Carbon Capture Journal

CCS in Canada

Carbon Capture & Conversion Institute created to accelerate CO2 conversion technology

CCEMC Grand Challenge moves to Round 2

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XPRIZE offers $20 Million for breakthroughs in CO2 Conversion

North Sea 'preferred' CO2 storage for Europe and Scottish CO2 hub

Carbon dioxide stored underground can find multiple ways to escape

Yanchang CO2 EOR: unique geology, unique challenges

One policy measure to keep oil flowing - and hit the country's CO2 targets

Here's a fairly simple idea for a single policy measure which can extend the life of Aberdeen's North Sea oil and gas fields - and hit the country's CO2 targets - a reduction in gasoline tax paid by motorists if the oil is zero carbon.

By Karl Jeffery

'Zero carbon oil' is defined as oil which causes zero net CO2 going into the atmosphere. In practise it could be achieved in two ways - by sequestering CO2 in the ground into the reservoir oil is being pumped from (enhanced oil recovery) so that the CO2 in and CO2 out of the reservoir is balanced; or by an oil company paying for carbon capture and storage elsewhere (as Shell was planning to do, with the Peterhead project).

The motorists would pay the same price at the pump for gasoline however it is made - we work on the basis that most motorists don't care enough about zero carbon oil to pay more for it - but the reduction in gasoline tax compensates for the increase costs of producing zero carbon oil.

An added benefit is that it gives the UK oil and gas industry some protection against lower cost Middle East operations (lower cost because the reservoirs are much easier to extract oil from). There is a special market in 'zero hydrocarbon oil' which the UK could dominate. As 'zero hydrocarbon oil' spreads around the world, the UK companies would have the necessary expertise which they could then sell around the world.

It would be a story of reinventing the British oil and gas industry to create something high value - in the same way that the British car industry has reinvented itself to make Aston Martins.

Costs and revenues

Whether it would work depends on the following costs and revenues.

(1) how much the 'zero carbon oil' would cost to produce compared to conventional oil

(2) if the UK Treasury reduces gasoline tax on 'zero carbon oil' so that motorists end up paying the same amount, does the UK Treasury end up positive or negative - taking into consideration the increased revenue it would get from more operations in the North Sea, in the form of employee payroll tax, oil company corporation tax, plus additional benefits such as deferred decommisioning costs, profit and payroll tax from North Sea suppliers, and maintaining the UK's base of oil and gas technology and service companies which then sell outside the UK generating more government revenue. Plus there are benefits if this turns out to be a cheaper way to meet the UK carbon targets than wind and solar.

Rather than the Treasury ask oil companies how much it would cost to make zero carbon oil, we suggest the Treasury sets a target, which can then be reviewed on an annual or five yearly basis. Oil companies can go ahead with projects if the economics make sense on this basis.

For example, currently UK gasoline tax is 58p per litre and the petrol pump price is around £1, so the cost of the entire oil industry chain, including oil prices, transport, refining and retail costs and profit are 42p per litre.

The government could agree to a 20% reduction in gasoline tax (to 46p per litre), which would mean that the oil industry chain receives 54p per litre instead of 42p, so 28% more. The oil and gas industry can work out if it can come up with a 'zero carbon' product within these margins.

Questions to answer

Here are some questions about whether it might work, with our answers.

TIMEFRAME - oil industry projects are on a very long term basis, perhaps 50 years. So there would need to be committment from government that this scheme will be in place for a similar timescale, or at least 5-10 years?

CO2 EOR - many commentators believe that a CO2 EOR business in the North Sea could be self-supporting, since the cost of getting CO2 into the ground (including CO2 capture costs at a power station) are less than the value of increased oil which is produced. The problem is the vast capital costs of building everything. This above plan does not mitigate the capital costs, but it does provide more ongoing revenue, which might make a project more investable.

COMPETITION LAW - is it plausible for government to come up with a taxation regime which covers legal and commercial issues at the same time like this? Does it create an unfair advantage for any group which might be challenged?

DOES IT WORK - perhaps the cost creating zero carbon oil is so high that the scheme wouldn't work - the loss to the government Treasury of gasoline tax would be lower than the increased benefits

WHO WANTS TO INVEST IN OIL - many investors have been burned by the recent oil price crash and Saudi Arabia seeming to want to show the world that its still boss when it comes to the oil market. Although Saudi Arabia needs a $70 oil price too.

WHERE WILL THE OIL PRICE GO - Let's say, CO2 + EOR needs an oil price equivalent to at least $80 to work. So we'd need a market price of perhaps $60, so oil companies would get their $80 with the 'markup' this syhstem would achieve.

More information

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Front cover: Shell's CEO Ben van Beurden (centre) and Canada Country Chair Lorraine Mitchelmore (second from left) are joined by Alberta's Minister of Energy Margaret McCuaig-Boyd (left) and joint venture partners from Chevron and Marathon Oil (right), for the ceremonial valve turning (Image ©Shell)

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Leaders - CCS in Canada

Projects and policy

Capture and utilisation

Transport and storage

Canadian institute focused on accelerating CO2 conversion tech

Three organizations in western Canada have teamed up to create the Carbon Capture & Conversion Institute, aimed at advancing technologies to capture carbon from industrial facilities and convert it into valuable products.

By Mark Lowey

Based in Vancouver, British Columbia, the Institute is the first initiative of its kind in Canada. It will bring together a global community of experts to accelerate the development, piloting, scale-up and validation of new carbon capture and conversion technologies, while also training the next generation of engineers, scientists and technicians. The institute is a collaboration between CMC Research Institutes, headquartered in Calgary, Alberta, and the University of British Columbia, and BC Research Inc. – both located in Vancouver.

The new institute will address the "pressing challenge" to develop and deploy carbon capture and conversion technologies in existing industrial plants, and is expected to help Canada fulfill its Paris Agreement commitments to significantly reduce greenhouse gas emissions, says Richard Adamson, president of CMC Research Institutes which spearheaded the initiative.

"In addition to the electric power sector, within the industrial economy there are a lot of processes that result in CO2 emissions, whether it's cement production or chemicals and plastics production or metallurgical processing or mining," he says.

Since there are already trillions of dollars invested in such facilities around the world, "we can't just flip a switch and change out all of that investment all at once. So we have to find a way to address, in the near term, the emissions associated with the industrial economy we have now," Adamson says.

A huge hurdle for the widespread deployment of carbon capture technology is cost. Existing technologies, such as capturing CO2 from flue gas streams with amine 'scrubbers,' which is the most common commercial application, are expensive – typically about $80 per tonne of CO2.

"The challenge is to find an alternative technology which is economic," says Hassan Hamza, president of BC Research. "This technology must be properly scaled up, through bench-scale to pilot scale, to demonstration plants, for successful commercial deployment."

The new institute will focus not only on technologies that reduce the cost of the CO2 capture process, but which also use the captured CO2 to produce valuable products that will generate revenue to offset the carbon capture costs.

Each partner brings particular strengths

"The Carbon Capture & Conversion Institute is an ecosystem, with all three organizations bringing experts able to address challenges ranging from fundamental science all the way through to commercial implementation," Adamson says.

Richard Adamson, President, CMC Research Institutes

CMC Research Institutes, the mission-driven, not-for-profit operator of the institute, works with researchers and institutions across Canada and worldwide, such as the U.S. Department of Energy, Norwegian research laboratories like SINTEF and others, private companies in the U.K. and U.S., and research groups in Europe and Korea.

"We reach broadly to be able to integrate technology elements into what might become a solution or solutions," Adamson says. The new institute is the second of several centres across Canada – each focused on key challenges for decarbonizing the industrial economy – envisioned by CMC. The first one was the Containment & Monitoring Institute, hosted by and affiliated with the University of Calgary, and its Field Research Station (featured in the May-June, 2015 issue of Carbon Capture Journal).

The University of British Columbia (UBC), the host academic institution for the Carbon Capture & Conversion Institute, is critical in sourcing and evaluating early-stage ideas, with a research team at the university's Department of Chemical and Biological Engineering and a multidisciplinary group at its

affiliated Clean Energy Research Centre. The UBC team focuses on developing industry-compatible processes to adapt research from bench-scale and batch processes to continuous, large-scale operations.

Naoko Ellis, professor of chemical and biological engineering at UBC and the new institute's acting senior research director, says a team that includes all three partner organizations will assess technologies and select the most promising for further development. "We need to accelerate the rate and number of technologies reaching commercial status," she says. "Another key benefit of the institute will be training the next generation of engineers – the next generation of leaders – by exposing them to research challenges unique to industry and providing the opportunity for significant interactions with the industrial partners," Ellis notes.

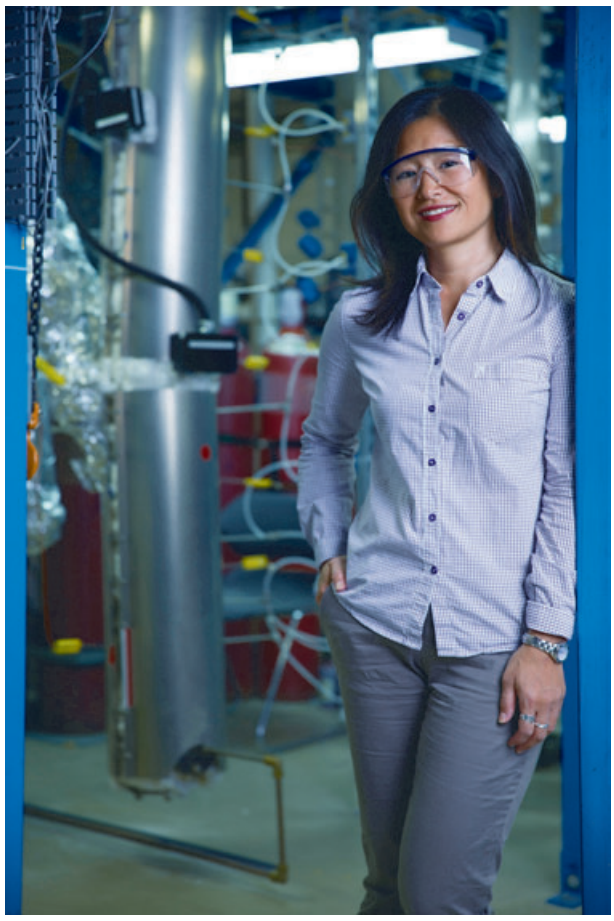
To support the institute's core research team at UBC, the collaborating organizations are seeking $1.5 million from an industry partner or conglomerate to establish a five-year research chair, co-sponsored by the Natural Sciences and Engineering Research Council, a federal funding agency.

BC Research Inc., a leading innovation centre specializing in the incubation and commercialization of emerging technologies, brings engineering design, development and scale-up capacity to the institute. Its services include experimental research, process development, pilot plant design, construction and operation, mechanical and material process engineering consulting, and laboratory analysis and testing.

"We are very good at scale-up of technologies – this is our business," Hamza says. BC Research is also the R&D arm of Vancouver-based NORAM Engineering and Constructors Ltd., a global firm that develops, engineers, and commercializes technologies for the process and resource industries. NORAM also owns Axton Incorporated, which is able to fabricate pilot plant components and can provide insights into development paths that will lead to capital cost savings at full scale.

New pilot-scale testing centre being built

BC Research will host the Carbon & Capture Institute at its new Technology Commercialization and Innovation Centre, now under construction in Richmond, B.C. and scheduled to open by early 2017. About one-third of the $4.5-million (for construction and furnishings), 40,000-square-foot facility will be devoted to the institute, Hamza says. The centre will provide the capacity to demonstrate, operate, test and analyze carbon capture and conversion technologies capable of handling up to one tonne of CO2 per day.



Dr. Naoko Ellis, Department of Chemical and Biological Engineering, University of British Columbia

Along with on-site analytical services for improving process operational performance, the centre will provide CO2-rich streams (using natural gas) and utilities for operating large-scale pilot plants. The centre also will be able to accommodate a range of technologies – from solvent systems, membranes and sorbents on the capture side, to chemical, electrochemical and biological systems in the conversion stream.

"We are creating a platform of infrastructure in the facility where an innovator or a company can plug in their technology for testing and comparison, side-by-side, with a known technology," Hamza says. The centre will create a "hotbed" of innovation, he says, bringing together students and professors, researchers from universities, industry and government, experienced field engineers and new innovators, international collaborators, and companies that are looking at a technology that can solve their problems. "The outcome will be a sprint forward of technologies which are economic and viable."

The three organizations have chosen two

New TCIC Building – Currently under construction, the new Technology Commercialization and Innovation Centre has space dedicated to piloting facilities for carbon capture and conversion technologies.

technologies for initial testing. One uses metal organic frameworks – networks of metal ions or iron clusters bridged by organic molecules into a porous structure – for CO2 capture. Its development is being led by George Shimizu, professor of chemistry at the University of Calgary.

The other technology uses the formation of gas hydrates from flue and fuel gas mixtures to capture CO2. This approach is being developed by Peter Englezos, professor and department head of chemical and biological engineering at the University of British Columbia.

Converting CO2 into valuable products

Converting CO2 into valuable products is technologically feasible and is already being done. CarbonCure Technologies Inc., based in Dartmouth, Nova Scotia, retrofits concrete plants with a technology that recycles waste carbon dioxide to make affordable, greener concrete products.

Another Canadian firm, Carbon Engineering based in Calgary, Alberta, and which operates a pilot plant in Squamish, British Columbia, is commercializing technology to capture CO2 directly from the atmosphere, for use in producing ultra-low carbon fuels.

Carbon dioxide can also be used to make methanol, although there already is a global industry producing this product. Other potential products include dimethyl ether, which can be used as a substitute for diesel fuel in engines, or perhaps a construction material that displaces carbon-intensive cement.

"Each one of these technologies and target products only take off a relatively thin slice of the total, global CO2 emissions profile," CMC's Adamson notes. "But as we develop the pathways and drive the costs down and get more versatile processes in place, the wedges will add up substantially."

Dr. Hassan Hamza, President, BC Research Inc.

The Carbon Capture & Conversion Institute may find solutions for addressing emissions from natural gas combustion, which could make natural gas not only a "transitional" fuel to a low-carbon world but a "destination" fuel with a longer economic life, Adamson says.

Significantly reducing natural gas emissions would also help British Columbia shrink the carbon footprint of its planned liquefied natural gas export industry and associated natural gas production. CMC Research Institutes is also working with industry in Alberta on related activities that may be linked with the new institute.

So what would success for the institute look like?

"My vision is for it to become a globally renowned and acknowledged centre for innovation in addressing carbon emissions associated with continuous industrial processes," Adamson says.

"Innovation means that the products developed through the institute are commercially or industrially applied broadly around the world. Solutions are incorporated into legacy plants and next-generation plants that are being installed all around the world to address greenhouse gas emissions."

Mark Lowey is the managing editor of EnviroLine and has worked as a professional journalist in Calgary for 35 years.

Carbon capture and conversion technologies, such as the systems being developed by Mantra Energy Alternatives, will be piloted at the new Technology Commercialization and Innovation Centre in Vancouver, British Columbia. Photo courtesy Mantra Energy Alternatives

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Shell opens landmark CCS project

Shell officially opened its flagship carbon capture and storage (CCS) project – Quest – in November 2016 at its Scotford facility in Alberta, Canada. Quest will capture over 1 million tonnes of CO2 from Shell's Scotford Upgrader on an annual basis, which is equivalent to the emissions from about 250,000 cars. To date, Quest has successfully captured over 500,000 tonnes of CO2.

By Shell Canada

At the official opening gala, Shell CEO Ben van Beurden said, "Quest represents a significant milestone in the successful design, construction and use of CCS technology on a commercial scale. Quest is a blueprint for future CCS projects globally."

Quest was made possible through strong support from the governments of Alberta and Canada.

As part of the government funding arrangements, Shell is actively sharing information about Quest design, processes and lessons learned to help make CCS more accessible and drive down costs of future projects.

"Together with government and joint-venture partners, we are sharing the know-how to help make CCS technologies more accessible and cost-effective for the energy industry and other key industrial sectors of the economy," said Van Buerden.

Other collaborations include field testing advanced MMV technologies for underground CO2 storage with the US Department of Energy and secondment of a doctoral university student at Quest, to deliver on the UK-Canada joint statement on CCS issued in 2014.

Shell's Quest CCS project will capture and permanently store over 1 million tonnes of CO2 annually (Image ©Shell)

Shell CEO Ben van Beurden addresses guests at the official opening of Quest (Image ©Shell)

Quest is a fully integrated CCS project that includes pre-combustion capture facilities, pipeline transport and storage wells into a saline aquifer (the Basal Cambrian Sands). The Basal Cambrian Sandstone formation underlying large parts of Alberta is considered particularly ideal for safe CO2 storage with more than 2-kilometre depth and multiple overlying layers of impermeable rock formations that act as seals.

The comprehensive and sophisticated system in place for measurement, monitoring and verification (MMV) further ensures the captured CO2 remains safely and permanently stored. The robust MMV programme design earned Quest the world's first Certificate of Fitness for safe CO2 storage from world-renowned risk management firm Det Norske Veritas (DNV).

CCEMC Grand Challenge continues to accelerate innovation

The Alberta-based Climate Change and Emissions Management Corporation (CCEMC) received 59 submissions for the second round of the CCEMC Grand Challenge: Innovative Carbon Uses. The CAD $35 million international competition is seeking out projects that will create new carbon-based, value-added products and markets that significantly reduce GHG emissions by fostering the development and deployment of technologies.

The second round of the competition closed February 1 and included submissions from 10 different countries, with the bulk of applicants hailing from North America. A team of experts will vet the submissions and shortlist projects for more detailed submissions that are due in May. Up to five winning projects will be selected for awards of CAD $3 million each.

"This Grand Challenge will help identify and fund projects with real promise to totally change how we deal with carbon dioxide emissions" said CCEMC CEO Steve MacDonald.

This round of the competition set the bar high. Successful projects will have a clear path towards reducing greenhouse gas emissions by a megatonne annually and have an executable plan for deployment in Alberta.

"Alberta is committed to delivering solutions that will accelerate the transition to a future with lower greenhouse gas emissions," said MacDonald. "This Grand Challenge is an important part of Alberta's leadership in responding to the challenges of climate change."

The CCEMC Grand Challenge is designed to accelerate commercialization of carbon conversion technologies by providing funding through all three rounds of the competition. A final winner will be selected from the round 2 projects in 2019 and awarded CAD $10 million to help commercialize their technologies in Alberta.

Round 1 projects also considered for funding in round 2

CCEMC selected 24 projects for CAD $500,000 in funding in round 1 and they are also eligible to compete for round 2 funding. Round 1 winners must submit a final report, a financial report and a technology transfer plan by the end of May. Their round 2 submissions are due at the end of July.

Focus areas for Round 2

Focus areas for round 2 projects include, as examples:

- Technologies or processes that produce high value goods from carbon dioxide.
- Technologies that fix captured carbon into solid or readily transportable starting materials.
- High-value materials with high carbon content that could be produced from carbon dioxide.
- Biological processes that convert carbon dioxide into a new viable product (e.g., oils from algae).

More support for carbon conversion technologies

CCEMC and SDTC make CAD $40 million in funding available

CCEMC and Sustainable Development Technology Canada (SDTC) are offering up to CAD $40 million for projects led by companies registered in Canada. The organizations are seeking innovative projects linked to energy efficiency and conservation, new and better uses of carbon dioxide, methane reduction, or cleaner energy production and usage projects.

The joint process offers applicants a streamlined, harmonized model with one window for access to two pools of money, with a maximum of CAD $10 million per project. The matching funds available here (up to 66.7%) are more than applicants could get through either the SDTC or CCEMC processes individually.

Eligible Projects must be led by applicants incorporated and operating in Canada with fewer than 500 employees and less than CAD $50 million in annual gross revenue. Submissions are due April 13. Full details are available online at **ccemc-sdtc.ca.**

NRG COSIA CARBON XPRIZE

The NRG COSIA Carbon XPRIZE is a US $20 million competition that is complementary to the CCEMC Grand Challenge. This competition awards a prize purse to the innovators who convert carbon dioxide emissions from an industrial facility at a commercial-scale into a product with the highest net value. **carbon.xprize.org**.

More information

To stay apprised of CCEMC funding opportunities, subscribe to the organization's newsletter:

ccemc.ca

Ambient mineral carbonation of Québec ultramafic mining wastes

Carbonation of mining wastes is a cheap and environmentally friendly process that can help reduce atmospheric levels of CO2.

By Ali Entezari Zarandi, Faïçal Larachi, Georges Beaudoin, Benoît Plante, Bruno Bussière, Michelle Sciortino

Research is rapidly developing a variety of novel solutions that can help to mitigate the accumulation of CO2 in the atmosphere. Mineral carbonation of mine wastes is quickly becoming one of the most attractive of these new solutions, primarily because of its relative simplicity, use of otherwise valueless materials, and its ability to be implemented passively and at a large-scale. Furthermore, the products of mineral carbonation are considered to be environmentally-benign and stable.

The province of Québec is the perfect location in which to assess the proof-of-concept of mineral carbonation given its long-standing history with mining industry and its projected and current production of ultramafic wastes from the exploitation of mineral resources. In this special CCJ issue on Canada, some of the salient findings from the research on ambient carbonation of ultramafic mining residues will be reviewed.

Carbon Mineralization In response to growing concerns over climate change, new technologies are being intensively researched with the goal of developing robust and reliable strategies for the long-term storage of carbon emissions.

Carbon mineralization of alkaline, mafic and ultramafic minerals is a naturally-occurring kinetically slow weathering phenomenon during which Ca/Mg-rich rocks gently react with the atmospheric CO2 that is dissolved in rain droplets. While the removal of CO2 from the atmosphere by natural carbon mineralization is too slow to match the rapid rate of anthropogenic emissions, accelerated carbon mineralization might allow for greater control over the concentration of atmospheric CO2 while also allowing mining operations to sum up with a positive carbon balance.

Particle size, and thus, specific surface area, is a critical factor that affects carbon mineralization by controlling the leaching rate of the reactive metal ions, the sibling moiety involved in solid carbon storage. While comminution is an essential part of the mining process because it allows for the liberation of key metal-containing minerals from the surrounding rock, it also advantageously produces tailings with specific surface areas that are large enough to increase weathering by carbon mineralization.

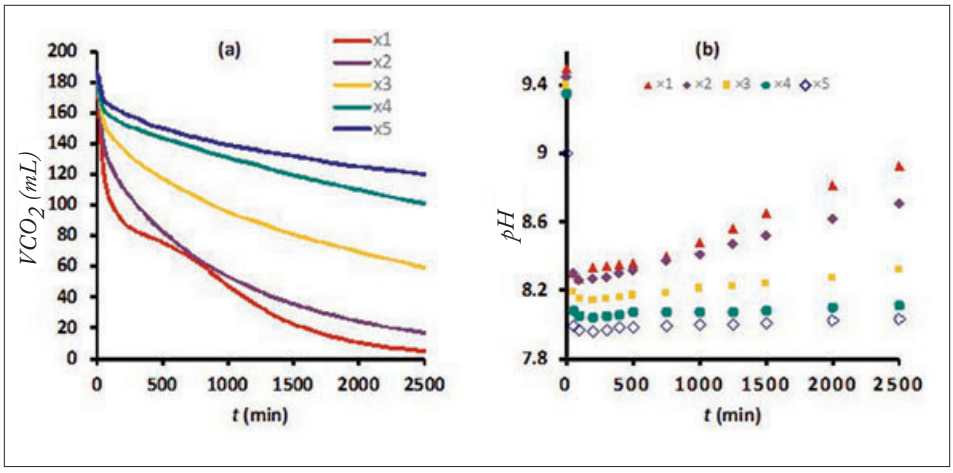

Figure 1- Carbon mineralization behavior of the DNP tailings (50% water saturation) at ambient temperature and pressure across multiple carbonation cycles: (a) volumetric consumption of CO2 over time (b) transient evolution of the pH of the pore water

Mg-rich mine waste, which consist of either coarse-grained waste rocks, or fine-grained mineral processing tailings, can therefore be considered to represent some of the largest man-made chemical reactors that accelerate CO2 sequestration from the atmosphere. Such reactors exhibit highly heterogeneous spatiotemporal reactivity patterns which depend upon their contact with meteoric water, wind and exposure to solar radiation.

The variability of these factors can result in the creation of dry, semi-saturated, and fully-saturated zones at different temperatures. Understanding the carbonation behavior in correlation with the conditions prevailing in each zone is therefore a prerequisite to the precise quantification of the carbonation efficiency of mining wastes.

Several chrysotile mine tailing sites in southern Québec (e.g., Black Lake and Thetford Mines) are good examples of passive carbon mineralization reactors currently active. It is estimated that two billion metric tonnes of chrysotile mining residues in Québec have the potential to capture ~700 million metric tonnes of atmospheric CO2 [1].

The Dumont Nickel Project (DNP), located in northwestern Québec, is predicted to be the fifth largest nickel sulfide producer worldwide and will involve mining a ~1.4×109 m3 ultramafic sill. Over its 31 year lifetime, the DNP will mine and mill ~1.18 billion metric tonnes of serpentinized ores, which will be disposed of as brucite-rich lizardite/chrysotile mineral processing tailings [2,3], in addition to the ~1.16 billion metric tonnes of peri-

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dotite/gabbro waste rocks that will be excavated to access the nickel-rich dunite ore.

Ambient Carbon Mineralization of Nickel Mine Tailings The research conducted in our group to date shows that carbon mineralization is sensitive to pore water saturation and also to the watering frequency of the mining waste [4,5]. Virtually no sign of carbonation is observed when desiccated tailing materials – mined and milled wastes alike – are contacted at ambient temperature with moisture-free CO2-containing gas.

At the opposite end of the spectrum, carbonation of fully wetted tailings is also barely active as a result of the slow CO2 diffusion rate in stagnant waters, which is a few orders of magnitude slower than its gas phase analog. On the contrary, relatively high CO2 uptake rates are measured for partially wetted materials where the degree of carbonation is prompted by the acidity of the solution which drives metal leaching and by the minerals alkalinity which promotes the precipitation of (hydrated) carbonate minerals.

Typical kinetic trends of the CO2 uptake behavior of the DNP tailings are illustrated in Figure 1 along with the dynamic evolution of the solution pH over the course of multiple carbonation cycles. The reactivity of the tailings diminishes from cycle 1 to cycle 5 (Figure 1a); this is mirrored by the material's dwindling ability to alkalinize the pore water (Figure 1b). These observations are in accord with the fact that brucite, and, to a lesser extent, chrysotile, react primarily with CO2 and water to produce nesquehonite ($MgCO_3.3H_2O$).

Interestingly, an unanticipated outcome of carbon mineralization in terms of run-off water alkalinization and metal content could reflect in lowering, in the long-term, the mine environmental impact as alkaline mine drainage is expected to be attenuated by carbonation of the waste piles. Contrary to the well-known problem of acid mine drainage, in mines that exploit ultramafic bodies, there is an unavoidable risk of producing alkaline mine drainage.

Although high alkalinity is essential for the formation of solid carbonated species, high pH run-off waters can be harmful to the environment because metal hydroxide compounds (e.g., $Al(OH)_3$) known to be sparingly soluble in neutral water may become soluble in alkaline media, while some neutral pH soluble metals can precipitate as hydroxide (e.g., $Co(OH)_2$, $Ca(OH)_2$ and $Cu(OH)_2$) [6].

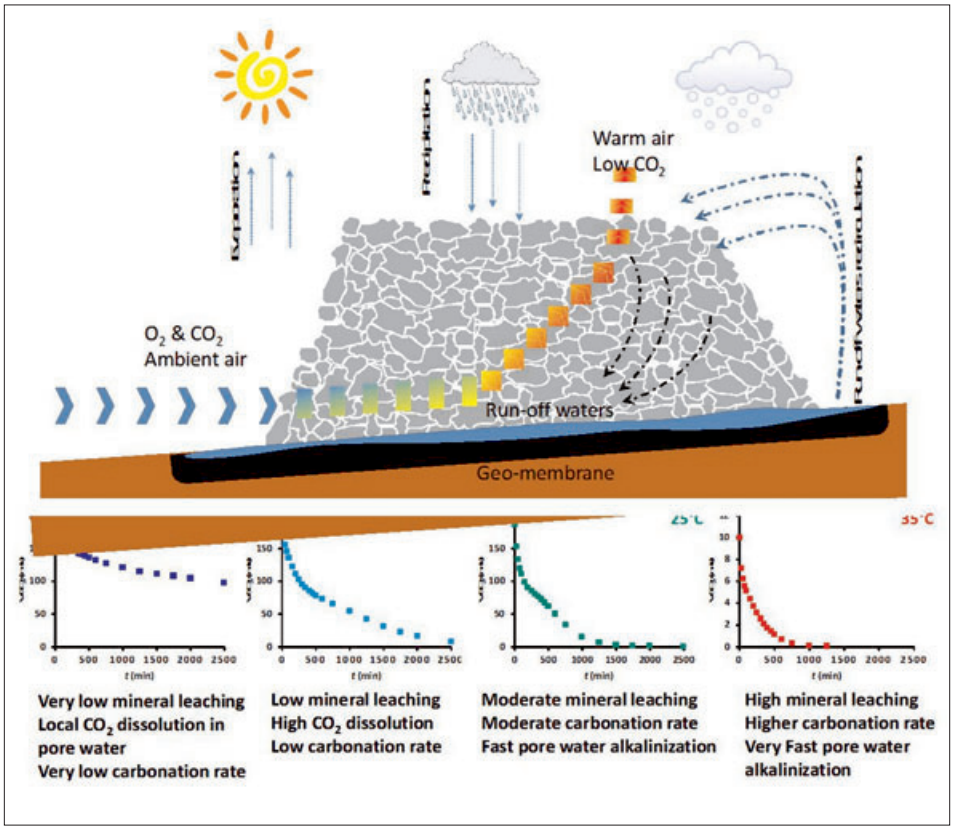

Figure 2 - Schematic representation of the impact of temperature on the carbon mineralization of ultramafic nickel tailings in outdoor conditions. Variations in seasonal temperatures as well as the volume of precipitation will greatly affect the carbonation rates

Temperature is another crucial factor that impacts carbon mineralization, and is especially relevant for disposal sites in Québec which are exposed to long, cold winters and short, but hot, summers. There are two short transitional periods during the spring and fall which are characterized by moderate temperatures and an abundance of rain showers.

Though sparingly soluble in water, CO2 increases in solubility in colder conditions, thus resulting in a stronger acidification. This serves to partially offset the decline in silicate mineral dissolution that positively correlates with temperature (Figure 2). Laboratory observations emulating outdoor conditions suggest that carbonation virtually never stops even under very cold conditions (e.g., -5°C), whereas the carbonation rates are notably stimulated (up to 40°C), provided that pore water is present, under warmer conditions [4,7].

These observations agree with the field tests conducted by our group during winter where warm (~14°C) vents of CO2-depleted air were detected at the surface of mine waste heaps through a relatively thick snow cover with a background air temperature around -20°C [8].

Bottom Line Mineral carbonation of mine wastes can be considered as an immediate tool to withdraw carbon dioxide from the atmosphere where the presence of pore water in the heaps is increasingly documented in the literature as being a crucial participant in the carbon mineralization processes [9].

1-Geo-engineered solutions applied at scale of mine waste dumps and highly-reactive tailing ponds can provide pathways to further intensify air and water circulation and, thus ensure optimal degrees of water saturation and CO2 availability across the entire inner structure of the piles.

2-A further improvement could be realized by taking advantage of the heat released due to carbonation within a structure's core. This heat can be recovered and used to pre-warm, prior to their injection, CO2–containing streams, such as those resulting from pre-/or post-combustion flue gases, thus further accelerating the carbonation reaction.

3- Canada's metal mining effluent regulations (MMER) forbid discharge of waters with pH > 9.5.

Carbon mineralization consumes both metal

and hydroxide ions in order to form hydrated metal carbonates. Optimal geo-engineered designs of a tailings site will not only withdraw substantial amounts of CO2 from the atmosphere, but will also contribute to producing environmentally benign minerals that can mitigate the alkalinity of the run-off waters as well as their dissolved metal content.

References

[1] J. Pronost, G. Beaudoin, J. Tremblay, F. Larachi, J. Duchesne, R. Hébert, et al., Carbon Sequestration Kinetic and Storage Capacity of Ultramafic Mining Waste. Environmental Science & Technology 45 (2011) 9413-9420.

[2] L. P. Staples, J. M. Bowen, S. B. Bernier, D. A. Warren, C. C. Scott, J. F. Duncan, et al., Technical Report on the Dumont Ni Project, Launay and Trécesson Townships, Quebec, Canada. Royal Nickel Corporation. July 2013.

[3] M. Sciortino, J. E. Mungall, and J. Muinonen, Generation of High-Ni Sulfide and Alloy Phases During Serpentinization of Dunite in the Dumont Sill, Quebec. Economic Geology 110 (2015) 733-761.

[4] G. P. Assima, F. Larachi, J. Molson, and G. Beaudoin, Impact of temperature and oxygen availability on the dynamics of ambient CO2 mineral sequestration by nickel mining residues. Chemical Engineering Journal 240 (2014) 394-403.

[5] G. P. Assima, F. Larachi, G. Beaudoin, and J. Molson, Dynamics of carbon dioxide uptake in chrysotile mining residues – Effect of mineralogy and liquid saturation. International Journal of Greenhouse Gas Control 12 (2013) 124-135.

[6] C. A. Cravotta III, Dissolved metals and associated constituents in abandoned coal-mine discharges, Pennsylvania, USA. Part 2: Geochemical controls on constituent concentrations. Applied Geochemistry 23 (2008) 203-226.

[7] G. P. Assima, F. Larachi, J. Molson, and G. Beaudoin, New tools for stimulating dissolution and carbonation of ultramafic mining residues. The Canadian Journal of Chemical Engineering 92 (2014) 2029-2038.

[8] J. Pronost, G. Beaudoin, J.-M. Lemieux, R. Hébert, M. Constantin, S. Marcouiller, M. Klein, J. Duchesne, J.W. Molson, F. Larachi, X. Maldague, CO2-depleted warm air venting from chrysotile milling waste (Thetford Mines, Canada): Evidence for in-situ carbon capture from the atmosphere. Geology 40 (2012) 275-278.

[9] K. Lechat, J.-M. Lemieux, J. Molson, G. Beaudoin, R. Hébert, Field evidence of CO2 sequestration by mineral carbonation in ultramafic milling wastes, Thetford Mines, Canada. International Journal of Greenhouse Gas Control 47 (2016) 110-121.

More information

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XPRIZE offers $20 Million for breakthroughs in CO2 Conversion

Do you have what it takes to convert CO2 into valuable products? Do you have a process or technology poised for development, scale-up, and investment? Are you ready to connect your novel CO2 conversion process to willing markets? Then the XPRIZE is for you.

By Dr. Marcius Extavour, XPRIZE

This is the challenge put forth by the organizers of the NRG COSIA Carbon XPRIZE, a US$20 million global competition to convert CO2 into valuable products. This XPRIZE is the latest and largest push in a CO2 utilization field that is gaining attention, investment, and technology acceleration worldwide.

The competition will plug into and support global CO2 conversion networks embodied by the EU Horizons 2020 €1.5 million Prize, the Smart CO2 Transformation (SCOT) Network, and many others in cleantech technology, policy, and finance.

Inspiring Innovation and Catalyzing Markets

All XPRIZE competitions set audacious but achievable targets that drive teams to innovate and demonstrate tangible, transformative solutions. By articulating a clear goal that is beyond anything that has been demonstrated to-date, XPRIZE challenges scientists, engineers, entrepreneurs, and all creative thinkers to design and deploy real solutions that are truly inspiring.

With carbon mitigation and CO2 conversion specifically, the NRG COSIA Carbon XPRIZE aims not only to support technology game-changers, but to catalyze the markets and investor communities that can take these ideas to the next level by deploying, scaling-up, and reducing the cost of CO2 conversion and other CO2 mitigation technologies. XPRIZE has found that teams who enter the competition benefit tremendously from the focused support of investors, media, technology communities, and the public momentum gained with every XPRIZE.

The Canadian Context

The NRG COSIA Carbon XPRIZE has a unique Canadian connection, and comes at a time when Canada's newly elected Federal government is signaling re-alignment of public investments toward a low-carbon future.

In this context, Canada's Oil Sands Innovation Alliance (COSIA) has partnered with XPRIZE as a co-sponsor of the competition. Siting the Track B (natural gas) facilities in Canada will attract innovators to Canada for the XPRIZE and beyond, and support ongoing activities in CO2 conversion, mitigation, and utilization elsewhere in Canada.

These include efforts led by the Climate Change and Emissions Management Corporation (CCEME), an independent body created as a key part of the Canadian province of Alberta's Climate Change Strategy and movement toward a stronger and more diverse low-carbon economy, and Carbon Management Canada (CMC), a Canadian research network focused on carbon management in Canada's fossil energy sector, and their affiliated Research Institutes.

About the NRG COSIA Carbon XPRIZE

The NRG COSIA Carbon XPRIZE is a 4.5 year global competition open to any team that can demonstrate the conversion of post-combustion CO2 - from either a coal-fired or natural-gas -ired power plant - into valuable products. The winning team will convert the largest quantity of CO2 into one or more products with the highest net value, taking into account production costs, market prices of product(s) produced, and market volumes of product(s) produced. With an eye toward encouraging sustainable solutions that may ultimately be deployed at scale, there are also limits on freshwater consumption and total land footprint of team solutions.

The competition itself will proceed in three Rounds along two parallel tracks. Teams are encouraged to register on or before April 30, 2016, though late registrations will be accepted up to July 15, 2016. In Round 1, teams submit an electronic document package and are evaluated on their technology, process, team, business and operational plan. The most promising teams will advance to Round 2, during which teams will have one year to demonstrate an operating process that consumes 200 kg of CO2 per day at a facility of their choosing. In Round 3, up to 10 teams will demonstrate their technologies at approximately 2 ton/day scale at one of two new Test Facilities built specifically for the competition. Track A finalists will demonstrate at a test facility adjacent to a coal-fired power station in Wyoming, USA. Track B finalists will demonstrate at a test facility adjacent to a natural-gas-fired power station in Western Canada (site to be announced).

Test Facilities as Lasting Innovation Hubs

Dr. Marcius Extavour, Director of Technical Operations , XPRIZE

In parallel with the Test Facility under development in Western Canada, Track A finalists will demonstrate their technologies at the Integrated Test Center under development near Gillette, Wyoming, USA. Attached to the Dry Fork Station operated by Basin Electric Power Cooperative, the ITC will also serve not only as the site of Track A XPRIZE finals, but as a center of excellence and innovation in carbon capture, conversion, and utilization in the coming years.

XPRIZE co-sponsor NRG Energy has been a crucial partner in ensuring that Wyoming Governor Mead's vision for the ITC is executed to align with the timing and scale scale of the NRG COSIA Carbon XPRIZE.

Both Test Facility are expected to have long-term positive impact for the CO2 conversion community, and CO2 mitigation communities generally. Set to open during Round 3 of the XPRIZE in early 2018, this pair of facilities will be among a very small number of such facilities anywhere in the world that are equipped to test, develop, and refine CO2 conversion technologies at pilot and demonstration scales.

The initial 2 ton/day to 5 ton/day CO2 capacity of these facilities places them at the sweet-spot for technology commercialization, between grams-per-day early stage projects and megaton-per-year industry-ready facilities. This testing and evaluation infrastructure could prove to be as valuable and impactful in the long-term as the core technology innovation inspired by the XPRIZE competitors.

Impact

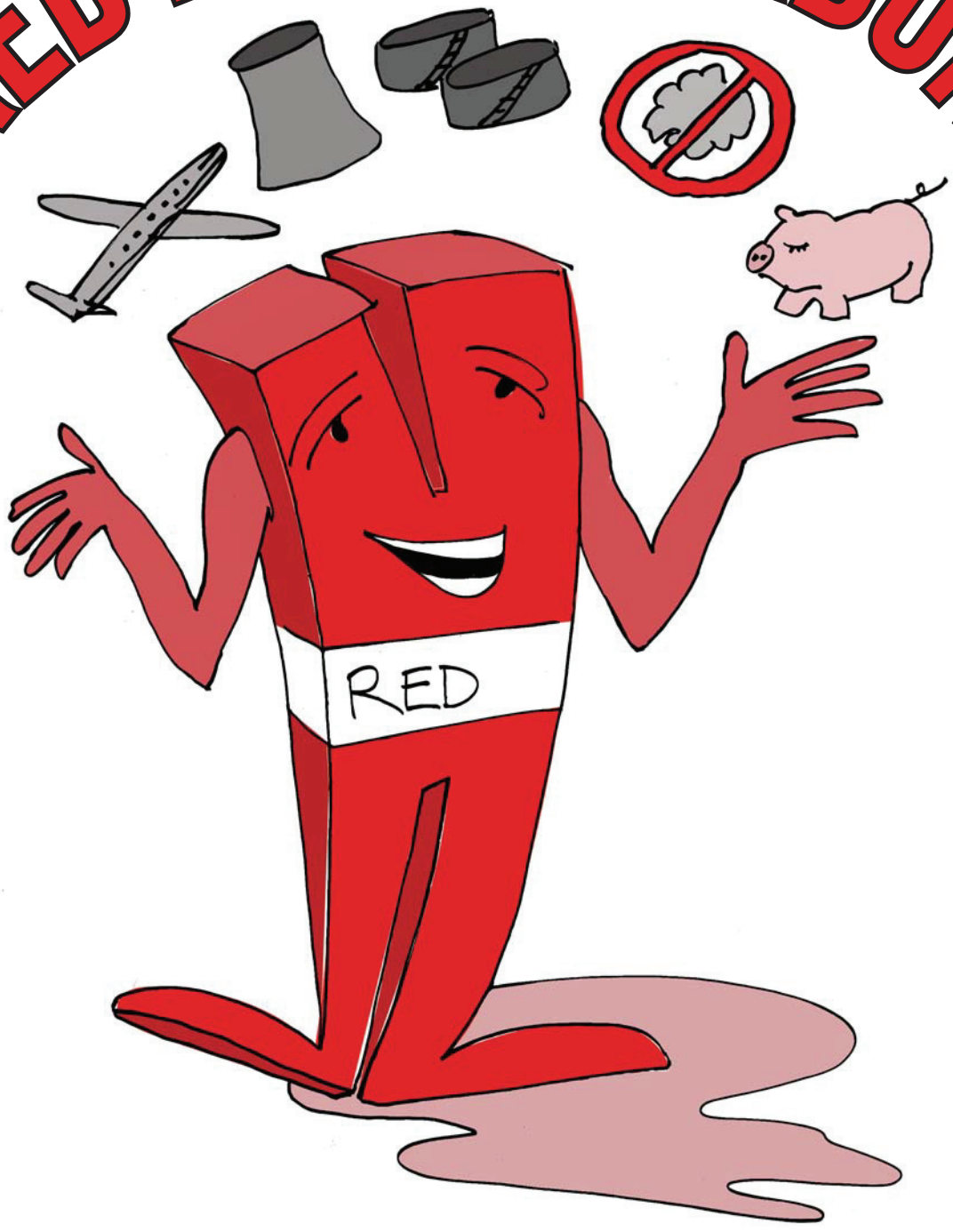
The Carbon XPRIZE will accelerate development of breakthrough technologies that turn CO2 emissions into valuable products, proving to the world that innovation can enable solutions to climate change. Ultimately, we intend that this competition will stimulate new markets for CO2 mitigation technologies, attract new investment, and inspire other industries, governments, and educational institutions to take concrete positive actions to combat climate change. At the same time, we hope to help shift public attitudes to be more optimistic about the future of energy and how we tackle climate change.

More information

carbon.xprize.org

Carbon Capture Journal

RED HYDROCARBON



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USING COMMERCIALLY AVAILABLE CAPITAL INVESTMENT, NO SUBSIDY AND ENERGY PRICES PEOPLE CAN ACCEPT - A MARKET INSTRUMENT FOR HYDROCARBON WHICH DOES NOT EMIT ANY NET CO2, WHICH CAN BE DRIVEN BY ENERGY BUYERS, REGULATORS AND INVESTORS, TO ENCOURAGE OR FORCE AN INCREASING AMOUNT OF CARBON CAPTURE EVERY YEAR

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£40 per household now or £200 per household each year from 2050

Scottish Carbon Capture & Storage Director Stuart Haszeldine says the failure to deliver CCS will have wide and costly consequences across the UK economy.

The UK Committee on Climate Change (CCC) spelt out what the political agreement made at the COP21 climate talks in Paris means for UK climate policy, including energy, industry and transport. At those talks, 195 nations pledged to keep global warming to less than 2°C, and to aspire to keep global warming to less than 1.5°C.

This means that today's net release of fossil and biomass carbon into the atmosphere must decline rapidly. So that, by 2050, every tonne of carbon released or used in fuels, manufacturing, products, and services has to be either eliminated – by substituting different energy sources and production methods – or has to be captured and stored securely for the long-term in deep geology, in soil or in weathered minerals. Reductions of present day emissions must decrease by at least 2% year-on-year from now until 2050.

The UK Conservative Government came to power in May 2015 using a manifesto alluding to the "greenest government ever" and promising £1 billion for Carbon Capture and Storage (CCS). This government's legacy from its first 8 months has been a systematic and unprecedented pull-back from financial incentives for all types of low-carbon electricity production, energy efficiency, and financing of "green" commercialisation.

Of particular note was the cancellation on 25 November, separate from the Chancellor's Autumn Spending Review speech, of the 10-year, multi-government, cross-party support for constructing Europe's first CCS projects. These projects had been 40 months in detailed development.

The Peterhead project led by Shell and SSE would be the first CCS project on gas power in the world. This is of particular relevance to the UK because of the government's ambition to construct multiple gas-fuelled power plant as replacements for about 30% of UK electricity generation from coal and nuclear (which will be retired during the 2020s).

When attempting to explain the cancellation of CCS, unsubstantiated reasons were stated by different government ministers, from "not working yet", and "only a long-term need" to "costs £170 per Megawatt hour compared to gas at half that" – all have been shown to be untrue by expert witnesses to the Energy and Climate Change Committee (ECCC).

Fundamental problems are that the first projects of any new technology are deliberately more expensive so that they will work; and the Prime Minister and others in government are choosing to quote CCS numbers that include costs of pipes and boreholes, which are not included in the costs quoted for gas or nuclear – because these are national infrastructure asset costs.

> "Failure to deliver CCS will have wide and costly consequences across the UK economy"

The CCC letter today recommends that their proposed budget to 2032 is a minimum, and suggests that government must be prepared to do more, not less, in order to reduce total UK domestic carbon emissions in line with the Paris agreement objectives.

The committee also notes that increased decarbonisation ambition will be needed by the European Union. In short, we need to make more reductions. For that, CCS is essential and an urgent plan is needed for a minimum of 7GW clean power by 2030, and support for industry decarbonisation.

The CCC also appears to bear out what expert witnesses told the ECC – that the first CCS projects will deliver at a strike price of £170/MW hr but then drop to £110/MW hr.

The CCC letter today makes clear that rapid delivery of CCS is part of the least-cost package of techniques and technologies to achieve UK carbon budgets. And that failure to deliver CCS will have wide and costly consequences across the UK economy. To achieve that, the UK needs at least two CCS projects operating by 2020, and a development of five more following on from those.

Professor Stuart Haszeldine, SCCS Director, said: "To stay on track in the 'high ambition coalition' of leading nations agreed in Paris climate talks, the UK needs to do a lot more on UK electricity, and a lot more on UK low-carbon industry and low-carbon heat. But now this government is doing a lot less.

There is no sign yet that facts, unbiased scientific evidence and rationality are regarded as more important than lobbying by corporations and colleagues wishing to take the UK back to the 1960s energy mix. It's a choice between spending £40 per household in 2016 or spending £200 per household each year from 2050. We can afford it."

Through delaying CCS development for at least 10 years, the UK will fail to demonstrate the commercial-scale operation of CCS on gas power plant and, additionally, will fail to demonstrate the collaboration of different types of companies in the UK's uniquely disaggregated electricity market. It will also fail to build the first geographic centres of pipeline infrastructure essential to transport CO2, and will fail to demonstrate the secure integrity of UK geological storage of CO2.

This means that, even if the UK attempts a future "buy in" of CCS capture equipment from the US, China or Canada, there will be many years of recovery time, rebuilding and re-skilling of people and infrastructure, which are right now being lost through decommissioning of the North Sea offshore industries.

More information

www.sccs.org.uk

Future of carbon capture and storage in the UK inquiry

UK Parliament has released a critical report looking at the future of CCS in light of the Government's cancellation of CCS funding.

The report was published by the Energy and Climate Change Committee and summarises evidence given during a special hearing on January 20, 2016.

The report concludes that the manner in which the carbon capture and storage competition was cancelled, weeks before the final bids were to be submitted and without any prior indication given to the relevant parties, was both disappointing and damaging to the relationship between Government and industry.

"In addition, the delay in bringing forward any subsequent plans for carbon capture and storage seems to be in direct contradiction with the direction of energy policy set out in [UK Energy Secretary Amber Rudd's] reset speech. With gas and without CCS, we will not remain on the least cost path to our statutory decarbonisation target. If Government is still committed to its decarbonisation targets, it cannot afford to sit back and simply wait and see if CCS will be deployed at the moment when it is needed."

The report sets out a number of recommendations. It says DECC (The Department of Energy and Climate Change) must now devise a new strategy for carbon capture and storage in conjunction with a new gas strategy, taking into account the infrastructure challenge in the future.

"t has already interrupted the momentum that had built up over recent years. It must not allow what is left to be lost. The Department must be clear over its plans, particularly with respect to CCS contracts-for-difference. Given initial costs and

lead time for projects, if we do not commit to CCS now, we may have to accept that it will not be part of the future UK energy policy.

Dr Luke Warren, Chief Executive of the CCSA, welcomed the report, saying, "The Spending Review decision to withdraw funding for CCS has had an extremely negative impact on the industry. What may have seemed like a good short-term saving risks loading significant costs onto the UK economy in the longer-term as the cost of meeting decarbonisation goals will increase substantially if CCS is not available."

"We very much welcome the Energy and Climate Change Committee's call for the UK Government to urgently come forward with a clear strategy for CCS. As today's report has emphasised, such a strategy needs to clearly set out the Government's ambitions for CCS in the near-term and address the challenge of providing transport and storage infrastructure."

"We look forward to working with Government to deliver a successful CCS strategy that can ensure the decarbonisation of the UK's power sector at least cost, enable a long-term sustainable future for vital energy intensive industries, and retain the opportunity to maximise our North Sea oil and gas assets."

Speaking on behalf of more than 22,000 members working in energy generation, distribution, transmission, decommissioning and research, Garry Graham, deputy general secretary of UK Trade Union Prospect, said,"This report reflects the views of many in the industry that the government does not understand the energy challenges facing the UK and the need to provide confidence for companies to invest for the long term."

"Unless industry has confidence and stability, our ability to meet our climate change obligations and keep the lights on is in jeopardy."

Recommended actions for DECC

- A detailed reflection and analysis of the lessons learned from the White Rose and Peterhead projects;
- If CCS has a potential role in the long-term, DECC must clarify whether this means in 2020s, 2030s or whether it envisages no need for CCS at all;
- What DECC's plans are for bringing forward new gas-fired power stations, how much of this new generating capacity is expected to be retrofitted with CCS and by when. DECC must then work backwards and explain when the mechanisms for achieving this will be set out;
- A clarification of whether CfDs for CCS will be available for this and/or the next Levy Control Framework period;
- A detailed study of the potential of existing and new storage sites in the North Sea, including an analysis around the risk of losing access to North Sea storage as platforms get decommissioned;
- Details of what is required for the development of industrial CCS in the UK.

More information

The report can be downloaded here:

www.parliament.uk

www.ccsassociation.org

Limited future for gas power in UK without CCS

Gas has only a limited role as a 'bridging fuel' to a low carbon future, according to new research by the UK Energy Research Centre (UKERC).

The research highlights the 'lack of a clear vision of the future role for gas' in the UK's energy system, and cautions that, without CCS, a second 'dash for gas' could compromise decarbonisation ambitions.

The research also finds that without carbon capture and storage (CCS), the scope for gas use in 2050 is little more than 10% of the 2010 level.

Previous research by UKERC published in 2014 found that gas did have a role as a bridge, but only in some countries (mostly those that use a lot of coal). Today's research confirms that the scope for a gas bridge in the UK is very limited.

"Without CCS, there is little scope for gas use in power generation beyond 2030" - Professor Jim Watson, Director, UK Energy Research Centre

The authors caution that any new CCGT gas-fired power stations built to replace coal plants will have to operate at very low load factors in the 2030s and beyond unless they are retrofitted with CCS, and that it is unlikely investors will be willing to build this capacity without strong policy incentives in place.

The UK has legally binding greenhouse gas emissions reduction targets in place, requiring an 80% reduction by 2050 from the level in 1990. But until more low- and zero-carbon energy sources come on stream, we need to consider options for keeping emissions at a manageable level.

The report asks how much gas use is compatible with meeting emissions reduction targets, how this will be affected by the availability (or lack) of carbon capture and storage technologies, and how long the timeframe for the use of gas might be. It also explores the potential role of natural gas in the UK through to 2050, looking at the historical role of coal-to-gas substitution in decarbonising the UK energy system, asking what potential remains, and considering how the role of gas in the energy system might change in future.

Mike Bradshaw, Professor of Global Energy at Warwick Business School and one of the report's authors, commented, 'A "second dash for gas" may provide some short term gains in reducing emissions but may not be the most cost-effective way forward and may even compromise the UK's decarbonisation ambitions. If all coal-fired power generation is to

Summary

Two models were used to generate scenarios in the report, which are designed to analyse a range of possible futures. Both are optimising energy system models, which minimise energy system costs, or maximise the social welfare that they deliver, under different scenario assumptions.

The first of these models developed by the Energy Technologies Institute (ETI), is called ESME. This model was used to generate a large number of sensitivity scenarios with a wide variety of technological, resource, and price assumptions to explore the affects these key uncertainties have on the development of the future energy system. From these runs, CCS emerges as a critical technology if gas is to have a significant role, consistent with UK carbon reduction targets, out to 2050. Indeed, without CCS, UK gas consumption should fall continuously through to 2050 to only about 12% of the 2010 level if the UK is to meet the 80% emissions reduction target.

The second model, called UKTM, is used to project the future of UK energy use under five discrete, but more precisely characterised, scenarios. Three of these scenarios do not meet some of the UK's emission reduction targets. Two of them comply with legislated carbon budgets and the 2050 target.

In the two UKTM scenarios that meet the 80% carbon emissions reduction target for 2050, the availability of CCS, as in the ESME runs, makes a huge difference to 2050 gas use. Figure 1 summarises gas consumption over time for these two scenarios: Maintain and Maintain (tech fail).

These scenarios permit some strong conclusions to be drawn about future UK gas use, in the context of meeting UK carbon emission reduction targets in 2050.

The take-home message from the report is clear, say the authors. The UK debate should not be reduced to a choice between a future with gas and a future without it. However, if all coal-fired power generation is to be removed by 2025, and the Government is no longer willing to support the development of CCS, policy makers must think very carefully about how best to replace that capacity. A 'second dash for gas' may provide some short term gains in reducing emissions. However, this may not be the most cost-effective way to reduce emissions and, in the absence of CCS technologies, it may well compromise the UK's decarbonisation ambitions.

be removed by 2025, and we are no longer supporting the development of CCS, policy makers must think carefully about how best to replace that capacity. as can play only a modest role between now and 2020, and in the medium to long-term has no role as a bridging fuel because the UK has already exploited a large amount of the decarbonisation potential in the power sector'.

Professor Jim Watson, Director of the UK Energy Research Centre, added, 'Without CCS, there is little scope for gas use in power generation beyond 2030 and it will need to be steadily phased out over the next 35 years, and almost entirely removed by 2050. This represents a major challenge in relation to the decarbonisation of domestic heat, and undermines the economic logic of investing in new CCGT gas plants rather than low- or zero-carbon generation in the first place'.

Paul Ekins, Professor of Energy and Environment Policy, UCL Energy Institute, concluded, 'A key challenge will be managing a "soft landing" for the gas industry that keeps sufficient capacity on the mix as its role changes. Alternatives to the use of gas outside the power sector, particularly in heating homes, need to be explored urgently. It's not clear that current policies will achieve this, and we need a much clearer vision of the future role for gas in the UK's low carbon energy system'.

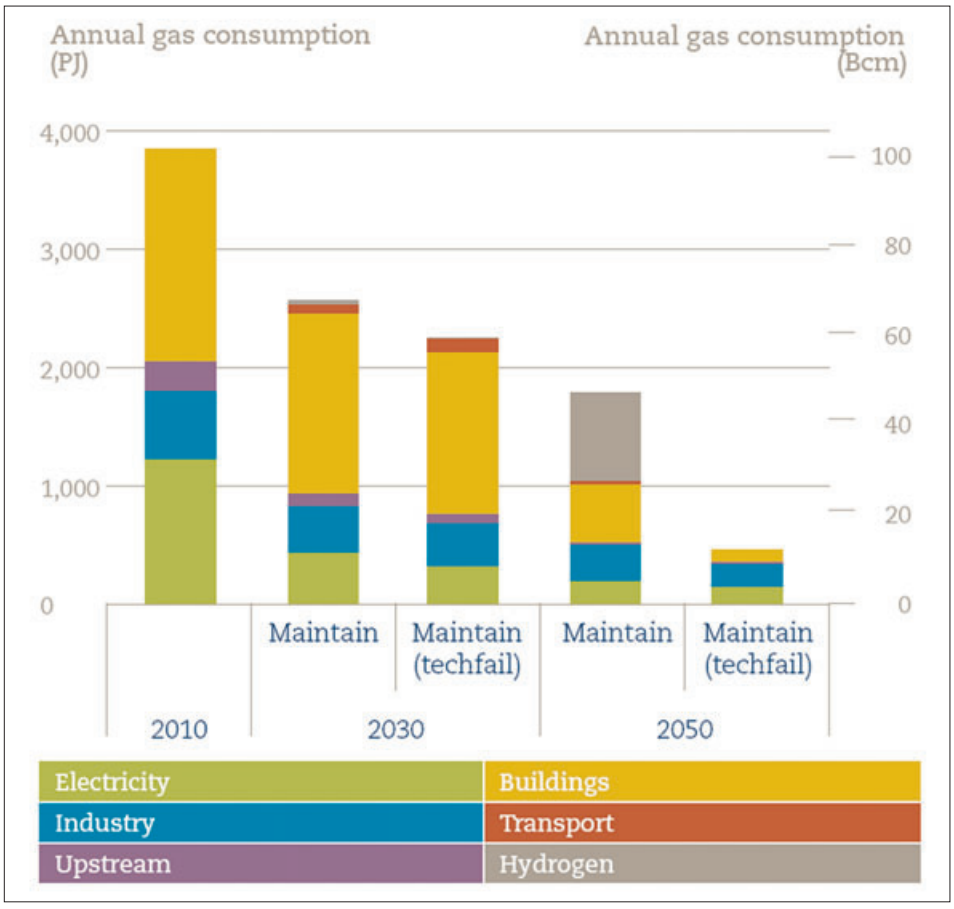


Figure 1: Sector gas use in UKTM scenarios that meet the UK's 2050 carbon targets

Conclusions

The first conclusion is that gas is unlikely to act as a cost-effective 'bridge' to a decarbonised UK energy system. In the report, the term 'bridge' is used to describe scenarios in which gas demand rises in future from current levels before declining; or in which there are emissions reduction scenarios that have higher gas demand than scenarios that do not include emisisons reduction targets.

The analysis shows that gas could only act as a bridge from 2015-20. We therefore conclude that gas is more likely to provide a short-term stop-gap until low- or zero-carbon energy sources can come on stream.

The second conclusion is that, without CCS, the scope for UK gas use in 2050 is little more than 10% of its 2010 level. The recent decision of the UK Government not to support CCS demonstration is therefore at odds with its seeming perception of a long-term future for UK gas consumption in a context of meeting the UK's carbon targets, unless it envisages that commercial-scale CCS will be developed and demonstrated elsewhere, and the technology subsequently imported into the UK.

The third conclusion is that, with or without CCS, there may be limited cost-effective scope for gas use in power generation beyond 2030. This is the case even though CCS is clearly beneficial to helping the UK meet its emissions reductions. This means that gas-fired power stations built between now and then will need to operate on relatively low load factors, which is something that investors will doubtless take into account in their decision whether to invest in these power stations.

Such considerations may be behind Amber Rudd's acknowledgement in her recent announcement that new gas-fired power stations will need subsidy in the form of assurance of future returns if they are to be built.

The fourth conclusion is that, with or without CCS, meeting the 2050 target will constrain the role for natural gas in the UK's energy system in the 2020s and beyond. Both the ESME modelling and the UKTM scenarios make this clear. The nature of that role is dependent on other developments in the wider energy system—such as new nuclear, the rate of energy efficiency improvement and the scale of renewable energy—and the availability of key technologies.

The ESME results show the significance of CCS to keeping gas in power generation and certain sectors of industry. Without CCS gas must be steadily phased out over the next 35 years and almost entirely removed by 2050. This represents a major challenge in relation to the decarbonisation of domestic heat and potentially undermines the economic logic of investing in new CCGT gas power generation capacity.

More information

The report can be downloaded here:

www.ukerc.ac.uk

EU presents gas strategy – while aiming to avoid fossil lock-in

The European Commission has presented a package consisting of four legislative proposals which aim to enhance European energy security. Central to this challenge is the future of gas in the European energy mix. The EU has been clear: This future is short.

In response to the package, Bellona President Frederic Hauge said that "what the EU has presented today tells us two things: That gas will be important for a while still, but not without carbon capture and storage. Unless Norway actually builds such technology, they need to stop their gas-crusade and place not just a part, but all of their attention on alternative energy sources, for instance the interconnections to be built between Norway and the UK and Germany."

"It's not the first time the EU is clear on investments in gas and LNG infrastructure risking fossil lock-in, if one doesn't plan for CCS. This is determined already in the EU's 2050 Energy Roadmap", Hauge continued.

"When it comes to Norway, they continue talking about gas as a bridge, but it could just become a bridge to high future emissions," Hauge concluded.

It is therefore good to see the LNG strategy addressing this risk, as it reads: Energy efficiency measures and lower carbon sources such as renewables are also crucial, and care should be taken with regard to investment in LNG or gas infrastructure to avoid the risk of technology lock-in or stranded assets in fossil fuel infrastructure.

The EU's Vice-President for Energy Union Maros Sefocvic and Climate and Energy Commissioner Miguel Arias Cañete today presented the much awaited 'energy security package'.

The EU's energy security package presented in Brussels comprises four pieces of legislation:

1. Revision of the Regulation on Security of Gas Supply which intends to improve the EU's resilience to supply disruptions

2. Revision of the Intergovernmental Agreement (IGA) Decision which will increase transparency and ensures that IGAs in the energy field comply with applicable EU legislation and policies

3. Strategy for Liquefied Natural Gas (LNG) and gas storage which ensures that the EU can take full benefit of the diversification potential offered by Liquefied Natural Gas

4. Strategy for heating and cooling that aims at identifying energy saving potential in heat and cool buildings and industry

The EU's Climate and Energy Commissioner, Arias Cañete said in a speech last week that "It is no coincidence that we launch the Energy Security Package at this time. The developments in the international energy context and the post-Paris scenario are posing new challenges that need to be addressed without delay."Today the EU imports 53% of the energy it consumes and some countries, particularly in Eastern Europe, depend for their gas imports on one main supplier – Russia. Diversification of energy sources has therefore been a central driver of both the European Energy Security Strategy and the overarching Energy Union initiative.

Climate change has been the other driver. With the EU's 2030 targets of at least 40% greenhouse gas emission reductions, at least 27% renewable energy and at least 27% energy efficiency, the package presented today, particularly regarding heating and cooling, is a step on the way to a low-carbon economy.

Summary

With these proposals the Commission seeks to:

- Reduce energy security vulnerability by diversifying energy sources and increasing robustness through more energy storage capacity
- Increase the energy efficiency of buildings so as to reduce demand for fossil fuels
- Make it more difficult for operators to halt gas flows
- Strengthen internal European 'solidarity' by ensuring that in the case of a crisis energy is prioritised where it is most needed or people are most vulnerable
- View intergovernmental gas agreements before they're signed and in cases where a country is particularly vulnerable to one supplier, get access to contracts so as to ensure one country's short-term interests to not contradict the strategic interests of Europe as a whole

More information

www.bellona.org

Projects and policy news

U.S. budget requests $170.3 million for carbon capture R&D

www.energy.gov

President Obama's Fiscal Year (FY) 2017 Budget includes $878 million for the Office of Fossil Energy.

Research under the CCS and Advanced Power Systems program is focused on reducing carbon emissions by advancing the environmental performance and efficiency of fossil energy systems integrated with CCS technologies.

The President's FY 2017 budget requests $170.3 million for carbon capture R&D focused on the development of post-combustion and pre-combustion CO2 capture and compression technologies for new and existing fossil fuel-fired power plants and industrial sources. Under the budget restructuring, this subprogram also now include advanced combustion technologies that facilitate CCS.

FY 2017 funding will enable selection of one additional large-scale post-combustion capture pilot and will fund a total of three large scale-scale post-combustion pilots. Funding will also enable continued transformational R&D technology development for pre- and post-combustion capture. The program will also support a Front End Engineering Design (FEED) study and initial construction of a large pilot facility to capture CO2 from a natural gas power system. The increase in FY 2017 funding will support two additional (four total) FEED studies for advanced combustion systems.

For FY 2017, the President is requesting $90.9 million for carbon storage R&D to develop and validate technologies to ensure safe and permanent geologic storage of captured CO2 from both coal and natural gas power systems.

The FY 2017 funding Request supports: 1) storage field management projects, including the Regional Carbon Sequestration Partnerships, and other field characterization and injection projects; 2) risk and integration tool development; and 3) advanced storage R&D efforts, as part of the Department's Subsurface crosscut, to develop laboratory and bench-scale technologies for identifying and obtaining new subsurface signals, ensuring wellbore integrity, and increasing understanding of the stress state and induced seismicity.

The President's FY 2017 Budget Request also includes $47.8 million for the Advanced Energy Systems (AES) program to increase the availability and efficiency of fossil energy systems integrated with CO2 capture, while maintaining the highest environmental standards at the lowest cost.

The program elements focus on gasification, advanced turbines, supercritical CO2 (sCO2), and solid oxide fuel cells. The program will be refocused to support the Supercritical Transformational Electric Power (STEP) initiative, which supports the Department of Energy's Supercritical CO2 crosscut targeted at technology development for supercritical carbon dioxide-based power conversion cycles.

There is also $59.35 million for Crosscutting Research and Analysis which fosters the development of innovative systems for improving availability, efficiency, and environmental performance of advanced energy systems with CCS. It also leads efforts that support university-based fossil energy research including science and engineering education at minority colleges and universities.

Crosscutting Research and Analysis will also support the Mickey Leland Energy Fellowship Program, which aims to increase in the number of women and under-represented minorities entering the scientific and engineering career fields within the U.S. workforce.

FY 2017 funding will support the development of new materials, catalysts, water-efficient systems and technologies for power plants, and desalinization technologies for water produced through CCS. It will also support immersive, interactive visualization technology and data communication optimization methods to improve the design and operation of advanced power systems with CCS.

U.S. leads International CCS Network

www.nationalcarboncapturecenter.com

The U.S., represented by the Office of Fossil Energy, takes over the two-year leadership of the ITCN from Norway, which has chaired the network since 2013.

The International Test Center Network (ITCN) was formed by the National Carbon Capture Center (NCCC) in Wilsonville, Alabama and the Technology Centre Mongstad in Mongstad, Norway to facilitate knowledge transfer from carbon capture test facilities around the world. U.S. Secretary of Energy Ernest Moniz and Norway's Minister of Petroleum and Energy Tord Lien announced their nations' commitment to the network during the Carbon Sequestration Leadership Forum Ministerial meeting in November 2013.

The ITCN also includes facilities in Australia, Canada, Germany and the United Kingdom. The NCCC, which is sponsored by the DOE and managed by Atlanta-based Southern Company, provides test facilities for the network in the U.S, and will lead the network's activities for the next two years with DOE's Office of Fossil Energy. The ITCN hopes to expand its membership over the next two years.

"Since its inception, network members have shared lessons learned from a broad base of carbon capture R&D – lessons that are paving the way for commercial deployment of carbon capture and storage (CCS) technologies to reduce carbon dioxide emissions from energy systems and industrial operations," said the DOE.

Universities of Edinburgh and Regina collaborate on CCS research

www.sccs.org.uk

The Universities will establish MSc scholarships for joint research.

The Memorandum of Understanding, signed at an international academic summit hosted by SCCS in Scotland, will establish up to three C$10,000 MSc scholarships each year with funding support from SaskPower.

Successful students for this competitive award will be accepted as visiting graduate students at Regina after completing two semesters of the University of Edinburgh's MSc in CCS.

Though UK Government policy on CCS is

going through an adjustment in emphasis, the research and development (R&D) budget on CCS is being increased and international collaboration is being actively encouraged. Important strides are being made on CCS in other countries, such as Canada, where two of the world's first full-chain CCS projects have begun operating. International collaborations, such as the agreements signed today and others to be discussed at the academic summit, are essential for continued momentum and the delivery of CCS technology worldwide.

The SCCS summit has been made possible due to funding from the UK Foreign and Commonwealth Office in Canada and the Carbon Sequestration Leadership Forum (CSLF) Capacity Building Fund.

Dr David Malloy, Vice-President (Research), University of Regina, said: "The University of Regina is set to have a major impact on reducing global carbon emissions. Our research into CCS and our subsequent technologies are cutting edge. This agreement is an exciting step toward building international capacity in CCS, and we are thrilled to be able to share our knowledge with University of Edinburgh students as we welcome them to our hub in CCS. Working together we have the potential to provide real solutions to climate change around the world."

Mr Alan Mackay, Director International Office, Deputy Vice Principal International, the University of Edinburgh, said: "The collaboration between our two universities is an excellent example of how international collaboration can tackle an international problem, such as climate change. These student placements not only build links between the UK and Canada, but will also contribute to finding solutions to the urgent challenge of tackling increasing CO2 emissions worldwide."

TCM shares expertise with ROAD

www.tcmda.com

Technology Centre Mongstad (TCM) and SINTEF shared some important lessons learned with the key project partners in Holland's planned fullscale CCS project, ROAD.

The Rotterdam Capture and Storage Demonstration Project (ROAD) is an initative of Uniper Benelux (previously E.ON Benelux) and ENGIE Energie Nederland (previously GDF SUEZ Energie Nederland). As of 2015, ROAD plans to capture 1.1 million tonnes of CO2 per year from a new power plant at the Maasvlakte and will store the captured CO2 in a depleted gas reservoir under the North Sea.

It is worldwide one of the first projects to realise an integrated chain of CO2 capture, transport and storage on a large scale. ROAD aims to demonstrate the technical and economic feasibility of CCS and it can be deployed on a large scale on power plants and energy-intensive industries.

"We have gained lots of knowledge i.e. about degradation of solvents and emissions , which is very useful in the ongoing planning of fullscale project in Norway and abroad. These issues are crucial to have an understanding of to secure stable operations, to mimimize environmental impact, and to reduce costs," said TCMs managing director Roy Vardheim.

"We are proud of the broad expertise built up at Mongstad and i.e. at SINTEF in Trondheim, and this workshop is the most recent in a number of similar knowledge sharing sessions we have had with fullscale projects and the CCS community.".

ROAD is co-financed by the European Commission within the framework of the Energy programme for recovery, the Government of the Netherlands and the Global CCS Institute.

On behalf of the Norwegian Government, Minister of Petroleum and Energy Tord Lien has replied positively to an invitation from the European Commissionen to participate in a research programme under the Horizon 2020 Programme. The Norwegian contribution will help establish a programme aiming to support research activities in the operative phase of a full scale CCS project in the EU.

Any project fulfilling the requirements of a joint call would be eligible to apply. The ROAD project in the Netherlands is currently the most mature project in Europe, and could be a possible candidate.

MIT Energy Initiative partners with Exelon

mitei.mit.edu

Exelon's MITEI membership will support research including carbon capture.

MITEI's eight Low-Carbon Energy Centers — first called for in MIT's Plan for Action on Climate Change in October 2015 — bring together researchers from multiple disciplines at MIT to engage with companies, governmental agencies, and other stakeholders, including the philanthropic community, to develop deployable solutions through a uniquely inclusive model.

Each center aims to advance research on solutions in a specific technology area: solar energy; energy storage; materials for energy and extreme environments; carbon capture, utilization, and storage; nuclear fission; energy bioscience; and electric power systems. Centers are led by MIT faculty directors, with broad involvement from researchers across schools and departments. Members can join one or more centers, based on their research needs and interests, and engage by providing financial support as well as offering technical and market expertise.

"Engagement with industry to accelerate deployment of clean energy technologies is a crucial component of MIT's Plan for Climate Action, a driving force behind the development of the Low-Carbon Energy Centers, and an important strategy for academia and governments to pursue to meet the objectives of the Paris climate agreement," said MITEI Director Robert Armstrong. "By joining the MIT Energy Initiative to support research

through the Centers, Exelon demonstrates a strong commitment to advancing the affordability, scalability, and rapid deployment of low- and zero-carbon energy technologies."

"By collaborating with world-renowned research university MIT, Exelon is taking a leadership role in creating a clean energy future," said Exelon President and CEO Chris Crane. "We know the energy system of the future will need new technologies such as energy storage, smarter grids, advanced nuclear generation, solar energy, and more. Together with the MIT Energy Initiative, we will actively identify and develop the most promising innovations in our sector, as the centers bring together a perfect trifecta of academia, government agencies, and private organizations to tackle long-term challenges in reducing our carbon footprint and evolving our energy system. "

"Conducting research into promising low-carbon technologies is a major part of MIT's overall effort to address the urgent problem of climate change," said Maria T. Zuber, vice president for research and the E. A. Griswold Professor of Geophysics at MIT. "Exelon's collaboration not only enables us to expand this important research but also provides the expertise to help ensure that breakthroughs can move quickly and successfully from the lab to the marketplace."

Exelon and other members of the centers participate through activities including semi-annual research development workshops for leadership and staff with MIT principal investigators to identify priority research areas, and participation in MITEI's Annual Research Conference and Spring Symposium. Each member also has one seat on the advisory committee for the centers. Membership fees will not only fund ongoing research and techno-economic analysis, but will also provide seed funding for early-stage research projects and commission white papers in areas of interest to center members.

"The purpose of MITEI's Low-Carbon Energy Centers is to promote collaboration among members in specific technology areas and speed the scale-up from the laboratory to commercial use by leveraging the expertise of center members. The research coming out of the centers will also help inform public policy and further public understanding," said Louis Carranza, associate director of MITEI, who is spearheading the development of the centers in collaboration with each center's directors and members.

Inaugural Legal Fellow appointed by Global CCS Institute

www.globalccsinstitute.com

International experts are being recruited to help advance CCS in Asia Pacific, with the introduction of a CCS Fellowship Programme by the Global CCS Institute.

The Institute's first Fellowship appointee is Dr Meredith Gibbs, a prominent Australian environmental and climate change lawyer and a partner at HWL Ebsworth Lawyers in Melbourne.

Commenting on her appointment, Dr Gibbs said the Fellowship provided an opportunity to contribute to the global body of knowledge about the kind of legal frameworks that will foster and promote CCS as part of a low-carbon future.

"My research will identify the key features of an effective enforcement regime for the underground storage of carbon dioxide," said Dr Gibbs.

"This issue is important because the perception of an effective enforcement regime that ensures the permanent and safe storage of carbon dioxide will be crucial in increasing public and industry confidence in CCS as an important technology for a low-carbon future."

According to Institute CEO, Brad Page, the CCS Fellowship Programme will be a valuable addition to the global research effort in key policy and legal areas.

"Pursuing the climate targets set in Paris will require a substantial shift in the way governments and businesses seek to decarbonise the world economy," said Mr Page.

"CCS is a vital technology for meeting the world's targets for mitigating global warming at least cost – the very objective is simply impossible without CCS.

"As a global organisation the Institute recognises that governments the world over need access to detailed, expert research and knowledge, especially in policy, legal and regulatory areas.

"The CCS Fellowship Programme is one part of the Institute's commitment to developing greater knowledge in critical areas of study, to assist our Members, governments and corporations in making informed decisions about their own commitments to CCS.

"As our Legal and Regulatory Indicator highlights, much more work needs to be done to ensure efficient legislation is in place to facilitate CCS deployment.

BHP Billiton and SaskPower Establish Carbon Capture and Storage Knowledge Centre

www.bhpbilliton.com

BHP Billiton will contribute C$4 million per year for five years to fund the Knowledge Centre, which will operate as a not-For-profit Canadian Corporation in Regina, Saskatchewan.

Under the agreement, BHP Billiton and SaskPower will each appoint two directors to the Board of the Knowledge Centre and another three independent directors will be appointed collectively.

It is intended that the Knowledge Centre will help inform a range of interested parties, including governments, universities, industry and research organizations, on practical considerations in the development and use of CCS. It will be staffed by people with appropriate knowledge of CCS and Boundary Dam, either seconded from SaskPower or employed directly by the Knowledge Centre.

BHP Billiton Chief Commercial Officer, Dean Dalla Valle, said accelerating the development and deployment of low-emissions technologies was vital in addressing the challenges posed by climate change.

"By enhancing global access to the data, information and lessons learned from SaskPower's unique Boundary Dam facility – the first power project to successfully integrate CCS – we aim to stimulate broader deployment of the technology," Mr Dalla Valle said.

In welcoming the agreement Premier of Saskatchewan Brad Wall said Saskatchewan continued to be a pioneer in carbon capture and storage technology.

"SaskPower's partnership with BHP Billiton will allow us to share the benefits of CCS with the world while continuing to reduce carbon emissions here at home," Premier Wall said.

Capture and utilisation news

Copper's potential for reducing CO2 emissions in chemical looping

www.energy.gov/fe

NETL researchers are using copper to economically remove CO2 from power plant emissions.

In traditional power plants, coal is pulverized and then burned in air to create the steam that powers electricity-producing turbines. In chemical looping, the fuel (pulverized coal or natural gas) is combusted through reaction with oxygen-bearing materials like iron oxide, called oxygen carriers. After combustion, the oxygen-depleted carrier is circulated to an air reactor, where it is again oxidized, in preparation for transport back to the fuel reactor to begin a new coal-burning cycle.

One of the advantages of chemical looping is that the process produces a nearly pure exhaust stream of CO2 that can be easily captured without expending the additional energy usually required for separating gas streams. The CO2 can then be used to produce other products, or it can be permanently stored underground. The chemical looping process can also help reduce emissions of smog-causing nitrogen oxides.

But for chemical looping to become a widespread commercial reality, more efficient oxygen carriers have to be found. That's where copper comes in. When copper is used as a key ingredient in oxygen carriers, it appears to improve the efficiency of chemical looping.

NETL's Ranjani Siriwardane explained that preliminary testing of a new copper-based oxygen carrier has shown outstanding potential. "In our tests, a copper-based oxygen carrier was prepared and used in the chemical looping process," she said. "It showed good solid circulation, good methane conversion and good heat management."

The possibility of using copper as an oxygen carrier has always been limited by copper's low melting point. This has caused copper-containing carriers to accumulate or stick together at high temperatures—known as agglomeration—which reduces effectiveness of the process.

Siriwardane said the NETL breakthrough came when researchers were able to design a mixed metal oxygen carrier containing iron oxide and a high concentration of copper oxide to create a highly reactive oxygen carrier that can withstand high temperatures, eliminating agglomeration problems.

Tests on the oxygen carrier were conducted in a pilot scale chemical looping combustor unit at NETL. And the results were promising. "We conducted the tests at around 800 and 900°C. What we found was the design we developed can function in a chemical looping reactor more efficiently than traditional oxygen carriers," Siriwardane said. "It takes us closer to the possibility of deploying chemical looping on a large scale as a less expensive way to reduce CO2 emissions."

NETL researchers have applied for a patent on the new approach. The next step in its development will be testing at commercial scale.

Texas researchers develop one step CO2 to fuel process

www.uta.edu

A team of University of Texas at Arlington chemists and engineers have proven that concentrated light, heat and high pressures can drive the one-step conversion of carbon dioxide and water directly into useable liquid hydrocarbon fuels.

This simple and inexpensive new sustainable fuels technology could potentially help limit global warming by removing carbon dioxide from the atmosphere to make fuel. The process also reverts oxygen back into the system as a byproduct of the reaction, with a clear positive environmental impact, researchers said.

"Our process also has an important advantage over battery or gaseous-hydrogen powered vehicle technologies as many of the hydrocarbon products from our reaction are exactly what we use in cars, trucks and planes, so there would be no need to change the current fuel distribution system," said Frederick MacDonnell, UTA interim chair of chemistry and biochemistry and co-principal investigator of the project.

In an article published in the Proceedings of the National Academy of Sciences titled "Solar photothermochemical alkane reverse combustion," the researchers demonstrate that the

one-step conversion of carbon dioxide and water into liquid hydrocarbons and oxygen can be achieved in a photothermochemical flow reactor operating at 180 to 200 C and pressures up to 6 atmospheres.

"We are the first to use both light and heat to synthesize liquid hydrocarbons in a single stage reactor from carbon dioxide and water," said Brian Dennis, UTA professor of mechanical and aerospace engineering and co-principal investigator of the project. "Concentrated light drives the photochemical reaction, which generates high-energy intermediates and heat to drive thermochemical carbon-chain-forming reactions, thus producing hydrocarbons in a single-step process."

The hybrid photochemical and thermochemical catalyst used for the experiment was based on titanium dioxide, a white powder that cannot absorb the entire visible light spectrum.

"Our next step is to develop a photo-catalyst better matched to the solar spectrum," MacDonnell said. "Then we could more effectively use the entire spectrum of incident light to work towards the overall goal of a sustainable solar liquid fuel."

The authors envision using parabolic mirrors to concentrate sunlight on the catalyst bed, providing both heat and photo-excitation for the reaction. Excess heat could even be used to drive related operations for a solar fuels facility, including product separations and water purification.

The research was supported by grants from the National Science Foundation and the Robert A. Welch Foundation. Wilaiwan Chanmanee, postdoctoral research associate in mechanical and aerospace engineering, and Mohammad Fakrul Islam, graduate research assistant and Ph.D. candidate in the department of Chemistry and Biochemistry at UTA, also participated in the project.

MacDonnell and Dennis have received more than $2.6 million in grants and corporate funding for sustainable energy projects over the last four years.

FuelCell Energy and Cenovus fuel cell CCS study

www.fuelcellenergy.com

FuelCell Energy has hired Cenovus to complete a pre FEED study for a fuel cell system to capture CO2 from flue gas.

The system would be at an existing 14 megawatt natural gas-fired co-generation facility located at the University of Calgary in Alberta, Canada.

Cenovus, a Canadian integrated oil company, is the lead partner of a Joint Industry Project (JIP) and acts on behalf of the JIP participants that include Alberta Innovates-Energy Environment Solutions as well as Cenovus, Devon Canada and Shell Canada, three members of Canada's Oil Sands Innovation Alliance (COSIA). This project is intended to quantify the benefits of the fuel cell carbon capture solution for the separation of CO2 from the flue gas of boilers used to make steam in oil sands production.

The FuelCell Energy solution is one of the least costly options for removal of CO2 emissions from coal-fired power plants, as demonstrated under a multi-year project from the U.S. Department of Energy (DOE). Completion of the pre-FEED project for Cenovus will verify the unique capability of the Direct FuelCell® (DFC®) power plant to capture carbon from gas-fired power generation and combustion facilities while simultaneously producing clean power. The project is focused on separating 75% of the CO2 from the flue gas of the cogeneration plant at the University of Calgary, which provides electricity and heat for the campus.

"Cenovus and our COSIA partners on this project are focused on innovation and technology development to reduce greenhouse gas emissions, and this fuel cell carbon capture project illustrates our commitment to this goal," said Craig Stenhouse, Manager, COSIA at Cenovus. "We're encouraged by the growing commercial adoption of FuelCell Energy power plants, and configuring them for carbon capture is a compelling application for us to pursue."

"Cost is a critical aspect for Canadian oil sands operators, and our carbon capture solution can efficiently and affordably concentrate CO2, while also producing ultra-clean power that supports economics from the sale of electricity," said Chip Bottone, Chief Executive Officer, FuelCell Energy, Inc. "Our solution is delivered in an environmentally friendly manner, and the scalable nature of our carbon capture solution is attractive, as additional capture capability can be incrementally added over time."

Fuel cell power plants configured for carbon capture will use natural gas as the fuel source and process the flue gas from the natural gas-fired turbine into the fuel cell air system, where CO2 is transferred across the fuel cell membrane for concentration in the fuel exhaust stream during power generation. This efficient CO2 concentration is a side reaction of the standard fuel cell power generation process. An added benefit is that approximately 70 percent of smog producing nitrogen oxide (NOx) emissions in the gas-fired power plant flue gas is destroyed by the fuel cell power generation process.

NETL capture tech used in commercial biomass conversion

www.cognitek.com

The National Energy Technology Laboratory (NETL) has granted a license for two patented sorbent technologies that capture CO2 from streams of mixed gases.

The license was granted to renewable energy systems developer CogniTek Management Systems through the company's MG Fuels.

Sorbents are materials that can absorb gases, like CO2, and CogniTek plans to incorporate these sorbent technologies into its integrated biomass-to-biofuels conversion process with power generation. This innovative process includes carbon capture and represents a sustainable solution for distributed power. The liquid biofuels produced by the process can also be used as transportation fuels.

Biofuels are usually derived from corn, but CogniTek plans to use a wide range of plant matter for feedstock, including quick-growing grasses and trees, nuisance crops, and agricultural and commercial waste. Biomass is an abundant domestic resource and may significantly contribute to the renewable fuel market within the next decade.

The CogniTek process will have naturally low carbon emissions because the plants used as feedstock consume CO2 from the atmosphere as part of their growth process. Incorporating the NETL technologies, which employ a regenerable magnesium hydroxide to capture CO2, makes an inherently green process even greener and will result in a near 100 percent "carbon negative" process.

But these new technologies will make a difference only if they're deployed commercially. To accomplish that goal, NETL is dedicated to transferring newly developed processes and products, like this sorbent technology, from laboratory to the marketplace.

Transport and storage news

Project to test CO2 monitoring from a subsea leak

www.stemm-ccs.eu

The STEMM-CCS project will develop a system to monitor CO2 released from a subsea store.

The world's first 'real world' deep-water controlled experiment simulating emission from a submerged carbon dioxide storage reservoir is to take place in the North Sea, with the aim of further verifying the safety of offshore carbon dioxide (CO2) capture and storage (CCS).

Small quantities of CO2 will be injected into mud on the sea floor in the North Sea, 100km North East of Aberdeen. This site is in the vicinity of a depleted gas field and is a typical location that could be used for carbon dioxide storage.

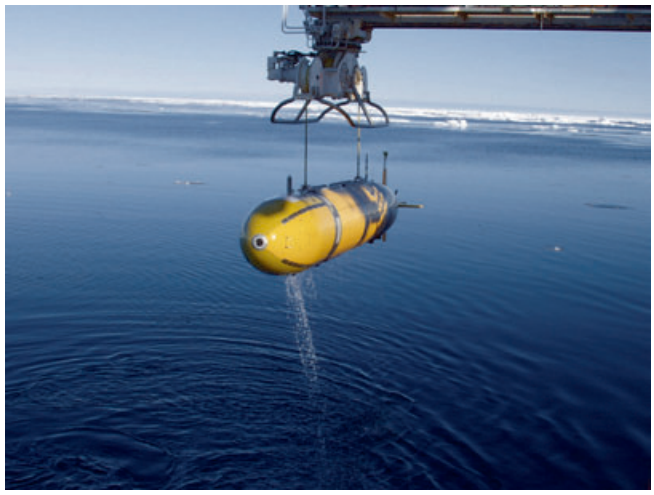
This first of a kind experiment, due to take place in 2018, will form part of a €16M collaborative project led by the National Oceanography Centre (NOC), which will enable scientists to develop a system for detecting and quantifying the volume of any CO2 released. This work will help provide greater reassurance around the safety of CCS operations in the future.

Project leader, Dr Doug Connelly from the NOC, said "Currently, it is challenging to detect and quantify CO2 emissions in the marine environment because of dispersion and attenuation effects, the small volumes involved and considering large existing natural variability. This project is a really exciting opportunity to develop innovative, safe and cost effective technology to address these problems."

In order to 'listen' for the released CO2, the project partners will be developing acoustic and chemical sensors that can be fitted into robot-subs. Automated photographic analysis software will also be developed to enable the detection of any visual changes at the release site. Additional technology used by this project will include devices in the water and on the seabed to monitor changes in the chemistry, temperature, salinity and currents in the water.

All this technology will be launched at the site in Scotland a year before the controlled release in order to acquire an in-depth picture of the natural variability of the environment on a daily, weekly and seasonal timescale. This information will enable scientists to better differentiate natural changes from those resulting from the controlled release.

This project, called STEMM-CCS (STrategies for the Environmental Monitoring of Marine CCS), has received funding from the European Union's Horizon2020 project. In addition to the industry partner Shell, this project will bring together the University of Southampton and Heriot Watt University, Plymouth Marine Laboratory, GEOMAR and MPI from Germany, NIVA, Uni Research and the Universities of Bergen and Tromso from Norway, the Technical University of Graz from Austria and Seascape Consultants Ltd.



STEMM-CCS - In order to 'listen' for the released CO2, the project partners will be developing acoustic and chemical sensors that can be fitted into robot subs

ETI studies brine removal from subsea CO2 stores

www.eti.co.uk

The Energy Technologies Institute (ETI) has launched a new project which will study the impact of removing brine from undersea stores that could, in future, be used to store captured carbon dioxide.

The £200,000 nine-month long "Impact of Brine Production on Aquifer Storage" project will be carried out by Heriot-Watt University, a founder member of the Scottish Carbon Capture & Storage (SCCS) research partnership, and Element Energy. T2 Petroleum Technology and Durham University will also participate in the project.

Although the Government recently announced it was not continuing with its £1bn Carbon Capture and Storage (CCS) its view is that CCS can still play a potential role in the long-term decarbonisation of the UK energy system.

This latest ETI project will build on earlier CCS research work and help develop understanding of the potential CO2 stores, such as depleted oil and gas reservoirs or saline aquifers, located beneath UK waters. It will also help to build confidence among future operators and investors for their operation.

An earlier ETI CCS project led to the development of the UK's principal storage screening database, CO2Stored, which estimates the capacity and injectivity for each of an identified 550 stores off the UK's coast. As part of the analysis one of the assumptions was that brine was not produced from the reservoir store before, during or after CO2 injection.

However, if pressure builds within a store as a result of CO2 injection then brine can potentially be removed from the store through a purpose-built well or wells to depressurise it whilst still retaining the store's operation and integrity.

Brine management is a recognised way within the oil and gas industry of controlling reservoir pressure and fluid flow. Brine production is a feature of every oil and gas development. The removed brine could be sent to another aquifer or displaced to the sea.

Recent work published by Heriot-Watt University has showed that producing brine on the UK Continental Shelf may be beneficial to CO2 injection rates and storage. Using this experience of brine production means researchers from the university are well placed to deliver on the objectives of this project.

Scottish CO2 hub 'opportunity for UK'

The creation of a Scottish CO2 Hub can help tackle Europe's greenhouse gas emissions by providing a stepwise, affordable route to a CCS industry in the UK using existing infrastructure, established shipping technologies and well-characterised storage assets in the Central North Sea.

This is the message of a report published by Scottish Carbon Capture & Storage (SCCS) outlining a concept proposal to re-energise the deployment of CCS in the UK and Europe. The hub would serve as a central collection point for CO2 emissions from different sources across Europe, from where the greenhouse gas would be transported for permanent storage in rocks deep beneath the North Sea.

By starting with a modest industrial and power CCS cluster in Central Scotland that can make use of existing pipelines and offshore infrastructure to establish CO2 storage in the Central North Sea quickly and affordably, the study indicates how this could develop into a new large-scale industry for the UK while helping solve Europe's CO2 storage challenge.

The proposal can be achieved economically and rapidly by reusing existing infrastructure (avoiding decommissioning costs); by value generated from a CO2 utilisation market created through CO2-Enhanced Oil Recovery to help maximise economic recovery of oil; and through a flexible shipping solution for CO2 transport from southern UK and European sources.

Using technology already well established for shipping liquefied CO2 between European ports, a ship transport system requires lower initial capital investment than building pipelines and allows sequential, project-by-project expansion of the system. This reduces the financial risks and makes investment more attractive.

"The beauty of this proposal is its flexibility and adaptability," said Stuart Haszeldine, Professor of CCS at the University of Edinburgh and SCCS Director. "From a small start capturing emissions in Scotland with transport and storage based on existing assets, the system can be progressively expanded to receive CO2 from England and Europe using shipping, instead of large expensive pipes."

"By the early 2020s this can achieve a key milestone in the deployment of CCS – the establishment of commercial storage operations in the North Sea – with a whole new industry following from that. A critical point is that while re-evaluation and consideration of CCS options is underway, it is essential that no decommissioning of potentially relevant pipelines, boreholes or offshore facilities is agreed by the UK Government or the Oil & Gas Authority.

Summary of the report

Storage sites in the Central North Sea (CNS) are well characterised and existing pipeline infrastructure can be converted to CO2 use at lower capital cost than the building of new pipelines. CO2 utilisation in EOR gives a value to stored CO2, offsetting costs and providing a range of further benefits. Shipping enables rapid development of CO2 transport whilst being cost-competitive with pipeline for initial CO2 volumes over North Sea distances.

The combination of shipping and re-use of pipelines not only enables low entry costs but also adds system flexibility, important to CO2-EOR, and allows sequential, project-by-project development across the full range of plant emission scales. While re-evaluation and consideration of options for deployment of CCS in the UK is underway, it is essential that no decommissioning of potentially relevant pipelines, boreholes, or other offshore facilities is agreed by Government or its agencies.

Opportunities for development of CO2 transport infrastructure and shipping in the CNS, potentially supported by CO2-EOR value generation, can enable early-stage, high volume storage of Europe's CO2 emissions.

More information

The full report is available from Scottish Carbon Capture and Storage:

www.sccs.org.uk

North Sea 'preferred' CO2 storage for Europe

A Global CCS Institute report, "Global storage portfolio: a global assessment of the geological CO2 storage resource potential," confirms the North Sea as an ideal area for CO2 storage.

The GCCSI report collates data from countries covered by existing estimates of storage potential and gives clear 'dashboard' indicators of the state of preparation for CCS in terms of storage technical readiness, policy, and regulatory position.

The report is the first report of its kind to provide a comprehensive worldwide summary of geological storage resource assessments from almost 50 countries. Nations identified as leading the way on storage readiness include Canada, Norway, the United States and the United Kingdom.

Andrew Purvis, the Institute's General Manager Europe, Middle East and Africa, said identification and quantification of storage sites were critical to the deployment of carbon capture and storage (CCS) as part of global efforts to closing the gap between current international climate commitments, and what scientists say is needed in order to limit global warming to well below 2° Celsius.

"CCS is a vital technology for meeting the world's targets for mitigating global warming at least cost – the very objective is simply impossible without CCS," said Mr Purvis

"Availability of storage space for the injected CO2 is a critical precondition of a CCS project. Not knowing how much storage potential is available could significantly undermine a nation's ability to meet emissions reduction targets, by hampering their ability to deploy CCS in a timely fashion.

"Regional resource assessments are important in providing policymakers and other stakeholders with an indication of the storage potential in any given location, and can serve as an important first step in selecting and proving storage sites to support project deployment.

"The assessment of offshore storage resources in the North Sea, complemented by detailed evaluation of the storage capacity at several specific sites and the availability of oil industry infrastructure for re-use, should provide a significant advantage to CCS deployment there," said Mr Purvis.

Only proven storage scenarios are considered in the report, including deep saline formations, depleted or depleting oil and gas fields, and enhanced oil recovery using CO2. All three scenarios have been successfully utilised for existing CCS projects around the world.

Many countries use different evaluation criteria for their assessments and use different methods to calculate their storage resource. By consolidating this work the Institute has been able to review and compare the results from regional studies for each country.

Previous work by Scottish Carbon Capture and Storage (SCCS) researchers and others suggests that capacity in the North Sea is sufficient for several decades worth of CO2 storage requirement for the whole of the European Union.

This supports the widely held view that a recent UK government announcement putting the brakes on CCS in the UK was a mistake. The COP21 climate talks in Paris last year saw the United Nations agree that greenhouse gases, including CO2, must be eliminated from emissions or stored securely through Carbon Capture and Storage (CCS) to avoid dangerous climate change. The UK should actively make use of North Sea assets for secure geological storage of CO2.

The report shows that the UK is exceptionally well positioned to enact CO2 storage with technical assessment well advanced, and regulation and policy indicators near to full-marks. This is no surprise to companies and researchers interested in CCS in the UK. They have consistently argued that the North Sea is an ideal location to demonstrate CCS technologies that would form the basis of a valuable new industry collecting and storing CO2 emissions from the UK and mainland Europe.

Despite the recent setback when the UK Treasury withdrew 'ring-fenced' funding from two leading demonstration projects, the North Sea CO2 storage industry could be established at relatively low cost and financial risk by using existing infrastructure from the declining oil and gas industry repurposed for CO2handling and a flexible shipping solution for long distance transport. Several on-going projects are looking to move forward with CCS demonstration in the UK, despite limited political support, with the aim of decarbonising electricity supply and industrial production.

In welcoming the GCCSI report, SCCS Director Professor Stuart Haszeldine said:

"From the global compilation of data by the Global CCS Institute it is clear that worldwide, there is plenty of CO2 storage capacity that can be developed, many times that estimated by the International Energy Agency as needed by 2050. The storage potential beneath the seas around the UK is highlighted as exceptionally well known, understood and accessible, and this presents a real opportunity for Scotland and the UK which the Government should grasp.

"CCS in the UK is far from dead, and North Sea industries could be looking to widen their interests into a long-duration sustainable future of CO2 storage, as well as concentrating on cost reductions in their existing businesses."

More information

The full report is available from the Global CCS Institute for members only:

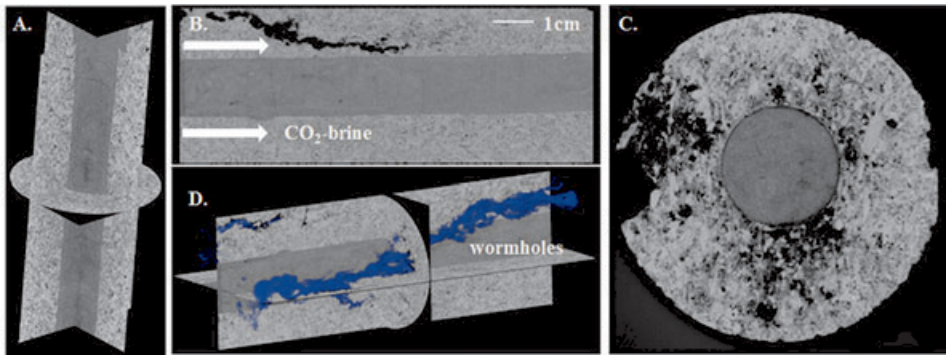
www.globalccsinstitute.com

Carbon dioxide stored underground can find multiple ways to escape

Multiple escape pathways exist due to chemical reactions between carbon dioxide, water, rocks and cement from abandoned wells, according to Penn State researchers.

The researchers investigated the properties of porous rocks into which carbon dioxide is injected. These rocks, known as host rocks, function like containers for the carbon dioxide. The team looked at two abundant host rocks, limestone and sandstone, which have different chemical properties.

"We were interested in examining these rocks because they are widely found underground, but there have been concerns that carbon dioxide may escape once it's injected underground," said Li Li, associate professor of petroleum and natural gas engineering. "Even if it doesn't escape to the Earth's surface, there are concerns that it may leak into groundwater drinking aquifers."



Researchers examined chemical reactions taking place underground during carbon sequestration to identify potential leakage pathways. (A) is a cross-section of a limestone/cement sample before the experiment. (B) shows dissolving in the limestone but not the cement (at the center of the image). (C) is a sandstone/cement sample, indicating that the sandstone remained intact when contacting carbon-dioxide-infused saltwater, and the cement at the core of the sample began to dissolve. (D) shows the pathways created in the limestone from the experiment. Image: Zuleima Karpyn / Penn State

In addition to encountering host rocks, carbon dioxide stored underground may also contact and dissolve into saltwater deposits. When this happens, the carbon dioxide increases the acidity of the saltwater. The high-acidity saltwater-carbon dioxide mixture can dissolve certain types of rocks, such as limestone, as well as cement casings on abandoned oil and gas wells.

"If this plume of carbon dioxide-saturated brine reaches an abandoned well, it will react with the cement," said Zuleima Karpyn, associate professor of petroleum and natural gas engineering and Quentin E. and Louise L. Wood Faculty Fellow in Petroleum and Natural Gas Engineering.

"This may open up cracks in the cement depending on the conditions, which would increase the likelihood of carbon dioxide escaping. We were trying to assess what would happen in the process if the host rock itself were to react with the carbon dioxide-saltwater mixture."

To recreate natural settings, the researchers conducted an experiment by flowing carbon-dioxide-rich saltwater into two different systems -- cement embedded in a sandstone host rock, and cement embedded in limestone. They monitored the chemical reactions that took place and measured changes occurring in the host rocks and cement. Their findings, published in the current issue of the International Journal of Greenhouse Gas Control, indicate that the host rocks can create different types of escape pathways.

The saltwater-carbon dioxide solution dissolved parts of the limestone, which lowered the acidity of the solution. In eight days, the limestone lost 3 percent of its mass and became 24 times more permeable than at the start of the reaction, which means liquids and gases can move through it much easier. The carbon dioxide-saltwater liquid also became less acidic in the dissolution process. As a result, it did not dissolve any of the cement.

"In the limestone interactions, the rock itself becomes the dominant medium for the dissolution reaction while the cement was the secondary reactant," said Karpyn. "This means that wellbores are more likely to stay intact if you have limestone. But dissolving the limestone can create leakage pathways, for example, by forming finger-like channels of dissolved rock."

The researchers found the opposite to be true for the sandstone sample. Rather than dissolving the sandstone, the solution degraded the cement. The sandstone lost very little mass, and the cement lost mass and became more porous.

These findings highlight the complexity of underground carbon sequestration, which is a process under investigation as a method to reduce carbon dioxide levels in the atmosphere.

"The process of assessing whether a site is appropriate for injection has to be system-specific and take into account not only the chemistry and composition of the rocks, but also the ease with which water and carbon dioxide can flow through host rocks," said Li.orated on this research.

More information

Peilin Cao, Penn State Ph.D. student, collaborated on this research.

Penn State, the Quentin E. and Louise L. Wood Endowed Faculty Fellowship and the U.S. Department of Energy supported this work.

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Yanchang CO2 EOR: unique geology, unique challenges

The Global CCS Institute has commissioned four knowledge-sharing reports on key aspects of Yanchang Petroleum Group Integrated CCS Demonstration Project in China. The second report in this series is now available, covering the application of CCS to enhanced oil recovery (EOR). In an Insight article for the Institute, Chris Consoli, Senior Adviser for Storage, Asia–Pacific, provides an overview of the project and introduces the report.

Carbon capture, utilisation and storage (CCUS), primarily through enhanced oil recovery using carbon dioxide, or CO2-EOR, has historically been the largest driver for the development of CCUS technologies. CO2-EOR is driven by the need to extract greater volumes of oil from producing reservoirs. As a consequence CO2-EOR operations have enabled the development and commercialisation of more sophisticated methods for the capture, transportation, injection and monitoring of CO2.

Chinese governments and industries have a clear mandate to support CO2-EOR technologies leading to the construction of several projects. Also in China, maturing oil fields have been the catalyst for second and third generation of oil production techniques, including CO2-EOR. In the Shaanxi Province of China, Yanchang Petroleum have committed to undertake CCUS pilot and demonstration projects through the integration of their coal-to-chemicals industry with their CO2-EOR operations.

CO2-EOR

Carbon dioxide flooding for enhanced oil recovery (CO2-EOR) has been undertaken in West Texas in the United States for over four decades. The technique and technologies of CO2 EOR have been critical to the development of the CCS industry for two reasons.

Firstly, the technology and experience behind the transportation, injection and monitoring of CO2 was developed through CO2-EOR operations. For example, in Canada over 25 Mt of anthropogenic CO2 has been injected into the Weyburn and Midale oilfields in Saskatchewan, which have served as a 'field laboratory' for the IEAGHG Weyburn-Midale CO2 Monitoring and Storage Project.

Secondly, CO2-EOR has been an important commercial driver for the development of first-of-a-kind large scale CCS projects, including from power stations such as the Boundary Dam Carbon Capture and Storage Project and Kemper County Energy Facility, as well as from industrial processes such as the Emirates Steel Industries' Abu Dhabi CCS Project.

CO2-EOR is also an important commercial driver for the Yanchang Integrated CCS Demonstration Project. This project will demonstrate the cost-effective capture of CO2 from coal-to-chemicals processes and its injection into low permeability geological formations. Both of these developments will enable a wider application of CCS and greater potential emissions reductions.

The Yanchang project

Yanchang Petroleum Group (Shaanxi Province) owns large reserves of oil, gas and coal. To optimise the utilisation of its resources, Yanchang has developed technologies to convert coal, natural gas, and residual heavy oil to chemical products at its Jingbian Industry Park. In 2012 the Yanchang Petroleum Group built a 50,000 tons per year (Tpa) CO2 capture plant at its Yulin Coal Chemical Coal Company coal-to-chemical plant.

The captured CO2 has been used for the pilot CO2-EOR project. An additional 360,000 Tpa of CO2 will be taken from a separate coal-to-chemicals plant in Jingbian and will enable the expansion of the CO2-EOR activities. The captured CO2 from the Jingbian plant will be transported to the CO2-EOR site by 20 ton truck over a distance of about 140 km. See CCS: A China Perspective Yanchang Petroleum Report 1: Capturing CO2 from Coal to Chemicals, 2015 report for more information relating to the CO2 capture and transport processes.

Yanchang's CO2-EOR operations are located in the Triassic Yanchang Formation on the eastern slope of Ordos Basin, a vast basin in the west of North China hosting abundant energy and mineral resources including coal, gas and oil. The Yanchang Formation is an important oil-bearing rock unit, with about 60% of proven total reserves in the region. Using CO2 from the Yulin Plant, a pilot CO2-EOR operation has been operating since 2012, injecting around 41,000 tonnes of CO2 to date into the Qiaojiawa oil field in the Yanchang Formation.

Using CO2 for EOR is the a preferred option for the Yanchang Project because the northern Shaanxi Province is arid and semi-arid. Access to water for water flooding is difficult, and CO2 is alternate material for EOR. Furthermore, Yanchang can capitilise on CO2-EOR because it will produce a near pure stream of CO2 from its coal-to-chemicals plants, which are positioned close to fields - thereby reducing the costs and emissions associated with transportation.

Key Findings

Yanchang evaluated 176 different oil reservoirs in the Yanchang Formation to produce a set of geological criteria which can be used to help identify oil fields that are suitable for CO2 flooding operations. In this analysis they also identified which reservoir properties had an impact on oil production during CO2-EOR operations.

For example, the reservoir temperature has little effect on oil production during CO2 flooding but reservoir depth, pressure and thickness are all very sensitive variables. Based on this analyses, the report's authors found 153 oil fields which could be suitable for CO2 flooding, which was around 80% of total oil reservoirs. The site of the pilot CO2 injection project in the Qiaojiawa oil field was found to be the best match for potential CO2-EOR oper-

ations during this evaluation and was chosen for expansion of the CO2-EOR operations.

The pilot project is located in the 203 well block of the Qiaojiawa oil field. The operation has initially injected CO2 from 20 injection wells (grouped with 68 oil production wells). The operation will switch to water alternating with CO2 (known as WAG) in the future. In the meantime a measurement, monitoring and verification (MMV) process is underway and will continue beyond the CO2-EOR operation.

Despite the low permeability, Yanchang is expected to achieve an injection rate of up to 10 ton per day from each injection well, achieving a total injection capacity of up to 200,000 tpa.

The Yanchang Formation has low to ultra-low permeability of less than 1 millidarcy (Darcy is a measurement unit of permeability, which is how easily fluids can pass through rocks). A low permeability rock means the pore space between the grains of sand and silt which holds the oil, and eventually the CO2, are not well-connected or those connections are narrow. For example, the CO2-EOR Weyburn-Midale project, which is typically referred to as a low permeability operation has measured permeability ranges from 1 to greater than 50 mD in one of its reservoirs. The reservoir properties from the Yanchang Formation are detailed in Table 1.

The report outlines the results of laboratory experiments completed on the oil, CO2 and reservoir of the Yanchang Formation and mostly focuses on determining the solubility of the oil when it comes into contact with CO2. Above a certain pressure in the reservoir the oil and CO2 will become soluble, or what is known as miscible and mix increasing the recovery of both.

This is called the minimum miscibility pressure (MMP) and for the Yanchang CO2-EOR reservoir the MMP was 22 megapascals. The MMP is very dependent on oil composition and reservoir conditions. MMP experiments are standard but critical experiments to complete for any CO2-EOR operation because it can influence your injection style, or even if the CO2-EOR flooding will increase oil production.

Reservoir Characterisation	
Thickness	105-150 m with an average thickness of 127 m
Temperature	40 deg C
Pressure	8.2 MPa
Porosity	8-13.0%, and average porosity is 10.5%
Permeability	0.05-2 mD, and average permeability is 1.02 mD
Total salinity of formation water	50.52g/L~95.11g/L
pH	5.5
Oil reserves	4,354,100 ton

Table 1 - Yanchang Formation reservoir characteristics

The report also outlines the computational modelling results. According to injection modelling simulations, the WAG will increase production of oil by around 18% and almost 20% if CO2 alone is injected. Around 40% (WAG) to up to 60% (CO2 only) of the CO2 will be stored permanently and under maximum potential this could rise to 80%. If the 200,000 tpa is reached it could mean that a minimum of around 120,000 tpa is stored permanently in the Yanchang Formation.

Finally, the report details the storage resource of the primary CO2-EOR reservoir using the volumetric calculation method of the US Department of Energy. The theoretical storage resources (the entire pore volume of the reservoir) is 4.3 million tonnes (Mt). However, the practical storage capacity in the primary reservoir which takes into account the pore space that can actually host CO2 including well injection scenarios and economic constraints is estimated to be around 2 Mt; a substantial capacity given this calculation is based on one low permeability reservoir in a single field.

Interestingly, the CO2 storage efficiency factor is 23%, which is very high compared to the 1-4% efficiency factor that is typically used for more generalised CO2 storage projects worldwide. According to several basin-wide studies the effective storage resource of the entire Ordos Basin could be up to 60-100 Gt.

The report also outlines the economic evaluation of the CO2-EOR operations and found that injection costs is approximately 200 Yuan/ton (~US$30/ton CO2). The report also outlines the baseline and future measurement, monitoring and verification strategy (Table 2).

Technology	Reason
Groundwater well monitoring	Understand the groundwater system in the area
Surface and near-surface monitoring	Catalogue surface water sources Catalogue vegetation growth/change Catalogue soil type and distribution Soil gas composition Atmospheric CO2 concentration and isotopic composition
Dynamic monitoring of injection and production wells	Produced fluid analysis including oil component Production rate Pressure and temperature Interwell tracer injection Corrosion monitoring

Table 2. - Baseline surveys

Conclusion

The Yanchang Integrated CCS Demonstration Project will be China's first full-chain, fully-integrated project using coal-to-chemicals for CO2 to be used for enhanced oil recovery in a low permeability reservoir. Typically, low permeability reservoirs are avoided because injection rates of the captured CO2 cannot be matched, but in this case Yanchang, through using multiple wells and variable injection scenarios, can achieve sufficient injection rates.

For the EOR operation, using CO2 is clearly seen as a beneficial method to increase oil production rates whilst reducing water use and reducing the emissions of the coal-to-chemical operations though the permanent storage of up to 80% of the total injected CO2. The capture of carbon dioxide from coal-to-chemicals processes and the use of low-permeability reservoirs opens up greater potential for CCS to contribute to global emissions reductions.

More information

This article originally appeared as an Insight on the Global CCS Institute website. Download the full report here:

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