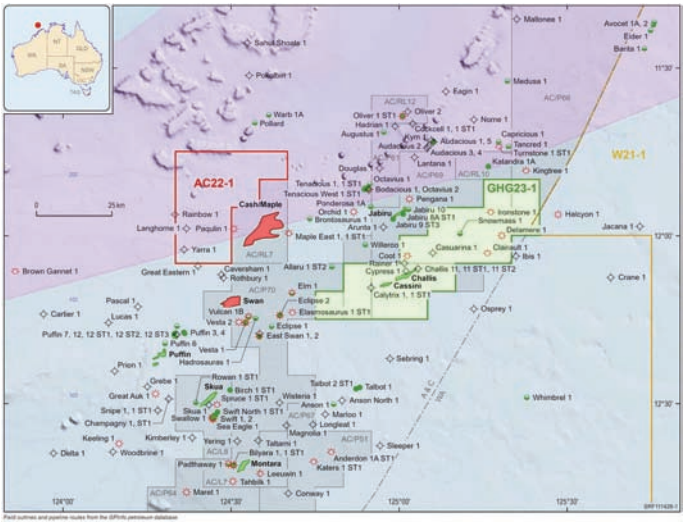
More information

www.ga.gov.au/ccs

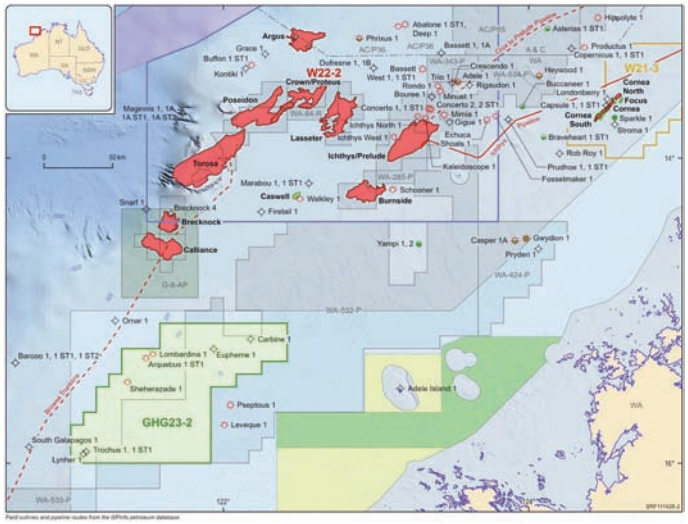
www.csiro.au

deepC Store and Azuli win Australia offshore CO2 storage licences

Greenhouse Gas Assessment Permits in the Bonaparte and Browse Basins have been awarded to the companies, who also entered into a Joint Study Agreement for a strategic partnership with J-POWER.



GHG23-1: Challis and Cassini



GHG23-2: Carbine and Leveque

The agreement cements the likelihood that this will comprise a commercial-scale Australian sequestration opportunity for CO2 volumes from Japan and Australia as well as the surrounding region.

deepC Store Pty Ltd and Azuli (Australia) Pty Ltd have been awarded two GHG Acreages offshore Australia comprising blocks GHG23-1 and GHG23-2. The Parties have also entered into a Joint Study Agreement for a strategic partnership with Electric Power Development by which J-POWER intends to become a joint venture participant in the GHG Acreages, which have the potential to permanently store up to one gigatonnes of CO2.

The Parties and J-POWER intend to develop a full value chain project from liquified CO2 receipt at locations in Japan and Australia as well as surrounding region, with the LCO2 transported by ship to floating storage and injection facilities in Australian waters.

The GHG Acreages are both located in Commonwealth waters offshore Australia some 200-250km off the Northwest coast. The GHG Acreages awarded to dCS and Azuli are as identified in pale green in the maps above.

deepC Store Managing Director Daein Cha said, "we are very pleased to be awarded the 2 GHG Acreages that both show a good fit for "CStore1," our LCO2 shipping and FSI based CCS development concept. Also following on from our partnership established with J-POWER, a significant global player and pioneer in the electric power industry, we are committed to accelerating the development of CStore1 and advancing Australia and Japan's strategic alliance in the CCS business."

On award of the GHG Acreages, the Parties and J-POWER have entered into a Joint Study Agreement under which:

- The GHG Acreages will be matured in compliance with Australian Government requirements
- Opportunities will be considered to accelerate development of the GHG Acreages, such that the resulting projects can support the objectives of the Australian and Japanese Government in respect of decarbonisation targets
- Three distinct component projects of the Carbon Capture and Storage value chain will be established comprising: LCO2 shipping, floating storage and injection (FSI) and Storage.
- J-POWER makes a cash contribution on the joint study, which is for early work of this project, and secures rights to participating interest in the joint venture that will further develop the GHG Acreages.

More information

www.deepcstore.com
www.azuliccs.com
www.jpower.co.jp

Australia news

Vopak to develop CCS infrastructure hub in Northern Australia

www.vopak.com

The Northern Territory Government and Vopak signed an MoU to develop a common CO2 import, storage and handling infrastructure in Darwin.

The CO2 import, storage and handling infrastructure will be designed to manage the import, storage and distribution of carbon dioxide in an efficient and accessible way. The facility will be shared infrastructure that can be used by various companies to help manage CO2 emissions.

"The Lawler Labor Government is committed to developing the Middle Arm Sustainable Development Precinct, strategic industrial land to accommodate advanced manufacturing and green energy production. CCUS capability is a core component of the circular economy design of this Precinct," said Eva Lawler, Chief Minister of The Northern Territory.

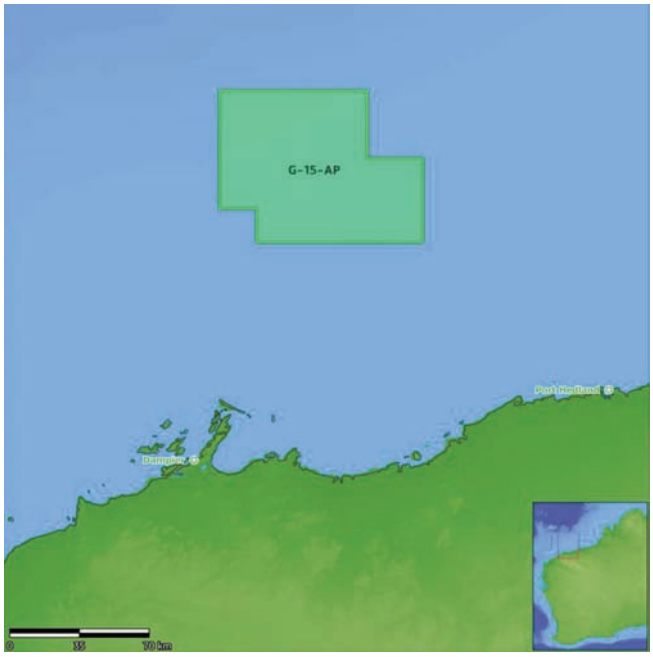
"I am excited to be partnering with Vopak who have been contributing to the energy security and economic development of the Northern Territory with their operations in East Arm for almost 20 years. This project contributes to the NT's goal of a $40 billion economy by 2030 and our transition to net zero by 2050. This agreement leverages Vopak's global expertise in developing infrastructure solutions to accelerate the energy transition worldwide."

The imported CO2 can come from different sources such as industrial plants that capture CO2 to prevent it from being released to the atmosphere. Also CO2 from neighbouring countries can be handled. Once the CO2 is imported, it needs to be stored safely in large tanks before it will be transferred to a permanent destination, for example in underground facilities CCS, or followed by recycling the CO2 for utilisation.

"For nearly 20 years, Vopak has been contributing to the energy security and economic development in East Arm near Darwin city. This project not only signifies our ongoing commitment to growth but also contributes to playing a role in decarbonisation ambitions for both the Northern Territory and Australia. Together with the Northern Territory Government, we look forward to playing a key role in Australia's transition to net zero. This development of CO2 infrastructure is fully in line with Vopak's global strategy to develop infrastructure solutions to accelerate the energy transition," said Paul Kanters, Managing Director, Vopak Terminals Australia.

InCapture secures permit for Australian NW Shelf

www.incapture.com.au
eng.skearthon.com



The InCapture appraisal area in Northwest Australia

Greenhouse Gas Assessment Permit G-15-AP, strategically situated on the North West Shelf of Australia, will allow the company to develop a CCS project for local industries to store CO2 emissions.

The southern part of the G-15-AP permit area lies only 120km from the major industrial ports of Dampier and Port Hedland, spanning an area of over 6,500km^2 and providing a viable solution for hard-to-abate sectors in the region.

Julia Davies, General Manager of InCapture, emphasised the critical role of CCS in achieving sustainability goals, "CCS is essential for Australia and its neighbouring countries to meet their net-zero commitments. The recent award of greenhouse gas assessment permits by the Australian Commonwealth Government is a testament to our collective commitment to secure safe and effective storage sites for domestic emitters. The G-15-AP project is poised to play a pivotal role in decarbonizing Australia's industrial sectors, with a special focus on hard-to-abate industries."

InCapture is already appraising several storage options within the permit area, with the ambitious goal of launching a fully operational CCS project by the early 2030s. This initiative will not only support Australia's net-zero pledges but also extend its impact to neighbouring countries in South-East Asia, Korea, and Japan, offering world-class storage solutions in the carbon management chain.

The G-15-AP project is a collaborative venture, operated by InCapture holding 75% equity in the project alongside partners SK earthon Australia Pty Ltd with a 20% equity interest and Carbon CQ Pty Ltd with a 5% interest.

SK earthon, a wholly owned subsidiary of South Korea's SK Innovation, brings a wealth of experience in CCS projects, including the notable Shepherd Project which aims to capture CO2 from Korean industrial zones and transport to Malaysia for storage. SK earthon also participates in South Korea's National CCS R&D projects including marine CO2 storage monitoring projects and geophysical surveys for large-scale CCS storage evaluations.

Carbon CQ, based in Perth, specialises in CCS consultancy and project development, providing technical, commercial, and regulatory expertise.

Davies added, "Our world-class storage sites at G-15-AP will not only support local efforts but will also enhance the carbon management capabilities of our valued trading partners in South-East Asia, Korea, and Japan."

How can CDR start-ups survive a static voluntary carbon market?

In June, Running Tide, a start-up focused on ocean based carbon removal, announced that it would be ceasing operations, blaming a lack of demand for removals credits due to a static voluntary carbon credits market. The company claimed it removed 28,000 tons of CO2 in 2023, including for Microsoft. By Marian Krüger & Hans Westerhof, Co-Founders, remove.

The announcement came as a shock to the wider carbon removal industry. But it also came as no surprise. Despite the critical importance of near-term demand for carbon dioxide removal (CDR) reaching climate-relevant scales, availability of buyers in the global voluntary carbon markets, outside of a few pioneers such as Microsoft and Frontier, has been stalling.

This issue is hitting start-ups focused on carbon dioxide removal the most, because the market impetus to permanently remove carbon from the atmosphere at this moment is low. This is unlike in fossil-fuel focused CCS where there are stronger financial and regulatory incentives for heavy industry, such as in the EU and US, to reduce their CO2 emissions at source.

The problem with a stalling market

That's despite the knowledge that CDR will play a critical role if the world is to meet its climate goals to limit global warming to 1.5°C, helping governments and industry compensate for hard-to-abate emissions, which can be difficult or expensive to avoid. Additionally, some organisations plan to compensate for their historical emissions or aim to go net-negative beyond their net-zero commitment, which can also only be realised through CDR.

However, for the time being, there simply is no incentive or need to purchase removals. Companies do not need removals for their business operations, and there are yet to be no rules or regulations governing removal markets. The vast majority of organisations are prioritising emission reduction efforts, aligning their strategies with the Science Based Targets initiative (SBTi). This is of course crucial, but it is not an either/or situation, we need both reductions and removals. This lack of incentive to purchase CDR credits today is leading to a unique problem, the future market for removals is massive, but in the immediate term there is no market.

Unlocking new, non-credit revenue streams

This peculiar situation means CDR start-ups can't rely on using established entrepreneurial playbooks for scaling, and price discovery is challenging. However, one area in which we're seeing a number of start-ups innovate is finding new go-to-market strategies which don't solely rely on carbon credit sales.

These new strategies, such as selling ecosystem restoration services, by-products such as hydrogen, bacterial strains or CO2 for utilisation, can generate new revenue streams, which in turn can help finance and scale the climate solution.

Take Airhive, for example, a DAC start-up from the UK which has received investment from Coca-Cola to carbonate its drinks at one of its European's plants using its direct air capture system.

Neustark currently has 19 carbon capture and storage plants in operation with 40 more planned across Europe. The company recently secured $69 million in funding led by Decarbonization Partners. Image: Decarbonization Partner's Global Head & Chief Investment Officer Meghan Sharp (left) and neustark's co-CEO and founder Johannes Tiefenthaler (right).

Or Neustark, which sells its machines to recycling plants, which use it to store CO2 in demolition waste. The end product can be used to create recycled concrete or spread across roads under asphalt. Removing a sole reliance on removals credits is helping these teams to grow and develop their CDR solutions, and therefore reduce their current dependency on the fickle CDR market.

The importance of policy and regulation

The CDR ecosystem is not only nascent but also complex. Potential buyers encounter a variety of CDR methods with substantially different quality parameters, risk profiles, and environmental and social impacts.

Without internal resources or expertise, assessing and comparing different methods and suppliers proves difficult and is resource-intensive. The nascent CDR market also lacks a consistent price discovery mechanism to indicate quality. This has resulted in wide price fluctuations, complicating the decision-making process for prospective buyers further.

As long as carbon markets remain voluntary, these challenges will remain. The change will only happen when voluntary markets move to some form of compliance, which recognizes that net-zero needs carbon removal, and that carbon removal therefore needs transparent markets with clear rules for minimum standards, quality assurance, accounting and so on.

This is why we need to bring legislators closer to the industry, to understand the intricacies and importance of every CDR method, and to pass technology-agnostic policies which encourage growth, and regulations which establish trust and impetus in purchasing removals credits.

We're confident the CDR market will eventually gather pace. It simply has to if we want a habitable earth. In the meantime, start-ups must do what they can to survive, and the wider ecosystem must do everything it can to support them.

Remove is a non profit accelerating startups to kickstart the Carbon Removal Revolution.

More information

www.remove.global

Deep Sky to build world's first carbon removal innovation centre

The Canadian carbon removal project developer has selected a site in Innisfail, Alberta to build the world's first carbon removal innovation and commercialization centre, Deep Sky Labs.

Strategically located an hour north of Calgary, Innisfail is an emerging clean energy hub. Deep Sky Labs' mission is to accelerate the path to low cost, low energy intensity and highly scalable carbon dioxide removal (CDR) to produce high integrity carbon credits. The project represents an industry first for the private development of scalable CDR, the first cross-technology project in the world, and the first commercial direct air capture project in Canada.

Engineering and design work has been conducted in partnership with leading engineering firm BBA, and construction will begin imminently. The facility will be operational this winter, and will have the capacity to capture 3,000 tons of CO2 per year, or 30,000 tons over a 10-year period, via up to 10 different technologies. It will also include room for future expansion.

Labs makes it possible for many different Direct Air Capture (DAC) concepts to be tested simultaneously. Its tech-agnostic nature decreases delivery and operational risks while increasing the speed at which the industry can scale. This novel approach solves for the delivery delays that have plagued past global carbon removal projects.

At first, eight state-of-the-art DAC technologies will be deployed at the facility, sitting side by side with standardised instrumentation for the collection of operational data. Here, they'll be tested and optimised for performance year-round in the Canadian climate and validated before they can be committing at commercial scale. Proprietary Deep Sky software will track and benchmark all operational data to accelerate the R&D of technology partners and the industry at large – another industry first.

The eight technologies will have full access to renewable power and carbon storage, enabling a life cycle analysis to ultimately produce verified carbon removal credits validated by third-party carbon registries. These elite DAC providers include Airhive, Avnos, Phlair (formerly Carbon Atlantis), Greenlyte Carbon Technologies, Mission Zero, NEG8 Carbon, Skyrenu, and Skytree. Together, the partners represent the world's foremost CO2 carbon removal technologies, convening for the first time in Canada, the carbon removal capital of the world.

Labs is purpose-built with space for 10 different DAC technologies, with room to expand. While eight world class technologies are already confirmed, Deep Sky Labs is actively seeking additional technology developers interested in piloting their direct air capture technology. Priority criteria include a pathway to low energy intensity (1,000 kWh per ton of CO2 captured or lower at scale), simplicity and focus on removing CO2 (no utilisation pathways), manufacturing and scalability, and a strong team. Any DAC providers interested in deploying at Deep Sky Labs can fill out this form.

"I cannot overstate the significance of the world's first carbon removal innovation and commercialization centre, and what this means for Canada and our planet at large," said Damien Steel, Deep Sky CEO. "This project represents a world first and serves as a testing ground from which the nascent industry can grow into Canada's multi-trillion-dollar enterprise. We're in the business of scaling carbon removals, and this first facility represents a giant step forward for the health of our planet and our economy."

The CO2 collected at Labs will be trucked to an existing well at the Meadowbrook Carbon Storage Hub facility operated by Deep Sky's storage partner Bison Low Carbon Ventures, north of Edmonton in Sturgeon County. Bison is advancing the Meadowbrook project through the regulatory approval process and has a dedicated injection well capable of handling all Labs volume. Their Deep Sky partnership also makes Bison the first in North America to support a DAC hub.

More information

www.deepskyclimate.com

Commercialising zero-emission vessels for CO2 shipping

The maritime industry stands at a point where the transition to zero-emission vessels, like ammonia-powered ships, is not just an environmental imperative but a commercial necessity. The economic dynamics of this shift affects our ability to scale CCS infrastructure globally. In this article, we'll dive into why these ships are critical for CCS, the commercial risks involved, concrete developments in the market, and how these factors can shape the timeline for deploying CCS at scale.
By Oliver T. Edwards, Business Developer at Normod Carbon.

Shipping infrastructure is vital for CCS

Imagine running the world's greatest chocolate factory without the logistical infrastructure needed to deliver your product. Similarly, capturing CO2 emissions is pointless without the means to transport them. In 2022, global CO2 emissions from fossil fuels was about 40 billion tons—enough to covering America's three largest states (Alaska, Texas and California) in over eight meters of CO2 gas (Tso, 2023, How much is a ton of carbon dioxide?, MIT).

That's a massive volume, and we need reliable shipping to move it to storage sites. This is where ammonia-powered ships play a critical role.

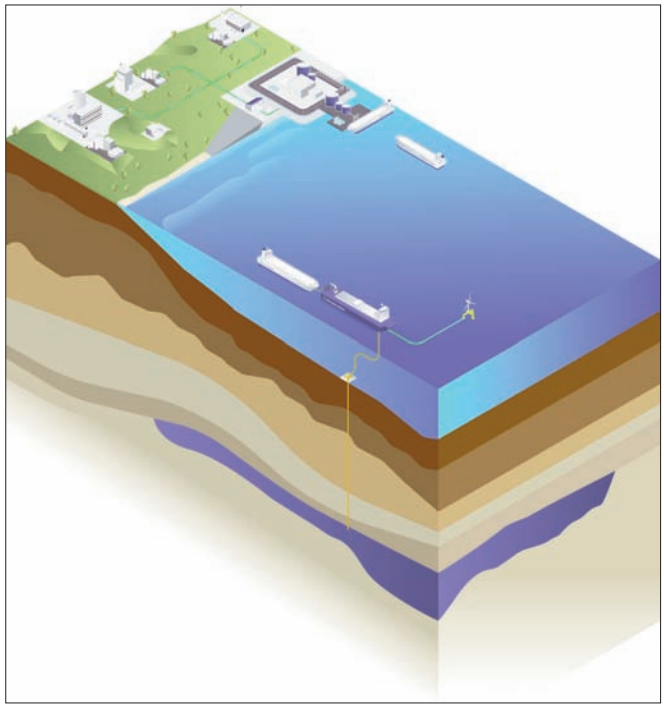
Why ammonia fuel?

Ammonia is a scalable zero-carbon fuel that is suitable for serving long-distance shipping routes. Its adoption in maritime transport ensures that CO2 captured from emitters can be moved to storage sites without emitting additional CO2, aligning perfectly with CCS objectives. Ammonia-powered vessel designs are generally deemed mature for deployment (Global Maritime Forum, 2022, Nordic Green Ammonia Powered Ships: Phase 2).

However, deployment is a challenge. Ammonia vessels are 50-130% more expensive than conventional ships due to their novelty and the economic risks of building a global ammonia-fuel network. With limited capital support, widespread deployment will take time, which creates uncertainty around the practical costs of CO2 transport for both shipowners and emitters.

These logistical uncertainties cause delays in deploying CCS at scale. It also increases the overall cost of CCS to a degree where industrial emitters can loose their incentive to implement CCS despite the significant carbon taxes imposed on their operations.

How can we enhance the willingness of institutional investors to provide capital support for these projects and strengthen the case for quickly rolling out CO2 transport, ensuring that transport infrastructure does not become a bottleneck?



Floating storage and injection unit injecting CO2 into an offshore saline aquifer. Source: Normod Carbon

Commercial risks of deploying ammonia ships

Deploying ammonia ships is costly due to the need for specialised fuel infrastructure making it significantly more expensive than traditional marine fuels. This creates commercial risks in the form of:

• Market risk: Shipowners bear the initial cost of adopting more expensive fuel technology, with uncertain returns on investment.

• Credit risk: Financiers are cautious about the long-term viability and profitability of ammonia-powered ships, given their higher operational costs.

• Infrastructure risk: The lack of a comprehensive fueling network for ammonia adds uncertainty to operational planning and cost structures.

• Technology risk: Unforeseen technical issues or advancement of newer and more efficient designs could render current work obsolete.

The high costs associated with ammonia as a marine fuel stem from several factors:

• Lower energy density: Ammonia's lower energy density requires larger fuel storage on ships and on land, increasing design complexity and capital costs.

• Advanced engine technology: Developing engines that efficiently use ammonia necessitates heavy investment in research, testing, and certification, adding to the cost burden.

• Safety equipment: Ammonia's toxicity and corrosiveness demand specialised safety systems for storage, handling, and fueling, further driving up costs.

Limited capital support for vessel deployment

Currently, the maritime industry's shift towards ammonia as a fuel source is met with cautious optimism but also with financial hesitancy. Public grants and subsidies (often the lifeblood of innovation in critical infrastructure) are primarily focused on research and development rather than widespread deployment (Global Maritime Forum, 2022).

This gap in funding underscores a critical challenge: while the technology for ammonia-powered vessels exists, the economic framework to support their commercial rollout is still in nascent stages.

Multi-fuel ships for bridging costs and risks

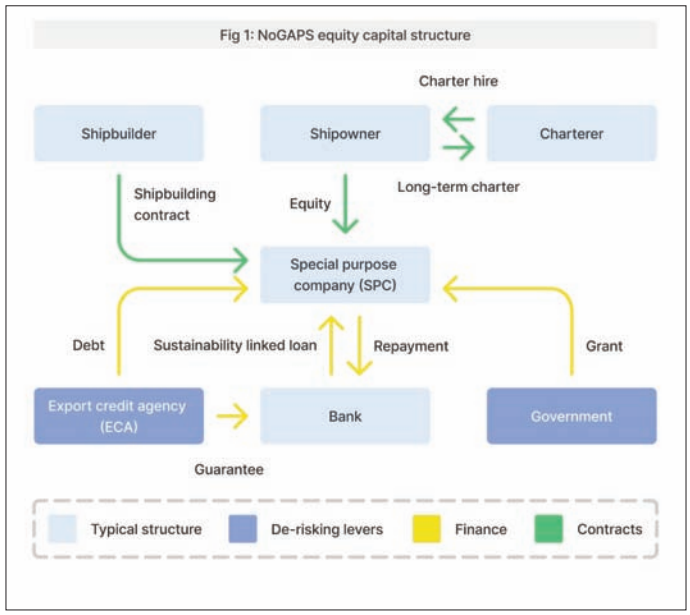
Given limited capital support and stricter emission regulation, shipowners have sought out solutions for de-risking the transition for themselves, solutions such as multi-fuel engines that can use both conventional fuel and ammonia, which lowers the risks and immediate costs associated with transitioning to ammonia fuel. That means they can run the ships purely on ammonia when the fuel network is ready.

Recently, the Norwegian shipowner, Höegh Autoliners, took delivery of 1 of 12 new ammonia and methanol certified pure truck and car carrier ships (PTCT) in China. Not only is this a significant investment, but when such an industry heavy weight commits to such an order, it not only reduces their own risk during the transition, it signals to the remaining industry that we're nearing the time to drive capital into global ammonia fuel infrastructure.

The fact that Höegh Autoliners has invested so heavily in innovative fuel solutions is not just about compliance, but about setting new standards. With sustainability as a key investment criterion, these initiatives are likely help attract more capital, driving further innovation and adoption. Multi-fuel ships are a platform for bridging the risk of the transition, while sustainable fuel infrastructure is being scaled up and costs go down.

Capital structures to scale up institutional investment

Achieving commercial viability for ammonia-powered ships requires significant investment, particularly in developing a global ammonia fuel network. Institutional investors must play a central role in this process because deep-sea shipping is integral to the global economy.



NoGAPS Phase 2 - Equity structure. Diagram drawn by OTE based on the original report. Source: Global Maritime Forum, 2022

By pooling resources, these investors can collectively lower the costs of developing the necessary fuel production and distribution infrastructure, making large-scale adoption feasible.

However, institutional investment hinges on several factors. For one, investors must see a clear path to profitability, which includes ensuring that the infrastructure for ammonia is robust and that ammonia-powered ships themselves are financially viable. The Nordic Green Ammonia Powered Ships (NoGAPS) project proposes four key levers to reduce financial burned on shipowners and lower risks for institutional investors:

1. Cost-efficient, dual-fuel vessel design: This lever (reflecting our previous multi-fuel ship examples) focuses on minimising both capital and operational costs while mitigating residual value risks (depreciation of asset values like ships). Dual-fuel engines allow vessels to switch between conventional and ammonia fuels to make them adaptable to a developing market.

2. Competitive financing arrangements: Securing cost-effective financing is crucial for the business case of ammonia-powered ships. This includes traditional bank loans and sustainability-linked loans, where interest rates decrease if environmental targets are met.

3. Public sector de-risking measures: Governments can play a significant role by offering capital expenditure (CAPEX) grants and export credit guarantees, which directly reduce the financial burden on shipowners and make investments in ammonia-powered vessels more attractive.

4. Premium long-term charter agreements: Securing long-term contracts with reputable charterers provides stable revenue streams, reducing credit and residual value risks for lenders and investors.

How do these levers work in practice? Let's look at two capital structures proposed by the NoGAPS project for deploying ammonia-powered ships.

Equity capital structure

In our first example, the ship is owned by a special purpose company (SPC), a legal entity created solely for owning and operating the vessel. The SPC utilises funds to secure a shipbuilding contract to ensure construction.

This structure is designed to manage the risks associated with deploying new technology while providing sufficient capital to bring the vessel to market:

• Equity from the shipowner: The shipowner provides a significant portion of the equity,

which is crucial for securing additional financing.

• Sustainability-linked loan: A bank offers a loan to the SPC, tied to specific sustainability targets. Meeting these targets could result in improved loan terms, reflecting the ship's lower environmental impact.

• Government grant: A government grant helps offset the high initial costs associated with building an ammonia-powered ship, bridging the cost gap between traditional and zero-emission vessels.

• Debt or loan guarantee from an export credit agency (ECA): An ECA provides a guarantee for the loan, reducing the financial risk for the bank and encouraging investment by securing more favorable loan terms.

• Long-term charter agreement: The shipowner secures a long-term charter agreement, which provides stable revenue but can be challenging due to the costs associated with ammonia-powered ships.

Leasing capital structure

Our second example presents a leasing capital structure, designed to reduce the upfront capital requirements for the shipowner and mitigate risk during the transition:

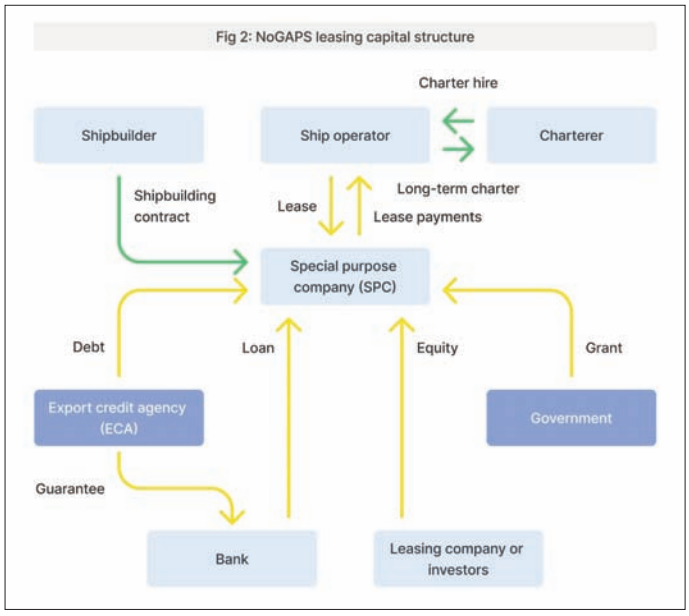
• Equity from investors/leasing companies: Unlike the previous model, equity is provided by a group of investors or leasing companies, which spreads the risk across multiple parties. This equity, combined with contributions from the shipowner, is directed to the SPC.

• Bank loan: A bank provides a loan to the SPC, similar to the previous model, but this time the loan is directly associated with the leasing arrangement.

• Government grant and ECA guarantee: As in the first model, a government grant and a loan guarantee from an ECA are crucial to reducing financial risks and securing more favorable loan terms.

• Leasing agreement with the SPC: The ship operator enters into a leasing agreement with the SPC. This arrangement allows the operator to use the vessel without the need for significant upfront capital investment, making it an attractive option for operators who are cautious about the financial risks of new technology.

• Long-term charter agreement: As in the previous model, the operator also secures a long-term charter agreement with a charterer, providing stable cash flow and further reducing the financial risk.



NoGAPS Phase 2 - Leasing structure. Diagram drawn by OTE based on the original report. Source: Global Maritime Forum, 2022

Market readiness

The maritime sector's move toward ammonia as a zero-carbon fuel is not just an environmental milestone; it's a foundation for advancing CCS. Currently, Clarksons' (world leading maritime consultancy) data shows a combined ammonia-ready fleet and orderbook of about 430 ships (Splash, 2024, China Merchants Inks 10 Tanker Newbuilds at DSIC), and with the Viking Energy's conversion into the world's first ammonia-powered offshore support vessel by 2026 (Eidesvik, 2024, Viking Energy makes history as first ammonia-powered offshore vessel), the market indicates a tangible shift towards ammonia.

These developments highlight both technological readiness and a general commitment to reducing emissions through new fuel solutions. The inclusion of shipping under the EU Emissions Trading Scheme (EU ETS) from 2025 will also continue to drive the adoption of ammonia and contribute to CCS advancement by:

• Accelerating infrastructure development, which will also support CO2 transport and storage.

• Stabilising or reducing transport costs for CCS, making it more financially viable.

• Encouraging long-term carbon management projects through predictable costs and operations.

However, to fully anchor this development, it's imperative that institutional investors actively participate in the transition. Their capital is key to scaling the infrastructure to a point where CCS and zero-emission shipping are not just feasible but fundamental to our global environmental strategy. Imagine that our oceans can be more than highways for global trade but also a venue of environmental stewardship on an industrial scale.

About the author

Oliver T. Edwards holds a master's degree in architecture, with further specialisations in urban infrastructure and corporate finance. He is a business developer in Normod Carbon, a company providing end-to-end carbon transport and storage solutions to industrial emitters in Northern Europe.

More information

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CATF review of major CCS projects shows the technology is working

The report from Clean Air Task Force (CATF) finds that several large-scale projects have consistently met high levels of technical performance.

The report "Carbon capture and storage: What can we learn from the project track record" examines the performance of 13 significant CCS projects and provides a means to evaluate the success of existing projects to better understand the technology's future impact on climate action.

"This review shows that carbon capture and storage projects can perform well at large scales and that the technology is already contributing to global efforts to reduce emissions," said Toby Lockwood, Technology and Markets Director for Carbon Capture at CATF.

"Many of the projects operating today were not aimed at prioritizing benefit to the climate, but they have nonetheless driven technological progress that will pave the way for more ambitious, climate-focused initiatives. When combined with innovation and thoughtful policy -- like we're beginning to see in the U.S., Europe, and Canada -- we can ensure that the emerging wave of large-scale CCS projects build on these early successes and establish a high standard for climate performance moving forward."

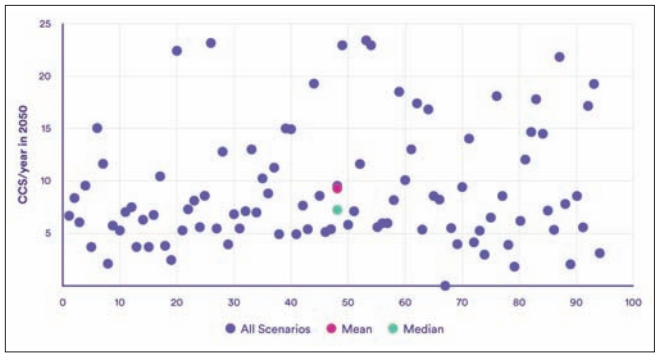
The report's findings highlight that:

• Several large-scale projects, including Sleipner, the Alberta Carbon Trunk Line, and Quest, have consistently met high levels of technical performance, demonstrating an achievable standard that should – and must – be built upon by an increasing proportion of projects so climate goals remain in reach.

• Commonly cited 'large-scale' CCS projects represent a fraction of the many commercial technologies actively capturing, transporting, and storing CO2.

• Most early large-scale CCS projects were designed to meet a narrow set of objectives, specific market conditions, or regulations, and the majority have not been incentivized to maximize their CO2 mitigation potential. By understanding these factors, we can better evaluate project success.

• Operational experience, technological learning, and innovation can help overcome technical challenges that arise as CCS is used at larger scales or in more diverse applications. Several large-scale CCS projects have been developed primarily to gain such experience and have led to clear improvements in reliability and performance. Maximizing continuous technical performance, however, is often subordinate to this goal.



Billion tonnes (Gt) of CO2 stored annually in 2050 across the 95 IPCC scenarios that are compatible with 1.5°C of global warming with limited temperature 'overshoot' (Figure: CATF)

• To help build public confidence and accelerate technology improvements, CCS projects should be encouraged or required to report their performance data and challenges as transparently as possible.

• The right policies and regulations can ensure that new CCS projects are designed and operated to maximize their climate impact. As the current wave of planned CCS deployment is increasingly driven by climate-focused policies, project performance can be expected to steadily improve.

Lockwood continued: "Climate science and energy system modeling affirms we need CCS technology at massive scales to both cut emissions quickly from existing sources and remove emissions from the atmosphere. While its role in climate mitigation is relatively new, the constituent technologies have been successfully used in commercial settings for decades. Future projects will increasingly be incentivized to focus on deep carbon reductions, but this report provides a critical resource for interpreting the performance of previous projects with narrower objectives."

In the U.S., the passage of the Inflation Reduction Act (IRA) and bipartisan Infrastructure Investment and Jobs Act (IIJA) have generated momentum to combat the climate challenge and meet U.S. emissions targets by installing critically needed carbon capture and storage technologies. The dedicated spending and expanded tax credits in the IRA and IIJA have given developers even more reason to focus on capturing carbon pollution from air emissions waste streams and permanently storing it underground.

In Europe, the Net Zero Industry Act (NZIA), which aims to boost investments and market conditions for clean tech, includes carbon capture and storage as one of the key technologies for the clean energy transition. In February 2024, the European Commission adopted the Industrial Carbon Management Strategy (ICMS).

It outlines actions at EU and national levels to scale up carbon management, establish a single CO2 market, and attract investments in carbon management technologies. Several countries of the European Union, such as Germany, France, and Austria have already published national carbon management strategies, and more countries are expected to introduce their plans soon.

More information

www.catf.us/carbon-capture

Oxford researchers propose 'Carbon Removal Budget'

Research published in the journal Carbon Management makes the case for a novel 'Carbon Removal Budget' to help tackle climate change, sitting alongside the Carbon Budget that governs how much CO2 can safely be emitted globally.

Dr Ben Caldecott, the Lombard Odier Associate Professor at the University of Oxford Smith School of Enterprise and the Environment and lead author said, 'Carbon removal is the 'net' in 'net zero' and it is mission critical for tackling climate change. However, carbon removal is not in infinite supply and is certainly not free to produce.'

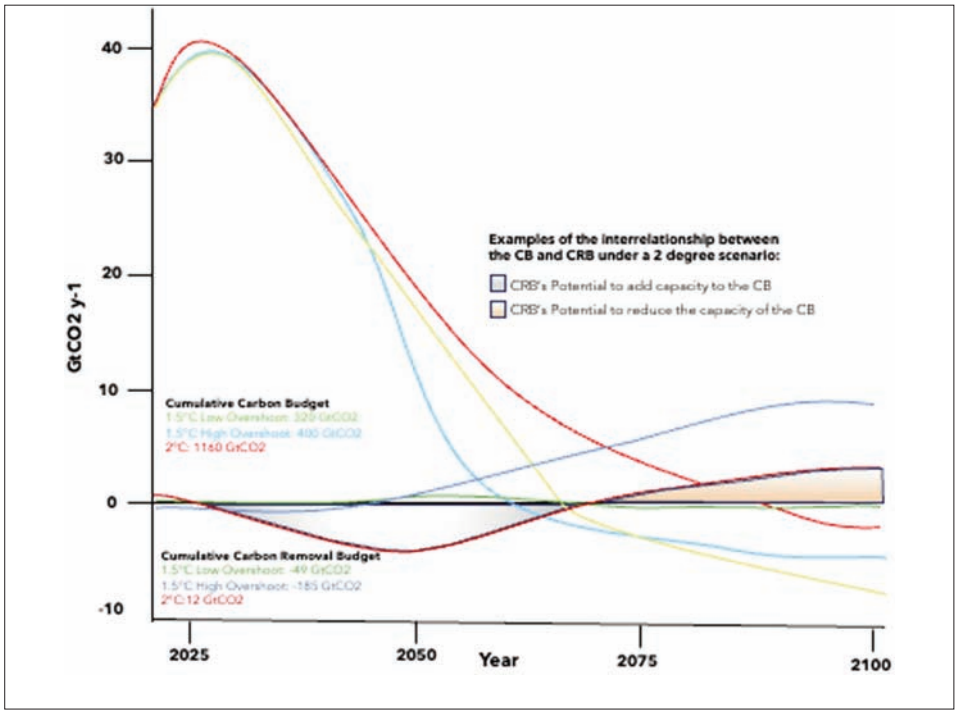
To limit global warming we need to level off the cumulative stock of carbon in the atmosphere and achieve 'net zero', when all emissions that can be eliminated are, and any residual emissions are neutralised by durably removing carbon from the atmosphere.

Traditional carbon removal methods like planting trees and restoring wetlands are part of this mix, as are more novel options like biochar and technologies that directly capture and store carbon. The availability of carbon removal is, however, constrained. For example, some carbon removal methods depend on significant energy consumption and require vast tracts of land.

Dr Caldecott added, 'The Carbon Removal Budget is the cumulative amount of carbon removal available to realise global temperature goals. We need a way to value this finite removal capacity and allocate it in a fair and effective way. The Carbon Removal Budget allows us to do this, in the same way that the Carbon Budget allows us to value remaining carbon emissions and figure out how we distribute that globally between different countries, sectors, and companies.'

Dr Injy Johnstone, Research Fellow at the Oxford Sustainable Finance Group and co-author said, 'We have seen growing interest by private and public actors alike in how we can scale carbon removal. Companies like Microsoft, for instance, are making big voluntary investments in new types of carbon removal."

"At the same time, many countries, including the UK, are also considering how they too can drive demand for carbon removal, including by integrating carbon removal into existing compliance emissions trading or tax regimes.'



Stylised interplay between the carbon budget and the carbon removal budgets

Dr Johnstone added, 'However, carbon removal is a scarce resource, one which not all countries or companies have the same capacity to develop and deploy, meaning we need a Carbon Removal Budget to help equitably manage both supply and demand.'

The authors argue that carbon removal budgets can help to answer several urgent questions. How much carbon removal is needed and when? What methods for carbon removal should be prioritised? What impediments exist to the different types of removal supply and how can we overcome them?

Critically, how should we allocate the finite, even if growing, carbon removal supply between different countries, companies, and financial institutions?

Dr Caldecott said, 'For example, it is not clear why a fossil fuel company should be using carbon removal today when there are ways to reduce its emissions today, especially when we need to preserve removals for future emissions that are extremely hard or impossible to eliminate.'

'Embedding carbon removal budgets into decision-making is necessary for an effective response to climate change. It will become an essential part of net zero transition plans, whether for countries, companies, or financial institutions.'

More information

www.smithschool.ox.ac.uk

Projects and policy news

Suez advancing two CCS projects in UK East Coast Cluster

www.suez.com
www.fluor.com
www.ten.com

Fluor is supporting the Pre-FEED for the existing energy-from-waste facility at the Haverton Hill Industrial Estate on Teesside, while Technip Energies have partnered on the Pre-FEED for the energy-from-waste facility operated by SUEZ at Wilton.

SUEZ recycling and recovery UK have worked with Pre-FEED contractors for two of its carbon capture projects in the East Coast Cluster in preparation for an application for funding through the Industrial Carbon Capture Track-1 Expansion project from the UK Government.

A visualisation of Suez' proposed Tees Valley energy from waste CO2 capture plant

Stuart Hayward-Higham, Technical Development Director for SUEZ recycling and recovery UK said, "As a leader in environmental services, SUEZ is committed to driving the ecological transition in the waste and water sectors. Carbon Capture is vital to decarbonisation and we have the expertise to make this a reality."

"We are confident in our strategy and are ideally placed to showcase what this technology can do. Our technology partners, Fluor and Technip Energies, were chosen based on their experience, capture rate and design costs. We're hopeful that government will back these projects to maximise the potential that can be captured across Teesside and Humber."

Funding is already in place for the main East Coast Cluster pipeline for Teesside, which will transport carbon captured from a range of projects across Teesside to an aquifer 145km off the coast beneath the North Sea, where it will be stored safely.

The East Coast Cluster project will play a key role in helping the UK to achieve Net Zero, with the Government's Climate Change Committee describing the process of Carbon Capture as "a necessity rather than an option to achieve Net Zero by 2050".

The successful implementation of these projects will pave the way for a large scale roll out of the carbon capture solution across Suez's energy-from-waste plant portfolio, with plans already being developed in other parts of the UK. Technip Energies are using their expertise not just for Wilton, but also for the energy-from-waste facility in Severnside, Bristol (part of the 7CO2 cluster).

Canada Growth Fund invests US$100 Million in Svante to accelerate growth

www.svanteinc.com
www.cgf-fcc.ca

A financing commitment of up to $100 million will help to accelerate the development and construction of Svante's commercial carbon capture and removal projects in Canada and the US.

CGF has a mandate to invest in Canadian clean technology businesses that are scaling technologies currently in the commercialisation stage of development. Svante is a leading developer of carbon capture and removal technology, with significant potential to accelerate emissions reductions in hard-to-abate sectors.

CGF's investment enables the Company to focus on its first-of-a-kind (FOAK) deployment opportunities and will encourage the business to prioritise opportunities in its Canadian pipeline. The investment marks CGF's first venture in British Columbia, supporting local jobs in the province and diversifying its investment portfolio.

"CGF is working to accelerate the deployment of key Canadian carbon capture technologies, and to scale the manufacturing and export of promising solutions to showcase Canadian technologies internationally," said Patrick Charbonneau, President and CEO of CGF Investment Management.

"Svante has a tremendous market opportunity, globally and here at home, and we look forward to supporting this company in its growth."

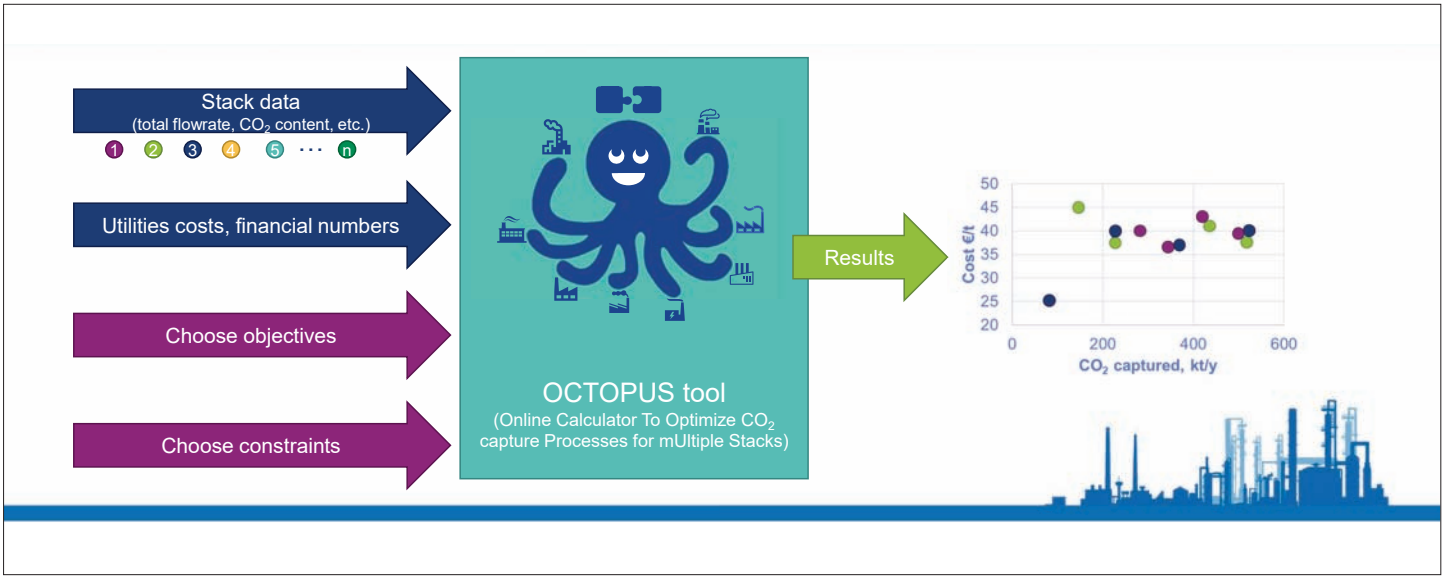
CGF will fund its investment in two tranches: (i) an initial tranche of US$50 million will be used to accelerate and de-risk FOAK commercial projects currently underway and (ii) a potential second tranche expected to be tied to project-specific requirements to match Svante's capital needs for the development and construction of projects alongside the Company's co-development partners.

Svante is constructing a 141,000 sq. ft. facility in Burnaby, BC, Canada, which will produce filters capable of capturing 10 million tonnes of CO2 annually and serve as the company's global headquarters and R&D center.

The market for carbon capture and sequestration, and carbon removals, is expanding, with supportive regulations in place in Canada, the USA, and Europe, highlighting the growing demand for emissions reduction and removal technologies.

Octopus – free online tool for sizing carbon capture systems

A free software tool, from TNO in the Netherlands in collaboration with NTNU and SINTEF in Norway, can help you work out an initial estimate for the expected size and utility demand of a carbon capture system. It will be particularly useful where multiple CO2 sources are combined. By Karl Jeffery.



How to integrate and optimize carbon capture from multiple sources

Researchers at the Netherlands Organisation for Applied Scientific Research (TNO) have developed an online software tool, running on Python, to work out the best sizing for a CO2 capture system, with multiple CO2 emission sources.

It could be used for initial design of CO2 capture systems for industrial facilities with many different sources, such as refineries. It could also be used for first level feasibility studies for people considering capture projects.

It can also be used for evaluating options when you have multiple different sources – should you combine the flue gases into a single capture plant, or have separate capture plants?

You tell the software what solvent you want to use, your desired capture rate and your flue gas composition and flow rate.

Additionally, economic parametera can be added, such as the costs of steam, electricity and cooling water. You can choose the objectives you want to optimise for (energy consumption or capital costs) and add constraints.

The tool contains a large database of simulation results from which it can draw the relevant information following the input of the user. Therefore, no simulations have to be performed in the tool, and it can generate results withing seconds.

Once you have your design, the software will tell you how much CO2 will be captured, the capex of absorber packing and shell, the height and diameter of the absorber, the packing height in the absorber, and the total demand for steam, cooling water and electricity. Additionally, it calculates the total capex and opex of your design.

The capex calculation includes the cost of the equipment, including the absorber and desorber, and installation costs. It takes estimates for economics from open literature. The tool includes a manual that describes all assumptions used in the tool.

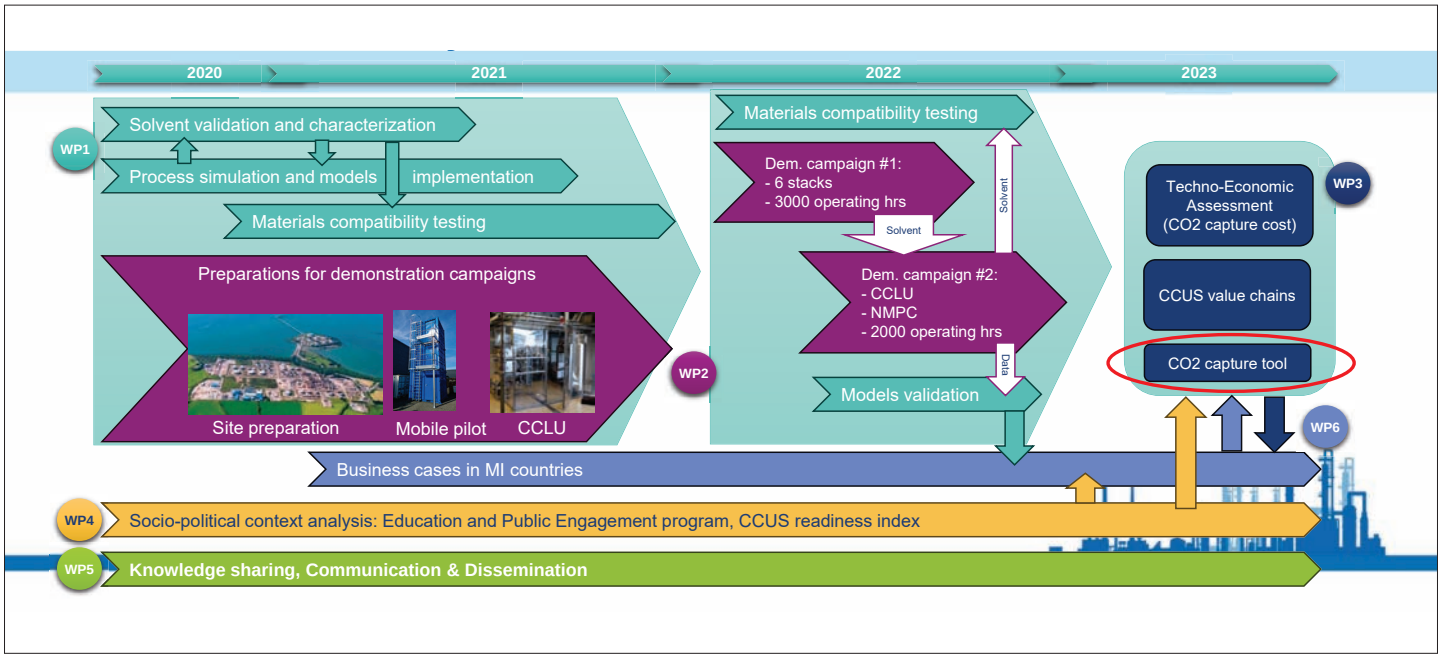
The reboiler is where heat is provided to the desorber system, to release the CO2 from the solvent. The energy consumption is usually the biggest cost, so the main factor people want to optimise.

The software

The tool can currently model capture systems with two solvents, standard MEA, and HS3. Capture rates can be 90 or 95 per cent. The tool covers CO2 concentration ranging from 3 to 20 volume per cent, which "should cover the majority of flue gases."

Flue gas is assumed to be a mixture of nitrogen, oxygen and CO2, at atmospheric pressure.

The absorber packing heights included in the toolrange from 7 to 30 metres. 30m is "nor-



The REALISE story - decarbonising refineries using CCUS

mally more than enough to capture 90-95 per cent", he said. "7 is close to the minimum if you have high solvent flowrates".

The Octopus tool can handle flue gas flow rates of between 100k normal m3/hour to 500k normal m3/hour. The total number of simulations results available in the tool is 15,000.

In future developments, the tool may be extended to cover other solvents, cover more detailed cost calculations, and have other options, such as where there is limited energy availability or land space. It could include higher capture rates, such as 99 per cent.

REALISE

The software was developed as part of the "REALISE" project funded by the European Union Horizon 2020 Programme, which focusses on decarbonising refineries using CCUS.

The tool development was led by Jasper Ros, a scientist at TNO specialising in carbon capture. The tool was created in collaboration with SINTEF and NTNU.

REALISE started in May 2020, and had 14 EU partners, plus two from China, one from South Korea, and a budget of Euro 7m.

As part of the project, a test case was done modelling data for the Irving Oil refinery in Cork, Ireland. It also worked with data from project partners in South Korea and China.

Commingling options

The software tool may be particularly useful for companies planning capture clusters, and considering whether it is more cost effective to co-mingle the flue gas streams into a single capture plant, rather than pay for three separate ones. They can use the software to see the costs of different options.

Capturing CO2 requires a quencher to cool the gas down, an absorption column to bring it into contact with the solvent, a desorber, and CO2 compression system.

Companies doing this will need to decide whether to integrate the untreated flue gases before or after the quencher, integrate the CO2 rich solvent (so each system has its own capture plant but a common desorber to release the CO2), or to integrate the captured CO2 streams post compression.

Flue gas is typically 80 to 90 per cent nitrogen, so needs large diameter pipes. Once CO2 is absorbed into a liquid solvent, the diameters are much smaller. CO2 can account for 10 per cent of the total liquid weight. So, the cost of a pipeline to move CO2 rich solvent can potentially be much less than a flue gas pipeline.

If the CO2 sources are far apart, pipeline costs will be a major part of overall cost, and so companies will be keen to find ways to reduce them.

Or maybe it is most cost effective to have separate plants but join streams of uncompressed CO2 to a single compression station.

More information

This article is based on a webinar held on June 19, "Multi-emission point integration of carbon capture with OCTOPUS tool". Presentation slides are online here https://co2-cato.org/publications/cato-webinar-19-june-2024-octopus-tool/

The tool is available online at https://octopus.sensorlab.tno.nl. To request a free account, you can email jasper.ros@tno.nl.

A video demonstration of Octopus is online at:
www.youtube.com/watch?v=mG8e6nQWP_8

More information

www.realiseccus.eu

UCF researcher develops lotus-inspired tech to convert CO2 to fuels, chemicals

Nanoscience Associate Professor Yang Yang has designed a nature-inspired filtration and conversion system that extracts carbon dioxide gas from the atmosphere to create useful chemicals.

Yang Yang, an associate professor in UCF's NanoScience Technology Center, created an innovative device that captures carbon dioxide with a microsurface comprised of a tin oxide film and fluorine layer. The device then extracts gaseous carbon dioxide via a bubbling electrode and selectively converts the gases into carbon monoxide and formic acid, which are important raw materials for manufacturing chemicals.

It could be located at power plants, industrial facilities, or chemical production plants where carbon dioxide is captured from emissions and converted into useful products.

This technology, detailed in a recent study in the Journal of the American Chemical Society, aims to reduce humanity's carbon footprint sustainably while addressing the need to produce alternative energy.

"We want to create a better technology to make our world better and cleaner," says Yang, who also is a member of UCF's Renewable Energy and Chemical Transformation (REACT) Cluster. "Too much carbon dioxide will have a greenhouse effect on the Earth and will heat it up very quickly. It's the motivation for why we want to develop this new material to grab and convert it into chemicals we can use."

Yang Yang, an associate professor in UCF's NanoScience Technology Center, works with a device that helped develop his triple-phase device that captures and converts carbon dioxide.

Yang Yang, an associate professor in UCF's NanoScience Technology Center, works with a device that helped develop his triple-phase device that captures and converts carbon dioxide. (Photo by Antoine Hart)

Design Blossomed from Nature

The inspiration for the device and mitigating our impact on the environment came directly from nature itself, Yang says.

"We as scientists always learn from nature," he says. "We want to see how the animals and the trees work. For this work, we learned from the lotus. We know that the lotus has a really hydrophobic surface, which means when you drop water on the surface, the water will go quickly away from the surface. We also know that green plants absorb carbon dioxide and convert it to oxygen through photosynthesis."

The lotus helped Yang conceive of carbon dioxide capture technology that mimics the lotus surface, in which water trickling down a device's fabricated hydrophobic surface would be separated from the carbon dioxide conversion reactoin.

It's necessary to carefully manage the amount of water on the surface of materials that may flood the device or disrupt carbon dioxide conversion, Yang says.

Once captured, the carbon dioxide gas is then routed through an electrode and converted through a more customizable process than naturally occurring photosynthesis.

The electrocatalytic carbon dioxide reduction reaction converts carbon dioxide gas into carbon-containing chemicals, such as methanol, methane, ethylene, ethanol, acetate, and propanol, depending on the specific reaction pathways on the catalysts.

"We want to create a better material which can quickly grab carbon dioxide molecules from the air and convert them into chemicals," Yang says. "We just reduce the concentration of carbon dioxide in the air and convert it in the liquid and gas phase so we can directly use those converted chemicals and fields for other applications."

One of the most challenging components of the research was reducing the amount of water spread out on the surface of the catalytic materials when exposing the components of gaseous carbon dioxide in the liquid electrolyte, he says.

"If you have too much water surrounding

your materials, you may produce hydrogen instead of converting carbon dioxide to chemicals," Yang says.

"That will decrease the energy efficiency of the overall process. The materials we use can repel the water from the surface, so we can avoid the formation of hydrogen, and we can greatly enhance the carbon dioxide reduction efficiency. So that means eventually we can use almost all of the electricity for our reaction."

Scaling Up

There are many existing efforts around the world to reduce, capture or convert carbon dioxide including planting trees and developing large-scale carbon dioxide capture technologies.

Yang says he hopes his carbon dioxide capture and conversion device may serve as a viable alternative option to other more time-consuming or costly methods.

Harnessing environmentally sustainable electricity is another step in implementing the carbon dioxide conversion technology into reality, Yang says.

"In our process, we can use intermittent electricity, like the electricity coming from the solar panel or from the wind farm," he says.

The technology is built off Yang's previous energy efforts at UCF nearly three years ago in developing new materials for fuel cells that used fluorine-enhanced carbon.

The research serves as an important first step and a is fundamental study that may pave the way for more large-scale carbon dioxide capture methods, Yang says.

"For this, we validated our concept from the fundamental point of view," he says. "We tested the performance in our reactors, but in the future, we want to develop a bigger prototype that can show people how quickly we can convert and reduce the carbon dioxide concentration and generate chemicals or fuels very quickly from our large-scale prototype."

Yang collaborated with the University of Houston; the University of California, Berkley; Stanford University and the Eastern Institute for Advanced Study in Ningbo, China.

The research was funded the by U.S. National Science Foundation and The American Chemical Society Petroleum Research Fund.

More information

nanoscience.ucf.edu

Irish company unveils groundbreaking innovations in DAC

NEG8 Carbon has made significant upgrades to its Direct Air Capture (DAC) technology, improving both the efficiency and effectiveness of the system.

The latest innovations focus on a revolutionary approach to the deployment of sorbents. Traditionally, sorbents are packed into thick beds, requiring substantial amounts to be effective, however, NEG8 Carbon's technology reduces the quantity of sorbent needed by 80%.

This change also speeds up the CO2 capture and release process, cutting regeneration time by 90%, which means a much more efficient system.

Meanwhile, a second key innovation advances the heat exchange process within the DAC system. It enables much faster heat transfer as it optimises heat transfer to the sorbent material, improving the efficiency of the sorbent's regeneration process and increasing CO2 uptake by 50%.

Energy consumption is also reduced by over 20%, making the DAC system more cost-effective and environmentally friendly.

According to NEG8 Carbon, the key to the widespread adoption of DAC technology is the cost per tonne of CO2 captured, and this technology breakthrough allows NEG8 Carbon to drive down this cost

"As the global community strives to combat climate change, reducing carbon emissions is important, but it is only part of the solution. Equally important is removing existing carbon dioxide from the atmosphere. Direct Air Capture technology plays a crucial role in this effort by capturing CO2 directly from the air, offering a scalable solution to help meet global net-zero targets," saidDr John Breen, CTO of NEG8 Carbon.

"These innovations are making significant improvements to our Direct Air Capture technology. They enhance both efficiency and sustainability, reinforcing our dedication to providing effective solutions in the fight against climate change".

The company plans to integrate these innovations into its demonstration unit in a real-world setting by the third quarter of 2024. It has a mission to capture 100 million tonnes of CO2 annually by 2050.

After successfully launching Ireland's first operational DAC system in 2023, the NEG8 Carbon team is set to manufacture and test a large-scale pilot system throughout 2024 in collaboration with Deep Sky in Canada. A partnership with Walton Institute this year focuses on a two-year AI project using machine learning to monitor and optimise the conditions for carbon capture.

"The innovation announced today brings NEG8 Carbon one step closer towards meeting the global demand for effective and scalable carbon removal systems as governments and corporations intensify their efforts to reach net zero emissions."

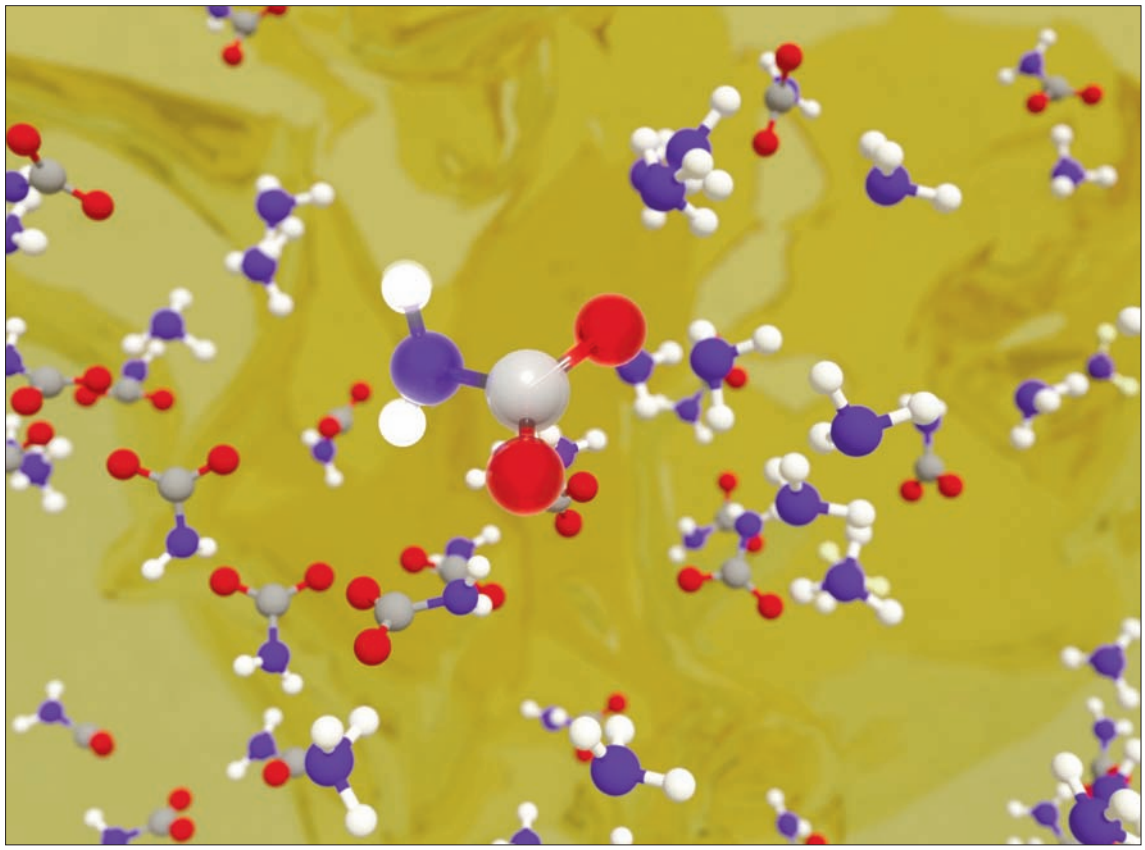
More information

www.neg8carbon.com

Probing carbon capture, atom-by-atom to enhance DAC efficiency

A team of scientists at Lawrence Livermore National Laboratory (LLNL) has developed a machine-learning model to gain an atomic-level understanding of CO2 capture in amine-based sorbents.

The innovative approach promises to enhance the efficiency of direct air capture (DAC) technologies. The research is funded by the Department of Energy, Office of Science, Basic Energy Sciences, Materials Sciences and Engineering Division.



A machine-learning potential derived from first-principles calculations unveils the intricate mechanisms of CO2 capture in liquid ammonia. (Illustration: Liam Krauss/LLNL)

Amine-based sorbents have emerged as a promising solution, efficiently binding CO2 even at ultra-dilute conditions. The low cost of these sorbents has enabled several companies to scale up this technology, demonstrating DAC as a feasible way to combat global warming. However, significant knowledge gaps remain in the chemistry of CO2 capture under experimentally relevant conditions.

The LLNL team's machine learning model has revealed that CO2 capture by amines involves the formation of a carbon-nitrogen chemical bond between the amino group and CO2, alongside a complex set of solvent-mediated proton transfer reactions. These proton transfer reactions are critical for the formation of the most stable CO2-bound species and are significantly influenced by quantum fluctuations of protons.

"Our method can be extended to amines with different chemical compositions, highlighting the impact of machine learning in understanding the fundamental chemistry involved in CO2 capture under realistic conditions," said Marcos Calegari Andrade, lead author of a paper appearing in Chemical Science.

Using a combination of grand-canonical Monte Carlo and enhanced sampling methods in molecular dynamics, the researchers obtained quantities directly accessible by experiments.. These results provide a vital connection to laboratory measurements and pave the way for a future feedback loop between simulations and experiments.

"By integrating machine learning with advanced simulation techniques, we've created a powerful approach that bridges theoretical predictions and experimental validations of CO2-capture mechanisms in a way not accessible by traditional simulation techniques," said LLNL scientist Sichi Li, co-corresponding author and project theory lead.

"This research not only advances our understanding of CO2 capture mechanisms but also provides a new and critical tool for designing next-generation materials that can contribute to net-zero greenhouse gas emissions", said Simon Pang, co-corresponding author and project principal investigator.

LLNL co-authors also include Tuan Anh Pham and Sneha Akhade.

More information

www.llnl.gov

doi.org/10.1039/D4SC00105B

Biomass-based polymer can capture and release CO2 without extremes

A new, biomass-based material developed by FAMU-FSU College of Engineering researchers can be used to repeatedly capture and release carbon dioxide without high pressure or temperature.

The material is primarily made from lignin, an organic molecule that is a main component of wood and other plants, and it can take up carbon dioxide from concentrated sources or directly from the air. The research was published by Advanced Materials.

"The beauty of this work is the ability to precisely control the capture and release of CO2 without high pressure or extreme temperatures," said study co-author Hoyong Chung, an associate professor in the FAMU-FSU College of Engineering at Florida State University.

"Our testing showed that this material's structure stayed the same even after being used multiple times, making this a promising tool for mitigating carbon emissions."

In previous research, Chung's team developed a lignin and CO2-based polymer that represented a potential alternative to traditional petroleum-based plastic.

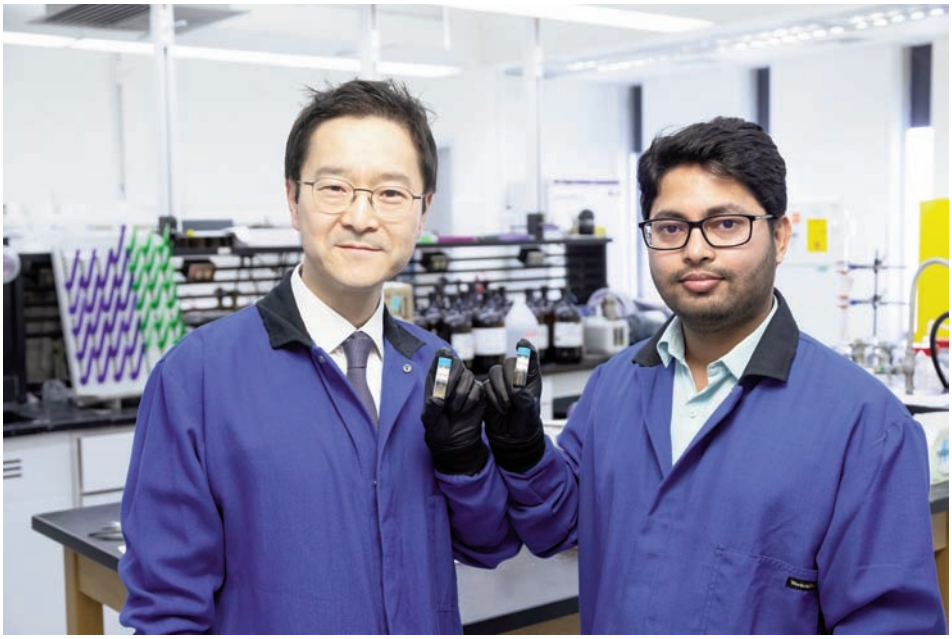
This paper takes that research further, showing the possibility of reversing the process and of reusing the material to absorb CO2 again in the future.

Because it is found in plants, lignin is abundant and cheap, and it is often harvested as a byproduct from wood processing. Scientists are working to find new ways to use this natural resource.

One gram of the material developed by Chung's team captured 47 milligrams — about 5% of the weight of the original material — of CO2 from a concentrated source and 26 milligrams from exposure to ambient air.

The absorbed CO2 can be permanently sequestered, or it can be released for use in various applications, such as manufacturing, agriculture and others.

Researchers were surprised by the release mechanism. While using nuclear magnetic resonance spectroscopy to analyze a sample, they saw bubbles appear when the sample was heated.



Hoyong Chung, an associate professor in the FAMU-FSU College of Engineering, and postdoctoral researcher Arijit Ghorai developed a new, biomass-based material that can be used to repeatedly capture and release carbon dioxide. (Scott Holstein/FAMU-FSU College of Engineering

"That sparked our curiosity," Chung said. "What's going on here? Why do we see these little bubbles every time we try to analyze this polymer?"

Further investigation revealed that heat was causing the material to release CO2. The researchers investigated the reaction and found that by controlling the heat applied to the sample, they were able to control the amount of CO2 released. They also showed the possibility of using that captured gas in other reactions.

It only takes temperatures of about 60 degrees Celsius at normal atmospheric pressure to release the CO2, meaning high temperatures and pressures aren't necessary for the reuse process. This CO2 release temperature can be increased or decreased for different applications.

"This is like a sponge for CO2, absorbing it, releasing it and drying up so it can capture more," Chung said. "It's fascinating to see what is possible with this material."

Postdoctoral researcher Arijit Ghorai was the lead author of the study. This work was supported by the U.S. Department of Agriculture National Institute of Food and Agriculture.

More information

chy979797.wixsite.com/chunggrou
doi.org/10.1002/adma.202406610

Capture & utilisation news

Air Liquide selected by Stockholm Exergi for world scale CCS

www.airliquide.com
www.stockholmexergi.se

Air Liquide's large scale CO2 liquefaction technology, Cryocap™ LQ, has been selected by Stockholm's energy company for its BECCS project.

Under the agreement, Air Liquide will provide the CO2 liquefaction technology and equipment for the BECCS project to be built at an existing heat and power biomass (biocogeneration) plant in Stockholm. The Cryocap™ LQ CO2 liquefaction unit will be one of the largest in the world with a capacity of 3,500 tonnes per day.

After liquefaction, the CO2 will be transported for permanent storage. The BECCS facility aims to liquefy and store around eight million tonnes of biogenic CO2 over the first 10 years of operation. The project is supported by the European Innovation Fund, one of the world's largest programs for promoting innovative low-carbon technologies.

Air Liquide's innovative Cryocap™ LQ technology is chemical free and has a non-flammable process and compact design. The setup will also enable the recovery and reuse of heat generated from the process in order to supply Stockholm's district heating network. These features allow enhanced sustainability and safety as well as best-in-class energy efficiency compared to traditional liquefaction solutions.

Philippe Merino, Group Vice President supervising Engineering & Construction at Air Liquide said, "We are pleased that Air Liquide's technology has been selected for the Stockholm Exergi innovative CCS project. Cryocap™ LQ CO2 liquefaction technology is a new addition to Air Liquide's portfolio of low-carbon technologies, and is particularly suited to large scale CCS projects."

"In line with Air Liquide's strategic plan ADVANCE, Air Liquide's ambition is to contribute actively to the emergence of a low-carbon society. Drawing on our innovative capabilities and expertise we are able to help our customers achieve their decarbonization goals and forge a sustainable future."

Bridging the 'valley of death' in carbon capture technologies

rccs.hw.ac.uk

A team of scientists from Heriot-Watt University are using advanced simulations and machine learning to find the most cost-effective and sustainable material-capture process combinations prior to implementation.

A major obstacle for net zero technologies in combatting climate change is bridging the gap between fundamental research and its application in the real world.

This gap, sometimes referred to as 'the valley of death', is common in the field of carbon capture, where novel materials are used to remove carbon dioxide from flue gasses produced by industrial processes.

The team has developed a pioneering platform named PrISMa (Process-Informed design of tailor-made Sorbent Materials). The platform and its associated research have been published in Nature.

PrISMa is already yielding impressive results with the platform having been used to accurately simulate the implementation of carbon capture technologies in cement plants located in different regions of the world. It found suitable materials for each location, cutting costs by half when compared with previous technologies.

PrISMa also offers an interactive tool that allows users to explore the potential of over 1,200 materials for carbon capture applications.

Professor Susana Garcia, from the School of Engineering & Physical Sciences, led the study and is the project coordinator for PrISMa. She explained, "Over the past decade, there has been a huge amount of effort devoted to identifying promising materials capable of capturing CO2."

"Chemists have proposed thousands of novel porous materials, but we did not have the tools to quickly evaluate if any materials are promising for a carbon capture process. Evaluating such materials requires a lot of experimental data and detailed knowledge of the capture process. And a careful evaluation of the economics and life-cycle assessment of the process."

Aker Solutions partners on zero-emission power station

www.akersolutions.com

www.miscgroup.com

An MoU marks the start of a pilot project featuring the Zero Emission Power Station (ZEUS), a pioneering energy solution that uses advanced oxyfuel combustion with immediate CO2 capture and storage.

Aker Solutions has signed an agreement with PETRONAS Carigali, MISC and Clean Energy System during the ONS Conference 2024 in Stavanger, Norway.

The ZEUS pilot project represents an exciting step toward sustainable and affordable energy production, and Aker Solutions, along with its partners, is eager to see its impact on the industry.

"We're excited to bring ZEUS to life alongside our partners. This collaboration marks a significant step forward in our mission to solve energy challenges using innovative technology," said Jo Krabbe, executive vice president of Power Solutions at Aker Solutions.

The ZEUS technology employs oxyfuel combustion to convert high CO2 natural gas into dispatchable power while capturing 100% of the CO2 emissions. The CO2 is immediately injected into a reservoir for permanent storage or can be used to increase production of both oil and gas before being permanently stored.

The advantage of the ZEUS technology is the ability to handle the combustion at elevated pressures, enabling more compact and simplified process equipment. This could lead to significant cost savings while enhancing CO2 management capabilities. In short, ZEUS aims to deliver zero-emission, affordable and reliable power and it is positioned to be a significant bridge technology in the transition to a more sustainable energy landscape.

Another unique characteristic of oxyfuel combustion is that it can burn untreated gas straight from the well, including gas with up to 90% CO2. This opens the door for using gas reserves that would otherwise be considered uneconomic to develop. As world demand for power grows, ZEUS has the potential to be an important bridge technology in the transition to a more sustainable energy landscape.

Shipboard carbon capture – trial finds no 'dealbreakers'

A Dutch research project "EverLoNG" put a CO2 capture system onboard a TotalEnergies LNG carrier, and found that there are no 'dealbreakers' behind doing CCS onboard ships. Further research would be very helpful. By Karl Jeffery.

A carbon capture system was placed onboard a TotalEnergies LNG Carrier "Seapeak Arwa," to see how well it would operate and to compare it to onshore systems.

The project wanted to see how much CO2 would get captured, how fast the capture solvent would degrade, what impact the sea conditions (including movement of the vessel) would have, and the effect of impurities in the vessel's exhaust on the capture solvent.

Project partners include gas shipping company Anthony Veder, heavy lift vessel operator Heerema, Bureau Veritas, DNV, Lloyd's Register, MAN, SINTEF, TNO and TotalEnergies. The project was funded by the "Accelerating CCS Technologies" (ACT) initiative, which for this project was funded by governments of Netherlands, Germany, Norway, UK and US.

The conclusion is that carbon capture on a ship was "successfully demonstrated", with 2475 running hours. No "dealbreakers" were identified for implementation of ship-based carbon capture from a technical perspective.

The behaviour is "pretty much comparable" to what has been seen in land-based carbon capture systems, the researchers said.

The system

The carbon capture system was brought onboard in three 20-foot box containers and installed close to the vessel's funnel.

One box contained the capture tower, where the flue gas is brought in contact with a solvent which attaches to the CO2, and the regeneration tower, where solvent is heated to release the CO2 it is holding.

It used a solvent containing 30 per cent MEA by weight. This is a very well understood solvent, which has been used in many carbon capture pilots.

A second box container held the systems to dry the captured CO2 and liquefy it. A third container contained the CO2 storage tank, holding liquid CO2 at 15 bar. At this pressure, CO2 stays liquid at about minus 25 degrees C.

The system was only of a scale to be able to treat a portion of the vessel's flue gas. A system to treat the full flue gas flow will be the same but with much wider columns. A full-scale system would also require more heat input, and so would need more consideration on the best way to integrate with the vessel's systems.

The study

In the study, the carbon capture system was operated for 2475 hours, from October 2023 to February 2024. The engine was running at high load for most of the time, but not all of it.

The carbon capture system was operational 62 per cent of the time in this period. It was taken offline when Diesel was used as a fuel, LNG was being offloaded and when the engine was being maintained. There were some operational issues with the capture system, and times when specialist operators were not available onboard.

Data was gathered from sensors analysing the ship exhaust. Data about the solvents was gathered by collecting and analysing liquid solvent samples.

The study also compiled data about vessel operations, including motion, engine load and wind speed.

In the first month, it was operated for 400 hours with 7 per cent MEA solvent; in the second month, operated for 500 hours with 17 per cent MEA; in the third month operated for 600 hours with 30 per cent MEA.

The campaign was run by specialists in carbon capture (rather than maritime professionals).

Results

The untreated flue gas of the vessel contained on average 4.78 per cent CO2. As would be expected, the amount of CO2 captured increased with the concentration of the solvent.

With solvent at 5-7 percent (low concentration), the outlet of the capture system contained about 4 per cent CO2; with MEA at 16-18 per cent (medium concentration), it was 2 per cent CO2; and at 30 per cent MEA (high concentration), it was 1 per cent CO2.

Expressed in terms of the percentage of all the CO2 in the flue gas which was captured, it means with low solvent concentration the capture rate was around 23 percent; with medium concentration solvent it was around 54 percent; with high concentration solvent it was around 80 percent.

It is possible to capture more than 80 per cent with higher packing heights (a taller column).

After 600 hours of operation at 30 per cent MEA, the solvent was 20 per cent degraded. Degradation is usual, but the rate of degradation affects the overall project viability, because the capture is less effective and eventually solvent needs to be replaced.

The system showed stable operation, including stable temperatures, despite the vessel operating at one time in wind speed of Beaufort 10, meaning a storm (between a strong gale and a hurricane).

"The observed stability of the process shows a reliable process control system was implemented," said Jasper Ros of TNO. There was "quite robust technology implemented onboard."

There was one person onboard dedicated to operating the system.

Concerns

One concern is that NO2 in the exhaust can react with the amine solvent causing oxidative degradation of the solvent. This can make the whole project more expensive.

NO2 can also form nitrosamines if it is able to react with secondary amines, which would be a safety concern.

These concerns could be mitigated by using NOx emission reduction technology far beyond current Tier III regulations and avoiding the use of secondary amines as a solvent. However, also degradation of primary amines (like MEA) to secondary amines can lead to nitrosamine formation in primary amine systems.

There was on average 69.2 ppm NO2 in the capture system outlet (the exhaust gas was only measured at this position). This compares with 0.5ppm NO2 in the inlet of the carbon capture system in an onshore study conducted at Technology Centre Mongstad in Norway in 2015. This used the same solvent, although this project was 400 times bigger in terms of gas volume handled.

Another concern is that ammonia can be formed through oxidative degradation of MEA. The ammonia emissions were measured at 45 mg per normal cubic metre of flue gas, when operating at 30 per cent MEA, around three times higher than what was observed at TCM.

One observation was that amine emissions increased after the load on the engine changed, which could be caused by aerosol based amine emissions, but more research is needed towards this.

The degradation of solvent could be as much as 3.5 to 4kg per tonne of CO2 captured, which is high compared to other research projects, but not "off the charts," said Juliana Monteiro, senior scientist at TNO.

Further research

The research has only focussed on one specific engine type and one vessel.

It may be useful to run pilots on other exhaust streams with different NOx levels, to see how much this disturbs the capture process.

LNG carrier chartered by TotalEnergies containing the CO2 capture unit (Image courtesy Seapeak Arwa)

One challenge with shipboard carbon capture systems, which onshore systems do not normally have, is that the flue gas flowrate is highly variable, depending on the engine load. The capture system will be designed for a specific flow rate. It may be necessary to do trials with capture systems handling flow rates different to the one they were designed for.

The project trialled amine solvents and post combustion carbon capture since it is the 'most mature technology,' and so probably the best to start with for maritime trials. The selection of solvent will have an impact on cost, safety and environment, Ms Monteiro said.

However it is unclear whether these novel technologies will actually lead to better performance than the classical amine systems.

"If you were thinking about implementing 10 years from now, there might be other things to look into [such as] rotating packed beds and membrane contactors that could lower the volume and height of equipment onboard," she said. "Ships may have limitations in terms of height, that might bring advantages."

The equipment onboard with the biggest volume is the CO2 storage tank, and there is no way to reduce this.

Shipboard carbon capture research has other specific difficulties shore based projects do not have, including the long time taken to deliver samples from the ship to the laboratory. Also if something fails and the spare part is not available onboard, it takes a long time to deliver a new one. "We have to wait months. For us it is something we have to learn to deal with," Ms Monteiro said.

EverLoNG's second demonstration campaign recently got underway as the SSCV Sleipnir from Heerema Marine Contractors-set sail.

The objective of the Sleipnir campaign is to test all aspects of the capture and onboard storage system on the LNG-fuelled vessel. This will be done over an operating period of around 500 hours and includes storing CO2 on board as a liquid in a specially designed container. The container will then be offloaded, and the CO2 transported to an industrial site for utilisation, or stored permanently in the geological subsurface.

More information

This article is based on a webinar "Results from the first EverLoNG capture demonstration campaign", held on June 25 2024. It can be viewed here:

www.youtube.com/watch?v=e7cqqUfBtJY

Study finds limits to storing CO2 underground to combat climate change

Imperial College London research has found limits to how quickly we can scale up technology to store gigatonnes of carbon dioxide under the Earth's surface.

Current international scenarios for limiting global warming to less than 1.5 degrees by the end of the century rely on technologies that remove carbon dioxide from Earth's atmosphere faster than humans release it. This means removing CO2 at a rate of 1–30 gigatonnes per year by 2050.

However, estimates for the speed at which these technologies can be deployed have been highly speculative. Now, findings from a new study led by Imperial College London researchers show that existing projections are unlikely to be feasible at the current rate of growth.

The study found that it might be possible by 2050 to store up to 16 gigatonnes of CO2 underground each year. However, reaching this target would require a huge increase in storage capacity and scaling over the coming decades, which is not anticipated given the current pace of investment, development and deployment.

With the UK Government aiming to position Britain as a clean energy superpower and scale up and invest in carbon capture and storage, the study underscores the importance of aligning ambitious initiatives with realistic objectives for how quickly CO2 can be safely stored underground..

Realistic goals

The team from Imperial's Department of Earth Science and Engineering created models showing how quickly carbon storage systems can be developed and deployed, accounting for the availability of suitable geology, and technical and economic limitations to growth.

While the results suggest it is possible to reduce CO2 emissions at a huge scale, they also suggest that the path to achieving this and the contribution from key regions might differ from what current models project, including those from Intergovernmental Panel on Climate Change (IPCC) reports.

Lead author Yuting Zhang, from Imperial's Department of Earth Science and Engineering, said, "There are many factors at play in these projections, including the speed at which reservoirs can be filled as well as other geological, geographical, economic, technological, and political issues. However, more accurate models like the ones we have developed will help us understand how uncertainty in storage capacity, variations in institutional capacity across regions, and limitations to development might affect climate plans and targets set by policymakers."

Co-author Dr. Samuel Krevor, also from Imperial's Department of Earth Science and Engineering, said, "Although storing between 6 to 16 gigatonnes of CO2 per year to tackle climate change is technically possible, these high projections are much more uncertain than lower ones. This is because there are no existing plans from governments or international agreements to support such a large-scale effort.

"However, it's important to keep in mind that 5 gigatonnes of carbon going into the ground is still a major contribution to climate change mitigation. Our models provide the tools to update current projections with realistic goals for how and where carbon storage should be developed in the next few decades."

Existing projections unlikely to be feasible

In their analysis, the researchers found that the IPCC included results from integrated assessment models (IAMs)—tools combining different sources of information to predict how carbon storage methods can impact our climate and economy—that often overestimate how much CO2 can be stored underground.

In particular, the analysis suggests that projections from IPCC reports for Asian countries including China, Indonesia and South Korea, where current development is low, assumed unrealistic rates of deployment—which means existing projections are unlikely and unreliable.

Co-author Professor Christopher Jackson, also from Imperial's Department of Earth Science and Engineering, said, "While integrated assessment models play an important role in helping climate policymakers make decisions, some of the assumptions they make when it comes to storing large amounts of carbon underground appear unrealistic."

Global benchmark

The team's calculations suggest that a more realistic global benchmark is in the range of 5–6 gigatonnes of storage per year by 2050. This estimate aligns with how existing, similar technologies have been scaled up over time.

Their modeling approach uses growth patterns observed in real-world data from different industries, including mining and renewable energy. By looking at how these industries have grown in the past, and combining existing amounts of stored CO2 with a flexible framework to explore different scenarios, the new approach offers a reliable way to make attainable, long-term projections for underground CO2 storage and could be a valuable tool for policymakers.

Dr. Krevor said, "Our study is the first to apply growth patterns from established industries to CO2 storage. Existing predictions rely on speculative assumptions, but by using historical data and trends from other sectors within the industry, our new model offers a more realistic and practical approach for predicting how quickly carbon storage can be scaled up—helping us set more attainable targets."

The results are published in Nature Communications.

More information

www.imperial.ac.uk/earth-science

CCS-EOR could lower global emissions more than CCS-Storage

Analysis shows that CCS-EOR will often deliver lower emissions and better support the energy transition, according to a series of reports from Wood Mackenzie.

Captured CO2 for enhanced oil recovery (CCS-EOR) has fallen out of favor in recent years and been supplanted by captured CO2 to dedicated sequestration (CCS-Storage).

"CCS-EOR has its detractors, most of whom centre their opposition to the practice around the notion that CCS-EOR continues incremental global hydrocarbon production, exacerbating climate change and keeping the world reliant on fossil fuels," said Peter Findlay, Director, CCUS economics for Wood Mackenzie.

"However, as new oil supply must be developed in decades to come in even the most aggressive decarbonisation scenarios, CCS-EOR is not necessarily more likely than any other competing supply sources – whether from producing, discovered, or to-be discovered fields – to increase global oil demand."

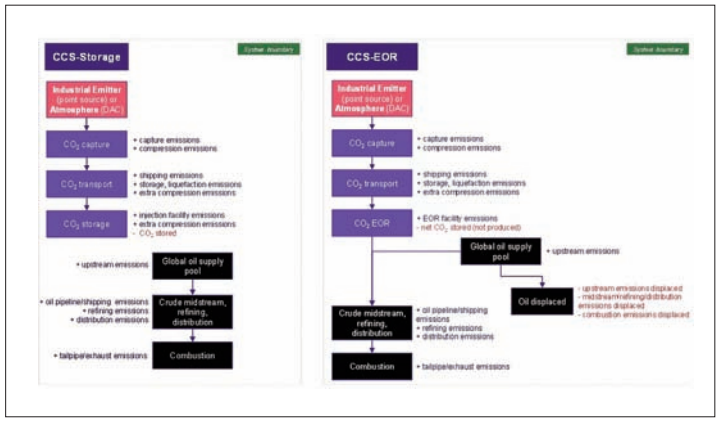
According to Wood Mackenzie, the world will need 30 million barrels per day of global oil supply by 2050 in its most aggressive Net Zero by 2050 scenario. In its three-part "Enhanced oil recovery with captured CO2" report series, Wood Mackenzie analysis finds that CCS-EOR would displace nearly all volumes it produces from the global market and not have a material effect on global oil demand and concomitant emissions.

"Yet, although we believe CCS-EOR can deliver lower net emissions in many global plays due to its relatively low incremental emissions and lighter oil production, we acknowledge that there are some cases where CCS-Storage will deliver a lower net impact to global emissions," said Findlay. "It all depends on the project, the geology, and the oil and carbon markets."

Subsidy support

According to the reports, subsidising CCS-EOR on a per-ton basis at commercial scale less than CCS-Storage Storage, and even CCU (Carbon Capture and Utilisation), will ultimately result in less CO2 captured globally and less overall decarbonisation for the economic burden imposed.

"Our findings show that subsidizing CCS-EOR less than CCS-Storage, and even CCU, will ultimately result in substantially less global carbon captured and less overall decarbonisation for the given economic burden placed on the economy — on taxpayers, consumers and businesses," said Findlay.



Viable strategy for producers?

As firms look to maximize shareholder returns, decarbonize portfolios, and maintain supply amid geopolitical tensions (for OECD producers and national oil companies alike), leveraging CCS-EOR could offer a pragmatic solution for the energy transition that could yield a lower carbon footprint than traditional oil and gas operations, said Findlay.

According to the Wood Mackenzie analysis, CCS-EOR becomes an energy transition solution only when the CO2 used in EOR operations derives from anthropogenic sources extracted from industrial point sources or directly from the air, known as Direct Air Capture (DAC). CCS-EOR also allows producers to vary production between EOR and non-EOR (storage) wells depending on prevailing oil and carbon markets conditions (and subsidies).

"Some CCS-EOR operators like Denbury and Occidental Petroleum have looked at pushing the capture benefit into the product value chain to create a net zero oil," said Findlay. "Maximizing injection of this CO2 into depleted oil and gas reservoirs and storing more CO2 than the lifecycle emissions of the incremental oil and gas produced are the second and third steps to create an effective net zero oil. But the devil is in the details: the accounting and demarcation details as to what is included in the net zero oil calculation. And assuming net zero oil is credible, it is in most cases not yet economically viable for producers to pursue without increased market demand."

The report concludes that now, like many other decarbonisation initiatives, growing CCS-EOR to meaningful scale requires some level of certainty in either future subsidisation schemes or carbon price – a clear incentive to decarbonise. (An imposed carbon price would favour CCS-EOR production enough to spur its growth vis-à-vis other options in many cases.)

More information

www.woodmac.com

Transport and storage news

SLB launches carbon storage well integrity assessment solution

www.slb.com/CCS-well-integrity

The new methodology simplifies carbon storage site selection and evaluation by quantifying well integrity risk.

SLB has launched a well integrity assessment solution that helps carbon storage developers quantify the risks associated with wells at prospective storage sites with previous drilling activity.

SLB's new methodology for quantifying the probability and potential impact of carbon leakage helps customers understand the risks associated with each well, informing remediation strategies and ultimately estimating the project's long-term viability.

"The significance of the risks associated with each well and the costs of remediation to mitigate leakage risks can make a project economically unfeasible," said Frederik Majkut, senior vice president of Industrial Decarbonization, SLB.

"By addressing potential well integrity issues early in the development process, SLB's well integrity assessment solution can help storage developers avoid costly delays or operational disruptions, and drive companies toward their net zero ambitions."

Many prospective carbon storage sites are located in either mature or retired oil and gas fields. Having a large number of wells at a site can increase the risk of potential leakage pathways for the stored carbon.

Using almost 100 years of expertise in well construction and intervention, SLB's well integrity assessment solution incorporates failure mode effect and criticality analysis (FMECA) to assess potential leakage pathways, well barrier, failure mechanisms and resulting consequences. Using advanced multiphysics 3D modeling, SLB can assess the volume and flow rates of brine and carbon leakage over time to better estimate risk.

The announcement was made as part of Offshore Northern Sea (ONS), the leading conference and exhibition for discussions on energy, technology and innovation, taking place in Norway.

First LR class notation for onboard carbon capture assigned to EPS tanker

www.lr.org
www.valuemaritime.com

Installation of the Value Maritime Filtree System will enable a 2020-built chemical tanker to reduce CO2 emissions by up to 40%.

Lloyd's Register (LR) has assigned its first class notation for carbon capture onboard a ship to Eastern Pacific Shipping (EPS) owned Pacific Cobalt. The 50,000 dwt mid-range chemical carrier retrofit features a prefabricated Onboard Carbon Capture & Storage (OCCS) system supplied by Value Maritime, to significantly reduce exhaust emissions.

Nick Brown, LR CEO, said, "This class notation for an OCCS is the first for Lloyd's Register and the first for a vessel of this size. Eastern Pacific Shipping is a pioneer in onboard CCS and this installation demonstrates its commitment to reducing emissions in its operations in line with IMO ambitions. This class notation will further support OCCS installations on ships giving industry confidence in the technology's ability to support shipping's decarbonisation goals."

The Emission Abatement Carbon Capture & Storage (EACCS) (Amine, HFO) class notation assigned by LR provides assurance that any safety risks associated with the OCCS installation have been mitigated and the solution is effective and reliable.

The Filtree System combines a SOx exhaust cleaning system with CO2 capture. The system flushes 99.9% of the sulphur oxide and 99% of particulate matter from the exhaust gas using seawater.

It can remove and capture up to 40% of CO2 from exhaust gases, which is then stored onboard. CCS is an established technology onshore with OCCS for ships gaining traction only recently as a viable short- to mid-term pathway to achieving IMO emission reduction targets.

LR awarded Approval in Principle (AiP) to Value Maritime's Filtree System in September 2022. The 2020-built Pacific Cobalt is one of three EPS MR tankers that have been refitted with the CCS system, with equipment surveys currently underway on the other two vessels.

Marsh launches first-of-its-kind insurance solution for CCS projects

www.marsh.com

The insurance broker and risk advisor has launched a new insurance solution specifically designed for the transportation and storage of carbon dioxide.

Available to projects globally, the solution addresses critical insurance limitations that have previously hindered the rapid advancement of the CCS industry.

Created by Marsh's Energy & Power team and underwritten by Canopius, the solution provides comprehensive coverage that enables upstream energy operators to meet their financial security obligations when captured CO2 is being transported and injected into suitable geological structures.

Hannah Jennings, Global Carbon Capture and Storage Initiative Leader, Energy and Power, Marsh Specialty, said, "Carbon capture, utilisation and storage has a fundamental role to play in reducing emissions globally and delivering the net zero energy system."

"Designed to support the upstream energy market as it adapts to the energy transition, Marsh Specialty's new solution not only represents a meaningful shift in the parameters of traditional energy insurance but also delivers greater certainty and confidence to investors and users of CCS mechanisms."

Traditional insurance provision for these risks requires physical damage or disruption to operations caused by an out-of-control well in order for policies to respond.

Importantly, Marsh's solution adds a new non-damage trigger for the geological leakage of CO2, providing an indemnification for the costs of corrective measures, as well as a trigger for the associated business interruption.

Marsh's solution also includes an indemnification for the costs incurred to acquire carbon credits for the mass of CO2 leaked, where applicable to the project's geography. This indemnification is available across the leak removal chain, whether the leak occurs from scheduled onshore facilities, the CO2 pipeline or ship, or from the storage complex itself.

Image: ©Calix

Calix's Leilac demo for lime and cement CO2 capture