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 Chief Executive Officer

Victoria, located in Australia's south, has some of the world's best brown coal. It is extremely low in mineral impurities and sulphur, and its low mining cost means that it is used to generate around 90% of the electricity used in the State, as well as power for export to Australia's northern states. Projects are also progressing for conversion of Victorian brown coals into a range of products such as liquid fuels, hydrogen, fertilisers, and fine chemicals.

Today's uses of brown coal, however, are emissions intensive. If we are to continue to use this resource into the future, far greater effort will need to be made with environmental controls – particularly around CO_2 emissions – by increasing efficiency of use and capturing and storing CO_2 to prevent it entering the atmosphere.

To date in Australia, most State policies for reducing CO_2 are focussed on increasing the use of renewables, primarily solar and wind, and these certainly have a major role to play in a low emissions future. However, in the short term, the application of greater coal combustion efficiency to reduce emissions can be extremely cost effective. For example, a back of the envelope calculation shows that if it was possible to increase the combustion efficiency of Victoria's brown coal power stations today by one tenth of one percent (0.1%), you could get a greater reduction in CO_2 emissions than by installing $200 million of roof-top solar panels.

Research being undertaken in Australia today shows how, by focussing on combustion processes, new brown coal power stations could be built that increase efficiency not by fractions of one percent, but by 30% to 50% (see for example the articles 'High Efficiency Power Generation from Victorian Brown Coal at CSIRO' and 'MILD Combustion of Pulverised Brown Coal'). Those present at the latest BCIA research symposium also heard about research that could lead to reduced emissions from current power stations through use of advanced on-line flue gas analysis (see article 'Overview from Latest BCIA Research Symposium').

BCIA's mission is to fund research and skills development to deliver advances in technologies such as this. Only through an ongoing programme of research, development and demonstration of such advanced technologies can we create cost-effective ways to deploy stable, lower emissions power generation, and provide the world with increased options as it pushes towards restricting atmospheric CO_2 levels. However, investment in such low emissions R&D has all but dried in recent years, and BCIA is finding sourcing the funds it needs for its work increasingly difficult.

This issue of BCIA's *Perspectives* newsletter includes a variety of articles showing how the emissions intensity of brown coal can be reduced. The article by Quanrong Fan ('Dynamic Fuel Injection for Flameless Combustion – A Retrofit Option for Victorian Power Stations?') suggests the potential for retrofitting a novel, free-swinging coal injector, together with the use of MILD combustion to existing power stations. This could theoretically lead to significantly reduced CO_2 emissions, at low cost.

Christopher Munnings of CSIRO provides an update on a BCIA-funded project looking to Direct Carbon Fuel Cells. While this is a longer-term option, with further development this offers the potential to reduce brown coal CO_2 emissions by 50% comported to today's power stations.

BCIA supports a range of PhD projects, and this month we showcase two of them – the article by Manabendra Saha provides more information on the application of MILD combustion, while the article by Rahmat Dirgantara shows how by using brown coal fly ash, it may be possible to reduce the CO_2 emissions associated with cement manufacture in Australia.

In this issue you will also find articles on BCIA's most recent research seminar (presentations are available on **NEWS AND EVENTS**), the ATSE-CERI workshop on Australia and China's low emissions coal technology developments. I trust that you will enjoy this issue of *Perspectives*.

RESEARCH

Dynamic Fuel Injection for Flameless Combustion – A Retrofit Option for Victorian Power Stations?

By Quanrong Fan, Independent Researcher, Fansmelt

Retrofitting power stations to improve fossil fuel combustion efficiency can be a low-cost, and rapidly implemented option to reduce carbon emissions. In recent times, the drive for higher efficiency has led to the introduction of high temperature (supercritical / ultra-supercritical) boilers. However high temperature combustion leads to the formation of nitrogen oxides (NO_x), and costly NO_x scrubbers are required to prevent air pollution. The high temperatures also require the use of exotic materials, further increasing the installation and maintenance cost of the boiler. For these and other reasons it is generally not possible to retrofit high temperature burners to existing boilers.

Australia's current brown coal power stations use standard boiler materials and relatively low temperature combustion, however this comes at the expense of much lower efficiency. Recently there has been interest in so-called MILD or 'flameless' combustion, which by using lower oxygen levels and re-cycled flue gas can reduce NO_x production and deliver up to a 30% improvement in thermal efficiency under lab conditions. This article explores how dynamic fuel injection, combined with flameless combustion (which is the subject of a BCIA-supported PhD project – see article *MILD Combustion of Pulverised Brown Coal*), might be an answer to enabling high efficiency retro-fit for Australia's power stations.

Quanrong Fan has had success in working with steel-making manufacturers to test a dynamic injection lance for retro-fit applications, and approached BCIA to seek partners in the power sector interested in developing this technology – please contact BCIA if you wish to receive further information.

Conventional combustion – with a visible flame – has been perceived as natural phenomenon since ancient times and was unchallenged for use in high temperature industries until the arrival of flameless combustion. For flameless combustion, the injection nozzles for fuel and air are arranged so that flue-gas near the burner can be entrained to dilute the fuel and air. Flameless combustion is thus conducted under lower O_2 concentration, and within the entire furnace instead of by the formation of bright flame near the burner (see Figure 1 below).

Flameless combustion can deliver up to an order of magnitude reduction in NO_x production. With combustion occurring over the entire furnace, there are no hot spots available in the furnace. NO_x production is proportional to the peak temperature of combustion – while it takes a few seconds to produce a substantial amount of NO_x at about 1,900K, it only takes a few milliseconds in a flame at a temperature of 2,300K. Added advantages of flameless combustion include reduced thermal stress on the burner and furnace, and reduced burner noise.

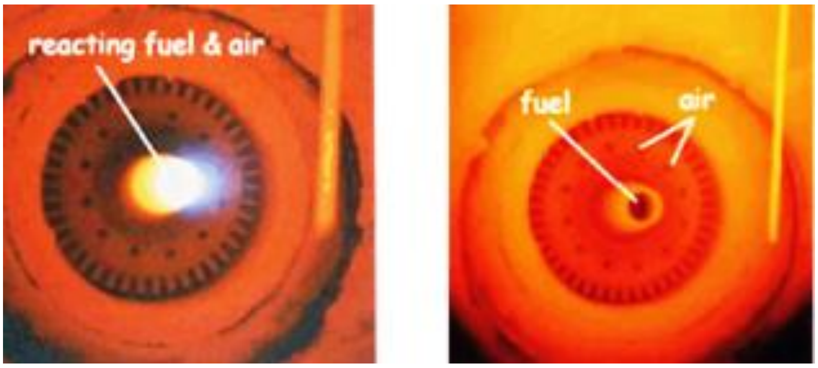


Figure 1: Comparison of flame combustion and flameless combustion by Milani and Wunning.

Milani and Wunning[1] defined flameless combustion by a recirculation ratio of K_v which is the mass flow rate of recirculated flue-gas with respect to that of the fuel and air.

$$K_v = M_{rec} \ / \ (M_{air} + M_{fuel})$$

The ratio K_v depends on the burner design for flue-gas recirculation involved in the air / fuel dilution. When a limited quantity of flue-gas is recirculated for the dilution, combustion takes place with a visible flame attached to the burner as shown in the left photo of Figure 1 (above). To achieve flameless combustion, the burner needs to entrain a large amount of flue gas for significant dilution of the oxygen, thus flameless combustion can be established within the entire volume of the combustion chamber as shown in the right picture of Figure 1 (above).

Research groups around world have used various terms for flameless combustion such as Flameless Oxidation FLOX, High Temperature Air Combustion HTAC and MILD combustion. To date, all these approaches for flameless combustion have been associated with the use of a stationary burner for the injection of the fuel and air.

Flameless combustion using a stationary burner is constrained by the mixing pattern of flue-gas recirculation, and a burner with one injection nozzle has been used for the illustration in Figure 2 (below). In the stationary burner as shown in Figure 2A (below), fresh fuel / air is injected into the middle of the symmetrical flame, and there is limited space for the flue-gas to be entrained for the air dilution before the combustion.

A fundamental game-changer for the mixing pattern, leading to highly efficient dilution, is proposed by means of dynamic fuel injection using a moveable burner.

[1] Ambrogio Milani, J. G. Wünning, "Flameless Oxidation Technology", Advanced Combustion and Aerothermal Technologies, NATO Science for Peace and Security Series C: Environmental Security, 2007, pp 343-352.

In dynamic injection, mixing is related to the movement of the burner. This firing mode is demonstrated with the burner movement to the right as shown in Figure 2B (below), where the flame is pushed to the left to form an asymmetrical flame due to the drag force of the flue gas. Dilution of fuel / air takes place above the nozzle, where there is 90° angle between the streams of flue-gas and fuel / air, and the extent of mixing of the two streams is related to the movement speed of the burner.

Flameless combustion in a dynamic injection mode can be expressed by a mixing ratio, K_m, which is the ratio of the mass flow rate of flue-gas with respect to that of fuel and air.

$$K_m = M_{mix} \;/\; (M_{air} + M_{fuel})$$

The mixing pattern of dynamic injection is no longer an entrained recirculation of flue gas, but a direct mixing between two streams with a contact angle. The amount of flue-gas involved in dilution is now proportional to the movement speed of the burner. With a slow movement of the burner, only a small amount of flue-gas is available for dilution, and flame combustion can be established as shown in Figure 2B (below). As the movement speed of burner increases, flameless combustion is expected due to the increase in the amount of flue-gas available for direct mixing with the air before the combustion.

Figure 2C (below) displays the burner changing the moving direction towards the left side; the burning flame is now located on the right side of the burner under the drag force of the flue-gas. The contact mixing of two streams can be seen above the nozzle on the left side of the flame, where mixing dilution of fuel and air can be achieved before combustion.

With continuous movement of the burner, the burning flame is under the drag force of the flue gas at all times. At the lower part of the flame near the nozzle, arriving flue-gas will heat up and dilute the fuel / air, and flameless combustion can be achieved above the self-ignition temperature; near the top of the flame, heat energy generated by the combustion will be removed by the stream of lower-temperature flue-gas.

While further experimentation is required, it is expected that flameless combustion with dynamic injection will have three advantages:

1. Improved mixing pattern and dilution of the fuel / air before combustion;
2. Improved dilution of combustion due to fuel injection by the dynamic burner across the volume of the furnace, and from different angles; and
3. Improved transfer of heat energy to the flue-gas.

It is expected that flameless combustion with dynamic injection might be obtained at a lower value of the mixing ratio K_m due to the contact dilution, and the temperature is expected to be more homogeneous in the combustion chamber due to the dynamic flame.

The investigation of the flame and flameless combustion by means of the dynamic burner should expand our knowledge and understanding of the burning efficiency, burner design, combustion dynamics and NO_x formation. Such a design with related benefits may be well suited for retrofit to improve the efficiency of existing boilers for Australia's power stations.

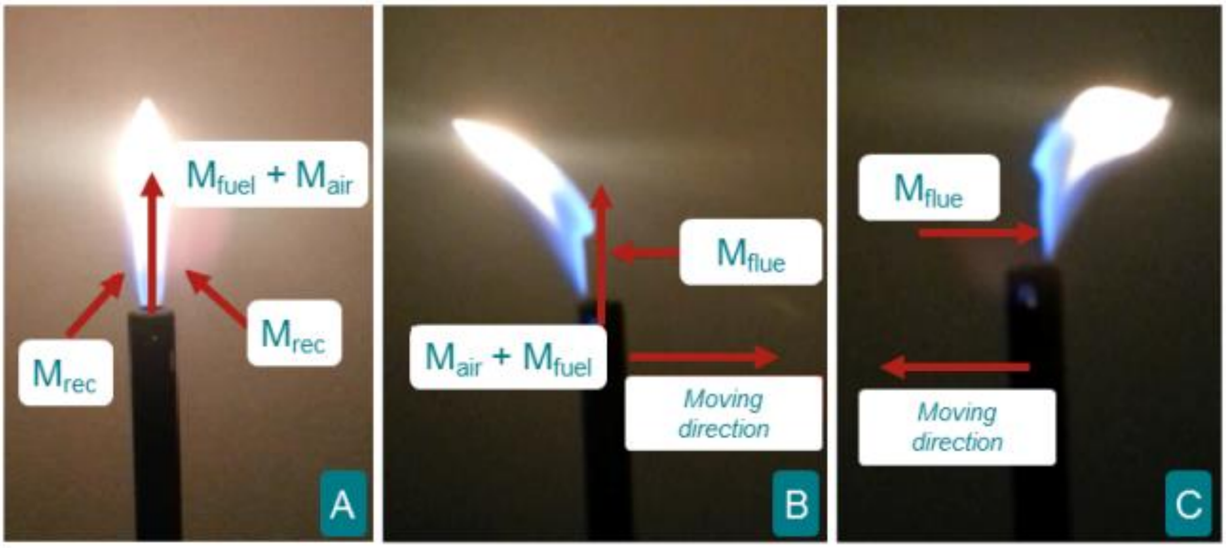


Figure 2: A. Stationary burner with flue recirculation as the mixing pattern; B. Dynamic injection with burner moving to the right direction; C. Dynamic injection with burner moving to the left direction.

SKILLS

Development of Brown Coal Geopolymer Concrete

By Rahmat Dirgantara, PhD Candidate, RMIT University; Supervised by Dr David Law and Assoc. Prof. Tom Molyneaux at School of Civil, Environmental and Chemical Engineering

World-wide, the production of cement releases almost 2 billion tonnes of CO_2 into the atmosphere annually. Fly ash from coal-fired power generation contains silicate materials that can be used as a binder material, and could replace the use of ordinary cement in some applications.
Rahmat Dirgantara's has commenced a BCIA-supported PhD investigating the specific chemical make-up of brown coal fly ash from Victorian power stations, how brown coal derived fly ash can be used to make a novel geopolymer concrete, and the factors that contribute to optimal mechanical strength.

The purpose of the research is to investigate the use of brown coal (BC) fly ash (FA) as a binder to produce geopolymer concrete and to assess its mechanical properties. The potential use of BC FA as a binder in geopolymer concrete could result in utilisation of an industrial by-product from BC burning power stations.

The use of Ordinary Portland (OP) cement as the main binder material in concrete raises a number of environmental concerns due to the energy consumption and the emission of CO_2. It is estimated that one tonne of cement releases between 0.7 and 1.0 tonnes of CO_2. Other concerns have also highlighted the use of coal as a primary energy source and the release of FA as a by-product, some of which becomes environmental waste.

Annual production of BC worldwide in 2008 was estimated to be 938 million tonnes. In Australia, the use of BC in Victoria alone annually produces more than 500Kt of combined BC FA and bottom ash. So far little research has been undertaken on the feasibility of using BC FA as a waste product and there is no commercial use of the material in the construction industry with the majority of the material being sent to landfill at present.

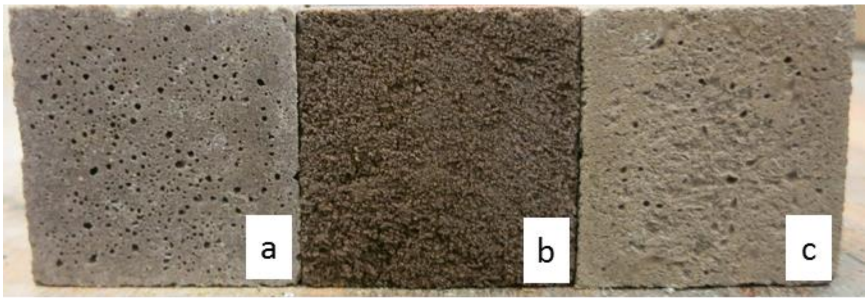
FA can be categorised as either class F or class C. Class F FA is produced from burning anthracite and bituminous coals, while class C FA is produced from sub-bituminous coal and lignite. FA as an industrial by-product contains silicate materials that have been used as an alternative binder material to OP cement.

The activation process to create alkali-activated concrete, known as geopolymer concrete, uses 100% FA as a binder and is due to the activation of the aluminosilicates by high concentration alkali. Its reaction is distinctly different to the activation of the FA by the $Ca(OH)_2$ produced by hydration of the OP cement when FA uses as cement replacement. To date research has focussed on class F FA with high aluminosilicate content, which is required for the activation process. Therefore, if the composition of the aluminosilicates in BC FA is sufficient it may be feasible to use them to produce geopolymer concrete.

The FA used in this study comes from three separate sources located in the Latrobe Valley; Loy Yang, Yallourn and Hazelwood; and was recovered directly from the electrostatic precipitators with no pre-treatment prior to being supplied. Large variation in the chemical composition of the FA has been observed over time, despite being from the same source and this is attributed to the natural variations in the coal.

Initial trials were undertaken on mortar specimens using BC FA from all three Latrobe Valley power stations. The maximum strength of the geopolymer mortar obtained from the Loy Yang BC FA was 56 MPa, while Yallourn and Hazelwood BC FA gave compressive strengths of approximately 10 MPa. The results showed that the critical factor determining the compressive strength was the aluminosilicate content of the FA. The mineralogical composition, morphology, liquid to solid ratio and sulphate content were also all identified as influencing the overall performance.

Further trials have been undertaken using Loy Yang BC FA to manufacture concrete specimens. The concretes produced had a maximum compressive strength of 60 MPa, more than sufficient for a construction grade concrete. However, the results did show considerable variability between 20–60 MPa, which is attributed to the variability in the unrefined FA. Overall, the research demonstrates that the manufacture of concrete is feasible using BC FA as a geopolymeric material. At present further investigation is being undertaken to determine the optimum mix design, the mechanical properties, durability characteristics and the treatment of the raw BC FA.



Above: Above: Brown Coal Geopolymer Mortar BC FA from A. Loy Yang; B. Yallourn; and C. Hazelwood.

Above: Brown Coal Geopolymer Concrete BC FA from Loy Yang.

MILD Combustion of Pulverised Brown Coal

By Manabendra Saha, PhD Candidate, The University of Adelaide; Supervised by Prof. Bassam Dally, Centre for Energy Technology, School of Mechanical Engineering, The University of Adelaide

Coal is the cheapest and most abundant fuel resource in many parts of the world. Whilst combustion of pulverised coal is linked to global warming and air pollution (where additional environmental controls are not used); it supplies 30% of the total global energy demands and is forecast to continue to do so until at least 2035.

Pulverised coal combustion can contaminate the environment through emissions of nitrogen oxides (NO_x), sulfur dioxide (SO^2), unburned hydrocarbons (UHC), particulate matter (PM) and mercury to the atmosphere. These emissions are associated with a variety of environmental concerns such as the formation of acid rain and photochemical smog in urban air.

In many jurisdictions across the world, environmental agencies mandate the use of additional control measures such as particulate filters, Flue Gas Desulphurisation (FGD), and NO_x controls, however implementing such measures adds cost. Thus, there is great interest in the development of advanced coal combustion technologies that alter the combustion conditions and prevent (at source) the generation of pollutant emissions, in particular controlling NO_x, UHC, PM and trace element emissions.

In view of this, 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. This novel concept is based on the recirculation of exhaust gas and heat to create a volumetric reaction zone at reduced temperatures. Consequently thermal stress and pollutant emissions are strongly reduced in MILD combustion. MILD combustion differs from conventional combustion because of the absence of any visible or audible flame at optimized conditions. As a result, MILD combustion is often called 'flameless combustion' or 'flameless oxidation'.

MILD combustion technology has been studied extensively for gaseous and liquid fuels, and has been implemented in various industrial sectors (e.g. 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.). The use of solid pulverised coal under MILD combustion conditions has received much less attention than that of gaseous fuels, so its burning characteristics are poorly understood.

A preliminary investigation was conducted to investigate the MILD combustion characteristics of pulverised brown coal in a laboratory-scale self-recuperative furnace. Low rank and high volatile Kingston brown coal with particle size in the range of 38–180 µm were injected into the furnace using either CO_2 or N_2 as a carrier gas.

Measurements of in-furnace gas concentration of O_2, CO and NO, in-furnace temperatures and exhaust gas emissions were measured and analysed.

MILD conditions were achieved in all cases, and no visible flame was observed. The temperature was almost uniformly distributed across the furnace, with a variation of less than 100°C. It was found that there was a strong NO reburning reaction inside the furnace, because of the strong recirculation of the combustion products. Ash content analysis showed that the extent of carbon burnout was incomplete, which is thought to be due to the relatively short residence times inside a small furnace.

To augment the experimental measurements, computational fluid dynamic (CFD) modelling was used to investigate the effects of coal particle size and inlet air momentum on furnace flow dynamics and global CO emissions. It was found that increasing the air jet momentum broadened the reaction zone and facilitated MILD combustion.

The results of this work was recently published in 'Energy & Fuels' (M. Saha, B.B. Dally, P.R. Medwell and E.M. Cleary. Moderate or Intense Low oxygen Dilution (MILD) combustion characteristics of pulverized coal in a self-recuperative furnace (2014). Energy & Fuels 28: 6046-6057.

Following the successful experimental and numerical investigation, further work is under way to better understand the formation and destruction of pollutants and the burning characteristics of pulverised brown coal under MILD combustion mode. In particular the interaction of the volatiles with the vitiated co-flow and its impact on the formation and emission of PM, NO_x and other pollutants will be investigated.

To probe these parameters under controlled conditions a vertical furnace (Figure 1 below) with a cross section of 260 mm^2 × 260 mm^2 has been designed and built. The furnace wall, co-flow temperatures and local oxygen concentrations are controlled by the secondary swirling burner using non-premixed natural gas combustion. Loy Yang brown coal with particle size in the range of 53–125 µm will be injected into the furnace using either CO_2 or N_2 as a carrier gas through the insulated central jet.

Following the completion of this work, a better understanding of pulverised brown coal combustion in MILD mode will be achieved, and will provide better data for ongoing MILD combustion research. The outcomes of this research will be a step forward to allow industry to have better confidence in utilising the MILD combustion technology.

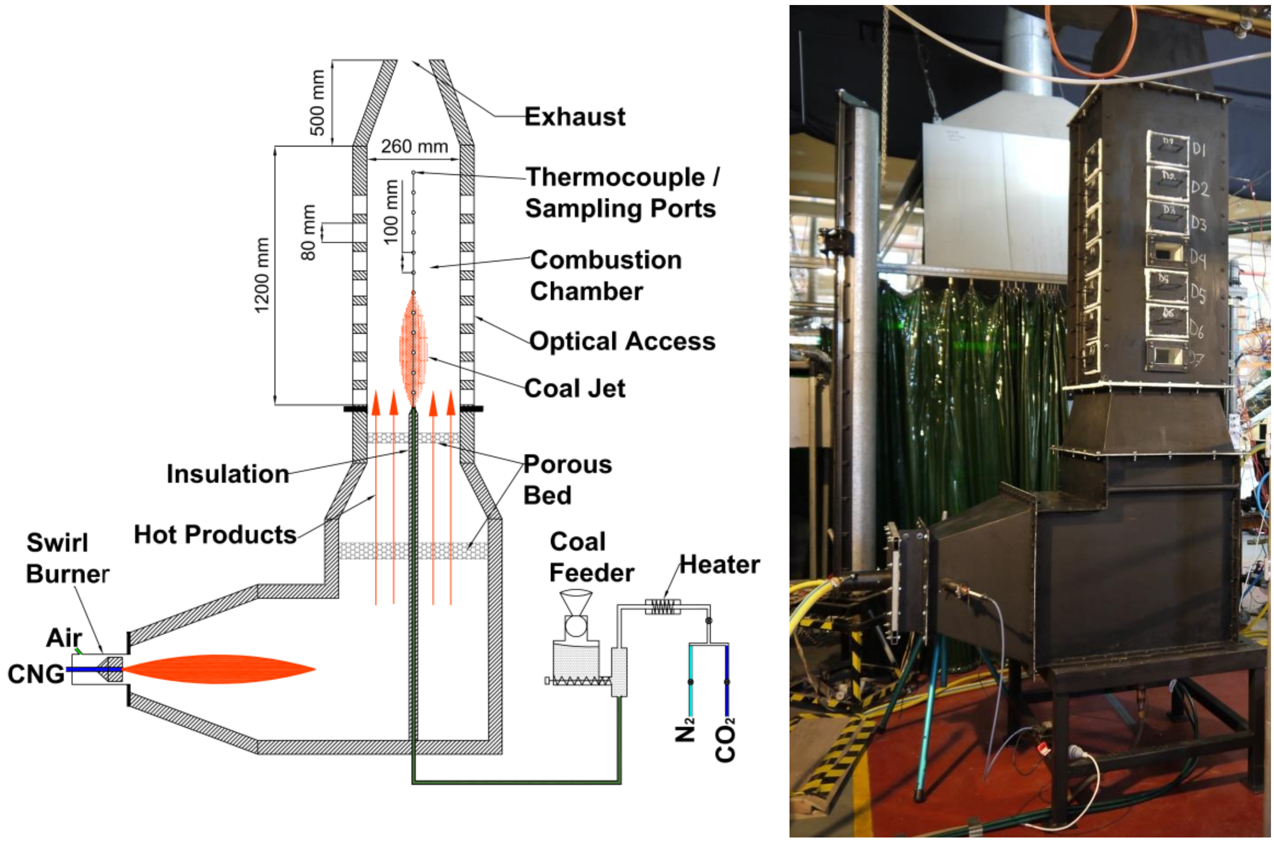


Figure 1: Schematic (left) and photograph (right) of the Adelaide MILD Combustion Furnace.

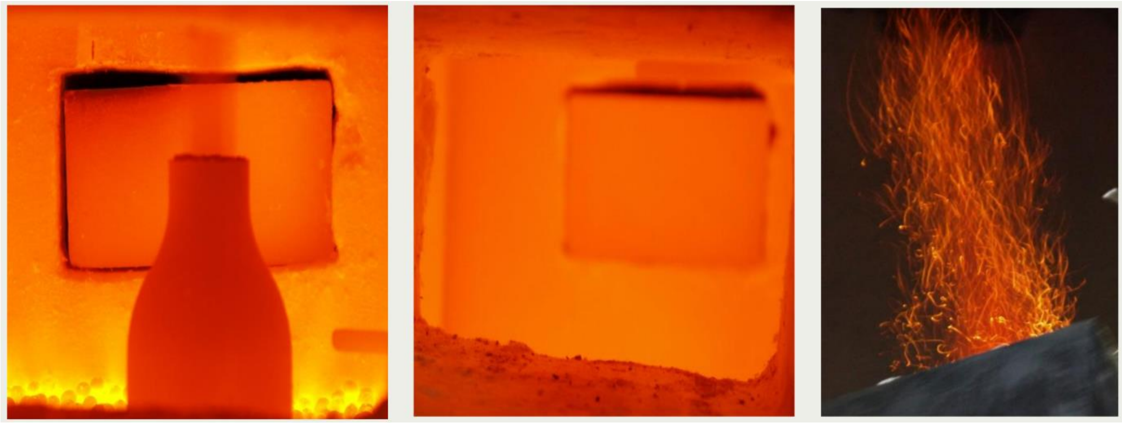


Figure 2: Photograph of the bottom, middle, and exit of the furnace when operating under MILD combustion condition with Loy Yang brown coal carried by CO_2.

TECHNOLOGY

High Efficiency Power Generation from Victorian Brown Coal at CSIRO

By Dr Chris Munnings, Senior Research Scientist and Dr Sarb Giddey, Research Team Leader, CSIRO

Direct carbon fuel cells (DCFC) are a promising technology that offer the potential to generate power from coal at double the best current electric efficiencies (i.e. to 65%–70%), and half the CO_2 emissions compared to today's coal fired power plants.

The exhaust gas from the DCFC reactor is almost pure carbon dioxide, requiring no or minimal gas separation and processing for sequestration. Therefore, the energy and cost penalties to capture the CO_2 will be significantly less than for other technologies. No other technology can offer such a high efficiency for power generation. The technology is at an early stage of development, but early indications show that it is best suited to low ash highly reactive fuels such as Victorian brown coal with untreated brown coal chars offering the highest power output of any fuel tested at CSIRO as part of its DCFC program.

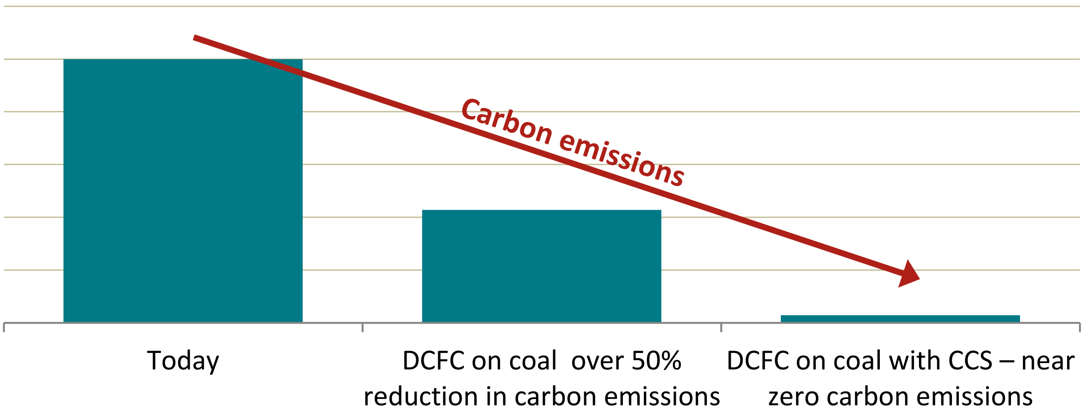


Chart 1: DCFC with capture – a zero emission technology.

BCIA and CSIRO are currently working together, looking at how best to move this technology towards the market and what would be the most effective way of using brown coal. The project includes experimental work to investigate the optimum way to take advantage of brown coal's high reactivity, catalytic ionic species, good electric conductivity and low ash content. The results of this study should lead to a greater understanding of the benefits and technical challenges in the development of DCFC for brown coal utilisation.

CSIRO has been developing direct carbon fuel cell technology since 2008, and has established state of the art facilities and collaborations with other institutes (Monash University, St Andrews University, Imperial College London, Australian Synchrotron and BCIA) to investigate the range of issues relating to the development of this technology, including fuel (coal) characterisation and preparation, fuel feed mechanisms, fabrication of scalable geometry of the cells, system design, DCFC reactors, operating and electrochemical diagnostic techniques, and post-mortem analysis (in-house and at Australian Synchrotron) for materials development.

The support we have received from BCIA in this project is allowing us to move from the very early fundamental investigations into the use of brown coal via a previously funded collaborative partnership between Monash and CSIRO (funded by BCIA through a PhD scholarship) to more applied work utilising tubular fuel cells and modified reactors capable of simulating both direct reaction and gasification processes.

Tubular fuel cells can be used within chemical reactors and are employed to investigate the performance of the scaled up version of the direct carbon fuel cell in 'direct contact of carbon (packed bed of carbon)' and in 'carbon gasification' modes. This allows for the investigation of more system-related phenomena such as current collection and gas distribution. These factors can have a dramatic effect on performance with optimisation of electrode materials and trialling of different modes of operation increasing the power density by almost a factor of 2 during this project.

Fuel cells can be operated in several different modes. From early studies on synthetic carbon we have found that in the gasification mode of operation, where carbon was not in direct contact with the anode, the power densities were around 20% lower than direct contact (packed bed) mode. The higher performance in direct contact DCFC seems to be due to the better current collection in the packed bed of carbon compared to gasification only mode.

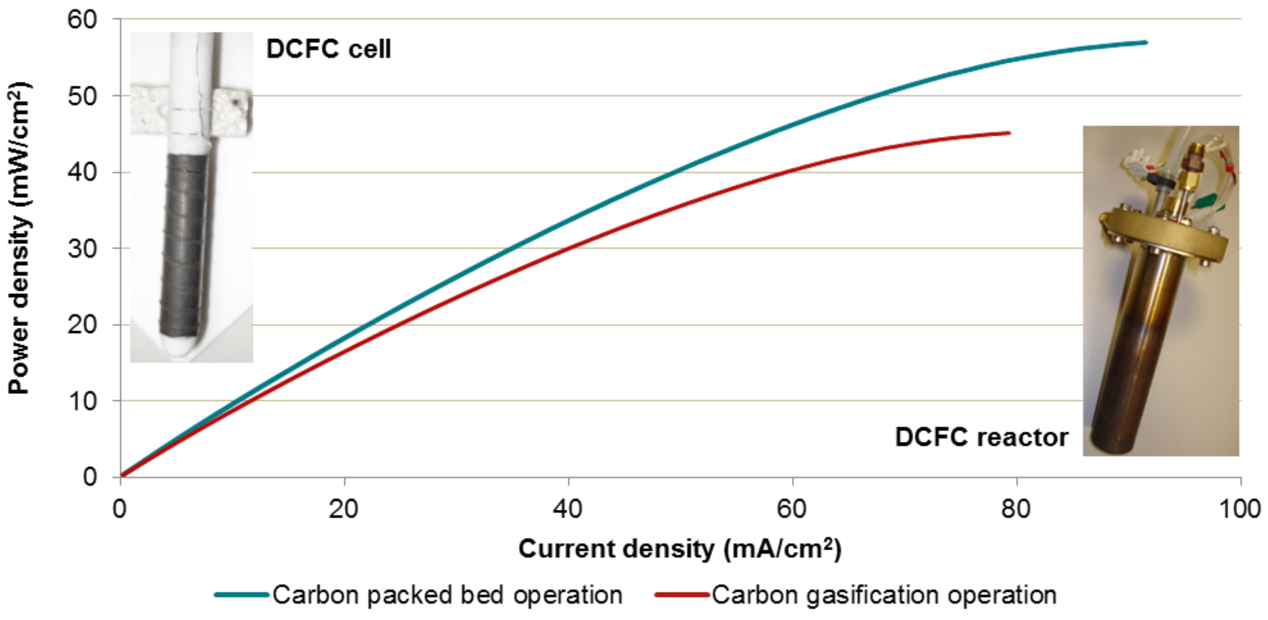


Chart 2: Power density obtained from a scalable DCFC.

The next steps for our work on DCFC and Victorian brown coal are to trial our new setup on brown coal char, to tune the electrode for higher performance and to operate for longer periods. This work could conceivably push CSIRO's DCFC technology well beyond the 100 mW/cm^2 limit seen by many as the minimum commercial operating power density of a fuel cell. If this can be achieved on a realistic fuel composition for a significant operating time, it would push DCFC from the shadows of fundamental research into the more applied R&D mainstream.

For more information visit csiro.au.

SPOTLIGHT ON BCIA

Overview from latest BCIA Research Symposium

By David McManus, Research Investment Manager, BCIA

On 19 February, BCIA held a Research Symposium to showcase the nine projects involved in its 2013 Funding Round. This was the first opportunity for the brown coal community to gain an overview of the scope of the various projects and their progress to date. Due to space limitations at the venue (CSIRO, Clayton), invitations to the event were limited mainly to interested parties in Victoria. Fortunately, the researchers agreed to share their presentations through the BCIA website, making them accessible to the wider community.

The nine projects presented in the 2013 Funding Round were selected to address three broad areas of technology development:

1. Improved efficiency of brown coal-fired power generation.
2. Adaptation of carbon capture technologies for use with brown coal-fired power generation.
3. Oxy-fired brown coal combustion technologies to further reduce the cost of carbon capture.

The first area involves three projects, having short-, medium- and longer-term horizons for commercialisation:

- 'Laser based O_2 and CO monitoring', presented by Mr Tom Cooper of HRL Technology, is evaluating the potential of laser instruments to provide tighter control of boiler operation, with the potential to deliver significant efficiency improvements and cost savings.
- 'Victorian DICE development – derisking and small scale development', presented by Dr Louis Wibberley of CSIRO Energy Technology, will demonstrate the potential of stationary diesel engines to deliver high-efficiency power using micronized coal-water mixtures as fuel.
- 'Feasibility study for Direct Carbon Fuel Cell on Victorian brown coal', presented by Dr Christopher Munnings of CSIRO, is developing a roadmap for development of ultra-high efficiency electricity from brown coal, without combustion, by using fuel cell technology.

The second area involves four projects, investigating different aspects for adapting carbon capture technologies to deal with brown coal-specific issues:

- 'Evaluation of advanced PCC systems', presented by Dr Erik Meuleman of CSIRO, is a major collaboration between CSIRO and IHI of Japan, to gain long-term operating data with efficient carbon capture technology and advanced amine solvents.
- 'Combined capture of CO_2 from flue gas', presented by Dr Erik Meuleman of CSIRO , is an extension of a successful previous project and is developing technology to recover both CO_2 and SO_2 in a single system, thereby eliminating the cost of a separate process step.

- ‘Carbon monoliths for capture of CO_2 by electrical swing adsorption’, presented by Prof. Alan Chaffee of Monash University, involves a collaboration with Prof. Paul Webley, of the University of Melbourne, and an EU-funded consortium of industry and academia. This project is investigating the use of brown coal itself as a carbon capture substrate, in conjunction with energy-efficient electrical swing adsorption technology.
- ‘Dispersion modelling for CO_2 pipelines: Fit for purpose and best practice techniques’, presented by Dr David McManus of BCIA, is compiling a best-practice report which will provide guidance on dense gas dispersion modelling techniques for use in the design of CO_2 transportation pipelines in Australia.

The third area involves two projects that are developing technologies to produce highly concentrated flue gas streams, thereby reducing the size and cost of the carbon capture equipment required:

- ‘Accelerating the deployment of oxy-fuel combustion technology’, presented by Dr Lian Zhang of Monash University, is investigating the propensity for ash formation and fouling when brown coal is burned in oxygen instead of air.
- ‘Advancing the development of chemical looping combustion technology’ presented by Professor Sankar Bhattacharya of Monash University, is investigating the cost-effectiveness of new oxygen-carrier materials in a pilot-scale fluidized bed reactor system.

BCIA has invested $3.65 million in these nine low emissions R&D projects. Altogether, the total leveraged value of these projects is nearly $12 million, including contributions from research institutes, companies and the State and Commonwealth Governments (via Australian National Low Emissions Coal R&D).

The significance of these projects extends well beyond the confines of Victoria, through the active involvement of coal-fired power companies in NSW and Queensland. Major international technology providers are taking a leading role in these projects, intending to utilise the research outcomes to further the development of low emissions technologies for the world market.

From the feedback received from some of the 70 or so attendees at the Research Symposium, participants were impressed at the sophistication of the skills and equipment involved in the creation of new options for brown coal power production. It is quite remarkable to see engineers gaining hands-on training with advanced analytical equipment and modelling software, including gaining rare access to the ultra-high resolution capabilities of the Australian synchrotron. It is clear that the projects in BCIA’s 2013 Funding Round are providing the next generation of engineers and scientists with skills that will be highly regarded both in Australia and overseas.

Edited versions of each of the nine presentations given at the Research Symposium may be accessed from the BCIA website.

Please click **NEWS AND EVENTS** and scroll down to 'Recent Events' to find the BCIA Research Symposium Presentations.

BCIA PhD Top-up Scholarships

By David McManus, Research Investment Manager, BCIA

BCIA is helping to build the highly educated workforce needed to create new opportunities for Australia's brown coal resource, through its 2013 Research Scholarship program. This program currently supports ten PhD candidates at five universities, in Victoria and South Australia, as shown in the table below.

BCIA is providing scholarships of $10,000 per year to each of the ten PhD candidates, to help with living expenses and to support attendance at conferences overseas.

Each of the projects supported by BCIA is looking toward new, more environmentally friendly uses of brown coal, including more efficient combustion techniques, adaptation of CO_2 capture technologies to suit local conditions, and the creation of valuable new products from brown coal and fly-ash.

It is very exciting to see the diversity of ways that brown coal can be transformed into new products. These range from relatively simple to quite complex, from blending brown coal with fertiliser to help boost soil carbon levels, to producing industrial chemicals via gasification, to storing renewable energy in the form of hydrogen within beds of activated carbon. Fly-ash, a by-product of coal combustion that currently has no practical value, shows great promise as for use in concrete for construction.

It is a foregone conclusion that there can be no long-term future for brown coal in Australia if we do not make the effort to think creatively and actively develop new, low-emissions uses for this abundant resource. BCIA is therefore proud to support the development of new opportunities for Australian industry, and to help train the future leaders in this area.

BCIA PhD Scholarship Candidates

PhD Candidate	Host Institution	Project Topic
Manabendra Saha	The University of Adelaide	Experimental and computational study of solid fuels under MILD combustion
Anthony De Girolamo	Monash University	Developing advanced computer modelling program for the prediction of brown coal ash slagging / fouling propensity under oxy-fuel combustion mode
Baiqian Dai	Monash University	Coal blending combustion and gasification – the mixing of beneficiated brown coal and high-rank bituminous coal
Tao Xu	Monash University	Development of oxygen-blown entrained glow gasification for use with a range of Victorian brown coals
Biplob Saha	Monash University	Optimising fertiliser formulation utilising brown coal, biomass wastes, and conventional fertilisers
Hiep Lu	The University of Melbourne	The impact of impurities on the performance of cellulose acetate membranes for CO_2 separation
Rahul Chowdrey	Federation University	Degradation of amine solvent by reactions with metal surfaces and fly ash during post-combustion capture of CO_2
Adeel Ghayur	Federation University	Environmental management of new process streams from post-combustion capture of CO_2 in the Latrobe Valley
Amandeep Oberoi	RMIT	Reversible electrochemical storage of hydrogen in activated carbons from Victorian brown coal and other precursors
Rahmat Dirgantara	RMIT	Development of brown coal geopolymer concrete

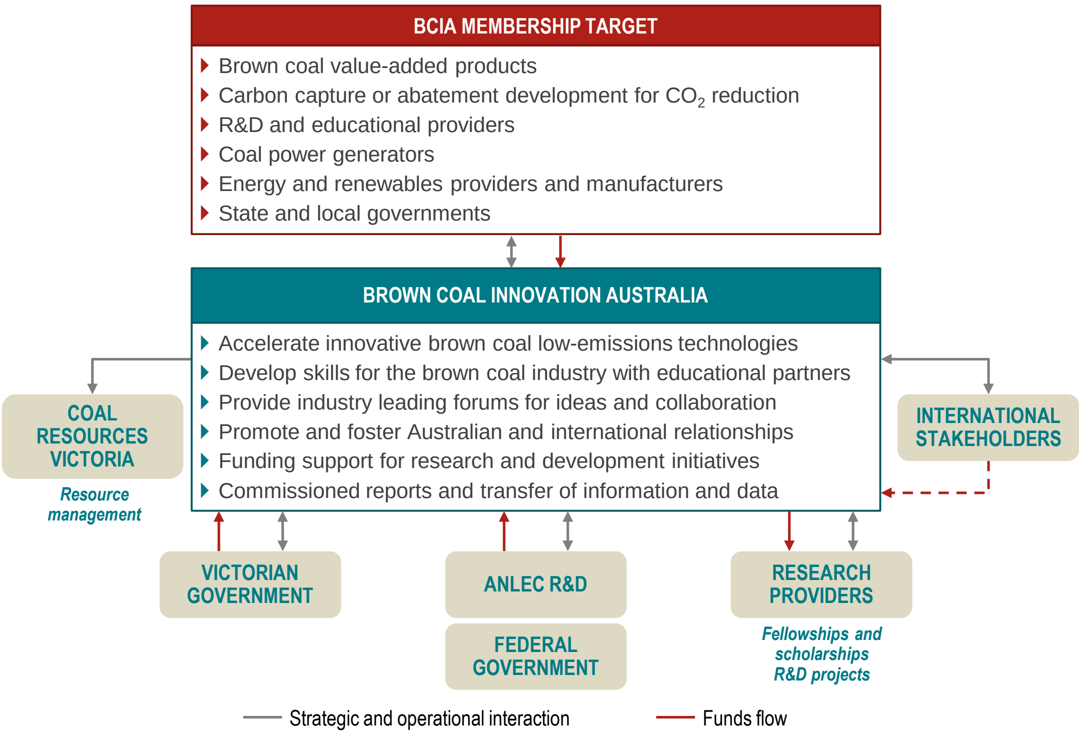
MEMBERSHIP

Advantages of a BCIA Membership

BCIA is committed to driving a low emissions future for Australia's world-class brown coal resource through active participation in our skills, networking and R&D programmes. 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 seeks like-minded organisations within industry, government, research and education providers, 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.

Below is an illustration of BCIA's involvement in the sustainable development of Australian brown coal and the organisations BCIA is involved with to achieve this aim.



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 programme including development and demonstration projects.
- **Wide-ranging Expertise** in government, industry and R&D 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 organisation through the BCIA newsletter *'Perspectives'* and website.

If your organisation currently holds a BCIA membership, you may be interested in BCIA's recent update to our **MEMBERS** web portal. In addition to creating easier access to various Member only presentations and reports, the portal now includes an area that gives members links to BCIA recommended 'Research Databases' to assist our members in finding brown coal related articles. As a member you will now also have access to the BCIA Member logo, which can be downloaded from our **MEMBERS** web portal to sight on your organisation's website or promotional material.

If you are interested in becoming a BCIA member and benefiting from our comprehensive membership programme, please contact Shae Ford, Membership Support Manager on +61 3 9653 9601 or email shae.ford@bcinnovation.com.au.

Current BCIA Members

EVENTS

8th Australia-China Joint Coordination Group Meeting on Clean Coal Technology

The 8th meeting of the Australia-China Joint Coordination Group on Clean Coal Technology (JCG) was held this year in Perth on Thursday 5 February and attracted over 150 delegates, including BCIA's Chief Executive Officer, Dr Phil Gurney, who chaired session 5 on up-grading low rank coals.

The event is specifically designed to aid the developing relationship of the Australian-Chinese CCS community through the Australian Department of Industry and Science and the China National Energy Administration, who support the ongoing collaboration between Australia and China in Low Emission Coal Technology (LECT). Carbon Capture Storage (CCS) technologies are expensive for commercial implementation and the joint collaboration between the two countries is intended to help drive cost of development down. The event facilitates this coalition, as China can progress CCS at a cheaper cost than Australia, however it seeks Australian support of skills and R&D resources, particularly from CSIRO.

Discussed at this year's meeting was the China PCC Feasibility Study (PCCS) project, the largest co-ordinated agreement between Australia and China funded by the Australian Government. Currently in Phase 1 of the study, the next phase would be to develop a pilot demonstration. Other initiatives discussed at the meeting were the ATSERI-CERI, which enhances teamwork on CCS through workshops and exchange programmes, and the other CAGS, which focusses on storage, public awareness, technical exchanges and potential environmental practice.

The ATSE / CERI Workshop (Australian Academy of Technological Sciences and Engineering / China Huaneng Clean Energy Research Group) allowed strategic relationship building and networking opportunity for the CCS research community. Presentations that covered current research activities and potential future exploration were followed by collaborative conversation. Highlighted in this workshop was the need for the JCG to expand its effort with continued R&D obligation and policy commitment on developing LECT technologies to continue success, and presenters recognised the contribution of sponsoring governments, CERI and ATSE to clean coal technology.

For more information on the ATSE / CERI Workshop, you can access presentations at atse.org.au.

Above: Dr Phil Gurney from BCIA (left) and Roland Davies from AGL Loy Yang (right) at the 8th Australia-China Joint Coordination Group meeting on Clean Coal Technology.