carbon capture journal

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Scottish Carbon Capture and Storage Global CCS map relaunched

CO2 Capture Project factsheet on CO2 migration

CATCHING OUR FUTURE

CO2 Technology Centre Mongstad in Norway contributes to a series of advancements in reducing the cost and the technical, environmental and financial risks of implementing CO2 capture technology.

The two technology demonstrations of Aker and Alstom have been overlaid onto TCM's core utility infrastructure; which provides access to 100,000 tonnes per year of gas-fired and simulated coal CO2 flue gases.

At present we are also running a MEA test, and the results will provide base line performance criteria for technology vendors to establish a complete benchmark and reference point for comparison to future amine plant users.

TCM is the world's largest and most advanced facility for testing and improving CO2 capture, and is a joint venture set up by the Norwegian state (75.12 %), Statoil (20 %), Shell (2.44 %) and Sasol (2.44 %).

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United House, North Road, London N7 9DP
www.carboncapturejournal.com
Tel +44 (0)207 017 3405
Fax +44 (0)207 251 9179

Editor
Keith Forward
editor@carboncapturejournal.com

Publisher
Karl Jeffery
jeffery@thedigitalship.com

Subscriptions
subs@carboncapturejournal.com

Advertising and Sponsorship
Richard McIntyre
Tel +44 (0)208 150 5296
rmcintyre@onlymedia.co.uk

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Front cover: Minister of Energy Diana McQueen and Conservative MP Mike Lake tour the Quest Carbon Capture and Storage facility at Shell's Scotford plant near Fort Saskatchewan on April 17, 2014. The project is retrofitting the Scotford bitumen upgrader for carbon capture, designed for up to 1.2 million tonnes of carbon captured per year, piped 80 kilometres north and injected more than two kilometres below the Earth's surface. (Photo: Chris Schwarz/Government of Alberta)

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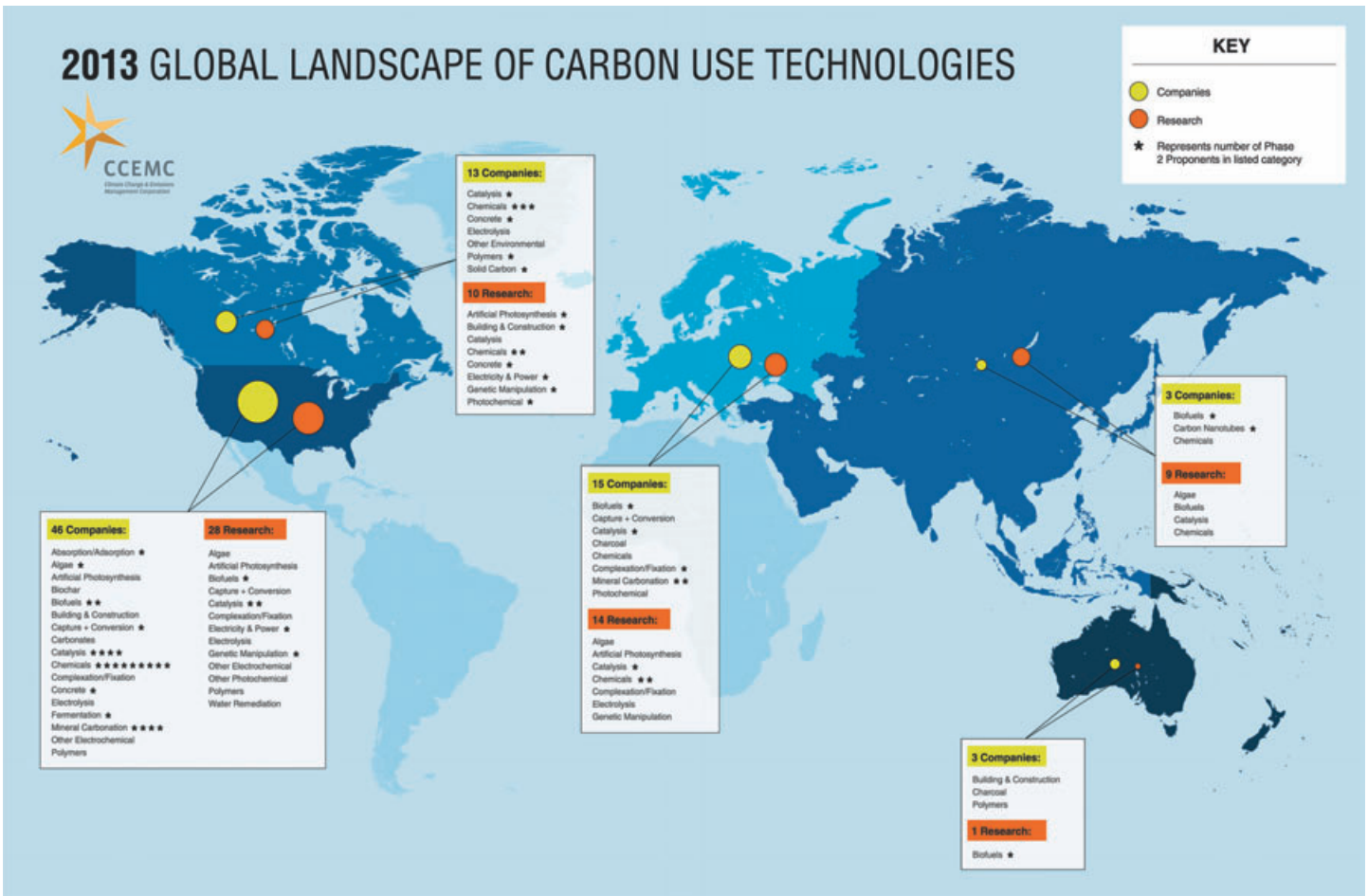
CCEMC $35 million Grand Challenge: Innovative Carbon Uses

The Alberta-based Climate Change and Emissions Management Corporation (CCEMC) has named 24 winners for the first round of the organization's $35 million international carbon use competition. The group was selected from 344 submissions from 37 countries on six continents.



CCEMC engaged NineSigma to provide a technology landscape of 2013's current and emerging technologies for carbon use. Some of the findings are represented in this world map. The information represents a baseline of activity at the end of 2013. Future monitoring by NineSigma will provide regular updates

"While efforts to mitigate greenhouse gas emissions around the world are making progress we still need to pursue other strategies that can reduce emissions as global demand for fossil fuels grows," said CCEMC Chair Eric Newell. "We applaud the leaders behind these projects who are taking action through developing new carbon utilization technologies."

The CCEMC launched the multi-year competition in February 2013 with a goal to significantly reduce greenhouse gas emissions by fostering the development of technologies that create new carbon-based, value-added products and markets.

"The CCEMC Grand Challenge will foster the innovation and collaboration required to accelerate the development of these critical technologies and help Alberta and the world to reduce GHG emissions," said Paul Clark, Chair of the CCEMC Grand Challenge Steering Committee.

The projects selected are from Canada (7), the United States (14) and the UK (3). Each winner receives $500,000 and access to a support team who will help them to develop their idea.

Diverse projects

The CCEMC Grand Challenge projects are diverse and include, as examples, a fuel cell, fertilizers, concrete, a product to treat wastewater, and one project that will create graphene - a "miracle material" that's stronger than a diamond and conducts electricity a thousand times better than copper. They also include a variety of chemicals that are used to produce consumer goods -- like ski boots, fishing rods, and fleece jackets.

"We expect that some Grand Challenge solution providers will build alliances and partnerships as the competition runs its course, and that ideas may broaden as people understand and build on each other's ideas," said CCEMC Managing Director Kirk Andries.

The finalists include three biofixation projects. Bio-fixation is the use of biological organisms to sequester and convert carbon dioxide into a variety of products.

These projects include bio-fixation

Forward Thinking

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The winners of the first round of the CCEMC Grand Challenge

For biofixation

- **University of Maryland – USA**
  An Innovative and Highly Efficient Microalgae-Based Carbon Sequestration System to Reduce CO2 Emission and Produce Valuable Byproducts Including Biofuels in all Climates
- **OakBio – USA**
  Conversion of Industrial CO2 Emissions into Biofuels and Chemicals
- **Industrial Microbes, Inc. – USA**
  Biological Co-fermentation of Carbon Dioxide and Methane to Malate

For solid products

- **New Sky Energy – USA**
  Soda Ash and Bicarbonate from a Low Energy Natural Gas Sweetening Process
- **Skyonic Corporation – USA**
  Skyonic SkyCycle Pilot Demonstration
- **Solidia Technologies – USA**
  Solidia Concrete - A Sustainable Method For Cement Production and CO2 Utilization
- **Blue Planet Ltd. – USA**
  Carbon Capture and Mineralogic Sequestration: Addressing the World Wide Epidemic on a World Wide Scale
- **McGill University – CANADA**
  Use of Carbon Dioxide in Making Carbonate-Bond Precast Concrete Products
- **CCm Research – UK**
  High Efficiency Capture Using Novel Fibres in the Production of Soil Conditioning Agents Polymer Replacements
- **Carbon Cycle Limited – UK**
  Process to Capture Carbon Dioxide and Produce Structured Calcium Carbonate and Fertilizer
- **ARCTECH, Inc. – USA**
  HUMASORB®-L for Removal of CO2, NOx GHGs, along with SOx and Trace Metals from Fossil Fuel Combustion Gases and Recycling of CO2 into a Value Generation HUMASORB®-CS, a Stable Multipurpose Water Filter
- **Carbon Upcycling Technologies** [formerly JRE Petroleum Services] (Canada)
  CO2 to Graphene Reactors

For chemical synthesis

- **RTI International – USA**
  Captured-CO2 Catalyst for the Production of Ethylene Oxide (C3-PEO)
- **Liquid Light – USA**
  Converting Carbon Dioxide into Chemicals and Fuels Using Clean, Domestic Sources of Energy in Alberta
- **E3Tec Service, LLC – USA**
  Production of Dimethyl Carbonate (DMC) from Captured CO2 and Methanol
- **Gas Technology Institute – USA**
  Direct Catalytic Synthesis of Acetic Acid from CO2 AND CH4
- **University of British Columbia - CANADA**
  A Coupled CO2 and Wastewater Treatment Process to Create High Value Gas/ Oil Field Chemicals

For fuels

- **Pioneer Energy – USA**
  High-Value Synthetic Chemicals and Gasoline Drop-In Liquid Fuels from Canada's CO2 and Flare Gas Emissions
- **University of California Riverside – USA**
  CO2 Conversion to Methanol through Bi-reforming
- **Quantiam Technologies – CANADA**
  Green Methanol From Carbon Dioxide and Renewable Hydrogen (Methanol +)
- **McGill University – CANADA**
  Chemical Transformation of Carbon Dioxide via Solar-Powered Artificial Photosynthesis
- **Robert Gordon University – UK**
  Integration of Advanced Hybrid Inorganic Membranes for Carbon Dioxide Conversion
- **University of Alberta – CANADA**
  Novel Internal Dry Reforming Solid Oxide Fuel Cell Technology for CO2 Utilization
- **Enerkem Inc. - CANADA**
  Valorizing Industrially Produced CO2: A Reliable and Cost-Effective Solution for Carbon Capture and its Conversion to Marketable Products

from algae, bacteria, and yeast. Industrial Microbes has a biofixation process that doesn't need light and produces plastics -- usually algae or bacteria require a light source.\

The CCEMC Grand Challenge is also supporting nine projects that use carbon dioxide to create solid products. For example, Solidia Technologies produces a new form of concrete that reduces the CO2 footprint associated with the production of cement and the use of cement in concrete products by up to 70 percent. Globally, the cement industry is a significant industrial emitter of carbon dioxide.

Carbon Upcycling is creating graphene. The uses for graphene are continually being developed and represent significant potential. Carbon Upcycling sees potential opportunities in industries such as plastics, water purification, and the semiconductor industry.

ARCTECH has technology with potential applications for coal-fired power generation as well as other industries. Their technology aims to remove CO2, NOX GHGs, along with SOX and trace metals from fossil fuel combustion gases and recycle CO2 into a multi-purpose water filter.

Five CCEMC projects are related to chemical synthesis, including one from the University of British Columbia that uses CO2 to desalinate industrial wastewater, creating an economical alternative to conventional desalination technology.

Seven projects fall generally in the area of fuels, including one from McGill University that draws on artificial photosynthesis using solar power to create a fuel.

Pioneer Energy uses flare gas, and rather than flaring, creates liquid fuels and high-value chemicals.

Round two launches in 2015

Round two of the Grand Challenge launches in September 2015 and after a second international intake five winners will each receive $3 million.

From that group, a final winner of the competition will be awarded a $10 million grant in 2018 to establish a business that annually reduces greenhouse gas by one net megatonne in Alberta.

More information

The CCEMC focuses on stimulating transformative change by funding projects that reduce greenhouse gas emissions and help Alberta adapt to climate change. Funding for the CCEMC is sourced from Alberta's large industrial emitters.

In Alberta, large emitters have a mandatory legislated requirement to achieve specified reductions of greenhouse gases. If they're unable to reach their target one option is to pay a levy of $15 per tonne into the Climate Change and Emissions Management Fund. The fund is administered by the Government of Alberta and the CCEMC receives grants from the fund to support its work. The CCEMC operates arms-length of government.

ccemc.ca

CCEMC Grand Challenge finalists from 24 different organizations take the stage at a conference in Edmonton on April 15.

CO2 Solutions' heavy oil pilot project

After positive results from its oil sands project, CO2 Solutions will operate a pilot CO2 capture plant at Husky Energy's Saskatchewan heavy oil operations

CO2 Solutions recently announced that it has exceeded a second set of technical performance milestones for its oil sands project.

Its patented process operated at the 0.5 ton/day scale and demonstrated that it can realistically lower the cost of CO2 capture to well below that associated with current carbon capture technology on the basis of cost per tonne captured, the company said.

Under the terms of a Collaboration Agreement, CO2 Solutions will now install and operate a pilot unit capturing approximately 15 tonnes of CO2 per day at Husky's Pikes Peak South, Saskatchewan heavy oil site on a once-through steam generator.

Operation of the pilot unit is expected to commence in early 2015 with completion of testing expected in the third quarter of 2015. Subject to a positive review by Husky of the results of the pilot test, the Agreement provides for Husky to consider the use of CO2 Solutions' technology for commercial carbon capture projects.

The project will be funded in part by the Government of Canada's ecoENERGY Innovation Initiative (ecoEII) program, as previously announced on January 24, 2013.

"The pilot demonstration of our technology is a significant milestone towards the commercial deployment of our technology for CO2 capture and beneficial utilization applications such as enhanced oil recovery," said Evan Price, President and CEO of CO2 Solutions. "Husky is a recognized leader in the energy industry and will provide valuable expertise to this project."

"Through the ecoENERGY Innovation Initiative, our Government is investing in projects that drive energy innovation, create jobs and generate new economic opportunities that protect the environment," said the Honourable Greg Rickford, Minister of Natural Resources and Minister for the Federal Economic Development for Northern Ontario. "Today's announcement demonstrates that these investments are successfully bringing innovative clean technologies from concept to reality."

The pilot test is expected to confirm the positive techno-economics of CO2 Solutions' carbon capture process and will provide an operational basis to compare the process against other new and conventional technologies in terms of performance and cost.

A successful project will pave the way for the CO2 Solutions technology to be applied broadly for cost-effective carbon emissions mitigation in heavy oil and oil sands operations in Western Canada and other industrial applications.

A CO2 Solutions prototype installation

More information

www.co2solutions.com

Alberta continues investment in two major CCS projects

As part of its Budget 2014, The Government of Alberta is continuing to invest in two carbon capture and storage projects that will reduce greenhouse gas emissions from oil sands upgrading: the Alberta Carbon Trunk Line and Shell 's Quest Project.

In its Budget 2014, the Alberta government is investing $144 million in CCS projects. Alberta will invest almost $1.3 billion over 15 years in these two large-scale, oil sands-related CCS projects – the Alberta Carbon Trunk Line operated by Enhance Energy and Shell's Quest Project.

These projects will start up in 2015 and will store 2.76 million tonnes of carbon dioxide per year.

Quest

Quest will capture 1.2 million tonnes of CO2 annually from Shell's Scotford oil sands upgrader and then transport it by a 65-km underground pipeline to three injection wells north of the upgrader in Thorhild County where it will be permanently stored.

Minister of Energy Diana McQueen saw the significant progress being made on carbon capture units under construction at the Scotford Upgrader during a visit to the site on April 17.

The project has now reached midway point in its construction process and the facility is expected to commence operating in late 2015.

In addition to the environmental benefits, the project creates value for Alberta by developing technology expertise. The numbers of skilled trades people working on construction peaked at 900. The project is also using an Edmonton module fabrication yard to construct modules for the capture facilities.

ACTL

The ACTL, built and operated by Enhance Energy, is a 240 kilometre pipeline that will collect CO2 from industrial emitters in and around Alberta's Industrial Heartland and transport it to mature reservoirs throughout central and southern Alberta for secure storage in enhanced oil recovery (EOR) projects.

At full capacity the ACTL route will provide access to reservoirs capable of producing an additional one billion barrels of high quality light crude oil. These reservoirs will safely and securely store 14.6 million tonnes of CO2 per year as the oil is produced. At full capacity this will be equivalent to removing 2.6 million cars from Alberta's roads.

The ACTL will be the largest carbon capture and storage project in the world and will store six times more carbon dioxide than the Weyburn project in Saskatchewan.

The Alberta Carbon Trunk Line will transport CO2 240km from industrial emitters to mature reservoirs for enhanced oil recovery and CO2 storage

More information

www.energy.alberta.ca
www.shell.ca
www.enhanceenergy.com

Potential of Canadian mining residues for ambient carbonation

Intensive mining activities in Canada have opened up a potentially resourceful opportunity into atmospheric and industrial CO2 capture.

By Gnouyaro P. Assima and Faïçal Larachi (Department of Chemical Engineering), John Molson and Georges Beaudoin (Department of Geology and Geological Engineering), Université Laval, Québec, Canada.

The use of mining residues under ambient conditions as CO2 sinks offers all the benefits of CO2 mineral sequestration. It also stands out as one of the most affordable approaches of the CCS arsenal to sustainably and safely sequester ambient CO2.

Usability of mining residues for CO2 capture

Research on a variety of CO2 mitigation techniques has generated promising approaches and technologies since the 2000's in all three main point-emitting pathways (post-, pre- & oxy-fuel/combustion). The high CO2 content in exhaust gases largely justifies the practical and economic aspects for implementation of most CCS technologies.

Although CO2 capture at source emitters has received growing interest, the steady increase of CO2 concentrations in ambient air over time reflects the scarcity of technologies for addressing the air-laden component from diffuse CO2 sources. The usability of cheap and abundant mining residues could be an alternative for limiting the buildup of CO2 in air.

In Canada, colossal amounts of mining residues are produced annually [1]. Mining activities in southern Québec alone has accumulated about two billion tons of waste over the past several decades. The accumulated mining residues, mainly magnesium-rich in composition, hold great potential for CO2 capture as a number of studies have estimated they contain high enough amounts of magnesium (~12-19 wt.%) which is able to chemically bind to ambient CO2 via above-ground natural weathering mechanisms [2].

The most significant chemical reactions arising from the ambient mineral carbonation process can be summarized as follows: CO2 dissolution into the pore water within the mining residues (reactions 1-4), magnesium leaching from mining residues (5) and magnesium precipitation as stable and safe magnesium carbonates (6-7) [3]:

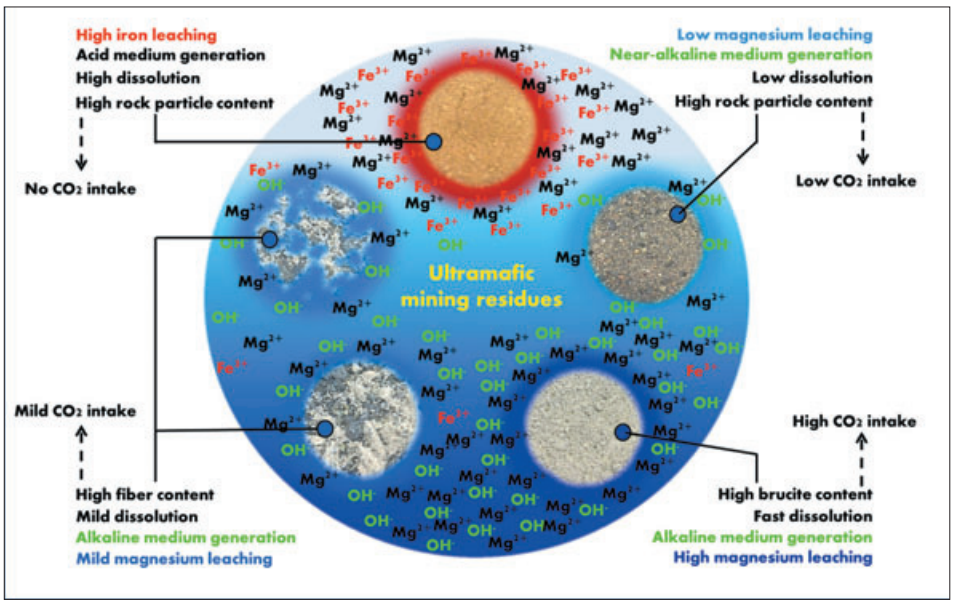

Figure 1: Criteria for ultramafic mining residue suitability for ambient direct CO2 mineral sequestration

$$CO_2(g) \rightarrow CO_2(aq) \quad (1)$$
$$CO_2(aq) + H_2O(l) \rightarrow H_2CO_3(l) \quad (2)$$
$$H_2CO_3^- + H_2O \rightarrow H_3O^+ + HCO_3^- \quad (3)$$
$$HCO_3^- + H_2O \rightarrow H_3O^+ + CO_3^{2-} \quad (4)$$
$$Mg_3Si_2O_5(OH)_4 + 5H_2O \rightarrow 3Mg(OH)_2 + 2H_4SiO_4\ (2SiO_2 + 4H_2O) \quad (5)$$
$$Mg^{2+} + 2HCO_3^- + 2H_2O \rightarrow MgCO_3.3H_2O + CO_2 \quad (6)$$
$$5Mg^{2+} + 8HCO_3^- + 2OH^- + H_2O \rightarrow Mg_5(CO_3)_4(OH)_2.5H_2O + 4CO_2 \quad (7)$$

Previous research findings and state of knowledge

Past research into CCS using mining residues has been directed towards the use of magnesium sources as carbon sinks, e.g., magnesium silicates which are much more abundant at the earth's surface. Past studies have then granted greater importance to the rate of CO2 mineral sequestration by mining residues and their parent geological formations.

In order to sequester CO2 from gas combustion exhaust streams (down to the very-diluted atmospheric levels), the rate of mineral carbonation has to be high enough. Yet, the dissolution rate under ambient conditions of ultramafic mining residues, especially magnesium silicates contained therein, is slow [4]. Moreover, the use of chemical reagents and energy to enhance the dissolution was found to be not cost effective on account of the relatively low magnesium content in mining residues [5,6].

It was concluded that the rate of CO2 capture hitherto achieved by mining residues might be insufficient to keep pace with the level of industrial emissions, hence their use as a CO2 binder was deemed nonviable.

What really matters?

Most studies presented in the literature have been conducted on pure magnesium silicates (serpentines) or on mining residues almost exclusively composed of serpentines which have proved to be less responsive to concentrated CO2 streams [7]. However, mining residues often consist of multi-component systems with several minerals including brucite, magnesium silicates and some iron bearing minerals.

The magnesium silicates are encountered in the form of fibres (chrysotile) or rocks containing various proportions of lizardite, antigorite, talc, phlogopite, etc., that are known to dissolve inconsistently in water. Brucite is the fastest to dissolve, followed by chrysotile fibres and the non-fibrous silicate minerals. For example, lizardite/antigorite, phlogopite and talc dissolve approximately 10, 50, and 100 times slower than brucite, respectively [8].

Recent work conducted by our research group on the Black Lake mining residues (Thetford Mines, Québec) revealed that despite the inability of serpentinized mining residues to deeply convert CO2 from post-, pre- and oxy-/combustion flue gas, they can progressively and directly withdraw sizeable amounts of CO2 from air in an effective way by optimizing their storage condition [9].

Moreover, the reactivity of mining residues was found to be reliant on their mineral composition, most specifically, their brucite and fibre contents; brucite-rich residues being more reactive than brucite-poor (or brucite-free) residues (Figure 1).

Assessment of mining residue suitability for atmospheric or industrial CO2 capture

Since the brucite content of mining residues is crucial to categorize and benchmark their reactivity vis-à-vis to CO2, we have developed an original method that accurately quantifies brucite in mining residues. Primarily based on a combination of isothermal/non-isothermal thermogravimetry - mass spectrometry analyses, the method provides a cheap, reliable and straightforward tool for brucite quantification.

Unlike various methods currently employed for brucite quantification, the developed technique is not affected by the sample particle size [10], and achieves an accuracy unequalled by other current techniques.

Application of the above-mentioned quantitative method to five different types of mining residues in Québec, namely, *Asbestos* and *Black Lake* chrysotile mines (Asbestos and Thetford Mines, Québec), *Dumont Ni-Cu mine project* (Royal Nickel, Amos, Québec), *Raglan Ni-Cu-EGP mine* (Xstrata Nickel, Nunavik, Québec), and *Renard Diamond project* (SOQUEM/Stornoway Diamond, in north-central Québec) enabled determining brucite contents ranging from 0 to 10.9 wt.% [10].

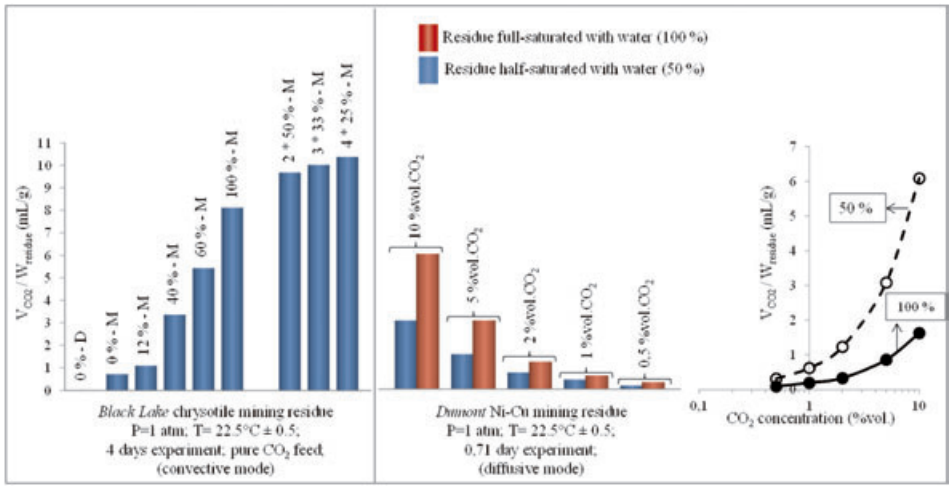

Figure 2: Effect of watering on CO2 uptake by Black Lake (X%-D, percent of pore saturation with liquid water–dry CO2; X%-M, idem–moist CO2) and Dumont mining residues under ambient conditions

Knowledge of the exact brucite content provides more insights into predicting the reactivity of mining residues, their suitability for industrial, near atmospheric and/or atmospheric CO2 capture processes and especially their short- and long-term reaction rates.

Key outcomes of CO2 capture using mining residues

The reactivity of several Canadian mining residues was tested at Université Laval where ambient and enriched CO2 gas uptakes were monitored under simulated outdoor conditions where meteoric precipitation, gas diffusion, temperature variation, and residue mineral composition was addressed. The main outcomes are summarized as follows:

• Presence of abundant water in the pores was found to promote densification of silica gel, a dissolution by-product from ultramafic mining residues causing passivation (by coating the surface of mining residues particles) thus slowing down further dissolution. Furthermore, under full pore water saturation, CO2 gas diffusion was hampered and its displacement towards reactive magnesium-enriched sites was controlled by slow migration of its dissolved species.

• Low water content in residue pores significantly reduced the carbonation reaction rate. Although CO2 gas diffusion was greatly enhanced in dry mining residues, its dissolution and that of magnesium are key factors to carbonation.

• Maintaining partial pore saturation of mining residues considerably boosted both carbonation rate and yield. Ambient carbonation was enhanced by ca. 750% within four days by maintaining liquid pore saturation around 30-50%. This range of pore saturation proved optimal for fast diffusion of gaseous CO2 and its subsequent dissolution in Mg-rich leached-off pore water.

In the context of outdoor carbonation, translation of laboratory observations presented in Figure 2 as field features has led to the conclusion that high meteoric water precipitation episodes (leading to full pore liquid saturation) and likewise dry episodes are unlikely to be the best conditions for ambient carbonation [11-12].

To maintain partial pore saturation and thereby improve the carbonation conditions, a proposed affordable and practical approach is the incorporation of high-permeability areas with low water retention within residue piles in so-called structured residue heaps. Such *in-situ drainage systems* built directly from the mining residues, using coarser particles, are thought to provide permeable channels to vent and drain the mining residue piles in addition to allowing air/CO2 and water to penetrate deep inside the residue pile to promote efficient CO2 uptake [12].

These draining systems also help foster retrieval of leached magnesium unlike in non-structured heaps where water retention is likely to remain at higher levels. Another advantage is the potential reuse of the collected Mg-rich leachate for prospective watering in dry periods in order to maintain optimal conditions for mineral sequestration [12].

• Cold and warm episodes are both con-

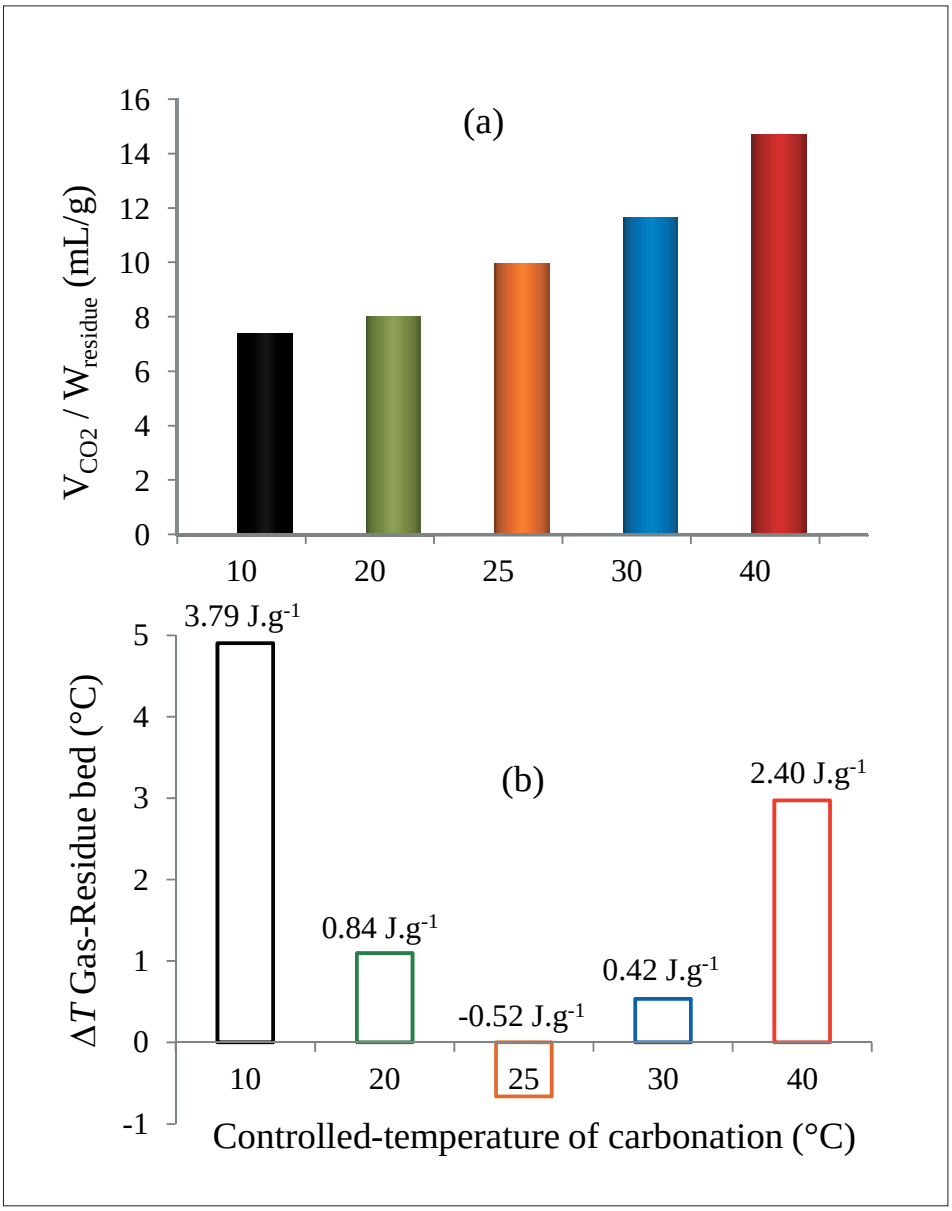

Figure 3: Dumont Ni-Cu mining residues ambient carbonation: (a) CO2 uptake under varying ambient temperatures (10, 20, 25, 30 and 40°C) over 0.71 day experiment and (b) average temperature difference between gas and mining residue samples

covered by means of low-temperature geothermal systems [13].

• Brucite-rich mining residues reacted fast, depleting CO2 even in concentrated gas feeds unlike brucite-free (or brucite-lean) mining residues, especially rock-rich (e.g., lizardite, antigorite, talc, phlogopite), which were sluggish to carbonate.

• Fibre (chrysotile)-rich mining residues reacted moderately with high concentrate CO2 gas feed but rapidly with low concentrate CO2.

The CO2 uptake results obtained by reacting mining residues with various mineral compositions are presented in Figure 4. The indigenous brucite content of mining residues reflected their ability to rapidly sequester large amounts of CO2 [12-14]

Bottom line

In conclusion and based on our laboratory findings, the huge amounts of mining residues accumulated in Canada can effectively serve at capturing atmospheric, near-atmospheric and eventually industrial CO2 effluents. A tool was provided to precisely identify the suitability of mining residues for each CO2 composition range. An optimum condition of partial pore water saturation of (30-50%) was provided for an enhanced direct ambient carbonation while an affordable approach to maintain such partial pore saturation was proposed.

The approach consisting of coarse granulometry structured residues may prove to be an asset for enhanced direct CO2 sequestration and is also regarded as a cheap means to improve stability of mining residue piles. Moreover, an enhanced carbonation process might generate substantial amounts of potentially retrievable and useful heat (Figure 5).

ducive for CO2 ambient mineral sequestration by mining residues.

• Under optimal liquid saturation, an increase of temperature from 10 to 40°C led to ca. a 10 fold increase in the ability of mining residues to sequester CO2. As long as partial water saturation is achieved, warm conditions favor greater CO2 uptake.

• Owing to the exothermic character of carbonation which releases a significant amount of heat, carbonation in mining residues in cold weather was not completely inhibited.

The results of CO2 uptake by non-structured mining residues under varying temperatures and the corresponding heat release are displayed in Figure 3. Besides the captured CO2, the heat released by the carbonation reactions might potentially be re-

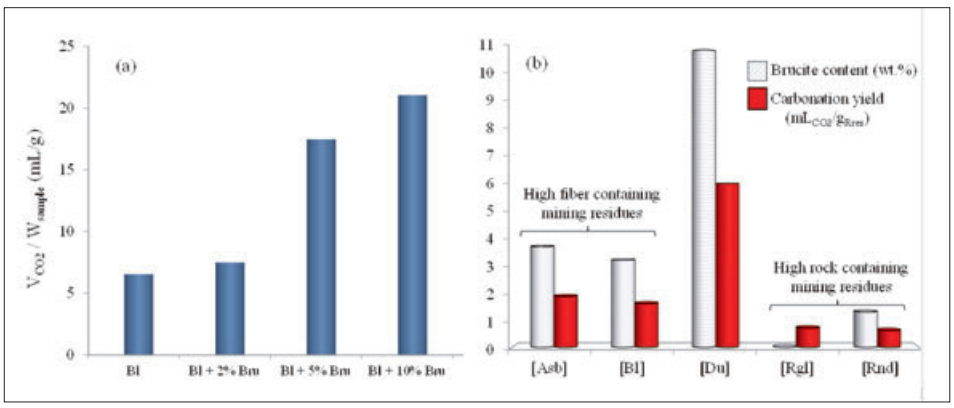

Figure 4: Volume of CO2 converted into carbonates in: (a) Black Lake chrysotile mining residue upon brucite doping (loading in wt.%), runs for 4 days with initially water-saturated residue pores and (b) comparative portrayals of carbonation yield and brucite content of ultramafic mining residues. Acronyms: [Asb]- Asbestos, [Bl]- Black Lake, [Du]- Dumont Ni-Cu, [Rgl]- Raglan Ni-Cu-EGP and [Rnd]-Renard Diamond mining residues

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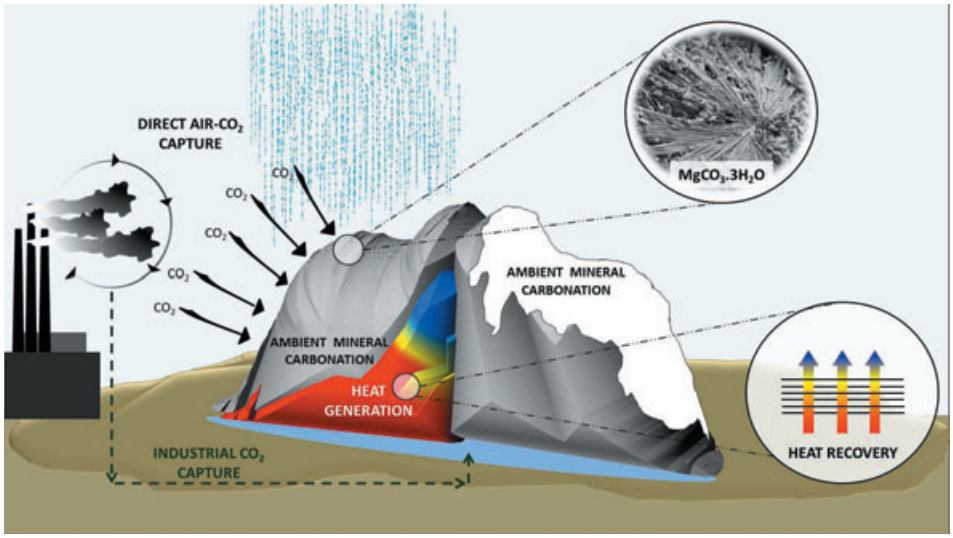

Figure 5: Ambient direct CO2 mineral sequestration using ultramafic mining residues

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More information

Gnouyaro P. Assima holds a doctoral degree in Chemical Engineering and is currently a postdoctoral researcher in the department of Chemical Engineering, Laval University (Québec City, Canada). He is working on application of mining residues for CO2 capture under ambient conditions.

Faïçal Larachi is a Professor of Chemical Engineering and the holder of a Tier-1 Canada Research Chair "Process intensification for cleaner and sustainable energy and materials". He holds a doctoral degree from the Institut National Polytechnique de Lorraine in France. His research interests encompass multiphase reactor engineering, chemical kinetics, process intensification, and new approaches for mitigation of greenhouse gas effect via mineral carbonation, ionic liquids and enzymatic catalysis.
Faical.Larachi@gch.ulaval.ca

John Molson is an Associate Professor in the Dept. of Geology & Geological Engineering at Université Laval, Quebec City, and holds a Tier-2 Canada Research Chair in Quantitative Hydrogeology of Fractured Porous Media. He is also an Adjunct Professor in the Department of Earth & Environmental Sciences at the University of Waterloo, Ontario. His research focuses on the development of numerical models for simulating coupled hydrogeological processes including groundwater flow, transport and biodegradation of organic contaminants, heat transport, geochemical systems and acid mine drainage.
john.molson@ggl.ulaval.ca

Georges Beaudoin is a Professor of Economic Geology in the Dept. of Geology & Geological Engineering at Université Laval. He holds the NSERC/Agnico-Eagle Industrial Research Chair in Mineral Exploration. He holds a PhD in Geology from the University of Ottawa. His research interests comprise indicator mineral methodologies, the geochemistry or hydrothermal mineral deposits, and the processes of ambient mineral carbonation.
Georges.Beaudoin@ggl.ulaval.ca

CCS in the finance community: from apathy to activity

At Carbon Capture Journal's conference 'Keeping the momentum with CCS' on March 25th in London, Allan Baker, Global Head of Power Advisory & Project Finance, Société Générale talked about how the finance industry was waking up to CCS and how we can keep their interest.

Apathy was the generally perceived attitude of the finance community until recently, said Allan Baker, but that was starting to change.

CCS should be an interesting area for banks, he said, because it is an essential part of decarbonising the power sector and the project finance community in banks has focussed heavily on this sector. It is also attractive because the scale is large and many hundreds of projects will be required worldwide. However, up to now that interest has largely been sidetracked by renewables.

In the last two or three years, a number of sounding exercises have demonstrated a move in the finance community from apathy to increasing interest in CCS. In 2011, a survey from The Climate Group and Ecofin indicated that banks actually didn't understand even what CCS was, had never looked at CCS and by definition were not particularly interested in financing it.

Similarly, Société Générale together with the Carbon Sequestration Leadership Forum (CSLF) in the U.S., ran a round table for banks, export credit agencies and Government/multilateral entities in Paris and the message there was that they could see that CCS had a role to play in decarbonising power but not probably for many years.

"One of the more memorable questions was why I was actually bothering with CCS, wasting my time on something that would not materialise for years."

One of the things banks found hard to understand was the opportunity. When you look at the Global CCS Institute Status report, he said, there was a continual revolving door of projects coming into that at the bottom and then dropping off at the top, which is symptomatic of an industry that is trying to find its place.

"If you look at the most recent report there is a reduction in the number of projects, which was seen by some as being negative. But we see that as a positive development as it focusses the attention on the best projects. The more stable that list is, the more we see those projects at the top of the list coming closer to taking a final investment decision, the more banks are going to see an industry that is ready for financing."

Delegates discuss how to keep momentum with CCS in the library of the Geological Society in London

The landscape has changed now and the most recent work done as advisor to White Rose and with the Global Institute has been very much more encouraging, he said.

"We've actually engaged with the financial community, including many of the top banks in project finance, with real projects to talk about, something that we could actually describe to them, with a real risk allocation process, and technology they could understand and see."

"The result of that has been some very, very supportive comments and letters of interest from those institutions and a continuing interest in the projects that are going ahead around the world."

"One of the key things for us in that exercise has been the supportive environment that we have now in the UK, and whilst Energy Market Reform (EMR) has caused the financial community problems in some senses in terms of traditional power, I think the creation of the Contracts for Difference (CfD) mechanism and the bespoke contracts that are available under the competition, have been very positive for the projects that are going ahead and could potentially be very positive for the follow on projects if they're structured as we hope they will be or believe they will be."

The key is to maintain interest in the sector, he said, and it is important that the industry promotes confidence by keeping projects moving and showing that progress is being made. There is a lot of pressure to justify continued work on CCS within banks he said, as it is not seen as being profitable yet, and there needs to be a reason not to divert attention to other areas such as offshore wind.

One of the key issues for carbon capture as well the regulatory framework, is cost. The first of any kind of project is going to be expensive, particularly if you're developing a hub for future projects to access. There is additional cost incurred with demonstrating the technology, there are various layers of contingency put on by each of the suppliers in those projects, the sponsors, the financial community to reflect the first of a kind risk so early projects become expensive, and you're also potentially bearing the burden of common infrastructure for the benefit of later projects as well.

"So cost reduction, for us, is crucial if CCS is to become a technology that can rank alongside offshore wind and other low carbon generation that we finance."

Finance costs will also come down as

projects become less risky. With offshore wind, he said, the first projects were around fifty percent debt and fifty percent equity, and the banks required a completion guarantee from the sponsors as there were doubts about the technology, the offshore construction and shipping. Now the latest projects have around 25 percent equity and a completion guarantee is no longer required.

"As projects become less risky and more certain, financing becomes more cost effective and more available and that is what we need to achieve with CCS."

"So to conclude the finance community is waking up to CCS and it is gaining credibility. Actually I am now in the strange position of helping my competitors develop a strategy paper in relation to CCS, to present to their management to say this is a sector we should be involved in."

"What we need to keep working on is a template for financing these kinds of projects, based on experience from the first demonstrations."

Banks are nothing if not predictable, he said. If there is a template that works then they will continue to use it and more institutions will join in and push the margins down.

"On White Rose part of the approach has been to keep those banks interested by keep them up to date with development of the project as progress is being made, but that's not just something for White Rose to focus on, that's something for the industry and the Government to also focus on."

"The message I will leave you with is that the banks are ready today, but if something else comes up to divert their attention they will be gone. They have no attention span and we have to keep showing them projects and get them involved in financing as quickly as possible."

More information

Allan Baker is the Managing Director, Global Head of Power for Societe Generale UK, a French multinational banking and financial services company headquartered in Paris. He joined the company in 2007. He was also Head of Energy for Credit Agricole, formerly called Calyon.

www.societegenerale.com

CO2CRC Otway project update

CO2CRC, one of the world's leading CCS research and development organisations, is progressing with the Otway project, researching carbon storage at its Nirranda South facility. A new book recording the work to date will be published later this year.

What's in the water

CO2CRC has just completed the 14th groundwater survey of the area around the Otway Project at Nirranda South.

Monitoring of the area's groundwater began in 2006, two years before carbon dioxide injection took place at the Otway Project site. These early surveys provided a baseline measurement that scientists have been comparing to the more recent results, in order to see if there have been any changes to the groundwater over time.

This kind of monitoring is one important part of demonstrating that the carbon dioxide has not been leaking from the storage reservoir.

Dr Patrice de Caritat from Geoscience Australia has been leading the now annual survey for the past seven years, this year with the assistance of Chris Harris Pascal. The team spent about a week in the region, taking samples and measurements from both shallow and deep bores, on both State and private land.

A wide range of measurements are taken in the field, including measuring water levels in the bores and analysing samples for acidity, alkalinity, dissolved oxygen and some mineral concentrations. Patrice is also looking for any sign of the special tracer gases injected with the carbon dioxide in 2008.

Not all the tests can be done in the field and a big part of the job is bringing samples, which almost fill a trailer, back to Canberra for more complex analysis in the lab. Patrice is happy to share the results with farmers curious about what's in their water.

Over the years of sampling some clever techniques have developed for getting the correct measurements. It's not easy to take a water sample from 800 metres underground and a special pump is required, often taking a full day to complete sampling from just one bore.

The regular survey is a lot of work and so far has shown no evidence of any changes to the levels or chemical composition of the groundwater since the carbon dioxide was stored, aside from the natural variability caused by seasonal variation, droughts and so on. This is one case where no news is good news.

Patrice and Chris at the deep bore near Curdievale

Stage 2C final planning

Research at the CO2CRC Otway Project has proven to be very successful over the years, with many scientific papers published and a great deal of national and international interest. CO2CRC have developed a new experiment, known as Stage 2C, and is talking to the community about their plans.

The experiment involves a relatively small injection of 15,000 tonnes of carbon dioxide deep underground, and the use of new seismic equipment and techniques to monitor how it moves and stabilises over time. Seismic surveys bounce sound waves off the rocks deep underground, with the reflections picked up by sensors to provide an image.

Stored carbon dioxide actually becomes more secure over time, becoming trapped in the little pores between grains as it moves through the rock. By running seismic surveys over time, CO2CRC scientists will be able to 'see' and measure this process in the field, for the first time anywhere in the world.

The experiment will also help design seismic monitoring systems that are high resolution and cost-effective but also less disruptive for local landowners.

Learning from the Otway Project Experience

The CO2CRC Otway Project, involving an investment of over $70 million over nearly a decade, has established itself as one of the world's most significant sites for field-based research programs investigating geological storage of carbon dioxide, with research still underway.

Stage 1 of the project, the first trial of geological storage in Australia, broke new ground in several areas. The lessons learnt have informed legislation, government policy and the science and technology of reservoir modelling, geophysics, geochemistry, monitoring and verification, and community engagement. Stage 2 of the Project applied new techniques to better understand the trapping of CO2 in saline aquifers.

A record of this remarkable project has been in development for over two years and is now nearing completion, with the publication of the book, "Geologically Storing Carbon: Learning from the Otway Project Experience" scheduled for mid-2014.

The book, edited by project conceiver Professor Peter Cook, comprises eighteen comprehensive chapters written by leading experts in the field. The book is concerned with outstanding science, but it is not a collection of scientific papers; it is about "learning by doing". For example it explains how the project was organised, managed, funded and constructed; and the approach taken to community issues, regulations and approvals. It describes how the team tackled understanding the site and addressed questions such as are the rocks mechanically suitable; will the CO2 leak; is there enough storage capacity; and, crucially, is monitoring effective?

The book will be of interest to geologists, engineers, regulators, project developers, industry, communities and anyone who wants to better understand how a carbon storage project really works.

Available mid-2014, the book will be jointly published by CSIRO Publishing and Wiley.

More information

www.co2crc.com.au

The Climate Institute report shows crucial role of bio-CCS

Technologies that remove carbon pollution from the atmosphere are now central to a lower risk strategy to avoid climate change, finds a study by the Australia-based The Climate Institute.

The report, "Moving Below Zero: Understanding Bio-energy with Carbon Capture & Storage" includes a world first study examining the role of carbon removal technologies in national climate policy scenarios. Carried out by leading economics firm Jacobs SKM, the modelling finds that bio-energy with carbon capture and storage, or bio-CCS using food wastes, sustainable forest biomass, or crop residues, has the potential to contribute significantly to climate change efforts in Australia.

"Physics tells us that if we are to avoid very dangerous global warming of 2°C or more above pre-industrial levels, Australia and other countries need not only zero carbon technologies like solar and wind but also to go further, and employ carbon removal technologies," said John Connor, CEO of Australia-based The Climate Institute.

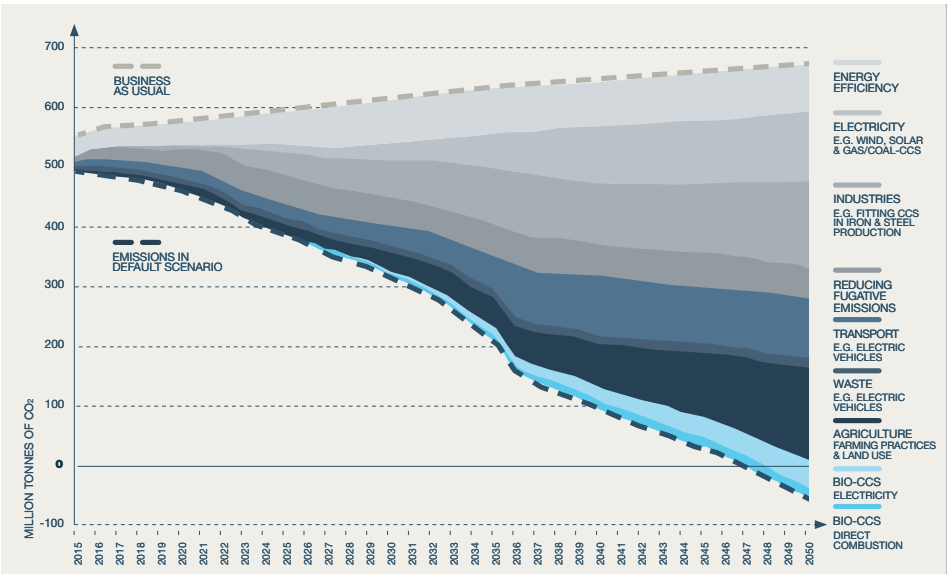
"We examined a range of carbon removal options including afforestation, biochar and bio-CCS."

"Bio-CCS is potentially the most climate safe technology as it involves removing carbon from the air and storing in in the earth over geological timescales. Globally it could remove a substantial amount of carbon pollution from the air – up to 10 billion tonnes of pollution per year in 2050, according to the International Energy Agency."

While global agents like the IEA and the IPCC are urging the use of carbon removal and include the technologies in their modelling, this is not the case on national level. Using Australia as a case study, Jacobs SKM economic modelling concluded that:

Bio-CCS could play a significant role in Australia, with a capacity to remove and displace up to 65 million tonnes of CO2 equivalent (MtCO2-e) annually by 2050. That is around 1.5 times current emissions from all cars in Australia.

Early and strong action on climate is needed, with renewables and other low-carbon technologies being critical from today. For example, energy efficiency and other renewable energy sources like wind and solar are required to reduce electricity emissions by 50 per cent, from around 200 Mt CO2-e today to 100 Mt CO2-e in 2030 across all scenarios.



Bio-CCS could play a significant role in Australia, mitigating 63 million tonnes of CO2 equivalent by 2050

Recommendations

- A strongly endorsed long-term Government vision for the CCS sector.
- Immediate and steady rollout of CCS projects: including a minimum of 2 projects from the current CCS competition, ready to begin operating from 2018; and positive final investment decisions for shovel ready projects outside the competition within the next parliament.
- Successful implementation of the Government's Electricity Market Reform, particularly through the development of low-carbon support mechanisms, such as the Feed in Tariff with Contracts for Difference, that catalyse CCS investment.
- Development of CO2 transport and storage infrastructure that can service the needs of not just current emitters, but also future power and industrial facilities.
- The development of support mechanisms for CCS in industrial applications.

Without bio-CCS and other carbon removal technologies, Australia and other nations will face difficult trade-offs: accept more dangerous levels of climate change, pay more for emission reductions, and/or purchase more and more emission reductions from other countries. The report finds that failure to adopt carbon removal technologies could increase climate action costs by up to $60 billion to 2050.

"Carbon removal technologies are hugely important but they have to be employed correctly. If bio-energy is not sourced from sustainable sources and consider energy used at all stages of the process, it can lead to other social and environmental impacts and undermine the viability of, and public confidence in, the technology."

"With carbon dioxide levels now 40 per cent above pre-industrial levels, it is critical that we begin the conversation now about how to sustainably integrate carbon removal technologies into national climate policies with long term decarbonisation signals and deployment incentives," concluded Connor.

More information

www.climateinstitute.org.au

Bellona: IPCC confirms that bio-CCS is a key technology

The IPCC, which met recently in Berlin to complete its third interim report, says the world must pursue more nuclear power or a massive deployment of CO2 Capture and Storage. Bellona looks at the implications for climate policy.

Last year the IPCC told of the overwhelming scope of the climate challenge, and recent weeks have seen many warning bells rung as it has described dramatic and costly adaptation measures.

This third report, which describes possible solutions, therefore becomes the report of hope: What is needed to prevent catastrophic climate change? International media, the IPCC and other climate scientists have now confirmed the working hypothesis Bellona has had since the last IPCC report in 2007: A massive expansion of renewable energy is imperative. As is energy efficiency. Unfortunately, this will not be enough. Carbon negative technologies will also be critical.

The IPCC draft report says the world must pursue more nuclear power or a massive deployment of CO2 Capture and Storage (CCS). This will come as a political bomb in Berlin: Germany has decided to phase out nuclear power, but has not wanted to invest in CCS either.

Bio-CCS is a key technology

CCS can be used for more than reducing fossil fuel combustion emissions: CCS is key to ensuring the stabilization of the climate – as the only technology capable of removing CO2 from the atmosphere on a large scale.

It may sound like science fiction, but it is only a matter of using technology that already exists. Bellona has worked for many years with the combination of CCS and sustainable biomass, a combination which will lead to negative CO2 emissions.

Biomass – wood, crops, seaweed, algae – absorbs CO2 from the atmosphere as it grows. The CO2 will be released again when the biomass is combusted to generate energy or other products. This provides a virtually CO2-neutral cycle. But if those emissions were instead captured and stored, for instance in depleted oil and gas fields, it would remove CO2 from the atmosphere over time. This is why we call Bio-CCS a carbon negative climate solution.

Half of EU power emissions and 200 times Norway's emissions

Following the IPCC report from 2007 Bellona published "How to Combat Global Warming: The Bellona Scenario" and already then stressed the necessity of Bio-CCS. The report has since formed the basis of much of our work. From Bellona's office in the EU-capital Brussels, we took the initiative in 2009 to establish a joint taskforce between the EU technology platforms for CCS (ZEP) and biofuels (EBTP).

The goal was to bring together researchers and industry actors who worked with the two issues, but rarely spoke, to see how Bio-CCS can be done in practice. The Joint Task Force Bio-CCS presented its firstreport in 2012 in the European Parliament, with the European Commission and the International Energy Agency in attendance. It also saw a visit from the Midwest Geological Sequestration Consortium, which operates a Bio-CCS facility in the USA.

The report showed that Bio-CCS globally can remove up to 10 billion tonnes of CO2 from the atmosphere annually by 2050. This is nearly 200 times the annual emissions of major oil and gas exporter Norway. As a country which has earned its wealth from fossil fuel Norway has primary responsibility to contribute to the development of solutions like CCS. The Norwegian government needs to take responsibility and ensure that the cancelled CCS project at Mongstad is not all Norway that was able to contribute when the world needed it most.

In Europe, Bio-CCS could remove 800 million tonnes of CO2 annually by 2050. This represents more than half of the emissions from Europe's power sector. Bio-CCS will also be important for energy-intensive industries, which have limited efficiency gain options to reduce emissions. If these industries are to survive and preserve their jobs, even thrive through the EU's Industrial Renaissance push, CCS and Bio-CCS must be rolled out.

The Bio-CCS report also provides some recommendations for steps to make Bio-CCS a reality. First, regarding incentives, carbon negative emissions need to be rewarded in emission trading schemes like the EU ETS. Second, individual countries and the EU needs to step up commitments to CCS, both conventional and bio, and secure a fleet of large-scale projects. Third, research and development into sustainable bioenergy, be it biomass co-firing or advanced biofuels production, needs to be accelerated. Bellona opened theSahara Forest Project in 2012 and is currently working on Ocean Forest. These are practical, integrated solutions that we need and hope to see more of.

Nuclear is hardly attractive

To invest enormous sums in new nuclear power – which is both expensive and leaves us with radioactive waste issues still lacking solutions – does not appear to be a viable path. Finland's experience with the Olkiluoto nuclear project is a warning: The original budget was €3 billion, but the current cost estimate is €8.5 billion.

The compass then points to CCS, which can and must make existing fossil energy more climate friendly. Bellona was the first environmental organization to put CCS on the agenda more than 20 years ago and has since worked on both technological and political tools to roll it out in Norway and in Europe.

The IPPC report will be a reality check not only for Germany but also for many of our friends in the environmental movement. Many have been negative to investing in CCS, calling it a subsidy for the fossil industry, which caused the climate problem to begin with. Many propose that all money be invested in renewable energy. While perhaps understandable idealism, creating such antagonism does not take the scope of the climate challenge seriously.

More information

To find out more about Bio-CCS, visit Bellona CCS Web for information on going carbon negative.

The **Joint Task Force Bio-CCS report** and the **Bellona Environmental CCS Team (BEST) Romania Roadmap** addressing Europe's largest Bio-CCS potential can also be downloaded from the website:

www.bellona.org/ccs

Policy, projects and regulation news

SaskPower and Vattenfall sign carbon capture agreement

www.saskpowerccs.com

The Memorandum of Understanding (MOU) signed sets out the two parties' intentions to explore opportunities for collaboration in order to advance their common interests concerning carbon capture and storage opportunities.

Examples of such collaboration may include: mutual support for the development of CCS projects through technical exchange; informing and guiding the overall development of CCS infrastructure; and sharing CCS developments relating to health, safety and the environment.

"SaskPower's carbon capture and storage project at Boundary Dam Power Station will be the first commercial post-combustion carbon capture system in the world. The project has created a unique opportunity to share practical yet groundbreaking knowledge with the global energy community," said President and CEO Robert Watson. "We're very happy to have a partner like Vattenfall join us in building from this innovative work."

"We see a need for CCS in the future and we are very proud that the research results from our CCS pilot plant, Schwarze Pumpe, will contribute to the further development of the technology," said Hubertus Altmann, managing director of power plants at Vattenfall. "SaskPower and Vattenfall are convinced that carbon capture and storage is an important technology to reduce global CO2 emissions to acceptable levels."

Vattenfall has gained significant previous experience in CCS technologies at a pilot scale through several demonstration projects in Germany, the Netherlands, and the United Kingdom.

SaskPower's Boundary Dam project will be the first commercial post-combustion carbon capture system in the world

Saskatchewan renews investment in CO2 storage research

www.ptrc.ca

The Saskatchewan Government has announced a new funding agreement with the Petroleum Technology Research Centre (PTRC).

The funding will support the Saskatchewan CO2 Oilfield Use for Storage and EOR Research Project that will continue Saskatchewan's research on the geological storage of carbon dioxide.

The $400,000 investment will augment additional funding from the United States Department of Energy, which has recognized Saskatchewan as a world leader in carbon storage research. This funding will address important technical issues associated with carbon dioxide storage, including well bore integrity, predicting carbon dioxide migration underground, and identification of effective monitoring techniques. It will also allow the PTRC to continue their mandate to conduct carbon dioxide enhanced oil recovery research designed to increase oil production in Saskatchewan.

"Our ability to innovate and develop new technology is critical to maintaining the future viability of Saskatchewan's oil and gas industry," Energy and Resources Minister Tim McMillan said. "Promotion and development of carbon dioxide enhanced oil recovery methods provides the province with both economic and environmental benefits, and will help us meet our oil and gas related objectives in the Plan for Growth."

This project will build upon previous work undertaken by the PTRC in the Weyburn-Midale CO2 Monitoring and Storage Project. The joint work with the United States and the PTRC will also address important emerging issues that could potentially constrain future carbon storage activity in Saskatchewan and through out the world.

"Recognition of CO2-EOR as valid geological storage is an important part in the commercial deployment of CCS," PTRC CEO Ken From said. "The technical guidance provided by this research will make a valuable contribution to industry."

CCEMC makes $65 million available for GHG reduction projects

www.ccemc.ca

The Climate Change and Emissions Management Corporation (CCEMC) is inviting funding submissions for projects that will help Alberta to reduce greenhouse gas emissions.

Successful projects will focus on energy efficiency and conservation, carbon capture and storage, or cleaner energy production and utilization. Initial submissions are due by August 28 and successful projects will be announced in 2015.

"The CCEMC is interested in finding the best ideas from around the world to help Alberta stimulate the development of transformative technologies that can reduce greenhouse gas emissions," said CCEMC Chair Eric Newell.

All projects must be applicable for the province of Alberta. Projects may include laboratory or bench scale proof-of-concept demonstrations, prototype development and testing, small scale or field scale pilot demonstration and deployment projects.

Technology development and small demonstration projects can occur anywhere, as long as the development is suitable for Alberta. Applicants will need to demonstrate the suitability of the technology and describe how it will be transferred to Alberta during or after the project. Large demonstration and deployment projects must take place in Alberta to be considered.

The CCEMC will contribute a maximum of $25 million per project, and will support up to half of the project's eligible expenses. The maximum project term for this call for proposals is three years.

Successful projects will have the potential to result in significant, verifiable and sustainable reductions in greenhouse gas emissions.

Submissions are accepted online and guidelines are available on the website. There are no restrictions on the number of projects that any one applicant can submit.

New NRDC analysis shows U.S. can cut carbon emissions far more than projected

www.nrdc.org

A Natural Resources Defense Council proposal on how to cut carbon pollution from America's power plants can achieve even greater reductions than previously thought, and at less cost, an updated analysis of NRDC's initial 2012 plan shows.

NRDC's new analysis finds that that 470 to 700 million tons of carbon pollution can be eliminated per year in 2020 compared to 2012 levels, equivalent to the emissions from 95 to 130 million autos. At the same time, the NRDC approach would yield $28 billion to $63 billion in health and environmental benefits that far outweigh the costs of putting first-ever limits on carbon pollution.

By comparison, NRDC's 2012 analysis put those numbers at 270 million tons and $25-60 billion.

The improved outcomes result from updating the 2012 approach to reflect recent trends in the electricity industry, including lower electricity demand than previously expected and reduced costs for wind turbines, and natural gas.

Furthermore, the updtated analysis demonstrates there are various paths, not just one, to achieve dramatic reductions in the carbon pollution power plants release through a range of solutions that rely, to varying degrees, on energy efficiency, wind energy, and carbon capture and storage.

NRDC's original power plant carbon reduction proposal, released in December 2012, has been widely seen as a possible model for standards the U.S. Environmental Protection Agency is developing as part of the Administration's National Climate Action Plan.

Climate and energy experts at NRDC have shown that the nation can create jobs, grow the economy and curb climate change by going after the largest source of climate-changing pollution: emissions from hundreds of existing power plants.

NRDC's proposal shows how the EPA, in partnership with the states, can set new carbon pollution standards under existing authority in the Clean Air Act that will cut existing power plant emissions 20 to 30 percent by 2020 (relative to 2012 emission levels).

The approach includes an innovative provision that will drive investment in cost-effective energy efficiency, substantially lowering the cost of compliance, lowering electricity bills, and creating thousands of jobs across the country. Further, NRDC's updated analysis shows that the benefits -- in saved lives, reduced illnesses, and climate change avoided -- far outweigh the costs, by $21 billion to $53 billion in 2020.

Having endured recent years where climate change contributed to damaging floods, widespread wildfires, record drought, and superstorm Sandy which cost Americans hundreds of lives and hundreds of billions of dollars, we can't afford to wait any longer to act. For the health and welfare of Americans, for the nation's economy, and for the stability of the planet, now is the time to reduce pollution from America's power plants, dramatically increase the energy efficiency of our economy, and reduce the threat of climate change.

In the United States, electric power plants emit about 2.2 billion tons of carbon dioxide (CO2) each year, or roughly 40 percent of the nation's total emissions. The EPA has taken important first steps by setting standards that will cut the carbon pollution from automobiles and trucks nearly in half by 2025 and by proposing standards to limit the carbon pollution from new power plants. Now the EPA is working on tackling the CO2 pollution from hundreds of existing fossil-fueled power plants in the United States.

The EPA has both the authority and responsibility to reduce pollution from these plants under the Clean Air Act, the nation's bedrock air pollution law adopted in 1970. NRDC has crafted an effective and flexible approach to cut carbon pollution from existing power plants that:

• uses the legal authority under the Clean Air Act.

• recognizes differences in the starting points among states.

• charts a path to affordable and effective emissions reductions by tapping into the ingenuity of the states.

• provides multiple compliance options, including cleaning up existing power plants, shifting power generation to plants with lower emissions or none at all, expanding renewables, and improving the efficiency of electricity use.

Using the same sophisticated integrated planning model used by the industry and the EPA, NRDC calculated the pollution reductions that would result from the proposed approach -- and the costs and benefits of achieving those reductions.

The updated analysis shows NRDC's approach would cut CO2 pollution from America's power plants by 21 to 31 percent from 2012 levels by 2020, and 25 to 36 percent by 2025. It would deliver benefits in saved lives and damages avoided from climate change that would surpass the cost by as much as $21 billion to $53 billion by 2020. For Americans' health and welfare, for the nation's economy, and for the health of the planet, we can't afford not to curb the carbon pollution from existing power plants.

South Korea signs CCS collaboration with Australian and German scientists

kcrc.re.kr/eng

The Korea CCS R&D Center (KCRC) has signed strategic agreements with Australian and German researchers to advance CCS.

Korea's largest grouping of CCS researchers has signed strategic agreements with Australia's leading CCS research group, Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) and Helmholtz Centre Postdam GFZ German Research Cenre for Geosciences (GFZ), that will see scientists from these countries work together to develop technologies for reducing carbon dioxide emissions from power generation and industry.

As well as creating a framework for a joint program of research, it will also enable the flow of knowledge between the two institutes and provide training opportunities for researchers from all three countries.

The two MoUs are the first such agreement to be signed between South Korean and Australian CCS researchers and between South Korean and German CCS researchers.

Dr. Sang-Do Park, Director of KCRC, said: "Recognizing the importance of CCS for the solution to climate change, the Korean government, as well as developed countries, makes significant investment to develop advanced CCS technologies. Being at the core of the Korean government's CCS project, KCRC is strengthening international collaboration and networking."

Capture and utilisation news

Washington University receives $3.4M for oxy-combustion research

cccu.wustl.edu

Washington University in St. Louis has been granted a $3.4 million grant from the U.S. Department of Energy.

Richard Axelbaum, PhD, the Stifel & Quinette Jens Professor of Environmental Engineering Science in the School of Engineering & Applied Science, received the three-year grant to further develop his novel staged, pressurized oxy-combustion technology, or SPOC.

"By staging the combustion, the temperature and heat transfer can be controlled in a way that has, heretofore, not been attainable," says Axelbaum, director of the Consortium for Clean Coal Utilization (CCCU) and the Laboratory for Advanced Combustion and Energy Research. The CCCU is also providing funding for the project.

Oxy-combustion systems use oxygen, not air, to combust coal and produce a highly concentrated carbon dioxide (CO2) stream that can be easily captured, so that it can be used or stored underground. While first-generation oxy-combustion systems have shown viability, more research is necessary to develop transformational oxy-combustion systems to meet the U.S. Department of Energy's target of no more than a 35 percent increase in the cost of electricity produced from these plants.

Axelbaum, principal investigator of the project, will collaborate with the Electric Power Research Institute, Praxair Inc. and Ameren Corp. to design and construct a laboratory-scale pressurized oxy-combustor, and conduct experiments to characterize the process and further optimize the boiler and system designs.

Pratim Biswas, PhD, chair of the Department of Energy, Environmental & Chemical Engineering in the School of Engineering & Applied Science and the Lucy & Stanley Lopata Professor, and Ben Kumfer, PhD, research assistant professor in energy, environmental & chemical engineering, are co-investigators on the project.

In 2012, Axelbaum received a one-year, $836,000 grant from the U.S. Department of Energy to fund a techno-economic analysis of this process, as well as a three-year, nearly $500,000 grant from the State of Wyoming's Advanced Conversion Technologies research program, which supports staged oxy-combustion research, specifically atmospheric pressure experiments using Powder River Basin coal at the university's Advanced Coal and Energy Research Facility (ACERF).

Richard Axelbaum, PhD, performs research at the university's Advanced Coal and Energy Research Facility (ACERF) at Washington University in St. Louis (Image: Washington University in St. Louis School of Engineering & Applied Science)

TCM report on next generation CO2 capture technologies

www.tcmda.com

CO2 Technology Centre Mongstad (TCM) commissioned the report, which was compiled by the research organization SINTEF.

The report, titled "Technology survey and assessment for piloting of CO2 capture technologies" analyzes the maturity of 23 new CO2 capture technologies from pre, post and oxy-combustion technology groups.

TCM says it commissioned the study as part of its commitment to reduce the risk and cost of CO2 capture technologies worldwide through further testing of second and third generation technologies at the available site.

"This report has been developed to set a marker for where carbon capture technology is today, as well as to identify future technologies that could be tested out at TCM and enable a step change in the advancement of CCS," said Frank Ellingsen, Managing Director of TCM. "In the spirit of international collaboration, TCM is openly sharing the report with the CCS community."

The report distinguishes between three different categories of CCS technology: post-combustion (carbon capture after regular combustion); oxy-combustion (carbon capture after combustion using oxygen rather than air); and pre-combustion (producing a CO2 rich gas under high pressure before combustion). Within these groupings, the report assesses the maturity of each technology as many begin to move beyond their initial concept and lab-testing phases and starts to require testing sites to pilot their findings.

EU OCTAVIUS project reports on amine emissions

www.octavius-co2.eu

OCTAVIUS concludes that solvent and degradation products emissions should not be a showstopper for the majority of post-combustion CO2 capture processes implemented in industrial facilities.

This was the main conclusion to emerge from an international workshop organized in Heilbronn (Germany) on 13 & 14 February 2014 as part of the European OCTAVIUS research project.

OCTAVIUS (Optimization of CO2 Capture Technology Allowing Verification and Implementation at Utility Scale) is a European FP7 project dedicated to the demonstration of post-combustion CO2 capture processes. Coordinated by IFPEN, the project brings together 16 other partners from the worlds of research and industry.

A significant amount of progress has been made over the past few years since several other international meetings have been held focusing on the state of the science, such as the IEAGHG/CLIMIT workshop in February 2010 and the EPRI workshop in May 2012. This information has led to a better understanding of emissions phenomena and the

potential risks of post-combustion CO2 capture processes with respect to these emissions.

As a result of extensive research work carried out around the world, our knowledge of the health and environmental impacts of amines used in CO2 capture has improved substantially.

The main conclusion drawn from the wrap-up session is that there should not be any showstoppers in terms of emissions for most of the post-combustion CO2 capture processes using amines as solvents. The knowledge developed and presented at this workshop shows that the risks are much lower than previously reported.

There is now sufficient expertise to conduct risk assessment studies for the preparation of discharge permits for industrial-scale CO2 capture units. Rather than dealing with general risk, it was found that the potential environmental impact is highly case-specific and should be evaluated separately for each case study.

It also appears to be very important to continue research focusing on the development of standards in terms of emission levels and emission measurements. This research needs to be conducted as part of joint international projects, such as the OCTAVIUS project, TCM (CO2 Technology Centre Mongstad) or the Working Group initiated by EPRI.

University of Calgary receives $500k grant

www.ucalgary.ca

A University of Calgary researcher, Nader Mahinpey, has received a grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada to support CO2 capture research.

Nader Mahinpey, associate professor and associate head (research) of chemical and petroleum engineering in the Schulich School of Engineering, is receiving a NSERC Strategic Project Grant of $583,082 over three years, toward developing a novel integrated approach to energy production and gasification, the process which converts organic or fossil-based carbon material into carbon monoxide, carbon dioxide and hydrogen.

His approach combines gasification technology with newly created solid absorbent materials to provide cost-effective solutions for capturing the greenhouse gas carbon dioxide (CO2). He will use pilot-plant studies to take laboratory-scale knowledge to what's required for commercialization.

"This proposed solution will address major challenges that hinder transformative innovation in the area of CO2 capture, with benefits to Canada's economy, energy and environment," said Mahinpey, who leads the Energy and Environment Research Group at the University of Calgary.

A common method of capturing CO2 in industrial processes involves wet scrubbing of flue gases with chemicals (amine solvents). However, this causes a serious loss in process thermodynamic efficiency, so is unlikely to be cost-effective on a large scale.

Mahinpey's approach uses a "dry process" to capture CO2. The technology is expected to reduce greenhouse gas emissions and lead to sustainable production of hydrogen, and involve the training of highly qualified personnel for Canada's natural resources and energy sectors.

Skyonic receives $500,000CAD to support SkyCycle pilot plant

www.skyonic.com

Skyonic Corporation has been selected to receive a $500,000CAD grant from the Climate Change and Emissions Management Corporation (CCEMC).

The funding will support the continued research and development of the pilot plant for Skyonic's SkyCycle technology.

The funding will support the continued research and development of the pilot plant for Skyonic's SkyCycle technology.

"We are working quickly to bring SkyCycle™ to scale," said Joe Jones, CEO, president and founder of Skyonic. "SkyCycle™ was designed to put profitable carbon capture technology in the reach of any stationary emitter. We're continuing to drive the cost of carbon capture down below the level where it becomes an economically viable solution, as well as expanding the market for our outputs by producing a different set of carbon negative mineral byproducts."

SkyCycle is Skyonic's third offering in their suite of emissions management technologies. The company's patented electrolytic carbon capture process SkyMine® is being deployed at a commercial scale at the Capitol Aggregates Cement Plant in San Antonio, where it is expected to be fully operational later this year. The plant will be the first commercial-scale carbon capture and mineralization plant in the United States.

SkyCycle is a thermolytic mineralization technology, producing primarily calcium carbonate, limestone, and hydrochloric acid. The technology is currently being demonstrated at the Capitol Aggregates Cement Plant. According to Skyonic, both SkyCycle and SkyMine operate at a significantly lower cost and energy penalty than other carbon capture technology, while driving profits through carbon negative product sales, making them economically viable solutions.

Understanding Northern Australia's carbon storage potential

The completion of a recent study by Geoscience Australia indicates that the Petrel Sub-basin (Bonaparte Basin), offshore Northern Territory, is suitable for the geological storage of CO2.

By Dr. Chris Consoli, Geoscience Australia

Following the Carbon Storage Taskforce report of 2009, the Petrel Sub-basin was selected because of its prospectivity for CO2 storage and its proximity to current and future LNG processing plants near Darwin.[1]

The Petrel Sub-basin CO2 storage assessment study is the first major CO2 storage assessment undertaken by Geoscience Australia as part of the Australian Government's multi-year program to assess highly prospective offshore basins for their CO2 storage potential. The Project was funded through the Australian Government's National Low Emissions Coal Initiative.

Reservoir characteristics of the Petrel Sub-basin

For the CO2 storage assessment, the Petrel Sub-basin study adapted a regional assessment methodology similar to that used for oil and gas exploration.

The study focused on two Mesozoic–aged saline reservoir-seal pairs located over the central and eastern flank of the sub-basin. The lower reservoir-seal pair comprises the Jurassic Plover and Elang formations and the sand-dominated lower part of the Frigate Shale. The Jurassic saline reservoir is highly prospective due to its thickness (average 300 m) and fair to good reservoir properties for CO2 injection and storage. The conventional seal for the Jurassic reservoir is the upper section of the Frigate Shale, a sub-regional mudstone covering the central and northern parts of the sub-basin.

The Early Cretaceous Sandpiper Sandstone is a stratigraphically higher saline reservoir and in this study was identified as a highly prospective secondary target. It is generally thin (average 150 m) across the sub-basin, but has good to excellent reservoir properties for CO2 injection and storage. The Bathurst Island Group, in particular the Wangarlu Formation, is the primary seal for the Cretaceous saline reservoir and for the sub-basin in general.

The seal capacity of the upper Frigate Shale and Bathurst Island Group is sufficient to contain the modelled CO2 column from injection into the reservoir over the expected life of the proposed Darwin LNG processing plants.

A geomechanical study revealed that, under the current stress regime, the major faults do not compromise the integrity of the seals.

CO2 storage potential

Dynamic reservoir simulations show that the dominant CO2 trapping mechanism in the Petrel Sub-basin is migration-assisted trapping, with residual and dissolution trapping mechanisms the dominant process for permanent storage. CO2 injection reservoir simulations predict that a total of 420 MT of CO2 can be injected into the Jurassic reservoir at a rate of 14 MTPA over 30 years, a rate commensurate with the predicted emissions from the Darwin LNG hub in 2020 as estimated by the Carbon Storage Taskforce (2009).[1]

During 30 years of injection, the simulated plume migrated laterally 5 km, and after the cessation of injection, migration slowed to around 12 m per year. After 100 years, the modelling indicated that over 50 per cent of the CO2 would be permanently trapped through residual and dissolution processes, and after 1,700 years, over 83 per cent of the total injected CO2 would be trapped. When taking into account the spatial and physical properties of the reservoirs and seals, the best estimate (i.e., P50) combined effective storage capacity of the two saline reservoirs was 15,930 MT.

Based on the geological evidence and modelling above, the Petrel Sub-basin was then sub-divided into regions showing the relative suitability for secure and permanent CO2 storage, with the most suitable regions located to the west and north of the sub-basin (Figure 1).

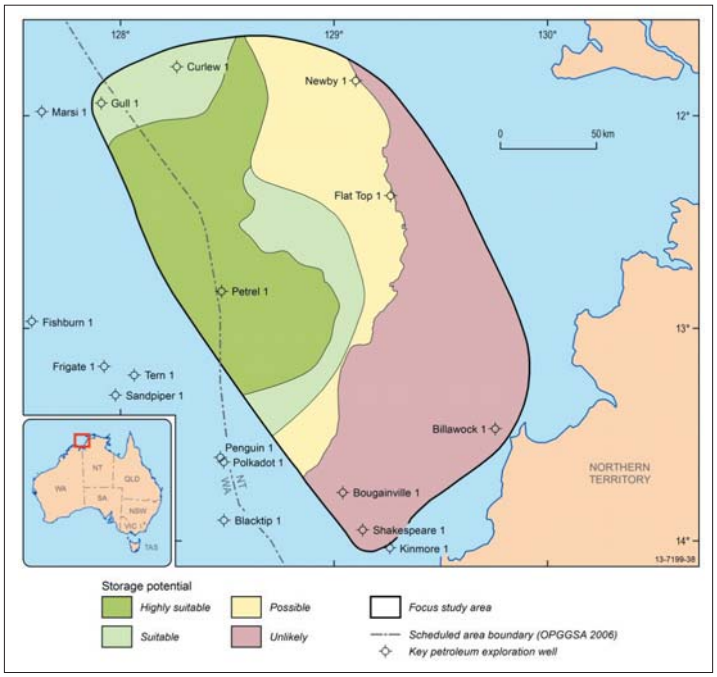


Figure 1 - Map showing the CO2 storage potential of the Petrel Sub-basin (©Commonwealth of Australia (Geoscience Australia) 2014)

Industry will be able to use the report and associated datasets to make more informed decisions regarding the suitability of the site for CO2 storage.

Combined results

This multi-disciplinary, integrated assessment contributes to a wider program to develop a comprehensive understanding of Australia's total CO2 storage potential and adds vital information to support development of the carbon capture and storage industry.

More information

The original article, "Regional assessment of the CO2 storage potential of the Mesozoic succession in the Petrel Sub-basin" is available for download on the Geoscience Australia website:

www.ga.gov.au

1. Carbon Storage Taskforce, 2009. National Carbon Mapping and Infrastructure Plan – Australia: Full Report, Department of Resources, Energy and Tourism, Canberra.

Survey of potential EU CO2 storage pilots

A report from CGS Europe provides an overview of the many potential CO2 storage pilot projects across Europe.

In June 2013, the Zero Emissions Platform (ZEP) published a report, "Accelerating the demonstration of CO2 geological storage in Europe – the case for up to six new storage pilots". This highlighted the need to establish a portfolio of large CO2 storage pilots by 2016 in order to complement CCS demonstration projects, accelerate state-of-the-art technology and increase public confidence in CO2 storage.

The report proposes criteria for such projects, as well as defining R&D deliverables. Although CO2 Geological Storage (CGS) is well advanced from a technological point of view, research based on real field sites is now strongly needed in order to maximize the efficiency of these technologies, to optimize the tools needed for monitoring and verification, and to be able to adapt to the specificity of local geological conditions.

In this context, a new report, "Opportunities for CO2 storage pilot projects across Europe", published in the framework of the Pan-European Coordination Action on CO2 Geological Storage (FP7 CGS Europe project), provides an overview of the many potential pilot projects across Europe. All CGS Europe partners considered the potential for pilot projects in their home countries or surrounding regions, producing a report with Pan European coverage that may lead to new pilot projects. Overall, 22 potential pilot projects in 15 European countries are presented for consideration in this report.

CGS Europe is a FP7 coordination action of the EC over 3 years (Nov. 2010 – Oct. 2013), with the objective of building a credible,independent, long-lasting and representative pan-European scientific body of expertise on CO2 geological storage that will:

1. Instigate a durable networking of research capacity on CO2 storage in all the relevant EU Member States and Associated Countries;

2. Liaise and coordinate its activities with other stakeholders and existing initiatives in Europe to help define and coordinate CO2 storage research roadmaps and activities at national, European and international level;

3. Help reduce the existing gap between the 'forerunner' countries, where CCS activities have been started or planned, and those countries where these actions are not yet happening;

4. Contribute to the large-scale demonstration and industrial deployment of CCS;

5. Support the implementation of the European Directive on the geological storage of CO2 and other regulatory regimes.

The report was generated based on questionnaires completed by the CGS Europe project partners. This report provides not only the raw material of completed questionnaires, but also an analysis of the information provided and the potentiality of the proposals. Although currently most pilots presented are still in the early proposal stage, here the report takes stock of the wide range of scientific achievements that could be gained if some of the projects become a reality in the near future.

This report is a very valuable information source for the current debate on the future CO2 Capture and Storage in Europe. The CO2GeoNet Association, the European network of excellence on CO2 geological storage, in close connection with the CGS Europe FP7 project, here expresses the views of a pan-European consortium involving 34 research institutes from 24 EU Member States and 4 Associated Countries.

Conclusions

Answers collected from CGS Europe partners prove that options for pilot project development are widely distributed across Europe and the scientific community is ready to provide these ideas to the industry and to the national and European authorities in order to develop this kind of projects.

The report presents several options in different types of storage formation (saline aquifers, active hydrocarbon fields, depleted hydrocarbon fields), therefore making available the improvement of technologies under different conditions. We need to note that each storage site is unique and therefore needs specific exploration, operation and monitoring plans. Pilot scale projects will be open research platforms to allow field experiments that will supply very relevant information for future design of such plans.

Diversity is also available from the point of view of geological setting. Proposals are provided in sandstones, sands and carbonated rocks, even coal, sealed by clays, shales or marls, rocks where CO2 behaviour is expected to be quite different from one to the other. Although most of the proposals are located in the onshore, providing examples closer to the affected communities, there are also offshore proposals.

The geographical distribution of the proposals is well balanced in the European level, as proposals have been submitted from a significant number of countries, both from the North and the South, from the East and the West. In CGS Europe opinion, it is desirable that this geographical distribution is maintained when deploying real projects. In any case, results need to be integrated, perhaps by including pilot scale projects into the EU CCS Project Network.

CGS Europe partners have reported a general lack of funding schemes to develop these projects. In this aspect, the ZEP report "Accelerating the demonstration of CO2 geological storage in Europe", provides a good starting point to study combined options for funding in absence of the present lack of a viable self-financing model for geological storage. Engagement of research programmes, national and regional funding, industry and other associated revenues may provide an adequate framework for these projects.

Average budgets are from 20 to 50 M€ but expected added value is considerably larger than that. Some of the consortia that have been proposed by CGS Europe partners already include actors from the scientific community, but also from different industrial sectors, in some cases supported by national and local authorities.

Continued progression in this field is crucial for pilot project deployment and therefore for the technology itself. Moreover, the experience gathered in these projects will increase confidence in tackling new situations when demonstrations are deployed.

Finally, because of the amount, diversity and quality of the answers that have been provided to this report, it can be concluded that CGS Europe – CO2GeoNet is in a very good position to provide support in the coordination of pilot projects, in the creation of links between them, in integrating research and results and in transferring newly acquired knowledge to the industrial sectors and the society as a whole.

More information

The full report can be downloaded here:
www.cgseurope.net

Scottish Carbon Capture & Storage relaunches Global CCS map

The Global CCS Map seeks to provide an accurate and trustworthy source of information on projects that support the development of the full CCS chain.

The Global CCS Map seeks to provide an accurate and trustworthy source of information on projects that support the development of the full CCS chain, so facilities capturing CO2 for more traditional uses – such as for the food and drink industry – are generally not included.

Projects that have been cancelled several years ago with little likelihood of revival have been weeded out, although those of historical interest have been retained.

The map has been extensively updated while retaining most of its original useful features. These include:

• Information on over 200 CCS projects, ranging from small to large scale and across the CCS chain

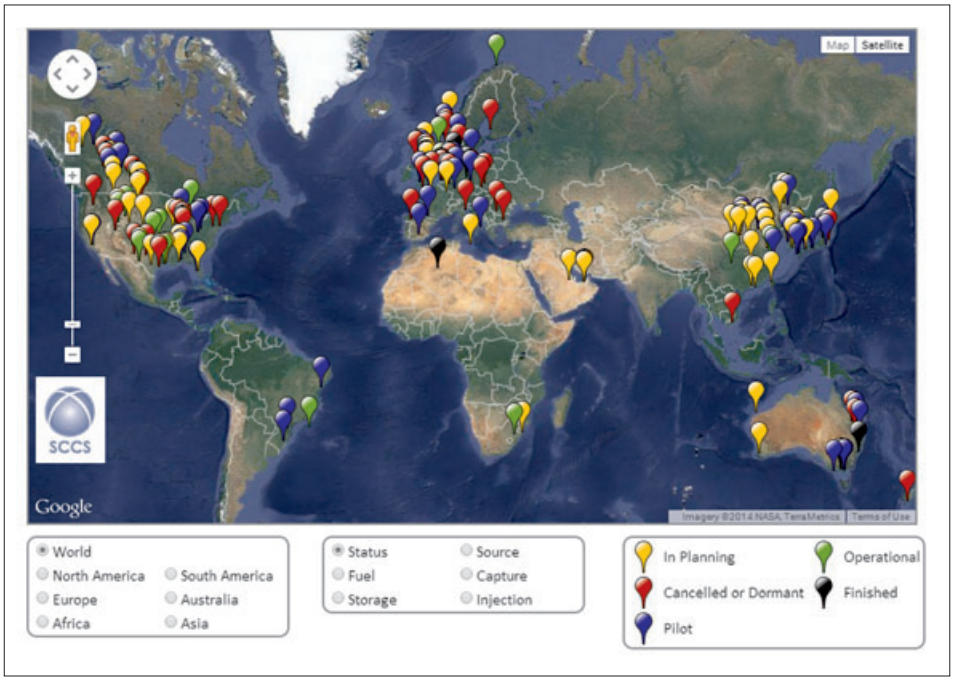
• Display buttons allowing the user to "filter" information in the viewing window

• At-a-glance information including, for example, the project's developer, current status (e.g. planned, being built, operating) capture method, and planned volume of CO2 storage

• A deeper level of information providing project data, useful links and news updates

Dr Peter Brownsort, SCCS Scientific Research Officer, said: "After extensive research, verification and updating, our interactive map is one of the most up-to-date sources of information on CCS projects worldwide."

"Where possible, the data has been checked at a number of sources and project locations have been pinned down. Where we cannot find any reliable data we make this clear, and we also encourage project operators to come to us with information to add."



The Global CCS map provides information on projects of all scales and at all stages of development – planned and operating, and including cancelled projects of interest

"As far as possible we are free from any regional bias, with a consistent depth of project coverage across continents. However, the end user will be the final judge, so we'd really like to know if people find the map a useful and easy-to-use resource."

The database underpinning the map is available under a 12-month licence from Edinburgh Research and Innovation, which promotes commercialisation of research from the University of Edinburgh.

More information

Anyone with comments or questions about the Global CCS Map is encouraged to email the SCCS Team on info@sccs.org.

www.sccs.org.uk

CCP factsheet on CO2 migration

The CO2 Capture Project has released its lastest factsheet which covers detecting, characterizing and intervening in out of zone migration of CO2 in geological storage sites.

Escape of CO2 from a storage site into groundwater or the atmosphere is one of the most frequently cited concerns about CO2 Capture and Storage (CCS) and it is essential that ways are found to allay such fears if CCS is to become more widely accepted and adopted.

Each potential storage site, whether in deep saline formations or in depleted oil and gas reservoirs, is geologically unique - which represents a risk profile that needs to be managed through field development plans and operational monitoring.

Experience to date at industrial scale CCS projects has shown that in well-chosen sites, with interactive injection management and monitoring, CO2 is stored securely. Developing the capability to detect, characterize and intervene in unanticipated CO2 or displaced brine migration will add an additional layer of protection to economically or environmentally important receptors.

While rigorous pre-injection site screening and assessment, operational monitoring, and post injection sealing of wells are the most important safeguards for ensuring the safe and permanent storage of CO2, confidence still needs to be built around what can be done if CO2 does unexpectedly migrate from the storage zone.

A CCP program was initiated in 2011 to address this additional safeguard. The aim of the CCP "Contingencies" Program is to detect, characterize and intervene in out of zone migration of CO2 or displaced fluids (e.g. brine). The program is a unique initiative that leverages existing industry expertise to favourably impact the future development of CCS. The CCP Storage Monitoring and Verification (SMV) Team has been working with a cross-section of respected experts from academia, national labs and industry consultants on the first phases of the project, producing some intriguing results which may culminate in testing selected technologies in a field experiment.

Defining the scope (Phase 1)

An initial scoping workshop was held in 2011, attracting 35 experts from the oil and gas field services industry, national laboratories and academia. The workshop looked at the vulnerabilities of natural and engineered systems to anomalous CO2 and brine migration and the potential impacts on a project's effectiveness and compliance, as well as on health, safety and the environment (HSE). From this, a plan for the project was produced, encompassing modelling and technology development.

Modelling and simulation of potential CO2 migration scenarios (Phase 2)

Stanford University was selected to conduct Phase 2 of the Program - a modelling-based approach to the detection, characterization and intervention of unexpected CO2/fluid migration.

This involved using geologic models with simulation of CO2 injection with and without features that would allow CO2 to migrate out of zone via conduits (e.g. undetected faults). For the migration cases, a range of fracture and fault conduit flow estimates and sensitivity to detecting CO2 migration via surface seismic was estimated and intervention techniques simulated. Injection profile management, above-seal water injection and CO2 extraction, along with injection of sealants into the top seal breach were simulated.

Other specialized studies, including efficacy of commercial well sealants and novel chemical sealants were also conducted.

The significant results of the studies were presented at the end of 2013. They include:

• CO2 injection stops the bulk of out of zone CO2 migration. Hydraulic controls are effective but would have to be operated over an extended period of time and CO2 injection would probably have to cease

• Surface seismic detection and characterization of unexpected CO2 migration is limited but could be improved using above seal pressure monitoring and borehole seismic techniques

• Injection of sealants could be highly effective and perhaps allow continued injection of CO2. More development work would be needed, however, to extend the setting time under subsurface conditions.

• Conduit "self-healing" via salt and other mineral precipitation may occur under some circumstances.

Intervention technology development (Phases 3 and 4)

The last two stages of the project aim to identify a suitable site to test an intervention technology with the development of a detailed characterization, engineering, surveillance and analytical plan (Phase 3), then potentially to deploy it(Phase4).

The design work and ultimately deployment of a "fracture-sealing" experiment is proposed for the Mont Terri Underground Lab in Jura Canton, Switzerland. The experiment would entail:

• Creating multiple sets of isolated hydraulic fractures into the rock via an 'active' well

• Drilling multiple 'passive' wells through the fracture planes

• Completing each of these wells into a single fracture set and establishing water circulation with the active well

• Injecting selected sealants (conventional well sealant, biofilming microbes with substrate, 'triggerable' nano particle 'smart gel') into the active well and through the fractures with monitoring of pressure and fluid flow rate to assess sealing

• Overcoring the rock volume to analyze the sealing with respect to fracture aperture size. Geophysical monitoring boreholes would be drilled prior to operation for pre- and post-injection characterization of acoustic property changes in the rock volume

A feasibility study has been conducted for the fracture-sealing experiment at Mont Terri with further deployment-ready engineering work considered for 2014. Depending on the results of the Mont Terri fracture sealing experiment (if deployed), CCP would investigate other options for further testing of through-conduit CO2/brine flow mitigation.

Possibilities include experiments in other underground laboratory facilities or deep well-well settings where seal rock clay minerals have characteristics closer to those expected at CO2 storage facilities (i.e. smectite to illite conversion has occurred).

More information

The CO2 Capture Project (CCP) is a partnership of major energy companies working to advance the technologies that will underpin the deployment of industrial-scale CO2 capture and storage.

www.co2captureproject.org

Status of CCS projects

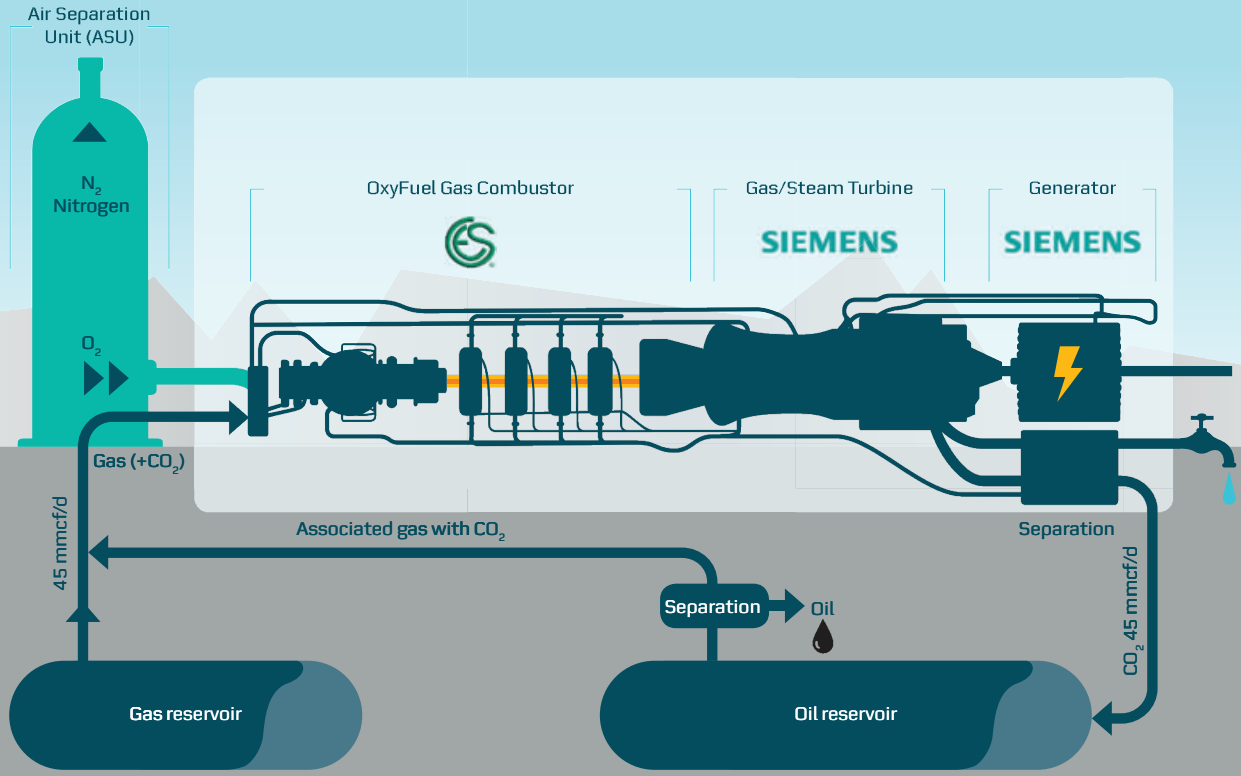
The status of large-scale integrated projects data courtesy of the Global CCS Institute

For the full list, with the latest data as it becomes available, please download a spreadsheet at:
www.globalccsinstitute.com/data/status-ccs-project-database

Project Lifecycle Stage	Project Name	State / District	Country	Volume CO_2 (mtpa)	Operation Date
Operate	**Air Products Steam Methane Reformer EOR Project**	Texas	UNITED STATES	1.0	2013
Operate	**Century Plant**	Texas	UNITED STATES	8.4	2010
Operate	**Coffeyville Gasification Plant**	Kansas	UNITED STATES	1.0	2013
Operate	**Enid Fertilizer CO2-EOR Project**	Oklahoma	UNITED STATES	0.7	1982
Operate	**Great Plains Synfuel Plant and Weyburn-Midale Project**	Saskatchewan	CANADA	3.0	2000
Operate	**In Salah CO2 Storage**	Wilaya de Ouargla	ALGERIA	0	2004
Operate	**Lost Cabin Gas Plant**	Wyoming	UNITED STATES	0.8-1.0	2013
Operate	**Petrobras Lula Oil Field CCS Project**	Santos Basin (off the coast of Rio de Janeiro)	BRAZIL	0.7	2013
Operate	**Shute Creek Gas Processing Facility**	Wyoming	UNITED STATES	7.0	1986
Operate	**Sleipner CO2 Injection**	North Sea	NORWAY	0.9	1996
Operate	**Snøhvit CO2 Injection**	Barents Sea	NORWAY	0.6-0.8	2008
Operate	**Val Verde Natural Gas Plants**	Texas	UNITED STATES	1.3	1972
Execute	**Alberta Carbon Trunk Line ("ACTL") with Agrium CO2 Stream**	Alberta	CANADA	0.4-0.6	2015
Execute	**Alberta Carbon Trunk Line ("ACTL") with North West Sturgeon Refinery CO2 Stream**	Alberta	CANADA	1.2-1.4	2016
Execute	**Boundary Dam Integrated Carbon Capture and Sequestration Demonstration Project**	Saskatchewan	CANADA	1.0	2014
Execute	**Gorgon Carbon Dioxide Injection Project**	Western Australia	AUSTRALIA	3.4-4.1	2015
Execute	**Illinois Industrial Carbon Capture and Storage Project**	Illinois	UNITED STATES	0.8-1.0	2015

Facility Details	Capture Type	Transport Length (km)	Transport Type	Storage Type
Hydrogen Production	Pre-combustion capture (gasification)	101-150	Pipeline	Enhanced hydrocarbon recovery
Natural Gas Processing	Pre-combustion capture (natural gas processing)	69	Pipeline	Enhanced hydrocarbon recovery
Fertiliser Production	Industrial Separation	112	Pipeline	Enhanced hydrocarbon recovery
Fertiliser Production	Industrial Separation	225	Pipeline	Enhanced hydrocarbon recovery
Synthetic Natural Gas	Pre-combustion capture (gasification)	315	Pipeline	Enhanced hydrocarbon recovery
Natural Gas Processing	Pre-combustion capture (natural gas processing)	14	Pipeline	Dedicated Geological Storage
Natural Gas Processing	Pre-combustion capture (natural gas processing)	Not specified	Pipeline	Enhanced hydrocarbon recovery
Natural gas processing	Pre-combustion capture (natural gas processing)	Not specified	No transport required (i.e. direct injection)	Enhanced hydrocarbon recovery
Natural Gas Processing	Pre-combustion capture (natural gas processing)	403	Pipeline	Enhanced hydrocarbon recovery
Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.11	No transport required (i.e. direct injection)	Dedicated Geological Storage
Natural Gas Processing	Pre-combustion capture (natural gas processing)	152	Pipeline	Dedicated Geological Storage
Natural Gas Processing	Pre-combustion capture (natural gas processing)	132	Pipeline	Enhanced hydrocarbon recovery
Fertiliser Production	Industrial Separation	240	Pipeline	Enhanced hydrocarbon recovery
Oil Refining	Pre-combustion capture (gasification)	240	Pipeline	Enhanced hydrocarbon recovery
Power Generation	Post-combustion capture	100	Pipeline	Enhanced hydrocarbon recovery
Natural Gas Processing	Pre-combustion capture (natural gas processing)	7	Pipeline	Dedicated Geological Storage
Chemical production	Industrial Separation	1.6	Pipeline	Dedicated Geological Storage

TriGen delivers full carbon capture with commerciality



The TriGen™ Oxycombustion Process by Maersk Oil

Clean power for over 100,000 homes while boosting oil recovery

Net electric power
180 MWe

Pure water
0.5 MGD

Enhanced Oil Production
~ 7,000 bpd

TriGen produces clean energy, pure water and 'reservoir ready' CO_2 by burning natural gas with pure oxygen. The oxygen is first obtained from an Air Separation Unit (ASU) that also produces significant quantities of nitrogen that can be used for fertilizer or reservoir pressure maintenance.

As all of the TriGen products are useful, it enables zero emission energy from fossil fuels. Maersk Oil is working with Siemens and Clean Energy Systems (CES) on commercial scale power plants. A single train TriGen plant can deliver:

- 180 MW clean electricity net
- 500,000 gallons/day pure water
- 45 mmcfd 'reservoir ready' CO_2 which can then produce ca. 7,000 bbls/d incremental oil via Enhanced Oil Recovery (EOR)

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