Carbon Capture Journal

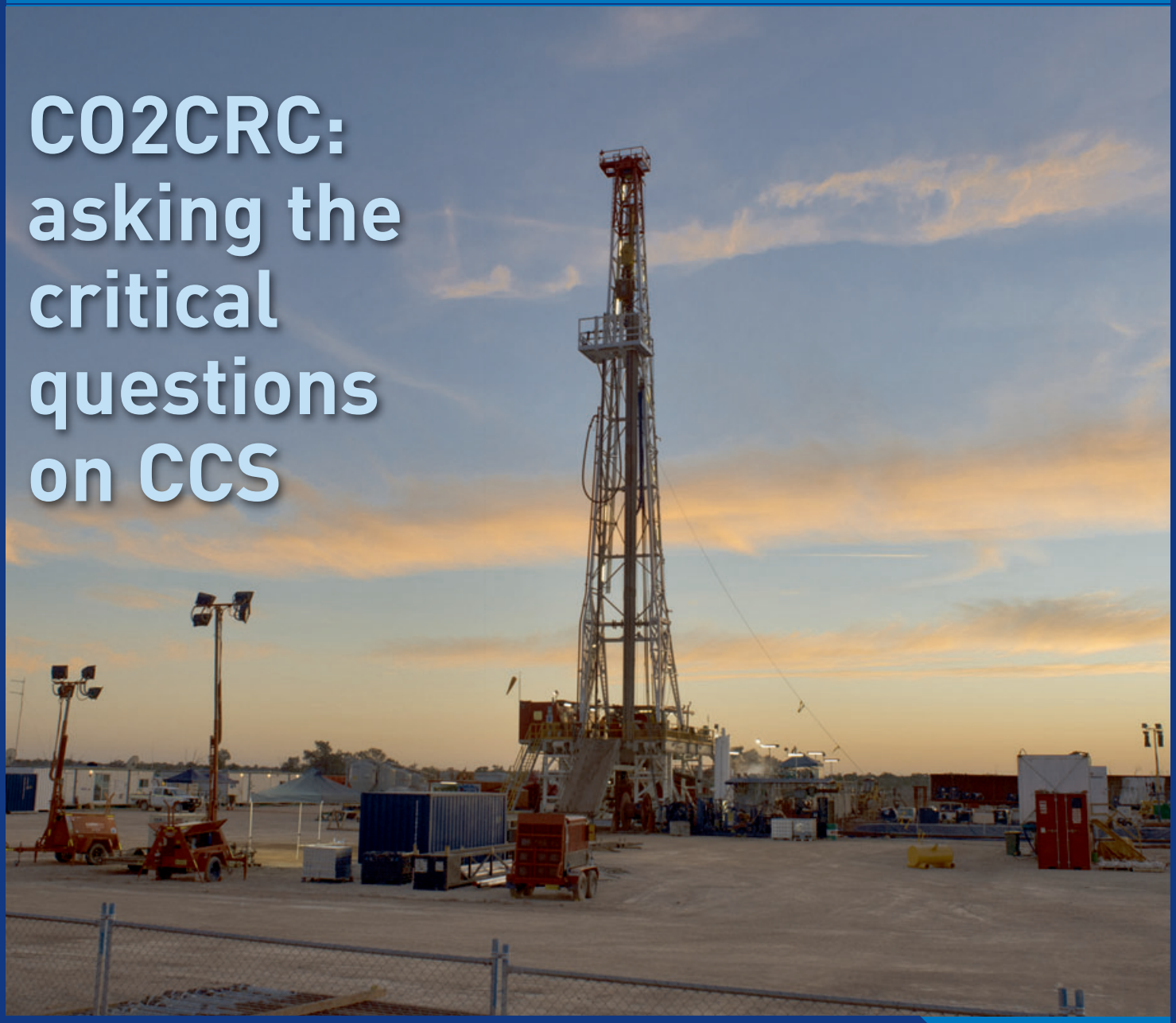
## CCS in Australia

CarbonNet: developing an integrated CO2 network in Victoria

National Geosequestration Laboratory launched in Western Australia

July / Aug 2015 Issue 46

# CO2CRC: asking the critical questions on CCS



Monash University shaping technology to produce CO2 sorbents

KEPCO's dry sorbent pilot plants produce results

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

**Editor**
**Keith Forward**
editor@carboncapturejournal.com

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

**Subscriptions**
subs@carboncapturejournal.com

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

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*Front cover: Investigating the storage potential at the Darling Basin site in New South Wales. Understanding the potential underground storage capacity will help the State make more informed policy decisions and choices on the rollout of carbon capture and storage*

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## Leaders - CCS in Australia



## Projects and policy



## Capture and utilisation



## Transport and storage

# CarbonNet achieves international storage certification milestone

**The CarbonNet Project (CarbonNet) in Australia is investigating the potential for establishing a large-scale, multi-user carbon capture and storage network in Victoria's Gippsland region.**

By Ian Filby, Project Director, The CarbonNet Project

**The network could integrate multiple carbon dioxide (CO2) capture projects transporting CO2 via a common-use pipeline and injecting it deep into offshore underground storage sites in the offshore Gippsland Basin (Fig 1).**

Victoria has the world's second largest brown coal deposit. Offshore, a storage potential of at least 31 Gigatonnes of CO2 exists alongside Australia's largest producing oil and gas fields.

CarbonNet seeks to:

• design scalable infrastructure to underpin growth and deployment of a CCS network.

• identify and demonstrate the capacity and integrity of CO2 storage in the offshore Gippsland Basin.

• attract private sector funding and participation in the foundation project.

• enable Government's role in CarbonNet and the CCS industry to evolve.

CarbonNet aims to initially capture, transport and store one to five million tonnes of CO2 per annum, with the potential to increase capacity significantly over time.

As part of demonstrating safe storage, CarbonNet has engaged the services of an international risk verification agency, Det Norke Veritas (DNV GL), to certify that key stages of the project conform to international best practice.

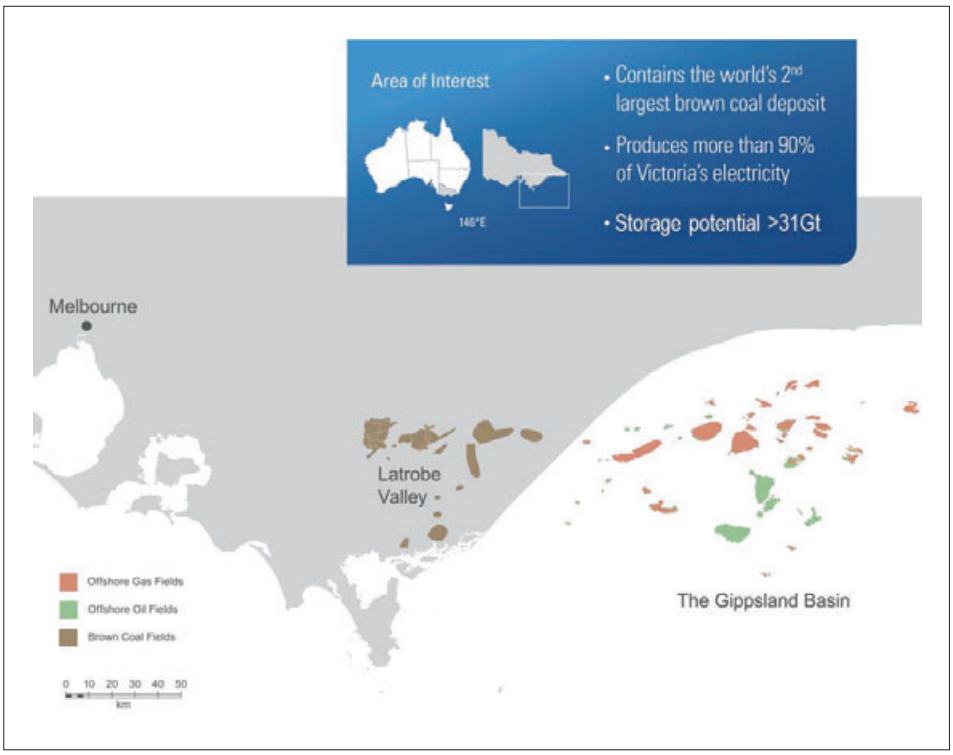



*Figure 1: Area of Interest*

## Funding and support

CarbonNet was established in 2009 and has received joint funding from Victorian and Australian governments since 2010. In February 2012, the Australian government awarded CarbonNet CCS flagship status and, jointly with the Victorian government, provided a further $100 million in funding to the project. The Global CCS Institute has also provided financial support to enable a range of knowledge share activities and products to be developed.

With the support of a range of research organisations including Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) and Australian National Low Emissions Coal Research & Development (ANLEC R&D) CarbonNet has been able to significantly advance the prospectively of commercial scale CCS in Victoria.

Through a range of collaborative and joint work programmes CarbonNet has also received support from industry, particularly investigating options for commercial scale capture projects.

CarbonNet continues to seek opportunities to collaborate with industry across the full CCS value chain and realise the significant economic opportunities that Victoria has to offer through CCS.

## Current project stage

The CarbonNet project is nearing the end of its feasibility stage, during which evaluation of storage has been a key focus. The following list identifies some of the key challenges the project team have addressed during this stage of the project:

**Storage certainty**: CarbonNet has conducted a comprehensive evaluation of potential storage sites. The site selection process, described below, involves Australian and international experts and has identified viable locations for

the safe and secure long-term storage of CO2.

**Technical integration**: Potential carbon capture plants and technologies have been investigated for participation in an economically viable network to capture, transport and store CO2.

**Regulatory requirements**: Testing the regulatory framework to demonstrate it is effective and that the local and wider community has confidence in its integrity.

**Commercial viability**: demonstrating that CCS can be economically viable and attract private sector participants and investment over time.

**Public perception**: Ongoing engagement of the local community and other stakeholders will continue throughout the project's lifecycle.

CarbonNet is now in the process of preparing the business case for options to progress the project in the next stage, including consideration of field appraisal of a prioritised storage site via an offshore seismic survey and drilling an offshore well.

## Technical work on storage to date

Early storage assessment work was undertaken by a number of organisations from around 2000, supported by Government, to identify highly ranked areas for CCS projects in Australia. By 2009, the Australian Government's Carbon Storage Taskforce had compared the geological storage potential of sites around Australia and found the Gippsland Basin to have the highest technical ranking of all Australian sites, and contain the largest storage potential of any east coast basin.

The present CarbonNet portfolio of storage sites refined that assessment with detailed modelling studies, examining sub-regions within the Gippsland Basin, then compiled an inventory of potential storage sites and progressively winnowed that inventory to retain only large and secure prospects. As a final step, a prioritised site was identified for further investigation (appraisal).

In undertaking the screening process, CarbonNet has worked to a carefully-designed technical program known as the Geoscience Evaluation Program which was implemented in two phases:

Phase 1 (2010-2011) conducted reconnaissance-level screening of the nearshore part of the basin and developed an inventory of 20+ exploration leads and prospective storage sites.

Phase 2 (2012-2015+) comprised 19 modules and included periodic Independent Scientific Peer Reviews. It progressively high-graded prospective sites, with initial deterministic reviews of capacity and containment, followed by a sophisticated probabilistic evaluation, assisted by the construction and progressive elaboration of regional and local static geologic models in PETREL and dynamic simulations in Eclipse E100 and E300 to study plume movement and multiphase flow. Injection of up to 125 Mt was modelled to assess CO2 plume pathways, pressure, and pH development and stabilisation.

Sensitivities of key seal and reservoir parameters have been tested to enable evaluation of the range of potential plume paths as required by Australian legislation. The modelling has confirmed long term containment over 1000 years of modelling.

## Storage site selection and certification

As an addition to the peer review contained within the original Phase 2 Implementation Plan, CarbonNet has adopted external certification to provide an independent and informed technical audit and to provide further assurance to stakeholders.

Following a tender process, eleven proposals were considered from a wide range of international service companies, geological survey and scientific organisations, and risk specialists. DNV GL was selected. It is a worldwide, leading organisation in the field of risk management for the safeguarding of life, property, and the environment. DNV GL Recommended Practice DNV-RP-J203 involves a multi-step, stage-gated process for assessing storage projects. It was selected on the basis that it:

- was commercially available and published.
- had been peer reviewed by industry and government.
- is applicable to both onshore and offshore environments.
- is risk based and not prescriptive, consistent with the Australian regulatory context.
- is transparent and includes International Peer Reviews.
- is administered by industry-experienced and professional geoscientists and engineers.
- had received partial bench testing during the Shell Quest Project.

The DNV-RP-J203 requires a systematic approach, based on understanding and minimising storage risks and analysis of diverse geoscience and environmental factors. The main areas of investigation include:

- selection and qualification of storage sites.
- documentation of site characterisation and site development plans.
- risk management throughout the life cycle of CO2 geological storage projects.
- monitoring and storage performance verification.
- well assessment and management planning.
- planning for site closure and subsequent stewardship.

CarbonNet site selection process was assessed by DNV GL. A Statement of Feasibility was issued by DNV GL for the portfolio of three short-listed sites in January 2013. The Statement certified that each of the sites was conceptually feasible and thereby suited for further development and qualification.

A comprehensive Appraisal Plan has been developed for a prioritised site in conjunction with Schlumberger Carbon Services to detail how additional subsurface information would be collected that would enable an application for an Injection Licence.

This Appraisal Plan was then submitted to DNV GL for verification that it would, if successfully completed, meet the needs of DNV-RP-J203, and also meet Australian legislative requirements for a future Injection Licence application. Certification was achieved in 2015.

Further phases of DNV GL certification exist through to project closure.

## Results of seal analysis

Effective seal is key to safe and secure storage of CO2.

The Gippsland Basin has a world-class topseal in the Lakes Entrance Formation. This is the topseal to 80% of all the petroleum resources in the basin, and is an obvious candidate for a CO2 topseal. This seal unit has been well-studied in the existing literature, but contains significant complexity of sub-units and facies variations that may affect its seal capacity locally.

Intraformational seals within the Latrobe Group are important targets for the CarbonNet Project. Using these seals offers a number of advantages:

• deeper trapping with better volume efficiency due to greater compression of the CO2.

• avoidance of top-Latrobe Group petroleum activities – whether direct conflict or pressure interaction with neighbouring developments in the same stratigraphy.

• opportunity for multi-level stacking of CO2 storage and hence greater volume per storage site.

• lower-risk storage if the Lakes Entrance Formation is available as an additional backup seal, rather than being the primary seal.

Intraformational seals are demonstrated to trap 20% of hydrocarbons by volume and about 70% of the number of accumulations in the Gippsland Basin and therefore these seals are proven in principle, but must be checked in detail on a site-specific basis for seal continuity and capacity. CarbonNet measurements of these seals show that some are as good as, or even better than the traditional Lakes Entrance Formation petroleum topseal, with hydrocarbon gas columns in excess of 100m being retained in some cases.

CarbonNet work on the Traralgon T2 interval has demonstrated that it acts as a seal between different sub-aquifers of the Latrobe Group. Salinity and pressure differences are noted in four key wells in the nearshore area, and intraformational oil pools are trapped by the T2 in five other nearby wells. The next stage of CarbonNet work will be to test the T2 seal in an exploration well on the prioritised site.

## Results of reservoir analysis

The ability to inject CO2 into the reservoir is a fundamental requirement for storage, and several projects worldwide have been abandoned or substantially modified because reservoir injectivity was insufficient. CarbonNet is working with assured high quality reservoirs, proven by decades of offshore oil and gas exploration.

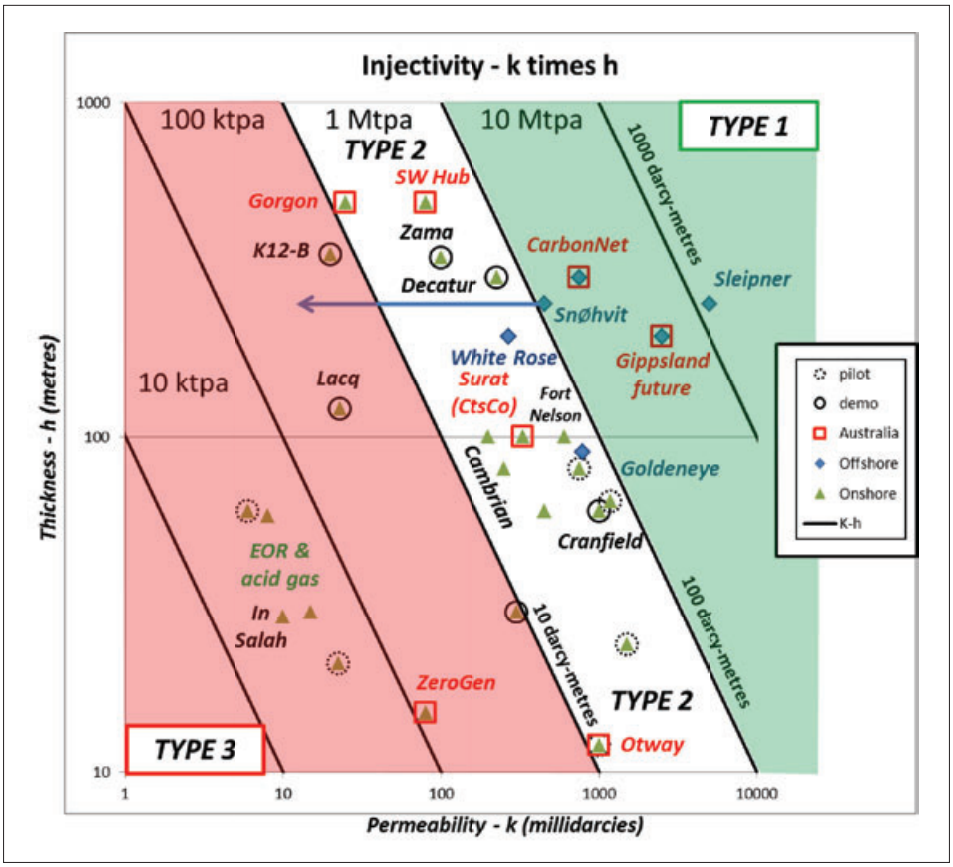



*Figure 2: Thickness-Permeability crossplot for Injectivity*
*The proposed classification is colour-coded for TYPE One (green fill), TYPE Two (white fill), and TYPE Three (red fill). Type Three reservoirs are not recommended for CCS projects*

The oil industry has invested over 100 billion dollars of present-day value to investigate and exploit the offshore oil and gas fields of Bass Strait, and the CarbonNet Project is benefitting from that investment through a worlds-best data access regime that places all exploratory data on public file after a short confidentiality period.

With this data, it can be shown that Gippsland Basin reservoirs of the Latrobe Group are world-class for CO2 storage. The reservoir units have excellent porosity and permeability. In petroleum extraction, these reservoirs are renowned for high initial oil saturation (up to 85%), low residual water saturation, and excellent sweep efficiency with primary oil recovery of 85%+.

In recent publications from the CarbonNet Project (Hoffman et al. 2015) the concept of classification of carbon storage projects into three reservoir types was introduced (Figure 2). This method graphically demonstrates reservoir quality, offers immediate visual comparison between different projects, and allows calculation of likely project scale and well injectivity. The figure shows a crossplot of permeability (measured in darcies) and thickness (in metres) for the main reservoirs as reported by a number of projects worldwide. These reservoir types are relatively homogenous clastic reservoirs that form distinct layers or units from 10m to 1km+ in thickness.

The diagram is a log-log plot, and each order of magnitude of injectivity is marked by a bold black diagonal line. The right-most of these is 1000 darcy-metres, and it can be seen that the Sleipner project exceeds this value of injectivity. The Gippsland Basin falls in the next segment below Sleipner, at about 18% of its injectivity. In the future, if depleted oil and gas fields at top Latrobe Group become available, they will have an injectivity of about 40% that of Sleipner.

For now, slightly deeper reservoirs are being

targeted, trapped beneath the T2 seal. Sleipner is the "gold standard" for injectivity and 18% of that rate is still an excellent outcome. The CarbonNet plume is anticipated to behave in similar ways to the Sleipner plume (high mobility) and be similarly visible on 3D seismic images.

Type One reservoirs are of the highest quality for injection. The limit on injectivity is not the reservoir itself, but the rate at which fluid can be pumped down the wellbore. In Type One reservoirs, injection pressure is easily dispersed through the reservoir and formation pressure is unlikely to become an issue.

Type Two reservoirs are of "reasonable" quality where the limit on flow is the reservoir, rather than the tubing. At the upper end of Type Two, injection pressure is still adequately distributed, but at the lower end, reservoir pressure management becomes important.

Type Three reservoirs are generally unsuitable for CCS projects. Reservoir injectivity is inadequate and reservoir pressure management is difficult.

The proposed classification is colour-coded for TYPE One (green fill), TYPE Two (white fill), and TYPE Three (red fill). Type Three reservoirs are not recommended for CCS projects.

## Conclusion

CarbonNet has completed a robust and comprehensive review of Carbon storage potential in the data-rich nearshore area of the Gippsland Basin, using petroleum industry data to define a portfolio of high-graded storage sites. Three of these have been short-listed and one is a prioritised site for future appraisal operations to prove storage of up to 125 Mt of CO2.

The storage site selection process has been guided by external peer reviews and by the DNV GL Recommended Practice DNV-RP-J203.

The challenges of completing the work under exceptionally exacting technical conditions to the satisfaction of a wide range of stakeholders has resulted in the identification of an excellent prioritised site. The whole site selection process represents some 20 man-years of geoscience work for an estimated investment of ~$20million.

Significant learnings have been acquired in the areas of cost-efficient site search and reservoir and seal definition, using a play fairway approach to characterise multiple potential sites in one pass.

CarbonNet continues to seek opportunities to collaborate with industry across the full CCS value chain and realise the significant economic opportunities that Victoria has to offer through CCS.

## More information

Ian Filby
Project Director
The CarbonNet Project
**Ian.Filby@ecodev.vic.gov.au**
**www.vic.gov.au**

# CO2CRC is asking the critical questions on CCS

**CO2CRC is focussing on the critical questions that must be asked and answered in Australia in order to develop carbon capture and storage and discover how the country can best contribute to the global progress of the technology.**

**In the lead up to COP21 many technologies for reducing greenhouse gas emissions are being fully considered, as they should be, and it is important for carbon capture and storage to remain relevant. There should be no doubt that if we are to limit emissions to 2oC that CCS must be an option for markets to consider.**

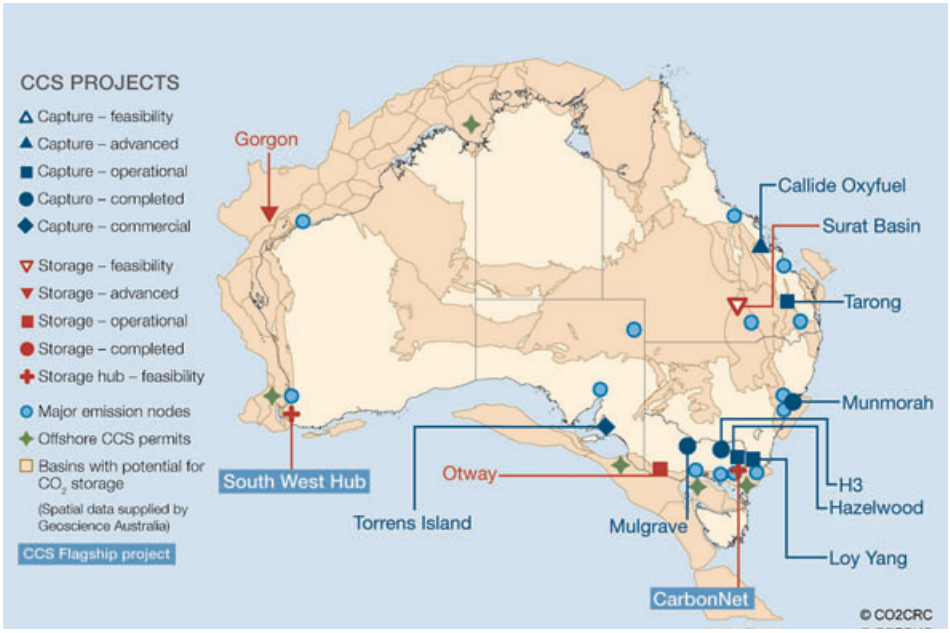
CO2CRC is taking a strategic view of the work being done on CCS in Australia with a focus on 'what are the critical questions we have to ask and answer in Australia', and 'how is Australia contributing knowledge to the global progression of CCS'.

Tania Constable, CO2CRC CEO said, "It's important to identify what Australia's niche opportunities in CCS are in the global context. Therefore, a collaborative approach is important not only with the research itself, but also with promoting the outcomes and value to government and industry decision-makers of both the extensive work to date and key areas of need."

"Five major areas come to mind and they are: how can we make existing processes more efficient; improving the connections of sources and sinks; how to get real world projects on the ground; paving the way to move beyond first generation CCS; and critically, getting the economics right."

The focus of the CO2CRC capture research program is on the research, development and deployment of technologies (solvent, membrane and adsorbent) to cut capture costs by up to 80 percent and provide Australia with a research and education capability to support industries using these technologies.

The objective of these projects is to lower the cost of capture by reducing the energy penalty associated with capture, as well as improving the different capture technologies. For example, the solvent and adsorbent teams are engaged in developing new materials and processes to achieve high recovery and purity of CO2 which increases the potential for commercial use. The membrane research teams are also developing new materials and systems.




*Map of CCS projects in Australia*

CO2CRC's technique for production of ultra-thin membranes using continuous assembly of polymers (CAP) synthesis developed at the University of Melbourne has now been patented. Results at small scale in the laboratory suggest that these membranes should have the necessary combination of selectivity and permeability to be economic for large-scale implementation. Membrane samples will soon be sent to the United States for testing under pre-combustion systems.

The Callide Oxyfuel Project near Biloela in Central Queensland, was the world's first power station to be retrofitted with oxyfuel and carbon capture technology for testing under live conditions. The plant operated from June 2012 to March 2015 and demonstrated over 10,000 hours of oxy-combustion power generation and over 5,500 hours of CO2 capture plant operation.

In a collaboration between the Callide Oxyfuel Project and the CO2CRC, a number of tanker loads of Callide Oxyfuel CO2 product were transported by road to the CO2CRC Otway site for injection testing. The tests included a number of important experimental elements: the investigation of the geochemical effect of pure Callide CO2 product with and without added impurities; and the downhole characterisation of the storage capacity of the reservoir rock, referred to as residual saturation testing.

"Using and analysing the carbon dioxide product from the Callide Oxyfuel Project at CO2CRC's Otway facility has further advanced investigations into the viability of carbon dioxide storage and gives global decision makers greater confidence that fossil fuel resources are viable in a future carbon constrained world", Ms Constable added.

Improving the connections of sources and sinks, and site characterisation, is an area in which CO2CRC plans to increase its collaboration across the CCS landscape. For example, support was recently provided to the Division of Resources and Energy within the NSW Department of Trade and Investment, Regional Infrastructure and Services in efforts to identify a prospective subsurface site within the Darling Basin as part of a wider study investigating the CO2 storage resources of NSW.

CO2CRC led the analysis and interpretation of the petrophysical, petrological and geophysical data obtained during the drilling campaign. This study was conducted with its affiliated research institutions—CSIRO, Geoscience Australia and the Universities of Adelaide and Melbourne. During the six-month study, the CO2CRC-led team used the data collected to geologically characterise the rocks intersected in two sub-basins, identify prospective reservoir/sealing units in one of these, known as the Pondie Range trough, and model the overall CO2 storage capacity of this site and likely movement of CO2 in the rock. Geochemical evaluation of the reservoir and sealing formations, as well as the mineral trapping potential, and geomechnical evaluation, were also undertaken to compliment the analyses.

The CO2CRC analysis of available data indicates that the Pondie Range Trough of the Darling Basin is potentially viable for geological CO2 storage within the range 48–1,730 Mt. These are the first underground rocks discovered in NSW which have the potential to store the greenhouse gas emissions from commercial scale power generation. In addition, should geological characterisation and storage modelling be extended to include other underexplored regions of the Darling Basin, it is likely that the geological CO2 storage resource for NSW would expand significantly, offering the state a safe, long-term option to manage its greenhouse gas emissions.

Such collaborative work has enormous value as understanding the storage potential of a region such as NSW will help Government, CO2 emitters, and infrastructure and technology developers understand the potential capacities of the State's CO2 storage resources and make more informed policy decisions and choices on the rollout of carbon capture and storage.

"The opportunity for real world application of CO2CRC's research is a key reason the work of CO2CRC has been well supported by industry. Certainly, CO2CRC's Otway facility provides a secure environment for researchers to develop, execute and operate safe CO2 storage research projects that can reduce both commercial and environmental risk." Ms Constable said.


*Truck delivering CO2 from the Callide Oxyfuel Project to CO2CRC's Otway site for test injection*

Over the past twelve months, CO2CRC's work at its Otway facility has included installing and commissioning monitoring and verification technologies to identify the most effective and cost efficient methods. This includes the installation of a buried 4D receiver array, improving the signal to noise ratio, and allowing a comparison of various technologies such as distributed acoustic sensing and single component geophones.

A key objective of the next stage of work at the Otway facility, Stage 2C, is to seismically monitor the migration of a 15,000 tonne CO2 plume in a saline formation during injection. The plume will continue to be monitored using 4D seismic as it stabilises in order to demonstrate that what has been modelled is what occurs in a live situation.

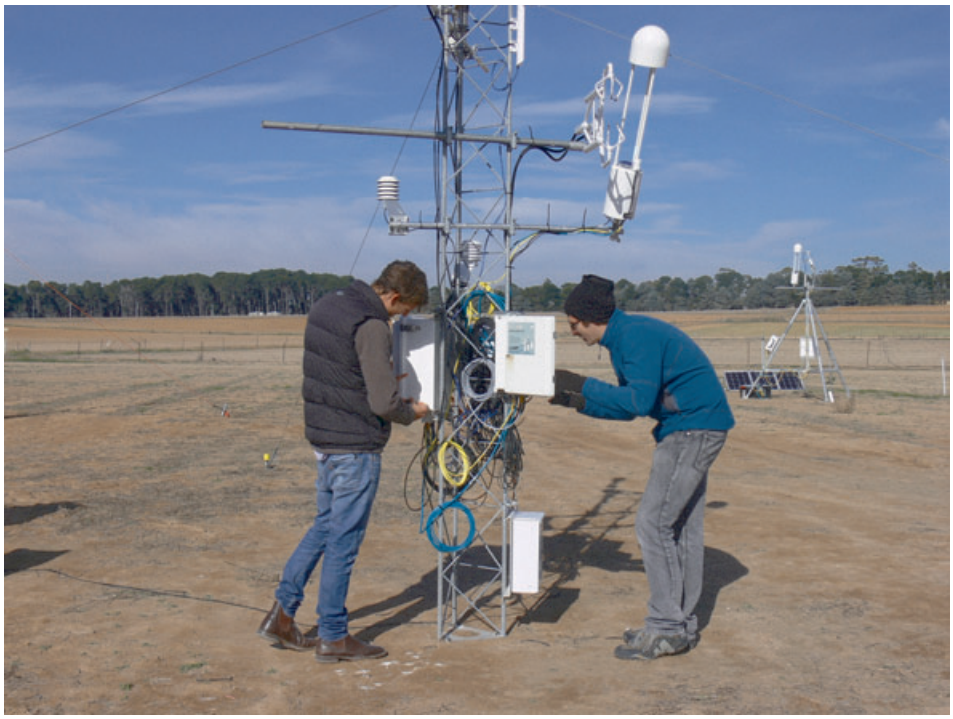
This determination of seismic detection threshold and demonstration of stabilisation

*The Otway project site – people tend to think CCS has huge infrastructure but that is not always the case as this image shows*

is highly valuable to industry, and to provide confidence to regulators.

Enhancing next generation CCS is being done in a number of ways, including through collaborative Australian and global research. The Ginninderra Greenhouse Gas Controlled Release Facility in Canberra has been designed and developed by CO2CRC and Geoscience Australia, with CSIRO hosting it at its Ginninderra Experimental Station in north Canberra. It is part of an international network of research facilities that share and compare information.

Research undertaken at the facility evaluates and compares methods for detecting and quantifying simulated leaks of greenhouse gases. The facility has been designed to allow researchers to evaluate, under controlled conditions, a range of current and new technologies and methods used to measure gases in the soil and atmosphere. Monitoring technologies and techniques under development can also be safely tested and evaluated.



*Equipment at he Ginninderra Greenhouse Gas Controlled Release Facility in Canberra*

Accurately quantifying greenhouse emissions such as CO2 and methane is essential for research into climate change mitigation technologies. Coupling more sensitive and accurate instruments with advanced mathematical models gives us better greenhouse gas accounting techniques, and help us evaluate new technologies for reducing our CO2 emissions, such as carbon capture and storage (CCS). The facility is also able to research the effect of carbon dioxide on plant growth and ecology.

A 100 metre long, slotted horizontal pipe has been installed approximately two metres below the surface of the ground. When a controlled release is undertaken, gaseous carbon dioxide, is injected into the distribution system. The amount of CO2 released per day is small and equivalent to the amount of CO2 released at night from approximately 0.4 hectares of forest. The gas flows upward through the soil and is slowly released into the atmosphere. Various carbon dioxide monitoring technologies are located within the soil, on the surface, and adjacent to the facility to measure the movement and leakage of the gas.

CO2CRC works with more than 100 Australian and international experts in CCS technologies. It collaborates with researchers from CSIRO, Geoscience Australia, and major international universities including Curtin University, the Universities of Melbourne, Adelaide, and Western Australia, UNSW Australia, Lawrence Berkeley National Laboratory, University of Edinburgh and the Korea Institute of Geosciences & Mineral Resources.

Developing the next generation of researchers to further develop commercial CCS is also an essential aspect of CO2CRC's work and an area where significant international collaboration is important. CO2CRC and the UK CCS Research Centre identify opportunities for exchanges for PhD students and postdoctoral researchers. Most recently, in December 2014, a postdoctoral research associate was chosen to accompany researchers from the University of Edinburgh to undertake their study on Quantifying Residual and Dissolution Trapping at the Otway facility. The work undertaken will provide reliable estimates of the levels of residual and solubility trapping at the site.

All of the work being done must be considered from an economic perspective, and to that end, CO2CRC has commissioned a study on current power generation technology cost and performance data in Australia. Policy makers and power professionals need current and high quality data on power generation technologies in order to make informed decisions about the changing energy sector. This study will be available to CO2CRC members later this year.

Australia's wealth of energy resources positions it as a prominent global energy exporter in the Asia Pacific but we differ from many other OECD countries. Coal plays a much larger role, reflecting our large, low-cost resources located near demand centres. Currently, Australia's coal export annual value represents 15% of Australia's total goods and services trading. However, Australia's total emissions last year were approximately 542 million tonnes. This has important implications for Australia's energy sector and shows Australia's vulnerability.

CCS will be an option as part of Australia's future energy mix, however, as Tania Constable added, there is no competition - both renewable and non-renewable (fossil fuel) energy sources are required to meet world energy demand. CCS technologies supports jobs and education outcomes by offering a level of security to industries, including coal mining and electricity generation, that deliver significant economic benefits.

## More information

Maureen Clifford
External Relations & Media Manager
**Maureen.Clifford@co2crc.com.au**
**www.co2crc.com.au**

# National Geosequestration Laboratory up and running in Western Australia

Australian CCS research has taken another step forward with the formal launch of the National Geosequestration Laboratory in Western Australia this month (July 2015).

**The National Geosequestration Laboratory, or NGL, is a partnership between Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), the University of Western Australia (UWA) and Curtin University.**

Developed with an initial investment of $AUD48.4 million of Australian Government funding, the NGL boasts cutting edge infrastructure and laboratory and field equipment, making it one of the best equipped carbon storage research organisations in the world.

According to NGL Director of Science, Dr Linda Stalker, the NGL has two key purposes.

"The first is to work alongside industry and government to provide certainty through research and assess long term commercially viable carbon transport and storage options," Dr Stalker said.

"The second is to provide education, training and community outreach through sharing knowledge and data and by engaging with the public."

The resulting infrastructure spans facilities at three sites in Western Australia and several mobile laboratories. Equipment is dedicated in the first instance to carbon storage research, development and deployment at demonstration and commercial scale.

In addition, the majority of the NGL equipment and existing equipment co-located at the three partner institutions has application to the oil and gas sector, mineral resources, water resources and unconventional hydrocarbon exploration and production.

As a result, the NGL is gaining significant interest across the world from CCS and oil and gas corporations.

Dr Stalker said the NGL had already been working on collaborative projects across six continents, in particular, the South West Hub Carbon Capture and Storage Flagship Project (South West Hub) in south-west Western Australia and the CO2CRC's Otway project in the country's east coast.

"A key priority is to support the South West Hub," Dr Stalker said.

"In addition the NGL also provides similar support to other CCS activities in Australia. The Australian CCS space is increasingly active with Flagships, such as CarbonNet in Victoria, site characterisation in New South Wales, and the broader CCS community, such as Chevron's Gorgon CO2 Injection Project on Barrow Island, and research at the CO2CRC Otway Project, is also underway.

The NGL also engages internationally with industry and research organisations to provide world class research support.

Dr Stalker added that the NGL offered an integrated pathway across the entire value chain of carbon storage, from providing instrumentation and mobile assets and technicians to interpretation of data and delivery of results.

A fully integrated laboratory information management system ensures samples can be taken through multiple stages of the research process, from rock characterisation to geochemistry, and deliver clear and consistent results.

## The South West Hub project

The NGL has been working closely with the Western Australian Government, through the Department of Mines and Petroleum, in aiding the site characterisation of a potential carbon dioxide storage site in WA.

Extensive investigation was conducted prior to the South West Hub being identified as a potential storage site and formally named a CCS Flagship Project.

A review of emission sources and sinks in 2009 by the Carbon Storage Task Force identified that the Perth/Kwinana area could produce emissions of up to 25 mtpa but were adjacent to potential areas of storage capacity (P90) of 29 mtpa (offshore) and 5 mtpa (onshore) in the North Perth Basin.

Further work identified potential storage in the Southern Perth basin offshore (Vhlaming sub-basin) and onshore.

Investigations to identify sites adjacent to the Collie power plants showed no nearby geological storage capacity and the area was deemed unacceptable. The research process revealed site characterisation is equally important to confirm geologically unsuitable sites which should not be pursued.

At the South West Hub, investigations have continued and an area now referred to as the Lesueur was identified for further characterisation. This has been a key focus of the NGL's collaborative research with WA DMP. For further details see WA DMP's website:

**www.dmp.wa.gov.au/19393.aspx**

## NGL facilities and equipment examples

The full suite of capabilities extends beyond carbon transport and storage research capability into broader oil and gas research. The following is a subset of the equipment and functional research areas within the comprehensive scope of NGL capabilities.

### Chemical tracers

Chemical tracers have been used extensively by NGL staff in field deployment at the CO2CRC Otway project and in research for other organisations. They are useful to understand migration and dispersion of CO2 in the subsurface.

However in the past it has been difficult to make detailed measurements of how much of a chemical tracer may partition (also known as partition coefficients) into the supercritical CO2 phase and how much might stay in the formation water phase at reservoir temperature and pressure. So NGL has redesigned and modified its batch reactor apparatus for measuring partitioning coefficients to improve understanding of tracer behaviour.

The laboratory also uses a slim-tube flow cell to measure and monitor chemical tracers on different rocks and mineral surfaces to investigate how much tracer might be lost during movement in the subsurface.

The new facility is part of a strategy to evaluate chemical tracers for use in CCS and other purposes, such as monitoring groundwater, natural gas, or oil for enhanced recovery. Integrating laboratory data with analysis from field deployment is part of an overall workflow for testing chemical tracers in which numerical modelling plays a significant part.

### Smaller seismic trucks for site screening and monitoring

The NGL's two new compact seismic trucks allow scientists to conduct a range of seismic surveys including 4D and smaller scale high resolution surveys. The trucks' availability to researchers allow greater consistency between surveys, producing more accurate data, which is essential for monitoring the migration of the CO2 over time and reporting conformance to regulators in onshore environments where time-lapse seismic is more difficult to achieve.

Another benefit is that the trucks are smaller than commercial seismic trucks, which allows them to access normal roads, and they can be fitted with floatation tyres to significantly reduce impact to farmland and other ecosystems. The trucks can also be used in tandem to increase signal strength underground.

The trucks have already completed a 'nested' 3D seismic survey at the Harvey-4 well which produced high resolution data providing better accuracy on the location, length and orientation of nearby faults and the formations they intersect.

This has helped researchers understand potential compartments or blocks where the CO2 might reside during injection and gain a better insight into the surrounding fault properties; whether they are sealing, or open, allowing CO2 to migrate between blocks.

### Mobile containerised laboratories

Three new mobile containerised laboratories allow NGL researchers to conduct accurate and timely research in the field.


*A small scale Vibroseis Truck, designed to have minimal impact on the environment (Photo courtesy ofAndrew Ross)*

Each container is fully equipped with a high level of safety certification for on and offshore use. Air conditioning and flexible power options allow analytical equipment and computing hardware to be operated in a stable electrical environment in any location.

The **analytical laboratory** hosts geochemical equipment and mass spectrometers to measure concentrations and isotopes of CO2 and CH4 and analyse gases and chemical tracers. A U-tube sampler can take pressurised fluid samples from a deep well onsite to more accurately analyse them for CO2 and pH levels.

**The wet chemistry laboratory** allows other analyses and processing of samples from monitoring surveys, subsampling of fluids from depth, or conducting basic tests on groundwater samples. A built-in fume hood can be used for sensitive sample preparation.

The **data and communications centre** records and preserves all data. This includes data collected from the chemical laboratories and geophysical and physical data collected from adjacent wells installed with down-hole instrumentation.

The three laboratories are part of a larger body of equipment that includes generators, geochemical, geophysical, and environmental monitoring equipment.

## Rock characterisation

New equipment has been commissioned by the NGL to complement existing rock mechanics capability amongst its partners.

New autonomous triaxial cells (ATCs) have been re-designed to deal with the challenges of working with supercritical CO2. The ATCs house core samples which can be heated and compressed to replicate reservoir conditions and can undergo a series of tests to evaluate strength and other rock properties.

The data are used to better understand how rocks behave in the deep subsurface. It can also be compared with field data from seismic methods to better predict the rock properties and improve mapping of the rocks in the subsurface.

The data are also used to design and develop models for estimating how CO2 will migrate through the subsurface and whether the loca-

tion of the CO2 plume can be identified remotely via seismic surveys.

By testing in the ATCs we can better determine if the rock properties change before and after the CO2 arrives so mapping the movement of the CO2 becomes more accurate and can be reported to regulators, demonstrating that its behaviour and movement in the subsurface is well understood.

True Triaxial Stress Cells (TTSC) are similar to ATCs but allow researchers to test rock properties using larger cubes of rock (up to 300mm) that can be stressed in three different orientations. This provides a more realistic stress regime.

Both rigs have CO2 wetted surfaces completed with materials that are more corrosion resistant to CO2. This reduces stress on the equipment and long term maintenance costs and increases safety.

*Dr Lionel Esteban of CSIRO places a section of core sample in the Medical CT scanner at the National Geosequestration Laboratory in Perth, Western Australia (Photo courtesy of Andrew Ross)*

## Research, training and calibration well

As a part of the NGL's research and education program, a 900m research well for calibration and training has been drilled at the Curtin University campus.

The well is completed with plastic casing to allow conventional methods of wire line logging as well as electromagnetic methods to be deployed without interference. Plastic screens allow fluid flow and direct contact with the rock surface and fluid samples to be taken.

The facility provides unprecedented access to a well in an urban location allowing researchers to calibrate equipment before being deployed to remote settings or in expensively completed commercial wells. New tools and methods for logging can also be trialled, compared and evaluated against results from conventional equipment.

As a training facility, the well provides hands-on experience to geoscience, geophysics and engineering students from both universities. Students and researchers are trained to deploy equipment, retrieve data and overcome technical problems before using deeper and narrower wells in the field.

An adjacent storage facility houses various survey equipment such as geophones and sensors, a logging truck and the NGL's seismic trucks which can also be used during testing in the well.

## CO2 Geosequestration Research Laboratory

The CO2 Geosequestration Research Laboratory at The University of Western Australia is a purpose built facility to house:

- CO2 processing equipment
- near surface seismic equipment
- teaching spaces and facilities for students and graduate researchers.

Equipment includes geo-reactors designed to conduct high temperature/high pressure experiments to evaluate the impact of supercritical CO2 on different rock and mineral types at varying conditions over time.

Experiments to assess complex chemical reactions that might result from using solid or liquid materials can be conducted with a fluidised bed reactor. This information also contributes to our understanding of CO2 behaviour in the subsurface and the data contribute to improved geochemical models.

## Environmental monitoring

Environmental monitoring is an essential component of the monitoring and verification process. It is used to establish baseline data, and for risk-based monitoring. The NGL has a comprehensive suite of monitoring equipment which is used to measure concentrations of CO2 and other gases in the atmosphere, soil and groundwater. Passive seismic monitoring is a major focus for CCS and other industries where fluids may be mobilised in the subsurface.

The equipment is deployed throughout the carbon storage process from site characterisation to injection and post injection.

## Open for business

While the NGL will have a formal launch in July, it is clear that we have been working away on a variety of research projects utilising new and existing equipment at the partner institutions as they have been commissioned and come on line.

## More information

For further information on the types of equipment available, their specifications and availability contact:

**linda.stalker@csiro.au**

or call 61 8 6436 8909 for information or a tour of the facilities

**www.ngl.org.au**

# Monash University develops new shaping technology to produce sorbents

**Monash University scientists Dr. Gregory Knowles and Prof. Alan Chaffee, in collaboration with Australia's leading research organisation CO2CRC, have developed new shaping technology to facilitate the production of pellet forms of highly prospective amine type CO2 sorbents for the post combustion capture of CO2 via adsorption.**

**There is keen interest in the development of adsorbents to provide a cheaper alternative for the post combustion capture of CO2 than energy intensive solvent based solutions. The study is part of a larger effort by CO2CRC to develop CCS technologies towards commercialisation.**

*Figure 1: ~1 g amounts of a MCF-PEI composite sorbent product in powder form (left) and in pellet form (right) as prepared in accord with the patent technology via a commercial pellet press*

Simple admixtures of amines and mesoporous framework powders provide for a highly attractive alternate solution. The strength of appeal is in their potential to provide large, water tolerant and highly selective CO2 working capacities, and fast sorption kinetics, under suitable process conditions. Also, their preparation is straight forward, and their precursors are readily available.

These composite materials utilise a mesoporous support, which contains a lot of free (void) volume that can then be filled with the active amine. This approach provides for very effective interaction with the CO2 which can then be readily recovered, for example, by a vacuum swing. Frameworks with larger mesopore volumes, and composites with higher amine loadings, each provide for products with larger CO2 processing capacity. Their tolerance of water is particularly important, as water is a major component of air-fired fossil fuel combustion emissions, and it would be particularly costly to have to remove this water to protect the CO2 sorbent.

Shaped (pelleted), rather than powdered, sorbents are necessary for industrial scale gas separation processes, to avoid the large pressure drop that would otherwise exist across the lengths of powdered sorbent columns. It is this requirement that set the scene for the new discovery.

It was found that the shaping via a conventional compression technique of one such composite sorbent, a mesocellular siliceous foam (80 % void volume) combined with polyethyleneimine (MCF-PEI), did not work as planned. Instead, this and other similar composite products produced sticky pellets and the amines appeared to partially extrude around the pellet die under the applied compression force. It was readily apparent that these complications, the production of sticky pellets and product extrusion, would constitute a major problem for mass sorbent production, and so would be a roadblock to the scale-up of these products.

Fortunately this problem led to the discovery of a straight forward means of overcoming these complications, and, so, to the production of dry robust forms of this sorbent type (fig 1). Furthermore, these new pellet forms were found to facilitate CO2 capture capacities that were nearly identical to those of their powder precursors.

This simple new technology was thus found to remove the roadblock of product stickiness and extrusion to the mass production of these highly prospective sorbents in dry robust pellet forms, and in so doing, has shortened the path towards their testing at pilot scale. Moreover, it was found that this approach was equally relevant to a broad range of such composite products, encompassing a broad range of amines, framework supports and amine loadings.

The inventions are described in patents PCT/AU2013/001364 and PCT/AU2014/050376, and were recently promoted at the TechConnect World Innovation Conference in Washington DC.

To validate the utility of these materials for CO2 capture, they are typically subjected to CO2 partial pressure swing adsorption (PPSA) processing in conjunction with combined thermal and gravimetric analysis. In one scenario the partial pressure of CO2 passed over the sorbent is varied, stepwise, using argon as an inert. The pressure of CO2 is progressively increased to promote adsorption, and then reduced to promote desorption, at isothermal temperature.

In a second scenario the impact of water on the sorption / desorption processes is studied. Here, a fraction of the feed gas is first passed through water, maintained at precise temper-

atures chosen to regulate the water content at the desired partial pressure. The validation of the sorbent behaviour using these approaches facilitates an assessment of their potential for post combustion capture via thermal swing adsorption (TSA) and vacuum swing adsorption (VSA).

The amount of gas adsorbed at the end of the 15 % CO2 / Ar equilibration step is indicative of the sorbent's potential selective CO2 working capacity for a TSA type process since, here, the thermal swing would be applied to remove all of the adsorbed gas to regenerate the sorbent for a new cycle. The 15 % CO2 composition of the feed gas is chosen, because it represents a typical combustion flue gas (see Fig 2). The amount of gas desorbed as the partial pressure is then reduced to 5 % CO2 / Ar provides a measure of the CO2 working capacity for a VSA process (see Fig 2).

Such tests demonstrate that the shaped composite sorbents provide potential water tolerant CO2 working capacities of up to ~10 wt % (2.2 mmol.g-1) for TSA processing and ~5.0 wt % (1.1 mmol.g-1) for VSA processing at 105 °C, which rank them among the highest capacity robust pellet form sorbents under consideration for PCC under practical conditions. This new development paves the way forward for the large scale production of pellet forms of these highly prospective composite sorbents, so as to facilitate pilot scale trials in the first instance.

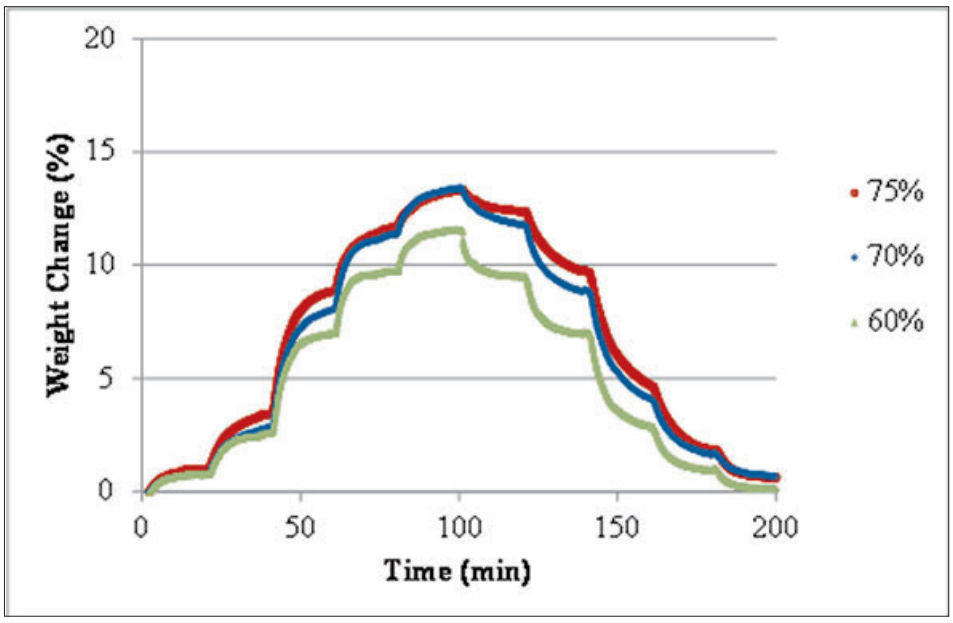



*Figure 2: Thermogravimetric records obtained for CO2 Partial Pressure Swing Adsorption processing (105 °C) of MCF-PEI pellet products incorporating 60, 70 & 75 % MCF void volume equivalent loadings of PEI, via a custom modified Setaram TAG24-16 Simultaneous Symmetrical Thermoanalyser, highlighting the potential CO2 working capacity of the product with 75 % void volume loading for processing via a Thermal Swing Adsorption process (TSA) and Vacuum Swing Adsorption process (VSA) respectively.*

## More information

Prof Alan Chaffee, alan.chaffee@monash.edy, +61 3 99054626,

Dr Gregory Knowles, greg.knowles@monash.edu, +61 3 99054531,

Monash University, Ms Angeline Bartholomeusz, Business Development Manager, angeline.bartholomeusz@monash.edu, +61 3 99054613,

CO2CRC Ltd, Prof Dianne Wiley, Capture Program Manager, dianne.wiley@co2crc.com.au, +61 2 93854755

**www.monash.edu**

# Amber Rudd: White Rose / Peterhead FID "Last quarter 2015"

**UK Secretary of State for Energy and Climate Change Amber Rudd says she expects Final Investment Decision from the companies involved in White Rose and Peterhead CCS projects in the last quarter of 2015, and the government to make its final decision about allocating the billion pounds of funding 'soon after that'.**

At a lunch on June 24 for the UK's Carbon Capture and Storage Association (CCSA), Amber Rudd, UK Secretary of State for Energy and Climate Change, said "we expect companies [behind UK CCS projects White Rose and Peterhead] will make the final investment decision in the last quarter of 2015, and governments will make decisions [on funding] shortly after that."

The UK government has allocated a billion pounds funding to carbon capture and storage to the winners of a competition, and White Rose and Peterhead were the winners.

This is perhaps the most optimistic estimate Carbon Capture Journal has heard over the past year about when construction work on White Rose and Peterhead projects might start, with some experts predicting it might not be until late 2016 (unless 'shortly' in government terms can mean a year).

"We know CCS will be an important part of our [government's] goals," she said.

"However it is essential that the government also considers the short and medium term cost to taxpayers," she said.

"We must ensure we take sufficient time to ensure the investment decisions are right," she said. "We have to balance long term benefits with looking after taxpayers' money."

"There's more we can do [with CCS]. A lot of public are very unaware of opportunities," she said. "It has potential to be a game changer."

"This government is committed to making sure we reach the goals."

"In Europe, Britain is leading the development of CCS."

"We can continue to use fossil fuel reserves and keep the North Sea ongoing here."

There is also an Energy Entrepreneur's Fund with money allocated to CCS projects, she said.

Ms Rudd was challenged by some members of the audience present at the lunch, who asked what security she was able to provide that there would in fact be a carbon capture industry.

One questioner said, "We were promised four projects, the conservatives promised they would accelerate the pace."

"Can the [UK CCS] supply chain bank on two projects going ahead and a move to the second phase, Teeside, Don Valley, Grangemouth, which we see as part of phase 2?"

Ms Rudd replied, "In terms of timing, you can't entirely blame government, there's been various hitches along the way."

"We know it works, we don't know how to make it commercial."

"I appreciate you are asking for line of sight [but it] won't provide all the certainty you want. This is an immature industry.

Another questioner said, "you see 200 people [in this room], many of whom are sitting on their hands waiting for an industry, something beyond these two projects.

"Lots of people doing a lot of things - but none of them are doing anything."

"We don't know if there's going to be anything in Phase 2. When will we know if there's Phase Two?"

"Sorry to disappoint but I don't have the answer yet," Ms Rudd replied. "I can't give you clarity this early in the government."

Another audience member said, "You can be assured the industry sees low cost as a big issue - we're funding it from our own pockets."

"The only way we can deliver it is at scale."

"When you see the line of financiers, they need a stream of projects."

"You've got an opportunity to set a belief set that's there's a long term belief in it. We need financiers to believe in it. That's a good starting point."

## Lord Oxburgh

Also at the event, Lord Oxburgh, honorary president of the Carbon Capture and Storage Association (and a former non-executive chairman of Shell), said in his introductory words, "all our members have a clear conviction that there is almost no chance of this country meeting carbon reduction targets, or EU or the world, without CCS.

"That's the simple message, the clock is ticking and we have to do it soon."

Mike Gibbons, chairman of CCSA and also a director of 2CO Power, said that Canada's Boundary Dam project has now been operating for 9 months, and that should be proof to anyone who doubted that CCS could be made to work. He calculated that there are 20 CCS projects now around the world. "It's a shame there's no such project in the EU," he said.

"The environmental and economic arguments [for CCS] have been made so well by so many people in so many ways."

For example, "The Energy Technologies Institute said, 'no other technology has such a dramatic impact in lowering the cost of the low carbon economy as CCS. Deploying CCS would keep electricity bills as low as possible, 15 per cent lower than without CCS.'"

"It is the only technology to decarbonise steel and chemical," Mr Gibbons said.

"We all know decisions in this parliament are the key to deploying CCS on a large scale."

Mr Gibbons said he had 3 messages for government.

The first is that it is important to deliver the 2 competition projects, White Rose and Peterhead. "It will mean we're going to build actual projects [providing] reliable non-intermittent low carbon electricity," he said. "They must set foundation for projects to follow."

The second message is that it is essential to "enable the second phase of projects in parallel with phase 1."

Currently only 1.5GW of carbon captured power is planned to be in operation by 2020, he said.

The second phase of projects "will drive cost competitiveness in CCS," he said.

"I count industrial CCS in this step. It is important to maintain funding on Teeside for example."

"There remains a need from DECC for a clear line of sight to a Contract for Difference (CFD", he said. "There are no draft CFDs. I used exactly these words one year ago."

The third message is to enable funding to further explore CO2 storage capacity, to deliver confidence that it will be available, he said.

## More information

Connected with the event, CCSA produced a pamphlet "Delivering CCS" (which can be downloaded here:

**www.ccsassociation.org**

# Potential for CCS in Nigeria

**Recently there has been some interest in Nigeria in developing projects under the Clean Development Mechanism for storing CO2 which is currently flared from gas projects, but many challenges remain.**

By Mohammed Dahiru Aminu, Cranfield.University

**Nigeria, and to a large extent, West Africa, according to recent researches is seen as having very promising potential for CCS especially in the areas of both enhanced oil recovery as well as storage in deep oil and gas fields which have been produced from, and therefore decommissioned.**

Being a developing country and given Nigeria's level of technological advancement, it is instructive to say that in order for safe and secure CCS to be implemented, there must be very stringent legal frameworks that should be put in place to safeguard the carrying out of this technology.

Other impediments which make CCS a potential risk in Nigeria must be settled by outlining long-term CCS implementation strategies, effective technologies to absolve gas leakage from storage formations as well as issues that relate to the costs of implementing such projects.

Presently, companies have, in the meantime, started showing interest in identifying and implementing the Clean Development Mechanism (CDM) in Nigeria. The CDM is an agreement under the Kyoto Protocol where industrialised countries are allowed to design and invest in projects that cuts down the CO2 emissions in developing countries.

## Current reforms in the Nigerian oil and gas sector

Currently, it seems that there are a number of ongoing economic reforms in the oil and gas sector of Nigeria. These reforms usually aim at increasing the vibrancy of the sector and also to attract large investments to Nigeria. Some of these reforms include but are not limited to:

• the Nigerian Gas Master Plan

• the legislation—although still ongoing—on gas flaring which could be part of the proposed Petroleum Industry Bill.

But what is surprising in Nigeria is that despite the huge economic profits that could have accrued to government's coffers through the effective utilisation of natural gas, much of Nigeria's gas is still flared and wasted—which, by implication, causes both huge loss of revenue as well as degradation of the environment.

It is therefore thought that given these reforms in the oil and gas sector, there is a naturally emerging avenue upon which an outstanding backdrop for CCS projects could be implemented under the CDM.

## Gas projects in Nigeria

Because an integral part of the CDM mechanism is to idealise projects that help in reducing Green House Gas (GHG) emissions in developing countries such as Nigeria, two major projects have been currently developed for reasons of recovering associated gas. These projects are the Kwale oil and gas processing plant project and the Ovade Ogharefe gas capture and processing projects.

### The Kwale-Okpai project

The Kwale-Okpai project is jointly run by Nigeria's state oil company (Nigerian National Petroleum Corporation, NNPC), Nigerian Agip Oil Company (NAOC), Royal Dutch Shell, and Philip Oil. The project started in 2005 in Ndokwa land of Delta State as one of the projects for the United Nations Framework Convention on Climate Change (UNFCC) in Nigeria.

The main reason for establishing this project is to recover and utilise the associated gas—derived from the extraction process—that could have otherwise been flared in the environment.

This project makes use of the bulk amount of

the gas produced at the Kwale oil and gas field and thereafter transports it by pipe to the Okpai combined cycle gas turbine where it is used for generation of electricity. With this project, there is an aim to reduce emission of CO2 to the tune of perhaps more than a million tonnes.

### The Ovade-Ogharefe project

The essential purpose of the Ovade-Ogharefe project is to totally diminish flaring of gas produced from the Ovade-Ogharefe oil fields which is being run by NNPC in partnership with the Pan Ocean Oil Corporation.

After the capture and processing of associated gas, the project then injects gas into an existing transmission system where it is sold by the Nigerian Gas Company (NGC). Following this project, flaring has been reduced to nearly zero emission, a promising path for substantially reducing GHG in Nigeria.

*Map of Nigeria showing Delta State in which the gas projects are located*

## Possible challenges of implementing CCS in Nigeria

There are basically two major challenges that would face CCS implementation in Nigeria: 1) geologic challenges, and 2) costs of implementation.

Perhaps one of the most important challenges that sequestration projects for CO2 face is developing the effective technology to a level where the risks are mitigated to an extent where they can be implemented to address CO2 storage in the light of tackling challenges to climate change.

This means that for any viable CO2 storage facility, its ability to mitigate climate change by ensuring safety and security of stored CO2 is crucial. Thus, large field demonstration projects as well as site-specific investigations are needed as part of processes of dealing with geological challenges.

It is important too, to emphasize that industry experience has shown that managing the injection of CO2 into sedimentary basins requires a high technical skill of sharing and coordination of project operations, as well as the support for research and development. Equally basic is that a system of monitoring long-term programmes of operation must be developed in order to be assured of environmental protection.

Both CO2 capture and sequestration technologies are costly simply because to implement CCS means that a novel industry must emerge to capture, store and inject CO2 deep in geological formations. Because it is also true that technology is always dynamic rather than static, the cost of keeping up to date with latest technologies in the CCS industry is a challenge on its own.

## Conclusions and recommendations

This piece has summarily discussed an overview and reasons for CCS; why Nigeria needs CCS; reforms in the Nigerian oil and gas sector; gas projects in Nigeria; and possible challenges of implementing CCS.

It could therefore be summarised here that although even in developed countries where large scale CCS projects are at their commencement stages, Nigeria, being a developing country, has the potential to start the processes of capturing and storing excess CO2 as a response to the threats of climate change.

The successes of the two already existing gas projects—the Kwale-Okpai and Ovade-Ogharefe—if there are any real clues to derive from them, are an indication that gas projects in Nigeria could be viable after all. Because Nigeria is blessed with abundant sedimentary basins, there is certainty that basins like the Niger-Delta, and the Benue Trough can be likely candidates for CCS operation.

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## More information

Mohammed Dahiru Aminu, a Ph.D. candidate in Cranfield University, is researching on the integrity of cap- and reservoir rock system during CO2 injection for geological storage.

**mohd.aminu@gmail.com**

**www.cranfield.ac.uk**

# Chris Davies: we'll need EU CCS to reach the targets

Chris Davies, former EU MEP and rapporteur for carbon capture and storage, believes that European countries will support CCS once they realise they need it to meet their targets.
By Karl Jeffery

**Chris Davies, former rapporteur for carbon capture at the European Commission and Member of the European Parliament from 1999 to 2014, believes that EU countries will start making plans to implement carbon capture, once they realise they need it to meet their 2050 carbon emission reduction targets**

EU leaders agreed on 23 October 2014 to a domestic 2030 greenhouse gas reduction target of at least 40 per cent compared to 1990.

But countries have not yet been required to make detailed plans for how they will achieve it, Mr Davies says.

"They don't have to announce how they will do it," he says. "It is up to member states to start working towards it. There's a lot of flesh to be put on the bones."

The European Union should push every country to publish its plans to cut emissions by 80 per cent by 2050, he believes. "They should have to expose their thoughts to public scrutiny."

So far, the European Council of Prime Ministers, "has made specific reference to CCS as one technology that needs to be developed," he said. But "they've shied away from setting any targets."

As an indication of how much work needs to be done, consider that countries have so far only really been considering greenhouse gas emissions from electricity, which is about a quarter of the total, he says.

Emissions from energy intensive industries have barely been considered so far. "You simply cannot reduce CO2 emissions from energy intensive industries without CCS," he said.

Once it has support, the rollout of carbon capture and storage could happen very quickly in Europe, Mr Davies believes.

It might be a useful example to consider that the UK managed to cover the entire country with railway in just 19 years, between 1830 and 1849, he says. Also, consider that the US already has 4,000 km of CO2 pipeline, he says.

A lot of Brussels resources have been spent on the Emission Trading Scheme (ETS), he says.

At the time it was set up in 2003, "The commissioner always said, 'we're going to make mistakes, we're going to learn by doing.' It has taken a lot longer than any of us thought."

Chris Davies was a United Kingdom member of the European Parliament from 1999-2014. He served as rapporteur for the CCS Directive in 2008-9 and for the Parliament's implementation report on CCS in 2013-14. He introduced and promoted the idea for a European funding mechanism that became known as the NER300, one of the world's largest funding programs for innovative low-carbon energy demonstration projects.

## Compare with renewables

There is an interesting comparison between carbon capture and renewables in the way the European Commission has supported it.

In renewables, there was a requirement for every European country to set a target to get 20 per cent of its electricity from renewables, and projects have actually been funded.

"The fear was that the emission trading system was not providing sufficient funding for renewable energy. So additional means could be found," he says.

Meanwhile the mothballing of many carbon capture projects has been attributed to a low carbon price, with governments saying that the project can only go ahead if the carbon price is high enough to make them viable.

So if the Commission set a target for how much CO2 should be buried using carbon capture, it might be very helpful.

Ultimately, "it is a matter of what people want to see happen," he says. "People want to see renewable energy developed."

## Making the public pay

"Money for low carbon electricity projects has to come from somewhere, either from taxation or from electricity consumers, and it makes sense to get it directly through electricity bills," Mr Davies says.

"In Germany they pass all the costs of renewables onto consumers, and protect industry by not requiring industry to pay that contribution! That's why Germany has the highest electricity prices."

## New Energy Commissioner

Mr Davies reports that the new European Commission Climate and Energy Commissioner, Miguel Arias Canete in April 2015, is proving to be a carbon capture enthusiast.

Mr Davies had a meeting with Mr Canete in April 2015, together with Graeme Sweeney, Chair of the Advisory Council of the European Technology Platform of Zero Emission Fossil Fuels Power Plants (ETP-ZEP), and Andrew Purvis. General Manager, Europe, Middle East and Africa with the Global Carbon Capture and Storage Institute (GCCSI), and Frederic Hauge, the founder and CEO of Bellona.

"We had an hour with the commissioner," Mr Davies says. "He showed obvious support for CCS. We knew we were having a meeting to discuss ideas. We had a willing commissioner."

"He told us that since becoming Commis-

sioner he had rarely made a speech without making a reference to the need for CCS and that he would continue to do so."

Mr Davies believes that the commissioner does have a large amount of influence over what the European Commission does. He might not have personal powers to direct funding to CCS projects, but he is "essential to shaping the agenda," he says.

"For example, he can say CCS should be part of the Energy Union Strategy. He can say member state governments have to prepare a strategy for reaching their 80-95% CO2 reductions by 2050."

"When the climate ministers get together, the commissioner is their team leader," he says. "It is the commissioner who shapes Europe's climate and energy agendas."

So when it comes to decisions about whether Brussels will support European carbon capture projects such as ROAD, "I think the Commissioner could have huge influence," he said. "If the Commission can pull together the key partners there is nothing technical that need stop ROAD going ahead."

## Germany and France

Mr Davies believes that Germany will eventually start supporting carbon capture, probably for industrial CCS, and France is a stronger supporter of carbon capture than many people believe.

"Germany has been very hostile to CCS as you know," he says. "They are against nuclear, they are now wanting to close down coal fired power stations. Probably they'll end up importing electricity from Poland. It's not quite thought through here."

"There are days in the year when Germany gets half of its electricity from renewables, and other days it is less than five per cent."

"There's a major role for renewables [but] you have got to have fossil fuel back up, otherwise you're importing fossil fuel electricity from other countries."

Mr Davies thinks that the North Rhine-Westphalia region of Germany could be the first region to set up carbon capture, since it is close to the coastline, with possibility to connect to offshore sites by sending CO2 by barge or pipeline.

There are many chemical works in the region, including ammonia manufacturing, where pure CO2 is vented into the atmosphere. This provides opportunities to store CO2 without any separation processes required.

There is more happening in France with carbon capture in terms of pilot projects than the UK, Mr Davies says. This includes a coal fired plant in Le Havre, an Air Liquide plant in Le Havre, and a Total site in Lacq.

France also had the only carbon capture project to qualify for funding on the first round of the NER 300 scheme, with its 'ULCOS' project, for capturing CO2 from a steel plant. Unfortunately this project was shelved because the steel plant generating the CO2 was closed.

## Other regulatory vehicles

Another regulatory vehicle which could support CCS could be an 'emissions performance standard', where coal power plants are restricted in how much CO2 they can vent to the atmosphere, similar to how they are restricted with SO2 and NO2 emissions.

"That's something that's been discussed, nothing more than that," he said. "We need to get off the discussion bench and off the drawing board and into practise."

We already have a kind of emission standard in Britain, in that there are restrictions on building new coal power plants without carbon capture.

## U.S.

Another way to put pressure on Europeans to do something with carbon capture is explain what is happening in the US and China, he says.

"The US is burying 60m tons of CO2 a year, from a mixture of natural sources (40m) and industrial sources (20m) tons. "Most of it is stored together with enhanced oil recovery. But the CO2 goes down there and stays down there."

By contrast, In Europe, we are capturing about 1.5m tons, of which 1m tons is from the Sleipner project in Norway, which is not even part of the European Union.

"I had a meeting in Washington in March with the US Department of Energy. They say, "'we have no doubt CCS is going to come forward, globally it is essential. The American industry in competition with Chinese industry.'"

"The implication is Europe is being left behind."

## Fossil fuel companies doing carbon capture

"Getting the fossil fuel industry to make the changes or make the investments [in carbon capture] makes a lot of sense to me," Mr Davies says.

But "the fossil fuel providers would be opposed to it to begin with."

For example, Eurocoal, the European Association for Coal and Lignite, is still opposed to early deployment of carbon capture, he says.

"It will require a degree of political support [to force them to pay] which I don't think is on the cards yet. In order to overcome this sort of resistance, "you'd need majority support in the European Council for something like that," he says.

"I think you are five years off before you can start floating the idea."

# UK CO2 EOR gives 7x financial returns

**The benefit to the UK economy from implementing CO2 storage with Enhanced Oil Recovery in the North Sea could be 7.2x the money invested according to a Scottish Carbon Capture and Storage report.**

By Karl Jeffery

**A study by Scottish Carbon Capture and Storage (SCCS), founded by Shell, Nexen and 2CO Energy, has calculated (among other findings) that any money provided by the UK government for carbon capture and storage (CCS) with the oil used for enhanced oil recovery (EOR) will lead to a return to the UK economy of 7.2 x the money invested.**

This compares to a multiplier of 2.6 for carbon capture fitted to coal, and 3.3 for offshore wind.

The calculations were made by Professor Karen Turner, director of the Centre For Energy Policy, Strathclyde Public Policy Institute, part of the University of Strathclyde, Glasgow.

The calculations are based on offshore wind being supported (through government funding) by Contracts for Difference, carbon capture and storage supported by CfDs in coal powered electricity generation, and CO2-EOR with the CfDs from pure CCS partly replaced.

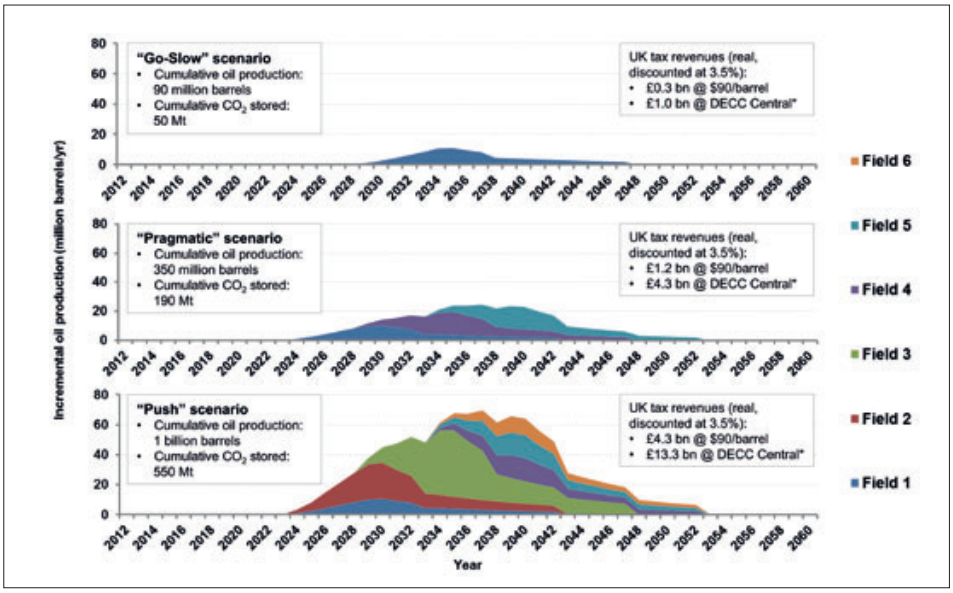
The multiplier does not show the financial return to the government, but the return to the UK economy.

It might also be expected that the costs of building additional CCS /EOR infrastructure will go down after the initial construction. This was not factored into the multiplier calculation, Professor Turner said.

This means that CO2-EOR is "the most cost-effective pathway to UK decarbonisation targets," the report proposes.

Benefits to the wider UK economy come from extending the producing life of the North Sea, encouraging further development of existing fields, reducing imports of oil, employment, developing new capability (leading to UK exports) and of course tax revenues.

Also bear in mind that the UK North Sea oil and gas operations are currently under threat due to the low oil price, and adding CO2 EOR may enable them to be kept operating longer and avoid decommissioning costs over the short term.




*Predicted UKCS CO2–EOR oil production, CO2 storage and tax revenues*

It also potentially reduces the amount of government subsidy required for wind and solar construction, since CO2 EOR is able to help the UK meet its low carbon targets.

This will also help get carbon capture moving in the UK faster.

The benefits continue, since once developed, the UK could accept CO2 from other countries in Europe, particularly Germany, Denmark, Poland and the Netherlands, if they have not yet managed to develop CO2 storage themselves.

There have been questions about whether it is legal to move CO2 across boundaries in Europe - SCCS believes that it is, since CO2 is already moved across boundaries when it is used in food.

The CO2 could be delivered by ship, using the same type of vessel currently used to transport liquid petroleum gas (LPG) rather than build an expensive pipeline.

SCCS' calculations show that shipping is in fact cheaper than a pipeline for transporting carbon dioxide by sea over distances greater than 1000km, he says

"The beauty of this new analysis is that it shows how to help develop big projects in the power industry, while also supporting a transition of the abilities and profits from offshore hydrocarbons into new, sustainable jobs," says Professor Stuart Haszeldine, SCCS Director at the University of Edinburgh.

SCCS suggests that the financial aid would best be provided to UK oil companies in the form of a reduction of tax required to be paid from field developments, similar to existing brownfield and development allowances.

The calculation studied how much tax allowance the UK government would need to make to UK oil companies in order to make-CO2 EOR viable, or get over the 'hurdle rate' of profitability.

It was made on the basis that CO2 is made available to oil companies at a zero transfer price.

It might be realistic to expect that a transfer price (paid from the power station operator to the oil company, or the opposite), of from -£20 to +£20 a ton.

An oil company would want to be paid for accepting the CO2, and a power company would want to be paid for providing it - but presumably the two would reach a negotiated price they could both work with.

## Why aren't we doing it?

Mr Haszeldine said that in his discussions with the UK HM Treasury, the first question eople ask is, "if it's so good, why isn't everybody doing it?"

"That's a fair question," Mr Haszeldine says.

But the answer starts by point out that no CO2 supply is currently available for the North Sea - and for an oil company to create ne by itself "is a fairly expensive investment".

Another common question is why the current CCS projects in the UK do not include EOR - the answer is that the government wanted to make sure that the first projects were successful - and getting just CCS moving is a big step, without adding EOR as well, he said.

Now we're within sight of grasping these 2 projects - the homework has been done. We're hoping we'll get gold stars [of final investment decision] in early 2016.

The economics here are calculated on the basis that CO2 is being made available to oil companies free of charge, as it would be if there was already a carbon capture and storage plant running, such as one of those proposed in Aberdeen (Peterhead) and Yorkshire (White Rose).

Currently, the UK carbon capture and storage projects expect to pay themselves for the CO2 to be stored in offshore reservoirs, so for oil companies to agree to handle the CO2 would be doing them a favour.

Already methane is being used in the North Sea for enhanced oil recovery in the same way that CO2 would be, by BP for its Magnus Field. The project was announced in 2000.

## Injection patterns

The study also looked at the best possible injection patterns (water alternating gas, and continuous injection). It found that the best way to get the most oil production is to inject as much CO2 as possible - in other words to store the CO2 as fast as possible.

## Oil company finances

A study of what financial incentives would make the projects viable from an oil company point of view was made by Element Energy, Dundas Consultancy and Professor Alex Kemp from the University of Aberdeen.

The study showed that if the tax rate (which includes Petroleum Revenue Tax + corporation tax + supplementary charge) is put at its standard rate of 81 per cent, CO2 EOR isn't viable.

If tax is reduced to 30 per cent, CO2 EOR adds value on all fields and oil companies make more profit - so this is perhaps too generous.

The study group suggested that the government could provide a variable field allowance, set to be high enough to make it economic.

Emrah Durusut of Element Energy suggested that if the government announced a tax incentive for CO2 EOR projects now, that would give a strong positive signal to oil companies that the government was willing to support this financially. They could be negotiated on a project by project basis, he said.

## Public perception

A study on public and stakeholder perceptions for CO2 EOR was made by Dr Leslie Mabon of Robert Gordon University, together with Chris Littlecott of Scottish Carbon Capture and Storage.

Groups being questioned included Non-Government Organisations (environmental groups), Aberdeen public, Edinburgh public, offshore stakeholders (people working in the offshore industry), energy / climate professionals, financial professionals and oil and gas professionals early in their careers.

They were asked what they thought about the North Sea recovery goals (how much oil would be produced from the North Sea) and the climate goals (whether carbon emission s would be reduced), both what they desired to sea, and what they expected to see.

Every group wanted to pursue climate goals and expected much less to actually happen than they wanted, Mr Littlecott said.

The 'offshore stakeholders' were highly sceptical about both the ability to reach North Sea recovery goals and the ability to reach climate-goals, Mr Littlecott said. "They thought decline was baked into the North Sea."

The energy / climate professionals showed a lot of scepticism as to the financial viability of CO2 EOR, he said.

The respondents all seemed quite capable of coping with the idea of doing more than one thing at once (meeting climate goals and improving North Sea recovery), he said.

A number of respondents mentioned electoral timescale conundrums, people don't think politicians are willing to do anything which might take longer than 5 years to show results, he said.

People seemed to be much more persuaded about CO2 EOR if they could see it as part of a broader vision for the UK to improve its climate performance, he said.

## Moving forward

What would be helpful to move forward is a full worked example about the finances from an oil company's point of view, Mr Haszeldine said.

There is some reluctance among oil companies to reveal their full financial calculations in public, but at the same time, the UK government needs reassurance that it won;t be subsidising 'castles in the air' if it goes for this, he says.

Also, the UK oil and gas industry is yet to see the full impacts of the low oil price - it could lead to an even faster acceleration of decommissioning.

Currently, there is potential to use much of the offshore oil and gas infrastructure for CO2 storage, but if it is decommissioned, it would all need to be built again if needed for CO2, he said.

In other words, the CO2 disposal system is available right now for very low cost.

## More information

The full report and further information about how the calculations were made is online at **http://bit.ly/co2eor15**

# IEA - tracking clean energy progress

**Market viability of some clean energy technologies is progressing, but the overall rate of deployment falls short of achieving the ETP 2°C Scenario (2DS), finds the International Energy Agency report, "Tracking Clean Energy Progress 2015", an excerpt from Energy Technology Perspectives 2015.**

**Deployment of CCS passed a milestone in 2014 when CO2 capture was demonstrated in a large-scale power plant for the first time. CCS investment needs to increase significantly, however, to ensure that enough projects are being developed to meet the 2DS.**

## Recent trends in CCS

In October 2014, SaskPower's Boundary Dam unit 3 in Canada became the world's first commercial electricity generating unit with full CO2 capture. Around 1 million tonnes of CO2 (MtCO2) per year – 90% of CO2 emissions from the unit – will be captured and stored underground through enhanced oil recovery (EOR). In Mississippi, construction of the Kemper Country energy facility continued, with the goal of commencing operations in 2016. And in Texas, the final investment decision was taken on the Petra Nova Carbon Capture project.

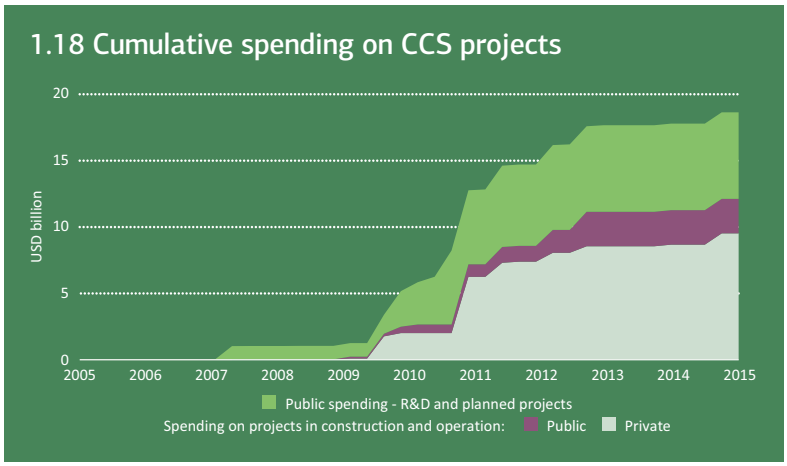
The three components of CCS – CO2 capture, transport and storage – are now all being undertaken at commercial scale. By the end of 2014, 13 large-scale CO2 capture projects were operating globally across five sectors, with the potential to capture up to 26 MtCO2 per year.

Over the past five years there has been a slow but steady increase in the number of CCS projects under construction. Final investment decisions were taken on two projects in 2014, bringing the number of projects under construction to nine. A further 13 projects are in advanced stages of planning.

Of the 13 CO2 projects operating, five store CO2 with monitoring and verification focused on demonstrating storage permanence, while eight are using the captured CO2 for EOR without storage-focused monitoring.

The demand for CO2 for EOR in some places has created or strengthened the business case for carbon capture, enabling its demonstration. In the long term, however, all CO2 storage, including for EOR, will need to be subject to monitoring and verification to account for the CO2 stored.

The United States is leading the deployment of CO2 capture, largely because of demand for CO2 for EOR.




Seven of the 13 projects in operation, and seven of the 22 in construction and development, are in the United States. To realise the 2DS CCS will have to increase markedly, particularly in OECD non-member economies which capture over half of the global total by 2025.

The USD 1 billion investment in the Petra Nova Carbon Capture project brings total global cumulative investment in large-scale CCS to USD 12 billion since 2005. OECD governments have made available USD 22 billion in support for large-scale projects, but much of this has not yet been spent.

## Tracking progress

While CCS is making progress, it is well below the trajectory required to match the 2DS. At the end of 2014, 13 large-scale projects were capturing a total of 26 MtCO2 per year, but only 5.6 Mt of the captured CO2 is being stored with full monitoring and verification.

The 35 projects currently in operation, under construction or in advanced planning have the potential to capture 63 MtCO2 per year by 2025; however there remains a short window for additional projects to begin development in the coming years and be operating by 2025.

## Recommended actions

Governments and industry need to work together to ensure that final investment decisions are taken on as many as possible of the projects in development. It is vital to keep a consistent stream of projects moving through construction to build experience and foster growth in the industry.

To meet the 2DS, the rate of CO2 being stored per year will need to increase by an order of magnitude.

Governments should invest now in characterising storage resources and ensure that all CO2 storage is appropriately monitored and verified.

Governments should identify opportunities where policies and local and commercial interests align to encourage CCS deployment, and introduce measures targeted at creating new and strengthening existing markets.

## More information

Read "Tracking Clean Energy Progress" and Energy Technology Perspectives at:

**www.iea.org**

# Projects and policy news

## ETI seeks partners for power with CCS concept

**www.eti.co.uk**

**The Energy Technologies Institute (ETI) is seeking co-venturers to develop an investable concept for major new power generation capacity fitted with carbon capture and storage.**

ETI's Thermal Power with CCS investment will support development of the business case for an investable, low cost, low carbon power scheme supported by a Contract for Difference (CfD).

It is designed to take early advantage of the new CCS infrastructure being built and deliver momentum into the next phase of CCS sector development.

Analysis carried out on behalf of the ETI by Pöyry and AECOM has identified that key features are likely to include:

• Sharing existing transport and storage assets to reduce cost, complexity, schedule and scope;

• Low planning cost, time and risk, e.g. already-consented sites, based near pipeline infrastructure;

• Use of 'best proven' technologies, balancing cost against investor risk premium;

• Rapid, low risk project delivery;

• Risk-sharing, by attracting multiple investors in a co-venturing model;

• Business models with a clear allocation of risk along the CCS chain.

The ETI will invest up to £2m in the project which will identify the technical and commercial foundations and create the business case for a specific Phase 2 CCS project. It will include identifying funding and establishing a vehicle to take the project forward to Financial Investment Decision and beyond.

Andrew Green, ETI CCS Programme Manager said:

"Our analysis of the UK energy system clearly identifies the strategic importance of timely development of a sizeable CCS sector.

"Although initial CCS demonstration projects would require a high strike price, we believe that costs will fall rapidly to below £100 per MWh for follow on projects as a result of sharing infrastructure, economies of scale, engineering learning and greater confidence from investors.

"We will adopt a collaborative, co-venturing approach with our partners to enable risks to be shared amongst multiple investors and ensure that our co-venturers will be well-placed to take advantage of not just this investment opportunity but future opportunities presented by widespread CCS roll out."

The ETI's recently-published insights document "Building the UK Carbon Capture and Storage Sector by 2030 – Scenarios and Actions" identified the practical steps needed over the period to 2030 to build an effective CCS sector.

It suggested three possible scenarios that would allow CCS to realise its long term potential and play a key role in decarbonising the UK's energy sector with the development of around 10 GW of capacity by 2030.

All three scenarios depend on implementing both DECC Commercialisation 'Phase 1' projects at Peterhead in Scotland and White Rose in Yorkshire and building a credible pipeline of investable 'Phase 2' projects using the infrastructure developed in the first phase.

"Phase 2 needs to be developed in parallel with Phase 1 if widespread roll out of CCS is to be achieved by 2030 and this project will help achieve that aim," said Andrew Green.

The request for proposals will close on 14th September 2015. The deadline for notification of intention to submit a proposal is 14th August 2015.

## CCS needs greater investment

**www.iea.org**

**www.lse.ac.uk**

**Current investment levels in carbon capture and storage need to be increased for the technology to play its part in tackling climate change, finds two reports.**

Both the International Energy Agency's (IEA) World Energy Outlook Special Report on energy and climate change and the Grantham Research Institute's (GRI) report into improving the CCS framework in Europe have found that CCS is vital to achieving our long-term climate change goals – but that the current levels of investment are not enough to ensure the technology reaches its full potential.

Brad Page, CEO of the Global CCS Institute, says: "CCS is vital to decarbonise industry and to enable the power sector's transition to a low carbon future. As the IEA report notes, without CCS, other sectors will have to shoulder more of the burden. However, investment is urgently needed now to get more projects operational, bringing costs down in the long run as experience grows."

The IEA cites a main challenge to widespread deployment of CCS in the power sector as "the need to bring down the costs to a level that sustains competition with other low-carbon technologies".

Its solution to wider deployment includes: regulatory measures and targeted incentives; continued R&D alongside policies that encourage development of carbon dioxide

(CO2) storage capacity. Importantly, the IEA finds in the absence of the full uptake of CCS, "other pathways would require more difficult changes in how energy is supplied and used, could reduce the quality of energy services and would incur higher costs."

The GRI's report echoes the IEA's call for additional policies to be put in place, finding that within "the European Union (EU), CCS is expected to play a crucial role in achieving emissions reduction targets at the lowest cost."

It calls for greater EU and Member state incentives to support the development of commercial-scale CCS in Europe, arguing that these need to be combined with reforms to the EU Emissions Trading Scheme and Innovation Fund to accelerate investment.

Mr Page says that both reports highlight the need for urgent action; "If we are serious about tackling the climate challenge, we need to use all the technologies available. These reports show what needs to be done in the EU and globally to make sure CCS is deployed at scale.

## Oil and gas majors call for carbon pricing

**www.bp.com**

**BG Group, BP, Eni, Royal Dutch Shell, Statoil and Total called to governments around the world and to the United Nations Framework Convention on Climate Change (UNFCCC) to introduce carbon pricing systems.**

In a joint press release the companies called for the creation of clear, stable, ambitious policy frameworks that could eventually connect national systems. These would reduce uncertainty and encourage the most cost effective ways of reducing carbon emissions widely.

The six companies set out their position in a joint letter from their chief executives to the UNFCCC Executive Secretary and the President of the COP21. This comes ahead of the UNFCCC's COP21 climate meetings in Paris this December.

With this unprecedented joint initiative, the companies recognize both the importance of the climate challenge and the importance of energy to human life and well-being. They acknowledge the current trend of greenhouse gas emissions is in excess of what the Intergovernmental Panel on Climate Change says is needed to limit global temperature rise to no more than 2 degrees Centigrade, and say they are ready to contribute solutions.

As the chief executives write:

"Our industry faces a challenge: we need to meet greater energy demand with less CO2. We are ready to meet that challenge and we are prepared to play our part. We firmly believe that carbon pricing will discourage high carbon options and reduce uncertainty that will help stimulate investments in the right low carbon technologies and the right resources at the right pace. We now need governments around the world to provide us with this framework and we believe our presence at the table will be helpful in designing an approach that will be both practical and deliverable." (Helge Lund, BG Group Plc; Bob Dudley, BP plc; Claudio Descalzi, Eni S.p.A.; Ben van Beurden, Royal Dutch Shell plc; Eldar Sætre, Statoil ASA; Patrick Pouyanné, Total SA).

The chief executives also sent an additional letter that has been published in newspapers, setting out this position on carbon pricing and also the role that natural gas can play in reducing carbon emissions.ducing CCS projects around the world.

## Pre-feasibility study on potential full-scale CCS projects in Norway

**www.gassnova.com**

**Gassnova has delivered a study on potential full-scale CCS projects in Norway to the Ministry of Petroleum and Energy.**

The pre-feasibility study shows that several industrial actors could be willing to continue studying the possibilites for CCS. Their interest in participating in a CCS project depends on the framework conditions established by the state.

"Gassnova's pre-feasibility study indicates that it may be possible to realize our ambition of a full-scale CCS demonstration project in Norway," said Minister of Petroleum and Energy Tord Lien. "We will study the report thoroughly and consider how we'll follow up the input from the industrial actors and Gassnova's recommendations."

The Government's ambition is to realize at least one full-scale CCS demonstration project by 2020. This ambition is also part of the Government's CCS strategy, which was presented last autumn.

With progress as outlined in the study, a basis for an investment decision for a CCS project could be presented autumn 2018 at the earliest. The Goverment will now examine the pre-feasibility study and its recommendations, and will provide an orientation in the fiscal budget for 2016.market."

## Mott MacDonald appointed on Peterhead CCS project

**www.mottmac.com**

**Mott MacDonald has been awarded a contract by Shell UK Limited to provide project management organisation services during the front end engineering design (FEED) phase of the Peterhead CCS project in north east Scotland.**

The project, which is part of the UK government's CCS commercialisation programme, involves the capture, compression and transportation of CO2 from the existing Peterhead power station to long-term storage sites deep under the seabed of the North Sea.

The contract, which is already under way, sees Mott MacDonald provide owner's engineer services to Shell for the onshore FEED study phase, as well as technical interface and project management support across the entire end-to-end CCS chain.

This contract supports a core team of five Mott MacDonald employees throughout the two-year project duration, with a larger part-time team of up to 30 staff during peak periods to support the various engineering disciplines and project roles required to deliver the overall scope.

David Brown, Mott MacDonald's project director, said: "We are delighted to be working on this world-leading project, which builds on our relationship and knowledge from previously working with Shell on the Longannet CCS project. This appointment helps reinforce Mott MacDonald's dominant position in this emerging energy sector."

The consultancy's commission is due to be completed in 2015.

## Jacobs providing technical advice to support DECC

**www.jacobs.com**

**Jacobs Engineering Group's Consultancy business has been awarded a contract by the Department of Energy and Climate Change (DECC) to provide technical advisory services to DECC's Office of Carbon Capture & Storage (OCCS).**

Under the terms of the contract, Jacobs is providing an assessment of the agreed deliverables from two developers of full chain CCS projects as technical advisor to support the delivery of the CCS Commercialisation Programme.

The scope involves review of key technical aspects of the projects including design deliverables, project risks and their mitigation, methodology for quantification of clean energy production, as well as advice on the development of the project contracts with the developers, preparation of the bid evaluation criteria and technical support for evaluation of the bids. The two projects are the Peterhead Project in Aberdeenshire and the White Rose Project in Yorkshire.

The UK CCS Commercialisation Programme has £1 billion capital funding available to support the practical experience in the design, construction and operation of commercial-scale CCS.

# KEPCO's dry sorbent pilot plants

KEPCO has successfully completed the long-term operation of the world's first large scale 10 MW CO2 capture facility. The results will help to reduce the capture costs of CO2 released from thermal power plants.

By Tae Hyoung Eom, Senior Researcher, Carbon Capture, Recycling and Storage Group, Future Technology Research Laboratory, KEPCO Research Institute

*Figure 1 - the 500 MW coal-fired power plant of the Korea Southern Power Co., LTD (KOSPO) located in Hadong where the pilots are based*

**In September 2014, KEPCO's consortium, which is currently leading a dry regenerable CO2 capture technology worldwide, successfully completed the long-term operation of the CO2 capture facility at the Hadong Thermal Power Station in Korea.**

This is the world's first large scale dry regenerable CO2 capture plant integrated with coal-fired power plant for post-combustion and is capable of capturing about 70,000 tCO2/y.

## Background

In March 2013, the Korean government announced that 25 units of new coal-fired power plants will be constructed by 2027 released in the 6th Basic Plan of Korean Government for long-term electricity supply and demand. In such case, coal-fired power plants will account for around 35% based on the peak load of the facilities for electricity generation.

Since the share of coal as a source of electric power generation is increasing, the government confirmed its commitment to reduce CO2 emission by 30% compared to BAU (Business As Usual) by 2020. In an effort to meet BAU's target, Korean government led by Ministry of Trade, Industry & Energy (MOTIE), started the development and demonstration of various CCS technologies to secure commercially available techniques.

KEPCO and KEPCO's five subsidiary power companies have been leading the CCS research, development and demonstration

(RD&D) in Korea. In particular, an eco-friendly dry regenerable CO2 capture technology which uses a solid sorbent developed by KEPCO with the circulating dual fluidized-bed process, developed by Korea Institute of Energy Research (KIER), is one of the advanced concepts for capturing CO2 cost-effectively and energy-efficiently from large stationary CO2 source such as flue gases from coal-fired power plants.

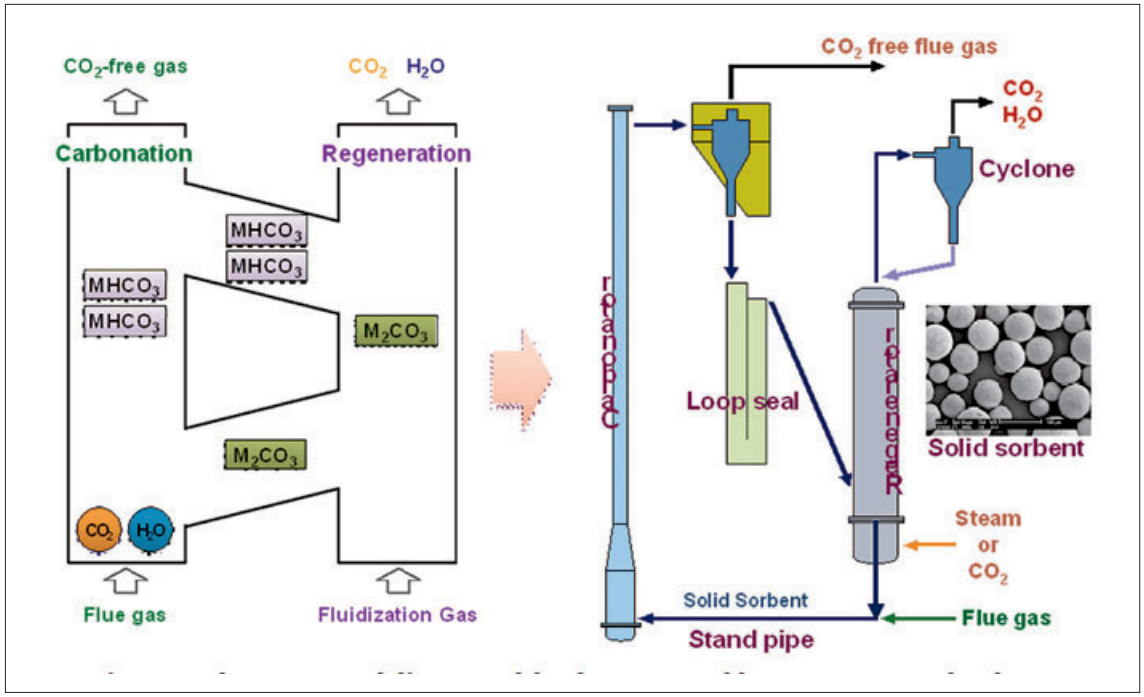



*Figure 2 - the conceptual diagram of the dry regenerable CO2 capture technology*

The capture process consists of two fluidized-bed reactors called as a carbonator (or riser) and a regenerator. In the carbonator, solid sorbents selectively react with CO2 in a flue gas and the CO2 captured-sorbents were transported into the regenerator. In the regenerator, CO2 captured-solid sorbents are regenerated by heat, subsequently releasing high concentrated CO2. In this manner, solid sorbents continuously circulate between the carbonator and the regenerator.

## Overview of pilot plants

From 2002 to 2011, the first stage of this project funded by Ministry of Education, Science and Technology (MEST) was carried out to develop the composition of a sorbent and its production technique, and to evaluate various conditions of a capture process for the 0.5 MW (10 tonnes CO2 per day) facility design.

In 2010, the 0.5 MW dry CO2 test-bed was installed. It used slip-stream of the flue gas from a Unit #3 of 500 MW coal-fired power plant of the Korea Southern Power Co., LTD (KOSPO) located in Hadong, Korea. The second stage was conducted to improve the performance of the solid sorbent and to develop 300 MW Front-End Engineering Design (FEED) based on the construction and operation of 10 MW (200 tonnes CO2 per day) dry CO2 pilot plant for 4-year duration since 2010. The total budget of this project was US$ 40 M and the about half of its budget supported from the government, the Ministry of Knowledge Economy (MKE).

In September 2013, the 10 MW dry CO2 pilot plant was constructed in annex to Unit #8 of the Hadong coal-fired power plant. In December 2014, the new project was launched to aim to improve the performance of the 10 MW dry CO2 pilot plant, to secure the track records for commercialization, and a more than 100 MW FEED development, equivalent to CO2 capture-rate of 100 MtCO2/y.

During the first stage, the conceptual dry regenerable CO2 capture process in the scale of 2 Nm3/h was developed and, in 2006, CO2 removal from simulated flue gas was obtained up to 80% using Na2CO3- and K2CO3-based solid sorbents supplied from KEPCO. In 2008, the bench process in the scale of 100 Nm3/h continuously showed 85% CO2 removal for 50 hours using the K2CO3-based solid sorbent, KEP-CO2P, under the simulated-flue

*Figure 3 - the 10 MW dry CO2 pilot plant*

gas condition.

The 0.5 MW dry CO2 test-bed constructed in March 2010 was operated to evaluate various conditions and to complete basic design of the 10 MW dry CO2 pilot plant by 2012. During this period, KEPCO developed K2CO3-based solid sorbents (KEP-CO2P, KEP-CO2P2 and KEP-CO2P3) and supplied bulk volume to the process developer (KIER) by commercial spray-drying technique.

In March 2012, the 0.5 MW dry CO2 test-bed which uses KEP-CO2P2 showed over 80% CO2 removal and the purity of the regenerated CO2 was over 90% during 30 days campaign and then, in July 2012, 0.5 MW test-bed continuous operation using KEP-CO2P3 sorbent during 2 weeks kept more than 85~90% CO2 removal.

## The 10 MW pilot

Based on these results, a 10 MW dry CO2 capture pilot plant was constructed on Unit 8 of the Hadong power station between October 2012 and September 2013. Main facility was installed next to the Flue Gas Desulfurization (FGD). It is the first and the largest scale facility integrated with coal-fired power plant in the field of dry regenerable CO2 capture technology. The overall aims of this project were:

• to develope a cost-effective and energy-efficient technology aiming at less than the capture cost of $30/tCO2 (2008 USD Basis).

• to operate more than continuous 1,000 hours and to develop 300 MW FEED.

• to improve the durability of a solid sorbent and to optimize the techniques of mass production.

The pilot plant was attempted three times for total 3,400 hours from November 2013 to September 2014. First campaign of the 10 MW dry CO2 pilot plant was operated from November 2013 to May 2014 for approximately 1,800 hours. From 7 July 2014 to 30 September 2014, the second campaign was operated for about 1,600 hours including continuous 1,000 hours operation after modification and fix of the pilot plant based on the results of the first campaign.

During the 1,000 hours operation, the performances showed that the CO2 removal and the purity of regenerated CO2 reached was more than 80% and 90%, respectively.

Based on long-term operation results, the basic conceptual design and FEED in the scale of 300 MW were developed as well as the economic evaluation on the dry regenerable CO2 capture technology (early US$ 50/tCO2).

## The next project

A new project will be carried out from December 2014 to September 2017. The target of this project is to develop the engineering package of the dry regenerable CO2 capture technology for commercialization. The detailed aims are:

• to optimize the performances of the commercial solid sorbent and to develop the mass production process (> 100 tonnes/y).

• to optimize the 10 MW dry CO2 pilot plant and to develop the engineering package (> 100 MtCO2/y) for commercialization.

• to operate long-term (two 160-day campaigns) including two continuous > 1,000-hour campaigns of the 10 MW dry CO2 pilot plant integrated with CO2 compression and purification process for building up the track records.

KOSPO, which is one of the KEPCO's 5 subsidiary power company, with KC Cotrell will operate the 10 MW dry CO2 pilot plant integrated with CO2 compression and purification process developed by DAESUNG Industrial Gases Co. Ltd., and will secure track records of the plant operation. The 10 MW dry CO2 pilot plant will be operated after the overhaul of the Unit 8 power plant by October 2017.

*Figure 4 - the 0.5 MW dry CO2 test-bed*

## Conclusion

KEPCO's consortium has succeeded in operating that the dry regenerable CO2 capture technology is possible as well as realistic. The results will contribute to advance development of the dry CO2 capture technology for commercialization and will help to reduce the capture costs of CO2 released from thermal power plants.

## More information

Tae Hyoung, Eom
Senior Researcher, KEPCO Research Institute
**pantyeom@kepco.co.kr**
**www.kepco.co.kr**

# Capture and utilisation news

## IEA Clean Coal Centre report looks at microalgae for CO2 capture from flue gas

**www.iea-coal.org.uk**

**A new IEA CCC report looks at whether microalgae can be used to remove CO2 from the flue gas of coal-fired power plant.**

Microalgae grow fast and take up CO2 through photosynthesis so they could have a role in CO2 capture. Microalgae have some other advantages which make them suitable for capturing CO2 from coal combustion flue gas:

• They do not need high purity CO2 gas so there is less requirement to separate CO2 from flue gas• Some combustion products such as NOx or SOx can be used as nutrients for microalgae which reduces the need for flue gas scrubbing systems• Microalgae could yield high value commercial products• The process is perceived as a renewable cycle with minimal negative impacts on the environment.

Using microalgae to capture CO2 is a complex process, especially in flue gas environments. There are many factors to consider, such as CO2 concentration, presence of pollutants in the flue gas, the initial inoculation density, culture temperature, light, nutrients and pH; and hydrodynamic parameters include flow, mixing and mass transfer. The growth of microalgae and its tolerance to the environment depends on all the process factors and how they interact.

The choice of microalgae species is also important as it directly influences the photosynthesis efficiency, and so the rate of carbon fixation and biomass production. The best microalgae species for capturing CO2 need to have a fast growth rate, a high rate of photosynthesis, strong tolerance/adaptability to the trace constituents of flue gas, high temperature tolerance, the possibility to produce high value products, and be easy to harvest and process. The economics of CO2 capture can be significantly improved if the algae products can be sold.

Microalgae cultivation can be carried out in open pond or closed photobioreactor systems. Open culture systems are normally cheaper to build and operate, more durable and have a large production capacity compared with large closed reactors.

However, open ponds are more susceptible to weather conditions, and do not allow the control of the culture medium temperature, water evaporation and light. Potential contamination is also a serious threat to the operational success of outdoor open ponds or raceways. Most importantly, they require an extensive land area and consume large amounts of water.

In contrast, closed system photobioreactors have more operational stability and condition control. But the capital and operating costs are higher and are barriers to the mass cultivation of microalgae.

Technologies are available to harvest, process and produce valuable products from microalgae. Most of the existing technologies are adapted from those already in use in the food, biopharmaceutical and wastewater treatment sectors and have not been developed specifically for algae production. As a result they are inefficient and require a large amount of energy. The economics of carbon fixation by algae could be improved by work in this area.

Selecting energy efficient harvesting and processing methods and high value strains to produce commercially sound applications is also a key to promoting capture of CO2 by microalgae. Flue gas transport is another issue. Keeping algae cultivation systems close to the CO2 source is one solution to avoid the cost of building long pipelines. But, microalgae cultivation requires a large land area. For new power plants to use microalgae bio-fixation as a CCS approach, a site with land available for large scale cultivation would be needed. This land requirement could be a problem for existing power plant.

Another potential advantage of the bio-CCS approach is the combination of CO2 fixation, biomass production and wastewater treatment. The nitrogen and phosphorous compounds in wastewater can be used by some algae strains.

In her latest report for the IEA Clean Coal Centre, Microalgae removal of CO2 from flue gas, Xing Zhang found that the CO2 fixation rate of microalgae tends to be too low to compete with conventional CCS methods. Using flue gas to culture algae is more applicable to the production of high value products than CO2 fixation. Power companies will only be willing to invest large amounts of capital, land and water if the microalgae products can be sold at a good price. Algae companies are almost ready to bring their bio-carbon capture and utilisation efforts to the marketplace as a viable alternative to conventional CCS. They need a large, constant amount of CO2 for the technology to work. However, those strains which can thrive under flue gas conditions do not often have a high commercial value. If algae companies have to pay the power companies to reuse the flue gas, they may not have the motivation to produce low value algae biomass just for the purpose of endorsing CCS. Therefore, it is very important for algae companies and power companies to form a win-win partnership to share the costs and profits.

It is clear that using microalgae to capture of CO2 is technically feasible and has economic potential. But before cheap, efficient photobioreactors become available, algal capture of CO2 is better viewed as a means of providing high value end products rather than as a direct competitor to conventional CCS technology.

The report Microalgae removal of CO2 from flue gas CCC/250 by Xing Zhang, 95 pp May 2015 is available for download from the IEA Clean Coal Centre Bookshop. Residents of member countries and employees of sponsoring organisations can download the report at no charge after a one-off registration.

## CO2 Solutions announces successful start-up of demonstration plant

**www.co2solutions.com**

**The 10 tonnes per day (tpd) CO2 capture demonstration project at Salaberry-de-Valleyfield, Quebec has undergone successful first commissioning.**

The solvent has been run through the system and all controls and equipment are responding according to design parameters. As the project was moved forward from its original timeline to run in Valleyfield, training of operating staff was accelerated and concluded on May 15th .

The facility has been configured for autonomous operation, meaning the unit has been adapted to produce its own heat and flue gas from a natural gas-fired boiler. CO2 is captured from the flue gas, and subsequently stripped from the solvent using hot water

generated by the boiler. The flue gas produced by the boiler is the same type as produced by a Once Through Steam Generator (OTSG) employed in oil sands and heavy oil extraction, ensuring test data will be relevant for application in the industry.

The operation at Salaberry-de-Valleyfield is scheduled to run for at least 1,000 hours. All test results will be independently reviewed by third parties.

## Carbon Clean Solutions awarded "most promising new technology"

**www.carboncleansolutions.com**

**Carbon Clean Solutions, a company which makes carbon capture solvents based in Mumbai, Berkshire (UK) and Cumming (USA), has won an award for 'most promising new technology' at the 2015 Cleantech Forum Europe, held in Florence.**

The solvent has been tested at the US National Carbon Capture Centre in Alabama, also at Solvay Chemicals in India, and at EON's Maasvlakte carbon capture power plant. It is also being tested at another "large scale capture demonstration" plant which cannot be disclosed currently for commercial reasons.

The company claims that the solvent reduces the thermal energy required for carbon capture by 30 per cent, reduces aerosol emissions by 50 times, reduces foaming to zero, and reduces corrosion by about 20 times.

All this can mean capital costs can be reduced by over 40 per cent, says Aniruddha Sharma from Carbon Clean Solutions - for example by enabling a switch from carbon steel to stainless steel due to lower corrosion rates.

It also means reducing operating costs by over 30%, all leading to carbon capture of under $33 a ton, Mr Sharma claims.

The company has sold a license for the technology to a CO2 capture plant which captures 174 tons of CO2 a day from power plant emissions, which is fed into a chemical plant. The company was previously paying $100 / ton to buy CO2 on the open market, and these costs have been reduced by a third, he said.

The solvent has a 'new chemistry' with a mixture of amines and salts, he says. This means that the reaction goes faster (so smaller equipment is required), and there is less energy required.

## AGL and Air Liquide partner to reduce carbon emissions

**www.airliquide.com**

**AGL Energy Limited (AGL) has partnered with Air Liquide to recover carbon dioxide at its Torrens Island power station site in Adelaide.**

A CO2 recovery plant will be built and operated by Air Liquide at the AGL Torrens site to capture and purify up to 50,000 tonnes of CO2 emissions from the power station's exhaust per year.

Following recovery from the AGL Torrens site, the CO2 will be used in the merchant CO2 market in South Australia, which is currently supplied predominantly from Victoria. The CO2 is typically used in applications such as carbonation of beverages, carbon dioxide snow for the wine industry, waste water treatment instead of using acids, and in public swimming pools.

The Torrens CO2 recovery plant will be the only plant in South Australia to capture CO2 from existing emissions and will be the first plant to capture CO2 from a power station for the CO2 market in Australia.

Construction of the CO2 plant will commence shortly and is expected to be operational by the second half of 2016.

A post combustion capture pilot plant has been operating at AGL's Loy Yang power station in Victoria since 2008, capturing up to 500 tonnes of CO2 per annum. A second plant will be constructed at the site by the end of 2015 which will capture 200 tonnes of CO2 per annum. These plants are part of a carbon capture storage research project with the CSIRO.

## Fabricom and CCS TLM partner on CCS consultancy

**www.fabricom-gdfsuez.co.uk**

**www.ccstlm.com**

**CCS TLM and Fabricom have formed a strategic alliance to deliver integrated, full value chain services and solutions to the CCS sector.**

CCS TLM has been working to deliver commercially advantaged CCS value chains for more than a decade and has brought together a team of experienced experts whose capabilities include pre, post and oxy-fuel capture of CO2. The team has developed projects using partially depleted oil fields (with Enhanced Oil Recovery, EOR), gas fields and saline formations as storage sites.

Previous project experience of the CCS TLM team includes: White Rose (UK), ROAD (Netherlands), Teesside Low Carbon Project (UK), ZeroGen (Australia), DF1 (Scotland), HECA (USA), DF3 (Australia) and HPAD (UAE).

CCS TLM was incorporated in 2010 to provide carbon capture & storage (CCS) consultancy while Fabricom is the UK Oil Gas and Power Business Line of GDF Suez Group.

The immediate plan is to provide CO2 solutions in the UK and Europe.

# Transport and storage news

## DNV releases data to enhance CO2 pipeline safety

**www.dnvgl.com**

**The DNV GL led CO2PIPETRANS joint industry project (JIP) has just released a third batch of valuable experimental data that will greatly assist in the design process of CO2 pipelines.**

To assess the consequences of an accidental release from a pipeline, computer models for gas dispersion are used. To-date, such computer models have had little or no CO2-specific validation due to the lack of relevant experimental data.

The data made available by the CO2PIPETRANS JIP can be used to validate computer models used in CO2 pipeline design, thus strengthening the design process.

"The data and associated material made publicly available by the CO2PIPETRANS JIP will enable CO2 pipelines to be designed using more robust computer modelling which will lead to reduced design conservatism

whilst maintaining acceptable levels of safety", says Hamish Holt, Senior Principal Consultant at DNV GL.

The data being released this week is the third batch of experimental material that has been publically shared by the CO2PIPETRANS JIP. It was collected at the DNV GL Spadeadam test site in the UK in 2013 as part of the second phase of the CO2PIPETRANS JIP.

The data was collected during a programme in which liquid phase CO2 at initial pressures up to around 100 barg was released through release holes ranging in diameter from 25mm to 150 mm (1 – 6 inches). The data and other material that support the use of the data can be downloaded freely from DNV GL's website (www.dnvgl.com/ccus).

Also available from this website is the first batch which includes release and dispersion data from liquid and supercritical CO2 releases through holes with diameters up to 25mm (1 inch), and the second batch which includes data from long pipe depressurisation experiments.

The CO2PIPETRANS JIP has also undertaken experimental work to improve knowledge and data availability within the important subject areas of CO2 pipeline propagating crack prevention and corrosion rates with various CO2 stream impurities.

The CO2PIPETRANS JIP consists of 15 partner organisations: Arcelor Mittal, BP, DNV GL, Endesa, ENI, Eon Ruhrgas, Gassco, Gassnova, Health and Safety Executive (HSE) UK, Maersk Oil, Petrobras, Petroleum Safety Authority (PSA) Norway, Shell, V&M Deutschland, and Vattenfall.

The DNV GL recommended practice 'DNV-RP-J202 Design and Operation of CO2 Pipelines' will be updated to reflect the new knowledge to help ensure the highest standards of safety are delivered in transporting CO2. This recommended practice is one of a number widely-adopted industry guidelines developed by DNV GL for CO2 handling which cover: CO2 capture, CO2 wells and storage, and CO2 safety.

## Can carbon dioxide be stored safely offshore?

**www.eco2-project.eu**

### Research Project ECO2 presents approach for a sound environmental risk assessment of sub-seabed CO2 storage.

Storage of carbon dioxide in the offshore sea bed as part of a Carbon Capture and Storage (CCS) strategy is often discussed as a means to reduce further the increase of carbon dioxide to the atmosphere. Funded by the European Union, the ECO2 project developed recommendations for the selection and monitoring of submarine storage sites as well as an approach to a sound environmental risk assessment (ERA).

27 partner institutions from nine European countries cooperated in the project that has been coordinated by GEOMAR Helmholtz Centre for Ocean Research Kiel from May 2011 to April 2015. The outcome of ECO2 helps to adjust CCS regulations and to operate sub-seabed CO2storage sites more safely.

A broad variety of experts from 27 institutions in nine European countries investigated possible risks of marine carbon dioxide capture and storage (CCS) and their consequences.

The work of the multi-disciplinary consortium was coordinated at GEOMAR Helmholtz Centre for Ocean Research Kiel and funded by the European Union within its 7th framework programme with 10.5 million Euros.

During expeditions to the Norwegian storage sites Sleipner and Snøhvit and to several natural CO2 seepage sites (e.g. Aeolian Sea, Barents Sea, North Sea), ECO2 scientists identified possible pathways for CO2 leakages, monitored seep sites, traced the spread of CO2 in bottom waters and studied the responses of benthic animals and plants to CO2. Their results and conclusions are compiled in a guide for the selection and monitoring of storage sites that has now been presented to the European Union.

ECO2 developed a generic approach for estimating consequences, probability and risk associated with sub-seabed CO2 storage based on the assessment of the environmental value of local organisms as indicated for example by the Natura 2000 network of nature protection areas or the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), the vulnerability of environmental resources and possible impacts on them as well as consequences and risks.

The major new element of this approach is the "Propensity to Leak Factor" which has been developed by ECO2 combining a compact description of the storage complex and heuristic techniques accommodating for the large number of parameter uncertainties. "It is not possible to simulate all relevant geological features, processes and events with reservoir modelling software currently available", Todd Flach, principal research engineer at DNVGL explains. "We therefore found a way to realistically estimate how likely a storage complex is to leak."

For site selection, ECO2 recommends to avoid geological structures that may serve as conduits for formation water and gas release, geological formations containing toxic compounds and low-energy hydrographic settings with sluggish currents and strongly stratified water column. Also, storage sites should be established distant to valuable natural resources or areas in which biota is already living at its tolerance limits.

Based on its extensive field programme, ECO2 recommends that overburden, seabed, and water column should be monitored with 3-D seismic techniques, high-resolution bathymetry or backscatter mapping of the seabed, hydro-acoustic imaging of gas accumulations and outlets, video and photo imaging, chemical detection of dissolved CO2 in ambient bottom waters.

"Most of the monitoring technology is available or developed and will soon become state-of-the-art", Klaus Wallmann, coordinator of the ECO2 project, points out. According to the ECO2 consortium, additional targeted studies have to be conducted if formation water or gas seeps and if pockmarks with deep roots reaching into the storage formation occur at the seabed.

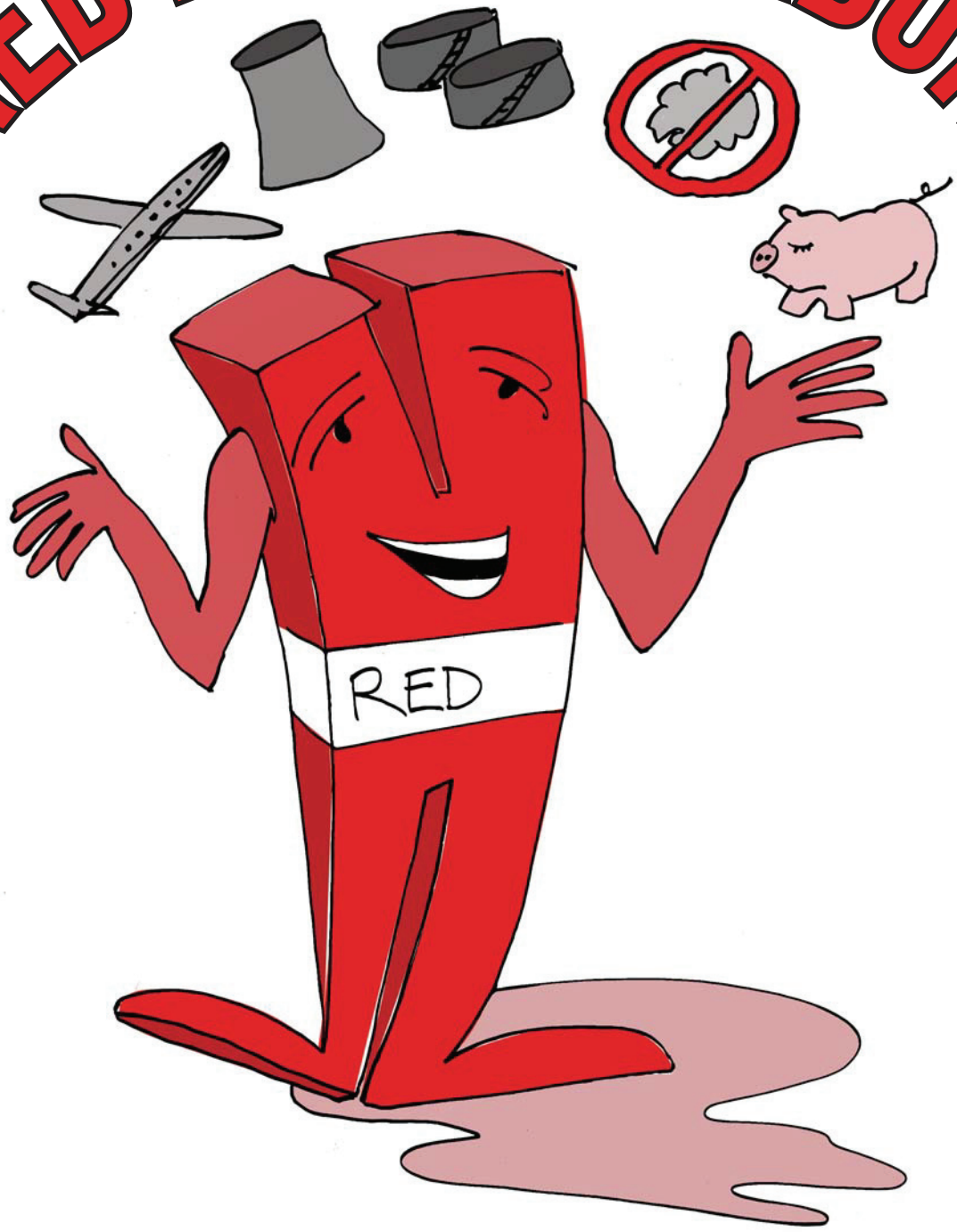
Wallmann: "It is important to check emission rates of gases and fluids and make sure that seepage is not invigorated or pockmarks are re-activated by the storage operation."

"Geophysicists, geologists, biologists, geochemists, oceanographers, legal experts, social scientists and economists worked closely together to create a multi-layered assessment of sub-seabed CO2 storage", Wallmann summarizes.

"We hope that our results help to update and adjust existing CCS rules and to develop new regulations. The knowledge we have gained is also very useful for companies planning or realizing CCS. And it can help to substantiate the discussion about CCS."

Carbon Capture Journal

# RED HYDROCARBON

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