TOTAL AND WOODSIDE ENERGY JOIN AS INDUSTRY MEMBERS

CARBON CAPTURE AND STORAGE WORKSHOP FULLY SUBSCRIBED

UPGRADED OTWAY NATIONAL RESEARCH FACILITY ACCOMMODATES MORE VISITORS AND PROVIDES MORE EDUCATIONAL EXPERIENCES THROUGH GCCSI SUPPORT

EXPERIMENTAL CAPTURE RIG DEPLOYED AT VALES POINT POWER PLANT IN NSW

STANFORD AND CAMBRIDGE UNIVERSITIES JOIN AS RESEARCH PARTNERS
In order to limit global warming to 2°C we must employ all available technologies.
OUR FLAGSHIP STAGE 3 STORAGE RESEARCH PROJECT IS NEARING A FINAL INVESTMENT DECISION. THIS IS OUR LARGEST PROJECT TO DATE, AIMING TO DELIVER HIGH RESOLUTION, ON DEMAND CO2 PLUME MONITORING CAPABILITIES AND EARLY WARNING SOLUTIONS FOR INDUSTRY AND REGULATORS. IT WILL ENSURE CO2 MONITORING IS COST EFFECTIVE AND CONTRIBUTING TO CCS’S PLACE IN A LOW CARBON ECONOMY.
Late in this reporting period CEO, Tania Constable, informed us that she would be leaving CO2CRC to head up the Minerals Council of Australia (MCA). Tania led CO2CRC for 3.5 years, achieving significant milestones in this relatively short period. Her tenure saw an increase in membership and the groundwork laid for acquisition of funding for the Otway Stage 3 project. Tania fostered mutually beneficial relationships with all partners and will be missed. We wish her all the best in her challenging new role.

Our flagship program, Stage 3 Storage Research Project, is nearing a final investment decision. This is our largest project to date, aiming to deliver high resolution, on demand CO₂ plume monitoring capabilities and early warning solutions for industry and regulators. It will ensure CO₂ monitoring is cost effective and contributing to CCS’s place in a low carbon economy.

Lack of progress on energy and emissions policy remains a challenge for all. However, promising opportunities are arising out of innovations such as the Hydrogen Energy Supply Chain (HESC) project. This aims to produce hydrogen from Victoria’s Latrobe Valley coal and export it to Japan. If commercialised, the project will use CCS to produce a near carbon neutral fuel. CO2CRC is pleased to be contributing expertise to the project. Internationally, we are heartened to see promising CCS developments in the United Stated and Norway. These and HESC are both promising indications for wider application of the technology, which will likely lead to cost reductions in deployment.

2017/18 saw public interest and awareness of CCS technology grow, as demonstrated by close to 300 visitors to the CO2CRC Otway National Research Facility throughout the year. Our annual open day continues to gather momentum, with 70 visitors taking the opportunity to participate in 2017. In 2018 this experience will be enhanced with the vibrant new deck at the Visitor’s Centre providing a fantastic outdoor space. This was made possible by a very much appreciated grant from GCCSI.

CO2CRC’s membership numbers are strengthening. We warmly welcome new research members Cambridge University and Stanford University along with industry members Total E&P Rescherche Developpement and the return of Woodside Energy.

In October 2018, close to 1000 delegates descended on Melbourne for the 14th International Conference on Greenhouse Gas Control Technologies (GHGT-14). CO2CRC played a key role in organising and hosting this event. The option to visit the Otway National Research Facility post-conference booked-out, with 140 people taking up the offer.

Operation of the Otway National Research Facility would not be possible without the continued support of the surrounding communities and the partnership of landholders upon whose properties we operate. We owe a great deal of thanks to these stakeholders.

We aim to foster similar levels of confidence in the Gippsland community as we oversee the deployment of the Gippsland Monitoring Network, GipNet. This project is verifying environmental monitoring technologies and methods ahead of potential CCS projects in the region.

Of course, none of this is possible without the hard work and expertise of the CO2CRC board and staff, working together to ensure CO2CRC remains a leader in CCS research.

Martin Ferguson AM
Chairman

David Byers
CEO (from 23 July 2018)
CUTTING-EDGE SCIENCE AND A SCENIC EXPERIENCE ARE ALL PROVIDED AT THE OTWAY NATIONAL RESEARCH FACILITY. THE STRIKING MODERN DESIGN AND PRACTICALITY OF THE NEW VISITOR CENTRE DECK PROVIDES A REFRESHING OUTDOOR SPACE TO COLLABORATE AND ENJOY THE SURROUNDING NATIVE GARDENS.
ENGAGEMENT, OPERATIONS AND MAINTENANCE

SITE VISITS AND VISITOR CENTRE UPGRADE

The Otway National Research Facility welcomed nearly 300 visitors in 2017/18, consisting of partners, scientists, contractors and interested community members. Ensuring visitors feel welcome and comfortable is important to CO2CRC. To enhance this experience, the Visitor Centre’s parking, outdoor viewing and working area were all recently upgraded.

An attractive garden of indigenous Australian flora is now growing with a shelter belt of local species behind the Visitor Centre. The new garden is in keeping with the surrounding environment as well as providing the centre with much needed wind protection.

An eye-catching entry wall now provides shelter to visitors viewing the site from the deck and an extended roof enables this area to be utilised in all conditions. Building work, design and landscaping was all undertaken by local companies with funding provided through a grant from the Global CCS Institute.

This year, visitors included representatives from Japan Electric Power Civil Engineering Association, the International Organisation for Standardisation, Moyne Shire Council, Woodside Petroleum, University of Texas, Stanford University, Cambridge University, Shizouka Gas, NICE and BHP.

In October 2018, 140 international CCS experts visited the site in conjunction with the Carbon Storage Leadership Forum and the international GHGT-14 Conference. During this period, Melbourne was the focus of the global carbon capture and storage community. With the assistance of the Global CCS Institute, CO2CRC have invested in interpretive signage across the site that provides detailed scientific and engineering facts on key components of the facility’s infrastructure. These signs are particularly useful for tours with larger sized groups.

OPERATIONS AND MAINTENANCE

Site operator, Upstream Production Solutions, continue to provide outstanding service. Their introduction of a new on-line induction system has enabled visitors to undertake inductions prior to site visits, making their time at the facility more productive.

Over summer, CO2CRC undertook maintenance on a 1km² buried seismic array. This involved excavation of sections of eleven 1km long lines of buried fibre optic cable and geophones on the properties of surrounding land owners. This work, undertaken primarily by the array’s manufacturer, has allowed corrections to some faults. With about 20 percent of the array replaced, the team are ready for upcoming seismic surveys that will be undertaken as part of the Stage 3 campaign, including signals generated by Surface Orbital Vibroseis (SOVs).

As in the above example, much of CO2CRC’s operations are undertaken on private land. Access to this is obtained through the goodwill of neighbouring farmers. A special thanks is owed to these landholders for their cooperation and assistance.
LOCAL ENGAGEMENT AND SUPPORT

Work with the local Nirranda and Nullawarre communities continues to be a high priority for CO2CRC. Community Reference Group meetings are chaired by Councillor Colin Ryan from Moyne Shire Council, featuring reports on recent activities and those planned for the following period. Apart from the local community, the meetings are frequently attended by regulators and other government representatives.

Further informing the community, newsletters were distributed to thousands of local households in October 2017 and March 2018 providing updates on the research occurring on site and other interesting and useful information about CO2CRC.

The November 2017 Open Day was one of the most successful to date, with 70 members of the community participating in tours of the wells and capture facility, expertly guided by CO2CRC staff. Children had the option of participating in science-based activities in the Visitors Centre or burning off some energy on an inflatable slide. Those attending enjoyed a gourmet barbeque lunch from the Nullawarre Primary School parents club. Participants at the Open Day included members of the local community, people from nearby regional cities and towns, families and individuals. A small bus was provided for visitors from Melbourne to reach the site, with this option enthusiastically accepted by interested university students.

CO2CRC values the local community and provides support where possible. This year uniforms for the Nirranda Football Netball Club netball teams were sponsored. Many rural areas in South West Victoria were dramatically affected by the Saint Patrick’s Day bushfires, with local CFA brigades groups, including the Nirranda South CFA, and local landholders heavily involved in the firefighting efforts. The facility was thankfully not impacted by these bushfires. Following the fires, CO2CRC reached out to the Nirranda South CFA to see what equipment may benefit their operations. On that basis, a generator for the unit’s new water trailer was donated.

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RESEARCH AT SITE

SEISMIC SURVEY

In February and March 2018, CO2CRC undertook a seismic survey on 15 properties surrounding the Otway National Research Facility. The survey, the fifth since the commencement of the injection in 2016, was completed using a combination of geophones and fibre optic sensors in the wells and seismic buried array. In association with Sercel and Curtin University, operations to repair sections of our 1km² seismic array were undertaken over the summer with the cooperation of four neighbouring landholders. CO2CRC is grateful for permission granted by landholders to undertake these unanticipated maintenance works that involved reopening trenches to obtain access to sections of the array. Completion of this work enabled quality data to be obtained from the seismic survey.

Favourable relationships with our local landholders and the expertise developed over recent years by our partner Curtin University have ensured that the seismic surveys required for the finalisation of Stage 2C have run smoothly, with an additional parcel of land added to the most recent survey.

SHALLOW CO₂ MIGRATION

CO2CRC’s collaborative project with Geoscience Australia, to model and demonstrate movement of CO₂ vertically through a surface fault, is progressing well with site work set to commence in 2019. CO2CRC will drill an appraisal well across Brumby’s Fault, collecting core to confirm the injection location and obtain the information necessary to obtain regulatory approvals. An electromagnetic survey is proposed.
in late 2018, followed by equipping the area immediately surrounding the fault with piezo bores to monitor groundwater surrounding the research site. A better understanding of CO₂ migration in faults will assist with designing targeted monitoring strategies for storage sites.

**OTWAY STAGE 3 STORAGE RESEARCH PROGRAM**

Stage 3 of the Storage Research Program involves a $50 million investment in additional monitoring wells and related infrastructure to test and refine non-invasive monitoring techniques that satisfy regulator and community expectations. The Stage 3 project aims to deliver high-resolution, on demand monitoring capability and an early warning solution for industry and regulators.

In the lead up to a drilling program, in principle agreements have been signed with landholders for wellpads, SOV installation and gathering line extension.

Stage 3 requires the construction of a gathering line, installation of a number of Stationary Orbital Vibrators and building a second well pad on the land of neighbouring farmers. Preliminary negotiations with those directly affected by the infrastructure required have been positive with a new well pad planned to be located on privately owned land to the East of Sodas Lane.

**STAFFING**

Site Operations Manager, Rajindar Singh, was fondly farewelled this year, retiring after eight years with the organisation. Kwong Soon Chan, joined CO₂CRC to take up this position, with a wealth of experience from a 25-year international career with Schlumberger and Baker Hughes. KS, as he likes to be known, comes equipped with skills in management, project management, drilling, sales and marketing.
THE CO2CRC CAPTURE PROGRAM CONTINUES TO INNOVATE AND ADVANCE METHODS TO DRIVE DOWN THE COSTS OF COMMERCIAL CAPTURE OPERATIONS.
OTWAY CAPTURE RIG AND TRIALS

Project Leader: Dr Abdul Qader, CO2CRC
Science Leaders: The University of Melbourne and UNSW Australia

The objectives of the capture rig are to:

› Reduce the cost of CO₂ capture from natural gas streams (on shore and off shore).
› Develop robust and compact CO₂ capture technology in a modular design for natural gas separation.
› Test pilot scale second generation capture technologies.

Continuous operation of the state-of-the-art high-pressure capture rig at the Otway National Research Facility has resulted in a significant milestone for CO2CRC. The rig has been used to bench mark data using commercially available materials for both membranes and adsorbents. This work forms the basis for comparison against laboratory tested materials that will be trialled on the rig.

These advanced materials, developed by The University of Melbourne and University of New South Wales (UNSW), are expected to show substantially enhanced performance. Some of those previously only tested in the laboratory are:

› New adsorbents with enhanced kinetics by ion-exchange, developed by The University of Melbourne. Laboratory experiments demonstrate three times faster adsorption than commercial adsorbents.

› Continuous assembly of polymers membranes and ultrathin composite membranes developed by The University of Melbourne are expected to give 30 per cent higher permeability than commercial membranes.

› ZIF/Pebax based hollow fibre composite membranes from UNSW are expected to give orders of magnitude higher permeance.

These materials, as well as others, will be tested using real Butress gas. This provides a testing environment against impurities present in real natural gas. The facility will further accommodate testing the effects of impurities, like H₂S, by mixing it within the gas.

The high-pressure capture rig is unique. It is flexible enough to provide a range of feed compositions ranging from 10 to 79 per cent CO₂ in natural gas, thereby mimicking various field compositions. Results obtained from the capture skid are likely to be used in scale-up engineering work and applied to commercial-scale natural gas facilities.

If successful, this type of capture rig would open opportunities for high CO₂ content natural gas reserves, which would remain undeveloped if relying on conventional processes.

This facility, in line with CO2CRC’s capture strategy, offers a flexible capture technology testing base for members and fee-for-service customers. The rig’s unique properties will deliver opportunities for international collaboration. A leading oil and gas company has already signed up to use the capture skid in late 2018 to test a range of their technologies.
PCC AT VALES POINT, NSW – MEMBRANE-SOLVENT CONTACTOR

Project Leaders: Dr Abdul Qader and Dr Jai Kant Pandit, CO2CRC
Science Leaders: The University of Melbourne

Coal Innovation New South Wales (CINSW) has provided CO2CRC with $1.22 million to test new capture technologies at the Vales Point power station, NSW.

Researchers from The University of Melbourne are collaborating with CO2CRC to test advanced membrane-solvent contactors to capture CO₂ from the plant’s flue gas. This novel approach aims to capitalise on the best of both membrane and solvent technologies by being compact and demonstrating higher separation kinetics than membranes alone. It has the promise to dramatically reduce the capture plant’s footprint, compared to conventional solvent-based systems while having comparable separation efficiency thereby reducing capital and operational costs.

The membrane contactor process incorporates the absorption of CO₂ from the flue gas into the solvent and the regeneration of the solvent. It uses membrane in both cases, resulting in a rich CO₂ product stream. Commercially available membrane modules will be tested to see if they are of sufficient capacity to ensure successful CO₂ capture and solvent regeneration. This innovative technology has two features - absorption and desorption, both using membrane modules.

The project will establish the viability of commercial membrane contactors for both applications and provide the necessary data to enable design scaling to support large-scale membrane contactor processes for CO₂ capture. The project commenced in 2016 and will be completed in 2019.

The project will trial membrane contactors on a pilot plant to evaluate their performance and provide the necessary information to assist in future scaling of the technology. The objectives are to:

› Develop a novel, compact and hybrid carbon capture technology for coal fired power plants.
› Reduce the cost of capturing carbon from flue gases in coal fired power plants.

CAPTURE RETROFIT STUDY IN LATROBE VALLEY

Project Leader: Dr Abdul Qader CO2CRC

A capture retrofit study was undertaken at a Latrobe Valley power station during the year. The study investigated whether it would be technically feasible for several full-scale, solvent-based capture systems to be installed on the specific site (with an acceptable power generation impact). This resulted in the development of technical specifications, construction requirements and performance predictions.

Crucially, this retrofit study was conducted using non-proprietary MEA solvents and the proposed new design has been found to be applicable in Latrobe Valley.

The study also found that the maximum power output of retrofitted units need not be compromised, since the capture plant can be temporarily taken off-line during periods of high demand. There is also the option of an extra gas turbine to provide additional output.

Australia is perfectly placed to make use of CCS technology with selected coal plants suitable for retrofit, vast reserves of fossil fuels and excellent CO₂ storage sites. It also enables coal fired power stations to introduce value-added projects like hydrogen from coal.

It is to be noted that the owners of the reference plant provided technical information and expertise in relation to the power station to facilitate this study, but the report does not imply that it should be retrofitted with PCC.
OTHER CAPTURE RELATED PROJECTS UNDER CO2CRC

STEEL INDUSTRY FOCUS

The capture program is undertaking additional initiatives to expand its focus beyond the energy sector. A technical study proposal, with the support of Blue Scope steel has been submitted to Coal Innovation NSW (CINSW). The study will seek to examine how emissions can be cut in steel production, particularly through CCS. This project will explore the pathways for reducing CO₂ emissions from a steel plant, utilising exhaust streams that contain carbon monoxide and CO₂.

In March 2018, the Asian Development Bank engaged CO2CRC for its expertise in promoting CCS to developing countries. This will yield a report on sources of CO₂ in iron and steel industries and opportunities for capture. The study also involves collecting data on the potential growth of the steel industry in member countries and predicting emissions based on manufacturing inputs and techniques. Importantly, the report will prepare a determination of CCS readiness for the steel sector.

NEW INNOVATIVE PROJECT IDEAS IN CO₂ UTILISATION

Talks are underway with three Australian universities regarding CO₂ utilisation research that includes:

› Carbon negative biodegradable plastics, bio-graphene and biofuels from lignocellulose. CO₂ utilisation to convert biomass into value added chemicals.

› High dispersion catalysts for CO₂ conversion to fuel and chemical products after energy efficient “internal” heating assisted CO₂ capture via adsorption processes (di-electric, induction and ohmic heating).

INTERNATIONAL COOPERATION IN CAPTURE AREA

CO2CRC is a member of the International Test Centre Network (ITCN), participating in international meetings to share technological knowledge, construction/operational experience, establish generic performance indicators and promote technology standardisation for CCS. Current members include the US National Carbon Capture Centre (NCCC); the Norwegian Technology Centre Monstad; CSIRO Australia; the UK CCS Research Centre; the Canadian CCS Knowledge Centre, SINTEF in Norway, CERI in China and KIER in Korea. Participation in the network confirms CO2CRC’s place as a global CCS research and development leader.

EXPANDING CAPABILITY

As an outcome of expanding capture work, CO2CRC plans to develop a strong in-house process modelling capability. This capability will underpin the engineering scale-up needed from data obtained from capture facilities and enable development of new projects in line with CO2CRC’s business model.
STORAGE PROGRAM

Testing how geological features can most efficiently and safely be used as CO2 storage sites is a critical part of CO2CRC’s research. A clear focus on reducing the cost of monitoring this process is crucial to the competitiveness of CCS.

The storage program is executed under four themes of research priority:

- Geological Integrity
- Engineering Storage
- Fit-for-Purpose Monitoring and Verification (M&V)
- Geochemical Engineering
High quality data is producing excellent images of the plume, helping achieve the project’s core objectives, to:

› Detect injected CO₂ in the subsurface and ascertain minimum seismic detection limit.

› Observe the gas plume development using time-lapse seismic.

› Verify stabilisation of the plume in the saline formation using time-lapse seismic.

Research partners Curtin University, CSIRO and Lawrence Berkley National Laboratories continue interpreting incoming data, with results allowing the understanding of the behaviour of the injected CO₂. With the final active seismic survey undertaken in Feb – Mar 2019 along with continuous pressure monitoring, this project is well on track to demonstrate stabilisation of a CO₂ plume in an open saline formation, the first of its kind internationally. Importantly for our partner organisations, this body of research will provide a validated workflow for verifying plume behaviour in saline formations.

Key findings/developments to date:

› A broadly applicable workflow of procedures to predict, monitor, verify and assure CO₂ storage in saline formations.

› Established technical limits of various seismic technologies to detect and monitor CO₂.

Planned for next period:

› Analysis of all time-lapse seismic data and integration with pressure data to determine whether the plume has stabilised.

› Analysis of results of seismic acquisition design, processing and interpretation methods for the monitoring of CO₂ migration and leakage detection for Otway which may lead to workflows for other CCS projects.
FAULT SEAL INTEGRITY CHARACTERISATION
RESEARCH & DEVELOPMENT

Geological Integrity

Project Lead: Fiona Koelmeyer, CO2CRC
Science Lead: Eric Tenthorey, CO2CRC / Geoscience Australia

The Fault Seal Integrity Characterisation Project refined a technical workflow that provides a mechanical understanding of fault zone properties when limited or no observational fault data is available. This workflow uses various mechanical properties of rock to understand the potential behaviour of faults during CO2 injection and storage. It predicts key fault properties to reduce risk and uncertainty at a given CO2 storage site. Data, models and samples from the Otway National Research Facility were used to undertake this work.

Core from the CRC-2 well has been characterised in terms of the rock’s strength and frictional forces. This core data was successfully transformed to log scale. For fault-intersecting wells, in which core is not acquired, this predictive work provides the necessary fault properties to assist in determining safe injection and operating parameters.

Key findings:
› Demonstrated the value of scratch testing to provide a detailed, high resolution understanding of rock strength.
› Development of a rock strength proxy which is able to be applied to other well logs to allow quantification of fault cohesion properties.

OTWAY PROJECT – STAGE 3
FIT-FOR-PURPOSE MONITORING AND VERIFICATION (M&V)

Engineering Storage

Project Lead: Paul Barraclough, CO2CRC
Science Lead: Dr Charles Jenkins, CO2CRC / CSIRO

CO2CRC is developing fit-for-purpose monitoring technologies that aim to provide on-demand key information on CO2 storage sites with minimal surface impact. This technology will deliver substantial cost savings in future storage site monitoring design.

The Otway Stage 3 Project is the next major undertaking at the Otway National Research Facility, where up to four new wells will be installed and equipped with cutting-edge downhole seismic and pressure monitoring equipment. A trial injection of CO2 will be used to validate these subsurface monitoring approaches on the resulting CO2 plume. Primary monitoring methods being evaluated are pressure tomography and downhole seismic, with other monitoring modalities and techniques also being investigated as added components to the base design where possible.

In 2017, CO2CRC successfully drilled the CRC-3 well, an appraisal well for the Otway Stage 3 Project. The 1,667 metre well demonstrated clear pressure communication between itself and the CRC-2 well, providing strong evidence to the success of demonstrating pressure tomography in the future Stage 3 operation.

Subsequent formation evaluation work stemming from the CRC-3 well has led to selection of the injection interval for the Stage 3 Project and provided the necessary key data for modelling the future distribution of CO2, constraining the design of the future injection and monitoring operation.

Key findings to date:
› Refined reservoir models provide greater certainty on plume prediction and the effect of reservoir uncertainties on plume shape and migration path.
› Pressure tomography has evolved as M&V technique with significant progress made to where it can be applied to the Stage 3 reservoir model and the complex geology of the Otway Site.
› Further monitoring well locations are being tested using the reservoir models and the M&V models.

Planned for next period:
› Peer review workshops will test the science behind pressure tomography methods, the development of the reservoir model and its ability to predict the Stage 3 plume. Also tested will be well design, well layout and the M&V operational plans.
› Stage Gate – ‘Define to Execute’
› Drill and log the four monitoring wells in the first half of 2019 and install the downhole completion for all five project wells.

OTWAY PROJECT – STAGE 3
FIT-FOR-PURPOSE MONITORING AND VERIFICATION (M&V)

Core from the CRC-2 well has been characterised in terms of the rock’s strength and frictional forces. This core data was successfully transformed to log scale. For fault-intersecting wells, in which core is not acquired, this predictive work provides the necessary fault properties to assist in determining safe injection and operating parameters.

Key findings:
› Demonstrated the value of scratch testing to provide a detailed, high resolution understanding of rock strength.
› Development of a rock strength proxy which is able to be applied to other well logs to allow quantification of fault cohesion properties.
The project utilises a multiscale workflow developed in a parallel ANLEC R&D project to address the impact of small-scale geological heterogeneity on static and dynamic rock properties.

**Phase 1 focused on:**
- Building an integrated CT image data set with calibrated static and flow properties from 40 meters of core, from key intervals of interest in the Otway 3 well.
- Generating core parameters, including permeability and relative permeability for various reservoir rock types.
- Performance of in situ imaging of CO₂: brine fluid distribution and contact angle on samples at reservoir pressure and temperature, plus sensitivity and uncertainty analysis of core parameters.

**Phase 2 will:**
- Upscale static data to whole core scales and calibrate the model to well log data.
- Use solvers that honour the physics of dynamic flow and geological heterogeneity at scales up to whole core.
- Generate core parameters at whole core for fluid trapping curves and other key parameters such as relative permeability.

**MULTI-SCALE FLOODING DYNAMICS OF OTWAY**

**RESEARCH & DEVELOPMENT**

**Engineering Storage**

*Project Lead: Fiona Koelmeyer, CO2CRC*

*Science Lead: Prof Mark Knackstedt, CO2CRC / Australian National University*

This program intends to demonstrate the importance of using realistic and multi-scale geological structures to increase confidence in models of CO₂ flow prediction.

The CO2CRC Otway Stage 3 Project requires accurate predictions of the plume movement within the storage reservoir.

However, small-scale geological features and heterogeneities have a significant impact in the subsurface that cannot be directly incorporated into field scale simulation models because of limitations in computer speed.

These small-scale heterogeneities can now be accounted for via an integrated multiscale workflow.
PASSIVE SEISMIC AND SEISMIC INTERFEROMETRY

RESEARCH & DEVELOPMENT

Fit-for-Purpose M&V

Project Lead: Fiona Koelmeyer, CO2CRC Science Lead: Dr Stanislav Glubokovskikh, CO2CRC, Curtin University

This project plans to leverage learnings gained in the Otway 2C Passive Seismic Monitoring project to drive down the community impact and cost associated with conventional seismic monitoring.

Permanently deployed seismic receiver arrays lead to a significant reduction of long-term monitoring costs and site access requirements. Further gains could be achieved through reductions of the active seismic source effort through the use of seismic energy from ambient noise and other passive seismic sources.

Information about plume movement and its pressure front could also be gained through analysis of the seismic response to injection. The Otway Stage 3 Project is uniquely positioned to provide such a data set to test concept feasibility, on account of its closely spaced distributed acoustic sensor (DAS) -equipped wells.

PREDICTION AND VERIFICATION OF SHALLOW CO₂ MIGRATION

RESEARCH & DEVELOPMENT

Fit-for-Purpose M&V

Project Lead: Fiona Koelmeyer, CO2CRC Science Lead: Dr Andrew Feitz, CO2CRC / Geoscience Australia

This project, operating at the Otway National Research Facility, seeks to characterise the near-surface, to design, execute and operate a controlled CO₂ release and monitoring project, phased as follows:

- Phase 1: Characterisation of the CO2CRC Otway site near-surface, including the identification of a suitable structural control (fault) for CO₂ migration.
- Phase 2 (current): Experiment site appraisal and subsurface sampling.
- Phase 3: Controlled release experiment.

Key findings to date:

- A fit-for-purpose workflow for characterisation of the near surface of a potential onshore storage site has been developed and trialled.
- A work scope for gaining an increased confidence in fluid flow modelling predictions in faults has been developed and will be refined in the appraisal phase for the project.
- Fault behaviour requires research to accurately predict its influence on CO₂ behaviour in the subsurface.

Current industry modelling applications are limited to extensional faults, in which the horizontal transmissibilities are estimated by looking at the degree of fault offset and the associated shale gouge ratio (SGR). This approach proves useful in the oil and gas industry but its application to CCS is limited.

For geological storage of CO₂, the interest is both in identifying fault-bound structural traps, and characterising the risk of vertical gas migration through fault zones. Such migration is often controlled by jogs and bends along the fault that cannot be assessed using SGR type algorithms. Therefore, SGR analysis does not provide useful information on the vertical permeability of predominantly strike-slip faults (i.e. horizontal displacement mainly displacing the same formation against itself).

Faults are typically modelled as a simplified vertical plane rather than as a heterogeneous structure composed of variable permeability elements, as observed in fault outcrops. This project will provide data to enable increased accuracy in the modelling of migration through faults compared to the representation of faults as single plane structures applied conventionally.
MARINE M&V METHOD DEVELOPMENT
RESEARCH & DEVELOPMENT

Fit-for-Purpose M&V
Project Lead: Fiona Koelmeyer, CO2CRC
Science Lead: Dr Andrew Ross, CO2CRC / CSIRO

An Unmanned Surface Vehicle (USV) is being tested to verify it’s effectiveness in monitoring off-shore carbon storage sites.

The USVs offer uninterrupted monitoring activities for up to 12 months at sea at low cost.

Key deliverables to date:
Two sail drones were received in February 2018. The Saildrone team and the United States’ National Oceanic and Atmospheric Administration arrived in Hobart in March and worked with CSIRO staff to setup and test USVs and sensor calibrations.

USV testing commenced in March with a mission to Maria Island’s carbon mooring, and comparative side-by-side testing with the RV Investigator sensors. All tests so far have shown exceptionally good data quality and the ability to control sail drone movements.

A USV is currently mapping the Eastern Australian Convergence zone in Bass Strait prior to deployment off the coast of Gippsland.

GEOCHEMICAL BARRIERS FOR ENHANCING CONTAINMENT
RESEARCH & DEVELOPMENT

Geochemical Engineering
Project Lead: Fiona Koelmeyer, CO2CRC
Science Lead: Prof Ralf Haese, CO2CRC / The University of Melbourne

The Enhanced Containment through Barrier Formation Project is developing mechanisms that create a barrier to assist with CO₂ containment in a storage reservoir.

Experiments at The University of Melbourne have shown evidence of the formation of precipitates. This offers insight into the reactive barrier formation mechanism. However, these results are formative, and a number of challenges remain.

Applicability of these laboratory experiments under reservoir conditions is being addressed currently by numerical simulation, using the reactive transport program, TOUGHREACT.

Key findings to date:
› A low-cost reagent and its respective action has shown to form a barrier gel. The barrier is formed when the reagent comes in contact with supercritical CO₂ or CO₂-enriched water. Laboratory experiments show a reduction in permeability of two orders of magnitude caused by the reactive barrier.

› Simulations have use reactive barrier formation at top of injection interval as a diverter of CO₂ leading to slower migration which is expected to result in increased residual trapping.
CCSNET DELIVERS A RESEARCH INFRASTRUCTURE NETWORK INTENDED TO PROVIDE VITAL COMPONENTS OF AUSTRALIA’S EMISSIONS REDUCTION RESEARCH INFRASTRUCTURE OVER THE NEXT DECADE.
Significant findings to date are:

› Modelling results show CO₂ residual trapping can be significantly enhanced by heterogeneity. Residual saturations approach 60% for samples showing the most heterogeneity within 5mm cubic sub-volumes. Residual trapping is enhanced when the heterogeneity is in the form of laminations running perpendicular to the flow direction.

› The new pore network model enables realistic exploration of the sensitivity of residual trapping to contact angle of the grains. It shows that an increase in contact angle from 20° to 40° reduces residual trapping by approximately 25%, while at 60° the trapping capacity is reduced by half.

› Traditional measures, such as variability in porosity or anisotropy in permeability, are not necessarily the best indicators to quantify heterogeneity. It is more variation in pore size and pore throat size which influences relative permeability and flooding endpoints.
FLUID FLOW AND GEOCHEMISTRY LABORATORY

This laboratory at The University of Melbourne examines the impact of contaminants on CO₂ storage, and trials various corrosion-resistant materials. Trialling of injected CO₂ with impurities is necessary to better understand the potential role of impurities for long-term CO₂ storage.

Research into developing subsurface barrier technologies to mitigate potential CO₂ leakage has also been conducted. A procedure has been developed leading to a precipitation of a gel in the pore space once the given reagent comes in contact with CO₂.

Significant findings to date:
› Reduction in permeability of up to three orders of magnitude has been observed in core incubations using the multi-phase core flood facility.
› Research using the single-phase core flood facility and water analysers investigated opportunities to enhance injectivity in reservoirs with low permeability through dissolution. Results showed an enhancement in permeability in siliciclastic reservoirs is minimal using conventional acids of pH 2 and bases of pH 12 and does not lead to a significant increase in injectivity.
› Using water analysers and a gas mass spectrometer, this research investigates the geochemical reactivity of reservoir and seal rocks under CO₂ storage conditions. It includes minor amounts of impurities such as SO₂, H₂S, O₂ and NO₂. The results show barely detectible differences in water composition following the injection of CO₂ compared to CO₂ with minor concentrations of impurities.

CAPTURE ANALYTIC EQUIPMENT AND LABORATORY (CAEL)

At Federation University, the CAEL focuses on reducing capture system degradation and plant corrosion by examining samples of chemicals built up in an experimental capture plant attached to an electricity power plant in Latrobe Valley. The laboratory is uniquely positioned given its location only a few kilometres from the capture site. This in-field research provides an opportunity to recommend how different materials may be used to reduce or halt corrosion of capture plant components.

Significant findings to date:
› Continued on-the-ground collaboration with CSIRO using a pilot capture plant on a brown coal power station using novel solvent/contactor systems.
› Progressive development of an analytical method specifically tailored to the unique combination of contactor conditions afforded by Australian brown and bituminous coals.

DYNAMIC CCS MODELLING PLATFORM (DCCSMP)

The DCCSMP is a comprehensive system-wide modelling platform built to study the full CCS value chain. It allows for analysis and decision-making by multiple stakeholders in a capture project, including the emissions producer. The computer software for the model has been installed and is currently being configured to meet the needs of the research objectives.

The capture plant, compression system, transport network and storage site are all examined as part of this model. The platform will seek to prove technical efficiencies which can be applied at post-combustion sites in Australia and around the world. The result will be cost savings embedded in the design and construction of the CCS plant.

OTWAY SUBSURFACE LABORATORY (OSL)

The OSL, which accounts for 40 percent of the EIF grant, will provide the infrastructure to undertake research activities associated with CO2CRC’s Otway Stage 3 Monitoring and Verification Project.

Significant progress on the OSL took place during 2017-18, including interpretation of the formation evaluation results of CRC-3, and detailed planning and design for the injection and monitoring wells CRC-4, CRC-5, CRC-6 and CRC-7.
The multiple interfaces between the research teams and other parties required for the delivery of project objectives, mean that effective stakeholder engagement is essential. Hence, a dedicated Gippsland-based Stakeholder Engagement Officer commenced in October 2017.

Key activities during 2017–18:

› Completion of a project risk assessment.
› Regulatory pathway review.
› Instrumentation site evaluation and installation.
› Implementation of the stakeholder engagement strategy.

CO2CRC, together with GipNet research partners, have fostered good relationships with local councils, regulators, authorities, landowners and marine operators. This has enabled the smooth deployment of assets for the monitoring network.

GipNet research projects utilise assets funded by the Commonwealth of Australia under the Education Investment Fund (EIF). The operational costs of GipNet research projects are funded by ANLEC R&D with substantial in-kind contributions by CSIRO, The University of Melbourne, University of Wollongong and CO2CRC.

Foundation work undertaken by CO2CRC ahead of research commencing includes business case development, project scoping, development of a stakeholder engagement strategy, public land access facilitation, and commencement of risk assessment, regulatory review and securing of stakeholder engagement resources.
Dr James Johnson
BSc (JHons), PhD

Dr Johnson is a geologist with over 30 years’ experience, including private sector mining and mineral exploration. He has led teams of geoscientists for over 20 years with a range of diverse achievements. These range from discovery of over 2 million ounces of gold reserves in industry, to national scale pre-competitive geoscience programs that have attracted exploration investment to Australia.

Dr Johnson first joined Geoscience Australia in 2006 and in that time has been head of various divisions with diverse duties including carriage of energy and mineral programs. He has also been a member of the Board of the CO2CRC since 2014 and the National Computational Infrastructure (NCI) at the Australian National University since 2017.

Dr Johnson was appointed as CEO of Geoscience Australia in 2017.

Special responsibilities:
Member of Program Advisory Committee

Martin Ferguson AM
BEc (Hons)

Mr Ferguson joined the Company as Chairman in 2014, bringing decades of experience working with the resource sector from a government and private sector perspective.

Mr Ferguson served as the Member for Batman from 1996 to 2013 and held a variety of Shadow Ministerial portfolios including Resources and Energy.

Upon the Rudd Government’s election in December 2007, Mr Ferguson was appointed Minister for Resources and Energy, and Minister for Tourism, positions he held until March 2013.

During his time as Minister, he oversaw Australia’s largest ever investment in the oil and gas sector, and the rapid expansion of the mining sector.

Post politics, Mr Ferguson holds a number of positions in the oil and gas industry, including Group Executive in Natural Resources at Seven Group Holdings, Non-Executive Director of the BG Board, and Chairman to the APPEA Advisory Board.

Special responsibilities:
Chairman of the Board, Chairman of Appointments and Remuneration Committee

Tania Constable PSM
MInt Law, MBA, Grad Cert Econ

Ms Constable was chief advisor in the Personal and Retirement Income Division of Treasury, working on tax-related matters. Prior to her work at Treasury, she held senior resources and energy roles in the Department of Industry. Ms Constable was the Head of Resources for more than four years. She had responsibility for policy advice to the Minister for Industry on oil and gas regulation, exploration and development, and mining activities.

During her time Ms Constable also had the privilege of being the Australian Joint Commissioner and Sunrise Commissioner for Australia and Timor Leste leading joint activities on the development of the Joint Petroleum Development Area and Greater Sunrise Project. She was awarded the Public Service Medal in 2014 for outstanding public service in the development of Australia’s Liquefied National Gas and other resource and energy industries.

Special responsibilities:
Chief Executive Officer until July 2018

Special responsibilities:
Member of Appointments and Remuneration Committee
Mr Walton joined the Company board in November 2014 as a research sector representative. He is the Director, Energy Research Initiatives, at Curtin University’s Office of Research and Development in Perth, WA.

With a professional background in corporate communications, government policy and strategy, Mr Walton has worked in science administration and resources development within the Western Australian Government’s minerals and petroleum, and science and innovation portfolios.

Previously he has worked in a diverse range of areas including conservation education, natural resources management, policy and regulation, heavy industry and port logistics.

Mr Walton is a Board member of the Western Australian Energy Research Alliance which oversees a joint venture in offshore oil and gas research engagement between CSIRO, Curtin and the University of Western Australia. The National Geosequestration Laboratory is also managed by the Alliance. He has been a Board member of the Centre of Renewable Energy in Sustainable Transport (CREST), the Parker Centre CRC for Hydrometallurgy and the Australian Centre for Natural Gas Management.

**Special responsibilities:**
Chairman of Operations, Safety and Environment Committee, Member of Appointments and Remuneration Committee

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**Brian Kitney**
GAICD, MBA, MA

Mr Brian Kitney has over 25 years industry experience in oil and gas in Australia and Asia. He has held senior industry positions including Vice President Commercial at Osaka Gas Australia, having spent nine years in the company. As head of the Commercial team, based in Perth, his primary responsibilities included managing the company’s upstream investments in Australia and Papua New Guinea, Australia, he held the position of Vice President Commodities at JP Morgan Securities Japan, based in Tokyo. Mr Kitney has also held senior positions at Apache Energy Ltd and Mitsui & Co (Australia) Ltd. He was previously a Director of a number of Osaka Gas subsidiaries as well as evaluating new investment opportunities. Prior to joining Osaka Gas.

**Special responsibilities:** Member of the Finance, Risk and Audit Committee

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**Mick Buffier**
BE (Civil) (Hons) from The University of Sydney, MBA from The University of Newcastle

Mr Buffier is responsible for Sustainable Development and Industry Relations for Glencore’s coal assets, a role he took on following Xstrata’s merger with Glencore in May 2013.

Mr Buffier has more than 30 years’ experience in the coal mining industry. Appointed Group Executive, Xstrata Coal in March 2009, he was responsible for Corporate Affairs, Government Relations and Sustainable Development across Xstrata’s global coal operations.

From 2002-09, he was Chief Operating Officer of Xstrata’s NSW coal mining operation.

Mr Buffier is the former Chairman and a current Director and member of the NSW Minerals Council (NSWMC), a Ministerial appointee to the NSW Coal Innovation Council, a Director of the Australian Coal Association Low Emission Technologies Pty Ltd (ACALET) and ANLEC R&D.

On an international level, he is a former Chairman and current Vice Chairman of the World Coal Association (WCA) and an Associate of the International Energy Agency (IEA) Coal Industry Advisory Board (CIAB).

**Special responsibilities:** Member of Finance, Risk and Audit Committee
Dr Fiona Wild  
Bachelor and PhD degrees in Chemistry (resigned 20 Sept 2018)

Dr Wild has over 20 years’ experience in the oil and gas industry, working in both frontline and corporate roles. During that time she has worked with BP in the United Kingdom and Australia before joining BHP in 2010. In her current role as Vice President, Climate Change and Stability, she leads the design and implementation of BHP Billiton’s climate change strategy and is also accountable for the company’s public policies on sustainability issues.

Dr Wild brings extensive academic and business experience dealing with climate change, carbon capture and storage and related operational and policy issues, and is also a Director of IETA and a member of the Financial Stability Board’s Task Force on climate related financial disclosures, reporting to the G20.

**Special responsibilities:** Member of Appointments and Remuneration Committee

Bill McKenzie  
BE (Chem) Hons, FICHEM, CEng, RPEQ, MAICD

Mr McKenzie is a chartered chemical engineer with significant experience across oil refining, coal bed methane developments and conventional oil & gas developments.

After 16 years with BP in refining, he joined Origin Energy in 2008 where he led their Oil & Gas Division’s safety, engineering and operations functions before becoming General Manager Technical in 2010.

In 2011 he became accountable for APLNG’s Upstream CSG operations as General Manager Qld CSG. In 2013 he joined QGC becoming Vice President Developments in 2015. With the Shell acquisition of BG Group in 2016, Mr McKenzie joined Shell as General Manager QGC Development and is accountable for Shell’s exploration, appraisal and development activities in eastern Australia.

Mr McKenzie has previously served as a member of the editorial panel of the Institute of Chemical Engineer’s Loss Prevention Bulletin and has been appointed as a Fellow of the Institute of Chemical Engineers.

**Special responsibilities:** Deputy Chairman of the Operations, Safety & Environment Committee

Fiona Hick  
BEng(Hons), BappSci, FIEAust, MAICD, AFAIM

Ms Hick is responsible for Health, Safety, Environment and Quality (HSEQ) across Woodside, leading corporate HSEQ direction and strategy as well as providing operational support to all parts of Woodside’s global business.

Fiona has over 20 years’ experience in resources across both the oil and gas and mining industries.

She is a member of the Australian Institute of Company Directors, Associate Fellow of the Australian Institute of Management and a Fellow of the Institute of Engineers.

Fiona has held various engineering and business roles across Exploration, Development, Operations and corporate in Woodside. Previous roles include Head of Strategy and Governance for Australia Business Unit, Chair and Director of Pluto LNG’s Burrup Train 1 LNG Pty Ltd and Burrup Facilities Company and Acting Senior Vice President Engineering. Prior to joining Woodside, Fiona worked for a number of years with Rio Tinto both in corporate and site-based roles.

**Special responsibilities:** Member of the Finance, Risk and Audit Committee
GOVERNANCE

The company is privileged to have a Board of Directors who contribute valuable and complimentary skills, exercising critical oversight of the Company’s strategy. Much of the Board’s work is done with the assistance of the four Board sub-committees, which deal with specialist issues and provide recommendations to management and to the Board as required. These committees are:

› The Finance, Risk and Audit Committee
› The Operations, Safety and Environment Committee
› The Program Advisory Committee and
› The Appointments and Remuneration Committee.

The Finance, Risk and Audit Committee and the Operations, Safety and Environment Committee are both chaired by independent experts who compliment the capabilities of Board Directors who are also represented on each of the four sub-committees.

BOARD APPOINTMENTS & DEPARTURES

The Board of Directors remained a consistent group during the year. The resignation of CEO Tania Constable was the only change. Ms Constable completed her service on 23rd July 2018, and Mr David Byers commenced as CEO and a Director of CO2CRC on the same date.

ADMINISTRATION

CO2CRC moved to its current head office in Argyle Place South, Carlton, in July 2017, after the closure of ‘Lab 14’ for redevelopment. The Company continues to sub-let from the University of Melbourne.

NEW BUSINESS

Revenue derived from members is integral in providing a strong foundation for growth. This continues to be an area of continued focus for CO2CRC. During the year Total E&P Recherche Developpement joined the membership, and we were pleased to welcome Woodside Energy back to the membership. The University of Cambridge, and Stanford University joined as research members.

Fundraising for the upcoming Stage 3 CO₂ Storage Management and Subsurface M&V program remained the focus of new business effort in 2018.

LEGAL & COMPLIANCE

The Company remains in good legal standing in relation to all commitments.

HUMAN RESOURCES

Staffing levels remained consistent throughout the year, with few changes in personnel.
Carbon capture and storage is a proven and safe emissions solution that is globally capturing almost 40 million tonnes of CO$_2$ a year, with 220 million tonnes of CO$_2$ already in safe underground storage. Australia is well placed to boost the use of CCS to benefit industry and the community.
Global energy demand continues to grow and fossil fuel use has risen for 25 of the last 26 years, with more coal-fired power generation under construction in China, India and South-East Asia. The global energy mix is unlikely to shift easily or quickly from the fossil energy sources that currently dominate. Carbon capture and storage is a pivotal technology to achieving deep cuts in emissions of carbon dioxide.
CO2CRC acknowledges and appreciates the strong relationships it has with industry, community, government, research organisations, and agencies in Australia and around the world.

BUILDING A LOW EMISSIONS FUTURE

OUR MISSION
Develop carbon capture, utilisation and storage as a socially, technically and commercially viable option for net zero emissions

OUR VISION
To be the safest and most innovative carbon capture, utilisation and storage company in the world

OUR VALUES
Teamwork, Operational Excellence, Integrity, Courage, Transparency

RESEARCH
Australian National University
CSIRO
Curtin University
Federation University Australia
Geoscience Australia
Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences
King Abdullah University of Science and Technology (KAUST)
Korea Institute of Geoscience & Mineral Resources
Lawrence Berkeley National Laboratory (LBNL)
Stanford University
University of Adelaide
University of Cambridge
University of Edinburgh
University of Melbourne
University of NSW
University of Western Australia
University of Wollongong
UK CCS Research Centre

INDUSTRY
ANLEC R&D (on behalf of ACALET)
BHP
Chevron Australia
Coal 21
Global CCS Institute
J-POWER
Shell Australia
Total
Woodside Energy

COMMUNITY
Landowners near Otway National Research Facility
Moyne Shire
Nirranda South

GOVERNMENT
Australian Government: Department of Education and Training
Australian Government: Department of Industry, Innovation and Science
CarbonNet Project
Coal Innovation NSW
Victoria: Department of Economic Development, Jobs, Transport and Resources