RESEARCH

PROGRESS AGAINST KEY CHALLENGES

As stated in the CRC Funding Agreement, key challenges facing CCS are:

- identification of suitable storage sites
- the cost of separating CO_2 from flue gases
- addressing public concerns
- establishing an effective regulatory regime.

IDENTIFYING SUITABLE STORAGE SITES

Successful experiments conducted at the CO2CRC Otway Project as part of Stage 2B, and those planned as part of Stage 2C, are particularly important to establishing saline aquifers for CO_2 storage. To date, reliable data on the extent to which CO_2 can be residually trapped in saline aquifers has been lacking. CO2CRC Otway Project experiments seek to fill this gap in knowledge. Given that much of Australia's storage potential is believed to be in saline aquifers, this work is especially important if CCS is to play a major role in making deep cuts in Australia's emissions.

THE COST OF SEPARATING CO_2 FROM FLUE GASES (CAPTURE)

Work has continued at the laboratory and pilot scale into a range of capture options and CO2CRC is increasingly confident that costs will decrease significantly. While the UNO MK 3 process continues to show promise for a range of post-combustion capture (PCC) options, especially in the power generation sector, recent testing of membranes both in the laboratory and in the field, as well as laboratory testing of adsorbents, have raised confidence that these technologies may be prospective as third generation capture technologies.

One of the great challenges facing CCS is the extent to which it can be retrofitted to existing power stations. A range of recent assessments by CO2CRC support the argument that carefully selected, designed and operated capture systems that are tailored to the needs of particular end-users and sites can be competitive for retrofit. This finding could have important economic implications for the uptake of CCS.

ADDRESSING PUBLIC CONCERNS

During the reporting period, CO2CRC continued to provide information about CCS to the media in Australia and overseas. Nine media releases were issued and followed up with journalist briefings, media interviews, letters to editors, articles and provision of images for general, industry and CCS publications. The releases contributed to 174 published stories that mentioned CO2CRC, up from 110 the previous financial year.

CO2CRC maintained effective community consultation at the Otway Project, including through publications, events, public meetings and site visits.

The CO2CRC website is a comprehensive central point for information on CCS and the Cooperative Research Centre (CRC). The website provides information on CCS and CO2CRC research and access to CO2CRC publications, videos and downloadable images. CO2CRC also engages in social media through a live newsfeed, a LinkedIn group and Twitter account (@CCS_Research). CO2CRC tweets CCS news daily and has more than 770 followers.

ESTABLISHING AN EFFECTIVE REGULATORY REGIME

Stage 2B of the CO2CRC Otway Project and the planning and approvals for Stage 2C have contributed to the development of effective regulations for CCS. Experience gained at the Otway Project has been used directly by Victorian instrumentalities, particularly the Environmental Protection Authority and Southern Rural Water, to guide their regulatory processes.

RESEARCH PROGRAM SUMMARY

PROGRAM 1: STORAGE OF CO_2

Program Management: Dr Matthias Raab, Storage Program Manager

The CO2CRC Storage Research Program focuses on understanding fundamental mechanisms of geological carbon storage resources in saline aquifers in Australia and worldwide. The Program comprises 10 major research projects and associated sub-projects that involve a range of applied research projects to develop suitable technologies and strategies for managing CO_2 injection and storage. Projects are based in the field – at the CO2CRC Otway Project – in laboratories and via desktop studies.

Commercial geological storage projects in Australia will require storage formations to store millions of tonnes of CO_2 a year. Safe and permanent geological carbon storage in saline formations relies on dissolution, residual saturation and ultimately mineral trapping of CO_2, all within the bounds of a permitted storage complex. Stage 2 of the CO2CRC Otway Project focuses on the interplay between various trapping mechanisms during CO_2 migration and the resulting changes to the subsurface through a series of complex experiments. While surface and well-based seismic have been demonstrated to be key storage surveillance technologies, the full capabilities and limitations of seismic will be further developed through detailed migration monitoring in 4D and demonstration of plume stabilisation during the Otway Stage 2C experiment.

Significant resources from across the storage program were committed to the comprehensive feasibility study of the Stage 2C experiment. The work detailed geological characterisation, assessed the likelihood of fault activation, determined the sealing properties of the main faults, and addressed uncertainties in the spread of the CO_2 plume. Design optimisation has increased the likelihood of seismic detection and gas monitoring in 4D. International peer reviews and industry-led due diligence were conducted and the CO2CRC's Program Advisory Committee endorsed the project in May 2013. Substantial additional funding has been obtained to execute the project over the next five years.

A final investment decision for Stage 2C is expected to be made by the CO2CRC Board in November 2014. The CRC-2 well will be recompleted in February 2015, followed by the installation of a dense grid of 1,100 buried 3D geophone array over one square kilometre for high resolution CO_2 plume monitoring. The first baseline seismic survey is scheduled for April 2015 and the injection of 15,000 tonnes of Buttress CO_2 will commence in early December 2015. From then on, until 2019, the plume will be monitored by 3D seismic surveys. The seismic sources will be provided by the National Sequestration Laboratory, funded under the Australian Government's Education Investment Fund scheme (EIF).

CO2CRC has been contracted by Callide Oxyfuel Services Pty Ltd to perform a geochemistry test and inject approximately 11 tonnes of captured Callide CO_2 at the CO2CRC Otway Project site, including trace amounts of sulphur oxides and

'SIGNIFICANT RESOURCES FROM ACROSS THE STORAGE PROGRAM WERE COMMITTED TO THE COMPREHENSIVE FEASIBILITY STUDY OF THE STAGE 2C EXPERIMENT'

nitrogen oxides. The geochemistry test is the first part of the Stage 2B Extension test. The second part of the experiment, also referred to as the Reservoir Characterisation Test, will entail the injection of 100 tonnes of CO_2 and is partly a repetition of the Otway Stage 2B test conducted in 2011. This part of the test will provide a measure of the repeatability and accuracy of the characterisation measurements. It will also confirm that CO_2 was successfully injected into, and remains in, the formation, at what residual saturation level and at what distance into the reservoir.

In total, the Stage 2B Extension experiment entails the cumulative injection of approximately 130 tonnes of pure CO_2 gas in various stages, with and without tracer level impurities/noble gases, into the existing perforations in Paaratte Formation via the wellbore CRC-2. The experimental part at the CO2CRC Otway Project site will be executed from 1 October to 24 December 2014.

CO2CRC leads the New South Wales (NSW) Darling Basin CO_2 Storage Study to support the efforts of the Division of Resources & Energy, within the NSW Department of Trade and Investment, Regional Infrastructure and Services, to identify and characterise a viable subsurface site within the Darling Basin to form the CO_2 storage component of the integrated Delta Demonstration Project. The study is tightly linked with the NSW drilling program and involves the geological characterisation of the target area, dynamic injection and plume migration modelling, geomechanical evaluation and geochemical analysis and modelling. The work will conclude in October 2014.

CO2CRC was awarded $51.6 million for CCS research infrastructure, a project known as CCSNET, under the Australian Government's EIF. The majority of funds will go toward assets dedicated to research relevant to geological carbon storage. CCSNET assets will support research and technology development related to the CCS Flagship projects in Australia, (the CarbonNet Project in Victoria and the South West Hub Project in Western Australia).

CCSNET has three major components:

- OSL: The Otway Subsurface Laboratory (Stage 3 of the CO2CRC Otway Project)
- GippNet: The Gippsland Monitoring Network, including assets for atmospheric, seismic and marine monitoring
- LabNet: The Australian CCS Research Laboratories Network, with assets for CO_2 capture and storage research.

The Otway Subsurface Laboratory will support Stage 3 of the CO2CRC Otway Project; $23 million has been allocated to test a risk-based 'above-seal-monitoring' program at the CO2CRC Otway Project site. The concept is to develop and test cheaper alternative CO_2 monitoring methods. By monitoring between horizontal boreholes above the geological seal, downhole seismic and electromagnetic methods for near continuous surveillance of the storage formation can be tested, substantially reducing the need for costly repeat surface or marine seismic. The conceptual design study for this experiment will be available in early 2015. Additional co-investment for operating the Stage 3 project from financial year 2017–18 onwards is required.

The first stage of the CO2CRC Otway Project has been documented and published in the book *Geologically Storing Carbon: Learning from the Otway Project Experience*, which details Australia's first demonstration of deep geological storage of CO_2. One of the most comprehensive books written on the topic, it describes the CO2CRC Otway Project's organisational, operational, governance, and decision making processes, as well as the scientific insights gained over the period 2003–13. And it clearly shows that CO_2 storage is a safe, credible, long-term option for reducing greenhouse gas emissions.

PROGRAM 2: CAPTURE OF CO_2

Program Management: Professor Dianne Wiley, Capture Program Manager

The CO_2 Capture Research Program focuses on the research, development and deployment of technologies that can achieve cuts in capture costs of up to 80 per cent and provide Australia with a research and education capability to support industries using these technologies. A framework of economic evaluation is used to measure and validate research directions and integrates with energy-production systems, transport networks and storage infrastructure.

Our capture research consists of research activity at three levels – basic laboratory research, pilot scale demonstration projects, and future large-scale designs. The objective of all projects in the capture research program is to lower the cost of CO_2 capture by reducing the energy penalty associated with capture, as well as by improving the different capture technologies.

In 2013–14, the solvents and engineering research teams focused on testing the CO2CRC UNO MK 3 precipitating solvent system, which is based on potassium carbonate. The University of Melbourne's laboratory mini-plant, part-funded by Australian National Low Emissions Coal Research & Development (ANLEC R&D) was used to characterise the fundamental performance of different components of the solvent system with synthetic flue gas under different operating conditions.

A range of methods for removing impurities (especially sulphates and nitrates) was assessed. The majority of the experimental laboratory research was completed in December 2013. Meanwhile, the pilot-scale facility in the Latrobe Valley, co-funded by Brown Coal Innovation Australia (BCIA), was used to establish the performance of the solvent system with real flue gas under different operating regimes, absorption columns and column packings. The field trials were completed in the first half of 2014.

Ongoing research is focused on using data from both plants to develop and validate simulation models for use in the design of larger plants. Engineering assessments are investigating the integration of the solvent system to new build and retrofitted black coal-fired, brown coal-fired and natural gas power plants. By integrating the capture process with a power station, CO2CRC has estimated that the energy use for this system should be reduced by at least 25 per cent compared to commercial monoethanolamine (MEA) systems.

The membrane research teams are developing new materials and systems for CO_2 separation, including assessing the use of membrane systems in conjunction with a cryogenic system. Our technique for production of ultra-thin membranes using continuous assembly of polymers synthesis has resulted in membranes that at small scale have the necessary combination of selectivity and permeability suggested to be economic for large-scale implementation. We also now have three high flux hollow fibre membranes that look attractive for PCC applications and are being trialled in the field. A commercial spiral wound membrane has been tested in the field and shown enhanced performance when wet. Our integrated silica metal oxide membrane for separation of CO_2 from hydrogen is displaying promising results and stability.

The adsorbents materials and process teams have expanded their rapid screening tool for PCC of CO_2 for pressure swing adsorption and temperature swing adsorption. Further development of chabazite materials for CO_2 separation from natural gas continues to deliver promising outcomes. Polyethyleneimine (PEI) materials have been successfully pelletised and are being produced in sufficient quantity for larger scale laboratory testing. The pelletisation process has been patented by Monash University.

Assessment of a hybrid adsorbent/cryogenic system is showing encouraging possibilities for PCC of CO_2.

Our capture field facilities in the Latrobe Valley have received fewer visitors in the past year compared with previous years. Visitors have included delegations from the Australian Institute of Energy, BCIA, BDH Korea, CarbonNet, Malaysian Universities, Hokkaido Shimbun Press, the National Institute for Clean and Low Carbon Energy in China and students from The University of Melbourne.

During 2013–14, the capture, economics and engineering research teams jointly produced 64 presentations, 49 posters, 43 journal articles, 12 major reports and five conference papers.

The UNO MK 3 technology was a highly commended submission for the 2013 IChemE Energy Award.

Dr Rackel San Nicolas was awarded a CO2CRC–CMC exchange fellowship to visit Professor Guy Mercier and his team in the Institut National de Recherche Scientifique Eau-Terre-Environnement in Quebec, Canada, to learn about their unique method of CO_2 sequestration.

Dr Brad Wells was awarded a CO2CRC–CMC exchange fellowship to visit Professor Tom Woo's group at the University of Ottawa, Canada, to learn about their algorithms for generating metal organic framework (MOF) geometries and test their carbon capture potential.

Several of our PhD candidates were also recognised with awards: Joel Scofield won the 2014 Clive Pratt Scholarship; Andri Halim won the 2013 Eugen Singer Award; Anita D'Angelo won 1st prize for the PhD oral presentation at AXAA 2013; and Jinguk Kim won a poster prize at IMSTEC 2013.

PROGRAM 3: FACILITATING CCS

Program Management: Dr Richard Aldous, Chief Executive Officer (CEO)

The aim of this program is to bring together the research and development activities of CO2CRC's capture and storage research and demonstration projects and facilitate the deployment of CCS.

CO2CRC industry participants identified economic assessments of integrated CCS systems based on sound science and research as a high priority. In late 2013, CO2CRC published a simple ranking methodology for CCS projects, outlining a proposed method to rank CCS project options as well as their implementation pathways. This is one of a suite of high-level economic tools that CO2CRC has developed to facilitate CCS demonstration projects. Also published in the reporting period were findings on reducing the cost of CO_2 capture from flue gases using aqueous chemical absorption.

Drawing on the prioritised technical and economic research programs, CO2CRC is positioned to respond to the increasing interest of governments and the finance sector in CCS technologies and systems. Through provision of accurate and high quality technical and economic information on CCS, the CO2CRC economics team at The University of New South Wales (UNSW) assists the work of the Global CCS Institute, National Low Emission Coal Council and other organisations, such as the Clinton Foundation, in encouraging uptake of low emission technologies. This in turn assists the finance and investment banking sectors, as they work with companies to develop bankable projects that will directly contribute to the G8 aim of 20 large-scale CCS projects by 2020. The team has developed a computational economic model to estimate the total cost of CCS (Integrated CCS Economic Modelling or ICCSEM). During the reporting period this model was updated with new cost information.

CO2CRC holds an annual research symposium to bring together CO2CRC researchers, industry and government partners, and the Australian and international CCS communities to share and discuss CCS research and developments. In November 2013, almost 200 delegates came together in Tasmania to network, debate and share their insights about CCS, and to learn about CO2CRC research progress.

CO2CRC provided support for the planning and promotion of the third National CCS Week and National CCS Conference 2014. The biennial event brings together Australian and international experts in climate change and CCS.

CO2CRC publications published during the reporting period are listed in Attachment 1.

'CO2CRC INDUSTRY PARTICIPANTS IDENTIFIED ECONOMIC ASSESSMENTS OF INTEGRATED CCS SYSTEMS BASED ON SOUND SCIENCE AND RESEARCH AS A HIGH PRIORITY'