

## **LOW EMISSION TECHNOLOGY FOR COAL: THE AUSTRALIAN CONTRIBUTION**

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### **ABSTRACT**

This paper reviews the research programs and contribution that Australia is making to the development of low emission technologies for coal. It summarises the strategies, the measures and cooperative arrangements that Australia is pursuing domestically and internationally to support the development of low emission technologies. It also points to potential opportunities for international collaboration in Australian research programs and demonstration projects.

Australia has considerable economic, social and environmental interests in ensuring a sustainable future for the coal industry through the development and deployment of technologies that reduce the greenhouse impact of coal. The Australian Government is working in partnership with Australian industry to support initiatives that encourage research and development (R&D), innovation and investment in clean coal technologies (CCTs). Key low emission technology research areas for Australia are carbon capture and storage (CCS); coal gasification; CO<sub>2</sub> capture enabling technologies that can be retrofitted to existing plants (or incorporated in new pulverised coal plants) such as oxy-firing and post combustion technology; and technologies where Australia is making a leading contribution such as brown coal gasification and Ultra Clean Coal.

The Australian Government's \$500 million Low Emissions Technology Demonstration Fund and the Australian coal producers' \$300 million COAL21 flagship fund are providing the financial support that is needed to address the non-commercial costs of demonstrating new low emissions technologies in Australia. Australia is also actively engaged internationally through bilateral, regional and multilateral partnerships for the development of practical solutions to address greenhouse gas emissions from coal.

### **OVERVIEW**

Coal plays a central role in the Australian economy. Coal is Australia's single largest merchandise export item and underlies Australia's trading relationship with many countries. Coal is also the primary fuel source for electricity generation in Australia accounting for around 80% of domestic power supply. The relatively low cost of coal based electricity enhances the standard of living in Australia and provides a comparative advantage for energy intensive minerals processing and manufacturing. Australia's demand for energy is expected to continue to grow strongly well into the future and domestic demand for coal will continue to expand even though coal's relative share of total energy consumption will decline. Australia has considerable economic, social environmental and greenhouse interests in the development and early deployment of technologies that reduce the greenhouse impact of coal and ensure the future use of coal is sustainable.

Cooperative arrangements and partnerships have been developed between industry, researchers and governments to support the development and deployment of advance technologies that will lead to a step change improvement in the greenhouse performance of coal power generation. The focus of coal utilisation research, development and demonstration in Australia has shifted to low or zero emission technologies involving the capture and storage of carbon dioxide – or carbon capture and storage (CCS). Attention is also focused on technologies and processes that can be developed in conjunction with CCS for power generation that will add value to coal as an energy resource, either through its contribution to liquid fuel security or the longer term development of the hydrogen economy.

Australia can make an important and valuable contribution to the development of low emission technologies for coal. However, Australia's relatively small size in the global economy means that we cannot sustain the large capital investments in R&D needed to be a leader in all technologies. For the most part Australia is a fast follower in deploying new technologies developed offshore. Australia needs to participate in the development of these technologies to the extent that we need to understand them in detail, to ensure Australian interest are considered and be positioned to adapt them to Australian circumstances. International collaboration and partnerships therefore play a major role in Australian strategies for developing and deploying low emissions technologies for coal.

Coal researchers in Australia and Japan have a long history of successful research collaboration based on the open exchange of information and joint research and development projects. For instance, collaboration with JCoal on upstream coal supply technology on projects such as COSFLOW (an integrated gas simulation software package) and Nexsys (a real-time risk management system for coal mines) are making invaluable contributions to improving the economic and safety performance of coal mining in Australia. The Australia - Japan Workshop, *CO<sub>2</sub> Capture and Enabling Technologies for Coal-Fired Power Generation*, at the Aichi International Expo in 2005 has paved the way for downstream collaboration on low emission technology research and development. It is proposed that the Aichi Coal R&D Joint Statement between JCoal and CSIRO will be enhanced with Australia Coal Research Ltd, which manages the Australian coal producers' generic research program – ACARP- become a party to the Statement at Japan Coal Day 2006. The early involvement of ACARP in the development of joint projects will in particular ensure that these projects are fully factored into ACARP's funding priorities.

## **POLICY FRAMEWORK**

The Australian Government's long term policy framework for the energy sector is set out in the Energy White Paper, *Securing Australia's Energy Future*, released by the Prime Minister the Hon John Howard MP in 2004. Three themes – prosperity, security and sustainability – underpin the Australian Government's approach. This framework recognises the important role that Australia makes to global energy security as the world's leading coal supplier and the need for Australia to play an active role in developing an effective global response to climate change.

The Australian Government has allocated over \$1 billion to a comprehensive approach to greenhouse abatement over the last few years. A major goal outlined in the Energy White Paper is to move strongly to reduce the cost of meeting any future greenhouse constraints without harming the international competitiveness and reliability of the Australia energy sector. The challenge for Australia, as it with many other countries, is to deliver technology improvements that reduce the future cost of low emission technologies for power generation. The Energy White Paper recognises that much of this technology will be developed offshore and that Australia must work collaboratively to adapt and adopt technologies to meet our circumstances.

The Energy White Paper builds on and supports government-industry initiatives on climate change that encourage research and development, innovation and investment in clean coal technologies. A major initiative from the White Paper was the \$500 million Low Emission Technology Demonstration Fund (LETDF) to support the demonstration and application of large scale low emissions technologies in Australia. The fund is designed to lever a further billion dollars in private sector investment for projects that demonstrate technologies that have the potential to reduce Australia's greenhouse emissions by 2% between 2020 and 2030. Projects are being considered on a competitive basis with the Australian Government expected to make announcements in October/November 2006 on projects to be funded under the first round of the LETDF.

Australia is also actively engaged internationally through bilateral, regional and multilateral partnerships for the development of practical solutions to address greenhouse gas emissions from

coal. These efforts are underpinned by a substantial funding and in-kind commitment from both the Government and the Australian coal industry, with Australia taken a leadership role in international partnerships such as the Carbon Sequestration Leadership Forum, the Methane to Markets Partnership and more recently the Asia Pacific Partnership on Clean Development and Climate (AP6).

## **DOMESTIC CLEAN COAL TECHNOLOGY INITIATIVES**

The Australian Government has in place substantial support for energy sector innovation, spending some \$223 million on energy innovation in 2001-02. The National Research Priority Goal has been established for '*reducing and capturing emissions in transport and energy generation*'. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has established *Energy Transformed* as one of its seven flagship programs that received additional Government funding in 2004-05 budget. Cooperative Research Centres (CRC) covering coal and CCS also make an important contribution to researching and developing clean coal and low emissions technologies in Australia. Government and industry are reviewing arrangements to deliver this coordinated national research effort so as to ensure that Australia has the capability to deploy low emission technologies over the next decade.

The following summarises the key Government and industry initiatives that encourage research and development, innovation and investment in clean coal and low emissions technologies.

### **COAL21**

COAL21 is a flagship program that aims to develop and implement a national clean coal strategy for Australia. COAL21 focuses on potential 'breakthrough' technologies to reduce greenhouse gas emissions arising from the use of coal in power generation. The initiative involves close collaboration between Australian Federal and State Governments, the Australian coal industry, researchers and power generators.

The *COAL21 Action Plan* was launched in March 2004 and provides a practical way forward for developing low emission technology for coal based power generation in Australia. The Plan focuses on priority technologies and their ability to support low or zero emissions technologies, increase coal-use efficiency and facilitate hydrogen production. These priority technologies are:

- Carbon capture and storage (CCS);
- Integrated Gasification Combined Cycle (IGCC);
- Oxy-fired Combustion
- Lignite Dewatering and Drying; and
- Ultra Clean Coal (UCC).

Post Combustion Capture was subsequently added to this list as a key enabling technology for carbon capture and storage.

The implementation of the COAL21 Action Plan will focus on private/public partnership support for pilot and demonstration scale projects, the upfront and ongoing research needed to support the development and demonstration of these technologies; international technology transfer and collaboration; and increasing awareness of low emission technologies while improving community perceptions of coal.

COAL21 commissioned the IEA Clean Coal Centre (IEACC) review, *RD&D on Coal Use in Australia and the COAL21 Action Plan*. The abstract for this report released in September 2005 indicates:

*... the proposed pilot and demonstration projects under active consideration are consistent with the objectives of the COAL21 National Action Plan, are supported by appropriate and*

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*adequate R&D programmes and there are currently no significant gaps or overlaps at the programme level. There are projects and proposals for work to cover all the important areas of CO<sub>2</sub> abatement, from efficiency improvement through to CO<sub>2</sub> capture and storage. Australia is therefore well positioned compared with most other countries with respect to its plans.*

*Funding mechanisms for Research and Development (R & D) need consideration and possible revision to support the long term nature of the COAL21 programme as, if this issue is not addressed, continuity will be a problem with the conclusion of current financial and participatory technical support commitments.....*

In March 2006 the Australian Coal Association announced the establishment of the COAL21 Fund. All Australia's black coal producers have agreed to make a voluntary contribution based on production-based levy of approximately 20 cents/tonne. This levy will raise an amount in the order of \$300 million over a five year period. The Fund will support demonstration projects for reducing greenhouse gas emissions from coal-fired power stations and key research programs.

### **Commonwealth Scientific and Industrial Research Organisation (CSIRO)**

CSIRO is Australia's national science agency and serves governments, industries, business and communities across the nation. CSIRO's main support for coal industry R&D is through its Energy Technology Division based in Newcastle and through the Energy Transformed Flagship.

CSIRO is working in partnership with industry and governments to develop new clean coal technologies to reduce greenhouse gas emissions, in combination with techniques to clean carbon from emissions and store it safely. Its research programs provide technical data and expertise to support the use of Australian coal in advanced, low emission power generation technologies and to assist in optimising the processes of existing power stations. For instance CSIRO is taking a lead in the research, development and demonstration of post combustion capture technologies. The work of the CSIRO's Energy Technology Division also aims to ensure the Australian coal industry remains cost competitive by making coal processing plants more "intelligent" and improving the basic science of separation processes. Its project work is focused on improving coal quality, maximising coal recovery, reducing emissions from mines and lowering industry costs. CSIRO was closely involved in developing of ultra clean coal (UCC) and continues to work closely with UCC Pty Ltd in the further development of this technology.

The Energy Transformed Flagship aims to develop solutions for reducing greenhouse gas emissions in the energy sector by developing low-emission technologies and systems for electricity production and transportation. In the longer term these technologies will support the widespread use of hydrogen as an energy carrier across the economy. The Flagship has developed the following project themes:

- energy futures
- distributed energy
- low emission electricity
- low emission transport.

Energy futures research aims to identify optimum sustainable energy pathways and to supply information to the energy sector regarding current research in this field. The Energy Futures power generation research programs will:

- Create a national energy model developed in response to the needs of industry, government and the community. CSIRO is working with the Australian Bureau of Agriculture and Resource Economics (ABARE) to develop these models. As part of this work, in July 2006 ABARE published *Economic Impact of Climate Change Policy: the Role of Technology and Economic Instruments*. This report highlights the need to develop a well focused and

internationally coordinated technology strategy for the enhanced development, adoption and transfer of energy efficient technologies.

- Develop and implement technologies that eventually lead to zero-emission power generation from fossil fuels and large-scale hydrogen generation. This work includes the widespread retrofitting of technologies such as Post Combustion Capture equipment or oxy-fired combustion on existing coal fired power stations, the widespread introduction of clean coal technologies such as integrated gasification combined cycle power plants, the development and commercialisation of viable sequestration methodologies and transitional energy paths for other low emission technologies.

CSIRO has specifically identified coal gasification and carbon dioxide geological sequestration leading to zero emissions power from coal as a key component of the Energy Transformed Flagship's research.

CSIRO has developed working partnerships with industry and other institutions to support the implementation of its programs. CSIRO is a major contributor and participant in the CRCs (referred to below) and to the Centre for Low Emission Technology (referred to below). CSIRO also takes a leading role in bilateral and international research collaboration.

### **Co-operative Research Centres (CRC)**

The CRC programme was established in 1990 by the Australian Government to bring together researchers and research users and to improve the effectiveness of Australia's R&D effort. The programme emphasises the importance of collaborative arrangements to maximise the benefits of research through an enhanced process of utilisation, commercialisation and technology transfer. It also has a strong education component with a focus on producing graduates with skills relevant to industry needs.

There are currently 71 CRCs operating in 6 sectors. Since the commencement of the CRC Programme, all parties have committed more than \$11 billion (cash and in-kind) to CRCs. This includes more than \$2.6 billion from the Australian Government CRC Programme, \$2.8 billion from universities, \$2.1 billion from industry and more than \$1.1 billion from CSIRO.

Three CRC's with a specific focus on coal (both black and brown) or low emissions technologies have been established:

- CRC for Coal in Sustainable Development (CCSD);
- CRC for Clean Power from Lignite (which closed in June 2006); and
- CRC for Greenhouse Gas Technologies (CO2CRC).

Each CRC has a seven year life but can seek an extension for a second term. It is unusual for a CRC to be granted a third term. The three coal/low emissions CRCs have already been extended for a second term. The wind-up year for the CRC for Coal and Sustainable Development is 2007/08 and it seems unlikely at this stage that it will be applying for a third term. The CO2CRC second term expires in 2009/10.

The IEA Clean Coal Centre Review of coal R&D in Australia highlighted the important role played by CRCs in bringing all parties together to undertake a coordinated and comprehensive research program for low emission technologies. However, with many of these institutional arrangements coming to an end, the IEACC warned of the need to develop alternative arrangements to maintain continuity of effort and to support the longer term research objectives associated with the development and deployment of low emission technology.

Future arrangements for funding and implementing low emission technology R&D for coal are currently under review by industry and the Federal and State Governments.

### **Centre for Low Emission Technology (cLet)**

The Centre for Low Emission Technology is a collaborative partnership between the State of Queensland, CSIRO through CSIRO Energy Technology and its Energy Transformed Flagship Program, the Australian Coal Research Limited, Stanwell Corporation Limited, Tarong Energy Corporation Limited and the University of Queensland.

The Centre will advance research and development in the field of low emission technologies for electricity generation in Queensland and the rest of Australia. It is specifically developing a program of support for coal gasification focusing on gas cleaning, gas separation and gas processing. This coal gas stream program builds on the work of Entrained Coal Gasification Research Centre (jointly managed by CSIRO and the CCSD) which has been operating since the late 1990s to evaluate the gasification properties and performance of different coals.

### **Australian Coal Association Research Program (ACARP)**

All black coal producers in Australia have come together under the ACARP to support generic coal research in Australia. Under this program, all black coal producers pay a levy of 5 cents per tonne of coal produced to an industry managed fund. In financial year 2004-05, ACARP received almost \$13.6 million in revenue from this levy. Since commencing in 1992, ACARP has provided \$117.7 million in funding from the levy and other industry contributions to support 780 projects.

ACARP offers a variety of projects under the following categories: coal utilisation; greenhouse; coal preparation; open cut; and underground projects. While the main focus is on the coal mining, its coal utilisation research program is of direct relevance and benefit to power generation and related activities. ACARP funding has supported overall involvement by Australian coal producers in the CCSD, CO2CRC and the Queensland Centre for Low Emissions Technology (cLet). It also funds coal producers' involvement in pilot CO<sub>2</sub> geological storage projects. ACARP has supported and funded key research that has supported the development of technology to capture and utilise coal mine methane including drainage gases and ventilation air methane.

ACARP has also played an important role in providing financial support for joint research projects between Australia and Japan. As indicated above, the importance of this contribution is reflected in the proposal to incorporate ACARP into Aichi Coal R&D Joint Statement between JCoal and CSIRO.

Most Australian coal producers also maintain their own research programs in addition to the funding they provide to ACARP. The Australian Government has R&D Tax Concessions that aim to encourage and support private research.

## **INTERNATIONAL CLEAN COAL TECHNOLOGY INITIATIVES**

Australia's relatively small size in the global economy means it cannot be a leader in all technologies. In many cases, we are "fast followers" in technologies developed by countries such as Japan. This approach requires active international engagement to ensure Australia is in a position to select and adapt technology to Australian circumstances. Australia therefore places strong emphasis on international engagement on policy and technical solutions to greenhouse emissions from coal.

### **Carbon Sequestration Leadership Forum (CSLF)**

Australia has been an active member of the CSLF since its inception in June 2003. The CSLF is an international climate change initiative to develop CCS technologies as a means to accomplish long-term stabilisation of greenhouse gas levels in the atmosphere through coordinated research and development. The purpose of the CSLF is to make these technologies broadly available internationally, and to identify and address wider issues relating to CCS. This could include

promoting the appropriate technical, political, and regulatory environments for the development of such technology.

The activities of the CSLF are conducted by a Policy Group, which governs the overall framework and policies of the CSLF, and a Technical Group, which reviews the progress of collaborative projects and makes recommendations to the Policy Group on any needed actions. Australia is currently the Vice-Chair of the Policy Group and a key contributor to the work of the Technical Group. Australia also hosted the 2nd Ministerial Meeting of the CSLF in Melbourne in September 2004. The key outcomes of the CSLF to date include:

- CSLF Strategic Plan
- Acceptance of a CSLF Technical Roadmap;
- Recognition of CSLF projects – international collaboration efforts;
- Acceptance and release of a CSLF international regulatory issues report; and
- Agreement on a CSLF Stakeholder Engagement Strategy
- Public Awareness Strategy
- Capacity building in developing countries strategy

The CSLF brings together expertise from 22 countries that supports the development of Australia's own CCS capabilities and provides an international forum that addresses policy and regulatory issues associated with CCS. It also facilitates the transfer of Australian expertise in this area.

### **Asia Pacific Partnership (AP6)**

Australia is involved in the Asia Pacific Partnership on Clean Development and Climate (AP6), which brings together the United States, China, India, Japan, South Korea and Australia to address the challenges of climate change, energy security and emissions in a way that encourages economic development and reduces poverty.

The AP6 is an important initiative that engages, for the first time, the key greenhouse gas emitting countries in the Asia Pacific region. It represents around half the world's greenhouse emissions, energy use, GDP and population.

At the inaugural AP6 Ministerial meeting in Sydney on 11-12 January 2006, three outcome documents were released: a Communiqué; a Charter that sets out the framework to implement the vision; and a Work Plan detailing the formation of eight Task Forces. The Australian Prime Minister also announced \$100 million over five years for the initiative. The funding will support Australia's participation in the initiative by allocating \$80 million to support clean technology projects; \$15 million to support capacity building activities within the Partnership; and \$5 million to support Australia's involvement in taskforces.

The inaugural meeting also brought together international business leaders from the Partner economies to seek their commitment and participation in the eight taskforces established. These are: cleaner fossil fuel, aluminium, coal mining, steel, cement, buildings and appliances, power generation and transmission, and renewable and distributed energy. The Australia Government and industry are active members in all taskforces with Australia chairing the cleaner fossil fuel and aluminium taskforces and is vice chair of the renewable energy taskforce.

The Cleaner Fossil Energy Taskforce met in Tokyo in July 2006 to develop an Action Plan that aims at accelerating the development and deployment of advance technologies covering five broad themes. These themes cover CO<sub>2</sub> capture and storage; coal gasification; other technologies that support major improvements in the greenhouse performance of fossil fuel use including oxy-firing technologies and post combustion capture (PCC); gas energy market access; and technologies to improve the infrastructure and environmental performance of natural gas.

Some twenty projects were endorsed by the taskforce. This includes projects jointly supported by Australia and Japan such as the Callide A Oxy-fuel Demonstration Project in Australia, the establishment of an Oxy-fuel Ad Hoc Working Group to progress the development of this

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technology in member countries, and a joint project between CSIRO and JCoal to support CO<sub>2</sub> storage in China through enhanced coal bed methane (ECBM).

Australia put forward other projects on CO<sub>2</sub> geological storage assessment with both China and India, and assessing PCC for Chinese and Indian coal-fired power stations. Australia is also endorsing a number of gas projects on emissions reduction through application of improved gas processing and transportation technologies, public education programs and information exchange on LNG, its interchangeability in terms of standards to increase LNG investment and trade in the Asia Pacific region, as well as a project on cooperation in relation to gas hydrate and for evaluation of methane emissions from LNG facilities. Another project that was endorsed by Australia relates to costs and diffusion barriers to deployment of low emission technologies for AP region.

The Coal Mining Taskforce met in New Delhi in August 2006 to develop an Action Plan that aims to make a significant contribution to emissions reductions and workplace safety in the coal mining sector. The projects endorsed by the Taskforce at this meeting will improve the efficiency of mining and processing of coal, improve the monitoring and control of coal mine methane gas, address reclamation and rehabilitation of mined and abandoned mines and promote leading safety practices. The Coal Mining Task Force will work collaboratively with the Cleaner Fossil Energy Task Force to ensure that synergies are captured in improving coal processing and developing new coal-based generation technologies.

### **Methane to Markets Partnership**

The Methane to Markets Partnership (M2M) is an international initiative that advances cost-effective, near-term recovery and use of fugitive methane emissions as a clean energy source. The goal of the Partnership is to reduce global methane emissions in order to enhance economic growth, strengthen energy security, improve air quality, improve industrial safety, and reduce emissions of greenhouse gases. The Coal Mine Sub-committee aims to capture fugitive methane emissions from coal mining and use it in profitable and practical ways to improve worker safety, enhance mine productivity, increase revenues and reduce greenhouse gas emissions.

Australia is using the partnership to support the transfer of leading edge technologies to developed by Australian industry capture and utilise drainage gases and methane in ventilation air. Australia has been working closely with Japan and the US in this partnership holding a joint workshop in China in 2005 where a number of Chinese coal mine case studies were considered. The US is sponsoring a Coal Bed Methane Outreach Workshop in Australia in October 2006 to gain a fuller understanding of Australian technologies and its potential application to projects in Asia and Eastern Europe.

## **CLEAN COAL TECHNOLOGIES AND CCS BEING DEVELOPED IN AUSTRALIA**

### **CO<sub>2</sub> Storage**

The Geological Disposal of Carbon (GEODISC) program, conducted during 1999-2003, put Australia at the forefront in identifying and mapping sites suitable for the geological storage of carbon dioxide. The Cooperative Research Centre for Greenhouse Gas Technologies (CO<sub>2</sub>CRC) is building on the key findings of the program and carrying out further studies. This expertise is being passed on to other members in the CSLF and through other forums including APEC and the Asia Pacific Partnership (see below). Australia has also applied its experiencing in developing technology roadmaps for CCS in Australia to take a leading role in developing the CSLF Technology Roadmap for capture and geological storage of carbon dioxide.

Geoscience Australia, which is part of the Department of Industry Tourism and Resources, provides geo-scientific information and advice to Government on risk, regulatory regime and management associated with the geological storage of CO<sub>2</sub>. Geoscience Australia is contributing to the work of the CO<sub>2</sub>CRC through its assessment of selected areas of Australia (including SE

Queensland; Otway, south Perth Basin and Browse basins) to identify environmentally sustainable sites for carbon dioxide injection and storage. Geoscience Australia is also actively developing collaborative projects with China and India to build the capacity in these countries to identify and assess geological storage potential.

The CO2CRC storage program aims to *research develop and deploy technologies that can achieve significant cuts in storage and/or usage costs and provide Australia with a research and education capability to support industries using these technologies*. As well as reducing the cost of CO<sub>2</sub> storage, this program aims demonstrate that storage is a safe and secure option in the long term.

The CO2CRC is undertaking a pilot CO<sub>2</sub> injection and monitoring project in the Otway Basin in Victoria. The aim of the pilot project is to demonstrate that geosequestration is a viable option for CO<sub>2</sub> mitigation under Australian conditions. The project will capture, transport, inject, geologically store and monitor 100,000 tonnes of CO<sub>2</sub> in a range of geological structures more than one kilometre below the ground. The program is also going to consider appropriate regional strategies for CO<sub>2</sub> mitigation and keep abreast of international developments through participation in other international demonstration projects.

Several projects involving CO<sub>2</sub> storage have been proposed in Australia. These include the Gorgon LNG project on Barrow Island in Western Australia, where it is proposed up to 125 million tonnes of carbon dioxide contained in natural gas will be reinjected over the life of the project, and the Monash Energy Project in Victoria which will store carbon dioxide from a brown coal based, coal to liquids project. Two demonstration scale projects in Queensland are also being developed (the Stanwell and CS Energy projects), which aim to capture and store carbon dioxide produced from power generation.

#### Regulatory Framework for CCS

These project proposals have necessitated the need to develop a sound guiding regulatory framework for CCS in Australia. There has been considerable effort between all Australian jurisdictions and stakeholders to examine regulatory and approvals issues in relation to CCS. In September 2003 the Ministerial Council on Mineral and Petroleum Resources (MCMPR) established a Regulatory Working Group to develop draft regulatory guiding principles for CCS. Key participants in a consultation group included industry peak bodies, environmental bodies, research organisations and community groups. The membership was representative of all relevant stakeholders groups with individual members bringing together the views of their individual constituents.

The major driver was a Council of Australian Governments (COAG) Regulation Impact Statement (RIS) which analysed and evaluated options for the management of key issues relating to elements of CCS. On the basis that the energy sector in Australia operates under longstanding, proven and comprehensive regulatory and approvals frameworks a detailed study of existing regulatory regimes and their applicability to the various stages of CCS was examined.

The resulting document, *Carbon Dioxide Capture and Geological Storage - Australian Regulatory Guiding Principles* (the Principles), was endorsed by the MCMPR in November 2005.

The general finding was that while there is not yet a CCS-specific regulatory regime in place in Australia, technical understanding of the individual elements of CCS is advanced. This is mainly through experience developed by the petroleum and minerals exploration and production industries. These industries have longstanding, comprehensive regulatory frameworks, covering approvals processes, environmental protection, transport of gases by pipeline (although not specifically CO<sub>2</sub>), a legislative regime for storage and injection of gases as part of a petroleum recovery operation, and considerable technical, legislative and regulatory know-how for industry operations. One of the Principles' express recommendations is that wherever possible, these existing frameworks should act as a basis for the development of a regulatory system for CCS. This recommendation is supported by the International Energy Agency document, *Legal Aspects of Storing CO<sub>2</sub>* which makes a similar recommendation.

### **Coal Gasification / Integrated Gasification Combined Cycle (IGCC)**

As indicated above, Australian black coal gasification research has focused on understanding the gasification performance of different coals. This work is being extended through cLet to develop a research facility that can examine the coal gas streams. This is an area where there is currently not a lot of depth in international research efforts and where Australia can be expected to make a significant international contribution. This work ties in with work being coordinated by the CO2CRC on the range of different technologies to separate different gases in gas streams. It will also provide valuable research support for the proposed ZeroGen project.

The application of CCS to black coal gasification in Australia is being progressed through the ZeroGen project. ZeroGen is a demonstration project that is investigating the viability of integrating IGCC and carbon capture and storage (CCS) to produce low emission base load electricity. The project is being managed by Stanwell Corporation. Shell Development (Australia) Ltd has recently entered into an Agreement to provide ZeroGen with access to the full range of Shell's intellectual property in the area of carbon capture and storage and its support services for phased test drilling program which is currently being undertaken in the northern Denison Trough in Central Queensland. This test phase will involve drilling three wells up to two kilometres deep to test the viability of safely storing CO<sub>2</sub> in deep saline aquifers in Central Queensland. Drilling of the first well commenced in June 2006.

Australia has made substantial progress in researching and developing brown coal gasification based on Victoria's extensive low cost lignite resources. HRL Pty Ltd has developed a process that integrates brown coal drying and gasification – Integrated Drying Gasification Combined Cycle (IDGCC). This technology has been demonstrated in a 10 MW plant connected to the grid. It is expected that this technology achieve a 30% reduction in greenhouse gas emissions compared to the most efficient current Latrobe Valley generation plant. Capital costs are also expected to be competitive full scale commercial IDGCC plants.

HRL in partnership with Harbin Power Engineering Company (HPE), a subsidiary of Harbin Power Equipment Group Corporation, China's largest manufacturer of power generation equipment and power station developer, have signed a Memorandum of Understanding (MOU), to develop a 400 MW IDGCC demonstration power station in Victoria's Latrobe Valley. They have sought support for this demonstration project under the first round of the LETDF. The plant has been designed to be CCS ready allowing for add-on equipment and processes to support the future separation and capture of CO<sub>2</sub> from the coal gas stream prior to combustion.

The Monash Energy Project, also in the Latrobe Valley, proposes to develop a brown coal gasification and combined cycle plant which will produce electricity and around 60 000 barrels a day of ultra low-sulphur diesel (and potentially hydrogen). The CO<sub>2</sub> emissions, of approximately 13 million tonnes per year, will be captured, stored, compressed and transported to a sub-sea geological storage site in Bass Strait. A pre-feasibility study of deep geological storage, 2-3 km beneath Bass Strait, has been completed by the CO2CRC with the assistance of a grant provided to Monash Energy by the Commonwealth Government. This evaluation supports the storage of up to 50 Mtpa of CO<sub>2</sub> with a confirmed storage capacity of 2 billion tonnes and a probable capacity of several times this amount. The first stage of Monash Energy project is a coal drying and gasification demonstration plant due to commence in 2007, ultimately leading to the operation of the full commercial plant, complete with geological storage, by 2015. Monash Energy has sought LETDF funding for the demonstration plant.

### **Oxy-Fuel Combustion**

Oxy-fired combustion is an enabling technology for the capture and storage of CO<sub>2</sub> from fossil fuel power stations. This technology has been tested in various pilot plants (less than 2-3 MWth). The

further development of oxy-fired combustion requires operating experience from larger scale demonstration trials.

The proposed Callide A Oxy-fired combustion project in Australia will be the world's first fully integrated demonstration of oxy-fuel pulverized coal technology with CCS retrofitted to an existing power station. This project involves retrofitting oxy-firing combustion equipment and processes to a 30 MW (electrical) scale plant, and capture and storage of up to 30,000 tonnes of CO<sub>2</sub> pa. The project is being developed as a joint venture between industry participants from Australia and Japan. Callide A participants are CS Energy Ltd (CSE), Ishikawajima-Harima Heavy Industries Co., Ltd (IHI), IHI Engineering Australia (IHEA), Japan Coal Energy Centre (JCOAL), Electric Power Development Co., Ltd (JPower) and Schlumberger Oilfields Australia. Australian research organizations supporting the project include the CCSD and CO2CRC, with CSIRO providing indirect supporting through its involvement in these CRCs.

### **Post Combustion Capture**

CSIRO is leading Australia's post combustion capture (PCC) research and development effort. CSIRO has developed a PCC laboratory with a small scale pilot plant and has developed research relationships with RITE and Mitsubishi Heavy Industries (MHI) in Japan and has joined an international research alliance on PCC based at the University of Texas. CSIRO has joined with Rio Tinto and the Australian Coal Association to form PCC Ltd to support a national PCC and storage RD&D program. This program proposes to develop a large scale demonstration project in Australia involving the capture of 50,000 tpa of CO<sub>2</sub> and the trial storage of 10,000 tpa of CO<sub>2</sub>. PCC Ltd has applied for LETDF Funding.

Under the Asia Pacific Partnership, CSIRO has proposed a PCC pilot project program in China and India involving a transportable pilot plant (1,000 tpa CO<sub>2</sub> capture) that can trial PCC at various operating power stations. There is a need to evaluate solvents under real flue gas conditions in order to develop a more cost effective integrated emission control technology. This work in China and India will link in with CSIRO's PCC research, development and pilot plant program in Australia. If the results from this work are successful it could lead to the development of a small demonstration plant similar to the one proposed by PCC Ltd in Australia (50,000 tpa) through to a full scale demonstration (225,000 tpa) and concept designs for a full scale plant (3.3 million tpa). A key first step will be to use existing relationships CSIRO has with Japan and the US to review the status of PCC R&D in China and India, and to apply these collaborative relationships to the development and implementation of the pilot RD&D program.

### **Ultra Clean Coal**

The Ultra Clean Coal (UCC) is new fuel produced through a chemical process that removes nearly all ash from coal. UCC can be ground into a fine powder that can be directly fired in gas turbines or suspended in water as a heavy fuel oil substitute. It reduces power station environmental emissions, eliminates ash handling by power stations and when used in conjunction with combined cycle can achieve major reductions in greenhouse gas emissions compared with pulverised coal power stations. There is the potential to link in with either oxy-fired combustion or post combustion capture to enable CO<sub>2</sub> capture and storage.

UCC was originally developed by CSIRO with financial support provided by the White Mining Group, through its subsidiary UCC Pty Ltd. The Australian government provided some \$14 million towards the construction of a pilot plant to produce UCC for combustion trials in Japan in 2001/02. These trials were undertaken by Mitsubishi Heavy Industry who is working with UCC Pty Ltd to develop the turbines and combustion chambers to run on UCC. Idemitsu Kosan Co Ltd and Kyushu Electric Power Company Inc were also involved in the initial evaluation of UCC in Japan, with the Japanese Centre for Coal Utilisation (CCUJ) – now JCoal – coordinating this work.

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UCC Pty Ltd has applied for LETDF to support a prototype 6-10 MW UCC power station based on turbines supplied by MHI. The operating experience from the prototype plant in Australia and a scaled up UCC production plant will feed into the design of a full scale commercial plant. Datang International, a major Chinese power utility, has expressed interest in building the world's first full scale UCC power station, once again using gas turbines supplied by MHI.

## **CONCLUSION**

Australia has a comprehensive framework of policy and research initiatives to facilitate the development and early deployment of clean coal technologies. The successful application of these technologies will be critical to the long-term sustainability of Australia's coal industry. A key feature of Australia's approach to CCT is a strong emphasis on government-industry partnerships and active engagement with the international community. Australia values its relationship with countries such as Japan and looks forward to future opportunities for collaboration on practical solutions to greenhouse emissions from coal.

氏名 : **John Karas**

Manager, Coal Industry Section  
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John Karas manages the Coal Industry Section, the principle source of coal policy advice in the Australian Government. The Section contributes to the development and implementation of policies that support the sustainable development of the Australian coal industry and progresses the development and implementation of low emissions technology for coal.

Mr Karas has been working in this area since 1992 and has been managing the Section since the late 1990s. He has developed policy response to major structural changes in the industry, its operating environment and its changing fortunes. Some of the major issues that Mr Karas has been involved in include developing a practical response strategy to the UN Framework Convention on Climate Change in 1992; coal export facilitation and market access strategies; the application of industrial relations reforms to coal; and addressing coal transport infrastructure constraints. He has played major roles in establishing initiatives such as the APEC Ad-Hoc Group of Coal Policy Makers, Bilateral Climate Action Partnerships, COAL21, the Methane to Markets Partnership, and the Asia Pacific Partnership on Clean Development and Climate its Cleaner Fossil Energy Taskforce. A major focus of Mr Karas's current work is the development and implementation of a comprehensive strategy to accelerates the development and deployment of carbon capture and storage technologies for coal.

John Karas has an economics degree from a major Australian University. He started his Australian Government career in the Treasury Department in 1980 and joined the Resources portfolio in the mid 1980s. His policy responsibilities have covered most Australian mineral commodities, uranium policy and the development of Australia's National Sustainable Development Strategy in the early 1990s.

John Karas 氏は石炭産業セクションを管理。本セクションは豪州政府の石炭政策に関する提言をとりまとめる主要部署である。本セクションは、豪州石炭産業の持続可能な開発をサポートする政策の策定と実施、石炭の低排出技術の開発と実施の促進を行なう。

Karas 氏はこの分野に 1992 年以来従事。本セクションの管理は 1990 年代終わりから担当。大きな産業構造・事業環境の変化、財政変化に対応する実現施策を立案した。Karas 氏が携わった大きな問題の中には、1992 年の国連の気候変動に関する枠組み条約に対応する実現施策、石炭輸出振興と市場アクセス戦略、産業関連改革の石炭への適用、石炭輸送インフラの制約への対応がある。同氏はまた、APEC の石炭政策立案者アドホック・グループ、2 ヶ国間気候アクションパートナーシップ、COAL21、メタン市場化パートナーシップ、クリーン開発と気候に関するアジア太平洋パートナーシップのよりクリーンな化石燃料タスクフォース、などのイニシアティブ確立に大きな役割を果たした。Karas 氏が現在注力している重点項目は、石炭の炭素分離回収と貯留テクノロジーの開発と実用化を加速する総合戦略の開発および実施である。

John Karas 氏は豪州の主要大学で経済学士を取得。豪州政府のキャリアとしては 1980 年財務省に入省、1980 年代半ばから資源関連部門に従事。政策立案に関しては豪州の鉱物資源のほとんどを網羅、ウラン政策、1990 年代半ばの豪州の持続可能な開発戦略に携わった。