Carbon Capture Journal

CCUS in Canada

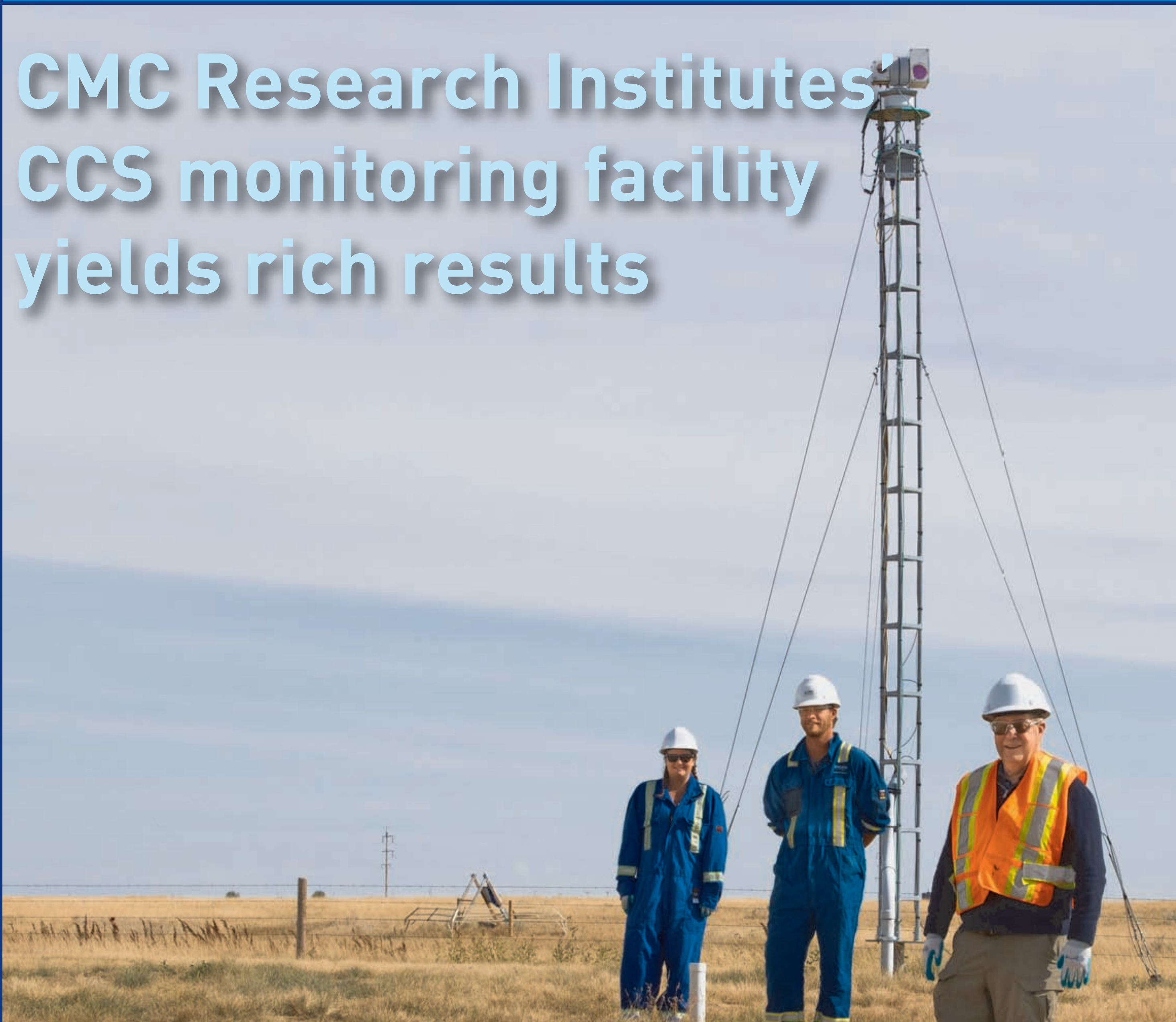
Evolution of CCS Hubs in Canada - the value of networking

Incentivising CCS in Canada with ‘kick-start’ support

CCS in Canada: the stats

Sept / Oct 2020 Issue 77

CMC Research Institutes’ CCS monitoring facility yields rich results



Brattle: CCS could play key role in decarbonising U.S. electricity

ExxonMobil and Berkeley advance metal-organic frameworks

CO2 Capture Project annual report highlights two decades of work

Oil and Gas Climate Initiative: Scaling up CO2 capture, use and storage

Petra Nova's Carbon Capture System works - and has proved its worth

Although plummeting oil prices have caused the suspension of the Petra Nova demonstration project in Texas, rather than being seen as a failure it should be recognised for achieving its objectives and even surpassing its target of 90% CO2 capture efficiency.

"It's worth repeating - Petra Nova's carbon capture system works," says Beth Hardy, Vice-President, Strategy & Stakeholder Relations at the International CCS Knowledge Centre.

"NRG's & JX Nippon's CCS initiative at Petra Nova, located in Texas, at the W.A. Parish Generating Station, was not only successful in its project delivery in 2016 (on time and on budget), and recipient of Power Engineering's Project of the Year (2017), but also had continued to operate successfully capturing 90% of CO2 emissions."

The plant is designed to meet its goals and it does.

"The great news is that Petra Nova logs-in with a 92.4% capture efficiency (Petra Nova's final technical report submitted to US Department of Energy) which not only surpasses its 90% target, but points to the plant's long-term reliability for the capture process," explains Corwyn Bruce, Vice-President, Project Development and Advisory Services also at the International CCS Knowledge Centre.

"The CCS facility operates well and has overcome many of the risk items that have proven to be a challenge in other installations."

"As a matter of fact, Petra Nova's capture facility is tight to its performance metrics even exceeding them in positive ways. So, the plant does what it was set out to do and then some. In addition to the higher than expected capture rate, salient points include: lower power consumption and steam requirements than anticipated; CO2 purity beyond the 99% required; and a volatile organic compound (VOC) emissions rate at 2.8 tonnes per year – which surpasses the Rules in Title 30, of the Texas Administrative Code for the National Ambient Air Quality Standards for ozone."

"Furthermore, the amine consumption meets its specifications. The amine chemicals used in solvent-based capture systems are prone to breaking down and losing their ability to complete the chemical reactions that separate the CO2 from the flue gas stream. This would be evidenced by declining capture rates, higher chemical replacement, and increased maintenance costs. The carbon capture facility at Petra Nova doesn't report an issue with amine consumption being higher than anticipated."

The problem with the plant was not the carbon capture operations, but that it relied on a complicated set of factors to be viable, factors which will not be a model for future commercial plants.

"Like nearly all CCS facilities operating today, Petra Nova relied on using captured CO2 for enhanced oil recovery (EOR) at a nearby oil field to make a commercial case for the, otherwise unvalued, business of storing CO2 underground," explains Toby Lockwood, a Senior Analyst at the IEA Clean Coal Centre.

"Unsurprisingly, this kind of operation is vulnerable to low oil prices and, in May this year, the capture facility was turned off while the power plant continues to run unabated. Plant owners NRG have said that the plant can be brought back online when economics improve."

"Like other early CCS facilities, its business case rests on a rather cobbled-together set of factors, including the government grant, cheap credit from Japan, and maximising the oil income through part-ownership of the oil field. This kind of scenario is not expected to be, and cannot be, the model for future CCS projects with the primary goal of mitigating CO2 emissions, so it is somewhat irrelevant how this has worked out for Petra Nova."

"EOR has proved to be a useful means of providing some kind of financial viability to early CCS projects, but it is not considered the long-term future of the technology."

Much of the criticism has come from the Institute for Energy Economics and Financial Analysis (IEEFA) says Lockwood, a vocal anti-CCS organisation based in the USA.

"IEEFA have taken the situation at Petra Nova as an opportunity to draw various negative conclusions on the prospects for CCS in general, linking the project's closure to a fundamental lack of commercial and technical viability," he says.

"Above all, it should be remembered that Petra Nova is a technology demonstration facility, aimed at testing a specific carbon capture process (MHI's KM-CDR technology) at a scale ten times larger than previously trialled. A fundamental goal of such demonstrations is to identify and resolve any technical issues, so that future, fully commercial facilities may benefit. In this respect, Petra Nova has already proved its worth. Based on experience at the plant, as well as development of an improved solvent, MHI have stated they can reduce construction costs of future units by 30%.

"The project has shown that the technology works, and both the cost and dispatchable nature of CCS-power have led to its inclusion in many lowest-cost pathways to decarbonisation. From there, it is the job of policy makers to create an environment in which CCS makes sense for investors; this must include some form of revenue stream to compensate for the cost of storing CO2."

"Fortunately, long-term energy strategy is not dictated by what will hopefully prove to be a short-lived hit to the global economy. Bipartisan support for CCS in the US remains, and interest has gathered pace since clarifications on the tax credit were issued earlier this year."

More information

ccsknowledge.com
www.iea-coal.org/blogs

Carbon Capture Journal

Sept / Oct 2020 Issue 77

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

Editor
Keith Forward
editor@carboncapturejournal.com

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

Subscriptions
subs@carboncapturejournal.com

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

Carbon Capture Journal is your one stop information source for new technical developments, opinion, regulatory and research activity with carbon capture, transport and storage.

Carbon Capture Journal is delivered on print and pdf version to a total of 6000 people, all of whom have requested to receive it, including employees of power companies, oil and gas companies, government, engineering companies, consultants, educators, students, and suppliers.

Subscriptions: £250 a year for 6 issues. To subscribe, please contact Karl Jeffery on subs@carboncapturejournal.com Alternatively you can subscribe online at www.d-e-j.com/store

Front cover:

The Dual Comb Laser Spectrometer (background) for the continuous monitoring of GHGs including methane and CO2

Back cover: Stephen Lougheed, CMCRI President and CEO (left), and Greg Maidment, Project Manager, at Field Research Station (pg.2)

Carbon capture journal (Print) ISSN 1757-1995
Carbon capture journal (Online) ISSN 1757-2509

Leaders - CCUS in Canada

Projects and policy

Capture and utilisation

Transport and storage

CMC Research Institutes' CCS monitoring facility yields rich results

Data from the southern Alberta test site will improve monitoring processes in commercial CO2 storage and CO2-enhanced oil recovery operations.

Office and classroom building available on site

Research at a carbon capture and storage monitoring facility in southern Alberta is showing results that will improve monitoring procedures and increase the understanding of how CO2 behaves in storage reservoirs.

The field research station (FRS), developed by CMC Research Institutes and the University of Calgary, is host to a number of applied research studies aimed at testing technologies and methodologies for characterizing the subsurface and tracking injected C02. Findings from work at the 200-hectare facility are providing rich data to inform best practice implementation for monitoring CCS projects and CO2 enhanced oil recovery operations.

"This work is of interest to anyone doing enhanced oil recovery or storage. For instance, any reservoir engineer who wants to understand rate of penetration will be interested in the ERT (electrical resistivity tomography) tests we're conducting," says Greg Maidment, project manager at the site.

The site has one injector well drilled to a depth of 300 metres, two observation wells, and six water wells at varying depths. Site infrastructure includes a CO2 storage vessel, CO2 injection facility, motor control centre, an office/classroom for operations, and an extensive array of installed monitoring equipment.

The work program involves small amounts of CO2 that are injected into a sandstone horizon which is being monitored with data-linked geophysical, geochemical, well surveys and logging with subsurface, surface and aerial deployment.

Measurement, monitoring and verification technologies employed at the FRS include multi-component surface and borehole seismic surveys, distributed acoustic sensing (DAS) using novel optical fibre geometries, distributed temperature sensing (DTS), micro-seismic surveillance, continuous seismic recording and interferometry, and continuous borehole-to-surface electrical resistivity tomography for detecting changes in conductivity of pore fluids.

Staff are also evaluating newly developed concepts of co-injection of magnetic nanoparticles for increased contrast for enhanced monitoring electromagnetic methods.

CO2 tank and cooling tower

Vertical ERT monitoring employed

Projects at the site are redefining ways to use existing technologies. For example, geoscientists installed an electrical resistivity tomography array in one of the observation wells to image CO_2 migration in the reservoir. While the technology has been in use for decades, it has been most often employed in the mining and groundwater industries. But researchers were interested to see if the technology could be used to collect reliable, stable data in the subsurface.

Dr. Marie Macquet, an expert in seismic monitoring, says the technology is very sensitive to CO_2 saturation levels, and the downhole installation is enabling her to map levels of CO_2 saturation in the reservoir as the CO_2 plume expands from the injection well.

"The ultimate goal is to be able to use this method to say there's 20% saturation here and 50% here," says Macquet who is running the project in collaboration with researchers at the Helmholtz Centre Potsdam, GFZ German Research Centre for Geoscience.

A surface array is also installed at site, but because it's located 300 m above the injection zone, the ERT current is less sensitive to resistivity changes than the vertical array which is located 20 m from the injection well. This close proximity of electrodes to the injection well has led to a clear and immediate picture of CO_2 presence and migration.

"The change is linear, so if there's a 50% change in resistivity you see it right away," notes Macquet.

Another benefit of the downhole installation is that it provides a vertical view of how the plume is interacting with the caprock and the injection well. The system can prove containment and breeches can be rapidly detected. And because the installation is permanent, it's easy to take frequent, periodic measurements. For instance, the ERT installation at the research station can be operated remotely – allowing for quick, easy daily imaging.

Results available to industry

New understandings of reservoir/gas interaction and best practices in monitoring are increasingly important to the fossil energy and other industries as they look for ways to reduce emissions. CMCRI offers access to results from its projects to industry through a Joint Industry Project (JIP).

Subscribers to the JIP are provided with data results, project reports and regular feedback from experts. They are also able to partner with FRS staff in collaborative research projects. The JIP was created to empower energy companies and other industries with information to improve efficiencies and reduce risk in CCS programs.

"What's most important is that members of the JIP also have access to advice from our world-renowned experts. The ability to disseminate all of our information to industry helps them to become more efficient, quicker, as well as more cost-effective," says Maidment.

CMC Research Institutes acknowledge financial support from the University of Calgary's Canada First Research Excellence Fund program: the Global Research Initiative in Sustainable Low-Carbon Unconventional Resources.

More information

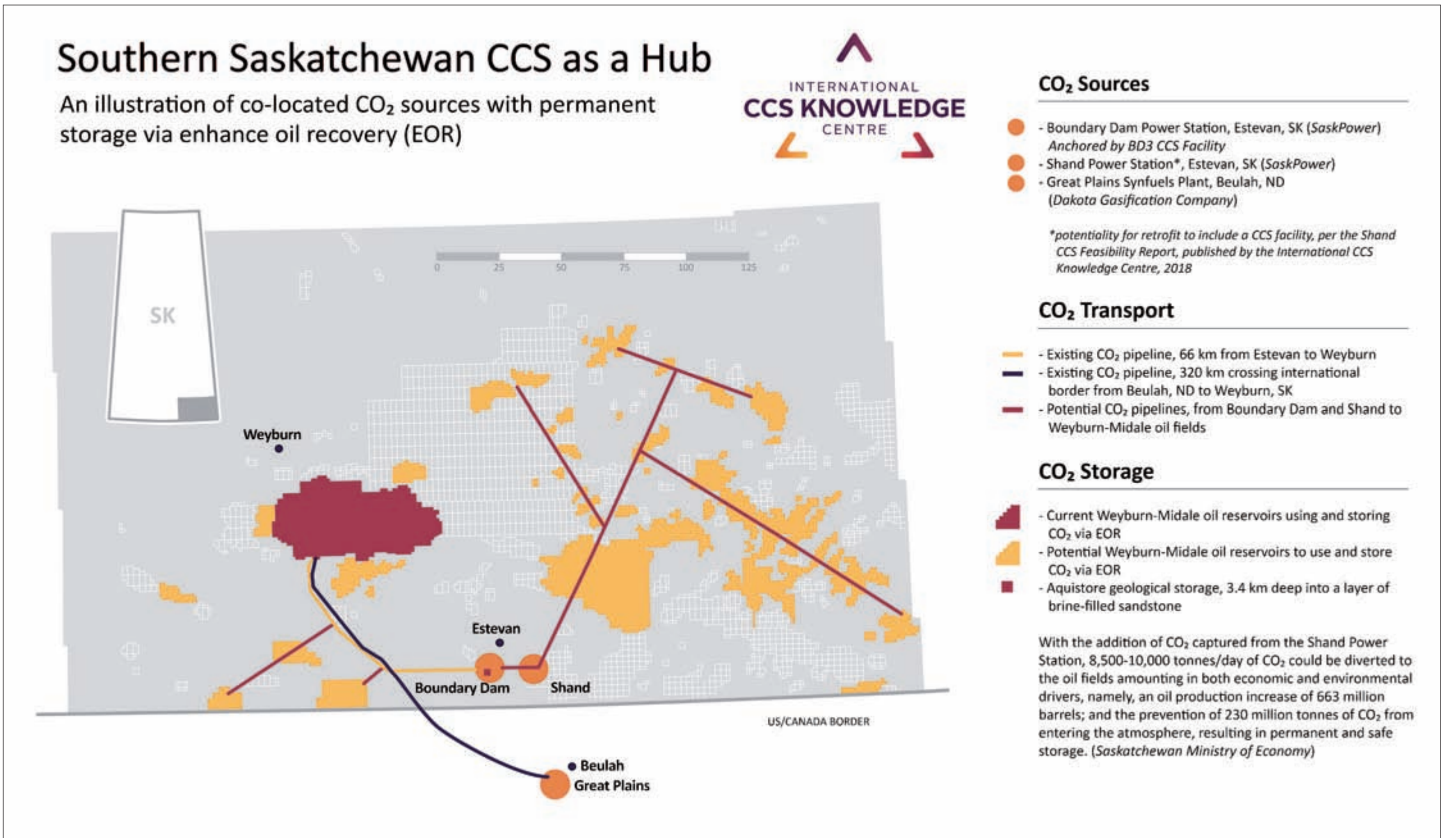
To learn more about services and programs offered at Field Research Station, contact Greg Maidment at:

Greg.Maidment@cmcghg.com

www.cmcghg.com

Evolution of CCS Hubs in Canada

The emergence of carbon capture utilization and storage (CCS/CCUS) hubs and clusters are demonstrating the value of networking full chain CCS infrastructure to reduce the investment costs and risks associated with CCS projects; creating the market conditions needed to deploy CCS in both the power and industrial sectors.



An illustration of co-located CO2 sources with permanent storage via enhanced oil recovery (EOR) in Southern Saskatchewan, Canada – a potential carbon capture and storage hub

Identification of new opportunities as well as pre-existing conditions to support CCS networks is actively evolving in Canada.

"Hubs receive the benefit of shared infrastructure, an economic marketplace, and, in general, a cluster of activity happening around it and as a result of it," explains Beth (Hardy) Valiaho, Vice-President of Strategy & Stakeholder Relations at the International CCS Knowledge Centre (Knowledge Centre), in a recent blog[i].

Aside from reducing large-scale carbon dioxide (CO2) emissions in the energy sector, CCS is also widely known to play a vital role in decarbonizing heavy-emitting industries, such as cement, steel, and chemical production, where no other low-carbon technologies exist.

Sharing CO2 transport and storage infrastructure among multiple emitters and off-takers can create a network of industrial CCS hubs or clusters that can support large-scale emission reductions and potentially do so across various energy systems.

"The world can collectively work to meaningfully reduce emissions across sectors as it moves to sharing infrastructure within an economic marketplace and working together to understand the regional and local nuances of development, fostering a CCS network for years to come," adds Valiaho.

While CCS hubs and clusters are an emerging global trend, North America has successfully operated a transborder CO2 transportation and storage network for more than two decades between Southern Saskatchewan, Canada and North Dakota, US– infrastructure that can be readily expanded upon to form a hub.

Additionally, the province of Alberta recently completed construction on an integrated large-scale CCUS system.

Southern Saskatchewan as a CCS hub

In its Shand CCS Feasibility Study[ii], the Knowledge Centre worked with the Government of Saskatchewan and identified a potential hub for southern Saskatchewan. Currently there are two pre-existing anchor projects in the area – the first of which was established two decades ago - with an international agreement between the US and Canada for a border crossing from the Dakota Gasification Company's (DGC) Great Plains Synfuels Plant outside Beulah North Dakota to Whitecap's Weyburn Oil Unit.

The second network includes CO2 captured from Boundary Dam 3 CCS Facility (BD3) in Estevan that is transported 66km to Weyburn by pipeline. This hub includes permanent storage utilizing enhanced oil recovery (EOR) into the Permian basin and also sees a portion of the CO2 captured from BD3 being stored 2km away at the Aquistore Storage Project.[iii]

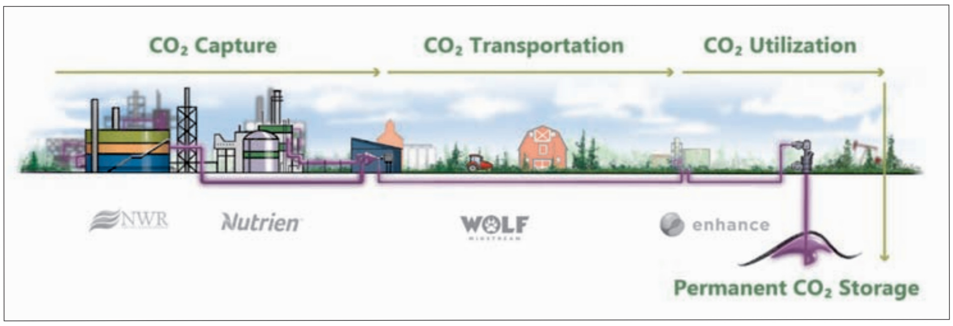
Thirty-two fields in southern Saskatchewan were found to satisfy the Government of Saskatchewan Ministry of Economy's screening criteria for field selection for CO2 EOR with an ability to store at least 200Mt of CO2, and potentially produce an additional 663 million barrels of oil. Further deployment beyond the identified fields could also be possible. There are several potential sources of CO2 that can be gathered from the area for this potential hub. [iv]

Albert Carbon Trunk Line

The Alberta Carbon Trunk Line (ACTL) system, launched in Alberta, Canada in June 2020, is another example of a hub with the commendable addition of a "build it and they will come" approach to their 14.6Mt capacity pipeline. Self-defined, the ACTL is "designed as the backbone infrastructure needed to support a lower carbon economy.[v]"

The ACTL system currently captures CO2 from two anchor projects – a refinery and a fertilizer facility (Sturgeon Refinery owned by North West Redwater Partnership (NWR) and Nutrien's Redwater Fertilizer Facility), offering a sustainable solution for reducing emissions in both the energy and agricultural sectors.

The CO2 then travels down a 240-kilometre pipeline, which is owned by Wolf Midstream, to a storage reservoir owned by Enhance Energy. The refinery and fertilizer plants are two large-emitting facilities that have the capacity to capture about 1.6Mt/yr; the pipeline itself has the capacity to see many more projects use this shared infrastructure.



The Alberta Carbon Trunk Line (ACTL) is an integrated, large-scale carbon capture, utilization, and storage (CCUS) system in Canada that consists of a 240-kilometre pipeline for transporting CO2 from an oil sands refinery and a fertilizer manufacturing plant

In a news release announcing the completion of the ACTL, Jeff Pearson, president of the Carbon Business Unit at Wolf Midstream, claims that a lower carbon economy and the future of energy are dependent on this "critical piece of infrastructure" that is only the beginning of supporting "significant future emissions solutions, new utilization pathways and innovation in the carbon capture space."[vi]

With the collective network that supports lower greenhouse gas emissions (GHGs) coming from enhanced oil recovery (EOR) in Alberta's oil sands, and aided with the price on carbon and the EOR offset protocol, ACTL is set to gain momentum.

Financing and investing

CO2 hubs can support low-carbon economy investments; leveraging multiple players including, government, industry, and the finance community. Shared infrastructure with access to available storage capacity (either in a reservoir or with EOR) would allow emitters to separate investment decisions to focus on their GHGs versus the entirety of full chain development. There is a potential that increasing the viability and advancement of networks will see an increase CCS deployment and minimize investment risk.

Government contributions still remain crucial for CCS

A pipeline like the ACTL is positioned to stimulate infrastructure dollars that can be actively utilized by several emitting industries interested in implementing carbon capture at their facilities, particularly if they are co-located or have a nearby route to CO2 storage.

"In the same way that governments function to provide infrastructure dollars for shared road usage, a CO2 highway with on and off ramps is a great example of where government dollars could have an exponential impact," explains Valiaho. The 'highway networking' could apply to land-based hubs with pipelines as much as it does to ports with trucked or shipped CO2.

The ACTL CAD$1.2B system received government support for the network: the Canadian government contributed CAD$63.2M in funding under its ecoEnergy Technology Initiative and Clean Energy Fund and the province of Alberta provided CAD$459M through its dedicated Carbon Capture and Storage Fund.

Government support has an important role to play for CCS to really reach a larger scale globally. In some countries like Canada, funds have been restricted due to CCS not meeting 'first of a kind project' grant requirements. As a result, other mechanisms to leverage government support may be necessary.

There is value for investors too

Financiers and the investment community are also taking note of the advantages to hubs and the value to reducing costs via shared CO2 infrastructure. Wolf Midstream's ACTL pipeline is backed by the Canadian Pension Plan Investment Board (CPPIB) committing up to CAD$305M to Wolf to fund the project.

The Oil and Gas Climate Initiative (OGCI) has also looked at the value of network systems. In 2019, as a part of their Climate Investment's USD$1B+ fund, the initiative launched five "kick-starter" CCUS global hubs with prospects for up to 25 additional ones around the world.

The aim is to facilitate large-scale commercial investment and create market conditions for CCUS to play a significant role in decarbonization – specifically by pursuing CO2 capture at several industrial sources within one region, using economies of scale, and sharing transport and storage infrastructure.

Earlier this year, Michael Ryan, OGCI-CI Vice-President of Carbon Capture Utilization & Storage, told S&P Global Platts how "the acceleration of CCUS depends upon strong collaboration among policy makers, investors, regulators and developers."[viii]

Ryan also mentioned that OGCI has a desire to create clusters and hubs and is excited to start gaining traction with state and federal regulators on funding for larger infrastructure projects in talks with the Knowledge Centre for its 'Lead. Care. Adapt' video series, focused on sustainable economic recovery from COVID-19.[ix]

OGCI-CI's KickStarter Initiative[x] hubs total a potential of 230Mt CO2 capture per year. Probably the most impactful OGCI Climate Investments' KickStarter hubs are in the Gulf of Mexico with total CO2 emissions targeted at over 200Mt/yr in Texas and Louisiana spanning various industries: power plants, refineries, chemical plants, fertilizers, and hydrogen; and leveraging involvement from companies like Occidental, Shell, ExxonMobil, BP, Chevron, Repsol, and Total.

The clusters of industry coupled with the 45Q tax credit in the US and the nature of the Gulf Coast and large oil company action in the area make this an optimal hub for CCS. The 45Q tax credit creates a government grant-like incentive for innovation in CCS as an emission reduction technology, providing USD$50 per tonne of CO2 geologically stored, and USD$35 per tonne for CO2 utilization – including EOR, with no cap on the amount possible to be received.

This provides certainty for developers and creates fast moving action because to qualify, projects have to start construction before the end of 2023. It is interesting to note that OGCI member companies and Climate Investments are active in eight of the CCUS projects announced that plan to use 45Q tax credits.

Next steps for CCS hubs in Canada

In Canada, the price of oil is less than in the United States because of the limited ability to get oil to various markets (in March of this year, a barrel of oil was cheaper than a pint of beer[xi]). Despite the record low oil prices in Canada where the oil fields are located, the BD3 CCS Facility is still going strong. In fact, the main off-taker for BD3's CO2 for EOR, WhiteCap Resources, stated publicly in September of 2019 that it wants more CO2, not less.[xii]

With ACTL system now underway and seeking to expand its network of suppliers and users of CO2; and with Saskatchewan's decades of experience in CO2 capture, transport and storage, the importance and success of collaborations to form hubs and clusters are primed and ready for investments and government incentives.

Ranked a top global leader of energy production and manufacturing exports, Canada's advanced industry sectors support the infrastructure development and growth that lends itself to CCS hubs and clusters needed to accelerate commercial full-scale emissions reductions, advance low-carbon energy transitions while also allowing vital industries to thrive.

More information

ccsknowledge.com

www.ptrc.ca

www.actl.ca

i Importance of CCS Hubs. Valiaho (Hardy), B. 14 July 2020. https://ccsknowledge.com/blog/importance-of-ccs-hubs

ii Shand CCS Feasibility Report, https://ccsknowledge.com/initiatives/2nd-generation-ccs---shand-study

iii Petroleum Technology Research Centre. Accessed 01 September 2020. Aquistore Project. https://ptrc.ca/projects/co2-eor-and-storage/aquistore

iv International CCS Knowledge Centre. 14 July 2020. Southern Saskatchewan CCS as a Hub. https://ccsknowledge.com/blog/importance-of-ccs-hubs

v Alberta Carbon Trunk Line. Accessed 01 September 2020. Frequently Asked Questions. https://actl.ca/actl-project/faqs/

vi Wolf Midstream. 02 June 2020. New carbon solution in Alberta delivers use for industrial emissions. https://www.wolfmidstream.com/new-carbon-solution-in-alberta-delivers-use-for-industrial-emissions/

vii Alberta Carbon Trunk Line (ACTL) System. Accessed 31 August 2020, https://actl.ca/actl-project/about-actl/

viii S&P Global Platts. 28 February 2020. California's Elk Hills carbon capture plant gets backing from oil and gas industry fund https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/022820-californias-elk-hills-carbon-capture-plant-gets-backing-from-oil-and-gas-industry-fund

ix International CCS Knowledge Centre. March 2020. Lead. Care. Adapt. Take 10 [a video series]. https://bit.ly/LeadCareAdapt-2

x Oil and Glas Climatate Initiative Climate Investments. Accessed 01 September 2020. Carbon Capture Utilization and Storage (CCUS). https://oilandgasclimateinitiative.com/action-and-engagement/ccus/

xi CNBC Markets "A barrel of oil is now cheaper than a pint of beer in Canada", 30MAR20, https://www.cnbc.com/2020/03/30/a-barrel-of-oil-is-now-cheaper-than-a-pint-of-beer-in-canada.html

xii Pipeline News. 24 September 2019. Whitecap wants more CO2 for Weyburn EOR https://www.pipelinenews.ca/news/local-news/whitecap-wants-more-co2-for-the-weyburn-unit-1.23954882 Petroleum Technology Research Centre. Accessed 01 September 2020. Aquistore Project. https://ptrc.ca/projects/co2-eor-and-storage/aquistore


MAN
Your efficiency rises
MAN Energy Solutions
Future in the making
Oil & Gas solutions expertise
Innovative decarbonizing systems
Satisfying the world's demand for more energy and lower carbon emissions requires imaginative solutions that are both sustainable and profitable. Make use of our expertise in resource-efficient, low environmental impact technologies and services for the upstream, midstream and downstream sectors.
www.man-es.com

Snapshot of large-scale CO2 CCS in Canada

BOUNDARY DAM 3 CCS FACILITY Launched October 2014 Operated by SaskPower Estevan, Saskatchewan	**CO_2 Captured** 3.5Mt[i] (as of July 2020)	Captured CO_2 from the Boundary Dam 3 CCS Facility (BD3) is sold and transported via a 66-kilometre pipeline from to the Weyburn-Midale oilfields for Enhanced Oil Recovery (EOR) before it is permanently stored. CO_2 not sent for EOR is sent two kilometres from BD3 to the Aquistore site via pipeline where it is injected 3.4 kilometres deep in a naturally occurring layer of brine-filled sandstone for permanent storage.

ALBERTA CARBON TRUNK LINE Launched June 2020 Operated by Wolf Midstream Alberta, Canada	**Anticipated Capacity** 14.6Mt CO_2/yr[ii]	The ACTL system currently receives CO_2 from the North West Redwater Partnership (NWR) Sturgeon Refinery and Nutrien's Redwater Fertilizer Facility, both located in Redwater, Alberta. Captured CO_2 is safely transported through a 240-kilometre pipeline to mature oil fields in Central Alberta for use in EOR before it is permanently stored.

WEYBURN-MIDALE CCUS Launched 2000 Operated by WhiteCap Resources Weyburn, Saskatchewan	**CO_2 Stored** 34Mt[iii] (as of June 2020)	CO_2 is supplied via a 320-kilometre pipeline from the lignite-fired Dakota Gasification Company synfuels plant site in Beulah, ND, which crosses the international border into Canada, near Goodwater, Saskatchewan for use in EOR in the Weyburn and Midale oil fields before it is permanently stored. CO_2 is supplied via a 66-kilometre pipeline from BD3 CCS Facility in Estevan to the the Weyburn-Midale oilfields for Enhanced Oil Recovery (EOR) before it is permanently stored.[5]

Quest CCS Facility Launched November 2015 Operated by Shell Canada (on behalf of the Athabasca Oil Sands Project) Fort Saskatchewan, Alberta	**CO_2 Stored** 5Mt[iv] (as of July 2020)	Captured CO_2 transported via a 65-kilometre pipeline to be stored more than two kilometres underground in a sandstone rock reservoir.

i SaskPower. BD3 Status Update: July 2020. 12 August 2020. https://www.saskpower.com/about-us/our-company/blog/bd3-status-update-july-2020
ii Alberta Carbon Trunk Line. New carbon solution in Alberta delivers use for industrial emissions. 2 June 2020. https://actl.ca/wp-content/uploads/2020/06/ACTL-Press-Release-REAL-FINAL.pdf
iii Whitecap Resources. Environmental and Social Governance Report. 15 June 2020. P.13. https://www.wcap.ca/application/files/6215/9191/1116/Whitecap-2020-ESG-Report_Final-002.pdf
iv Shell Canada. Quest CCS facility captures and stores five million tonnes of CO2 ahead of fifth anniversary. 10 July 2020.https://www.shell.ca/en_ca/media/news-and-media-releases/news-releases-2020/quest-ccs-facility-captures-and-stores-five-million-tonnes.html

Incentivising CCS in Canada with a 'kick-start'

There is an increase in interest across energy and industrial sectors globally for the expansion of large-scale carbon capture and storage (CCS) activities, and that is no different in Canada. With post-COVID economic stimulus being directed towards clean development considerations and climate action, CCS is an active part of the conversation for net-zero ambitions.

By the International CCS Knowledge Centre

Achieving emissions reduction goals is the result of using the right policies with significant investments in clean energy and greening of industrial processes – this includes support for large-scale CCS technologies. It is important that there is a value stream and a business case to support successful deployment of CCS that are tied to sustainable and environmental policies.

While advances in the technology toward second generation CCS show the potential for a sharp decline in operating costsi, there still remains – for many regions and industries - a need for a kick-start incentive to ensure that opportunities to use CCS to reduce large amounts of emissions are maximized.

Beyond One-Time Grants

One-time grants for first of a kind projects have already been realized in Canada for both the Shell Quest and Boundary Dam CCS projects. Federal dollars have supported shared infrastructure for the Alberta Carbon Trunk Line and could hopefully be available for new sectors entering into first of a kind projects like cement or other manufacturing.

However once direct government injections of support are no longer available, it raises a key question: what happens to the next projects? While it is imperative for sectors to transition from government grants to industry uptake, government support remains crucial.

Production tax credits have a history in proving to be effective environmental levers, such as the past success in the US for projects with wind. This is now happening for CCS in the US – where the 45Q incentive has spurred interest from almost 30 projects - so it is gathering attention from other governments to examine if such grant-like incentives for innovation in CCS have potential as a sound option in their jurisdictions.[i]

There needs to be an examination of other mechanisms to help sectors leverage government support. An exact replica of 45Q may not be the best path for all countries, though incentive pathways likely still exist. In Canada, for instance, other pathways in the tax system could likely open doors for kickstart support. And now is the time.

Climate and Competition Agree: Time is Now

Investing in advancing large-scale CCS projects now improves two things: 1) a quicker acceleration of a proven, reliable and deployable technology to meet climate goals; and, 2) a retention in competitiveness – by way of example, projects like Canada-created Carbon Engineering's Direct Air Capture are now seen pursuing a 45Q tax credit opportunity in Texas[ii].

If Canada wants to ensure it remains a leader in CCS deployment domestically, it may need to consider what it can provide to ensure that those early years of operations have enough clout and interest from financiers to get over the capital-intensive hurdle of the first few years. The carbon price can assist in the long run, but there is undoubtedly a gap between start and five years down the road that presents a challenge to get the math working for investors.

The International CCS Knowledge Centre and RSM Canada[iii] will be releasing a White Paper on incentive options for Canada in the coming months. With kick-start support, Canada could readily see a handful of proponents who could successfully finance carbon capture projects over the next 10 years in response to a tax credit; aligning hand-in-hand with the continued development of the Pan-Canadian Framework on Clean Growth and Climate Change.

More information

ccsknowledge.com

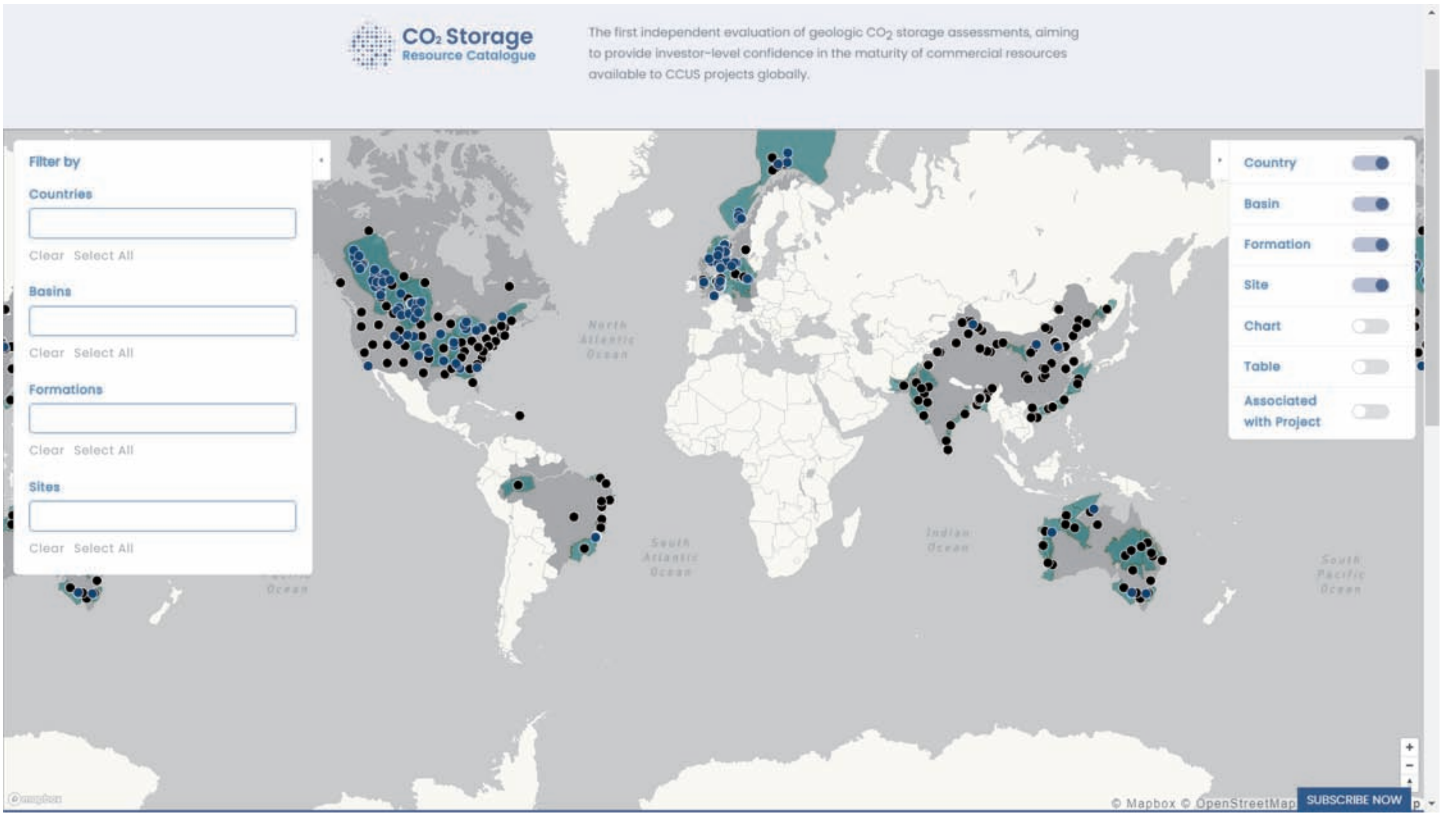
rsmcanada.com

i Report on Second Generation CCS, https://ccsknowledge.com/initiatives/2nd-generation-ccs---shand-study

ii Oxy Low Carbon Ventures, Rusheen Capital Management create development company 1PointFive to deploy Carbon Engineering's Direct Air Capture technology, https://carbonengineering.com/news-updates/new-development-company-1pointfive-formed/

Oil and Gas Climate Initiative: Scaling up CO2 capture, use and storage

The Oil and Gas Climate Initiative is a CEO-led consortium of twelve companies that aims to accelerate the industry response to climate change. OGCI member companies explicitly support the Paris Agreement and its goals through a range of targeted actions. One of the most important is the creation of a CCUS industry at scale, an ambition that we are working with industry, governments, NGOs and other investors to achieve. By Sue-Ern Tan, OGCI's CCUS Champion



OGCI has launched the CO2 Storage Resource Catalogue, in collaboration with the Global Carbon Capture and Storage Institute (GCCSI) and Pale Blue Dot, which aims to become the global repository for all independently published information on safe, secure and permanent geologic storage resources

Why is the OGCI interested in CCUS?

As the CCUS champion at OGCI I am passionate about the vital role that CCUS needs to play as part of a broad package of solutions needed to achieve net zero emissions. Every scenario constructed by credible sources like the IPCC and IEA highlights the critical role that the CCUS industry must play if we are to reach the goals of the Paris Agreement. CCUS is also necessary to help accelerate the decarbonization of heavy industries like steel, cement, power, refineries and chemicals. It can also support the scale up of a clean hydrogen industry, as well as the deployment of negative emissions through direct air capture.

Moving the industry forward

OGCI member companies have the expertise, experience and the balance sheets to make an impactful contribution to the future of the industry.

Last year, OGCI launched its KickStarter initiative to facilitate large-scale commercial investment in CCUS, by enabling the creation of low-carbon industrial hubs around the world.

Member companies are also key players in some of the largest CCUS facilities in operation, and are working to develop innovative technologies and applications. In parallel, the $1B+ OGCI Climate Investments fund set up by OGCI member companies in 2016 has invested in CCUS projects and technologies that open up new areas of opportunity.

But the key to these and other CCUS efforts is a high level of confidence in the availability of suitable geological storage resources in the places they are needed. These are largely depleted oil and gas reservoirs and saline aquifers, but also result from CO2 enhanced oil recovery (EOR) operations.

Currently, almost 40 Mt of CO2 is stored each year – however, according to the International Energy Agency, by 2030 that volume would have to expand to around 1.5 GT a year – over 30 times more – to be on track to achieve the Paris goals. This requires a quantum leap in terms of storage capacity and our understanding of the available resources.

Assessing and publicising available storage

At present, assessments are fragmented, non-standardized and insufficient for understanding the readiness of storage resources for commercial use. That's why OGCI has launched the CO2 Storage Resource Catalogue, in collaboration with the Global Carbon Capture and Storage Institute (GCCSI) and Pale Blue Dot, which aims to become the global repository for all independently published information on safe, secure and permanent geologic storage resources.

The Catalogue provides a centralized and publicly available database of storage sites, as well as a common terminology for classifying them. It uses the Storage Resource Management Scheme (SRMS) to identify the size and maturity of the resource. This classifies sites as 'undiscovered' and 'discovered', with many sub-categories that define the degree of commercial readiness, based on both technical and regulatory aspects.

Even in its first iteration, covering 525 sites across 13 countries, the analysis backing the Catalogue shows that there is already sufficient storage space available. Across all maturity classes there is a total of 12,300 GT of potential capacity, taking into account published evaluations of oil and gas fields and saline aquifers where the CO2 could be injected.

Just 3% of these sites (representing 408 GT) are classified as 'discovered', meaning that drilling has taken place and reporting is available – but even that is more than enough to meet Paris Agreement goals.

Nevertheless, more work is still needed to get an investor-level of confidence in the capacity to store CO2 in these resources. At present, only 106 Mt is classed as 'commercial', which means that regulatory and policy conditions are also in place to enable commercial development. (The Catalogue does not include EOR operations in the US, which make up a large share of CO2 currently stored) That is why it is in these locations – especially the US, Canada, Norway and the UK – that the next round of CCUS projects is likely to take place.

How does the catalogue support a safe and permanent CCUS industry?

The catalogue will make a uniform set of data and references available to every interested stakeholder, whether they are investors, industrial emitters or the community. It will be a centralised, publicly available data base to support ongoing monitoring of storage.

Our expectation is that this enhanced visibility will help promote confidence in the safety and permanence of C02 storage around the world. In turn, investor understanding of commercial development and maturity of CCUS storage resources will be bolstered. CCUS needs many more investors for it to be deployed at scale, and we hope that the catalogue will help foster confidence.

Where next?

The creation of the catalogue is only the beginning. We are now asking for all stakeholders to engage with the catalogue and help to update and expand the scope. Researchers can use it as a global reference point, and we are open to constructive feedback as we work to continuously improve the catalogue.

More information

Interested parties can visit the Catalogue web portal for more information on submitting published resources:

oilandgasclimateinitiative.com/co2-storage-resource-catalogue/

IEA Clean Coal Centre report: CCUS - Status, barriers and potential

The case for CCUS: fuel power generation fitted with CCUS is a key part of the transition to a net zero CO2 emissions future. The International Panel for Climate Change has shown that excluding CCUS from the portfolio of technologies to reduce emissions would double the cost.

Around 170 GWe of coal-fired power generation with CCUS will be needed by 2050 to limit global temperature rise to 2°C or below. The Asia Pacific region accounts for more than 50% of global CO2 emissions and should become a key focus for the roll-out of commercial CCUS.

CCUS technology status – The elements of the CCUS technology chain are in place for commercial deployment, indicating that the barriers to widespread large-scale deployment of CCUS are not technical. Several other next generation technologies that could provide step change cost reductions and increase efficiency are being researched and developed and could in time be on the market.

The cost of CCUS, which is probably the single most important lever for wide-scale roll-out of the technology, has reduced significantly. Recent project studies including the Shand FEED study predict CO2 capture costs at around 43–45 US$/tCO2 removed cost, within a proposed timescale for commencement of plant operations by 2024-28. Further cost reduction can be expected through 'learning by doing' where perhaps 50–70% cut could be achieved from the current cost of around 65 US$/tCO2, as the technology is rolled out commercially.

Levelised cost of electricity for large-scale coal power generation plant with post-combustion CO2 capture

Availability of the power plant was an issue in the early CCUS demonstrations, but it has now reached acceptable levels. For example, the Boundary Dam CCUS facility has increased its availability to around 85% over the last two years, in line with the facility's design availability of 85%.

CCUS capture levels will need to increase from the current 85–90% to closer to 100% to allow the power plants to continue to operate in a net-zero emission future as any residual CO2 emissions from CCUS facilities will not be compliant without offset from negative CO2 emissions elsewhere. Where auxiliary plant are used to provide steam and energy for the CCUS facility, they will also need to include CCUS to achieve very high capture levels overall.

Next steps – Despite the cost reduction that has been achieved to date, CCUS has been deployed in relatively few countries and in general has relied on the revenue stream from enhanced oil recovery (EOR). While this has enabled the first demonstration projects to get off the ground, the policies currently in place are insufficient and further actions need to be taken.

More positive carbon price signals need to be sent to drive the growth in CCUS. Whether the carbon price is effectively valued through carbon emitted, emissions trading schemes or tax credits on the amount of CO2 stored, the value needs to be around 40–80 US$/tCO2 by 2020, increasing to 50–100 US$/tCO2 by 2030. Currently, less than 5% of global CO2 emissions have a carbon pricing regime which is consistent with this, a notable initiative being the 45Q tax credit system in the USA which provides 50 US$/tCO2 for geological storage or 35 US$/tCO2 for EOR by 2026.

The 'hub and cluster' approach enables the sharing of transport and storage networks which can improve the economics of CCUS due to economies of scale and overall de-risking of storage liability and cross-chain issues. There is however likely to be an initial investment barrier to the hub and cluster infrastructure where the balance of risk and return is insufficient for initial private sector investment. Here, governments should consider taking this role to kick-start development with the option of privatising the business after it has gained sufficient CO2 source and sink 'customers'.

The availability of debt financing for CCUS projects needs to increase significantly, with banks having a critical role to play. To qualify for debt financing, CCUS projects will need to provide assurance that key risks are identified with mitigations in place and that 'hard-to-manage' risks are allocated to government in the short term. The cost of debt will need to reduce from the current 14–15% level to below 10% in the medium term, as successive CCUS projects are able to address risk and drive down the cost of debt risk premium.

System/network operators need to recognise the auxiliary services such as reactive power and frequency response provided by coal powered plant and allow for financial compensation for these services. Such services will become increasingly important as the share of non-dispatchable renewable power sources, primarily wind and solar, increase in global power systems. The integration of a CCUS facility must therefore not adversely affect the power plants ability to provide these services.

Compliance with SDGs – CCUS is a key technology contributing in particular to SDG13 – Climate Action, as part of the transition to a net-zero CO2 emissions future. A combined approach of limiting global temperature rise, whilst providing access to reliable and affordable energy to support economic development and improved living standards should be pursued.

The IEA Clean Coal Centre is organised under the auspices of the International Energy Agency (IEA) but is functionally and legally autonomous. Views, findings and publications of the IEA Clean Coal Centre do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

More information

This is a summary of the report: Carbon capture utilisation and storage – status, barriers and potential by Greg Kelsall.
For the full report visit:

www.iea-coal.org

Analysing the potential of bioenergy with carbon capture in the UK to 2050

In a report for the UK Government, Ricardo Energy & Environment seeks to evaluate the costs and benefits of BECCS and analyse what the UK needs to consider in the coming decade to speed the deployment of BECCS.

The UK Government's net zero emissions target for 2050 requires significant reduction of emissions across a wide range of sectors including power generation and industry, says the report. It is now well-recognised that carbon capture, utilisation and storage (CCUS or CCS) will play a key and necessary role in achieving this target. Not only does CCS represent a huge opportunity for the UK to become a global technology leader but it also has a key role to play in tackling climate change and significantly reducing CO2 emissions.

The deployment of CCUS in the next three decades in the UK has the potential to further decarbonise the power sector while ensuring the continued use of flexible gas generation as the UK transitions to the increasing use of renewables. CCUS could also play a major role in decarbonising UK industry and protecting jobs as well as creating new jobs.

In addition, CCUS is now seen as a key element in creating a hydrogen infrastructure across the UK through the demonstration and production of blue hydrogen which is seen as an essential step in transitioning to green hydrogen. Furthermore, CCUS combined with biomass is considered a carbon dioxide removal (CDR) technology which offers a great opportunity to achieve negative emissions.

The development of BECCS requires widescale deployment of CCS. Despite major BECCS technologies being mature, to date, there are only few BECCS plants worldwide, mainly in industrial applications (dominated by the bioethanol sector) and not power plants. The Global CCS Institute quotes a wide range of costs for BECCS ranging from $15 to $400/tonne CO2 avoided with BECCS on bioethanol plants being cheapest (due to high CO2 concentrations released from bioethanol plants in comparison to that in flue gas from biomass power plants).

Drax are currently demonstrating the use of innovative solvents and technology (developed by C-Capture) to capture CO2 from a side stream from one of the power station's biomass boilers. A recent announcement of collaboration between Drax and Mitsubishi Heavy Industries (MHI) will lead to a new 12-month CO2 capture pilot to capture 300 tonnes of CO2 /day.

Wide scale deployment of BECCS in the UK will have great benefits in terms of negative emissions and will have economic benefits in terms of employment and GVA. However, this is associated with challenges, barriers and costs which need to be understood in order to target policies effectively.

The study relies on review of the recent literature, key stakeholder consultation and modelling of the techno-economics and life cycle emissions of BECCS technologies. While BECCS also has significant potential for negative emissions through deployment on energy-from-waste (EfW) plants across the UK, the focus of the current study is on wood feedstocks (mainly wood pellets, agricultural wastes and waste wood) and energy crops.

Supported by evidence from previous studies, the study emphasises that the main obstacle for BECCS worldwide is the availability of land, water and fertiliser to supply biomass. The UK access to some of the global biomass sources would decrease to 2050 as countries establish their own biomass plants or inter-regional competition as increased Climate Change targets begin to take effect.

In order to understand the full potential of BECCS in the UK, the availability of biomass worldwide needs to be considered. Another consideration is to locate BECCS in such a way as to minimise fuel transport (i.e. reducing life cycle emissions from biomass transport) while at the same time being close to CO2 storage sites. Sites where biomass can be sourced locally are attractive but impacts on the ecosystem, land requirements, flooding and other environmental factors need to be considered.

Another consideration for BECCS is to start with low-hanging fruit in terms of CO2 capture technology. Currently chemical absorption via amines and other innovative solvents is the most established and well-understood from an operational point of view. Although the energy penalty for CO2 capture with amines is significant (3.2-4 MJ/kg CO2 captured), innovative solvents which halve this energy requirements are being developed.

Still, efforts and support should continue to demonstrate emerging technologies on biomass plants such as the supercritical CO2 cycle technology by NetPower, chemical looping and Molten Carbonate Fuel Cells (MCFCs).

Despite the key role NETs can play, currently there is no mechanism to support their deployment and no regulatory framework in place mandating or incentivising them. For examples BECCS and DACCS are not mandated or sufficiently incentivised in the EU ETS and efforts are currently underway to address this issue.

Government has indicated that a call for evidence on negative emission technologies, including methods to incentivise them, will be issued later this year. Developing support mechanisms and framework is considered essential to help the deployment of BECCS as soon as the technology becomes available.

This support should consider large power stations where large and complex CO2 transport and storage infrastructure is needed as well as small scale localised units where the carbon dioxide can be captured and stored locally for further distributions via major suppliers thus taking advantage of an existing supply chain.

More information

www.ricardo.com

Brattle Economists: CCS could play key role in decarbonising U.S. electricity

A new study by Brattle consultants assesses the cost-effectiveness of carbon capture and sequestration for utilities in meeting decarbonization goals and suggests that with the benefit of recent tax credits and under the right market circumstances, CCS can be developed today at a minimal incremental net cost.

The study shows that some opportunities currently exist to retrofit coal-fired power plants with CCS at low net costs. In the future, the economics of CCS are likely to become more favorable, as the value of emission-free dispatchable energy in deeply decarbonized systems, which CCS can provide, is likely to be very large.

The study shows that the value of CCS has the potential to grow as utilities and states fully decarbonize their systems. This value will increase because, as renewable penetration becomes material, the marginal costs of decarbonization with only wind, solar, and battery storage can become very high.

CCS may also help supply decarbonization in settings where renewables are not as abundantly available. Therefore, the study authors suggest that utilities should start to consider CCS in their planning, anticipate the tradeoffs of CCS with other emerging technologies, and lay the long-run foundation for this technology.

Until recently, the development of CCS has progressed slowly, due to the more favorable economics of other clean generation technologies, as well as uncertainty about public policies for decarbonization. The recent expansion of US federal tax credits (45Q), which provide $35 or $50 per ton of emissions sequestered depending on the storage location, combined with the possibility for enhanced oil recovery (EOR) revenues in some locations, have created a material new incentive for CCS.

The study authors find that retrofitting a fairly efficient coal plant with present-day CCS technology can add little or no incremental operating cost to the owner with these tax benefits, EOR revenues, and moderate emission allowance pricing. Retrofitting may also provide other benefits – such as job preservation and dispatchable clean power – that are difficult for renewables to match.

The Brattle study focuses on the costs of CCS rather than value. Currently, even a clean coal plant is likely not as economical as renewables. However, they note that the value of non-intermittent clean backup and round-the-clock generation is likely to be substantially higher in a deeply decarbonized system than the value today, in an environment where renewable penetration is low and its integration is fairly easy.

"Utilities should shift their perspective of CCS as a 'retrofit technology' to a technology that is a valuable option in a long-range solution set to reduce costs and improve the reliability of achieving a very clean grid," noted Brattle Associate Kasparas Spokas, a study coauthor who has been involved in CCS analyses.

Brattle's analysis finds that the amount and timing of when CCS becomes cost-effective will depend on the renewable resources in the power system's region, opportunities to sell or

Conclusions

Utilities need to shift their perspective of CCS as a "retrofit technology" to a technology that should be evaluated as part of a larger solution set that substantially reduces costs of achieving a clean grid.

• CCS can present system-wide benefits for deep decarbonization in the right circumstances, utilities need to evaluate CCS along with complementary technologies to understand tradeoffs and plan a cost-effective clean electricity system

• The amount and timing of when does CCS becomes cost-effective will depend on the renewable resources in the region, opportunities to sell or sequester CO2, cost of alternative technologies, and degree of decarbonization desired

• Given the potential of CCS, utilities need to consider the value of CCS along with competing technologies with a longterm policy compliance perspective. Excluding CCS based on current economics and technologies might prove shortsighted and may stunt development of technology, especially for gas-CCS where little experience exists

• Regulated-utilities and State Commissions are uniquely positioned to include and facilitate CCS in long-term integrated planning that considers economy-wide state energy sources, uses, and goals

- Integrated planning for CO2-pipeline infrastructure (if necessary) can help overcome chicken-and-egg challenges, and facilitate crossindustry collaboration to reduce transport and geologic storage costs (e.g. cement or steel manufacturing)

- Most promising in states with aggressive decarbonization goals but limited attractive renewable hosting, e.g. no offshore wind. EOR potential in the state provides an additional incentives.

sequester CO_2, the cost of alternative technologies (including emerging technologies such as the Allam Cycle), and the degree of decarbonization desired. In a future where many as-yet unproven and improving approaches and technologies will be needed, CCS may become an important part of that tool kit.

Understanding Tradeoffs Between Emerging Complementary Technologies Will Be Key

CCS is not the only technology that provides clean backup generation. There are considerable uncertainties regarding the cost, performance, and circumstances for emerging non-intermittent clean power, all of which appear similarly untested.

Utilities will need to understand tradeoffs to ensure cost-effective decarbonization as opportunities will vary regionally.

COMPANY	STATE	SECTOR	CAPTURE CAPACITY (TONNES/YEAR)	STORAGE	STATUS
Prairie State Generating Company	IL	Power - Coal	6,241,500 to 8,212,500 (design dependent)	Saline Storage	Front End Engineering & Design (FEED) complete
Glenrock petroleum	WY	Power - Coal	1,260,000	Enhanced Oil Recovery	Unavailable
City of Farmington, NM / Enchant Energy	NM	Power - Coal	6,000,000	Saline Storage	FEED
Basin Electric Dry Fork Station	WY	Power - Coal	2,200,000	Saline Storage	FEED
Minnkota Power	ND	Power - Coal	3,265,865	Saline Storage & Enhanced Oil Recovery	FEED
Nebraska Public Power/ Ion Eng	NE	Power - Coal	Unavailable	Unavailable	FEED
Southern Company	MS or AL	Power - Natural Gas	2,250,000	Unavailable	FEED
California Resources Corporation / OGCI	CA	Power - Natural Gas	1,400,000	Enhanced Oil Recovery	FEED
Panda Energy	TX	Power – Natural Gas	Unavailable	Enhanced Oil Recovery	FEED
Golden Spread Electric Coop	TX	Power – Natural Gas	Unavailable	Enhanced Oil Recovery	FEED
Clean Energy Systems	CA	Power - Biomass	300,000	Saline Storage	Pre-FEED
Illinois Clean Fuels	IL	Industrial - Biofuels	8,125,000	Saline Storage	Unavailable
Velocys / Oxy	MS	Industrial - Biofuels	330,000	Saline Storage	Pre-FEED
Blue Flint Ethanol	ND	Industrial - Ethanol	181,437	Saline Storage	FEED
White Energy / Oxy	TX	Industrial - Ethanol	350,000	Enhanced Oil Recovery	FEED
Pacific Ethanol	IL	Industrial - Ethanol	680,389	Saline Storage	Pre-FEED
Lake Charles methanol	LA	Industrial - Petrochemicals	4,000,000	Enhanced Oil Recovery	Final financing
Wabash Valley resource / OGCI	IN	Industrial - Hydrogen	1,500,000-1,750,000	Saline Storage	FEED
Svante / LafargeHolcim / Oxy / Total	CO	Industrial - Cement	725,000	Enhanced Oil Recovery	FEED
Carbon Engineering / Oxy	TX	Direct Air Capture	1,000,000	Enhanced Oil Recovery	FEED

U.S. CCS Project pipeline (Source: Clean Air Task Force CCS Project Tracker)

• Batteries: Batteries provide cost-effective value for short-term storage, though long-term storage technologies suitable for multi-day renewable droughts or seasonal storage remain limited and future costs are uncertain

• Renewable Natural Gas (RNG): While RNG variable cost estimates are high (up to 3 times CCS VOM by 2050), RNG may presents capital cost savings at low capacity factors and can operate in areas where CCS is not technically feasible

- Recent AGF study estimates RNG potential ranges only 6%-15% of total U.S. fossil NG consumption, though future gas demand likely to be considerably lower

- Recent Brattle study suggests declining RNG prices could become comparable with increases in NG + carbon prices, but not until 2050. RNG may be able to utilize existing gas infrastructure

• Direct air capture: Direct air capture aims to capture carbon from a more diluted environment, and therefore faces higher costs ($100-$250 /ton of CO_2)

• New CCS Technologies are Developing: Net Power promises to deliver performance comparable to NGCC with no additional CO_2 capture cost

- This technology burns natural gas in pure oxygen, instead of air, and actually uses the CO_2 byproduct to continue the cycle

• Allam-cycle technology doesn't consume water, making it suitable for water stressed regions

Impediments, Barriers, and Challenges of CCS Remain for Power Generation

1. Economics remain challenging for retrofits and new CCS power plants

• Lack of carbon pricing and CCS mandates makes economic incentives limited and tax credits have long-term policy uncertainty

• New renewable energy remains most cost-effective clean MWh if integration is not a concern (as shown in San Juan)

2. Widespread CCS deployment will depend on a CO_2 pipeline network to transport and offload captured emissions and continued fossil extraction. Developing such a pipeline might present NIMBY and organizational challenges

• While some convenient storage locations exist, CO_2 transmission planning will be essential to facilitate power-sector CCS

— Chicken-and-egg problem: Pipeline needs multiple sources to finance, but capture facilities need pipeline to finance

• Upstream fossil extraction emissions and pollution need to be addressed to provide environmental benefit

3. Regulatory risk is decreasing, but still remains. Existing regulatory regime for sequestration and operating projects in the US has significantly evolved over the last decade, including project siting and permitting.

4. Experience, confidence, and demonstrated successes remain limited for power CCS projects

• Previous project cost-overruns (Kemper and Boundary Dam) raise doubts, despite some successes (Petra Nova) and estimates of costimprovements for future projects

"The Emerging Value of CCS for Utilities: Shifting from Retrofits to System-Wide Decarbonization" is authored by Brattle Associate Kasparas Spokas, Principal Frank Graves, and Senior Research Analyst Katie Mansur.

More information

www.brattle.com

CO2 Capture Project annual report highlights two decades of work

The CCP (CO2 Capture Project) has published its 2019 Annual Report, which covers the activities of the organisation during the past year as well as looking back over the history of CCP.

The fourth and final phase of CCP began in late 2014 and has been extended to the end of 2021 to allow for completion of projects delayed by the impact of the coronavirus pandemic. Two decades of pioneering work by CCP will come to an end at that point - work which has helped prove the technical viability of CCUS in a range of applications and scales, from research to demonstrations, and built the foundations for commercial-scale deployment.

This final Annual Report reflects on some of the highlights of this history – as well as summarising key 2019 developments from each of the four CCP workstreams – Capture; Storage, Monitoring & Verification; Policy & Incentives; and Communications.

The year saw important work conducted to bring the remaining capture and storage projects to (or close to) completion. This included:

• Pilot testing of a piperazine solvent

• 3D printing of sorbent capture structures

• The testing of the final sealants in the Mont Terri underground laboratory project.

Although there will not be an annual report published in 2021, the final CCP results volume will be published during the course of that year and available for download. This will contain full details of all projects undertaken in Phase 4 of the CCP programme. CCP also plans to take part in the GHGT-15 conference in Abu Dhabi, now rescheduled to March 2021.

CCP Chairman, Tony Espie, commented, “This Annual Report reports on the work of our Technical teams during the last year and is also a fitting conclusion to the achievements of CCP over the last two decades. During that time, we have been proud to share the learnings and insights from our pioneering work with others in the world of CCS and emissions reduction technologies. We are most grateful to all who have supported and worked with us during that time and hope that they enjoy this latest update from CCP.”

2019 Overview - Capture Program

In 2019, the CCP4 Capture program has seen Raja Jadhav and his Capture Team completing and making continued progress on projects initiated earlier in CCP4, while also initiating a few new capture initiatives. A number of these projects are set for completion during 2020 and results will be made available in the CCP4 Results Book due for publication in 2021. A small number of projects are expected to be completed after 2020.

Pilot testing of novel solvents by CCP and its partners in 2019 has indicated potential capture cost reduction of up to 20 30% when applied to post combustion NGCC flue gas. This included testing of a novel solvent (piperazine) which was completed during the past year – a summary of the results is contained in this Annual Report. Testing of a further novel solvent (non amine) is currently undergoing pilot testing at a biomass fired power plant in the UK.

A number of other projects were initiated, including piloting capture of CO2 from cement production processes and small scale gas engines, subsea removal of CO2 from natural gas using membranes, as well as looking at novel alternatives to conventional CO2 membranes for flue gas applications.

CCP4 Scenarios

The Capture program consists of four key scenarios. Much of the work has focused on applications in refining operations, heavy oil extraction, natural gas combined cycle (NGCC) power generation, and natural gas extraction.

Refinery: Identify and develop technologies for pre combustion capture from steam methane reformer (SMR) H2 plants

NGCC: Seek and develop breakthrough capture technologies with less than $50/tonne CO2 avoided cost

Natural gas extraction: Understand landscape and potential for CO2 capture from offshore gas production and support pilot testing of a promising technology

Heavy oil: Seek and develop breakthrough capture technologies with less than $50/tonne CO2 avoided cost

Storage, monitoring and verification

The main projects comprising the CCP4 Storage, Monitoring & Verification (SMV) program achieved major milestones during 2019.

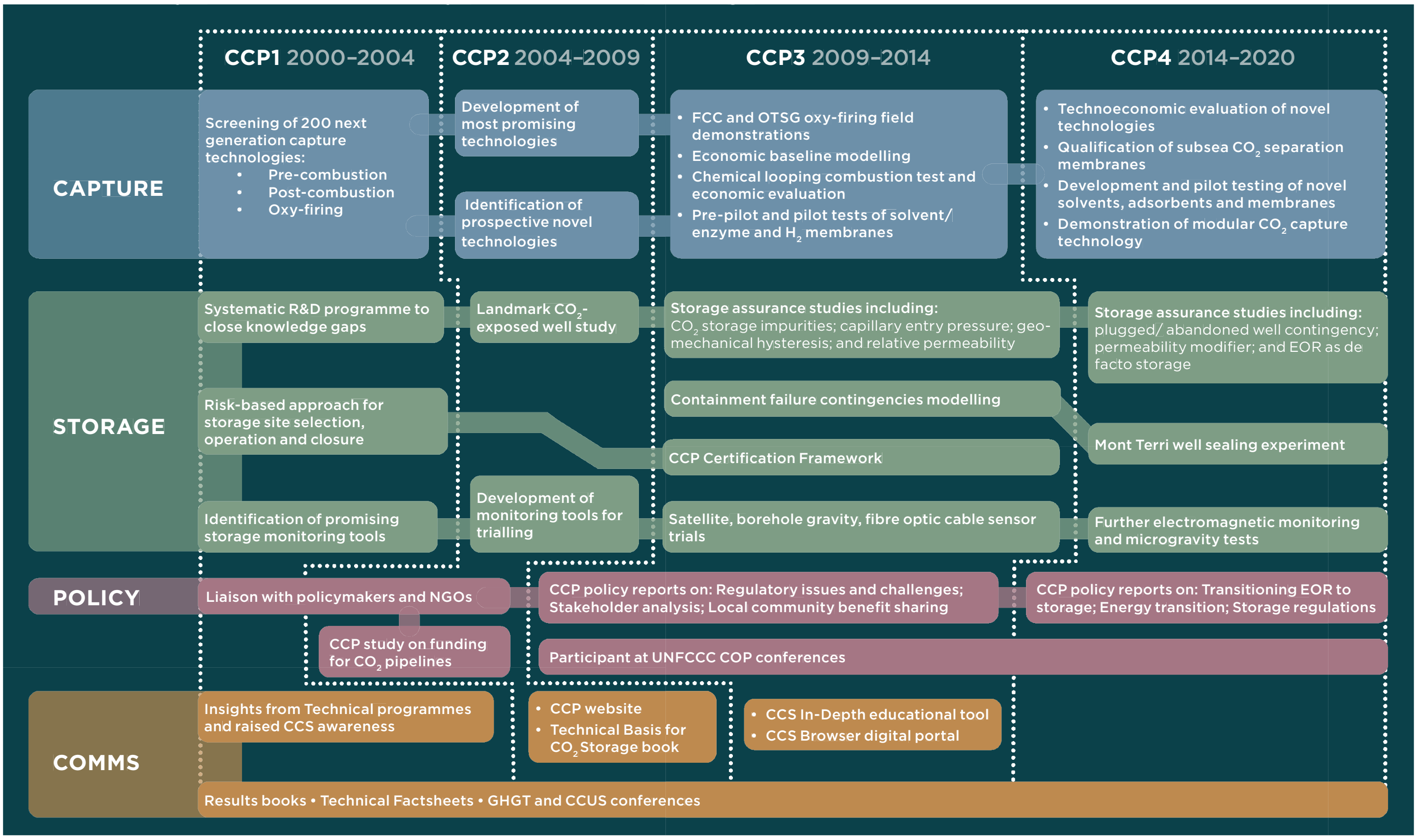
The long standing assurance and contingencies work at the Mont Terri underground laboratory in Switzerland has proved immensely valuable and 2019 saw the completion of all the sealant testing.

Field trialling programmes also continued at the Aquistore reservoir facility in Canada, with the Borehole microgravity tests and the repeat electro magnetic (EM) survey both completed during the course of the year.

CCP4 Themes

The SMV Team’s CCP4 work has the overarching objective of ensuring the long term security of geologic CO2 storage approached through the following themes:

Storage assurance: Subsurface processes - clarification and understanding of complex processes impacting storage security; Well integrity - solutions to identify and mitigate



Some of the key milestones in CCP's history are outlined above, covering all four CCP workstreams

CO2 leakage; Monitoring & Verification - modeling the cost effectiveness of emerging and integrated sensors

Contingencies: Models for detection, characterization and mitigation of out of zone fluid migration (CO2, brine) through wells and natural or induced geologic conduits

Field trialing: Deployment and integrated assessment of emerging monitoring technologies at third party sites with research and operator partners

Policy and incentives

In 2019, the Policy & Incentives Team led by Arthur Lee published a new report looking at selected recent developments in regulations for CO2 storage projects globally – with particular emphasis on key developments, outstanding issues and gaps that might help or hinder the commercial success of CCS.

The report, entitled Survey of CO2 Storage Regulations, reviewed regulations from the USA, Canada, the EU, the UK, the Netherlands, Norway, Indonesia, Japan and Australia. These included regulations for permitting and for qualifying CO2 storage projects for incentives. The focus was on CO2 storage projects relevant to oil & gas as well as other industries. Increased CCS policy confidence and a growth in regulatory regimes for CO2 storage worldwide were among the key findings of the report.

A detailed comparison was undertaken of five different regulatory frameworks that best address the key regulatory issues:

• EPA UIC Class VI Well Permits

• California LCFS

• Alberta CCS Regulatory Framework Assessment recommendations

• EU CCS Directive

• Australian Offshore Petroleum Amendment

The regulations for CO2 storage were found to be inconsistent, with various disparities in the treatment of long term liability and post injection monitoring requirements. Despite this, there are some areas – such as the need for proof of financial ability to cover potential liabilities and public engagement – which are, on the whole, being approached in a similar way.

Overall growth in CCS policy confidence is reflected in the development of new regulatory frameworks – such as for tax incentives provided by the Internal Revenue Service's 45Q provisions in the United States and California's LCFS provisions. Also, certain countries, such as the United Kingdom, has expressed growing ambition by creating the CCS Council and CCUS Cost Challenge Taskforce with the aim of making CCS economically feasible.

Communications

The Communications team continued its activity to publicise the work of the CCP Technical teams to the CCS world, wider industry, government and academia. It did this by extending its range of project technical factsheets, providing updates to the CCP website and providing news alerts to CCS influencers and media.

More information

Read the full report at:

www.co2captureproject.org

A method to calculate the positive effects of CCS and CCU on climate change

A report from the Zero Emissions Platform defines three fundamental characteristics for the classification of technologies for climate change abatement of CCU and CCS projects: mitigation effect, net energy consumption, and implementation period.

The value of CCS and CCU projects to climate change mitigation is crucial, however, how to assess the added value, to be more exact, is complex. There are many factors that could play a major role, such as which boundary conditions and assumptions to use.

Fundamentally, Life Cycle Analyses is the instrument that should be used for these assessments, but the resources and time needed for such analyses are significant. There is need for a methodology for fast checks and comparisons.

In 2017, ZEP published a paper with the so-called Indicative Sink Factor (ISF). That approach was too simple. Now, we are introducing three fundamental characteristics for the classification of technologies for climate change abatement of CCU and CCS projects.

Each characteristic has its own Key Performance Indicator:

1. Mitigation effect: CO_2 to the Atmosphere (C2A) The objective of climate change mitigation is to prevent or reduce greenhouse gas emissions into the atmosphere. The factor measuring the CO_2 emitted into the atmosphere (C2A) describes the net effect on the atmosphere per tonne of CO_2, intended to be captured and subsequently used or stored permanently.

In short: Not all described as CO_2 emissions reductions are in reality CO_2 emissions reductions.

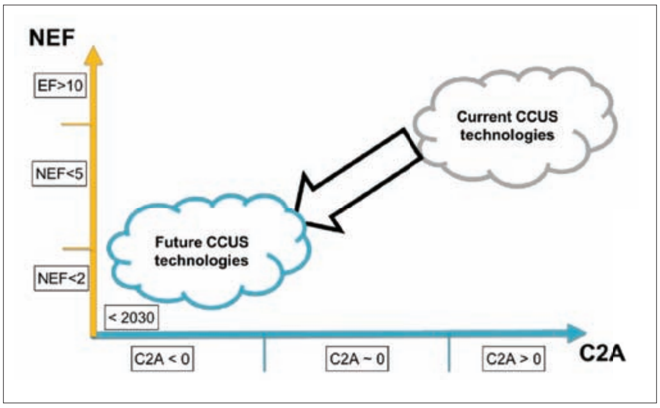
2. Net energy consumption: Net Energy Factor (NEF) CO_2 abatement by CCS or CCU cannot, due to thermodynamics, be done in an energy-neutral manner. The net energy factor (NEF) reflects how much extra energy needs to be added to the CCU and CCS technologies compared to the energy needed for the production process alone.

The energy use and the linked emissions will be a key driver and limiting factor for CCU (and less for CCS).

3. Implementation period

Technologies that are available now can already contribute to the climate neutrality ambitions. New technologies and improvements in existing technologies will come and reduce costs and improve the energy efficiency of CCUS in the future.

Four periods have been identified to characterise the timeframe to 2050.



The net energy consumption: Net Energy Factor (NEF) and mitigation effect: CO2 to the Atmosphere (C2A) should decline over time

The report also includes examples showing the value of this concept. On the basis on these three KPIs, a simple and easy assessment of each technology is possible. The abatement potential of any CCS or CCU technology is dependent on:

1. The source of the CO_2: geological/fossil, biogenetic, atmospheric.

2. The phase to which the CO_2 is being converted: geological storage, short-term living product, long-term living product, fuel, atmosphere, etc.

3. The energy source used for the conversion.

Conclusions

A simple and fast assessment of the positive effects on climate change of CCU and CCS technologies has been developed on the basis of three key performance indicators. The CO_2 to Atmosphere factor indicates for technologies the positive contribution to climate change mitigation in units of CO_2 emissions prevented, reduced or (permanently) sequestered. The Net Energy Factor indicates the additional energy needed for the use of each technology. And the Time Period indicates the timeframe when commercial use is feasible.

The combination of the three factors puts each technology and its implementation in a perspective of others. Each technology will have its own merits, advantages, and disadvantages. The three KPIs combined do not indicate which technology is to be used or not to be used, but creates an overview of all possibilities within a certain timeframe.

For example, a high Net Energy Factor might be an advantage when renewable energy supplies are available at irregular times, or a higher CO_2 to Atmosphere factor is currently acceptable as other and better technologies are not available.

More information

zeroemissionsplatform.eu

Offshore energy integration can deliver 30% of UK's net zero target

The integration of offshore energy systems, including oil and gas, renewables, hydrogen and carbon capture and storage, could contribute to deliver approximately 30% of the UK's total carbon reduction requirements needed to meet the 2050 net zero target.

The Oil and Gas Authority's (OGA) Energy Integration Project report in collaboration with Ofgem, The Crown Estate and the Department for Business, Energy and Industrial Strategy (BEIS concluded that not only is the close co-ordination of these technologies valuable in terms of energy production and cutting greenhouse gases, but that their integration would help technologies become economically more attractive.

The findings of the report include:

• Re-using oil and gas reservoirs and infrastructure can accelerate Carbon Capture and Storage (CCS), connecting to onshore net zero hubs and saving 20-30% Capex on specific projects.

• To reach the CCS scale in support of net zero, the UK needs to develop around 20 individual CO2 stores for a total capacity of over 3GtCO2 by 2050 (with large CCS projects featuring multiple stores)

• Blue hydrogen (produced from natural gas) has the potential to decarbonise around30% of the UK natural gas supply by 2050, potentially supporting circa half of CCS expansions in the same timeframe.

• Green hydrogen (from renewables) can support and enable the significant expansion of offshore renewables in the 2030s and beyond, providing an efficient storage and energy transportation solution. Reducing the costs of the technology involved (electrolysis) would be needed to support the faster uptake of this technology.

The report includes an Annex specifically covering Carbon Capture and Storage which found that:

• CCS can be critical to achieve UK net zero, and UKCS role is key

- 75-175 MtCO2 / yr captured and stored by 2050, or up to one third of the current UK's emission baseline

- 78 GtCO2 potential storage capacity on the UKCS, could be sufficient for 100s of years of UK's demand

• Accelerating projects would be needed to achieve expected CCS volumes

>2 pilots followed by >2 commercial-scale projects developed by 2030 necessary to provide critical learnings for the subsequent expansion

- 130 MtCO2 /yr by 2050 flow rate (central case) would then require ~4 Gt CO2 storage capacity developed across >20 individual stores

• CCS could be economically competitive as emission abatement technology

- Levelised transport and storage costs of £12-30/tCO2 could be attained

- Adding onshore capture costs, CCS is cost-competitive against long-term carbon price forecasts

- Combination with blue hydrogen can enhance economics and create scalable business models

- Levers to reduce CCS costs include economies of scale (e.g. CCS clusters and hubs) and reuse of O&G infrastructure

The report included the following recommendations:

1. Ensure the timely ramp up of CCS

- The Government emphasised the importance of CCS to support its Clean Growth Strategy and net zero target, with an aim to deploy the technology at scale during the 2030's.

- The Government has been providing funding towards CCS technology deployment and the establishment of net zero industrial clusters

- BEIS has been consulting industry and other regulators on critical enablers, including business models, market frameworks and O&G infrastructure reuse policy

- It is key that this good progress and industry engagement are maintained, to ensure CCS pilots and first commercial-scale projects are deployed in the 2020's

- Accelerating initial CCS projects is critical to mature the technology for the subsequent ramp-up in the 2030's

- In addition, this would allow to fully leverage the UK's O&G industry expertise, supply chain and existing infrastructure.

2. Enhance regulatory coordination on CCS and hydrogen

- Regulators coordination to expedite industry projects

- Align planning and consenting regimes to support crossindustry opportunities (e.g. O&G, CCS and blue H2)

3. Improve data availability

- Improved access to data (including on subsurface, existing facilities and infrastructure developments) is critical for both government and industry to develop optimal CCS buildout plans

More information

Download the full report:

www.ogauthority.co.uk

Projects and policy news

CO2CRC and NERA launch major study into Australian CCUS

www.nera.org.au

NERA (National Energy Resources Australia) and CO2CRC have announced a new landmark study into CCUS to assist the nation's energy resources sector reduce CO2 emissions while securing Australia's energy future.

The study is being undertaken in two phases. The first phase, led by CO2CRC in collaboration with Geosciences Australia and supported by COAL21, will rank Australian oil and gas basins for the potential use of CO2 Enhanced Oil Recovery (CO2-EOR). The second phase of the project will provide insight to industry and government on potential opportunities for CO2-EOR at the field level in Australian onshore basins.

Enhanced Oil Recovery (EOR) using CO2 is the process of increasing the volume of oil that can be recovered by injecting CO2 into the reservoir. Natural oil production from the oil reservoirs declines over time either due to pressure depletion or water breakthrough. CO2 injection not only helps to re-pressurise the reservoir, but the CO2 also acts like a solvent and causes the oil to expand and flow more easily to production wells.

CO2-EOR can increase the oil recovery by up to 25%. It also has the added benefit of permanently storing CO2 in the underground reservoirs, providing a meaningful contribution to overall emissions reduction efforts.

The study will also evaluate and recommend a framework of policies, incentives or regulations that would help accelerate Australian adoption of CO2-EOR for oil recovery and CO2 storage, while assuring safe and efficient application of the technology.

NERA CEO Miranda Taylor said the project has the potential to help Australia meet the recommendations of the Final Report of the Expert Panel examining additional sources of low-cost abatement (the King Review) and take important steps to opening up new emissions reduction opportunities across the Australian economy.

"Australia has an opportunity to make significant reduction to its CO2 emissions through CCUS; however, in the absence of an integrated study in Australia, the full potential for CCUS is difficult to ascertain," Ms Taylor said.

"This project will assist in removing these barriers by examining the economic and technical feasibility and potential of using CO2 in EOR and as a pathway to long-term CO2 storage in Australia. NERA is pleased to support this vital study as it will promote cross-sector collaboration and knowledge transfer, supporting the competitiveness of the Australian oil and gas industry while helping Australia meets its international commitments and create a pathway for ongoing emissions reductions beyond 2030."

CO2CRC CEO David Byers said the funding and networking support from NERA will assist Australia's energy resources sectors in making decisions on the potential opportunities for enhanced oil recovery in Australia.

"CO2-EOR has the potential to significantly reduce CO2 emissions while improving Australia's energy security by boosting oil recovery in mature basins. All of the injected volume of CO2 will be permanently stored in underground reservoirs by the end of the operational life cycle," Mr Byers said.

The analysis from the first phase of the project will provide Australia wide basin screening for CO2-EOR as well as potential CO2 sources near the basins that can be used for CO2-EOR. Phase one of the project is expected to be completed towards the end of 2020.

The second phase will evaluate the high-level economic and technical feasibility of using CO2-EOR to enhance the recovery of oil in Australia's onshore oilfields (including those in the Cooper and Surat basins). It will also assess the potential for CO2-EOR to contribute to efforts to reduce greenhouse gas emissions through permanent CO2 storage during the CO2-EOR process.

"Enhanced oil recovery is one of the ways CO2 can be used and stored at an industrial scale, helping energy intensive industries significantly reduce their carbon emissions. This study complements COAL21's other projects which are all focussed on a similar outcome, and will be an important step forward in understanding opportunities for storing carbon safely, permanently and in an economically viable way," said Mark McCallum, CEO of COAL21.

With results from the study to be shared across Australia's energy resources sector, its key findings can help both industry and governments make sustainable and long-term infrastructure investment decisions that meet the public's expectations for a low carbon future.

$11.5 Million funding for FLExible Carbon Capture and Storage (FLECCS) program

arpa-e.energy.gov

The U.S. Department of Energy has awarded $11.5 million in funding for 12 projects as part of Phase 1 of the Advanced Research Projects Agency-Energy's (ARPA-E) FLExible Carbon Capture and Storage (FLECCS) program.

FLECCS project teams will work to develop carbon capture and storage (CCS) processes that better enable technologies, such as natural gas power generators, to be responsive to grid conditions in a high variable renewable energy (VRE) penetration environment.

"The FLECCS projects will work to address critical carbon capture and storage needs in our nation's power systems." said ARPA-E Director Lane Genatowski. "The FLECCS program is intended to enable the next generation of flexible, low-cost, and low-carbon electricity systems, and we are eager to work with these teams to innovate the grid of the future."

FLECCS project teams are developing CCS retrofits to existing power generators as well as greenfield systems that intake fossil carbon-containing fuel like natural gas or biogas and output electricity. FLECCS Phase 1 teams will design, model, and optimize CCS processes that enable flexibility on a high-VRE grid. Later in the program, teams that move to Phase 2 will focus on building components, unit operations, and prototype systems to reduce technical risks and costs.

In FLECCS Phase 2, up to $31 million in additional funding will be available for teams. At the conclusion of the Phase 1 period, teams will be down-selected based on an engineering design review and the projected economic impact of their Phase 1 projects on a future electricity grid. Selected teams will move on to receive additional funding, further develop their technologies and address Phase 2 challenges.

FLECCS projects include:

Linde Gas North America – Murray Hill, NJ

Process Integration and Optimization of an NGCC Power Plant with CO2 Capture, Hydrogen Production and Storage - $479,966

Susteon Inc., – Cary, NC

A Rapid Temperature Swing Adsorption Carbon Capture Technology for Optimal Operation of a Fossil Power Plant- $789,009

Climeworks, ON Power and Carbfix lay the foundation to scale up CO2 removal

climeworks.com

Climeworks has signed agreements with both Carbfix and ON Power to lay the foundation for a new plant.

The new plant will be able to permanently remove 4000 tons of carbon dioxide from the air per year.

Under the agreement with ON Power, Climeworks will build facilities within their Geothermal Park to capture CO2 from the air. This will be done using Climeworks' direct air capture technology (DAC). The geothermal power and heat provided by ON Power secures a constant supply of renewable energy to power the DAC technology.

Climeworks' agreement with Carbfix ensures the safe storage of the CO2 through natural underground mineralization. The underground basaltic rock formations in Iceland provide the ideal conditions for this process, providing a permanent solution for CO2 storage.

Jan Wurzbacher, co-founder and co-CEO of Climeworks: "This collaboration with ON and Carbfix marks a big step forward in reducing the CO2 in our air. The site in Iceland provides ideal conditions: the supply of renewable energy and a safe and natural storage space for our air-captured carbon dioxide. All partners have developed pioneering solutions and are experts in their field. We are proud, together with our partners, to bring the permanent and safe removal of carbon dioxide from the atmosphere to the next level."

CCUS deployment at dispersed UK industrial sites

www.element-energy.co.uk

An independent report identifying and assessing high-level deployment options for carbon capture, usage and storage technology at dispersed industrial sites in the UK has been published by the Government.

The report identifies and assesses a range of high-level deployment options for industrial carbon capture, usage and storage (CCUS) technology located in non-clustered 'dispersed' sites that are isolated from potential carbon dioxide transport infrastructure in the UK.

It provides:

• an identification of the challenges and barriers to CCUS deployment specifically at these dispersed sites

• an appraisal of the range of high-level options for CCUS deployment and the risks associated with each challenge

• an assessment of the most promising options based on their cost, risk and emission reduction potential

The report found that the dispersed location of a site can be a significant challenge towards CCS deployment, but not necessarily a showstopper. The main risks are categorised into the following: cross chain, policy and technical.

Cross chain risks - For all sites considered there is uncertain availability of transport & storage, which leads to risk of stranded assets with no alternative use.

Policy risks, with knock-on effect as economic & market risk - For all sites not located in industrial clusters, there is currently no comprehensive plan, policy or regulatory framework to facilitate carbon capture, including formal permitting process.

Technical risks - Many dispersed industrial sites may have issues with energy (for CO2 compression / liquefaction), feedstock, oxygen (O2) e.g. for O2 separation for oxyfuel combustion in the cement sector, and water use of capture plant.

The analysis of risks and challenges highlighted that the transport of CO2 has a high perceived risk for dispersed industrial sites

BEIS commissioned Element Energy to produce the report.

Start up and shut down times of power CCUS

www.gov.uk/beis

An investigation into start up and shut down times of gas-fired power carbon capture, usage and storage (power CCUS) facilities has been published by the UK Government.

The technical report is based on a literature review and desk-based engineering study, investigates the start up and shut down times of a standard configuration gas-fired post combustion carbon capture, usage and storage plant facility (power CCUS). It also identifies potential improvements to the standard configuration.

AECOM carried out the report on behalf of BEIS.

The study found that all the improvement options considered effectively decoupled the power plant from the PCC plant and allowed the whole complex to maintain 95% capture through start-up and shut-down events, with the exception of segregated amine inventory alone (87% overall start-up capture).

There were no incremental impacts expected on the overall process during normal operation and no strong reasons to prefer one option over another. The estimated costs to implement any of the flexibility improvement options identified were within the same order of magnitude. Therefore, the configuration of process options woud likely be site- and project-specific rather than converging on any single approach and indeed most likely to tend towards a combination of options.

For example, a fast-starting steam cycle (which would likely be an advantage in the current market even without PCC) would be complemented by segregated amine inventory and some additional dedicated start-up storage if found necessary during engineering work. This option would likely give a PCC power plant ready to respond quickly to grid demand, starting quickly and maintaining high capture rates through the start-up, operating phase and shut-down phases.

Novel 3D-printed device demonstrates enhanced capture of CO2 emissions

The Department of Energy's Oak Ridge National Laboratory researchers have designed and additively manufactured a first-of-its-kind aluminum device that enhances the capture of carbon dioxide emitted from fossil fuel plants and other industrial processes.

ORNL's device focuses on a key challenge in conventional absorption of carbon using solvents: the process typically produces heat that can limit its overall efficiency. By using additive manufacturing, researchers were able to custom design a multifunctional device that greatly improves the process efficiency by removing excess heat while keeping costs low.

Absorption, one of the most commonly used and economical methods for capturing CO2, places a flue-gas stream from smokestacks in contact with a solvent, such as monoethanolamine, known as MEA, or other amine solutions, that can react with the gas.

The team tested the novel circular device, which integrates a heat exchanger with a mass-exchanging contactor, inside a 1-meter-tall by 8-inch-wide absorption column consisting of seven commercial stainless-steel packing elements. The 3D-printed intensified device was installed in the top half of the column between the packing elements.

Additive manufacturing made it possible to have a heat exchanger within the column, as part of the packing elements, without disturbing the geometry, thus maximizing the contact surface area between the gas and liquid streams.

"We call the device intensified because it enables enhanced mass transfer (the amount of CO2 transferred from a gas to a liquid state) through in-situ cooling," said Costas Tsouris, one of ORNL's lead researchers on the project. "Controlling the temperature of absorption is critical to capturing carbon dioxide.

When CO2 interacts with the solvent, it produces heat that can diminish the capability of the solvent to react with CO2. Reducing this localized temperature spike in the column through cooling channels helps increase the efficiency of CO2 capture.

"Prior to the design of our 3D printed device, it was difficult to implement a heat exchanger concept into the CO2 absorption column because of the complex geometry of the column's packing elements. With 3D printing, the mass exchanger and heat exchanger can co-exist within a single multifunctional, intensified device," said ORNL's Xin Sun, the project's principal investigator.

Embedded coolant channels were added inside the packing element's corrugated sheets to allow for heat exchange capabilities. The final prototype measured 20.3 centimeters in diameter, 14.6 centimeters in height, with a total fluid volume capacity of 0.6 liters. Aluminum was chosen as the initial material for the intensified device because of its excellent printability, high thermal conductivity, and structural strength.

In 2019, ORNL researchers Costas Tsouris and Eduardo Miramontes operated the intensified device inside of the absorption column, which contains commercial stainless-steel packing elements. Credit: Carlos Jones/ORNL, U.S. Dept. of Energy

"The device can also be manufactured using other materials, such as emerging high thermal conductivity polymers and metals. Additive manufacturing methods like 3D printing are often cost-effective over time because it takes less effort and energy to print a part versus traditional manufacturing methods," said Lonnie Love, a lead manufacturing researcher at ORNL, who designed the intensified device.

The prototype demonstrated that it was capable of substantially enhancing carbon dioxide capture with the amine solution, which was chosen because its highly reactive to CO2. In results published in the AIChE Journal, ORNL researchers conducted two separate experiments — one that varied the CO2-containing gas flow rate and one that varied the MEA solvent flow rate. The experiments aimed to determine which operating conditions would produce the greatest benefit to carbon capture efficiency.

Both experiments produced substantial improvements in the carbon capture rate and demonstrated that the magnitude of the capture consistently depended on the gas flow rates. The study also showed a peak in capture at 20% of carbon dioxide concentration, with percent of increase in capture rate ranging from 2.2% to 15.5% depending on the operating conditions.

More information

www.ornl.gov

New catalyst efficiently turns carbon dioxide into useful fuels and chemicals

By efficiently converting CO2 into complex hydrocarbon products, a new catalyst developed by a team of Brown researchers could potentially aid in large-scale efforts to recycle excess CO2.

A team of Brown University researchers has found a way to fine-tune a copper catalyst to produce complex hydrocarbons — known as C2-plus products — from CO2 with remarkable efficiency.

In a study published in Nature Communications, the researchers report a catalyst that can produce C2-plus compounds with up to 72% faradaic efficiency (a measure of how efficiently electrical energy is used to convert carbon dioxide into chemical reaction products). That's far better than the reported efficiencies of other catalysts for C2-plus reactions, the researchers say. And the preparation process can be scaled up to an industrial level fairly easily, which gives the new catalyst potential for use in large-scale CO2 recycling efforts.

"There had been reports in the literature of all kinds of different treatments for copper that could produce these C2-plus with a range of different efficiencies," said Tayhas Palmore, the a professor of engineering at Brown who co-authored the paper with Ph.D. student Taehee Kim. "What Taehee did was a set of experiments to unravel what each of these treatment steps was actually doing to the catalyst in terms of reactivity, which pointed the way to optimizing a catalyst for these multi-carbon compounds."

There have been great strides in recent years in developing copper catalysts that could make single-carbon molecules, Palmore says. For example, Palmore and her team at Brown recently developed a copper foam catalyst that can produce formic acid efficiently, an important single-carbon commodity chemical. But interest is increasing in reactions that can produce C2-plus products.

"Ultimately, everyone seeks to increase the number of carbons in the product to the point of producing higher carbon fuels and chemicals," Palmore said.

There had been evidence from prior research that halogenation of copper — a reaction that coats a copper surface with atoms of chlorine, bromine or iodine in the presence of an electrical potential — could increase a catalyst's selectivity of C2-plus products.

Kim experimented with a variety of different halogenation methods, zeroing in on which halogen elements and which electrical potentials yielded catalysts with the best performance in CO2-to-C2-plus reactions. He found that the optimal preparations could yield faradaic efficiencies of between 70.7% and 72.6%, far higher than any other copper catalyst.

The research helps to reveal the attributes that make a copper catalyst good for C2-plus products. The preparations with the highest efficiencies had a large number of surface defects — tiny cracks and crevices in the halogenated surface — that are critical for carbon-carbon coupling reactions. These defect sites appear to be key to the catalysts' high selectivity toward ethylene, a C2-plus product that can be polymerized and used to make plastics.

Ultimately, such a catalyst will aid in large-scale recycling of CO2. That requires an efficient catalyst that is easy to produce and regenerate, and inexpensive enough to operate on an industrial scale. This new catalyst is a promising candidate, the researchers say.

"We were working with lab-scale catalysts for our experiments, but you could produce a catalyst of virtually any size using the method developed," Palmore said. The research was funded by the National Science Foundation.

More information

www.brown.edu

ExxonMobil and Berkeley make important advance in CO2 capture

Developed by researchers at the University of California, Berkeley, Lawrence Berkeley National Laboratory and ExxonMobil, the new technique uses a highly porous material called a metal-organic framework resulting in six times greater capacity than current amine technology.

In experiments, the technique showed a six times greater capacity for removing CO2 from flue gas than current amine-based technology, and it was highly selective, capturing more than 90% of the CO2 emitted. The process uses low temperature steam to regenerate the MOF for repeated use, meaning less energy is required for carbon capture.

"For CO2 capture, steam stripping — where you use direct contact with steam to take off the CO2 — has been a sort of holy grail for the field. It is rightly seen as the cheapest way to do it," said senior researcher Jeffrey Long, UC Berkeley professor of chemistry and of chemical and biomolecular engineering and senior faculty scientist at Berkeley Lab. "These materials, at least from the experiments we have done so far, look very promising."

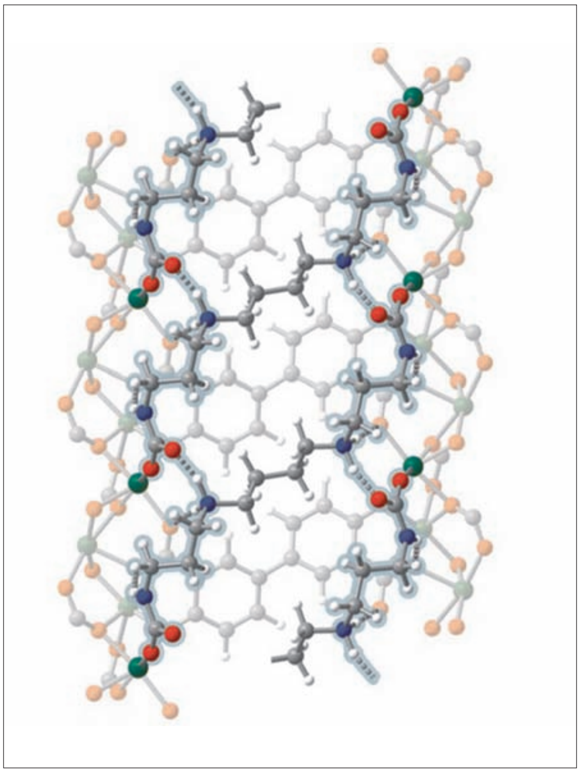
Because there's little market for most captured CO2, power plants would likely pump most of it back into the ground, or sequester it, where it would ideally turn into rock. The cost of scrubbing the emissions would have to be facilitated by government policies, such as carbon trading or a carbon tax, to incentivize CO2 capture and sequestration, something many countries have already implemented.

The work was funded by ExxonMobil, which is working with both the Berkeley group and Long's start-up, Mosaic Materials Inc., to develop, scale up and test processes for stripping CO2 from emissions.

Long is the senior author of a paper describing the new technique that appeared in the July 24 issue of the journal Science.

"We were able to take the initial discovery and, through research and testing, derive a material that in lab experiments has shown the potential to not only capture CO2 under the extreme conditions present in flue gas emissions from natural gas power plants, but to do so with no loss in selectivity," said co-author Simon Weston, senior research associate and the project lead at ExxonMobil Research and Engineering Co. "We have shown that these new materials can then be regenerated with low-grade steam for repeated use, providing a pathway for a viable solution for carbon capture at scale."

Six years ago, Long and his group in UC Berkeley's Center for Gas Separations, which is funded by the U.S. Department of Energy, discovered a chemically modified MOF that readily captures CO2 from concentrated power plant flue emissions, potentially reducing the capture cost by half. They added diamine molecules to a magnesium-based MOF to catalyze the formation of polymer chains of CO2 that could then be purged by flushing with a humid stream of carbon dioxide.



The atomic structure of a single pore in a MOF showing how carbon dioxide molecules (gray and red spheres) bind to the tetraamines (blue and white spheres), building a CO2 polymer that threads through the pore. Low-temperature steam can strip out the carbon dioxide for sequestration, allowing the MOF to be reused to capture more carbon from power plant emissions. (UC Berkeley graphic by Eugene Kim)

A major advantage of the amine-appended MOFs is that the amines can be tweaked to capture CO2 at different concentrations, ranging from the 12% to 15% typical of coal plant emissions to the 4% typical of natural gas plants, or even the much lower concentrations in ambient air. Mosaic Materials, which Long co-founded and directs, was created to make this technique available widely to power and industrial plants.

But the 180 C stream of water and CO2 needed to flush the captured CO2 eventually drives off the diamine molecules, shortening the life of the material. The new version uses four amine molecules — a tetraamine — that is much more stable at high temperatures and in the presence of steam.

"The tetraamines are so strongly bound within the MOF that we can use a very concentrated stream of water vapor with zero CO2, and if you tried that with the previous adsorbents, the steam would start destroying the material," Long said.

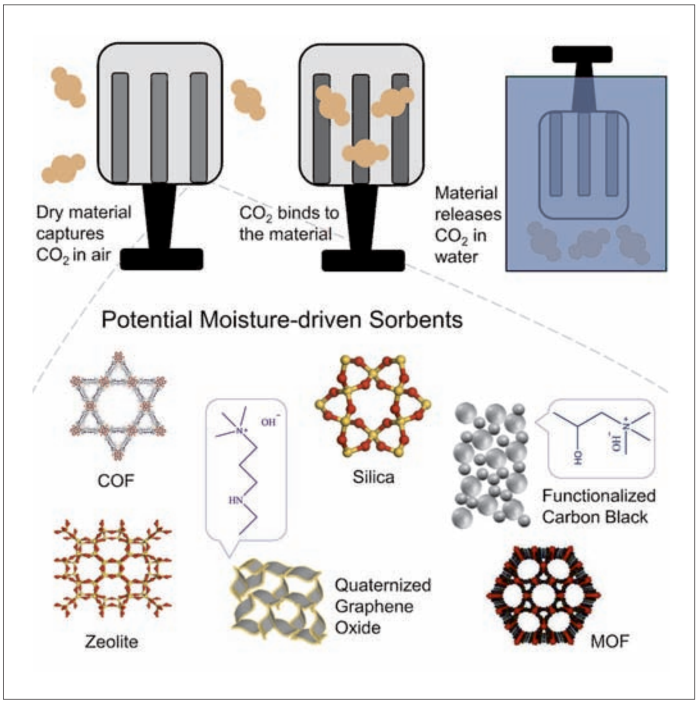
"I have been doing research at Cal for 23 years now, and this is one of those times where you have what seemed like a crazy idea, and it just worked right away," Long said.

More information

www.berkeley.edu

Researchers pinpoint how sorbent materials catch and release CO2

A paper from Arizona State University describes in detail what is happening with a sorbent material when it is dry, it binds to carbon in the air, and when it is wet, it desorbs the carbon.



The study can lead the way toward the optimization of sorbents for direct air capture

A key component of ambient direct air capture (DAC) systems that remove carbon dioxide from the air is the sorbent material that is used to first capture the carbon and then to release it. Certain sorbent materials can pull carbon dioxide from the air as it flows over the material. It then releases the carbon when water is applied. As the material dries again, it absorbs carbon, and so on.

This elegant function of specific materials has been observed for several years by those working on DAC systems, like Klaus Lackner, an Arizona State University professor in the School of Sustainable Engineering and the Built Environment. Lackner has developed a system called "MechanicalTree" that uses sorbent materials to remove carbon from air.

Now, in a new paper in the early, on-line edition of Joule, Lackner and his colleagues lay out exactly how some of these sorbent materials capture and release carbon, a finding that could lead to the smarter design of sorbent materials at the heart of all carbon removal systems.

"We developed a better understanding of the moisture swing mechanism of these sorbents by demonstrating it in various materials and by developing computational tools and models that explain the concept," Lackner said. "We now understand the effect that drives the moisture swing, and this insight increases the range of materials that can do that."

The paper describes in detail and on a microscopic scale what is happening with the sorbent material when it is dry, it binds to carbon in the air, and when it is wet, it desorbs the carbon. The system was examined with quantum mechanics simulations and verified in experiments.

"This concept is not surprising to me because I've been playing with this stuff for a decade, but the moisture swing concept is still very novel and very different from other ways of loading and unloading a sorbent," Lackner explained. "We discovered this phenomenon 14 years ago, and for a long time it was a mystery on how it worked. Now it seems pretty obvious."

Overall, Lackner added, "this advance opens the door for more candidate materials and rational design. Many of those materials are far cheaper than what is often used as sorbents."

Co-authors on the paper "Moisture driven CO2 sorbents" are Xiaoyang Shi, Hang Xiao and Xi Chen, of Columbia University in New York City; and Kohei Kanamori and Akio Yonezu, of Chuo University in Tokyo. In addition to being a professor at ASU, Lackner is the director of the Center for Negative Carbon Emissions.

Lackner, a pioneer in the field of negative carbon emissions, has developed a device, called the 'MechanicalTree' that acts like a tree but is thousands of times more efficient at removing CO2 from ambient air. The MechanicalTree, which is being commercialized by Silicon Kingdom Holdings, Dublin, Ireland, allows the captured gas to be sequestered or sold for re-use in a variety of applications, such as synthetic fuels, enhanced oil recovery or in food, beverage and agriculture industries.

Sorbent materials to capture the carbon are at the heart of Lackner's device.

Unlike other carbon capture technologies, SKH's technology can remove CO2 from the atmosphere without the need to draw air through the system mechanically using energy intensive devices. Instead, the technology uses the wind to blow air through the system.

This makes it a passive, relatively low-cost and scalable solution that is commercially viable. If deployed at scale, the technology could lead to significant reductions in the levels of CO2 in Earth's atmosphere, helping to combat global warming.

More information

www.asu.edu

Capture and utilisation news

Nano-sponges of solid acid transform carbon dioxide to fuel

www.tifr.res.in

Researchers at the Tata Institute of Fundamental Research have developed nano solid acids that transform CO_2 directly to fuel (dimethyl ether) and plastic waste to chemicals (hydrocarbons).

Solid acids are among the most essential heterogeneous catalysts, which have the potential to replace environmentally harmful liquid acids in some of the most important processes, such as hydrocarbon cracking, alkylation, as well as plastic waste degradation and carbon dioxide to fuel conversion

Two of the best-known solid acids are crystalline zeolites and amorphous aluminosilicates. Although zeolites are strongly acidic, they are limited by their inherent microporosity, causing extreme diffusion limitation; and although aluminosilicates are mesoporous, they suffer from low acidity and moderate stability. Thus, it is a synthetic challenge to design and synthesize solid acids with both strong acidities like zeolites and textural properties like aluminosilicates, speculated as "amorphous zeolites," which are ideally strongly acidic amorphous aluminosilicates.

By using the techniques of bicontinuous microemulsion droplets as a soft template, Prof. Vivek Polshettiwar's group at Tata Institute of Fundamental Research (TIFR), Mumbai, synthesized amorphous zeolites with a nano-sponge morphology, exhibiting both zeolitic (strong acidity) and amorphous aluminosilicate (mesoporous high surface area) properties.

The presence of zeolite-like bridging silanol in AAS was proved by various catalytic reactions (styrene oxide ring-opening, vesidryl synthesis, Friedel-Crafts alkylation, jasminaldehyde synthesis, m-xylene isomerization, and cumene cracking), which requires strong acidic sites and larger pore sizes. The synergy between strong acidity and accessibility was reflected in the fact that AAS showed better performance than state-of-the-art zeolites and amorphous aluminosilicates. This was also confirmed by detailed solid-state NMR studies.

Thus, it was clear that the material possesses strongly acidic zeolite-like bridging silanol sites, even though materials are not crystalline but amorphous. Therefore, they fall into a new class of materials at the interface between crystalline zeolite and amorphous aluminosilicate.

Thus, the approach may allow the development of solid acid catalysis for plastic degradation as well as carbon dioxide to fuel at the significant rates, scales, and stabilities required to make the process economically competitive. The protocol has scientific and technological advantages, owing to its superior activity and stability.

The work is published in Nature Communications.

MIT develops CO_2-free hydrogen production system

energy.mit.edu/ccus

The Carbon Capture, Utilization, and Storage Center, one of the MIT Energy Initiative (MITEI)'s Low-Carbon Energy Centers, has awarded \$750,000 in funding to a new research project to advance technologies that avoid carbon dioxide emissions into the atmosphere and help address climate change.

The winning project, led by principal investigator Asegun Henry, the Robert N. Noyce Career Development Professor in the Department of Mechanical Engineering, and co-principal investigator Paul Barton, the Lammot du Pont Professor of Chemical Engineering, aims to produce hydrogen without CO_2 emissions while creating a second revenue stream of solid carbon.

Henry and Barton's project, "Lower cost, CO_2-free, H_2 production from CH_4 using liquid tin," investigates the use of methane pyrolysis instead of steam methane reforming (SMR) for hydrogen production.

Currently, hydrogen production accounts for approximately 1 percent of global CO_2 emissions, and the predominant production method is SMR. The SMR process relies on the formation of CO_2, so replacing it with another economically competitive approach to making hydrogen would avoid emissions.

"Hydrogen is essential to modern life, as it is primarily used to make ammonia for fertilizer, which plays an indispensable role in feeding the world's 7.5 billion people," says Henry.

"But we need to be able to feed a growing population and take advantage of hydrogen's potential as a carbon-free fuel source by eliminating CO_2 emissions from hydrogen production. Our process results in a solid carbon byproduct, rather than CO_2 gas. The sale of the solid carbon lowers the minimum price at which hydrogen can be sold to break even with the current, CO_2 emissions-intensive process."

Henry and Barton's work is a new take on an existing process, pyrolysis of methane. Like SMR, methane pyrolysis uses methane as the source of hydrogen, but follows a different pathway. SMR uses the oxygen in water to liberate the hydrogen by preferentially bonding oxygen to the carbon in methane, producing CO_2 gas in the process.

In methane pyrolysis, the methane is heated to such a high temperature that the molecule itself becomes unstable and decomposes into hydrogen gas and solid carbon — a much more valuable byproduct than CO_2 gas. Although the idea of methane pyrolysis has existed for many years, it has been difficult to commercialize because of the formation of the solid byproduct, which can deposit on the walls of the reactor, eventually plugging it up.

This issue makes the process impractical. Henry and Barton's project uses a new approach in which the reaction is facilitated with inert molten tin, which prevents the plugging from occurring. The proposed approach is enabled by recent advances in Henry's lab that enable the flow and containment of liquid metal at extreme temperatures without leakage or material degradation.

The project was selected from a call for proposals that resulted in 15 entries by MIT researchers. "The application process revealed a great deal of interest from MIT researchers in advancing carbon capture, utilization, and storage processes and technologies," says Bradford Hager, the Cecil and Ida Green Professor of Earth Sciences, who co-directs the CCUS center with T. Alan Hatton, the Ralph Landau Professor of Chemical Engineering.

"Given the short-term focus of the industry, a project like this might not have otherwise been funded."

Transport and storage news

Mitsubishi Shipbuilding to test world's first marine-based CO2 capture system

www.msb.mhi.co.jp

The world's first marine-based demonstration test of CO2 capture is to take place on "K" Line's coal carrier for Tohoku Electric as part of a Japanese Government initiative.

Mitsubishi Shipbuilding Co., Ltd., a part of Mitsubishi Heavy Industries (MHI) Group, is working in cooperation with Kawasaki Kisen Kaisha, Ltd. ("K" Line) and Nippon Kaiji Kyokai (ClassNK), to conduct test operations and measurements for a small scale ship-based CO2 capture demonstration plant, in order to verify the equipment's use as a marine-based CO2 capture system.

This project is being conducted with support from the Maritime Bureau of Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT), as part of its assistance project for research and development of technological advancements in marine resource development.

The demonstration involves converting the design of an existing CO2 capture system for onshore power plants to a marine environment, and installing it on board an actual ship in service. This project, called "Carbon Capture on the Ocean" (CC-Ocean), is intended to achieve CO2 capture at sea, a world first.

The project is planned to last for two years. In August 2020, with verification from ClassNK, a hazard identification (HazID) study will be launched for the design of the demonstration plant and the onboard installation. Manufacturing of the small scale CO2 capture demonstration plant and safety assessment of the system will be conducted by Mitsubishi Shipbuilding.

The demonstration plant will be manufactured in mid-2021, and following operational tests at the factory, will be installed on board a coal carrier for Tohoku Electric Power Co., Inc. operated by "K" Line. Through operational and performance confirmation in an actual marine environment, Mitsubishi Shipbuilding will then determine the system specification requirements as a marine-based device and will also consider how to make the plant more compact.

This demonstration experiment conducted at sea is the first of its kind in the world. The knowledge gained will be used for future development of technologies and systems to capture CO2 from the exhaust gases of marine equipment and ships. Further, the captured CO2 can be recycled for use as a new source of CO2 for enhanced oil recovery (EOR) processes, or as raw material in synthetic fuel, providing a significant contribution to reductions in greenhouse gas (GHG) emissions.

Mitsubishi Shipbuilding, amid rising awareness of decarbonization globally since the enactment of the Paris Agreement, has continued its efforts to find solutions for reducing GHG emissions from ships and marine equipment, and is contributing to environmental conservation.

Wyoming geophysical survey begins next stage in CCS project

www.uwyo.eddu

Work toward a commercial-scale geological carbon dioxide storage complex near Gillette will move to the next stage next week with a geophysical survey covering about nine square miles of rural land around the Dry Fork Station power plant.

Seismic source “thumper” trucks will begin covering the area Monday, Aug. 24, generating vibrations using a metal plate that is pressed to the ground and shaken side to side. The vibrations travel deep into the earth and are reflected back to the surface, where sensors record the reflected vibration to give geophysicists a more complete picture of the underground formations.

“We will use this survey to help evaluate the rock layers nearly 2 miles below the surface, develop more accurate computer models to simulate where injected CO2 might travel, identify potential risks, and determine the best location for injection and monitoring wells,” says Scott Quillinan, the project manager and the University of Wyoming School of Energy Resources’ (SER) director of research. “These benefits help the permitting authority decide whether the geologic storage project can move forward.”

UW, Basin Electric Power Cooperative and other partners are working to develop a site near Basin Electric’s 385-megawatt Dry Fork Station and the Wyoming Integrated Test Center to store over 50 million metric tons of CO2 underground. The three-year, $19.1 million project is the third phase under the Department of Energy’s Carbon Storage Assurance Facility Enterprise (CarbonSAFE) initiative, which seeks to help mitigate CO2 emissions from consumption of fossil fuels.

The geophysical survey, similar to many conducted across Wyoming by companies involved in hydrocarbon extraction, will involve four seismic trucks and sensors inserted into the ground every 220 feet along lines spaced 660 feet apart. At 220-foot intervals, the trucks will stop and vibrate the ground for one to two minutes.

A low-level noise similar to that of a passing truck is generated; a person standing 100 feet from the source will not feel the ground vibration. The trucks will not vibrate the ground within 300 feet of buildings and other infrastructure.

“Safety and courtesy are top priorities,” says Quillinan, who notes that landowners are being contacted to request permission to drive vehicles and place sensors on their land. “Care will be taken to avoid or minimize environmental impacts and maintain normal traffic flow. The goal is to complete the work with minimal disruption.”

Over the next three years, the project partners intend to conduct rigorous, commercial-scale surface and subsurface testing, data assessment and modeling; prepare and file permits for construction with Wyoming’s Department of Environmental Quality; integrate this project with a separately funded CO2 capture study by Membrane Technology and Research Inc. (MTR); and conduct the required National Environmental Policy Act analyses in support of eventual commercialization of the site.

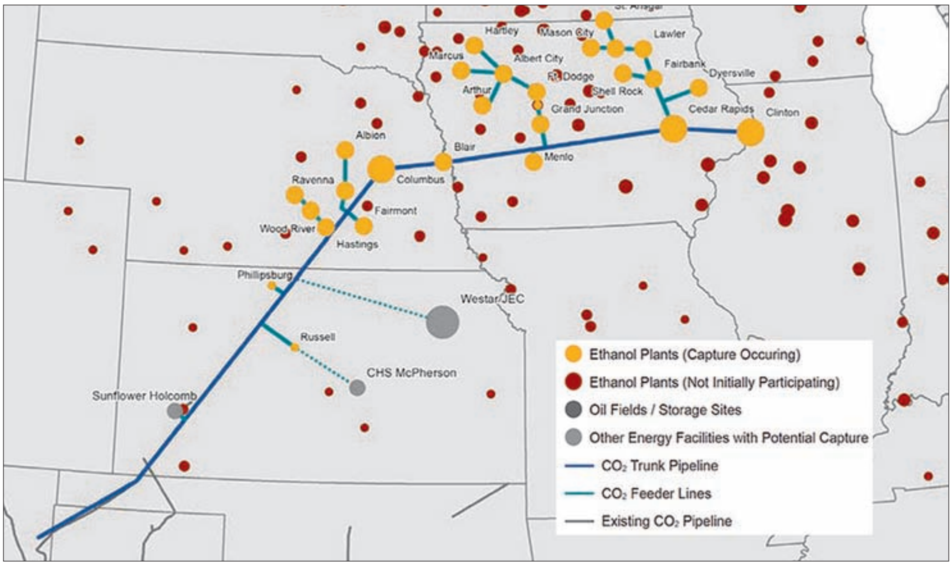
Joining SER’s Center for Economic Geology Research, Basin Electric and MTR as partners in the project are the Energy and Environmental Research Center; Advanced Resources International Inc.; Carbon GeoCycle Inc.; Denbury Resources Inc.; Los Alamos National Laboratory; Oxy Low Carbon Ventures LLC; and Schlumberger.

Other UW participants are the Enhanced Oil Recovery Institute, the College of Business and the College of Law.

Partnership established to research underground CO2 storage

The Carbon Utilization and Storage Partnership, or CUSP, is led by the Petroleum Recovery Research Center (PRRC) at the New Mexico Institute of Mining and Technology, which was awarded $6.24 million by the U.S. Department of Energy (DOE) for the project. www.kgs.ku.edu

For two decades, the Kansas Geological Survey has been investigating the state's subsurface geology and industrial infrastructure to determine the safety and viability of injecting carbon dioxide (CO2) from industrial sources into underground rock formations for long-term storage and to recover hard-to-reach oil.



A scenario showing placement of potential pipelines used to transport CO2 from ethanol plants to enhanced oil recovery projects (gray dots). Initially Ethanol production capacities range from 40 to 350 million gallons per year (small to large orange and red dots). Source: State CO2-EOR Deployment Work Group. Data from DOE, Great Plains Institute, and KGS.

As part of an initiative to share data and advance research on the process, the KGS is now partnering with 15 other state and federal entities from throughout the central and western United States.

The KGS will receive about $310,000 of the funding and could get additional funding for database development and other purposes as the project progresses through 2024.

"Nationwide, CCUS is moving ahead. There are multiple large-scale commercial project announcements and the portfolio is growing," said Eugene Holubnyak, petroleum engineer and the project's lead investigator at the KGS. "KGS has developed a very strong CCUS program on its own and this time around we want to play a central and integral role in CUSP."

The Osage, Viola, and Arbuckle Groups, porous rock formations that contain extremely saline water separated from shallower, freshwater aquifers by thousands of feet of impermeable rock, are the key targets for CO2 storage in western Kansas. Pore space in subsurface rock units has been used for more than a century for disposal of waste fluids produced through industrial processes, petroleum production, municipal water treatment, and other operations.

Over the past 10 years, the KGS has led or played a key role in five large-scale CCUS projects funded by DOE. Working with private partners, the KGS has successfully injected CO2 for Enhanced Oil Recovery in the Wellington Field in Sumner County south of Wichita and the Hall-Gurney Field in Russell County. During previous and ongoing projects, the KGS has amassed large quantities of seismic data, drilling data and rock cuttings, and drill cores - cylindrical segments of rock brought up intact from thousands of feet underground.

The KGS team is participating in all five CUSP focus areas - data management, data analysis, policy and law, economics, and outreach

"Currently, the KGS team is selecting database architecture to create an interactive, open-access dataset that will include subsurface, infrastructure, industrial, and other data," said Franek Hasiuk, KGS geologist and co-principal investigator at the KGS on the project. "It will include information from all CUSP member states, and possibly beyond, that will be very useful for CCUS projects, the oil and gas industry, regulators, and other stakeholders."

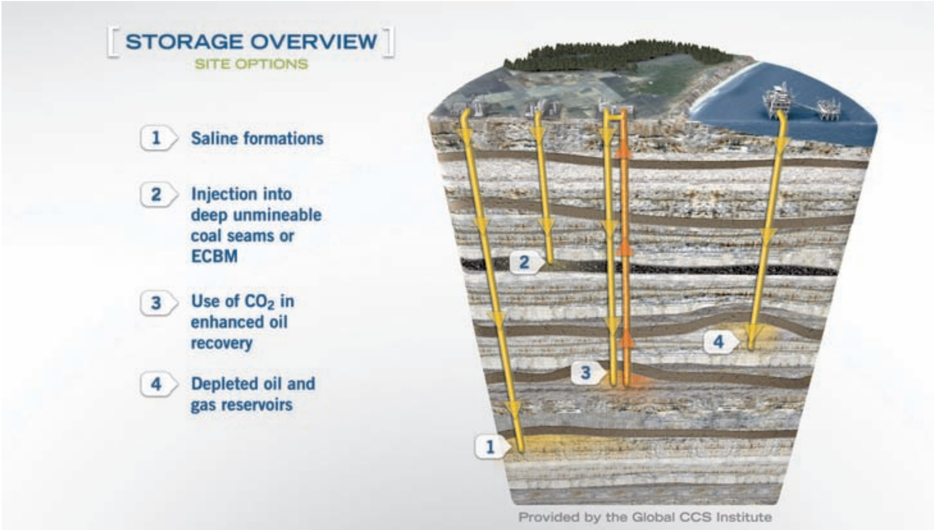
For long-term storage, CO2 is injected into UIC Class VI wells. The Safe Drinking Water Act, passed by Congress in 1974, established the requirements for the Underground Injection Control (UIC) program, which consists of six classes of wells designated for underground disposal of different levels of non-hazardous and hazardous waste.

"The KGS is helping well operators prepare sites to qualify for 45Q credits and apply for UIC Class VI permits", Holubnyak said. "We are working with developers to screen geologic sites for potential commercial projects."

The KGS also is working with the Los Alamos National Laboratories and other CUSP members on methods to analyze data that will provide a better understanding of local and regional infrastructure development potential, infrastructure costs, and ways to optimize future project development.

Scotland and Malaysia study highlights role of subsurface saline aquifers

A new study by scientists from Scotland and Malaysia has provided insights into the role of natural mechanisms within rocks deep below ground for securely storing anthropogenic carbon dioxide.



The study showed that saline formations can capture and store CO2 securely for thousands of years (Image provided by Global CCS Institute)

The team from the University of Edinburgh and Universiti Teknologi PETRONAS carried out a comprehensive review of past, recent and ongoing developments in CO2 storage in saline aquifers.

Their findings have boosted understanding of how different trapping methods can maximise the security and storage potential of any CO2 storage site, which will be of value to countries seeking to develop carbon capture and storage (CCS) projects.

CCS technology, if delivered at scale alongside other measures, can substantially reduce society's carbon emissions from different sectors, such as industry and power generation, and help tackle climate change.

The researchers studied the different ways that CO2 can become trapped within the pore space of rocks of aquifers considered ideal for carbon storage.

The CO2, once captured and injected into these saline reservoirs, will displace saline water and take its place within the tiny gaps between rock grains. An overlying caprock, which is impermeable to fluids, will then provide a permanent seal.

The greenhouse gas can also dissolve within the reservoir fluid – a mechanism known as solubility trapping – and, over a long period of time, can react with the rock and saline water to form new minerals, resulting in geochemical trapping.

In addition, as CO2 flows through the storage rock, some can become separated from the main flow and get left behind as disconnected droplets. This is known as residual trapping.

Dr Katriona Edlmann, Chancellor's Fellow in Energy at the University of Edinburgh said: "Our research provides further evidence that captured CO2 emissions can be stored securely for thousands of years in rocks deep underground. Commercial-scale CCS as part of a global transition to net zero carbon is moving even closer. Within the UK, that includes the establishment of the net-zero carbon industrial cluster in the Humber and the Acorn CCS project at St Fergus in north east Scotland."

Dr Jalal Foroozesh, Senior Lecturer in Chemical Engineering Department and Research Member in Institute of Hydrocarbon Recovery at Universiti Teknologi PETRONAS, said, "With real concern currently on the global warming issue due to CO2 as one of the main greenhouse gases, subsurface CO2 storage as a part of CCS technology offers a practical solution to reducing the concentration of anthropogenic CO2 in the atmosphere."

"Although other subsurface geological formations, such as depleted hydrocarbon reservoirs, are available for underground trapping of CO2, saline aquifers have attracted more attention due to their large storage capacities and rock properties that allow high injectivity of CO2. Our review summarises the key technical and economic parts of CO2 storage projects in subsurface aquifers that can help engineers and scientists with better planning and designing and also assist managers in making better business decisions on such projects."

The study, published in the Journal of Natural Gas Science & Engineering, was supported by the research project under Yayasan Universiti Teknologi PETRONAS (YUTP). It is available for free until 15 August 2020.

More information

www.sccs.org.uk


CMC