Carbon Capture Journal

CCUS in Canada

Maintaining the momentum to achieve massive CCS opportunity

Canada-UK collaboration critical for climate action

Deep Sky testing Skytree and Avnos DAC units

May / June 2024 Issue 99

enfinium invests £200m in UK CO2 capture from waste plant

Image: enfinium

- Study finds port readiness key to onboard carbon capture
- A comparative look at DAC and CO2 capture from biogas upgrading
- The critical mix of finance, technology and policy for green investment
- A transformative approach to carbon emissions management - AspenTech

ECO-AI workshop and hackathon fuels innovation in CCS

From March 11th to March 15th, 2024, Heriot-Watt University hosted a novel collaborative event aimed at harnessing the power of artificial intelligence (AI) to tackle the challenge of achieving Net Zero through CCS, underscoring the importance of collaboration, innovation, and determination in building a more sustainable world for future generations.

The ECO-AI Workshop and hackathon brought together a diverse array of researchers, professionals, and students keen to learn about using AI-driven solutions to combat climate change and achieve Net Zero targets.

Professor Ahmed H. Elsheikh from the School of Energy, Geoscience, Infrastructure and Society at Heriot-Watt University is the project lead. "The ECO-AI Workshop and Hackathon signifies a significant stride forward toward Net Zero goals," he said. "By integrating AI, we're delving into promising territory for sustainability. It's a reminder that with concerted effort and persistence, we're making tangible progress in tackling the complexities of carbon capture and storage."

Exploring AI Solutions for CCS

The two-day workshop kicked off with sessions led by experts from the ECO-AI project team at Heriot-Watt University and Imperial College London. Participants delved into a wide range of topics during the AI4NZ project talks and academic presentations. These included discussions on digital twins and decision making for Net Zero under uncertainty, as well as incorporating surrogates into large-scale deterministic optimisation models for integrated decision-making in complex systems.

Academic talks covered topics such as Hybrid AI and physical modelling for accurate and rapid environmental prediction and management, optimizing carbon capture using molecular- and macro-scale modelling, data, and AI/ML, and upscaling the porosity–permeability relationship of a microporous carbonate for Darcy-scale flow with machine learning.

In the industry talks, themes ranged from AI for science with a focus on applications to imaging and large-scale experiments to discussions on SSE thermal's vision for CCUS in the UK. Other topics included measurements, monitoring & verification of a CCS site: insights and technology developments, as well as the AI potential in CCS Deployment from an 'industrial' perspective.

"The ECO-AI Workshop and Hackathon signifies a significant stride forward toward Net Zero goals. By integrating AI, we're delving into promising territory for sustainability" - Professor Ahmed H. Elsheikh from the School of Energy, Geoscience, Infrastructure and Society at Heriot-Watt University

Throughout these discussions, attendees explored innovative AI applications, including AI materials discovery for energy-efficient CO2 capture and AI-solvers for modelling CO2 flow in geological storage formations. Special guest speakers from other UKRI-funded projects under the AI for NetZero research initiative provided valuable insights, fostering collaborative learning and knowledge exchange.

Following the workshop, participants embarked on a three-day hackathon, where they were challenged to work on unique problems related to CO2 capture, CO2 storage, and CCS policy and economics. Teams consisting of PhD students, and post-doctoral research associates from across the UK collaborated to develop AI-driven solutions. With access to tools, support, and data provided by Heriot-Watt University and Imperial College London experts, participants tackled challenges such as materials discovery, subsurface flow modelling, and clustering of CCS patents all using AI.

The event provided opportunities for networking and collaboration, allowing participants to connect with leading scientists, professionals, and industry experts in the field of environmental sciences. Through discussions and mentorship sessions, attendees gained insights into AI's role in achieving Net Zero targets and addressing the challenges of CCS technologies.

Peter Cummings, Bicentennial Professor in the School of Engineering and Physical Science, said, "This workshop shows how the ECO-AI project is contributing to the broader goals of reaching net zero greenhouse gas emissions by harnessing the tools of artificial intelligence and machine learning. It fits in very well with our university-wide goals in net zero."

Cummings is co-leader of the Heriot-Watt Global Research Institute for attaining Net Zero and Beyond (iNetZ+), an interdisciplinary institute established by Heriot-Watt in 2023. iNetZ+ will bring in 55 new academic staff and over 30 support staff during the next 5-7 years.

More information

Read more at:
www.hw.ac.uk

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

Editor
Keith Forward
editor@carboncapturejournal.com

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

Subscriptions
subs@carboncapturejournal.com

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

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Front and back cover: enfinium's Parc Adfer energy from waste facility in North Wales could capture up to 235,000 tonnes of carbon dioxide every year. With CCS installed, Parc Adfer will support the Welsh Government's ambition to have 100% zero carbon power by 2035 and support over 1,000 jobs in the green economy. (pg. 21)

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Canada has a massive carbon capture and storage opportunity

A research report from Clean Prosperity's Net-Zero Pathways for Canada project examines the potential of CCUS technology to address emissions from Canada's major industrial sectors, mapping storage resources and industrial emissions across the country.

CCUS is emerging as an important opportunity in Canada's path towards net zero. Altogether, industry produced over 317 megatonnes (Mt) of emissions in 2021, almost half of Canada's total.

Canada has rich potential for geological carbon storage — approximately 389 gigatonnes of prospective onshore storage, located mostly in Saskatchewan, Alberta, and Manitoba. That's almost 600 times the mass of Canada's total 2021 emissions.

"Evaluation of carbon capture and storage potential in Canada," looks at the expanded use of saline aquifers for permanent carbon dioxide storage in five key Canadian provinces: British Columbia, Alberta, Saskatchewan, Ontario, and Quebec.

To assess the potential for using CCUS to decarbonise industry in these provinces, the report maps the locations and emissions of high-emitting industrial facilities that could integrate CCUS technology.

These facilities are grouped according to their distance to potential geological storage basins, and to functioning or planned infrastructure for CO2 transport and injection.

Key findings by province

• Most of British Columbia's prospective geological storage is in the province's remote northeast region. Only about 1.2 Mt, or 20%, of the province's industrial emissions are close to storage, suggesting that CCUS applications are currently limited without the discovery of new storage basins, the development of new technologies, or the construction of CO2 pipelines.

• Alberta has significant opportunities to leverage its 79,000 Mt of geological storage and existing CCUS infrastructure to help decarbonize sectors like the oil sands and utilities. Currently many high-emitting facilities are located close to storage, as well as to CO2 transport and injection infrastructure. The theoretical emissions capture potential from current industrial sources in Alberta could be as high as 104 Mt per year, equivalent to more than 40% of the province's total 2021 emissions. To realize this potential, proposed infrastructure needs to be developed, including capture facilities, pipelines, and injection hubs.

• Saskatchewan overlies 290,000 Mt of prospective storage, which represents 70% of Canada's estimated total geological storage potential. The province also has a history of developing CCUS infrastructure. Industrial emitters are scattered geographically, which may present challenges for the development of shared infrastructure. But with its significant storage resources, Saskatchewan could be a particularly attractive destination for developing a large-scale atmospheric carbon dioxide removal sector.

• Ontario's CCUS potential is significantly constrained by the province's limited geological storage, estimated at 730 Mt. Ontario lacks existing CCUS infrastructure, and would have to make significant investments to capture and store its 31 Mt per year of industrial emissions. With such limited storage potential, the Ontario basin could reach capacity by 2060-2075, so a CCUS development strategy in this province needs to be selective and balanced with other emissions reduction measures.

• Quebec has significant geological storage resources (up to 3,200 Mt), and 44%, or 6.4 Mt, of point-source emissions located above storage. Like Ontario, Quebec currently lacks carbon management infrastructure. Given the relatively low volume of emissions from large point-sources in the province, CCUS development should be evaluated alongside other decarbonization opportunities, or in tandem with atmospheric carbon dioxide removal.

Existing and planned infrastructure that can support CCUS in Canada

The CCUS sector is under active development in Canada, principally in Alberta and Saskatchewan. Up to 4 Mt per year of CO2 is currently captured for use and geological storage, and the federal Carbon Management Strategy estimates that 16 Mt per year can be stored by 2030 based on existing policy commitments and assumptions regarding the timing of project investment decisions, approvals, and construction.

As it is often not technically and/or economically feasible to inject and store CO2 at all capture sites (i.e., at every point-source), shared transport and injection infrastructure is needed to enable capture and storage at a more extensive scale. Infrastructure that is currently in use and under development aims to allow emitters to transport CO2 via pipelines to wells that inject it into deep storage.

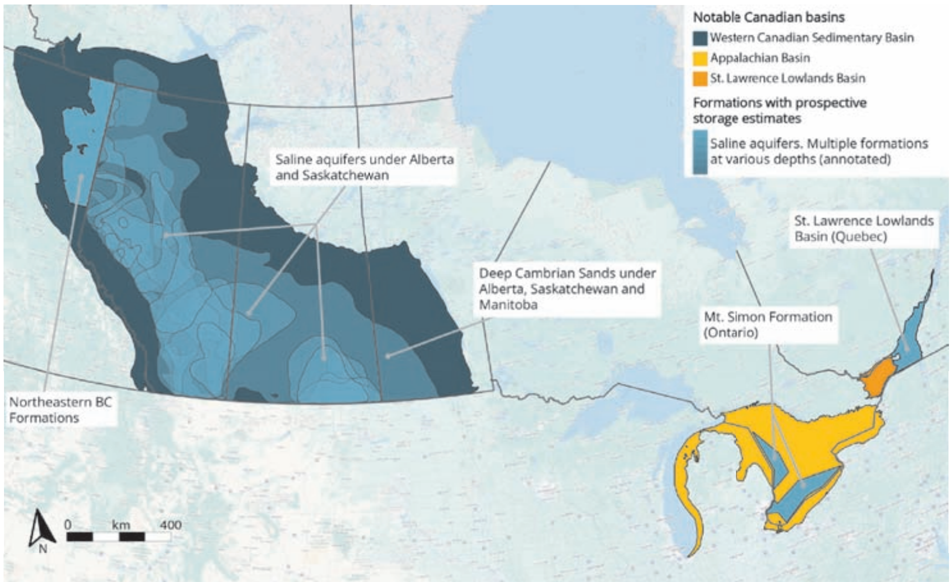
Moreover, many first-of-a-kind CCUS projects have been "full-chain" (from capture to injection) infrastructure builds involving a single developer. However, this model suffers from high investment, risk, and liability burdens that must be shouldered by the developer. More recent projects have focused on "splitting up the CCUS value chain," with shared access to underground injection and long-term storage via CCUS "hubs".

In Canada, the "open hub" model is currently the most common form of CCUS infrastructure proposed for future development. The open hub model entails open access and affordable use of the CCUS transport and saline aquifer injection infrastructure by emitters.

Conclusions

The results show that Canada has rich geological potential for long-term carbon storage in its saline aquifers, and the beginnings of larger-scale infrastructure for CO2 injection and pipeline transport. Canada's geology is projected to be able to support nearly 400 Gt of prospective storage, 99% of which is in the deep Cambrian sands spanning large parts of Alberta, Saskatchewan, and Manitoba.

The CCUS opportunity varies significantly by province and thus should be assessed at the provincial, rather than national, level. Alberta has a large CCUS opportunity. It currently has the most developed carbon management infrastructure of all of the provinces. This infrastructure can support deployment of CCUS for permanent carbon storage at a number of major point-source emission sites, as well as serve as the basis for expansion to other emitters located in relatively close proximity to these assets.



Basins in Canada that contain potential reservoirs for CCUS storage, demarcated by provincial boundaries. Formations in blue are deep saline aquifers that have been evaluated to provide prospective storage estimates

In Saskatchewan, which has 70% of Canada's prospective onshore storage potential, the relative paucity of existing point-source emissions — and the fact they are dispersed across the province — makes the economics and logistics of shared storage sites more challenging (though these challenges would be less applicable to CDR).

For Ontario, the limited basin potential characterized to date — along with the lack of existing CCUS infrastructure — suggests that the province may need a selective approach to CCUS development that is coupled with alternative means to address large point-source emissions.

In terms of sectors, our GIS analysis shows that the most near-term opportunity for CCUS exists for oil sands and electricity/cogeneration facilities in various regions across Canada, given the proximity of these sectors' facilities to onshore geological storage and, in some regions, to existing CCUS infrastructure. However, the oil sands and utilities sectors have lower concentrations of CO2 in their emissions streams, which raises the cost of capture for emitting facilities. For these facilities to be able to apply CCUS most economically, lowering the cost of transportation and storage will be important to help balance these higher capture costs.

The open hub models (that can connect a number of diverse point-sources into centralized injection sites) can help enable the economies of scale required to support CCUS capture for such sectors. Carbon capture technologies can also play a modest role in the short- to medium-term decarbonization of other economically important sectors, including oil and gas extraction outside the oil sands, manufacturing, and mining.

Although total emissions from these sectors are much lower than from oil sands and utilities (see Table below), analysis indicates that in some regions, developing CCUS for these sectors may be of interest. We note, however, that capturing these emissions would require added infrastructure buildout, due to their distance from existing/planned infrastructure.

Overall, there is significant untapped potential in Canada for CCUS deployment with respect to infrastructure and geology — particularly for the utilities and oil sands sectors. Development of this CCUS potential will require careful consideration of costs, risks, and other factors at each specific location. Such work will help better inform the role of carbon capture in Canada's near-term emission reduction opportunities and net-zero future.

	Sectors associated with major point-source emitters										
	Chemical manufacturing	Lime and cement manufacturing	Metal manufacturing	Mining	Oil and gas extraction (except oil sands)	Oil sands	Other manufacturing	Petroleum refineries	Pipeline transportation of natural gas	Pulp and paper	Utilities
Total emissions (Mt CO_2) in 2021*	6.5	12.4	21.2	5	7.9	73.8	9.6	16.4	1.2	0.4	56.4
Number of facilities	9	17	20	11	22	31	11	13	2	2	50
Within 50 km of existing infrastructure	24.6%	4.8%	1.4%	0%	3.8%	3.7%	75%	29.3%	0%	0%	13.7%
Within 50 km of proposed CO_2 pipelines, or within land areas for proposed hubs	9.2%	9.7%	0%	0%	15.2%	95.5%	0%	0%	0%	50%	41.5%
Above storage geology (no infrastructure)	50.8%	15.3%	34.4%	28%	57%	0%	5.2%	37.8%	0%	0%	20.4%
Within 50 km of existing infrastructure	15.4%	14.5%	19.8%	0%	7.6%	0.4%	15.6%	11.6%	0%	0%	4.3%
Far from infrastructure and storage geology	0%	55.6%	44.3%	72%	16.5%	0.4%	4.2%	21.3%	100%	50%	20.2%

* The 2021 data provided here is illustrative of current conditions, recognizing that emissions values (with associated proportion values) will likely change over time, especially if more mitigation measures are implemented (data source: 2021 ECCC facility emissions inventory).

Total sectoral emissions (CO2) from large point-source emitters in relation to existing/proposed carbon capture infrastructure and storage geology, Canada. Yellow boxes show the highest value for each sector, and blue boxes show the second-highest value(s).

More information

Read the full report at:
https://cleanprosperity.ca

How can Canada maintain its carbon capture momentum?

While Canada is ideally placed to to become a major carbon capture hub, it must lay solid foundations of infrastructure and work force to maintain its advantage and make good on its potential.

Co-authored by Demi Babatunde and David Bahr, Wood Consulting.

The opposing pressures of energy security, environmental sustainability and energy equity, coined the energy trilemma, have forced nations across the world to consider an energy transition to meet these needs with decarbonisation as the leading priority. In Canada though, the energy transition poses a greater challenge than it does for others. As one of the world's largest producers of fossil fuels, the energy sector is critical to its economy. As part of the Paris Agreement in 2015, Canada committed itself to net zero by 2050. Therefore, introducing carbon reduction tactics that allow its existing energy production to continue as the nation reduces its dependence on fossil fuels is essential.

To balance the opposing pressures, the nation's government has set ambitious goals to apply carbon capture technology to its existing energy production sites. Canada's current federal emissions reduction plan expects national CCS and carbon capture utilisation (CCU) capacity to triple in the next decade. Transforming Canada's energy system will require enormous investment in innovation, infrastructure, and industrial processes.

To date, Canada has been a leader in the global deployment of carbon capture projects, diversifying decarbonisation efforts across various industries such as cement, oil & gas, and mineral processing. Plans are already underway to establish facilities capable of capturing, storing, and sequestering at least 15 million tonnes of carbon dioxide annually by 2030.

However, maintaining this momentum poses challenges such as cost control, increasing its research and development capabilities, and growth in trade skills to meet increases in requirements in new infrastructure. Troubleshooting from an early stage in its development will therefore be key in avoiding these hurdles as Canada continues to advance its CCS and CCU capabilities. To maintain its momentum within the carbon capture space and ultimately address the challenges set by the energy trilemma, the nation must create a sound environment to encourage further growth and innovation within this field.

What challenges does energy transition pose to Canada's economy?

A successful energy transition will require Canada to balance investment and technology developments between the decarbonisation of existing industries and greenfield projects. Carbon capture offers a valuable solution for Canada to achieve a just energy transition which avoids large portions of its industries and workforce being shut down to achieve climate goals. Its capability to decarbonise critical industries ensures the continuous supply of energy and critical materials needed to facilitate the energy transition. Furthermore, the nation's evolving commitment to climate policy has created a pathway for the country to become a leader in CCS and CCUS deployment worldwide.

For almost three decades the nation's government has produced a myriad of climate-focused legislation aimed at decarbonising its economy. Despite this, the nation is still falling short of meeting its climate goals. As one of the world's top oil reserve holders, energy production and export accounted for approximately 9.7% of the country's GDP in 2021, with $154.3 billion worth of exports sent to 142 countries. In Canada, the oil and gas industry are at the centre of attention to decarbonise. However, a majority of the opportunities to achieve the decarbonisation goal could mean slower production, reduced revenue from exports, and job losses.

Beyond the oil and gas sector, Canada's heavy industries currently account for 11% of its greenhouse gas emissions. Sectors such as cement and mining, are coined as "hard to abate" as they largely require high quantities of high-temperature heating or produce non-heating related CO2 and these inputs/outputs are intrinsic to their process chemistry. Therefore, addressing the emissions associated with these sectors via energy transition is critical to achieving net zero goals and uncovering decarbonisation strategies which are efficient and cost-effective is of paramount importance to many business owners. Carbon capture is often considered to be a critical solution for emissions reduction in these sectors as implementing the technology will not require a lot of downtime in operations. However, the high price tag associated with the technology can often be off-putting to stakeholders, as making large investments into sustainable practices can risk driving up operating costs and ultimately slashing their competitive advantage in the global market.

What is the cost of accelerating Canada's energy transition?

As with any facet of the energy transition, cost is a primary barrier standing in the way of scaling up Canada's carbon capture capacity. The Royal Bank of Canada has estimated that the total cost of Canada's energy transition could be upwards of $2 trillion. A recent report broke down the expenditure required per sector to reach the nation's climate goals in the next 30 years. The report showed a cost of $25 billion per year for building out electric vehicle infrastructure in the transportation sector, $13.7 billion on emissions reductions in the oil and gas sector, $5.4 billion for retrofitting old buildings, $5.4 billion in the electricity sector, $4.4 billion in the heavy industries and $2.5 billion in the agricultural sector annually.

Ensuring this high-level spend will be no easy feat thus targeted carbon policy in Canada's marketplace will be instrumental in incentivising an uptick in decarbonisation adoption across the nation. Policies already in place have proven this type of federal intervention is capable of making deep cuts to its carbon footprint. In 2022, its government announced an $81.5-million call for interest to support research, development, and demonstration projects for in-country CCUS. In addition to this, in 2024, it introduced the investment tax credit (ITC), the federal government's flagship CCUS support vehicle, designed to give the heavy industry what it needs to build CCUS projects by covering 50% of project capital costs between 2022 and 2030. These initiatives have been a driving force behind the nation's 8% drop in emissions since 2019.

Incentives such as this will continue to be fundamental in accelerating the expansion of carbon capture across the nation. However, government funding alone will not be enough to fully unlock the potential of CCUS to advance Canada's energy transition. Enabling private funding for commercial CCUS projects will be crucial in driving down its cost and making integrating carbon capture technology on a wider scale economical for businesses. As previously mentioned, implementing decarbonisation solutions of any form into existing industrial operations poses a great monetary risk, therefore safeguarding those who choose to invest in carbon capture technology will be critical.

Those best placed to ramp up carbon capture deployment are the players operating in Canada's existing energy landscape, such as major oil and gas companies. A great example of this is Shell's Quest facility in Alberta, which has captured 7.7 million tonnes of CO2 as of 2022. Several private entities have split ownership of this project, making it a safer investment for those involved as the overall risk of capital has been split. It is important to note that due to many of these businesses being embedded in traditional fossil fuel extraction, front-end development support by broadening the general understanding of carbon capture and its potential will be key.

However, as with many forms of new technology, the first generation will always be the most expensive. The majority of common hurdles for large-scale CCS can be addressed when projects share knowledge and do not start from ground zero in their development. Next-generation CCUS technology will be significantly cheaper, more efficient, and integrate well with renewable energy and other sectors thanks to the existing infrastructure and workforce already in place. That is why making these advancements now is crucial to driving down the cost of carbon capture deployment for decades to come.

Building the foundations for scaling up Canada's carbon capture potential

While Canada has large ambitions for its carbon capture capability, this means very little if it cannot make certain that the projects being rolled out are sustainable. To guarantee this, the correct infrastructure must be in place to support large-scale carbon capture activities. The carbon capture boom Canada is anticipating is very likely to be costly to build but it offers a unique opportunity to bolster economies across the country; unlocking new jobs for many who would have otherwise been adversely affected by the energy transition. Virtually, the country's resource-based sectors, from cement, steel, or fertilizer manufacturers to mining, electricity, and oil and gas, are looking to add CCS/CCUS to their infrastructure. Each one of these sectors represents the potential for thousands of high-quality jobs and training, economic partnerships with indigenous groups, and ongoing employment to operate and maintain these facilities, many of which are the lifeblood of local communities. Also, as a lot of the CCS infrastructure is planned close to populated cities, this provides an opportunity to educate communities and gain their support therefore abiding by the obligation of a "social license to operate."

However, while the opportunity is plentiful for Canada's workforce to greatly benefit from the CCS/CCUS revolution, a growing skills gap could unravel this. Generating a sustainable supply chain and workforce capable of facilitating the front-end engineering and design (FEED) work associated with carbon capture and its construction is a challenging process. Strategic planning from stakeholders across industry and government from the pre-FEED stage will be crucial in achieving this. With the typical lead time to plan, build and bring a one-megaton CCS facility into service being at least six years, the race is truly on to ensure that Canada's growing pipeline of projects has a feasible supply of resources and workers on hand. This rings particularly true in rural areas, where the CCS projects are moving towards final investment decisions.

Canada's current carbon capture landscape

It's evident through Canada's existing carbon capture projects that operational expertise is prevalent throughout the country. However, there is no one-size-fits-all approach to carbon capture, an assumption which has caused many projects to succumb to pitfalls whilst still in their early phases. With more than 30 years of experience, Wood has worked on more than 200 carbon capture studies and projects y across the globe and our team of carbon experts based in Canada have played a crucial role in supporting several in-country CCS projects. From pilot plant installation to FEED projects, our experience and expertise thus far have demonstrated that carbon capture isn't just of interest to Canada's oil and gas industry. Stakeholders from mineral processing businesses, cement and steel manufacturers have all expressed interest in integrating the technology into their operations. For example, we have recently supported Teck Resources Limited in installing a carbon capture pilot plant at the Teck smelter in Trail, British Columbia. Teck's smelter and refining complex in Trail is one of the world's largest integrated zinc and lead operations, producing a variety of speciality metals, chemicals, and fertilizer products. This pilot was installed to capture CO2 from one part of the operation to assess the technical and economic viability of the selected technology in this environment. Through creating both basic and detailed designs for Teck, we worked to install this first-of-its-kind solution for capturing carbon from sulphide ores in the smelting process. The technology has the potential to pave the way for more sustainable operations in mineral processing industries across the world. Completing this project required a tremendous amount of front-end work, including completing a carbon capture technology assessment, and several phases of study for the integration, procurement, and installation of the pilot plant at the Trail site. As well, Wood conducted the FEED for the Enbridge-Heidelberg Material's CCS project, the Cement industries first global full scale CCS facility. Working alongside companies for major carbon capture projects such as these has been instrumental in identifying how we can support clients across Canada's energy and industrial sectors to meet their decarbonisation goals. Taking each learning opportunity into consideration for each new project is vital for streamlining and improving the approach taken towards carbon capture implementation across different sectors.

Conclusion

Canada is undoubtedly well-placed to become a major carbon capture hub in the coming decades. The country's early adoption of tactical legislation to bolster the implementation of the technology has given it a competitive advantage in scaling this production up for years to come. However, to ensure the momentum of carbon capture innovation and deployment continues in the coming decades, the country must prioritise creating a sound foundation for the growth of this technology. Infrastructure, capital and having a steady workforce in place are all key components of this.

The opportunity to remain a leader in carbon capture deployment is Canada's for the taking. With the awareness of these challenges and the willingness to mitigate them from an early phase of development, Canada has the potential to continue to be at the forefront of the carbon capture revolution.

More information

www.woodplc.com

Canada-U.K. collaboration critical for climate action

The United Kingdom and Canada are both leaders in advancing solutions to cut carbon dioxide emissions, and we are actively collaborating to reach our shared commitment of net-zero emissions. By Ruth Herbert, Chief Executive of the Carbon Capture and Storage Association & James Fann, President and CEO of the International CCS Knowledge Centre.

The transition to net zero is the greatest challenge of modern times, facing not just one nation but the global community. And not net zero at any cost - the Herculean task facing nations is to achieve carbon neutrality by 2050 whilst creating jobs and delivering a just transition for our industrial communities.

When it comes to reducing CO2 emissions, the U.K. is at the forefront of the industrialized world. In 2019, the U.K. became the world's first major economy to adopt a legally binding 'net-zero by 2050' target, and we have been decarbonising our economy faster than any other G7 country – cutting greenhouse gasses more than 50 per cent since 1990 while our economy has seen robust growth over the same period.

While the geographies, economies and political landscapes are very different between G7 nations, the U.K.'s climate achievements provide a useful model for countries like Canada that are still working towards absolute reductions in CO2 emissions while sustaining jobs and economic growth.

The next stage in developing a U.K. net zero economy will require significant development of hydrogen energy systems, along with addressing the emissions from heavy industrial sources primarily through the use of carbon capture utilisation and storage (CCUS) technology.

The U.K. government is aiming to store 20 to 30 million tonnes of CO2 by 2030 by developing its world leading 'CCUS clusters', where power plants, cement factories, refineries and other industrial facilities will be able to capture their CO2 emissions at source and store them in deep geological storage sites.

The U.K. government CCUS cluster programme has selected four regions for government support – North-West England, North-East England (Teesside and Humber) and North East Scotland. Developing clusters like this across the U.K. will support its industrial heartlands by protecting 77,000 and creating 70,000 high skilled jobs, generating up to £30bn of inward investment by 2030, all whilst helping the U.K. reach net zero.

But the prospect of bringing this CCUS economy to life is a daunting one, where valuable knowledge and decades of experience in Canada can help pave the way for a successful CCUS industry in the U.K..

Canada's influence in the CCS field exceeds its relative size, housing five of the world's 41 commercial CCS facilities and accounting for approximately 15 percent of the world's current CCS capacity. CCS projects in Canada have securely stored over 47 million tonnes of carbon dioxide, equivalent to taking more than 10 million cars off the road.

Canada's CCS projects include SaskPower's Boundary Dam Unit 3 CCS facility, the world's first CCS facility on a commercial power plant, which has captured more than 5.5 million tonnes of CO2 since 2014. Similarly, the Quest CCS facility, operated by Shell, has effectively sequestered over 7 million tonnes of CO2 from a refinery near Edmonton since 2015.

Further along the CCS value chain, the Alberta energy sector's extensive expertise in engineering capital-intensive projects, reservoir geology, and pipeline development played a pivotal role in constructing the world's largest-capacity CO2 pipeline, the Alberta Carbon Trunk Line, and the most extensive storage project for anthropogenic CO2 in the Weyburn-Midale oil field of southeast Saskatchewan, where more than 38 million tonnes of CO2 have been securely and permanently stored since 2000.

As with any evolving technology, the rapid expansion of CCS is accompanied by uncertainties and unforeseen challenges. Applying the lessons learned from the first generation of CCS projects is instrumental in mitigating risk, reducing costs, and enhancing the performance of the multitude of new projects planned worldwide.

Furthermore, Canada's experience in CCS regulation and policy development can offer valuable guidance to the U.K. Canadian provinces like Alberta and Saskatchewan have established clear regulatory frameworks for CCS projects to promote environmental safety and build public confidence and acceptance of these large-scale infrastructure and underground storage projects.

By learning from Canada's regulatory approach, the U.K. can address potential barriers to CCS deployment and streamline the approval process for our CCS projects.

By working together, we can achieve greater results in less time and see the development of net zero economies with CCS to lead us into the next chapter in the U.K. and Canada's industrial futures.

Ruth Herbert is Chief Executive of the Carbon Capture and Storage Association, the U.K. and EU's leading trade association advocating for the commercial deployment of CCUS

James Fann is President and CEO of the International CCS Knowledge Centre

An edited version of this column originally appeared in the Calgary Herald on March 26, 2024.

More information

www.ccsassociation.org
www.ccsknowledge.com

Deep Sky to deploy DAC units from Skytree and Avnos in Canada

Deep Sky is working to build large-scale carbon removal and storage infrastructure in Canada. As a project developer, the company is bringing together the most promising carbon dioxide removal and sequestration technologies to commercialize solutions at scale.

Skytree will deliver and install a modular DAC Air Processing Unit (APU), called Skytree Stratus, at Deep Sky Labs.

"As we continue to source the world's best DAC technologies from around the world, we're thrilled to welcome Skytree to Deep Sky Labs," said Damien Steel, Deep Sky CEO. "A product of the European Space Agency, Skytree has developed a cost effective and energy efficient DAC unit over its decade in business. Skytree agrees that there's no net zero without carbon removals, and we're proud to deploy their tech and contribute to a cleaner, greener future."

Deep Sky will operate Skytree's APU in its Labs innovation center. The system will be installed in Canada in 2024, using the region's renewable hydroelectric energy. The partners will also explore scaling up to a Skytree Stratus DAC hub as part of the evaluation phase at Deep Sky Labs. A Skytree DAC Hub consists of multiple Stratus units, each with a capacity of 900 tonnes per year and can be installed to accommodate any CO_2 site capacity requirement.

It has a small carbon footprint and minimal energy consumption, a characteristic Deep Sky prioritizes in each of its partners. Through the company's Uptime Assurance program, Skytree guarantees high uptime, monitors and measures CO_2 generation, and conducts all preventive and corrective maintenance to ensure uninterrupted operations.

Once in operation, the partners will monitor the performance of the APU at Deep Sky Labs. Data will be collected on the performance of the unit in terms of carbon dioxide removal (CDR), energy consumption, temperature, humidity and more. Together, the partners aim to validate the technology for commercial deployment in Canada as part of Deep Sky's mission to develop Canada into a world-leading hub for carbon removal.

"We are extremely pleased to partner with Deep Sky. This is a significant milestone for us in North America, and kicks off Skytree's launch into Canada. Our partnership will give us yet another opportunity to demonstrate the value of our Stratus DAC system and Skytree Cloud, which remotely monitors and maintains Stratus units in the field. Deep Sky has quickly become a leading global innovator in the sector, and our participation in their CDR project is an exciting step forward," said Rob van Straten, Skytree CEO.

Avnos

Meanwhile Avnos will build and install a Hybrid DAC Air Handling Unit (AHU) at Deep Sky Labs with the capacity to remove 450 tons of CO_2 per year.

Once operational, Avnos will have AHUs in both Montreal and Bakersfield, CA, showcasing its adaptability across diverse environments, humidities, and temperatures. This operational flexibility enables an operator like Deep Sky to position an AHU in close proximity to carbon sequestration and renewable power capacity, thereby optimising the net negativity of the hub.

"Our partnership with Avnos is crucial to Canada's decarbonisation strategy," said Damien Steel, CEO of Deep Sky. "Adding Avnos' novel Hybrid DAC to our Deep Sky Labs project is a significant addition to our portfolio as its technological approach and business model speeds up carbon dioxide removal in Canada."

Avnos has pioneered HDAC, capturing both CO_2 and water from the atmosphere in a single system. It then uses this water to regenerate its moisture-responsive sorbents, in contrast to other DAC processes that need heat to separate the captured CO_2 from their sorbents. Avnos' dual capture, then, equates to cost savings for a plant operator and a positive addition to the surrounding community, as Avnos' tech contributes both water and jobs. Both partners value both the climate and economic potential of commercial deployment in Canada.

"We recognize we will need to cross borders for the global community to successfully address legacy emissions and capitalize on the enormous economic potential of carbon dioxide removal (CDR)," said Will Kain, CEO of Avnos. "Our partnership with Deep Sky demonstrates our commitment to achieving gigaton scale carbon removal and steering the nascent CDR industry toward creating opportunity and shared benefits."

As a project developer, Deep Sky is actively constructing expansive carbon removal and storage infrastructure across Canada. It is incorporating leading carbon dioxide removal and sequestration technologies to scale up a portfolio of solutions. Avnos' licensing business model simplifies this process. Cross-border partnerships like this are vital for achieving drawdown and effectively addressing the impacts of climate change.

More information

www.deepskyclimate.com

Canada news

MHI and Kiewit selected for Heidelberg Edmonton CCUS project

www.heidelbergmaterials.us

MHI Low Carbon Solutions Canada and Kiewit Energy Group have been selected together as one partner team and awarded a FEED contract for the carbon capture technology at the Edmonton CCUS project.

Heidelberg Materials' CCUS project in Edmonton, Alberta, is a global first mover initiative, creating the world's first first full-scale carbon capture project at a cement plant

Heidelberg Materials North America has taken the next step in its two-stage competitive procurement process as it works to select the carbon capture technology and contractor for providing the CO2 separation solution for its Edmonton project, which is planned to be the first full-scale application of CCUS in the cement sector.

The FEED study will use MHI's proprietary Advanced KM CDR Process™ developed jointly with The Kansai Electric Power Co., Inc., which uses the KS-21™ solvent.

"We are pleased with this latest step in advancing our Edmonton project and moving even closer to our goal of delivering the first full-scale application of CCUS in the cement sector," said Joerg Nixdorf, Vice President Cement Operations, Northwest Region for Heidelberg Materials North America. "This latest development represents meaningful progress on the path to achieving a net-zero future."

Heidelberg Materials North America will be commissioning the world's first full-scale net-zero cement plant at its Edmonton location by adding CCUS technology to an already state-of-the-art facility. The plant could eventually capture and store an estimated 1 million metric tons of carbon dioxide each year. Subject to finalisation of federal and provincial funding agreements, the company anticipates the final investment decision to be taken in 2024.

International CCS Knowledge Centre brings in new leadership

www.ccsknowledge.com

Calgary-based energy executive Caralyn Bennett and Randy Brunet, a partner with Western Canadian-based law firm MLT Aikins LLP, recently joined the Knowledge Centre's volunteer board.

The volunteer board includes seven members who bring diverse international perspectives and provide strategic guidance and oversight of the organisation.

"The addition of Caralyn and Randy, along with the appointment of James Fann as president and chief executive officer earlier this year, ensures the Knowledge Centre is well positioned to be a leading source of independent, trusted advice and unparalleled expertise to help industry, governments and other decision-makers accelerate the deployment of CCS technology," said Graham Winkelman, chair of the Knowledge Centre's board of directors.

The International CCS Knowledge Centre is a non-profit organization founded in 2016 by BHP and SaskPower to advance large-scale CCS projects as a critical means of managing greenhouse gas emissions and achieving the world's ambitious climate goals.

Knowledge Centre staff were instrumental in the design, construction, start-up and ongoing optimisation of SaskPower's Boundary Dam Unit 3 (BD3) CCS facility that began operation in 2014 and has captured more than 5.5 million tonnes of CO2 . It is supporting a wide range of clients and projects including the world's first full-scale CCS facility at a cement plant that is currently under development at Heidelberg Materials' Edmonton operation, 11 large-scale CCS/CCUS projects that are receiving funding from Emissions Reduction Alberta's Carbon Capture Kickstart competition, and several CCS projects in the power generation and refinery sectors in the United States and the United Kingdom.

Manitoba Government introduces CCS legislation

www.gov.mb.ca

The legislation will help reduce greenhouse gas emissions by creating a framework for industries to begin work on underground carbon capture and storage projects.

"This is an important step forward in our work to make Manitoba a leader in the low-carbon economy," said Economic Development, Investment, Trade and Natural Resources Minister Jamie Moses.

"By working with industry to develop carbon capture and storage projects that would reduce emissions, we're keeping Manitoba competitive while helping to reach our net zero targets."

The proposed legislation would allow the Manitoba government to implement a robust licensing process for carbon capture and storage?projects including comprehensive assessment for each project. In addition to this license, businesses would also require an Environment Act license, the minister noted.

A transformative approach to carbon emissions management

Asset-intensive companies today are challenged with meeting aggressive abatement targets, visualising enterprise emissions in real time and prioritising the right moves to reduce emissions without impacting operational performance. By Ron Beck, Senior Director, AspenTech

Asset-intensive companies today are challenged with meeting aggressive abatement targets, visualising enterprise emissions in real time and prioritising the right moves to reduce emissions without impacting operational performance. There is also the need for transparency. Multiple external stakeholders, such as auditors, government regulators, activist investors, non-government organisations (NGOs), and employees, are all looking to see validated and auditable reporting of carbon emissions and carbon abatement actions. Also, emissions reduction creates value – via carbon credits.

For asset-intensive industries, optimising energy efficiency to reduce emissions represents one of the most readily attainable and impactful steps toward advancing their ambitious sustainability objectives

The challenge is clear. In Canada, for example, The Early Estimate of National Emissions for 2022 shows that total emissions increased 2.1% from the previous year, an increase of 14.2 megatonnes of carbon dioxide-equivalent (Mt CO2e), with emissions from oil and gas and buildings accounting for 72% of the total rise.

However, most businesses struggle to gain comprehensive visibility into the nature and volume of carbon emissions across their global asset portfolios in a timely manner. That's a problem because they need to be able to measure the emissions they are making before they can start to reduce them.

Europe has made greater strides in this endeavour, primarily due to making greater progress with regards to energy shifts toward renewables and natural gas, although Latin America and the Caribbean are doing well in this respect too. Renewables, spearheaded by hydropower, account for 60% of the region's electricity, doubling the global average. Notably, countries such as Brazil, Mexico, Chile, and Argentina boast some of the world's premier wind and solar resources. Additionally, bioenergy is extensively utilised throughout the region, with significant contributions from biofuel exports.

Companies in the United States and elsewhere are also beginning to advance in their understanding of carbon emissions. In November 2023, the U.S. Environmental Protection Agency (EPA) put forward new carbon emission standards for U.S. coal and natural gas-fired power plants. This initiative represents a significant step toward combatting climate change by reducing pollution and working towards a carbon-free power sector by the year 2040.

Canada's Clean Fuel Regulations are also essential to the country's climate plan to meet its enhanced Paris Agreement target to reduce emissions by 40-45% from 2005 levels by 2030 and achieve net-zero emissions by 2050. There is much work to do across multiple countries, however. More precise and timely carbon emissions data across an enterprise will lead to better understanding of how to invest effectively to reduce carbon footprint of a company's assets.

Gauging the challenge

On one level, the problem is that of siloed departments working in isolation. Carbon mitigation has become so strategic that there are frequently multiple teams and functions, each with their own distinct agendas and ways of working, presenting very different analyses and views of the company's sustainability challenges and progress to the CEO.

Today, different teams such as sustainability (under the CSO), operations (under the site or plant manager), and asset integrity (under the technical services executive) are using different data, different assumptions, and inconsistent modelling systems to develop recommendations.

This siloed approach is perhaps less surprising when you consider that many asset-intensive companies lack a dedicated carbon emissions management software solution capable of rapidly delivering the kind of real-time analytics needed to support strategic decision-making around carbon emissions at an enterprise-wide level.

Where companies do have a good picture of their emissions status across their assets, it is usually through the use of consultants or spreadsheet-based approaches. In both those cases, it takes weeks at best and usually months to roll up carbon emissions data into an enterprise view. Additionally, companies struggle to gain sufficient detail, or "granularity," of their emissions information, to effectively decide which assets and units to focus on, and what actions make most sense.

Scoping a solution

To overcome these barriers, a transformative approach is required, where technology and people unite in pursuit of sustainability goals. Mere emissions reporting tools fall short in this context.

Any process chosen also needs to be auditable, of course. Instead of providing auditors with access to internal spreadsheets, a secure and inspectable digital solution provides a more accurate, transparent, and controllable way of providing the appropriate level of detail to the right people. And beyond auditability, it needs to present the real time tradeoffs between emissions, energy use, quality production, and operational excellence that can enable agile decision-making.

The best tools will mobilise more of the data, contextualise data quickly, and apply industrial AI to guide analysis.

This kind of digital technology is now unveiling some interesting emission trouble spots across industrial facilities. Consuming materials demands significant energy and forms the foundation of various production processes, notably in refining metals, manufacturing batteries, and producing chemicals like fertilizers. Leaks represent another common issue, often challenging to detect, particularly in aging pipelines and equipment.

Furthermore, when equipment failures force sudden shutdowns at plants, restarting production requires a surge in energy consumption, leading to heightened emissions. Digital solutions can pinpoint and address these blind spots for manufacturers, alerting teams in advance by offering targeted identification and remediation strategies.

By providing an enterprise-wide view of key metrics, such solutions, which are increasingly coming on stream, empower informed decision-making, enabling businesses to identify and prioritise actions for managing and reducing carbon emissions. To truly advance sustainability objectives, this decision support capability can be complemented by digital twin and planning solutions. These additional tools act as catalysts, propelling organisations towards their emission reduction targets with greater efficiency and precision.

Reaping the rewards

Today, digital tools are enabling better emission-control approaches in multiple ways. Digital solutions empower asset-intensive organisations to not only report emissions but also make informed decisions that align with sustainability objectives. Manufacturers can precisely identify areas with high carbon emissions or operational inefficiencies within their facilities, allowing them to invest strategically in emission reduction. These solutions replace vague spreadsheet calculations with precise measurements, considering compliance with EU or US guidelines.

Automation and consistency are fostered by digital tools. Teams across all organisational levels can promptly identify and address issues in real-time, preventing delays that might render problems unsolvable. Moreover, teams working on different aspects of emission reduction can collaborate effectively using the same data and interfaces.

Digital solutions introduce a new level of transparency, catering to regulators, auditors, investors, and company leadership. In the near future, emissions auditing will parallel financial audits. Providing up-to-date, detailed emissions reports ensures compliance, streamlines reporting, and facilitates efficient audit processes.

One of the most complex refineries in Europe, which is coupled with a power plant, is using this digital emissions decision support approach already, and in the first year is seeing emissions visibility change from quarterly to daily, with projected savings of millions of dollars in carbon taxes avoided, coupled with ability to sell carbon credits at advantaged prices in the carbon market. Even though it had already been reporting emissions correctly, as required by the EU, it is now able to understand this information in a proactive decision context to achieve improved results, rather than simply reporting after the fact.

Unlocking environmental gains

Manufacturing and operational facilities that tackle the common blind spots discussed here have the potential to achieve a substantial enhancement in overall energy efficiency within just a few years—typically around 10%. This boost directly translates into CO2 reduction, and for some, it could even reach as high as 30%. Multiplied over many energy-intensive assets, the diminution in emissions achieved is likely to be even more significant.

For asset-intensive industries, optimising energy efficiency to reduce emissions represents one of the most readily attainable and impactful steps toward advancing their ambitious sustainability objectives.

Looking to the future, in essence, the path to sustainability demands the integration of cutting-edge technology with human expertise. Armed with comprehensive insights and a strategic approach, asset-intensive companies can turn the tide, moving decisively towards a greener and more sustainable future.

More information

www.aspentech.com

CCUS: Accelerate deployment to keep 1.5°C alive

With the world again heading for record yearly greenhouse gas emissions in 2024, the need for accelerating a just energy transition has never been greater.
By Tegan Norster, Rotating Machinery Engineer, DNV.

Research from the EU's Copernicus Climate Change Service made for a sobering start to 2024. According to the scientific body, 2023 was the hottest year on record, with global temperatures creeping ever nearer to 1.5˚C, putting the aims of the Paris Agreement in jeopardy.

It's a prediction backed up by DNV's latest UK Energy Transition Outlook (ETO)[1] report, which highlights a worrisome trend towards a 2.2˚C global warming scenario.

Fossil fuels aren't going anywhere

As it stands, close to 80% of all UK primary energy supply comes from fossil fuels, as shown in Figure 1. Fossil fuels include oil, coal and gas, of which just over 50% is produced in the UK and the remainder imported. Even with expected build-out of renewables, the ETO forecasts that fossil fuels are expected to continue as the primary energy supply for the next decade, accounting for 70% of the UK's primary energy in 2030.

By the middle of the century, the picture will change significantly and DNV predicts an uptake in low-carbon energy sources, such as bioenergy, nuclear energy, onshore and offshore wind, and solar photovoltaics (PV). Despite this strong shift, a third of the UK primary energy supply will still be fossil fuels, dominated by their remaining unabated use in household heating and aviation. Hydrocarbons and their associated carbon dioxide (CO_2) emissions seem likely to feature in UK energy systems for decades to come.

As progress is driven towards a decarbonised energy system, there is responsibility to ensure that the energy transition is done in a way that is as inclusive and equitable as possible.

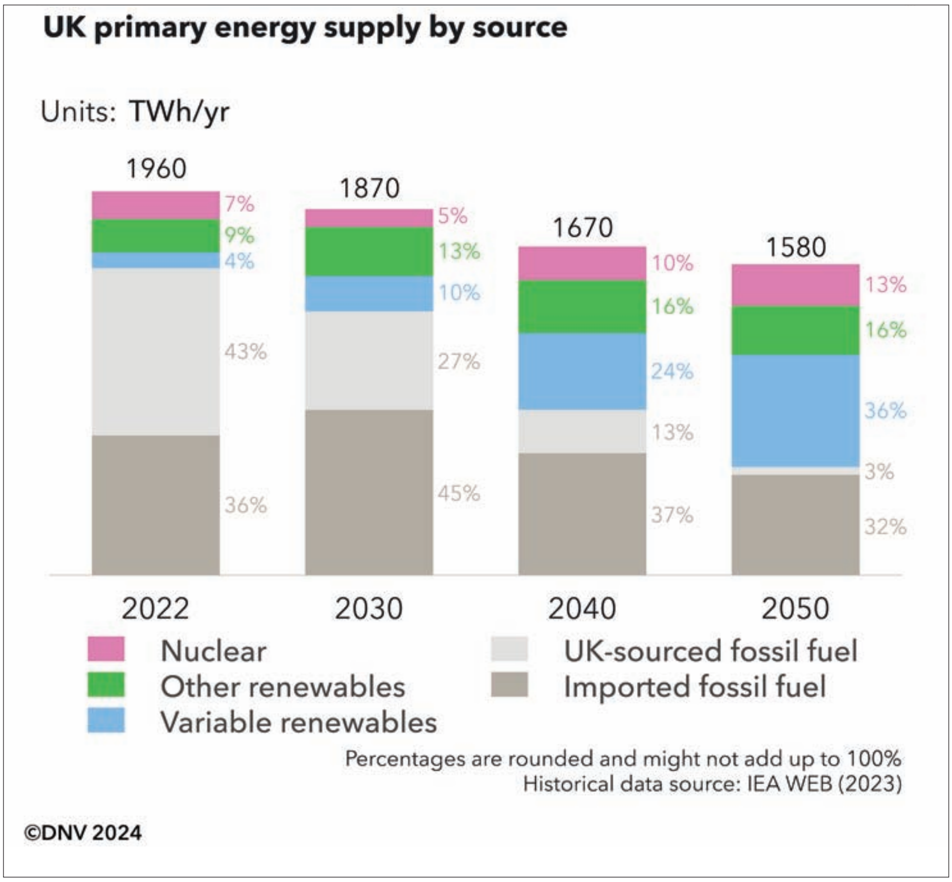


Figure 1 - UK primary energy supply by source

Carbon capture and storage deployment in the UK

Deploying carbon capture and storage (CCS) will be crucial for meeting net zero by 2050. It is an indispensable tool, one that can be retrofitted to existing emission sources, enabling the decarbonisation of crucial, hard-to-abate and hard-to-electrify industries. In some processes, like cement manufacture, producing CO_2 is unavoidable, but in 2050 the UK will still need cement. Here, CCS currently stands out as one of the few viable decarbonisation solutions and, pending a major technological breakthrough, is likely to remain so for some time.

Moreover, CCUS infrastructure also paves the way for the large-scale rollout of Carbon Dioxide Removal (CDR) initiatives. Technologies like Direct Air Capture (DAC) and bio-energy CCS give us the chance to reduce the impacts of climate change by extracting CO_2 directly from the atmosphere and stor-

1. *https://www.dnv.com/energy-transition-outlook/uk/index*

ing it permanently in deep geological formations or using it in selected applications.

CCS is a key element of the UK's strategy to deliver net zero, which includes an ambition of capturing and storing 20-30 million tonnes of CO2 per year by 2030. Within our ETO, DNV forecasts that UK capture rates will reach 14 million tonnes CO2 per year by the end of the decade – well short of the target. Initially, carbon capture will be associated with power generation and manufacturing, focusing on storing emissions from the large industrial clusters formed across the UK. Production of hydrogen and its derivatives will ramp up in the middle of the next decade, at which points this sector will become an important driver for carbon storage in the UK.

Some of the key reasons for missing the 2030 targets are the current lack of clarity around the Power Bioenergy and Carbon Capture and Storage (Power BECCS) and Greenhouse Gas Removals (GGR) business models; slower than expected development of the Track 1 clusters (these have yet to take a Final Investment Decision (FID)) and the expectation that only in the early 2030s will carbon prices start to approach the cost of CCS.

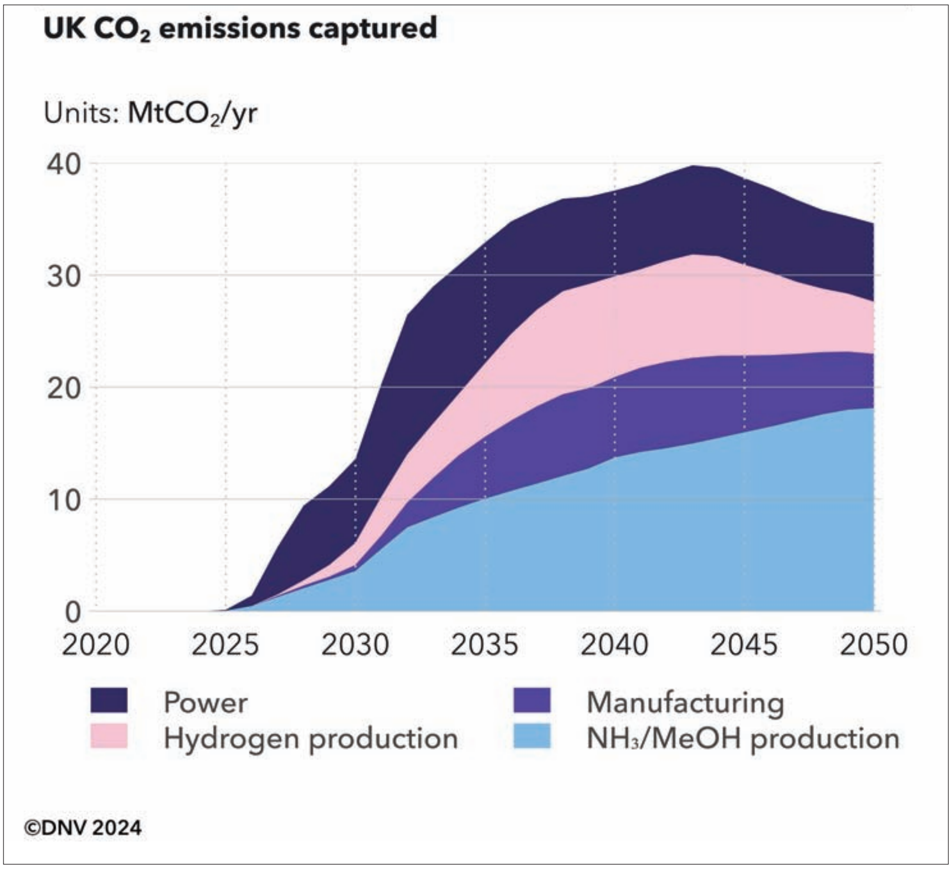


Figure 2 - UK CO2 emissions captured

Advancing CCUS deployment

If the world is to stay within reach of the Paris Agreement's 1.5°C aspiration – a tough challenge that is becoming ever tougher – the deployment of CCUS must be fast-tracked.

Policy and regulatory challenges are currently acting as barriers to the acceleration of deployment, but the technology itself is proven, with over 40 large-scale CCUS facilities operational globally. Amine-based CO2 capture, today's state-of-the-art post-combustion capture technique, is well-established and available for commercial use.

For the UK, the 'Track 1' and 'Track 2' industrial clusters were selected based on their ability to deliver CO2 transport and storage networks in line with government timelines for CCUS and hydrogen adoption. Hence, the development of CO2 storage sites is a critical aspect of all the selected industrial clusters, and subsequently the UK's decarbonisation strategy.

Additionally, with our estimates within the ETO model, we expect to see carbon prices for Europe (including the UK) increase significantly between today (75 USD/tonne) and 2050 (250 USD/tonne). Current estimates indicate that the cost of emitting CO2 will start to exceed the cost of capturing CO2 for most applications within the 2030-35 period – incentivising installation of CCS for industrial use, power generation and H2 production without the need for government support.

Government, industry and investors need to synchronise

If governments are to hit the decarbonisation targets that they have set then a substantial and rapid scale-up of CCUS is a necessity, not an option. Deployment at the required scale will require collaboration between industry, the financial sector, and governments. Industries must identify potential carbon capture projects and the necessary value chains, while the financial sector must play its part to support climate change strategies and enable sustainable finance. Governments should formulate policies and incentives designed to underpin a portfolio of projects and ensure repeatability, with mechanisms shifting towards enabling industries rather than individual projects.

With the favourable geology of the UK Continental Shelf (UKCS), there is a significant CO2 storage potential compared to other countries in Europe. There is estimated to be over 70 billion tonnes of CO2 storage deep under the UK seabed[2]. If a lucrative carbon market is established, along with the removal of legislative obstacles and the establishment of bilateral agreements, the UK could stand to become a net importer of CO2 from the EU; something that could deliver significant economic benefits.

Whilst CCUS deployment in the UK is progressing, the forecasts in the UK ETO should act as a call to action. The forthcoming decades require a significant acceleration in CCUS deployment globally. To keep 1.5°C within reach, industry, governments, and financiers must align to ensure we are positioned to deploy CCUS at the scale needed and within the required timeframes.

More information

www.dnv.com

2. *https://www.bgs.ac.uk/geology-projects/carbon-capture-and-storage/co2-storage-capacity-estimation/*

The critical mix of finance, technology and policy for green investment

In this article, Dr. Valentina Dedi, Lead Economist at KBR, explores how the right mix of supportive policies, financial mechanisms, and technological innovation can de-risk investments in CCUS and maximise the potential for green investment amid uncertain times.

The global community finds itself at a pivotal moment in the battle against climate change. As the urgency to transition from a fossil fuel-dominated energy system to one driven by greener sources intensifies, governments and investors alike are managing the challenges and opportunities presented by this shift.

Governments around the world have acknowledged the urgency of accelerating the energy transition and have prioritised capital allocation in their national and energy policies. The Paris Agreement sets ambitious targets for reducing greenhouse gas emissions and limiting global temperature rise to well below 2°C above pre-industrial levels. Meeting these targets requires an unprecedented level of investment in clean energy technologies and infrastructure.

According to S&P Global Platts, if the targets agreed by the world's major economies under the Paris Agreement were to be met by 2050, it would mean more than $5 trillion in investment each year between now and 2050. To put this into perspective, this is equivalent to investing more than today's size of Germany's entire economy every year for the next two and a half decades. This scale of investment is well beyond what government budgets can afford. Large-scale private sector engagement will be critical too.

In recent years, significant capital has been directed towards energy transition projects. However, these investments have been largely constrained to commercially viable projects, primarily favouring renewable power generation, such as wind and solar. These technologies have matured and are now market-ready thanks to a continuous decline in technology costs and the advances in efficiency over the past decade.

While they are crucial to the energy transition, they alone cannot address the full scope of the challenge, and especially in decarbonising the hard-to-abate sectors.

The In Salah CCS project in central Algeria is a world pioneering onshore CO2 capture and storage project which has built up a wealth of experience highly relevant to CCS projects worldwide. Carbon dioxide from several gas fields is removed from the gas production stream in a central gas processing facility and then the CO2 is compressed, transported and stored underground in the 1.9 km deep Carboniferous sandstone unit at the Krechba field

Decarbonisation potential of CCUS projects

CCUS has the scope to play a pivotal role in the latter sectors. It can be readily deployed at fossil fuel power plants and industrial facilities, such as cement, iron and steel, and chemicals, where CO2 is captured and stored or used to create products such as fuels and chemicals (CCU). CCUS can also provide a low-cost pathway for low-carbon hydrogen production, which can further contribute to the decarbonisation of the industry and transportation sector, or it can enable the removal of CO2, which is unavoidable or technically difficult to abate, directly from the atmosphere through Direct Air Capture with Storage (DACS) or Bioenergy with CCS (BECCS).

Although the adoption of CCS has lagged behind initial projections, there has been a substantial increase in activity and interest in recent years. Across the globe, novel technologies are being piloted with the goal of driving down expenses for both the power generation and industrial sectors. In addition to chemical absorption and physical separation, the two most advanced capture technologies, other separation technologies are also being tested, including membranes and looping cycles.

To meet net-zero targets, CCUS deployment must increase by several orders of magnitude within the next two to three decades. In the case of the US, it would mean a scale up to as much as 100 times today's levels, according to the US Department of Energy's Office of Clean Energy Demonstrations (OCED). While an ever-increasing number of projects across the entire value chain are being announced, only a fraction of them can take a final investment decision.

CCS is not a new technology, but the challenge lies in its economically large-scale deployment as investors face several uncertainties and risks. These can entail technology failures, cost overruns, extended timeframes, and high capital costs, among others. Another significant risk factor is the lack of clarity with respect to the demand outlook, which makes it challenging for investors to understand the scale of opportunity, and, thus, for projects to reach a financial investment decision. Scaling up the infrastructure needed to transport and store captured CO2 also requires the development of new business models which secure the required revenue streams, as well as partnerships between emitters, technology providers, and storage operators.

The importance of policy and regulation

Realising the full potential of the CCUS technology, especially at these early stages, will require continued policy support and collaboration between governments, industry, and investors. Coming up with the right policy framework and financing and incentive mechanisms will be critical. Governments and policymakers must establish an environment which creates stability and revenue predictability to attract the required investment and support the acceleration of the technology.

Thus, setting clear targets and priorities over the short-, medium- and long-term, including legally binding policy and regulatory frameworks, will be crucial to minimise policy uncertainty. At the same time, policy efforts should centre around the introduction of de-risking mechanisms and incentives that support green growth and foster green investment. This is especially pertinent for technologies and infrastructure, such as CCUS, which stand at a risky point of their deployment curve. This can be achieved through a wide range of instruments and approaches, including innovation funding, carbon pricing instruments, carbon credits, tax incentives, guarantees, and low interest loans, among others.

Dr. Valentina Dedi, Lead Economic Advisor

Recent policy developments in the US, such as the Inflation Reduction Act and the Infrastructure Investment and Jobs Act, have started driving investment in clean energy technologies. The Inflation Reduction Act, in particular, is expected to be a game-changer for the CCS industry as it provides significant tax incentives for capturing and storing carbon dioxide. At the same time, as the UK envisions to become a global technology leader for CCUS, the government announced a funding of £20 billion to support the initial deployment of projects, aiming to unlock further investment from the private sector as it provides the much-needed certainty to investors. Back in 2011 and 2015, a lack of agreement on government budgeting and capital allocation, in tandem with a lack of understanding of the commercial risks had led to CCUS project cancellations in the UK.

The Tangguh CCUS project operated by bp is the most advanced CCUS project in Indonesia with a development plan that has received approval from the Government of Indonesia in 2021, ongoing FEED work and planned project sanction in the near future. Holding ca 1.8 GtCO2 in ultimate storage capacity, Tangguh is well-positioned and has a tremendous potential to become the country's first CCS hub for domestic and international emitters

The path forward

Mobilising the capital needed to achieve the ambitious targets will require careful design of policies, financing mechanisms & incentives, and innovation funding. These measures must work together to de-risk investments, boost capital availability, and ultimately make clean energy technologies economically sustainable.

The path to a sustainable energy future is complex and challenging, but it is also filled with opportunity. By harnessing the power of policy, technology, and finance, we can unlock the vast potential of green investment and accelerate the transition to a low-carbon economy. Governments must continue to lead the way, while at the same time, the private sector steps up and embraces its role as a catalyst for change, channelling capital towards innovative technologies. Recent policy developments in the US and Europe are a promising sign of the growing momentum behind the energy transition. However, much more needs to be done.

About the author

Dr. Valentina Dedi is an economist specialising in global oil and gas markets and energy transition projects. She serves within the international consulting business of KBR as their Lead Economic Advisor.

Over the years, she has worked for different stakeholders globally, including governments, development banks, international corporations, conglomerates, oil and energy companies, and national oil companies, among others.

Valentina is the Vice President of Access for Women in Energy and of the Greek Energy Forum. She has also been involved with academic institutions, teaching at the University of Surrey and London Bayes Business School in the UK, as well as The American College of Greece and University of Ioannina in Greece.

More information

www.kbr.com

Report from U.S. webinar - how US tax credits are driving CCS

Tracking of US CCS projects, and permit applications for CO_2 injection wells, shows how much the Inflation Reduction Act has motivated projects. John Thompson from CATF explained. By Karl Jeffery.

The reason CCS has not yet taken off on a big scale is purely about money, not the technology, said John Thompson, technology and markets director with non-profit environmental organisation Clean Air Task Force, speaking at Carbon Capture Journal's webinar on February 22, "Developments with US carbon capture and storage".

"Until August 2022 with the Inflation Reduction Act (IRA) there was no economic story, no financial reason to really develop the technology, because projects couldn't be economic. That's beginning to change."

The US has offered a tax credit for CO2 storage since 2009, but it was initially only $20 a tonne for saline storage, $10 if CO2 was used for EOR. The saline storage credit increased to $50 in 2015, and to $85 with the Inflation Reduction Act.

CATF's tracking of US carbon capture projects shows that there are many more projects in the US now than pre-IRA.

You can also track applications for "Class VI wells" (CO2 injection wells) on the US Environmental Protection Agency website (https://www.epa.gov/uic/current-class-vi-projects-under-review-epa).

This page shows when applications were filed and when a final decision is expected. It shows a huge growth in applications after IRA was passed. In 2021 there were only 15 applications, by 2023 there had been 122 applications, Mr Thompson said.

Initial interest was mainly in carbon capture projects with a highly concentrated stream of CO2, so carbon capture is less expensive. This is found with manufacturing of ethanol, hydrogen and ammonia. There have been a small number of permit applications for direct air capture projects and natural gas power generation, which have a much lower concentration of CO2 in the gas stream.

There remains an important question about whether the 45Q tax credit is high enough to justify investing in carbon capture in steelmaking, cement, refineries, and other 'hard to abate' industries. They have many chemical processes which themselves emit CO2, and so cannot be simply replaced by renewable electricity. Typically CO2 from these is in a gas stream at a low concentration, so it is expensive to separate, he said.

"It is an open question whether 45Q at its current level is enough to drive some of the really hard-to-abate sectors," he said.

"First mover projects are vital," he added. "The ones that go first are going to unlock a lot of the issues we're going to see. How quickly we get permitting, what's public acceptance like, do we have enough funding, what are the policies we need to fill those gaps if they exist."

Before the Inflation Reduction Act, nearly all carbon capture in the US has been for EOR, because it was the only way to make it work commercially.

But it could only work in locations with a cheap source of CO2 close to an existing oil patch. It was also subject to the volatility of the oil price, he said.

But the $85 tax credit under 45Q is big enough to make it viable to store CO2 in saline aquifers, as with the CENLA Hub, he said. And although a $35 to $60 tax credit is available for CO2 used in EOR projects, it is not leading to any new EOR projects, so far.

Mr Thompson's role at CATF includes developing its "Industrial Impact" area of work, which aims to bring decarbonisation tools to specific industries, using learnings from its carbon capture team.

He also leads CATF's carbon capture group. This team has made a big contribution to developing low carbon policy in the US, including a role in designing the 45Q tax credit scheme.

Refinery of the future

The Zero Carbon Fuel team at CATF will shortly release a report "Refinery of the Future", covering how to use CCS, hydrogen and electrification in a refinery.

The report was written together with consultancy Advisian. It studied typical designs for refineries in Singapore, GCC countries, US Gulf Coast and Europe. It looked at their announced decarbonisation plans, their options to reach net zero, and their costs.

It identified that different pieces of equipment would use different decarbonisation strategies – some would use CCS, some would run on hydrogen, some could be electrified.

CO2 pipeline safety

On the question of CO2 pipeline safety, Mr Thompson noted that there have been CO2 pipelines in the US in commercial operation for over 50 years, without a single death. CO2 pipelines have a better safety record than natural gas pipelines.

It is not risk free. There was a major CO2 pipeline breakage in Mississippi, when a landslide severed a pipeline, and 30-40 people went to the hospital. "We are lucky no-one was killed in that," he said.

CO2 pipeline safety is highly regulated, and new regulations are about to be announced by the US Pipeline and Hazardous Materials Safety Administration (PHMSA).

"We don't ignore [risks] or minimise it; I think it's a risk that is easily addressed," he said.

More information

www.catf.us

CapturePoint's CO2 storage in Louisiana

CapturePoint is planning perhaps the largest onshore CO2 storage project in the US and has a major initiative to engage the local community by supporting the training of young people. CEO Tracy Evans told the story.

CapturePoint, an oil and gas producer and CO2 storage company based in Allen, Texas, is planning perhaps the biggest onshore CO2 storage project in the US.

Tracy Evans, CEO, told the story in a Carbon Capture Journal webinar on February 22.

The project is called "Central Louisiana Regional Carbon Storage Hub," abbreviated to CENLA Hub. The injection and storage site is in Vernon Parish, in central / west Louisiana, midway between the city of Shreveport, in the northwest corner of the state, and the Gulf Coast.

It has multiple aquifer injection sites which can each handle 7.5 million tonnes a year (mtpa) CO2 injection and store 250 million tonnes CO2. Total storage capacity is estimated at 1 gigatonne, based on data from test wells, including logs and cores.

The company considers the region to have "excellent geology" for CO2 storage. "This particular site is probably one of the best, if not the best in the US - at least onshore," Mr Evans said. "It basically ticks almost every category you could come up with for a great CO2 sequestration site."

Most of the CO2 is coming from gas processing plants, removing CO2 from produced gas which would otherwise be emitted to the atmosphere. There are around 30 gas processing plants in the region. The natural gas processing reduces CO2 in the gas to under 2 per cent, the typical specification for a natural gas pipeline.

To date, the CENLA Hub team has signed up with 5 gas processing plants and one methanol plant, to receive 1.75m tonnes a year of CO2. There will be a 125-mile pipeline from the processing plants to the CENLA Hub site, where CO2 will be injected to the subsurface.

CapturePoint is sponsoring a training program in pipeline construction (see next section). This is in a region where there are so few working opportunities for young people that they are forced to move away to start a career, according to a representative of the school board.

CapturePoint, formerly Perdure Petroleum, is also an oil and gas producer and specialist in CO2-EOR. It has existing CO2-EOR operations in Texas, Kansas and Oklahoma, sequestering around 1m tonnes CO2 a year in total.

It is also developing new CO2 deep underground storage projects in Colorado, Oklahoma, New Mexico, Mississippi and Wyoming. Its work is financed by private equity investors.

Tracy Evans, CEO, CapturePoint

The subsurface

In the first stage of the CENLA Hub, the CO2 will be injected into three individual "injection zones" comprising one "injection site". Two wells will be drilled into each zone.

Each injection site's subsurface has been modelled, to confirm it has a "confining zone," which ensures that CO2 stays in each zone. There is a further "confining zone" above all three zones, Mr Evans said.

The thickness of the first injection zone ranges from 300 feet to 800 feet. The second is around 1500 feet thick, and the third is 2500 feet thick. The 1500- and 2500-feet zones are 50-60 per cent sand.

CapturePoint has already drilled through the confining zones and injection zones, taken core samples and analysed them, to confirm the porosity of the rock for holding CO2, and that there are seals above it.

Geographically, the site covers 15,000 to 20,000 acres (60 to 80 square kilometres).

The shallowest interval is 4500 feet below the surface, and the deepest is 7,500 to 10,000 feet underground. At these depths and pressures, CO2 behaves more like a liquid than a gas, and so does not flow in the way that a gas would. "We typically only work on sites below 3000 feet," he said.

The storage zones also have a very low dip of 1 to 2 degrees (nearly horizontal). With CO2 being less dense than water, it will move to the top of a space filled with water. If the zone has a significant dip, all the CO2 will flow to the higher end of it; having a low dip is very helpful.

The aquifers can be described as "railroad tracks", with a parallel top and bottom, and no faults. The permeability is "several hundred millidarcies to darcies," he said.

The rock has a sequence of sand and shale horizontal layers, with the shale acting as a "baffle," limiting vertical migration of the CO2.

A reservoir simulation showed that there would be a limited increase in pressure in the aquifer over the expected injection lifetime of 30 years, and with no need to produce any of the water in the aquifer to reduce pressure.

The limiting factor on the injection rate is actually the size of the wellbore – but a bigger diameter hole would be much more expensive to drill. The site is being designed with additional wells to provide the ability to continuously inject CO2 if another well is down for any reason.

A handful of wells previously drilled in the site for oil and gas exploration (between 5 and 7 on each site) have been plugged, but the project team needs to ensure that the plug makes a complete seal.

It can be easier to prove you have a "confinement zone," with enhanced oil recovery projects compared to aquifers, because if you did not have one, the oil would not still be trapped, Mr Evans said.

Development plan

The company has filed two permit applications for Class VI carbon sequestration injection well sites for the CENLA Hub. The permits are currently undergoing technical evaluation with the Louisiana Dept of Energy and Natural Resources (LDENR), which now conducts and enforces U.S. Environmental Protection Agency permitting procedures within the state.

LADENR has stated a goal of processing class VI permits within 24 months, but it is not a legal requirement, he said.

Getting the pipeline permits should be easier to achieve, since they are typically issued by states or local authorities, rather than the federal government, he said. In oil and gas states, there is historically less opposition to pipelines. CENLA already has landowner permission to survey 100 per cent of its pipeline.

"Our best guess is we should be able to have first injection in Q1 2026, if we get our Class VI permit in summer of 2025," Mr Evans said.

"These things take 9 months to a year to physically construct - building the capture facilities, the 125+ mile pipeline, drilling 6 wells on each site."

Each of the six wells should be able to take "slightly over" 1 million tonnes CO2 a year. The wells will be 9 5/8-inch diameter.

The 45Q tax credit has a 12-year life span, so investors have understandably raised questions of how the project will be profitable after this. Mr Evans responds that the project could be funded after the 12-year 45Q period through voluntary carbon credit markets or carbon taxes. "We do not think CO2 will go back to being vented," he said.

Mr Evans has been involved in CO2 for enhanced oil recovery (EOR) for 20 years. CO2-EOR is commercially viable by itself, leading to more oil production. But there are not enough EOR projects to handle all of the CO2 which needs to be captured, he said.

Also, the amount of CO2 which can be injected into a reservoir will quickly decline as the reservoir pressurises, so it can be of limited value when the goal is maximising CO2 storage.

Motivating emitters

Mr Evans was asked for ideas on how the chicken and egg problem can be solved in carbon capture - how emitting companies can be better motivated to invest in capture equipment if they don't know for sure there will be a service available to collect and store the CO2.

"The only way I know is to continue to show progress," he replied. The more people can see developments being made in CO2 storage, the more confidence they can have that storage will be available when they need it.

Many emitters initially tried to run CO2 storage projects themselves and are now showing more willingness to partner with a specialist company.

"I do think over the last 12 - 18 months there seems to be more willingness to sign contracts," he said.

It doesn't help that there is no economic penalty for atmospheric release of CO2 emissions in most of the US, he said.

CENLA Hub's community involvement plan

CENLA Hub's community involvement plan is to support training of young people from Vernon Parish in pipeline construction and maintenance. Vernon Travis, from the Parish school board, told the story.

Louisiana Department of Energy and Natural Resources requires that every project must have some community involvement plan in order to obtain a Class VI permit to inject CO2.

CENLA Hub's community involvement plan involved co-sponsoring a training program for local young people attending the nine Vernon Parish high schools, called the "Capturing Better Futures" Initiative.

The program is in partnership with the United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry of the United States and Canada, a union. Its name is commonly shortened to the United Association, or the UA.

Vernon Parish School board is also a partner in the initiative.

Louisiana is divided into 64 parishes, as other states are divided into counties. One of the CENLA Hub injection sites is in Vernon Parish.

The training program is co-ordinated by Vernon Travis, an elected member of Vernon Parish School Board in Louisiana. He is also a former army officer and chair elect of the US Consortium of State School Boards Associations (COSSBA).

The initiative will offer training to 30 students every year, for a two-year program, learning skills in pipeline construction and maintenance, steamfitting, and pipelaying.

The sponsors built out and furnished a classroom and training workspace at Leesville High School, and provided instructors, materials and transportation for students.

After the 2-year program, students can "go out and do limited work". But if they continue on a UA apprenticeship, they can eventually earn $50 to $60 an hour. The apprenticeship will only take four years, where it normally takes five.

CapturePoint will receive tax credits for its support under the 45Q tax rules, which authorise additional tax credits for carbon capture and sequestration (CCUS) projects that pay prevailing wages and employ apprentices from federally registered programs.

Mr Travis first met Sherry Tucker, CapturePoint's Vice President of Communications, Community Engagement and Government Relations, at a Washington DC reception in January 2023, when the idea was initially proposed, he said.

"I was able to go back to my school and superintendent and say, 'I have someone that really wants to partner with us and bring us training,'" Mr Travis said.

"We've always lacked partnering with some industries. You think, 'why not'. Well, we don't have any industry in our community. It is small, rural, it's a dying community. There's the Vernon Parish school system, a military base and Walmart. Those are the opportunities people have to get a job. Seniors are staying on jobs longer, so positions are not opening."

"Our kids graduate high school, they go to college or leave for big cities, where the jobs are."

"The number of kids in our schools decline by 200 kids a year. That shows how much we are losing our children and our families," he said. "A project like this has really changed the way we look at the future."

The project may be particularly suitable for children who are not suited for university. "I told our curriculum people, 'I don't want the college bound kids. I want them to go to college, get their degrees,'" Mr Travis said. "I want the 'at risk' kids, kids that were borderline, trouble, problem kids.

"We find those kids come to the conclusion, about 8th grade, they don't have any hope in the future, school is not for them."

"When you tell them they are going to get a program like [the one] CapturePoint and the UA has formed, they can join the UA, continue apprenticeships, that's amazing."

"One parent heard that, looked at the kid and said, 'do not screw this up.' The parents understood there was true hope, true future, something for them. They don't have to worry about kids driving to Lake Charles or Houston to find a job, 2.5 hours away. These students will be able to work at home, grow their families at home."

Explaining the project

In setting up the project, CapturePoint staff held many meetings with "all the public groups, the chamber of commerce, Vernon Parish Police Jury (the governing authority), city council, mayor," Mr Travis said.

"I knew CapturePoint needed to build pipelines and facilities; I knew the UA needed employees. I knew I had the bodies to fill those positions."

It helped that Mr Travis "went to school with both our state legislators," he said. He was able to liaise between them and CapturePoint, ensuring their questions and concerns were addressed.

Capture Point was able to explain to the relevant people how the storage would work, and the risks mitigated. It enables the legislators to assess the risks and potential gains to the community together, to see how they weigh up.

"There was some doubt in the beginning. They didn't know or understand. Any time I said, 'I need you to talk to so and so,' CapturePoint and the UA were willing to come."

Building a base

The training program aims to do far more than train students to work on the CENLA Hub project. It will give students a base to build their training further, and then find highly paid employment around the US.

Vernon Travis, an elected member of Vernon Parish School Board in Louisiana

It also aims to make Vernon Parish more attractive for other industries, because they will see it has a trained workforce. "We don't have a reason for companies to say, 'we can't come to your area because you don't have a workforce.'"

Many industries in the US complain that they have a shortage of trained workers. Mr Travis points out there is no shortage of schoolchildren in the US, they just need to be trained. "You watch those yellow [school] buses every day full of workforce capable people," he said. "You have to train those kids the way they want."

Mr Travis also hopes the region will become an industrial hub for carbon emitting industries and carbon capture, building together over the coming decades.

More information

This article is based on a Capture Journal webinar held on Feb 22, 2024, "New Capture and Storage Projects in the US". To see the video, go to www.carboncapturejournal.com, then events / past events

A 5 minute video about the Capturing Better Futures Initiative is on YouTube at:

www.youtube.com/watch?v=QmGvS7Jj0y0

How to move CCUS faster – Baker Hughes event

Speakers from Wabash Valley Resources, GCCSI, Evida and Baker Hughes shared perspectives on how to get CCUS moving faster during the Baker Hughes Annual Meeting in Florence. By Karl Jeffery.

Wabash Valley Resources, a company based in Indiana, USA, is planning a very low carbon intensity fertiliser plant, using blue hydrogen. Peter Sherk, a board member and investor, told the story, at a technical session at the Baker Hughes annual meeting in Florence in January.

The company acquired a gasifier complex in 2016. In 2017, it decided to add carbon capture to the process so it would produce very low carbon hydrogen which can be used to manufacture ammonia.

The plant is situated close to the NuStar ammonia pipeline which connects to the US Gulf Coast and runs through Midwest agricultural markets , so this could potentially be used to carry the ammonia to customers.

The plant is situated within the Illinois basin geological formation, where another CO2 sequestration well was drilled in 2014 and has operated successfully ever since, safely sequestering 1 million tons of CO2 per year

In the US, landowners need to be compensated for the use of the 'pore space required to put CO2 in the subsurface under their land, just as they are compensated for oil and gas reserves associated with their land when a company produces hydrocarbons there.

Companies have been injecting waste water and chemicals into the subsurface for decades without having to pay for pore space that they go into, but CO2 is viewed differently because there is direct revenue attached to the injection via the 45Q tax credits, he said.

Some landowners have high expectations for the revenues their pore space can earn, for example demanding payment of half of the CO2 storage company's payments from the 45Q tax credit.

While payment this high "is not available," at the end of the day agreement on a price needs to be reached, he said.

By the time it's expected to come online in 2026, Wabash Valley Resources' fertiliser plant will have the capacity to capture and store as much as 1.65 million tons of carbon dioxide annually

The process of getting permits for a CO2 injection well, known as a "Class VI permit", took five years, finally being received in January 2024. The plant now plans to be in production in 2026-2027, capturing 1.65m tonnes CO2 a year.

A large part of the Class VI well application process requires the drilling of an 8000 foot deep test well, retrieving samples of the rock and then having those samples analysed for the ability to absorb CO2. Then sophisticated modelling is performed to anticipate the future flow of the CO2 in the sub-surface. as well, the application requires cataloguing all the historical wells which may reach into the storage site, and determining that they are all safely plugged. It took half the five years to do prepare all this information, plus gather other data, and the other half for the EPA to review the data, Mr Sherk said.

There is an advantage in having a robust process in that it is easier to satisfy investors and all stakeholders that thorough investigations have been made to ensure the safety and effectiveness of the process , he said. When they have questions, they can be referred to the permit application.

Asked about the biggest risks with the project, Mr Sherk said that it is similar to any new venture, in that there is never enough money. You should carefully calculate how much it will cost to develop your project , and then double your estimate, he said.

The way to manage the CO2 storage risk, like any business risk, is to identify all of the risks and then determine who is best placed to 'hold' the different risks. The insurance sector is engaged but has not yet fully developed insurance based solutions, he said.

Asked how much it costs to do CO2 storage, we can see that the government's tax credit of $85/tonne under 45Q has proven to be a number which works, he said.

Another possible financial mechanism is the emerging market for clean (low carbon) ammonia, with the Korean and Japanese governments willing to pay a specified amount for it,.

US policy is not showing any preference for green hydrogen over blue hydrogen, but instead sets standards about the carbon intensity, he said.

GCCSI

Although conversations about CCS have been going on for decades now, it is "only just taking off' as a large scale, wide scale industry, with "aims to have climate-scale impact," said Erin Billeri, business development manager, Americas at Global CCS Institute.

GCCSI is headquartered in Australia and has 91 members in Americas, 56 in Europe, 31 in Japan, 24 in Australia, 8 in the MENA region, and 5 in China.

"We need to remind ourselves of the human aspects of getting a new industry off the ground," she said. "You need to build an army of expertise and resources."

People "need to be educated on the risks and opportunities to deploy capital to projects. Industry needs to invest in and develop projects."

Industrial companies which emit large volumes of CO2, such as manufacturers of steel, cement and ammonia, will have staff with engineering and project management skills, but they will not yet have much CCS understanding.

Finding a provider to transport and store CO2 is not a readily available service in many regions. You can't just search on the internet for a company which will accept it.

Delegates discussed how to get CCUS moving faster at the Baker Hughes Annual Meeting in Florence

In one example, Ms Billeri described the Global CCS Institute's role in supporting a member company develop its CCS strategy.

The company found it easy to choose a CO2 capture technology but got stuck on the storage and transportation piece. The company's facilities were not near any planned CCS networks, and the volume of CO2 produced per year proved not to be enough to justify the cost of building a new storage facility.

The company tried to persuade other nearby CO2 emitters to form a mini-CCS hub, but the other companies were not so motivated to capture their emissions, or prioritise working on such a complex project.

It considered selling the CO2 to be utilised, for example to make sustainable aviation fuel, but this would mean the company would not achieve its reduced CO2 emission goals.

Asked about the biggest risks in CCS projects, she said that the risk of projects being cancelled is much less than it was in the period 2010 to 2020. There are fewer "cost surprises" in projects today, and stronger policy drivers. But it still needs funding, development of storage resources, and community engagement.

Evida

Evida, a gas distribution company in Denmark, is developing a new business line as a CO2 pipeline operator, with pipelines collecting CO2 from various emitting companies, and taking it to storage sites, maritime terminals or facilities which can utilise it, said Claus Myllerup, Technical Lead CO2 Program Evida. "We're trying to establish a many to many infrastructure."

The Danish government is making subsidies available for CO2 emitters to cover the costs of capture and storage. There are not enough subsidies available to support every emitting company. But Evida envisages that there is likely to be enough subsidy 'winners' in the capital city, Copenhagen, to justify planning CO2 pipelines to Copenhagen now.

"We're developing a hub that reaches to the city and connects to various locations emitters are located," he said.

The Danish government subsidy is conditional on CO2 being stored from January 1 2029. It will be agreed in two rounds, end 2024 and 2025.

Baker Hughes

Being able to say that you know exactly what is happening with the CO2 in the subsurface is extremely important to ensure that these project are accepted by the community and sustainable in the long term, said Alejandro Duran, Vice President, Reservoir and Consulting Services at Baker Hughes.

Baker Hughes has a structured offering on CO2 storage monitoring services – the Carbon Watch - to help quantify the risks of a site and determine the right monitoring approach, he said.

The risks of CO2 storage are well-known, leaks through old wells, leaks through the caprock, existing or reactivated faults which could allow CO2 to pass through. The challenge we tackle is working out the best way to mitigate these risks in the most effective and economic way.

Our technology today allows to continually listen for noise from the subsurface with microseismic, use spot seismic (which can identify change in subsurface composition in a specific spot of the subsurface), use fibre optics in wells, log through several strings of casing, etc.

All this, powered by a digital twin of the resource, will allow identify any potential condition and intervene timely if needed.

More information
www.bakerhughes.com

Projects and policy news

enfinium advances negative emissions waste CO2 capture plans with £200m investment

www.enfinium.co.uk

enfinium plans to invest around £200 million in CCS technology at the Parc Adfer energy from waste facility in Deeside, North Wales.

The project could capture up to 235,000 tonnes of carbon dioxide every year. As over half of the waste processed at the facility is organic, installing CCS would enable the plant to take more CO2 out of the atmosphere than it produces. The Welsh Government's Carbon Budget makes clear that Wales needs carbon removal solutions to mitigate other polluting parts of the economy to achieve a Net Zero economy.

Mike Maudsley, CEO of enfinium, said, "To deliver a net zero carbon economy, Wales needs to find a way to produce carbon removals, or negative emissions, at scale. Installing carbon capture at the Parc Adfer facility would transform it into the largest generator of carbon negative power in Wales, decarbonise unrecyclable waste and support the green economy in Deeside and wider North Wales region."

Opened in 2019 in partnership with the five local authorities that make up the North Wales Residual Waste Treatment Partnership (NWRWTP), Parc Adfer currently diverts up to 232,000 tonnes of unrecyclable waste from climate damaging landfill. As recognised by the National Infrastructure Commission, emissions from energy from waste plants are lower per tonne of waste compared to landfill.

The proposal has been put forward for grant support from the UK Government as part of the expansion of their 'Track-1' carbon capture programme. The captured carbon will be transported using the pipeline network currently being developed in the region for the HyNet carbon capture cluster, one of the first two priority carbon capture clusters selected for development in the UK.

Planning and consenting for the Parc Adfer CCS project will begin later this year. The UK Government is expected to provide an update on which projects are progressing through the Track-1 HyNet Expansion programme by the summer.

SLB acquires majority stake in Aker Carbon Capture

energy.slb.com
www.akercarboncapture.com

A new joint venture company will combine technology portfolios, expertise and operations platforms to bring carbon capture solutions to market, faster and more economically.

Bringing together complementary technology portfolios, leading process design expertise and an established project delivery platform, the partnership will combine ACC's commercial carbon capture product offering and SLB's new technology developments and industrialisation capability.

It will create a vehicle for accelerating the introduction of early-stage technologies into the global market on a commercial, proven platform. Following the transaction, SLB will own 80% of the combined business and ACC will own 20%.

The cooperation between ACC and SLB as shareholders of the combined business, will be governed by a shareholders' agreement. This will provide for board representation and certain other governance and minority protection rights for ACC, for SLB to finance the realisation of the business plan by shareholder loans and for the possibility for ACC to sell its 20% stake in the combined business in the future.

"The decision to combine ACC and SLB's carbon capture business is underpinned by a strategic vision that reflects our commitment to accelerate the industrial adoption of carbon capture," said Egil Fagerland, chief executive officer, ACC. "By partnering with SLB, we will become a diversified, global carbon capture player. Our combined suite of technologies and global reach will make a platform positioned to profitably scale faster, to the benefit of customers, employees and shareholders."

The transaction is subject to regulatory approvals and is expected to close by end of the second quarter, 2024.

After a lock-up period of three years, ACC will be entitled to sell its stake in ACCH to SLB during a period of six months (put option). Conversely, SLB will after expiry of the put option have a right to purchase ACC's 20% stake in the combined business during the following six months (call option).

TotalEnergies acquires Talos Low Carbon Solutions

www.totalenergies.com
www.talosenergy.com

Talos has investments in several carbon capture projects including Bayou Bend on the Texas Gulf Coast.

After completion of the transaction, TotalEnergies will own a 25% share in the Bayou Bend project, alongside Chevron (50%, operator) and Equinor (25%). Bayou Bend project is a major CO2 storage project located along the Texas Gulf Coast, close to the company's assets in the region.

TotalEnergies will also own a 65% operated interest in the Harvest Bend (Louisiana) project and a 50% interest in the Coastal Bend (Texas) project. With Coastal Bend and Harvest Bend being located farther away from the company's other existing assets, TotalEnergies' intention is to divest its interest in these two projects after closing.

The Bayou Bend project is a carbon transportation and storage solution for industrial emitters located in the Houston Ship Channel and Beaumont – Port Arthur region, one of the largest industrial corridors in the United States. Comprising licenses dedicated to CO2 storage, offshore and onshore, covering about 600 km2, it could enable the storage of several hundred million tons of CO2. Thanks to its location, its size and favorable geological characteristics, Bayou Bend is a world-class CCS opportunity.

"TotalEnergies is pleased to enter the Bayou Bend project through the acquisition of Talos Low Carbon Solutions. Ideally located close to our Port Arthur refinery and our petrochemicals assets in La Porte, this project will be instrumental for the reduction of direct emissions from our US operations. This transaction gives momentum to the decarbonization of hard-to-abate US emissions and marks a milestone on our journey to get to Net Zero by 2050, together with society", said Patrick Pouyanné, Chairman and CEO of TotalEnergies.

Bayou Bend CCS recently commissioned Sulmara to conduct an archaeological and geohazard assessment of the proposed Bayou Bend pipeline route which it said had unearthed the "best data we've seen" from an uncrewed surface vessel (USV) during a high-resolution geophysical survey.

A comparative look at Direct Air Capture and CO2 capture from biogas upgrading

This article focuses on the comparative analysis and synergistic potential of air-based and biogenic CO2 capture techniques, highlighting their central roles in advancing carbon management practices. By Alexa Grimm, research and development engineer, Nordsol.

In our collective effort to address climate change, carbon capture technologies have become pivotal in achieving both European and global climate objectives. Direct Air Capture (DAC), which involves capturing carbon dioxide directly from the atmosphere, is a relatively recent innovation that has attracted a lot of attention due to its potential to significantly reduce atmospheric CO2 levels.

A less well-known but equally important method involves capturing CO2 during biogas upgrading, where CO2 is separated from biomethane – a renewable energy source derived from organic materials. The biogenic CO2 generated in this way, being free from climate-relevant emissions, presents a valuable resource for various applications.

The DAC sector is rapidly expanding as new companies explore various technologies. Similarly, interest in biogenic CO2 capture is on the rise. At Nordsol, we acknowledge the significance of this approach and are actively contributing to this growing field.

Direct air capture: advancing carbon reduction efforts

Direct air capture technology represents a considerable advancement in our efforts to reduce atmospheric CO2 levels. This innovative method involves extracting CO2 directly from the atmosphere, where it exists at a concentration of about 0.04% or 410 ppm. One of the key strengths of DAC is its flexibility in terms of location – it can be set up in a variety of environments due to its minimal land and resource requirements. This characteristic positions DAC as a potentially global solution for atmospheric CO2 reduction.

There are currently two main methods of capturing CO2 from the atmosphere: chemical absorption, where chemical solvents such as amines absorb CO2, which is then released by heating, and temperature-pressure swing adsorption (TPSA), where CO2 is adsorbed onto a solid material and later released through temperature and pressure adjustments. Each method has its own challenges, particularly in terms of the energy required for effective operation [1].

The energy-intensive nature of DAC becomes evident when considering the minimum theoretical energy required for separating CO2 from gas streams of varying concentrations. This relationship is illustrated in Figure 1, which shows the higher energy requirement for capturing CO2 from lower concentration sources - a fundamental challenge for DAC technology. Currently, the cost of DAC technology is between 600 and 1000 euros per ton of CO2 captured [1].

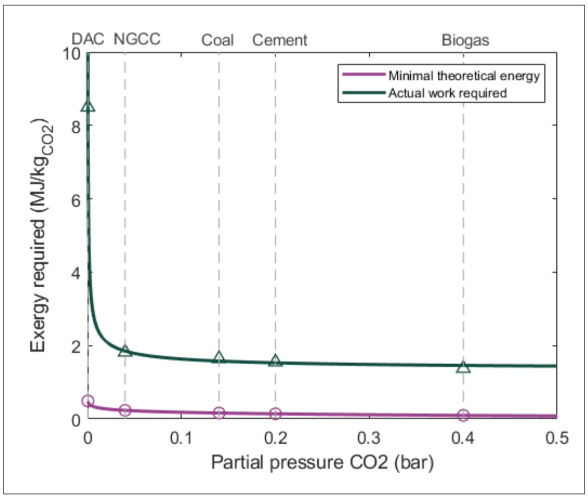


Figure 1 This graph compares the minimal theoretical energy required to separate CO2 from gas streams (represented by the purple line, indicating Gibbs free energy) against the actual energy requirements for various CO2 capture methods (green line). It includes data for Direct Air Capture (DAC), natural gas combined cycle (NGCC) power plants, advanced supercritical (ASC) coal power plants, and carbon capture and storage (CCS) from cement production, adapted from [4]

This figure relates solely to the capture process and does not include the additional costs of liquefying and transporting the captured CO2. According to forecasts, advances in DAC technology could reduce these costs to less than 150 euros per ton by 2050 [2]. In addition, the technology requires significant sustainable power, necessitating a large land area for energy sources, such as solar or wind farms, to operate efficiently and sustainably.

As of the end of 2023, the total DAC capacity in the European Union stood at 0.51 MtCO2/year. Projections for 2026 indicate an increase in capacity to between 1.1 and 2.1 MtCO2/year, including contributions non-EU member Norway. Looking further ahead, the European Commission has set an ambitious target of capturing 5 MtCO2 per year by 2030 [2].

This emerging technology, while still developing, holds considerable promise for future carbon reduction strategies, offering a solution that can be tailored to various geographic and environmental conditions.

Biogenic CO2 capture: an immediate and practical approach

Capturing CO2 from biogas installations represents a significant opportunity in carbon management and stands out for its practicality and effectiveness. The technique focuses on CO2 produced during the anaerobic digestion of organic materials, leading to the creation of biomethane—a renewable substitute for fossil methane—and a stream of biogenic CO2. The latter, free from climate-relevant emissions, emerges as a crucial resource for a range of applications, marking an essential step toward sustainable carbon management.

Beyond biogas upgrading, capturing CO2 from the combustion or gasification of biomass in bioenergy production is one of several additional pathways that contribute to making biogenic CO2 usable for sustainable development. A key aspect of biogenic CO2 capture is the sustainability of biogas production, which is influenced by the choice of biomass used. In recent years, there has been a shift towards more environmentally sustainable feedstocks, such as agricultural residues, municipal biowaste, and sewage sludge, away from reliance on food and feed crops [3].

This shift is not only in line with the sustainability criteria of the Renewable Energy Directive, but also supports the reduction of greenhouse gas emissions and the wider goals of sustainable climate change mitigation. The use of waste biomass and agricultural residues reduces environmental and social impacts and steers bioenergy production in a more sustainable direction.

One advantage of CO2 capture from biogas is the high concentration of CO2 in the gas, typically ranging from 30-50% (Figure 1). This concentration enables efficient capture processes. Capturing biogenic CO2 can be considered cost-neutral as it is a by-product of biomethane or bio-LNG production, with its purity largely depending on the biogas upgrading technology employed.

The primary methods—adsorption, chemical absorption, membrane separation, and cryogenic separation—are all capable of producing high-purity CO2. Traditional methods, such as using liquid solvents, require regeneration at high temperatures, additional equipment, and chemicals, potentially leading to waste streams. Furthermore, the cyclic nature of adsorption can result in fluctuations in gas flow and temperature, impacting system stability. Membrane separation is notable for its continuous, energy-efficient operation that requires neither heat nor chemicals and produces no waste, thereby simplifying CO2 capture.

Although cryogenic separation directly liquefies CO2, it is more energy-intensive compared to other methods. For technologies other than cryogenic separation, integrating a liquefaction unit incurs additional costs ranging from 50 to 150 euros per ton for liquefying captured CO2. While all methods can produce high-quality CO2 suitable for liquefaction, intelligently integrating these processes is essential to ensure operational ease, minimize CO2 losses, and reduce energy consumption.

In 2020, the biogas and biomethane production in Europe indicated a theoretical potential of capturing 24 Mton of biogenic CO2, with approximately 3.9 MtCO2/year already being separated during the biogas upgrading process [3]. As production is expected to double by 2030, the potential for CO2 capture could increase to 46 Mton. Assuming these projections hold true, this would exceed DAC capacity by more than nine times. Looking ahead to 2050, this potential is projected to reach 124 Mton, equivalent to 3% of the EU-27's greenhouse gas emissions in 2020 [3].

Such projections underscore the vital role of biogenic CO2 capture in the overarching strategy for achieving climate neutrality, offering a cost-effective, sustainable, and immediately actionable solution within the broader spectrum of carbon management technologies.

Nordsol opened the first Dutch bio-LNG plant in October 2021 with Renewi and Shell. This plant upgrades and liquefies 8 million Nm3 biogas from organic waste into 3.4 kilotons of bio-LNG and 6.3 kilotons of biogenic liquid CO_2 per year

Conclusion

The fight against climate change requires a variety of solutions, with both Direct Air Capture (DAC) and CO2 capture from biogas upgrading plants playing crucial roles. DAC, often highlighted in literature and media, is recognized for its broad potential. CO2 capture from biogas plants, though receiving less public attention, has shown great promise and provides an immediate and efficient strategy. These technologies complement each other, each playing an important role in the common global strategy to combat climate change.

At Nordsol, we developed a technology that smoothly integrates CO2 capture into bio-LNG production, and our technology highlights the economic and environmental synergies achieved through this process. Our membrane concept for treating biogas combines very well with the liquefaction of biomethane and biogenic CO2, resulting in no losses of CO2 or CH4 during production.

Although bio-LNG production remains our primary focus, the capture and liquefaction of CO2 not only helps to improve the environmental impact of our operations but also increases the profitability and attractiveness of our technology. By intelligently combining CO2 liquefaction and bio-LNG production, we can streamline the process, minimize losses, and improve overall efficiency. This approach embodies the principles of a circular economy that optimizes the use of resources while minimizing environmental impact.

Our Amsterdam demonstration plant already captures approximately 5500 tons of CO2 annually, equivalent to the emissions from around 1300 average cars per year. As we expand our projects, we expect this contribution to CO2 reduction to increase significantly in the future. While our current efforts are just the beginning in the broader context of climate action, they are crucial and impactful steps toward realizing the full potential of available technologies. By combining the possibilities of CO2 capture from biogas with bio-LNG production, we are confident that together, we will achieve the EU's carbon neutrality goal.

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[2] McQuillen, J. (2022). European CO2 availability from point-sources and direct air capture. Report for: Transport & Environment. 2022

[3] EBA 2022. EBA Statistical Report 2022. Brussels, Belgium, November 2022.

[4] Grimm, A., Kramer, G. J., Gazzani, M., Sabatino, F., van Sint Annaland, M., Gallucci, F. (2019). Process modeling and optimization for production of carbon-neutral solar fuels. Poster presented at GHGT-13. Switzerland.

More information

www.nordsol.com

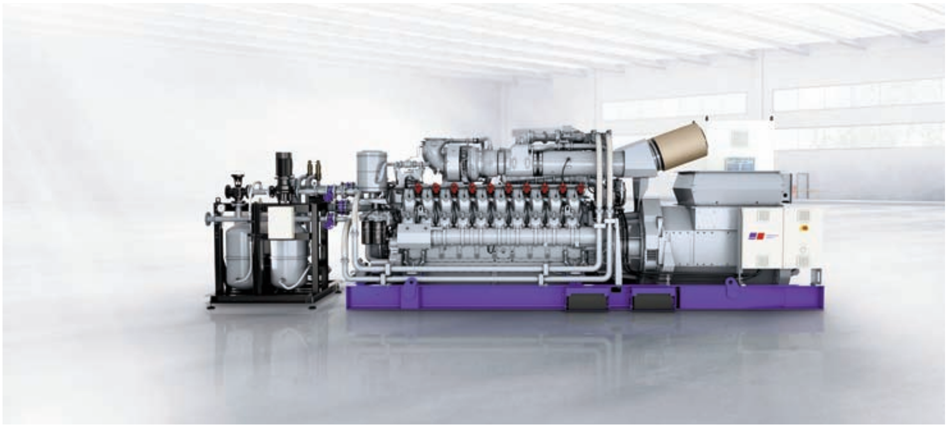
Rolls-Royce, Landmark and ASCO collaborate on CO2 recovery engine

The consortium is looking at developing scalable solutions for clean power generation with carbon capture from mtu gas reciprocating engines.

"Power generation is a highly attractive, growing market segment and an area of strategic focus for Rolls-Royce, where partnerships can help further grow market position and broaden its power generation offering, as set out at last November's Capital Markets Day," said Tobias Ostermaier, President Stationary Power Solutions at Rolls-Royce Power Systems. Rolls-Royce is committed to becoming a net zero company by 2050 and supporting customers to do the same.

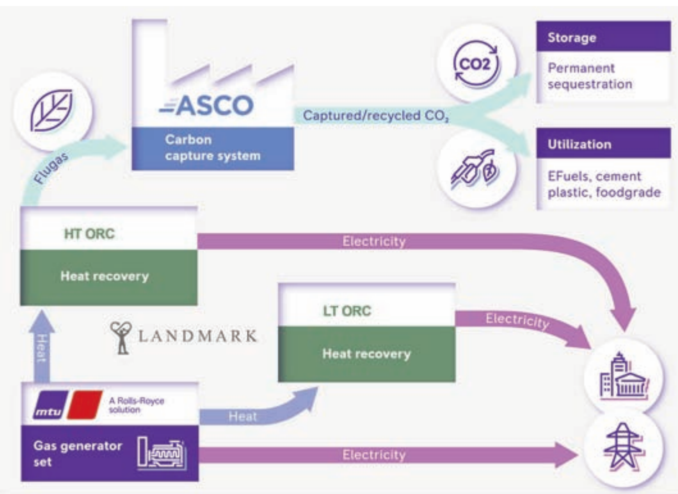
The plan is to make the captured CO2 available (utilisation) for use in various industries such as food production, Efuels, sustainable aviation fuel (SAF), cement and plastic production (utilisation). The captured CO2 will also be ready for transportation should permanent sequestration be preferred (storage).

Rolls-Royce is contributing its extensive experience and global network in the field of decentralized power generation to the cooperation through its Power Systems division with the mtu product portfolio. The contribution of LMPH, a developer of high-efficiency Combined Heat and Power (CHP) projects, is its patented FLEXPOWER PLUS® concept, combined with technical expertise and patented technologies. ASCO has over 50 years of experience in developing and building carbon capture (or CO2-Recovery) plants and will be providing valuable insights and solutions from the carbon capture industry.



Developing scalable solutions for clean power generation with carbon capture from mtu gas reciprocating engines. n the picture a 20 cylinder version of mtu Series 4000 gas genset

Tobias Ostermaier, President Stationary Power Solutions at Rolls-Royce Power Systems, said, "We are convinced that CO2 capture and storage systems in combination with our mtu gas gensets are an important building block on the way to Net Zero. As a complement to renewable energy sources, internal combustion engines can already provide clean, cost-effective and extremely reliable power generation."



The captured CO2 is to be made available for use in various industries such as food production, efuels, sustainable aviation fuel (SAF), cement and plastics production (recycling)

Ralph Spring, CEO of ASCO Carbon Dioxide, explained, "We want to serve hard-to-abate industries with a cost-effective solution and this cooperation is a huge step into the right direction."

First plant under construction in UK

The technology that will be used in the scalable solution is already showcased in a first-of-its-kind decarbonised flexible power generation and carbon capture plant that is currently under construction in Rhodesia, Nottinghamshire in the UK.

The Rhodesia plant is the first developed under the Landmark Power Holdings, FLEXPOWER PLUS® concept for flexible power generation with natural gas-powered mtu engines and ASCO carbon capture technology. The plant will support the UK electricity grid, providing power for those living in the area, while turning the resulting CO2 emissions into food-grade carbon dioxide.

More information

www.mtu-solutions.com
www.lmph-uk.com
www.ascoco2.com

Engineers find a new way to convert carbon dioxide into useful products

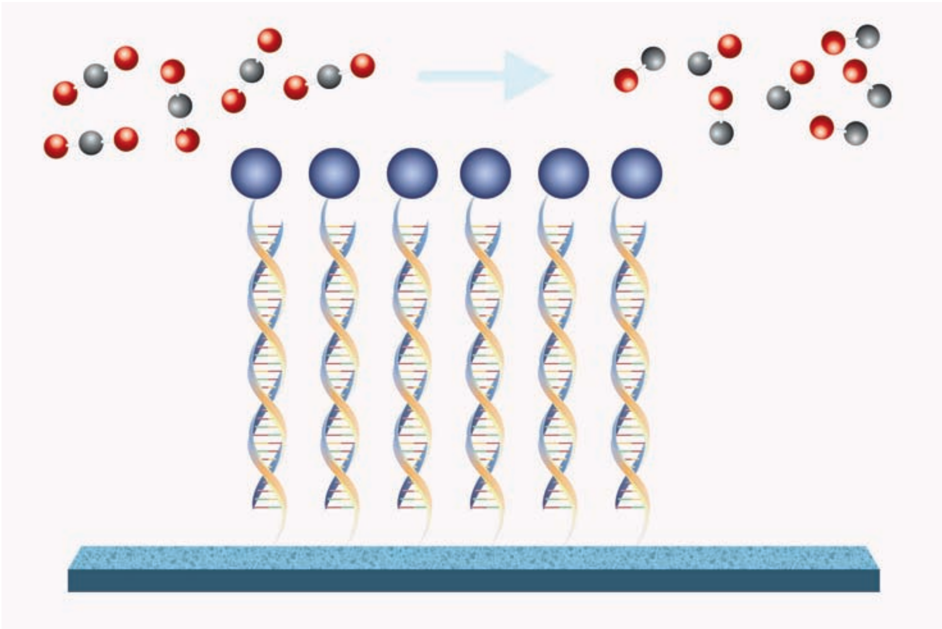
MIT chemical engineers have devised an efficient way to convert carbon dioxide to carbon monoxide, a chemical precursor that can be used to generate useful compounds such as ethanol and other fuels.

A catalyst tethered by DNA boosts the efficiency of the electrochemical conversion of CO2 to CO, a building block for many chemical compounds.

DNA strands attached to the surface of a cathode, a blue bar, with catalysts, depicted as blue circle, attached to the ends. Set of five tri-molecules change from carbon dioxide to carbon monoxide, indicated by change in red and gray circles.

If scaled up for industrial use, this process could help to remove carbon dioxide from power plants and other sources, reducing the amount of greenhouse gases that are released into the atmosphere.

"This would allow you to take carbon dioxide from emissions or dissolved in the ocean, and convert it into profitable chemicals. It's really a path forward for decarbonization because we can take CO2, which is a greenhouse gas, and turn it into things that are useful for chemical manufacture," says Ariel Furst, the Paul M. Cook Career Development Assistant Professor of Chemical Engineering and the senior author of the study.



MIT chemical engineers have shown that by using DNA to tether a catalyst (blue circles) to an electrode, they can make the conversion of carbon dioxide to carbon monoxide much more efficient. Credits: Credit: Christine Daniloff, MIT; iStock

The new approach uses electricity to perform the chemical conversion, with help from a catalyst that is tethered to the electrode surface by strands of DNA. This DNA acts like Velcro to keep all the reaction components in close proximity, making the reaction much more efficient than if all the components were floating in solution.

Furst has started a company called Helix Carbon to further develop the technology.

Breaking down CO2

Converting carbon dioxide into useful products requires first turning it into carbon monoxide. One way to do this is with electricity, but the amount of energy required for that type of electrocatalysis is prohibitively expensive.

To try to bring down those costs, researchers have tried using electrocatalysts, which can speed up the reaction and reduce the amount of energy that needs to be added to the system. One type of catalyst used for this reaction is a class of molecules known as porphyrins, which contain metals such as iron or cobalt and are similar in structure to the heme molecules that carry oxygen in blood.

During this type of electrochemical reaction, carbon dioxide is dissolved in water within an electrochemical device, which contains an electrode that drives the reaction. The catalysts are also suspended in the solution. However, this setup isn't very efficient because the carbon dioxide and the catalysts need to encounter each other at the electrode surface, which doesn't happen very often.

To make the reaction occur more frequently, which would boost the efficiency of the electrochemical conversion, Furst began working on ways to attach the catalysts to the surface of the electrode. DNA seemed to be the ideal choice for this application.

"DNA is relatively inexpensive, you can modify it chemically, and you can control the interaction between two strands by changing the sequences," she says. "It's like a sequence-specific Velcro that has very strong but reversible interactions that you can control."

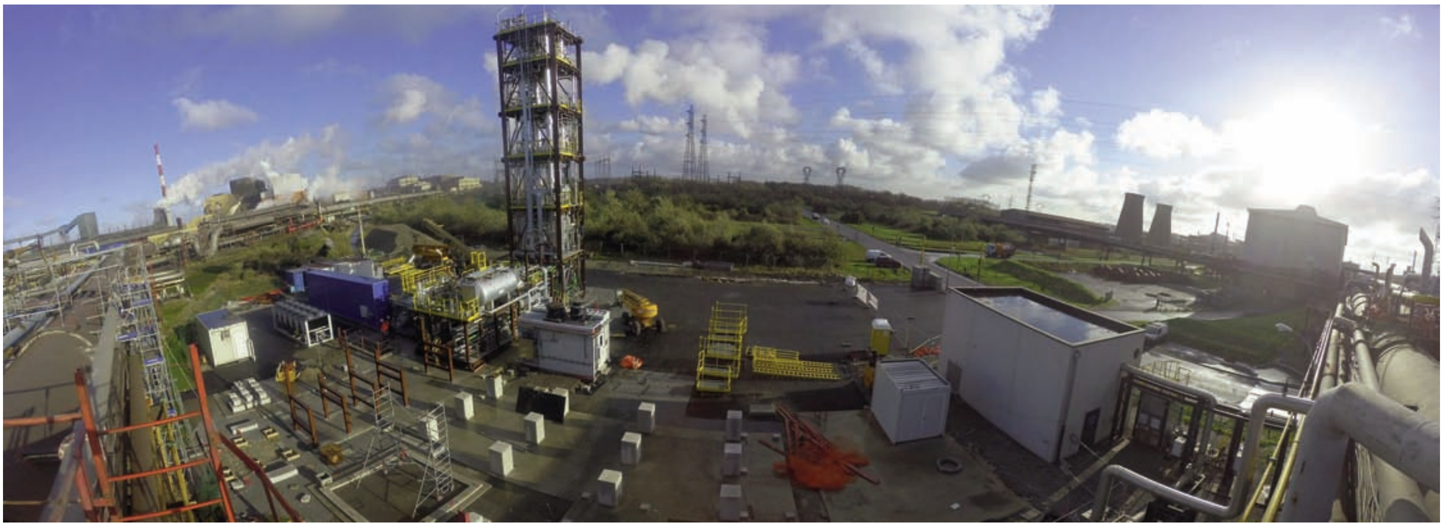
To attach single strands of DNA to a carbon electrode, the researchers used two "chemical handles," one on the DNA and one on the electrode. These handles can be snapped together, forming a permanent bond. A complementary DNA sequence is then attached to the porphyrin catalyst, so that

More information

https://furstlab.mit.edu/

CO2 capture from steel using the DMX™ process successful

The "3D" project (DMX™ Demonstration in Dunkirk) process demonstration pilot has been operating in stable conditions since April 2023 to capture the CO2 present in blast furnace gases emitted during steel production at ArcelorMittal's Dunkirk site.



Piloting a new form of carbon capture and utilisation or storage (CCU/S) technology on an industrial scale at ArcelorMittal's Dunkirk in collaboration with partners

Coordinated by IFPEN, the "3D" project brings together 11 partners from research and industry from 6 European countries: ArcelorMittal, Axens, TotalEnergies, Air Products, Brevik Engineering, John Cockerill, DTU, Gassco, ETHZ and Uetikon.

Developed and patented by IFPEN, the DMX™ process, a French technology marketed by Axens, uses an amine demixing solvent to capture CO2 contained in the flue gases produced by heavy industries.

The objectives of this pilot test run are to show the operability of the process, validate good energy performances, confirm the stability of the solvent and demonstrate the purity of the captured CO2. Results obtained since April 2023 are in line with expectations for the technology and confirm, even at this early stage, the efficiency and energy performance of the technology.

A comprehensive series of operational tests has been conducted with the unit operating 24/7. CO2 capture rates exceeded 90%. The pilot unit produces CO2 with a high level of purity (> 99.5%) while energy consumption remains remarkably low. Moreover, after thousands of operational hours, no solvent degradation has been observed in spite of the high concentrations of contaminants present in the gas treated.

Vania Santos-Moreau, 3D and DinamX project manager, said, "After 15 years of development of this innovative technology at IFPEN from proof of concept through to the laboratory, we're proud to have demonstrated the performance of the DMX™ process for an industrial gas flow."

"It's all thanks to intensive teamwork, conducted with our partners since the launch of the 3D project back in May 2019. And it represents an important step towards the decarbonization of industry in France and around the world."

The significant reduction in the energy required for the process and the excellent stability of the solvent make the DMX™ process a unique, innovative, efficient and flexible solution.

The marketing of a competitive French technology like DMX™ fits squarely with the CCUS strategy launched by the French government and will contribute to the country's national industrial decarbonization objectives.

Clément Salais, manager of the CO2 capture team at Axens, said, "The step we've taken with this demonstrator is essential to enable Axens to commit to performance guarantees, and to support our customers in their future decarbonization projects."

More information

https://3d-ccus.com

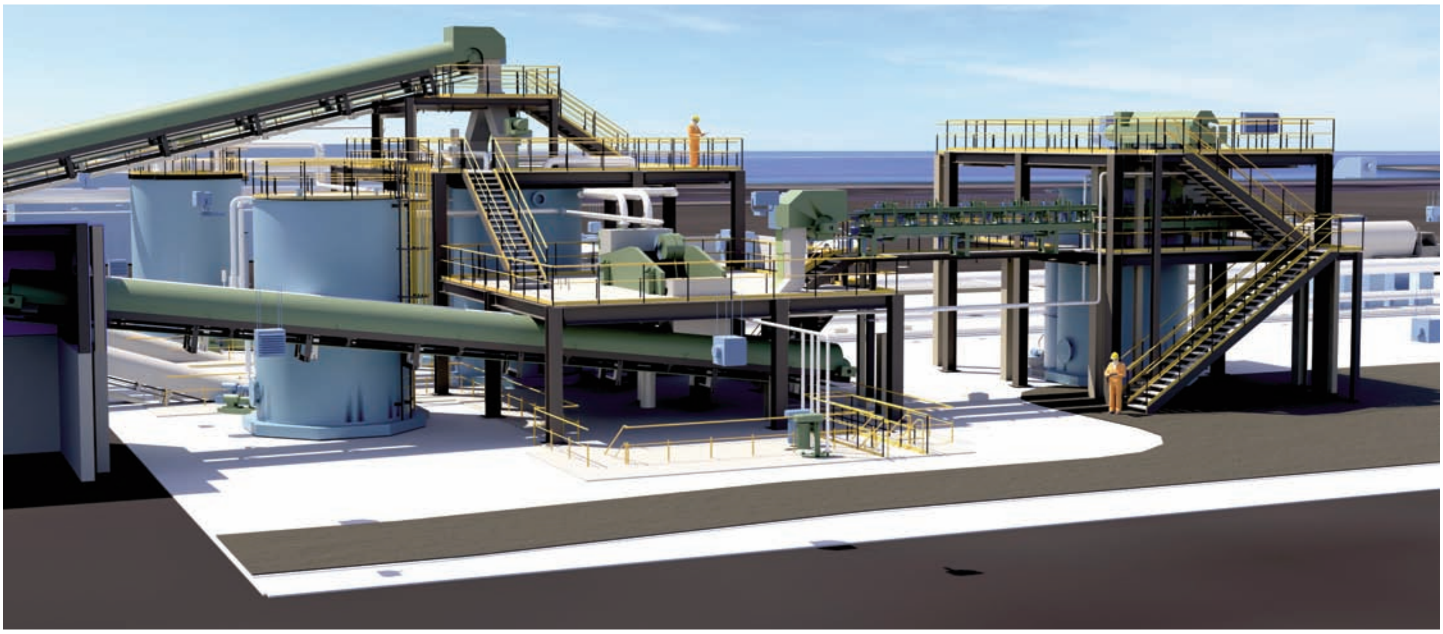
www.axens.net

corporate.arcelormittal.com

www.ifpenergiesnouvelles.com

U. S. Steel and CarbonFree sign agreement on steel plant CO2 capture

CarbonFree's SkyCycle™ technology will capture and mineralise up to 50,000 metric tons of carbon dioxide annually at U. S. Steel's facility in Gary, Indiana, to convert emissions into specialty-grade, carbon-neutral calcium carbonate.



Construction on the SkyCycle plant in the U. S. Steel Gary Works facility is expected to begin in summer 2024 with operations projected to begin in 2026

The companies have signed a definitive agreement to capture carbon emissions generated from U. S. Steel's Gary Works Blast Furnaces in a first-of-its-kind project, which will have the opportunity to be expanded in the years to come.

The initial SkyCycle project responds to the increasing demand for low emissions products, such as verdeX™ advanced sustainable steel, from customers. The project is the first step in exploring the scalability of this technology for potential future implementation across the enterprise.

CarbonFree's patented SkyCycle solution captures carbon emissions from hard-to-abate industrial sources and converts them into a carbon-neutral version of calcium carbonate, which is essential to the creation of paper and plastics, as well as personal care, paint, and building products. CarbonFree-produced calcium carbonate made from captured carbon dioxide can help decarbonise global supply chains by enabling manufacturers to reduce Scope 3 emissions, or it can be stored in an environmentally conscious way without the need for pipelines or disposal wells.

"U. S. Steel is setting a precedent for how manufacturers can and must proactively manage their carbon emissions, and CarbonFree is honored to play a role in this legacy," said Martin Keighley, CEO of CarbonFree. "At CarbonFree, we are pioneering profitable carbon capture utilization through disruptive specialty chemical manufacturing using waste carbon dioxide as a primary feedstock. As carbon capture continues to be recognized as an indispensable solution on the path to carbon neutrality for carbon-intensive industries, we look forward to helping U. S. Steel achieve its decarbonization goals while providing economic and environmental benefits to the city of Gary and state of Indiana."

The partnership will likely enable U. S. Steel to offer steel used in the automotive, appliance, and packaging industries with a significantly reduced carbon footprint. In addition to capturing carbon dioxide, CarbonFree will use slag produced by the blast furnace operation as part of the calcium carbonate production process.

"Innovating to capture carbon at an integrated mill is the latest example of how steel is enabling a more sustainable future," said Scott Buckiso, Senior Vice President & Chief Manufacturing Officer, U. S. Steel. "Moreover, U. S. Steel has a history of 'firsts' that we're confidently building on. Using SkyCycle technology for the first project of its kind in North America should benefit the community for generations to come."

More information

www.ussteel.com

www.carbonfree.cc

Flue2Chem: initiative to make products from CO2 begins

Carbon dioxide from factory chimneys in the UK will this week start its journey towards being recycled into household detergent ingredients.

The innovation is part of a cross-sector collaboration to find an alternative raw material to virgin fossil fuel for many manufactured goods, from cosmetics to plastics. The Flue2Chem initiative will examine the potential for using valuable carbon dioxide emissions from industry as an alternative source of carbon.

Flue2Chem is a two-year demonstration project supported by Innovate UK. It seeks to redesign and validate a UK value chain to convert valuable carbon emissions into sustainable materials for consumer products.

17 organisations including global manufacturers of fast-moving consumer goods (FMCGs), universities and innovation experts are working together in the unprecedented collaboration. In this first step, the partners will examine the industrial-level transformation of carbon dioxide emissions from paper manufacturing into surfactants, contained in products such as dishwashing and laundry products, paints.

Beena Sharma of CCUI with the carbon capture equipment for Flue2Chem. Credit: Flue2Chem

5.3% of the world's fossil fuel carbon is used to manufacture everyday materials and household products such as plastics, textiles and cleaning products.

The findings will inform industry and the Government about the feasibility of using non virgin fossil fuel sources for many household and consumer products. The group will assess both the technical feasibility of the new and highly-innovative processes, as well as the economic impacts for creating a new supply chain.

This week, the first carbon dioxide for the project will be captured at the Holmen Iggesund Paperboard Mill in Workington, Cumbria. Later in March 2024, the first batch of CO2 will be sent to specialist facilities at the University of Sheffield and CPI in Redcar, Teesside. There it will begin the first stage of the innovative processes to convert it into the chemical building blocks of surfactants.

Al Sanderson, Flue2Chem Project Manager, said, "For the last 14 months, we have been preparing for this moment. The chemical processes that will turn carbon dioxide into surfactants contained in many cleaning products have been identified and are being optimised."

"Each step is being closely measured so that we can understand the socio-economic and environmental impact of this new way to make common chemicals used in everyday products."

"This will support the design of potential future supply chains that could eliminate the need for virgin fossil carbon to make these product ingredients in future."

Carbon dioxide from paper manufacturing sites in Irvine, Scotland as well as Workington will be captured using technology developed by CCU International (CCUI), a technology spin out business at the University of Sheffield. The pioneering technology was manufactured in Dewsbury, West Yorkshire.

Beena Sharma, CEO and Co-Founder of CCUI, said, "Capturing carbon dioxide and utilising it back into the industry supports a circular carbon economy and makes significant contributions to net-zero goals. This project highlights the importance of collaboration, and we look forward to deploying the technology in the coming months to a second emitter site in Scotland."

The Flue2Chem project could form the basis for the development of carbon harvesting on a commercial scale. As well as cutting emissions from manufacturing, it could reduce the need for oil and gas extraction in future to make detergent and other consumer products.

More information

www.soci.org/flue2chem

Cost of direct air carbon capture to remain higher than hoped

ETH researchers concluded the cost of removing large quantities of CO2 from the air will fall in the medium term, but not as much as previously hoped.

Switzerland plans to reduce its net carbon emissions to zero by no later than 2050. To achieve this, it will need to drastically reduce its greenhouse gas emissions. In its climate strategy, the Swiss government acknowledges that some of these emissions, particularly in agriculture and industry, are difficult or impossible to avoid.

Swiss climate policy therefore envisages actively removing 5 million tonnes of CO2 from the air and permanently storing it underground. By way of comparison, the Intergovernmental Panel on Climate Change (IPCC) estimates that up to 13 billion tonnes of CO2 will need to be removed from the atmosphere every year from 2050.

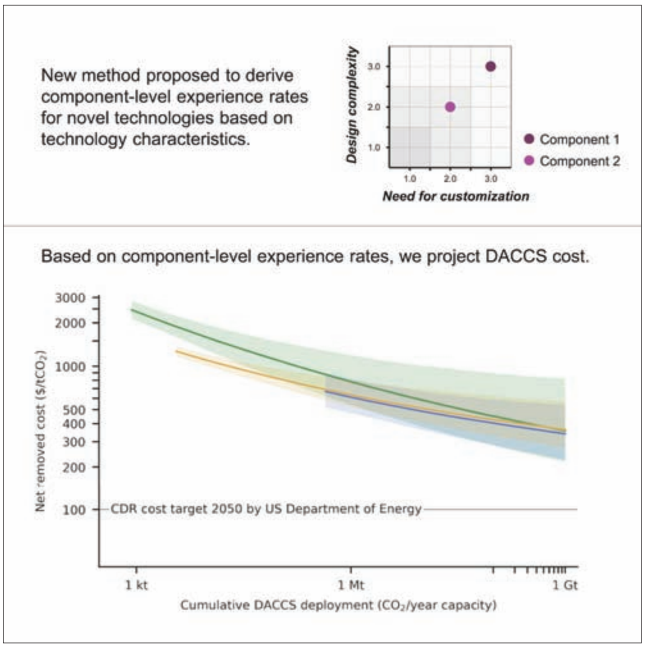
These targets will be hard to achieve unless ways can be found to reduce the cost of direct air capture (DAC) technologies. ETH spin-?off Climeworks operates a plant in Iceland that currently captures 4,000 tonnes of CO2 a year, at a cost per tonne of between 1,000 and 1,300 dollars. But how quickly can these costs come down as deployment increases?

ETH researchers have developed a new method that provides a more accurate estimate of the future cost of various DAC technologies. As the technologies are scaled up, direct air capture will become significantly cheaper – though not as cheap as some stakeholders currently anticipate. Rather than the oft-?cited figure of 100 to 300 US dollars, the researchers suggest the costs are more likely to be between 230 and 540 dollars.

"Just because DAC technologies are available, it certainly doesn't mean we can relax our efforts to cut carbon emissions. That said, it's still important to press ahead with the expansion of DAC plants, because we will need these technologies for emissions that are difficult or impossible to avoid," says Bjarne Steffen, ETH Professor of Climate Finance and Policy. He developed the new method together with Katrin Sievert, a doctoral student in his research group, and ETH Professor Tobias Schmidt.

Three technologies and their costs

The ETH researchers applied their method to three direct air capture technologies. The goal was to compare how the cost of each technology is likely to evolve over time. Their findings suggest that the process developed by Swiss company Climeworks, in which a solid filter with a large surface area traps CO2 particles, could cost between 280 and 580 US dollars per tonne by 2050.



The estimated costs of the other two DAC technologies fall within a similar range. The researchers calculated a price of between 230 and 540 dollars a tonne for the capture of CO2 from the atmosphere using an aqueous solution of potassium hydroxide, a process that has been commercialised, for example, by Canadian company Carbon Engineering. The cost of carbon capture using calcium oxide derived from limestone was estimated at between 230 and 835 dollars. This latter method is offered by US company Heirloom Carbon Technologies, among others.

Focus on components

Estimating how the cost of new technologies will change over time is particularly difficult in situations where very little empirical information is available. This lack of real-?world data represents a challenge for DAC technologies: they haven't been in use long enough to allow projections to be made as to how their cost might evolve in the future.

To address this dilemma, the ETH researchers focused on the individual components of the different DAC systems and estimated their cost one by one. They then asked 30 industry experts to assess the design complexity of each technological component and determine how easy it would be to standardise.

The researchers based their work on certain assumptions: namely, that the cost of less complex components that can be mass-?produced will fall more sharply, while the cost of complex parts that must be tailored to each individual system will fall only slowly. DAC systems also include mature components such as compressors, which cannot feasibly be made much cheaper. Once the researchers had estimated the cost of each individual part, they then added the cost of integrating all the components and the costs of energy and operation.

Despite significant uncertainties in their calculations, the researchers' message was clear: "At present, it is not possible to predict which of the available technologies will prevail. It is therefore crucial that we continue to pursue all the options," says Katrin Sievert, lead author of the study, which recently appeared in the journal Joule.

More information

https://ethz.ch/en.html

National Carbon Capture Center begins first cryogenic carbon capture testing

Carbon America is beginning testing of its FrostCC cryogenic carbon dioxide separation process which could halve capital costs.

Managed and operated by Southern Company for the U.S. Department of Energy's National Energy Technology Laboratory (NETL), the NCCC is dedicated to advancing viable and innovative carbon capture technologies. Carbon America's FrostCC project offers an exceptional opportunity for a collaborative team effort to demonstrate a next-generation cryogenic carbon capture technology in coordination with NETL and DOE's Office of Fossil Energy and Carbon Management

"Cryogenic separation has enormous potential for post-combustion carbon capture from various sources," said John Carroll, NCCC principal engineer. "Our team is excited to host Carbon America's field test of its cryogenic technology at the pilot scale here at the National Carbon Capture Center – a first for our facility."

Carbon America's FrostCC cryogenic CO2 separation technology requires no external refrigerant. The process compresses and expands the flue gas stream with recuperative heat integration, producing a self-refrigerating flue gas. The technology freezes the CO2 and, importantly, nearly all other emissions in the flue gas. CO2 is then collected as a liquid product. The process can effectively and efficiently reduce carbon emissions from fossil power plants, cement, pulp and paper, and iron and steel facilities, as well as certain chemical production plants.

The Carbon America team has successfully demonstrated carbon capture on natural gas flue gas with FrostCC at the NCCC. The team is currently further tuning the controls of the system to get to 24/7 continuous carbon capture operation.

"The NCCC has a strong history of working with technology developers to deploy their processes in an industrial setting for the first time. All of Carbon America's previous testing has occurred at their facilities in Colorado, which limited them to batch operating campaigns," said John Northington, NCCC Director. "The pilot testing at NCCC will be the first continuous demonstration of both 'frosting' of CO2 and collecting it as a liquid. To date, the NCCC has been able to provide our experience with construction, installation and commissioning to support Carbon America.

The Carbon America team has successfully demonstrated carbon capture on natural gas flue gas with FrostCC at the NCCC

Carbon America's objectives for the NCCC field test are:

• Continuous operations for 1,000 hours

• Capture capacity at a minimum of 500 tonnes per year, with a maximum of 1,000 tonnes per year

• Capture rate of up to 99%

• Test data validating Carbon America's thermodynamic models of the FrostCC technology to allow confident development of scale-up designs

"Carbon America is excited to be testing our new FrostCCtechnology at the National Carbon Capture Center," said Miles Abarr, Chief Technology Officer at Carbon America.

"Our cryogenic point-source capture system is a low-cost, mass-manufacturing solution with modular, scalable components. FrostCC, which doesn't use added chemicals or water and is fully electrically driven, can be readily applied to a full range of industries and power plants. The design enables us to drive down capital costs of carbon capture projects to half of what they are today."

More information

www.carbonamerica.com

www.nationalcarboncapturecenter.com

Capture & utilisation news

Chevron takes stake in ION Clean Energy

www.chevron.com
www.ioncleanenergy.com

Chevron New Energies (CNE) led the $45 million investment round which will help fund commercial deployment of ION's ICE-31 liquid amine carbon capture technology for hard-to-abate emissions.

CNE said it will look to use ION's ICE-31 technology to service customers with high volume and low concentration CO2 emissions and also partner with ION customers on projects to scale the technology sooner.

"We have truly special solvent technology. It is capable of very high capture efficiency with low energy use while simultaneously being exceptionally resistant to degradation with virtually undetectable emissions. That's a pretty powerful combination that sets us apart from the competition. This investment from Chevron is a huge testament to the hard work of our team and the potential of our technology," said ION founder and Executive Chairman Buz Brown.

"We appreciate their collaboration and with their investment we expect to accelerate commercial deployment of our technology so that we can realize the kind of wide-ranging commercial and environmental impact we've long envisioned."

In conjunction with this investment, ION also announced Timothy Vail will join the company as Chief Executive Officer. Vail was previously CEO of Arbor Renewable Gas, LLC. He was also Founder and CEO of G2X Energy, Inc., and serves as an Operating Partner for OGCI Climate Investments, LLP.

"With this investment, we are well positioned to grow ION into a worldwide provider of high-performance point source capture solutions." said Vail. "This capital allows us to accelerate the commercial deployment of our carbon capture technology."

This investment in ION expands Chevron's technology portfolio to include conventional amine-based capture technology while complementing an existing portfolio of CCUS technologies. CIBC Capital Markets served as the exclusive financial advisor to ION for the raise.

Celanese achieves certification for low carbon CCU methanol

www.celanese.com
www.iscc-system.org

The process demonstrated a greater than 70% reduction in carbon footprint relative to a global average benchmark for fossil-based methanol production.

As part of its Fairway Methanol joint venture with Mitsui, International Sustainability and Carbon Certification (ISCC) has certified Celanese's Low Carbon CCU Methanol under the ISCC Carbon Footprint Certification (CFC) system.

Celanese began operating one of the largest active CCU facilities in the world at its Clear Lake, Texas, site in January 2024. Using CCU, Celanese now offers customers low-carbon options across its Acetyl Chain and Engineered Materials products under the ECO-CC name. CCU takes CO2 industrial emissions that would otherwise be emitted into the atmosphere and applies reduced-carbon-intensity hydrogen to chemically convert the captured CO2 into a methanol building block used for downstream production.

"We're proud to be the first to receive ISCC CFC certification for CCU materials, which allows us to strengthen our ability to offer customers a wider range of lower-carbon footprint products," said Kevin Norfleet, global sustainability director, Acetyls at Celanese. "This is another industry-leading step Celanese has taken to provide third-party validation of sustainable product benefits while helping our customers to meet the growing demand for more sustainable solutions."

The ISCC CFC system establishes a structure and methodology to validate appropriate accounting for the CO2 capture benefits of the CCU process as well as tracking of sustainable feedstocks using the mass balance system.

"We have observed an increasing interest, especially from the chemical industry, in certifying the carbon footprint of their products and making credible claims towards their customers. With our new carbon footprint certification, we provide the respective solution," said Jan Henke, director ISCC.

Strategic Biofuels secures investment from Japanese consortium

www.strategicbiofuels.com

The investment from M-SEP, which brings additional carbon capture expertise, will be used to further advance the company's flagship Louisiana Green Fuels (LGF) project..

Strategic Biofuels, a leading sustainable aviation fuels (SAF) project developer, has received a strategic investment commitment from Magnolia Sustainable Energy Partners (M-SEP), a newly formed Japanese-based investment consortium created by Sumitomo Corporation of Americas (SCOA) and JX Nippon Oil & Gas Exploration Corporation (JX).

"Our partnership with JX and Sumitomo through their new consortium, M-SEP, will bring both financial support and the deep carbon capture technical expertise that is needed to continue advancing toward construction," said Dr. Paul Schubert, CEO of Strategic Biofuels. "Our LGF project has first and foremost been a mission of low-carbon sustainability, and the milestones we have achieved to-date are a testament to how strategic and collaborative partnerships like this one can advance cleaner technologies."

In addition to being a strategic investor through the consortium, JX will add its expertise to the company's LGF project, using its CCS experience gained in building and operating the Petra Nova CCUS project near Houston. The LGF project, which will convert sustainably managed forestry waste into responsibly developed SAF, has a CCS component that will capture and store carbon dioxide onsite from both its biomass-fired power plant and biorefinery.

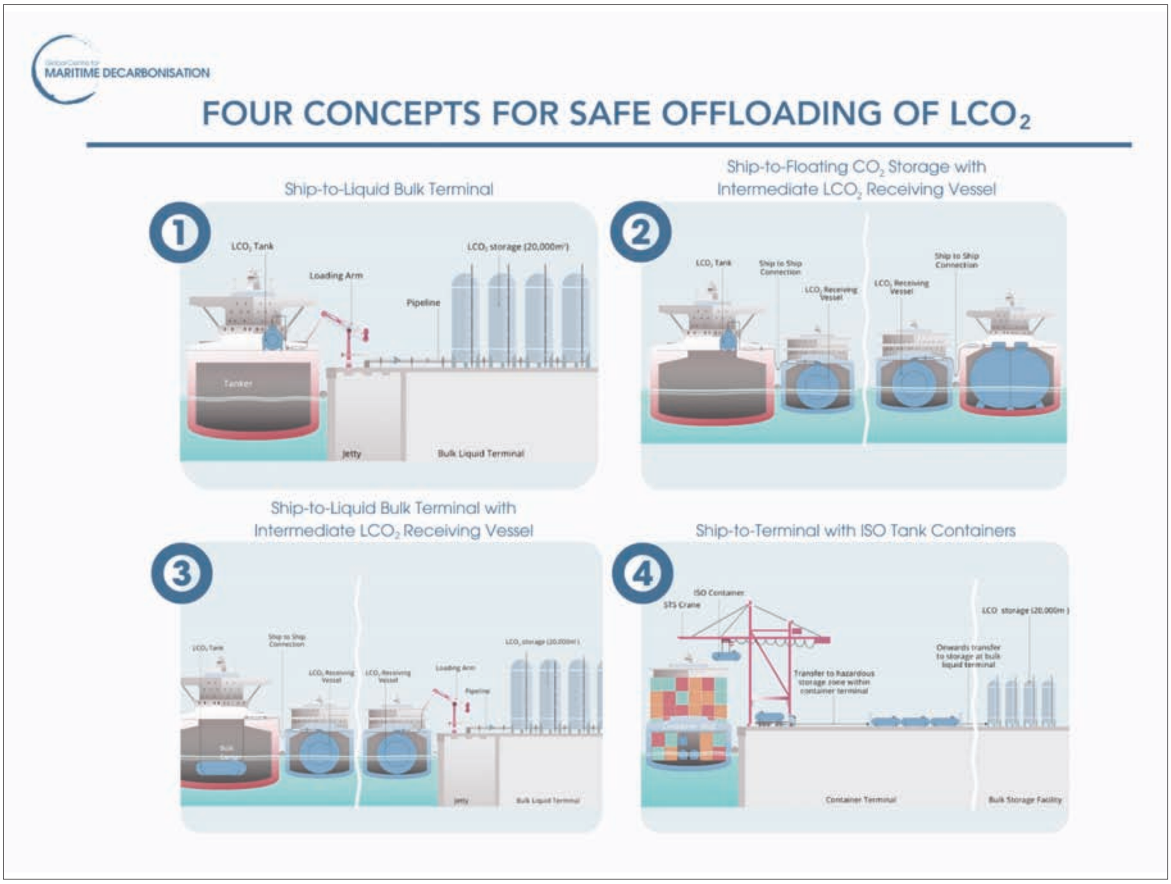
"The LGF project presents an excellent opportunity to enhance our capability for the greater energy transition by leveraging our CCS experience," said Toshiya Nakahara, President and CEO of JX. "It's an honor to work with Strategic Biofuels and SCOA, who possess remarkable technical, project management, business, and financing expertise and leadership to help us achieve our goals."

In February, SCOA announced a major investment commitment to Strategic Biofuels.

Study finds port readiness key to onboard carbon capture

A landmark study by the Global Centre for Maritime Decarbonisation (GCMD), in collaboration with Lloyd's Register and ARUP, has identified low port readiness as a major hurdle bottlenecking the adoption of onboard carbon capture.

The report found that a of lack suitable port infrastructure is the main obstacle to Onboard Carbon Capture and Storage (OCCS) adoption, which has seen a surge of interest over the last two years as stakeholders in the maritime value chain seek to limit their carbon emissions.



The report 'Concept study to offload onboard captured CO2' found:

- While a limited number of ports possess the infrastructure to offload liquefied CO2 (LCO2), they are primarily designed to handle food-grade CO2. The higher purity standards that accompany this use limits the interoperability of facilities to handle onboard captured CO2

- Captured CO2 in its liquefied form is likely the most efficient and cost-effective option for onboard storage and transport

- Ship-to-Ship and Ship-to-Shore transfers using an intermediate LCO2 receiving vessel as the most promising modalities for offloading at scale, with captured CO2 eventually sequestered or used as feedstock for manufacturing synthetic fuels

- Ship-to-Terminal transfer of captured CO2 stored in ISO tank containers is most compatible with existing port infrastructure and therefore easier to pilot today

Complementing GCMD's Project REMARCCABLE (Realising Maritime Carbon Capture to demonstrate the Ability to Lower Emissions) this offloading study addresses the feasibility of OCCS as a practicable, end-to-end solution at scale. For OCCS systems to be operationally feasible, the industry needs to develop a collaborative ecosystem to enable the value chain for managing captured CO2.

The study examines over ten planned LCO2 related infrastructure projects worldwide projects which are likely to handle much larger volumes of captured CO2 than that from OCCS systems. These examples highlight how port infrastructure needed for offloading, storing and transporting onboard captured CO2 will likely need to be integrated with these projects for economies of scale.

The study also investigates the concepts for safe offloading of LCO2 alongside the safety considerations for its onward handling.

On the release of the report, Professor Lynn Loo, GCMD chief executive of GCMD, said, the study high the safety and infrastructure build-up challenges that need to be addressed if onboard carbon capture is to be used.

"This study sheds light on these challenges, and highlights recommendations to holistically address these concerns for parties interested in advancing onboard carbon capture and storage, and liquid CO2 offloading concepts."

More information

www.gcformd.org
www.lr.org
www.arup.com

Transport and storage news

NETL publishes catalog of subsurface sealing formations for CO2 storage

edx.netl.doe.gov

Researchers at NETL recently published a new dataset, the Catalog of U.S. Prospective Subsurface Storage Reservoir Sealing Formations, that aggregates prospective seal units for potential storage resources within the U.S. for geologic carbon storage in both onshore and offshore basins.

The catalog lists prospective seals by unit name along with associated data and resources that are available, including lithology, position with respect to the reservoir (primary, secondary, intraformational, etc.) and age (geologic period), for prospective domestic geologic storage resources.

"The catalog aims to guide users to available literature and data resources related to containment systems for carbon dioxide storage, a vital component in the mission to achieve a net-zero carbon emissions energy sector and economy by 2050," said NETL Geologist Paige Morkner. "This is the first version of this catalog and is a valuable resource for researchers, policymakers and industry professionals interested in geologic carbon storage and the identification of prospective seal units in U.S. sedimentary basins."

The information source for each record in the catalog also includes the published citation, year of publication, resource type (journal article, event proceedings, etc.) and additional record notes. The catalog is the result of a significant effort to aggregate disparate data resources into a single dataset that guides users to understand what prospective seal units exist in deep sedimentary basins.

Guidance for managing North Sea CO2 storage sites

www.nstauthority.co.uk

The North Sea Transition Authority (NSTA) has published two sets of guidance which will help the developing carbon storage industry prepare for first injection.

The Guidance for Measurement of Carbon Dioxide for Carbon Storage Permit Applications provides licensees with information on NSTA expectations regarding the proper measurement of CO2 being injected in a storage site and suggestions on how that can be achieved.

It is important that injection flow rates are accurately determined, as this information is used in modelling the behaviour of the CO2 in the reservoir. In addition to the overall volume being injected, the exact composition of the gas is also measured. This ensures that the correct payment is made under the Carbon Trading Scheme.

The second set of guidance, Requirements for the definition of a carbon storage site, storage complex and hydraulic unit provides clarity on determining the extent of subsurface storage site and focus for licensees on the area they must manage to prevent/detect leakage.

This piece of guidance advises licensees of the requirement to provide precise definitions of the spaces in which carbon dioxide will be stored and the surrounding areas that it must be contained within.

This precise definition is required so that any deviations from the expected CO2 movement and containment are clearly identifiable so that preventative or remedial action can be taken. The NSTA does not instruct independent businesses on how they should operate, but planned monitoring for such events is a requirement for each carbon storage application.

The guidance will immediately help the licensees of the Track 1 clusters at Hynet and Northern Endurance, and Track 2 at Acorn and Viking, which are the most far advanced projects, as well as new licensees.

ClassNK certifies world's first onboard CCS installation for EVERGREEN

www.evergreen-line.com

ClassNK has granted its "SCCS-Full" class notation to "EVER TOP", a container vessel owned by EVERGREEN, making it the world's first Neopanamax vessel to be retrofitted with onboard CO2 capture.

The CCS systems, designed and developed by Shanghai Marine Diesel Engine Research Institute, were installed at Huarun Dadong Dockyard Co., Ltd. (HRDD). ClassNK reviewed the system components and the installation plan, aligning with its comprehensive "Guidelines for Shipboard CO2 Capture and Storage Systems."

The risk assessment through Hazard Identification (HAZID) and the onsite installation process were also examined. Following confirmation of compliance with the relevant requirements, the first "SCCS-Full" notation was duly affixed to the vessel.

Masaki Matsunaga, Corporate Officer / Director of Plan Approval and Technical Solution Division, ClassNK said, "As the crucial action of first movers, ClassNK deeply respects the ambitious and practical application of CCS systems taken by EVERGREEN and involved parties to advance GHG abatement technology implementation. It is our great honor to be a part of this outstanding collaboration, and we are committed to supporting proactive initiatives toward decarbonization by providing appropriate standards, surveys, and certifications."


Image: enfinium