Perspectives
ON BROWN COAL

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OFFICAL NEWSLETTER OF BROWN COAL INNOVATION AUSTRALIA

IN THIS ISSUE

CEO'S UPDATE

Dr Phil Gurney
BCIA CEO & Director

International partnerships point the way for the future of brown coal

This issue of Perspectives has a strong focus on international and industry partnerships – partnerships that BCIA is supporting to take brown coal R&D out of the laboratory and towards commercial adoption. In doing so, BCIA's research and industry partners are helping to accelerate the deployment of improved, environmentally responsible uses of brown coal.

BCIA's focus in funding R&D activity is to ensure that Australia has access to the skills and technologies necessary to continue the economically beneficial use of brown coal - in an emissions-constrained world. By supporting top-class Australian researchers to partner with international R&D facilities, BCIA encourages the cross-fertilisation of ideas, and enables access to equipment that is not available locally. When research is nearing commercialisation, BCIA also assists researchers to work with appropriate local and international industry partners, enabling full economic evaluation of the benefits of R&D, and access to facilities that enable the rapid scale-up of technologies.

In this issue of *Perspectives*, Seng Lim provides an update on the Chemical Looping Combustion project; an excellent example of how BCIA funded research projects are collaborating locally and internationally. David McManus provides an overview on a range of other BCIA funded research, and how the links to Europe, Japan and China are helping these projects to fulfil their true potential.

In an exciting development, the BCIA funded PICA project, a collaboration between AGL Loy Yang, CSIRO, IHI (Japan) and BCIA, has recently started capturing CO_2 from the power station flue gas. This project uses a new carbon capture plant (the fourth pilot plant BCIA has helped fund) to enable long-term testing of CO_2 capture - we feature an update on the launch event on page 16.

Over the last five years, BCIA has directly supported 16 PhD students, with around 40 research students involved in our program of R&D. In this issue, we hear from two of these PhD students about their projects. Adeel Ghayur has recently commenced work on how CO_2 capture will change the industrial ecology of the Latrobe Valley, while Manabendra Saha has now submitted his thesis on MILD combustion and its application to Victorian brown coal. We also feature a "where are they now" section on some of BCIA's PhD students who have recently completed their projects – if you are looking for highly skilled and motivated employees, you will find them here!

The Victorian State Government has recently announced an aspirational target of "net zero" CO_2 emissions for the State by 2050. This will be a difficult target to achieve, and will have an impact on all sectors of the economy, not least in how the State uses its brown coal resources into the future. Through the Take2 initiative, the State Government is calling on Victorian companies to drive innovation and technology to address climate change. BCIA has taken the "Take 2" pledge, as you can see on page 15.

As always, I trust that you find this issue of *Perspectives* interesting and informative, and hope that it will inspire you to contribute to the future for brown coal in Australia!

RESEARCH PROJECT UPDATES

Advancing chemical looping combustion technology for Victorian brown coal

By Dr Seng Lim, Group Leader - Energy Resource Processing, CSIRO Energy Flagship

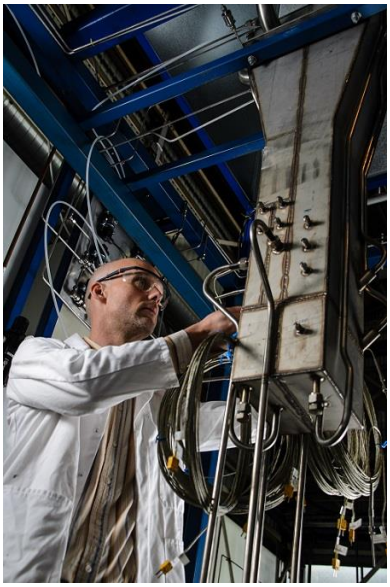
It is recognised that CO_2 capture contributes about 50 per cent of the overall cost of the carbon capture and sequestration (CCS). Chemical looping combustion (CLC) of fossil fuel is considered to be a promising emerging technology for facilitating the capture of CO_2 at a lower cost and energy penalty than the other pre- and post-combustion capture technologies. R&D in this area is being actively pursued in a number of EU countries (such as Sweden, Germany, Spain, Belgium, Netherlands, Austria), USA, Canada, Japan, Korea and China.

The Chemical Looping Combustion (CLC) process uses metal oxides as oxygen carriers to enable the combustion process. This approach results in highly concentrated streams of CO_2 without the need for an expensive air separation unit (ASU) – a system that contributes to the high cost of other pre-combustion CO_2 capture technologies, such as oxy-combustion and gasification.

BCIA is currently sponsoring a CLC project, co-led by Monash University and CSIRO, to evaluate the technical efficacy and economic viability of the CLC process with Victoria's world class brown coal resource. This project builds on an

earlier BCIA sponsored project at Monash University, which confirmed that the high reactivity of Victorian brown coal makes it very suitable for CLC.

The current project is a truly international collaboration. On the technology development side, it involves the Flemish Institute for Technological Research (VITO), Belgium, a major research institution with expertise in the synthesis of advanced oxygen carrier materials. On the commercial development side, it involves ALSTOM Boiler/GE, France, with expertise in CLC process modelling and techno-economic evaluation. The project is further supported with the local expertise of EnergyAustralia and Lycopodium Engineering. The project partners provide highly relevant and complementary expertise critical to further advancing CLC technology for Victorian brown coal.



Above: Trevor Hadley of CSIRO inspects the CLC Rig

A major focus of this project is the use of a nominally 10kW continuous compact CLC reactor system at the CSIRO Clayton Laboratory. This custom-built facility is the first continuous looping CLC reactor in Australia. It is designed to enable continuous feeding of fuel into a fully looped reactor system, which consists of inter-connected fuel and air reactors. The facility is fully supported with online gas analysis and the appropriate control and monitoring systems.

The continuous looping CLC reactor allows brown coal CLC research to progress from small-scale batch processing to continuous operating conditions. This will provide a better understanding of the longer term coal and oxygen carrier interaction effects. The research in this facility will enable scientific and engineering evaluation of the CLC process conditions, and the performance of a range of metal oxide oxygen carriers including Australian natural minerals and synthetic materials.

Significantly, the data generated through this project will assist in techno-economic evaluation of a commercial scale brown coal based CLC plant (i.e. ~500MW). The credibility of this modelling will be boosted through the collaboration with Alstom/GE, which has extensive commercial expertise in CLC technologies. The project will also provide training and capacity-building for new skills and expertise in this exciting new technology area.

Figure 1: Chemical looping (a) bench scale system (Monash University) and (b) compact fully looped, continuously fed 10kW CLC reactor system (CSIRO).

Participants

The BCIA project participants have the following expertise:

- Monash University - Fundamental understanding of kinetic, reaction and interaction of Victorian brown coal with metal oxide under simulated CLC environment. Analytical experience with electron microscopy, synchrotron, XRF, XRD, XPS and process simulation.
- CSIRO - Fluidised bed process know-how in experimental design with industrial relevance. Engineering evaluation and scale up of fluidised bed processes. Mineral processing and mineralogy understanding.
- EnergyAustralia - Power generation know-how, commercial and economic understanding, interest in CTX applications, asset evaluation.
- Southeast University - Experimental technique and test regime relevant to Chinese lignite in CLC environment.
- University of Alberta - Experimental technique and test regime relevant to Canadian lignite in CLC environment.
- VITO - Oxygen carrier development and bulk production expertise.
- Lycopodium - Process modelling, evaluation and engineering scale up and economics.

Above: Participants in the industry-academia collaborative project for the advancement of chemical looping combustion technology for Victorian brown coals

An update on brown coal projects

By Dr David McManus, Research Investment Manager, BCIA

One of BCIA's objectives in developing its research portfolio is to cultivate significant international collaborations that will create new opportunities for Victoria's massive brown coal resource. This is exemplified by the projects currently being funded by BCIA, in the areas of efficient brown coal combustion and reduced cost carbon capture.

Given the urgent need to rapidly reduce global greenhouse gas emissions, coal-fired power generation must be coupled with carbon capture and storage (CCS) technologies to remain relevant. To facilitate this, the current round of BCIA-funded power generation projects are targeted at (a) achieving higher efficiency power generation, to reduce the quantity of CO_2 produced; (b) reducing the cost of post-combustion carbon capture (PCC); and (c) combustion in oxygen rather than air, to produce a concentrated stream of CO_2 and eliminate the need for PCC equipment altogether.

In each of these areas, BCIA-funded projects are leveraging local expertise with the involvement of major international companies, to maximise the prospect of rapid commercial outcomes that will be of benefit in Victoria.

Higher efficiency power generation

The 'Victorian DICE Development' project, led by CSIRO in Newcastle, aims to demonstrate that a 50:50 mixture of brown coal in water can be successfully used as a fuel in a large, two-stroke diesel test engine in Japan. Previous BCIA-funded research by CSIRO established the feasibility of this concept at laboratory scale, which attracted the commercial interest of MAN Diesel & Turbo SE, the world's leading provider of large-bore diesel engines and turbomachinery for marine and stationary applications.

MAN Diesel & Turbo is based in Augsburg, Germany, while its two-stroke engines are developed in Copenhagen, Denmark. These engines, ranging in capacity from 2MW to 87MW, are manufactured by international licensees for use in large container vessels, freighters and oil tankers.

MAN Diesel & Turbo is providing the technical expertise needed to develop new engine components capable of handling abrasive coal-based fuels. A successful outcome for the 'Victorian DICE Development' project will open a pathway to a new type of coal-fired power generation, with the potential for the efficient, flexible operation needed for integration with intermittent renewable energy sources.

Reduced cost of PCC

The 'Evaluation of advanced PCC with two advanced liquid absorbents' project is led by CSIRO in Newcastle. CSIRO is the lead developer of advanced PCC technologies in Australia, and for this project has partnered with IHI Corporation, of Japan.

IHI Corporation is one of the major international manufacturers of coal-fired boilers, and has supplied 15 boilers for coal-fired power plants in Australia. IHI is actively developing two types of clean coal technologies, i.e. oxyfuel

combustion and PCC to reduce the greenhouse gas emissions from coal-fired power. IHI Corporation was a partner in the demonstration of oxyfuel combustion technology at the Callide Oxyfuel Project, which was successfully completed in March 2015. IHI Corporation is now accelerating its efforts with PCC, and has developed a new liquid absorbent, an advanced packing system and an advanced PCC process.

IHI Corporation, with technical support from CSIRO, has designed and constructed a new PCC pilot plant which is now successfully operating at the AGL Loy Yang power station. The PICA (derived from first letters of PCC, IHI, CSIRO, AGL) research plant is 21 metres high and is capable of operating around the clock, capturing 150 to 200 tonnes of CO_2 each year. Throughout the two-year program, researchers will study the energy efficiency of various CO_2 capture configurations and the effectiveness of two new CO_2 capture solvents.

This research program is targeting a 40 per cent reduction in the energy required for CO_2 capture, representing a substantial step toward the commercial implementation of PCC. IHI Corporation's Executive Officer, Vice President of Energy and Plant Operations, Mr Yahagi has said, "Without doubt, this PICA project will be a great catalyst for the future of low-emissions technologies in both the Australian and Japanese coal and energy industries."

Looking further into the future, BCIA is also funding a project that is being run jointly by Monash University and the University of Melbourne. This project, called "Development of carbon monoliths for capture of CO_2 by electrical swing absorption", is an international collaboration involving five universities, two R&D institutes, three small to medium sized enterprises (SMEs) and two large industries.

The aim of this collaboration is to develop an innovative post-combustion capture technique called Electric Swing Adsorption (ESA), by using hybrid honeycomb monoliths to selectively remove CO_2 from flue gas streams. The hybrid honeycombs will be manufactured by combining an electrically conductive matrix with a surface coating of CO_2 adsorbent material. An electrical current and waste heat will be used to regenerate the adsorbent, releasing the CO_2 at high purity.

In this project, researchers at Monash University and the University of Melbourne are working in collaboration with two major European companies, Linde Engineering and Corning SAS. Linde Engineering is a world leader in cryogenic technology, with expertise in CO_2 purification and liquefaction. Corning SAS has expertise in fabrication of complex cellular ceramic substrates and particulate filters that form the core of pollution control systems used worldwide in cars, trucks, construction equipment and power plants. The project also involves Biokol KB, a Swedish company, with expertise in fabricating porous carbon-based materials.

Researchers at Monash University and the University of Melbourne are leveraging the expertise of these project partners to fabricate an electrically-conductive honeycomb material from Victorian brown coal, coat it with a polymer that can selectively adsorb CO_2, demonstrate the use of this material in an innovative ESA process, and develop a process model to aid in system design. If successful, this work will pave the way for a new generation of cost-effective CO_2 capture technologies.

Combustion in oxygen to produce concentrated CO_2

The "Accelerating the deployment of oxyfuel combustion technology project", led by Monash University, involves a close collaboration with Shanghai Boiler Works Limited (SBWL), the largest boiler manufacturer in China. SBWL has established expertise in ultra-supercritical combustion boilers and integrated gasification combined cycle (IGCC), and is collaborating with Monash University to develop oxyfuel combustion technology.

In oxyfuel combustion, coal is burned in pure oxygen instead of air. Separating the nitrogen from the air before combustion creates a flue gas that is highly concentrated in CO_2. This facilitates capture of the CO_2 without the need for expensive PCC equipment. A previous BCIA-funded project established the feasibility of oxyfuel combustion of brown coal at pilot scale in Shanghai. The current project extends this work to provide a detailed understanding of ash deposition and slag-forming behaviour, and is helping to identify appropriate steel alloys to withstand corrosion by the ash.

This project could not proceed without a significant investment by SBWL in modifying its 3MW pilot boiler. Monash University has licensed its detailed process modelling codes to SBWL for use in commercial boiler design. SBWL is using the knowledge gained through this collaboration to progressively scale up oxyfuel combustion as a commercial process, through retrofit of a 30MW steam boiler in Xinjiang Province, to be followed by a new design 300MW oxyfuel power plant in Shanxi Province. SBWL has already completed a techno-economic study for an oxyfuel power station in the Latrobe Valley, demonstrating the feasibility of the technology produced through this collaboration to reduce the greenhouse gas footprint of power generation in Victoria.

The main disadvantage of oxyfuel combustion is the need for an expensive air separation unit (ASU) to produce a stream of pure oxygen for burning coal. Exciting new developments are emerging in improved ASU design, which are likely to substantially reduce costs. In the meantime, BCIA has supported the development of an alternative oxyfuel combustion process, known as chemical looping combustion (CLC).

The ”Advancing Chemical Looping Combustion Technology” project, led by Monash University, builds upon an earlier project which established that Victorian brown coal is an excellent fuel for use with CLC. The current project involves scaling up the CLC process using a custom-built continuous-flow reactor at CSIRO in Clayton, which is described by Seng Lim in an article on page 2 of this newsletter. The project has attracted the interest of GE-Alstom of France, a major international power generation technology provider.

GE-Alstom believes that CLC represents the lowest cost option for coal power generation with CCS, and is working to develop two different CLC technologies. In Europe, research is focused on developing metal-oxide based CLC, while limestone-based CLC is being developed in the USA.

The current BCIA funded CLC project involves the use of metal oxides as a carrier of oxygen for combustion of Victorian brown coal, with the metallic oxygen carrier being continually regenerated in an air-blown reactor. This process allows the combustion of brown coal with pure oxygen, without the need for an expensive ASU. GE-Alstom is providing technical and commercial expertise in the development of an appropriate techno-economic model for CLC. This will enable the publication of the first credible techno-economic assessment of metal-oxide based CLC in the public domain.

BCIA research collaborations involve major technology providers from Europe, Japan and China, and aim to cost-effectively capture the CO_2 produced from brown coal-fired power stations in Victoria. The Andrews Labor government has recently pledged to eliminate greenhouse gas emissions from power generation in Victoria by 2050. The only practical way to achieve this is to develop new coal-fired power technologies with affordable CO_2 capture. By leveraging local expertise with the active involvement of major international companies, BCIA is laying the necessary groundwork for this goal to be achieved.

BCIA PhD RESEARCH UPDATES

BCIA's program of postgraduate research scholarships is part of our commitment to strategic investment in skills development. The aim of BCIA's support is to secure the scientific, engineering and trades expertise required for the development of new low-emissions brown coal technologies.

To date, BCIA has awarded 16 research scholarships to PhD candidates at top-ranking Australian universities. In this edition of *Perspectives on Brown Coal* we will hear from BCIA scholarship recipients, Adeel Ghayur from Federation University and Manabendra Saha, from The University of Adelaide.

Latrobe Valley Industrial Ecology for CO_2 utilisation: some preliminary reflections

By Adeel Ghayur, BCIA PhD Top-up Scholarship Recipient, Federation University Australia

The Latrobe Valley has the potential to become Australia's first industrial ecosystem with Carbon Capture, Utilisation and Storage (CCUS). The Latrobe Valley is home to vast brown coal reserves, turning it into an electricity production hub. However, the current generation of inefficient brown coal power plants generate more CO_2 per watt of electricity than black coal power stations. The challenge of tackling climate change thus leaves us with two options; either to shut down the main industry in the Latrobe Valley or to make use of Post-Combustion Carbon Capture (PCC) technologies.

The world is on the cusp of large scale implementation of mature PCC technologies, with Australia taking a lead in the global research. The Latrobe Valley is primed for PCC plants, having a history of successful pilot projects. In a future scenario in which all the CO_2 from power stations is captured, the Latrobe Valley would be accumulating millions of tons annually. The Victorian government's CarbonNet project has confirmed that suitable long term CO_2 storage capacity exists offshore in the Gippsland Basin, close to the Latrobe Valley.

Storing CO_2 under the sea bed is based on the philosophy of treating CO_2 as a major waste stream. However, CO_2 can also be regarded as a resource. In other countries, recovered CO_2 is being used for enhanced oil and gas recovery. Research is being conducted into conversion of CO_2 into fuels, chemicals and plastics, production of fuels and chemicals in algal biorefineries, and applications in the cement, paper and energy industries.

At the moment there are no industrial applications which could consume the enormous quantities of CO_2 produced in the Latrobe Valley, so this is where the work lies ahead. Concerted efforts and focused dedication is needed to find commercial and industrial applications for CO_2 that could be implemented in the Latrobe Valley.

My research project at Federation University Australia, with support by BCIA, is titled "Latrobe Valley industrial ecology with CO_2 capture". My aim is to help develop an Industrial Ecology in the Latrobe Valley, in which the impact of a PCC industry is minimal to the local community and the environment, and CO_2 is valorised. Large scale PCC would allow the coal-fired power plants to continue their operations, while CO_2 applications would help off-set PCC costs and generate local economic activities. A few options are being investigated in this regard.

It is understood that any proposed solution would need to be carefully woven into an intricate net traversing the boundaries of industry, economics, environment, society and public policies. Whichever option is selected for the Valley, the important point would be ensuring its economic feasibility and competitive product generation.

A daunting task lies ahead in the challenge of mitigating climate change and the Latrobe Valley can become a beacon of light by making its contribution towards CO_2 emission reduction. If CO_2 is converted into marketable products in the process, it would be a win-win situation for all – the local and global community.

Adeel Ghayur
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Overview of Victorian brown coal under MILD combustion conditions

By Manabendra Saha, (PhD Candidate), Professor Bassam Dally, Centre for Energy Technology, School of Mechanical Engineering, The University of Adelaide

Moderate or Intense Low oxygen Dilution (MILD) combustion has been identified as an innovative approach that offers ultra-low pollutant emissions, high thermal efficiency, enhanced combustion stability, thermal field uniformity, and broad fuel flexibility. MILD combustion differs from conventional combustion because of the absence of any visible or audible flame at optimised conditions. As a result, MILD combustion is often called 'flameless combustion' or 'flameless oxidation'.

Figure 1 illustrates the operating principles of MILD combustion: low oxygen concentration in the reaction region while the local temperature of the combustible mixture is greater than that of the self-ignition temperature (Tsi) of the reactants. The high temperature of reactants and low oxygen concentration alter the reaction zone to be classified as "volumetric", leading to lower and more homogeneous temperatures. These characteristics reduce the generation of pollutant emissions, in particular controlling NOx, unburned hydrocarbons, particulate matter and trace element emissions.

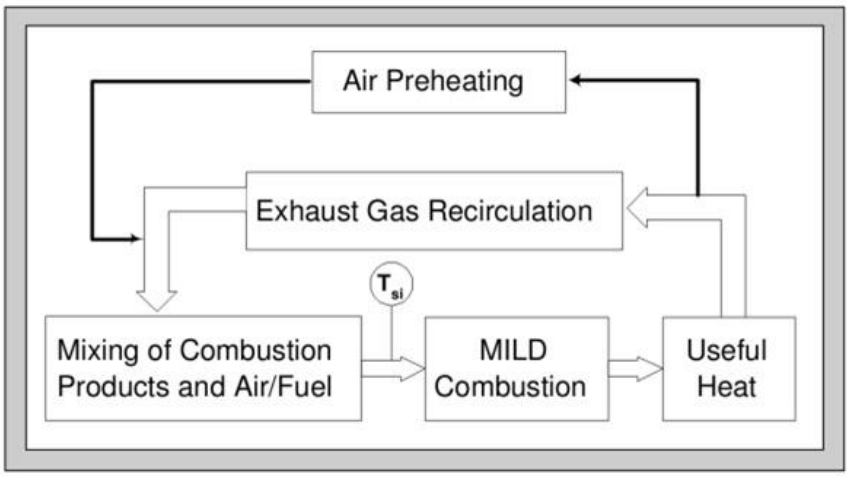

Figure 1: Operation principle of MILD combustion (J. Wünning, U.S. Patent 5154599, 1992)

A knowledge base on MILD combustion has been developed progressively for gaseous and liquid fuels. The International Flame Research Foundation (IFRF) conducted a set of experiments using a semi-industrial 580kW furnace operating on natural gas and reported the potential of MILD combustion. Moreover, MILD combustion technology has been successfully implemented in various industrial sectors for gaseous fuels in various industrial sectors (eg beam furnace at Degerfors in Sweden; annealing furnace for steel industry at Terni in Italy; MILD combustion reformer for the generation of hydrogen fuel at Munich airport in Germany; Les Dunes plant by Ascometal in France; rotary hearth furnace in US etc.).

Despite a successful application of MILD combustion technology for gaseous fuel, this technology is still in its infancy for solid fuels, especially for pulverised brown coal. Thus far, a few studies have been conducted on MILD combustion of pulverised fuels, finding that this technology has potential for increased combustion efficiency with a substantial NOx reduction. BCIA has provided financial support for my PhD project, to deepen understanding on the applicability of MILD combustion for the more efficient use of Victorian brown coal.

The main focus of my research was to investigate the burning characteristics of pulverised Victorian brown coal under MILD combustion conditions. In particular, to investigate the influence of jet inlet velocities of a stream of CO_2 and brown coal (at room temperature) on both the flame stability and the formation and destruction of pollutants. Moreover, the project investigated the impact of turbulence on the devolatilisation of brown coal and the reaction of volatile species under MILD combustion conditions.

A new vertical co-flow furnace was designed and built for the experimental part of this project, as shown in Figure 2 (left). The furnace contained an insulated and water-cooled central jet surrounded by a hot and diluted co-flow. Loy Yang brown coal with two particle size distributions (i.e. 53-125 µm and 250-355 µm) was injected into the furnace using CO_2 as a carrier gas. Flameless combustion was successfully achieved with brown coal, as shown in Figure 2 (right).

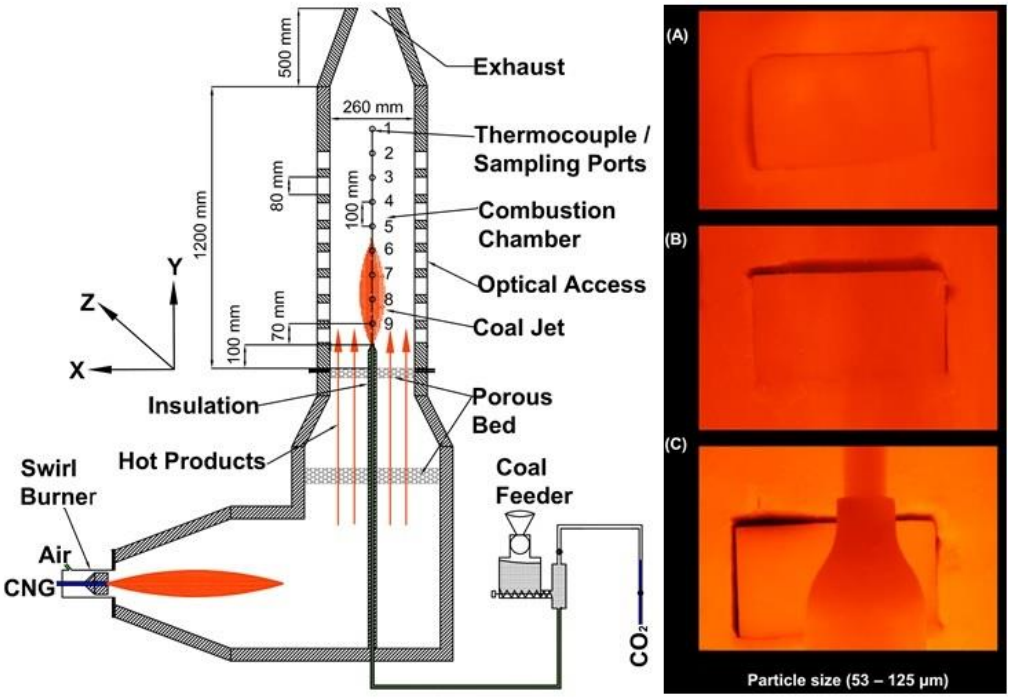

Figure 2: Schematic (left) of the Adelaide MILD combustion furnace and photographs of the inside of the furnace; photographs (right) of flameless combustion in the (A) top, (B) middle, and (C) bottom part of the furnace.

In-furnace temperatures and chemical species were measured (as shown in Figure 3), together CH chemiluminescence (CH*) imaging at the bottom, middle and top parts of the furnace. The CH* signal intensity was found to be significantly lower at the top part of the furnace, which is an indication of the slow rate of heterogeneous combustion of char particles. The highest CO concentrations were measured for the highest jet velocity, suggesting that with increasing turbulence there is a better mixing and formation of a broad devolatilisation zone which produces more CO. Under all conditions, the measured NO emission was less than 125ppmv, which is about half the level reported for power stations in the Latrobe Valley.

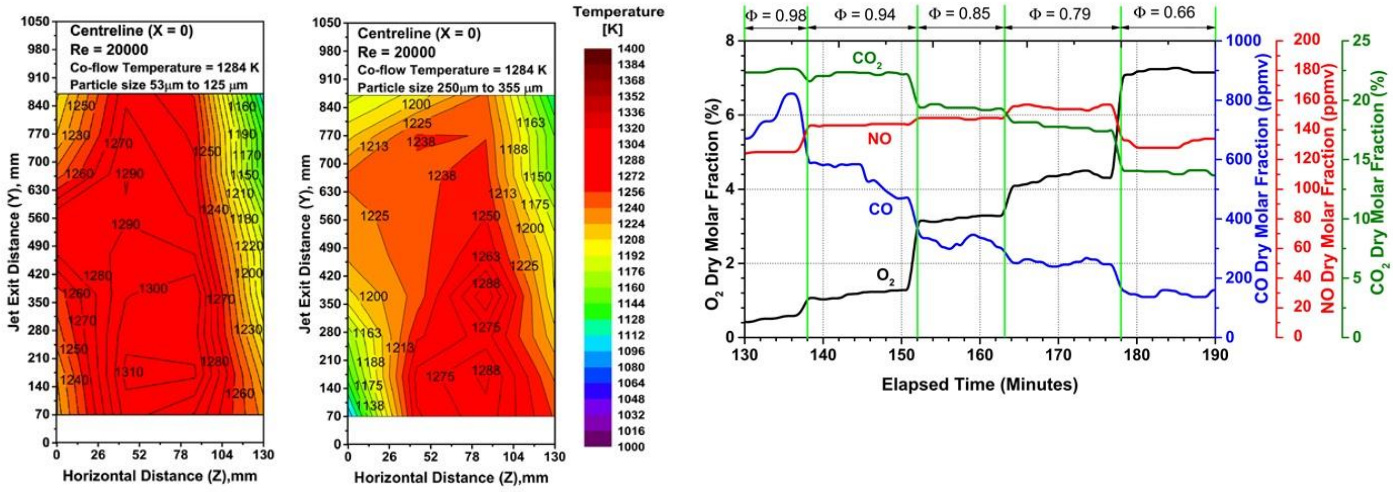

Figure 3: Measured in-furnace temperature distribution (left) and temporal alterations of measured O2, CO, NO and CO_2 in the exhaust when operating under MILD combustion condition with Loy Yang brown coal carried by CO_2.

In addition to the comprehensive experimental investigations, a computational fluid dynamics (CFD) model was developed to better understand the flow field, turbulence intensity, volatiles release rate, combustion of volatile matters, and overall carbon consumption inside the furnace. The model indicated that increasing the turbulence of the jet increases the volatiles release rate. It was found that, for all cases, stable MILD combustion is established with a similar large recirculation vortex around the centre of the furnace. Devolatilisation starts earlier with smaller particles and was completed by the end of the recirculation vortex, while the devolatilisation of larger particles occurred after the recirculation vortex. The difference was found to be related to the particle dispersion within the jet and differences in Stokes number. Importantly, no evidence for soot formation was found under any set of operating conditions.

This study has provided valuable systematic data that has helped to create a fundamental understanding of the MILD combustion of Victorian brown coal. My project has established that MILD combustion of Victorian brown coal is feasible, and has resulted in a CFD modelling tool that can help design the next phase of research. This represents a significant step toward the development of a cleaner, more efficient way to utilise Victorian brown coal for power generation.

SKILLS

Past BCIA PhD scholarship recipients - where are they now?

BCIA supports a range of PhD students, through scholarships, project funding and training. Below we hear from students that have completed their scholarships and are either pursuing or looking for the next step forward in their careers.

Manabendra Saha

2013–2014 Round BCIA PhD Scholarship Recipient

Project topic: Experimental and computational study of solid fuels under MILD combustion

Manabendra Saha is a highly motivated, accomplished and diligent PhD candidate in the School of Mechanical Engineering at The University of Adelaide, who submitted his PhD thesis for examination.

His PhD project is about solving the current energy crisis and exhaust emission problems by innovative and new combustion technology called Moderate or Intense Low Oxygen Dilution (MILD) combustion.

He has gained extensive problem solving skills through designing, and built a 50kW novel reactor/ combustion furnace. In addition, he has developed sophisticated CFD models for solid fuels combustion that were validated by his experimental results.

Manab is currently looking for an opportunity to apply the skills he has learned in the advancement of energy technologies, within a team environment. To find more information on Manab's PhD work, please refer to the article in this newsletter on page 9.

Please contact Manab at manab04me@gmail.com if you know of any suitable job opportunities.

Mamun Mollah

2012 Round BCIA PhD Project Placements

Project topic: Blast furnace coke from lignite

Mamun's PhD titled "Blast furnace coke substitute from Victorian brown coal" was awarded on the 15th September 2015 and he graduated on the 20th April 2016. He is currently working as a part time research assistant on upgrading Victorian brown coal to obtain a blast furnace coke substitute, with Prof. Alan Chaffee and Prof. Roy Jackson in the School of Chemistry, Monash University. He is also working as a teaching associate in the same school.

From the results of Mamun's PhD, he has published three journal papers in "Fuel" and a provisional patent has been filed in Australia. Mamun is currently seeking a full time position where he can utilise his skills in a challenging new role.

Please contact Mamun at mamun.mollah@monash.edu if you know of any suitable job opportunities.

Alicia Reynolds

2010–2011 Round BCIA PhD Scholarship Recipient

Project topic: Identification and monitoring of by-products generated from amine based solvents and adsorbents during post-combustion CO_2 capture (PCC) from brown coal flue gases

Alicia is currently employed at Federation University Australia's Carbon Capture and Storage (CCS) laboratory. She has been enjoying the challenge of commissioning a wide range of new chromatography and mass spectrometry equipment as well as a new scanning electron microscope. A new group of post graduate students are also keen to take advantage of her knowledge and advice for their own research issues.

The CCS laboratory is building a research and consulting capability to meet the needs of local industry, with projects that range from day-to-day troubleshooting in partnership with electricity generators, to working towards a long-term vision of a safe, environmentally friendly CCS industry. With such a wide variety of high quality equipment available, Alicia can be involved in determining the source of a bad smell or oil stain on one day and taking SEM images of metal, ceramic or polymer failures the next.

Karen Little

2010–2011 Round BCIA PhD Scholarship Recipient

Project topic: Sustainable soil carbon and soil health through brown coal-derived products

Karen completed her PhD at Monash University in November 2014 titled 'Commercial lignite coal-derived amendments for improved pasture growth and soil health', supervised by Assoc. Prof. Tony Patti (Monash University), Assoc. Prof. Tim Cavagnaro (University of Adelaide) and Prof. Roy Jackson (Monash University). Her project was to source a range of Victorian brown coal-derived agricultural products and assess the potential benefits, as claimed by manufacturers, around improvements in crop yield and soil health parameters including pH, nutrient availability and microbial communities.

Prior to her PhD study Karen had a biotechnology background but very limited agricultural experience. The BCIA scholarship gave her the opportunity to develop a range of new skills as well as extend her existing skills into new areas.

Since completing her PhD project, Karen has continued to work at Monash University as a post-doctoral researcher, working with Prof. Patti and Prof. Jackson on agricultural projects and completing industry-linked projects that have assessed the application of industrial organic waste streams to pasture and the effects on growth, nutrient cycling and the soil microbial community. Currently they are working with Greenpower Energy to assess the agricultural benefits of a biostimulant product that is in development. The product is made from Victorian brown coal and is unique to the biostimulant market in both its manufacture and composition.

"I'm very grateful for not only the learning opportunities that the scholarship provided but also the support facilitated by BCIA, in particular Dr David McManus and Dr Phil Gurney. I hope to continue to work with brown coal in agriculture and contribute to our current knowledge of soil, plant and humic interactions with the aim of increasing crop yields without detrimental effects to the soil or the environment."

Joanne Tanner

2010–2011 Round BCIA PhD Scholarship Recipient

Project topic: Brown coal derived syngas generation for utilization in higher value product processes

Dr Joanne Tanner received a full BCIA PhD scholarship in 2011, and undertook her postdoctoral studies in the Department of Chemical Engineering at Monash University from 2012-2015.

Her project, entitled "High temperature, entrained flow gasification of Victorian brown coal and Rhenish lignites", was conducted in close collaboration with the Thermochemistry group at the Forschungszentrum Jülich (FZJ) in Germany. Joanne travelled to Germany twice during her candidature to conduct experiments related to her project and to present her results to an international audience.

Following the submission of her thesis in August 2015, Joanne took up an offer from her colleagues at FZJ to return to Germany as a postdoctoral researcher. She worked in the Thermochemistry group for 5 months on the design and commissioning of a new apparatus for assessing inorganic gaseous emissions from Victorian and Rhenish coal pyrolysis, combustion and gasification.

In February 2016, Joanne returned to Monash University as a lecturer and researcher in the Department of Chemical Engineering, where she currently teaches the undergraduate and Master level courses in Reactions Engineering. Her PhD was ratified in March 2016 and the degree conferred at the University graduation ceremony held on 25 May 2016.

Joanne continues to be interested in value added applications for low rank coals, and is also looking to diversify her research to include other potential alternative fuel and chemical feedstocks such as agricultural and industrial waste. She will apply for the ARC DECRA in 2017, with the view to continuing her academic career at Monash University.

Adam Rady

2010–2011 Round BCIA PhD Scholarship Recipient

Project topic: Evaluation of Victorian brown coals as fuel for direct carbon fuel cells (DCFC)

Adam currently works at Ceramic Oxide Fabricators (Aust) Pty Ltd, or COF for short, a family owned business established over 40 years ago, with its roots in Bendigo, Victoria. The company specialises in high purity alumina and zirconia products for science and industry. This includes insulation material, furnace wear such as tubes and crucibles, as well as custom fabrication and ceramics machining capabilities. The company is a world leader with its SIRO2 C700+ solid zirconia electrolyte oxygen sensor, used around the world for furnace control, and scientific applications.

The transition between zirconia fuel cells which Adam studied during his PhD and zirconia oxygen sensors has been fitting. The PhD has enabled him to find commercial solutions to the technical challenges which their customers present them with. Adam is directly involved in oxygen sensors which will enable furnace operation in extreme environments. He is also handling customer enquiries for custom fabrication jobs, which involves making new ceramic components to tolerances defined in engineering drawings.

"I have now been working for COF for 9 months and am thoroughly enjoying the opportunity to engage in industrial R&D as well as facing new engineering challenges on a daily basis, drawing on problem solving skills developed during my PhD."

Amandeep Oberoi

2013–2014 Round BCIA PhD Scholarship Recipient

Project topic: Reversible electrochemical storage of hydrogen in activated carbons from Victorian brown coal and other precursors

Amandeep Oberoi was awarded a 2013 PhD Top-up Scholarship from BCIA to support a postgraduate research project through RMIT University, working with Professor John Andrews. The project, which was completed in April 2016, investigated experimentally the reversible electrochemical hydrogen storage capacity of activated carbon (aC) made from different precursors, including selected activated carbons made from Victorian brown coal. See Issue 16 of BCIA's Perspective newsletter for more information on Amandeep's project.

Amandeep is now an Associate Professor at Chitkara University Punjab, India and besides teaching postgraduate students he is extending his services in CURIN (Chitkara University Research & Innovation Network) where he is involved in various research projects. He is also looking for research funding from the Indian government and industry to support his early career research in electrochemical storage of hydrogen in porous materials.

CLIMATE CHANGE

Take2 – Victoria's climate change pledge

The Victorian Government has recently announced an aspirational target of "net zero" CO_2 emissions for Victoria in 2050. Through the Take2 initiative, it is calling on Victorian companies to drive innovation and technology to address climate change.

Victoria currently relies heavily on brown coal for its power generation. Indeed, Victoria's brown coal power stations are often called on to produce up to 110 per cent of the electricity Victoria uses, thanks in part to exports of electricity to other states.

The way we use brown coal today produces the largest contribution to Victorian emissions of CO_2 into the atmosphere. A net zero target will require substantial changes to the way Victoria uses its coal resources.

BCIA is committed to supporting the Take2 initiative through our R&D and skills development activities. In particular, BCIA supports activities that:

- Accelerate the development of cost-effective carbon capture technologies adapted to Victorian requirements
- Significantly improve the efficiency of coal fired power generation
- Investigate the production of alternate, low or zero CO_2 emissions fuels (such as DME, hydrogen) from brown coal
- Fast-track the commercial deployment of such technologies through funding and partnerships

For more information visit the Take2 website www.take2.vic.gov.au

EVENTS

PICA launch in Latrobe Valley

BCIA was part of a milestone event for the Latrobe Valley on 18 March with the launch of a new carbon capture pilot plant at AGL Loy Yang, attended by over 60 stakeholders. BCIA has partnered with CSIRO, AGL and Japan's IHI on the PICA post-combustion capture (PCC) project, a two-year research program to improve efficiency of carbon dioxide (CO_2) capture. The program will evaluate innovative processes using gases drawn from AGL's Loy Yang brown coal-fired power station.

The name PICA is an acronym formed from PCC and the project partners IHI, CSIRO and AGL. In 2014, BCIA contributed a $650,000 research and development grant towards the $5.3M PICA project, led by CSIRO, the lead developer of advanced PCC technologies in Australia. The PICA project builds on CSIRO's existing PCC program at Loy Yang, which began operation in 2008.

The PICA plant (pictured right) stands 21 metres high and was built in Japan by IHI and transported to AGL Loy Yang, where it is capable of operating 24/7, capturing 150 to 200 tonnes of CO_2 per year.

CO_2 is already being captured at large scale around the world, however cost and efficiency challenges remain an obstacle to wide-scale commercial implementation. In order to overcome these challenges, the PICA project is targeting a 40 per cent reduction in energy use compared with current capture processes.

BCIA Chief Executive Officer Dr Phil Gurney said that to meet Australia's commitment to limit dangerous climate change, emissions of CO_2 from the use of coal must be reduced.

"BCIA has invested heavily in research and development to improve the efficiency of brown coal power generation and reduce the costs of carbon capture technologies," Dr Gurney said.

Pictured from left, Mr Yahagi (IHI), Dr Phil Gurney (BCIA), Jeni Coutts (AGL), Dr Peter Mayfield (CSIRO), local MP Harriet Shing and Gerry Morvell (BCIA) in front of the PICA post-combustion project plant at AGL Loy Yang.

"The PICA project is a major step forward and will make a significant contribution to the broader roll-out of CCS for power generation and the manufacturing sector in the longer term."

It is expected that the PICA plant testing and evaluation campaigns will be completed by the end of 2017. Successful completion of the project is expected to enable scale-up of the next technology phase; most likely a demonstration project at a scale of between 100 and 1000kton CO_2 per year.

SPOTLIGHT ON BCIA MEMBER

Australian National Low Emissions Coal R&D (ANLEC R&D)

ANLEC R&D has invested over 100 million dollars in research and development effort to support demonstration of low emissions coal technologies (LECT) for power generation.

This focus is driven by the recognition that early projects must succeed for LECT to be accepted as a viable option in the full suite of technologies. This will be required to achieve substantial global reductions in CO2 emissions while meeting growing energy demand.

Research at ANLEC R&D addresses the near term risk reduction and technology developments necessary for successful demonstration of LECT in Australia. They provide support for, and investigation of, issues affecting the performance of the early demonstration projects.

Research results to date have:

- Validated lower cost approaches for oxy-fuel to delivery of acceptable flue gas CO_2 quality for transport and storage
- Reported on the environmental performance of post combustion capture for power generation using selected amines
- Enabled the development of 3D digitising technology to reduce reservoir characterisation time
- Reported on prospects for favourable injectivity in the Surat basin
- Delivered leading edge research to inform appraisal well locations and containment for the Perth Basin
- Provided research recommendations for managing multiple resource interactions in the subsurface

ANLEC R&D funding is provided by the Australian Government Department Industry, Innovation and Science through the National Low Emissions Coal Initiative, and by the ACA Low Emissions Technologies Ltd (ACALET) through the COAL21 Fund.

For more information visit www.anlecrd.com.au

BCIA MEMBER
Positioning brown coal for a low-emissions future

MEMBERSHIP

Advantages of a BCIA Membership

BCIA is committed to driving a low-emissions future for Australia's world-class brown coal resource. Being a member-based organisation, BCIA facilitates stakeholders to actively participate in the acceleration of technologies for emissions reduction and the development of high-value products derived from brown coal.

BCIA MEMBER
Positioning brown coal for a low-emissions future

BCIA members encompass a broad range of stakeholders within industry, government, research and education, and international coal technology organisations, who are involved in the conversion of brown coal to value-added products and services operating in the brown coal sector.

BCIA membership enables stakeholders to work with like- minded organisations to drive the future of the brown coal sector through active participation in BCIA skills, networking and R&D programmes to ensure brown coal is heading for a sustainable future.

For more information about BCIA membership please visit bcinnovation.com.au/Membership. If you are interested in becoming a BCIA member, call us on +61 3 9653 9601 or email info@bcinnovation.com.au.

Key benefits of a BCIA membership

- **Commissioned Research Reports** including intelligence gathering and in-depth analysis of global activities and R&D.
- **Research Reports and Symposiums** with the ability to inform and identify focus areas for BCIA sponsored PhD projects.
- **Seminars and Published Reports** on BCIA's extensive research program including development and demonstration projects.
- **Access to a Wide-ranging Expertise** including access to our MEMBERS only web portal.
- **Participation in BCIA's Skills Development activities**, international linkages and networks and community forums.
- **Recognition of each member** organisation's commitment to a low-emissions future for brown coal with opportunity to promote member organisations through the BCIA newsletter *Perspectives* and website.

Brown Coal Innovation Australia Current 2016 Members

CALENDAR OF EVENTS

4–6 July 2016
2016 Energy Future (EF) Conference and Exhibition
Location: Sydney, Australia
Held at the University of New South Wales, this conference provides a unique platform to generate and foster nexus between the scientific world, policy makers, investors, industry and the community and will focus on energy storage – from generation to distribution – and cover international advances alongside an impressive exhibition showcasing advanced energy technologies across the energy sector.
For further details visit: www.ozenergyfuture.com

22 July 2016
2016 Victorian Engineering Excellence Awards
Submission: Online
These awards recognise outstanding, innovative and leading-edge engineering projects and products being developed and delivered by Victorian Engineers. The Victoria Engineering Excellence Awards are an opportunity for businesses of all sizes, across a wide range of sectors to showcase their engineering achievements. It also acts as an excellent platform to highlight and showcase your company and its project to industry leaders, engineering peers, political representatives and the media. Entrants into the VEEA's must complete their online submissions by 5pm on 22 July 2016.
For further details visit: www.engineersaustralia.org.au/victoria-division/awards

8–12 August 2016
The 2016 Pittsburgh Coal Conference
Location: Cape Town, South Africa
The PCC is the "premier" annual event devoted to all aspects of coal, energy and the environment. It aims at fulfilling the ultimate goal of efficient and effective use of coal while protecting the environment. The conference is dedicated to providing a unique opportunity for in-depth and focused exchange of technical information and policy issues among representatives from industry, government and academia throughout the world.
For further details visit: www.engineering.pitt.edu/pcc

5–7 September 2016
11th European Conference on Coal Research and its Applications
Location: University of Sheffield, UK
The purpose of this conference is to bring together researchers in universities and participants from industry who are also carrying out research or are interested in the application of the research in industry.
Papers were invited which describe current academic and industrial research into both high and low rank coals and their applications.
For further details visit: maggichurchouseevents.co.uk/CRF/index.htm

14-15 September 2016
6th IEA CCC Workshop on Cofiring biomass with coal
Location: Sardinia, Italy
This is the 6th workshop in the cofiring coal with biomass series. The last workshop in this series attracted audiences from utilities, industry, universities and research institutes and this year delegates will be attending from Brazil, China, France, Germany, Italy, the Netherlands, Pakistan, Spain, Ukraine, the UK, the USA and others. The following

subjects will be covered in the workshop - biomass supply, sustainability and logistics; pellets and torrefaction; combustion and gasification; slagging and corrosion issues; power plant conversion/adaptation; emissions and ash management; algae cofiring, relevant policies, and case studies.
For further details visit: cofiring6.coalconferences.org/ibis/cofiring6/about-event

5–6 October 2016
European Biomass to Power
Location: Seville, Spain
Already on its 6th edition, this event will give latest updates on the European biomass market and its new developments, as well as focus on sustainability challenges. Over the two days, ACI's conference will give you in-depth look into case studies giving practical examples of planning, finance and technology strategies utilised for biomass co-generation projects.
For further details visit: wplgroup.com/aci/event/european-biomass-to-power/

10–12 November 2016
The 6th Low Carbon Earth Summit (LCES-2016).
Location: Qingdao, China
This is a three day conference comprising four professional parallel forums including Climate Change, Emission Trade, Low Carbon & Smart City, Low Carbon & Clean Technologies. The aim of the conference is to strengthen the technical and business ties in the field of low carbon, and bring experts and industry leaders around the world to exchange state-of-the-art research, development, identify research needs and opportunities in this field
For further details visit: lcesummit.com/2016/ProgramLayout.asp

23–25 November 2016
Australian Engineering Conference 2016
Location: Brisbane, Australia
The Australian Engineering Conference will bring together all areas of the engineering profession, with national and international keynote speakers inspiring delegates and influencing the future direction of engineering in Australia. The conference will advance the engineering profession by providing an opportunity for professionals and industry leaders to share expertise, knowledge and innovations and to forge long-term partnerships through exclusive networking.
For further details visit: www.ausengcon.com.au