Carbon Capture Journal

CCUS in Canada

Delta CleanTech: Canada driving innovation in emissions reduction

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Shell's new large-scale CCS project in Alberta

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- VSA, membrane and PSA tech for steam methane reforming CO2 capture

Electrification not enough to meet net zero target: DNV

Hard-to-decarbonize sectors - heavy industry, shipping, trucking and aviation - need significant research, development and investment now warns DNV's Energy Transition Outlook 2021.

A new forecast of the energy transition from DNV has warned that even if all electricity was 'green' from this day forward, the world will still fall a long way short of achieving the 2050 net zero emissions ambitions of the COP21 Paris Agreement.

DNV's Energy Transition Outlook, now in its fifth year and launched two months before COP26 takes place in Glasgow, provides an independent forecast of developments in the global energy system to 2050.

The 2021 report highlights the global pandemic as a "lost opportunity" for speeding up the energy transition, as Covid-19 recovery packages have largely focused on protecting rather than transforming existing industries.

Electrification is on course to double in size within a generation and renewables are already the most competitive source of new power however, DNV's forecast shows global emissions will reduce only 9% by 2030, with the 1.5˚C carbon budget agreed by global economies emptied by then.

The COP21 Paris Agreement was intended to keep global warming to "well below 2˚C" and strive to limit its increase to 1.5˚C. DNV has been consistent in forecasting a rapid transition to a decarbonized energy system by mid-century.

As rapid as that transition is, DNV's forecast is that despite every effort being made, it remains definitively not fast enough for the world to achieve the ambitions of the Paris Agreement and warns the planet will most likely reach global warming of 2.3˚C by end of the century.

Remi Eriksen, Group President and CEO of DNV, said, "We've seen governments around the world take extraordinary steps to manage the effects of the pandemic and stimulate a recovery. However, I am deeply concerned about what it will take for governments to apply the resolution and urgency they have shown in the face of the pandemic to our climate. We must now see the same sense of urgency to avoid a climate catastrophe."

"Many of the pandemic recovery packages have largely focused on protecting, rather than transforming, existing industries. A lot of 'building back' as opposed to 'building better' and although this is a lost opportunity, it is not the last we have for transitioning faster to a deeply decarbonized energy system."

Reductions in the use of fossil fuels have been remarkably quick however these sources, especially gas, will still constitute 50% of the global energy mix by 2050 – making the need to invest in and scale hydrogen, and carbon capture and storage all the more important. Oil demand looks set to halve, with coal use reduced to a third by mid-century.

ETO 2021 also reveals that while 69% of grid-connected power will be generated by wind and solar in 2050, and indirect electrification (hydrogen and e-fuels) and biofuels remain critical, none of these sources are scaling rapidly enough.

Hydrogen is the energy carrier that holds the highest potential to tackle hard to abate emissions however, our forecast indicates hydrogen only starting to scale from the mid-2030s and, even then, only building to 5% of the energy mix by 2050.

"Extraordinary action will be needed to bring the hydrogen economy into full force earlier - but these are extraordinary times. The window to avoid catastrophic climate change is closing soon, and the costs of not doing so unimaginable.", says DNV's Group President and CEO Remi Eriksen.

DNV perspective on CCS

CCS uptake will be very limited in the near to medium term says the report, and effectively too late and minimal in the longer term. It is only in the 2040s, when carbon prices start to approach the cost of CCS, that deployment begins at scale. By 2050, total carbon capture will amount to just 6% of all annual energy-related emissions.

CO2 capture technologies are mature and commercially available for large scale projects in all industrial sectors, finds DNV in its separate Technology Progress report. Within the next decade, additional capture processes will reach commercial maturity. Capture costs, not technology, remain the major limitation for CCS implementation.

Developing transport infrastructure and qualifying storage sites, is key to enabling CCS. In the coming years the development of CCS value chains is mainly expected in Europe which already has tailored regulations for CO2 storage as well as a favourable financial and political support.

Atmospheric CO2 removal has limited application but can be accelerated by deploying BECCS at significant scales if supported by appropriate policies and certified offsetting methodologies. With the exception of EOR applications, CCU needs to develop commercially and technically before it can apply at significant scale (i.e. >500 kt/yr) to more than a few specific applications; for this reason it is not expected to be a major contributor to cutting CO2 emissions in the short term.

CCS is growing at faster pace thanks to favourable conditions. However, the pace is not fast enough for a Paris-compliant energy future; that will require much more robust carbon pricing and other incentives at a global level. With the right support, CCS will be able to play the necessary role it has to aid the transition to a net-zero energy system.

More information

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Leaders - CCUS in Canada

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Front and back covers:

STRYDE nodes being deployed at CMC's Field Research Station in southern Alberta. Carbon Management Canada, STRYDE, and Explor recently collaborated to demonstrate the suitability of STRYDE nodes and Explor's Pinpoint® source technology for CCUS operations (pg. 6)

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Delta CleanTech: how Canada is driving innovation in emissions reduction

Canada has set an ambitious target for emissions reduction and implemented an aggressive regulatory regime to support this goal. The current objective is to slash emissions 30% by 2030, to levels below what they were in 2005. To incentivize this, Canada's carbon tax is planned to increase to $170/tonne by 2030. By Jeff Allison, President, Delta CleanTech Inc.

The carbon tax is established as a federal floor nationally, but individual provinces have the authority to tax carbon more aggressively should they elect to do so. Due to this planned increase, it is increasingly important to adopt a CO2 emissions reduction strategy for any large CO2 emitter in Canada.

Both the federal and provincial governments have also established CO2 grants funded from those carbon taxes that will be used to reduce the cost of the capital expenditure (CapEx) of CO2 capture projects.

The Canadian Minister of Natural Resources announced in August 2021 that the federal budget will include $319 million in R&D money for carbon capture and utilization technology investments.

Further driving this shift is increased interest in environmental, social, and governance (ESG) which has also grown in importance to companies, investors, and consumers. ESG is focused on finding financial opportunities that take into account the ethical impact and sustainability of the project.

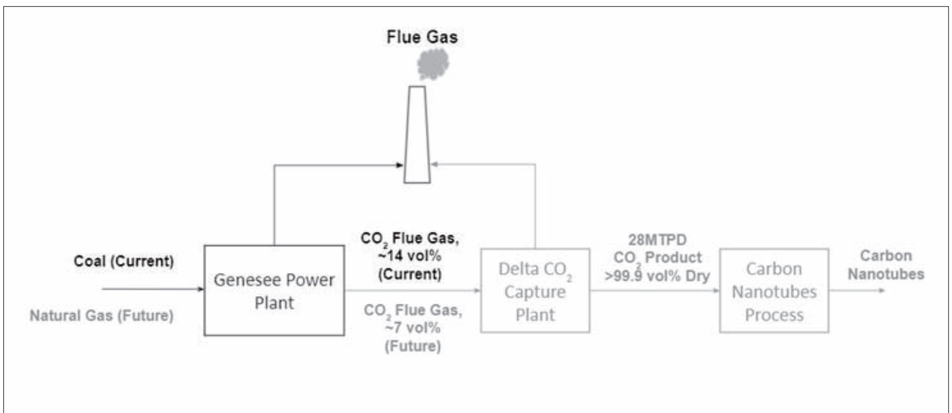
A March 2021 report from EY highlighted that 2019 saw a record inflow into ESG funds, up 4x from 2018. 2020 levels then further increased again to twice that of 2019 levels.

The Greenhouse Gas Reporting Program (GHGRP) in Canada estimated that there are 1,066 emitters that produce 10 to 50 kt of CO2 per year, meaning that in Canada alone, there could be north of $32 billion of investment in carbon capture technology in the coming years.

Coal-fired power plants are heavy emitters, and at present, there are four provinces that operate these plants: Alberta, Saskatchewan, New Brunswick, and Nova Scotia. Stricter emissions requirements over the next few years will eventually require coal-fired power plants to be shut down or be retrofitted with carbon capture and storage technology. In Alberta, most coal plants are projected to be converted to run on natural gas.

Delta CleanTech's off-the-shelf oilfield technology, fabricated in a factory setting, is used to reduce CapEx costs and enable a quick set-up, while also easing the transition from coal to natural gas.

Jeff Allison, President, Delta CleanTech Inc.



Delta CleanTech designed a a flexible CO2 capture plant able to accommodate variable CO2 contents and flue gas rates for Capital Power – a world first

Recent Project: Dual-Design of Delta CleanTech CO2 Capture Plant to store CO2 Permanently with Nano Carbon-Tubes

Capital Power is a growth-oriented North American wholesale power producer with a strategic focus on sustainable energy headquartered in Edmonton, Alberta. It builds, owns, and operates high-quality, utility-scale generation facilities that include renewables and thermal.

They have also made significant investments in carbon capture and utilization to reduce their impact and are committed to being off coal in 2023.

Capital Power sought to utilize its captured CO2 to make carbon nanotubes, which can be added as an additive to cement to enhance its strength and other properties or be used in advanced carbon fibers.

However, the company sought a flexible CO2 capture plant that could both accept the current flue gas from its coal-fired power plant, while also being able to be configured to easily accept the future flue gas from the natural gas firing once implemented.

Delta's modularly designed, commercially ready, CO2 capture unit

Delta CleanTech has approached this problem by providing its Low-Cost Design Post-Combustion CO2 capture technology (LCDesign®).

To achieve the same CO2 production capacity, the challenge lies in how to deal with the different compositions of each flue gas. The coal-fired flue gas has a high CO2 concentration, which means that the required flue gas volume would be small, while the natural gas-fired flue gas has a smaller CO2 concentration, making the required flue gas volume three times higher than in the coal case.

Delta CleanTech used multiple design tools including its process design PDOEngine® to invent a solution that is able to accommodate both scenarios of variable CO2 contents and flue gas rates. This is the first design of its kind with this functionality in the world.

With this technology, both plants can match the operating data with less than ±5% average absolute deviation. The plant will process a slip stream from the flue gas stream and then send the off-gas back to the flue gas stack while the captured CO2, which contains more than 99.9 mol% dry, which is suitable for manufacturing carbon nanotubes.

A detailed design engineering study is currently being carried out and it is expected to be operational in 2022.

An August 2021 Market Research Future report forecasted that the carbon nanotube market alone could be worth nearly $19 billion (USD) by 2028.

Captured CO2 would traditionally be used for enhanced oil recovery, sequestration, chemicals manufacturing (i.e. urea), or on a smaller scale, used for dry ice or food-grade CO2 utilizations. But today, many new technologies have emerged to utilize captured CO2, such as the production of methanol/ethanol, the injection of CO2 into concrete to make it lighter and stronger, the production of bioplastics, and more.

Applications for Sequestered CO2: COSIA Carbon XPrize competition

Delta CleanTech was selected to supply captured carbon to participants in the NRG COSIA Carbon XPrize competition, which recently named CarbonCure out of Nova Scotia, as the competition winner. That five-year global competition challenged companies to develop breakthrough technologies to transform carbon emissions into usable products.

The competitors were judged on how much carbon they used and the resulting net value of the products created. CarbonCure injects captured CO2 during concrete fabrication to chemically convert it to a mineral. Its technology is in use at more than 300 plants around the world.

The installation of Delta CleanTech's technology for this project occurred at the Enmax Sheppard natural gas-fired power plant in Calgary, Alberta. Delta Cleantech's construction partners built and commissioned the CO2 capture plant which included integrated solvent reclaiming technology. This plant was the first in the world to be recognized ISO Certified for its process design and technology solutions.

Delta's post-combustion CO2 capture technology has been perfected over the past 15 years and is considered to be a cutting-edge, commercially available carbon capture technology that can handle any kind of flue gas – from natural gas turbines to coal plants, and from hydrogen-generating units to refineries.

Delta CleanTech also recently completed a highly-anticipated listing on the Canadian Securities Exchange (CSE: DELT). The clean energy investment community is recognizing the value that Delta CleanTech is bringing to the CO2 capture market globally.

More information

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Canada leans on industry in its design of CCS tax credit

Canada, one of the first countries to throw support behind large-scale carbon capture, utilization, and storage (CCUS/CCS), had been relatively silent over the last number of years - though recently the country signaled a renewed focus on the technology to help meet its global commitment to target emissions reductions 40-45% below 2005 levels by 2030[i].

September saw a wrap up of a broad reaching consultation process conducted by the federal government – asking for input in Canada's proposed investment tax credit (ITC) for capital invested in CCUS. The country pointed to the need for the ITC to support technological advancement, lower its costs, and make sure Canada stays ahead of the curve in the global market for CCUS. Interest is keen with a declared access to the ITC to start as early as 2022.

While the results of the consultation process and its translation into policy have yet to be released, the International CCS Knowledge Centre, based in Saskatchewan, Canada (home of the famed Boundary Dam 3 CCS Facility) worked closely with industry, governments, and other organizations to provide input into the process.

"We are big supporters of CCS as one of major contributors to see significant emissions reductions and so we are encouraged by the signals in Canada to see funds allocated to bridge the gap from concept to operation," says Beth (Hardy) Valiaho, VP Strategy & Stakeholder Relations at the International CCS Knowledge Centre.

For context, for Canada to reach their net zero targets, 7.2 million tonnes (Mt) of carbon dioxide (CO2) would need to be captured and permanently stored by the year 2030 with an acceleration to 127 Mt by 2040 and then to 309 Mt by 2050[ii].

With still only a few commercial iterations of large-scale CCUS in operation, costs remain a hurdle. A market barrier exists currently between the price of carbon and the price of a CCS facility. Canada's ITC could act as a bridge by offsetting the large upfront capital costs required to get projects off the ground. "It's important that funds from the ITC be first awarded to entities outlaying the capital for the CO2 capture facility at the front end where emissions are captured," says Valiaho.

Canada has existing mechanisms, such as through the Canadian Infrastructure Bank or its Strategic Innovation Fund that could also be considered for CO2 transportation and storage stages of a full chain CCS program; and if these mechanisms are not available, then the ITC could be relied upon as a backstop program.

The US's 45Q – which is a production tax credit -is associated solely with the sequestration and final phase of CCS – once the CO2 is permanently stored in the ground. With 80 percent of the cost of full-chain CCS taking place with the capital intense capture process – and 10 percent to each transport and storage, industry in Canada is seeking the removal of the barrier at the front end. "It is essential to maximize emissions reduction potential in step with available dollars," says Valiaho.

A critically important element in supporting an entity to get to a final investment decision is the front-end engineering and design (FEED) study. This key piece is a comprehensive evaluation and analysis that provides certainty and minimizes risk. FEEDs can cost up to 5% of a project and need to be completed in advance of a final investment decision. "Essentially a FEED enables the go / no-go decision to deploy a large-scale project," says Valiaho, "We'd like for governments to recognize this and consider supporting project advancement with funds for FEED-based work."

Additionally, industry wants to ensure that there won't be a cap on either the dollars to support carbon capture or on the goal of number of emissions to be captured (striving past the federal government's proposed 15 Mt floor to 70 Mt or beyond). It's a lesson from the US's 45Q - once the cap was reached, organizations stopped applying.

In an accelerated timeline, it would take six years for large-scale CCUS projects to get from concept to operation and into maintenance and future optimization. "While all projects should be eligible for the ITC, immediate attention ought to be given to fast-track those projects that are in an early mover stage," says Valiaho. "This would provide both an injection of operational benefits for the economy as well as momentum toward having large reductions of emissions by 2030 – we can't see the delays we saw in the US for 45Q."

Essentially a three tracked approach is an ideal way to deploy CCS in Canada before 2030, and out to 2050, with the incentive boost from the ITC. Fast tracking early movers could coincide with support for two other tracks to see Canada establish an enriched CCUS program. These include seeing the tax credit assigned for projects with final investment decisions by the year 2030 in order to incent projects to occur in the nearer term, as well as support for ongoing research and development for Canadian grown technology to take hold in the further term, as the third track.

"We are hopeful that a strong and reliable ITC in Canada will provide greater certainty, increase value, and reduce risk in projects," says Valiaho, "With these in place they'll act to leverage greater private investment, increase future deployment, and most critically, aim to reduce even more emissions."

More information

ccsknowledge.com

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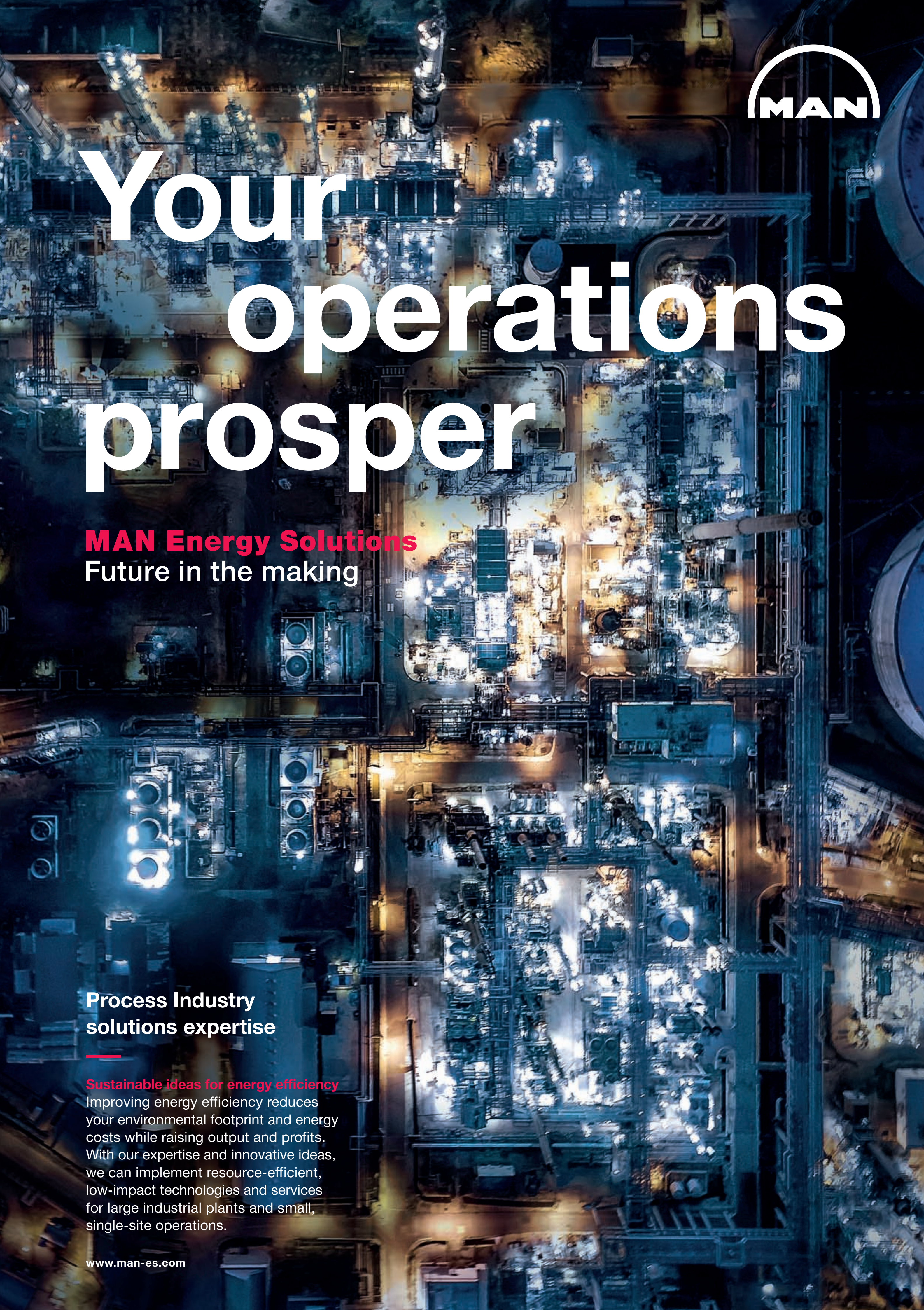
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Light, portable, cost-effective: new seismic technology changes the game

A new seismic technology is proving to be faster, more accurate and easier to deploy than traditional seismic source and sensor systems that require large vibe trucks and kilometers of cable.

Carbon Management Canada, STRYDE, and Explor recently collaborated to demonstrate the suitability of STRYDE nodes and Explor's Pinpoint® source technology for carbon capture, utilization, and storage (CCUS) operations. In the process the partners also set a new global record in land seismic trace density at CMC's Field Research Station in southern Alberta.

According to Carbon Management Canada's scientific director Don Lawton, this new technology provides a more accurate picture of the CO2 stored underground.

"This is a really important technology for the type of work we're doing here. We're developing monitoring technologies to verify the secure storage of CO2. In our case, we're just doing carbon storage and so when we inject CO2 underground, we change the properties of the rocks a little bit and we can see that change by seismic measurements," he said.

"It's very subtle so we need very detailed seismic methods to be able to see the differences because what we want to do is to be able to know where the CO2 is going underground and verify that it's staying where we think it's going."

STRYDE nodes and Explor's PinPoint source were used to map out and monitor the subsurface for CO2 injection without the need for clearing the area or compromising on data quality. The one km2 field test has delivered a new world record of over 256 million traces/km2.

"We did what we call a baseline seismic survey here in 2014 which was at that time an industry standard project where we have about 1,400 geophones laid out and 1,400 source points over one km2," said Lawton. "In this new survey, we've got 20,000 receiver nodes and 20,000 source points so that increase in trace density allowed us to get very, very high-resolution data to enable us to track where the CO2 is going and provide a much clearer picture of what's happening underground."

Carbon Management Canada's Field Research Station in Alberta

Subsurface monitoring is critical to the secure operation of any CCUS facility but faces several challenges, including cost and space. As storage projects are usually built near existing infrastructure, subsurface image quality is hampered by the constraints of costly and cumbersome legacy seismic acquisition technology and methods. As a result, many CCUS projects struggle to produce high-quality subsurface imaging due to the wide spacing between seismic nodes and constraints over source positioning.

"With a greater magnitude and greater trace densities than what we've seen previously we are very excited about the technology that's being demonstrated," said Lawton. "This is a game changer in many ways partly due to the flexibility of these nodes. It enables us to put them in complex areas. We have here an open field, but you could use this technology in other industrial CCUS operations."

Allan Châtenay, President of Explor, added that the technologies could be easily deployed in different settings because of their portability.

"The other thing that we got here is everything is person portable. Everything we're doing here at the FRS, we can do in uncut boreal forests, and we can do it without preparing conventional wide seismic lines," said Châtenay. "Our collaboration with STRYDE and Carbon Management Canada is changing the game for subsurface imaging in support of CCUS, and we are proud to have achieved trace density 2.5 times the previous Canadian record. We are delighted with the performance of our next generation PinPoint system, which weighs less than two kilograms and can fit in your pocket. The agility and cost-efficiency of this system are driving a step-change in imaging the subsurface and sets a new benchmark for what can be achieved for CCUS."

Carbon Management Canada, STRYDE, and Explor plan to make data from the demonstration project available under a no-cost license to academic institutions to help drive scientific research and technology development. Datasets will also be available to license for companies who are considering CCUS.

"We believe that CCUS has a huge role in enabling the world to tackle global CO2 levels. Put simply, we are making high-density seismic acquisition accessible for CCUS developers, which will help drive the uptake of this crucial technology," said STRYDE CEO Mike Popham.

More information

www.cmcghg.com
www.strydefurther.com

Alberta – a renewed momentum for CCS in Canada

If you are looking for a country with a critical mass in creators in large-scale carbon capture, utilization, and storage (CCUS/CCS) technologies – look to Canada says Beth (Hardy) Valiaho, Vice President Strategy & Stakeholder Relations, International CCS Knowledge Centre

Canada can boast decades of experience right through and along the full chain, including innovative advancements and commercial operation in carbon dioxide (CO2) capture, pipelining, use, and permanent, safe geological storage and more recently, innovations direct air removals.

With a renewed momentum and drive for emissions reductions nationally and globally, much of this activity in centred across the vast province of Alberta – which is positioning itself as a world leader in CCS with the potential to see that realized in the very near future.

Alberta relies on revenues from large industries – they are the backbone of the province's economy. On the flip side, with 70 percent of emissions coming from these sectors, Alberta's economic identity is tied to the province's large emissions profile[i].

In contrast, the industrial sector in Canada contributes approximately 36 percent of the country's total emissions. So, Alberta is primed to take action and is doing so with both a sense of urgency as it leans on Canada's formidable expertise in CCS.

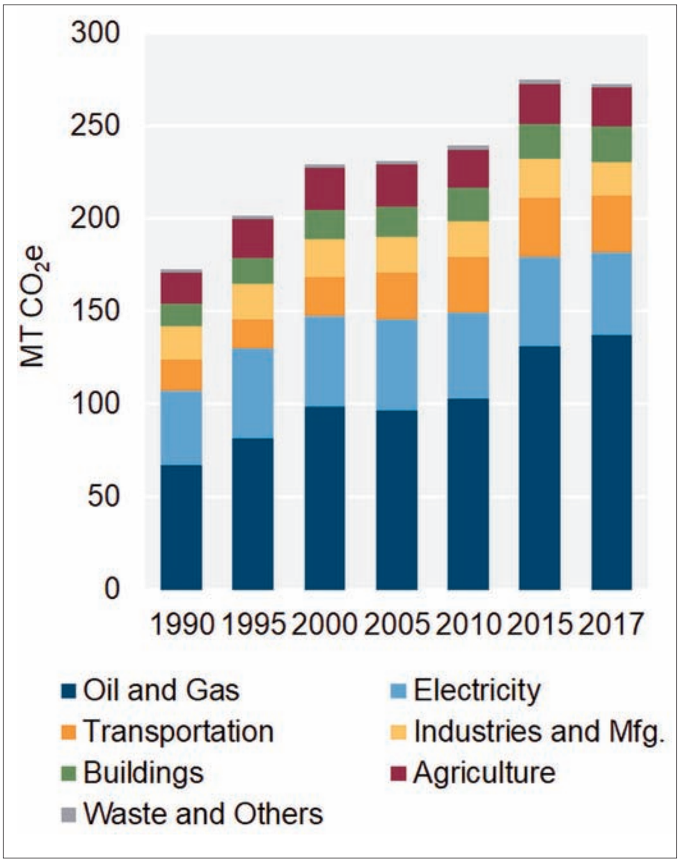
Alberta's $30B ask for their next 30Mt

In the spring, Alberta underscored their commitment to Canada's ambitious 2030 and 2050 targets by publicly announcing they would substantially reduce the province's major sources of industrial emissions with large-scale CCS. The goal is to double their already ongoing emissions reduction contribution of 30 million tonnes (Mt) to 60Mt or more with a pitch for a CDN$30 billion investment from the Canadian federal government.

This money will likely be made available through funding program such as the Strategic Investment Fund, Canadian Investment Bank, and/or Investment Tax Credit and accessible to all provinces.[ii]

The two levels of government (federal and provincial) have now established a bilateral working group to jointly "leverage Alberta's early CCUS leadership to advance climate goals, attract project investments and support economic recovery and future prosperity".[iii]

Jointly the group will determine avenues to leverage value from existing mechanisms and construct financial structures that integrate or stack other investment options. This would support CCS project advancement in Alberta by maximizing funds from both levels of government, streamlining processes, addressing duplications, and reducing administrative burdens.



GHG emissions in Alberta by sector, 1990 - 2017

This stacked column graph shows GHG emissions in Alberta by sector every five years from 1990 to 2017 in MT of CO2e. Total GHG emissions in Alberta as of 2017 was 273 MT of CO2e

Source: Environment and Climate Change Canada -National Inventory Report

The positive ripple effect of CCS investment for communities and economies is substantial. The construction and development of only three CCS projects in Canada would directly generate nearly CDN$1.1B in GDP; roughly CDN$2.7B in when taking into consideration indirect and induced effects over the construction horizon; and support over 6,100 jobs across Canada[iv].

i. Environment and Climate Change Canada. National Inventory Report

ii. CBC (March 2021) Alberta asks federal government to commit $30B to advance carbon capture technologies

iii. Government of Canada. Canada and Alberta Launch Steering Committee to Advance CCUS - Canada.ca

iv. International CCS Knowledge Centre (2020) Incentivizing Large-Scale CCS in Canada

With at least 30Mt on the table, that number would multiply, potentially by a factor of 10. So, with the CDN$30B ask by Alberta injected into large-scale CCS, the return on investment would not only prevents megatonnes of CO_2 emissions into the atmosphere, but it would also have significant ripple effect for the Alberta and Canadian economies.

CCS on a Roll in Alberta

While Alberta has a long history in CCS technology stemming from oil and gas, it also has a unique broad sector approach to emissions reductions in working with large emitters (refineries, fertilizer plants, cement plants, etc). There are many available emission reduction pathways in Alberta, with CCS being just one of those avenues – but one with immense potential for the future.

Two existing projects that stand out among Alberta's largest emission reduction projects are Quest and the Alberta Carbon Trunkline (ACTL). Operating since 2015, Quest captures and sequesters 1Mt CO_2 annually. Operating since 2020, ACTL has a 14.6Mt CO_2 pipeline capacity - designed as a trunkline connecting and transporting infrastructure for captured CO_2 to move from point sources to sinks in a hub.

Sinks are the deep geological formations that are well suited for safe, permanent sequestration of CO_2. Alberta is blessed with an abundance of them. In fact, between Alberta and Saskatchewan, there is almost 400Gt of storage potential[v]. With a motivated industrial sector willing to capitalize on bringing together their needs and cluster infrastructure into hub opportunities, Alberta is on the cusp of a new wave of full chain CCS.

Recently five Alberta companies which account for 90% of Canada's oil sands production committed to a joint strategy to reach net zero gas emissions by 2050.[vi] With a 3-phased approach to reducing emissions of 68Mt per year by 2050, the first phase includes a major CCUS trunkline connecting oil sands facilities to a carbon sequestration hub, with phased expansion capability to gather captured CO_2 from more than 20 oil sands facilities and available to other industries.[vii]

Some of the additional encouraging signals of CCS projects in Alberta include announcements, such as: the Lehigh CCS Feasibility Study, in partnership with the International CCS Knowledge Centre and funding through Emissions Reduction Alberta, completing an examination of carbon capture on the process emissions from the Lehigh cement plant (to be published October 2021);[viii]

Shell Canada's Polaris project, looking to collect CO_2 emissions from its refinery and chemical facilities;[ix] Pembina and TC Energy partnership to construct a pipeline, referred to as the Alberta Carbon Grid with a capacity to transport 20Mt of CO_2 per year;[x] and, Air Products goal to construct a net-zero hydrogen energy complex.[xi]

Policy and Regulatory Framework Promotes Certainty

The depth of experience in the application of CCS in Alberta expands beyond the companies that build and operate facilities to include the tried-and-true practices and guidelines that are necessary for safe and fair operations. Alberta has put in place policy and regulatory frameworks that ensure public interest and assurance as well as environmental sustainability.

This includes well established regulations and practices for measuring, monitoring and verification, rules for long-term liability, and the establishment of a carbon capture fund with required knowledge sharing criteria.

These frameworks also improve the confidence and certainty of investors. An example is the Technology Innovation Emissions Reduction (TIER) regulation.

The TIER implements Alberta's industrial carbon pricing and emissions trading system and helps industrial facilities find innovative ways to reduce emissions and invest in technology to stay competitive and save money.

There is also a proposed Carbon Sequestration Tenure Management framework where the government of Alberta intends to give carbon sequestration rights through a competitive process to strategically store CO_2 in various storage hubs – as opposed to one-off sequestration projects (this process will not limit or apply to the current process for enhanced oil recovery permitting).[xii]

The intent of this framework is to provide confidence to industry investors (and Albertans) that captured CO_2 will have a place to be sequestered at an open access basis and at a fair service rate with the operator managing credits and monitoring criteria.

Alberta's Offerings in the Global CCS Space

The momentum and clear direction of development for CCS in Alberta coupled with its substantial experience in operation, regulatory know-how, and hub opportunities make the province a good model for other regions.

This is an inspiration within Canada, and Alberta's lessons offer a springboard for further advancements in CCS, and therefore large emissions reductions, in the near-term at the global level.

More information

Beth (Hardy) Valiaho is the VP of Strategy & Stakeholder relations at the International CCS Knowledge Centre. She has been working intimately with the province of Alberta on its plans for CCS on behalf of the Centre. Beth currently sits on 5 different CCS working groups in Canada amongst government officials, businesses, NGOs, and industry associations.

ccsknowledge.com

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vi. Oil Sands Pathway to Net Zero
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x. TC Energy (June 2021) Pembina and TC Energy Partner to Create World-Scale Carbon Transportation and Sequestration Solution: The Alberta Carbon Grid
xi. Air Products (2021) Air Products Announces Multi-Billion Dollar Net-Zero Hydrogen Energy Complex in Edmonton, Alberta, Canada
xii. Carbon capture, utilization and storage – Overview | Alberta.ca

Shell proposes large-scale CCS project in Alberta

The proposed Polaris CCS project, the largest in a series of low-carbon opportunities Shell is exploring at Scotford, would capture CO2 from the Shell-owned Scotford refinery and chemicals plant.

The initial phase is expected to start operations around the middle of the decade, subject to a final investment decision by Shell expected in 2023. Polaris would have storage capacity of about 300 million tonnes of CO2 over the life of the project.

“Shell is making bold moves to decarbonize our operations, and wider industry, and the Polaris CCS project is the latest example,” said Susannah Pierce, Shell Canada President and Country Chair.

“Our plans for Scotford are in line with Shell’s target to become a net-zero emissions energy business by 2050, in step with society. We are creating a world-class site that will provide customers with lower-carbon fuels, products and CO2 storage. Polaris would also make a significant contribution to Shell’s aim to have access to an additional 25 million tonnes a year of CCS capacity by 2035.”

The Polaris CCS project follows the success of the Quest CCS facility at Scotford, which has captured and safely stored more than six million tonnes of CO2 in its six years of operation. Recently, Shell has also taken a final investment decision on the Northern Lights CCS project in Norway and is part of the Porthos CCS project in the Netherlands.

"Our government is committed to developing carbon capture, utilization and storage (CCUS) to help reduce emissions and capitalize on emerging economic opportunities,” said Sonya Savage, Alberta Minister of Energy. “Projects like Shell’s Polaris CCS show that Alberta is open for business and our oil and gas industry confidently looks to be a global player in a low-carbon future.”

The initial phase of the Polaris CCS project would capture and store approximately 750,000 tonnes a year of CO2 from the Scotford refinery and chemicals plant. It would reduce Shell’s direct and indirect emissions (Scopes 1 and 2) by up to 40% from the refinery and by up to 30% from the chemicals plant. It would also create up to 2,000 jobs.

CO2 emissions captured from the first phase of Polaris CCS would be transported via a 12-kilometre pipeline to storage wells located near Josephburg, Alberta. There, CO2 would be stored more than 2 km underground in the Basal Cambrian Sands, the same formation used to store CO2 from the Quest CCS facility. This formation, which stretches across much of Alberta, has worked exceptionally well for Quest's CO2 storage, the company said.

Aerial view of the Scotford upgrader, site of the Quest CCS project which has successfully captured and stored more than 6 million tonnes of CO2 since 2015

In its first phase, Polaris would capture more than 90% of the CO2 emissions related to hydrogen production in the Scotford refinery hydrogen plants. The project is designed in a way that no additional freshwater resources are required for the operation of the facility.

The second phase of the Polaris CCS project involves the creation of a CO2 storage hub in Alberta, further decarbonizing Shell’s facilities and storing emissions on behalf of third-party industry sources as a trusted and reliable CO2 storage operator. Fully built, and contingent on acquiring pore space leases from the Province of Alberta, Polaris could serve as a CO2 storage hub for more than10 million tonnes of CO2 each year.

Once fully built, Polaris would contribute to the Edmonton region becoming Canada’s first hydrogen hub. In the initial phase of Polaris, CO2 captured from the refinery’s hydrogen plants would produce blue hydrogen for use in the refining process, with the potential for large-scale blue hydrogen production in future phases. Shell is also exploring the development of additional volumes of blue and green hydrogen at Scotford that leverage Alberta’s abundance of natural gas and availability of renewable sources of power.

Worley wins engineering contract

The company will provide preliminary front-end engineering and design services for Shell Canada's proposed Polaris CCS project.

“Delivering a more sustainable world for our customers is at the core of everything we do. Working with Shell Canada on its Polaris CCS project reinforces our commitment to helping our customers navigate the energy transition. And underpins our position as industry leaders in low-carbon fuels and decarbonization.” said Karen Sobel, Group President, Americas at Worley.

More information

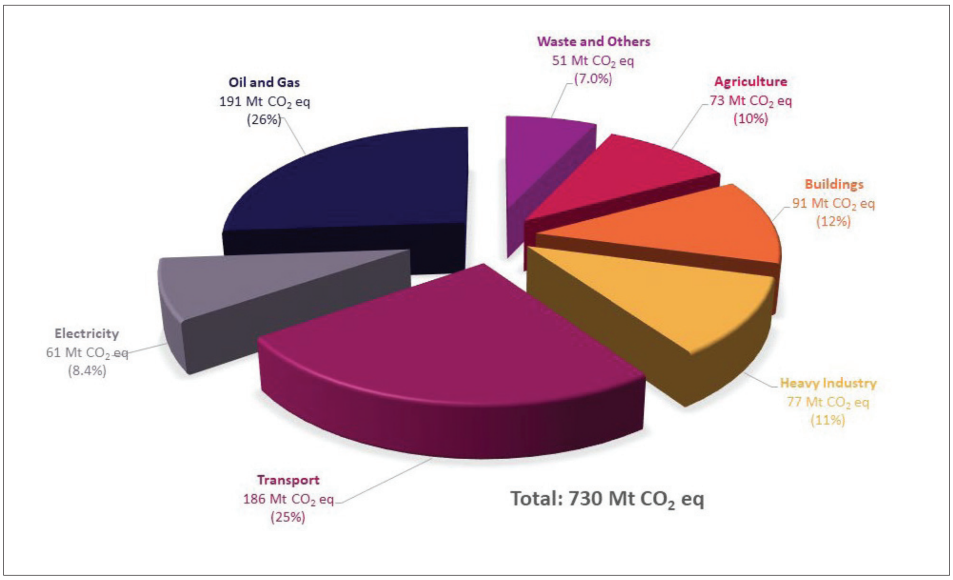
www.shell.ca

www.worley.com

Canada's landscape – CO2 sources and sinks

In April 2021, the International CCS Knowledge Centre published a report, "Canada's CO2 Landscape: A guided map for sources and sinks," which looked at Canada's large point sources and the location of "sinks" that will absorb the carbon dioxide or put it back into the ground.

The impact of anthropogenic greenhouse gas (GHG) emissions and the sources of those emissions is a hot topic among environmental think tanks and NGOs, governments, industry, and communities as the world looks at building a climate action strategy. As any nation looks to reduce its emissions, understanding the connection between its sources and sinks is a vital combination for the application of carbon, capture, usage, removals and storage (CCUS/CCS).



Breakdown of Canada's GHG Emissions by Economic Sector, 2019. This graph comes from the National Inventory Report, 1990-2018, Greenhouse Gas Sources and Sinks in Canada

Source: Environment & Climate Change Canada

What are Canada's Emissions Sources

Today, GHG emissions are approximately the same level they were in 2005 and are projected to climb at an annual rate of 815Mt by 2030[i]. The oil and gas, and transportation sectors account for a quarter of the country's total emissions with 377 million tonnes (Mt) of CO2 being emitted directly into the atmosphere each year. Buildings, heavy industry, agriculture, and electricity emissions were all under 100Mt, seeing emissions as 91Mt, 77Mt, 73Mt, and 61Mt respectively[ii].

In its report, the Knowledge Centre focused on the importance of aligning any large CO2 sources that could apply CCUS, with large reservoirs for permanent storage if Canada is to meet its Nationally Determined Contribution commitments under the Paris Agreement of 40-45% below 2005 levels by 2030, and 2050 net-zero ambitions. [iii]

Are Sources near Sinks?

Mapping CO2 sources and sinks is at the core of any large-scale CCS project, as deployment depends on the proximity of potential reservoirs. As Canada, and the world, focus on the deep emission cuts necessary to achieve such targets, many are turning to the exponential benefits of gathering industry (i.e., emitters) through shared infrastructure and supporting CCS Hubs. The Knowledge Centre, working with Navius Research, and referencing the Boston Consulting Group, mapped large point source emitters across Canada, atop the known storage reservoirs. [iv]

Building off Canada's well known geological formations, the report points to sinks that offer secure and permanent CO2 storage – which are predominantly located in Western Canada's Alberta and Williston basins, providing 390 gigatonnes (Gt) of storage potential. It also points to potential storage opportunities, while yet unproven, off the west cost of Vancouver Island, in southern Ontario, and Atlantic Canada.

Pages 6 and 7 of the report highlight Canada's history in utilizing CO2 for enhanced oil recovery (EOR), which has been proven to permanently sequester CO2 in depleted oil reservoirs. The Knowledge Centre does however point to several active storage projects already sequestering millions of tonnes of CO2 in Western Canada, with 'tonnes' of storage still likely available in the Basal Saline System.

i. Government of Canada. "Canada advanced climate action and remains committed to ambitious global action as United Nations Climate Change Conference concludes" (December 16, 2019) https://www.canada.ca/en/environment-climate-change/news/2019/12/canada-advanced-climate-action-and-remains-committed-to-ambitious-global-action-as-united-nations-climate-change-conference-concludes.html

ii. Government of Canada. "National Inventory Report 1990 –2018: Greenhouse Gas Sources and Sinks In Canada" (2020) https://www.canada.ca/en/environment-climate-change/services/climatechange/

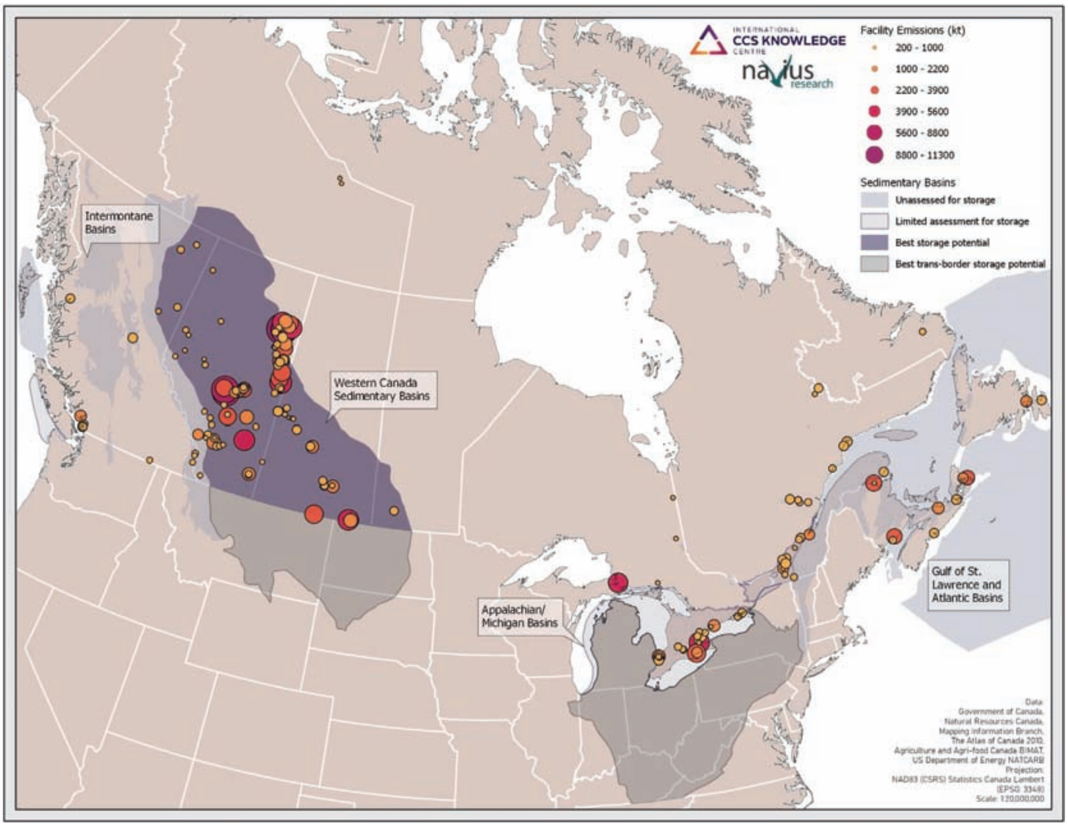
iii. Government of Canada. "National Inventory Report 1990 –2018: Greenhouse Gas Sources and Sinks In Canada" (2020) https://www.canada.ca/en/environment-climate-change/services/climatechange/greenhouse-gas-emissions.html

iv. Boston Consulting Group, "Think Small to Unlock Carbon Capture's Big Potential" (September 21, 2020), https://www.bcg.com/publications/2020/unlocking-carbon-captures-potential

Negative Emissions with Capture and Sinks

The report adds that, while Canada has an abundance of storage opportunities, it also has formidable land mass with forests, marsh and wetlands, farmland, and other natural CO2 sinks. Negative emission technologies such as bioenergy with CCS (referred to as BECCS) are also highlighted as a key factor to consider when mapping sources and sinks.

With insight from Dr. David Maenz, the report indicates that Canada is rich in the resources required for successful implementation of BECCS. It surmises that, if fossil fuel driven industries like coal-fired power plants in Alberta, Saskatchewan and Atlantic Canada, and iron and steel mills in Southern Ontario, as well as cement facilities were to fuel switch to biomass with CCS, the emissions abatement potential could be approximately 70Mt/year of CO2 avoided.



Canada's Carbon Capture & Storage Potential. This map indicates large heavy industry emitters across Canada, as well as storage 'sink' potential

Source: The International CCS Knowledge Centre

The report also notes that actual implementation of BECCS will likely be constrained by access to geological storage and biomass supply, and that optimal implementation would be dependent on establishing ideally located hubs/clusters. Additionally, with carbon prices over $65 USD, the value of the carbon removal potential of one tonne of biomass exceeds the energy value of a barrel of oil.

Sources and Sinks and Net Zero Ambitions

The Knowledge Centre underscores that understanding sources and access to sinks is essential and arriving at net-zero emissions in under 30 years is a lofty ambition which requires all innovative technologies to ramp up. Government regulations and incentive programs can aid in the advancement of CCUS and attempt to correct market barriers to uptake.

Such measures are progressing quickly in Canada such as the Canadian carbon pricing system, Strategic Innovation Funding, the Net-Zero Accelerator, Canadian Infrastructure Bank low-interest loans, the Clean Fuel Standard, and the Investment Tax Credit; as well as Alberta's Technology Innovation and Emissions Reduction (TIER) regulation and Storage Tenure Management. These types of levers are expected to spur many projects with far ranging economic and environmental benefits.

As Canada's climate change landscape changes, the Knowledge Centre can help next generation projects understand what steps to take. One of its key pillars is helping industry get to net-zero by not starting at ground-zero. By building off the knowledge and lessons learned of operating facilities like the Boundary Dam CCS project, we will see greater success in deploying shovel worthy CCS projects into the future.

More information

You can find more information about the International CCS Knowledge Centre at:
www.ccsknowledge.com/initiatives/incentivizing-large-scale-ccs

Update on UK CCS cluster projects

An update was provided on the UK's CCS cluster projects, Northwest England, Wales, East England and Scotland, in a CCSA webinar on July 21. By Karl Jeffery.

A webinar organised by the Carbon Capture and Storage Association on July 21 reviewed developments with the 4 UK clusters, Northwest England, Wales, East England and Scotland, with speakers from the leading figures in each.

The idea of carbon capture and storage in regional clusters has grown in momentum over the past 5 years, as an improvement to the initial carbon capture plans, based on single CO_2 sources and single CO_2 storage sites, which failed to get developed.

The advantages of clusters, from a government funding perspective, is that money is seen to be put into a region of the country, which in most cases is a less wealthy part. It avoids government being seen to be "subsidising oil companies". And a cluster may offer more opportunities than a point source / point storage project, if it is easier to extend and for more companies to join.

The UK government announced in December 2020 that it wanted to have four "low carbon" clusters to be set up by 2030, of which two would be operational by the mid-2020s.

The UK government also announced in December 2020 that its target was 10 mtpa (million tons per annum) CO_2 storage by 2030. This ambition is being revised upwards, after the Committee of Climate Change's 6th Carbon Budget" (also released in Dec 2020) said the UK will need 75 to 180 mtpa of CO_2 storage by 2050.

As a pathway to getting there, it suggested 22 mtpa CO_2 storage by 2030, 53 mtpa by 2035, 79 mtpa by 2040, which would lead to having 104 mtpa by 2050. For comparison, the UK's total GHG emissions were 454 mtpa CO_2 equivalent in 2019.

The two most well-known clusters in the UK are Northeast Scotland (Aberdeen), where there have been attempts to get projects running for about 15 years, and in Northeast England (Teesside / Humber), where the projects are now in advanced stages. The webinar shared news about developments about the Wales and Northwest England clusters.

None of the projects yet have funding confirmed to actually operate. The business model is expected to come from some mixture of carbon prices, taxes or other restrictions on unabated emission. So far, all the funding these projects have is from government development funds, or from companies capable of giving some financial support without a clear view of the returns.

"At the moment we're not charging people for the cost of emitting CO_2.

That has to be the destination," said Andy Lane of the East Coast cluster.

Our partners are demanding the infrastructure as their own route to decarbonisation" - David Parkin, Director Progressive Energy and HyNet project director

Northwest England

The Northwest England low carbon cluster goes under the name "HyNet", with the core of the project being a hydrogen network.

David Parkin, project director, said he sees a "sense of growing momentum" for the project over the past 12-18 months, with growing interest both from government and industry.

"We're not building infrastructure and hoping people will come. Our partners are demanding the infrastructure as their own route to decarbonisation," he said.

"That's put the project in a really good position, we can stand up in front of government and say this is a project industry wants and needs."

The project might be best understood as a number of separate projects rather than an integrated project, he said.

There is a 1 GW hydrogen production plant being built in a joint venture with Progressive Energy and Essar, near Ellesmere Port on the site of the Essar Oil refinery, with plans to expand to 4GW by 2030.

Progressive Energy is a "small, independent, project development company", and Essar is an Indian conglomerate with revenues of $14bn.

The hydrogen generated will initially be consumed on site in the refinery, and by "closely adjacent" industries.

There are plans to deliver the hydrogen to consumers in the cities of Manchester and Liverpool and connect with an underground gas storage site in Cheshire.

For the CO_2 sequestration part, oil and gas company ENI is the transport and storage partner. It will store the CO_2 in depleted gas reservoirs offshore in Liverpool Bay, re-using old well head platforms and pipelines. ENI owns and operates fields in the Bay.

A 30km pipeline will need to be installed between the hydrogen plant in Ellesmere Port, and infrastructure in Connah's Quay, where the pipeline leaves the shore.

HyNet has signed MOUs with manufacturing companies and power stations stating their intent to use the blue hydrogen when it becomes available, adding up to 4GW of demand.

This could displace "just under half" of all natural gas use in the region, Mr Parkin said. This includes cement and fertiliser plants, which are major process emitters of CO_2.

This means 11 million tonnes per annum of CO_2 sequestration from 12 industrial companies.

There is a trial at glass manufacturer Pilkington, to see if it can make glass using hydrogen fuel.

Also involved in the project are Cadent, which operates the UK's biggest gas distribution network, and chemicals company Inovyn. The University of Chester is an academic partner.

Waste company Viridor joined in May, planning an energy from waste facility in the region, which will connect to the network. This is arguably carbon negative, on the basis that it removes biogenic components in the waste, such as food waste, which would otherwise be sent to landfill and give off methane as they rot, which is a powerful greenhouse gas, Mr Parkin said.

Power generation company InterGen plans to build a low carbon power station connected to its "Rocksavage" power station. Encirc, a company making glass containers for beverages, will connect to HyNet.

So far £72m of funding has been secured, £39m from industry and £33m from government. Money has been spent on FEED for the first hydrogen production plant.

For the storage, the plan is to inject CO_2 at a lower pressure and let pressure in the reservoir build up slowly, and then only inject at a high pressure in around 2030, Mr Parkin said. High pressures allow higher gas flowrates through the pipeline, but the risk is that if it cools when it expands into the reservoir, it could potentially freeze and block the well bore, he said.

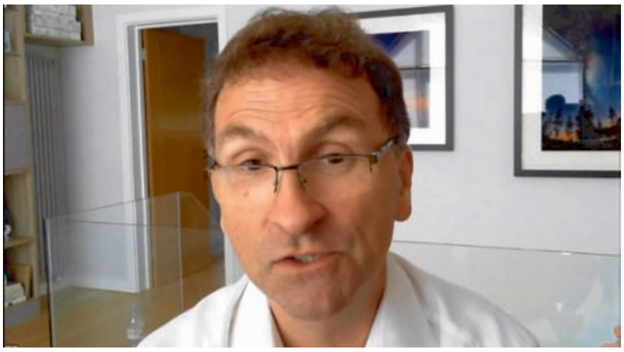
Wales

The Wales project is led by Chris Williams, who has a PhD in waste heat and steam, and has a role as head of industrial decarbonisation with a body called Industry Wales. He formerly worked with Tata Steel.

The big challenge of a CCUS cluster in South Wales is that no local CO_2 storage site has yet been identified. There has been no oil and gas production in the region. So the plan is to ship CO_2 by tanker, probably to the nearest facility, HyNet in Northwest England, Mr Williams said.

South Wales has many CO_2 emitting industrial sectors, including steelmaking, oil refining, chemical production, nickel refining, and manufacture of insulation and paper. There is also a gas power station.

The industrial facilities are located in 5 "mini clusters", all on the coast, in Milford Haven, Swansea, Barry, Cardiff and Newport. One possibility is that a CO_2 tanker ship could do a "milk round", collecting CO_2 from each, he said.



Andy Lane, Managing Director, Northern Endurance Partnership and East Coast Cluster said he sees CCUS as providing four different "services"

Total CO_2 emissions from industry in the region are 10m tonnes per annum, and from power generation are 6m tonnes per annum, he said.

There is a large LNG import facility in Milford Haven in West Wales, which has capacity to receive 30 per cent of UK's natural gas needs. It could potentially be connected to a hydrogen production plant, injecting hydrogen into the national gas infrastructure, he said.

There are three work streams for the Wales project, looking at technological options for each site, working out the best way to develop infrastructure, and looking at policy / financial mechanisms.

In addition, "we're working on an investigative program to work through the challenge of developing a flexible multipurpose CO_2 shipping industry," he said.

East Coast Cluster

The UK's "East Coast Cluster" incorporates the carbon capture projects for the industrial regions of Teesside and Humber, which are around 100 miles apart.

The Humber region contains the UK's biggest single point emissions source, the Drax Power station in Yorkshire.

The East Coast Cluster includes the Northern Endurance Partnership, an offshore transport and storage infrastructure, which connects to both Teesside and Humber. The storage site, a saline aquifer also called "Endurance," is 145km from Teesside and 103km from Humber. It is an aquifer, not a depleted hydrocarbon field, and there are no existing pipelines.

In addition, there are plans from Harbour Energy, the UK's largest oil and gas producer, to connect Humber with two depleted southern North Sea gas reservoirs, to form the "V Net Zero" CO_2 transport and storage system. The name Harbour Energy is not yet well known – the company was formed from a merger between Chrysaor and Premier Oil in 2021. Chrysaor was itself formed from acquiring North Sea assets from Shell in 2017 and ConocoPhillips in 2019.

Andy Lane, Managing Director, Northern Endurance Partnership and East Coast Cluster said he sees CCUS as providing four different "services" – abating emissions from industries which have no other way to avoid emitting, providing decarbonised flexible power, providing decarbonised hydrogen, and negative GHG emissions via CCS with bioenergy.

The project has a capacity of 20m tonnes CO_2 per year, which is enough for 50 per cent of the UK's total industrial emissions, Mr Lane said.

The industrial region of Teesside is smaller and more condensed than Humber, Mr Lane said. The Teesside gathering pipeline will be 7-10 km long, while Humberside will need 130km of onshore pipeline, including to reach Drax, which is about 80km inland.

Altogether, there are 17 "primary emitters" which can be part of the project by 2030, including a fertiliser manufacturing plant and an existing hydrogen plant.

The total capital spend for all the projects is predicted to be £12bn, most of that to be spent before 2030, and the lifetime spending of the project predicted to be £50bn.

The project is expected to create 25,000 direct jobs, plus another 25,000 indirect jobs, such as in hospitality.

“The people I’m working with tend to come from a hydrocarbon background. People with that kind of motivation will find opportunity in the CCS space," he said.

Phil Kirk, president and CEO Europe for Harbour Energy, said that his company board increasingly recognises that CCS offers business opportunities. “My board used to talk about CCS as my hobbies,” he said.

The Harbour Energy storage in depleted gas reservoirs has potential for 11 mtpa CO_2 storage by the end 2029. “By re-using the infrastructure we have a pretty competitive cost of abatement.”

Northeast Scotland

Carbon capture in Northeast Scotland is being developed around a project called Acorn. This is the third major project plan for carbon capture in the region, following previous efforts led by BP and Shell, going back to the mid-2000s.

Acorn has financial support from Harbour Energy, Shell, the UK government (via UK Research and Innovation, and the Department for Business, Energy and Industrial Strategy) and the European Union, through its “Connecting Europe” facility.

The region is very large, reaching down as far as Grangemouth, Northwest of Edinburgh, from which there are existing pipelines to Northeast Scotland.

It has licensed a large amount of North Sea storage space, including both depleted gas fields and saline aquifers. All offshore development will be subsea, so not requiring any infrastructure above sea level, said Alan James, chief technology officer of Storegga, a company which owns Pale Blu Dot Energy, lead developer of the Acorn project.

Initial engineering work (known as ‘pre-Feed’) has been completed on a hydrogen production plant near the St Fergus terminal in Northeast Scotland. About 35 per cent of the UK’s natural gas arrives at this point, from North Sea gas fields.

The hydrogen can be generated from the natural gas, with CO_2 sent back offshore for storage. This hydrogen could also be injected into the UK’s natural gas supply, since it is thought that natural gas systems can handle a blend of hydrogen up to 20 per cent and used through existing gas appliances without modification.

This will create around 300,000 tonnes per year of CO_2 for storage.

Without a standard specification, “we're going to get emitters designed for one thing, and clusters designed for another” - Phil Kirk, President and CEO Harbour Energy Europe

Then the project can be extended to include CO_2 emissions from Peterhead power station (gas fired), INEOS chemical plant and the Petroineos refinery, both in Grangemouth, connected to Peterhead by the Feeder 10 pipeline.

The Peterhead port can receive deep water tankers, taking CO_2 from elsewhere. There are emitters in Europe committed to provide CO_2 to the project, Mr James said.

The transport and storage offshore will be provided by Harbour Energy, Shell and Storegga.

The first CO_2 pipeline to be used going offshore is called Goldeneye, it already exists, and could carry 5m tonnes CO_2 a year. “We just completed an intelligent pig run to confirm its integrity and suitability for re-use,” he said.

Other pipelines will be added after that. “Multiple lines gives you a huge amount of resilience,” he said.

A direct air capture plant is planned to be operational in 2026, providing a service to UK airlines and airports, and UK financial companies, as a means for them to remove their emissions. Its CO_2 can be sequestered through the same system.

The investment decision on the CO_2 storage is planned to be made in the end of 2022 or early 2023, with first CO_2 flowing in 2025, fully commercial operations in 2026, and Peterhead port capable of receiving CO_2 from late 2026.

“By the time we get to 2030 we're heading towards 10m tonnes / year of CO_2 going through the system,” he said.

CO2 utilisation

When asked how important they think CO_2 utilisation will be, the general answer was, not much. HyNet’s David Parkin said that while he thinks utilisation will form part of the mix, “I struggle to see it as a large part of the overall CO_2 volume.” Storegga’s Alan James agreed. “From a scale perspective it’s not going to move the needle very much.”

Standards

Speakers discussed the importance of the UK developing a standard specification for CO_2, including the level of water content and impurities which are allowed, and the mix of gas and liquid content allowed.

Without a standard specification, “we're going to get emitters designed for one thing, and clusters designed for another,” said Harbour’s Mr Kirk. “We need to be able to swap between clusters, and tell import customers, ‘you give me this, and I'll take it, and the price is x.’ Then we can begin to join these clusters together.”

Industry Wales’s Chris Williams added that there can be lessons learned from the development of railways in the UK, when the government left it to the market to determine standards, and as a result railway lines in the country did not connect. He would like the Wales project to have a choice of CO_2 storage sites, which would only be possible if they have the same standards.

More information

A video of the webinar is online here:

https://vimeo.com/579533663

Assessing the sustainability of chemical and polymer production

The latest techno-economic report from the Carbon Dioxide Capture and Conversion (CO2CC) Program collates and reviews the sustainability of various chemical process routes for a range of chemicals, intermediates and polymers, demonstrating what has been achieved so far and the challenges that remain.

The report, "Life Cycle Assessment (LCA) for Sustainable Chemical and Polymer Production," documents the wide variety of approaches that are applied to quantify the sustainability improvements and carbon reduction measures for a set of common basic chemicals, intermediates and polymers.

Five polymer value chains are covered: polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) polystyrene (PS) and polyurethanes (PU).

Information was gathered which relates to the life cycle analyses or assessments (LCA), global warming potential (GWP), carbon footprints and other energy related metrics for the production of a number of chemicals, intermediates and polymer value chains.

The most impactful method for decarbonisation of all value chains is summarised by sources used in the report with a range of boundary conditions in the respective LCAs.

Different routes to each of the substances listed are covered including, as appropriate, routes from biobased, CO2-based and wastepolymer based feedstocks.

For each of the products in the report, a number of process routes are described and then compared to routes intended to lower the carbon intensity (CI) of the product. The cost of carbon reduction is considered according to available information and the remaining hurdles and challenges are indicated.

Basic Chemicals, Intermediates and Polymers Included in the Report		
Basic Chemicals	**Intermediates**	**Polymers**
Methanol	Monoethylene Glycol (MEG)	Polyethylene (PE)
Ethylene	Purified Terephthalic Acid (PTA)	Polypropylene (PP)
Propylene	Polyether Polyols (PETP)	Polyethylene Terephthalate (PET)
p-Xylene (PX)	Polyester Polyols (PESP)	Polystyrene (PS)
Styrene	CO2 Polyols (PECP)	Polyurethanes (PU)
Ethylene Oxide (EO)	Natural Oil Polyols (NOP)	
Propylene Oxide (PO)	Biosuccinic Acid (SA)	

Table of chemicals included in report

Life Cycle Assessment

LCA is a methodology for assessing the environmental impacts of certain stages in a product's life cycle:

Metrics within LCA include global warming potential (GWP) which allows the effects of all greenhouse gases (GHG), in particular methane (CH_4) to be included in one figure, rather than just CO2

Non renewable energy use (NREU) looks at the cumulative energy demand for the system across the chosen boundaries, e.g. cradle to grave.

Carbon intensity (CI) relates to the rate at which a GHG is produced relative to a particular activity e.g., electricity generation.

Exergy is a measure of the quality of energy a system has and represents the amount of resources that can be converted into work given the environmental conditions.

Cumulative exergy demand CExD) has been proven to be a useful sustainability metric in the context of an LCA.

The term carbon footprint may be used slightly loosely but is intended to denote the amount of carbon dioxide equivalent (CO2 eq) released into the atmosphere as a result of an anthropogenic (human related) activity.

The report highlights the scale of the challenge of decarbonising chemical value chains which are so deeply integrated into 21st century life and the likely need for policy support if that challenge is to be overcome.

The economies of scale over time offset the high initial CAPEX and project complexity of switching to sustainable processes, but Renewable Energy Sources (RES) are not globally implemented into mainstream processes as opposed to fossil fuels. Many commercial institutions and government organizations target 2030 or 2050 as a goal to convert to a zero carbon future.

Polyethylene (PE) Value Chain

The production of methanol, ethylene and polyethylene were covered in this value chain. Methanol is produced from a mixture of carbon monoxide and hydrogen (syngas) derived from a range of fossil fuels – over 85% comes from steam methane reforming (SMR) and coal gasification. A small proportion of syngas is derived from renewables e.g. biomass or CO2.

The majority of methanol synthesis' environmental impact relates to the high energy requirements for the conversion of methane to syngas (an endothermic reaction).

The emissions for the production methanol via different production routes were reviewed, with the GWP of methanol changing between -1.37 kgCO2eq/kg and 2.97 kgCO2eq. The use of biorenewables, green hydrogen and carbon capture and storage (CCS) all had a beneficial effect on the GWP. However, techno-economic challenges remain in particular with CCS and electrolysis for green hydrogen.

For ethylene, the GWP100 of the routes studied ranged from -1.91 to 1.58 kgCO2eq/kg. Improvements to conventional steam cracking processes including novel reactors – use of autothermal reforming (ATR) with combined reforming and the use of renewable energy in the processes provide the best short-term solution for reducing GWP.

More step-out techniques such as the Siluria Technologies oxidative coupling (OCM) process or green ethylene or bioethylene both have great potential, but the former is not yet proven and the latter struggles to compete with petrochemical feedstocks.

For polyethylene, the production route for ethylene is the major factor effecting the GWP but in addition electricity is a contributing factor. Production of ethylene from recycled polymer has potential but the recycling costs currently make the process unprofitable.

Polypropylene (PP) Value Chain

The production of methanol, propylene and polypropylene were covered in this value chain.

Methanol has been discussed above. For propylene, the range of GWP100 in the various LCA's and other data reviewed was -10.43-2.09 kgCO2eq/kg. Use of biorenewables such as wood achieve the lowest end of this range but are very expensive to implement. Mitsui's new route to biopropylene via isopropanol has potential at a lower cost than other biobased production methods for propylene.

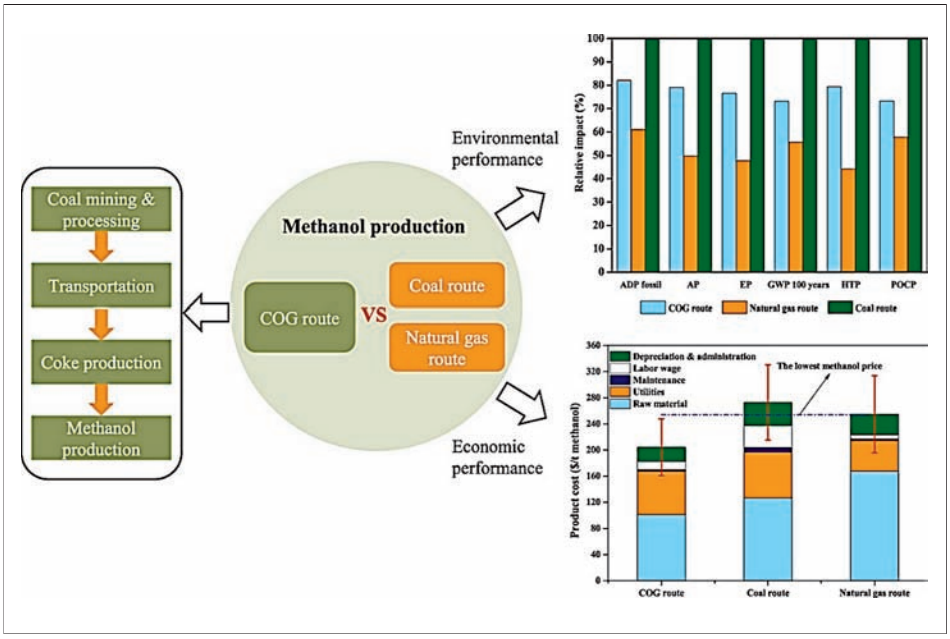


Figure 1: Environmental and economic performance of methanol production via coal, natural gas and coke-oven gas (COG) Source: Li, 2018

Steam cracker optimisation, as with ethylene is a viable near-term strategy, and combined with renewable electricity for the process could reduce conventional plant emissions by up to 90%. Fluid catalytic cracking (FCC) in refineries combined with CCS is another possibility, although it would add considerable expense, to some degree which could be ameliorated by the use of oxy-fuel technology and pre-combustion CCS.

Methanol to olefins (MTO) became a popular route in China in recent years however based on this review its GWP cannot be lowered at a cost which would be considered economically viable compared to other options. The same is true of the olefin metathesis route from ethylene to propylene.

Polypropylene's GWP is related directly to that of propylene. Mitsui's route looks to be a promising route going forward. Use of renewable electricity in the polymerisation process would also have a significant benefit on GWP. Consumers would need to be prepared to pay a green premium as green polypropylene does not offer any special technical benefits over the petrochemical analogue.

Polyethylene Terephthalate (PET)

The production of ethylene, monoethylene glycol (MEG), p-Xylene (PX), purified terephthalic acid (PTA) and polyethylene terephthalate (PET) were covered in this value chain. Ethylene has been covered above and for MEG, the least polluting route will be the one which is based on the least polluting ethylene.

Reducing the GWP of p-Xylene from conventional methods relies on process intensification, rather than a CO2 recovery process and further substantial reductions are not feasible. The production green p-Xylene via the BioT-Cat™ process from Anellotech claims to be able to save 70% in p-Xylene emissions and to be able to compete with the petrochemical route.

Transferring this process through to the production of PTA results in a GWP100 of just 0.75 kgCO2eq/kg compared with the range of 0.75-5.38 kgCO2eq/kg in all of the processes studied. This would also transfer through to the production of PET if used in conjunction with the least polluting method for MEG. Manufacture of recycled PET (RPET) has a lower GWP100 than other methods however the recycling process does not have favourable economics, and this is deterring more capacity from being built.

Polystyrene (PS)

Styrene monomer and polystyrene (PS) were covered in this value chain. The reduction of non-renewable styrene emissions requires intervention in multiple petrochemical processes. As an alternative, the BioT-Cat™ process, from Anellotech, allows for the production of cost-competitive green styrene using its green benzene.

If green ethylene is also employed, the GWP100 can be reduced from 2.52-2.92 for the conventional ethylbenzene dehydrogenation process to 0.63-0.67 kgCO2eq/kg. These benefits can be brought through to the production of PS and this results in a GWP100 for PS of 0.74 kgCO2eq/kg compared with 2.25 kgCO2eq/kg for conventional PS. Styrene emissions contribute to 85-95% of polystyrene emissions.

Polyurethanes (PU)

Ethylene oxide (EO) and propylene oxide (PO), polyether polyols (PETP), polyester polyols (PESP), polyethercarbonate polyols (PECP), natural oil polyols (NOP) and bio-succinic acid (Bio-SA) as well as the corresponding polyurethanes (PU) prepared from PECP, NOP and Bio-SA were covered in the report.

GWP of PU chemicals have largely been achieved by the introduction of state-of-the-art conventional fossil-fuel based approaches. Improved EO catalysts and process intensification and the HPPO route to PO have made those routes much cleaner. Further improvements can be achieved if all utilities across EO, PO and polyols are switched to renewable energy. The downside to this is that the industry will be content to accept these improvements even though the carbon footprints achieved are still positive.

The use of biobased raw materials can provide the only way to achieve carbon-negative products as much of the emissions involved in the manufacturing stages are not able to be captured as CO2. However, these carry many challenges and risks such as the variability of biomass and the need for other chemicals to recycle polymers.

CO2-approaches by comparison look relatively straightforward, if CCS can be implemented on a wide enough scale. A waste refinery type of approach can combine the benefits of all the separate approaches and provide a method to share the risks and benefits.

There are considerable challenges to reducing carbon for PU. It is a vastly diverse value chain with many 10,000's of grades needed across different industries. Even when a clear basis for decarbonising PU raw materials has been achieved – the ability to pass this on in PU may be thrown by other factors required to adjust the formulation. While there may be larger quantities of commodity grade PU which could require less reformulation effort – these would be less likely to tolerate the price premiums required for greener products.

In the near term it is likely to be specialised grades offered – and generally these are based on consumer pull. Companies may offer a NOP-based PU for instance because a particular automotive OEM, retail chain or building company has requested low carbon products which it can use to enhance brand image. But this is a far cry from achieving the kind of carbon-neutrality across the industry that climate goals are targeting.

Policy development and further regulation will undoubtedly be needed to remove some of these hurdles – but that must be achieved in very close cooperation with the industry stakeholders who know exactly what properties are required in their PU portfolios.

Outlook

There are many challenges to consider when it comes to the transition of non-renewable precursors to sustainable improvements in chemical and polymer production:

Negative GWP was obtained when renewable feedstock, such as biomass or CO2 and renewable hydrogen, was used for the production of methanol. When non-renewable feedstocks were used CCS was proven to be a powerful tool to reduce the carbon footprint of methanol.

The reduction of ethylene's carbon footprint is, in the short term, related to the improvement of the emissions of steam crackers. Completely changing the heat source for renewable electricity can bring more significant emissions reductions, 90% less, but still has technical challenges to overcome. Additionally, the continuous supply of renewable electricity on this scale is also a problem.

The carbon emissions of propylene from MTO can vary significantly depending on the sources associated with methanol. Typically, using renewable feedstocks, such as biomass or CO2, for the production of methanol allows for the production of low carbon emissions propylene from MTO.

The Bio-TCat™ process by Anellotech focuses on the production of benzene, toluene, and xylenes and has very reduced selectivity to ethylbenzene (<1%)

Increasing recycling rates is essential for polymers, not only to reduce their carbon footprint but also to reduce their leakage into the environment. However, due to contamination problems and separation costs, the recycling of most polymer resins is not economical, which prevents its widespread application to all polymers.

PU are a highly important class of materials which over their lifetime effect considerable carbon savings due to their durability and insulative properties. This is a factor which is often missed when looking purely at LCA's for production of the various materials. There are considerable challenges to reducing carbon for PU. It is a vastly diverse value chain with many 10,000's of grades needed across different industries.

References

Figure 1 - Li. 2018. "Life cycle assessment and economic analysis of methanol production from coke oven gas compared with coal and natural gas routes." Journal of Cleaner Production 185: 299-308.

Next articles

This is the first in a series of articles summarising recent key reports from The Catalyst Group Resources Carbon Dioxide Capture and Conversion (CO2CC) Program. The next issue will feature, "Energy Efficiency/CO2 Mitigation Case Study Series – Vol. 3: Allied Industries" and the following issue, "The Role of CO2 Emissions Reduction in Overall Corporate Sustainability Initiatives."

More information

More information about this report and other services of the CO2CC Program can be found at:
www.catalystgrp.com/tcg-resources/member-programs/co2-capture-conversion-co2cc-program

www.catalystgrp.com/php/tcgr_CO2cc.php

Seismic acquisition tech needed to make the CCS revolution a large-scale reality

Simon Illingworth, Managing Director and Chief Executive Officer of Blue Ocean Seismic Services, outlines some of the new technologies being developed to ensure marine seismic is cheaper, faster, less carbon intensive and fit for the future.

Earlier this year, bp and Shell joined forces to develop carbon capture and storage infrastructure in Teesside and the Humber in a project that will create 25,000 jobs across North England. The multi-billion-pound plan aims to capture carbon dioxide emissions from heavy industry, new power stations and hydrogen production plants and pipe them offshore for permanent disposal under the North Sea.

Separately, Sir Jim Ratcliffe (CEO of Ineos) has recently signed up to a major carbon capture project in Scotland. Ineos aims to use the planned Acorn carbon capture storage system to help eliminate the emissions from its Grangemouth petrochemicals plant and oil refinery. The company said it aims to store one million tonnes of carbon dioxide from Grangemouth under the North Sea annually by 2027.

Climate advisers have been unanimous in their support for these developments, as they are essential to achieving Britain's net zero goals. These major UK projects could also provide a blueprint for deploying carbon storage, both in the UK and around the world.

Whilst these projects are undoubtably good news for the fight against climate change, the industry still has further to go if it wants to maximise the environmental credentials of its operations and to facilitate rapid, efficient roll out of CCUS (Carbon Capture Usage & Storage).

One problem is the carbon-intensive nature of the diesel-powered acquisition methods currently used to identify and then monitor potential carbon storage opportunities below the seabed. Marine seismic data acquisition still remains mostly heavily dependent on technology developed over half a century ago. Streamer cables are laid from the aft of a diesel-powered vessel and towed on a previously designated track line traveling at 2 to 5 knots.

The airguns that are being towed along with cables are filled with high pressure air and have a mechanism to release them as air pulses. These air pulses hit the seabed, causing a seismic reaction, which is picked up by pressure-sensitive hydrophones inside the streamer cables.

This out-fashioned method is much more carbon intensive than it needs to be. Furthermore, the expense incurred potentially hinders the economic viability of smaller CCUS projects. Therefore, it is critical that we transform old methods of exploration with dynamic, new technologies that are faster, safer, cheaper and less carbon intensive.

The encouraging news is that innovation is underway to enable reduced carbon, lower-cost ocean bottom seismic acquisition. Long endurance, self-repositioning autonomous underwater nodes are now being built to operate offshore seismic surveys for the exploration of carbon storage opportunities. The nodes will be launched off the side of a boat, then navigate themselves down to the seabed where they will sit and collect seismic data before moving autonomously to the next position.

This ground-breaking technology is expected to reduce seismic survey costs by more than 50 percent and remove the need for energy-intensive exploration vessels. The use of autonomous OBSrV's (Ocean Bottom Seismic Robotic Vehicles) significantly reduces vessel-based personnel requirements as well as the length of the survey duration and costs. Powered by rechargeable batteries, the nodes will also make seismic exploration much less carbon intensive.

The vehicles can remain submerged for almost three months, relocating from different locations under water, where thousands of these underwater nodes can be deployed at one time. As a result, they can offer a precise image of what lies below the seabed.

"It is critical that we transform old methods of exploration with dynamic, new technologies that are faster, safer, cheaper and less carbon intensive" - Simon Illingworth, CEO Blue Ocean Seismic

The importance of carbon capture in achieving global net zero ambitions is evident. However, without efficient technology, the industry will not reach its full potential. The current costs and environment pressures are high, in addition to the significant expense, time and safety risks involved, which are turning some energy companies away from exploring carbon storage prospects.

Through adopting and investing in technology fit for the 21st century, energy companies can identify the key carbon storage opportunities under the seabed, and in doing so, make a meaningful step in the fight against climate change.

More information

www.blueoceanseismic.com

Update on Shell's CCS perspective

Al Tucker, general manager CCUS at Shell, gave an update on Shell's perspective on CCS in a webinar on August 23rd, organised by Aberdeen branch of the Society of Petroleum Engineers. By Karl Jeffery.

Shell's approach to carbon capture and storage is evolving, as projects become more like any other major oil and gas project, and more business cases are emerging, such as supplying hydrogen or providing CO2 sequestration services to heavy industry.

Al Tucker, general manager CCUS in Shell, gave an update, in a webinar on August 23rd, organised by Aberdeen branch of the Society of Petroleum Engineers. Mr Tucker's role is to "to develop and mature Shell's CCUS portfolio globally through leading engagements with external customers and partners."

Mr Tucker is somewhat unique in the oil and gas industry as having a background in subsurface, petroleum engineering and major project management, all of which are needed in CO2 transport and storage. He has a Masters degree in geology, and a background as a North Sea petroleum engineer.

His prior role in Shell was as manager for Shell's Penguins project / Brent field and the Brent Charlie platform. The Brent Field and Brent Charlie platform began decommissioning in 2017, and the Penguins field was redeveloped to produce to a FPSO. So these were major projects at Shell.

Today's CCS projects are "big capital investment projects [with] long lifetimes and long payback periods," Mr Tucker said. "Understanding how it operates, understanding where value is, is really important."

When the discussion gets to project delivery and operations, "I think that's when it gets really exciting," he said. "We're going to do stuff, and stuff which will influence things."

"The skills we have as engineers go such a long way in this new space. Not just the traditional elements and building blocks we have [but also] project delivery and technical credibility."

Mr Tucker had some involvement with Shell's CCS projects around 2015 with its Peterhead project, but is fairly new to his current role. In his job interview, he asked why CCS is different now to how it was in 2015. His talk showed the answer he now has to this question.

Background

Shell's ambition is to store 25m tonnes CO2 a year by 2035, and to support the development of CCS hubs.

Shell is putting its focus on reducing its Scope 3 (value chain) emissions, which include emissions from the use of energy produced by Shell, and from the use of energy produced by others and then sold by Shell. This can be over 90 per cent of the total of Scope 1, 2 and 3, he said. "That's the backdrop."

It has joined the South Wales cluster, based on an interest in hydrogen production from LNG – Shell is one of two shareholders in the Dragon LNG receiving terminal in West Wales. There is no CO2 storage facility in Wales, but Shell can build on its experience with Norway's Northern Lights project, where CO2 is initially transported by ship from its emitters.

Shell is looking hard at shipping of CO2 in other areas. It may prove to be more important in Asia than in Europe, where distances between capture and storage may be too far to use pipelines. Pipelines are also more problematic in earthquake prone regions, such as around Japan. "If you want to enable this globally, ship based is going to be key."

In the big picture, while many countries have stated their policies to reach net zero, "the paths to get there aren't always clear," he said. That includes in the UK. "We may have a shared target, but I don't think anybody has all the answers at this stage."

On the other hand, there are much less discussions happening now about whether climate change is actually happening, then there were a few years ago. "The conversation has moved beyond the story of climate change," he said, and this is something he finds "refreshing".

CCS business models

Shell has evolved its thinking in where the value from CCS might be, in particular if it can offer services to help other industry sectors decarbonise, including cement, steel and power. It is also looking at supply of hydrogen.

In Europe we are starting to see carbon pricing leading to "people seeing real bills," and "real pain potential going forward," he said. This is pushing increased interest from heavy industry in CCS.

But the value case of CCS to industries varies, based on their volumes, the costs of capturing CO2 from their flue gases, and the costs of transporting their CO2 to a storage site.

There are some industrial emissions which are nearly 100 per cent CO2. "That's very easy to manage." But with some other industries, with dirtier flues, capturing CO2 out of the emission stream can be two thirds of the total cost.

The cost of providing CO2 storage services depends on how close the emitter is to the coast, where the CO2 can be taken away by ship or pipeline. "If you're further inland that drives costs up."

Shell is looking at business models with bioenergy with carbon capture, and direct air capture. Although they are not usually put together, they both have the capability of creating negative emissions (taking CO2 out of the atmosphere) and so generating carbon credits, which can be sold.

"Direct air capture is really exciting," he said. "It's quite expensive [but] the cost challenges are there for us to get after."

Big technology companies are taking an interest, for example Microsoft stating that it would like to remove all the CO2 from the atmosphere that it has ever emitted by 2050. So that would require direct air capture with CCS.

Shell is finding itself working with familiar companies as partners and customers but having different conversations with them. "A lot of traditional industries are finding different ways to work with each other on the energy transition. One person's waste is another person's feedstock."

We see familiar companies taking on different roles, for example some EPC companies "wanting to play a role in technology space," and "you see tech companies wanting to understand what happens in the subsurface."

Overall, it is reasonable to expect that the CCS market and systems will evolve in a standard way, as we have seen with conventional gas and LNG, he said.

In terms of putting together projects, including with financing and construction, "there is nothing different about this in terms of building blocks that we haven't done before," he said.

CO_2 shipping is similar to LNG shipping, and Shell is very familiar with offshore gas injection and finding reservoirs.

Emissions with hydrogen

Shell is also looking at the business model of producing and selling hydrogen from natural gas, with the CO_2 sequestered.

At the time of the webinar, some environmental groups were claiming that the greenhouse gas emissions associated with making blue hydrogen may be so high that they negate the carbon benefits. The carbon capture processes are 90-95 per cent efficient in removing CO_2 from a flue gas, not 100 per cent, and there may be some methane leakage along the way.

Mr Tucker acknowledges that "green" (purely renewables based) hydrogen is "obviously the king of hydrogen" and what "everybody wants". It may be better to have a classification system which shows the level of emission associated with the hydrogen production. So rather than a simple blue/green denoting whether the hydrogen comes from fossil fuels with CCS or renewables, we could see an A B C D E rating, like with some domestic appliances. "That clarity drives the consumer - with real choice in the market."

Subsurface expertise

CO_2 storage offers many opportunities for subsurface experts and petroleum engineers, not just characterising the storage, but also ensuring safety and reliability of storage, and perhaps enhanced oil recovery.

In the world of CCS, the subsurface part is at the end of the chain rather than the beginning, as it is in hydrocarbon production. We can say that the subsurface part is now the "downstream," he said.

This means that subsurface people need to operate in different ways, and some people need to get used to working with the subsurface who did not before. For example, people in oil refining are not familiar with subsurface activities, and some people with a background in exploration "aren't that familiar with being the customer," he said.

People operating CO_2 storage services will be expected to provide some kind of guarantees of availability, because it will be hard to find interim storage if the subsurface storage is unavailable for a short period. "So it is kind of analogous to a capacity contract for LNG production," he said.

We may see categorisations of storage into proven, probable and possible, like with hydrocarbon reserves. And there may need to be standards for fields as to how contained the storage is thought to be. There also needs to be plans for "if things don't go to plan" – intervening and isolating CO_2 which is stored. There remain "some very open questions at this stage."

Subsurface professionals need to engage with the challenge of how to make society feel comfortable that CO_2 sequestration is right. "I think it is fine to convince ourselves as engineers and investors that it's all good, but we need to bring wider stakeholders with us and that isn't always easy."

CO_2 can be trapped in different ways – buoyancy trapping (due to liquid CO_2 being denser than water and so being held below water), dissolution (when gaseous CO_2 is dissolved in water), capillary trapping (when CO_2 is trapped in small pores in rock) and mineral trapping, when CO_2 reacts with rock to form a new substance.

One of the biggest risks, when injecting into oil and gas fields, is wells, perhaps very old, which were not sealed as well as was thought. So the "man-made risk of leakage" can be lower for aquifers than depleted oil and gas fields, since there are no pre-existing wells, he said.

The Goldeneye CO_2 store offshore Aberdeen is a depleted field, while the Quest CO_2 storage project in Canada is an "aquifer type store".

In Mr Tucker's previous work on well plugging and abandonment for the Brent field, he found "it was always more complex than we thought. From a modelling and engineering sense, what we had to do, to get ourselves happy, was extensive."

The geological task of identifying caprock seals (an impervious rock layer above the storage), is very similar in both CO_2 storage and oil and gas exploration.

There have been some conversations with government where people see CO_2 storage similar to storage of nuclear waste and expect similar risk management systems to be in place.

But oil companies are familiar with the challenges of maintaining injection rates (as it has done with water injection on some fields for decades), being able to respond to outages and issues, and monitoring what's happening underground.

"We've taken very managed and considered risks in oil and gas, that knowledge is quite specialist," he said.

Oil and gas companies recognise all wells everywhere have the potential to leak. But oil and gas companies have developed a wide range of techniques to manage the risks.

One of the most important techniques is "ensuring things are inspected properly in the first place", such as how we log and evaluate wells, he said.

Then there is work to study possible migration pathways, and what would happen if there was a leak through one barrier, and how the overburden might respond to any small leaking.

Monitoring and surveillance are "absolutely critical. We've seen a number of occasional bubbling around wells rather than leaking itself," he said. But still, petroleum engineering has "a key role to play" in ensuring that CO_2 storage is seen by society as reliable, credible, and recognised.

Another factor is EOR. Shell has done a lot of projects with CO_2 in the US onshore. There may be some EOR opportunities associated with CO_2 storage projects, he said. But, "the context is different."

More information
www.spe-aberdeen.org

UK Government must commit to CCS technology by 2030

The UK government must commit to the wide-scale deployment of new greenhouse gas removal technologies by 2030 in order to meet its climate change obligations, according to a report by the National Infrastructure Commission.

The report sets out how the engineered removal and storage of carbon dioxide offers the most realistic way to mitigate the final slice of emissions expected to remain by the 2040s from sources that don't currently have a decarbonisation solution, like aviation and agriculture.

Given the scale of removals likely to be needed, these technologies would represent a whole new infrastructure sector that could reach revenues matching that of the UK's water sector by 2050.

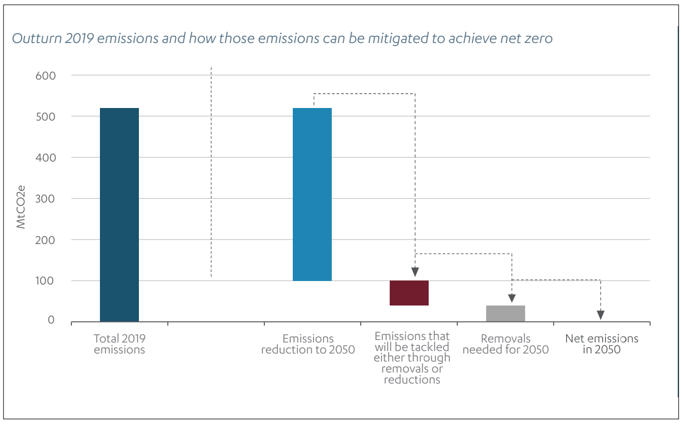
The removal technologies explored by the Commission fit into two categories: extracting carbon dioxide directly out of the air; and bioenergy with carbon capture technology – processing biomass to recapture carbon dioxide absorbed as the fuel grew. In both cases the captured carbon dioxide is then stored permanently out of the atmosphere, typically under the seabed.

The Commission stresses that the potential of these technologies is "not an excuse to delay necessary action elsewhere" and cannot replace efforts to reduce emissions from sectors like road transport or power, where removals would be a more expensive alternative.

The critical role these technologies will play in meeting climate targets means government must rapidly kick start the sector so that it becomes viable by the 2030s, according to the report, which was commissioned by government in November 2020.

The report notes that early movement by the UK to develop the expertise and capacity in greenhouse gas removal technologies could create a comparative advantage, with the prospect of other countries needing to procure the knowledge and skills the UK develops.

The Commission recommends that government should support the development of this new sector in the short term with policies that drive delivery of these technologies and create demand through obligations on polluting industries, which will over time enable a competitive market to develop. Robust independent regulation must also be put in place from the start to help build public and investor confidence.



Removals will be needed to achieve net zero

Source: Commission analysis based on Climate Change Committee (2020), Sixth Carbon Budget; Gov.uk (2021), Impact Assessment for the sixth carbon budget; The Royal Society (2018), Greenhouse gas removal; Energy Systems Catapult (2020), Innovating to net zero; National Grid ESO (2021), Future Energy Scenarios; University College London: Institute for Sustainable Resources (2021), The role of bioenergy with carbon capture and storage in the UK's net-zero pathway

The Commission's analysis suggests engineered removals technologies need to have capacity to remove five to ten megatonnes of carbon dioxide no later than 2030, and between 40 and 100 megatonnes by 2050. With costs ranging between £100 and £400 million per megatonne of carbon dioxide removed, this market could see revenues reach £2bn a year by 2030.

While the burden of these costs could be shared by different parts of industries required to pay for removals or in part shared with government, the report acknowledges that, over the longer term, the aim should be to have polluting sectors pay for removals they need to reach carbon targets. The report acknowledges that polluting industries are likely to pass a proportion of the costs onto consumers. While those with bigger household expenditures will pay more than those on lower incomes, the report underlines that government will need to identify ways of protecting vulnerable consumers and to decide where in relevant industry supply chains the costs should fall.

Chair of the National Infrastructure Commission, Sir John Armitt, said, "Taking steps to clean our air is something we're going to have to get used to, just as we already manage our wastewater and household refuse. While engineered removals will not be everyone's favourite device in the toolkit, they are there for the hardest jobs. And in the overall project of mitigating our impact on the planet for the sake of generations to come, we need every tool we can find.

"But to get close to having the sector operating where and when we need it to, the government needs to get ahead of the game now. The adaptive approach to market building we recommend will create the best environment for emerging technologies to develop quickly and show their worth, avoiding the need for government to pick winners. We know from the dramatic fall in the cost of renewables that this approach works and we must apply the lessons learned to this novel, but necessary, technology."

More information

www.nic.org.uk

Public give conditional support to CCUS rollout

Participants in a new public dialogue generally supported the use of carbon capture usage and storage as part of a pathway to meeting net zero.

This support was conditional on safety and CCUS being an effective way to reduce CO2, alongside other technologies such as renewables. Participants also wanted CCUS deployment to benefit local communities.

The dialogue was commissioned by the Department for Business, Energy & Industrial Strategy (BEIS) and UK Research and Innovation's Sciencewise programme to better understand public attitudes towards the development of CCUS technologies in the UK.

Developing CCUS is part of the UK Government's strategy to deliver net zero emissions by 2050. The Government is aiming to deploy CCUS in two industrial clusters by the mid-2020s, and for two more clusters to be operational by 2030.

Top 10 participant conditions for UK CCUS development

Energy & Climate Change Minister Anne-Marie Trevelyan, said, "Carbon capture usage and storage technology will play a key role in meeting our world-leading climate commitments and as we build back greener from the pandemic. We want the UK to become a world-leader in this technology and studies like this will ensure public views will be one of the key influences in our decision-making on this, ensuring communities benefit from this exciting technology and the jobs that can be created as it's developed."

"The public dialogue was held online, with over 100 participants from five locations across the UK. The majority represented UK geographies already favoured by heavy industry, or well-suited to future CCUS cluster development, while a fifth of those consulted were from a location which is less likely to be directly impacted by CCUS deployment."

"The majority of participants supported the role CCUS could play in the UK's pathway to net zero, alongside a national portfolio of other low carbon solutions, such as renewable energy. However, support for CCUS was conditional on two key factors: that CCUS must be safe and that it must make a meaningful contribution to UK CO2 emissions reductions. Strength of support was also conditional on additional factors, such as transparency around procurement and local public engagement, clearly identified community benefits (including the creation of local jobs), and commitments to minimise disruption to the local residents and the local natural environment."

Tom Saunders, Head of Public Engagement, UK Research and Innovation, said, "I'm very glad that Sciencewise has supported the first major public dialogue on carbon capture technologies and their deployment within the UK. In our race to reach net zero carbon emissions through the development of new technologies we must ensure that the perspectives and priorities of local communities and the wider UK public are listened to."

"This will help policymakers think about the benefits that local communities want to see and the challenges that they might face living with particular technologies. It is important that this dialogue is the start of a process and that public attitudes and priorities continue to inform and shape policy for carbon capture over the coming decade."

Participants were more comfortable with the idea of CCUS being deployed nationally than in their local area. Participants thought that job creation was the key benefit of local deployment and participants in Aberdeen and Teesside were more positive than other locations because they could see a clear link between the CCUS project they considered in the dialogue and local jobs. Participants felt CCUS projects must deliver benefits to local communities, particularly in terms of job creation.

Participants wanted it to be clear how CCUS projects were being funded and for contracts to be awarded transparently and fairly to what they described as ethical companies. Participants placed high importance on engagement with local communities impacted by CCUS and on this engagement being inclusive and meaningful.

More information

sciencewise.org.uk

VSA, membrane and PSA technologies for steam methane reforming CO2 capture

More than 95% of the current hydrogen production worldwide is derived from fossil fuels and Steam-Methane-Reforming is the dominant technology. Stephen B. Harrison, Managing Director, sbh4 consulting looks at some of the ways CO2 can be captured. **www.sbh4.de**

Methane and steam are converted into hydrogen and CO2 with a typical content of 76% hydrogen, 17% CO2, and 7% unreacted methane and other gases.

The SMR operates at pressures of up to 25 bar. To purify the hydrogen, a Pressure Swing Adsorption (PSA) unit is used, which takes advantage of the elevated pressure of the gases produced by the SMR. The tail gas from the PSA is fed back into the fired burners in the SMR, and its calorific value is used to enhance energy efficiency.

Under current practices, the CO2 is either released into the atmosphere or, in the case of hydrogen production for ammonia for fertilizers, the CO2 is captured to be reacted with ammonia to produce urea. In such applications, a water wash tower to cool the gas and remove particulates followed by a twin-tower amine-based CO2 absorption and CO2 stripping system is a common configuration to capture the CO2 gas.

As an alternative to amine-wash technology, VSA or PSA adsorption can be used to capture the CO2 gas. To employ these technologies in this way, there are two basic process flow sheet options to capture the CO2 content from the process gases leaving the SMR. In the first variant, the carbon dioxide is separated directly after the SMR, hence the hydrogen PSA only needs to separate additional impurities.

In a second process flow sheet option, the hydrogen PSA remains unchanged, and the CO2 is sequestered from the hydrogen PSA tail gas. This process flow sheet may be favourable due to the high CO2 concentration in the hydrogen PSA tail gas of more than 80%. Both process flow sheet options have been implemented in demonstration plants.

VSA CO2 capture

Air Products operates two SMR trains at their premises in Port Arthur, Texas. The purified hydrogen is fed into a 1,000 km long transmission pipeline with a capacity of 1.3 million Nm3/hr of hydrogen, which extends from Houston, Texas to New Orleans, Louisiana. It connects more than 20 industrial hydrogen users in a very efficient way.

To capture the CO2 content of the product gas Air Products opted for the first process flow sheet option and installed an additional PSA unit between the SMR and the hydrogen PSA unit. As it draws the high purity CO2 gas at sub-atmospheric conditions, it is also referred to as Vacuum Swing Adsorption (VSA).

In the VSA process, adsorber vessels are fed with high-pressure product gas. CO2 is selectively adsorbed onto the adsorbent bed. The hydrogen-rich gas which was not adsorbed is fed into the standard hydrogen PSA for further purification. Afterwards, the vessel undergoes a series of pressure equalisations with other vessels of lower pressure levels. The adsorber vessel contains now high-purity CO2. The CO2 gas is drawn out by an 'evacuation' step, which brings the pressure below atmospheric pressure. In a second step, blowdown gas is taken from a lower pressure bed, compressed, and fed back to a higher-pressure bed to 'rinse' the vessel. Both steps of 'rinse' and 'evacuation' are essential to achieve high CO2 purities.

More than 90% of the carbon dioxide is removed in each of the VSA trains. This equates to more than 1 million Tonnes of CO2 capture per year resulting in a major contribution to the decarbonisation of hydrogen production and industrial gases operations.

The CO2 is subsequently compressed in an intercooled 8-stage centrifugal compressor to 140 bar, which is about 70 bar above the critical pressure of CO2. A purpose-built 21 km long CO2 pipeline connects the VSA units at Port Arthur to an existing 60 cm diameter CO2 transmission pipeline with a total length of about 500 km. This transmission pipeline connects oil fields in Texas and Louisiana. Ultimately, the captured CO2 is used for Enhanced Oil Recovery (EOR) within these oil fields.

Membrane and PSA CO2 capture

Air Liquide has developed a CO2 sequestration process, based on the second process flow sheet option, for the CO2-rich tail gas from SMR hydrogen PSA units. The PSA tail gas is dried by means of an additional PSA. The gas stream is compressed to a pressure at which CO2 can be separated by liquefaction at around -50°C, close to the triple point. An additional control loop avoids freezing of CO2 under all operating conditions to avoid system blockages.

Within the cryogenic unit, partial condensation and distillation techniques are applied to separate the CO2 from impurities present in the stream. The non-condensable gases are fed to a cryogenic membrane system, where additional hydrogen and CO2 are recovered. This 'Cryogenic Capture' stage is unique to the Air Liquide process and gives its name to the technology, which is known as Cryocap™. It leads to an increased hydrogen productivity of 10-20%, as well as a CO2 recovery rate of more than 98%. All other residual gases are sent back to the burners in the reformer furnace, where their calorific value is utilised.

The high purity (>99.5%) CO2 stream leaves the cryogenic unit before it is further compressed to supercritical pressure. If food-grade CO2 is the requirement, hydrocarbon and methanol traces originating from the SMR process can then be removed in a final purification step.

The first of its kind Cryocap™ demonstration installation in Port-Jérôme at a large-scale hydrogen SMR has a CO2 capture capacity of 100k Tonnes / year. Since 2013 Air Liquide has been planning to install a Cryocap™ unit at its Rozenburg SMR in the Netherlands, which would have a capture capacity of 500,000 Tonnes of CO2 per year. In 2020 Air Liquide applied for government funding within the SDE++ grant scheme to ensure the economic viability of this scheme. If the final investment decision is taken in 2021, the project could start capturing and storing CO2 by 2024.

Projects and policy news

Sinopec launches China's first megaton scale CCS project

www.sinopecgroup.com

China Petroleum & Chemical Corporation (Sinopec) has begun the Qilu-Shengli Oilfield CCUS project, set to become China's largest whole industrial chain CCUS demonstration.

Sinopec initiated China's first megaton carbon capture, utilization and storage project - the Sinopec Qilu-Shengli Oilfield CCUS project

The megaton-scale Project launched by Sinopec consists of two parts – Sinopec Qilu's carbon dioxide capture and Shengli Oilfield's carbon dioxide displacement and storage. Sinopec Qilu captures the carbon dioxide and transports it to the Shengli Oilfield for further displacement and storage, achieving an integrated application of carbon capture, displacement and storage to seal the carbon dioxide underground.

The Project is estimated to reduce carbon emissions by 1 million tons per year, the equivalent of planting nearly 9 million trees and shutting down 600,000 economy cars. China's large oil initially in place (OIIP) is suitable for carbon dioxide displacement and advancing development of the CCUS industry will establish sound support for ensuring China's energy security and promoting low-carbon transformation of the fossil energy industry.

As an essential technological path for achieving carbon neutrality, CCUS has tremendous potential for emissions reduction and broad prospects for industrial use. Studies have shown that CCUS will neutralize China's 1 billion tons of carbon emissions in the future, effectively promoting the purification of fossil energy, the scaled development of clean energy and low-carbon production.

Mr. Zhang Yuzhuo, Chairman of Sinopec, noted that CCUS is an important measure to effectively promote carbon emissions reduction.

"According to IEA, CCUS will contribute about 14 percent of carbon dioxide emissions reduction by 2050, and the market application prospects are very promising," said Mr. Zhang, "developing CCUS is a trend as well as a mission."

"Sinopec will research and establish a carbon capture, utilization and storage R&D center to advance a series of core technologies and bottleneck problems throughout the links of carbon capturing, transportation, utilization and storage, as well as a carbon dioxide utilization technology innovation system of 'technological development-project demonstration-industrialization,' extending the clean carbon sequestration industry chain and creating an innovative hub for carbon emissions reduction technologies."

Sinopec aims to build another megaton CCUS demonstration base in the next five years, realizing industrialized CCUS development and widening further prospects as China advances to achieve peak carbon and carbon neutrality.

CSIRO Roadmap highlights opportunity for Australia to lead in CCUS

www.csiro.au

Australia could turn carbon dioxide waste into a valuable revenue stream according to a new report from Australia's national science agency, CSIRO.

The CO2 Utilisation Roadmap explores the opportunities presented by emerging carbon capture and utilisation (CCU) technologies for Australia to support new industries and reduce carbon emissions.

The Roadmap identifies how emerging CCU technologies could be used to support growth opportunities in Australia's food and beverages industry, the creation of zero or low carbon building products and materials, and position Australia for the export of low emissions chemicals and fuels.

CSIRO Chief Executive Dr Larry Marshall said CCU technologies can help transition Australia towards a lower emissions future while creating economic growth.

"No single technology will take us to net zero – the scale of our challenge in adapting to climate change and decarbonising our industries requires us to draw on every available tool," Dr Marshall said.

"The development and demonstration of high abatement technologies like CCU has the potential to have a significant impact, as part of our broader efforts to both reduce emissions and lift the competitiveness of our industries."

Currently, industries such as cement, steel, plastics and heavy transport still rely on fossil fuels or have inherent emissions in their processes and are traditionally 'hard to abate'.

These industries are unable to rely on renewable technologies alone and account for about a sixth of Australia's emissions and around a third of global emissions.

CCU technologies capture CO2 from the waste streams of industrial processes, or directly from the atmosphere, and convert it into useful new products, ranging from synthetic fuels to food and beverages, chemicals, and building materials.

Associate Director of CSIRO Futures Vivek Srinivasan said Australia is well-placed to lead in CCU technologies.

"Our analysis shows that Australia is well positioned to capitalise on the CCU opportunity and become a leader in this emerging area," Mr Srinivasan said.

"Australia's advantages include capacity to implement the low-cost, low-emission electricity needed for CCU technologies, a track record for developing internationally competitive export industries, and established international bilateral agreements on low emissions technologies."

The Roadmap draws on extensive national and international consultation, modelling and analysis to determine the key advantages, barriers, and considerations to support scale-up for identified areas of CCU opportunity for Australia.

By acting as a potential major user of hydrogen and helping to reduce CO2 emissions, CCU complements CSIRO's investment in Australia's hydrogen and emissions reduction research through the Hydrogen Industry and Towards Net Zero Emissions Missions.

CSIRO worked with government and industry to develop the CO2 Utilisation Roadmap including the Australian Department of Industry, Science, Energy and Resources, Woodside, Santos, BHP, Wesfarmers Chemicals, Energy & Fertilisers, APA Group, Mineral Carbonation International, the Victorian Government, KBR, Advisian, Australian Trade and Investment Commission and CO2 Value Australia.

Summit Carbon Solutions awards contracts on "world's largest" CCUS project

www.summitcarbonsolutions.com

The awards have advanced the $4.5 billion Midwest Carbon Express project towards its commissioning date in 2024.

Summit has awarded contracts and deployed Contract Land Staff (CLS) and TRC Companies (TRC) to provide field services and lead right-of-way acquisition efforts across the five-state footprint. CLS and TRC provide Summit with decades of experience in managing landowner relationships.

Additionally, Summit has awarded contracts to EXP, Merjent, and Perennial Environmental Services to lead the environmental survey and permitting efforts throughout project development. Merjent and Perennial will lead the boots-on-the-ground efforts while EXP will provide overall project coordination and oversight.

EXP, Merjent and Perennial bring a full suite of environmental services and dedicated teams of biologists, scientists, cultural resources specialists, and environmental professionals with a keen focus on achieving environmental compliance.

A $4.5 billion investment, the Midwest Carbon Express project is expected to be the single largest carbon capture and storage project in the world. By connecting more than 30 ethanol facilities in Iowa, Minnesota, North Dakota, South Dakota, and Nebraska, this infrastructure investment will be capable of safely capturing and permanently storing 12 million tons of carbon dioxide every year.

Summit Carbon Solutions seeks to lower greenhouse gas emissions by connecting industrial emitters via strategic infrastructure to store carbon dioxide safely and permanently in the Midwestern United States.

Port of Corpus Christi to develop large scale CCS

www.portofcc.com

www.portofcc.com

The Port of Corpus Christi Authority and the Texas General Land Office (GLO) have signed a MoU to develop a carbon dioxide storage solution.

Such a solution would involve infrastructure to transport and permanently store CO2 captured by various industrial target sources in the greater Port of Corpus Christi area.

Industry leaders recognize the detrimental impacts of excessive CO2 emissions. Partnering to capture and sequester these emissions has unmatched environmental benefits. A recent report from the American Petroleum Institute and the International Petroleum Industry Environmental Conservation Association and the International Association of Oil and Gas Producers calls on energy developers to adopt unified actions to help mitigate emissions that meet global carbon reduction goals. Specifically, this report recommends immediate action to reduce carbon emissions by investing into the development of infrastructure to capture and permanently store carbon.

"Our modern society relies on Texas' rich natural resources for a variety of products that impact countless aspects of our daily lives," said Texas Land Commissioner George P. Bush.

"Utilizing new, innovative carbon storage methods is a critical step in demonstrating that energy development and environmental stewardship are not mutually exclusive. This partnership will ensure that Texas energy developers continue to responsibly utilize resources for future generations, as well as provide good paying jobs, and abundant and affordable energy. We are excited to establish this partnership with the Port of Corpus Christi and look forward to its future success."

The GLO has already displayed strong leadership in this area, most recently issuing a Request for Proposals from entities interested in constructing carbon storage infrastructure on GLO lands in Jefferson County, Texas.

"The Port of Corpus Christi is uniquely suited geographically and commercially to become the nation's premier hub for carbon management capture and storage," said Jeff Pollack, Chief Strategy and Sustainability Officer for the Port of Corpus Christi.

"We have a high density of industrial CO2 target sources, a robust network of existing pipeline infrastructure, and we own a full transect of land from our customers' fence lines out to GLO waters in the Gulf of Mexico."

Academics from the University of Texas at Austin have mapped the geology of the Texas Gulf Coast and determined this region is ideal for injection and storage of pressurized CO2.

With today's announcement, the GLO and the Port of Corpus Christi have identified the Texas Coastal Bend region as the next focal point for developing a scalable carbon management solution.

Which products are best suited for emerging carbon capture technologies?

A University of Michigan study has analysed 20 potential uses of captured carbon dioxide in three categories: concrete, chemicals and minerals and ranked them by climate benefit.

By some optimistic estimates, CCU could generate annual revenues of more than $800 billion by 2030 while reducing carbon dioxide emissions by up to 15%. Captured CO2 could potentially be used to make concrete and other building materials, fuels, plastics, and various chemicals and minerals used in industry, agriculture, medicine and elsewhere.

But which of these products would be most helpful to the climate? Until now, there has been no comprehensive study comparing the climate benefits of a full range of potential CCU-derived products.

The U-M researchers found that only four of the 20 "CCU pathways" they analyzed—two that use CO2 to make concrete and two that use it to manufacture chemicals—have a greater than 50% likelihood of generating a net climate benefit. A net climate benefit means the emissions avoided by using CCU technology outweigh the emissions generated while capturing the CO2 and making the final product.

The study, conducted by researchers from the Center for Sustainable Systems at U-M's School for Environment and Sustainability and at the U-M Department of Mechanical Engineering, was published online Aug. 22 in the journal Environmental Science & Technology.

"Decisions to globally scale CCU operations will require guidance on identifying products that maximize the climate benefits of using captured CO2," said lead author Dwarak Ravikumar, a former postdoctoral researcher at U-M's Center for Sustainable Systems who is now at the National Renewable Energy Laboratory.

"Our rankings will help prioritize R&D strategies toward products with the greatest climate benefit while avoiding pathways that incur a significant climate burden and that offer little hope for improvement," Ravikumar said.

The new study also showed that, at the present time, electricity produced from renewable sources such as wind often leads to a greater climate benefit if it is supplied to the grid to offset fossil fuel emissions, instead of being used to make CCU products. That will change over time as fossil fuels are gradually phased out, according to the study authors.

"Currently, there is a greater opportunity to reduce carbon emissions by using renewable energy sources to displace fossil fuel-based electricity generation than investing in many of the CCU technologies," said study co-author Greg Keoleian, director of the Center for Sustainable Systems.

"This study is important for prioritizing and guiding the future development and deployment of CCU technologies, particularly as energy supplies decarbonize," Keoleian said.

In carbon capture and utilization, carbon dioxide gas can either be pulled from flue gases at facilities such as power plants and cement factories, or it can be removed from the ambient air through a process called direct air capture. In the U-M study, the carbon dioxide is assumed to have been captured from a natural gas power plant.

In their study, the U-M researchers determined the lifecycle carbon dioxide footprints of the materials and energy needed to make the CCU products, then compared those values to the materials and energy needed to make conventional versions of those products. They developed a climate return on investment metric to rank and prioritize the CCU products.

The four CCU pathways with a higher than 50% likelihood of generating a net climate benefit included two methods that use carbon dioxide to mix concrete, one method to produce formic acid through the hydrogenation of carbon dioxide, and one method to make carbon monoxide from methane.

Formic acid is used as a preservative and an antibacterial agent in livestock feed and is used to tan leather and to dye textiles. Carbon monoxide is used in various industrial processes including synthetic chemical manufacturing and metallurgy.

"While we highlight four technologies, many of the others addressed in our study will provide a climate benefit under the right boundary conditions and will generate the products we need," said study co-author Volker Sick, a U-M professor of mechanical engineering and director of the Global CO2 Initiative.

"It's just that the options to achieve these benefits are more restricted. In this study, that is expressed as the likelihood of a climate benefit."

CCU is distinct from carbon capture and sequestration (CCS), which involves sucking up carbon dioxide and burying it underground.

The other author of the Environmental Science & Technology paper is Shelie Miller of the Center for Sustainable Systems, a professor at the School for Environment and Sustainability and director of U-M's Program in the Environment.

The research was supported by the U-M-based Global CO2 Initiative, the Center for Sustainable Systems, the School for Environment and Sustainability, and the Blue Sky Program at the U-M College of Engineering. The mission of the U-M-based Global CO2 Initiative is to get carbon capture and utilization recognized and implemented as a mainstream climate solution.

More information

css.umich.edu

www.globalco2initiative.org

Capture and utilisation news

Amine technology capable of 99% CO2 capture

www.imperial.co.uk

A study at Imperial College has shown that amine-based carbon capture technologies can capture 99 per cent of carbon emissions for little increase in cost.

Scientists have identified that post-combustion capture of CO2 using amine absorption is capable of capturing up to 99 per cent of CO2 from emission sources. This presents a promising opportunity for energy and industrial decarbonisation, and a step towards achieving net zero targets.

In the study, published in Environmental Science & Technology, researchers from Imperial College London's Department of Chemical Engineering and the Centre for Environmental Policy used computational models to demonstrate that amine-based CCS could cost-effectively capture high levels of CO2 across a wide range of applications in power and industry, highlighting the areas with the strongest potential for cost reduction.

Maximising the CO2 captured for post-combustion applications will also reduce the reliance on carbon dioxide removal technologies which are currently limited in availability, less developed and potentially more expensive.

Chemical absorption is one type of CCS technology and is based on the reaction between CO2 and specific compounds called solvents that form chemical bonds between the CO2 and the solvent.

Lead author Dr David Danaci said, "We hope our research can challenge the traditional assumption that 90 per cent CO2 capture is the upper limit by showing that 99 per cent capture is possible for little increase in cost."

Twelve and LanzaTech partner on polypropylene from CO2

www.lanzatech.com
www.twelve.co

The two companies are partnering to develop polypropylene using carbon transformation, an approach that takes into account the global health crisis and climate change.

Carbon transformation company Twelve and biotechnology company LanzaTech have partnered to transform CO2 emissions into polypropylene, a key polymer used for medical devices including syringes and IV bags, as well as for large-scale applications in automotive, furniture, textiles and other everyday products.

Twelve's carbon transformation technology converts CO2 into materials that are traditionally made from fossil fuels. The company helps brands eliminate emissions by replacing the petrochemicals in their products and supply chains with CO2Made® carbon negative chemicals and materials, as well as carbon neutral fuels.

LanzaTech's carbon recycling Pollution To Products™ technology uses nature-based solutions to produce ethanol and other materials from waste carbon sources. The partnership will bring together the two platform technologies to enable additional product development from CO2 streams, representing just one of many pathways to scale carbon transformation solutions.

"Polypropylene is a key material for essential medical supplies and for many products we rely on in our daily lives" said Twelve Chief Science Officer, Dr. Etosha Cave.

" Today, 100 percent of new polypropylene in use worldwide is made from petrochemicals. We now have a way to produce this critical material from CO2 and water instead of from fossil fuels, with no tradeoffs in quality, efficacy or performance. Replacing all of the world's fossil polypropylene production with CO2Made polypropylene would reduce carbon emissions by an estimated 700 million tons per year or more."

Making methane from CO2: carbon capture grows more affordable

www.pnnl.gov

In their ongoing effort to make carbon capture more affordable, researchers at the Department of Energy's Pacific Northwest National Laboratory have developed a method to convert captured carbon dioxide (CO2) into methane

By streamlining a longstanding process in which CO2 is converted to methane, the researchers' new method reduces the materials needed to run the reaction, the energy needed to fuel it and, ultimately, the selling price of the gas.

A key chemical player known as EEMPA makes the process possible. EEMPA is a PNNL-developed solvent that snatches CO2 from power plant flue gas, binding the greenhouse gas so it can be converted into useful chemicals.

Earlier this year, PNNL researchers revealed that using EEMPA in power plants could slash the price of carbon capture to 19 percent lower than standard industry costs—the lowest documented price of carbon capture. Now, in a study published Friday, August 21 in the journal ChemSusChem, the team reveals a new incentive—in cheaper natural gas—to further drive down costs.

When compared to the conventional method of methane conversion, the new process requires an initial investment that costs 32 percent less. Operation and maintenance costs are 35 percent cheaper, bringing the selling price of synthetic natural gas down by 12 percent.

Different methods for converting CO2 into methane have long been known. However, most processes rely on high temperatures and are often too expensive for widespread commercial use.

In addition to geologic production, methane can be produced from renewable or recycled CO2 sources, and can be used as fuel itself or as an H2 energy carrier. Though it is a greenhouse gas and requires careful supply chain management, methane has many applications, ranging from household use to industrial processes, said lead author and PNNL chemist Jotheeswari Kothandaraman.

"Right now a large fraction of the natural gas used in the U.S. has to be pumped out of the ground," said Kothandaraman, "and demand is expected to increase over time, even under climate change mitigation pathways. The methane produced by this process—made using waste CO2 and renewably sourced hydrogen—could offer an alternative for utilities and consumers looking for natural gas with a renewable component and a lower carbon footprint."

Transport and storage news

Aker Carbon Capture supports Greensand CO2 storage project in Denmark

projectgreensand.com
www.akercarboncapture.com

The Danish Greensand CO2 transport and storage project announced the formation of a strong industry consortium to drive forward one of Europe's leading CO2 infrastructure projects.

Project Greensand aims to validate technical and commercial feasibility of CO2 storage in the Danish part of the North Sea.

The project will form the basis for a decision to enable CO2 storage as early as 2025, positioning Greensand among the frontrunners of CO2 storage projects in Europe.

"Open access infrastructure for transport and storage of CO2 is key to deliver on the Paris agreement, and Aker Carbon Capture is proud to support national infrastructure projects with key capabilities and experience," said Henrik Madsen, Chairman of Aker Carbon Capture.

"Greensand can be an enabler for a sustainable Danish industry by offering permanent CO2 storage to a variety of greenhouse gas emitters, and thus supporting a strong common European drive towards Net Zero," added Madsen.

Aker Carbon Capture is proud to support the Greensand project as one of 29 Danish and international companies and research institutes that have joined forces to carry out a dedicated pilot project.

The project, which is led by Ineos Oil & Gas and Wintershall DEA, aims to demonstrate that CO2 can be injected into the Nini West reservoir offshore Denmark, as well as supporting the deployment of cost-effective and environmentally safe monitoring technologies.

"New cost-effective CO2 storage capacity is an important enabler of decarbonization for our customers. Through our Danish entity, Aker Carbon Capture Denmark, we are well positioned to serve not only the growing CCS market in Denmark, but also accelerate other markets in Europe," said Jon Christopher Knudsen, Chief Commercial Officer of Aker Carbon Capture.

Aemetis CCS drilling study confirms CO2 storage feasibility in California

www.aemetis.com

The study conducted by Baker Hughes concluded that more than 2 million metric tonnes per year of CO2 can be removed from the atmosphere and injected safely into the earth at two ethanol plant sites in California.

The Carbon Capture & Sequestration (CCS) geologic formation review and drilling study was completed by Aemetis Carbon Capture, a subsidiary of Aemetis, and was conducted by Baker Hughes, a global energy services company with operations in 120 countries.

The Baker Hughes study estimated that 1.0 million MT per year of CO2 can be sequestered in the saline formations located deep underground at or near the Aemetis Keyes ethanol plant site. The study noted that up to 1.4 million MT per year of CO2 should be injectable at or near the Aemetis Riverbank site due to the favorable permeability of the saline formation and other factors.

"The conclusions from the initial Baker Hughes geologic formation and pre-drilling study confirm the feasibility of Aemetis plans to construct two CO2 injections wells at or near the Aemetis biofuels sites," stated Brian Fojtasek of ATSI, the project manager for the Aemetis Carbon Capture construction phase.

"We have completed Front End Loading engineering and are now working on the Front End Engineering Design (FEED) and permitting for the Aemetis CCS projects."

Once complete, the Aemetis Carbon Capture CCS project is expected to capture and sequester more than 2 million MT of CO2 per year at the two Aemetis biofuels plant sites in Keyes and Riverbank, California. The amount of CO2 sequestered each year is expected to be equal to the emissions from 460,000 passenger cars each year.

"This latest study for Aemetis builds on our deep experience in providing storage site evaluation, well placement, underground formation review and drilling technology for CCS injection projects," said Ajit Menon, energy transition leader for Oilfield Services at Baker Hughes.

"This is another step in the development of CCS capacity, which will be a key part of the energy transition going forward."

Each MT of CO2 is planned to generate approximately $200 per MT from the California Low Carbon Fuel Standard and $50 per MT of IRS 45Q tax credit.

Legislation is pending in Congress to increase the federal tax credit to $80 per MT of CO2 and to provide billions of dollars of grants and loans to finance CCS projects in the U.S.

World's first CO2 Capture Plant on vessel installed

www.kline.co.jp

K LINE has been conducting a joint project with Mitsubishi Shipbuilding and Class NK to develop CO2 capture onboard vessels.

A small CO2 capture plant has been installed on the coal carrier CORONA UTILITY operated by "K" LINE for Tohoku Electric Power Co. at Mitsubishi Heavy Industries Yokohama Works.

For the installation of this plant, Class NK has conducted a Hazard Identification Study (HAZID) and verified the viewpoint of safety.

After departure of the vessel from MHI Yokohama, experts from Mitsubishi Shipbuilding will be on board for one voyage to commission the small CO2 capture plant, evaluate its operational performance at sea, and analyze the captured CO2.

After that, until the end of FY 2021, the ship's crew will evaluate the operation, safety and operability of the CO2 capture plant, and will conduct demonstration tests in order to commercialize the plant such as downsizing in size and weight, efficiency of CO2 capture system with Mitsubishi Shipbuilding.

Based on the "K" LINE Environmental Vision 2050, the company says it will continue to research, develop, and introduce various environmental load reduction technologies, including the CC-OCEAN project, and contribute to activities aimed at achieving GHG reduction targets and realizing a carbon-neutral society.

SECURe project makes CO2 storage recommendations

The SECURe project has significantly advanced knowledge of how best to manage subsurface geoenergy projects involving CO2 storage and unconventional hydrocarbons.

Faster roll-out of CCS is increasingly seen as critical if we are to limit global warming to below 2°C, as per the Paris Agreement. The three-year SECURe project, which finished in May, developed several innovative monitoring and remediation techniques which will help raise the storage readiness levels of potential sites. It has also provided guidance on communicating effectively with stakeholders and with communities – essential for building wider public acceptance of CCS.

The increased knowledge developed in SECURe will enable CCS projects to show that CO2 storage is a safe, efficient and viable option for advancing decarbonisation of industrial and energy emitters. Such projects are supported in the UK through last November's 10-point green industry plan and across Europe through the Innovation Fund and through Projects of Common Interest (PCI)

"Our novel research has furthered understanding of what baseline environmental conditions mean in the context of ensuring CO2 storage operations are conducted in a safe and reliable manner," said project coordinator Ed Hough of the British Geological Survey which led the project.

"SECURe has advanced environmental monitoring and remediation that will help the uptake of subsurface CO2 storage. We have also improved our understanding of how geoenergy projects are perceived by non-experts, which is valuable in designing messages to help the acceptance of schemes in host communities."

Funded by the EU's Horizon 2020 programme, SECURe brought together 16 research and commercial organisations from Denmark, France, Germany, the Netherlands, Norway, Poland and the UK. In all, the €8.5m project published 41 research reports. These detail advances in:

• risk assessment for leakage from CO2 storage and unconventional hydrocarbons extraction (UHE) sites and induced seismicity;

• environmental baseline and monitoring strategies;

• advanced monitoring and sensor technologies; and

• impact mitigation and remediation and development and exchange of best practice associated with CO2 storage and UHE sites.

Examples of specific innovations furthered by SECURe include: environmental baseline strategy synergies that allow deployment of multiple monitoring techniques in unison; integrated multi-tracer fingerprinting of fluid migration; methodology optimisation for methane and higher hydrocarbon concentrations/isotopic ratio measurements in groundwater and soil gas; an Unmanned Aerial Vehicle-based CO2 sensor; and a noble gas downhole sensor improved to successfully analyse gas-water ratios and volumes of inert gas.

Project recommendations

SECURe gathered unbiased, impartial scientific evidence. We identified four principal hazards associated with geological CO2 storage, and five associated with unconventional hydrocarbons extraction (UHE). We have summarised key recommendations for regulators and industry operators addressing each issue in a series of factsheets. Participatory monitoring was also a key part of SECURe's research: its value was captured and embedded within each risk assessment. Because of its broad relevance, we also created an overview participatory monitoring factsheet, with our recommendations in this area.

"Our recommendations seek to provide a pragmatic and reasonable response to concerns," said Ed. "They can be used to inform site development and management strategies from the perspective of multiple stakeholders - operators, regulators, legislators and the general public."

International research partnership

The SECURe team undertook fact-finding missions to the USA and Canada and to Australia – regions with some of the world's most advanced subsurface geoenergy research facilities and operations. We gathered valuable information on current understanding and good practice in site performance and environmental monitoring from a practical and operational perspective. Building on the positive connections made, SECURe has established the International Platform for Environmental Monitoring, a long-term collaboration initiative bringing together practitioners, regulators and researchers to facilitate knowledge and data exchange.

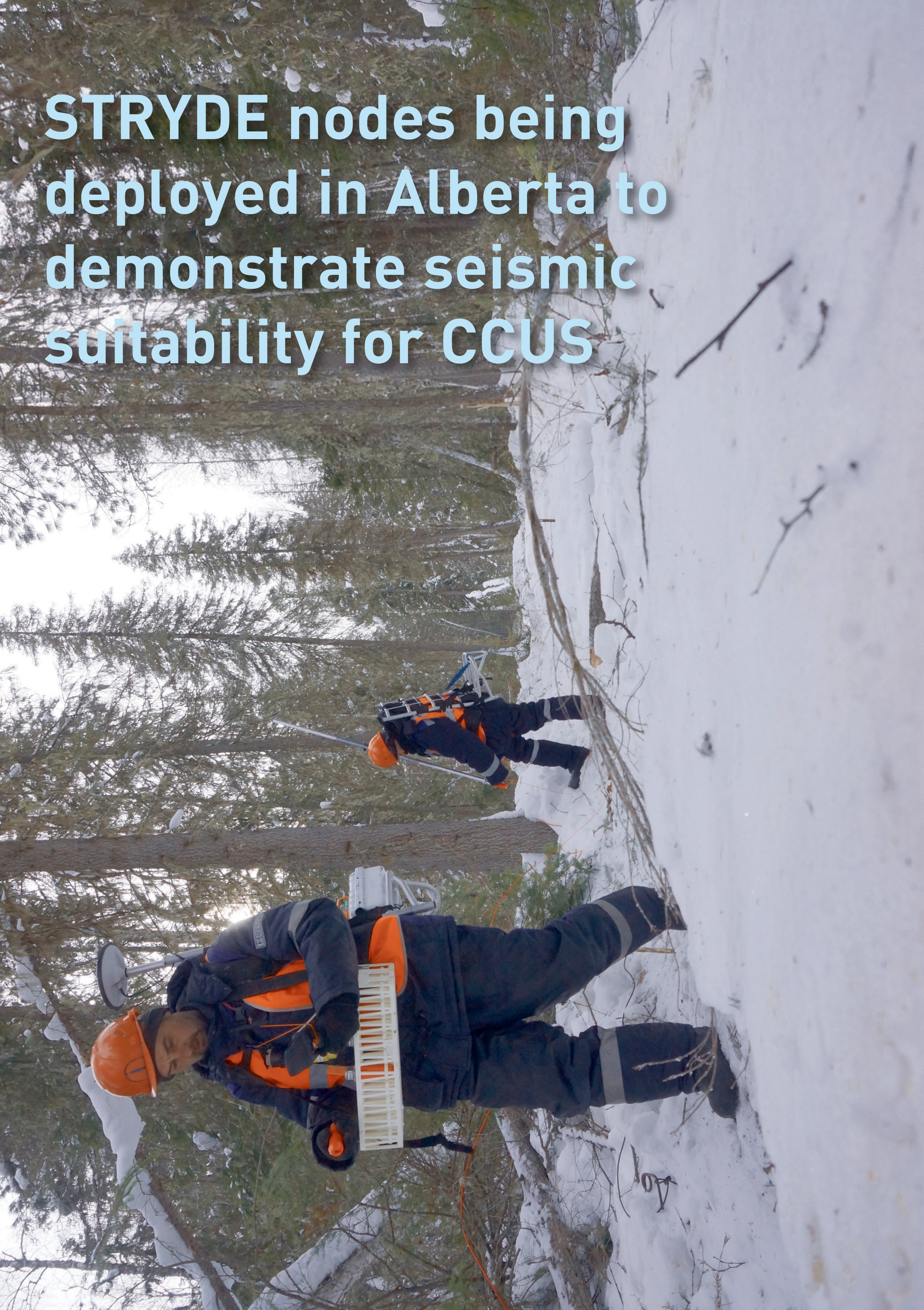
"Part of the legacy of SECURe is enhanced international collaboration between research teams and organisations that share common goals and interests in reaching lower carbon futures, environmental monitoring and risk reduction for new uses of the subsurface," said Ed.

"February's IPEM launch event resulted in a clear mandate to maintain this network beyond the life of the SECURe project, with an initial focus on environmental monitoring and effective community engagement for low-carbon geoenergy projects and related activities. We expect IPEM to take the form of a regular biannual event series. A steering/organising committee is now being actively sought to take on the coordination of IPEM beyond SECURe."

"We are delighted IPEM has been well received and hope it will develop into an enduring legacy of SECURe and the significant progress in advancing low-carbon geoenergy that the project achieved."

More information

www.securegeoenergy.eu


STRYDE nodes being deployed in Alberta to demonstrate seismic suitability for CCUS