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18 August 2006

Dear Sir / Madam

Inquiry into Geosequestration Technology

Anglo Coal and its subsidiary Monash Energy thank you for the opportunity to make a submission to this Inquiry.

Anglo Coal is a wholly owned subsidiary of the major international resource company Anglo American *plc*. Anglo Coal is one of the world's largest private sector coal producers, with major mining operations in Australia as well as South Africa, Colombia and Venezuela, and with prospects in several other geographies.

Anglo Coal has an active clean coal technology development programme based around coal gasification. It is a member of the FutureGen Alliance working to develop a coal-fuelled, near-zero emission power plant in the United States, and is also a member of CO2CRC working to research and develop CCS in Australia.

Through its subsidiary Monash Energy, Anglo Coal is planning its own Coal-to-Liquids project, the Monash Energy Project. Located in Victoria's Gippsland Basin, the Monash Energy Project is proposed as a world-scale coal to liquids plant (expected to cost in the order of A$5 billion) incorporating CCS to capture and store the large majority of the CO2 it would otherwise emit. The project will take advantage of the location of Victoria's vast Latrobe Valley coal fields in the onshore Gippsland Basin, close to the exceptional storage potential of the offshore Gippsland Basin oil and gas fields.

Anglo Coal is committed to incorporating CCS in the Monash Energy Project to achieve low emissions status, and in so doing, has taken the lead as the world's first coal producer to actively invest in the development of a commercial CCS project.

Monash Energy is an excellent illustration of the role of CCS as an enabling technology. CCS should be supported not as an end in itself, but because it allows us to pursue society's key objectives, including:

- managing climate change
- achieving energy security
- global social equity through clean development
- global sustainability

We do not pretend that CCS should be the sole means to pursue these objectives, but it is an essential part of the portfolio of measures that will be necessary to achieve sustainable development objectives while stabilising levels of CO2 in the atmosphere.

The work done in association with our project establishes the scale of the potential: from the Latrobe Valley alone approximately 50 million tonnes of CO2 per annum could be stored in the Gippsland Basin.

This would enable the Latrobe Valley to continue its historic role as a major generator of electricity, while opening up opportunities to utilise the outstanding brown coal resource in new and exciting ways. Production of synthetic diesel as envisaged by Monash Energy is just one example.

The search for "early deployment opportunities" is now a pre-occupation of international policy-makers. Due to the large amounts of capital invested in stationary energy, the "take-off" of CCS equipped power stations is not expected until about 2020. For that reason, projects which because of lower marginal cost and/or access to low-cost storage can be achieved in an earlier timeframe, could serve to advance the technologies and demonstrate the capacity of CCS to the wider world.

The science underpinning CCS is sound, and is based on decades of experience in the closely allied fields of petroleum. The remaining (and manageable) challenge is to refine the skills to model, monitor and verify the behaviour of CO2 throughout the CCS process. Australia already has a world-class capacity in this area which should continue to develop in coming years.

The establishment of public confidence in CCS is critical to new developments achieving investor and community support. For this reason, the regulatory regime currently being developed is a positive and urgent necessity, as it provides a transparent framework by which the public can be assured that each particular proposal will meet the requisite tests of storage and safety assurance.

Australian Governments, including the Commonwealth and the Government of Victoria, have been leaders in developing policy and searching for CCS deployment opportunities. The Committee's deliberations should contribute to what is recognised internationally as the already very high standard of debate in Australia.

We would welcome the opportunity to present our views to the Inquiry Committee. Our contact person is Bill Koppe, Development Manager, who can be reached on 07 3834-1340 or bill.koppe@anglocoal.com.au.

Yours sincerely
**Anglo Coal Australia Pty Ltd**

Neville Sneddon
Head of External Business
and Chairman of Monash Energy

Inquiry into the Science and Application of Geosequestration Technology in Australia

Submission by Anglo Coal
and Monash Energy
August 18, 2006

# Contents



Attachments:

A. IPCC Special Report 2005 - Carbon Dioxide Capture and Storage - Summary for Policy Makers and Technical Summary

B. CO2CRC Report 2005 - Latrobe Valley CO2 Storage Assessment (Executive Summary)

C. Monash Energy Submission, February 2006 Inquiry Into Australia's Future Oil Supply and Alternative Transport Fuels

# 1 Introduction

This submission was prepared by Anglo Coal, and its subsidiary Monash Energy, for the House of Representatives Standing Committee on Science and Innovation Inquiry into the science and application of geosequestration technology in Australia. It should be read in conjunction with the covering letter by which it was conveyed to the Committee.

The term geosequestration, or underground geological storage of CO2, is generally used in conjunction with the associated process of CO2 capture to describe the integrated process of Carbon Dioxide Capture and Storage (CCS). The Intergovernmental Panel on Climate Change (IPCC) has used CCS in this wider sense in its recent Special Report, and for that reason, and because the inclusion of the CO2 source and capture dimensions facilitates consideration of the terms of reference for the Inquiry, we will use the more inclusive term CCS for the remainder of this submission. We will however emphasize the geological storage component of the term, and specifically exclude any consideration of ocean storage - which we do not support.

Anglo Coal is a wholly owned subsidiary of the major international resource company Anglo American *plc*. Anglo Coal is one of the world's largest private sector coal producers, with major mining operations in Australia as well as in South Africa, Colombia and Venezuela, and with prospects in several other geographies. Anglo Coal supplies thermal and metallurgical coals to customers around the world and has an active clean coal technology development program based around coal gasification. It is a member of the FutureGen Alliance working to develop a coal-fuelled near-zero emission power plant in the United States and through its subsidiary Monash Energy, Anglo Coal is also planning its own Coal-to-Liquids project utilising low emissions technologies – the Monash Energy Project.

Located in Victoria’s Gippsland Basin, the Monash Energy Project is proposed as a world-scale coal-to-liquids plant (expected to cost in the order of A$5 billion) incorporating CCS to capture and store the large majority of the CO2 it would otherwise emit.  The project will take advantage of the location of Victoria’s vast Latrobe Valley coal fields in the onshore Gippsland Basin, close to the exceptional storage potential of the offshore Gippsland Basin oil and gas fields. Anglo Coal is committed to incorporating CCS in the Monash Energy Project to achieve low emissions status, and in so doing has taken the lead as the world's first coal producer to actively invest in the development of a commercial CCS project.

By taking the lead in the development of large-scale CCS, Monash Energy will also be establishing a platform for the development of a CCS regional hub of shared infrastructure capable of transporting and storing a large portion of the CO2 generated from the utilisation of Victoria's brown coal - which currently represents approximately 15% of Australia's CO2 emissions.

In the Victorian context, CCS could then be the enabler of a new wave of industrial development, enabling the development not just of power stations, but also other production facilities utilising the allied clean coal technology of gasification to produce an array of products from the synthetic gas.

# 2 Context

## 2.1 Global Context

An overview of the potential global role of CCS is provided here as context for discussion of the specific terms of reference of the Inquiry, given that the global community faces a series of major interlinked energy-related challenges in the 21st Century with a bearing on CCS:

| | |
|---|---|
| Climate Change | Abating the growth in energy related greenhouse gas emissions to ensure that the potential risks of serious adverse climate change consequences are mitigated; |
| Social Equity | Increasing access to affordable and sustainable energy as one of the steps required to raise the quality of life of the large proportion of the rapidly growing global population; |
| Energy Security | Avoiding the potential adverse social and economic consequences of a progressive tightening of the conventional oil supply / demand balance, and; |
| Sustainability | Preparing for a totally sustainable energy supply system in a post-carbon era. |

The priority given to each of these challenges varies between countries depending on their circumstances, with developing countries such as China and India understandably placing prime importance on social equity and energy security.

Secure, reliable and affordable energy supplies are fundamental to economic stability and development, and China and India's reliance on their coal resources to meet the energy and development needs of their large populations - with the associated rapid growth of their coal-derived emissions - is a crucial dimension of the climate change challenge for the global community.

It is now generally accepted there is no single technology solution to the global energy-related challenges; no so-called "silver bullet" solution.  Instead a portfolio of solutions and initiatives are required - including  energy efficiency, alternative transport fuels, renewables, CCS and possibly nuclear energy.

The International Energy Agency (IEA) has recently published a report *Energy Technology Perspectives*, confirming that accelerated deployment of all of these solutions and initiatives will be required to meet the major reductions in global emissions that the IPCC has concluded are required to minimise the risk of seriously damaging climate change[1]. In the IEA's accelerated technology scenarios, which address this challenge, CCS technologies contribute between 20% and 28% of total global CO2 emissions reductions below the Baseline Scenario by 2050. Whilst on this basis CCS is of major importance to emissions reduction on a global scale, it is especially vital for curtailing the burgeoning emissions growth of coal-dependent developing countries like China and India.

The IEA report concludes that '*clean coal technologies with CCS offer a particularly important opportunity to constrain emissions in rapidly growing economies with large coal reserves, such as China and India'*. It could equally be said that without the deployment of clean coal technologies and CCS in China and India, there is little realistic medium-term prospect of curtailing their emissions, or then of achieving the global reductions that the IPCC has concluded are needed to avoid seriously damaging climate change.

Consequently in our view CCS should be regarded as a key technology for abating greenhouse gas emissions during the 21st Century - as a substantial component of the global solution and as a vital component of the solution for coal-dependent countries.  CCS also has the added benefit that it enables the extraction of energy from coal whilst also substantially lowering the carbon footprint: that is, it leads to the "decarbonising" of coal.

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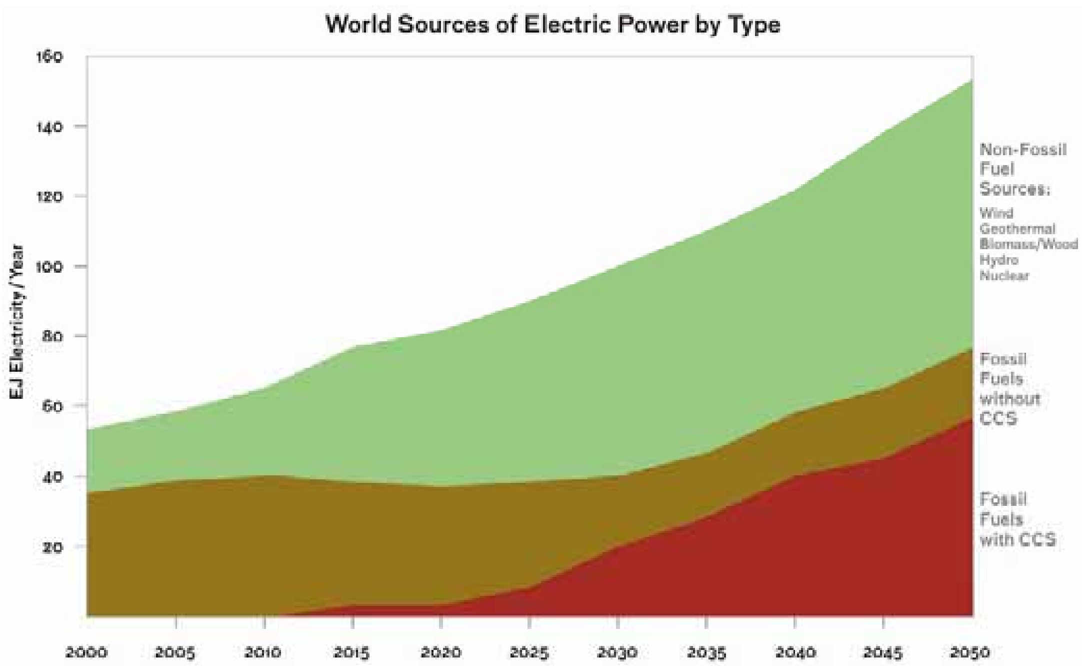
[1] *Energy Technology Perspectives: Scenarios and Strategies to 2050* (2006) OECD/IEA, Paris

This has the important outcome that much of the world's vast supplies of coal, and very importantly Australia's exceptional resources of coal, can be used to augment conventional oil and gas supplies in the production of power, transport fuels, chemicals, fertilisers and hydrogen whilst producing lower or comparable levels of carbon emissions to atmosphere.

By expanding the choice of energy sources, CCS indirectly supports the Social Equity aims through reducing the cost of low emission energy over time. A key conclusion of a recent report on CCS by Battelle's Joint Global Change Research Institute has concluded that CCS technologies have the ability to lower the cost of addressing climate change significantly - potentially by hundreds of billions of dollars.[2]

The major portion of global emissions reductions being sought is associated with stationary energy, but due to the long life of power stations and issues of capture cost from power stations it is expected that it will take till approximately 2020 before it makes a significant contribution. Thereafter, however, the impact from that point will be dramatic as is shown in the following diagram from the International Energy Agency's report on *Prospects for CO2 Capture and Storage*. [3]




[2] *Carbon Dioxide Capture and Geologic Storage: A Core Element Of A Global Energy Technology Strategy To Address Climate Change (2006),* Batelle, College Park, MD, USA, www.battelle.org/gtsp

[3] *Prospects for CO2 Capture and Storage*, International Energy Agency, 2004

Given that the “take-off” does not occur until approximately 2020, policy making bodies such as the G8 have asked the IEA and the CSLF identify and facilitate opportunities for early deployment of CCS. These opportunities, which centre mainly on by-product CO2 from the processing of natural gas and coal syngas, provide a wider benefit by demonstrating at commercial scale the application of CCS, and by lowering the cost of subsequent deployment by improvements in technology and potentially by sharing infrastructure.

By enabling the production of large amounts of affordable, low emission hydrogen from coal, and potentially using it in conjunction with biomass processing, CCS provides a bridge to a fully sustainable future. Consequently CCS directly contributes to solving the challenges of Climate Change and Energy Security, and indirectly to achieving Social Equity.

Consequently Australia has a very strong interest in the accelerated development and early deployment of CCS:

- for its role in facilitating the low emissions utilisation of our own coal resources,
- for its crucial role in mitigating the emissions from other coal-dependant countries - particularly China and India, and
- for its potential to facilitate the low-emissions development of coal-based synfuels to mitigate oil price and supply security concerns.

## 2.2 Australian Context

Australia has established itself as a world leader in the development of CCS science and technologies, and in particular in the systematic assessment and mapping of the nation’s storage potential. The GEODISC national storage mapping and source-sink matching program, carried out by the predecessor of the CO2CRC and by Geoscience Australia, was the world’s first continental-scale storage evaluation, and is widely seen by other countries as a model for emulation.

The GEODISC program provided a nation-wide identification and ranking of Australia’s storage resources and locations where the top ranking storage sites correspond closely with large stationary sources of CO2. In so doing the GEODISC program provided an informed framework for the initial identification of CCS development opportunities, including the low-cost opportunities that will underpin the early deployment of CCS in Australia.

The early deployment of CCS depends on the attainment of the following key pre-conditions:

1. A good CO2 source and sink match - a low-cost large-capacity secure geological storage site in close proximity to one or more large stationary CO2 sources.

2. A low capture cost for the CO2 - currently only from processes where high purity CO2 is produced as waste by-product, such as natural gas processing, and in future from planned coal gasification to produce liquids/chemicals.

3. Some form of offset to the combined costs of capture and storage - such as enhanced oil recovery, or some form of policy-based CO2 mitigation incentive.

The GEODISC program provided a comprehensive first-pass evaluation of the first of these requirements, showing that Australia's best and biggest storage resources were offshore in the North-west Shelf and in the offshore Gippsland Basin of Bass Strait. In terms of proximity to CO2 sources, the North-west shelf is remote from major power-stations, but does provide a potential storage site for CO2 produced as a by-product of natural gas processing.

The offshore Gippsland Basin is in relatively close proximity to the Latrobe Valley brown coal deposits of the onshore Gippsland Basin, and to the large CO2 sources associated with the utilisation of the brown coal. It therefore offers potential for the storage of Australia's brown coal-related CO2, currently over 60 million tonnes per year. A 2005 study by the CO2CRC, in association with Monash Energy, confirmed that the offshore Gippsland Basin has the potential to securely and economically store at least 50 million tonnes of CO2 per year (see attachment B: *Latrobe Valley Carbon Storage Assessment*).[4]

The second requirement for early CCS deployment, a low-cost capture process, is currently only met by processes in which the production of a concentrated CO2 by-product is inherent and imposes little or no additional capture cost. The processes in this category include natural gas processing and coal gasification for the production of either liquid fuels or chemicals, and require only the addition of compressors, pipelines and injection wells to complete the CCS process chain.

[4] see Appendix B: *Latrobe Valley Carbon Storage Assessment*

It has been estimated that the total unit cost of CCS for these early deployment sources with little or no capture cost can, in favourable locations such as the Gippsland Basin, be as low as A$10 per tonne of CO2 avoided (as per footnote [4] on previous page) . Current technologies for the capture of CO2 from power generation however impose significant additional costs. The IPCC Special Report on CCS has estimated that capture costs from conventional coal-fired power stations currently range between US$15 and US$75 per tonne of CO2 avoided - or roughly A$20 to A$100 per tonne.

Substantial reductions in the cost of CO2 capture from power generation are required for CCS to be deployed on the wide-scale needed for it to have a substantial effect on global emissions, and it is that challenge which is the main focus of current CCS research and development around the world.

There are not yet any policy-based incentives for CCS deployment in Australia, and the potential for cost offsets through enhanced oil recovery (EOR), for instance from the depleting Gippsland Basin oil-fields, has not yet been established.

It can clearly be said however that the least-cost CCS deployment opportunities in Australia, and those requiring the least policy-based incentives, currently centre on natural gas processing, and on the planned gasification of Victoria’s Gippsland Basin brown coal for the production of liquid fuels or chemicals.

## 2.3 Coal to Liquids Context

Oil supply security and cost concerns have led to a renewed world-wide interest in coal as an alternative source of oil-derived products - principally transport fuels and chemicals, using coal gasification technologies. With declining oil production and reserves, alternative sources will clearly be required for the liquid fuels and chemicals currently derived from oil - the issues are of technology, timing, cost and environmental impacts.

Coal conversion technologies, particularly Coal-to-Liquids (CTL) synthesis, applied to the world’s vast coal resources are increasingly seen as one of the most viable means of filling that requirement. Australia, with the world’s best and lowest-cost brown coal resources in Victoria’s Latrobe Valley, is well placed to take a leading role in developing CTL as a replacement for dwindling oil supplies.

The term CTL is most often used to describe coal gasification combined with Fischer-Tropsch synthesis to produce liquid fuels. Fischer-Tropsch synthesis is a catalytic process which combines the element of the synthetic gas ("syngas") derived from coal gasification or other sources. It was first developed in coal-rich Germany in the early decades of the twentieth century, and liquid fuels were synthesized from coal and used during the Second World War. By 1943 three quarters of Germany's petroleum was derived from coal.

South Africa, which like Germany has no significant oil reserves, developed and improved the CTL process during the Apartheid-era boycotts. Sasol currently operates two CTL plants in South Africa with a capacity of 150,000 barrels of crude oil equivalent per day.

China, which has responded to its growing dependence on imported oil by becoming the world's leading developer of coal gasification, mainly to substitute for oil in chemicals and fertilizer production, is now also beginning to develop CTL for liquid fuels production.

The United States, which developed some coal-based synfuels capacity in response to past oil supply constraints, has now adopted new tax credits and other incentives (Energy Policy Act of 2005) to drive the development of CTL projects to address its concerns about Energy Security and to help reduce its growing reliance on imported oil.

Domestically, concerns have been raised about the growing trade deficit on oil - forecast to be approximately $2 Billion per annum by the next decade - and the Prime Minister recently announced that he had asked the Industry Minister, Mr Macfarlane, "*to bring forward to Cabinet a proposal for a dedicated fund to position Australia as a leader in gas-to-liquids and coal-to-liquids research* [5].

While growing concern over oil supply security and prices is driving the development of CTL in coal-dependant countries around the world, the process does generate substantially more $CO_2$ on a life-cycle basis than crude oil derived fuels - unless it is combined with CCS to store the extra $CO_2$ generated.

[5] Hon John Howard MP, Ministerial Statement to Parliament on Energy Initiatives, August 14th, 2006.

Conversely, as we have seen, CTL also provides a low-cost CO2 capture stream which facilitates the early deployment of CCS, so the technologies are complementary. There is a technology and economic inter-dependency with CCS providing a low-emissions pathway for CTL, and CTL providing a low-cost early implementation pathway for CCS.

It is for this reason that the Monash Energy project is planned to be the world's first CTL project incorporating CCS. The project has its origins partly in the GEODISC program which identified the exceptional combination of world-class storage resource of the offshore Gippsland Basin in proximity to the world's best brown coal resources in the Latrobe Valley of the onshore Gippsland Basin. Anglo Coal has supported the investment in Monash Energy because of the world class CCS credentials of the Gippsland Basin and as a means of implementing CCS and demonstrating the practical application of clean coal technologies, within a commercial framework.

## 2.4 Monash Energy Context

The Monash Energy Project will utilise coal gasification in combination with Fischer-Tropsch synthesis and CCS for the low-emissions production of a range of transport fuels - initially ultra-low sulphur diesel, but ultimately hydrogen to support the longer-term development of a hydrogen economy.

The project will process brown coal from Victoria's Latrobe Valley, in the onshore Gippsland Basin, and will transport and store the CO2 produced in the process beneath the depleting oil fields of the offshore Gippsland Basin. The world-class source sink-match of the Gippsland Basin is a fundamental strength of the project.

Key features of the Monash Energy Project include:

1. The first stage Commercial Plant will produce about 60,000 barrels per day of synthetic hydrocarbon liquids of which 80% would be ultra low sulphur high quality automotive diesel. Commissioning of the plant is targeted for 2016.

2. The Project will compress approximately 13 million tonnes of super-critical CO2 per year, for transport via pipeline to store offshore, deep beneath the depleting oilfields.

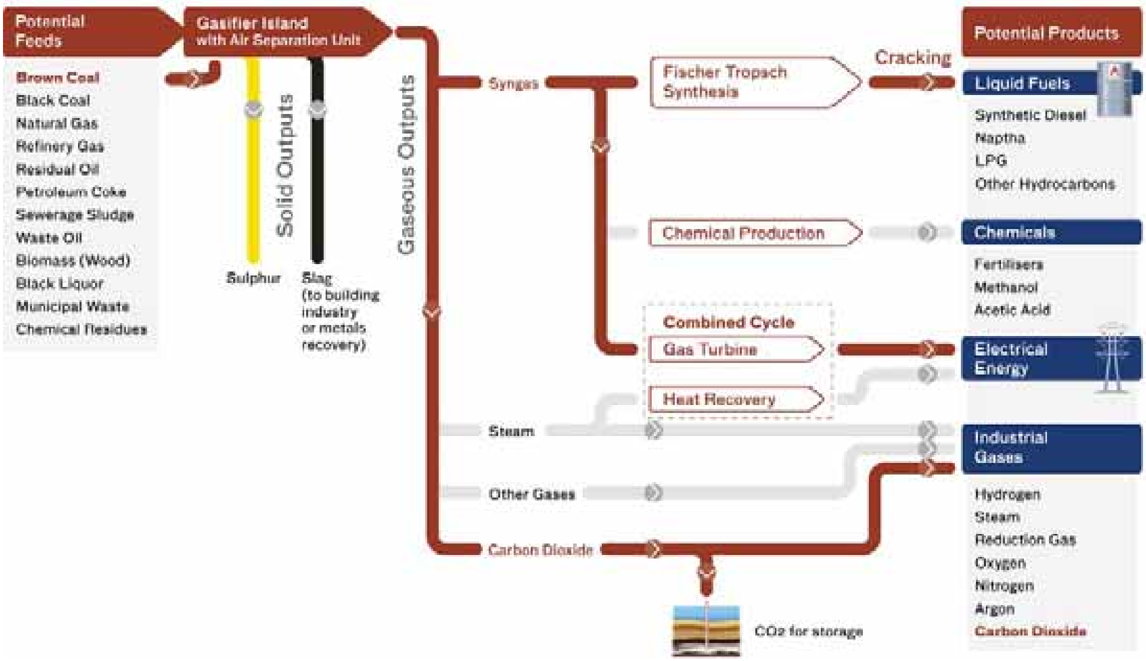
3. A 2005 CO2CRC study, initiated by Monash Energy and funded by the Australian Government (DOTARS) and the CO2CRC, has confirmed the potential for the offshore Gippsland Basin to provide secure, low-cost storage for at least 50 million tonnes per year of carbon dioxide[6] - that is enough for several projects or power stations of the scale of the Monash Energy project

4. While the Commercial Plant will be a "first of a kind" in respect of the combination of technologies, the individual technologies required are either proven and demonstrated at commercial scale, or will be within the next five years. The technologies chosen are also suitable for processing a proportion of biomass with the coal, offering the potential for further reductions in CO2 emissions.

5. The core coal transformation technologies which will be commercially established in combination by the Project (brown coal drying, entrained flow oxygen blown gasification, hydrogen production, carbon capture and storage) are identical to those required to produce low emissions synthetic gasoline, electricity, chemicals, fertiliser and hydrogen.

   The flexibility of production (and feedstock) enabled by gasification is illustrated in the following diagram.

[6] Hooper, B, Murray, L and Gibson-Poole, C (eds.), 2005. The Latrobe Valley CO2 Storage Assessment. Cooperative Research Centre for Greenhouse Gas Technologies, Canberra. CO2CRC Publication No RPT05-0220, November 2005. 15pp (given here as Attachment B)

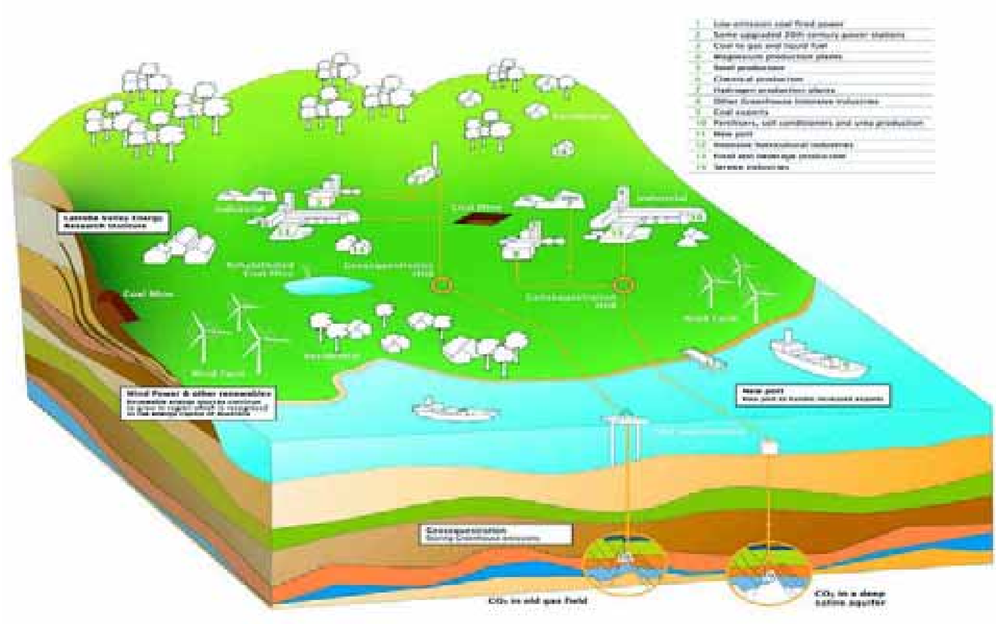



6. The CCS component of the project will utilise proven petroleum industry technologies - compression, pipelines, offshore pipelines and injection wells to inject the CO2 into geological reservoir formations at a depth of approximately 3 km. The developing technologies associated with CCS relate mainly to the modelling, monitoring and verification techniques used to track the injected CO2, and to the materials and techniques used to ensure that petroleum and injection wells are adequately engineered for CO2 containment.

7. At an indicative oil price of $US50/bbl, the output from the Monash Energy plant would make a positive contribution to the balance of payments of more than $1 Billion per annum. The Gippsland Basin brown coal resource is sufficient to underpin several such plants, each operating for 50 years, as well as low emissions electricity and future hydrogen production facilities.

8. Monash Energy has the potential to act as the catalyst for the development of CCS infrastructure to support the subsequent capture of CO2 from electricity generation in the Latrobe Valley once more cost-effective technologies have been developed to capture CO2 from power stations. Moreover, there is the potential for a new range of industries utilising the massive brown coal reserves of the Latrobe Valley, and for this reason the Victorian Government has identified in its own policies its support for the concept of a regional hub.

The following diagram of a potential hub format comes from its 2003 policy statement on *Geosequestration*[7].



# 3 Specific Responses to Inquiry Priority Issues

## 3.1 The Science Underpinning Geosequestration Technology

The science underpinning geosequestration or CCS technology has recently been the subject of comprehensive review by the Intergovernmental Panel on Climate Change (IPCC), culminating in the publication early in 2006 of an IPCC Special Report entitled "*Carbon Dioxide Capture and Storage*", which documented the findings of the key scientific experts working in this field from around the world. [8]

While there have been other recent highly authoritative reports covering the subject, such as the recent Battelle "*Carbon Dioxide Capture and Geologic Storage*" it is clear that the IPCC Special Report has been accepted by the international community as the principal authoritative view on CCS and its underpinning science. [9]

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[7] *Geosequestration: Putting the Carbon Back* (2003), Government of Victoria, www.dpi.vic.gov.au,
[8] Attachment A
[9] *Carbon Dioxide Capture and Geologic Storage: A Core Element Of A Global Energy Technology Strategy To Address Climate Change (2006),* Battelle, College Park, MD, USA, www.battelle.org/gtsp

The IPCC Special Report has clearly been very influential amongst the member countries of the United Nations Framework Convention on Climate Change (UNFCCC) who have called on its Subsidiary Body for Scientific and Technical Advice (SBSTA) to evaluate and advise on the accreditation of CCS for mitigation credits under Kyoto Protocol mechanisms.

That evaluation is work in progress, but at the Bonn SBSTA workshops, convened in May this year as part of the evaluation process, it was evident that the findings of the IPCC Special Report have been very widely accepted by the member countries of the UNFCCC.

There is no purpose to be served in summarising the relevant findings of the IPCC Special Report here, or for that matter of the Battelle report. We commend them both to the Committee, and will confine our comments in this submission to a high-level overview of the science and to the technology development required for the general commercial application of CCS.

### 3.1.1 The science and technology for CCS mirrors that of oil and gas development

For the most part the science that underpins CCS technology is the same science that underpins petroleum exploration and production technology. It centres on sedimentary geology and geophysics and on the behaviour of fluids within the underground sedimentary strata in which petroleum resources are found and which constitute the reservoirs for CO2 storage. Both the science and the technology have been enriched by over a century of intensive research, exploration and production experience.

The science and technology for identifying and characterising potential storage sites is essentially the same as that for identifying and characterising petroleum traps and accumulations, and the technology for extracting and transporting petroleum is essentially the same as for the transport and injection of CO2. The technical process for CCS injection and storage is essentially the same as the technical process for petroleum extraction - but applied in reverse. Overall the great majority of the technologies that CCS depends on are proven petroleum industry technologies.

### 3.1.2 Material science and technology differences

There are however a few material differences between CCS and petroleum science and technology that warrant attention. They centre mainly on the differences in the physical and chemical behaviour of CO2 relative to hydrocarbons and the effect that has on the migration and transformation of the CO2 after it is injected. Natural CO2 accumulations are however relatively common in sedimentary basins and they do provide valuable analogues for the behaviour of injected CO2, and the extraction of naturally occurring CO2 has also provided valuable experience applicable to CO2 injection and storage.

(a) Predictive modelling: The data from natural CO2 analogues and from CO2 production and injection experience is of great assistance in refining the petroleum-based CO2 migration and transformation models used to predict how the CO2 will behave once it is injected. In some geological settings the post-injection distribution of CO2 is tightly confined by the geology, and the predictive reliability of models is therefore not particularly important, but in some geological settings the post-injection migration of CO2 will be less constrained, and consequently the predictive reliability of migration modelling will be more important in those settings. Consequently there is a need for continuing development of post-injection models, and their continuing validation against the performance of a growing population of CCS projects.

(b) Monitoring and verification: The post-injection monitoring and verification of actual CO2 migration and containment goes hand in hand with pre-injection predictive modelling, and its reliability is an important consideration in community acceptance of CCS as a safe and reliable technology for the reduction of CO2 emissions to the atmosphere. The portfolio of technologies used to search sub-surface geology for oil and gas provides a very strong technology base for CO2 monitoring and verification. In particular 3D seismic has been very successfully applied to existing CCS projects such as Sleipner. While many of these techniques are well established and proven in other geological applications, and some have been demonstrated as viable in $CO_2$ demonstration projects, other potentially useful techniques require further research and development.

Different monitoring portfolios and techniques will be required for different geological settings and circumstances, and the emphasis of much of current research is the selection of appropriate technologies for particular sites - as illustrated in the figure below. The International Energy Agency's Greenhouse Gas Program provides a platform for international collaboration in this field, and is convening an international monitoring and verification workshop in Melbourne in early November 2006.

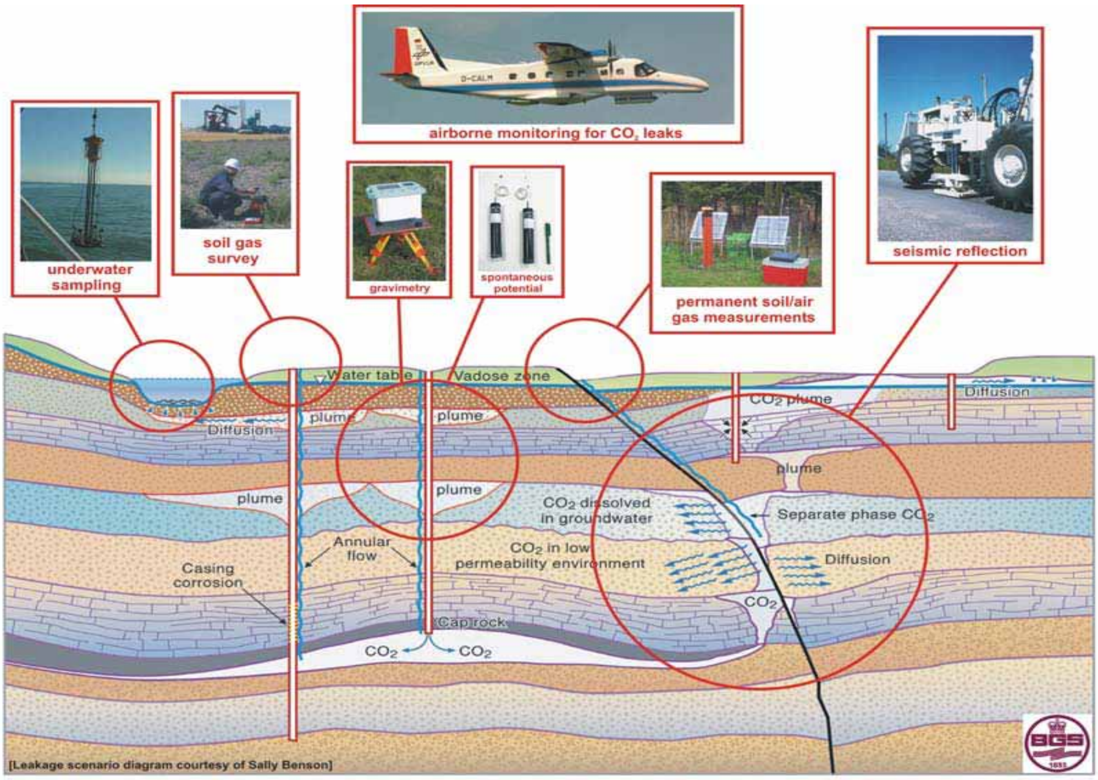



Image courtesy of British Geological Survey

**(c) Well-bore seepage potential:** The IPCC Special Report deals at some length with the well design and engineering issues to be addressed in ensuring that injection or petroleum wells do not become CO2 seepage pathways during the long periods of post-injection CO2 storage. The evidence so far is that conventional well decommissioning procedures are effective in sealing in sub-surface fluids, including CO2, but the history of the interaction of CO2 with well-bores is still only of about 30 years duration. New CO2-resistant materials may need to be employed in the de-commissioning of potentially affected wells, and well monitoring may be required for some time after CO2 injection has ceased. With appropriate design and engineering there should be no unacceptable risk of CO2 seepage from well-bores, however it is an area of sufficient importance to justify continuing research and development.

### 3.1.3 The key task - selection and characterisation of storage sites

The suitability of sub-surface geological strata for the storage of $CO2$ is highly site specific. There are good sites and bad sites, and some regions will be well endowed and others will not - and locating and proving up the good sites is the key scientific assessment task for CCS development.

Locations which have stored oil and gas many millions of years have good *prima facie* storage credentials, but there will be other good, less evident, storage sites where petroleum has not been generated, and where consequently storage credentials have not been self-evidently demonstrated. Saline aquifers, which constitute the larger part of global storage potential, are in this less evident category.

Intensive geological scientific assessment and exploration is required to locate good CCS sites, followed by intensive site characterisation to establish that they provide secure storage, with a capacity adequate to contain the CO2 source to be stored, and have the cost characteristics to be economically viable. The ideal site will have demonstrated storage security, large capacity and high-permeability reservoirs that minimise the number of wells needed for injection, and thereby minimise injection cost.

The GEODISC program showed that Australia has storage sites in this ideal category offshore in the Gippsland Basin and on the North-west Shelf, with less conspicuous areas of high potential in onshore Australia. The GEODISC program was a preliminary assessment however and follow-up geological assessment programs are required to further evaluate onshore storage potential, particularly in the black coal producing regions of Eastern Australia.

Whilst there is a need for further more intensive storage evaluations of some regions of Australia, the GEODISC program has put us ahead of the rest of the world in this regard. There is a need for programs in the GEODISC mould in many other parts of the world - particularly in carbon-intensive developing countries such as China and India.

## 3.2 The Potential Environmental and Economic Benefits and Risks

This aspect of the Inquiry's terms of reference has been investigated in most detail for Victoria's Latrobe Valley in the CO2CRC's 2005 "Latrobe Valley CO2 Storage Assessment" (LVCSA) study undertaken with the assistance of a Commonwealth Government grant to Monash Energy - which set the scope of work for the study, and participated in the steering committee guiding adherence to the scope. The study was the subject of stakeholder engagement workshops held in December 2005, and a number of papers based on it have been presented at industry, scientific and technical conferences around the world during 2006. A copy of the summary LVCSA report forms Appendix B to this submission.

The LVCSA study is the world's first detailed technical and economic study of large-scale CCS deployment designed to address the constraint placed on the economy and development of a major industrial community by the CO2 emissions of its industries. The Latrobe Valley is blessed with the world's most outstanding (thickest and economical to mine) brown coal deposits, which has made it the centre of Australia's lowest cost electricity generation, which in turn underpins the competitive position of much of the manufacturing industry of South-eastern Australia.

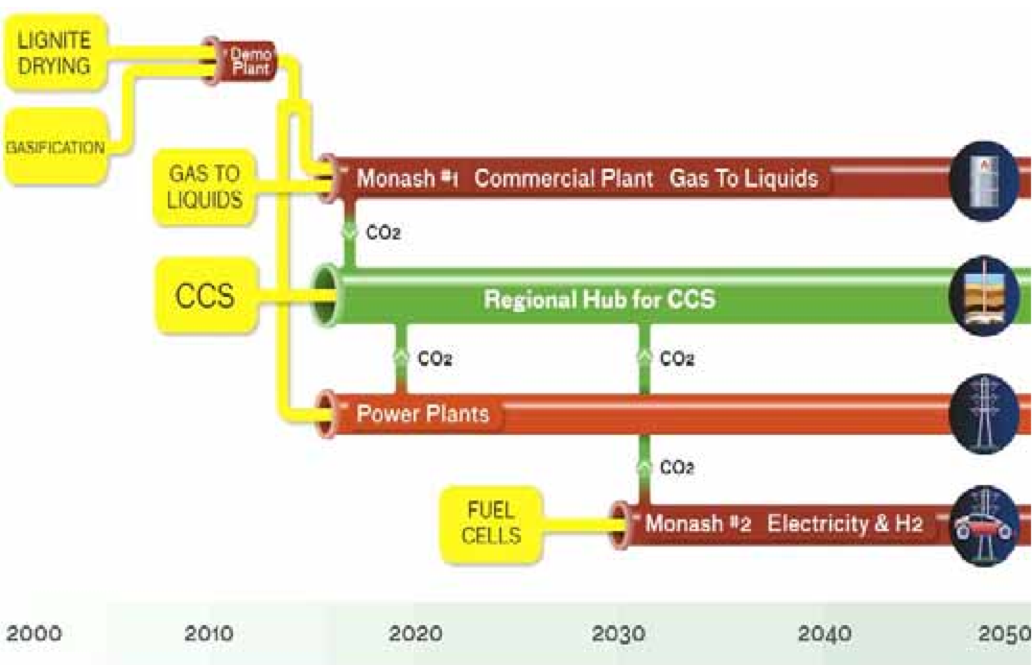
However the Latrobe Valley's brown coal also has a moisture content of over 60%, and the energy loss that is entailed in the vaporisation of this moisture when the coal is utilised results in a reduction in electricity generated per unit of CO2 emitted. Conventional electricity generation technologies produce roughly 50% more CO2 per unit of electricity from utilising this brown coal than they do from black coal - and consequently the Latrobe Valley produces over 60 million tonnes of CO2 per year; or roughly 15% of Australia's total.

The high emissions intensity associated with conventional utilisation of the Latrobe Valley's brown coal is clearly a constraint on the region's ongoing development in a carbon-constrained world. Unless a solution can be found to the CO2 emissions associated with conventional utilisation of brown coal, there would be very little scope to replace the regions power stations when they reach the end of their operating lives. A progressive shut-down of the Latrobe Valley power stations would have a major depressing effect on the economy and employment of the region, and the loss of its low-cost electricity supply would have a ripple effect well beyond the region.

While technologies to improve the efficiency of power generation can help to moderate the regions emissions, it is clear that only CCS can provide the major emissions reductions that the region is likely to need for its ongoing industrial viability.

The LVCSA study confirmed that the offshore Gippsland Basin has the technical and economic potential to securely and economically store at least 50 million tonnes of CO2 per year from the Latrobe Valley. The offshore storage sites have excellent geological characteristics, and the onshore coal deposits are closely bunched, facilitating the development of a joint-use pipeline hub system to gather CO2 from the Latrobe Valley sources and transport it to the storage sites for injection.

The development of CCS to serve the Latrobe Valley has the potential to significantly reduce its coal-derived CO2 emissions, and in the process make a substantial contribution to reducing Australia's overall emissions. The initial development of the Monash Energy project will provide a CCS infrastructure platform on which subsequent coal utilisation developments can build, progressively replacing the existing high-emissions power plants with near-zero emissions power plants and, with the development of a hydrogen economy, near-zero emissions coal gasification plants producing low-cost hydrogen. As described elsewhere in this document, the syngas produced from coal gasification is a highly flexible feedstock/source of energy for a range of potential commercial applications.



In this one area of Australia, the environmental and economic benefits of CCS are immense - largely eliminating its CO2 emissions over time and preserving its status as a powerful source of economic development and employment well beyond the Latrobe Valley region itself. The LVCSA study concluded that the leakage risks associated with the offshore Gippsland Basin are lower than the levels considered acceptable in the IPCC Special Report, and that the health and safety risks to the community associated with the CO2 pipeline infrastructure are no greater, and probably less, than those associated with natural gas pipelines.

It cannot yet be confidently said that comparable CCS opportunities exist elsewhere in Australia. The GEODISC program showed that there are comparable storage sites on the North-west Shelf that could be used for the storage of CO2 produced in association with natural gas processing, but those CO2 sources are significantly smaller than those produced from coal utilisation, so the Latrobe Valley potential identified in the LVCSA study may represent the largest-scale opportunity for CCS deployment in Australia. Further geological assessment work is required to evaluate and characterise the storage potential of the black coal producing regions of eastern Australia, to establish their technical and economic potential for the large-scale deployment of CCS, and to bring them up to the level of assurance that has been reached for the Gippsland Basin and the Latrobe Valley.

## 3.3 The Skill Base in Australia to Advance Geosequestration Technology

Australia has developed an enviable reputation as a world leader in CCS science and technology, particularly in the sphere of geological storage assessment. That reputation was earned largely as a result of outstanding geological assessment work undertaken on the GEODISC program by the CO2CRC and its predecessor, the APCRC, and by Geoscience Australia.

The capacity to continue the timely geological assessment of storage potential of priority areas in Australia (such as the black coal producing regions), and to provide expert geological storage assessment advice and services to key emissions-intensive developing countries (particularly China and India) is however being compromised by a shortage of geoscientists with the expertise required for storage assessment.

This skills shortage arises initially from limited numbers of young geoscientists coming through our universities and being trained in petroleum and CCS expertise, but is currently being exacerbated by the competing demand for oil exploration geoscientists. The salaries available to young geoscientists for oil exploration are very much higher than they can earn as employees of the CO2CRC organisations, or of Geoscience Australia. As a consequence there has recently been a steady drift of CCS geoscientists to the oil industry, making it difficult to maintain the schedules for established programs or to implement new programs.

In the short-term the retention of petroleum and CCS geoscientists within the government and research & development sector appears to require supplementary funding to enable the sector's institutions to reduce the very large salary gap that currently exists between them and the petroleum industry.

The longer term adequacy of the supply of suitably trained young geoscientists will also need to be addressed. Whilst there are a number of positive initiatives in this area being undertaken by the CO2CRC, there appears to be a case for establishing a new and more focussed initiative to develop centres of excellence for training petroleum and CCS scientists and technologists. Additional funding may also be required in this area to overcome institutional impediments to consolidation and to attract the best of students and teachers.

## 3.4 The Regulatory and Approval Issues Governing Geosequestration

### 3.4.1 Context

The limited number of existing CCS injection projects that have been developed around the world have all been developed under the terms of petroleum legislation and within petroleum tenements. They have been based on the early opportunity categories of CCS, the storage of CO2 derived from natural gas processing (Sleipner and In Salah), and enhanced oil recovery using CO2 derived from coal gasification synfuels production (Weyburn - Beulah)[10]. While some other similar projects may also be feasible under existing petroleum legislation, there is clearly a need to make regulatory provision for CCS on a broader scale, encompassing the much larger volumes of non-petroleum CO2 generated from coal utilisation.

[10] http://www.worldcoal.org/assets_cm/files/PDF/co2_from_coal_gasification_us_and_canada.pdf

At present there is no such CCS specific legislation anywhere in the world, and Australia has led the way in the development of CCS regulatory principles in consultation with key industry and environmental stakeholders. The *Principles* agreed by the Ministerial Council on Mineral and Petroleum Resources (MCMPR) in November 2005 were the result of two years deliberation by a government and stakeholder Carbon Dioxide Geosequestration Regulatory Working Group reporting to the MCMPR Standing Committee of Officials. The adoption of the *Principles* has provided a solid platform for the introduction of legislation to facilitate the development of CCS projects in Australia - the development and drafting of which is currently being undertaken by the Department of Industry, Tourism and Resources (DITR) in consultation with a re-convened regulatory Working Group [11].

We will not comment here in any detail on the legislative model being developed by DITR, but will offer some high level commentary on the broader issues of CCS regulation and approval.

### 3.4.2 CCS and Petroleum Interaction

One of the key regulatory issues is the interaction of CCS development with oil and gas exploration and production, given that the geological settings that are prospective for oil and gas are also often the most prospective sites for CCS injection and storage. For example the offshore Gippsland Basin is Australia's most promising CCS injection and storage location, but is almost entirely subject to petroleum tenure and still has a decade or more before the first of its oil-fields is depleted.

Consequently any new legislation to facilitate CCS development will need to ensure that existing petroleum rights are not prejudiced by CCS development, while ensuring that the national interest in reducing CO2 emissions is also recognised and that the regulatory regime provides a level playing field for CCS developers and petroleum producers. In practice this means that there needs to be a system of separate petroleum and CCS tenements, with provision for overlapping tenure and a process for developing co-development arrangements and for regulatory determination in the event that over-lapping tenement holders do not agree on voluntary arrangements. These kind of overlapping tenement provisions are by no means unique and have a working precedent in the coal and coal seam gas regulatory regime in Queensland.

[11] *Carbon Dioxide Capture and Geological Storage: Australian Regulatory Guiding Principles* (2005), Ministerial Council on Mineral and Petroleum Resources, Canberra, ACT.

Nor is the co-development of CCS injection and petroleum production unique or necessarily in conflict. Enhanced oil recovery by injecting CO2 into a producing reservoir is widely practised in North America, and the Weyburn CCS project in Canada is an example of the oil production and CCS co-development. One of the other larger CCS projects, In Salah in Algeria, involves CCS injection immediately down-dip of a producing gas field - and into the same reservoir. Whilst there will always be a need to ensure that CO2 injected for CCS purposes does not prejudice oil or gas production, there will be a general tendency for the increased reservoir pressure associated with CO2 injection to improve oil and gas production.

### 3.4.3 Legislative Framework

Another key issue that arises in the development of CCS legislation is the question of whether it should be incorporated into existing petroleum legislation or be governed by completely separate stand-alone legislation. As discussed earlier in this submission the activities and operations of CCS are essentially the same as those for petroleum exploration and production, and they will be carried out in much the same locations. On balance therefore we think incorporation into existing petroleum legislation is the most practicable route, given that there will be a vital need to promote co-development and to reconcile conflicts between overlapping tenements - both of which would be difficult to achieve if the respective tenements were housed in different regulatory structures with different regulators. While accepting that CCS is best dealt with by amending petroleum legislation administered by the petroleum regulator, care will need to be taken to ensure that in the process the rights of CCS tenement holders are not subordinated to those of petroleum tenement holders.

### 3.4.4 Sink-Source Linkage

There are also some key differences between CCS and petroleum that need to be taken into account in amending petroleum legislation and regulations to facilitate CCS development. For example there is a profound linkage between the source of CO2 and the site where it is proposed to be injected under an injection tenement, and the allocation of tenements must take into account the applicant’s access to a prospective source of CO2 and to the quantity of that source in determining the appropriate size of the tenement. Similarly the criteria for regulatory decisions must include consideration of impacts at the source, such as the reduction in CO2 emissions, economic and community impacts, as well as impacts at the injection site.

In the case of the Gippsland Basin for instance, the effect of $CO_2$ emissions reduction onshore in the Latrobe Valley and its implications for industrial development need to be taken into account along with impacts arising in the immediate site of offshore injection.

### 3.4.5 Approvals and Monitoring

While the operation phase of CCS essentially mirrors standard petroleum practice, there are some important distinctions to be considered in the pre-development approvals phase and in the post-injection monitoring and verification phase. As we have emphasized earlier in this submission the key to successful CCS is a rigorous process of geological site selection and characterisation, with the approvals process centred on the thoroughness of the characterisations, the rigour of the associated risk assessment process and the robustness of the corresponding risk management measures. The development proposal drawing on this process of site characterisation and risk assessment would also include a comprehensive proposal for monitoring and verification, using techniques appropriate for the site, to track the injected $CO_2$ to insure that it is behaving as inspected. Contingency plans would also be required for intervention in the event that unpredicted behaviour of the $CO_2$ plume posed a material risk of $CO_2$ seepage or of other material adverse impact.

## 3.5 How to Best Position Australian Industry to Capture Possible Market Applications

As was noted earlier in this submission, Australia has a very strong interest in the accelerated development and early deployment of CCS, for its role in facilitating the low emissions utilisation of our own coal resources, for its crucial role in mitigating the emissions from other coal-dependant countries, and for its potential to facilitate the low-emissions development of coal-based synfuels to mitigate oil price and supply security concerns.

That combination of interests has been recognised in the Australian Government’s support for CCS research and development, for its leadership in the development of a regulatory regime to facilitate CCS deployment, and for the support it is giving to the development of CCS in China and India through the Asia Pacific Partnership.

Positioning Australian industry to capture CCS opportunities requires the continuation and strengthening of current R&D and regulatory development initiatives. As has been noted, one of the key requirements for the widespread deployment of these technologies is a supporting skill base, the erosion of which needs to be addressed through an expansion of training and measures to retain young CCS geoscientists currently being lost to oil and gas exploration.

The development of significantly improved capture technologies will be required for CCS to be widely deployed in association with electricity generation, and that is an effort which should be actively pursued in parallel with initiatives to encourage the development of the early deployment opportunities associated with gas processing and coal-to-liquids production.

At present there are no incentives available in Australia to offset the additional cost of CCS deployment, and that is an issue that needs to be addressed in Australia, as elsewhere, to achieve significant uptake of even the lower cost early deployment opportunities.

Australia has made a very good start establishing a leadership position in CCS and with policies to build that momentum and take development on to its next stages, Australian industry will have a solid platform from which to capture new market applications arising from R&D and deployment, as well as to continuing derived value for the nation from our coal resources and markets.

SUBMISSION ENDS / THREE APPENDICES FOLLOW