Carbon Capture Journal

CCUS in Australia

Silixa CO2 storage monitoring with fibre-optics at Otway

Growing momentum for CCUS in Australia

Decarbonising steel production

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CarbonNet commercialisation in the pipeline

- Australian researchers set record for CO2 capture with MOFs
- Reducing the cost of CCS – Global CCS Institute webinar report
- Equinor, Shell and Total invest in Northern Lights
- First independent catalogue of CO2 storage resource for CCUS

CCS pipeline grows by 10 large-scale facilities globally

The Global CCS Institute has added 10 new facilities to its global database, bringing the total number of CCS facilities in various stages of development to 59 with a capture capacity of more than 127 million tonnes per annum. There are now 21 facilities in operation, three under construction, and 35 in various stages of development.

"Our recent CO2RE Database update shows that despite the current CV-19 crisis we are observing a significant increase in CCS facilities in the pipeline which demonstrates continued progress towards meeting climate targets, and will also result in significant job creation and economic growth", said Global CCS Institute CEO Brad Page.

In a recent flagship report on the value of CCS, the Global CCS Institute found that CCS deployment in line with the Paris Agreement and energy-related Sustainable Development Goals could create some 100,000 jobs in the industry by 2050.

The facilities added continue trends in CCS deployment that include innovative applications such as natural gas power, negative emissions and cement, as well as stacked and offshore geologic storage. Fuelled by targeted incentives and sustained government support the US adds nine facilities, while the UK adds one facility.

"We are thrilled to see the diversity of CCS applications. The average capture capacity of the new facilities is 2.6 mtpa, as opposed to 2 mtpa for those already in the pipeline, indicating that new facilities are aiming for economies of scale, and strengthening CCS' role in large-scale emissions abatement. Nonetheless, with 21 facilities operating today, we still need at least a 100-fold scale-up to reach climate goals", added Brad Page.

In the UK, the Drax bioenergy with CCS project aims to capture 4 mtpa from one of the existing biomass-fired power units by 2027, before converting all of its remaining biomass units to bioenergy with carbon capture and storage (BECCS) by 2035.

The CO2 will be transported by pipeline and stored in the southern North Sea via dedicated geological storage. and will be an anchor for the wider Zero Carbon Humber Cluster.

The US continues to add a large number of facilities mainly as the result of the 45Q tax credit, and the California Low Carbon Fuel Standard CCS Protocol. For example, the combined incentives contribute to the economic viability of both California Resources Corporation's (CRC) CalCapture Project, and Velocys' and Oxy Low Carbon Ventures' Bayou Fuels Negative Emission Project.

Multiple projects were also awarded US Department of Energy (DOE) front-end-engineering-design (FEED) study grants, or part of CarbonSAFE, seeking to establish large-scale storage of 50 mtpa and more. The Zeros Project in Texas, in an important development for the CCS facilities pipeline, has also completed its FEED and entered pre-construction.

"This is an important time for CCS in the US," says Assistant Secretary for Fossil Energy Steven Winberg. "Policy incentives and research from DOE projects are working together to help industry move forward towards the goal of net-zero carbon emissions."

While the US does not currently have any natural gas plants equipped with CCS, the database update includes three gas plant projects: Mustang Station in Texas, Plant Daniel in Mississippi and CRC's CalCapture facility in California. This brings the total natural gas-fuelled power plants with CCS under development globally in the database to six.

"The CalCapture project offers multiple benefits including substantial emissions reductions, prolific positive economic impacts across the California economy, and development of a key technology needed worldwide to meet future energy transition targets. The FEED for the Cal Capture project is expected to be completed by the end of 2020, which would position the project for permitting, construction and commissioning by mid-decade", said Shawn Kerns, CRC Executive Vice President of Operations and Engineering.

Moreover, two projects, the San Juan Generating Station and CRC's CalCapture facility, are also evaluating plans for stacked storage, using both geologic storage with enhanced oil recovery, as well as dedicated storage in saline formations.

Oxy Low Carbon Ventures (LCV) has teamed up with LaFarge Holcim and Total to evaluate the capture of CO2 from a cement plant in Colorado, and Oxy LCV also intends to store CO2 from Velocys' biofuel production, delivering negative emissions.

The facilities update comes on the heels of continued momentum for CCS, including the Alberta Carbon Trunk Line becoming fully operational, a positive investment decision by Equinor, Shell, and Total for the Northern Lights project, supportive policy momentum in Australia, and a $131 million funding announcement by the US Department of Energy.

The Oil and Gas Climate Initiative (OGCI), the Global CCS Institute and Pale Blue Dot Energy also recently launched the CO2 Storage Resource Catalogue, the first independent worldwide evaluation of geologic CO2 storage resource assessments.

The Catalogue aims to become the global repository for all future storage resource assessments, supporting the growth of a safe and commercially viable CCUS industry.

More information

View the Global CCS Institute database at: **co2re.co**

www.globalccsinstitute.com

oilandgasclimateinitiative.com

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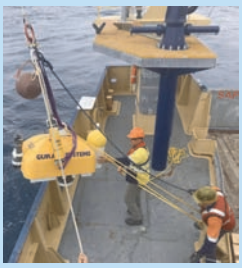

Front cover:
An Ocean Bottom Seismometer is deployed into Bass Strait for GipNet, photo courtesy CSIRO

Back cover: Crew on board the Noble Tom Prosser at CarbonNet's Pelican site, Bass Strait, December 2019 (pages 2 & 6)

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Leaders - CCUS in Australia

Projects and policy

Capture and utilisation

Transport and storage

CarbonNet commercialisation in the pipeline

The CarbonNet Project in Victoria, Australia is working to establish a commercial scale Carbon Capture and Storage network in Victoria's Gippsland region. CarbonNet is expected to proceed to construction and operation in the mid to late-2020s. The current focus is the project's prioritised offshore carbon dioxide storage site, Pelican.

The Noble Tom Prosser drilling rig at CarbonNet's Pelican site, December 2019

Why CCS? Why here?

CarbonNet's storage sites, located off the coast of South East Australia in the Gippsland Basin, are acknowledged as world class. The 2009 'National Carbon Mapping and Infrastructure Plan – Australia (PDF)' report identifies the offshore Gippsland Basin as containing the highest quality and largest capacity CO2 storage reservoirs out of 25 major geological basins across Australia.

The CarbonNet storage sites are also close to Gippsland's Latrobe Valley industrial hub and its skilled workforce. Successful implementation of CarbonNet will lead to a scalable commercial carbon transportation and storage system, enabling the establishment of new low-emissions industries in the Latrobe Valley and a significant reduction in carbon emissions in Victoria – supporting the government's target of net zero emissions by 2050.

Offshore activities

In 2018 the Polarcus Naila seismic vessel completed a 166km2 survey offshore from Gippsland in Bass Strait, extending to shallow water only 15m deep, approximately 1 km from the shoreline.

The purpose of the survey was to gain more detailed knowledge of the underlying geology of the area to help confirm the CarbonNet pre-seismic models that show excellent potential for geological CO_2 storage. Preparation for the survey involved stakeholder consultation and regulatory and environmental approvals.

The results of the survey provided CarbonNet with high quality 3D seismic data that confirm the pre-seismic geological models. The seismic data was matched to the Golden Beach-1A well, drilled in 1967, which lies at the crest of the Pelican structure where CO_2 is planned to be stored.

Using both well and seismic data provided CarbonNet with the advantage of observing and sampling actual rock types, along with known depths. These dual inputs have allowed the team to make more accurate predictions of the sub-surface geology over the whole area of the survey. Using this data, CarbonNet has shown that the seals and reservoirs of the Pelican storage site extend continuously across the entire planned storage area.

Offshore appraisal well

In December 2019 CarbonNet drilled an offshore appraisal well at the Pelican site. The well was drilled approximately eight kilometres offshore from the Ninety Mile Beach. The purpose of the well was to further calibrate the 2018 3D survey, and to collect data required to optimise design of a future injection well facility located near the appraisal well site.

Dynamic reservoir modelling scenarios indicate that the Pelican site can permanently contain at least 125 million tonnes of CO_2, injected at up to 5 million tonnes per year (GCCSI 2016). That injection rate would see an Olympic swimming pool volume of CO_2 injected every two hours.

The aim of the drilling program was to confirm that identified rock structures deep under the seabed can permanently store CO_2, thereby validating previous data collected by the CarbonNet project. The rocks found during drilling operations were very similar to the pre-drill prediction in both depth and rock type, thereby validating CarbonNet's predictive models of the subsurface.

Extracting core rods at the Pelican site. The core samples will be analysed to detail their physical and chemical properties and confirm the site's suitablility for CO_2 storage

An extensive dataset was successfully acquired during the operation, including geological rock and fluid samples and high-quality wireline formation logs. The rock samples are currently being analysed at world-class laboratories to confirm their composition and physical properties, and their strength and chemical resistance to CO_2. Almost 90m of core was cut, and this has all been X-ray CT scanned to reveal its 3D structure. The cores are currently being sliced open and measured with a range of scientific instruments to detail their physical and chemical properties.

Offshore stakeholder engagement

With its offshore field activities in full view from the shoreline, it was imperative that CarbonNet implement a comprehensive stakeholder engagement and communications program. During consultations undertaken prior to the MSS, underwater sound and its impact on the marine environment was a key issue raised by stakeholders, particularly commercial fishermen. In response, CarbonNet put in place initiatives to address concerns, including:

• undertaking offshore marine habitat assessments before and after the MSS

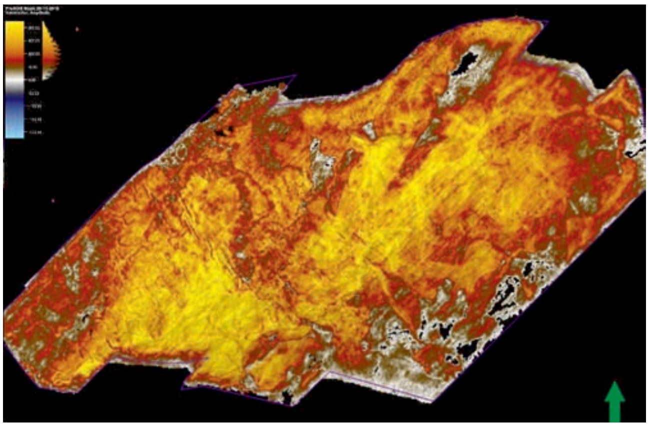
• establishing an independent Advisory Panel of fisheries experts to provide advice on the marine habitat assessments

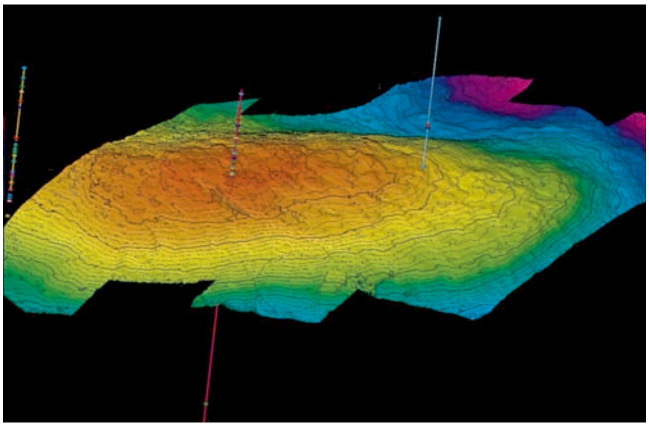
• monitoring underwater sound levels to confirm levels were consistent with predictions, and

• contributing to a scallop stock assessment by the Victorian Fisheries Authority.

The objectives of the habitat assessments were to confirm the presence of key marine species before and after the MSS, and to determine whether any differences could be attributed to the MSS. The pre- and post-MSS habitat assessments focused on commercial scallops (Pecten fumatus), southern rock lobster (Jasus edwardsii), finfish, and zooplankton.

Monitoring sites were selected within the MSS area and at reference locations surrounding it. A total of 68 sites were monitored during the assessments. To ensure that the marine habitat assessments were undertaken in a scientifically robust manner, an independent advisory panel was established consisting of representatives from government agencies, academia and the fishing industry.





Left: The Pelican 3D survey showed the excellent continuity and quality of sandstone reservoirs (red, orange, and yellow colours) within the Pelican structure. There are a few "islands" of shale (grey and black) preserved between the many meandering sand-filled channels. Towards the bottom left of the image, many individual meandering channels can be seen, similar to a modern river system. At other levels in the structure, it is the shales that are continuous, with no sand interruptions – these shales form the topseals for CO2 storage

Right: A 3D perspective view of the Pelican site looking towards the north. The three vertical lines are wells drilled on the structure – from left to right they are Golden Beach West-1 drilled onshore in 1965, Golden Beach-1A drilled in State waters in 1967, and Gular-1 drilled in Commonwealth waters by CarbonNet in 2019. Pelican could hold around 125 million tonnes of CO2

The advisory panel met eight times to discuss, review and make recommendations on the planning and the results of the habitat assessments. The CarbonNet Pelican 3D Marine Seismic Survey (MSS) Offshore Habitat Assessments Final Report found that, overall, no impact was observed in the marine habitat that could be attributed to the MSS.

The report (summary available on the CarbonNet website), was accepted by the Advisory Panel and provides an important contribution to the existing knowledge about the effects of seismic surveys on marine environments.

Broad stakeholder engagement

Over the past two years CarbonNet has implemented a broad range of communications and stakeholder engagement initiatives to promote the project and CCS more generally. Recognising regional media as key stakeholders in the project, senior CarbonNet staff regularly participated in radio, television and press interviews, and journalists were engaged at key milestones. A monthly e-newsletter was initiated, and the project's website content is regularly updated.

A Community Sentiment Survey was also carried out in key locations in Victoria to gauge the knowledge of, and interest in CCS. This activity revealed positive sentiment toward CCS as a climate change mitigation strategy across the local shoreline community, Gippsland and urban communities.

To keep the shoreline community informed about offshore activities, CarbonNet held regular community information sessions in Golden Beach. Several of these were in collaboration with external organisations including CSIRO and CO2CRC, who provided information about CCS initiatives in Australia and the role of CCS in carbon dioxide abatement globally. A series of six weekly drop-in sessions were also held while the rig was onsite over the 2019-20 Summer.

Australia's National Science Week has provided an opportunity to showcase the link between science and CCS. In 2019 more than 250 school children and families attended an interactive Science Week event in Gippsland. The event focused on the science behind CCS with a CO2 science show; a porosity experiment using chocolate and milk; interaction with seismology equipment; the Saildrone made an appearance; and kids enjoyed a CCS Virtual Reality (VR) experience hosted by CSIRO.

The event also shone a spotlight on Hydrogen – timely given the Hydrogen Energy Supply Chain (HESC) pilot project in Victoria's Latrobe Valley – with Toyota showcasing their hydrogen powered vehicle, the Mirai. The event included representation by CarbonNet, CSIRO, CO2CRC, GCCSI, HESC, Geoscience Australia and University of Melbourne.

Delicious cupcakes, topped with the elemental symbol for hydrogen, were a crowd favourite as were Hydrodogs - sausages cooked on a hydrogen-powered barbeque.

CarbonNet is continuing to evolve its communications and engagement initiatives and is currently looking to technology to help tell the CCS/CarbonNet story. Augmented reality and web-based VR technology are being explored for their potential role in targeted CCS education, especially post COVID-19. A 'CCS in Schools' program, led by the Global CCS Institute, is also scheduled for the second half of 2020.

Establishing a Gippsland-based Community Reference Group

As CarbonNet's focus began pivoting towards industrial CO2 capture possibilities in the Latrobe Valley, ahead of the project's planned commercialisation, a Gippsland-based Community Reference Group (CRG) was established. Membership includes individuals across a broad spectrum of interests, including environment, agriculture, local business and industry, education, Local Government and the general community.

Since its formation in 2019 the CarbonNet CRG has facilitated effective two-way engagement with local communities and stakeholders in Gippsland. Importantly, members have provided feedback and advice to the project team based on local sentiment and local experience.

Straddled sites: addressing a regulatory challenge

Legal access to CarbonNet's portfolio of storage sites has been obtained through competitive regulatory acreage release processes, providing the project with exclusive rights to explore and develop storage sites within its permits.

However, under the regulatory regime a site cannot be fully permitted where it straddles permit boundaries. For CarbonNet, this has presented a challenge as all three of its sites straddle either permit boundaries within Commonwealth waters, or in the case of Pelican, the Commonwealth and Victorian State offshore jurisdictional boundary.

On 12 May 2020 the Offshore Petroleum and Greenhouse Gas Storage Amendment (Cross-boundary Greenhouse Gas Titles and Other Measures) Bill 2019 was passed by the Australian Parliament. The passage of this Bill is a critical first step towards removing the prohibition on cross-jurisdictional and multi-permit straddling, which will allow CarbonNet to progress regulatory applications for its portfolio of storage sites – including its prioritised CO2 storage site, Pelican.

The Commonwealth Bill is a significant milestone towards achieving regulatory certainty for the CarbonNet Project, enabling a clear pathway for the project to succeed.

Project development

The Australian and Victorian Governments are investing $150 million into CarbonNet, with strong interest from private project developers in progressing CarbonNet.

The CarbonNet storage sites in the offshore Gippsland Basin are ideally situated close to Victoria's Latrobe Valley industries and its skilled workforce. The project will therefore not only contribute to emissions-abatement, but will also enable new industries and jobs in the Latrobe Valley, home to the state's brown coal power generators, all of which have deadlines for retirement in the next few decades.

Hydrogen provides a very real opportunity for new industry and local jobs, and of course will have a low emissions profile when paired with CCS. The Hydrogen Energy Supply Chain (HESC) is a world-leading pilot project to produce and transport clean hydrogen from Victoria's Latrobe Valley to Japan safely and efficiently. Should HESC proceed to commercialisation post-pilot, CarbonNet will be essential for the project's CO2 mitigation.

With the introduction of additional new industries, including carbon-negative production such as BioEnergy with CCS (BECCS), Australia will be well placed to offset those hard to reduce carbon emitting sectors, such as aviation.

Environmental monitoring: GipNet

GipNet – the Gippsland Monitoring Network - is a network of monitoring instruments deployed across Gippsland. The initiative is designed to test and validate equipment and technologies that will allow CarbonNet to monitor and, if necessary, respond to changes in the local environment.

Instruments are being tested to prove they are reliable and durable for the coastal and marine environments and to confirm that they return accurate measurements. Research partners include Australia's leading scientific research organisation CSIRO, the University of Melbourne and the University of Wollongong – supported by CO2CRC and ANLEC.

Testing of the monitoring instruments is wrapping up in 2020 and final outcomes are expected in early 2021. Marine research outcomes will be relevant not only to Australia but will help inform best practice CCS monitoring in shallow marine environments globally.

Declaration of Storage and Injection Licence

CarbonNet is currently working towards achieving the next steps in the permitting process for its Pelican site: a Declaration of Storage and an Injection Licence.

A declaration of an Identified Greenhouse Gas (GHG) Storage Formation (DoS) is an acceptance by Australian regulators that a site is suitable for safe and permanent storage of a GHG. It sets out the volume, composition, injection location and injection period for the site. CarbonNet is currently preparing a DoS application for the Pelican site - a prerequisite for an Injection Licence application.

A GHG injection licence is an authorisation to inject and store GHG, consistent with the DoS. The licensee must have plans for ongoing management and monitoring of the injected GHG, which CarbonNet is preparing.

CarbonNet acting director Steve Marshall on the Noble Tom Prosser drilling rig

And finally…where to from Pelican? The future of CCS in Bass Strait

While Pelican is the current focus, the Gippsland Basin contains significant capacity for future expansion, with many gigatonnes of safe CO2 storage identified through CarbonNet's extensive investigations.

CarbonNet is in the early stages of advancing additional sites in its portfolio, including a site similar in size to Pelican.

The Gippsland basin has been proven over a 50-year period to be a world-class region for production of oil and gas, which was stored naturally and securely for millions of years.

In the next decade or two, as additional oilfields become depleted, they - and the spaces between them - will become available for CO2 storage to help reduce Australia's emissions of greenhouse gases as we transition to a sustainable future and a hydrogen-electric economy between 2030 and 2050.

More information

earthresources.vic.gov.au

Validating monitoring technologies in Australia's near shore environment

CO2CRC led the deployment of equipment funded by the Australian Government in a network defined as the Gippsland Monitoring Network (GipNet). The research was defined and undertaken by the CSIRO, the University of Melbourne and the University of Wollongong.

The Victorian Government's CarbonNet Project plans to store carbon dioxide 8kms offshore from the Gippsland coast at the Pelican site. Being situated in this shallow near-shore environment gives rise to challenges when monitoring the surrounding marine, atmospheric and seismic conditions.

The outcomes of the project were to validate technologies and ensure their appropriateness for future monitoring of CarbonNet's Pelican storage site. This research was overseen and funded by ANLEC R&D.

Figure 1: A Saildrone trial run in Hobart - photo courtesy CSIRO

GipNet

GipNet gave rise to the development of Australia's most comprehensive seismic monitoring network, a state-of-the-art marine monitoring network and novel atmospheric modelling and monitoring techniques.

The deployment of equipment in a shallow near-shore marine environment poses unique challenges to installation and long-term operation of monitoring equipment. Marine conditions are turbulent, with high levels of sediment and erratic currents in the sea floor monitoring zone. Access to solid base rock for locating seismometers can be difficult due to the sandy coastline and high sediment load on the ocean bottom. The research conducted using GipNet equipment aims to ensure these challenges can be overcome and accurate long-term monitoring will occur.

Marine monitoring

CSIRO's marine scientists deployed GipNet equipment to understand natural variability and detect anomalous changes in the marine environment. New technologies were trialled to supplement other monitoring approaches (such as downhole and subsurface monitoring) of carbon storage sites.

CSIRO researched tools, technologies and approaches to optimise marine monitoring and verification solutions. An advanced new technology trialled by CSIRO was the unmanned surface vehicle - Saildrone. Controlled remotely via satellite and powered by wind and solar, these drones carry advanced monitoring technologies, capable of measuring a wide range of environmental parameters with data sent to researchers via satellite in near real time. A high level of consistency was recorded between the data collected by the Saildrone and other more established monitoring technologies such as moorings and landers.

The tests undertaken represent a significant demonstration of the technologies which may be employed for future CCS MM&V. The results have begun to inform an understanding of the utility of the platforms and sensors which may be applicable for use in CCS MM&V within the nearshore dynamic marine environment of the Gippsland coastal region. Key outcomes from the experimental investigation of optimal sensor configurations include:

• The validation, in-field, of sensors integrated on several platforms;

• Conclusion of initial testing (including field trials) of the sensor configurations on the Unmanned Surface Vehicle (USV), moorings and landers;

• The development of operational configurations and procedures for the USV;

The results of the research will be of high value for offshore CCS projects globally where many projects are focussed on shallow water or near shore settings (E.g. Gulf of Mexico, Texas).

Figure 2: Chris Caldow from the University of Wollongong tests the Open-Path FTIR, photo courtesy CO2CRC

Atmospheric monitoring

Atmospheric researchers from the University of Wollongong (UoW) installed a network combining open-path and in situ measurements to monitor sources and sinks of CO2 in the region of the Pelican site. They focused on characterising the existing CO2 fluxes in the region and attributing any changes in local sources or sinks to oceanic or biogenic sources.

Using GipNet equipment, UoW scientists enhanced the development of an Open Path – Fourier Transform InfraRed Spectrometer (FTIR). This instrument enables accurate detection and monitoring of extremely small changes in atmospheric gases across distances of up to 1.5kms.

Monitoring such large air samples increases the chance of detecting the micro changes that allow deeper understanding of variations in concentrations of greenhouse gases. Traditional techniques rely on much smaller air samples passing through a ‘point-source’ instrument which can limit the range of use.

Research outcomes will enable the proposal of an optimal network, account for its feasibility and the presence of many overlapping signals in the atmosphere.

Seismic monitoring

Seismologists from the University of Melbourne (UoM) deployed Australia’s most highly concentrated network of seismometers using GipNet equipment.

In any tectonic setting, the frequency of smaller events far exceeds larger ones. Capability to detect and locate these small events accurately enables identification and characterization of crustal deformation and its driving forces. UoM has built these monitoring capabilities in Gippsland, targeting CarbonNet’s Pelican site. As part of this project, Australia’s first high frequency shallow water Ocean Bottom Seismometer was deployed.

The establishment of network operation protocols (e.g. selecting an appropriate mix of instruments, site selection and deployment, data transfer, maintenance) applicable to seismic monitoring in shallow marine environments in general, for which off-the-shelf monitoring solutions are not available, provides CarbonNet and the CCS industry with valuable information for seismic monitoring targeting unique environments.

The monitoring network achieved the implementation of a theoretical framework to design and test seismic networks for offshore CCS monitoring based on detectable/locatable minimum magnitude. It also enables users to test multiple design options to optimise network performance prior to the deployment of assets.

These protocols and learnings will assist CarbonNet in foreseeing benefits and challenges of an onsite monitoring network as well as assessing the role of more costly offshore monitoring options.

The GipNet Project was a truly collaborative project. The Australian Commonwealth Government provided funding for the equipment through the Education Investment Fund with significant funding for research provided by ANLEC R&D. Further funding and in-kind support came from CO2CRC, and the research organisations and universities themselves.

Combining the three monitoring networks into the GipNet Project allowed for streamlined project administration and a coordinated approach to stakeholder engagement.

Further research of the seismic and marine monitoring has been commissioned by ANLEC R&D. Final outcomes are expected in 2021. Research outcomes will be relevant not only to Australia but will help inform best practice CCS monitoring in shallow marine and near shore environments globally.

More information

www.co2crc.com.au

www.csiro.au

www.uow.edu.au

www.unimelb.edu.au

Technology Investment Roadmap signals core role for CCS

The release of the Technology Investment Roadmap Discussion Paper was welcomed by the Global CCS Institute as another positive step forward for the acceleration of new and emerging emission reduction technologies, including carbon capture and storage (CCS), in Australia.

"Today's Discussion Paper release is an important development in Australia's progression towards implementing a technology neutral emissions reduction policy", said Brad Page, CEO of the international CCS think-tank.

"For too long policy makers in Australia have had a single-dimension view on emissions reduction policy that focuses solely on renewable electricity. While massively increased deployment of renewables is required, alone they cannot achieve the emission reductions necessary across the whole economy.

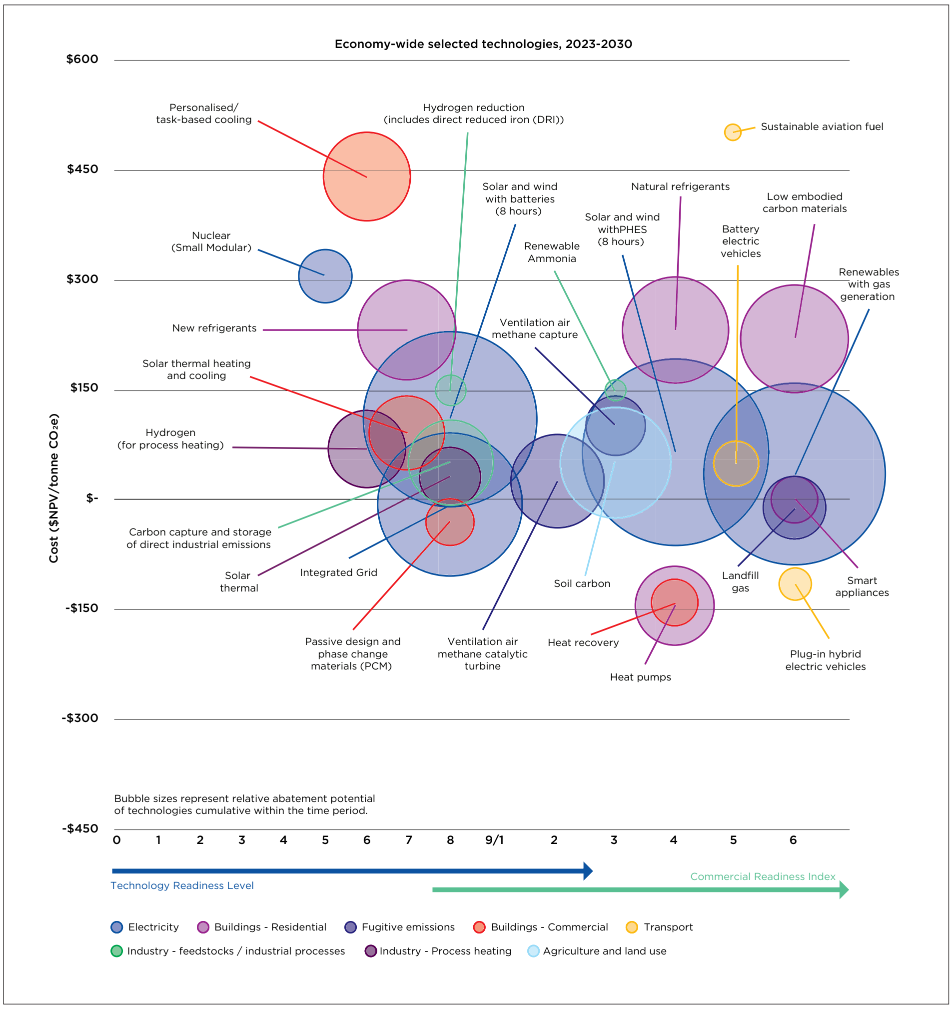
"CCS is a vital emissions abatement technology that is commercially available today and able to strengthen our economy and support jobs.

"The inclusion of carbon, capture use and storage in the Paper demonstrates the vital role of CCS in Australia's climate policy future and our sustainable economic recovery from COVID-19".

"As demonstrated by the IPCC, the IEA and others, the rapid deployment of large-scale CCS technologies is vital if we are to achieve net-zero emissions by mid-century and global climate change targets".

Mr Page noted the technology was of particular importance for reducing emissions across hard to abate heavy industry, such as steel, fertiliser and cement manufacturing, that has very few other options to decarbonise. "The Institute also welcomes the strategic and system-wide view to future investments in low emissions technologies enabled by this Roadmap.

"Achieving climate change targets requires a multifaceted emissions reduction strategy to decarbonise not only our energy sector but also transport, buildings, agriculture and – critically – hard to abate, emissions intensive industry that has very few alternative decarbonisation solutions.



Summary of selected technologies with the potential to reduce emissions across the economy, 2023–2030

Mr Page said creating market signals for CCS, stimulating investment and ultimately increasing deployment of the technology in Australia also provides the opportunity to transition to net zero emissions and secure a clean energy future, whilst unlocking new clean energy options, and sustaining local communities reliant on extractive industries.

Alongside CCS, the Technology Roadmap Discussion Paper signaled the Government sees enormous potential in the development of hydrogen, soil carbon sequestration, biofuels, resources and energy exports technologies.

More information

consult.industry.gov.au

www.globalccsinstitute.com

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Growing momentum for CCUS in Australia

CCUS can play a crucial role in achieving big reductions in global emissions and Australia is well positioned to play a leadership role in further development and deployment of CCUC technologies.

Momentum for Carbon Capture, Utilisation and Storage (CCUS) in Australia is growing with the early identification of CCUS as a priority emissions reduction technology under the Australian Government's Technology Investment Roadmap as well as the government's acceptance of the King Review recommendations for low cost greenhouse gas abatement that would ultimately support investment in CCS projects.

The prospects of securing bipartisan support for CCS has grown and with it the opportunity for securing the long-term stability needed for industry to make investments and for projects to get off the ground.

CCUS can play a crucial role in achieving big reductions in global emissions and Australia is well positioned to play a leadership role in further development and deployment of CCUC technologies.

Benefits to Australia in pursuing CCUS

Australia is already host to the largest CCS project in the world, the Gorgon Carbon Dioxide Injection Project. Significant benefits would arise from further CCUS R&D and project deployment:

• Support clean economic growth emissions reductions in the industrial and energy export sector.

Australia's economy and wealth are underpinned by its abundant natural resources. Export of hydrocarbon resources (coal, oil and gas) remains a significant proportion of government revenue as does iron ore which is foundational to global steelmaking.

CCUS is a critical technology for Australia's continued economic prosperity while meeting its international emissions reductions targets to 2030 and beyond. CCUS is the only feasible technology that can deliver deep and permanent emissions reductions in many industrial processes that are vital to the global economy such as LNG, steel, cement and chemicals production. CCUS therefore supports Australia's continued success as a global natural resource export leader.

• Support industry and jobs.

As Australia reduces CO2 emissions, CCUS technologies can protect and create more skilled and high value jobs in communities and regions with strengths in production of traditional sources of energy. One example is the Latrobe Valley in Victoria which has the potential to host a new low emissions industrial hub, servicing an international market that will increasingly value low emissions products.

• Support an ambitious National Hydrogen Strategy to enhance the value of Australia's natural resources.

Federal and state governments have developed a national strategy for hydrogen on the basis that clean hydrogen (produced using fossil fuels with CCUS or renewable energy) has a key role to play in an economically, socially and environmentally sustainable and prosperous future.

Clean hydrogen production from methane or coal is the lowest cost and most commercially mature method, accounting for just about all current hydrogen production globally. Continued development of CCUS technologies at scale will be vital for Australia to become a major global hydrogen supplier by 2030.

As Australia's Chief Scientist puts it:

"Australia is also well situated to take advantage of carbon capture and storage technologies to produce low-emissions hydrogen from coal and natural gas. Carbon capture is likely to be more cost-effective for hydrogen production than for electricity generation."

• Support further low carbon research and innovation through collaborations and investment from government, industry and academia.

The Resources 2030 Taskforce agenda highlighted the need for the resources sector to develop a focussed and collaborative effort across industry, governments, research bodies and community stakeholders to create a successful and technologically advanced sector that is globally competitive and sustainable. CCUS will play a critical role in supporting this vision.

CO2CRC's R&D supporting CCUS in Australia

CO2CRC's success to date is through the demonstration of CCUS at a field scale and validation of innovative CCUS technologies to improve the cost-effectiveness and provide technical evidence to accelerate commercial deployment.

The Otway research facility is one of the largest CO2 demonstration laboratories internationally and is unique in its variety of real world reservoir types, structures and seals. It has a ready supply of CO2 from an in-situ CO2 gas field, all necessary regulatory approvals and the support of local communities to undertake CCUS investigations.

Key CCUS elements demonstrated and verified at the Otway include:

• Fundamental Storage Processes: Verified CO2 migration and secondary trapping processes;

• Integrity & Assurance Monitoring: Demonstrated long-term integrity monitoring capability for verifying safe storage & assurance monitoring capability for freshwater aquifers and the near surface/surface environment;

• Ability to Predict CO2 behaviour – Validated the technical capability to predict, verify and assure CO2 migration and trapping;

• Large Scale Storage Options: Validated depleted gas fields and saline formations as geological sequestration sites for storing globally significant volumes of CO2;

• Long Term Stabilization: Verified the stabilisation of CO2 plume using seismic data and dynamic modelling

Technology Innovation	Innovation Purpose
U-tube (low invasive) sampling system	Fluid sampling of the CO_2 storage formation
Tracers (noble, isotopic, organic)	Creates a unique 'fingerprint' of the injected CO_2 to track migration and assure containment
Re-purposing existing wells	Cost effective alternative to drilling new wells
Downhole pressure analysis	Pressure measurements of reservoir and above zone to ensure safe injection and confirm CO_2 flow behaviour
Time lapse CO_2 saturation logging	Rapid, high resolution measure of CO_2 saturation downhole to confirm CO_2 flow behaviour
Distributed temperature sensing using down hole fibre optics	Along well temperature measurements to characterise reservoir properties and confirm CO_2 containment
Array of residual & dissolution trapping characterisation techniques	Cost effective evaluation for secondary trapping potential and to confirm CO_2 flow behaviour
Effective assurance monitoring	Cost effective assurance monitoring of the CCS operation from a health, safely and the environment perspective
***Distributed acoustic sensing using surface & down hole fibre optic**	*Acoustic measurements of storage system to ensure safe injection and confirm CO_2 flow behaviour*
***Permanent pressure tomography and inversion monitoring**	*Continuous pressure monitoring of reservoir and/or above zone to ensure safe injection and confirm CO_2 flow behaviour*
***Permanent multi-well time-lapse seismic monitoring**	*Continuous acoustic monitoring of storage system to ensure safe injection and confirm CO_2 flow behaviour*
***High-resolution, low invasive, on-demand monitoring**	*Enables on-demand confirmation of safe storage, confirm CO_2 flow behaviour with minimal impact to surface activities*

Table 1: List of major technology innovations trialled at the Otway Facility
** denotes technologies to be tested as part of the Otway Stage 3 project*

CO2CRC's current flagship research project, Otway Stage 3, has the broad goal of providing operators, regulators, financiers and the community with greater certainty around issues of CO2 containment, regulatory compliance and liability.

It aims to significantly reduce the ongoing costs of CO2 monitoring by taking new and innovative monitoring techniques, assessing their performance and demonstrating their application at the Otway site with the aim of providing on-demand, sub-surface and permanent monitoring.

The key monitoring technologies being demonstrated under Otway Stage 3 are:

• Imaging the CO2 plume by the continuous acquisition of seismic data as the plume passes between monitoring wells equipped with fibre optic cables and orbital vibrators on the surface; and

• The continuous acquisition of pressure data using high resolution downhole pressure sensors combined with novel techniques to interpret the data to image the plume's distribution.

These technologies are designed to lower long-term CO2 monitoring costs and deliver technical improvements for emerging commercial scale CO2 storage projects such as CarbonNet, CTSCo, future higher CO2 gas field developments, and international projects.

The Otway Stage 3 project has greatly enhanced the infrastructure available at the Otway facility with the addition of five new wells (making eight in total) which are connected in the subsurface and instrumented with the latest in fibre optic technology and pressure sensing equipment.

In addition, surface infrastructure upgrades include a networked array of permanent seismic sources, a variety of buried fibre optic systems for both acoustic sensing and data transfer and a new computing network to support onsite processing and data management which significantly improves the ability to remotely operate the site.

This makes the CO2CRC Otway site an internationally unique testing centre and the most comprehensive geological subsurface laboratory in the world, able to be utilised for the development of numerous subsurface technologies.

The Future

Through collaboration with leading Australian and international research institutions, CO2CRC's technology program has provided a solid base for CCUS R&D in Australia. As the opportunity and momentum for CCUS grows, CO2CRC will remain a vital partner for researchers and industry for R&D and technology deployment needs.

More information

CO2CRC welcome enquires from research organisations, universities, service providers and industry from Australia and internationally. Enquiries may be made to Ms Yaso Vesely, Business Development Manager on yaso.vesley@co2crc.com.au or Dr Max Watson, Senior Technology Development Manager on:

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Minimising the environmental impact of CO2 storage monitoring with fibre-optics

Silixa's Distributed Acoustic Sensing (DAS) monitoring with fibre-optic cables at the CO2CRC Otway project, Australia is advancing the development of technically and environmentally safe solutions for CO2 storage.

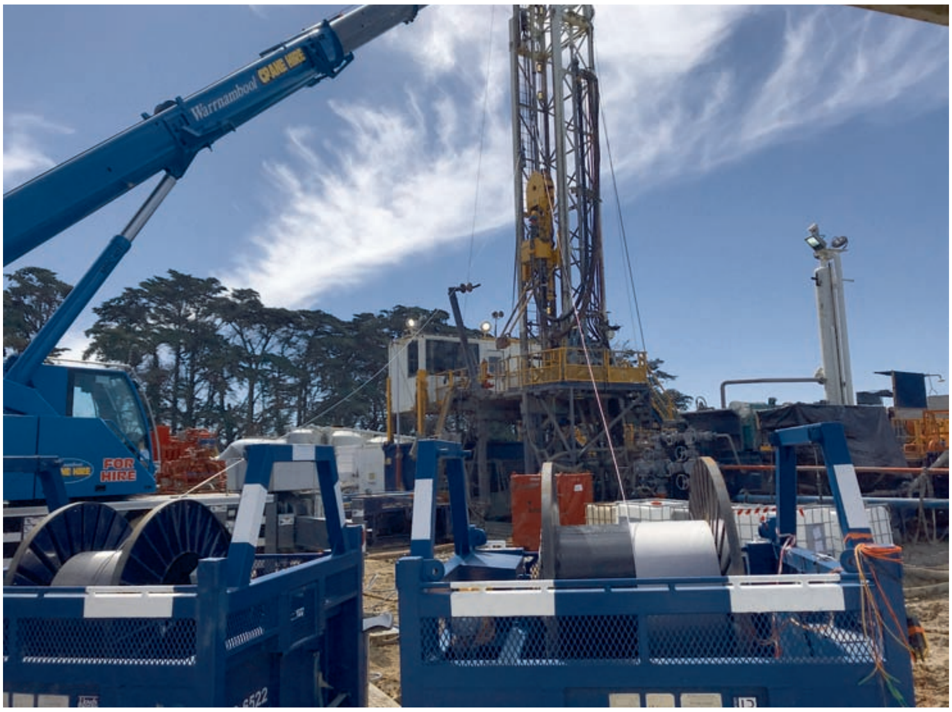
An extensive, world-class monitoring program is ongoing at the CO2CRC Otway CO2 storage test site in Victoria, Australia, where new capture and monitoring technologies are being benchmarked against conventional methods, such as traditional seismic surveys to monitor carbon capture and storage (CCS) sites.

Stage 3 of the project is now underway with the aim of developing continuous low-cost and low-environmental footprint solutions. This builds on the results from Stage 2 of the project which demonstrated safe injection of CO2 into a saline formation and successful monitoring of the CO2 plume evolution.

The inclusion of fibre-optic monitoring at Otway began in Stage 1 with a cable deployed on borehole tubing. Distributed Temperature Sensing (DTS) measurements were used to monitor the geothermal profile and identify potential leaks. During Stage 2, CO2CRC injected 15,000 tonnes of CO2 approximately 1,500 meters underground and a further fibre-optic cable was installed in one of the wells to benchmark DAS technology against seismic survey data recorded on geophones.

Fibre-optic DAS is a rapidly emerging technology to be applied to seismic monitoring. However, it is now accepted that, with careful survey design, the latest DAS technology rivals geophones in data quality and it provides many advantages such as the potential for long-term repeatable measurements and dense spatial sampling without the need for well intervention. This was tested during Stage 2 at Otway with a cable cemented behind casing in a borehole.

DAS technology makes use of the fact that fibre-optic cables deployed in the ground are strained by the passage of seismic waves. The effect is measured by firing a laser into the fibre from a DAS interrogator and recording the light scattered back to the interrogator from closely spaced points on the fibre.



Fibre optic cable installation at Otway, Australia

An interrogator is able to record the full acoustic signal simultaneously along the whole length of the fibre. The advantage of this type of monitoring technology for seismic surveys is that many thousands of measurements can be made with cables up to 10s of km long. Such dense spatial sampling is logistically difficult and expensive for traditional technologies, where the typical spacing of borehole sensors is 25m.

Cables can be permanently installed in boreholes, on tubing or behind casing, or trenched in the ground and repeat surveys may be conducted on the same cable for several 10s of years. The sensitivity of DAS measurements makes the technology particularly well suited to Vertical Seismic Profile (VSP) surveys, used to produce high resolution images of the subsurface around a borehole.

Ideally, borehole cables should be installed at construction so the fibre can be cemented in place behind casing to optimise cable coupling and signal-to-noise ratios. However, fibre cable installation is possible on tubing or suspended in-well.

Using 3D DAS VSP data recorded a tubing installation at Otway, researchers from Curtin University and Lawrence Berkeley National Laboratory found the data were of good quality and they were able to image geological interfaces beyond the CO2 injection depth.

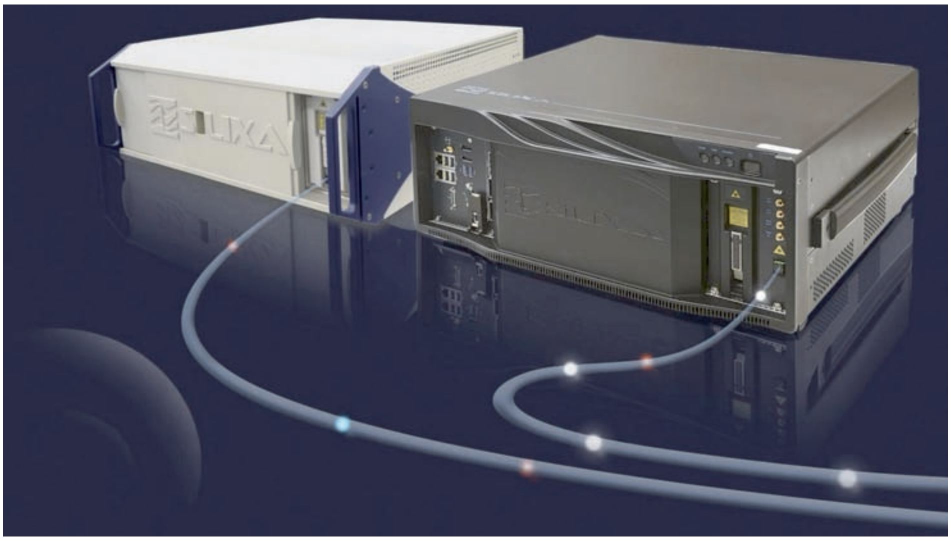
The use of Silixa's new Carina® Sensing System technology highlighted a step change in the ability of DAS technology with an improvement in noise levels of 20dB over previous systems. The advancement in technology enables far-offset surveys, facilitating monitoring over a wider area. These types of surveys are possible even if cables are not cemented in place.

Recently, for Stage 3 of the Otway project, further fibre-optic cables have been installed in five wells at the site. The technology will be tested not only for active seismic surveys but will also be applied to microseismic monitoring and passive seismic imaging using recordings of background noise.

In addition, the cables include optical fibres to monitor temperature profiles during injection and for early detection of potential leaks. Also as part of Stage 3, surface cables with different specifications were installed at the site and similar surveys will be recorded on these cables.

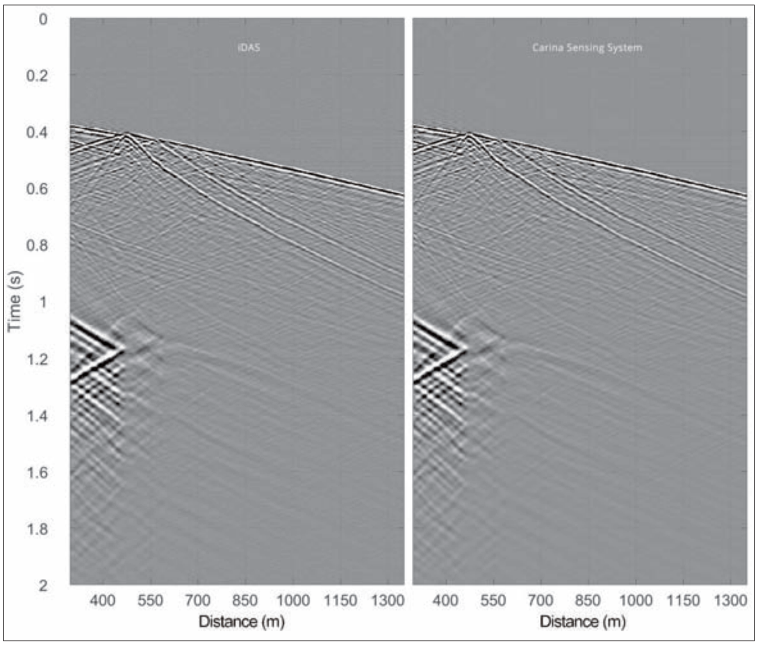
The environmental impact of monitoring is an important consideration for CO2CRC. Vibroseis trucks or dynamite are the most commonly used sources for land seismic surveys. Both these techniques have a significant environmental impact requiring the transport of heavy equipment and personnel. Once onsite the sources are also disruptive to local residents and/or farming activities because they are noisy and require access to extensive areas of land, up to a few square kilometres.

The deployment of large numbers (1000s) of geophones also requires considerable effort in terms of personnel. To reduce the environmental impact of seismic surveys CO2CRC, Curtin University and Lawrence Berkeley National Laboratory have been trialing the use of surface orbital vibrators (SOVs) in combination with fibre-optic sensors. SOVs are small seismic sources that are permanently deployed on the surface and can be operated remotely without disrupting local stakeholders.



Silixa's iDAS™ and Carina® Sensing System operate according to a radar-style process. The interrogator sends a series of pulses into the fibre and records the return of the naturally occurring scattered signal against time. In doing this, the distributed sensor measures at all points along the fibre

They have a small physical footprint and although they are much less energetic than a Vibroseis source, the remote operation of the SOVs over a period of time can impart total energy, and hence signal quality, equivalent to the data obtained from a Vibroseis survey.



VSP data recorded on iDAS (on the left) and Carina Sensing System (on the right)

The success and environmental, safety and cost benefits of the combined SOV operation with the Carina Sensing System recordings have resulted in the carrying forward of both these technologies to Stage 3.

It is envisioned that fibre-optic monitoring will be available for multipurpose monitoring; for use in continuous passive and time-lapse active seismic surveys, in-well temperature measurements and deformation measurements.

Detailed techno-economic studies will be performed as part of the Otway project, but it is estimated that overall a cost saving of up to 75 percent of monitoring costs over traditional monitoring technologies can be realised.

Stage 3 of the CO2CRC Otway project represents an exciting opportunity to decrease costs and minimise the environmental impact of CO2 storage projects, making the solution more attractive and hence facilitating uptake of CCS technologies globally. This is essential if targets for CO2 emission cuts are to be met.

The CO2CRC Otway Stage 3 project is jointly funded by the Commonwealth Government's Education Investment Fund (EIF), COAL21 through ANLEC R&D, BHP and the Victorian State Government.

Correa et al. (2019) 3D vertical seismic profile acquired with distributed acoustic sensing on tubing installation: A case study from the CO2CRC Otway Project, Interpretation, doi: 10.1190/INT-2018-0086.1

More information

www.co2crc.com.au

www.silixa.com

Decarbonising steel production

CO2CRC recently concluded a 12-month study to assess innovative and emerging technologies to reduce emissions from Australian based integrated steel mills. www.co2crc.com.au

Steel making is an energy and carbon intensive process with a global average energy intensity of 19.76 GJ/tonne of steel and a CO2 emission intensity of 1.83 tonne CO2 /tonne of steel. The steel industry consumes 5.9 % of global energy and emits 6-9 % of global CO2 emissions. There are two main processes of steel making; blast furnace/basic oxygen furnace process (BF/BOF) and the electric arc furnace process (EAF). The CO2 emission intensity of BF/BOF is around four times that of EAF steel making.

EAF uses recycled steel and production of steel through EAF is severely limited by availability of scrap steel and potential impacts to the steel quality. More than 70% of global steel is produced by carbon intensive BF/BOF by reducing iron ore. Modern infrastructure and economies are heavily dependent on steel. Steel's strength, durability, flexibility and ability to be endlessly recycled make it a critical component of sustainable infrastructure.

To realise a low carbon economy, it is essential to transform the steel industry by reducing its greenhouse gas emissions. The main source of CO2 emissions in a steel plant is the inherent use of coal and coke in the steel making process.

The CO2CRC study is a first of a kind for the Australian steel industry and was supported through funding by the Department of Regional NSW through the Coal Innovation NSW Fund, administered by the Minister for Regional NSW, Industry and Trade. Since its inception, the study has received strong support from BlueScope Steel through its Port Kembla Steel Works, which is the largest integrated steel plant in Australia with an annual production capacity of approximately 3.0 million tonnes of crude steel.

The goal of the study was to assess innovative technologies to reduce emissions from an integrated steel mill. This included energy efficiency improvement measures, carbon capture utilisation and storage, and the use of hydrogen in steel making. The project also explored the utilisation of CO, hydrogen and CO2 in steel mill gases to produce value added products like ethanol, methanol and fertilizers through biochemical and chemical processes. BlueScope Steel was actively involved in this project and provided required emission data for its Port Kembla Steel Works and other inputs to assess the suitability of various emission reduction options.

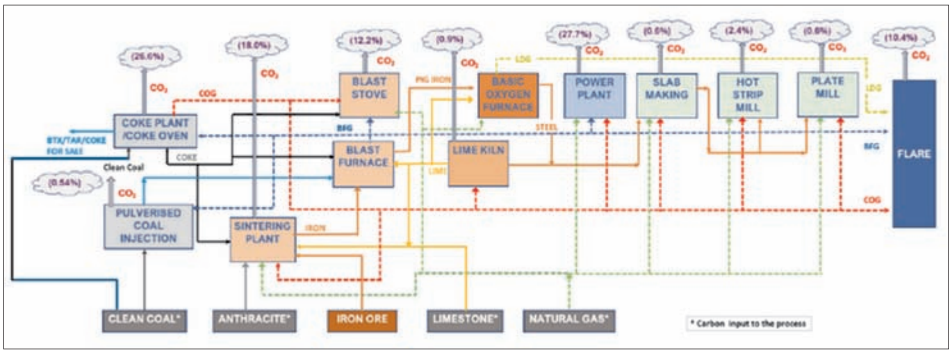


Figure 1:- CO2 emission points and distribution of BFG, COG and LDG in an integrated steel plant (drawn with input from BlueScope Steel)

Sources of Emissions in an Integrated Steel Plant

An integrated steel plant consists of primary steelmaking processes (raw material handling, including sinter production, coke making, ironmaking, steelmaking and steel re-heating and rolling) and ancillary operations (oxygen, nitrogen and argon production, steam generation, compressed air and electricity generation, and provision of cooling water).

Steel production in an integrated steel plant heavily depends on carbon bearing compounds for process and energy requirements. Coal is the primary source of energy and is used to produce the reducing gases used for iron ore reduction as part of the blast furnace iron making process. Limestone/dolomite are used as fluxes during iron making in the blast furnace.

In an integrated steel plant, coal is used to produce coke in a coke oven. Only a very small portion of carbon is retained by steel (up 0.3 wt% of steel). Most of the carbon is emitted to the atmosphere in the form of CO2.

According to the World Steel Association, integrated steelmaking based on the BF/BOF uses 1,370 kg of iron ore, 780 kg of metallurgical coal, 270 kg of limestone, and 125 kg of recycled steel to produce 1,000 kg of crude steel and 1,900 kg of CO2.

During steel production, three off gases are produced. Blast Furnace Gas (BFG) is the off gas from the blast furnace operation. The coke required for the blast furnace is produced in coke ovens. The off gas from coke ovens is called Coke Oven Gas (COG). The off gas from the BOF operation is known as Basic Oxygen Furnace Gas (BOFG) or Linz Donawitz Gas (LDG). These gases are commonly known as steel mill gases (SMG).

The majority of carbon contained in the coal is transferred to SMG i.e. BFG, COG and LDG, and the remainder to hydrocarbon byproducts e.g. coke, tar, and BTX (Benzene, Toluene and Xylene). SMG have carbon monoxide and hydrogen as major components and hence good heating values. SMG are used for generating steam and power and as a source of energy at various processes within the integrated steel plant where all the carbon of these gases is emitted as CO2. Therefore, unlike a fossil fuel-based power plant, an integrated steel plant has various sources of CO2 emissions as shown in Figure 1. The surplus SMG is flared to the atmosphere. Thus, a substantial amount of energy remained unutilised and flaring of SMG contributes 10-15% of total CO2 emissions from an integrated steel plant. With current available technologies, CO2 emissions from steel production could be reduced by utilising SMG to produce value added products.

Utilisation of SMG

SMG have CO and H2 as major components. Therefore, they are particularly suitable as a raw material to produce ethanol, methanol, urea and other chemicals through biochemical or chemical processes.

LanzaTech has developed a process that uses microbes to convert the carbon and energy in CO to fuels or chemicals at high selectivity. These microbes also can use a flexible H2/CO ratio feed gas. The chemistry of the LT-Process is understood to involve a highly efficient biological water-gas shift reaction where the process can tolerate numerous impurities, including the presence of significant amounts of sulfur compounds (e.g. H2S or COS). CO and H2 containing SMG can be a good raw material for the LanzaTech process.

$$6CO+3H2O \rightarrow C2H5OH+4CO2$$

$$6H2+2CO2 \rightarrow C2H5OH+3H2O$$

The LanzaTech (LT) Process is a low-temperature and low-pressure process compared with the conventional chemical synthesis routes. The LanzaTech process to produce ethanol from SMGs was investigated by CO2CRC with inputs from LanzaTech and BlueScope. All available LDG can be utilised through the LT process. However, the conversion and yield of the process can be improved by increasing the H2/CO ratio in the feed. Nevertheless, ethanol production from the process can be potentially economically viable. A preliminary life cycle analysis has shown around 65% reduction in life cycle ethanol emissions by utilising SMG using the LT process as compared to the traditional process of ethanol production through steam methane reforming.

Fisher-Tropsch gas-to-liquid (FT-GTL) technologies are well known to provide for the catalyzed conversion of syngas to various products. FT-GTL can be used to directly convert CO to methanol, or indirectly convert CO2 to methanol via the reverse water gas shift reaction. Therefore, FT-GTL could be applied to utilise the COx contents of steel mill gases to produce valuable liquid fuel products.

$$nCO+2nH2 \rightarrow (-CH2-)+n\ H2 \quad \text{(FT-GTL)}$$

$$CO2+H2 \rightarrow CO+H2O \quad \text{(RWGS)}$$

$$CO+2H2 \leftrightarrow CH3OH$$

$$CO2+3H2 \leftrightarrow CH3OH+H2O$$

Under the Carbon2Chem project, Thyssenkrupp Germany is leading the way to demonstrate the technologies for utilising steel plant gases for chemical production and successfully demonstrated use of SMG to produce urea and methanol.

For the assessment of the methanol production process, BlueScope provided SMG generation and consumption data for Port Kembla Steel Works. Preliminary assessment by CO2CRC and Thyssenkrupp Germany showed that methanol production, although feasible, is not economically viable with the current operation at BlueScope Steel's Port Kembla Steel Works.

This is due to low availability of COG which is the main source of H2 for the methanol production and current high cost of clean H2 from external source. However, with suitable operating conditions and availability of clean H2, methanol production can become an economically attractive option and has the potential to reduce BlueScope's direct CO2 emissions by 6 to 8%.

Barriers to Utilisation of SMG

As shown in Figure 1, there are many consumers of SMG in an integrated steel plant. Distribution of the SMG to the consumers is necessarily done on an energy basis. This means the plant needs to maintain the total energy and the calorific value (the Wobbe Index) to each of them. Making available optimum mix of SMG to utilisation processes (Biochemical/chemical) is a challenge that may require redistribution of SMG. As stated, the efficiency and economic benefits of ethanol or methanol production depends on availability and cost of clean H2. Currently, in most of the cases studied H2 prices are not favorable but in future H2 prices are expected to fall. A market for ethanol and methanol needs to be developed to encourage utilisation of SMG.

CO2 Capture & Storage

CCS is the most prominent technology option to reduce CO2 emissions at large emission point sources. CO2 capture is part of various global initiatives like STEPWISE, ULCOS, POSCO, AISI and COURSE 50 aiming to reduce CO2 emissions from steel production. CO2CRC has evaluated the feasibility of CCS for BlueScope Steel by capturing CO2 from three major sourses of CO2 emissions; power plant flue, coke oven flue and hot blast stove flue using solvent absorption-based CO2 capture. Forty-five % of CO2 emissions can be avoided by using CCS. However, this substantial reduction in CO2 emissions comes with a 16 to 25% expected increase in cost of steel production.

Emirates Steel is the first steelmaker in the world to capture its CO2 emissions which are then transported via a 50 km long pipeline to Abu Dhabi National Oil Company (ADNOC) oil reservoirs for enhanced oil recovery. BlueScope Steel Port Kembla does not have such an option open to it.

Other Initiatives

The World Steel Association has listed energy efficiency and deployment of best available technologies as the most effective measures to reduce CO2 emissions. Newer steel plants which are based on the best available technologies have lower energy and emission intensities. For older plants all the possible energy saving measures should be explored for their suitability.

There is broad global support for decarbonising steel production. Various global programs for emissions reduction have identified over 100 new technologies to reduce emissions. However, only a few can be implemented at a steel plant.

Implementation of these technologies depends on the process, raw material and geographical location of the steel industry. However, coal will continue to be used in steel making in the mid-term future, as the technologies to completely replace coal are at a nascent stage of development and not expected to be available until around 2040.

Reduction of emissions through utilisation of SMG has shown potential economic benefits which must be assessed on a case by case basis. CCUS is one of the most effective measures to reduce CO2 emissions and there is a need to make progress on utilisation of captured CO2 other than through EOR.

Hydrogen may have a crucial role to play in decarbonisation of steel production over the long-term. Availability of hydrogen at favorable prices will be a boost for utilisation of SMG. Moreover, it can partly replace coke in blast furnace as a reducing agent for iron ore reduction when such technology is available.

CO2CRC aims to provide a greater role in reducing industrial emissions through its focus on developing and commercialising low cost, compact CO2 capture and gas separation technologies to produce clean hydrogen from Australian coals.

Reducing the cost of CCS – Global CCS Institute webinar report

The Global CCS Institute held a webinar on June 8 "The Technology Cost Curve", looking at how the cost of CCS can be reduced to around $35 - $50 a tonne CO2, through a mixture of experience, bigger scale, and new technology. By Karl Jeffery.

The Global CCS Institute held a webinar on June 8 "The Technology Cost Curve", reviewing how the cost of CCS can be realistically reduced to $35 - $50 per tonne CO2, using a mixture of learning from experience, bigger scale, and new technologies including fuel cells and modular components.

The webinar had speakers from MHIA (Mitsubishi), FuelCell Energy and CCSL.

According to GCCSI analysis, the levelised cost of capturing a tonne CO2 reduced from $110 in 2015 (for the Boundary Dam project) to $68 in 2017 (Petra Nova project). It expects SaskPower's Shand Power Station in Saskatchewan, Canada, onstream in 2026, to have costs of $50.

MHIA, which developed the technology for all of these projects, additionally expects to be able to capture 95% of CO2 in the flue gas for future projects, an increase from 90%..

FuelCell Energy, Inc of Danbury, Connecticut, is developing ways to use fuel cells to separate CO2 from a flue gas. This separation process happens in parallel to the process of converting hydrogen to electricity, with carbonate ions in the fuel cell as an electrolyte. If used for carbon capture only, it costs $75 per tonne of CO2, but these costs can be offset by selling electricity, perhaps reducing carbon capture costs to $35.

Carbon Clean Solutions Ltd (CCSL), based in Reading, UK, is moving its company's focus to making modularised carbon capture components (previously it focussed only on solvents). It is developing a rotating drum system to put CO2 in contact with the solvent, rather than the traditional method with a tall absorption tower. The company is targeting costs of $30 per tonne.

David Kearns, senior consultant CCS technology at GCCSI, introducing the forum, said that the majority of costs for a CCS project are the capital costs, so the best ways to reduce the costs are to focus on these.

SaskPower's Shand Power Station in Saskatchewan, Canada, onstream in 2026, is expected to have levelised costs of $50 to capture a tonne of CO2

Increasing scale (project size) is a good way to improve capital costs. Saskpower's proposed Shand project will be twice as big as its Petra Nova project.

But there are other ways to reduce costs, based on GCCSI's analysis of projects worldwide. This includes from improving solvents, reducing energy consumption, reducing solvent degradation, using non solvent based capture technologies such as fuel cells, and improving CO2 compression strategies.

GCCSI's analysis is based on the costs of capture not storage, including the cost of CO2 compression after the power plant. They are based on 30 years operation, a discount factor of 8 per cent (for bringing future costs back to the present), and operating at 85 per cent capacity.

MHIA – how to reduce costs of big projects

Mitsubishi Heavy Industries America (MHIA), which provided CCS technology for major projects Boundary Dam and Petra Nova, is finding a number of ways to reduce the costs further

Mitsubishi Heavy Industries America (MHIA), which provided CCS technology for major projects Boundary Dam and Petra Nova, is finding a number of ways to reduce the costs of major projects further, as it learns from experience and projects get bigger.

In the next stage of its technology, which it calls "Advanced KM CDR Process", it anticipates a 30 per cent reduction in total EPC (engineering, procurement, construction) costs. This includes from having a smaller, modular cooler and absorber; from using reduced design margins overall (such as by reducing the regenerator diameter by introducing new packing); and from having a modular process and compact layout.

By fabricating the plant in a factory on movable "skids", rather than on site, it is possible to reduce construction labour hours by 60%, also improving productivity, schedule and budget control, said Jerrad Thomas, business development manager, MHIA.

It is finding ways to make big reduction in costs for pumps, heat exchangers, tower internals, the filtration system and tanks.

It will use 76% as much steel, 79% as much piping, and take up 75% of ground space area as the previous version of the technology.

Many of these improvements have been achieved by studying the large scale plants which have already been built, and exploring possible ways to refine, optimise, modularise and reduce the equipment design margin.

It is also developing ways to better customise the design to the flue gas conditions. Bigger equipment is required if you have more SO2 in the flue gas to remove.

The system is also being developed to be able to be adjustable, to handle different flue gas flow rates. It calls it "automatic load adjustment". You can configure a set capture rate or CO2 outlet flow, and the system will try to adhere to that, although the feed rate may be constantly changing.

All of its technology improvements could be applied to a carbon capture plant on any type of flue gas, including a natural gas fired power station, a gas turbine exhaust, a coal fired boiler exhaust, or oil fired boiler exhaust, or other industrial applications such as cement plants, steel plants, catalytic crackers and gas processing, Mr Thomas said..

Another result of the fine-tuning is that MHA is "getting to" a 95 per cent capture rate for the same price per ton as when it was 90 per cent, he said..

The Kansai Mitsubishi Carbon Dioxide Recovery (KM CDR) Process is installed in 13 commercial plants around the world. Graphic courtesy of MHI

Mr Thomas was asked if the capture rate might be increased beyond 95 per cent, as companies are under pressure to achieve "net zero", even 5 per cent emission to air may be unacceptable. He replied that the higher the capture rate, the bigger surface area you need in the absorber, and so bigger costs. So technically you could get close to 100 per cent capture, but at very high costs.

"We've settled on 95 per cent," he said.

The output stream from its systems is over 99.9 per cent pure CO2. Mr Thomas was asked if the costs might be reduced if a lower purity of CO2 output was acceptable.

He replied that the 99.9 per cent purity has been "baked" into the plans. Higher purity does not require any additional steps which could be removed, but the unit could be run a different way for lower purity output.

Typical availability of a plant in operation is 98 per cent. Maintenance of the capture unit can usually be done at the same time as maintenance as the host unit – so if the coal power system is typically taken offline every 18 months for maintenance, the carbon capture system can be maintained at the same time.

In terms of markets, Mr Thomas believes the most promising application of the technology is still power generation, as one of the biggest CO2 producers, with CO2 used for EOR, but there is "some increased interest in industrial applications," he said.

The best way to continue to reduce CCS prices could basically be for companies to get more experience. As business volumes increase they can make CCS systems faster, and more modularised, he said.

About MHI

Mitsubishi Heavy Industries (MHI) has industrial activities across a wide spectrum, including making entire aeroplanes, ships, chemical plants and defence systems. It has $40bn revenue a year. The company is Japanese but has a majority of sales outside Japan. Carbon capture sits in its "Plant and Infrastructure Systems Domain".

Its CO2 capture process is called Kansai Mitsubishi Carbon Dioxide Recovery, or KM CDR. It has been steadily optimised over the past 30 years.

MHI has developed its own amine solvent, which it calls "KS-1", which has a high CO2 capacity, low degradation and low regeneration energy requirement. The solvent was chosen after the company tested 200 solvents in 1990, made a shortlist of 20, and then settled on KS-1 in 1994.

The first commercial units were developed in the early 2000s, leading to the 500 tonnes per day "Plant Barry" in South Alabama in 2011.

FuelCell Energy – how fuel cells can do carbon capture

Fuel cells could be an unexpected commercially viable way to do carbon capture and make power at the same time, running at a large scale

Fuel cell technology is a well known, if not yet widely used, way to make electricity from fuels such as hydrogen, and being developed for vehicles, ships, and other applications which need electricity and are not connected to the grid.

A carbonate fuel cell, one of the most well known designs for making electricity from hydrogen, has circulating CO_3 (carbonate) ions. These are formed from CO_2 and electrons at the cathode, and split into CO_2 and electrons at the anode.

But instead of the CO_2 just circulating around the fuel cell in the other direction, the fuel cell can do carbon capture if it is taking CO_2 molecules from a CO_2 rich flue gas from elsewhere into the cathode. The pure CO_2 can then be removed at the anode, to be sequestered. It needs to be separated out of a mixture with water and unreacted hydrogen, but this can be done just by compressing and cooling.

This fuel cell does not need a supply of hydrogen – it has a supply of a hydrocarbon fuel (such as methane), mixed with steam at 600 degrees C. This is hot enough to do a "steam reforming" reaction, with gas reacting with water (H_2O) to form hydrogen and CO_2.

The full cell itself creates heat, which can be used to heat up the steam (and this also helps cool the fuel cell).

Additional benefits are that the system can destroy 70 per cent of any NOx in the flue gas stream. The system also produces water, which is useful in some parts of the world. Some of the hydrogen can be tapped off and sold separately, if there is a market for that.

It can be used with flue gases on coal and gas power plants, industrial boilers and steam generators.

The intake flue gas can be up to 70 per cent CO_2.

FuelCell Energy's largest carbon fuel cell plant, based near Seoul, uses 21 four stack modules, generating 1.4 MW

The units could be used on biogas, which is a mixture of methane and CO_2.

The systems have very low tolerance for sulphur and SOx in fuel, so this needs to be cleaned out before it enters the fuel cell. The sulphur can poison the catalyst. There is a somewhat higher tolerance for sulphur and SOx on the air side.

Each fuel cell is a flat plate. The set-up can reach megawatt scale with hundreds of fuel cells.

About FuelCell Energy

FuelCell Energy designs, manufacturers and operates the fuel cell power plants and power purchase agreements, and sells fuel cells.

The company usually sells them in a stack of 400, generating 250 to 400 kW of power. These stacks can be bundled into 4 stack modules, generating 1.4 MW (with some energy losses in power conversion), or a 2 module plant generating 2.8 MW.

The company's largest carbon fuel cell plant, based near Seoul, uses 21 of these 1.4 MW systems. Another system operating in Bridgeport, Connecticut uses 5 x 2.8 MW systems (total 14MW) and generates a further megawatt from waste heat from the system.

The cells are replaced every 7 years – basically by melting them down in the factory and recycling them.

After a fairly detailed examination of the cost, including capital costs, natural gas, fuel, CO_2 transport and storage, it works out $75 per tonne of CO_2, said Tony Leo, CTO, Fuel Cell Energy.

But if the power can be sold, it offsets the costs by around $40 depending on the local electricity market price. This can leave final costs in the mid $30s. The costs are lowest where there is a low price of gas and a high price of power.

It is also possible that hydrogen could be extracted from the system and sold separately, which could further offset the cost of carbon capture, perhaps pushing it to "way below $30", he said.

The system will typically have availability "in the high 90s", and it needs "really minimal" planned maintenance, he said.

The company is targeting 90 per cent capture rate, he said. "As you go higher – the fuel cell performance starts to go down, that power generation offset starts to go down. 95 per cent is probably the practical economic limit."

The technology can be commercially viable for smaller sized plants than for solvent carbon capture. That could make it more useful in industrial applications with lower CO_2 volumes, Mr Leo said.

Development work

The company is a "somewhat earlier stage" of technology development than MHIA, Mr Leo said. But the important thing is to get systems out there in the field. But outside the CCS technology, there do need to be better ways to monetise carbon capture. "We're all working on reducing the cost of capture, but it is not going to zero, so there has to be something to monetise," he said.

So far the technology might be described as "really good at making electricity and kind of good at capturing carbon", but with further development it could be "really good at capturing carbon," Mr Leo said.

Most development work until now has been funded by the US Department of Energy, looking at coal based systems with a fairly high CO2 level. This includes a project to do detailed design for a large scale system, doing carbon capture for a 550 MW coal plant. The study determined that you would need 319 MW of carbonate fuel cell systems to capture 90 per cent of CO2 from that plant.

The company is working on a research project with ExxonMobil to explore the capture of CO2 from flue gases from gas powered systems, which have a lower CO2 concentration.

CCSL – $30 a tonne using modularisation

CCSL is developing carbon capture systems using prefabricated modules, and with a rotating drum absorber rather than a column. It is targeting a capture cost of $30 a tonne CO2

Carbon Clean Solutions Ltd (CCSL) is exploring ways to build a carbon capture unit from prefabricated modules, and with a rotating drum absorber, instead of a tall column. It is targeting a capture cost of $30 a tonne CO2, with projects at small scales, gradually increasing size to 10 t/d by 2021 and 100 t/d by 2022 or 2023.

CCSL has recently brought in new investors including Chevron, Marubeni and a number of financial investors. "We are looking for partnerships with end users and EPCs, to get these solutions to market," said Will Shimer, commercial director of Carbon Clean Solutions (USA).

The company recently expanded its business offering to systems development, after a first decade mainly developing carbon capture solvents.

It is developing a system which could be provided in a number of modules, shipped to a site on a truck, and not requiring on-site construction, this achieving a much lower capital cost. Units could be stacked on top of each other, reducing the amount of required land space.

Modular carbon capture systems might be available only in standard sizes, so companies requiring more capacity would have a number of separate trains, Mr Shimer said. This is similar to how compressors are sold today.

CCSL also has two pilot projects, in the UK and US, testing a 1 tonne per day rotating pack bed absorber, which is much smaller than a conventional absorber, as a means of putting the solvent in contact with the gas. It calls it the "CCSL Gen2 Absorber."

The goal is to make a rotating absorber which is just 10-15 per cent of the height of a conventional absorber, and to reach Technology Readiness Level (TRL) 5 or 6 by the end of 2020.

CCSL is also looking to "intensify" its solvents. One idea is to have a solvent which has a higher viscosity, with less water. The solvent is heated to strip out the CO2, and the water in the solvent needs to be heated at the same time – so with less water, it could require less energy.

The company aims for 90 per cent capture rate, but it may be possible to build systems for less money if a slightly lower capture rate was acceptable, he said.

In terms of maintenance and reliability, Pumps, and other rotating equipment, are typically the highest maintenance item. The pre-treating of gas ahead of the carbon capture unit is very important in achieving high reliability, Mr Shimer said.

Markets

There could be many viable commercial applications at the 100 to 500 t/d range, including in cement, steel, refineries or waste to energy,

It has looked at a number of non-traditional carbon capture applications, including removing CO2 at a small scale from methane made with renewable methods, in order to meet a pipeline specification.

There is interest from the cement industry in capture from kilns, Mr Shimer said. It can be more viable for industrial plants which already have a source of heat available, which can be tied into the system.

There is interest in carbon capture on biofuels, particular in the US where there are tax benefits attached to carbon capture.

More information

This article is based on a GCCSI webinar "The Technology Cost Curve" held on June 8, 2020. You can view the whole webinar online at:

www.globalccsinstitute.com/resources/audio-and-visual-library/

Study shows world can capture enough CO2 to meet targets

The world is currently on track to fulfil scenarios on diverting atmospheric CO2 to underground reservoirs, according to a new study by Imperial.

A new analysis from Imperial College London suggests that just 2,700 Gigatonnes (Gt) of carbon dioxide (CO2) would be sufficient to meet the IPCC's global warming targets. This is far less than leading estimates by academic and industry groups of what is available, which suggest there is more than 10,000 Gt of CO2 storage space globally.

It also found that that the current rate of growth in the installed capacity of CCS is on track to meet some of the targets identified in IPCC reports, and that research and commercial efforts should focus on maintaining this growth while identifying enough underground space to store this much CO2.

The research team, led by Dr Christopher Zahasky at Imperial's Department of Earth Science and Engineering, found that worldwide, there has been 8.6 per cent growth in CCS capacity over the past 20 years, putting us on a trajectory to meet many climate change mitigation scenarios that include CCS as part of the mix.

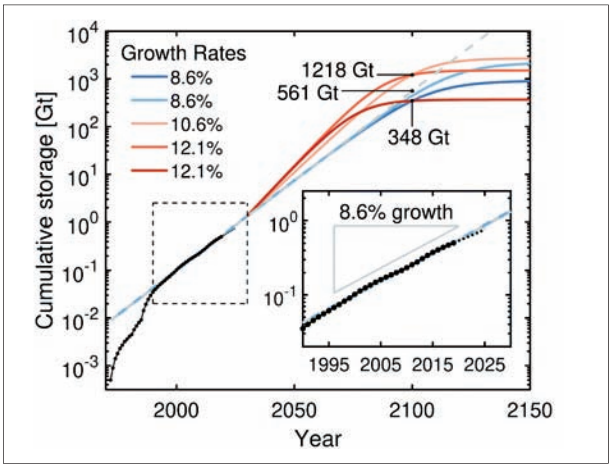
Dr Zahasky, who is now an assistant professor at the University of Wisconsin-Madison but conducted the work at Imperial, said: "Nearly all IPCC pathways to limit warming to 2°C require tens of Gts of CO2 stored per year by mid-century. However, until now, we didn't know if these targets were achievable given historic data, or how these targets related to subsurface storage space requirements.

"We found that even the most ambitious scenarios are unlikely to need more than 2,700 Gt of CO2 storage resource globally, much less than the 10,000 Gt of storage resource that leading reports suggest is possible.?Our study shows that if climate change targets are not met by 2100, it won't be for a lack of carbon capture and storage space."

Study co-author Dr Samuel Krevor, also from the Department of Earth Science and Engineering, said: "Rather than focus our attention on looking at how much storage space is available, we decided for the first time to evaluate how much subsurface storage resource is actually needed, and how quickly it must be developed, to meet climate change mitigation targets."

Speed matters

The study has shown for the first time that the maximum storage space needed is only around 2,700 Gt, but that this amount will grow if CCS deployment is delayed. The researchers worked this out by combining data on the past 20 years of growth in CCS, information on historical rates of growth in energy infrastructure, and models commonly used to monitor the depletion of natural resources.



Plot of cumulative CO2 storage as a function of time. The black markers indicate the historic cumulative CO2 injection along with planned projects up to 2025. The blue lines illustrate logistic curves with different 2100 storage targets assuming continued growth at the historic rate of 8.6%. The orange and red lines illustrate logistic curves with increases in growth rate starting at 2030. The light orange line describes the scenario where the growth rate increases from 8.6% to 10.6%, in 2030 while the medium orange line indicates an increase of 3.5%, from 8.6% to 12.1% in 2030. The rates were constrained to reach either the 348 Gt or 1218 Gt IPCC targets of CO2 stored by 2100

The researchers say that the rate at which CO2 is stored is important in its success in climate change mitigation. The faster CO2 is stored, the less total subsurface storage resource is needed to meet storage targets. This is because it becomes harder to find new reservoirs or make further use of existing reservoirs as they become full.

They found that storing faster and sooner than current deployment might be needed to help governments meet the most ambitious climate change mitigation scenarios identified by the IPCC.

The study also demonstrates how using growth models, a common tool in resource assessment, can help industry and governments to monitor short-term CCS deployment progress and long-term resource requirements.

However, the researchers point out that meeting CCS storage requirements will not be sufficient on its own to meet the IPCC climate change mitigation targets.

Dr Krevor said: "Our analysis shows good news for CCS if we keep up with this trajectory - but there are many other factors in mitigating climate change and its catastrophic effects, like using cleaner energy and transport as well as significantly increasing the efficiency of energy use.

More information

"Global geologic carbon storage requirements of climate change mitigation scenarios" by Christopher Zahasky and Samuel Krevor, published 21 May 2020 in Energy & Environmental Science.

www.imperial.ac.uk

Study shows hydrological limits in CCS

Research at Berkeley College of Chemistry shows water use is an important consideration in the implementation of Carbon Capture and Storage.

Our energy and water systems are inextricably linked. Climate change necessitates that we transition to carbon-free energy and also that we conserve water resources as they become simultaneously more in demand and less available. Policymakers, business leaders, and scientists seeking to address the urgency of climate change are increasingly looking to Carbon Capture and Storage (CCS) to help meet global climate goals.

While CCS minimizes emissions from the combustion of fuels, its impact on global water resources has not been widely explored. New research shows that CCS could stress water resources in about 43% of the world's power plants where water scarcity is already a problem. Further, the technology deployed in these water-scarce regions matters, and emerging CCS technologies could greatly mitigate the demand CCS places on water consumption.

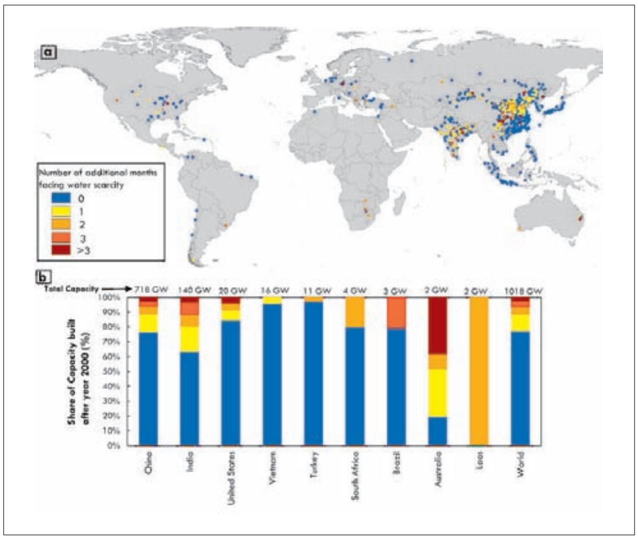
Energy-producing facilities such as coal-fired power plants consume large amounts of cooling water. The type of cooling method used in a power plant (wet cooling towers, once-through cooling, or air-cooled condensers) affects water consumption. Installing CCS at these facilities requires that they produce additional energy to compensate for the energy used by the CCS process. With that comes additional cooling water consumption. In addition, the CCS process itself adds to the overall water consumption in a fashion that depends upon the CCS technology deployed.

Most CCS projects currently operational worldwide use absorption technologies. Common absorbents are aqueous bases containing amine groups that bind to carbon dioxide, separating it from other gases in the flue mixture. The process of absorption of CO2 into these solvents and subsequent regeneration of the solvents require energy withdrawal from the power plant.

The circulation of large quantities of solvents results in water loss by evaporation. Other state-of-the-art CCS technologies use far less water as they separate the carbon dioxide from flue gas by adsorption onto solid materials, or pass the exhaust gas through membranes. These technologies potentially reduce both the energy load and water consumption.

In this research we examined how CCS can be implemented sustainably without compromising water resources. Specifically, does the addition of CCS to coal-fired power plants impact water consumption in any region of the world significantly enough to induce or exacerbate water scarcity?

We modeled the hypothetical implementation of four different CCS technologies at every global coal-fired power plant of significant size currently operating around the world and studied the impact on regional water withdrawals and consumptions. Using a global biophysical monthly hydrological analysis, we assessed where, when, and to what extent water scarcity could constrain the implementation of CCS.



Additional water scarcity with carbon capture amine absorption technology. The figure shows the number of additional months of water scarcity per year that CFPP built after year 2000 would face in the event they were retrofitted with the commercially available amine absorption technology. Detail (a) shows the geographical distribution of CFPP built after year 2000 and the number of months of additional water scarcity they would face if retrofitted with amine absorption, (b) shows country-specific share of coal-fired capacity built after year 2000 that would face additional months of water scarcity if retrofitted with amine absorption. Countries are listed in descending order based on additional capacity facing water scarcity

Somewhat surprisingly, we found that in cases where water scarcity does not already exist, the addition of CCS will not generally induce scarcity. However, we also found that 43% of the current installed global coal-fired power capacity is located within regions that now experience water scarcity for at least one month a year, and over 30% of global capacity faces scarcity for five or more months a year.

In these regions, implementation of CCS technologies worsens the water stress. Retrofitting power plants with less water-intensive capture technologies could mitigate competition for freshwater resources, and the choice of cooling methods becomes increasingly important.

Our results enable a more comprehensive understanding of water use by coal-fired plants with, and without, carbon capture. Careful trade-offs need to be considered, and the choice of carbon capture technology is very relevant. We believe that this work will serve as a guide to policymakers as we ramp up the implementation of CCS around the world.

More information

"Hydrological limits to carbon capture and storage" by Lorenzo Rosa, Jeffrey A. Reimer, Marjorie S. Went & Paolo D'Odorico published in Nature Sustainability.

chemistry.berkeley.edu

Projects and policy news

Equinor, Shell and Total invest in Northern Lights

northernlightsccs.com

Following the investment decision, the partners intend to establish a joint venture company. The initial investments will total almost NOK 6.9 billion.

Equinor, Shell and Total have decided to invest in the Northern Lights project in Norway's first exploitation licence for CO2 storage on the Norwegian Continental Shelf. Plans for development and operation have been handed over to the Ministry of Petroleum and Energy.

"The Northern Lights project could become the first step to develop a value chain for Carbon Capture and Storage (CCS), which is vital to reach the global climate goals of the Paris Agreement. Development of CCS projects will also represent new activities and industrial opportunities for Norwegian and European industries, says Anders Opedal, executive vice president for Technology, Projects & Drilling at Equinor.

The investment decision is subject to final investment decision by Norwegian authorities and approval from the EFTA Surveillance Authority (ESA). If the project receives a positive final investment decision from the Norwegian Government in 2020, Phase 1 is expected to be operational in 2024.

"This unique project opens for decarbonisation of industries with limited opportunities for CO2-reductions. It can be the first CO2 storage for Norwegian and European industries, and can support goals to reduce net greenhouse gas emissions to zero by 2050," says Opedal.

The investment decision concludes the study phase during which the Equinor, Shell and Total worked closely with Norwegian authorities to conduct engineering studies and project planning, drill a confirmation well and develop the necessary agreements.

"CCS is a crucial technology to help society and economies thrive through the energy transition. Shell is active in all parts of the CCS value chain and Northern Lights further strengthens our global CCS portfolio. We appreciate the leadership shown by the Norwegian Government to accelerate the development of CCS value chains and believe that the Northern Lights CO2 transport and storage solution has the potential to unlock investment in capture projects across Europe," says Syrie Crouch, vice president for CCUS in Shell.

The project will be developed in phases. Phase 1 includes capacity to transport, inject and store up to 1.5 million tonnes of CO2 per year. Once the CO2 is captured onshore by industrial CO2-emitters, Northern lights will be responsible for transport by ships, injection and permanent storage some 2,500 metres below the seabed.

The CO2 receiving terminal will be located at the premises of Naturgassparken industrial area in the municipality of Øygarden in Western Norway. The plant will be remotely operated from Equinor's facilities at the Sture terminal in Øygarden and the subsea facilities from Oseberg A platform in the North Sea.

The facility will allow for further phases to expand capacity. Investments in subsequent phases will be triggered by market demand from large CO2 emitters across Europe.

Equinor, on behalf of the partners, has already signed non-binding Memoranda of understanding with several European companies for the development of value chains in carbon capture and storage. Binding commercial agreements will depend on positive investment decision from Norwegian authorities and for individual third-party projects.

Consortium launches Sweden's largest CCUS plant

www.preem.se/en

Sweden's largest test facility for carbon dioxide capture has begun operation at Preem's refinery in Lysekil.

The Preem CCS project is a collaboration between Preem, Aker Solutions, Chalmers University of Technology, Equinor and the Norwegian research institute SINTEF. The Swedish Energy Agency and the Norwegian research and development program CLIMIT contribute with funding.

Within the pilot project, the entire value chain will be evaluated – from carbon capture at the refinery, local storage, transport to the planned storage location off the Norwegian west coast and for the storage itself. The results of the pilot project will then be made public – in order for more companies to be able to use the technology and reduce their carbon dioxide emissions.

In 2020, the test facility will capture carbon dioxide from the flue gases from Preem's hydrogen gas plant at the Lysekil refinery.

The technology for capturing and storing carbon dioxide is an important component for reducing greenhouse gas emissions and for achieving Sweden's climate goals. For Preem, this is an important piece of the puzzle to reduce carbon dioxide emissions and to become climate neutral by the year 2045. The goal is for the tests to form the basis for a full-scale CCS plant that can be operational by 2025.

"We see carbon capture and storage as a vital measure to reduce global carbon emissions. For Preem, a full-scale CCS plant could initially reduce emissions from our Lysekil refinery by 500,000 tonnes, which is close to a quarter of the refinery's total carbon emissions," says Petter Holland, CEO of Preem.

The carbon dioxide is planned to be stored in Norway, which is leading in this area and has better geological conditions for storage than Sweden. Preem made a statement of intent to collaborate with the Northern Lights project last fall.

Equinor plans UK hydrogen plant with CCS

www.equinor.com/en/what-we-do/h2hsaltend.html

Equinor is leading a project to develop one of the world's first at-scale facilities to produce hydrogen from natural gas in combination with carbon capture and storage.

The project, called Hydrogen to Humber Saltend (H2H Saltend), provides the beginnings of a decarbonised industrial cluster in the Humber region, the UK's largest by emissions.

H2H Saltend supports the UK government's aim to establish at least one low carbon industrial cluster by 2030 and the world's first net zero cluster by 2040. It also paves the way for the vision set out by the Zero Carbon Humber alliance, which Equinor and its partners launched in 2019.

The project will be located at Saltend Chemicals Park near the city of Hull and its initial phase comprises a 600 megawatt auto thermal reformer (ATR) with carbon capture, the largest plant of its kind in the world, to convert natural gas to hydrogen.

It will enable industrial customers in the Park to fully switch over to hydrogen, and the power plant in the Park to move to a 30% hydrogen to natural gas blend. As a result, emissions from Saltend Chemicals Park will reduce by nearly 900,000 tonnes of CO_2 per year.

In its later phases, H2H Saltend can expand to serve other industrial users in the Park and across the Humber, which employs 55,000 people in the manufacturing sector alone, contributing to the cluster reaching net zero by 2040.

This will enable a large-scale hydrogen network, open to both blue hydrogen (produced from natural gas with CCS) and green hydrogen (produced from electrolysis of water using renewable power), as well as a network for transporting and storing captured CO_2 emissions. It is estimated that fuel switching to hydrogen could create 43,000 new job opportunities in energy-intensive industrial sectors across the UK.

"The world continues to need more energy at lower emissions so we can achieve the ambitions of the Paris Agreement," says Irene Rummelhoff, executive vice president for marketing, midstream and processing at Equinor.

"This necessitates a substantial decarbonisation of industry, in which we believe carbon capture & storage and hydrogen can and must play a significant role. With private and public investment and supportive UK policy, the H2H Saltend project will demonstrate the potential of these technologies. Together we can make the Humber and the UK a world-leading example that others can learn from."

"px Group is delighted to be supporting H2H Saltend, a landmark project for UK energy transition. We are fully committed to helping industry reach net zero and both CCS and hydrogen will play a huge part in that. We're looking forward to collaborating with all the project partners as we work towards this common goal," says Geoff Holmes, chief executive officer of px Group, which owns and operates the Saltend Chemicals Park.

"As the UK's leading supplier of energy, we're proud of the role our natural gas and offshore wind has played in reducing carbon emissions in power. Now we want to go further by bringing hydrogen to the Humber region. With our partners, we plan to transform the UK's largest industrial cluster into its greenest cluster," says Al Cook, executive vice president and Equinor's UK country manager.

H2H Saltend will be part of the Zero Carbon Humber alliance's application for public co-funding in the second phase of the Industrial Strategy Challenge Fund, which launched on 23 June 2020. Subject to supportive UK policy, Equinor and its partners will mature the project towards a final investment decision during 2023 with potential first production by 2026.

In 2018 Equinor, Northern Gas Networks and Cadent, published the H21 North of England report showing how blue hydrogen could be produced and supplied to millions of homes and business across the north of England.

Equinor is also a partner in the Net Zero Teesside development which proposes to build a new-build gas-fired power station with carbon capture, and extending the CCS infrastructure to the neighbouring industrial cluster.

Drax and Mitsubishi collaborate on BECCS pilot

www.drax.com

spectra.mhi.com/the-road-to-net-zero

A new bioenergy with carbon capture and storage (BECCS) pilot facility will be installed within Drax's CCUS Incubation Area this year.

An engineer looks up at flue gas desulphurisation unit (FGD) at Drax Power Station. The massive pipe would transport flue gas from the Drax boilers to the carbon capture and storage (CCS) plant for CO_2 removal of between 90-95%

The pilot will test MHI's carbon capture technology – marking another step on Drax's journey towards achieving its world-leading ambition to be a carbon negative company by 2030.

MHI's 12-month pilot will capture around 300kg of CO_2 a day for the purpose of confirming its technology's suitability for use with biomass flue gases at Drax.

Two of MHI's proprietary solvents will be tested, one of which — KS-1 Solvent — is already being used at 13 commercial plants delivered by MHI, including Petra Nova in Texas, USA, the world's largest post combustion carbon capture facility, capturing 1.4 million tonnes of CO_2 a year.

The other is the newly developed KS-21 Solvent, designed to achieve significant performance improvements and cost savings.

Australian researchers set record for CO2 capture

Researchers from Monash University and CSIRO have set a record for carbon dioxide capture using Metal Organic Frameworks (MOFs).

Using a Metal Organic Frameworks (MOFs) nanocomposite that can be regenerated with remarkable speed and low energy cost, researchers have developed sponge-like technology that can capture carbon dioxide from a number of sources, even directly from air.

The magnetic sponge is used to remove carbon dioxide using the same techniques as induction cooktops using one-third of the energy than any other reported method.

Associate Professor Matthew Hill (CSIRO and Department of Chemical Engineering, Monash University) and Dr Muhammad Munir Sadiq (Department of Chemical Engineering, Monash University) led this research.

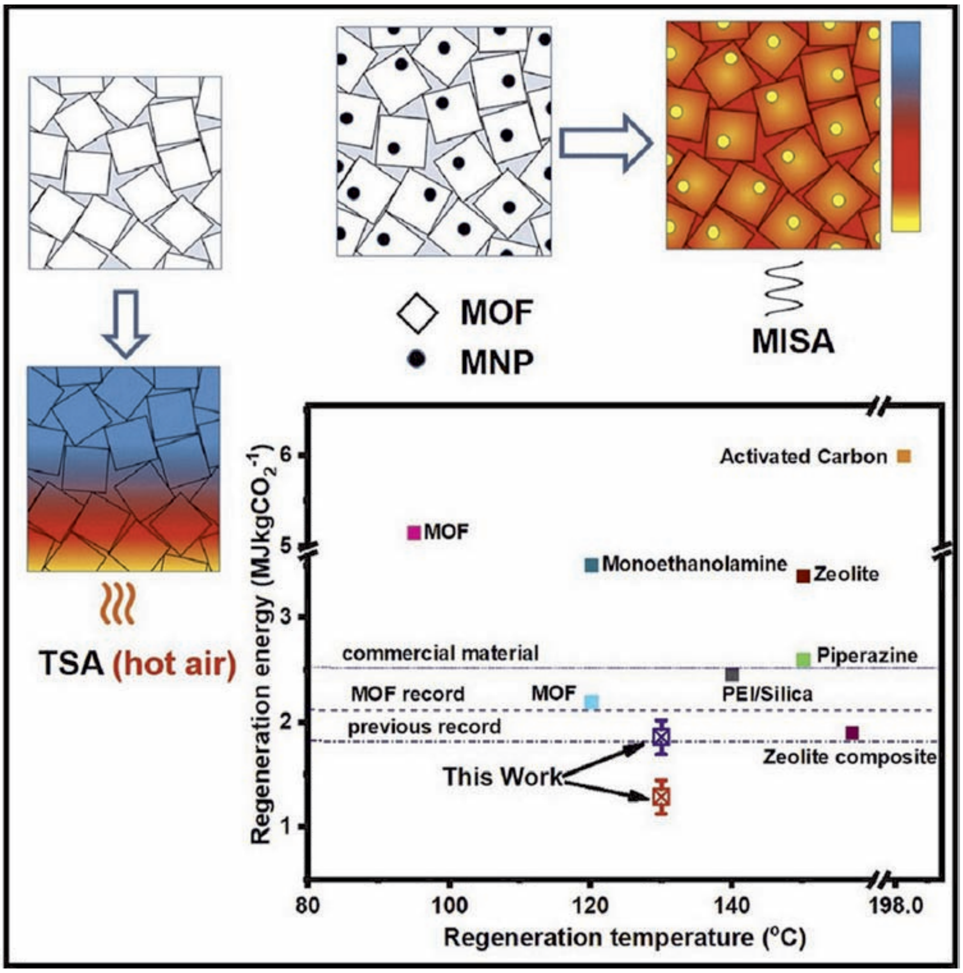
In the study, published in Cell Reports Physical Science, researchers designed a unique adsorbent material called M-74 CPT@PTMSP that delivered a record low energy cost of just 1.29 MJ $kg^{-1}CO2$, 45 per cent below commercially deployed materials, and the best CCS efficiency recorded.

MOFs are a class of compounds consisting of metal ions that form a crystalline material with the largest surface area of any material known. In fact, MOFs are so porous that they can fit the entire surface of a football field in a teaspoon.

This technology makes it possible to store, separate, release or protect valuable commodities, enabling companies to develop high value products.

"Global concerns on the rising level of greenhouse gas emissions and the associated environmental impact has led to renewed calls for emissions reduction and the development of green and renewable alternative energy sources," Associate Professor Hill said.

"However, existing commercial carbon capture technologies use amines like monoethanolamine, which is highly corrosive, energy intensive and captures a limited amount of carbon from the atmosphere.



"Our research shows the lowest reported regeneration energy calculated for any solid porous adsorbent, including monoethanolamine, piperazine and other amines. This makes it a cheap method that can be paired with renewable solar energy to capture excess carbon dioxide from the atmosphere.

"Essentially, we can capture CO2 from anywhere. Our current focus is for capture directly from the air in what are known as negative emissions technologies."

For MOFs to be used in CCS applications, it is essential to have materials that can be easily fabricated with good stability and performance.

The stability of M-74 CPT@PTMSP was evaluated by estimating the amount of CO2 and H2O captured and released via the researchers' magnetic induction swing adsorption (MISA) process over 20 consecutive cycles.

The regeneration energy calculated for M-74 CPT@PTMSP is the lowest reported for any solid porous adsorbent. At magnetic fields of 14 and 15 mT, the regeneration energy calculated for M-74 CPT was 1.29 and 1.44 MJ kg CO2-1.

More information

www.monash.edu

Cheap nanoparticle catalyst for CO2 to syngas conversion

Making catalysts to convert waste carbon dioxide into useful industrial products has been expensive and complicated – until now. UNSW engineers show it's as easy as playing with Lego.

Chemical engineers from UNSW Sydney have developed new technology that helps convert harmful carbon dioxide emissions into chemical building blocks to make useful industrial products like fuel and plastics.

In a paper published in the journal Advanced Energy Materials, Dr Rahman Daiyan and Dr Emma Lovell from UNSW's School of Chemical Engineering detail a way of creating nanoparticles that promote conversion of waste carbon dioxide into useful industrial components.

The researchers, who carried out their work in the Particles and Catalysis Research Laboratory led by Scientia Professor Rose Amal, show that by making zinc oxide at very high temperatures using a technique called flame spray pyrolysis (FSP), they can create nanoparticles which act as the catalyst for turning carbon dioxide into 'syngas' – a mix of hydrogen and carbon monoxide used in the manufacture of industrial products.

The researchers say this method is cheaper and more scalable to the requirements of heavy industry than what is available today.

"We used an open flame, which burns at 2000 degrees, to create nanoparticles of zinc oxide that can then be used to convert CO2, using electricity, into syngas," says Dr Lovell.

"Syngas is often considered the chemical equivalent of Lego because the two building blocks – hydrogen and carbon monoxide – can be used in different ratios to make things like synthetic diesel, methanol, alcohol or plastics, which are very important industrial precursors.

"So essentially what we're doing is converting CO2 into these precursors that can be used to make all these vital industrial chemicals."

Closing the loop

In an industrial setting, an electrolyser containing the FSP-produced zinc oxide particles could be used to convert the waste CO2 into useful permutations of syngas, says Dr Daiyan.

"Waste CO2 from say, a power plant or cement factory, can be passed through this electrolyser, and inside we have our flame-sprayed zinc oxide material in the form of an electrode. When we pass the waste CO2 in, it is processed using electricity and is released from an outlet as syngas in a mix of CO and hydrogen," he says.

The researchers say in effect, they are closing the carbon loop in industrial processes that create harmful greenhouse gases. And by making small adjustments to the way the nanoparticles are burned by the FSP technique, they can determine the eventual mix of the syngas building blocks produced by the carbon dioxide conversion.

"At the moment you generate syngas by using natural gas – so from fossil fuels," Dr Daiyan says. "But we're using waste carbon dioxide and then converting it to syngas in a ratio depending on which industry you want to use it in."

For example, a one to one ratio between the carbon monoxide and hydrogen lends itself to syngas that can be used as fuel. But a ratio of four parts carbon monoxide and one part hydrogen is suitable for the creation of plastics, Dr Daiyan says.

Cheap and accessible

In choosing zinc oxide as their catalyst, the researchers have ensured that their solution has remained a cheaper alternative to what has been previously attempted in this space.

"Past attempts have used expensive materials such as palladium, but this is the first instance where a very cheap and abundant material, mined locally in Australia, has been successfully applied to the problem of waste carbon dioxide conversion," Dr Daiyan says.

Dr Lovell adds that what also makes this method appealing is using the FSP flame system to create and control these valuable materials.

"It means it can be used industrially, it can be scaled, it's super quick to make the materials and very effective," she says.

"We don't need to worry about complicated synthesis techniques that use really expensive metals and precursors – we can burn it and in 10 minutes have these particles ready to go. And by controlling how we burn it, we can control those ratios of desired syngas building blocks."

Scaling up

While the duo have already built an electrolyser that has been tested with waste CO2 gas that contains contaminants, scaling the technology up to the point where it could convert all of the waste carbon dioxide emitted by a power plant is still a way down the track.

"The idea is that we can take a point source of CO2, such as a coal fired power plant, a gas power plant, or even a natural gas mine where you liberate a huge amount of pure CO2 and we can essentially retrofit this technology at the back end of these plants. Then you could capture that produced CO2 and convert it into something that is hugely valuable to industry," says Dr Lovell.

The group's next project will be to test their nanomaterials in a flue gas setting to ensure they are tolerant to the harsh conditions and other chemicals found in industrial waste gas.

More information

www.unsw.edu.au

Membranes to reduce industrial CO2

Researchers at Oak Ridge National Laboratory and the University of Tennessee, Knoxville, demonstrated a novel fabrication method for affordable gas membranes that can remove carbon dioxide from industrial emissions.

Results published in Chem demonstrate a fabrication method for membrane materials that can overcome current bottlenecks in selectivity and permeability, key variables that drive carbon-capturing performance in real environments.

"Often there is a trade-off in how selective or how permeable you can make membranes that filter out carbon dioxide without allowing other gases to pass through. The ideal scenario is to create materials with high permeability and selectivity," said Zhenzhen Yang of UT's Department of Chemistry.

Gas membranes are a promising but still developing technology for reducing post-combustion or flue gas emissions produced by fossil-fueled industries.

The concept is simple: a thin, porous membrane acts as a filter for exhaust gas mixtures, selectively allowing carbon dioxide, or CO2, to flow through freely into a collector that is kept under reduced pressure, but preventing oxygen, nitrogen and other gases from tagging along.

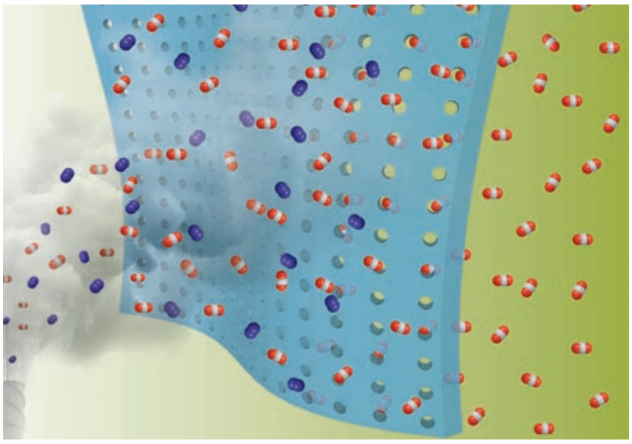
Unlike existing chemical methods to capture CO2 from industrial processes, membranes are easy to install and can operate unattended for long periods with no additional steps or added energy costs. The catch is that new, cost-effective materials are needed to scale up the technology for commercial adoption.

"Gas membranes need pressure on one side and typically a vacuum on the other to maintain a free-flow environment, which is why materials' selectivity and permeability are so important to developing the technology," said Ilja Popovs of ORNL's Chemical Sciences Division. "Underperforming materials require more energy to push gases through the system, so advanced materials are key to keeping energy costs low."

No natural and only a few synthetic materials have exceeded what is called the Robeson upper limit, a known boundary that constrains how selective and permeable most materials can be before these rates start to drop.

Materials with sufficiently high selectivity and permeability for efficient gas separations are rare and often made from expensive starting materials whose production requires either long and tedious synthesis or costly transition metal catalysts.

"We set out to test a hypothesis that introducing fluorine atoms into membrane materials could improve carbon-capture and separation performance," Yang said.



Researchers at Oak Ridge National Laboratory and the University of Tennessee, Knoxville, demonstrated a novel fabrication method for affordable gas membranes that can remove carbon dioxide from industrial emissions. Credit: Zhenzhen Yang/UT

The element fluorine, used to make consumer products such as Teflon and toothpaste, offers carbon dioxide-philic properties that make it attractive for carbon-capture applications. It is also widely available, making it a relatively affordable option for low-cost fabrication methods. Research on fluorinated gas membranes has been limited because of fundamental challenges of incorporating fluorine into materials to realize its carbon-loving functionality.

"Our first step was to create a unique fluorine-based polymer using simple chemical methods and commercially available starting materials," Yang said.

Next, researchers transformed, or carbonized, the material using heat to give it the porous structure and functionality needed for capturing CO2. The two-step process preserved the fluorinated groups and boosted CO2 selectivity in the final material, overcoming a fundamental hurdle encountered in other synthetic methods.

"The approach resulted in a carbon dioxide-philic material with high surface area and ultra-micropores that is stable in high-temperature operating conditions," Yang said. "All of these factors make it a promising candidate for carbon-capture and separation membranes."

The material's novel design contributes to its exceptional performance, observed in high selectivity and permeability rates that exceed the Robeson upper limit, something only a handful of materials have accomplished.

"Our success was a material achievement that demonstrates feasible routes for leveraging fluorine in future membrane materials. Moreover, we achieved this goal using commercially available, inexpensive starting materials," Popovs said.

The basic discovery expands the limited library of practical options for carbon-capture membranes and opens new directions for developing fluorinated membranes with other task-specific functionalities.

Researchers aim to next investigate the mechanism by which fluorinated membranes absorb and transport CO2, a fundamental step that will inform the design of better carbon-capture systems with materials purposely tailored to grab CO2 emissions.

More information

www.ornl.gov

Testing piperazine solvent for capturing CO_2 from flue gas

A project factsheet is available from the CCP (CO_2 Capture Project) on its work in the application of the piperazine solvent with advanced stripper technology to achieve a high capture rate in low-CO_2 flue gas.

Aqueous piperazine is a second-generation solvent that has superior kinetics, favourable vapor-liquid characteristics, large operational CO_2 carrying capacity, and good resistance to thermal and oxidative degradation. Modelling studies suggested that the PZAS technology may be uniquely suitable for application to low CO_2 concentration flue gases.

When used with an advanced stripper configuration, it can be regenerated at elevated pressures with reduced energy consumption. Previous work funded by the U.S. Department of Energy (Award number DE-F0005654) established that Piperazine with the Advanced Stripper (PZAS) is a superior technology for CO_2 capture from flue gas with ~12 vol% CO_2.

CCP was interested in PZAS application to lower-concentration flue gases that are more prevalent in the oil and gas industry. CCP worked with the University of Texas at Austin and the National Carbon Capture Center (NCCC), a U.S. Department of Energy-sponsored research facility in Wilsonville, Alabama to pilot the use of PZAS technology.

The pilot tested PZAS technology for capturing CO_2 from low CO_2 (4 vol%) flue gas, representative of flue gas from Natural Gas Combined Cycle (NGCC) power plants. Leveraging existing pilot facilities at NCCC, CCP sponsored a series of tests with 4% CO_2 flue gas.

In July 2019, CCP deemed the pilot tests a success, providing significant data to scale up the PZAS technology for low-CO_2 concentration applications such as flue gas from NGCC power plants.

The main goals of the project were:

1. Demonstrate the application of PZAS to low-CO_2 flue gas to achieve high capture rate at reasonable energy consumption

Pilot-scale testing site of the PZ solvent at the University of Texas, Austin. Image courtesy of UT

2. Generate data from model evaluation for scale-up, especially under different process conditions and configurations

3. Demonstrate long-term operability of PZAS under low-CO_2 conditions, evaluating emissions, degradation, corrosion and other operational performance.

The test campaign, including performance testing under different operating conditions and long-term tests for stability, lasted 2,100 hours and was completed in June 2019. New process configurations for absorber intercooling and process intensification concepts, to combine direct contact cooler with absorber cooling, were tested and confirmed.

CO_2 removal rates of up to 96% were demonstrated and energy performance at 90% capture was around 2.35 GJ/tonne CO_2. Solvent degradation, emissions, corrosion and operation were generally similar to other applications. The pilot data used for model validation under a variety of operational conditions and model performance shows that the PZAS technology is ready for scale-up to large pilot applications (>100 tonne CO_2 captured/day).

Prior to the NCCC project, initial testing was done at University of Texas, Austin's Separation Research Program pilot plant to ascertain the feasibility of using piperazine on a low CO_2 concentration flue gas stream simulated by mixing CO_2 and air streams.

More information

For the full results in detail download the factsheet:

www.co2captureproject.org

Capture and utilisation news

DNV GL approves Shell carbon capture technology for Fortum plant

www.dnvgl.com

DNV GL has approved as qualified, technology for a full-scale demonstration project to remove carbon emissions at a waste-to-energy plant in Oslo, Norway.

Gassnova, the Norwegian state agency for carbon capture and storage projects, is supporting the project, which tested Shell's CANSOLV CO2 carbon capture technology at Fortum Oslo Varme's Waste-to-Energy plant at Klemetsrud in Oslo.

This project will contribute towards Norway's target to reduce emissions with at least 50 %, and towards 55 % by 2030 compared to 1990 levels.

The Fortum Oslo Varme plant incinerates domestic and international sorted household and industrial waste. The excess heat is used to produce district heating and electricity.

DNV GL worked with Shell and Fortum Oslo Varme to verify the application of its recommended practices; DNVGL-RP-A203 Technology Qualification and DNVGL-RP-J201 Qualification procedures, for carbon dioxide capture technology. The recommended practices provide a systematic approach to technology qualification in a manner that ensures traceability throughout the process.

Steam and CO2 are emitted at Klemetsrud, where dust, dioxins, NOX HCL, SO2 and heavy metals are cleaned from the flue gas. The capture of more than 90 % of all CO2 in the flue gas was achieved during a pilot initiated in 2018.

Going full scale with CCS, and with 50 % of waste incinerated at the plant being of biological origin, the environmental performance of the plant will be significantly improved by achieving net negative emissions.

DNV GL has also undertaken technology qualification at a second pilot site supported by Gassnova. In April, the risk management and quality assurance company approved CCS technology developed by Aker Solutions and tested at Norcem's cement plant in Brevik, Norway.

Carbon8 Systems commercially deploys CCUS systems at Vicat cement plant

www.c8s.co.uk

www.vicat.com

The company has signed a commercial agreement with the Vicat Group cement company to deploy it's Co2ntainer system at a cement plant in France.

It is Carbon8 Systems' first commercial deployment of its CO2ntainer system (a modular, containerised solution) in Europe and follows successful demonstration projects at cement plants in the UK and Canada.

The CO2ntainer will be deployed directly onsite at Montalieu and integrated into Vicat's existing industrial processes. Crucially, it will capture CO2 directly from the plant's flue gas emissions, which will be used to convert cement bypass dust into lightweight aggregates through the use of Carbon8 Systems' patented Accelerated Carbonisation Technology (ACT) solution.

In its first phase of operation, Carbon8 Systems' CO2ntainer will process and convert up to 12,000 tonnes of cement bypass dust into valuable construction aggregates. Vicat can commercially repurpose the aggregates in various applications, for instance in lightweight concrete blocks.

Dr Paula Carey, co-founder and Technical Director of Carbon8 Systems, said, "Securing a commercial agreement with Vicat, a family-run cement company that has been in business for more than 150 years and with a strong commitment to process innovation and sustainability, is a massive endorsement of our technology and the R&D work that we have carried out over recent years. We are delighted that Vicat has chosen Carbon8 Systems to help reduce its carbon emissions and, at the same time, create a potential new income stream for their business."

With the cement industry responsible for 5% to 7% of the world's greenhouse gas emissions, Carbon8 Systems is in advanced discussions with other cement companies around the world to deploy its CO2ntainer solution. In addition, the company is pursuing opportunities in other sectors where waste residue disposal is increasingly expensive and CO2 emissions need to be reduced as part of the transition to Net Zero by 2050. By using the waste at source and onsite, companies using ACT will reduce the amount of waste going to landfill, so further reducing the environmental impact of their operations.

Dr Laury Barnes-Davin, Scientific Director of Vicat said, "As part of our commitment to limit our environmental impact, Vicat has looked at a number of innovative ideas to reduce its carbon emissions. We are attracted by Carbon8 Systems' two-part technology proposition: capturing the CO2 that Montalieu emits and using it to produce an aggregate that can be marketed to industry. We are excited by its potential for our operations elsewhere in France and around the world."

In addition to cement, other sectors where ACT can be used include power generation (Energy from Waste), the steel industry and the paper industry.

Size matters for bioenergy with carbon capture and storage

www.southampton.ac.uk

Research at University of Southampton has shown that Drax power station in North Yorkshire is the optimal size for carbon capture and storage facilities.

The new study, led by the University of Southampton and published in the journal GCB Bioenergy, looked at six potential locations for BECCS power plants across the UK. Each site was assessed on a number of criteria including proximity to CO2 storage sites, costs of transporting biocrops as well as the potential for soil sequestration (the process by which crops remove CO2 from the atmosphere) and flood mitigation. The researchers also calculated welfare value by integrated the costs and the potential for environmental benefits.

Drax was identified as one of the most positive UK sites for the delivery of ecosystem service benefits. However, these benefits decline with size with 1 Gigawatt (GW) BECCS being significantly less beneficial to the environment than 500 megawatt, suggesting that future BECCS requires site-specific ecosystem service valuations to assess trade-offs and co-benefits of this NET and that smaller power plants are preferred over large infrastructures.

Transport and storage news

First independent catalogue of CO2 storage resource for CCUS

oilandgasclimateinitiative.com/co2-storage-resource-catalogue

The CO2 Storage Resource Catalogue is a pioneering initiative to accelerate the deployment of CCUS by supporting the consistent evaluation of storage resources.

The Oil and Gas Climate Initiative (OGCI), the Global CCS Institute and Pale Blue Dot Energy have launched the CO2 Storage Resource Catalogue, the first independent worldwide evaluation of geologic CO2 storage resource assessments.

The Catalogue aims to become the global repository for all future storage resource assessments, supporting the growth of a safe and commercially viable CCUS industry. It will do this by bolstering investors' understanding of commercial development and maturity of published CO2 storage resources, thereby leading to increased investor confidence.

"OGCI's involvement with the CO2 Storage Resource Catalogue is part of a broad range of actions we are taking to accelerate the deployment of CCUS, enabling it to play a key role in achieving net zero emissions," said Sylvain Thibeau, CO2 Storage Workgroup lead of OGCI and CO2 Storage Expert for Total.

Information on the 525 potential CO2 storage sites currently in the Catalogue comes from the Global CO2 Storage Resource Assessment 2019, the first of a six-year programme which assessed more than 12,000 Gt of potential storage resource in 13 countries.

"While the scale of these estimates is encouraging, ongoing CO2 storage characterization and development is critical for the large-scale deployment of CCUS," said Dr Chris Consoli, Senior Consultant – Storage with the Global CCS Institute.

"In countries with supportive policy and legal and regulatory frameworks – such as in Canada, Norway, the UK and the US – storage resources are significantly more mature, making them more likely to be the countries where the next wave of CCS projects are announced," added Dr Consoli.

The Catalogue has adopted a methodology developed by the Society of Petroleum Engineers with OGCI contribution, the Storage Resources Management System. Using the template of the established Petroleum Resources Management System, the document establishes technically based evaluation standards for the classification of global CO2 storage resources.

The Catalogue will be updated annually, growing as more countries explore their storage resources. Potential contributors are encouraged to visit the Catalogue web portal for more information on submitting published resources.

ZEP Report: Developing cross-border CO2 transportation and storage infrastructure in Europe

zeroemissionsplatform.eu

The report entitled 'A Trans-European CO2 Transportation Infrastructure for CCUS: Opportunities & Challenges' provides an overview of CO2 transportation, particularly in industrial clusters, and highlights the importance of developing dedicated business models, as well as enabling policy framework, for CO2 transportation.

This report is particularly relevant in the context of the European Green Deal, as CO2 infrastructure is crucial to deliver large-scale decarbonisation across industry and energy sectors, which will be necessary to achieve climate-neutrality. In addition, the report analyses the technical specifications and challenges for CO2 transportation in Europe and identifies the current legal barriers.

CO2 transportation and storage projects are already up and running in Europe and have been for more than 20 years. Now, policymakers must send a strong signal in support of crossborder CO2 infrastructure in Europe and encourage industry to invest in the technology. Crossborder CO2 infrastructure would provide industry across the EU with fair access to CO2 storage, enabling member states to decarbonise and creating a level playing field. CO2 infrastructure must become a core competence of the EU as a driver of decarbonisation, outlined in the European Green Deal, and as a caretaker of the single market.

Dr Graeme Sweeney, Chairman of ZEP, commented, "Investing in large-scale deployment of CO2 transport and storage infrastructure, connecting CO2 emitters with storage sites, is a no-regret investment opportunity. This is crucial for the cost-efficient decarbonisation required to meet Europe's climate-neutrality target by 2050. The CO2 infrastructure would also enable a clean hydrogen economy and deliver carbon dioxide removals."

Liquefied carbon dioxide ready to sail

www.preem.se

Gothenburg and Sweden could be the first in the world to create a joint infrastructure for the transport of liquefied carbon dioxide extracted using CCS technology.

The project –CinfraCap – is a unique collaborative venture between Preem, Göteborg Energi, Nordion Energi, St1, Renova, and Gothenburg Port Authority.

CinfraCap stands for Carbon Infrastructure Capture. The aim behind CinfraCap is to produce a more comprehensive picture of the logistics chain required to transport captured carbon dioxide from different industrial facilities in western Sweden – from liquefication and intermediate storage, through to distribution to ships and onward transport to the repository site.

A collaboration agreement has been signed by all the parties involved, and the Swedish Energy Agency climate initiative Industrial Evolution (Industriklivet) has agreed to cover half the cost of funding a prestudy, which is being conducted by the consulting company COWI. The prestudy, which commenced this month with completion due in Q1 2021, will focus on the means of collecting captured carbon optimally from each company, transporting it down to the port, intermediate storage prior to loading, securing of permits, risk identification, and presentation of a business model.

"We are starting up CinfraCap in western Sweden although the ultimate aim is to share our experience and the business model behind the carbon capture infrastructure with the rest of Sweden and the world. We are joining forces with other partners to ensure the requisite resources are in place to rapidly reduce the climate impact of companies and contribute to a sustainable future," said, Karin Lundqvist, Business developer, Preem AB.

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