THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CONFERENCE

Clean Coal Technologies: Queensland and Wyoming - the case for cooperation

Thursday 10 and Friday 11 April 2008
Customs House, 399 Queen Street, Brisbane

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

UNIVERSITY OF WYOMING

CENTRE FOR LOW EMISSION TECHNOLOGY

RioTinto

Message from UQ Vice-Chancellor

I am very pleased to welcome you and thank you for participating in this conference. It is no overstatement to say that we are engaged with one of humanity's great challenges: the future use of our number one electricity-producing fuel.

Clean coal initiatives are a global priority and will soon be vital to the prosperity of Wyoming and Queensland, the major coal producing states in two of the world's most fossil fuel-hungry nations.

Cooperation between our researchers, corporations and governments could determine how we meet the clean coal challenge, and how history judges our generation of scientists, engineers, business people and policy makers.

It is therefore enormously encouraging for this conference to attract high level involvement from both states' governments, industries and research communities. The University of Wyoming, as that state's principal research institution, is an ideal partner for UQ. Collaboration between us will augment the potential for clean coal research to have powerful applications in our own regional and national communities, and also worldwide.

Professor Paul Greenfield AO

The conference *Clean Coal Technologies: Queensland and Wyoming - the case for cooperation* is hosted by The University of Queensland (UQ) in cooperation with the University of Wyoming (UW) and the Queensland and Wyoming State Governments.

CONFERENCE STEERING COMMITTEE

Prof. Paul Greenfield AO *(Chairman)*	Vice-Chancellor & President, UQ
Prof. Stephen Walker	Executive Dean, Faculty of Engineering, Physical Sciences & Architecture (EPSA Faculty), UQ
Mr John Morris	Director, Future Technologies Div., Dept. of Mines & Energy, Queensland Government (QLD Govn't)
Dr Kelly Thambimuthu	CEO, Centre for Low Emission Technology (CLET)
Mr Rob Hurless	Energy & Telecommunications Advisor to the Governor of Wyoming
Prof. Ovid A. Plumb	Dean (till 2007), College of Engineering, UW
Mr Peter Blondell	Principal Project Manager, Dept. of the Premier & Cabinet, QLD Govn't
Mr Allan Weatherley	Director, Future Technologies Div., Dept. of Mines & Energy, QLD Govn't

CONFERENCE HOST COMMITTEE

Dr Alex Klimenko *(Chairman)*	Div. of Mechanical Engineering, School of Engineering (SoE), UQ
Prof. Victor Rudolph *(Deputy Chairman)*	Div. of Chemical Engineering, SoE, UQ
Mr Trent Venables	Dept. of Mines & Energy, QLD Govn't
Dr Bo Feng	Div. of Mechanical Engineering, SoE, UQ
Dr Matthew Cleary *(Secretary)*	Div. of Mechanical Engineering, SoE, UQ

The Organising Committee acknowledges support and participation from the Office of the Premier and Cabinet, the Office of the Governor of Wyoming, Queensland Department of Mines and Energy, Wyoming Business Council, School of Energy and Resources and College of Engineering and Applied Science of the University of Wyoming, Faculty of Engineering, Physical Sciences and Architecture, School of Engineering of The University of Queensland. Assistance from The University of Queensland Office of Marketing and Communications is also greatfully acknowledged.

Mission

In the current economic environment of rising oil prices, many industrialised countries view their coal reserves as a vital source of secure energy for the coming decades. World coal consumption is projected to increase by 74% from 2004 to 2030. It is difficult to overestimate the importance of coal to continued economic growth in the United States (the world's second largest producer of coal) and Australia (the world's largest exporter of coal). At the same time, there is growing concern for the effects of combustion emissions on the environment and the global climate. In the 21st century, new coal technologies are needed to provide affordable and secure energy supplies while reducing our impact on the environment.

The States of Wyoming and Queensland are the largest coal producers in their respective countries with Wyoming producing around 400M tonnes/year (about 40% of the US total) and Queensland producing around 235M tonnes/year (just under 60% of the Australian total). Both states have sufficient reserves to sustain or increase current levels of production for many years to come and in both states coal production is vital to the economy. The States of Queensland and Wyoming face major challenges of utilising their natural resources to build smart and vibrant economies as well as strengthening their positions as the world leaders in clean coal technologies. The whole spectrum of new or improved technologies (including improved coal gasification and combustion, carbon capture and storage, coal-sourced synthetic fuels, gas separation and cleaning and others) is envisaged to play a major role.

The importance of coal production to the economies of Queensland and Wyoming makes the two states natural allies in achieving common goals. This provides a good incentive for partnership between the two major research universities – The University of Queensland and the University of Wyoming – and partnership between the two State Governments. These partnerships must involve the industries who extract, burn and process coal as well as research institutes and laboratories who are involved in clean coal research and development. It is for the purpose of fostering such partnerships that this conference "Clean Coal Technologies: Queensland and Wyoming - the case for cooperation" was organised.

Conference Sponsors

The University Of Queensland AUSTRALIA

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Topics

coal gasification

CO_2 capture and storage

coal bed methane recovery

synthetic fuels

Conference Program

DAY 1: THURSDAY 10 APRIL 2008

8.15am **REGISTRATION**

8.45am **CONFERENCE WELCOME**

9.00am **KEYNOTE PRESENTATIONS**
Chair: **Prof. Paul Greenfield AO**, Vice-Chancellor & President, UQ

The Hon. Geoff Wilson MP, Minister for Mines & Energy, QLD Govn't - *Queensland Government's Policy and Vision for Clean Coal Technologies*

Mr Bob Jensen, CEO, Wyoming Business Council (representative of the Governor of Wyoming) - *Wyoming's Commitment to Clean Coal Technologies*

10.00am ***MORNING TEA***

10.30am **INVITED PRESENTATIONS: SESSION 1**
Chair: **Prof. Stephen Walker**, Executive Dean, EPSA Faculty, UQ

Dr Jon Davis, Chief Energy Technologist, Rio Tinto - *A Coal Industry Perspective on Clean Coal Technologies*
Adj. Prof. Michael Blinderman, Director, Operations, Ergo Exergy Tecnologies Inc.; and **Dr Len Walker**, Managing Director, Cougar Energy Ltd - *Underground Coal Gasification – Queensland and Wyoming Experience*
Mr Bob Kelly, Executive Chairman, DKRW Advanced Fuels - *Coal Liquids in America's Energy Future*
Dr Cliff Mallett, Executive General Manager, Carbon Energy Pty Ltd; and **Mr Rusty Mark**, Business Development Manager, Carbon Energy Pty Ltd - *Wyoming UCG trials at Hanna – a template for commercial scale UCG production modules in Queensland*

12.00pm ***LUNCH***

1.15pm **INVITED PRESENTATIONS: SESSION 2**
Chair: **Mr Stuart Booker**, Acting Director-General, Dept. of Mines & Energy, QLD Govn't

Mr Howard Morrison, Manager, Emerging Technologies, Stanwell Corporation Ltd - *ZeroGen Clean Coal Power*
Dr Chris Spero, Callide Oxyfuel Project Director, CS Energy - *Oxyfuel Technology Development in Australia*
Dr Kelly Thambimuthu, CEO, CLET - *Research and Development in Coal Gasification Technologies*
Dr Mark Northam, Director, School of Energy Resources, UW - *Wyoming's Energy Future: Creating Options*
Prof. Robert Ettema, Dean, College of Engineering & Applied Science, UW - *Energy, Water, and Environment: Bellwether Themes for the University of Wyoming's College of Engineering and Applied Science*

Conference Program

3.00pm *AFTERNOON TEA*

3.30pm **INVITED PRESENTATIONS: SESSION 3**
Chair: **Prof. Ovid A. Plumb**, College of Engineering, UW

Dr John Wright, Director, Energy Transformed Flagship, CSIRO - *Clean Coal Research and Development in Australia*
Dr Peter Cook, CEO, CO2CRC - *Carbon Capture and Storage: From Research to Deployment*
Prof. Brian Towler, CEAS Fellow for Hydrocarbon Energy Resources, UW - *University of Wyoming Coal Gasification Research*
Assoc. Prof. David Bagley, Head of Civil & Architectural Engineering, UW - *Sustainable Methane and Water Production from Wyoming Coal-Beds*

4.55pm Discussion Group Planning for Day 2, **Dr Alex Klimenko**, Div. of Mechanical Engineering, UQ

7.00pm *CONFERENCE DINNER*

DAY 2: FRIDAY 11 APRIL 2008

9.00am **INVITED REVIEW**
Chair**: Dr Mark Northam**, Director, School of Energy Resources, UW

Prof. Victor Rudolph, Div. of Chemical Engineering, UQ - *Clean Coal Research at UQ*

9.40am *MORNING TEA*

10.15am **DISCUSSION GROUPS**

Gasification, Synthetic Fuels and Carbon Capture - Chair: **Dr Kelly Thambimuthu**
Carbon Storage and Coal Bed Methane - Chair: **Prof. Victor Rudolph**
Cooperation between the Universities - Chair: **Prof. Graham Schaffer**

11.30am *LUNCH*

12.45pm **REPORTS FROM THE DISCUSSION GROUP CHAIRS**
Chair: **Mr John Morris**, Director, Future Directions Strategy Div., Dept. of Mines & Energy, QLD Govn't

Mr Peter Blondell, Principal Project Manager, Dept. of the Premier & Cabinet, QLD Govn't - *Cooperation between the Governments*
Dr Kelly Thambimuthu, CEO, CLET - *Gasification, Synthetic Fuels and Carbon Capture*
Prof. Victor Rudolph, Div. of Chemical Engineering, UQ - *Carbon Storage and Coal Bed Methane*
Prof. Graham Schaffer, Head, SoE, UQ - *Cooperation between the Universities*

1.15pm **CONFERENCE CLOSURE**

Keynote Presentations

The Honourable Geoff Wilson MP, Minister for Mines and Energy, Queensland Government

Mr Bob Jensen, CEO, Wyoming Business Council (representative of the Governor of Wyoming)

QUEENSLAND GOVERNMENT'S POLICY AND VISION FOR CLEAN COAL TECHNOLOGIES

The Honourable Geoff Wilson MP, Minister for Mines and Energy, Queensland Goverment

The Bligh Government is at the forefront of exciting new technology to help combat climate change.

Drilling is well underway deep in the Denison Trough in Central Queensland in the search for clean coal solutions. It is called the ZeroGen project and it could become the first of its kind in the world to combine coal gasification with carbon capture and storage, to produce electricity with low carbon dioxide emissions.

ZeroGen is a two-pronged approach to bring about smarter, cleaner power. The first aims to convert coal into hydrogen gas to generate power. For this, ZeroGen plans to build a demonstration power plant close to the Stanwell power station near Rockhampton. The second aims to capture carbon dioxide released in the combustion process at the site, and store it underground in deep saline reservoirs in the Northern Denison Trough. We've committed $300 million towards the project from our Clean Coal Fund.

We are also on the front foot with an oxy-fuel project being developed by CS Energy near Biloela.

This project involves using a conventional power station and burning the coal in pure oxygen to make it easier to capture the carbon dioxide.

It is expected to demonstrate that coal-fired power stations can be retro-fitted with the new technology to achieve deep cuts to carbon emissions, which is important in a state with more than 32 billion tonnes of high-quality, low-cost, easily accessible black coal. Coal will continue to play a role in the global electricity mix. Our key challenge is to use it in a responsible and environmentally sustainable way.

The State Government has also set up a Clean Coal Council chaired by the Premier. We take our responsibilities seriously and have come up with sensible, workable solutions that we believe are in the best interests of Queenslanders and the environment.

WYOMING'S COMMITMENT TO CLEAN COAL TECHNOLOGIES

Mr Bob Jensen, CEO, Wyoming Business Council

Wyoming is committed to both energy production and environmental protection. With the growing worldwide demand for energy resources, we are going to need every form of energy we can harness including clean coal, natural gas and renewable resources. For the foreseeable future, carbon based resources like coal are a necessity if we want to keep the lights on. Hence, any serious carbon management effort must include aggressive support for carbon capture and sequestration and Wyoming is pursuing clean coal technologies in many ways.

Invited Presentations: Session 1

Dr Jon Davis, Chief Energy Technologist, Rio Tinto

Adjunct Professor Michael Blinderman, Director, Operations,
Ergo Exergy Technologies Inc.; and
Dr Len Walker, Managing Director, Cougar Energy Ltd

Mr Bob Kelly, Executive Chairman, DKRW Advanced Fuels

Dr Cliff Mallett, Executive General Manager, Carbon Energy Pty Ltd;
and Mr Rusty Mark, Business Development Manager,
Carbon Energy Pty Ltd

A COAL INDUSTRY PERSPECTIVE ON CLEAN COAL TECHNOLOGIES

Dr Jon Davis, Chief Energy Technologist, Rio Tinto

This presentation first examines the magnitude of the challenge in implementing fossil fuel low emission technologies at scale in the next two decades.

A number of critical issues are then considered against this background.

- The maturity of the required technologies
- Project cost increases over the last five years
- Different perspectives of the roles for R&D and demonstrations
- The critical importance of regulatory certainty and public acceptance
- Why the first generation of demonstrations will be expensive and hence why international co-operation will be required in this area.

UNDERGROUND COAL GASIFICATION - QUEENSLAND AND WYOMING EXPERIENCE

Adjunct Professor Michael Blinderman, Director, Operations, Ergo Exergy Technologies Inc.; and Dr Len Walker, Managing Director, Cougar Energy Ltd

The commercial application of Underground Coal Gasification (UCG) technology received a substantial boost over the period 1999 to 2002 with the initiation by the authors of a successful pilot burn at Chinchilla in Queensland, at a time when there was little international interest in the technology and its commercialization.

Dr Blinderman will highlight the care required in planning, initiating and controlling UCG field operations, with particular reference to the Chinchilla project, and specific aspects of his company's eUCG technology. He will also describe past UCG activity in Wyoming, current plans for a revival of the technology in that State, and his other international activity.

Dr Walker will discuss the early interactions with Queensland Government Departments, which enabled approvals to be achieved in initiating the 1999 Chinchilla test, and current experience in other States of Australia. He will also describe his Company's plans for further commercial development of the technology near Kingaroy in Queensland, and in Pakistan.

COAL LIQUIDS IN AMERICA'S ENERGY FUTURE

Mr Bob Kelly, Executive Chairman, DKRW Advanced Fuels

This presentation initially explains the market forces that are creating the incentives for the emergence of the coal to liquids industry in the US: high prices in the oil market, economic security issues relevant to the net outflow of dollars due to oil imports, and the national security issues related to the geopolitics of US oil imports. The presentation then goes on to discuss the development of the Medicine Bow Coal to Liquids Project in the State of Wyoming using the Exxon Mobil Methanol to Gasoline (MTG) technology. The project is a 19,000 barrel per day project producing regular gasoline and liquid CO2 for enhanced oil recovery. The technologies employed include GE coal gasification, UOP Selexol acid gas removal technology, Davy methanol technology and Exxon Mobil MTG technology. The coal will be produced from a reserve currently owned by Arch Coal that is on option to the project. The gasoline will be sold into the Denver gasoline market and the CO2 will used in enhanced oil recovery in Wyoming. The presentation will show that the net amount of CO2 emitted from the process is competitive with CO2 emissions from conventional oil refineries on a well to wheels basis.

WYOMING UCG TRIALS AT HANNA – A TEMPLATE FOR COMMERCIAL SCALE UCG PRODUCTION MODULES IN QUEENSLAND

Dr Cliff Mallett, Executive General Manager, Carbon Energy Pty Ltd; and Mr Rusty Mark, Business Development Manager, Carbon Energy Pty Ltd

The Rocky Mountain #1 UCG trial funded by the US Department of Energy at Hanna, Wyoming proved the feasibility of gasification between two in-seam boreholes in coal at depth. Ignition of the coal was initiated in a vertical borehole which was intersected by two horizontal in-seam boreholes. After ignition the vertical borehole was shut in and oxygen and steam was injected through one of the horizontal boreholes, with product gas removed through the other. The gasification chamber was developed in the angle between the in-seam boreholes. Chamber growth was controlled by progressive retraction of the injection well to expose fresh coal.

A commercial scale 1 petajoule per year UCG module has been developed from the Hanna experimental configuration by CSIRO, and is to be demonstrated by Carbon Energy P L in the Surat Basin, south east Queensland in Q3, 2008. In this design, the in-seam boreholes are drilled parallel, about 30 m apart, for approximately 600m in the coal seam. They come together and intersect a vertical borehole at the end of the panel.

The site at Bloodwood Creek is on a 100 Mt coal deposit where a 10m coal seam is found at a little over 200m depth. It is anticipated that 1000PJ of UCG syngas can be extracted from the currently defined coal resource. This will be a high quality, nitrogen free, syngas suited to applications in low emission power generation and ideally suited to currently available technologies which synthesis chemicals such as ammonia, methanol, and liquid fuels.

Invited Presentations: Session 2

Mr Howard Morrison, Manager, Emerging Technologies, Stanwell Corporation Ltd

Dr Chris Spero, Callide Oxyfuel Project Director, CS Energy

Dr Kelly Thambimuthu, CEO, Centre for Low Emission Technology

Dr Mark Northam, Director, School of Energy Resources, University of Wyoming

Professor Robert Ettema, Dean, College of Engineering and Applied Science, University of Wyoming

ZEROGEN CLEAN COAL POWER

Mr Howard Morrison, Manager, Emerging Technologies, Stanwell Corporation Ltd

ZeroGen Pty Ltd is leading a two stage program that will accelerate the deployment of low emissions electricity from coal. The two-staged approach will develop the world's first demonstration-scale low emission coal power plant of its kind by 2012, and one of the world's first large-scale plants by 2017.

Stage One will demonstrate Integrated Gasification Combined Cycle (IGCC) using 6F gas Turbine technology with carbon capture and storage (CCS). The IGCC power plant will be located adjacent to the existing Stanwell Power Station in Central Queensland, Australia. Up to 75 percent of carbon dioxide (CO2) emissions will be captured. This stage will also explore and advance the technology involved in storing CO2 in low permeable saline reservoirs through sequestration in the Northern Denison Trough.

The Initial designs for stage 1 are based on the application of Shell gasification technology provided by Shell Global Solutions International.

Stage Two will involve the development of a new 300 megawatt power plant with a 9F turbine capturing and storing up to 90 percent of CO2 emissions. The location will be determined in the pre-feasibility study that will investigate all suitable areas in Queensland.

The key objective of Stage 1 is to "de-risk" the technology through generating the required knowledge and experience in Stage One to accelerate large-scale deployment in Stage Two and in other clean coal power projects around the world.

The current focus of Stage One is the selection and confirmation of key process systems, system optimization, process design criteria and parameters for defining the process configuration. Shell Global Solutions International together with ZeroGen Pty Ltd and WorleyParsons Group Inc established the project process configuration; defined major system components, developed heat and mass balances, plant performance and emissions profiles, and characterized the carbon dioxide geosequestration.

This presentation provides an overview of the work that has been carried out to date on the ZeroGen Clean Coal Power Program.

OXYFUEL TECHNOLOGY DEVELOPMENT IN AUSTRALIA

Dr Chris Spero, Callide Oxyfuel Project Director, CS Energy

There are a number of clean coal technologies at various stages of development and deployment around the world that seek to achieve near-zero emissions from coal-fired electricity generation. Oxyfuel technology involves the combustion of coal in a mixture of oxygen and recycled flue gas in conventional pulverized coal-fired boilers and varies from the normal process of combustion in air in that oxyfuel conditions can be designed to dramatically reduce NOx emissions and at the same time yield a flue gas that is highly concentrated in CO2. Consequently, the oxyfuel process, when linked with CO2 geological storage has the potential to yield large cuts in NOx and greenhouse gas emissions. In this presentation, an overview will be given of the RD&D work on oxyfuel combustion in Australia, and the details and status of the Callide Oxyfuel Demonstration Project.

RESEARCH AND DEVELOPMENT IN COAL GASIFICATION TECHNOLOGIES

Dr Kelly Thambimuthu, CEO, Centre for Low Emission Technology

The Centre for Low Emission Technology established in 2003 is an unincorporated joint venture funded by the Queensland Government, CSIRO, Tarong Energy, Stanwell Corporation, the Australian Coal Association Research Program and The University of Queensland.

The primary focus of the centre's initiatives has been in the research and development of next generation low emission electricity and/or hydrogen production technologies from coal. The presentation will outline critical gaps in research and development, the work currently underway at the centre, and initiatives that would need to be progressed for the future implementation of low emission coal gasification technologies.

WYOMING'S ENERGY FUTURE: CREATING OPTIONS

Dr Mark Northam, Director, School of Energy Resources, University of Wyoming

Wyoming is among the leading energy-producing states in the USA.

Revenue from energy-related activities fund the largest part of the state's budget. After a long production history, the state has large remaining reserves of coal, oil, natural gas, and uranium. In addition, Wyoming has world-class wind energy potential, And, other renewable energy resources hold promise for development. The vast majority of energy resources produced each year in Wyoming exit the state as commodities because limited value-adding industrial capacity exists. In the past, normal supply/demand driven price fluctuations in energy markets have resulted in "boom and bust" cycles that cause serious shortfalls to state funding needs.

In 2006, the Wyoming Legislature provided funding to establish a School of Energy Resources at the University of Wyoming with the underlying notion that knowledge must lead the state's energy industry up the value chain. The mission of SER is to leverage and add to the already significant energy-related talent and resources in UW Colleges to develop human resources, know-how, and technical solutions to ensure a secure and sustainable energy future for the state. SER's resources are focused on value-adding endeavors through extensive academic, research, and knowledge transfer programs - which will be presented.

ENERGY, WATER, AND ENVIRONMENT: BELLWETHER THEMES FOR THE UNIVERSITY OF WYOMING'S COLLEGE OF ENGINEERING AND APPLIED SCIENCE

Professor Robert Ettema, Dean, College of Engineering and Applied Science, University of Wyoming

Energy, water, and the environment are bellwether themes for programs of education and research at the University of Wyoming's College of Engineering and Applied Science, and indeed at the University as a whole. Wyoming has large reserves of fossil-fuel energy resources, though marginal water resources. Discussion of coal soon conflates concerns about energy, water, and environment. Coal extraction is a major component of Wyoming's economy, with Wyoming being the largest coal-producing state in the United States. Yet Wyoming also is the archetypical wilderness headwater state. Freshwater from the state's largely pristine mountain ranges passes through its extensive, often semiarid basins and flows towards several major North American rivers: notably the Colorado, Columbia, and Missouri Rivers. Subterraneous water of varied quality exists in these basins, commonly alongside Wyoming's extensive coal reserves (as well as oil and gas reserves). The state is keen to find ways for processing coal into higher value products. The state, though, is mindful of the potential adverse impacts that coal extraction and processing pose for water and environment in Wyoming as well as elsewhere in the United States. Hence, within Wyoming there is keen interest to facilitate enhanced, environmentally neutral, clean-coal technologies.

This talk outlines the College's programs of education and research focused on energy (especially coal), water, and environment. In so doing, the talk provides background and context to the talks given by other members of the College's faculty participating in the present Workshop.

Invited Presentations: Session 3

Dr John Wright, Director, Energy Transformed Flagship, CSIRO

Mr Peter Cook, CEO, Co-operative Research Centre for Greenhouse Gas Technologies

Professor Brian Towler, CEAS Fellow for Hydrocarbon Energy Resources, University of Wyoming

Associate Professor David Bagley, Head of Civil and Architectural Engineering, University of Wyoming

CLEAN COAL RESEARCH AND DEVELOPMENT IN AUSTRALIA

Dr John Wright, Director, Energy Transformed Flagship, CSIRO

The energy scene in Australia is changing quickly. We have now ratified the Kyoto Protocol, have a national target of reducing our GHG emissions by 60% below 2000 levels by 2050, a target of 20% of our power to be supplied by renewables by 2020 and the introduction of an emissions trading scheme by 2010. As a result of the Garnaut review and other inputs, the government also intends to set a national 2020 GHG target by the end of the year. The cleaner use of our internationally competitive coal will fall directly into the line of sight of these targets and CCT will need to play a primary role in their achievement. Industry, governments and the R&D community are responding to the clean coal challenge. There are significant, and growing, activities across the research, development and demonstration spectrum. The presentation will present an overview of these activities with some specific examples of R&D particularly relevant to Queensland.

CARBON CAPTURE AND STORAGE: FROM RESEARCH TO DEPLOYMENT

Mr Peter Cook, CEO, Co-operative Research Centre for Greenhouse Gas Technologies

Oil companies have been injecting carbon dioxide into the subsurface as part of enhanced oil recovery (EOR) projects for the past 40 years, but the concept of mitigating carbon dioxide emissions through carbon dioxide capture and geological storage (CCS) was only suggested around 1990.

Initially the idea was met with a combination of indifference and scepticism. However the pioneering Sleipner Project of Statoil in 1996 provided an enormous boost to CCS credibility as a mitigation option. Despite that, the commercial uptake of the technology has been slow over the subsequent decade with only three additional projects – first the Encana Weyburn (EOR with storage), followed by the BP In Salah and most recently the Statoil Snovit storage project. To that can be added a number of acid gas disposal projects in Western Canada, undertaken as part of petroleum production operations.

Even at the research or demonstration level, few storage projects have been undertaken to date: these have included the Japanese Nagaoka Project (injecting up to 10,000 tonnes CO2), the Frio Brine Project in the USA and most recently the CO2CRC Otway Project in Australia.

The Otway Project represents an important step forward for CCS in Australia and internationally. In terms of the amount of injected CO2 (approximately 100,000 tonnes of CO2 over 12-18 months), it represents the largest scale of injection for any demonstration project. Similarly, the range of monitoring technologies deployed on site, is one of the most comprehensive anywhere.

Australia's experience in CCS is instructive, both for showing the technology pathway that has been adopted and also for demonstrating the time and effort to move from research to demonstration.

In the late 1990's the Gorgon JV partners commenced their work on geological storage. This work was sharply focussed on Barrow Island and was commercial-in-confidence. In 1998, the APCRC, (predecessor to CO2CRC), commenced the GEODISC Project to assess Australia's geological storage resources. This project was successful in that it demonstrated there was a large storage resource - enough to store a large proportion of Australia's stationary CO2 emissions. However the identification of a storage resource does not necessarily equate to a usable storage "reserve" and over the past five years, CO2CRC has sought to identify the usable (operational) storage capacity in a number of areas and also to move its work on capture from the laboratory to the pilot or demonstration scale. This it is now doing in pre and post combustion projects in the Latrobe Valley.

There are a number of other storage projects now proposed for Australia, but realistically none of these are likely to start storing CO2 before 2010 and it could be several years beyond that for most of them. Australia (and other countries) must seek to accelerate the rate of large scale deployment. Demonstration projects undertaken at a commercially significant scale, whilst not a substitute for large scale fully-commercial deployment, can nonetheless serve to accelerate commercial deployment by testing technologies, helping to clarify regulatory issues in an operational mode, providing confidence in monitoring and verification and helping to foster community confidence in CCS. These demonstrations should not be seen as an essential prelude to commercial deployment, but to be pursued in parallel and in a mutually supportive manner. The CO2CRC Otway Project site offers some exceptional opportunities for doing this under a range of conditions, in a speedy and cost effective manner, but there will also be a need for additional storage projects in a range of geological settings.

UNIVERSITY OF WYOMING COAL GASIFICATION RESEARCH

Professor Brian Towler, CEAS Fellow for Hydrocarbon Energy Resources, University of Wyoming

Wyoming is the number 1 coal producing state in the United States, producing more than the next five states combined. The University of Wyoming's College of Engineering and Applied Science has a strong program in coal conversion and utilization technologies. Faculty recently have designed and patented a new coal gasifier and a new IGCC design. We were motivated to commence work on this after the Wyoming State Government commissioned a report from Rentech to design a coal to liquids plant for Wyoming's Powder River Basin coal. PRB coal supplies about 40% of the nation's supply. But it is wet sub-bituminous coal, so it has particular design issues to gasify and liquefy. Rentech narrowed the search to four gasifiers (GE, Shell, Seimens and Conoco). Two of these gasifiers were slurry fed and consequently required significantly more oxygen and energy to vaporize the carrier water and then gasify the coal. The other two required a dry feed and so they had to dry the coal first before they could gasify it. So it appeared to us that no gasifier operated very efficiently on PRB coal. So we set out to design a completely new gasifier. Our design has the following features: 1) Reaction occurs in a fluidized bed. 2) The reactor is constructed as a low temperature pressure chamber containing a high temperature liner. 3) The liner utilizes thermal barrier coatings in conjunction with film cooling to lower the liner wall temperature. 4) The cooling vents are arranged so that they also supply additional oxygen and steam over an extended reactor length. 5) The reactor is designed to allow the velocity of the gases to be adjusted to the local particle density; thereby optimizing buoyancy and residence time and minimizing elutriation. 6) The exit of the reactor is fitted with a device that allows the fly ash to be efficiently separated from the flue gas stream.

Our IGCC design is applicable to a variety of fuel sources but is particularly well-suited for low sulfur bituminous and sub-bituminous Powder River Basin coal (Wyoming), in which:

1) No separation of compounds is done between the gasifier and the turbine.

2) Exhaust scrubbing may be done after combustion in the gas turbine.

3) A working aero-derived turbine is used to produce compressed air for process flow streams such as: (a) the air cycle machines (ACM) used to boost O2/H2O pressure to the gasifier, and (b) the pressure swing O2 generators.

4) Working aero-derived turbines not only drive the electric generation units but the hot exhaust is used to produce heat for water vaporization to be used in the steam turbine.

5) CO2 from the exhaust is recycled as carrier gas in the gas turbines.

The advantage of this design over other IGCC designs is that (1) the hot gases from the gasifier do not need to be cooled before being burned in the gas turbines and (2) no cleanup of the syngas from the gasifier is required before combustion in the turbine. Consequently the capital costs of this design over other IGCC designs are significantly less and the thermodynamic efficiency is significantly higher. The output stream from the gas turbines is primarily steam and CO2. After condensing off the steam the CO2 is almost pure and ready for enhanced oil recovery or CO2 sequestration. The Sox, and Nox produced is minimized and any that is produced is sequestered with the CO2. Mercury can be captured prior to gasification. This plant could be built and operated with almost zero air emissions.

SUSTAINABLE METHANE AND WATER PRODUCTION FROM WYOMING COAL-BEDS

David M. Bagley, Yiping Liu and Eric T. Sajtar
Department of Civil and Architectural Engineering, University of Wyoming

The methane found with sub-bituminous coals such as those in the Wyoming Powder River basin ranges from 20-90 standard cubic feet (SCF) gas/ton coal. Bituminous coal and anthracite, however, can have up to 350-500 SCF gas/ton. Only 4-18% of the methane associated with these harder coals would have been biogenically produced early in the coalification process, the rest is produced thermogenically. Un-mineable sub-bituminous coals therefore contain the potential to produce up to 260-480 SCF/ton more methane. Recovering only 15% of that potential could double the methane production from existing sub-bituminous coal-bed methane wells in the Wyoming Powder River basin alone, increasing estimated recoverable gas production from 25.2 to over 50 trillion cubic feet, for the same investment in mining, processing and recovery infrastructure. A key question, then, is how to achieve this increased methane production.

To recover methane from the Powder River basin coal-beds, however, requires the removal of water. Coalbed methane (CBM) co-produced waters in the Powder River Basin (PRB) can contain, among other constituents, sodium ranging from 110-800 mg/L, total dissolved solids ranging from 270-2,010 mg/L, and sodium adsorption ratios ranging from 5.7-33. Due to excess sodium concentrations, untreated CBM waters may negatively affect aquatic ecosystems, damage soil characteristics, or contaminate aquifers. These issues can make it necessary to treat these waters before discharge or use. Alternatively, these waters may be required to facilitate increased biogenic methane production. In either case, though, the questions are which technologies to use and how much do they cost.

During this presentation, the postulate will be presented that these two issues, secondary biogenic CBM production and water management, are integrally related and that sustainable production of both products can be achieved. Biogenic coal-bed methane production processes will be described and examined as well as the technologies suitable for treating these waters. The key challenges, both scientific and practical, to sustained production of both products will be identified and evaluated. Finally, steps taken so far to sustainably enhance production will be presented, including preliminary cost estimates for the water treatment technologies.

Invited Review

Professor Victor Rudolph, Division of Chemical Engineering,
The University of Queensland

CLEAN COAL RESEARCH AT THE UNIVERSITY OF QUEENSLAND

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There are over 30 billion tonnes of identified resources of black coal in the Queensland, the basis for a major industry and contributor to Queensland's economy. The State has for many years been the largest exporter of seaborne coal in the world. It would therefore be no surprise that the University of Queensland has a long history of research activity in almost all aspects of this area. A significant part of this effort over the past dozen or more years has been aimed at clean coal technologies.

At its most basic level, cleaner use of coal is directed at reducing emissions and improving efficiency per unit of useful product. Such a broad definition incorporates an equally wide variety of potential projects, so only a limited number of activity areas are covered here. Further, within a university research context, the focus is on forward looking enabling technologies, understanding and analysis of the natural principles and systems modeling at all levels of scale.

Our approach to 'clean coal' is twofold: as a resource that can be used and exploited in situ; and dealing with the consequences of using coal itself (primarily of course for its energy value). The former approach includes, as examples, coal bed methane (CBM), CO2ECBM, UCG, all of the engineering and geological activities associated with using coal as a reservoir, and best exploiting the high hydrogen content of methane. The latter includes flue gas cleanup (NOx, SOx, particulates…), CO2 separation technologies, both pre- and post-combustion, coal and ash behavior in different process configurations, systems integration, amongst others. Both approaches are underpinned and informed by a broad array of detailed scientific discovery projects e.g. in reactive and dynamic flow systems, material properties, surface science, thermodynamics of complex materials and many more.

This presentation provides a summary overview of some current projects associated with clean coal technologies at The University of Queensland and then focuses in on some specific examples related to CO2ECBM and membrane systems for gas separation relevant to both pre- and post-combustion CO2 capture.

Conference Outcomes

Conference Outcomes

The **Clean Coal Technologies: Queensland and Wyoming – a case for cooperation** Conference held in Brisbane, Australia, April 10-11, 2008, was attended by 70 representatives from government, industry, research institutes, and universities.

The Conference was organised in recognition that clean coal initiatives are paramount for satisfying a rapidly growing world demand for clean and affordable energy, a sector vital to the economies of the States of Queensland and Wyoming. Through partnerships involving government, industry, research organisations and universities we envisage the development of the technologies essential to provide sustainable energy supplies for future generations.

The Conference was closed on April 11 with reports from discussion groups representing the Governments of the States of Queensland and Wyoming, the Universities of Queensland (UQ) and Wyoming (UW) and the technical experts in attendance. The discussion groups were charged with developing conference outcomes in their respective areas. These outcomes are summarised in the following paragraphs.

Government: The Governments of Queensland and Wyoming identified the following areas for further discussion: sharing information on policies and programs to develop and promote clean coal and other low emission technologies, examining issues related to development of carbon storage policies in both States, exploring mechanisms to facilitate future collaborative projects between the two States, and developing opportunities to leverage other international relationships in the field.

Universities: A Memorandum of Understanding to promote increased future collaborations through coordination of research capabilities and activities, the exchange of postgraduate students and faculty, and the promotion of joint workshops and conferences was signed by the Dean of College of Engineering and Applied Science at the University of Wyoming and the Head of School of Engineering at The University of Queensland. The two universities will also pursue further opportunities for collaboration including joint funding of research and undergraduate student exchange.

Critical Technical Issues: The discussion of critical technical issues related to coal utilisation was broken down into four technical areas: gasification, synthetic fuels, carbon capture, and carbon storage and coal bed methane. Specific critical research and development needs were generated for each of these areas.

Several key topics related to underground coal gasification (UCG) were identified. These include the development of CFD (computational fluid dynamics) and integrated models capable of simulating scaled-up UCG operations, examination of the economics of oxygen blown versus air blown UCG, identification of ash forms remaining upon UCG completion and their impact on water, examining the possibility of CO2 storage in conjunction with UCG operations and development of strategies for groundwater management at UCG sites. In addition, it is recommended that existing cooperation in the UCG area between Queensland and Wyoming be extended to a network of groups interested in UCG research and development for the purpose of disseminating information about UCG technology.

Conference Outcomes

For surface gasification key research needs include ash behaviour and CFD models including model integration for reacting flows. It is recommended that, subject to approval by General Electric Corporation (GE), the University of Wyoming and the Centre for Low Emission Technology (cLET) exchange information related to project development and work on oxygen blown, entrained bed coal gasification.

Under the topic synthetic fuels the group concluded that the highest research priorities were new catalysts for various coal to liquid technologies including Fischer-Tropsch synthesis, development of processes to produce diesel from methanol, and the production of methanol from methane.

Continued development of carbon capture technologies will rely on improved understanding of algal and other biofixation, the development of solid sorbents for CO_2, new membrane separation systems and reactors, and sealing materials. Hot gas cleanup, CO_2 turbine development, evaluation of materials for gasification and cleanup equipment and associated CFD modelling were also identified as critical research areas.

The topics identified under the general heading carbon storage and coal bed methane (CBM) include injection of impure CO_2, economic monitoring strategies for adjacent aquifers, and modelling transport of CO_2 and mixtures containing CO_2 in appropriate geological structures. Topics more closely related to CBM as opposed to storage include CBM water treatment, stimulation of low permeability coal seams, CO_2 enhanced methane production for high permeability coal seams and the use of CO_2/CH_4 mixtures, biogenic methane production, and further work on the mechanical properties of coal. In addition, the CBM Symposium at UQ in September, 2008, was identified as an excellent venue for further discussion and interaction.

Finally, several facilities were highlighted as having potential to enhance collaboration in one or more of the above areas. These include isotope laboratories at both Universities, the new National Center for Atmospheric Research supercomputing centre under development in Wyoming, the three-dimensional X-ray tomography facility at UW, and the small scale combustion/boiler facility at Western Research Institute on the UW campus.

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CONFERENCE

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