Carbon Capture Journal

CCUS in the UK

CCU International: commercialising carbon capture technology

CBI report: overcoming unique barriers to CCS adoption

A vision for hydrogen in the Tees Valley

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Important scientific advances in CCUS over the past 3 years

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CSIRO takes stock of technologies for Australian carbon storage

CCS works technologically, its problem is an economic one

We don't need to choose between meeting our energy needs and limiting global warming. By implementing a Carbon Takeback Obligation, we can do both.
By Hugh Helferty, Margriet Kuijper and Myles Allen, PACE

The International Panel on Climate Change says that Carbon Capture and Storage (CCS) is a key technology to achieve Net Zero emissions by 2050. But CCS remains a point of contention, as many doubt its capabilities. Indeed, the Institute for Energy Economics and Financial Analysis (IEEFA) recently released a report promising the technology's failure. But such reports are oversimplifying the past problems with CCS projects. The question 'Does CCS work?' must be split in two: 'Does CCS work technically?', and 'Is it economic?'

The answer to the first question is, quite simply, yes. Industrial-scale CCS plants have been operating for 50 years. As of 2022, 29 CCS plants were operating with a capacity exceeding 35 million tons per year, and 131 more facilities are in development globally. Over time, there will be further advances in technology and operational efficiency. The US government, in fact, shares this belief: the US Dept. of Energy announced $30 billion in research and development funding towards carbon removal technology. Suggesting that CCS 'doesn't work,' when referring to the technology's literal ability to capture and store carbon, is false.

So the real question up for debate, and the reason reports like the one by the IEEFA call CCS a failure is, 'Is CCS economic?' Currently, CCS projects fail because they accrue costs that are not necessary to the success of the businesses funding them and are therefore shut down. Investing in the technology and discovering ways to make it even more scalable and cost-effective are simply not essential to good business.

What would make businesses invest in CCS at the scale necessary to achieve Net Zero? If we don't leave it to businesses' good will and dedication to protecting the habitability of our planet, then the answer lies in government policy. In the U.S., the Inflation Reduction Act is providing generous tax credits to encourage CCS investment. This approach will help CCS grow, but it places the cost on the backs of taxpayers, not the fossil fuel producers and users who are directly responsible for much of the CO2 that needs to be captured and stored.

Tax credits offer an incentive, or "carrot," for CCS investments. But regulation would create a mandate, or "stick," to focus on addressing climate change. Specifically, while fossil fuels remain a difficult-to-replace portion of our energy supply, governments could require fossil fuel producers to permanently store carbon, eventually in amounts equivalent to what they produce.

If we think of carbon dioxide emissions as another form of waste dumping, then this concept is not far-out at all, but rather falls within the familiar category of extended producer responsibility. Governments limit what producers can dump without paying for responsible waste disposal; why not extend this kind of limit to the fossil fuel industry?

Confronted with such a requirement, producers would either have to stop producing fossil fuels or take responsibility for the emissions that result. This would result in some producers accelerating their transition to alternative energy sources, while others drive innovation in the scalability and cost-effectiveness of CCS. Fossil fuels would continue to be available for hard to abate applications like jet fuel for airplanes, but this fuel would not be produced unabated.

So, CCS can be made economic. But perhaps the real problem is a third question: 'Do we want CCS to succeed?' Some object to CCS because some applications can help the fossil fuel industry. For example, the captured CO2 is sometimes used for Enhanced Oil Recovery, which can increase production from a given field. This contributes to CCS 's reputation as a lifeline for the oil industry. After the economic devastation caused by the fossil fuel industry, it is understandable why many say, 'Enough, just shut it down'.

Unfortunately, society is not at a point where 'just shutting it down' is realistic. 82% of global energy comes from burning fossil fuels, and this fraction is only expected to drop to 74% by 2050 (although requiring fossil fuel producers to capture emissions would make fossil energy more expensive, thus further chipping away at this number). Climate action is needed immediately, and phasing out fossil fuels won't happen quickly enough to be a successful defense against climate disaster.

Yes, much can—and must—be done to reduce fossil fuel use. But let's not bet on curing our addiction to fossil fuels overnight. Let's put in place CCS capabilities—paid for by the producers whose product puts the carbon in the atmosphere—so that we don't continue to burn fossil fuels unabated while we work diligently to complete the energy transition.

Carbon Takeback Obligation

To meet its commitments to greenhouse gas reductions, governments must use regulation to harness the capabilities of major oil and gas companies. Specifically, governments should require that all fossil fuels extracted or imported into its territory be offset by sequestering an amount of CO2 equivalent to the carbon content of the fuel.

This Carbon Takeback Obligation (CTBO) would be phased in starting immediately, reaching the requirement of storing 100% of emissions associated with oil, gas and any remaining coal production by 2050.

Failure to meet this requirement would result initially in financial penalties and ultimately in loss of the right to produce or import oil and gas.

More information

Producer Accountability for Carbon Emissions (PACE)

pacemissions.org

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Front cover: At the CCSA London Forum we heard perspectives about UK CCS developments, including from Equinor, GE, SSE, MakeUK, BP, Teesside, HyNet, Acorn, Humber Zero, Southampton (pg. 2)

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Leaders - CCUS in the United Kingdom

Projects and policy

Capture and utilisation

Transport and storage

How UK CCS is developing - a report from the CCSA London Forum

We heard perspectives about UK CCS developments at the CCSA London forum, including from Equinor, GE, SSE, MakeUK, BP, Teesside, HyNet, Acorn, Humber Zero, Southampton. Will we have 2 clusters in operation by the 'mid 2020s'? By Karl Jeffery.

The UK has been "ahead in the game" for CCS, said Dan Sadler, VP UK Low carbon solutions, Equinor, for at least the past 4-5 years he has been in his current role.

But the UK now has growing international competition, he said. Projects in Norway are gathering steam, and the US Inflation Reduction Act is making US projects much more commercially viable. This means that more CCS funding might be diverted to these countries at the expense of the UK, he said, including funding from Equinor.

"If others leapfrog us, investment could divert as well, also resources," he said.

Equinor has made a commitment to spend 50 per cent of its capital expenditure on renewables and low carbon projects by 2030, so it is putting "real money" behind its ambitions.

Mr Sadler's role includes managing Equinor's CCS and blue hydrogen projects in the UK. He was speaking at the Carbon Capture and Storage Association (CCSA) annual event in London on October 18-19, "CCUS 2022, Time to Deliver".

There is a project to build a pipeline connecting CO2 sources in mainland Europe, including Germany, to Equinor's CO2 stores on the Norwegian Continental Shelf. "That's a great offer to northwest Europe," he said, where there is not so much local CO2 storage potential.

"We're finding increasing momentum from northwest European governments, especially the Germans, in terms of supporting this type of scheme."

In the US, the Inflation Reduction Act means that CCS projects have a "very clear affordability envelope", in other words companies investing in projects can do so with the understanding that the costs will not become unaffordable.

Drinks reception at the CCSA London Forum in October 2022 (Images: Carbon Capture and Storage Association Conference 2022 © Lensi Photography)

"That has created a dash for these projects as opposed to a long-drawn-out protracted process," he said. "So, a real commercial environment which encourages international companies like ours to invest."

To keep ahead, the UK needs to maintain its CCS momentum and continue delivering projects.

Equinor is a partner in the East Coast Cluster project in the UK, which will be the world's biggest CCS scheme when executed in the mid 2020s, he said. "It connects the Humber and Teesside industrial regions. Its a fantastic scheme for the UK with huge amounts of jobs associated with it."

In UK policymaking, there is a disconnect between policy ambitions and funding available from the Treasury, he said.

The policy includes clear targets for CO2 storage, with 30m tonnes a year by 2030 and 50m tonnes by 2035; policies to have two industrial clusters set up by the mid 2020s, and a further two by the end of the decade.

But the UK Treasury is not providing funding behind these plans. "We can do business model development, policy development, but it has to be backed up by ring fenced money which allows us to execute."

"The CO2 transport and storage system is an enabler for all projects, whether blue hydrogen alongside green, post combustion power, industrial carbon capture, negative emissions. All those projects have a common need - infrastructure and storage."

"My plea and my hope is that we deliver the infrastructure and storage systems in the 20s then we have options to go as fast as slow as we want, based on our appetite for cost and carbon savings. If we don't build the infrastructure in the 20s we don't have any options."

GE Gas Power

Not enough investment is being made in renewables in the UK, which means that certain targets will be missed, said Martin O'Neill, VP Strategy, GE Gas Power.

It means that the electricity grid will be reliant on gas turbines with CCS to provide low carbon power, "all the way to the 2040s."

Mr O'Neill had a request for the media. "For every column inch I read about green hydrogen, could I read a column inch about carbon capture?"

For blue ammonia, Mr O'Neill believes the first movers could be countries in the Middle East. Projects have already been announced by Qatar and Abu Dhabi.

Martin O'Neil GE, Catherine Raw SSE, Dan Sadler Equinor

SSE Thermal

As an investor, "the key thing is long term, you should never just focus on the now," said Catherine Raw, managing director of the thermal power division of UK power supplier SSE.

"You factor things in and say, 'what's my equilibrium policy in the long term'. You learn [that] diversification has value. As long as the [elements] are not correlated, you improve performance of the fund."

In order to maintain its diversified portfolio, SSE is focussing on onshore and offshore wind, battery storage and hydrogen, as well as carbon capture. "All of these are solutions to wean us off a solution based on fossil fuels."

The company's target is to reduce CO2 emissions by 80 per cent by 2030. SSE Thermal has defined itself as a low carbon power company, with a focus on gas fired generation with carbon capture.

SSE is involved in two carbon capture projects: Keadby 3 Carbon Capture Power Station in the East Coast Cluster, and at Peterhead in Scotland.

MakeUK

Lord John Hutton, Chair of UK manufacturing industry group MakeUK and chair of the CCUS Council Supply Chains Working Group, noted that while there are some major challenges still in front of us, "we have a clear direction of travel."

The question is how the private sector can "build a framework for CCUS to deploy at scale," he said.

"Getting finance sorted out" remains a big challenge, he said. Government structures, such as the "dispatchable power agreement," where a company commits to provide low carbon power at any time in exchange for a certain price, will help finance CCUS projects.

From a manufacturing perspective, it would be a missed opportunity for the UK if the CCS components were manufactured from outside the country, he said. But UK manufacturers do not yet have so much confidence in the size of the market. Without this confidence, they are unwilling to invest in developing manufacturing capacity of CCS products.

There is also a skills shortage, with 93,000 live vacancies in manufacturing in the UK, and 26 per cent of them due to shortage of skilled people, he said.

Brexit did not help, with 200,000 EU nationals leaving the UK. "We need to get those workers back to the UK and leave the dogma aside," he said. "We need to rethink our approach to labour markets."

Net Zero Teesside

Andy Lane, managing director of the east Coast CCS project "Net Zero Teesside", and also VP CCUS at BP, said that the project has been in FEED (front-end engineering and design) since November 2021. There are currently 500 people working on various tasks connected with the project, such as shooting seismic, drilling boreholes, doing development work.

The project is one of two clusters selected by the UK government for the first phase, expected to be operational by 'mid 2020s'.

Mr Lane is a big enthusiast of the CCS cluster concept. "They create an ecosystem, an opportunity for supply chains, an opportunity to develop skills," he said.

The East Coast cluster is set up with a CO2 infrastructure company in the middle (Northern Endurance Partnership), with its own business model, and then individual emitting companies have their own business models. All of it is supported by government funding to help get started. "It is a cogent and joined up piece of policy," he said.

The US Inflation Reduction Act "has fundamentally changed the global footprint of CCS," he added. "You hear the thumping of feet of people leaving for the US."

The Phillips66 Humber refinery is planning to build a carbon capture system to connect to the Humber Zero CCS scheme, which is part of the East Coast cluster, said Jenny Sutcliffe, principal consultant regulatory affairs with Phillips66 Humber refinery.

"We are drafting planning applications for local authority targeting submission by the end

of this year, on track to complete FEED in 2023 and move on to EPC [engineering, procurement and construction]," she said.

HyNet

HyNet in North West England was selected to be one of the two CCS clusters to be included in the first phase by the UK government, expected to be operational by the 'mid 2020s'. HyNet will generate low carbon hydrogen, to be used by businesses in the region.

The project is challenged by complex planning and consent processes, and lack of clarity about which projects in the region will get funding to participate, said David Parkin, director of Progressive Energy, which runs the project.

"A chief executive of a plant called me [and said], 'we're committed to [spend] £3m. We would need to put in £20m next year. I can't put that to my board until we've got clarity of who is going to win contracts.'"

Today there are 40 companies agreeing to 'offtake' the low carbon hydrogen once it is available, he said. Although for now, nothing has been built. "Our industry is only a success when it has shovels in the ground. It is going to take a huge collective effort."

Mr Parkin said it would be useful if the planning and consent process could be simplified. "There are thousands and thousands of pages to be sent to regulators, and we have never issued a storage permit for CO2 in the UK. Our regulators are learning as they go."

Commercial contracts from the government would help, he said. "Will [UK government department] BEIS even have a chance to read contracts by the mid 2020s?"

HyNet was initially launched in 2016. Oil and gas operator ENI got involved in 2018 doing pre-FEED work for CO2 storage. "By 2020 the project looked the same as today, we knew the flowrates and pipeline routing," he said.

Acorn Project, Scotland

The Acorn Project, in North East Scotland, was a 'reserve' cluster in the first track of the UK's CCS cluster project. But Storeega, the lead developer of the project, is still developing plans.

It is looking to build Europe's first 'at scale' direct air capture plant, using Acorn for storage, working together with DAC company Carbon Engineering, said Nicola Cocks, Head of Policy & Regulation with Storegga, the lead developer of Acorn.

David Parkin, director of Progressive Energy, said it would be useful if the planning and consent process could be simplified

It would also like to offer CO2 storage services for customers bringing CO2 to the plant by ship, including from other countries.

Scottish CO2 storage services could be an industry equivalent in size to the Scotch Whisky market, around £5bn a year, she said.

Southampton

ExxonMobil has plans to develop a low carbon cluster around Southampton, UK, where it operates the Fawley refinery. This could "produce sustainable fuels for the marine and aviation sectors," said Michael Foley, UK low carbon solutions executive with ExxonMobil.

ExxonMobil could do carbon capture in many places in the world, but its geologists see that UK has particular advantages, with "really good rock," he said.

South Wales

Efforts are underway to set up a CCS cluster in South Wales. It could cover the South Wales coastline from Milford Haven to Newport. This includes the UKs largest Combined Cycle Gas Turbine power station at Pembroke. There are 100,000 people employed in related industries in the region, said Chris Williams, head of industrial decarbonisation at trade association Industry Wales.

Not every industry needs carbon capture – some might decarbonise by switching to biofuels or moving to hydrogen, he said.

There is no CO2 storage available in the region. "We desperately need CO2 shipping and somewhere to ship to," he said.

On track for mid 2020s?

Speakers were asked whether the UK is on track to achieve its carbon capture goals, particularly the target to have "two industrial clusters set up by the mid 2020s, and a further two by the end of the decade."

David Parkin from Progressive Energy said the clusters would not be set up by 2025 but would be achieved "some point between 2025 and 2030." So, it depends if that would count as 'mid 2020s'.

Lord Hutton from MakeUK said, "we've got al the hard work done." But progress needs to be done on planning and permitting processes, and regulations are needed. "I think we have a realistic prospect of doing something in 2025 - 27."

Stef Murphy from [government department] BEIS said, "we can be on track to 2025- 27."

UK storage and approvals

Concerns are rising about the amount of licensed CO2 storage available in the UK. The problem is the time taken to get licenses, not whether there is enough storage capacity.

Bill Senior, CCS expert advisor with Lapis Energy, said that it currently takes 7 years to set up storage sites in the UK. This "doesn't resonate with the urgency of what we're trying to solve," he said.

By comparison, Lapis is involved in a project in the US which has a 4-year lead time, from site identification to first CO2 injection, he said.

Filip Neele, senior project manager for CO2 storage for research organisation TNO, noted that some aspects of the development time can't be compressed. For example, doing detailed design for construction or drilling wells, or new seismic surveys and appraisal wells if it is aquifer storage. But the part in between, evaluating data, understanding the reservoir, and getting approvals to drill, could technically be compressed. "Maybe we are able to win a year."

Perhaps it could go faster if a structured 'workflow' or recipe for the work of defining CO2 storage could be created, he suggested. It should be easily understandable. Such a recipe might help give new companies confidence that they have the capability to do it, and the work won't take forever.

Meanwhile, governments, on the 'other side of the table,' should be given the knowledge to handle these new types of projects, he said. This way it would be faster to get to meaningful discussion between operators and regulators.

It could be possible to run many more projects in parallel, so more projects can be completed even if there are limits to how fast any individual project can be done, he said.

Equinor perspective

Dr Peter James McFadzean, UK CO2 transport and storage lead with Equinor, said that the company has an overall ambition to store 15-30m tonnes of CO2 a year internationally by 2030. It has a 25 per cent share in the European CO2 transport and storage market, and it is pursuing three license positions in the Southern North Sea.

More regulatory predictability would help it work out how much financial resources to allocate to different projects, he said.

The seabed leasing application, which is required alongside UK applications for CO2 storage, can be complicated. It would be useful if it could be integrated into the license process. "Anything that can be done to simplify it would be very helpful," he said.

Competing needs

An audience member from Neptune Energy noted that areas had been nominated for CO2 storage which contain wind farms.

Hamish Wilson, CEO of CO2 storage development company Lapis Energy, said that wind seemed to be "trumping everything else" when decisions were being made about how to prioritise areas of seabed. And the pace of decision making is glacial. "We could work it out in an afternoon."

Jennifer Godwin of The Seabed User and Developer Group (SUDG) said that her organisation sought to get agreement between different seabed users about what was needed and how it should be divided.

Its members are themselves trade associations, representing oil and gas, renewable energy, ports, marine aggregates, recreational boating, submarine cables and CO2 storage. It does not include shipping and fishing, because they are not directly using any seabed.

A balance needs to be found between protecting and enhancing the marine 'space' but allowing industry to develop, she said.

NTSA perspective

Scott Robertson, director of operations with the North Sea Transition Authority, which regulates CCS licenses, said it has received 26 applications for CO2 storage licenses in the UK. The licenses are being "stewarded" as of the time of the conference (early October 2022), with an aim to issue licenses in the first quarter of 2023.

"There were a few overlaps [between wind and CO2 storage]. There are storage areas which have been moved," he said. "We're confident we can meet storage targets and wind targets."

"We don't know much about aquifers [for storage]", he said. "We need to accelerate appraisal in these areas. Some areas, we will realise, are not good stores."

Norway storage perspective

Sverre Overå, project director with Norway's CO2 storage project Northern Lights, said that people in Norway joke that CO2 storage is "the most regulated, non-existing business there is."

But "in Northern lights we're doing it quite differently from the timeline shown. We are challenging the regulators on that," he said.

"We are not doing exploration. We are saying that exploration, in our case, is drilling of the injection well. We're not going to provide an injection application prior to making investment decisions. We're going to do it in time for the start of injection. This is how we have cut down on our execution time."

To illustrate, Northern Lights expects the second phase of storage to be approved in 2026, so just two years after the first phase is approved. This is expected to be a big step in storage capacity from the first stage's 1.5m tonnes per year, he said.

"We need to be able to challenge regulators on what they need, and challenge industry on their perception that its a regular oil and gas business where development has a long cycle time," he said.

More information

www.ccsassociation.org

Making CCS investable

CCS could be more investable through standardised predictable pricing; taking a broader, longer term view; and finding ways to reduce risk. Aker Carbon Capture, Société Générale and Clean Air Task Force shared perspectives.

Aker Carbon Capture is offering its clients carbon capture services for a fixed cost per tonne CO2 captured, including the cost of building the facility itself. It is a standalone company, spun out of Aker Solutions, an energy engineering company.

In order to deliver this predictability, the company has developing a modularised offering, and configuring it to the needs of a limited number of industries and regions, explained Valborg Lundegaard, CEO, Aker Carbon Capture, speaking at the CCSA London forum.

Geographically, it prioritised northern Europe, Scandinavia, Benelux and UK, because it saw the regulatory regime was more mature in these regions, he said.

By industry segment, it prioritised segments which would have the most appeal to investors - the cement industry, waste to energy including bio energy, blue hydrogen production, and gas power plants.

"Storage is a bottleneck in Europe" - Valborg Lundegaard, CEO, Aker Carbon Capture

Aker's standard service is for a 100,000 tonne a year plant, including financing (so the client does not have to pay all the capital expenditure upfront), operations cost and storage, she explained.

It developed a modular product, "Just Catch", which can be installed in multiple places with the same design, providing CO2 at purity of higher than 99.9 per cent.

The capital costs work out Eur 30-45 per tonne CO2 captured. This includes equipment to capture CO2 from flue gas, liquefy the CO2 and store it temporarily. It also includes the financing cost, so the client only pays per tonne of CO2 captured, rather than paying for the facility upfront.

The opex costs are 10-45 Eur a tonne, including solvent supply, energy, digital operations, labour, and maintenance.

The large range is due to variations in energy cost for the capture, with the lowest costs for customers who can use excess heat from another part of their facility, so have zero additional energy costs.

The transport and storage costs are Eur 30-60 a tonne, including onshore transportation, offshore transportation, and permanent storage. The price depends on what is involved in transporting the CO2 to a storage site.

This means the total cost for capture and storage is between 70 and 150 euros per tonne.

These prices are based on 100,000 tonnes a year. The system is also available at a 40,000 tonnes per year size.

To accelerate the CCS business, more modularisation and standardisation will help, she said. And, "there will have to be more technology development."

More storage is needed. "Storage is a bottleneck in Europe," she said.

Also there need to be more financial incentives, such as CO2 taxes. "Government must ensure it is more attractive to do CCS than continue to be an emitter," she said.

Clean Air Task Force

Toby Lockwood of the Clean Air Task Force (CATF) said that Europe differs to the US in that in Europe, motivating CCS is more sticks than carrots. For example Europe has the Emission Trading Scheme, the US has tax credits.

The CATF is a climate organisation headquartered in Boston with a mission to 'create an affordable zero carbon solution'.

CCS becomes more affordable the bigger picture view you take, he said. For example, while cement made with CCS will cost 70 per

cent more, if that cement is used in a building, the cost of the whole building will increase just 0.5 per cent.

Similarly, a 25 per cent price increase in steel to pay for CCS would push up the price of a car by under 0.5 per cent. A company building a bridge with cement and steel might pay 60 per cent more for cement made with CCS and 12 per cent more for steel with CCS. But the end cost of the bridge will be just 2 per cent more, he calculates.

CCS on a refinery's operating emissions will lead to a 0.87 per cent increase in the final price of its fuel.

Société Générale

Allen Baker, global head of power at bank Société Générale, noted that the investor perspective on CCS is different around the world, and it is useful to have a "global view of how CCS can work."

"The first project financing we do may be in the US," he said. "In Asia, shipping solutions may be custom built."

Mr Baker has "seven or eight" people working on carbon capture projects. It is very motivating for them to see projects finally happen, he said.

"Its becoming really interesting to the young generation," he said. "In the past it seemed like more of a pilot project. In the EU, 5-6 years ago, people talked about CCS as 'something you may need at some point.'"

"There's a massive wall of financing focussed on clean energy," he said. "Banks have got incentives to invest in clean energy. Any scheme which encourages that is going to be useful for the CCS industry."

But the ESG label doesn't motivate people to put money into higher risk projects. "Ask a banker, 'Will you take more risk for an ESG project,' the answer is no."

CO2 removal: BECCS and DAC

There's growing interest in CO2 removal projects which take CO2 from the atmosphere – either through bioenergy or direct air capture. We heard about new projects in Stockholm and the UK.

"CO2 removal" is defined as capturing CO2 from the atmosphere and storing it durably. That can be done either through growing plants and sequestering their carbon, or capturing CO2 from the atmosphere directly.

For the plant side of CO2 removal, Erik Rylander, head of carbon dioxide removals with Stockholm Energi, said his company is planning a full-scale bio energy with carbon capture and storage (BECCS) unit.

Stockholm Energi is an energy group owned by the City of Stockholm, and a supplier of heating, cooling, electricity, and waste management services.

It is building a bio-combined heat and power (CHP) plant which runs on forest residue. Feedstock includes woodchip, bark, branches, tops, and twigs sourced from Scandinavia, the Baltic countries and Russia. It will provide 280 MW of heat and 130 MW of power. There are plans to install a carbon capture test facility at the plant.

Using biomass for power in Sweden is not at all controversial, as it has been in the UK, he said. "Sweden is built on forestry and steel".

For BECCS to be certified for negative emissions, the biomass must be proven to be sustainable. This usually means that the overall carbon stock of the forest it is taken from must be stable or increasing. But, "there's very few clear standards on what is a 'good forestry'," he said.

The overall investment in the project is estimated to reach Skr4.4bn ($517m / Eur 501). The European Investment Bank (EIB) is providing a €260m ($287m) loan, and the Nordic Investment Bank (NIB) is providing a €155m ($177m) loan. So, there is a shortfall of around $55m. the project team hope to gain money from the voluntary carbon market.

The project will require co-operation between private and public funding, and there could be complexity in finding agreements on how to do the carbon accounting. "There is a lot of debate around double claiming," he said.

It would be easier if company and country carbon accounting was kept completely separate, just as company and country financial accounting is kept completely separate, he said. "When you mix the systems, you get very confused."

DAC /Carbon Engineering

The other way to remove CO2 from the air is to do it directly through direct air capture. The separation process is similar to any other carbon capture technology, except the concentration of CO2 in the inlet gas is far lower. One of the leaders is Carbon Engineering, based in Squamish, Canada.

Oxy Low Carbon Ventures, LLC, a subsidiary of oil and gas operator Occidental, and Rusheen Capital Management, a private equity firm, have formed a development company, 1PointFive, to finance and deploy Carbon Engineering's large-scale Direct Air Capture (DAC) technology. Occidental has announced plans to deploy 70 to 100 of its plants worldwide.

The aviation industry is showing strong interest in DAC, as a means to directly offset the CO2 from its emissions. Airbus has pre-purchased 100,000 tonnes of carbon removals per year over four years, said Amy Ruddock, VP Europe, and the Middle East with Carbon Engineering.

According to public data, DAC will cost $300 to $425 per tonne on the first plant, with a target of $125 to $150 a tonne when facilities are built at a bigger scale, she said.

Carbon Engineering has plans to build a plant in the UK, removing and storing half to a million tonnes a year, she said.

Having government incentives for removals, such as the US Inflation Reduction Act, is "critical," she said.

Carbon markets and CCS

In the US, there are several voluntary carbon markets, with prices at the time of writing of $3 to $5 a tonne. These markets could contribute to making CCS projects viable, and can be used together with other schemes.

Jean-Philippe Brisson, a partner with law firm Latham and Watkins, based in New York, thinks that carbon markets could have a big role to place in carbon capture and storage. Companies can choose to buy carbon credits to reduce the amount of emissions they need to report having caused, and companies operating CCS schemes can sell them. This would provide a revenue stream to CCS operators.

In the US, companies are allowed to 'stack' their incentive schemes, so CCS operators can both receive tax credits under the Inflation Reduction Act and sell carbon offsets. This means it is easier to make such costly projects affordable.

Asked about how carbon offset schemes should be made trustable, Mr Brisson said you have to buy offsets from the right place. "There are four registers online, all not for profit, with an independent board, each has a unique serial number. I don't know why you wouldn't buy from one of those. To my knowledge there hasn't been any accusation associated with these products. These offset programs have complete integrity."

However, "if a company buys the wrong types of offsets, I don't see why they should be protected," he said.

If personal or 'retail' investors were to get involved, they might expect some government protection, which means that the trading schemes themselves would need to be regulated. But perhaps it would be simpler just to not involve retail investors in these schemes, he said.

Companies buying offsets linked to CO2 storage should also not worry about leaks, he said, bearing in mind that the IPCC has estimated leakage of CO2 in storage to be "less than 1 per cent for 1000 years".

Hamish Wilson of Lapis Energy asked the panel how he could raise a billion dollars for a CCS scheme. "You just need to find an 'off taker'" Mr Brisson replied. In other words, you need someone who wants to spend $1bn to have emissions taken off their books through this scheme, as an offset project.

Jean-Philippe Brisson, partner Latham and Watkins, said companies buying offsets linked to CO2 storage should not worry about leaks

CCS+ initiative

In Europe, the CCS+ Initiative (www.ccsplus.org) is a project to develop methodologies for carbon capture and storage to be connected to voluntary carbon markets and compliance regimes. Its secretary general, Matthias Krey, is also managing director of consultancy Perspectives Climate Group. He is based in Hamburg, Germany.

CCS+ lists many major CCS project operators, oil companies and consultancies as its members.

The idea is that companies doing CO2 capture, including from the air, could then sell carbon credits, which could be purchased by companies seeking to reduce CO2 emissions from their own carbon balance sheets, or reduce their payments under the EU ETS scheme.

A complexity is that both companies and countries are counting their emissions and potentially creating credits to trade, which can potentially lead to the same emission reduction being traded twice. But companies are also very sensitive to the risk of accusations of criticism, so they are "taking it more carefully," he said.

Mr Krey said he thought that the US has been moving faster to set up offset trading schemes. But the CCS+ project is aiming to catch up.

CMS Energy

Dalia Majumder-Russell, partner with law firm CMS in its Energy and Climate Change Group, said that offsets are probably better as an "additionality" to a project, funding a project entirely through offsets is less likely to work. "It's not going to get the scale," she said.

Market systems like this need transparency of information and disclosure, although it is ultimately up to the investor to decide if they trust it, she said.

CCSA conference – company and country updates

We heard updates at the CCSA London conference about the world 'status of CCS' from GCCSI; installations at Aker Carbon Capture; technology at MHI; Heidelberg's CCS plans; update on Norway's Northern Lights and CO2 shipping.

The Global Carbon Capture and Storage Institute Global Status of CCS Report 2022 found that that the world's capture capacity in 2022 for projects in operation, under construction, or under development, is now 244m tonnes a year, a 44 per cent increase from 2021.

Guloren Turan, general manager, advocacy and communications at Global CCS Institute, presented the results at the CCSA conference in London.

These 244m tonnes a year come from 196 commercial CCS facilities in the project pipeline, which breaks down to 30 projects in operation, 11 under construction, and 153 in development. There were 61 facilities added to the project pipeline in 2022.

The Institute still estimates that CCS needs to be ultimately scaled up by "at least a factor of 100 if we are to achieve the Paris climate goals", defined by limiting the global temperature increase in this century to 2 degrees Celsius while pursuing efforts to limit the increase even further to 1.5 degrees.

If we can sustain the 41 per cent a year growth in the global project pipeline, that will mean a growth of 87x in 13 years, so by 2035, and a growth of 122x by 2036.

The Institute still estimates that CCS needs to be ultimately scaled up by "at least a factor of 100 if we are to achieve the Paris climate goals" - Guloren Turan, general manager, advocacy and communications at Global CCS Institute

Aker Carbon Capture

Aker Carbon Capture's technology has been selected for the two large carbon capture projects in Europe which are currently in construction phase, said Valborg Lundegaard, CEO, Aker Carbon Capture.

One is Norway's flagship project, Longship, where it is building a capture facility at the Heidelberg cement plant, capturing 400,000 tonnes CO2 per year.

"An existing cement facility has been there for decades, we are integrating our carbon capture plant," she said. "Equipment is being installed at the site and we are doing piping."

The other is in the Netherlands, where it is delivering its standardised 100,000 tonnes a year "Just Catch" capture system to the Twence waste to energy plant. "It is so standardised we can deliver in less than 2 years," she said. The CO2 will be used as fertiliser to greenhouses, delivered by road tankers.

Aker Carbon Capture is also supplying its technology to the Net Zero Teesside and Keadby 3 carbon captured power station in the UK, both handling 2 mtpa, currently in the FEED stage. Aker Solutions, Siemens Energy and Doosan Babcock were jointly awarded the FEED Contract for Keadby 3.

"These are very large, impressive gas to power plants with CCS and we are the carbon capture provider," she said.

"The UK market is so important to us, the gas to power segment and the waste to energy segment. We will set up an office in London in a couple of months."

"Aker's technology is proven, that is really important," she said. "There are so many companies and people that believe this is something new. No, we are ready to deliver projects now."

The 100,000 tonnes a year capacity is similar to the capacity of the Norwegian research carbon capture facility Technology Centre Mongstad. "But the footprint and cost is extremely different, reduced by almost 90 per cent," she said.

Mitsubishi Heavy Industries

John Picken, business development director – decarbonisation with Mitsubishi Heavy Industries (MHI), said that the company is expanding its range of technologies, including

developing carbon capture systems for onboard ships, and for cement, biomass, and LNG industries.

Shipping "is one of the last great unabated areas where CCS is needed," he said. MHI as a company started in shipbuilding in the 1800s.

MHI was perhaps the first company to develop carbon capture technology, with its first plant in 1992, capturing 2 tonnes per day of CO2. It tested 200 different solvents, and chose the best one, which was labelled "KS1".

By 2011 it was building carbon capture plants which could ramp up and down automatically according to output from the plant creating the flue gas. It was also developing rectangular towers, which were easier to transport and construct.

In 2016 it built the Petra Nova plant in Texas, capturing 5000 tonnes per day of CO2, and making improvements to the quality of its heat exchangers.

In June 2021 it signed an agreement with Drax Group in the UK to deliver the "world's largest carbon capture power project," capturing 10,000 tonnes per day (3.6m tonnes per year).

Heidelberg Materials

Building materials company Heidelberg Materials is building the world's first CO2 capture facility at a cement plant, the Brevik CCS project in Norway, said Winston Beck, its head of government affairs. The capture unit will be operational in 2024, planning to store 400,000 tonnes a year, 50 per cent of the plant's emissions.

It has another project in Northwest England, through its subsidiary Hanson UK, to capture 800,000 tonnes a year with expected operation in 2027, and a project in Sweden, planned for 2030, capturing 1.8m tonnes a year from 2030 onward.

There is a project in Bulgaria which could start in 2028, with a capturing capacity of 800,000 tonnes a year. Carbon emissions from the Devnya cement plant in Bulgaria are to be captured and transported to offshore permanent storage in the Black Sea.

But Heidelberg still has many plants which are not close to any CCS hub. "We have to start thinking how to connect them with pipelines or inland waterways," he said.

Project is "on track" to receive CO2 by ship by mid 2024 – Sverre Overå, project director, Northern Lights

Norway

Sverre Overå, project director with Norway's CO2 storage project Northern Lights, said that the project is "on track" to receive CO2 by ship by mid 2024.

The total project cost for Longship (including capture and storage) is NOK 25bn (US$3bn), of which the Norwegian state is paying NOK 17bn and partners contributing the rest. Northern Lights is the transport and storage component.

Northern Lights has a terminal in western Norway, which accepts CO2 from ships and feeds it into a pipeline. The only processing is tank storage, to enable CO2 to be discharged from ships at a faster rate than the pipeline accepts, to minimise vessel time. The CO2 is then sent down a 110km pipeline to storage.

CO2 shipping

Greek shipping company Ceres Hellenic Enterprises has set up a dedicated CO2 shipping subsidiary, Ecolog. It does not yet have any vessels, but is planning to acquire tankers with 20,000 or 80,000m3 capacity, said Jasper Heikens, chief commercial officer, Ecolog.

Ceres is well experienced in gas transportation. It operates 35 LNG carriers, of which it owns 21, through its subsidiary Gaslog. It also has a dry bulk shipping arm called Drylog, with 80 vessels. "We look at CO2 shipping] as not too different to any other shipping sector."

CO2 is easier to transport than fuel gases such as ammonia and LNG since it is not flammable, and if you must release it due to an emergency, it is not as damaging as ammonia or methane.

One obstacle to CO2 shipping is that under the current European Emission Trading Scheme (ETS) rules, CO2 volumes being sequestered to avoid having to buy ETS certificates cannot be sequestered outside the EU (ie in the UK or Norway). Ecolog requested this rule be changed, but it was not accepted, Mr Heikens said.

Dan Fletcher, head of global CCUS portfolio at bp, said he thinks cross border CO2 transport is relatively immature. It could ultimately be like the LNG value chain, and need appropriate policy and infrastructure to support it, just as we see with LNG. A difference is that it is handling a waste product, rather than a fuel.

If there was better interaction between the various CO2 trading schemes, it could be easier for CO2 sources to work together with CO2 storage sites, with vessels doing the transport.

Jon Gibbins, Professor of Power Plant Engineering and Carbon Capture with the University of Sheffield, noted that it could be viable to ship CO2 from Europe to the US for storage, if the storage cost in the US is low enough to make a margin to pay for the transport. We may see this, with incentives created through the Inflation Reduction Act.

Capturing the carbon opportunity: a report from the CBI

The CBI was recently commissioned by Policy@Manchester to interview 18 organisations across the CCS supply chain to uncover the unique barriers to CCS adoption and suggest policies to address them.

The UK government has a target to reach net zero greenhouse gas emissions across the UK by 2050. This ambitious target will necessitate a range of approaches to carbon reduction, and it is increasingly clear that CCS will play an important role. Businesses, as key drivers of economic growth, are also emitters, and so need to urgently adapt their business models and pivot their operations to decarbonise.

"Our report should act as timely reminder that there is still much work to be done to overcome barriers to CCS adoption, but also that government has the power to affect change," said Jack Malde, Senior Economist at the CBI. "Urgent policy action will allow us to grasp the immense potential of CCS."

CCS is at an earlier stage of commercialisation than other decarbonisation approaches. As such, there may be barriers to the adoption of CCS by businesses, whether they be policy, regulatory, socioeconomic, or technology-related. 18 interviews were conducted in July and August 2022, including international energy companies, power generation companies, manufacturers, infrastructure and machinery companies, stakeholder groups, and businesses across various sectors.

Businesses at different stages in their CCS journey were included, with some located in a CCS cluster. This report presents interview insights, case studies reflecting the views of specific organisations, and policy recommendations developed in collaboration with academics from The University of Manchester, to help make CCS a reality.

Findings from a literature review and subsequent organisation interviews, uncovered the following key findings around CCS perceptions and key barriers to adoption:

• There is general agreement that CCS will play a vital role in the transition to net zero, but that it must be part of a portfolio approach with other technologies

• CCS technology is generally perceived to be proven, and commercially-viable with government support. Recent momentum in CCS adoption is perceived to be strong, but with more transport and storage infrastructure required to spur further progress

• Uncertainties may be inhibiting the buy-in of CCS amongst employees, the general public and other stakeholders, and therefore the overall scale of CCS investment

• Economic barriers, including cost, skills availability, and access to transport and storage infrastructure are generally viewed as more severe than technical barriers

• There is a perception amongst stakeholders across the CCS supply chain that there is a lack of funding from government, contributing to investment hesitancy

With these findings in mind, CBI Economics and Policy@Manchester developed key themes and policy recommendations which require government action to address.

Key policy recommendations from the report

• Stimulate stakeholder engagement to mobilise action and change perceptions

- Continue to engage closely with industry to build on recent progress made in areas such as business models and industrial clusters.

- Seek further engagement with relevant NGOs, including those well-known by the general public, to improve awareness and perception of CCS.

- Review current stakeholder engagement channels to ensure that the right stakeholders are talking to each other and ensure that they are aligned on important processes and timelines.

• Improve awareness of the future direction of CCS and review funding levels to stimulate investment

- Clarify and improve awareness of full CCS timelines to remove business uncertainties, including around the development, location and access to vital infrastructure. Specifically, provide clarity on long-term carbon storage availability.

- Review the current total level of funding going towards CCS to determine if it is fit-for-purpose and sufficient given the scale of the decarbonisation challenge.

• Consider certain legislative and policy changes to stimulate adoption of CCS

- Consider mandating net zero in the construction of buildings across a wide range of sectors, just as in the health sector, to ensure CCS plays a larger part in construction.

- Review processes to ensure that sign-off for important CCS projects is given as quickly as possible, driving quicker adoption of CCS and enabling learning-by-doing.

- Review cost mechanisms to reduce the burden on businesses of adopting CCS. For example, the introduction of a carbon border adjustment mechanism could facilitate greater cost pass-on from businesses to customers.

More information

www.cbi.org.uk

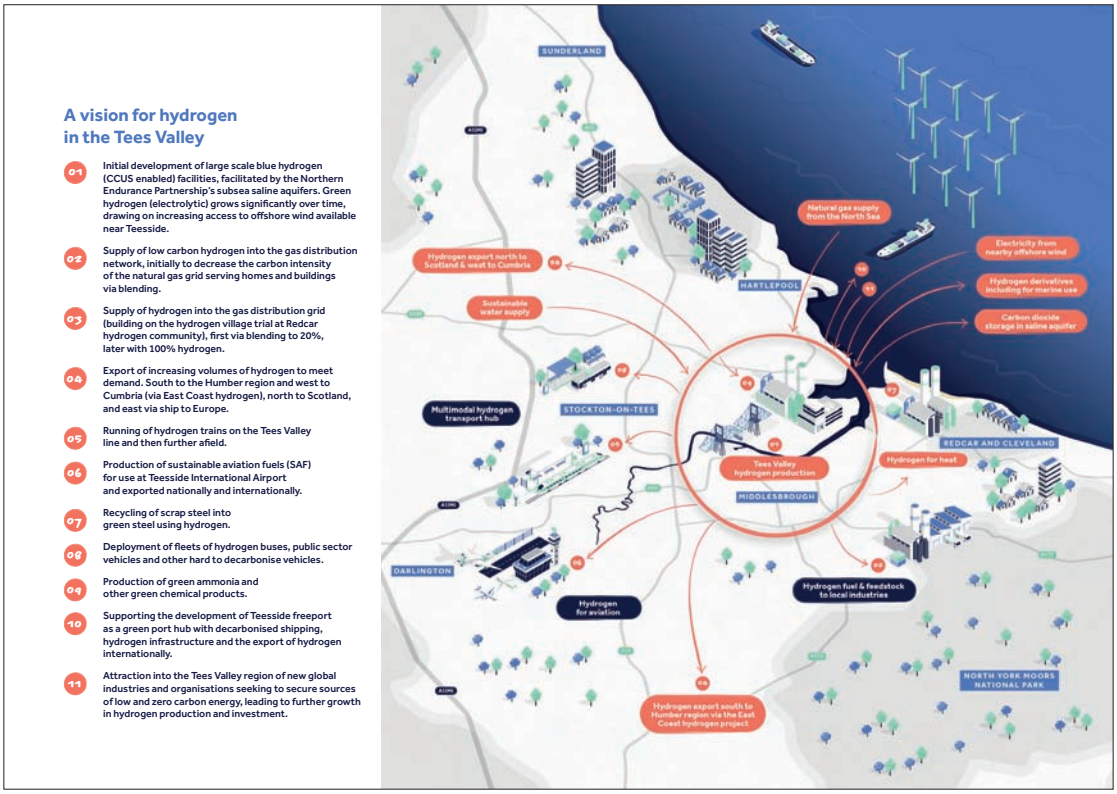
Read the report:

www.policy.manchester.ac.uk

Report: A vision for hydrogen in the Tees Valley

The Tees Valley's pioneering hydrogen sector is laying the foundation for the world's first net zero industrial cluster – a new paper sets out how the region will lead the UK in its energy ambitions and support the development of CCUS.

A Vision for Hydrogen on the Tees Valley details how the area can become globally significant in the production, consumption and export of low carbon hydrogen, while supporting emerging carbon capture, utilisation and storage initiatives and safeguarding and creating thousands of high-quality jobs.



By 2040, the report sees hydrogen supporting the Tees Valley's aim to become one of the world's first decarbonised industrial clusters, helping to accelerate the UK's overarching 2050 net zero goal.

Leading organisations operating in the region are already showing their commitment to new low carbon hydrogen production projects – with many businesses using it to decarbonise their operations. New production projects could see at least 2.5GW of hydrogen production capacity in Teesside by 2030.

This is a quarter of the government's ambition for 10GW of low carbon hydrogen production by the end of the decade, which was recently doubled from 5GW. This shows that the essential elements for a whole-system hydrogen "SuperPlace" are already at the heart of the area.

It could also play a central role in accelerating the use of the fuel in transport and help position Teesside as the UK's Hydrogen Transport Hub.

The report has been developed by a consortium of key stakeholders consisting of the Tees Valley Mayor and Combined Authority, Arup, bp, Kellas Midstream and Northern Gas Networks (NGN), the driving forces behind innovative projects in the sector.

Tees Valley Mayor, Ben Houchen, said, "Our region is at the forefront of the UK's clean energy ambitions, with transformative projects secured in low carbon and offshore sectors. Teesside already produces around half of the UK's hydrogen, so we're well-placed to become a leading force and 'SuperPlace' in the production, storage, distribution, and use of hydrogen for green projects of global significance".

"This landmark study sets out how hydrogen will bring the well-paid, high-quality jobs of the future to Teesside, Darlington and Hartlepool as our green economy continues to grow. If we seize the opportunity that stands before us today, our region can be to hydrogen in the 21st century what it was to steel and chemicals in the 19th and 20th."

Additional findings from the report are:

• Five hydrogen production sites could be built, having a capacity of 2.5GW by 2030 combined, this represents a quarter of the UK government's 2030 hydrogen production target

• The ramp up of a hydrogen-based economy could support up to 6,300 workers during a three-year construction period

• Teesside will accelerate the UK's overarching 2050 net zero goal

• Decarbonisation of the energy system is a challenge for everyone. Hydrogen will form a key part of meeting that challenge, with the Tees Valley well positioned to be at the forefront of the UK's clean energy revolution.

More information

www.arup.com

Keadby 3 Carbon Capture Power Station given consent

The application for a combined cycle gas turbine (CCGT) power station with a carbon capture and compression plant has been approved by the UK Government. The landmark project in the Humber could become the UK's first power station equipped with carbon capture technology.

Keadby 3 Carbon Capture Power Station, which is being jointly developed by SSE Thermal and Equinor, has been selected to be taken forward to the due diligence stage by the Department for Business, Energy and Industry Strategy (BEIS) as part of its Cluster Sequencing Process.

This process will give the project the opportunity to receive government support, allowing it to deploy cutting edge carbon capture technology, and to connect to the shared CO2 pipelines being developed through the East Coast Cluster, with its emissions safely stored under the Southern North Sea. The common infrastructure will also supply low-carbon hydrogen to potential users across the region.

The planned power station at Keadby – which would have a generating capacity of up to 910MW - could be operational by 2027 subject to reaching a final investment decision in 2023. It would capture up to one and a half million tonnes of CO2 a year, which represents at least five per cent of the UK Government's 2030 target, while providing low-carbon, flexible power to back-up renewable generation.

Equinor's H2H Saltend project, the 'kick-starter' for the wider Zero Carbon Humber ambition, has also been taken to the next stage of the process by BEIS. The planned hydrogen production facility could provide a hydrogen supply to Triton Power's Saltend Power Station as well as other local industrial users. In June, SSE Thermal and Equinor entered into an agreement to acquire the Triton Power portfolio.

The two companies are also collaborating on major hydrogen projects in the Humber. Keadby Hydrogen Power Station could be one of the world's first 100% hydrogen-fuelled power stations, while Aldbrough Hydrogen Storage could be one of the world's largest hydrogen storage facilities. In addition, they are developing Peterhead Carbon Capture Power Station in Aberdeenshire, which would be a major contributor to decarbonising the Scottish Cluster.

Visualisation of the proposed power plant with CCS (Image: SSE Thermal)

"As we continue to scale up renewables across the UK, the need for flexible generation to keep the lights on and provide vital backup becomes ever more critical. Keadby 3 Carbon Capture Power Station can do exactly that and will be crucial in meeting our net zero ambitions," said Catherine Raw, Managing Director SSE Thermal.

"The Humber is the UK's most carbon intensive industrial cluster, and our proposed plant will not only help to decarbonise the region but will also ensure a just transition for workers and communities. We are delighted that BEIS has recognised the strength of our project, which is being developed alongside Equinor, and we look forward to engaging with them as we move closer to delivering on the promise of carbon capture."

"Ultimately, both carbon capture and hydrogen will be essential to the UK's decarbonisation journey, and momentum continues to build towards this low-carbon future with SSE leading the way through its ambitious Net Zero Acceleration Programme, which will see £24bn invested this decade alone."

The first phase of the Cluster Sequencing Process saw the UK Government announce the two 'Track 1' clusters which will be supported to develop?carbon capture and storage infrastructure. The East Coast Cluster, which includes the Humber and?Teesside?regions, was named in 'Track 1'.

In the second phase, individual emitter projects within those clusters – including Keadby 3 Carbon Capture Power Station – submitted applications to be considered for government support. BEIS today announced the 20 projects across both clusters were selected to be taken forward to the due diligence stage.

More information

www.ssethermal.com

www.equinor.com

CCU International to open first funding round for patented tech

Scottish Climate Tech spinout CCU International is seeking £5-£10m to commercialise its patented 'game-changing' carbon capture and utilisation system which is suitable for emitters of all sizes.

The Aberdeen-based firm is set to launch its initial raise to fund equipment and overheads to target the global market for CCU, estimated to be worth $2.5bn today but more than $12bn by 2031. It's projecting revenue of at least £1bn over the next 10 years, focusing first on the UK and US markets.

The key innovation in its patented system is its multi-stage process developed over six years by technology advisor and respected expert, Professor Peter Styring at the University of Sheffield, where he is Professor of Chemical Engineering & Chemistry.

The process captures mixed gas emissions directly from flue stacks and passes them through a multiple-step process involving pressurisation through a unique silica gel. During the different process steps the pressure is specifically calibrated to ensure different gases are emitted from the silica gel until only CO2 remains.

The system is modular, able to deal with small to large volumes of input gases and CO2 concentrations and can be customised to each client's requirements. The captured CO2 is pressurised and liquefied for use in industry and can be used to create different industrial products.

The CCU international system has many benefits over existing carbon capture systems that mainly rely on capturing and storing CO2, have been developed for large emitters, are expensive and can take years to implement.

Designed to have a small footprint, the CCU International modules can be easily transported and can be deployed within weeks to ensure CO2 emissions are captured sooner rather than later. The modular systems are highly scalable and can capture from 300kg to hundreds of tonnes of CO2 per day.

CCU International's system is highly efficient and has been designed to operate on renewable energies with heat recovery. The entire solution produces additional revenue streams for clients - such as verifiable carbon credits and, with the addition of further downstream modules, also produces commercial products, such as food and medical grade CO2 gas, aggregates, diesel and surfactants.

"Capturing and utilising CO2 is a better strategy for emitters than buying carbon credits because it's measurable and verifiable," said CEO Beena Sharma.

"By enabling the creation of carbon credits and reducing the risk of emissions fines, it also turns a cost into a revenue stream."

CCU International's patented modular system is highly scalable and can capture from 300kg to hundreds of tonnes of CO2 per day

"Governments now recognise we can't achieve Net Zero without carbon capture and our system enables smaller-scale industrials and SMEs to decarbonise cost-effectively for the first time as well as making it more efficient and affordable for all scales of emitters by creating a number of revenue streams as part of the process."

As well as raising initial funding, CCU International is looking to agree partnerships and collaborations with players in several sectors including oil & gas, energy, petrochemical, shipping & ports, heavy industry, steel, cement, anaerobic digestion and industries which both emit and use CO2, such as carbonated drinks. It's being advised by Hutcheon Mearns.

More information

ccu.international

New carbon capture and storage projects funded

The UK Carbon Capture and Storage Research Centre (UKCCSRC) has announced the 13 proposals that have been awarded funding in their recent Flexible Funding 2022 call.

A total of £368,792 was awarded to the projects, which all support the UK Government's net-zero objectives and will last between 3-9 months. For the first time, early career researchers (ECRs) were eligible to apply, with £100,000 ring-fenced for ECR applicants. Five of the proposals are led by ECRs.

Ruqaiyah Patel, Joint Head of Energy and Decarbonisation at the Engineering and Physical Sciences Research Council (EPSRC) said, "Further research into carbon capture and storage will enable us to capture, store and utilise greenhouse emissions from essential processes that cannot be decarbonised and potentially save the UK tens of billions of pounds over the next two decades.

"Building on the significant impact and success delivered by UKCCSRC across technology and policy development, this call was essential in supporting a broad range of CCS research projects that can support and help the UK achieve its net zero target by 2050."

More information from four of the successful projects

Dr Amir Jahanbakhsh from Heriot-Watt University said, "Rockit is a multidisciplinary project developing a technique to eliminate CO2 from the atmosphere safely and permanently. Mineralization of carbon through the reaction of CO2 with rocks rich in calcium or magnesium converts CO2 into solid rock. I am collaborating with colleagues from the University of Edinburgh to successfully investigate different aspects of this technique and potentially contribute to taking it to a higher stage of technology readiness."

Dr Peter Clough from Cranfield University said, "Our project will advance and demonstrate a new technique for capturing fugitive amines released from CO2 scrubbers, which has already passed a mathematical proof-of-concept and captured industry's interest. The next step is to develop a physical prototype of the amine electrostatic precipitator (ESP), based on the design produced and modelling performed in collaboration with Petrofac, with previous UKCCSRC funding. This technology will ensure CCS plants can adhere to current and future emission limits and protect the environment."

Dr Salman Masoudi Soltani from Brunel University London said, "Biomass combustion ash is a challenging waste to manage. We have devised a practical pathway to utilise such waste and synthesise cost-effective yet efficient sorbents for carbon capture. The application of our waste-derived sorbents at scale must be investigated in terms of the associated environmental footprints and potential operational challenges."

Dr Tohid Borhani from the University of Wolverhampton said, "This project aims to examine the downflow gas contactor (DGC) to capture CO2 using different solvents. The impact of the study could be having a more efficient and cheaper carbon capture method that can be very promising for retrofitting cement factories, power plants and any other carbon emission sources. I am the first person to try to develop this DGC unit and use it for carbon capture, and the project, therefore, has great potential for more studies."

Full list of successful applicants

Efenwengbe Nicholas Aminaho (Robert Gordon University): Evaluation of Caprock Integrity for Geosequestration of CO2 in Low Temperature Reservoirs

Dr Tohid N.Borhani (University of Wolverhampton): Modelling and Simulation and Economic Evaluation of CO2 Capture Using Downflow Gas Contactor (DGC) Process

Dr Peter Clough (Cranfield University): Developing the understanding and prototyping of amine electrostatic precipitation

Dr Katriona Edlmann (University of Edinburgh): CarbNET Carbonation negative emission technology

Muir Freer (University of Manchester): Integration of CO2 Capture at Dispersed and Remote UK Cement Production with CCS Infrastructure

Dr Amir Jahanbakhsh (Heriot-Watt University): Rockit – the geochemistry of turning carbon to rock via geological CO2 storage in basalts

Professor Mathieu Lucquiaud (University of Sheffield): SMART – Solvent Management At Reduced Throughput – prototype demonstration

Dr Salman Masoudi Soltani (Brunel University London): Investigation of Environmental and Operational Challenges of Adsorbents Synthesised from Industrial Grade Biomass Combustion Residues

Dr Stavros Michailos (University of Hull): Co-DAC: Low-energy Direct Air Capture potential when combined with a Post Combustion Capture plant

Dr Nejat Rahmanian (University of Bradford): Evaluation of properties of biomass wood pellets in power generation

Dr Chenggong Sun (University of Nottingham): CO2 Utilisation for Accelerated Carbonation Curing towards Net-Zero Circular Concrete Industry

Professor Karen Turner (University of Strathclyde): Exploring wage-driven employment displacement in a supply constrained labour market as CCUS integrates into the UK economy

Dr Yongliang Yan (Newcastle University): Machine Learning for Perovskite-based Oxygen Carriers Development in Chemical Looping Hydrogen Production

More information

www.ukccsrc.ac.uk

Carbon Capture and Storage underpins the UK's journey to Net Zero

Dr William Joyce, Innovation Lead for Industrial Decarbonisation at UKRI, demonstrates how projects in the Industrial Decarbonisation Challenge are adopting a cluster wide approach to maximise the potential of decarbonisation to enable the world's first Net Zero industrial cluster. www.ukri.org

UKRI's Industrial Decarbonisation Challenge was setup to fulfil the ambitions of the Industrial Clusters Mission which outlined the largest 6 industrial clusters in the UK. This set a target of achieving 1 low carbon cluster by 2030 and the world's first net zero industrial cluster by 2040.

In June 2019 the UK Government amended the Climate Change Act from 80% to 100% greenhouse gas reduction or effectively Net Zero by 2050. These commitments made the UK the first major economy to legislate for Net Zero emissions – a hugely ambitious target set by a major polluting industrialised nation.

This followed a Climate Change Committee recommendation report in May 2019 which highlighted that Carbon Capture and Storage (CCS) is a necessity rather than an option. This led to the UK striving to deploy CCS in at least four industrial clusters by 2030, two by mid 2020s with a £1 billion commitment by Government to capture and store between 20-30 million tonnes of CO2 across the economy each year.

This unprecedented acceleration has put CCS at the fore of public policy with a very clear emphasis on its importance for the UK's Net Zero journey. The Industrial Decarbonisation Challenge is supporting 9 major infrastructure projects currently undertaking the complex engineering plans for wide scale infrastructure deployment in the mid-2020s.

The legacy of this programme will be the world's first Net Zero industrial cluster in either the Humber, North West, Scotland, South Wales or Teesside (and shortly followed by a full house).

UK is well placed to become a global leader

The UK has significant offshore CO2 storage potential on its continental shelf and enough storage to satisfy hundreds of years of domestic demand. Our unique offshore storage asset, in combination with our CCS projects in the Industrial Decarbonisation Challenge portfolio being in advanced stages of development, means the UK has a strong potential to become a world leader in carbon capture technologies. A figure published by BEIS estimated the global CCS market could be worth £260 billion by 2050.

Moreover, it's important to recognise the significance of hydrogen as a low-carbon source of fuel. Hydrogen, produced from natural gas and deployed in parallel with CCS, will create scalable business models – first decarbonising industrial sites. Once established for industrial applications, we can lay the foundations for broader regional hydrogen economies.

The IDC portfolio includes world leading hydrogen projects; examples include the H2H Saltend project in the Humber cluster developing a 600 MW autothermal reformer and a dual hydrogen and CCS pipeline connecting the region's major emitters. A further example is the full chain hydrogen network being developed by HyNet in the North West which will establish 30 TWh hydrogen production by 2030 from the Stanlow refinery.

Cluster decarbonisation approach

Previous industrial decarbonisation approaches targeted individual sites or sectors. The IDC programme is the first where projects work together at the cluster level through multi-sector consortia. Each project is underpinned by an onshore CCS network and then offshore pipeline enabling CO2 storage under the seabed in stores in the North Sea and Irish Sea. The projects in the IDC portfolio will account for nearly £0.5 billion of investment into industrial cluster decarbonisation creating ready-to-go projects – with final investment decisions being made in preparation for construction and operation in the 2020s.

It is clear from systems modelling that the most cost-effective and efficient ways of decarbonising are within industrial clusters rather than an industry or sector on its own. This approach is cross sector focussed as it is easier to share knowledge and learn from others. Our deployment portfolio includes 61 organisations across 6 onshore and 3 offshore projects including the highest emitting industrial sectors from steel, refining, chemicals, cement and plastics. Our industrial clusters include 13 out of the 15 largest single point emission sites in the UK. The cluster decarbonisation model enables a robust wide-reaching approach and for others to join the networks in the future.

This approach will also enhance the competitiveness of whole regions, creating attractive investment opportunities and creating tens of thousands of jobs as well as protecting those already in the industry. The UK's unique carbon storage assets, and carbon capture projects set to enter operation this decade, means we are well on our way to power toward a cleaner future.

UK CCS news

Hanson demonstrates new carbon capture process for cement

www.hanson.com

Hanson has demonstrated a novel carbon capture process at its Ribblesdale cement works in Clitheroe, Lancashire.

The team proved that enforced carbonation of recycled concrete paste (RCP) within the plant's existing wet scrubber allows for a high CO2 uptake within less than 30 minutes, preventing emissions entering the atmosphere.

During the trial 15 tonnes of industrial RCP were fed into the scrubber. The result was 100kg of CO2 being bound within each tonne of RCP, demonstrating another carbon capture breakthrough.

Sustainability director, Marian Garfield, said, "The trial was carried out with our parent company Heidelberg Materials' R&D team and marks another important milestone in our carbon capture journey."

"It confirmed the feasibility of enforced carbonation, which supports the circular economy by using waste recovered concrete fines to remove CO2 emissions from the production process while producing a secondary material that can then be used to replace virgin limestone in cement and concrete production."

The Ribblesdale trial follows one carried out under semi-dry conditions at Heidelberg Materials' Brevik plant in Norway and underlines that the company is at the forefront of carbon capture technology to enable its path to net zero. The learning from the two trials will accelerate Heidelberg Materials' planning and implementation of industrial pilot schemes in the coming years.

Hanson's Ribblesdale cement works in Clitheroe, Lancashire

Essar Oil UK to build £360 million carbon capture facility

www.essar.co.uk
vertexhydrogen.com

The company will build a major new carbon capture plant at its Stanlow refinery in line with its ambition to become a leading low carbon refinery by 2030.

Essar is investing over £1 billion into a range of energy efficiency, fuel-switching, and carbon capture initiatives, designed to decarbonise its production processes significantly by 2030.

Essar's energy transition strategy is based on five principles: running the core Stanlow refining processes as efficiently and safely as possible; decarbonising Stanlow's operations; building a hydrogen future through the launch of Vertex Hydrogen and as a key part of the HyNet consortium; developing green fuels (including Sustainable Aviation Fuels); and establishing the UK's largest biofuels storage facility through Stanlow Terminals Limited.

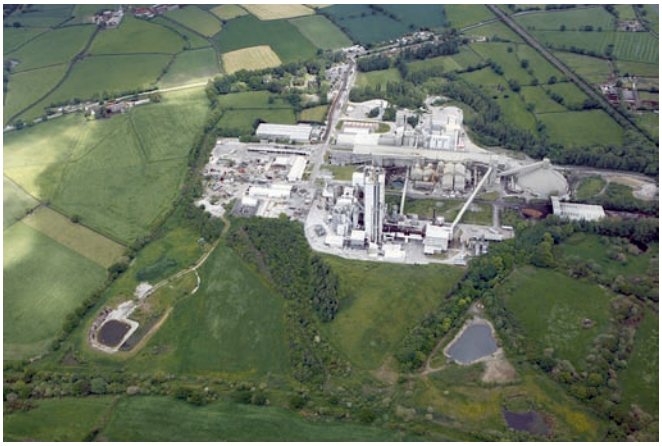
Kent plc has been awarded a pre-FEED engineering contract to develop the facility that will take the CO2 emitted from one of Europe's largest full-Residue Fluidised Catalytic Cracking units, located at the Stanlow refinery. The gas will be permanently sequestered into depleted gas fields under the sea in Liverpool Bay, as part of the HyNet cluster infrastructure in the North West of England.

Once complete in 2027, the plant will eliminate an estimated 0.81 million tons of CO2 per year – the equivalent of taking 400,000 cars off the road, eliminating nearly 40% of all Stanlow emissions. The project has been selected by BEIS as a Phase-2 winner in the CCUS cluster sequencing process earlier this summer, and as such, is currently progressing through the due diligence stage.

Deepak Maheshwari, CEO of Essar Oil UK said, "This new carbon capture plant is the single biggest initiative to decarbonise our processes and a core element to our hugely ambitious decarbonisation strategy. Our ambition is to become a leading low carbon refinery. This is a massive undertaking, but it is a journey we are fully committed to. Not only is it the right environmental thing to do, it will future proof the critical Stanlow refinery for the long term, protecting jobs and industry, while also placing Stanlow at the very centre of the UK's energy transition."

Essar is already making progress against its broader decarbonisation targets. In September, EOUK announced it had signed a 'Heads of Terms' offtake agreement with Vertex, a joint venture with Progressive Energy, for the supply of 280MW+ of hydrogen. The hydrogen will be used to help decarbonise Essar's existing production facilities including the new hydrogen powered furnace [1]which was delivered in August this year. The £45 million furnace is the first of its kind in the UK, capable of running on a 100% hydrogen source and will replace three existing furnaces at Stanlow.

Vertex is developing the first large scale, low carbon hydrogen production hub in the UK, as part of the HyNet cluster. This will produce (in its initial phases) 1GW of hydrogen (the equivalent energy use of a large UK city like Liverpool) and capture some 1.8 million tonnes of carbon per annum. By 2030, Vertex expects to deliver nearly 4GW of low carbon hydrogen, equivalent to c.40% of the UK Government's national target.



Hanson's Padeswood cement works located in Flintshire, Wales

Mitsubishi awarded contract for Hanson cement CO2 capture plant

www.mhi.com
www.hanson.co.uk

Mitsubishi Heavy Industries Engineering has been appointed by Hanson UK to deliver the preliminary front-end engineering design (Pre-FEED) for a CO2 capture plant at its Padeswood cement works located in Flintshire, Wales.

The contract represents MHIENG's third project involving CO2 capture at a cement plant, following a carbon capture and storage feasibility study for Lehigh Cement Company in Alberta, Canada, and a CO2 capture demonstration testing program currently underway for Tokuyama Corporation in Japan.

The project is part of a comprehensive effort to decarbonize the UK's cement industry. This plan constitutes the UK-based cement industry's first adoption of CCS technology.

This Pre-FEED is part of a project that will deliver a CO2 capture plant to the Padeswood Works. Once operational, the plant will capture 800,000 tonnes of CO2 per year and the plan is to store it in spent gas fields off the coast of North West England.

MHIENG will support the project by carrying out the Pre-FEED of a CO2 capture plant applying its "Advanced KM CDR Process," CO2 capture technology jointly developed with The Kansai Electric Power Co., Inc.

The UK Government has set ambitious targets for achieving net zero carbon emissions by 2050. To achieve this goal, it has been building the necessary infrastructure, including CCUS clusters that encompass all aspects of carbon capture, utilization and storage for implementation at designated industrial zones.

MHIENG promotes the adoption of CO2 capture technologies in diverse industrial applications globally: not only in conventional thermal power plants and chemical plants, but also in biomass power plants, steel mills, waste to energy plants, gas engines, ships, and amongst other applications.

Hanson UK is the UK group subsidiary of Heidelberg Materials, one of the largest building materials manufacturers in the world based in Heidelberg, Germany.

C-Capture wins international award for carbon capture technology

www.c-capture.co.uk

C-Capture's unique and innovative carbon capture technology won the Energy category at the 2022 IChemE Global Awards.

The Energy award recognises excellence in efficient energy use or the development of energy production methods that reduce energy intensity as part of the global awards celebration of chemical engineering excellence.

An innovation in the sector, C-Capture's carbon capture technology is based on fundamentally different chemistry to other commercially available solutions. Lower cost, environmentally benign and extremely robust, the solution has the potential to break through the barriers that are currently preventing the widespread adoption of carbon capture and storage technology to mitigate the impacts of climate change, the company said.

The technology was also a finalist in another category – 'Sustainability' - which recognises excellence in sourcing and consuming materials, reducing waste, and/or optimising the product life cycles.

Tom White, CEO, C-Capture, said, "Being shortlisted was honour enough, but to win the global energy award is fantastic recognition for the C-Capture team and our unique carbon capture technology. The IChemE Global Awards represent the pinnacle of excellence in chemical process engineering, this achievement is testament to our exceptional team and their commitment to accelerating the global adoption of carbon capture and storage to achieve net zero, by preventing greenhouse gases from entering the atmosphere."

Entries from across the world that demonstrated excellence in chemical, biochemical and process engineering were selected as finalists in a total of 17 categories. Global representation included winners and highly commended finalists from countries including the USA, Australia, UAE, New Zealand, Norway, South Africa, Serbia, Germany, Dubai, Saudi Arabia and Malaysia.

IChemE President, David Bogle, said, "The IChemE Global Awards provides an opportunity to recognise the best of our profession and it gave me great pleasure to welcome our finalists and guests for what was a fantastic evening celebrating chemical engineering in IChemE's centenary year."

"I particularly welcomed the focus on sustainability across the award categories, which clearly demonstrates how chemical engineers are already contributing to addressing some of society's major challenges due to their knowledge, innovation and commitment. Congratulations to all our winners. We hope their achievements inspire companies, teams and individuals to make further advances as chemical engineers will be critical to delivering solutions in the future."

"Thank you to everyone who entered, our sponsors, and to our committed and knowledgeable volunteer judges who embraced the monumental task of reviewing each finalist's submission and selecting the winners."

C-Capture was founded in 2009 as a spin-out from the Department of Chemistry at the University of Leeds. Investors include IP Group, Drax, and BP Ventures. It supplied the anchor technology for the world's first pilot project to demonstrate carbon negative power production, at Drax, the UK's largest power station.

A Future for Direct Air Capture

In the crucial next couple of decades as governments and industry are moving toward net zero emissions, we have to use every tool available to us. Achieving consequential reductions in greenhouse gas emissions will take an all-of-the-above approach, including emerging technology such as direct air capture (DAC).

By Prof Niall Mac Dowell, Special Advisor to the International CCS Knowledge Centre

Artist's rendering of Project Bison, a 5-megaton carbon removal project in Wyoming. (Graphic: Business Wire)

But first, what is DAC and how does it fit with other, more established carbon-reducing technologies such as carbon capture and storage (CCS)? The most developed DAC technologies remove carbon dioxide directly from the atmosphere, using either solid adsorbent methods or aqueous absorbent methods, creating diverted carbon that can either be injected into geological storage or used for secondary, non-emitting manufacturing processes.

In its current form, DAC is a relatively energy-intensive process. Of the two leading technologies, solid DAC (S-DAC) works at lower temperatures (80 to 1200C), and could be fuelled with low-emission energy such as renewables. Liquid DAC (L-DAC) requires higher-intensity heat (between 3000C and 8000C), so has been designed to use higher-emitting fuel sources such as natural gas, though these emissions would be captured within the process.

DAC is still in a nascent stage of development, and is inevitably more costly than conventional point source capture owing to the dilute nature of carbon in the atmosphere. The International Energy Agency (IEA) cost estimates for DAC currently land between $US125 and $US335 per tonne of CO2 captured in the case of a large-scale capture plant. However, the DAC industry is optimistic that this could be reduced to below $US100 as the technology is further developed.

Where does DAC fit into the net zero equation?

In its September 2022 report on DAC, the IEA stated that there are 18 direct air capture plants operating worldwide, capturing almost 0.01 MtCo2 per year. The largest existing plant, built in Iceland last year, captures 4,000 tonnes of CO2 per year. In the agency's Net Zero by 2050 Scenario, DAC will be scaled up by 2030 to capture 60 MtCO2, as part of a forecast 1.6 Gt CO2 per annum for all CCUS solutions. Given current investment levels and intentions, the IEA deems this level of capture possible but only with a significant deployment and demonstration of lowered capture and energy costs.

Direct air capture innovator Carbon Engineering recently announced front-end planning and engineering for a proposed 1 MtCO2 plant in Texas that could refine the technology and be replicated to extract up to 30 MtCO2 on the same site. This is the second capture and storage plant that Carbon Engineering has underway in Texas' Permian Basin, and is designed to build a commercial value proposition for the technology and engineering.

Advanced DAC projects have also been an-

nounced in locations including Chile, Norway, and the United Kingdom. Of the 11 facilities underway globally, the IEA estimates that together they will be capable of capturing approximately 5.5 MtCO2 per year by 2030, which is 700 times the current capture rate of all DAC facilities, but is still only 10 per cent of the capture needed to reach the agency's full net zero scenario.

How does DAC get to the next level?

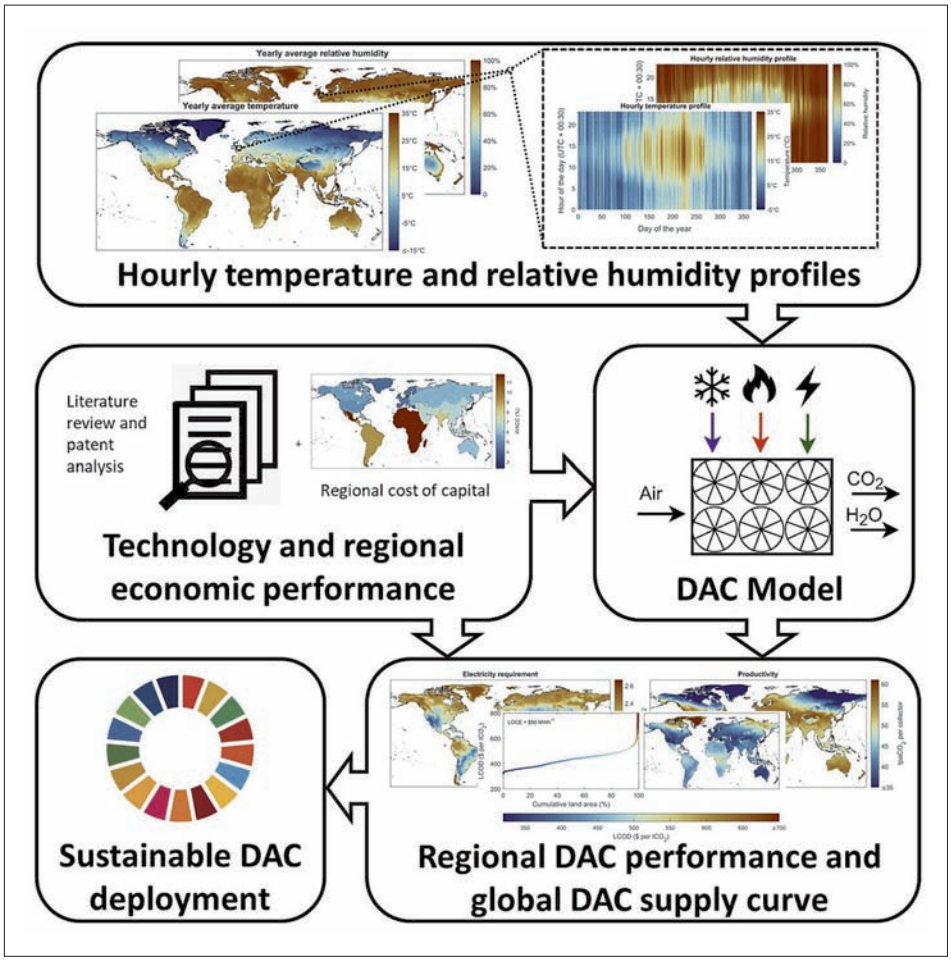
DAC technology performance is sensitive to changes in temperature and humidity, and given the significant investment needed to scale up operations to get closer to net zero targets, it is essential to identify regions around the world that will best accommodate DAC projects.

To determine this, colleagues and I at Imperial College London recently completed and published a detailed study into the long-term costs of DAC, with a particular focus on how costs may vary as a function of local conditions. The research led by Prof Paul Fennell shows that DAC is most effective in dryer, more moderate climates, and can be most readily accessed in northern geographical areas that have already established the investment value of emerging engineering for emissions reduction.

Our recently published study assessed the impact of regional climate variation on DAC performance, finding that approximately 25 per cent of the world's land is unsuitable for deployment of DAC, and that colder, drier regions are most favourable. The study found that the cost of developing DAC capability is dependent on local climate, including both temperature and humidity, and on the local cost of energy.

One of the key next steps for scaling up DAC as an investment opportunity is to agree on a global life cycle assessment for captured carbon that will allow it to be included in regulated carbon markets. Efforts have begun in the United States and Europe to assess DAC-sequestered carbon for certification.

The IEA cites several large companies, including Microsoft, Shopify, and Airbus who have already started to include DAC removal in voluntary carbon removal purchases, though DAC is not yet certified as meeting international mitigation targets under the United Nations Framework on Climate Change.



Graphical Abstract of the paper "Geospatial analysis of regional climate impacts to accelerate cost-efficient direct air capture deployment" by Manwan Sendi, Mai Bui, Niall Mac Dowell and Paul Fennell published in One Earth, Volume 5 Issue 10 Pages 1153-1164 (October 2022)

Meanwhile, DAC innovators are counting on exponential growth in the technology over the next decade. To meet ambitious climate targets, and to prove the technology is viable, investors and engineers will have to work quickly to make DAC a key factor in emissions reduction.

CarbonCapture expects its large-scale Project Bison DAC facility in Wyoming to be operational by the end of 2023 at a scale of 10,000 tonnes per year of carbon dioxide removed. The plan is to scale up to remove 5 MtCO2 per year by 2030, but will be built on a modular platform that could conceivably scale to what the company calls "no practical limits." CarbonCapture is already listing the carbon credit assets of the project, with precisely metered accounting.

Government policy and private investment are just starting to coalesce around DAC, and the IEA describes it as gaining momentum. This year's Inflation Reduction Act in the U.S. has already had an impact on the sector, providing substantially larger tax credits for carbon removal projects.

The United States government has also included DAC in its Carbon Negative Shot, launched at COP 26 last year in Glasgow – a portfolio of carbon direct removal approaches that have strong potential to reduce emissions at a scalable level and at a cost that will eventually approach less than $US100 / tCO2. With accurate certification, and a growing market for offsets, DAC could become even more cost-effective as an emerging technology. The next decade will set a foundation for the technology as a viable piece of the net zero puzzle.

Based in London, U.K., Niall Mac Dowell is Special Advisor to the International CCS Knowledge Centre.

More information

ccsknowledge.com

Important scientific advances in CCUS over the past 3 years

The report from the Carbon Dioxide Capture and Conversion (CO2CC) Program gives an update of the recent progress made in CCUS technologies, from the various advances in capturing CO2, to the use of CO2 as a feedstock for valuable commodities or for Enhanced Oil Recovery, and the safe storage of CO2 to prevent its return to the atmosphere.

The report, "Catalogue of most important scientific advances in CCUS over the past 3 years" presents recent developments in each aspect of the CO2 supply chain, using recent scientific papers, news, press releases, patents, and technical/economic reports to assess the technical and economic feasibility of each technology.

Many studies are focusing on the implementation of CCS to the top-emitting industries including iron and steel, cement, petroleum refining, and petrochemical. Unlike fossil fuel power plants, many industries have few or no CO2-free alternatives to manufacture products.

An overview of each technology is presented at the beginning of each section, followed by the recent advances, while current projects and future hurdles of each technology are outlined at the end of each section. Finally, the conclusion of each chapter includes the most important findings and the challenges related to each technology.

Chapter one outlines the developments in CO2 capture technologies which can be divided into three categories: post-combustion capture, pre-combustion capture and oxyfuel-combustion. The report covers a range of potential solutions including absorption, adsorption, membrane separation, calcium looping, chemical looping, and direct air capture (DAC).

Post-combustion capture (PCC) offers a mature technology which can be easily retrofitted to existing plants. For industrial applications, carbon capture via absorption is the most commercially mature technology to date, and in recent years a steady increase of CCS projects using this technology has been observed.

Developments in Carbon Capture and Utilization (CCU) technologies is the subject of Chapter two, which includes utilisation of CO2 to produce fuels, chemicals and construction materials. A careful assessment of the lifecycle emissions of each product and process is required to ensure the lifetime CO2 emissions of the product do not exceed the amount of CO2 utilised.

Growing interest in new technologies for CO2 utilisation, such as the production of synthetic fuels, chemicals and construction materials has been reflected in the increasing support from governments, industry, and investors. Carbonated aggregates, synthetic fuels and concretes represent the largest near-term opportunities for CO2 utilisation in terms of emissions reduction and market size.

The recent progress in CO2 storage methods including enhanced oil recovery (EOR), geological storage and natural sequestration is presented in Chapter three.

Ocean sequestration involves the injection and deposition of CO2 into the water at depths below 1 km, however environmental concerns mean that geological sequestration in saline aquifers or depleted oil & gas reservoirs remains the most mature technology and is the focus of all existing projects. Recent developments have focused on the effect of location, monitoring methods and site characterisation.

Nature-based solutions include reforestation, afforestation, biochar, and enhanced weathering rates of rock minerals. Geological CO2 storage when compared to nature-based solutions has clear advantages in the sense that nature-based solutions require continual interventions, significant land areas and has a low capacity of CO2 stored annually.

Despite the efforts made in membrane materials development and their fabrication, what is vital for large scale post-combustion capture (PCC) are effective techno-economic analysis of process flowsheets and pilot scale assessment of different system configurations using real flue gas streams.

Outlook: key takeaways from the report

- Converting CO2 to useful chemicals and or plastics could, under certain circumstances, have an impact on decreasing CO2 emissions.
- Currently various pathways for CO2 conversion to fuels are being explored. Electrocatalysis, photocatalysis and a combination of thereof are the most well studied pathways with the former being the most suitable for large scale deployment.
- In the United States, more than 70% of CO2 used for EOR is sourced from natural underground reservoirs due to the absence of infrastructure for capture from industrial emitters close to oil fields.
- Incentives to store CO2 through tax credits or a carbon market could shift CO2-EOR projects from producing more oil with less purchased CO2 to achieving a secondary goal of storing more CO2.
- Despite EOR being a long-established technology, CO2 monitoring, quantifying and reporting standards must be improved to validate the potential emissions benefit to meet climate change targets.
- There are a small number of active (Sleipner, North Sea, Norway; Snohvit, Barents Sea Norway) and completed (K12-B, North Sea Netherlands) offshore CO2 injection projects in Europe that provide confidence in the performance of offshore injection and storage.

Advances in CO2 capture

Post combustion capture is a mature technology with decades of use in industrial processes that can be easily retrofitted. The conventional PCC processes include liquid absorption, solid adsorption, and membrane separations. Currently, chemical absorption via amine solvents is the most mature PCC process technology. Chemical absorption offers high capture efficiency and high selectivity; however, it has significant solvent regeneration energy demand and thus high CO2 capture costs.

Many screening experiments have been performed for different solvents. Nevertheless, all solvents studied so far continue to exhibit several drawbacks such as low kinetics and stability issues when exposed to acidic gases like SOx and NOx as well as the presence of oxygen in the flue gas.

The membrane separation method can be applied to pre-combustion, oxy-combustion, and post–combustion carbon capture processes. This often has easy operation, however during operating it has a small processing capacity, poor selectivity, and low stability.

Several next-generation technologies including calcium looping, chemical looping and direct air capture are also reviewed.

Advances in CO2 utilisation

There is growing interest in CCU as a climate change mitigation tool where the captured CO2 is converted into valuable products rather than sequestered underground. Prize initiatives such as the NRG COSIA Carbon XPrize have been key enablers in promoting CO2 conversion technologies.

CCU provides a revenue stream for CO2 capture projects which could help to de-risk the early development of CCUS supply chains. The core challenge of utilisation technologies is that CO2 is one of the most thermodynamically stable carbon compounds. Therefore, converting CO2 into a high value product can involve a large amount of energy and materials (i.e., catalysts and other chemicals).

The three primary options for CO2 utilisation are conversion to fuels, chemicals, and building materials. The production of fuels could increase the CO2 demand by up to 2050Mt per year, while carbon conversion into chemicals represents a large CO2 sequestration potential of approximately 500 Mt/year. It is important to note that CO2 based fuels will eventually end up releasing CO2 to the atmosphere, thus conversion of CO2 into fuels can only be a carbon-neutral technology.

The most common fuels derived from CO2 conversion are methane (CH4) and methanol (CH3OH), although CO (syngas) and ethanol can also be produced via CO2 reduction. Various new conversion pathways and catalysts are being explored, however process scalability, costs, and above all energy use are still limiting the large-scale deployment of these technologies.

CO2 can be used as an alternative feedstock to natural gas and oil for chemicals synthesis. Captured CO2 can be used in mature processes (such as urea production), emerging technologies (such as formic acid production), and innovative processes that have emerged due to the need to reduce anthropogenic CO2 emissions.

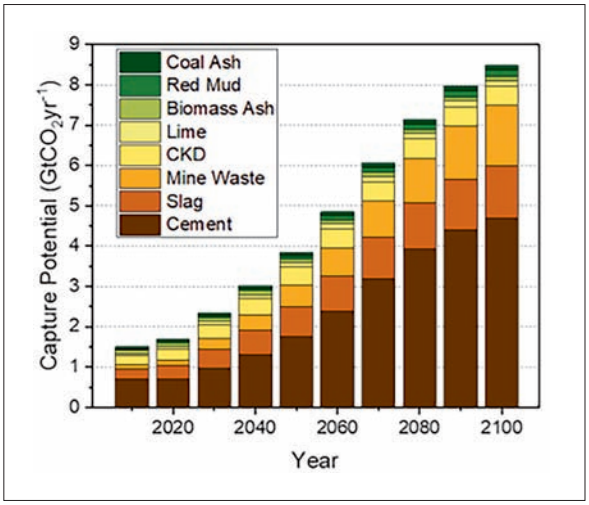


Figure 1 - CO2 capture potential of alkaline materials for the baseline shared socioeconomic pathway (SSP) where the world follows a path in which social, economic and technological trends do not shift markedly from historical patterns (SSP-2). (Source: Adapted from Renforth, 2019)

Lastly, the production of cement and aggregate are considered by some to be the largest near term opportunity for CO2 utilisation in terms of potential for emissions reduction and market size. Many start-ups focus on carbonated aggregates and CO2-cured concrete technologies, with Solidia, Carbon8 systems and CarbonCure being near or having achieved commercial deployment.

Advances in CO2 storage

Geological sequestration is relatively well understood and recent developments focus on the effect of location, monitoring methods and site characterisation. Furthermore, several studies recently focused on estimating storage capacity and showed that this is not a limitation.

Future research should focus on developing a deeper understanding of impurities and their effect on CO2 storage. In addition, it is important to develop mathematical models to mimic actual reservoir conditions and establishing databases where important information of storage sites is collated.

There has been renewed interest in EOR from unconventional reservoirs like the Bakken shale, the use of computer aided techniques for co-optimisation of oil recovery and CO2 sequestration, and the recovery of methane from methane hydrates by the exchange of CO2. There are currently 24 large-scale CO2-EOR projects in various stages of development.

Despite EOR being a long-established technology, CO2 monitoring, quantifying, and reporting standards must be improved to validate the potential emissions benefit to meet climate change targets.

Carbon mineralisation is a long-term and non-toxic method of storing CO2 in solid form which has the potential to mitigate health and environmental hazards in specific contexts. Carbonation of alkaline industrial wastes reduces chemical contamination and hence environmental hazards (Fig 1).

Next articles

This is a series of articles summarising recent key reports from The Catalyst Group Resources' Carbon Dioxide Capture and Conversion (CO2CC) Program. Look out for "Permanent Sequestration of CO2 in Industrial Wastes/Byproducts" in the next issue.

More information

More information about this report and other services of the CO2CC Program can be found at:

www.catalystgrp.com/tcg-resources/member-programs/co2-capture-conversion-co2cc-program/

Open letter: NGOs call for an EU Carbon Capture and Storage strategy

10 leading NGOs have called on the EU, demonstrating a coalition of like-minded European environmental groups which recognise the importance carbon capture and storage will have in meeting climate goals.

The letter, written by leading NGOs including Bellona Europa and the Clean Air Task Force, underscores the need for a policy framework for carbon capture and storage based on a robust set of guiding principles and safeguards to facilitate the deployment of this critical infrastructure for industrial decarbonisation at scale by 2030.

The coalition of signatories spreads well beyond Brussels, with signatory groups from no less than five Member States across various regions including the Netherlands, Denmark, Romania, Poland, and Germany, highlighting the need for carbon capture and storage deployment across the continent.

"As the Fit for 55 package nears completion, the CCS discussion has reignited in the EU as it has become clear that it will be needed to cut emissions fast," begins the letter.

"As CCS moves from planning to deployment, in part with the aid of the EU Innovation Fund, the need for a policy framework, based on a robust set of guiding principles and safeguards, is needed to facilitate the deployment of critical infrastructure for industrial decarbonisation at scale by 2030."

"Deployment of CCS in Europe should prioritise high-value applications, and hard-to-electrify industrial processes with unavoidable process emissions, while also implementing appropriate guardrails. These are necessary to achieve greater public acceptance."

"We welcome the European Commission's announcement to publish its Communication on the Strategic Vision on CCUS in early 2023. However, the European Commission's recently published Work Programme for 2023 excludes plans to publish said Communication."

"We strongly urge the Commission to grant such a Communication priority, in line with the need and urgency expressed by CCS stakeholders at the CCUS Forum and the commitment made by European Commission officials present."

"The European Commission is uniquely placed to facilitate high-level strategic leadership in the deployment of CCS in Europe. As various EU Member States such as Denmark and Germany have prepared or are preparing their own national strategies to accelerate CCS deployment, it is imperative that regional and international factors are accounted for in order to ensure consistency is maintained on CCS deployment in the EU."

Recommendations for the EU strategy

- Focus explicitly on delivering climate neutrality. CCS cannot be used as a distraction from the need to reduce emissions to the maximum extent possible, including upstream emissions. Exposure to the full price of the EU ETS should remain the primary tool to encourage industrial emitters to decarbonise in line with the "polluter pays" principle.
- To ensure a climate benefit is maintained, prioritise the permanent storage of CO2 in geologic reservoirs or products where CO2 is permanently chemically bound.
- Establish clear definitions for CCS, Carbon Capture and Utilisation (CCU) and Carbon Dioxide Removals (CDR) to avoid conflation of the concepts and their associated trade-offs.
- Ensure only sustainable uses of biomass for CCS/CDR by taxing biomass according to its actual environmental impact until proper regulation of loss of carbon stocks and biodiversity in forests is in place.
- Introduce rigorous standards, monitoring and certification mechanisms for permanence of storage, as well as clear liability provisions for stored CO2 that is released into the atmosphere. Bring into alignment funding provisions for CCS technologies with the magnitude of scale-up required to meet specific milestone targets outlined in the said Communication.
- Set appropriate deployment conditions which can act to accelerate scale up of CCS in the near term without disincentivising emissions reductions by other means, such as direct electrification or efficiency improvements. This could include a commitment to provide sufficient, accessible and fairly distributed capacity to permanently store CO2 across Europe, especially for those sectors where there are no immediate decarbonisation alternatives.
- Establish specific and verifiable emissions reduction targets in line with 2050-relevant emission reduction pathways to provide clarity on the overall direction for CCS stakeholders.
- Outline the development of CO2 capture and storage hubs, working towards a publicly regulated and open-access European CO2 infrastructure network, enabling all modes of transport, to ensure the capture, transport and permanent storage of CO2.

More information

www.bellona.org

$3.7 billion in funding to develop U.S. CO2 removal hubs

Four bipartisan infrastructure law programs will aid the commercialization of technologies to remove CO2 directly from the atmosphere.

The U.S. Department of Energy (DOE) and the National Energy Technology Laboratory (NETL) launced four programs that will help build a commercially viable carbon dioxide removal industry in the United States.

The programs, funded with $3.7 billion from President Biden's Bipartisan Infrastructure Law, will help accelerate private-sector investment, spur advancements in monitoring and reporting practices for carbon management technologies, and provide grants to state and local governments to procure and use products developed from captured carbon emissions.

"No matter how fast we decarbonize the nation's economy, we must tackle the legacy pollution already in our atmosphere to avoid the worst effects of climate change," said U.S. Secretary of Energy Jennifer M. Granholm. "President Biden's Bipartisan Infrastructure Law provides the transformative investments needed to scale up the commercial use of technologies that can remove or capture CO2, which will bring jobs to our regions across the country and deliver a healthier environment for all Americans."

In addition to this funding through the Bipartisan Infrastructure Law, President Biden's Inflation Reduction Act features improvements to the federal Section 45Q tax credit for the capture and geologic storage of CO2, which will provide substantial complementary incentives. DOE's analysis estimates that actions taken through the Inflation Reduction Act and the Bipartisan Infrastructure Law will drive 2030 economy-wide greenhouse gas emissions to 40% below 2005 levels.

DOE is announcing new efforts from the Bipartisan Infrastructure Law:

• Direct Air Capture Commercial and Pre-Commercial Prize – DOE's Office of Fossil Energy and Carbon Management (FECM) is announcing the Direct Air Capture Prize for support and prize awards totaling $115 million to promote diverse approaches to direct air capture. The Direct Air Capture Pre-Commercial Prize provides up to $15 million in prizes to incubate and accelerate research and development of breakthrough direct air capture technologies. The Direct Air Capture Commercial Prize provides up to $100 million in prizes to qualified direct air capture facilities for capturing CO2 from the atmosphere. Read the full Direct Air Capture Prize Competitions announcement here.

• Regional Direct Air Capture Hubs – DOE's Office of Clean Energy Demonstrations (OCED), in partnership with FECM, is announcing the Regional Direct Air Capture Hubs program. DOE will invest $3.5 billion to develop four domestic regional direct air capture hubs, each of which will demonstrate a direct air capture technology or suite of technologies at commercial scale with the potential for capturing at least 1 million metric tons of CO2 annually from the atmosphere and storing that CO2 permanently in a geologic formation or through its conversion into products. The first funding opportunity announcement under this program released today makes available more than $1.2 billion to begin the process for conceptualizing, designing, planning, constructing, and operating direct air capture hubs, with additional opportunities expected to follow in the coming years. Read the full funding opportunity announcement here.

• Carbon Utilization Procurement Grants – FECM will manage the Carbon Utilization Procurement Grants Program, which will provide grants to states, local governments, and public utilities to support the commercialization of technologies that reduce carbon emissions while also procuring and using commercial or industrial products developed from captured carbon emissions. The Notice of Intent released today informs stakeholders of DOE's intent to announce the first FOA issuance, which will provide grants totaling up to $100 million. Read the Notice of Intent here.

• Bipartisan Infrastructure Law Technology Commercialization Fund (TCF) -– DOE's Office of Technology Transitions (OTT), in partnership with FECM, will issue a Lab Call to accelerate commercialization of carbon dioxide removal technologies, including direct air capture, by advancing measurement, reporting, and verification best practices and capabilities. OTT anticipates awarding $15 million to projects led by DOE National Laboratories, plants, and sites, and supported by diverse industry partnerships spanning the emerging carbon dioxide removal sector. Visit OTT's TCF Lab Call webpage here.

DOE's Commitment to Carbon Capture Innovation

The Bipartisan Infrastructure Law programs support the goals of DOE's Carbon Negative Shot initiative, which calls for innovation in carbon dioxide removal pathways that will capture CO2?from the atmosphere and store it at gigaton scales for?less than $100/net metric ton of CO2-equivalent. They also contribute to U.S. responsibilities under the Carbon Dioxide Removal Launchpad, a coalition of countries that has committed to leveraging collective resources and best practices to accelerate innovation and cost reductions across a portfolio of carbon dioxide removal technologies.

The Carbon Dioxide Removal Launchpad members each agreed to build at least one 1,000+ ton/year carbon dioxide removal project by 2025, contribute to cumulative investment of $100 million collectively by 2025 to support demonstration projects, and support efforts to advance robust measurement, reporting, and verification.

Since January 2021, DOE has invested more than $250 million in 62 research and development projects and front-end engineering design studies to advance carbon management approaches that include carbon dioxide removal and carbon utilization projects.

More information

www.energy.gov

Projects and policy news

Adnoc invests $15 Billion in low carbon solutions

www.adnoc.ae

$15 billion has been allocated for landmark decarbonization projects by 2030 including carbon capture, electrification, new CO2 absorption technology and enhanced investments in hydrogen and renewables.

The announcement follows the guidance by ADNOC's Board of Directors in November 2022 to accelerate delivery of its low-carbon growth strategy and the approval of its Net Zero by 2050 ambition. This builds on ADNOC's strong track record as a leading lower-carbon intensity energy producer, which includes its use of zero carbon grid power, a commitment to zero flaring as part of routine operations and deployment of the region's first carbon capture project at-scale.

Acting on the Board's guidance, ADNOC has allocated $15 billion (AED55 billion) to advance an array of projects across its diversified value chain by 2030. These projects will include investments in clean power, carbon capture and storage (CCS), further electrification of its operations, energy efficiency and new measures to build on ADNOC's long-standing policy of zero routine gas flaring. ADNOC will apply a rigorous commerical and sustainability assessment to ensure that each project delivers lasting tangible impact.

Throughout 2023, a suite of new projects and initiatives will be announced, including a first-of-its-kind CCS project, innovative carbon removal technologies, investment in new, cleaner energy solutions and strengthening of international partnerships. Together with the recent formation of the ADNOC's new Low Carbon Solutions and International Growth Directorate, these represent tangible and concrete action as the company reduces its carbon intensity by 25% by 2030 and moves towards its Net Zero by 2050 ambition.

Building on ADNOC's Al Reyadah facility, which has the capacity to capture up to 800,000 tons of CO2 per year, the company will announce plans to deploy technologies to capture, store and absorb CO2 by leveraging the UAE's geological properties while preparing for its next major investment to capture emissions from its Habshan gas processing facility. Combined with ADNOC's planned expansion of its carbon capture capacity to 5 million tons per annum (mtpa) by 2030, the UAE will be firmly established as a worldwide hub for carbon capture expertise and innovation.

ADNOC's expansion of CCS is planned to support the significant scale-up of hydrogen and lower-carbon ammonia production capabilities in Abu Dhabi as ADNOC advances a world-scale 1 million tons per annum (mtpa) blue ammonia production facility at TA'ZIZ, the industrial services and logistics ecosystem that is enabling the expansion of the Al Ruways Industrial City, as well as Abu Dhabi's wider chemicals, manufacturing and industrial sectors. To-date, ADNOC has already delivered test cargoes of low-carbon ammonia to Europe and Asia.

ADNOC's expansion of its new energy portfolio will largely be delivered through its stake in Masdar, the UAE's clean energy powerhouse with over 20 gigawatts (GW) of clean energy today and plans to increase its capacity to 100 GW by 2030. Masdar is also spearheading the UAE's drive to develop a leading position in green hydrogen.

Detailed evaluation to begin on Pathways Alliance proposed carbon storage hub

pathwaysalliance.ca

The Pathways Alliance, representing Canada's largest oil sands producers, has entered into a Carbon Sequestration Evaluation Agreement with the Government of Alberta.

The agreement enables the Alliance to immediately start a detailed evaluation of its proposed geological storage hub which would be one of the world's largest carbon capture and storage (CCS) projects. This will help further assess the geological characteristics and properties of the deep underground CO2 storage formation.

"This agreement marks another significant milestone on the road to finalizing plans for our proposed CCS project in northeastern Alberta and achieving our goal of reaching net zero emissions by 2050 to help Canada meet its climate commitments," said Kendall Dilling, President of the Pathways Alliance.

The agreement paves the way to start the detailed testing required to further assess sequestration suitability, with field work set to start this winter.

This testing – and existing information collected by Pathways Alliance companies with operations in the area – will help with field development plans to support the final application for a storage agreement and further regulatory approvals.

The proposed carbon storage hub would be connected to a transportation line that would initially gather captured CO2 from an anticipated 14 oil sands facilities in the Fort McMurray, Christina Lake and Cold Lake regions. The plan is to grow the transportation network to include over 20 oil sands facilities, and to accommodate other industries in the region interested in CCS.

The project is critical to achieving Pathways Alliance's plan to reduce CO2 emissions from its member companies' oil sands operations by 22 million tonnes by 2030 and enabling the goal of net zero by 2050.

Engagement is ongoing with local stakeholders and First Nation and Métis communities along the proposed CO2 transportation line and storage network.

Launched in 2021, Pathways Alliance is a collaboration between Canadian Natural, Cenovus Energy, ConocoPhillips Canada, Imperial, MEG Energy and Suncor Energy, which together operate approximately 95 per cent of Canada's oil sands production.

PETRONAS proceeds with Kasawari CCS Project Offshore Sarawak

www.petronas.com

PETRONAS has reached the Final Investment Decision (FID) for the development of its Kasawari CO2 Sequestration project offshore Sarawak.

The CCS project, located in Block SK316 about 200 kilometres off Bintulu, is expected to reduce carbon dioxide volume emitted via flaring by 3.3 MtCO2e annually, making it one of the largest offshore CCS projects in the world.

The project aspires to pave the way forward for future decarbonisation plans for PETRONAS and Malaysia, as well as to support PETRONAS' progress towards achieving its Net Zero Carbon Emission (NZCE).

Researchers use machine learning to forecast amine emissions

Researchers have developed a machine learning approach to accurately predict potentially harmful amine emissions from carbon capture plants. The team from Heriot-Watt University and the Swiss Federal Institute of Technology Lausanne (EPFL) have had their findings published in the academic journal Science Advances.

Amine compounds are already used to capture carbon dioxide from natural gas processing and refining plants as well as in certain pharmaceuticals, epoxy resins, and dyes.

The problem is that amines could also be potentially harmful to the environment as well as a health hazard, making it essential to mitigate their impact. This requires accurate monitoring and predicting of a plant's amine emissions, which has proven to be no easy feat since carbon capture plants are complex and differ from one another.

A group of scientists has come up with a machine learning solution for forecasting amine emissions from carbon capture plants using experimental data from a stress test at a plant in Germany. The work was led by the groups of Professor Susana Garcia at The Research Centre for Carbon Solutions (RCCS) at Heriot-Watt University in Scotland and Professor Berend Smit at EPFL's School of Basic Sciences in Switzerland.

The experiments were done in Niederhau?en, on one of the largest coal-fired power plants in Germany. And from this power plant, a slipstream is sent into a carbon capture pilot plant, where the next generation of amine solution has been tested for over a year.

Professor Susana Garcia, Associate Director of Carbon Capture and Storage at RCCS, together with the plant's owner, RWE, and TNO in the Netherlands, developed a stress test to study amine emissions under different process conditions.

Professor Garcia describes how the test went, "We developed an experimental campaign to understand how and when amine emissions would be generated. But some of our experiments also caused interventions of the plant's operators to ensure the plant was operating safely."

These interventions led to the question of how to interpret the data. Are the amine emissions the result of the stress test itself, or have the interventions of the operators indirectly affected the emissions?

L-R: Prof. Susana Garcia and Dr Charithea Charalambous during the experimental campaign at Niederhauβen carbon capture plant in Germany

This was further complicated by the general lack of understanding of the mechanisms behind amine emissions.

To solve that challenge, the team of researchers developed a machine learning approach that turned the amine emissions puzzle into a pattern-recognition problem. In that way, they could predict the emissions caused by the interventions of the operators and then disentangle them from those induced by the stress test. In addition, they could use the model to run all kinds of scenarios on reducing these emissions.

The conclusion was described as "surprising". As it turned out, the pilot plant had been designed for pure amine, but the measuring experiments were carried out on a mixture of two amines: 2-amino-2-methyl-1-propanol and piperazine (CESAR1). The scientists found out that those two amines actually respond in opposite ways: reducing the emission of one actually increases the emissions of the other.

Professor Garcia concluded, "The potential impact of this work is enormous. We have been able to successfully forecast amine emissions from carbon capture plants that use the most advanced and latest state-of-the art amine-based technologies. This type of forecasting proved to be very challenging with any of the conventional approaches, so it may change the way we operate industrial plants."

"This work also highlights the key importance of having multidisciplinary teams if we want to successfully address global challenges."

"Machine learning for industrial processes: Forecasting amine emissions from a carbon capture plant" is published in Science Advances Vol. 9 No. 1.

More information

www.science.org

www.hw.ac.uk

KC8 to demonstrate cement carbon capture in Australia

Labelled the PACER (Potassium Carbonate Absorption for Clinker Emissions Reduction) project, Cement Australia will support KC8 Capture Technologies in scaling up their technology with the aim to make carbon capture affordable and sustainable for a greener global future.

The partnership will see KC8 design, construct, and install a demonstration plant to capture CO2 at Cement Australia's fully operational cement facility in Gladstone, QLD.

Cement Australia's CEO, Rob Davies said, "The PACER project objectives directly support Cement Australia's decarbonisation roadmap and pathway to net zero carbon emissions. We are excited to see the project get underway - it is key part of a number of complimentary initiatives Cement Australia is progressing as part of its decarbonisation priorities. The capture and use of CO2 into value added products is a strategic pillar of Cement Australia's decarbonisation roadmap."

KC8 said it has developed one of the most sustainable, cost effective, solvent-based carbon capture processes available today - the system has the potential to capture up to 95 percent of carbon dioxide emissions from heavy industry sources, such as cement plants, power stations and other large CO2 emitting industries.

The plant is estimated to be constructed by Q2 2023, with testing and full plant operation to follow.

A recent report produced on behalf of the Australian Cement and Concrete industries by VDZ, recommends that carbon capture in cement production be integrated into the national carbon capture plan. The PACER project addresses this recommendation, using new technology to capture carbon from an operational cement facility in Australia. If successful, the captured carbon will form a key input into value added products such as green methanol.

KC8 Executive Director, Greg Ross said, "We believe our carbon capture technology will provide an affordable pathway to reduce greenhouse gas emissions from the use of fossil fuels and heavy industries around the world. And we are very excited to partner with Cement Australia, as having access to their cement facility will become ground zero for having a larger impact both here in Australia and overseas."

KC8 Capture Technologies is installing a demonstration plant to capture CO2 at Cement Australia's plant in Gladstone, Queensland

Making carbon capture affordable

Fully developed in Australia from laboratory to pilot plant stage, the PACER project will be the final step in the full commercialisation of KC8's solvent-based capture process before launching globally. After 15 years in development, Mr Ross says the process has delivered proven and superior benefits over traditional solvent capture technology.

"Today's large-scale commercial CO2 capture processes use amine-based solvents. These are costly, have high energy usage and experience solvent degradation problems. KC8 has solved this issue. Our solvent is safe, easy to use and not harmful to the environment. The process is also 40% more cost effective, uses less equipment and has an overall lower carbon footprint." said Mr Ross.

Beyond Australia, large CO2 emitters could soon have a unique opportunity to utilise the KC8 capture process. The company hopes its system will help customers meet their emissions initiatives by retrofitting the technology into existing plants or integrating into new facilities from the design stage.

"We have a significant commercial opportunity to provide our low cost, eco-friendly capture process to industries required to meet green initiatives. And beyond Australia, we are actively engaged in multiple discussions, including with the U.S. Department of Energy" he said

More information

kc8capture.com

www.cementaustralia.com.au

An integrated, net-negative system captures carbon and produces ethylene

Engineers at the University of Illinois Chicago have built a machine that captures carbon from flue gas and converts it to ethylene.

The device integrates a carbon capture system with an ethylene conversation system for the first time. And, the system not only runs on electricity, but it also removes more carbon from the environment than it generates – making it what scientists call net-negative on carbon emissions.

Among manufactured chemicals worldwide, ethylene ranks third for carbon emissions after ammonia and cement. Ethylene is used not only to create plastic products for the packaging, agricultural and automotive industries but also to produce chemicals used in antifreeze, medical sterilizers and vinyl siding for houses, for example.

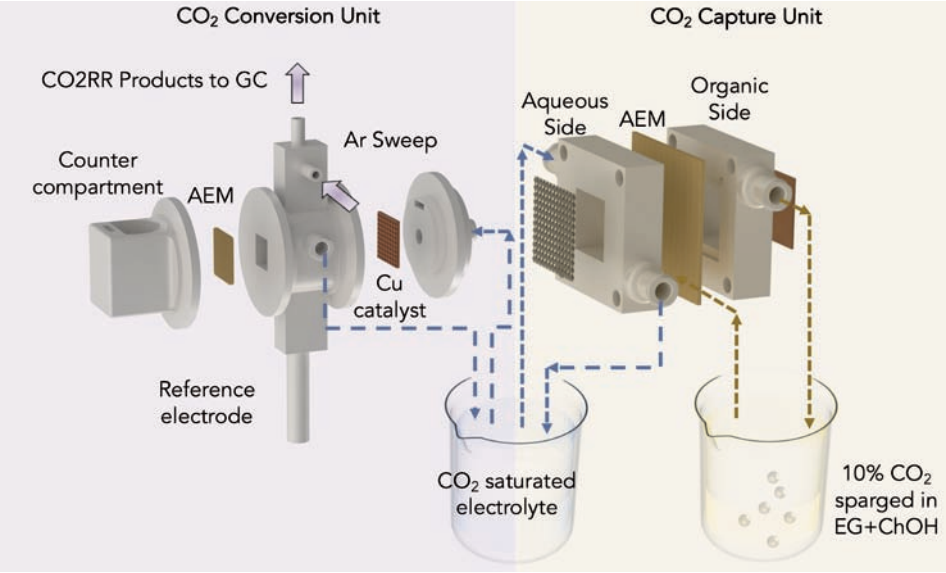
The system and the results of the UIC College of Engineering scientists' experiments are published in an Energy & Environmental Science paper titled "Fully-Integrated Electrochemical System that Captures CO2?from Flue Gas to Produce Value-Added Chemicals at Ambient Conditions."

"This is the first demonstration of a net-negative, all-electric integrated system to capture carbon from pollutants and create a highly valuable resource," said Meenesh Singh, UIC assistant professor in the department of chemical engineering.

"There is an urgent need to develop efficient technologies for integrated carbon capture and conversion to sustainably produce net-negative fuels. Currently, integrated carbon capture and conversion systems are highly energy-intensive and work in a discontinuous cycle of carbon dioxide capture and reduction. Efficiently integrating carbon capture with the conversion system eliminates the need for transportation and storage, and thereby increasing its energy efficiency."

The integrated carbon capture and conversion system developed at UIC continuously captures carbon dioxide from flue gas to produce high-purity ethylene.

To capture carbon from the air or flue gas, Singh's lab modified a standard artificial leaf system with inexpensive materials to include a water gradient — a dry side and a wet side — across an electrically charged membrane.



Schematic of the integrated system with migration-assisted moisture-gradient CO2 capture and electrochemical CO2 reduction reaction. (Image: Meenesh Singh, et al.)

On the dry side, an organic solvent attaches to available carbon dioxide to produce a concentration of bicarbonate, or baking soda, on the membrane. As bicarbonate builds, these negatively charged ions are pulled across the membrane toward a positively charged electrode in a water-based solution on the membrane's wet side. The liquid solution dissolves the bicarbonate back into carbon dioxide, so it can be released and harnessed for CO2 conversion.

The system uses a modular, stackable design that allows the system to be easily scaled up and down.

To convert captured carbon dioxide to ethylene, Singh and his colleagues used a second system in which an electric current is passed through a cell. Half of the cell is filled with carbon dioxide captured from a carbon capture system, the other half with a water-based solution. An electrified catalyst draws charged hydrogen atoms from the water molecules into the other half of the unit separated by a membrane, where they combine with charged carbon atoms from the carbon dioxide molecules to form ethylene.

The UIC researchers integrated the two systems by feeding the captured carbon dioxide solution to the carbon conversion system and recycling it back. The closed-loop recycling of solution ensures a constant supply of carbon dioxide from flue gas and its conversion to ethylene.

"In the journey to make ethylene production green, this is a potential breakthrough," Singh said. "Our next step is to scale up the integrated carbon capture and conversion system to produce ethylene at higher rates — a rate of 1 kilogram per day and capture carbon at a rate higher than kilograms per day."

More information

www.uic.edu

Using CO2 emissions from industry to make climate-friendly plastics

A research project coordinated by VTT examines the capture and utilisation of carbon dioxide from the forest industry and waste incineration in the manufacture of different types of plastic products.

Carbon from industrial emissions of carbon dioxide can be bound in the products of the plastics and chemical industries. This creates possibilities for the development of new, climate-friendly plastics and other polymeric products.

VTT has long studied the possibilities for capture and utilization of carbon dioxide in different sectors. The Forest CUMP project, which was launched in August 2022, continues this work, focusing on the carbon dioxide emissions of the forest industry and waste incineration. The intended end-products would be polyolefins – polyethene and polypropene – which are present in Finnish everyday life in many products and packaging. Today these materials are manufactured almost exclusively from fossil raw materials.

The results of the test plant can be used in the development and design of an industrial-scale plant

The Forest CUMP project aims at developing a processing concept which would enable the scaling of the technology up to the level of industrial production. An interim goal in the commercialisation of the process is to build a small test plant in a selected industrial environment in 2024.

"We can utilise the results of the test plant in the development and design of an industrial-scale plant. In addition to technological development, we are studying the applicability of different sources of CO2 and methods for capture and purification of CO2. We are also looking into the logistical angle linked with the transport and storage of the feedstocks – carbon dioxide and hydrogen – and the intermediate products – hydrocarbons", says VTT Research Professor Juha Lehtonen.

The project is being carried out in close cooperation with company partners as part of the Business Finland's Veturi ecosystems, which promote sustainable development. Borealis is one of the Veturi companies. Forest CUMP is part of Borealis' SPIRIT programme, which aims at green transition in the plastics industry.

"This is a significant development project that supports our vision, in which the carbon dioxide emissions from industry could be utilised for the production of e.g. durable plastic pipes out of them, which can bind carbon for long periods of time", says Antti Ilves of Borealis.

The project continues the work of the earlier BECCU project, which aimed at utilising carbon dioxide in the production of raw materials for polyurethane products such as insulation materials and industrial adhesives. The project developed technologies and a process concept for an entire value chain from the bioenergy production, and the capture of carbon dioxide, all the way to the production of chemicals and polymers. The Forest CUMP project is developing further the production technology of hydrocarbon intermediates developed in BECCU.

The project, funded by Business Finland, is part of Business Finland's Veturi ecosystem, which develops different kinds of solutions toward sustainable development and national carbon-neutral status together with some of the most significant Finnish companies. The project was launched in August 2022 and continues through the end of 2024. Participants in the project include the leading companies Borealis, Neste and ABB, and Metsä Spring, Kemira, Vantaa Energy, Stora Enso, Kleener Power Solutions, Carbon ReUse Finland, Fortum and Essity. LUT University is a research partner, alongside VTT.

The BECCU project was launched in 1 January 2020 and concluded in the autumn of 2022. The project received funding from Business Finland. VTT is one of the leading research organisations in Europe, with nearly 80 years of experience in cutting-edge research and science-based results. More than 2,000 professionals work to develop systemic and technological solutions that can bring about fundamental transformation.

More information

www.beccu.fi

www.vttresearch.com

Capture & utilisation news

ArcelorMittal, Mitsubishi Heavy and BHP collaborate on steel CCS

www.bhp.com
www.arcelormittal.com

They are collaborating on a multi-year trial of MHIENG's carbon capture technology with ArcelorMittal, following the signing of a funding agreement between the parties.

ArcelorMittal, Mitsubishi Heavy Industries Engineering (MHIENG), leading global resources company, BHP, along with Mitsubishi Development Pty Ltd will also conduct a feasibility and design study to support progress to full scale deployment.

The agreement, which involves a trial at ArcelorMittal's steel plant in Gent, Belgium and another site in North America, brings together the expertise of the various partners in identifying ways to enhance carbon capture and utilisation and/or storage (CCUS) technologies in the hard-to-abate steelmaking industry.

The industry is estimated to account for around seven-to-nine per cent of global greenhouse gas (GHG) emissions. CCUS has the potential to be a key technology for reducing emissions from existing global blast furnaces, which are anticipated to remain a significant portion of steel production over coming decades. The IEA estimates CCUS technology needs to apply to more than 53 per cent of primary steel production by 2050, equivalent to 700 Mtpa of CO2, for the Net Zero Emissions scenario.

There are no full scale operational CCUS facilities in blast furnace steelmaking operations at present, with only a limited number of small capacity carbon capture or utilisation pilots underway or in the planning phases globally. However, later this year ArcelorMittal Gent will commission its Steelanol project, a scale demonstration plant that will capture carbon-rich process gases from the blast furnace and convert them into ethanol.

To further understand how carbon capture technology can be incorporated into existing steel plants, ArcelorMittal is facilitating the trial at its five million-tonnes-a-year steel plant in Gent, Belgium, and at another location in North America, with MHIENG supplying its proprietary technology and supporting the engineering studies. BHP and Mitsubishi Development, as key suppliers of high-quality steelmaking raw materials to ArcelorMittal's European operations, will fund the trial that is anticipated to run for multiple years. In Gent, the trial will have two phases.

The first phase involves separating and capturing the CO2 top gas from the blast furnace at a rate of around 300kg of CO2 a day – a technical challenge due to the differing levels of contaminants in the top gas. The second phase involves testing the separating and capture of CO2 from the offgases in the hot strip mill reheating furnace, which burns a mixture of industrial gases including coke gas, blast furnace gases and natural gas.

ArcelorMittal is facilitating a trial at its five million-tonnes-a-year steel plant in Gent, Belgium

The parties plan to install the mobile test unit in one of ArcelorMittal's North American Direct Reduced Iron (DRI) plants, to test MHIENG's technology in this steelmaking route.

ArcelorMittal Belgium's Chief Executive Officer, Manfred Van Vlierberghe, said, "The decarbonisation of the steel industry is a huge challenge that we cannot solve alone: it is through pan-industry partnerships and collaboration that we will achieve ArcelorMittal's climate goals of reducing CO2 emissions by 35 per cent by 2030 in Europe, and by 30 per cent by 2030 worldwide. Alongside our continued energy efficiency improvements, we are developing two routes to decarbonize steelmaking: Smart Carbon and Innovative-DRI. Both routes will contribute in our journey to deliver carbon-neutral steelmaking. The Smart Carbon route also allows us to integrate carbon capture and re-use (CCU) or storage (CCS) technologies, capturing carbon emitted during the steelmaking process. We are therefore proud to be working with BHP, Mitsubishi Development and Mitsubishi Heavy Industries Engineering on this pioneering Carbon Capturing pilot project, in ArcelorMittal Gent."

Carbon capture activities are the largest cost component of the CCUS value chain and represent roughly two-thirds of the total capital cost and are the greatest consumer of additional energy. Improved understanding of carbon capture technology performance, cost, risk and sustainability outcomes are essential to determine its role in efforts to decarbonise the steel industry.

This latest collaboration marks a milestone in BHP's strategy to support decarbonisation efforts in steelmaking, which aims to achieve coverage of geographically diverse customer markets and potential technology pathways and follows partnerships in recent years with other global majors POSCO, China Baowu, JFE Steel, HBIS Group and TATA Steel. Collectively with ArcelorMittal, these companies account for more than 17 per cent of reported global steel production.

BHP's Chief Commercial Officer, Vandita Pant, said, "There is currently no certain or single pathway to net zero for steelmaking. CCUS is one of the key abatement technologies with potential to support development of some of those pathways, so working with industry leaders like ArcelorMittal, Mitsubishi Development and MHIENG, we hope to arrive at scalable solutions more quickly to help reduce carbon emissions in steelmaking."

"Steel is a critical product for the world to develop and decarbonise, and we must work hard, together, to enable lower GHG emissions steel, support the reduction of carbon intensity in the blast furnace and test new technologies for steel production," she added.

CSIRO takes stock of Australian carbon storage

CSIRO, Australia's national science agency, has published an assessment of 12 carbon sequestration technologies and the role they could play in helping Australia reach net zero emissions.

The report, prepared for the Climate Change Authority with co-funding from the Clean Energy Regulator, looks at a range of carbon sequestration options for supporting Australia's national emissions reduction goals.

In the report, carbon sequestration describes the process of capturing and storing carbon dioxide from the Earth's atmosphere and the management of existing carbon stocks, using natural or engineered solutions.

Co-lead author of the report, CSIRO Towards Net Zero Mission Lead Michael Battaglia, said the report brought together scientists with expertise across a range of nature-based and engineered sequestration technologies, to look at their sequestration potential, barriers to uptake, and co-benefits.

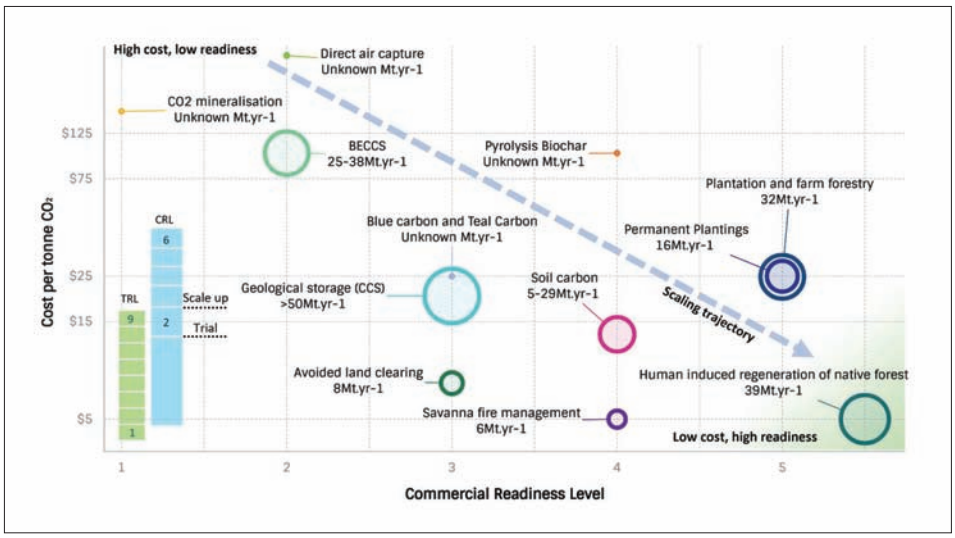
The technologies reviewed were permanent plantings, plantation and farm forestry, natural regeneration of native forest, avoided land clearing, savanna burning, soil carbon, blue carbon, pyrolysis biochar, geological storage (carbon capture and storage), bioenergy with carbon capture and storage (BECCS), direct air capture (DAC), and mineral carbonation.

"We found that nature-based technologies such as permanent plantings, plantation and farm forestry, and soil carbon currently provide significant potential; as does Australia's vast geological storage capacity," Dr Battaglia said.

"Biochar, mineral carbonation and DAC also have significant sequestration potential but are associated with higher costs. Further research and development of these technologies is needed to bring down costs and increase national sequestration potential," he said.

While the report considers the potential for each technology, it does not analyse the impact of competition for land, resources, or energy between different technologies.

These will be important considerations when it comes to implementation, as it will mean realisable sequestration is likely considerably lower than technical and economic potential sequestration estimates provided in the report.



Economic sequestration for reviewed technologies, indicating their commercial readiness level and cost per tonne. Note the anticipated scaling trajectory to the lower right corner, corresponding to low cost and high commercial readiness. Bubble size signifies the quantity of sequestration for each technology in Mt per year

Lead of CSIRO's CarbonLock Future Science Platform Andrew Lenton said to help Australia reach its emissions reduction targets, we will need to remove significant amounts of carbon dioxide from the atmosphere.

"No single technology will get us there. An integrated and optimised portfolio of technologies will be required," Dr Lenton said.

A comprehensive integrated assessment modelling approach will need to quantify potential and feasible sequestration opportunities and to guide development at the national and regional scales.

The report will inform an Insights Paper on carbon sequestration being published by the Climate Change Authority, which will help inform the advice to government on Australia's 2035 emissions reduction target.

Climate Change Authority CEO, Mr Brad Archer said understanding Australia's carbon sequestration potential will help us build greater ambition into our climate targets.

"This first ever stocktake of Australia's carbon sequestration potential provides a valuable synthesis of the current level of understanding. It also identifies ways to improve the evidence base to inform Australia's options for pathways to net zero and beyond," Mr Archer said.

"Carbon sequestration could bring many opportunities to Australia's regions and rural and remote areas, including new income streams, jobs, and valuing and protecting the knowledge and practices of First Nations Australians," he said.

More information

www.csiro.au

www.climatechangeauthority.gov.au

Horisont Energi and E.ON to further industrial-scale North Sea CO2 storage

Horisont Energi and E.ON are intensifying their existing collaboration to jointly build a European carbon value chain through the Errai project in Norway.

The companies signed a letter of intent, whereby E.ON intends to provide more than one million tons of existing CO2 per year from its European customer sites by 2030, starting from 2027 with gradual increase. Horisont Energi will provide services on CO2 marine transport and long-term storage.

Subject to license award, Horisont Energi targets to start operation of the carbon capture and storage project Errai, located in Norway. To this end, the development of a European carbon value chain will apply proven and mature technologies for capture, transport and storage of CO2 on an industrial scale.

The agreement is an important milestone in the cooperation between the two partners and for Horisont Energi's commercial CO2 transport and storage business. Horisont Energi will apply for the announced license to operate the CO2 storage Errai in the North Sea by early January. With this agreement, both Horisont Energi and E.ON position themselves as key players and Errai as a key project in the decarbonization of European industry and cities.

"It is great to take the next step towards a carbon neutral future together with our partner and shareholder E.ON. Decarbonisation can only be achieved on a European scale, with integrated value chains and large-scale CO2 removal solutions. Today's agreement is a significant step, not only for the realization of the Errai project, but also for a carbon neutral European industry and society," said Bjørgulf Haukelidsæter Eidesen, CEO of Horisont Energi.

Horisont Energi plans to store four to eight million tons of CO2 annually in the first development phase of the Errai project, potentially storing more in later phases. The project includes an onshore terminal for intermediate CO2 storage, with the intention to permanently store the CO2 in an offshore reservoir. With the current plans the Errai project will develop the second CO2 terminal in Norway. It was initiated by Horisont Energi in 2021, and CO2 storage is expected to start in 2026.

Horisont Energi and E.ON entered a strategic cooperation agreement in January 2022 for the development of a Europe-wide range of services for the capture, transport and storage of carbon dioxide, and the establishment of corresponding value chains. Horisont Energi shall be responsible for transport and storage, E.ON for carbon capture and liquefaction. The service will be offered to both existing and new E.ON customers. Together with its customers in Europe, E.ON is thus decisively driving the decarbonization of European industry, business and municipalities.

More information

www.horisontenergi.no

www.eon.com

Transport and storage news

EU funds for Air Liquide, Port of Antwerp-Bruges, Fluxys Belgium CO2 export hub

www.airliquide.com

The EU Commission announced it will grant Air Liquide, Fluxys Belgium and Port of Antwerp-Bruges €144.6 million under the Connecting Europe Facility for Energy (CEF-E) funding program.

The funding is earmarked for the construction of shared CO2 transport and export facilities on the Antwerp port platform. The grant award is a major step towards the final investment decision, expected in 2023.

The project, named "Antwerp@C CO2 Export Hub", is set up as an open-access infrastructure to transport, liquefy and load CO2 onto ships for onward permanent offshore storage. CO2 captured on industrial players sites on the Antwerp port platform will be collected and transported via an intra-port open-access pipeline network.

A shared liquefaction and export terminal will be built, including a CO2 liquefaction unit, buffer storages and marine loading facilities for cross-border shipping. This innovative project will be among the first and largest multimodal open access CO2 export facilities in the world.

As part of the project, Air Liquide and Fluxys intend to form a joint venture for the construction and operation of the CO2 liquefaction and export terminal. The joint venture will benefit from Air Liquide's expertise in CO2 liquefaction and handling and from Fluxys' experience in terminalling activities. Air Liquide will provide its proprietary technology for the CO2 liquefaction plant, which will be a first of a kind in its scale and design. The Port of Antwerp-Bruges reserved a plot of land for the terminal on a strategic location inside the port, and will build new quay infrastructures for the mooring of CO2 ships.

The project is the first phase of Antwerp@C, an initiative gathering Air Liquide, BASF, Borealis, ExxonMobil, INEOS, TotalEnergies, Fluxys and Port of Antwerp-Bruges with the ambition to halve the CO2 emissions in the Antwerp port area by 2030. In this first phase, Air Liquide and BASF will be the launching customers of the export hub through their joint CO2 capture and storage project "Kairos@C".

The Antwerp@C CO2 Export Hub will have an initial export capacity of 2.5 million tonnes per annum (Mtpa), with the ambition to reach up to 10 Mtpa by 2030. It will pave the way for future CCS initiatives in the region by providing scalable and modular infrastructures accessible to all industrial players.

Pascal Vinet, Senior Vice President and a member of Air Liquide's Executive Committee, supervising notably Europe Industries activities, said, We are very pleased that the Antwerp@C CO2 Export Hub project, supported by innovative Air Liquide technologies, has been selected by the Connecting Europe Facility for Energy program."

"Alongside the use of renewable energy, carbon capture technology is essential to achieve in a short time frame massive CO2 reductions and carbon neutrality objectives namely for hard-to-abate sectors. This initiative illustrates Air Liquide's expertise and ambition to actively contribute to the emergence of a low-carbon society and to support its industrial customers in their decarbonization strategies."

Ardmore Shipping makes tanker carbon capture ready with Value Maritime

valuemaritime.com

Product and chemical tanker company Ardmore Shipping Corporation has placed an order for Value Maritime's emissions-reducing Filtree system for an initial six vessels.

The tankers will be made carbon capture ready for collecting CO2 emissions onboard in the future. Taking place during regularly scheduled drydocks, the Filtree units will be installed in yards in Europe and Asia. Timing installations in this way ensures zero disruption to the commercial activities of Ardmore's vessels.

The Filtree system is based on innovative technology that will filter sulphur, CO2 and 99% of ultra-fine particulate matter from the tankers' exhaust stream. The system uses a Clean Loop mechanism which additionally filters its own washing water, removing oil residues and particulate matter, ensuring the pH neutral value of the water and contributing to reduced acidification of seas and rivers.

Ardmore Shipping is looking for sustainable solutions for its fleet, now and for the future. Due to the Filtree system's removal of sulphur from the exhaust gas flow, Ardmore can cut its emissions today while continuing to sail with more cost-effective high-sulphur fuel.

Additionally, this positively affects the vessel's performance and maintenance requirements. As a direct result, the Filtree system offers a rapid return on investment.

Value Maritime has designed the Filtree as a plug and play system. The Filtree system to be installed on the Ardmore tankers will be outfitted with a modular CO2 capture and storage system to help reduce further emissions when this becomes viable. With this, CO2 is captured from a vessel's exhaust and stored in tanks onboard. This is then discharged onshore where it can be used, for example, in the sustainable cultivation of greenhouse crops, methanol plants, and even the food industry.

ABS sets requirements for onboard carbon capture

ww2.eagle.org

Working with shipyards, ship owners and operators, ABS has developed an industry-leading set of requirements to guide the industry in the application of carbon capture technology at sea.

Experience and insight derived from pioneering carbon capture projects with stakeholders such as shipyards, ship owners and original equipment manufacturers (OEMs) have informed development of the ABS Requirements for Onboard Carbon Capture.

"Carbon capture could be a key transformational technology for shipping to achieve net-zero emissions by 2050," said Georgios Plevrakis, ABS Vice President, Global Sustainability.

"ABS is working with leading organizations to support safe development of the technology, which is still maturing but shows genuine promise. The requirements we have developed are a key step toward harnessing the potential of carbon capture to tackle the challenge of the energy transition for our industry."

The requirements also include an optional Ready notation for vessels based on their level of preparation, or readiness, for future OCCS installations.

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