BROWN COAL INNOVATION AUSTRALIA

Positioning brown coal for a brighter future

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BROWN COAL INNOVATION AUSTRALIA FUNDING ROUND FACTSHEET

Brown Coal Innovation Australia (BCIA) today announced $2.45 million in funding for five world class research and development projects as part of the company's current competitive funding round for low emissions brown coal power generation technologies.

BCIA's total innovation investment for the current funding round is expected to be $3.65 million; allocated across nine projects. When the current funding round allocation is finalised, the leveraged value of BCIA's new portfolio of low emissions R&D projects will total nearly $12 million including research institute, industry and State and Commonwealth Government (via Australian National Low Emissions Coal R&D) contributions.

BCIA is continuing to negotiate research plans and contracts for three additional R&D projects submitted via the current funding round; these projects are expected to be announced during the next few weeks.

ABOUT BROWN COAL INNOVATION AUSTRALIA

Brown Coal Innovation Australia (BCIA) is a not-for-profit, member-based company with a mandate to invest in the skills development of the future workforce and the technologies required to achieve a sustainable, low-emissions future for brown coal.

Established in late 2009, BCIA has received multi-million dollar funding from the Victorian government, through the Energy Technology Innovation Strategy, and the Australian Government, via a relationship agreement with Australia National Low Emissions Coal R&D (ANLEC R&D). The ANLEC R&D relationship agreement provides for BCIA to manage ANLEC R&D's brown coal energy research portfolio.

Australia has vast brown coal deposits; encompassing about a quarter of the world's known reserves. Innovation of improved technology for brown coal usage involves substantial costs, and time and investment in R&D has significant benefits for industry competitiveness and Australia's future economic prosperity.

BCIA funds and facilitates multi-million dollar research and skills development investments to drive innovation in the brown coal value-chain; from mine-mouth to the capture of CO2. Strategic management of its R&D investment portfolio underpins BCIA's innovation support and operational activities.

BCIA innovation funding supports research and development initiatives that are technically excellent and that will lead to increased commercial deployment of low-emissions brown coal technologies in the short, medium and long term.

Beyond emissions reduction, current and future international price indications for oil, gas and metallurgical coal provide new exploitation opportunities for the conversion of brown coal to liquids and other high-value commodities. BCIA's research investment objectives are:

- to advance and accelerate innovative technologies in Australia by supporting focused, collaborative research in high priority technologies
- to retain local expertise in, and attract international expertise to, Australia in support of investment in brown coal-related technologies
- to support growth in skills and capacity in Australian brown coal-related technologies for the domestic and international markets
- to make the results of that research available, as appropriate and respecting intellectual property, to BCIA's funders and to the Australian public.

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BCIA 2013/14 FUNDING ROUND PROCESS

The BCIA Research Advisory Committee (RAC) assessed the merits of all submitted proposals and provided advice to the BCIA Board. As a co-investor in brown coal research, BCIA sought well-leveraged projects that offered high value for the company's financial contribution. To be eligible, project participants were required to at least match the level of funding provided by BCIA and, preferably, to demonstrate a high level of industry involvement.

The BCIA Board considered all proposals; only project applications of the highest merit were selected. The amount of funding released and the funding allocations against each focus area were at the discretion of the BCIA Board. All approved projects will be stage-gated to ensure continuing support only on the basis of demonstrable achievement of clearly-defined milestones.

BCIA 2013/14 RESEARCH AND DEVELOPMENT PROJECT GRANTS

- $1,000,000 funding for *'Victorian Direct Injection Carbon Engine (DICE) development – derisking and small scale development';* submitted by Commonwealth Scientific and Industrial Research Organisation (CSIRO) Energy Technology. Project participants include MAN Diesel & Turbo Australia Pty Ltd, Exergen Pty Ltd, Ignite Energy Resources Pty Ltd, AGL Loy Yang Pty Ltd and Energy Australia.

This project is a significant progression of earlier BCIA-funded research and will inform development plans for commercial production of the world's first direct injection carbon engine (DICE) powered by water-based lignite slurry; within the next three years. The research program is targeting a step-change in fuel cycle efficiency which will enable a 48 - 50 per cent reduction in CO2 emissions compared with existing Victorian brown coal-fired power plants. The initial laboratory-scale research funded by BCIA achieved excellent ignition and combustion results from lignite slurries prepared by hydrothermal treatment and also addressed a range of technical issues related to fuel production and coal engine interactions.

The new research program includes development of an adapted engine design by MAN Diesel & Turbo, the world's largest manufacturer of stationary diesel engines, and testing of 20 tonnes of micronised refined carbon (MRC) from Victorian brown coal in a pilot-scale engine facility located in Japan. The increased efficiency of the direct injection carbon engine powered by lignite water fuel can be achieved at one fifth the unit capacity of proposed new low emissions coal fired power plants; thereby substantially reducing the capital costs of low-emissions brown coal energy in the near term. The direct injection carbon engine also offers the potential for increased operational flexibility to support peak load electricity demand and supply from intermittent renewable energy; thereby supporting a higher penetration of renewable energy supplies.

The DICE research plan encompasses an initial risk definition and mitigation project to address remaining technical uncertainties for the low ash Loy Yang lignite coal to be utilised in the integrated engine test program. Aspects to be covered include the fouling tendency of the lignite slurry under laboratory test engine conditions and optimisation of lignite water fuel preparation procedures. Successful completion of the risk assessment will facilitate a second-stage 30 month research project encompassing fuel production for DICE tests, engine facilities development and research on logistics, standards and fundamentals R&D. The latter stage is expected to provide MAN and coal fuel providers with key performance data which would facilitate commercial scale demonstration of the DICE technology.

- $650,000 funding for 'Evaluation of advanced Post Combustion Capture process and equipment with two advanced liquid absorbents for application in Victorian brown coal-fired power stations'; submitted by Commonwealth Scientific and Industrial Research Technology (CSIRO) Energy Technology in association with IHI Corporation, Japan and AGL Loy Yang Power Pty Ltd.

This research project is targeting a 40 per cent reduction in the parasitic energy penalty of current post combustion capture (PCC) processes and will see the installation of a $1 M Japanese-built PCC pilot plant at AGL Loy Yang Power station; the first in Victoria to operate around the clock. Existing PCC processes result in a significant reduction in power plant output – with today's commercial technology this could be up to 40 per cent for retro-fit to existing Australian brown coal plants. A substantial reduction in this energy penalty – as targeted by this project – would lead to significant savings in the cost of energy supplied to the consumer compared to implementing carbon capture using current-generation PCC plant.

Achieving a significant reduction in capital and operational costs for large-scale carbon capture plants is arguably the greatest challenge facing global commercial deployment of PCC for coal-fired energy plants. There are about 25 PCC

pilot plants currently in operation world-wide however most are focused on validation of liquid absorbents for PCC in standard process designs. This project entails a two-year evaluation of two advanced liquid absorbents, two advanced process designs and an advanced gas/liquid contactor. The combination of these three aspects represents a significant step forward in PCC technology application for Victorian brown coal-fired power stations.

This research project is a major collaboration between internationally renowned technology provider, IHI Corporation, and Australia's world-class research organisation; CSIRO. The collaboration is a world-first evaluation of a technology provider-developed PCC process in flue gases from Victorian lignite-fired power. 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 CO2 per year.

In the first year of the research program, a 0.5 tpd CO2 capture pilot plant - incorporating an advanced, low-pressure packing material - will be designed and manufactured by IHI in Japan. The plant will then be transported to Australia and re-commissioned at AGL Loy Yang Power station in Victoria's Latrobe Valley. The combination of three new technology innovations - simultaneous improvements in capture agents, equipment and process design - is expected to deliver almost a 40 per cent reduction in the absorbent energy requirement of the pilot plant compared to a standard amine process.

IHI's amine based PCC technology for brown coal-fired power stations will then be evaluated through a parametric study to determine the minimum thermal energy requirement for liquid absorbent regeneration for the two selected absorbents and two process configurations. Two year-long duration experiments totalling 5000 hours will also be undertaken to assess the robustness of the two liquid absorbents under brown coal flue gas conditions with the minimum thermal energy requirement.

The duration experiments differentiate this project from known PCC pilot plant test results and will make a significant contribution to the global body of research into amine based reactive gas/liquid absorption for CO2 capture; the leading PCC technology. The experimental campaign will provide critical knowledge about both the performance of the technology process over time and the robustness of the two liquid absorbents; the latter information is essential to enable deployment of commercial-scale PCC and is urgently required to facilitate assessment of the environmental impacts of PCC.$450,000 funding for *'Advanced chemical looping combustion technology for Victorian brown coals'*; submitted by Monash University in association with Commonwealth Scientific and Industrial Research Organisation (CSIRO) Energy Flagship; Alstom Boiler, France; Energy Australia; VITO, Belgium (oxygen carrier manufacturer); and Lycopodium Process Industries Australia (engineering consultancy); Southeast University, China and University of Alberta, Canada.

This project extends earlier BCIA-funded research - the first known study of chemical looping combustion (CLC) and gasification of Victorian brown coal - as an emerging alternate technology for the capture of CO2 at a significantly lower energy and cost penalty. A targeted focus of this research project is to advance the commercial prospects of this emerging technology through an evaluation of brown coal CLC performance under more continuous operating conditions and to improve understanding of the longer term coal and oxygen carrier interaction effects.

Chemical looping has been widely studied for the combustion of natural gas but research into its potential application for solid fuels commenced only in recent years. Utilising metal oxides as a major source of oxidising agent, rather than concentrated gaseous oxygen from air separation plants, the technology removes the energy and capital costs of air separation plants. The initial BCIA-funded project systematically assessed various oxygen carriers for use with Victorian and international lignite samples and found that the low ash content, high reactivity and high oxygen content of Victorian brown coal is particularly suited to chemical looping.

The current project will extend this research through both bench-scale research and targeted experiments to be conducted in a Victorian purpose-built, compact fully looped and continuously fed reactor system. The primary research objectives are to examine the feasibility of the CLC process in the continuously looping reactor, establish the techno-economics of a commercial scale brown coal CLC and develop a detailed process model for a commercial scale CLC plant. The techno-economic evaluation will identify the greatest opportunities for reducing the cost of CLC carbon capture and ascertain where a commercial brown coal CLC plant can meet international carbon capture targets of above 90 per cent CO2 capture efficiency with less than a 35 per cent consequent increase in power generation costs.

- $400,000 funding for *'Accelerating the deployment of oxy-fuel combustion technology for Victorian brown coal'*; submitted by the Department of Chemical Engineering, Monash University. Project participants include

Shanghai Boiler Works; Energy Australia; GDF Suez Australian Energy; Chubu University, Japan and Shanghai Jiao Tong University (University of Electric Power), China.

This project is a continuation of earlier BCIA-funded research (via ANLEC R&D) and is expected to accelerate the deployment of oxy-fuel combustion for Victorian brown coal; thereby improving power generation efficiency and significantly reducing CO2 capture costs. Oxy-firing technology is a process for the combustion of coal in a mixture of high-purity oxygen and recirculated flue gas. Through prior removal of nitrogen and the optimisation of boiler operating parameters, oxy-fuel combustion testing has delivered up to 95 per cent CO2 purity in flue gases which can be sequestered or utilised with minimal treatment.

The initial research project proved a range of outcomes including the stable and faster combustion of Victorian brown coal in a pilot-scale oxy-fuel fired furnace, production of high purity CO2 (up to 80 per cent) in flue gases and led to a greater understanding of the distinct slagging /fouling propensities of Victorian brown coal in oxy-fuel mode. The current research project will investigate technical issues related to oxy-fuel combustion of externally dried Victorian brown coal under supercritical and ultra-supercritical conditions. The project will undertake long-term ash exposure experiments and will also develop advanced modelling tools for the prediction of lignite ash slagging/fouling and water tube corrosion propensities in an industrial oxy-firing boiler.

The research program encompasses laboratory-scale experiments, pilot-scale tests in a 3MW air/oxy-firing facility built by Shanghai Boiler Works and computational fluid dynamic modelling. Techno-economic evaluation has previously indicated oxy-firing of Victorian brown coal can deliver a similar or lower levelised cost of electricity compared with existing post combustion capture processes. Integration with pre-drying of brown coal and super-critical steam conditions can significantly improve net efficiency and minimise the energy penalty of the plant air-separation unit and CO2 compression. This project recognises ash-related slagging/fouling and water tube corrosion propensities under optimised oxy-firing mode are critical issues which could hinder advancement of this technology through process scale-up to demonstration mode.

- $350,000 funding for *'Combined low-cost pre-treatment of flue gas and capture of CO2 from brown coal-fired power stations using a novel integrated process concept – closing the Sulphur loop (coCAPcO2)'*; submitted by Commonwealth Scientific and Industrial Research Organisation (CSIRO). Project participants include AGL Loy Yang Pty Ltd and Energy Australia.

This project builds upon earlier BCIA-funded research and aims to significantly reduce capital costs – by up to $200 million for a 550MW plant - in retrofitted post-combustion capture of CO2 from coal-fired power stations. The research objective is to integrate the removal of sulphur (SO2) and carbon (CO2) in a single column, with a single liquid absorbent, thus removing the requirement for a separate flue gas desulphurisation unit.

The initial BCIA-funded research project proved the sulphur pre-treatment and CO2 removal steps could be successfully integrated into a combined process for amine-based absorbents. This project aims to obtain a proof-of-concept for the removal of sulphur from amine based absorbents utilised in the combined SO2/CO2 removal process. Researchers will focus on the feasibility and cost-effectiveness of a range of methods for regeneration of these liquid absorbents including crystallisation and alternatives such as nanofiltration, electro-dialysis, ion-exchange and distillation. The research project is targeting a $40 to $50 per tonne avoided CO2 cost with specific application to Victorian brown coal-fired power plants.
The technology concept could be further developed and utilised to retrofit the State's existing power stations and existing flue gas desulphurisation units throughout the world. The expected outcomes of this project will also feed into the development route for deployment of a new combined technology as a viable alternative to the installation of a flue gas desulphurisation unit prior to post-combustion capture of CO2. The research plan comprises crystallisation and alternatives, such as nanofiltration, electro-dialysis, ion-exchange and distillation, to determine the best option for scale-up and continuous evaluation of the coCAPco process.

- $250,000 funding for *'Laser based O2 and CO monitoring'*; submitted by HRL Technology Pty Ltd with support from Energy Australia, Siemens Ltd, AGL Loy Yang Pty Ltd, GDF Suez Hazelwood, Macquarie Generation, Intergen - MOC, Origin Eraring, CS Energy, Alinta Energy and a number of other Australian power industry participants.

The performance of existing coal-fired power stations can be improved to reduce the coal utilisation and therefore CO2 gases emitted. Continuous measurement of the composition of the flue gases allows on-line modification of the plant boiler and fan operation to optimise coal combustion. However, power station boiler ducts present a very hostile

environment for sensors and, consequently, current-generation sensor technologies have proven to be unreliable for process control.

This research project will test state-of-the-art tuneable laser sensors to measure oxygen (O2) and carbon monoxide (CO) in brown coal-fired power station flue gases. Project trials will determine whether Tuneable Laser Diode Spectroscopy (TLDS) instrumentation, utilised successfully in the oil and gas industry, can provide a more accurate representation of oxygen and CO concentrations in station boiler economiser outlets.

Current CO measurement technologies in Australian coal-fired power stations are compromised by high levels of dust, moisture and the sheer size of the boiler ducts. Inaccurate readings of oxygen content within the boiler ducts can result in increased coal usage to generate the same amount of energy. This research project is targeting improved CO measurement in order to optimise the combustion of both brown and black coals; thereby reducing coal fuel demand and boiler draft fan power consumption.

This is the first trial of this technology in Australia and a successful outcome could lead to tuneable laser instrumentation being widely adopted in brown and black coal-fired power stations throughout the country. Improved plant efficiency will simultaneously reduce CO2 emissions produced in the boiler and achieve plant operational savings such as lower fuel and CO2 penalty costs and reduced auxiliary load.

For more information:

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