THE UNIVERSITY OF MELBOURNE

Peter Cook Centre for Carbon Capture and Storage Research

ANNUAL REPORT

2016/17

CONTENTS

ABOUT US

The Peter Cook Centre for Carbon Capture and Storage (CCS) Research is a world class research centre at The University of Melbourne.

The research we perform underpins the development of enhanced technologies for carbon capture and storage in Australia. Working closely with our partners in industry and governments the Centre's outputs delivers the next generation of skills and research and development services in CCS.

The Centre is named after Professor Peter Cook, CBE, FTSE, an internationally distinguished expert in carbon capture and storage research and a pioneer of CCS research and development in Australia. His profile and worldwide reputation for excellence in the field of geological storage makes him a fitting choice as patron for the Centre.

The Centre is in a unique and advantageous position building on outstanding achievements and momentum from the projects that have been running for more than a decade. A very strong team of CO_2 capture experts has been assembled at the University of Melbourne for a long time while the Centre has facilitated the development and expansion of CO_2 storage research as well as interdisciplinary studies relating to CCS at the University over the past five years.

MISSION

To develop environmentally and socially acceptable, cost effective carbon capture and storage solutions for a carbon constrained world.

VISION

The development of scientific and engineering expertise and personnel in Australia to enable the deployment of advanced carbon capture and storage technologies, thereby contributing to the nation's economic, environmental and social well-being.

RESEARCH

Increasing greenhouse gas emissions to the atmosphere is a key environmental issue facing Australia and the world.

Carbon dioxide, primarily from the combustion of fossil fuels for energy, is the most common greenhouse gas emitted by human activities and is causing an adverse impact on climate. Emission reduction will require a full suite of responses: increased use of renewable energy, greater energy efficiency, fuel switching, increased capture and use and geological sequestration of carbon dioxide.

CARBON CAPTURE

The Capture Program's primary aim is to reduce the cost and environmental impact of capture of carbon dioxide (CO_2) from a range of sources including coal and gas fired power stations, from steel and cement production, as well as from natural gas. The research focuses on developing and demonstrating technologies that will significantly reduce the costs of capturing CO_2 thereby mitigating financial risk for industry. We are interested in exploiting the captured CO_2 and have a portfolio of projects examining utilisation strategies

The program centres on the three technologies of solvent systems, membranes and adsorption all of which have application in specific areas. Research is being undertaken across a spectrum of work, from the fundamental through to demonstration of operating plants.

CARBON STORAGE

The Carbon Storage Program within the Centre is focused on the study and assessment of potential CO_2 storage sites through the provision of research, technical review and advice. The CO_2 storage research team is multidisciplinary with particular strengths in geochemistry, numerical modelling of subsurface fluid transport and the geological characterisation and modelling of sedimentary basins. Our projects are focused on developing a deeper understanding of the process of storing CO_2 in subsurface structures, with the aim of reducing the storage risks and developing monitoring and control technologies.

LEGAL AND SOCIAL POLICY

In today's political climate, carbon policy is uncertain. There is general acceptance that deep cuts in CO_2 emissions will be required of society in general, but inevitably with a major focus on major carbon emitters such those related to fossil fuels, power generation and energy-intensive industries. The Peter Cook Centre is a multidisciplinary research centre which crosses traditional discipline boundaries to provide access to expertise in carbon mitigation technology and address the legal, social and economic issues that will be critical to reducing greenhouse gas emissions in the future.

DIRECTOR'S REPORT

The Peter Cook Centre for CCS Research at The University of Melbourne has come a very long way since its establishment five years ago.

The last two years has been a period of tremendous growth and recognition in many ways: Several major new research projects involving more academic specialists have commenced. Dedicated new CCS laboratories have been established. We offer training for professionals and we have industry and government representative come to us to discuss and be briefed on the status of CCS and its opportunities in the future - we are very pleased with the breadth and depth of those activities.

This annual report for the Peter Cook Centre for CCS Research for the years 2016 and 2017 is a reflection of our achievements and it is my privilege to represent it. At the same time I would like to take the opportunity to express my gratitude to everyone in the Peter Cook Centre for their dedication, perseverance and creativity driving our research and our involvement in the important debate on low-emission technologies including CCS. I want to particularly acknowledge Prof. Paul Webley for serving as the Director of the Peter Cook Centre in 2016 and Prof. Geoff Stevens, the inaugural Director of the Centre, who retired last year. Assoc. Prof. Malcolm Garratt and Prof. Peter Cook helped the Centre by keeping us connected to our stakeholders and ensuring the Peter Cook Centre is heading in the right direction.

The Peter Cook Centre Science Advisory Committee is chaired by Assoc. Prof. Malcolm Garratt and is composed of external industry and government representatives. I appreciate the committee's strategic input to our research program and the way we operate the centre.

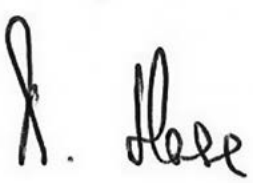
Many examples can be given illustrating the importance of partnerships for our success. The CO2CRC was not only a foundation partner of the Peter Cook Centre, but provided us with over $11 million of their EIF CCSNET funding in 2016 allowing us to build new laboratories and deploy field equipment. The CO2CRC, CarbonNet, ANLEC R&D, the Federal Government CCS RD&D Fund and the Coal Innovation NSW Fund are funders of our research projects and the Global CCS Institute supports our intensive course for professionals and post-graduate students and hosted the Australian CCS Research Conference 2017 together with us. Last but not least, the Minerals Council of Australia provided us with a donation to host an international Distinguished Guest Lecturer for three years, which provides a very useful expert perspective on low-emission technologies from outside of Australia and has stimulated many engaged discussions amongst our stakeholders. The Melbourne Energy Institute co-hosted public lectures and visiting academics and enabled us to engage with new stakeholders of the energy sector.

Our researchers and research leaders are at the heart of our centre. Their recognition is a reflection of the quality of their work and the Peter Cook Centre has seen several awards and distinguished appointments of their researchers over the last two years: Mr. Guoping Hu received the Global Award for Young Researchers Finalist by the Institution of Chemical Engineers (IChemE) and the Young Scientist Research Prize by the Royal Society of Victoria in 2017 whilst he was a student. Conference awards were given to the following students: Mr Guoping Hu (Best Poster, Capture Program, Australian CCS Research Conference 2017), Mr Achyut Mishra (Best Poster, Storage Program, Australian CCS Research Conference 2017) and Mr. Apoorv Jyoti (Best Oral Presentation, Dynamic Earth Session, Victorian Universities Earth and Environmental Sciences Conference 2017). Dr Kathryn Mumford was awarded the prestigious international IChemE Warner Prize in 2016, Prof. Sandra Kentish was named One of Australia's Most Innovative Engineers by Engineers Australia in 2017 and I had the honor of receiving the Faculty of Science Dean's Award of Excellence in Engagement (Industry) in 2017.

I am very pleased and excited about our new research collaboration with BHP addressing fundamental questions relating to the role of small-scale geological heterogeneity on multiphase flow and carbon trapping in sedimentary rocks. The University of Cambridge (UK) and Stanford University (USA) are research partners of this collaboration and with the CO2CRC Ltd. provides data and samples for this project. I have no doubt this consortium will deliver breakthrough research results in coming years and I wish them best of luck.

We have seen many international and national debates on the mix of future low-emission technologies where CCS plays its role right, left and center: The COP 21 (Paris) Agreement at the end of 2015 set an ambitious international CO_2 emission reduction target triggering debates at all levels on the path towards a carbon-constrained world. The nexus between future energy generation and CO_2 emission reduction was put on the Australian political agenda by Prime Minister Turnbull in his speech at the beginning of February 2017. The report by Chief Scientist Dr. Alan Finkel in June 2017 comprehensively addressed the trilemma of achieving affordable, secure and low-CO_2 emission energy and provided widely acceptable recommendations. CCS has been discussed as part of the future energy technology mix along the way and I have no doubt our research with the objectives to reduce the cost and remaining uncertainties of CCS will remain highly relevant and sought after.

Sincerely,



Prof. Ralf Haese

MEMBERSHIP

EXECUTIVE

Prof Peter Cook

A/Prof. Malcolm Garratt

Prof. Ralf Haese

Prof. Paul Webley

CENTRE COORDINATOR

Ms. Cara Jordan
(Until August 2017)

Mr Bill Stathopoulos

PROJECT LEADERS

Prof Michael Crommelin

Prof Geoff Stevens

Prof Ralf Haese

Prof Greg Qiao

Prof Sandra Kentish

Prof Paul Webley

Prof Stephan Matthäi

Dr Kathryn Mumford

Dr Colin Scholes

A/Prof Malcolm Wallace

Prof Peter Rayner

Prof Mike Sandiford

Dr John Moreau

RESEARCH SCIENTISTS AND ENGINEERS

Dr Jay Black

Dr Kathryn Smith

Dr Gabe da Silva

Dr Hong Vu

Dr Qiang Fu

Dr Penny Xiao

Dr Samintha Perera Perera

Dr Ella Maria Llanos Rodriquez

Dr Ranjeet Singh

Dr Gary Gibson

Dr Irina Sin

Dr Kuncho Kurtev

Dr Hossein Agheshlui

ASSOCIATES

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Dr George Carman

Mr Sandeep Sharma

Dr Dennis Van Puyvelde

STUDENTS

Mr Syed Anas Ali

Mrs. Meghalim Phukan

Mr Cesar Castaneda Herrera

Ms Nasim Pour

Mr David Danaci

Mr Philip Rossmanith

Mr Guoping Hu

Mr Joel Scofield

Mr Apoorv Jyoti

Mr Yue (Frank) Wu

Mr Angus Keillar

Mr Ke Xie

Mr Jinguk Kim

Mr Joel Yong

Mr Hiep Thuan (Bill) Lu

Ms Jianhua Zhao

Mr Nouman Rafique Mirza

Mr Qinghu Zhao

Mr Thomas Moore

Ms Qi Zheng

Mr. Achyut Mishra

Mr. Anthony Tran

Mr Andre Mu

Ms Elaheh Hosseini

Mr Ehsan Soroodan

Ms Xiaoyin (Shirley) Xu

Mr Angus Keillar

Mr Lefu Tao

Malcolm Garrett at GCCSI Asia Pacific Forum

MEMBERS OF THE PCC SCIENCE ADVISORY COMMITTEE

NAME	AFFILIATION
Dr. Andrew Heap	Geoscience Australia
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Dr. John Burgess	BCIA
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Mr. Geoff Gay	Energy Australia
Prof. Peter Cook	UoM
Dr. Alex Zapantis	GCCSI
Prof. Brian Lovell	Cambridge University (UK)
Mr. Ian Filby	CarbonNet, Victoria Government
Mr. John Krbaleski	Dept of Resources, Victoria Government
Dr. Graham Winkelman	BHP
Prof. Sally Benson	Stanford University (USA)

RESEARCH PROJECTS

CAPTURE PROGRAM

SOLVENT SYSTEMS

NOVEL PROMOTERS FOR CARBON DIOXIDE ABSOPTION IN POTASSIUM CARBONATE SOLUTIONS

Guoping Hu, Kathryn H. Smith, Sandra E. Kentish, Geoff W. Stevens

Carbon dioxide emissions to the atmosphere are major drivers for climate change. In this project, different promoters including carbonic anhydrase, amino acids and a carbonic anhydrase inspired polymer were examined in potassium carbonate solvents for enhancing the carbon dioxide absorption kinetics. Results indicate that the addition of effective promoters can significantly increase the carbon dioxide absorption rate by more than ten times and this can reduce the capital costs and operation costs of a carbon capture plant.

ENCAPSULATED SOLVENTS FOR POST-COMBUSTION CARBON CAPTURE

Thomas Moore, Kathryn Mumford, Geoff Stevens, Paul Webley

The separation of carbon dioxide from flue gases is typically the most expensive stage of a carbon capture and storage operation, and while many solvents and adsorbents could be used for this separation, at present no material is without significant disadvantages. This project aims to develop a new hybrid material, microencapsulated solvents (MECS), in which solvents are encapsulated in small (100-500 micron) polymer shells which are highly permeable to CO_2. Microencapsulation may allow corrosive, viscous or volatile solvents to be used in CCS operations. Further, the very high surface area of these particles enhances the kinetics of absorption, allowing the use of solvents with low regeneration energies, whose kinetics would otherwise be prohibitively slow. This project will investigate the industrial application of MECS for post-combustion capture of CO_2. Through a combination of large-scale process modelling, small-scale transport phenomena analysis and experimental measurements we hope to assess their industrial viability, analyse different process designs, and compare them with existing capture technologies.

INVESTIGATION AND MODELLING OF A PRECIPITATION ABSORBER USING CONCENTRATED POTASSIUM CARBONATE SOLVENTS FOR CARBON DIOXIDE CAPTURE

Yue Wu, Kathryn Mumford, Geoff Stevens

As anthropogenic carbon dioxide (CO_2) emissions are increasing, global warming has been drawing increased attention and concern across the world. This is particularly the case for countries and industries reliant on coal-fired power. One way to capture CO_2 from the flue gas from coal-fired power plants is to use solvent absorption systems. In this project, a precipitating CO_2 capture process using concentrated potassium carbonate (K_2CO_3) solvents is systematically investigated under post-combustion process conditions (approximately 1 bar and 20-60 °C) from three aspects: (1) thermodynamic properties of the solvent system; (2) precipitating kinetics; (3) process model (absorber) development.

Due to the strong electrolytes present in the concentrated K_2CO_3 solvent system, an electrolyte non-random two liquid (ENRTL) thermodynamic model is regressed through the Data Regression System (DRS) in Aspen Plus®. The model is successfully validated with experimental data, and used to predict the thermodynamic properties of the solvent system, such as CO_2 partial pressure, precipitate solubility, CO_2 reaction kinetics and CO_2 diffusivity etc.

The precipitation kinetics of the concentrated K_2CO_3 solvent system including primary nucleation, secondary nucleation and crystal growth is comprehensively studied in an unseeded batch cooling crystalliser using a focused beam reflectance measurement (FBRM®) probe and OptimaxTM workstation 1001. The supersaturation of the precipitates, a primary driving force for precipitation kinetics, is evaluated from the regressed ENRTL model.

A process model using the concentrated K_2CO_3 solvent system, in the form of an equilibrium-based absorber and a rate-based absorber, is developed in Aspen Custom Modeller by integrating the regressed ENRTL thermodynamic model. The use of Aspen Custom Modeller is able to provide a flexible and convenient platform for the process model. The process model can be further improved via the introduction of promoters or can be transformed as a dynamic column to monitor the absorption performance in Aspen Custom Modeller.

MEMBRANE SYSTEMS

MEMBRANE GAS SOLVENT CONTRACTORS FOR CARBON CAPTURE: PILOT PLANT DEMONSTRATION

Nouman Mirza, Sandra E. Kentish, Colin A. Scholes

The project is the pilot plant testing of membrane gas solvent contactor technology for the efficient capture of CO_2 from flue gas at a power station in NSW. The pilot plant process incorporates both the absorption of CO_2 from the flue gas into the solvent and the regeneration of the solvent, within compact membrane modules. Hence, the membrane contactor technology can replace traditional solvent columns for both the absorption and regeneration stages. The pilot plant is designed to process 50 kg/hr of flue gas, recovery 90% of the CO_2 and produce a high purity CO_2 product stream. Importantly, the technology is based on commercially available membrane modules, to ensure that the process can be easily scaled to handle greater amounts of flue gas. This pilot plant is the first in the world to trial a combined absorption and regeneration process through membrane contactors, developed on learns from two previous pilot plants of membrane contactors for absorption. The regeneration stage is more energy efficient than traditional solvent processes, because it takes advantage of the membrane ability to separate the solvent and gas phases. Hence, this enable the process to operate at a reduced steam duty. The first campaign of the pilot plant is scheduled for February 2018 with a subsequent campaign in July 2018. The successfully outcomes from this project is a viable membrane contactor process for efficient and low cost carbon capture that is competitive with traditional solvent absorption.

THE IMPACT OF IMPURITIES ON THE PERFORMANCE OF CELLULOSE TRUACETATE MEMBRANES FOR CO_2 SEPARATION

Hiep Lu, Colin Scholes, Shinji Kanehashi, Sandra Kentish

Cellulose triacetate (CTA) membranes have been widely applied in natural gas processing and have competitive CO_2/N_2 selectivity for both pre and post-combustion carbon capture. This project has investigated the effects of a range of gas impurities on CTA membrane performance in these applications. The membranes were relatively stable when exposed to liquid water at pH 3 and pH 7 with a 30% increase in CO_2 and N_2 permeability and no loss in CO_2/N_2 selectivity. However, the membrane failed at pH 1 due to hydrolysis of the CTA polymer chains. Similarly, the membrane performance declined significantly when exposed to 0.74 kPa NOx at 22°C over a 120 day aging period. This was due to the reaction of trace NO_2 in the gas mixture with the alcohol functional groups within the membrane structure.

In natural gas processing, the performance of CTA membranes can also be affected by ethylene glycol, which can be entrained into the membrane separation unit from the upstream dehydration unit. It was found that the glycols initially absorbed into the membrane reducing the permeation of He, CO_2 and CH_4 by a "pore-blocking" mechanism, but after a period of time, plasticised the membranes and enhanced the transport of CO_2 and CH_4. The membrane performance recovered when the glycols were removed from the polymer using a methanol wash. Hydrogen sulphide in the raw natural gas might also affect CTA membrane performance in both natural gas processing and pre-combustion carbon capture applications. The permeability of H_2S across a range of partial pressures (up to 0.75 kPa) and temperature (22°C - 80°C) was measured. The membrane was found to be stable at 0.75 kPa H_2S at 22°C for up to 300 days. At low CO_2 partial pressure (0.75 bar), the permeation of CO_2 and CH_4 through the CTA membrane declined when adding toluene and xylene of up to 0.5 vapour activity. However, the CTA membrane was plasticised when toluene vapour activity increased above 0.5 activity. At high CO_2 pressure (7.5 bar), the membranes were plasticised by both hydrocarbons at 0.3 vapour activity. The PhD thesis on this topic was submitted in January 2018.

EFFICIENT CO_2 DELIVERY FROM FLUE GAS TO MICROALGAE PONDS THROUGH A NOVEL MEMBRANE SYSTEM

Qi Zheng, Shirley Xu, Greg Martin, Sandra Kentish

During microalgae cultivation, carbon dioxide is supplied as the carbon source for photosynthesising microalgae. The traditional strategy is to directly bubble CO_2 gas into photobioreactors or microalgae ponds. However, most CO_2 is lost into the atmosphere. Several technologies, such as microbubbles, porous membrane spargers or non-porous membrane contactors, have been applied to reduce the CO_2 losses. However, these CO_2 delivery technologies cannot eliminate the energy associated with the compression and transportation of CO_2.

In the present work, a novel system, consisting of chemical absorption, membrane separation and microalgae cultivation, was demonstrated to capture and transport CO_2 from flue gas to microalgae. The novel approach can reduce energy requirements for the compression and transportation of CO_2 and avoid energy penalty for the regeneration of solvents as incurred in the conventional chemical absorption process.

Chemical solvents studied in the current work were potassium carbonate (K_2CO_3), monoethanolamine and potassium glycinate. They were studied in combination with a marine strain of Chlorella sp., freshwater Chlorella vulgaris, and marine Dunaliella tertiolecta. Potassium glycinate was identified as the optimum solvent while marine algae gave slightly better results than freshwater. The work has established a novel method for CO_2 delivery to microalgae, reducing the energy for compression and transportation of CO_2. It represents important implications in CO_2 capture and utilization.

Dr Qi Zheng has recently graduated, after a PhD thesis focussed on this topic. A new PhD student, Shirley Xu, has recently commenced to continue this work, with a focus on scaleup and pH control.

THE FABRICATION OF THIN FILMS ON HOLLOW FIBRE MEMBRANE CONTACTORS FOR PROMOTING THE ABSORPTION OF CARBON DIOXIDE

Joel Yong, Sandra Kentish, Frank Caruso

The use of a carbonic anhydrase (CA) enzyme as a reaction promoter may overcome the reduced overall absorption rates exhibited by K_2CO_3 relative to MEA. However, these enzymes tend to denature at higher temperatures and would not be suited for use in circulation within a traditional absorber-stripper process. The immobilization of the enzyme within the gas absorber or onto a membrane contactor can increase enzyme stability and avoid thermal denaturation in the stripper.

It was found in this investigation that the deposition of CA as a thin film on the surface of a flat sheet membrane was able to increase the membrane resistance to wetting by closing up the membrane pores. The scaling up of the immobilisation technique to hollow fiber membranes also yielded similar results, where the CO_2 mass transfer rates were significantly increased.

The hollow fibers were operated at elevated temperatures of 35°C and 50°C to determine the survivability of the CA in the membrane contactor at those temperatures. The immobilized CA was also contacted with toxic gases such as nitric oxide (NO) and sulfur dioxide (SO_2) or their associated nitrate (NO_3^-) and sulfate (SO_4^{2-}) ions in solution, as these are components of post-combustion gas streams that can inhibit the activity of the CA. The exposure of the immobilized CA to the dry gases or their associated anions did not significantly affect the activity of the immobilized CA. Dr Joel Yong has recently completed his PhD on this topic

SOLVING THE ENERGY WASTE ROADBLOCK SUB-PROJECT 3 – SCALE-UP AND DEVICE FABRICATION

Shinji Kanehashi, Hiep Lu, Alita Aguiar, Sandra Kentish

The work focussed on the potential for mixed matrix membranes to be use in CO_2 capture applications. A number of membranes were developed, including novel MOFs. Their performance under industrial applications was assessed. In particular, the work showed that most membranes containing MOFs would not be stable in the presence of SO_2 and NO_3 impurities. Conversely, porous organic polymers and carbon nanoparticle could be used to build more stable mixed matrix structures. This project is now complete.

BIOLOGICALLY ENHANCED CCS (BECCS)

ADAPTIVE MANAGEMENT SYSTEM FOR SUSTAINABLE BIOENERGY WITH CARBON CAPTURE AND STORAGE (BECCS)

Nasim Pour, Paul Webley, Peter Cook

This project concerns the sustainability of bioenergy with carbon capture and storage (BECSS). In BECCS the CO_2 derived from conversion of the biomass to energy is not released to the atmosphere but is sequestered, transported and permanently stored in a suitable geological formation. The biomass for energy generation is seen as carbon neutral in that the carbon released to the atmosphere during conversion of plant matter was first taken from the atmosphere during photosynthesis. Thus, a negative flow of CO_2 from the atmosphere to the subsurface is established. The potential of BECCS to remove atmospheric CO_2 in addition to generating energy makes it one of the more attractive approaches to achieve the ambitious atmospheric temperature targets such as +2°C. BECCS consists of various variables such as type of biomass resource, conversion technology, CO_2 capture process and storage. Each of these pathways has its own environmental, economic and social impacts. The scope of this study is to integrate these impacts into a three pillar sustainability framework. This framework is provided to assist decision-makers to evaluate sustainability of different BECCS options in a transparent and timely manner. BECCS is an inherently evolving system and fundamentally influenced by ecological, economic and social changes. Accordingly, the sustainability of such system is of an evolving nature as well. For this reason, such system is better to be managed as an adaptive system so that could thrive in an everchanging environment. An adaptive management system allows its components to interact, react and coevolve.

The new capture laboratory in the Department of Chemical Engineering

An essential part of an adaptive system is a decision-making tool. Given multi-faceted nature of BECCS, multi-criteria decision making (MCDM) methods are particularly suitable. The formulation of the MCDM is as follows; first, a set of alternatives for BECCS deployment are defined. To evaluate the sustainability of these alternatives, the most important criteria regarding their technical, environmental, economic and social performances are evaluated. Based on the circumstances and importance of each of these criteria, they are weighted. Then acceptable alternatives are introduced and ranked. A sensitivity analysis to examine the robustness of the alternatives under different circumstances and preferences is executed. The Analytic Hierarchy Process (AHP) is chosen as the MCDM tool. APH is one of the most widely applied decision making tools, which uses pairwise comparisons of criteria to score and rank the alternatives. In evaluation of all these criteria the whole BECCS supply chain from biomass production to CO_2 storage is considered. The adaptive management system proposed in this study will then be applied to investigate the sustainability of different BECCS options in the Australian energy sector.

ADSORBENT SYSTEMS

CO_2 CAPTURE FROM NATURAL GAS: DEVELOPMENT OF ADSORBENTS AND ACCOMPANYING PROCESSES

Lefu Tao, David Danaci, Ranjeet Singh, Penny Xiao, Paul Webley

Work continued on zeolite, ZSM-25 as little work exists on this material and it initial works show it to be promising for CO_2/CH_4 separation. Our work has shown that additional efforts are required on the reproducible synthesis of the material and initial adsorption work has demonstrated that there may be an application in the kinetic separation of CO_2 from CH_4 as the diffusion of CH_4 appears to be slower than CO_2. 2016 will see the completion of the fundamental ZIF study, ideally a successfully synthesised core-shell zeolite and an outcome on the suitability of ZSM-25 for CO_2 /CH_4 separations. In 2016/2017 we successfully synthesized several ion exchange versions of this material and it is currently under study.

In 2016 we started to operate the Otway carbon capture rig. This field unit is in the Otway basin and uses high CO_2 concentration well gas as the feed. A two bed PSA system capable of operation to 100 bar has been designed. Initial tests with silica adsorbent have been promising and we are now in the process of synthesizing a more advanced adsorbent for further testing.

A LOW ENERGY OPTION FOR CARBON DIOXIDE CAPTURE

Qinghu Zhao, Penny Xiao, Paul Webley

Compared with conventional temperature swing adsorption (TSA), electric swing adsorption (ESA), as an emerging CO_2 capture technology, has certain advantages including shorter regeneration time, and higher adsorbent regeneration efficiency. Most of studies of ESA have been done with activated carbon monoliths from MAST Carbon (UK) as adsorbents without considering fluid dynamics in the monoliths channels. The lower CO_2 adsorption capacity of activated carbon however, compared with zeolite, adversely affects its performance; its resistance is very small, and a high current has to be applied, which results in high heat loss. In this project we will develop zeolite/phenolic resin composites to form composite adsorbents to increase the adsorption capacity and resistance at the same time. In addition, we are using CFD based fluid profiles together with MATLAB adsorption models to simulate CO_2 breakthrough and study how fluid dynamics factors affect CO_2 adsorption. Finally, we will combine Vacuum Swing Adsorption (VSA) with ESA to develop new EVSA process to increase the total system efficiency and reduce energy consumption.

POLYMER METAL-ORGANIC FRAMEWORK COMPOSITE STRUCTURE FOR CO_2 CAPTURE APPLICATIONS

Ke Xie, Qiang Fu, Greg Qiao, Paul Webley

Metal-organic frameworks (MOF) are good candidates for gas separation due to their molecular sieving properties and high thermal stability. MOFs are cast into membranes (MOF membranes) or blended with polymer matrix to produce mixed matrix membranes (MMM). Neither of these techniques is optimal as the resultant membranes can have poor mechanical strength, defect-prone features and processing difficulties. In this study, the amino-functionalised MOF (NH_2- UiO-66) and the bromide functionalised MOF (Br@MOF) nanometric crystals (30~50 nm) were successfully prepared and characterised by XPS, XRD, TGA, SEM and TEM. Br@MOF was used to initiate the polymerisation of polyethylene glycol acrylate (PEGA) via atom transfer radical polymerisation (ATRP), resulting in a polymer grafted MOF composite (P@MOF). P@MOF was firstly applied as the catalyst carrier by loading Pd nanoparticles. Owing to its absolute water dispersity and pH-sensitive aggregation-deaggregation nature, Pd loaded P@MOF integrated the advantage of both high homogeneous (high activity) and heterogeneous (good recyclability) catalysts. Furthermore, the unique core-shell structure of P@MOF implies its potential for gas separation MMM. Currently, CO_2 separation measurements (over light gases like CH4 or N_2) are being performed to reveal the CO_2 capture capability of the membranes.

CO_2 CAPTURE FROM FLUE GAS BY VACUUM SWING ADSORPTION

Augustine Ntiamoah, Paul Webley, Penny Xiao

Vacuum swing adsorption is a promising low energy technology for recovering CO_2 from low pressure flue gas streams. In this process, the flue gas is contacted with the adsorbent at atmospheric pressure and the carbon dioxide adsorbs onto the adsorbent in the bed. The adsorbent bed is then reduced in pressure to remove and recover the adsorbed carbon dioxide. Since carbon dioxide is adsorbed much stronger than nitrogen, it is possible to obtain a stream of enriched carbon dioxide. Unfortunately, the purity of carbon dioxide achieved is still not sufficient for sequestration unless very low vacuum levels are used. To overcome this problem, we have developed novel vacuum swing adsorption cycles in which additional pressure equalisation and heavy product reflux steps have been added. This allows us to achieve high purity product without applying excessive vacuum levels.

MATERIALS DEVELOPMENT

CONTINUOUS ASSEMBLY OF POLYMER ON METAL-ORGANIC FRAMEWORK (CAP ON MOF)

Ke Xie, Qiang Fu, Paul Webley, Greg G. Qiao

As estimated by the International Energy Agent (IEA), fossil fuels fulfilled 81% of the world energy demand in 2013. In order to limit the global temperature rise to <2°C, 95% of coal fired and 40% of gas fired power plants need to be equipped with carbon capture and storage (CCS) facilities. Among various CCS approaches, post-combustion CCS is the most urgent one since it can be directly retrofit to existing fossil fuel-fired power generators. Thin film composite membrane (TFCM) systems have been shown to be one of the best ways to achieve high separation permeance. Most of the TFCMs consist of a porous substrate, a gutter layer and an ultra-thin (< 100 nm) top layer. With such a configuration, the gutter layer has always been considered essential since it can provide a smooth surface and prevent the penetration of dilute solution substance into the porous substrate. The performance of such TFCMs can be understood by a well-established resistance model, wherein the gutter layers in these TFCMs will increase the CO_2 capture cost by >100%. Thus, the gutter layer has become a major obstruction that hampers further improvement for membrane performance. We have developed a novel method to overcome this technical barrier by using a continuous MOF layer instead of a polymeric gutter layer. Furthermore, we have developed a bottom-up approach to fabricate what is now the thinnest (~30 nm) polymeric gas separation membrane on a rough micro-scale MOF layer, pre-gown on a substrate. This membrane exhibits excellent gas separation performance for CO_2 capture applications.

STORAGE PROGRAM

GEOCHEMISTRY

CHARACTERISTIC TRENDS IN THE EVOLUTION OF RESERVOIR WATER COMPOSITION DURING CO_2 STORAGE

Hong P. Vu, Ralf R. Haese

Site-specific characterisation, the prediction of CO_2 plume migration and changes in physical-chemical conditions over time are important elements during the exploration and appraisal of prospective CO_2 storage reservoirs. The formation water composition and lithologies can vary significantly between and within reservoirs. Consequently, the evolution of the formation water composition as a reflection of reactions between minerals and CO_2-enriched water will vary as well. For example, the presence of minor carbonate content will buffer the acidity of water and the dissolution of potassium feldspar leads to a characteristic enrichment in dissolved potassium.

This project will compile relevant properties from national and international reservoirs with highly variable lithologies, formation water compositions, temperatures and rock/water-ratios (porosity), which are currently assessed for their CO_2 storage prospectivity. The data will be used to determine the evolution of fluid-rock reactions and the respective formation water composition over time through reaction path modelling. We expect to identify characteristic trends and water quality indicators for particular reservoir conditions. The latter could be used for the development of monitoring plans. Our studies will also estimate the capacity to permanently immobilise CO_2 through mineral (carbonate) precipitation.

The targeted CO_2 storage reservoir in the Gippsland Basin is the Latrobe Group, which will be used as a case study to determine variations in the evolution of formation water within one reservoir. The Latrobe Group sandstone is a relatively homogenous high-porosity / high-permeability reservoir rock, which makes it highly suitable for CO_2 storage. However, intraformational baffles in the form of coals, shales and carbonate (ankerite/siderite) cemented zones are found within and greensands at the top of the Latrobe Group. The reactivity of those lithologies are poorly understood and will be determined in support of CarbonNet's assessments of CO_2 reservoirs the Gippsland Basin.

ENHANCED CONTAINMENT THROUGH BARRIER FORMATION

Jay R. Black, Cesar Herrera, Angus Keillar, Ella M. Llanos, John W. Moreau, Ralf R. Haese

Long-term CO_2 containment is a key criteria for safe CO_2 storage, which is currently assessed through a range of seal integrity studies. While these site-specific studies will always be necessary, developing and testing the process of creating a flow barrier will help to understand how to manage and remediate undesired migration in future storage sites where containment is at an insufficient risk level. The only robust CO_2 leakage mitigation technology so far is pressure management as demonstrated in modelling studies so far. However, this approach requires permanent termination of the CO_2 injection and continued pumping as a means to stir the CO_2 plume away from the leakage point. Here, we propose the development of procedures leading to 'engineered' permanent mineral barriers a) as a remediation option in case of a CO_2 leakage and b) as a (precautionary} CO_2 leakage mitigation technology for areas where seal integrity is possibly at risk. In addition, this project will characterize reservoir microbial communities and will test whether high CO_2 conditions may lead to biofilm formation and/or biomineralisation reducing CO_2 mobility. The two activities on 'engineered' barrier formation are scoped to derive the required information for the design of a field experiment at the CO2CRC Otway Project site demonstrating effective barrier formation as a mitigation and/or remediation technology. The project will integrate desktop studies, laboratory experiments testing microbial metabolic behavior, mineral dissolution and precipitation experiments, and reactive-transport modelling predicting barrier formation and its effect on CO_2 migration.

EVOLUTION OF THE SOLUTE PLUME COMPOSITION AT THE GLENHAVEN SITE (QUEENSLAND)

Nicolas Spycher (Lawrence Berkeley National Laboratory, USA), Ralf R. Haese

The site-specific geological characterisation, the prediction of CO_2 plume migration and changes in physical-chemical conditions under CO_2 storage conditions are important elements during the exploration and appraisal of prospective CO_2 storage reservoirs. The formation water composition, the gas composition of the injectate and lithologies can vary significantly within reservoirs. Consequently, changes in the formation water composition as a reflection of reactions between the injectate and formation water and the gas-enriched formation water and minerals will be dynamic in space and time. For example, minor concentrations of SO_2 can be present in the injectate and will lead to sulfuric acid formation as it dissolves into formation water in the presence of (minor concentrations of) O_2. The additional acid, however, can be buffered through the dissolution of carbonate minerals.

This project will assess the chemical evolution of formation water using two complementary approaches: Firstly, the speciation of formation water following the dissolution of the injectate gas will be calculated and reaction path modelling will be carried out to identify the most relevant fluid-mineral reactions and trends in the formation water evolution for a range of conditions (mainly variations in mineral reactive surface area and injectate gas compositions). Secondly, a 2-dimensional reaction-transport model will be developed for selected transects using the ToughReact software with input from the reaction path modelling in order to observe the extent and concentration changes within the water plume affected by the mixing and reactions with the injectate gas and reservoir minerals.

The targeted CO_2 storage reservoir is the Precipice Sandstone and its overlying regional seal, the Evergreen Formation, at CTSCo's Glenhaven site (eastern Surat Basin). The modelling will be based on an up-to-date geological model of the region and well-constrained formation water and injection gas compositions.

ARE VERTICAL JOINTS AND FRACTURES SELF-SEALING DURING BUOYANCY-DRIVEN CO_2 MIGRATION IN CONTINENTAL FLOOD BASALTS?

M. Phukan1, H. P. Vu1, R. Haese1

The permanent disposal of carbon dioxide in the subsurface has been considered a viable mitigation option to reduce global warming. Sedimentary basins have been studied over years as a conventional storage reservoir for CO_2 due to presence of caprock, but the mineralisation of CO_2 might take thousands of years to occur. Continental flood basalts are considered unconventional CO_2 storage reservoirs where interbedded massive basalt zones serve as barriers for upward CO_2 migration. However, vertical joints and sub vertical fractures in those massive basalt zones may serve as conduits for buoyancy-driven CO_2 migration and thereby pose a risk to CO_2 containment. Basalts have high concentrations in Ca-, Mg- and Fe-bearing silica minerals and basaltic glass, which are known to dissolve in low pH, CO_2-enriched water. The dissolution of basalt phases consumes protons and leads to an enrichment in dissolved silica and di-valent cations to the point when secondary minerals precipitate. Mineral precipitation in joints and fractures may be sufficient to reduce or fully block fluid flow. This research project will investigate the conditions and capacity of self-sealing of these joints.

Batch reactor and core flood experiments are used to determine the rate of dissolution and precipitation reactions and the required fluid residence time for self-sealing. The kinetics of mineral dissolution is studied in batch reactor experiments, using basalt wafers as the reactive sample immersed in CO_2-saturated fluid. Results from fluid analysis shows a rapid increase in cation (e.g., Ca and Mg) concentrations, followed by a significant reduction in those cations suggesting precipitation of secondary minerals. Further, geochemical modelling suggests the formation of clay minerals and zeolites, which could be potential sealants under the conditions of the experiments.

Future experimental work involves core flood experiments to better understand the reactive-transport of CO_2-saturated fluid and associated dissolution and precipitation reactions in basalt cores with artificial fractures.

GEOCHEMISTRY AND RESEVOIR ENGINEERING

QUANTIFYING $C0_2$ TRAPPING MECHANISMS AND CAPACITY IN OPEN SALINE AQUIFERS - THE ROLE OF RESERVOIR HETEROGENEITY

Kuncho Kurtev, Achyut Mishra, Ralf R. Haese, Stephan K. Matthai,

Injection of CO_2 in open reservoirs will greatly enhance storage opportunities, but requires capillary, dissolution and mineral trapping to act rapidly and on short time and length scales. The proposed research project will test the hypothesis that CO_2 migrating significant distances through 'open' saline aquifers will be trapped by capillary, dissolution and mineral precipitation mechanisms. In particular it will quantify how natural heterogeneity in saline aquifers enhances the trapping mechanisms, providing robust estimates of trapping rates in open and confined aquifers benchmarked against existing field data.

Transport, geochemical processes and the associated CO_2 trapping mechanisms in geological reservoirs are highly dependent on the nature of structural and lithological heterogeneities. However, important cm- to meter scale heterogeneities are not incorporated into storage complex models because they can neither be seismically imaged nor represented by grid cells. This project will determine capillary, dissolution and mineral trapping over time for open and closed saline aquifers accounting for such heterogeneities. A series of coordinated process studies using experimental, analytical and numeric approaches will be carried out with the aim to estimate the proportion of CO_2 trapping by the different mechanisms over time. The $C0_2$CRC Otway and the SaskPower Aquistore sites will be used as case studies, where detailed geological information is available. Ultimately, the project will advance the conceptual representation of CO_2 trapping over time in saline aquifers to a quantitative representation based on our case studies.

Core samples used for experiments and reservoir rock characterisation

RESEVOIR ENGINEERING

SIMULATION-BASED FORECASTING AND MONITORING OF SUBSURFACE BEHAVIOUR OF CARBON DIOXIDE

Lutz Gross (University of Queensland), Andre Revil (Université Savoie Mont Blanc, France), Stephan K. Matthai

Accurate simulation, forecasting, and monitoring of carbon dioxide behaviour is a prerequisite for safe and cost-effective subsurface CO_2 abatement. Supporting the Australian clean coal and energy sectors in this quest, with tools and expertise that will boost productivity by transforming traditional discipline-separated sequential workflows, is the goal of this reservoir engineering - hydrogeophysics - simulation-guided engineering project. Via new multiphysics software integrating: 1) fine-grained parallel space-time adaptive injection simulation, 2) forecasting of the CO_2 -plume geophysical signature, 3) inverse analysis of the plume, and 4) simulation-driven design of injection and monitoring systems, we will improve subsurface knowledge and advance the understanding of Australia's storage capacity. Demonstration and validation of this new carbon dioxide storage methodology will occur with datasets from Otway, Aquistore and a Chinese CCS site.

ALTERNATIVE MODELLING AND SIMULATION OF THE GREENSHANK CO2-GEO-SEQUESTRATION PROSPECT, GIPPSLAND BASIN, VICTORIA

Hossein Agheshlui, Caroline Milliotte (NFR Studies GmbH, Austria), Stephan Matthai,

Previous CO_2 -geo-sequestration simulations of the stratigraphic/aquifer trap referred to as Greenshank, indicate multi-pathing of the plume. Injection of 5Mtpa over 25 years (125Mt = desired storage capacity) creates a plume that reaches the boundary of the static model after 500 years. There are considerable uncertainties in these forecasts, and the use of regular (structured) corner-point grids (CPG) has imposed serious limitations on the physical realism of the representation and the accuracy of geologic structures in reservoir simulation models. The faults in the Greenshank area have complex shapes. Arguably these cannot be captured realistically by CPGs, but have a major impact on fluid flow.

Unstable displacement of the CO_2 that manifests itself in viscous- and heterogeneity-induced fingering is another uncertainty factor. The CO_2 displacement patterns are also strongly affected by buoyancy leading to gravity override and other phenomena. Such rate-dependent behaviour is not captured by standard saturation functions that perform poorly for injection processes in the presence of heterogeneity.

This project applies a more flexible alternative model building, (unstructured) finite-element meshing, and simulation approach. A suite of highly realistic geo- and reservoir simulation models of CarbonNet's Greenshank CO_2 -geo-sequestration target are being built for a sensitivity analysis of the effects of depth-conversion uncertainty (as will be captured by a suite of different horizon position models), connectivity between highly permeable geobodies, and permeability anisotropy. The analysis will be conducted with the CSMP++ CO_2 -geo-sequestration simulator, establishing a thorough understanding of how petro-physical variations and coupling/uncoupling of the component physics at work are likely to give rise to a plume behaviour where even small changes in the early path can lead through a "butterfly effect" to quite large changes in outcomes at later times. Understanding the impact of the faults on the plume spreading and how rate dependence and hysteresis of the saturation functions affect plume sweep and residual trapping will form part of this analysis and will lend more credibility to the forecasts. The central question that will be addressed concerns the storage capacity of the site: can 125 Mt be stored? – When will the boundary or spill-points be reached? How does the maximum amount vary with injection strategy?

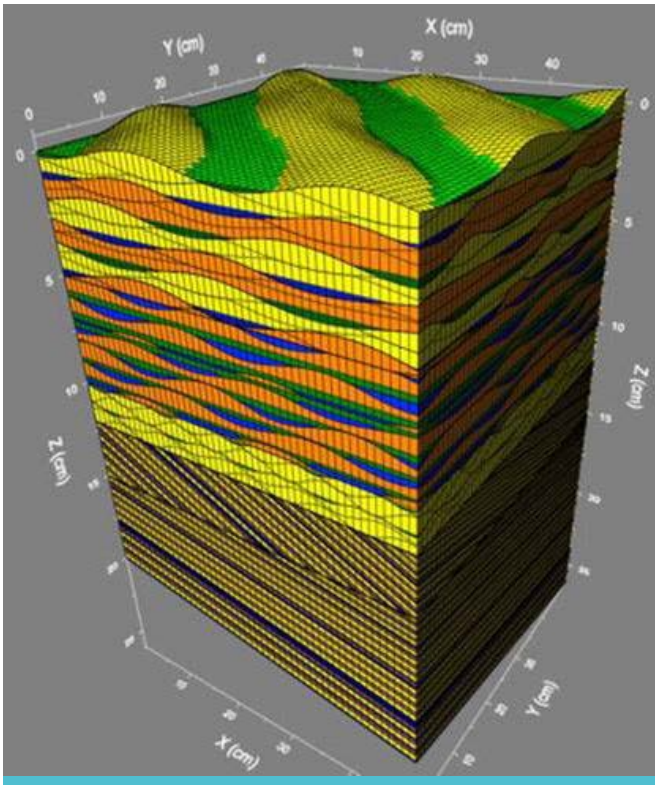
DEVELOPMENT OF UNSTEADY-STATE CONTINUUM SCALE SOLVER FOR CORE SCALE SIMULATIONS

Hani Akbari (University of Queensland), Stephan Matthai

This project develops a parallelised tensor-property hybrid finite element – finite volume solver for the upscaling of pore-network modelling derived saturation functions from the micro plug to the whole-core scale. The development is based on the software API CSMP++. The first step is the verification of this solver with classical CO_2 migration benchmarks, including analytical solutions and verification cases from the literature: A) Pruess et al. (2004) Problem 3: 1D radial flow salt precipitation problem; B) Pruess et al. (2004) Problem 4: migration up a fault zone; C) Pruess et al. (2004) Problem 7: layered system brine displacement; D) Class et al. (2009) Problem 1.2: leakage through an abandoned well.

The new CSMP++ unsteady state solver will facilitate the computation of equivalent relative permeabilities, in the presence of combined gravitational, capillary and viscous forces on the cm-scale (hybrid FEM-FVM pressure-saturation formulation including capillary pressure in global pressure equation). By contrast with standard tools, it will be suitable for computations between the capillary- and the viscous limits, and the algorithms will handle saturation functions in an effective manner for media with full tensor permeabilities. The methodology for unstructured mesh generation and quality will also be improved.

The project also includes A) the validation of the USS solver by comparing measured and observed CO_2 : brine fluid distributions. B) An initial demonstration of the impact of incorporating realistic bedding structure and geometries on equivalent relative permeability functions at the near wellbore and single geo-cell scale.



Well-spot facies and rock-type model for cross-bedded fluvial sandstone

SEISMOLOGY

OPTIMISATION OF EARTHQUAKE MONITORING FOR CCS APPLICATIONS ON LOCAL AND MICROEARTHQUAKE SCALES

Gary Gibson, Abraham Jones, Januka Attanayake, Mike Sandiford

This project focuses on earthquake monitoring in CO_2 storage sites in the Australian context. Seismic monitoring is relatively difficult for proposed CarbonNet storage sites in the Gippsland Basin because of soft near-surface rocks and unconsolidated sediments, together with the offshore location.

The issues include:

- the need to install seismographs on unconsolidated near-surface sediments resulting in high transitory noise from anthropogenic sources.
- deep sediments and soft rock, leading to strong surface wave noise from waves and wind.
- Site response, where near surface soft rock and/or unconsolidated sediments will significantly alter the seismic wave motion measured at the surface compared with that at bedrock. Low seismic wave velocities delay arrival times at the surface, affecting earthquake location accuracy if a time correction is not used. The effect on wave amplitude involves both amplification and attenuation. Amplification effects include impedance amplification and site resonance. Attenuation effects include absorption of energy, and reflection and refraction effects at layer interfaces.
- Very deep sediments and soft rock leading to rapid attenuation of signal amplitudes with distance, especially high frequency vibrations from smaller earthquakes.
- Ocean bottom seismographs at the seafloor interface between water and soft sediments will experience strong ongoing surface waves along this surface.

Measures to mitigate these problems include:

- using a high-density network in the target area to reduce the distance from earthquakes to the nearest seismographs, thus increasing signal to noise ratio.
- installing seismometers in postholes (~2 to 4 metres deep) or shallow boreholes (10 to 100 metres) to reduce both transitory and ongoing surface wave amplitudes.
- using new high-frequency seismometers and accelerometers with flat response to 100 or 200 Hz, which will record motion from small nearby earthquakes at frequencies above most of the ongoing surface wave noise, while still recording the long period motion from larger earthquakes required for focal mechanisms.
- improving epicentral location accuracy by installing some instruments on hard rock at greater distances that will not suffer from strong high-frequency attenuation and will give much clearer and more precise seismic wave arrival times,but giving little constraint on earthquake depth estimates.
- we can do little regarding attenuation or sea-floor surface wave noise, other than quantifying local attenuation using amplitude measurements, then using site-specific attenuation functions. These measurements will be complicated by the focal mechanism radiation pattern from each event.

BASIN ANALYSIS

DISTRIBUTION AND GEOMETRY OF LATROBE GROUP INTRAFORMATIONAL SEALS, GIPPSLAND BASIN

Julie Dickinson, Guy W. Holdgate, Malcolm W. Wallace

This project will provide a detailed understanding of the stratigraphy and structure of the Latrobe Group, with particular emphasis on the seal lithologies within the unit (largely coal and shale). The project will synthesize seismic, well log, core and lithological data onshore and offshore in order to produce a 3D map of seals within the unit. This will provide important information for the assessment of CO_2 storage sites in near- and off-shore areas of the Gippsland Basin. To date there is limited published work integrating the offshore to the onshore seismic coverage where there is more abundant well log and core data and extensive 2D seismic surveys. This project will therefore provide a better understanding of the way in which CO_2 will migrate and be stored within the Latrobe Group sediments. It will also provide a facies model for the Latrobe Group coals and sands that may be applied to other coal successions globally.

ATMOSPHERIC MONITORING

AN ATMOSPHERIC ASSURANCE SYSTEM FOR THE GIPPSLAND NEAR-SHORE ENVIRONMENT

Nicholas M. Deutscher (The University of Wollongong), Peter J. Rayner

This project establishes fit-for-purpose atmospheric monitoring methods and technologies for discriminate between detected environmental signals in CCS locations. This project achieves these goals by creating and demonstrating a passive, area-integrated measurement network that can detect and triangulate anomalous sources with high probability. It does this by combining the integrating effects of atmospheric flow with path-integrating measurements. The project addresses what the optimal instrument combination and configuration that might be effective for CCS application within the Gippsland environment.

AWARDS AND ACHIEVEMENTS

AWARDS BY POST-GRADUATE STUDENTS

Apoorv Jyoti received the Best Oral Presentation (Dynamic Earth Session), Victorian Universities Earth & Environmental Sciences Conference, 2017.

Achyut Mishra received the Best Poster Award (CO_2 Storage Session), Australian CCS Research Conference, 2017.

Guoping Hu received the Best Oral Presentation at the 10th Research Symposium for Chinese PhD Students and Scholars in Australia, November 2017

Guoping Hu received a Global Award for Young Researchers Finalist, IChemE, September 2017.

Guoping Hu won the Young Scientist Research Prizes, Royal Society of Victoria, August 2017.

Guoping Hu received the Best Poster Presentation, Australian CCS Conference, Melbourne, June 2017.

AWARDS BY ACADEMIC STAFF

Kathryn Mumford was awarded the IChemE Warner Prize in 2016. The medal is presented every two years to an individual, who has shown exceptional promise in the field of sustainable chemical process technology, nuclear technology or in making chemical engineering more accessible to a wider scientific community.

Sandra Kentish was listed as one of Australia's Most Innovative Engineers, by Engineers Australia in 2017.

Ralf Haese received the Dean's Award of Excellence in Engagement (Industry), Faculty of Science in 2017.

Guoping Hu receiving the Royal Society of Victoria Young Scientist Research Prize.

ROLES AND APPOINTMENTS OF ACADEMIC STAFF

PETER COOK

- Member of the Energy and Resources Expert Group of the Commonwealth Science Council, Australia
- Witness of the Nuclear Fuel Cycle Royal Commission established by the South Australian Government
- Member of the Technical Working Group, Coal Innovation NSW
- Principal Adviser for CO2CRC Ltd
- Member of the CarbonNet Project Steering Committee, Victorian Government

MALCOLM GARRETT

- Chair, Peter Cook Centre for CCS Research

RALF HAESE

- Director, Peter Cook Centre for CCS Research
- Science Leader Geochemistry, ANLEC R&D
- Member of the Melbourne Energy Institute Executive Committee
- Member of the Melbourne Collaborative Research Infrastructure Committee

SANDRA KENTISH

- Head of School, Chemical and Biomedical Engineering
- Scientific Evaluation Panel, Helmholtz-Zentrum Geesthacht, Germany.
- Technical Advisory Group for the Technical Programme Committee, International Conference on Greenhouse Gas Control Technologies (GHGT-14)
- Consultant to The Scientific Inquiry into Hydraulic Fracturing in the Northern Territory
- Drafting Group, ATSE CCS Action Statement.
- International Evaluation Panel of Chemical Engineering Studies, University of Bologna, Italy.
- Associate Editor, Clean Energy
- Editorial Board, International Journal of Greenhouse Gas Control
- Editorial Committee, Chinese Journal of Chemical Engineering
- Editorial Board, Food Engineering Reviews
- Invited Professor, Centre for Water, Earth and the Environment, INRS, Canada

STEPHAN MATTHAI

- Science Leader Reservoir Engineering, ANLEC R&D
- Board member, lead software developer, CSMP++ Originators Group of Universities
- Steering committee and review panel member, EAGE ECMOR – European Conference on the Mathematics of Oil Recovery
- Member of the Melbourne Energy Institute Executive Committee

KATHRYN MUMFORD

- Deputy Director, Peter Cook Centre for CCS Research

GEOFF STEVENS

- Associate Editor-in Chief of the Chinese Journal of Chemical Engineering (CJChE)
- Board Member of Separation and Purification Technology
- Editorial Board of the Chemical Engineering Journal
- Editorial Board of the International Journal Solvent Extraction and Ion Exchange
- Editorial Board of the international journal Hydrometallurgy
- Fellow of the Australian Institute of Mining and Metallurgy

PAUL WEBLEY

- Head of Department, Chemical Engineering
- Editor, Separation and Purification Technology
- Board Member and Vice President, International Adsorption Society

INTERNATIONAL ENGAGEMENT

The Melbourne Energy Institute, Prof. Peter Cook, Prof. Robyn Batterham and Prof. Paul Webley engaged with the Shenhua Corporation in China in 2017 to discuss a partnership for the development of low-emission technologies including CCS.

Prof. Paul Webley participated in the Mission Innovation workshop on CCUS in Houston (USA) from 26-29 September 2017.

Prof. Sandra Kentish continues to collaborate with the Centre for Water, Earth and the Environment (INRS) in Quebec, Canada, to develop a process for the sequestration of carbon dioxide into a mineral form. Most recently, she has been assisting a PhD student to assess the opportunities for energy integration within their process. This student will visit the University of Melbourne laboratories in February 2018. Sandra has been appointed as an invited Professor of the INRS since 2011 in recognition of her contribution to this work.

Prof. Sandra Kentish continues to collaborate with Meiji University in Japan. In 2017, a graduate student from the Meiji Membrane group, led by Professor Kazu Nagai, visited for three months. In 2018, a student will visit for one year. Professor Kentish also continues to collaborate with Dr Shinji Kanehashi from Tokyo University of Agriculture and Technology. Their latest journal publication resulted in media attention, notably in the Carbon Capture Journal.

Prof. Ralf Haese and Mr. Sandeep Sharma visited Ahmedabad and Delhi in India in February 2016 to prepare a proposal for the Australian CCS RDD Program. Meetings were held with our research partner, the Gujarat Energy Research and Management Institute (GERMI), two companies and a number of state and federal government departments.

Prof. Peter Cook, Prof. Ralf Haese and Prof. Stephan Matthai participated in workshops at the University of Cambridge (UK, November 2016) and Stanford University (USA, June 2017) as part of the GeoCquest project funded by BHP.

Dr. Kathryn Mumford attended the Global CCS Symposium – Advancing a Path Forward, in Regina, Canada, Oct 3-5, 2017. This symposium was hosted by the International CCS Knowledge Centre and occurred over two days and included a tour of SaskPower's Boundary Dam Integrated CCS Project, Aquistore and the Carbon Capture Test Facility in Estevan, Saskatchewan, Canada.

Prof. Peter Cook, Prof. Robin Batterham and Prof. Peter Doherty from The University of Melbourne met with delegates from the National Institute of Clean and Low-Carbon Energy (NICE) in Beijing, China.

NATIONAL ENGAGEMENT

ROUNDTABLE: BUILDING CCUS COALITIONS AND MOMENTUM

The Peter Cook Centre for CCS Research hosted and chaired a roundtable discussion on the 12th of July 2016 on behalf of the Department of Foreign Affairs and Trade (DFAT). It brought together representatives from Federal and State Government, industry, academia and other institutions to share knowledge, ideas and aspirations about the future role of CCUS in Australia and in partnering countries.

The momentum for the forum arose in light of Australian Government emission reduction commitments at COP 21, together with recognition that some of the nation's primary export commodities are at risk in a carbon constrained environment. The discussion was set in a content in which fossil fuels will continue to play a significant role in the global energy mix for decades to come. It also acknowledged that there is a need to decrease emissions from the domestic industrial sector where coal or gas use cannot be replaced by renewables.

The issues around cost, policy, and social license to operate were explored in depth by Roundtable participants. At the close of discussions, it was clear that the narrative around CCUS needs to strongly convey that for most industrial and chemical processes, there is no real alternative to the deployment of CCUS for the reduction of carbon emissions. Given these industrial processes account for 25% of total global emissions this is a critical area to address.

A renewed narrative on CCUS should also clearly capture the inevitable fact that many climate models call for negative emissions after 2050. There is no other technology available that can achieve this – CCS is the only technology that can remove CO_2 from the atmosphere.

The way forward in promoting deployment of CCUS is through collaboration, both domestically and particularly with like-minded countries working in partnership with Australia. DFAT are striving to facilitate collaborative projects with other countries via its network of its global trade links.

LAUNCH OF THE EIF CCSNET LABORATORIES

On the 28th of September 2016 the University of Melbourne and the CO2CRC Ltd. officially opened new dedicated CCS laboratories at the University of Melbourne. The Minister for Education and Training, Senator the Hon. Simon Birmingham was unfortunately unable to attend the event. Instead he sent a video message.

The new CCS laboratories together with field monitoring equipment, CCS modelling software and a 3D visualization room worth over $11 million are established at The University of Melbourne through an agreement with the CO2CRC Ltd. who received funding for the CCSNET project from the Australian Government's Education Investment Fund (EIF).

More than 60 guests listened to speeches by Mrs Tania Constable, CO2CRC's CEO and Prof. Ralf Haese, Deputy Director of the Peter Cook Centre for CCS Research. The University of Melbourne's Vice-Chancellor, Professor Glyn Davis, unveiled the plaque. Afterwards guests were given a guided tour of the impressive new facilities.

Prof. Ralf Haese, Mr. Greg Lewin, Prof. Glyn Davis, Mrs. Tania Constable, Prof. Geoff Stevens, Prof. Peter Cook, A/Prof. Malcolm Garratt

DISTINGUISHED GUEST LECTURER 2016:

Dr. Julio Friedman is a senior fellow at the Lawrence Livermore National Laboratory, where he serves as the Lab's chief expert in energy technologies and systems. He recently served as Principal Deputy Assistant Secretary for the Office of Fossil Energy at the Department of Energy. His portfolio includes R&D and programs in Clean Coal and Carbon Management, Oil and Gas systems, international engagements in clean fossil energy, and inter-agency engagements within the US government. Previously he held the position of Deputy Assistant Secretary for Clean Coal and Carbon Management, Office of Fossil Energy. He was responsible for DOE's R&D program in advanced fossil energy systems, large demonstration projects, carbon capture, utilization, and storage (CCUS), and clean coal deployment.

Dr. Friedman was hosted by the Peter Cook Centre for CCS Research from the 24th to the 28th of October 2016. Dr. Friedman visited Melbourne, Canberra and Brisbane where he held meetings with CO2CRC Ltd., the Global CCS Institute, BHP, the Mineral Council of Australia, the Victorian Department for Economic Development, Jobs, Transport and Resources, the Federal Department for Industry and the Office of the Prime Minister. Dr. Friedman discussed research priorities of the US Department of Energy (DOE) and provided feedback on the research portfolio of the Peter Cook Centre. He gave public lectures in Melbourne, Canberra and Brisbane on technology and R&D needs in order to achieve the CO_2 emission reduction targets set by the COP 21 Agreement in Paris at the end of 2015.

The Distinguished Guest Lecturer Series is co-hosted by the Melbourne Energy Institute and is supported by the Minerals Council of Australia.

DISTINGUISHED GUEST LECTURER 2017:

Professor Sally Benson is an eminent scientist and engineer, and a major contributor to developing technology options and pathways for decreasing greenhouse gas emissions. She has published more than 160 papers on energy and environmental issues during her career at Lawrence Berkeley National Laboratory and Stanford University, serves on many Boards and advisory bodies and was an IPCC Co-ordinating Lead Author. Professor Benson is currently Director of the Global Climate and Energy Project (GCEP) at Stanford and co-Director of the Precourt Institute for Energy, also at Stanford University.

Prof. Benson was hosted by the Peter Cook Centre for CCS Research from the 23rd to the 27th of October 2017. A very busy schedule allowed her to have meetings with the CO2CRC Ltd., the Global CCS Institute, BHP, the Minerals Council of Australia, the Victorian Department for Economic Development, Jobs, Transport and Resources, the Federal Department for Energy and Environment, the Office of the Minister for Resources and Northern Australia and the Office of the Prime Minister. Prof.. Benson gave a Peter Cook Centre Special Seminar on multiphase flow and CO_2 trapping in reservoir rocks and provided an overview of energy research at Stanford University to the Melbourne Energy Institute. Her public lecture discussed the role of energy system analysis to make good energy decisions.

The Distinguished Guest Lecturer Series is co-hosted by the Melbourne Energy Institute and supported by the Minerals Council of Australia.

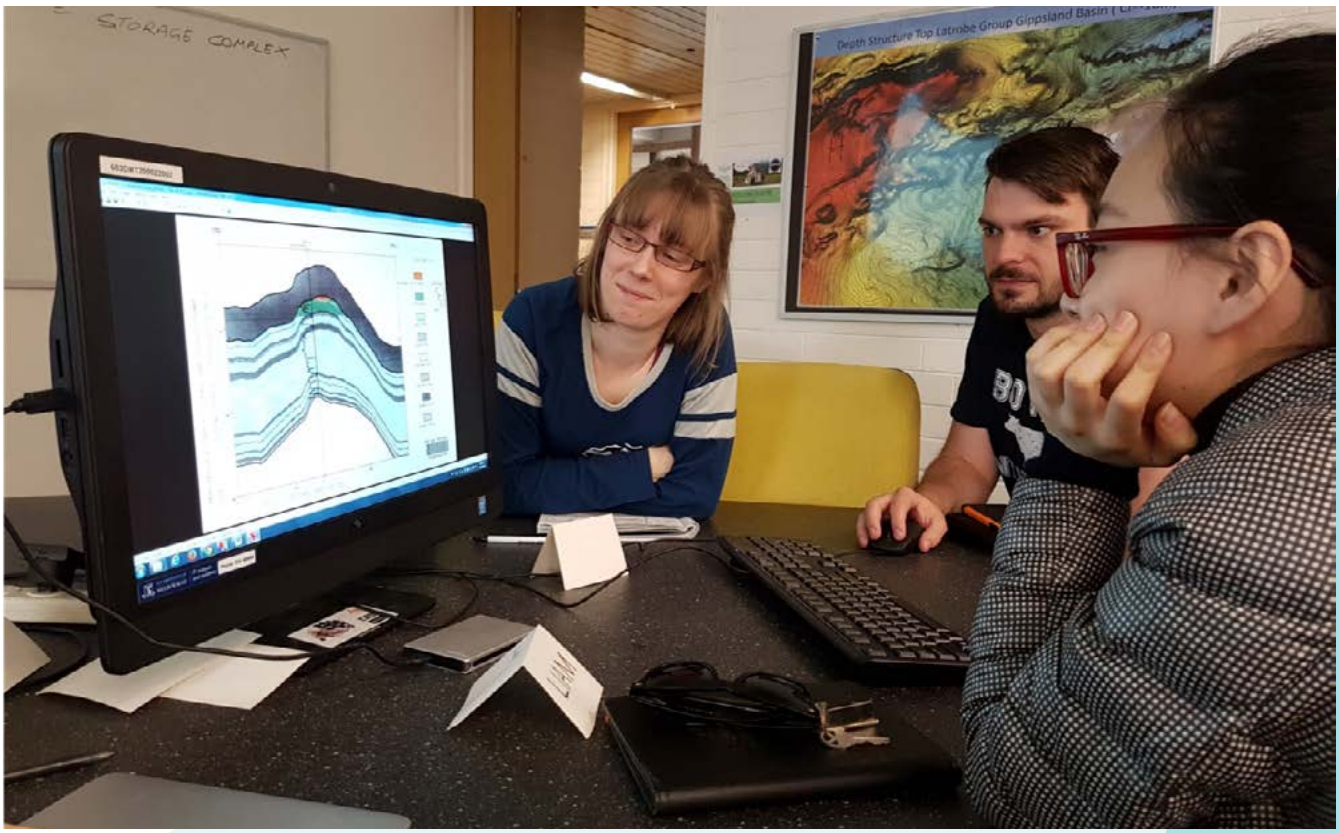
A COURSE FOR PROFESSIONALS AND POST-GRADUATE STUDENTS

FUNDAMENTALS OF GEOLOGICAL CARBON STORAGE

The Peter Cook Centre for CCS Research together with the School of Earth Sciences at The University of Melbourne is offering an intensive course on geological carbon storage. The course is open to professionals as well as to post-graduate students and was given in the last week of September 2016 and the first week of July 2017. The lecturer is Dr. George Carman, who has worked as a petroleum geologist throughout his career; he served the Victorian CarbonNet Project as Exploration and Development Manager and Subsurface Storage Director for more than 3 years.

The course covers a large range of technical and scientific aspects pertinent to geological carbon storage. It commences with basin and play scale analyses and rapidly focus onto portfolio management for storage site screening, storage site selection and site analysis for future appraisal and development operations. Whilst a sound basic knowledge of geosciences and/or reservoir engineering is required, the application of those skills sets is reviewed and applied in hands-on group exercises.

The course had 25 participants each year including 5 or 6 professionals from industry, the Victorian and Federal governments. The course is supported by the Global CCS Institute and offers participation at no cost to their member organisations.



THE AUSTRALIAN CCS RESEARCH CONFERENCE 2017

The Australian CCS Research Conference 2017 brought together Australian researchers for the first time in three years to discuss the latest developments in Carbon Capture and Storage (CCS) research. The conference was hosted by the Peter Cook Centre for CCS Research and the Global CCS Institute. Over 100 delegates gathered on the 20th of June 2017 in the award-winning Arts West Building at The University of Melbourne.

Presentations by delegates from governments, industry and research organisations covered important areas such as capture technology development, reducing the risks of CO_2 storage through improved monitoring and the reflection of CCS in the media in recent years. The conference was opened by Mrs. Samantha McCulloch, an energy analyst working at the International Energy Agency and lead author of the recent book, '20 Years of Carbon Capture and Storage – Accelerating Future Deployment'.

Over 60 oral and poster presentations were a tribute of the vibrant CCS R&D community in Australia. Presentations in plenary and parallel sessions included 'blue-sky', early conceptual research, experimental and modeling proof-of-concept studies, results from field demonstration experiments and updates on research progress at Australia's CCS Flagship sites. Many delegates stayed and continued their discussions after the formal closure of the conference. No doubt, the Australian CCS Research Conference 2017 was a great success and the Peter Cook Centre for CCS Research and the Global CCS Institute already agreed to organise this important event once again in one or two years.

PRESENTATIONS

Agheshlui, H., Matthai, S.K., (2017) Prediction of Fracture Aperture in Fragmented Rocks. Paper presented in SIAM Conference on Mathematical and Computational Issues in the Geosciences, Erlangen, Germany, 11-14 September.

Agheshlui, H., Matthai, S.K. (2017). "Ground Deflection Modelling Due to CO_2 Injection". Australian CCS Research Conference, Parkville, Vic, Australia,18 June.

Ali, S. A., Black, J. R. and R. R. Haese. Determining the intrinsic reactive surface area of minerals and the implications for near-wellbore geochemical reservoir stimulations. Goldschmidt Conference, Paris (France), August 2017. (Poster)

Black, J. R., Castaneda-Herrera, C. A., Llanos, E. M., Haese, R. R. and G. Stevens. Abatement of CO_2 leakage with silica gel barriers. Australian CCS Research Conference, Melbourne, June 2017. (Oral)

Black, J. R., Castaneda-Herrera, C. A., Llanos, E. M., Stevens, G.W., Haese, R.R. Silica gel formation as a barrier to CO_2 Leakage. Goldschmidt Conference, Paris (France), August 2017. (Oral)

Castaneda-Herrera, C., Black, J.R., Stevens, G.W., Haese, R.R., 2017. Preliminary experiments for a chemical reactive barrier as a leakage mitigation technology". Poster presentation. GHGT-13 Greenhouse Gas Control Technologies Conference 13, Lausanne (Switzerland), November 2016. (Poster)

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