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CO2CRC

RESEARCH

PROGRAM 1: STORAGE OF CO_2

Program Management: Dr Matthias Raab
Storage Program Manager

The focus of the CO2CRC Storage Research Program is to understand geological carbon storage resources in Australia and world-wide. The Program comprises nine major research projects and many sub-projects, undertaking a range of applied research projects developing suitable technologies and strategies for managing CO_2 injection and storage. Research is based at the CO2CRC Otway Research Facility in the field, in laboratories and by computer modelling.

A major focus in the storage program is Stage 2 of the Otway Project, researching geological carbon storage in saline aquifers. This includes drilling a new well (CRC-2 well, Stage 2A), defining key factors for estimating storage capacity through residual gas saturation tests (Stage 2B) and determining CO_2 detection limits with seismic acquisition (Stage 2C).

The CO2CRC Otway Research Facility is amongst the most comprehensive storage research facilities in the world. The major focus this year was the execution of the residual gas saturation and dissolution test, also referred as Stage 2B. The CRC-2 well, pivotal to this experiment, was instrumented with state-of-the-art U-Tube technology, high accuracy real time down-hole gauges, a Distributed Temperature Perturbation Sensor, a heating line, and various gas injection/gas lift mandrels.

The 90-day test sequence involved more than 30 scientists from Australia's leading research institutions and partners from overseas. The test sequence included: a) Hydraulic Pressure Tests, b) Organic and Noble Gas Tracer Tests, c) Thermal Test, d) Reservoir Saturation Tests measuring the hydrogen index via pulsed neutron log, and e) a CO_2 Dissolution Test.

After three months of continuous operations, the test sequence was successfully completed in September 2011. The high quality data sets obtained for each sequence were quality controlled and the final interpretations of each phase are expected for 2012-13. The impact of this experiment is not only to provide a new understanding of residual gas saturation of CO_2 in saline aquifers, but also to provide a novel experimental design for the characterisation of CO_2-storage reservoirs utilising a single well for comprehensive and cost-effective testing. This concept can easily be adopted by other CCS projects worldwide.

The monitoring program for the Otway Research Facility continued with the collection, quality control and analysis of data for atmospheric, soil gas, ground water, microseismic and deep reservoir fluid monitoring and sampling. As of January 2012 the sampling frequency had been amended. The atmospheric flux tower and Lo-Flo measurements are being discontinued allowing for extended interpretation of the comprehensive datasets measured continuously for the past four years. Periodic flask measurements continue three times a year and on demand. The frequency of groundwater surveys has been reduced from two surveys to one survey per year. Atmospheric monitoring for the deep water wells and the continuous measurement of CO_2 and CH_4 at the atmospheric station will continue. Soil gas surveys will continue on an annual basis.

The next major experiment planned at the Otway Project is Stage 2C. The experiment aims to test the seismic detection limits of CO_2 in saline aquifers by modelling, injection of 10-30 thousand tonnes of CO_2 into the Paaratte Formation and by seismic monitoring of the plume evolution until the plume has stabilised. The focus this year was on intensive modelling to test the feasibility of the experiment. Modelling will continue well into the next year and involves up to 25 researchers across several projects. A field trial to determine optimal equipment and its configuration for the full experiment was executed and completed at the project site in June 2012.

CO2CRC was announced as Lead Research Organisation (LRO) for the CarbonNet Project. A substantial effort in 2012 was dedicated to the $51.8m EIF submission to the Commonwealth Government for CCS research infrastructure. As LRO, CO2CRC will able to contribute research skills and experience to the project, such as the practical knowledge gained through drilling, injection and monitoring of storage operations at the CO2CRC Otway Project.

A key highlight was the publication by Jenkins et al. (2012) *"Safe storage and effective monitoring of CO_2 in depleted gas fields"* in Proceedings of the National Academy of Sciences (PNAS). The paper summarised key findings of Stage 1 of the Otway Project and not

only attracted a lot of international attention, but also firmly positioned the CO2CRC Otway Project as one of the most significant carbon storage research projects in the world.

Highlights of individual projects are outlined below.

Several journal papers, abstracts and overview papers were published on all topics throughout the year.

1.1 DEVELOPMENT AND OPERATION OF GEOLOGICAL STORAGE RESEARCH FACILITIES, OTWAY PROJECT

Project Leader: Rajindar Singh
CO2CRC, Melbourne

Aim: To provide a world class facility and operations at the Otway Project for use in leading edge CO_2 storage research. Conduct targeted small scale experiments at the Otway Facility to test and evaluate trapping concepts for the storage of CO_2 including non-structural trapping; testing seismic detection limit by small scale injection of CO_2; and effective modeling and monitoring, safe injection and storage of CO_2. Conduct targeted small scale experiments at the Otway Facility, to test and evaluate CO_2 trapping concepts that have been effectively modeled to assure safe injection and storage including well planned monitoring and verification activities.

Research Overview: The CO2CRC Otway Project continues to be developed in stages to be an extensive research laboratory. The site is promising in its capability as its subsurface structure consists of a depleted gas reservoir, unconfined saline aquifers and faults. These structures along with the readily available CO_2-rich Buttress gas from a nearby well provide exceptional opportunities for field-scale storage research to be conducted to study the effects of the injection of significant quantities of CO_2 (up to tens of thousands of tons) into a variety of rock types at a range of depths.

During this reporting period, the following workscope was completed:

The Stage 2B Residual Gas Saturation (Huff and Puff) experiment was successfully completed in a deep saline aquifer and high quality data was acquired. In order to do this, the gas gathering line was extended to a new well, CRC-2, and the site surface facility was upgraded and commissioned. Two prestart audits conducted by external advisors prior to start of operations ensured the plant was well prepared for the test. A multidisciplinary team of scientists and engineers conducted five independent in situ tests over a period of two and half months to acquire the required data.

At the end of the Stage 2B experiment, a controlled release of Buttress gas was conducted during favorable wind conditions, to allow calibration of various atmospheric sensors located on the site.

Two new shallow (forty metre) bores, were instrumented with microseismic sensors, bringing the total to three wells, set in a triangular pattern. This setup provides the capability to significantly assist interpretation of microseismic events and event location.

One short duration trial seismic experiment was conducted to understand signal to noise (S/N) improvement gains by burying discrete seismic sensors and comparing their response to the ones installed at the surface. The depth (1 to 12 meters) at which sensors were buried was also investigated. In addition, data was acquired using a buried fiber optics cable to understand signal quality and subsequent interpretation. Using fiber optics to acquire seismic data is an emerging technology that requires validation. The knowledge gained form this test and the Stage 2B test will be used to prepare for the upcoming Stage 2C experiment.

In previous years, Stage 1 of the program successfully demonstrated secure geological storage of CO_2 in a depleted gas reservoir in the Waarre Sandstone.

Various Measuring, Monitoring and Verification (MM&V) activities were conducted throughout the year specifically, annual soil gas sampling, annual ground water sampling and periodic atmospheric monitoring. Periodic (every six weeks) subsurface samples of the Waarre reservoir using U-tube sampling technology were also taken throughout the year. Most of these activities have been used as inputs to regulatory Key Performance Indicator reporting.

Engagement with local community and regulators continue throughout the project. Various channels to disseminate up-to-date information regarding the project continue to be used to keep the stakeholders informed including direct face to face community reference group meetings, a community newsletter, open days, group site visits and the CO2CRC website. During this period, various newsletters were disseminated; three community reference group meetings were held and one site open day took place.

1.2 OTWAY BOOK

Project Leader: Professor Peter Cook
CO2CRC, Canberra

Aim: Documentation of data and learning gathered during Otway Stage 1

Research overview: This project is not a research project per se, but it aims to summarise the conduct of CO2CRC's most high profile research activity, the CO2CRC Otway Project Stage 1, undertaken from 2004-2012, and the lessons from the Project. There are many papers published on the science undertaken as part of the project, but information on how the project was managed, operational details, information on the regulatory processes, the consultation process and details of some of the physical and chemical methodologies used are seldom discussed in the open literature for the Otway Project or indeed for most other storage projects. This book seeks to remedy that.

The outline of the Otway book has been prepared and agreed with all contributors. As is normal in a multi author book such as this, the pace of compilation is totally dependent on receiving the contributions from the authors. Several sections/ chapters have now been completed; some are well advanced and authors anticipate their contribution to the editor shortly. Authors of some sections have yet to make significant progress because of the demands placed on them by other projects and this is a concern which will need to be addressed in the coming months. Drafting of diagrams has commenced.

One of the important aspects that has yet to be fully addressed is the development of a project database, which can be used more broadly to begin development of a database for CO2CRC as a whole. Progress on this has been held up as a database manager has not yet been appointed. However, Otway datasets are being compiled and already are proving very useful as a template for an external contract for the IEAGHG program which is being undertaken to obtain the learning from all small scale injection projects.

MILESTONES: Because of delays in receiving manuscripts, the book will not be completed by the end of the calendar year. However it will be completed in the 2012-2013 financial year.

1.3 CO_2 STORAGE IN SALINE FORMATIONS—OTWAY BASIN

Project Leader: Dr Mark Bunch
Australian School of Petroleum, Adelaide

Aim: To define and characterise deep saline formations viable to host long-term subsurface storage of supercritical CO_2 within the Otway Basin.

Research Overview: This project seeks to describe the petrophysical and geochemical attributes of the deep saline Paaratte Formation of the Otway Basin. Data acquired at new wells drilled as part of the Otway Project are guiding development of two conceptual models. The first concerns the depositional environment for the succession including the architecture of discrete geological facies bodies that governs storage system performance at the site/ field scale. The second concerns the sequence of important diagenetic changes that overprint otherwise primary petrophysical and geochemical characteristics of the succession. Together these will provide a linked stratigraphic-geochemical model framework to predict chemical and physical responses of this formation to injection of supercritical CO_2 at site/field to basin scales.

In the last year an explicit transform has been developed that relates characteristic response within the Paaratte Formation of a standard suite of open-hole well logs (electro-facies) to core log-calibrated image log facies interpreted at CRC-1 and CRC-2. This provides a way to predict the vertical distribution of key depositional lithofacies that relate to storage system facies modeled previously. In addition to this, the characteristic architectural dimensions of a modern depositional analogue system to that encountered at CRC-2 are being captured in order to simulate the architecture of key injection intervals identified for Stage 2 of the CO2CRC Otway Project.

Microscopic analyses of CRC-2 core samples have identified a sequence of diagenetic cementation events that affected the Paaratte Formation since burial. Organic-rich groundwater leached through the best quality reservoir sandstone soon after burial as a result of high frequency sea level regressions. This led to development of early dolomite and ankerite cements that preserved the primary matrix framework but almost completely removed porosity in these most compositionally and texturally mature reservoir sandstones. Such cementation was limited in the presence of preexisting matrix clay coatings. As a result, the best sandstones available for CO_2 storage today were not necessarily the most promising deposits initially. In addition, this hypothesis rules

out development of thick, pervasive carbonate mineralization in response to migration of the CO_2-rich hydrocarbon fluids that charged local gas reservoirs at greater depth. Reactivity of these dolomite cemented zones with CO_2-rich formation fluid is not yet understood.

1.4 UNDERSTANDING CO_2 STORAGE IN SALINE AQUIFERS

Project Leader: Dr Karsten Michael
CSIRO, Perth

Aim: To better understand the near and far-field effects of CO_2 storage in saline aquifers, both as a basis for evaluating CO_2 impact on other resources and as a basis for effective management of large scale CO_2 storage in saline aquifers.

Research Overview: The initial approach adopted is to review documented aquifer systems in sedimentary basins and to develop a classification system for saline aquifer storage. Analytical models and generic numerical simulations will be employed to assess the difference in storage capacity estimations and injection strategies for various saline aquifer types. Ultimately, a spreadsheet-based tool box will be developed for pre-reservoir simulation screening of saline aquifers with respect to their suitability (capacity, injectivity) for CO_2 geological storage, including the estimation of required injection wells.

A review of sedimentary basins worldwide shows that in many cases a large amount of data, from petroleum and groundwater exploration, exists for characterising aquifers in these basins. The following results were obtained from this review and compiled in a report:

- An assessment of selected saline aquifers worldwide;
- A classification system considering aspects of CO_2 geological storage in saline aquifers;
- A simple screening process to be followed that helps identify potential issues with respect to interaction of CO_2 geological storage with other resources.

For basin-scale assessments of industrial-scale CO_2 geological storage in saline aquifers the most important aspects in addition to general parameters (i.e., average aquifer depth, thickness, area porosity and permeability) are general aquifer contiguity ('homogeneous' versus layered or compartmentalised), pressure boundary conditions (open versus closed system) and spatial relationship to other resource developments in the basin. For such an assessment, analytical tools in the form of equations for calculating injection pressure, radius of impact and storage capacity may be sufficiently accurate in relation to the level of uncertainty at this scale of investigation. If multiple resources (petroleum, groundwater, geothermal, coal) were exploited in a basin, a coarsely discretised basin-scale numerical model may be required for simulating potential resource conflicts.

For individual storage projects from pilot to demonstration scale, comprehensive, finely discretised static and reservoir models are required that account for detailed aquifer heterogeneity and are capable of constraining operational injection parameters (completion intervals, injection rates) within a higher level of confidence than required for basin-scale assessments. Even at this scale, analytical tools can help in quickly producing some first-order results of, for example, maximum bottom hole injection pressure, reservoir capacity and radius of influence, which can form the base and constraints for more detailed numerical simulations.

We have developed new software to predict the injectivity and storage capacity of CO_2 that contains a database of maximum injectivity of saline aquifers. The data are generated from several thousands of compositional numerical simulations for a wide range of formation properties such as formation permeability, relative permeability, porosity, thickness, depth and area. The software is capable of performing Monte Carlo analysis based on the probability distribution of formation properties and different injection rates. Built-in correlations can be used to determine CO_2 and brine properties required for analytical models.

The software also includes new analytical models to predict the injectivity of fully and partially penetrating wells in saline aquifers with solutions for different types of formation outer boundary conditions,

1.5 REACTIVE RESERVOIR ROCKS AND THEIR IMPACT ON CO_2 STORAGE POTENTIAL TRAPPING

Project Leader: Dr Ralf Haese
Geoscience Australia, Canberra

Aim: To better understand fluid-rock reactions during and post-injection and the respective implications for injectivity, containment and opportunities for in situ sealing in case of leakage. This project will assist our predictive capabilities in terms of short- and long-term trapping of CO_2 and the associated risks.

Research Overview:

The project has worked on the following five topics:

1. Geochemical results from the residual gas saturation test (Otway 2B) have been analysed and interpreted in collaboration with reservoir engineers from Project 1.7. The results have been written up as technical reports and scientific articles are currently being prepared. The results proved traditional interpretations derived from laboratory experiments or based on oil and gas exploration procedures are not applicable. One test showed very low recovery of the initially added tracer while the injection of CO_2-saturated water appears to have dissolved significant amounts of minerals leading to enhanced reservoir heterogeneity.
2. The study of naturally occurring CO_2-rich reservoirs in terms of their geochemical and mineralogical characteristics has lead to the submission of two journal articles and a report compiling attributes of international natural analogue examples. The review of international natural analogues has also led to a database where reservoir properties are quantified. Interestingly, the acidic, CO_2-saturated water appears to dissolve minerals primarily from highly permeable layers while mineral precipitation occurs at the boundary or within low permeability layers.
3. A new rig permitting high pressure / high temperature experiments with hazardous gases has been built in order to study fluid-rock reactions controlled by gas mixtures, that is, CO_2 plus SOx, and/or O_2. Experiments commenced in 2011 and show very acidic conditions when SOx is added in accordance with thermodynamic predictions. Intact rock blocks from prospective reservoirs in the Surat Basin (QLD) have been included in the experiments and show very high rates of dissolution. Experiments with CO_2 and SOx are expected to be completed in 2012 and the impacts of CO_2-SOx-O_2 will be investigated in 2013.
4. Three batch reactors have been used in parallel to study the reactivity of individual minerals under CO_2 storage conditions. Reaction rates have been derived for a particular chlorite and changes of reaction rates with time are currently being studied in terms of changes in the dissolution / precipitation mechanisms. In addition, powdered whole rocks have been incubated under CO_2 storage conditions to develop an understanding of the principal reactions expected.
5. Microbial communities from the Paaratte Formation have been sampled during the Otway Project 2B experiment and successfully characterised in terms of the microbial diversity before and after the injection of CO_2. These results are currently written up as a scientific manuscript. In addition, in situ microbial samples have been successfully used in culture experiments in the laboratory. Some cultures have formed biofilms, which is very promising for this project as it aims to research opportunities for in situ microbial barrier formation.

1.6 SEAL GEOMECHANICS & POTENTIAL FOR CO_2 LEAKAGE

Project Leader: Dr Eric Tenthorey
Geoscience Australia, Canberra

Aims: This project aims to understand the circumstances in which faults (and fractures) in mudstone seal rocks will impact on bulk permeability and the flow of CO_2 through these rocks. We also aim to characterise the other geomechanical processes that might result in loss of CO_2 containment.

Research Overview: The research conducted in this project is multi-faceted in that it uses different techniques to answer the questions posed. Detailed 3D geomechanical modeling techniques are used on active field-scale projects, including at the Otway Project, so that issues such as ground deformation and fault/cap rock integrity can be examined.

Fieldwork is also being conducted on natural mudstone outcrops, so that fault and fracture scaling laws and connectivity factors can be quantified. Finally, a multi-disciplinary seismic-based project on the Gippsland Basin is being done as part of a PhD thesis.

In the 2011-2012 year, a significant amount of work was done on the structure and geomechanics of the Paaratte Formation in advance of the Stage 2C injection experiment. The main focus has been on characterising the cross-cutting faults, especially the Naylor South splay fault, in terms of their hydraulic behaviour and also propensity for reactivation in response to CO_2 injection.

A significant amount of work has also been done in terms of risk analysis, as it pertains to vertical CO_2 migration and also fault reactivation. The results of this work indicate that the faults should not impede the successful storage of CO_2, nor will they adversely affect the anticipated migration pathway of injected CO_2. The results of this work have been written up and will be combined with other Otway work for a Stage 2C report.

The Iona Gas Field modeling work has been a focal point of the geomechanics project. The geomechanical modeling work was completed in the 2011-12 financial year and is now in the peer review process with an international journal. We have also initiated a new work package which will use Interferometric Synthetic Aperture Radar (InSAR) to characterise past and present ground motions at the Iona and Otway Project sites, so that the surface effects of underground gas storage can be better understood. This work is being conducted in collaboration with the Monitoring and Verification Project 1.8. The InSAR observations will not only yield numbers on surface deformation, but will also result in refinement of the geomechanical modeling, thus improving the accuracy of the modeling workflows going forward.

The Gippsland Basin study, which is centered on a PhD study at the University of Adelaide, has progressed well. A literature review/report was released and a first draft of a journal paper focused on faulting patterns within the Snapper field is being developed. Unfortunately this study has had to be down-sized due to some unexpected staffing issues.

During 2011-2012, some further fieldwork was carried out on the mudstone sequences in the Taranaki and Whakataki regions of New Zealand so that this study could be wrapped up and published. Although some unforeseen commitments by GNS have resulted in some delay to the results, publication of this work is expected to come to fruition during the 2012-13 financial year. The results of this work will be used to better understand fault and fracture connectivity in mudstones and will be incorporated into risk studies for CO_2 storage.

1.7 PREDICTIVE MODELLING OF STORAGE RESERVOIRS

Project Leader: Dr Lincoln Paterson
CSIRO, Melbourne

Aim: To improve the level of confidence in predictive model storage for a range of reservoir types, particularly through experimentation at the CO2CRC Otway Project, and other field and pilot-scale demonstration projects as they become available. This project provides the "home base" for CO2CRC reservoir simulation studies and for the extension of Otway Project "good practice" to other sites.

Research Overview:

The first quarter of the past year was devoted to operational aspects of the CO2CRC Otway Stage Project Stage 2B residual saturation and dissolution test. This activity included fine-tuning the ratio of CO_2 and water at some of the injection phases to prevent dissolution of the residual CO_2.

Once the field program was completed, effort concentrated on assembly and quality control of the pressure, temperature and flow rate data. This requires assigning correct depths to measurements, conversion to a common time scale, accounting for interruptions and tests for accuracy.

When the data quality control was complete, the various steps of the Stage 2B test were then systematically modelled. The approach was to history match each step and then successively combine these into a single model with consistent assumptions. Pressure, temperature and tracers have been modelled with the TOUGH2 code. The University of Texas Chemical Compositional Simulator, UTECHEM, was acquired and also used for modelling the tracer data. Interpretations of each phase of the Stage 2B test are progressively emerging and these will be reported during 2012/13.

Also during the year static and dynamic models were built for the next stage of Otway Project field testing, Stage 2C. Simulations using the Eclipse code were conducted to examine potential injected CO_2 plume movement and provide input into forward seismic modelling of the likely surface seismic response. This modelling is being used to decide on the injection interval and injection volume for Stage 2C, as well as assessing environmental impacts.

1.8 IMPROVED MONITORING AND VERIFICATION

Project Leader: Dr Charles Jenkins
CSIRO, Canberra

Aim: To use the Otway Project (and potentially other research opportunities) to develop more reliable and cost-effective monitoring systems for future demonstration and commercial projects. The objective is to develop and maintain an inventory of M&V techniques, with detailed information on the strengths, weaknesses and applicability of each technique, and on the interpretation and quantification of the measurements that can be made.

Research Overview: During the year, research effort has focused on three broad areas. The first is associated with the further development of soil gas and atmospheric monitoring techniques.

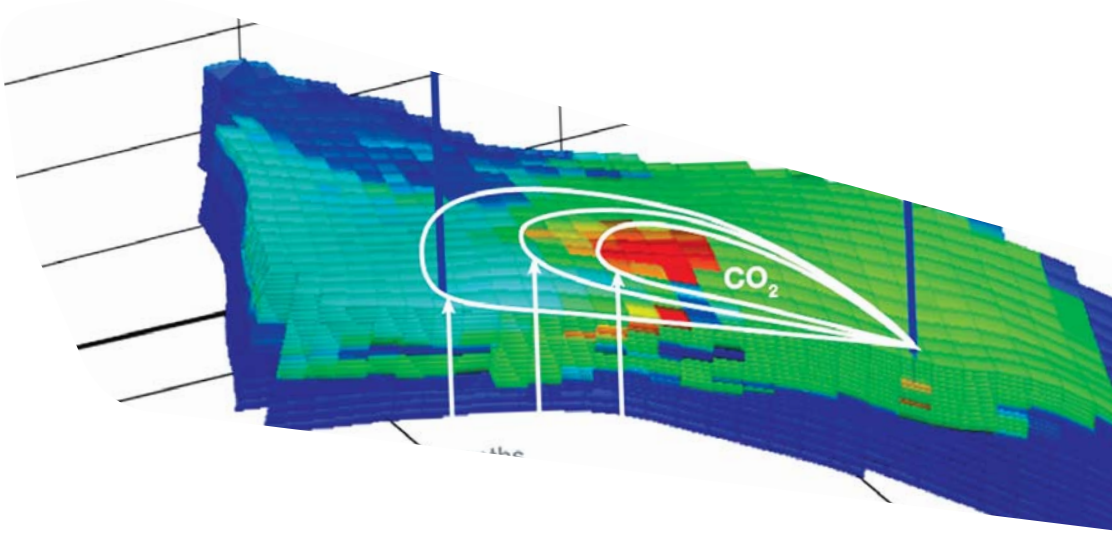
A sub-surface controlled release site has been developed at the CSIRO Ginninderra Experimental farm near Canberra and a second controlled release has been performed to calibrate soil gas techniques and test new microbiological sensor methods. Experiments were also performed to map soil conductivity before and after injection.

Releases of Buttress gas during the Stage 2B (residual gas saturation) experiment at the Otway Project are being used to calibrated the atmospheric monitoring system that has been deployed at the site for the past four years. Analysis of these is being done in conjunction with results from a network of atmospheric sensors that was deployed at the same time. Interpretation is proving more complicated than anticipated but steady progress is being made.

The modeling effort in preparation for the Otway Project Stage 2C injection continues. This is a small (10-30 thousand tonnes) injection into a saline aquifer. It was originally intended to test the limits of seismic detectability of small leakages. In conjunction with stakeholders, the scope has been broadened to include the mapping of plume stabilisation. Two peer reviews have now been held and the feasibility and survey design are planned to be complete by the end of 2012.

Finally, analysis has continued on the extensive datasets gathered on ground water and soil gas. These studies are invaluable in establishing the nature of natural variability and processes and hence quantifying the sensitivity and false alarm rate of these monitoring techniques. A paper has been published on the ground water surveys (Applied Geochemistry) and a draft paper on the soil gas surveys is being iterated between authors.

Looking ahead, and as mentioned under Project 1.6 above, a new project has been initiated to combine InSAR ground deformation mapping with geomechanical modeling of the Iona gas storage site, located not far from the Otway Project. A third release is being planned at Ginninderra, in conjunction with aerial hyper spectral imaging, to examine the effect of a CO_2 "leak" on crop growth.



3.2 RISK ASSESSMENT FOR CAPTURE AND STORAGE SYSTEMS

Project Leader: Matt Gerstenberger
GNS New Zealand

Aim: To develop and apply qualitative and quantitative risk-assessment methodologies for the long-term capture of geological storage of CO_2.

Research Overview: In the past year the CCS risk research has been focused on a broad range of topics that have worked to expand the overall risk method beyond the containment BBN. We have developed our method to include a range of stakeholder and timeline specific tools that can be used to address the risk at any time in the life of a project and can also be tailored to the needs of specific stakeholders. We have continued to refine our expert elicitation procedure and have now developed a set of expert calibration questions for use in weighting of expert judgement; additionally we developed a statistical optimisation method that will allow us to reduce the amount of information required from the experts. Work is also now underway to include carbon price and costs into the containment BBN. We have also begun developing the risk assessment procedure for transport, specifically pipelines, and for capture. Finally, we have been working with the Otway Stage 2C team and have developed a BBN that is helping to assess the risks posed by the fault. The risk research has resulted in several reports, including a review of international CCS risk assessment guidelines and standards, and has resulted in several conference presentations including an invited presentation at the CSLF Risk and Liability workshop and an invitation to an expert panel at the National CCS Conference.

PROGRAM 2: CAPTURE OF CO_2

Program Management: Professor Dianne Wiley
Capture Program Manager

The CO_2 Capture Research Program is focused on the research, development and deployment of technologies that can achieve significant 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 weaves together three threads of activity–basic laboratory research, pilot scale demonstration projects and future large scale designs –around the core objective of lowering the commercial cost of CO_2 capture by reducing the energy penalty associated with capture and improving capture technologies.

For 2011-12 a major focus of the solvents and engineering research teams has been on the continued development of the CO2CRC UNO MK 3 precipitating solvent system based on potassium carbonate. A laboratory mini-plant (part-funded by ANLEC R&D) has been commissioned at the University of Melbourne while a pilot scale facility (co-funded by BCIA) for the Latrobe Valley will soon be installed and commissioned. 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 MEA systems.

Meanwhile the membrane research teams are developing new materials and systems for CO_2 separation, including membrane systems that can be integrated with solvent systems. Piperazine-based membranes and ultra-thin membranes using CAP (continuous assembly of polymers) synthesis are currently showing particular promise. High flux hollow fibre membranes for post-combustion capture are also under development.

The adsorbents materials and process teams have developed a rapid screening tool to assess the suitability of new materials for CO_2 capture. Some highly promising chabazite materials for CO_2 separation from natural gas are under development. The cryogenics and hydrates research team has identified some new systems with particular application for pre-combustion and oxyfuel capture, promising greatly reduced energy requirements. A hybrid adsorbent/cryogenic system is also under investigation for post-combustion capture.

In the economics area, recent research has been focusing on frameworks for matching available technologies with emission sources and designing the CCS chain to maximize reduction of CO_2 emissions at the lowest cost while using the least amount of energy.

Key personnel achievements and changes are:

- At the University of Melbourne, Dr Josephine Lim has joined the membranes team to work on the removal of precipitates, replacing Dr Ludo Dumee. Dr Aravind Rabindran, Dr Nathan Nicholas and Dr Andrew Lee have joined the team working on the development of the precipitating solvent system.

- Professor Paul Webley and his adsorbent process development team have moved from Monash University to the University of Melbourne.
- At Monash University, Dr Mohammad Chowdhury has commenced work on an ANLEC R&D funded project involving the development of new adsorbents for the separation of oxygen from air for use in oxyfiring and gasification applications.
- At the University of Queensland, Dr Martens is working on the development of metal oxide silica membranes for the separation of CO_2 from H_2 streams.
- In the Latrobe Valley we have employed a local research assistant to help ensure smooth running of the pilot plants.

Our capture research continues to draw much local and international interest with significant delegations in 2011-12 from SASOL, Korea South East Power Corporation, South African Centre for Carbon Capture & Storage, Korean Environment Corporation and the National Institute for Clean-and-Low-Carbon Energy China.

During 2011-12, the capture and engineering research teams between them produced 85 presentations, 33 posters, 16 journal articles (including in the prestigious International Journal of Greenhouse Gas Control), 15 major reports and eight conference papers.

2.1 DEVELOPMENT AND OPERATION OF CAPTURE RESEARCH FACILITIES AND RELATED TECHNOLOGIES

Project Leader: Dr Abdul Qader
CO2CRC, Melbourne

Aims: To develop, operate and maintain CO2CRC's world-class capture facilities and nurture novel capture opportunities in early stages of development.

Research Overview:

Work is progressing on reconfiguring the 1 tpd solvent plant previously used for the CO2CRC/Mulgrave Capture Project and relocating it to the Hazelwood Power Station in Victoria's Latrobe Valley. The plant will test the new CO2CRC solvent, UNO MK 3, which uses precipitating potassium carbonate. The design and research plan for adsorbent and membrane pilot plants for installation at the Otway Project have also been prepared.

2.2 SOLVENT SYSTEMS

Project Leader: Prof Geoff Stevens
The University of Melbourne, Melbourne

Aims: To reduce the cost of CO_2 separation from a range of industrial applications including post- and pre-combustion capture in the power industry, CO_2 removal from natural gas and potentially other industries such as the cement and steel industry; and to develop, adapt and apply appropriate technologies to prevailing conditions and demonstrate the applicability of these technologies.

Key subprojects:

- Pilot plant simulations and analytical support
- Investigation of precipitating systems
- Investigation of rate promoters
- Investigation of the performance of membrane contactors

Research Overview:

The measurement of the physical properties of the precipitating solvent system is nearing completion. A range of VLSE curves have been developed and optimised to enable accurate physical property prediction.

An ion exchange column has been designed and constructed. Dowex 1 has been selected for the first phase of testing. Laboratory scale testing is underway to mimic the column performance.
An initial equilibrium study has been completed. Simulations of the performance are underway.

The stopped flow equipment and wetted wall column are now fully set up for screening potential promoters. A second wetted wall column has also been constructed and has been calibrated. A list of potential promoters and an experimental plan has been developed for testing these promoters. Studies into incorporating promoter performance into Apsen software has begun. MEA has been added to the carbonate solvent system in Aspen. Experiments are being conducted on evaluating amino acids (analine, glycine, sarcosine, proline), amines (MEA), phosphates, vanadates, aluminates, and silicates. Experiments on the impact of buffers are also underway.

A test program examining the long term (>1year) exposure of geopolymers to elevated temperatures has commenced. Samples were made and installed at temperature. Samples at 28 and 90 days of temperature exposure were removed and a comprehensive characterisation analysis completed.

Analysis of samples exposed for 180 days of aging is ongoing. Further samples will be removed and analysed incrementally up to >1 year of aging. A test program examining the interface zone (ITZ) between siliceous aggregates and 4 binders has commenced. Mortar samples were made and installed at ambient temperature. After 3, 7, 28 and 90 days the mechanical properties have been completed. BSE imaging in scanning electron microscopy was used to identify unreacted binder components, reaction products and porosity in this zone in each sample. Some experiments will be done with different aggregates binder ratio.

2.3 MEMBRANE SYSTEMS

Project Leader: Prof Sandra Kentish,
The University of Melbourne, Melbourne

Aims: To reduce the cost of CO_2 separation from a range of industrial applications including post- and pre-combustion capture in the power industry, CO_2 removal from natural gas and potentially other industries such as the cement and steel industry; to develop and apply new materials and membrane processes; to demonstrate the applicability of these technologies.

Key subprojects:

- Cost effective membrane systems
- Natural Gas Systems
- New membrane materials development
- Precursors to large scale implementation of gas separation

Research Overview:

Some unusual separation behaviour has been observed with some commercial membranes. Ash fouling experiments are underway.

Methods have been developed for lab-scale production of flat sheet membranes using interfacial polymerization. Initial experiments using mixed gases have been completed with positive results.

Work is progressing well on the synthesis of a series of triblock copolymers using click chemistry. Membranes have been cast either neat or as blends and are ready for gas testing. A series of brush PolyPOSS polymers were blended with PI and cast as membranes. Gas testing showed a reduction in permselectivities. Work has begun on ultrathin gas permeable membranes using different supports, gutter layers and selective layers as blends with an emphasis on highly permeable membranes. Different systems have been developed with varying success. Production of ultrathin membranes using the CAP process has begun with the functionalisation of the substrates.

Work on fabrication of improved gas separation polymer hollow fiber with PEG/PDMS co-polymer has progressed well. Strategies for the improvement of long-term membrane performance via suppression of plasticization has also progressed well. Evaluation of pre-conditioning and thermal annealing of hollow fiber membrane for plasticization suppression and aging is ongoing.

Sol-gel synthesis of metal oxide silica materials for CO_2/H_2 separation has been optimised by standard and seeding techniques. Further synthesis is progressing in conjunction with steam conditioning and characterisation and testing. Hydrothermal testing (15 hours) results for the membrane formed using the seeding process showed surface area reduction between 5-30%. A loading of 6-10% cobalt oxide into the silica sol-gel by the seeding process gave the lowest surface area reduction.

2.4 ADSORBENT SYSTEMS

Project Leader: Prof Paul Webley
The University of Melbourne, Melbourne

Aims: To reduce the cost of CO_2 separation from a range of industrial applications including post and pre-combustion capture in the power industry and CO_2 removal from natural gas; also potentially, other industries such as the cement and steel industries. CO2CRC will also develop and apply new materials and adsorbent processes and demonstrate the applicability of these technologies.

Key subprojects:

- Post-combustion capture of CO_2: Process research
- Pre-combustion capture of CO_2: Process and materials research
- CO_2 capture from natural gas streams

Research Overview:

Initial testing of PEI material at small scale has been completed. New higher capacity formulations have been identified recently. Initial tests have led to contamination so further additional development of this material is required. The new material is now being formulated and a large batch is being prepared.

Work has commenced on the adsorbent development

of cycles for treatment of humid flue gas for post-combustion capture using both a three-bed experimental apparatus and simulations. Several new cycles have been identified. The development of a PSA model for screening is now complete but must be extended to allow incorporation of water and TSA.

Some water stable MOFs for post-combustion adsorbent capture have been synthesised. Characterisation is ongoing; in particular, their stability needs to be confirmed. The performance of the MOFs in a VSA system is being characterised using molecular simulations. A series of new amine materials have been synthesised and are being tested in TGA and small scale VSA under humid conditions.

A large batch of PEI material is being synthesised for testing at high temperature and pressure for pre-combustion capture. A range of different metal oxides are also under development for this application. Cd-supported with NaI has been found to be very promising for high temperature reversible CO_2 capture.

Many process simulations have been completed for the integration of adsorbent-based CO_2 capture with LNG processing. Initial cycles have been identified. Modified commercial materials are being investigated for this application. NaUSY and several other zeolites are showing promise. Synthesis of hydrophobic PCPs for CH_4/CO_2 separation has commenced. Molecular sieving adsorbents are also undergoing screening and testing. A provisional patent was filed.

2.5 CRYOGENIC/HYDRATES SYSTEMS

Project Leader: Prof Moses Tade
Curtin University of Technology, Perth

Aims: To develop and apply new cryogenic and hydrate removal processes in order to reduce the cost of CO_2 separation from a range of industrial applications, particularly pre-combustion capture and oxyfuels in the first instance and then potentially in other industries such as the cement and steel industry, post-combustion and to demonstrate the applicability of these technologies.

Research Overview:

A hybrid VSA/Cryogenic capture scheme is under investigation. A preliminary economic evaluation of this scheme indicates about a 25% saving compared to conventional MEA systems. A study on pumping of dense phase CO_2 for transportation has been completed. Energy saving schemes have been developed for oxyfuel and IGCC GE flue gases.

2.7 (3.1) ECONOMICS

Project Leaders: Dr Peter Neal & Dr Minh Ho
The University of New South Wales, Sydney

Aim: To provide research reports and advice on CO_2 capture and storage economics for different technologies, specific capture and storage projects and industry hubs or regions.

Research Overview:

Economic assessment of capture opportunities for implementing flexible capture at individual power plants in NSW is currently focusing on a load shifting strategy based on real dispatch data.

The effect of inclusion of renewable energy sources has also been considered. In other work, a model for evaluating the effect of biomass co-firing is under development.

A review of groundwater salinity in Australia and produced water treatment focussing on South-East Queensland has been completed. Formation properties and groundwater salinities have been gathered for three injection plays. The effect of pressure relief on storage economics has been evaluated for these plays. The storage economics team has been involved in an economic analysis of CO_2 transport and storage for CCS Nova Scotia.

A preliminary dynamic model for a single pipeline has been developed. This is now being expanded to more realistic network expansion cases. A preliminary report has been produced outlining the methodology for optimisation of a pipeline with varying CO_2 flow rate.

A paper on a proposed Carbon Storage Capacity Management System (CSCMS) and its alignment with the SPE's Petroleum Resource Management System has been published. A database of required well injection rates based on a range of reservoir properties has been constructed. This enables preparation of probabilistic analyses of injection requirements, which are the basis for estimating storage capacities. A study on the storage capacity of a hypothetical storage formation with reservoir properties of the Precipice Sandstone in the Surat Basin has been undertaken.

A review of literature about future energy supply in Australia has been completed. A paper on energy supply to Eastern Australia using single greenhouse gas abatement technologies is in the final stages of preparation.

The CO2CRC economics methodology report has been revised. A preliminary assessment of the advantages and disadvantages of using real options

to evaluate CCS projects has been completed. Cost indices have been updated as data has become available. Fuel and power cost assumptions, as well as exchange rates, have been updated in the light of changes in global economic conditions and revisions to economics methodology. The second release of ICCSEM has been provided to CO2CRC members. The engine for the third release incorporates the injectivity tool and topographic cost information. Improvements have been made to the GUI to improve usability. The fourth release will incorporate updated cost models for pipelines and platforms.

2.1.1 LOW COST HYBRID CAPTURE TECHNOLOGY DEVELOPMENT

Project Leader: Prof Paul Webley
The University of Melbourne, Melbourne

Aims: To establish the case for a hybrid adsorbent/solvent system that will reduce capture costs by 20% over the best amine system. With this defined, the project will deliver a technical basis for, and the commercialisation plan of, this process for demonstration and large scale deployment.

Research Overview: Laboratory experiments to produce low purity CO_2 with the PVSA system are underway along with regeneration tests. A simulation of the complete hybrid system is also under development.

2.1.2 COST REDUCTION PROCESS: SOLVENT PRECIPITATION SYSTEM

Project Leader: Prof Geoff Stevens
The University of Melbourne, Melbourne

Aims: To demonstrate a complete carbonate based technology for post-combustion capture by providing an integrated impurity handling system and have primary energy usage (not including energy integration) at least 10% below the best amine. Overall capture cost reduction will be evaluated at the end of the first year: it is anticipated to result in a 20% reduction compared to the best amines including heat integration.

Research Overview: The mini-plant has been commissioned. Data collection has been completed for the non-precipitating system. The research is now moving to data collection for the precipitating system.

2.1.3 MEMBRANE PROCESSES FOR AMINE CONTAMINANT REMOVAL

Project Leader: Prof Sandra Kentish
The University of Melbourne, Melbourne

Aims: To test and validate improvements to CO_2 capture using membrane technology, results of which will be essential for significantly reducing the cost of future commercial CCS projects.

Research Overview: Both the NF and ED rigs have been commissioned. Early experimental results indicate that NF may not be as competitive as ED. Benchmark performance criteria for both NF and ED have been established.

2.1.4 LARGE SCALE COST REDUCTION THROUGH ADSORPTION BASED OXYGEN GENERATION TECHNOLOGY

Project Leaders: Prof Paul Webley & Prof Alan Chaffee
The University of Melbourne and Monash University

Aims: To develop adsorbents which are oxygen selective, reversible, stable, safe, and appropriate for oxygen production from air. To develop adsorption process cycles producing high purity oxygen (> 98%) at 30% lower capital cost and power requirement relative to current state-of-the-art air separation technologies. To develop a combined, validated process and economic model that will provide scaled-up evaluation of the oxygen selective adsorption process.

Research Overview: Different classes of materials for the separation have been identified. Several prospective adsorbents have been selected from the literature and initial synthesis is underway and preliminary characterisation has commenced. Process cycles are being developed for future evaluation. A MINSA process simulation of conventional O2VSA has been developed for benchmarking purposes.

2.1.7 CAPTURE DEMONSTRATION FOR COST REDUCTION

Project Leader: Dr Abdul Qader
CO2CRC, Melbourne

Aims: The project will undertake a range of studies targeted at cost and risk reduction to develop the CO2CRC precipitating solvent technology by making step-change improvements in process, equipment and materials specific to brown coal emissions handling especially in terms of impurities present and by evaluating process integration and economic/business opportunities.

Research Overview: A formal agreement between WES/PG/CO2CRC is progressing. There have been delays to the delivery of the rig due to ongoing design changes. A test program for the joint trials has been agreed. A Post-doctoral Fellow has been recruited by the University of Melbourne. A Research Assistant has been recruited by CO2CRC. The onsite location for the rig has been identified and a site installation work contract is under negotiation. Other auxiliaries, like column packing, ion-exchange resins and potassium carbonate solvent have already arrived. A CO2CRC HSE Framework for the project is under development.

2.1.8 EVALUATION OF CO_2 CAPTURE WITH HIGH PERFORMANCE HOLLOW FIBRE MEMBRANES FROM FLUE GAS

Project Leader: Prof Vicki Chen
The University of New South Wales, Sydney

Aims: This research aims to fabricate high performance hollow fibre membranes for CO_2 capture from flue gas and to compare their laboratory performance with synthesised gas mixtures with real flue gas streams in power plants.

Research Overview: A state of art report on membrane and module selection and screening has been completed including the selection of benchmarks for membrane and material performance at various project development phases. Selection of membranes for the first phase of on-site tests is nearing completion.

PROGRAM 3: FACILITATING CCS

Program Management: Professor Peter Cook
Principal Adviser (June 2011-May 2012)

Dr Julie-Anne White
General Manager – Business Development (from June 2012)

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

In the past year CO2CRC CCS risk research has been broadened and methods now include a range of stakeholder and timeline specific tools that can be used to address the risk at any time in the life of a project and be tailored to the needs of specific stakeholders.

Economic models for CCS developed by CO2CRC look at the whole CCS chain from capture to storage and monitoring. The CO2CRC economics research team has continued to develop a framework of economic evaluation used to measure and validate research directions and integrate energy-production systems, transport networks and storage infrastructure.

CO2CRC continued its significant contribution to State and Federal Governments though the National Storage Mapping Taskforce, the Flagships process and high level CCS consultations. Several international governments also received CO2CRC technical advice.

The Science Initiatives project has been active in monitoring & disseminating technology developments in the CCS storage discipline and providing relevant technical input to CO2CRC storage projects using the skills and experience of the Chief Scientist. The Chief Scientist has also played a major role in representing CO2CRC at key domestic and international forums, workshops and conferences, as well as being principal instructor for numerous international CCS schools.

The Technology Initiatives theme, led by the Chief Technologist, has been active in the engineering development and process integration aspects of all CO2CRC capture activities. In particular the team has been heavily focussed on the practical development of UNO Mk 3. The team has been exploring a range of opportunities to best utilise this exciting new technology. Work also continues on the investigation of retrofit pathways and hybrid technologies as well as leading edge research into CCS process integration at Monash University. The focus of the work is on cost reduction for large scale capture implementation.

CO2CRC continues to recruit post-graduate students and has more than 40 graduate students within its programs, making it one of the most significant CCS training programs anywhere in the world. The Education and Training program expanded its contribution to CCS capacity development in China, running workshops and hosting international students. The program's major activity in Australia, the CO2CRC CCS School, attracted government and industry professionals as well as international participants.

In addition to regular communications duties such as publications production, media liaison and event management, CO2CRC completed a new Otway Project video, revised the Otway Project communications strategy and undertook social research into community perceptions of the Otway Project and CCS technology. Community consultation at the Otway Project continued through newsletters, community reference group meetings and regular liaison with landowners.

CO2CRC has built on its successful commercialisation of knowledge with five new major consultancy projects for CO2CRC sponsor companies and for third parties, and four patents pending, all of which are supporting breakthroughs in new capture technologies and processes. In addition, its knowledge and experience was used in the public sector in the development of CCS regulations.

3.4 EDUCATION AND TRAINING

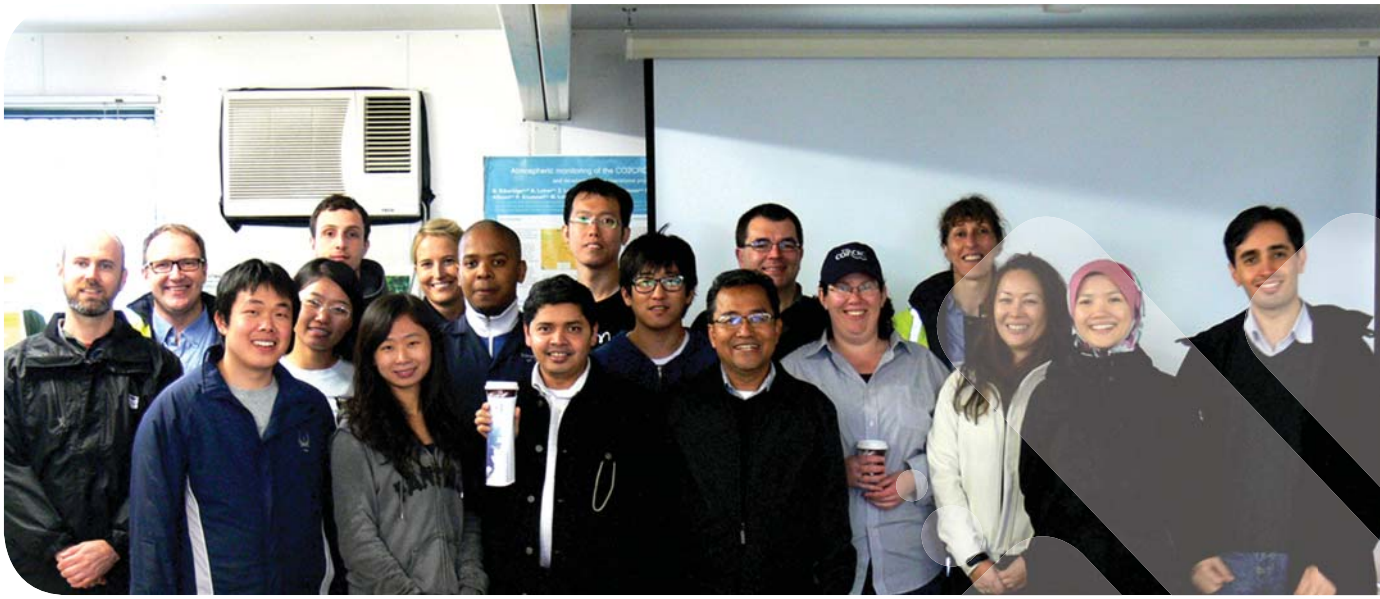
CO2CRC's Education and Training program has had another busy year with the book "Clean Energy, Climate and Carbon" being published and generating healthy interest, recruitment of new post-graduate students, Australian and international CCS schools and international capacity building in CCS.

Post-graduate students are a focus for the Education and Training program and fourteen new PhD students commenced research with the CRC this year while eight post-graduate students were awarded their PhD. Several post-graduates are in the final writing stages or their thesis is under examination. The total number of completed PhDs and Masters is now 26 with many more underway (see table below).

The 2011 CO2CRC CCS School was held at the University of Melbourne from 26-28 September 2011. The 2011 School continued the success of the 2010 CO2CRC CCS School in Brisbane and the IEA GHG International CCS Summer School in Champaign, Illinois. The Global CCS Institute provided 11 scholarships for PhD students and early career professionals from the Asia-Pacific region to attend the School. Interaction between students from different CCS sectors and nationalities provided an opportunity for considerable sharing of knowledge and experience. There were 39 participants comprising post-graduate students from CO2CRC, international participants, early-career scientists from industry and government workers. Over twenty speakers and mentors from CO2CRC's researchers and partner universities, outside research bodies, industry and government contributed to the School.

Considerable activity occurred in the Capacity Development work of the CRC this year. CO2CRC continued its collaboration with Geoscience Australia for the China-Australia Geological Storage of CO_2 (CAGS) Program, with CO2CRC researchers delivering several sessions at a CCS School in Sanya, China in August, 2011.

CO2CRC students presented posters and papers at the 2011 CO2CRC Research Symposium held in Adelaide, giving them the opportunity to present to a wide audience of researchers and industry partners. Many CO2CRC researchers and partners attended a writing workshop held during the Symposium. All gave positive feedback with suggestions for another workshop next year.



CO2CRC continued to work with the Global CCS Institute under an Alliance agreement. CO2CRC work under the Alliance included sharing of public communication/educational materials, meetings to provide advice to the knowledge-sharing team and representation on the Institute's Capacity Development Working Group. Under the Alliance the Global CCS Institute and CO2CRC will continue to work together on capacity building courses.

The book "Clean Energy, Climate and Carbon" by Professor Peter Cook was officially launched by the Minister of Energy and Resources, Martin Ferguson, on 1 March 2012. The book explores carbon capture and storage in the context of the challenges of energy needs, carbon dioxide emissions and climate change; and is written with a general audience in mind. The book is aimed at people who are concerned about climate change, or who want to learn more about clean energy technologies, including CCS, and fills the gap between a high level overview and the technical detail.

CO2CRC continued contributions to international CCS capacity building activities by being involved in and running workshops and schools in a variety of countries. In August 2011 CO2CRC ran a one day CCS workshop for the Asia Oceania Geosciences Society in Taiwan, focusing on the issues and opportunities for CCS in Taiwan's energy industry.

CO2CRC maintains high quality online resources including education and training material for Australian and international bodies.

Plans for the next financial year include:

- Organising a workshop for new PhD students at the annual CO2CRC Research Symposium
- Contributing to international CCS capacity-building activities in collaboration with international partners
- Continue talks with Petrobras about running a CCS school in Brazil in 2013
- Continue talks with Petronas about running a CCS school in Malaysia in 2013
- Develop the 'Train the Trainer' course on a country by country basis and increase international capacity building in education and training of CCS
- Expanding educational material.

Tally of CO2CRC students 2011/12

MSc or M Eng (including masters by coursework)	4
PhD	42
Total post-graduate students	46
Post doctoral appointments	4

3.5 COMMUNICATIONS

CO2CRC has two strategies in place to ensure communications activities are well-planned, focused and effective.

CO2CRC's overall Communication Strategy sets out the organisation's communications goals and objectives, and tactics to achieve them. It encompasses CO2CRC public communications on CCS, stakeholder relations, media liaison, issues management and internal communications, as well as a crisis communications plan.

The CO2CRC Otway Project Community Consultation and Communication Strategy specifically covers community consultation surrounding the CO2CRC Otway Project. The Strategy covers CO2CRC's communication with the Nirranda and regional community, as well as communication of project outcomes to the wider public. This strategy was revised during the year following the results of a second round of Otway Project social research completed in late 2011.

The following activities have been undertaken during the reporting period.

CO2CRC INTERNAL COMMUNICATIONS

- CO2CRC produces a biannual staff newsletter which provides CRC staff with updates on research, education & training, social news and awards and honours. A staff newsletter was issued in July and December 2011.
- CO2CRC holds an annual Research Symposium to bring together CO2CRC researchers, industry and government partners, and the Australian and international CCS community to share and discuss CCS research and developments. The Symposium an important annual update of CO2CRC research progress, providing opportunities for networking and debate while fostering collaboration. The 2011 CO2CRC Research Symposium was held in Adelaide in November.

CO2CRC EXTERNAL COMMUNICATIONS

- In late 2011 CO2CRC completed a six minute video production covering research at the Otway Project and in particular the Stage 2B experiments.
- CO2CRC commissioned and completed a social research project in late 2011, in order to gauge community perceptions of the Otway Project. The study also assessed changes in attitudes to CCS and the project since 2006 when a similar study was undertaken. The work found that residents living close to the project felt more comfortable with the technology and had an improved understanding of how CCS works.
- Eleven media releases were issued during the year, with follow up media liaison including journalist briefings, media interviews, letters to editors, articles and provision of images for general, industry and CCS publications.
- CO2CRC convened the second National CCS Week and National CCS Conference, to be held in October 2012, supported by nine industry, government and research organisations.
- There has been continuing demand for visits to the CO2CRC Otway Project and Latrobe Valley capture demonstration plants, from Australian and international industry, government, the research community and the media.
- CO2CRC publishes CO_2 Futures, a quarterly newsletter focusing on CO2CRC research stories and developments. The newsletter is distributed nationally and internationally to over 1000 subscribers, industry, government and the research community.
- Information products, such as fact sheets, brochures and banners, were produced throughout the year. A summary and map of Australian CCS projects is maintained and updated.
- The CO2CRC website is a comprehensive central point for information on CCS and the CRC. The website includes improved access to information on CCS and CO2CRC research, CO2CRC publications and a popular image library including online videos on CCS technology. A live newsfeed and social media engagement through Twitter (@CCS_Research) are proving to be popular.
- CO2CRC attends events, including information booths at relevant conferences such as APPEA (May 2012) and All-Energy (October 2011). CO2CRC speakers attend national and international conferences and fora.

CO2CRC OTWAY PROJECT COMMUNITY CONSULTATION AND COMMUNICATIONS

CO2CRC works with the Nirranda community to build public confidence and support for CCS and the CO2CRC Otway Project.

The locally-based Otway Project Liaison Officer acts as a conduit between researchers and local landowners and provides a point of contact for the local community. CO2CRC informs the community, including residents, local government, schools and NGOs, of research outcomes and changes to site operations via the Otway Project Liaison Officer, the project community reference group and regular community newsletters. Project update newsletters were mailed to 1300 residents in November 2011 and June 2012.

The community reference group includes representatives from local government, regulators, landowners and the local community. Regular public meetings are held that include project updates and the opportunity for discussions on issues affecting local residents. Community reference group meetings were held in December 2011 and June 2012 to update the community on the progress of Stage 2.

National and international interest in the project is high. CO2CRC conducts regular site visits of the Otway Project for visiting researchers, policy-makers, State and Federal government representatives, industry groups, community groups and students. Over 250 visitors toured the project during the reporting period.

Information on the Otway Project is continually updated and includes newsletters, posters, photographs, fact sheets and brochures.

3.6 UTILISATION

The CO2CRC Commercialisation and Utilisation Plan was approved by the Department of Education, Science and Training in May 2005 and released in June 2005. The strategic intents for commercialisation were subsequently reviewed at CO2CRC Executive workshops held in July 2005 and January 2006. CO2CRC commercialises and utilises its intellectual property through its commercial arm, CO2TECH.

The strategies are to:

- build on current CO2CRC opportunities, especially consultancy contracts;
- develop a clear and workable set of protocols to manage commercialisation processes;
- inform CO2CRC researchers and management of commercialisation protocols and processes through internal communications and commercialisation workshops;
- develop a peak-loading strategy for consultancy work using international consortia and researchers who can move between projects;
- identify and develop commercially aware CO2CRC researchers;
- develop commercial relationships including links with other international geosequestration and carbon capture and storage research and development organisations;
- protect and preserve project intellectual property; and
- regularly review the Commercialisation Plan.

The ongoing tasks are to:

- continue to expand the carbon capture and storage consultancy activities with a view to establishing a stand-alone spin off company,
- establish links and partnerships with international R&D agencies and companies with the aim of developing capacity;
- conduct commercialisation workshops;
- undertake annual IP audits;
- maintain and update the IP register; and
- always achieve requisite Commonwealth Agreement milestones.

ACTIVITIES IN THE REPORTING PERIOD

1. CO2TECH was successful in securing five new major consultancy projects for CO2CRC sponsor companies and for third parties. For the 12 month period ending June 30th 2012, CO2TECH generated gross fees totalling $668,000 and a gross margin of 21% before general expenses and disbursements. Activities during the year included commercial-in-confidence technical work, feasibility studies, economic modelling and due-diligence work for government.
2. CO2TECH manages all CO2CRC patents and trademarks and at 30 June 2012 has four patents, all of which are supporting breakthroughs in new capture technologies and processes. In addition CO2TECH has registered six trademarks primarily to protect CO2CRC and CO2TECH trading names and logos.
3. CO2CRC continues to refine the software for its Publications Tracking System. This is a very important tool that enables CO2TECH to manage IP issues, including copyright ownership, and provides publishers and conference organisers with formal licences to publish or reproduce CO2CRC publications.

3.8 SCIENCE INITIATIVES

Project Leader: Prof John Kaldi
CO2CRC, Adelaide

Aims: The principle aim of this project is to provide technical input, quality assurance and high level advice on relevant aspects of CCS to the CO2CRC program through leadership of the Chief Scientist (CS). Other aims are to represent CO2CRC at key domestic and international forums, workshops and conferences, and contribute to capacity building in CCS through key roles in domestic and international CCS Schools and workshops.

Key subprojects:

- Monitor & disseminate new technology developments in the Storage discipline
- Provide technical input to CO2CRC Storage projects
- Provide technical input into CO2TECH and associated CO2CRC projects
- Provide Storage Program Manager quality assurance of CO2CRC storage projects
  - Ensure that relevant science & technology are properly applied to each project
  - Review and/or recommend for approval technical manuscripts / presentations within storage disciplines
- Capacity building in CCS: Contribute to Education & Training Program through international leadership role in organisation and teaching of courses, schools and workshops in CCS
- CO2CRC delegate on Australian Consortium of IEAGHG (review & recommend R&D directions; member CCS Summer School International Steering Committee)
- Represent CO2CRC at domestic and international technical workshops and conferences on CCS
- Investigation of caprock and fault seal controls on containment of CO_2 (CS & team)

PROJECT UPDATE: JULY 1, 2011–JUNE 30, 2012

- Chief Scientist contributed to objectives of 3.8 by providing high level and detailed input/advice to global CCS projects (eg Decatur; CarbonNet; SACCCS)
- CS presented schools and workshops on CCS, eg:
  - Illinois Geological Survey & University of Illinois July, 2011
  - IEAGHG CCS Summer School (Illinois): July, 2011
  - KIGAM CCS School (Daejeon, S. Korea) August, 2011
  - AOGS & Taiwan Universities CCS School (Taipei, Taiwan) August, 2011
  - CO2CRC CCS School (Melbourne), September, 2011
  - CS convener and keynote speaker at numerous Conferences & workshops on CCS (eg AAPG, SPE, IEAGHG)

3.9 TECHNOLOGY INITIATIVES

Project Leader/Chief Technologist: Barry Hooper
Technical Leaders: Clare Anderson, Trent Harkin, Barry Hooper

CO2CRC, Melbourne

Aim: This project comprises activities led by the Chief Technologist covering engineering development/ process integration and commercialisation activities for centre IP (3.9.1/2.6), ANLEC Science Leaders role (3.9.2) and an Executive advisory role to the Chief Executive shown as Chief Technologist (3.9.3).

3.9.1 (2.6): ENGINEERING DEVELOPMENT/ PROCESS INTEGRATION

Research Objectives:

- To provide integration between research and practical engineering application for large scale plant
- To incorporate cost reducing engineering aspects to capture technologies, particularly through the use of process and heat integration and novel equipment concepts
- To provide engineering and technical support to the core research program aiding in the practical direction of capture research
- To drive commercialisation of CO2CRC IP.

The activities are organised in work packages, a number of which are listed below outlining 2011–12 highlights.

WORK PACKAGES

Technology Overview & Implementation

Research Objectives:

To identify the implementation pathways for all four technologies including a strategic view of the strengths and weaknesses of the respective separation technologies, the most promising markets for each and the key enablers required to make a separation technology commercially attractive.

UNO MK3

Research Objectives:

This work package deals with the large scale engineering development of the UNO MK 3 process leading to commercialisation.

Highlights:

- Completion of 10 engineering design cases for UNO MK 3 implementation and costing
- Provide direction for UNO MK 3, simulation assistance, review of impurity handling and absorption improvement options
- UNO Commercialisation Packages for European and US Roadshows complete and presented
- Operations and project input to UNO BCIA/ANLEC projects
- Patent review and support for all UNO IP

RETROFIT PATHWAYS

Research Objectives:

To identify the potential for cost reductions using CCS retrofits. To identify risk reduction opportunities for the commercialisation of CCS by assessing the potential for stage-wise introduction of CCS consistent with eventual full scale CO_2 capture in both coal and natural gas applications.

Highlights:

- Workshop on retrofit pathway options for Australian power plants completed
- Four reports prepared on NGCC capture and process integration

HYBRID CAPTURE TECHNOLOGIES

Research Objectives:

To evaluate the cost reduction potential of using a range of hybrid capture systems utilising all practical configurations of CO2CRC separation research pathways.

Highlights:

- Initial work complete and report issued on hybrid applications incorporating UNO MK 3.

PHD PROGRAM – PROCESS INTEGRATION

Research Leader: Assoc. Prof Andrew Hoadley, *Monash University*

Research Objectives/Activities:

- Two PhD students have been recruited to progress CCS process integration issues in the areas of;
  - Hybrids and novel separations (membranes and adsorbents)
  - Integration of renewables with CCS (with a particular focus on natural gas fired applications)

3.9.2 ANLEC R&D SCIENCE LEADER ROLE

(Barry Hooper)

Research Objectives/Activities:

Contributed to the development of ANLEC R&D Science Leaders interests and reviewed research proposals submitted to the ANLEC R&D Alternatives and Fundamentals Research program

3.9.3 CHIEF TECHNOLOGIST ROLE

(Barry Hooper)

Research Objective:

The provision of technical support and advice to the CE for the development of CO2CRC and CCS in Australia.