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BY:

SENATOR THE HON IAN CAMPBELL
Minister for the Environment and Heritage
Senator for Western Australia

Submission 5
CO2 Sequestration

Dr Andrew Southcott MP
Chairman
Joint Standing Committee on Treaties
Parliament House
CANBERRA ACT 2600

28 NOV 2006

Dear Dr Southcott Andrew,

I refer to the submission by Australia on 28 April 2006 to the Secretariat of the London Convention, proposing text to amend the 1996 Protocol to the London Convention, that would allow geosequestration of carbon-dioxide under the seabed.

I am pleased to advise that on 2 November 2006 Australia's proposed amendment was adopted with the unanimous support of the voting parties present at the Meeting of Contracting Parties to the Protocol.

In accordance with Article 22 of the Protocol, the amendments shall enter into force for each Party 100 days after the date of their adoption, unless a Party makes a declaration that they are not able to accept the amendment at that time. This amendment is very much in Australia's interest, as it supports the advancement of carbon geosequestration technology and will provide an international regulatory framework to ensure the technology is used appropriately.

The proposed amendment text was provided to the Joint Standing Committee on Treaties (JSCOT) for consideration on 14 August 2006. I can confirm that the text of the amendment remains unchanged from our proposed text. The amendment text is included with the National Interest Analysis, attached to this letter.

Officers from my Department also appeared before JSCOT on 9 October 2006. During the hearing the Department of Foreign Affairs undertook to provide some further background information on geosequestration projects, which I have also included with this letter.

I thank the Chairman and the Committee for their consideration of this matter.

Yours sincerely

Enclosure

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AMENDMENT OF ANNEX 1 TO THE 1996 PROTOCOL TO THE CONVENTION ON THE PREVENTION OF MARINE POLLUTION BY DUMPING OF WASTES AND OTHER MATTER 1972

Documents tabled on 28 November 2006:

National Interest Analysis [2006]
with attachment on consultation

Text of the proposed treaty action

Background information:

Current status list of Parties
Regulation Impact Statement

NATIONAL INTEREST ANALYSIS: CATEGORY 1 TREATY

SUMMARY PAGE

Amendment of Annex 1 to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972

Nature and timing of proposed treaty action

1. Australia is a Party to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (the London Protocol), which entered into force generally, and for Australia, on 24 March 2006.

2. In April 2006 Australia proposed the amendment of *Annex 1 – Wastes or other matter that may be considered for dumping*, to expand the list of 'wastes or other matter' to include carbon-dioxide streams sequestered in subseabed geological formations, otherwise known as offshore geosequestration.

3. The proposed amendment was considered at the First Meeting of Contracting Parties to the London Protocol, from 30 October to 3 November 2006. On 2 November 2006, the proposal was adopted unanimously, under the Rules of Procedure for the Protocol.

4. Pursuant to Article 22(4) of the Protocol, Parties wishing to declare that they are not able to accept the amendment are able to do so within 100 days after the date of its adoption that is, by 10 February 2007. Otherwise, the amendment will enter into force for all Parties on 11 February 2007.

Overview and national interest summary

5. The London Protocol obliges Parties to take effective measures to prevent, reduce and where practicable eliminate pollution caused by dumping at sea. The Protocol limits the types of materials that may be considered for dumping to those listed in Annex 1 of the Protocol.

6. The amendment of Annex 1 to include 'carbon-dioxide streams' allows Australia to permit offshore geosequestration in accordance with the requirements of the London Protocol,.

7. Offshore geosequestration is an important option to be considered for the mitigation of climate change and ocean acidification.

Reasons for Australia to take the proposed treaty action

8. The Australian Government's climate change and energy policies clearly identify the future potential of Carbon Capture and Storage (CCS) technologies, such as offshore geosequestration, as one important mitigation technology. The amendment of Annex 1 to allow offshore geosequestration is consistent with government policy to modify and augment our existing legislation relating to CCS assessment and approval processes.

9. CCS is a reality for Australia now, with several projects proposed to commence within the next few years. The amendment of Annex 1 will support Australia's efforts to remain at the forefront of the development and deployment of this important climate change mitigation technology.

10. The amendment also allows Australia to actively engage in technological developments in this field, and encourages other nations to adopt best-practice in the interests of climate change objectives and marine environment protection.

11. By adopting the amendment of Annex 1, the Parties to the London Protocol have acknowledged that geosequestration has a role to play, as part of a suite of measures to address climate change and related impacts on ocean acidification, and that the Protocol is an appropriate instrument to address the implications for the marine environment.

Obligations

12. The amendment of Annex 1 places no additional obligations on Australia above those already existing under the London Protocol. The amendment adds carbon dioxide streams to the list of allowable materials at Annex 1, and provides Australia with the option of permitting carbon-dioxide stream sequestration in sub seabed geological formations.

Implementation

13. Australia meets its obligations under the London Protocol through the *Environment Protection (Sea Dumping) Act 1981* (Sea Dumping Act). In accordance with Section 19(5)(a) of the Sea Dumping Act, a permit may only be granted for material that is listed in Annex 1 to the Protocol. Section 19(5)(b) of the Sea Dumping Act requires that permits only be granted in accordance with the assessment and permitting process set out in Annex 2 to the Protocol. The amendment ensures that Australia, and other Parties to the Protocol, may permit offshore geosequestration in accordance with the requirements set out in Annex 2.

14. No new legislation is required to implement the amendment.

Costs

15. There are costs associated with assessing permit applications and the ongoing regulation of approved permits. The amendment will not result in additional costs to the Commonwealth or State/Territory Governments.

16. The London Protocol and the Sea Dumping Act adopt a polluter pays approach to sea dumping. As such, and in line with the Australian Government's cost recovery policy, the *Environment Protection (Sea Dumping) Regulations 1983* prescribe fees for permit applications for the materials that may be dumped, which currently equal $16,500.00 for large-scale activities. The permit process is expected to be similar for geosequestration proposals..

Regulation Impact Statement

17. A Regulation Impact Statement (RIS) is attached.

Future treaty action

18. No future treaty action or amendments are anticipated as a result of this amendment. Any future amendments to the Protocol would be subject to Australia's domestic treaty processes, including prior consideration by JSCOT.

Withdrawal or denunciation

19. Australia may lodge a declaration of non-acceptance of the amendment within 100 days of the date of adoption at the Meeting, that is, by 10 February 2007, pursuant to Article 22(4) of the Protocol.

20. Australia may withdraw from the Protocol at any time after two years from the date on which the Protocol entered into force, which was 24 March 2006, pursuant to Article 27 of the Protocol. A withdrawal would take effect one year after receipt of the instrument of withdrawal by the International Maritime Organization.

Contact details

Director
Ports and Marine Section
Approvals and Wildlife Division
Department of the Environment and Heritage

Amendment of Annex 1 to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (including ATS or ATNIF number)

CONSULTATION

Public consultation has principally been through the development of a COAG RIS and *Regulatory Guiding Principles*. These were endorsed by the Ministerial Council on Mineral and Petroleum Resources (MCMPR), following public consultation and direct consultation with State and Territory governments, non-government organisations and industry.

Public comments on the COAG RIS were sought from 8 October 2004 to 29 November 2004. Comments were received from the following parties:

- Anna Tredwell (Eco Property Pty Ltd)
- Australian Coal Association (ACA)
- Australian Conservation Foundation (ACF)
- Australia Petroleum Production and Exploration Association (APPEA)
- Australian Power and Energy Limited (APEL)
- BHP Billiton
- Baker McKenzie
- Conservation Council of Western Australia (CCWA)
- Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)
- Cooperative Research Centre for Coal in Sustainable Development (CCSD)
- Climate Action Network Australia (CANA)
- EWN Publishing
- Friends of the Earth (FoE)
- National Generators Forum (NGF)
- New South Wales Minerals Council (NSWMC)
- Origin Energy
- PricewaterhouseCoopers Legal (PWC Legal)
- Rising Tide
- Stanwell Corporation
- Western Australian Government
- Woodside
- Xstrata Coal

Comments addressed a range of issues including, in relation to the natural environment, the need to adequately address environmental risks and uncertainties and to consider the use of alternate, 'clean' technologies.

Stakeholder consultation, comments from the COAG RIS submissions and further advice commissioned by the MCMPR were used to revise the *Regulatory Guiding Principles* and the COAG RIS for MCMPR endorsement. The Principles were endorsed by the MCMPR on 25 November 2005.

TEXT OF THE TREATY ACTION

AMENDMENT TO ANNEX 1 TO THE LONDON PROTOCOL

1.8 Carbon dioxide streams from carbon dioxide capture processes for sequestration

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4 Carbon dioxide streams referred to in paragraph 1.8 may only be considered for dumping, if:

.1 disposal is into a sub-seabed geological formation; and

.2 they consist overwhelmingly of carbon dioxide. They may contain incidental associated substances derived from the source material and the capture and sequestration processes used; and

.3 no wastes or other matter are added for the purpose of disposing of those wastes or other matter.

In paragraph 3, replace "1.7" with "1.8", to take account of the new paragraph 1.8.

BACKGROUND INFORMATION

CURRENT STATUS LIST OF CONTRACTING PARTIES TO THE LONDON PROTOCOL

Angola	Luxembourg
Australia	Mexico
Barbados	New Zealand
Belgium	Norway
Bulgaria	Saudi Arabia
Canada	Slovenia
China	South Africa
Denmark	Spain
Egypt	St. Kitts and Nevis
France	Sweden
Georgia	Switzerland
Germany	Tonga
Iceland	Trinidad and Tobago
Italy	United Kingdom
Ireland	Vanuatu

Council of Australian Governments (COAG)

CONSULTATION REGULATION IMPACT STATEMENT

DRAFT GUIDING REGULATORY FRAMEWORK FOR CARBON DIOXIDE GEOSEQUESTRATION

Prepared by Department of Industry, Tourism and Resources

INCLUDES:

1 INTRODUCTION

In the absence of a predictable and transparent regulatory mechanism, and uncertainty as to the adequacy or otherwise of generic regulatory processes, the Ministerial Council on Mineral and Petroleum Resources established a Carbon Dioxide Geosequestration Regulatory Working Group, in September 2003. The Regulatory Working Group was tasked to report to the Standing Committee of Officials of the Ministerial Council on Mineral and Petroleum Resources.

The Regulatory Working Group was chaired by a representative from the Western Australian Department of Industry and Resources. Other members included government resource sector representatives from the Commonwealth, South Australia, New South Wales, Queensland and Victoria. Tasmania and the Northern Territory participated by correspondence. There were also members from non-resource sector agencies with an interest in carbon dioxide geosequestration, such as the Queensland Department of Innovation and Information Economy, Department of Environment and Heritage, Australian Greenhouse Office, and the Department of Foreign Affairs and Trade.

A broader Carbon Dioxide Geosequestration Regulatory Reference Group, comprising all Working Group members as well as industry and research organisations, was also established to provide advice to the Regulatory Working Group. A set of draft regulatory guiding principles for carbon dioxide geosequestration were developed by the Regulatory Working Group for consideration by Ministers. These draft regulatory guiding principles are at Attachment A.

Broader consultation with the community, including non-government organisations will now be undertaken and this consultation process will give all interested parties the opportunity to be involved in the possible revision of the draft regulatory guiding principles. Input can be provided by attending workshops and submitting written comments in relation to the draft regulatory guiding principles.

It should be noted that this Council of Australian Government Regulatory Impact Statement is only concerned with a draft regulatory framework for carbon dioxide geosequestration. Significant work is being done on technological issues separately (i.e. not under the Ministerial Council on Mineral and Petroleum Resources), and as these begin to be solved, progress on legal and regulatory issues will be required, if only in the first instance by creating an enabling framework for consideration and facilitation of projects.

2 BACKGROUND

Energy and Greenhouse Gas Emissions

On 8 June 2001, the statement on Energy Policy from the Council of Australian Governments said that the energy sector, both stationary and transport, provides an essential underpinning of Australia's economic, environmental and social goals. Competitively priced and reliable energy services are a key part of our international industry competitiveness and standard of living. The Council of Australian Governments went on further to say that, Australian energy demand is growing rapidly, but at the same time energy supply and use is a significant source of greenhouse gas emissions.

In 2002, greenhouse gas emissions from the energy sector made up 68 percent of national greenhouse emissions as it is primarily dependent on fossil fuels. Carbon dioxide geosequestration, also known as carbon dioxide capture and geological storage, is one option in the medium term to reduce greenhouse gas emissions into the atmosphere from stationary energy sources.

The electricity generation sector which represents 33 percent of emissions is well placed to take advantage of carbon dioxide geosequestration technologies given that it is dominated by relatively few large emission sources. Other industry sectors, such as certain forms of chemical manufacture (including natural gas processing), the cement industry and aluminium production, all of which have large point sources of carbon dioxide, may also be able to utilise carbon dioxide geosequestration in reducing their greenhouse gas emissions.

Carbon dioxide geosequestration provides one of several options in the medium term to meet the objectives of sustainable energy use, lowering greenhouse gas emissions and utilising Australia's competitive advantage in low cost and abundant fossil fuels (coal and gas). Carbon dioxide geosequestration may present a practical, cost effective and hence viable option to Australia's greenhouse emissions out to 2030. It may provide a major role in enabling Australia to contribute meaningfully to achieving the international goal of stabilising greenhouse gas concentrations in the atmosphere, while maintaining our international competitiveness and economic growth.

Geosequestration – One of a Suite of Technologies

Geosequestration is one of a suite of possible technologies that the Australian, State and Territory governments are considering to enable Australia to meet future greenhouse constraints. Other options for reducing greenhouse gas emissions are likely to encompass end use efficiency programs, fuel switching, advanced renewable energy and other clean fossil fuel technology. Policies based on any one of these measures however, may not be enough to achieve sufficient reductions in carbon dioxide emissions.

Rapid change to non-fossil energy sources is unlikely according to the International Energy Agency's World Energy Outlook 2002, which projects global energy use to grow by two-thirds from 2002 to 2030, with fossil fuels meeting more that 90 per cent of that increase. This forecast of continued reliance on fossil fuels is based on the view that unless there is unforseen 'step change' in technology development costs, moving away from reliance on fossil fuels will have increase costs to the economy and energy security significantly.

It is recognised that given Australia's high level of fossil fuel resources, we can be expected to remain substantially reliant on fossil fuels for energy needs for the foreseeable future. For example, in the transition to a hydrogen economy, carbon dioxide mitigation will be required as hydrogen will be sourced mainly from fossil fuels.

The choice of greenhouse gas mitigation technologies is between low and high emissions outcomes – not between renewables and other energy sources. For example, in the Australian Government's recent Energy White Paper *Securing Australia's Energy Future*, the Government's current and future commitments to renewable energy and low emissions technology include:

- The Mandatory Renewable Energy Target will continue until 2020, providing incentives for over $2 billion in renewable energy investment;
- $14 million will be used to develop and install systems to provide accurate long-range forecasts for wind output;
- The new $500 million Low Emissions Technology Development Fund will provide support for low emissions technologies with significant long-term abatement potential;
- $75 million allocated to Solar Cities trials will directly support focused uptake of solar electricity and hot water as well as energy efficiency and efficient pricing signals; and
- $230 million was also included for the Australian Greenhouse Office to continue support for greenhouse technology projects under programs such as the Remote Renewable Power Generation and Greenhouse Gas Abatement programs.

Internationally - Carbon Sequestration Leadership Forum

Australia is contributing internationally to consideration of carbon dioxide geosequestration by being an active member of the Carbon Sequestration Leadership Forum. The Carbon Sequestration Leadership Forum is an international climate change initiative that is focused on the development of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage. The purpose of the Carbon Sequestration Leadership Forum is to make these technologies broadly available internationally; and to identify and address wider issues relating to carbon dioxide geosequestration. This could include promoting the appropriate technical, political, and regulatory environments for the development of such technology.

The charter of the Carbon Sequestration Leadership Forum establishes a framework for collaboration between governments, industry, researchers, and non-government organisations in sixteen countries and the European Commission. They are: Australia, Brazil, Canada, China, Colombia, European Commission, France, Germany, India, Italy, Japan, Mexico, Norway, Russian Federation, South Africa, United Kingdom, and United States.

In June 2003, at the inaugural meeting of the Carbon Sequestration Leadership Forum it was agreed that a Legal, Regulatory and Financial Issues Taskforce be established. One of the key priorities in the short term is the development of international regulatory principles for carbon dioxide geosequestration. Australia was nominated to take the lead on the Task Force and in November 2003 hosted an international sequestration regulatory workshop with eight of the then fifteen member countries of the Carbon Sequestration Leadership Forum. The purpose of the workshop was to share information on carbon dioxide geosequestration, particularly on regulation and to discuss an approach and proposed timeframe to address regulatory issues.

Australia presented a discussion paper to the Carbon Sequestration Leadership Forum Policy Group in January 2004 in Italy, which proposed a case study and gap analysis methodology to identify and prioritise key international regulatory processes and gaps. The paper was well received by Carbon Sequestration Leadership Forum member countries and it was agreed that the approach proposed in the paper would form the basis of a work program on legal, regulatory and financial issues relating to carbon dioxide geosequestration. In particular, a set of international best practice regulatory principles were drafted for consideration by Carbon Sequestration Leadership Forum member countries at the second Ministerial level Forum meeting in September 2004 in Melbourne.

The Carbon Sequestration Leadership Forum Legal, Regulatory and Financial Issues Taskforce report on considerations on regulatory issues is a non-binding report. Issues identified in the report emerged from the international experience on carbon dioxide geosequestration projects and where existing legislation is currently being applied to cover certain components of carbon dioxide sequestration projects. Carbon Sequestration Leadership Forum members are encouraged to consider the issues identified in the report in the context of their own domestic policies and frameworks.

Domestically – Carbon Dioxide Geosequestration Regulatory Working Group

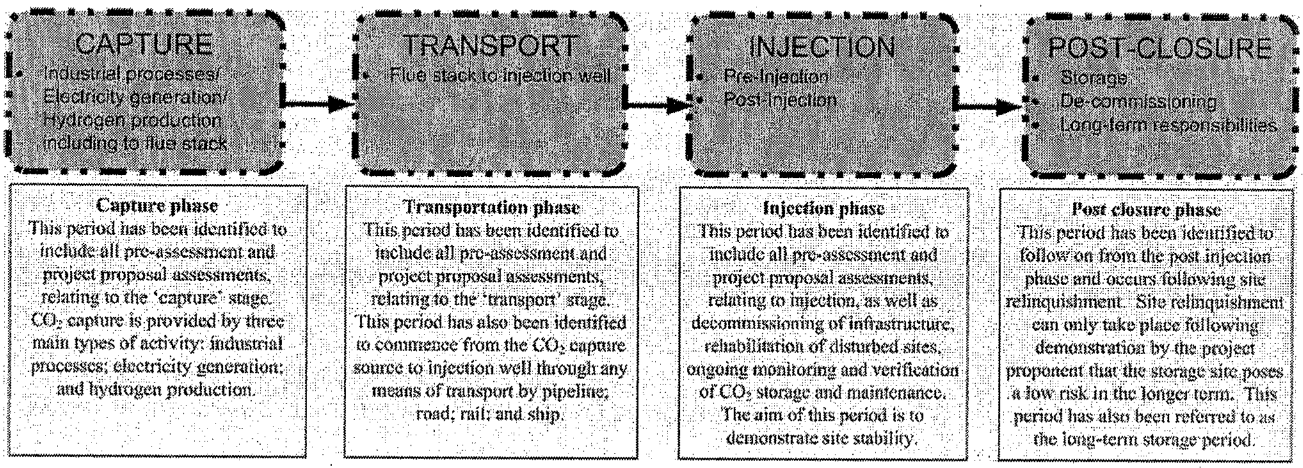
The domestic and international efforts should not be confused. The Australian draft regulatory guiding principles for carbon dioxide geosequestration and the Carbon Sequestration Leadership Forum Taskforce report on considerations for regulatory issues are two distinct documents.

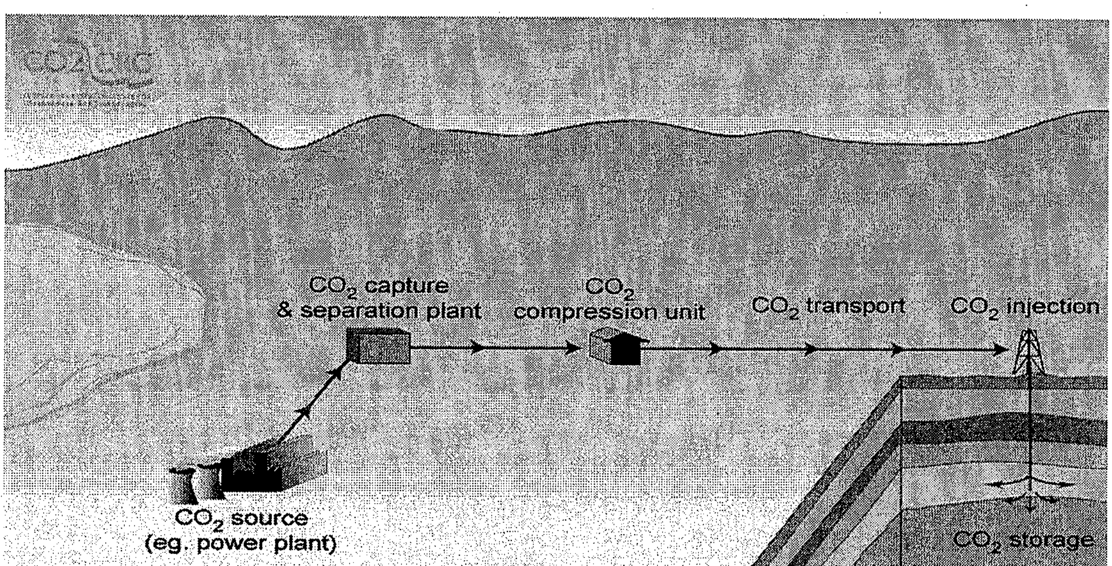
The Australian draft regulatory guiding principles have been drafted specifically with our own local regulatory needs in mind. However, they are consistent with the international principles and our international obligations.

Many aspects of carbon dioxide geosequestration, particularly capture, transport and injection are similar to current pipeline and oil and gas production regulation in Australia. Storage of carbon dioxide is a newer area. However, some of the monitoring technologies required for carbon dioxide storage are already used in the oil and gas industry. For example, seismic is a technology that is already used to assist in identifying oil and gas resources and can be used to monitor the migration of carbon dioxide. Seismic operation for oil and gas activities are regulated in Australia.

A carbon dioxide geosequestration project is structured around a continuum of activities from the emission of carbon dioxide through four broad stages: capture, transport, injection and post-closure. In this document, this continuum is simply referred to as ' carbon dioxide geosequestration' for ease of reference.[1]

Carbon Dioxide Geosequestration Project Life Cycle





Source: Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

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[1] It must be noted that geosequestration is injection and storage in geological formations, whereas ocean sequestration is injection into the ocean at depths of greater than 2000metres. Ocean sequestration is not being considered by Australia.

Carbon Dioxide Geosequestration Risks

Geological storage of carbon dioxide aims to mimic the geological processes involving the trapping and storage of hydrocarbons (often with carbon dioxide). It utilises well proven mature technology from the oil and gas industry for compression, injection, transportation and monitoring of gases and fluids. With appropriate site selection, monitoring and operation of the site, the likelihood of leakage from the subsurface will be extremely low.

The process of capture, transportation and sub-surface injection of gases and fluids are undertaken in Australia and internationally for applications such as gas storage. The operational standards of the existing industries that routinely undertake these activities and the applicable regulatory practices are well established and effective. For example, within the petroleum industry; enhanced oil recovery (which often involves transportation and injection of carbon dioxide) is a proven technology which has been used in the US and Canada for more than thirty years. This experience has led to tools and expertise needed for carbon dioxide transportation and injection to be managed safely.

The environmental impact and associated risks of carbon dioxide geosequestration are dependent on factors such as rock and fluid chemistry, physics of the reservoir, seal formations and the integrity of the encapsulating structures. Potential chemical and physical interactions between the carbon dioxide and the surrounding geology are the subject of ongoing research. However negative environmental impacts of carbon dioxide will not arise unless it migrates beyond the anticipated containment zone. The potential environmental impact associated with migration beyond the containment zone would dependent on factors such as location of emission and concentration of carbon dioxide.

The most common cause of carbon dioxide exposure from geosequestration projects would be well head failure that results in carbon dioxide leakage. In the majority of cases the problem is quickly identified and the well promptly repaired or plugged.

Subsurface lateral migration of fluids through geological formations occurs at the rate of millimetres to centimetres/year, such that during the post-injection phase of an injection project, the likely impact of carbon dioxide on adjoining subsurface regions will also be on geological timescales, i.e. hundreds of thousands to millions of years. The lateral migration rates of both carbon dioxide and the displaced formation fluids will be greater than this during injection[2], and monitoring technologies will need to be deployed to determine whether the behaviour of both the carbon dioxide and the displaced fluids is mirroring that predicted from pre-injection modelling.

Technical issues associated with injection sites can be deliberately targeted in the early phase of a project through exploration, testing, data acquisition and modelling and therefore can produce a highly developed understanding of any complexities and uncertainties.

Other Countries and their Projects

Carbon dioxide geosequestration projects have been operating successfully in other countries since 1996. Norway has been injecting one million tonnes of carbon dioxide per year since September 1996 in the sub surface beneath the North Sea in the Sleipner offshore gas field. Carbon dioxide has been stripped from the produced natural gas and injected into a sand layer. Since injection started, carbon dioxide has been injected without any significant operational problems observed in the capture plant or in the injection well. The Sleipner project is the first commercial application of carbon dioxide storage in deep saline aquifers in the world.

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[2] The rate of migration during the injection phase will be subject to project specific qualities, for example, the rate of injection, the pressure resulting from the injection rate and the characteristics of the reservoir.

The Weyburn project in the US and Canada is the latest opportunity to monitor the sequestration of carbon dioxide in geological formations. In this case, the geological formation is a depleted oil reservoir whereby carbon dioxide is being injected as part of an enhanced oil recovery project in the Weyburn oil field in Southern Saskatchewan in Canada. Enhanced oil recovery is a commercially proven technology. It has been used extensively in the US, where seventy four projects are now operating. Over the 20-year lifetime of the project it is expected that some twenty million tonnes of carbon dioxide will be stored in the Weyburn oil field.

3. THE PROBLEM – NO REGULATORY FRAMEWORK FOR CARBON DIOXIDE GEOSEQUESTRATION

Carbon dioxide geosequestration is a relatively new technology which, as yet, has not been used in Australia. It has the potential to reduce greenhouse gas emissions from stationary energy and other sources. While this relatively new technology is important because fossil fuels are likely to remain the major form of energy for the foreseeable future there are potential health, safety and environmental risks with carbon dioxide geosequestration which will need to be managed by governments to avoid negative consequences to the community.

For example, the environmental risks associated with carbon dioxide and its interaction with the atmosphere, soils, water and the biota are relatively well understood, however, further research and monitoring is required to fully understand the issues that may be associated with long term geological storage. A hazard can arise if carbon dioxide, which is denser than air, is allowed to accumulate in low-lying, confined or poorly ventilated spaces or if there is a gas cloud release occurs if injection fails due to the non-odorous nature of carbon dioxide. However, these risks can be easily managed with adequate monitoring. There is also the slight risk of carbon dioxide migrating out of the storage reservoir and into one or more surrounding geologic formations. This in turn could result in the contamination of freshwater aquifers, and/or interference with the activities at producing oil/gas reservoirs or coal mines.

Environmental issues that will need to be managed include:

- the potential implications of mixed gas streams (i.e. in the event of an unplanned release from either the capture, transport or injection stages of a carbon capture and storage project);
- the long-term implications of carbon dioxide in-situ in geological structures;
- the environmental implications of carbon dioxide migration or escape from containment zones and the risk of these events occurring; and,
- the environmental implications of the storage of non-pure carbon dioxide.

While, carbon dioxide is a naturally-occurring constituent of air which is essential to all life forms, is a non-toxic, inert gas and is generally regarded as safe, at elevated concentrations, carbon dioxide can cause harm to humans. The effects of elevated carbon dioxide levels depend not only on the concentration but also the duration of exposure. The ambient concentration of carbon dioxide in the atmosphere is currently about 370 parts per million (ppm) or less than 0.04 percent. For humans, there are no adverse health effects for carbon dioxide concentrations up to three percent. While some discomfort occurs for concentrations between three and five percent, it is only for concentrations above five percent that there are serious, possibly fatal, consequences. At concentrations above 25 percent to 30 percent, loss of consciousness occurs within several breaths and death quickly thereafter.

The three main concerns associated with carbon dioxide geosequestration in terms of health and safety are:

(1) The transport of carbon dioxide by pipeline presents a potential safety hazard to workers and the general public (negative externality).
(2) The injection of carbon dioxide into a geologic reservoir presents a potential safety hazard to workers (negative externality).
(3) The storage of carbon dioxide bin a geologic reservoir presents a potential safety hazard to the general public (negative externality).

A more detailed analysis of the negative externalities associated with health, safety and the environment for carbon dioxide geosequestration are described at Attachment B.

Another matter of concern for carbon dioxide geosequestration is the lack of a consistent framework has the potential to cause uncertainty for projects. That is, if proponents looking to invest in carbon dioxide geosequestration are faced with unclear and inconsistent requirements and little guidance on how to proceed, they could decide to invest elsewhere.

In this relatively new field, a regulatory framework to assess and manage carbon dioxide geosequestration activities is currently lacking, especially the aspect of storage. A nationally consistent regulatory framework that aims to minimise environmental, health and safety risks and provides methods for dealing with any long-term risks and investor certainty would provide a significant starting point for jurisdictions when considering their own regulatory needs. However, it is important to note that each jurisdiction would decide how to apply that regulatory framework.

It is also important to note that where regulation is recommended in this paper, the ultimate form of the proposed government regulation under the Council of Australian Government Regulatory Impact Statement process has not been decided. Further discussion and research will be required prior to making a decision.

4 OBJECTIVES

The objective of government is to introduce a regulatory framework within which industry can develop an emerging carbon capture and storage technological process. The framework needs to be transparent, predictable and practical providing community confidence and investor certainty. The purpose of the framework will be to improve economic efficiency and certainty in environmental, health and safety management wherever possible. The framework should provide for the development of regulation which will allow consistency in assessment and approval processes for regulators in cross-jurisdictional projects in Australia. The proposed framework does not explicitly increase the economic incentive to undertake geosequestration.

The framework will aim to be:

- in the best interests of the community in the areas of health, safety, environment, economic consequences and government accountabilities;
- based on sound risk management principles; science based and rigorous, yet practical in approach;
- clear and consistent in laying out rights and responsibilities of participants;
- efficient (cost-effective) from participant, government and community viewpoints;
- timely and comprehensive in considering planning and approval requests;
- adaptable and learning-oriented to profit from experience and future developments in technologies, markets and institutional arrangements;

- flexible to allow for future government decisions regarding possible greenhouse policy measures; and
- in a form that maintains Australia's international competitiveness.

The role for Government in the market is to optimise the competition and regulatory framework. There is a role for Government in correcting market failures, including countering socially or environmentally undesirable outcomes. For example, the market may not properly value externalities created by energy efficiency or innovation. But government intervention is justified only where it is well targeted, cost-effective, affordable and efficient, promoting appropriate signals within a credible long-term framework.

5. ANALYSIS

The seven key issues identified by the Regulatory Working Group as being fundamental to the successful implementation of a carbon dioxide geosequestration framework have been analysed. These key issues are:

- Access and property rights
- Long term responsibilities
- Environmental protection
- Authorisation and compliance
- Monitoring and verification
- Transportation
- Financial issues

Each issue will be analysed using three options.

Option 1 – Rely on market – no regulation
Market based methods provide firms and households with incentives to act in a socially preferred way. They can often be more cost-effective than regulations. The market should be relied on if there is the incentive for individuals and groups to act in a certain way which leads to the desired community outcome. Such incentives may include industry survival, market advantage or the threat of more severe regulation.

Option 2 – Self regulation
The option of self regulation involves industry developing and adhering to regulation itself. This should be considered where low risk events present no major public health and safety concerns and environmental or other impacts on the community. Self regulation in the context of this Council of Australian Governments Regulatory Impact Statement is characterised by industry formulating rules and codes of conduct. Sometimes rules or codes of conduct are developed to protect or confer commercial advantage on one group over another, or to exclude new entrants to an industry. On the other hand, standards can sometimes reduce the ability for consumers to choose lower cost and/or lower quality products and services. Self regulation is common amongst the professional and financial sectors.

Option 3 – Government regulation
Government regulation in the context of this Council of Australian Governments Regulatory Impact Statement is characterised by quasi-regulation, which refers to a wide range of rules or arrangements by which governments influence businesses to comply, but which do not form part of legislation. Co-regulation typically refers to the situation where industry develops and

administers its own arrangements, but government provides legislative backing to enable the arrangements to be enforced and explicit government regulation refers to primary or subordinate legislation. Explicit regulation should be considered only where the problem is perceived to be high risk, there is a need to provide legal sanctions and consistent application is required. Government regulation could also be a mixture of these different forms.

Each analysis will consider whether the option:

- aims to protect the community's interests, particularly to minimise risks to health, safety and the environment;
- will provide a nationally transparent and consistent approach to carbon dioxide geosequestration – this is important so that jurisdictions can learn from each other given it is a relatively new technology;
- is efficient (cost-effective) from project proponent, government and community viewpoints;
- is flexible to allow for future government decisions and possible greenhouse policy measures.

Each issue will be analysed using the three options i.e. no regulation, self regulation or government regulation and the objectives described above. In addition, the issue of cost recovery is also considered for each of the seven key issues described. When the cost or benefit of one of the seven key issues is not known, further information has been requested.

5.1 ACCESS AND PROPERTY RIGHTS

Externalities arise in the absence of well-defined, exclusive and enforceable property rights. A property right is an entitlement, or bundle of entitlements, defining the owner's right to use a resource and any limitations on its use. For property rights to be effective, the owner must be able to exclude others from the property, to appropriate the benefits from the property, to prevent others from damaging the property, and to enforce the property rights. When such property rights exist the costs and responsibilities associated with an activity are borne and behaviours are modified such that externalities no longer occur.

Resources may be used inefficiently where externalities exist. Therefore, ownership of carbon dioxide at each stage of a carbon dioxide geosequestration project needs to be established in legislation and be transferable, with the rights and responsibilities associated with ownership clearly defined and predictable, taking into consideration the long term risks and management.

In addition, the approval of carbon dioxide geosequestration proposals should take into account the public good aspect of carbon dioxide geosequestration in terms of greenhouse emissions avoided. Existing and future surface and sub-surface rights, as reservoirs and injection sites are likely to be subject to competing claims from other users.

To limit the concentrations of "impurities", such as hydrogen sulphide and nitrous oxide, in the gas the quality of carbon dioxide that can be sequestered will need to be defined to avoid carbon dioxide geosequestration gas being classified as a waste product.

Option 1 – no regulation
Contract, commercial and property law could be used to regulate the ownership and transfer of carbon dioxide. This would mean that prices would be set by market mechanisms and would therefore be consistent with other energy sources. In addition, carbon dioxide geosequestration is an application of a new technology where no precedent exists for contract, commercial and property law, in Australia, which could prove costly and timely if litigation was pursued.

The owner of the land could allocate pore space in accordance with freehold title in some jurisdictions. Landowners could also use veto rights to block site access to those wishing to sequester. Access arrangements would need to be negotiated with the landowner and this may impede carbon dioxide geosequestration if the owner utilised that veto power. Any contractual arrangement for the purchase of a geosequestration site would need to include such risks, which would be negotiated and agreed with the landowner prior to signature.

Market allocation methods such as auction and tenders could be used to allocate storage sites. This method would ensure that the market determines the price. However fears remain that a monopoly power could exist. Lack of competition could prevent third party access to the limited number of storage sites, monopolies could result in the society sub-optimal outcomes of decreased storage opportunities and prices being set at inefficiently high levels. The existence of substitute technologies could decrease the likelihood of monopolies developing.

Option 2 – self regulation

A code of conduct could be established to govern access and property rights for instance in negotiating access to land with landowners. This could include industry standards such as those that are already utilised in similar areas such as petroleum and mining, for instance native title. Where matters of access are uncertain common law (torts and contract) and existing legislation (eg. commercial and environmental) could be required for dispute resolution. However, there is likely to be uncertainty for both project proponents and landowners in relying on common law, because carbon dioxide geosequestration is a relatively new technology and as for the option of no regulation, precedent does not exist which could prove costly and timely.

Option 3 – government regulation

To provide certainty, the point of change in ownership/responsibility for the carbon dioxide needs to be clarified to allow storage and movement of carbon dioxide. In addition, ownership of storage sites including government or private landowners, veto power and compensation need to be clearly defined. The nature and scale of future carbon dioxide geosequestration projects will be influenced by technical practicalities, costs and the arrangements. While these factors cannot be anticipated, suitable carbon dioxide reservoirs may be scarce and contested, and there is a need to provide for the simultaneous and (where possible) subsequent use of reservoirs by multiple injectors.

Government regulation needs to ensure that a framework provides for issues including, permits that cover exploration and utilisation of storage sites, duty of care considerations, compensation, and cost recovery/pricing structure for storage and access. A statutory definition of storage site to store carbon dioxide is needed to ensure that only suitable storage sites, in terms of geological characteristics, are used to store carbon dioxide.

Different State and Commonwealth technical advisory bodies may exist to provide suitability assessment and project approvals for carbon dioxide geosequestration. These jurisdictions may have different approaches leading to a lack of national consistency. Developing a framework for carbon dioxide geosequestration based on existing frameworks, accommodating the best features of each option and ensuring consistency with existing regimes would avoid duplication. New regulation could be introduced where there are gaps in existing regulation or where existing regulation is inapplicable. Regulation could be in the form of new or existing arrangements/ regimes to resolve jurisdictional issues between State and Commonwealth to deal with offshore and onshore ownership.

Recommendation

Using existing contract, commercial and property law would not impose additional costs on interested parties unless there are conflicts. Explicit government regulation is the preferred option as it would be transparent, provide certainty and specifically regulate carbon dioxide geosequestration activities with the aim to minimise associated risks to health, safety and the environment. Government regulation would best protect the community's interests by including the best features of existing frameworks and introducing new regulation where there are gaps, codes of conduct would be enforceable, it would be nationally clear and consistent and it would be flexible enough to allow for any future changes.

5.2 LONG TERM RESPONSIBILITY

Potential sources of liability for carbon dioxide geosequestration include public health impacts and environmental and ecosystem damage. Carbon dioxide is generally considered a safe, non-toxic gas at low concentrations, and does not directly affect human health. However, the gas is denser than air and may re-accumulate in low-lying, confined or poorly ventilated spaces. The choice of appropriate sites is the best way to minimise any adverse effects related to carbon dioxide geosequestration storage, the possible increase in mitigation and management of risk and levels of fugitive emissions from capture, transport and injection facilities.

The issue of cost recovery may be a consideration in relation to long term responsibility for geosequestration sites. It has been proposed by the Regulatory Working Group that government accept long term responsibility for site monitoring and maintenance following demonstration by the proponent that a minimum set of criteria is met. Whatever the service provided, it may be appropriate to seek cost recovery from industry. If cost recovery is not undertaken, the costs to government are effectively borne by the community (taxpayers). However, where cost recovery is undertaken, the additional costs to those utilising government services may be passed on the final consumers of the product, (in this case energy), otherwise make carbon dioxide geosequestration an unfeasible technology.

The issue of legal liability is typically assessed in the terms of negligence and strict liability. Negligence is the failure of persons or corporations to follow reasonable care. That is, they would find a professional negligent if they did not exercise the skill and knowledge normally possessed by members of the same profession. Strict liability is an effort to internalise costs. That is, a person or corporation is held liable for the harm that his, her or corporate activity caused regardless of whether reasonable care was used.

Post closure liabilities in the post closure period will need to be clear. Analogies from the decommissioning of petroleum and mine sites operations, long term management of hazardous waste disposal sites and contaminated site remediation provide models to assist in understanding liabilities in the post closure phase. Using these models, the project proponents retain some liability over the site in the post closure period. However, it is likely that government will assume some liability for the project particularly in the longer-term. The scope, nature and allocation of liability following site closure needs to be resolved by deciding whether existing common law is adequate or whether amendments to existing regulation or new regulation is required to provide greater clarity.

Clearly defining long-term responsibilities and liabilities associated with carbon dioxide geosequestration projects is a priority. The lack of a clear framework with which to consider long term responsibilities and liabilities could leave government and future generations exposed in terms of environment, health and safety risk and financial cost. How long-term responsibilities are managed will be a key factor in gaining community acceptance of carbon dioxide geosequestration projects.

Option 1 – no regulation
Currently, common law would find a person negligent if they do not exercise reasonable care. While there is case law relating to environmental issues carbon dioxide geosequestration is a new technology and no precedent exists for this particular matter. Relying on common law could prove costly and timely for industry if litigation was pursued. This would create uncertainty for the community, government and industry.

Option 2 – self regulation
Most industry standards and codes relate principally to operational periods for up to several decades, perhaps as many as one hundred years. In contrast, carbon dioxide storage is required for thousands of years. New standards would need to be developed by industry, which would be costly for businesses but beneficial for government and the community. However, without some form of incentive, businesses are likely to take community concerns into account and therefore, industry may not voluntarily develop appropriate standards or codes for carbon dioxide geosequestration.

It could be argued that industry should be responsible for carbon dioxide geosequestration projects following closure in the long term. This will be costly for the industry to perform this function and could result in industry choosing between economic and social responsibilities. Common law would need to be relied upon similar to the option of no regulation which would cause uncertainty for the community, industry and government.

There is also the question of who pays if the proponent is declared bankrupt or cease to exist. In the event of a company bankruptcy, it is not clear how residual responsibility will be managed.

Option 3 – government regulation
Appropriate regulation and management from the planning and site selection can decrease long-term risks to public health and the environment. Any regulatory framework will need to place human health and safety at the forefront to gain public acceptance of carbon dioxide geosequestration.

Long-term responsibility for the decommissioning and rehabilitation of onshore carbon dioxide sequestration facilities will be largely a State based matter. In contrast, the offshore decommissioning and rehabilitation of facilities is more complex due to international guidelines and treaties, and due to the guidelines and treaties being set up prior to carbon dioxide geosequestration technology. Accordingly, the offshore decommissioning and rehabilitation of facilities will be, to some extent, dependent on the interpretation of these international treaties. This work is being progressed through the International Energy Agency in conjunction with Carbon Sequestration Leadership Forum members.

A multitude of State, Territory and Commonwealth regulations potentially apply to carbon dioxide geosequestration activities, both pre and post closure. A common and consistent government regulated framework that considers long term responsibilities and liabilities associated with carbon dioxide geosequestration activities will be required to ensure governments and future generations are not exposed to health and environmental and financial risks and financial burden.

Decommissioning and rehabilitation regulations that are currently in place for the mining and petroleum industries could be adopted for carbon dioxide geosequestration. In particular, the existing petroleum regulation at both a State and Commonwealth level provides guidelines for the decommissioning of facilities that are similar in nature to those for carbon dioxide geosequestration, which could be utilised. This is particularly relevant for high pressure pipelines and wells.

Petroleum and mine site operations, long-term management of hazardous waste disposal sites and contaminated sites remediation provide models to assist in understanding liabilities in the post closure phase. If these models are used, the project proponents will retain some liability over the site in the post closure period.

Governments should not permit site closure until they are satisfied to a high degree of certainty that future land use objectives are met, residual risks of leakage and liability are at an acceptably low level, and ongoing costs associated with the site are acceptably low or can be otherwise managed. The burden on government would include the initial assessing of site options and ensuring that the closure of sites is adequately addressed.

The cost of the developing post-closure management phase for the transfer of the environmental and health risk will fall to proponents. However, some benefits will accrue to the general public such as the reduction in possible liability on consumers by ensuring all prerequisite standards and conditions are met for transfer of ownership from private to public or between commercial parties.

Recommendation
The management of long term responsibilities and liabilities will be a key factor in gaining community acceptance of carbon dioxide geosequestration projects. The long-term risk of carbon dioxide geosequestration to health, safety and environment can be minimised by regulation of these aspects where possible at the commencement of the project. Therefore, the option of government regulation, which includes a combination of explicit regulation, co-regulation and quasi-regulation, would best achieve the desired objectives. That is, the community's interests would be best protected by appropriate regulation, modelling existing successful long-term management regulation, being in place from the outset of carbon dioxide geosequestration activities therefore minimising any possible risk and financial burden. Government regulation that is common and consistent rather than unrealistically relying on private owner/operators or industry to remain responsible for the site in perpetuity would ensure that the community's interests are protected.

It is still to be decided whether liability for carbon dioxide geosequestration will be treated in the same way as petroleum and mining activities which have imposed relatively low costs on operators due to a lower risk. Further work is proposed on the long-term risks and liability.

Question: Is information available on the costs and benefits of long-term liability for carbon dioxide geosequestration projects?

5.3 ENVIRONMENTAL ISSUES

The environmental issues and risks associated with carbon dioxide and its interaction with the atmosphere, soils, water and the biota are relatively well understood. However, further research and monitoring is required to fully understand the issues that may be associated with long-term geological storage. Existing environmental regulation at both Commonwealth and State levels could be applied to carbon dioxide geosequestration projects with minor amendments.

Commonwealth environmental regulation that may apply to carbon dioxide geosequestration includes the *Environmental Protection and Biodiversity Conservation Act 1999* and the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999. Additionally, State and Territory legislation covering environmental aspects of planning and approval processes for industrial projects may also apply.

The primary issue for carbon dioxide geosequestration projects however, from an environmental protection perspective is likely to be proving the science, public perception and confidence. Therefore, all existing Commonwealth, State and Territory environmental legislation may require amendments specifically to allow for carbon dioxide gas.

Option 1 – no regulation
Relying on the market and not regulating carbon dioxide geosequestration would not address the

community concerns of environment, health and safety. There would be no framework to guide the industry on what is expected of it, particularly in terms of what it should take into account in engaging the community and arriving at acceptable environmental performance standards. Industry would be responsible for developing its own processes for establishing appropriate operating standards. In the case of an environmental event where there was no regulation and the proponent was unable to finance the costs, government outlays would be substantial as they would be left to rehabilitate the site.

Question: Is it possible to quantify the costs of rehabilitation for a carbon dioxide geosequestration project?

Equally, the community and government would have no framework for being assured that industry proposals are subject to appropriate environmental scrutiny. Achieving acceptable standards and compliance would be through community reaction to operations, and this is likely to lead to uncertainty for all parties and a high potential for disputes between the industry and community groups.

Relying on the market would not provide any incentive for specific scientific research to be carried out to prove up the science required for greater confidence in the technology.

In the case of regulations ensuring certain levels of protection in relation to geosequestration activities, it is arguable that the broader community benefits through greater safety and environmental assurances. However, the only reason consumers require this additional protection is because companies undertake geosequestration activities. Externalities flowing from geosequestration activities, which include negative perceptions, make the community worse off, and regulations which seek to protect consumers against this return them to the status quo. Costs created by an unregulated environment are generated by the individual companies undertaking geosequestration activities therefore, the seeking of cost recovery may be appropriate in this instance.

Option 2 – self regulation

Self regulation would require industry to set the environmental performance standards it considered acceptable. Many of the potential natural, cultural, social, economic and environmental effects of carbon dioxide geosequestration operations would occur external to the operations. There would be significant community concern that these externalities would not be adequately accounted for by the industry in setting the performance standards.

Similarly to the option of no regulation there would be no framework to guide the industry on what is expected of it, particularly in terms of what it should take into account in engaging the community and arriving at acceptable environmental performance standards.

It could be argued that lack of regulation does not provide adequate oversight of industry activities, thus abrogating the government's responsibility to protect the environment on behalf of the community. Equally, industry could argue that there is inherent uncertainty and potential for costly delays and interruption of operations through the actions of groups opposed to the industry or particular developments.

Carbon dioxide geosequestration project proponents would be responsible to the community as a whole and not just to the parties involved in a contractual agreement. Therefore, environmental issues would need to be included in contracts and codes of conduct. However, if the dispute resolution mechanism set out in the contract or code of conduct is insufficient, common law and existing environmental legislation would be relied on to provide advice, compensation and penalty options. If situations arose where common law and legislation must be referred to, this could lead to increased costs in the form of legal fees and possible court costs, particularly because carbon dioxide geosequestration is a new technology and no precedent exists which could prove costly and timely if litigation was pursued. This would create uncertainty for the community, government and industry.

Option 3 – government regulation
As described in the section on long term responsibility, decommissioning and closure of petroleum and mine sites and long term management of hazardous and contaminated waste could provide a model for carbon dioxide geosequestration.

Industry would be required to comply with a regulatory regime, regulators would be required to ensure compliance and community interest groups would be involved to a greater or lesser extent in consultation during the approvals process and at times in assessing performance or impact of particular operations. Costs for government would include ensuring industry's compliance with the regulations, administration and public reporting on inventory and environmental aspects however, there would be reductions in government outlays through preventable health, safety and environmental damage.

Benefits for the general public of government regulation include decreased in carbon dioxide emissions, possible contribution to sustainable environment for future generations, potential improved health and safety, and increased potential for consumer/public satisfaction as risks are reduced.

Recommendation
In terms of the community's interests, having no regulation would not adequately address the protection of the environment s and the potential externalities. The options of no regulation and self regulation would both result in the industry being left to set the environmental performance standards it considered acceptable. Existing regulation could be generally applied to carbon dioxide geosequestration activities or could be slightly amended at minimal cost to specifically apply to carbon dioxide geosequestration. This would therefore be cost effective, clear and consistent as well as protecting the community's interests. Therefore, the option of explicit government regulation would best achieve the desired objectives.

See Attachment B for a more detailed description of the environmental risks associated with carbon dioxide geosequestration. However, further information is required on monitoring and verification. Please submit any further information available.

5.4 AUTHORISATION AND COMPLIANCE

Authorisation and compliance is important not only for financial reasons (assessment of royalties, possible government dues, determination of surface property and mineral rights) but also for practical reasons such as record keeping to avoid earlier carbon dioxide storage sites as well as data on wellbore features. Authorisation and compliance is also important to ensure the rights and responsibilities of commercial parties and interests of communities are addressed. Activities for authorising and ensuring compliance of carbon dioxide geosequestration operations are closely related to those processes associated with already established commercial industries, such as mining and petroleum.

Option 1 – no regulation
Common law and statute law could be used to enforce any authorisation and compliance issues that arise. This may not be publicly acceptable because authorisation and compliance is a major part of minimising risk, especially potential environmental risks. If situations arise where common law and legislation must be referred to, this could lead to increased costs in the form of legal fees and possible court costs particularly because carbon dioxide geosequestration is a new technology and no case law currently exists. This would create uncertainty for the community,

government and industry.

For business, a benefit would be no increase in costs such as compliance and monitoring costs that would be associated with having to alter production and time spent training staff. For government the potential costs would be to the environment, health and safety of the community. In addition, lack of authorisation and compliance for carbon dioxide geosequestration activities could lead to environmental events that would negatively impact on our international relations, particularly if it is the result of being inconsistent with international guidelines and treaties.

Option 2 – self regulation
A code of conduct could be established and utilised for monitoring, authorisation and compliance with environmental, health and safety standards. Public accessibility to this information would ensure transparency and aid in consistency and compliance. However, a code of conduct would lack enforceability except through contract law or if used in conjunction with regulation.

The lack of incentive for business to set standards as high as government might set may be beneficial as the cost of implementation and compliance may be less than if government regulation was introduced. If a code of conduct or industry agreement was introduced the compliance costs to business would increase.

Option 3 – government regulation
If carbon dioxide geosequestration regulations for authorisation and compliance mechanisms were introduced to address potential environment, health and safety risks, these regulations would need to address the rights and responsibilities of commercial parties while seeking to protect the community's interests.

Activities for authorising and ensuring compliance of carbon dioxide geosequestration operations are closely related to those processes associated with established commercial industries which form part of the chain of activities associated with carbon dioxide geosequestration.

Regulation equivalent to existing environmental regulations for mineral processing, chemical manufacturing or electricity generation plants could be applied to carbon dioxide geosequestration. Similarly, regulation equivalent to existing occupational health and safety regulations for chemical facilities could be applied to carbon dioxide geosequestration.
New regulation in the form of modified existing legislation or the introduction of new legislation may need to be adopted to ensure geological carbon dioxide storage sites are managed safely. Specifically, for each potential geological carbon dioxide storage site, it needs to be demonstrated that the leakages will be reduced to minimum levels and the dispersion sufficient enough to prevent the accumulation of hazardous carbon dioxide concentrations.

The costs to business include costs such as compliance with changes in applicable licensing or environmental requirements and compliance with changes in regulations governing operating procedures, which would adjust the costs of regulation on business. However, Government regulation would also benefit business by increasing certainty in regulatory compliance costs.

Recommendation
As authorisation and compliance is a major part of minimising risks, having no specific regulation or relying on a code of conduct without government backing may not be publicly acceptable because there would be no enforceability except through general common law and statute law. A nationally agreed framework for regulation on the other hand, which is common and consistent, could allow flexibility when necessary, could specifically address issues regarding the minimisation of risks, and could be cost effective because existing legislation

could be slightly modified to apply to carbon dioxide geosequestration activities therefore minimising costs. Therefore, the option of explicit government regulation would best achieve the desired objectives for authorisation and compliance.

Question: The risks to health and safety are described in more detail in Attachment B. However, further information is required on storage of carbon dioxide over long periods of time. Is there any information on the costs associated with the authorisation and compliance of long-term storage?

5.5 MONITORING AND VERIFICATION

After a carbon dioxide storage reservoir has been sealed, the time during which the reservoir is over pressured would appear to represent the greatest potential for short-term significant leakage. Current modelling calculations suggest that this time period is relatively short a few decades. Thus, effective sealing at abandonment would decrease the chances of leakage during this transient period. Drilling through the storage formation for other purposes also poses risks. Monitoring and verification of wellbore leakage in the decades following the end of carbon dioxide geosequestration injection is likely to be detected and therefore, can be remediated.

Ideally monitoring should be carried out pre injection, during injection and post injection. Monitoring sites should be varied, including several horizons, at the surface, in the shallow subsurface, in the deep surface, and in the injection zone. In addition, monitoring in and around the well bores should be carried out, which overlaps with the previous horizons.

Monitoring and verification of carbon dioxide geosequestration projects needs to be able to deliver high quality information that can be used to effectively and responsibly manage health, safety, environmental and economic risks; information on the volume and location of greenhouse gas emissions that have been abated and are stored underground which are accurate enough to meet inventory reporting and commercial requirements; and to engender public confidence.

Option 1 – no regulation
Commercial drivers for monitoring and verification are profit focused and therefore do not always account for the interests of the community, orderly market development, legal and/or statutory rights of commercial stakeholders and accurate accounting for emissions to meet government reporting obligations and policy needs.

This may benefit the proponent, as there would be no increase in costs such as compliance and monitoring costs associated with having to alter production and time spent training staff. On the other hand the community and government would incur health, safety and environmental costs. However, some companies may wish to do their own monitoring and verification.

Option 2 – self regulation
A code of conduct could be established but this option may not be sufficient because it may not meet the needs of the community. For example, possible increases in the mitigation and management of risk and the timeframe required for ongoing monitoring and verification for industry of levels of fugitive emissions from capture, transport and injection facilities would increase costs to industry. While industry standards could be utilised, currently industry standards are focused on short term rather than the longer-term.

Option 3 – government regulation
The main justifications provided for conducting monitoring once a project is complete are confirmation that there is no leakage, public confidence and accounting for greenhouse emissions. A regulatory framework should be able to deliver mechanisms for monitoring and verification to:

- establish data on the surface and subsurface environment;
- monitor the project environment to manage and mitigate health, safety and environment risks;

- ensure certain standards for health, safety and environment and subsurface behaviour of geosequestration gas are met before responsibility for the project is transferred from private to public interests; and
- develop and manage a monitoring and verification plan to cover the post-closure period after responsibility for the project has been transferred to public hands including outlining how this ongoing monitoring will be funded.

Monitoring and verification is carried out in relation to storage of other materials such as underground gas storage. Projects could be monitored under existing frameworks including, inter alia, for pipelines, petroleum, mining, or waste disposal with minor legislative amendments. A framework specifically for carbon dioxide geosequestration could be developed.

While existing regulation could enable carbon dioxide geosequestration projects to be managed effectively in the short term, carbon dioxide geosequestration is a different process from extraction of hydrocarbons, and may involve different monitoring and verification requirements that may not fit easily within current legislative frameworks. For example, new monitoring and verification standards and guidelines in management plans will need to be developed for carbon dioxide geosequestration before the site can be decommissioned. A new regulatory framework for monitoring and management of carbon dioxide in-situ over very long periods of time would also need to be developed. After the reservoir has been sealed, monitoring should continue as long as government considers it beneficial.

The costs to government would be the monitoring and administration of costs such as the regular review of plans and review of standards and actions. For example, five yearly ongoing reviews mainly by government plus post-closure for a specified period – long term, but this would be cost recovered. While the benefits would include: consistent reporting standards; the assurance that carbon dioxide geosequestration technologies meet national and international standards for accounting; reporting national carbon dioxide inventories across all jurisdictions allowing for a single Australian report to be produced meeting international standards; and an Australia wide mechanism which would cover the costs of long-term monitoring of decommissioned sites.

The costs to business would include audits and reviews of monitoring and verification. While benefits to business would include the development of strategic and project specific monitoring and verification strategies, and government regulation would ensure unambiguous allocation of responsibility for monitoring and reporting during long-term storage of carbon dioxide.

Question: Is there information that quantifies the costs and benefits of monitoring and verification over the long-term?

Recommendation
Relying on the market or on an industry code of conduct would be unsatisfactory because these mechanisms may be more profit focused rather than properly accounting for the interests of the community. These alternative options would probably also lack a nationally common and consistent approach. Alternatively, government regulation would specifically aim to protect the community's interests by minimising any possible risk and could be nationally consistent. Therefore, the option of government regulation which includes a combination of explicit regulation, co-regulation and quasi-regulation would best achieve the desired objectives.

5.6 TRANSPORTATION

The key differences between transporting natural gas and supercritical[3] carbon dioxide by pipeline from a safety/environmental perspective are:

[3] A supercritical fluid is any substance above its critical temperature and critical pressure. In the supercritical area there is only one state-of-the-fluid and it possesses both gas- and liquid-like properties. This is not new technology. The phenomena of enhanced solubilities in supercritical fluids has been known since the late 1800s. For decades it has been used in food processing industries to extract compounds such as caffeine and hop oil.

- when carbon dioxide mixes with water it becomes highly corrosive;
- carbon dioxide is heavier than air; carbon dioxide is odourless; and
- carbon dioxide is not flammable.

The risk associated with carbon dioxide transportation in terms of environment, health and safety are:

- the transport of carbon dioxide by pipeline presents a potential safety hazard to workers and the general public (but less that natural gas); and
- injection of carbon dioxide would have to be sufficiently regulated and monitored to manage the risk.

Option 1 – no regulation
There are currently no Australian industry standards governing carbon dioxide geosequestration. This could result in unsafe practices. Developing new standards would be costly for companies especially if they contract an outside organisation to develop the standards.

Question: What would be the magnitude of the costs of developing new standards or codes for companies?

Option 2 – self regulation
Industry standards or a code of conduct could be used. However, this may be a lower threshold than what the government and community would consider adequate. If industry is able to be made liable for damage caused, they would have an interest in developing a code of conduct which provides adequate environmental, safety and health protection.

As described above there is currently no Australian industry standard for carbon dioxide sequestration. Developing such standards would be costly for industry, and these costs would be passed onto consumers.

Question: What would be the magnitude of the costs of developing new standards or codes for companies?

Option 3 – government regulation
Environmental standards currently apply to the route selection, construction and operation of pipelines and in most jurisdictions relevant planning approval or environmental impact assessments are required. Additional regulation relating specifically to carbon dioxide pipelines may not be necessary. However, some amendments to existing pipeline legislation may be needed prior to new pipeline approvals.

All jurisdictions have relevant regulations governing major hydrocarbon pipelines. In some jurisdictions this is contained in State/Commonwealth Pipeline Acts while in others it is contained in Petroleum Acts. Any new regulation should allow access to private and public property for the purpose of transportation of carbon dioxide and construction of carbon dioxide pipelines.

Recommendation
Relying on the market is inappropriate because there are no industry standards that could govern carbon dioxide transportation. Self regulation in the form of a code of conduct would also be inappropriate because it may be perceived to have a lower threshold than what is publicly acceptable. Government regulation on the other hand, already exists in relation to activities using similar techniques as carbon dioxide geosequestration. While existing legislation exists for pipelines there are gaps in the existing legislation. Utilising this existing regulation should be cost effective as minimal new regulation would be required. The community's interests will also

be protected as this existing regulation takes environmental, heath and safety issues into account.

5.7 FINANCIAL ISSUES

Without Government intervention, companies would be required to accept long-term responsibility for site monitoring and maintenance. If businesses were unable to acquire insurance for this activity, companies undertaking geosequestration activities would be required to bear an unacceptably high level of financial risk. Businesses would be uncertain of all the costs associated with geosequestration, and would find it more difficult to make educated decisions as to whether geosequestration was a profitable option in their particular circumstance. This additional risk and uncertainty would result in geosequestration activities being taken up by industry at a lower rate than would otherwise have been the case. This would be an inefficient outcome, brought about by the existence of a market failure.

In this particular circumstance, the product not being supplied is insurance, and the reason it is not being supplied is the uncertainty about the magnitude and likelihood of potential risks associated with geosequestration activities. Where an incomplete market exists, government may have a role to play in providing the product in order to achieve a socially desirable outcome. There may be a need for government to intervene in relation to long term site responsibility, as failure to act will lead to inefficient market outcomes. However, there are a number of alternatives available; government may choose to provide any or all of the following services:

- Accept responsibility for sites in long term;
- Provide insurance to companies in the short term; or
- Provide insurance to companies in the long term (if the Government decides not to accept direct responsibility for site monitoring and maintenance).

Government provision of insurance would allow companies to undertake their own long term site maintenance with lower level of risk. However, there is a danger of a moral hazard situation where the industry has no/reduced incentive to maintain sites to a high level. Once the market has a greater understanding of the likelihood and types of risk associated with geosequestration, it is likely that private providers would be willing to provide an insurance service, at which point government support would no longer be required.

In relation to the issue of cost recovery, government agencies take the view that they should be able to implement full cost recovery, and industry takes the view that consideration should be given to public benefit of carbon dioxide emissions avoided and that therefore full cost recovery may not be appropriate in all cases.

One issue needing consideration in the drafting of future fiscal and regulatory measures is the distinction between normal commercial maintenance conducted as good commercial practice and any "special social" requirements. On competitiveness regulation, there appears to be no clear reason why normal competition policy principles (for example third party common access and common carriage) should not apply. At this stage no special fiscal issues are apparent in relation to competition policy and transportation of carbon dioxide.

Project viability (and hence financing) will be significantly impacted upon by:

- taxation treatment;
- overall regulatory costs; and
- the treatment of liability/ benefits (and associated insurance issues).

Resolving these issues expeditiously is necessary to give scenario analysts, economic modellers, project developers and finance greater certainty.

Option 1 – no regulation

Final determination of the cost of insurance is difficult; however there is no reason why normal insurance processes should not apply to carbon dioxide geosequestration technologies, transportation and for operation of above ground storage related equipment. However, insurance companies may refuse to insure projects involving storage of carbon dioxide due to the unknown associated risks.

Question: Would companies insure projects? If so, what would be the magnitude of these costs?

Option 2 – self regulation
Self regulation would not preclude industry from insuring against unforeseeable events. A company would need to prove they are managing the risks satisfactorily to qualify for insurance, and this may protect against using 'shelf companies'. However, as above insurance companies may refuse to insure projects involved in storage of carbon dioxide due to the unknown associated risks.

Question: Would companies insure projects? If so, what would be the magnitude of these costs?

Option 3 – government regulation
Regulatory processes should be least cost, should not undermine the international competitiveness of Australian industry, and undue fiscal burden should not be imposed on any jurisdiction or industry as a result of regulatory processes or outcomes.
It may be appropriate that company taxation treatment of capital expenditure be treated in accordance with existing taxation policies that is they are deductible via depreciation arrangements. Equally, for company tax, it may be appropriate that there is no differential treatment of operating costs of commercial corporations for carbon dioxide geosequestration.

There are fundamental differences between how petroleum and some mining royalties are calculated. For example in Western Australia there are three royalty systems that need to be considered for petroleum projects. In the case of mining, it is probably only in relation to deep coal seam gas recovery in Victoria that an issue may arise. In most other cases, since royalty is ad valorem based, the issue of deductibility of capture and storage costs does not apply. Therefore it is possible that in some circumstances costs of storage will be treated in a different manner.

In relation to the fiscal impact on State government instrumentalities and corporations prima facie it would appear that governments will need to consider how issues such as performance bonds and insurance needs are addressed by state instrumentalities for: company tax may not be a relevant issue; and royalty and the Petroleum Resource Rent Tax issues may not arise for a Crown entity. Given that in the longer term it is almost inevitable that governments will be taking legal liability for stored gases, there may be fiscal implications of such a change in responsibility that need to be considered by the relevant jurisdictions.

Recommendation
It may be appropriate that proponents self insure or go to markets as they would do for other similar scale activities. Final determination of the cost of insurance is difficult to assess due to limited demonstrations of the potential for long-term risks. It will depend on consideration of a broad range of issues. For example, issues of long-term ownership, unknown associated risks and public indemnity. Government regulation to clarify ownership is recommended in a form that is least cost while meeting the necessary hurdles of managing risks.

If information is available on the costs and benefits of the cost of insurance and the fiscal implications of a change in responsibility for carbon dioxide geosequestration projects in differing jurisdictions and on and offshore, please forward in submissions.

6. COMPARATIVE ASSESSMENT – FINAL RECOMMENDATION

Option 1 is not supported because it cannot be guaranteed that industry would ensure that risks are reduced to as low as possible. In addition, there is an abundant supply of fossil fuels particularly coal and gas that is expected to last for centuries. Without the certainty of regulation, it may not be a priority to use carbon dioxide geosequestration technologies for greenhouse gas mitigation due to their higher cost. However, the decision to utilise geosequestration technology should remain a commercial decision.

The issues surrounding health, safety and environment considerations may not be adequately addressed and sanctions may not be put in place if left to the market, particularly over the longer term. This would detract from the best environmental, health and safety outcomes and subsequently community understanding and awareness. It may also leave the community with an unfunded liability. .

Option 2 of self regulation is not a desirable option because there may be risks associated with carbon dioxide geosequestration if not managed and regulated properly. Although the industry may self regulate in a way that minimises the impact on the environment and third parties, it may not always act in the best interests of the community.
It is unlikely that self regulation would provide a framework capable of providing assurance to the community that the industry would operate in a manner that achieves community acceptable outcomes involving minimal risks to health, safety and the environment. Therefore, self regulation could also make it more difficult for project proponents to gain community acceptance.

Self regulation does have the benefits of reduced administrative and compliance costs, however, there can be no guarantee that all industry members would agree to self regulation especially if it is in the form of an agreement or arrangement such as an industry code of conduct. Another benefit to business of self-regulation is the freedom to choose the most appropriate, cost-effective technology/process, eventuating in least-cost approach.

Option 3 is the recommended option because, as specifically analysed above, it protects the community's interests, particularly minimises risks to health, safety and the environment; provides a nationally consistent approach to carbon dioxide geosequestration; may be cost-effective from project proponent, government and community viewpoints; and is flexible to allow for future government decisions and possible greenhouse policy measures.

The Australian economy is dependent on the continuing availability of competitively priced electricity. The bulk of base load electricity in the future is expected to be generated from coal and gas but it will need to be generated in an environmentally sustainable manner. Additionally, energy investments are generally long-term. By implementing government regulation, investors will be able to make decisions with full knowledge of what regulatory hurdles they will need to meet to get approval from government for a project. The community can also be assured that their interests are being protected.

Future projects may be cross jurisdictional. Stand alone State and Territory regulation will not cover all regions of Australia. Similarly, by virtue of the Constitution, the Commonwealth only has the power to regulate in 40 specific areas. A combination of Commonwealth, State and Territory regulation that draws on both new and existing regulation could be a possible form that a regulatory framework could take.

If existing legislation is to be relied upon decisions will need to be made how such legislation would manage carbon dioxide geosequestration activities. To avoid time and costs involved in duplication, existing regulation could be adapted and amended to address carbon dioxide geosequestration activities. New laws and regulations could be introduced where there are gaps in existing regimes or where the existing regime is not readily applicable to carbon dioxide geosequestration.

This regulation could be managed by the relevant jurisdiction and where appropriate in consultation with other affected jurisdictions to ensure national consistency. The analysis supports the use of existing legislation wherever possible to avoid additional regulatory burden. Most aspects of carbon dioxide geosequestration are similar to activities which have already been undertaken in the oil and gas industries for decades. Existing oil and gas regulations available in the Commonwealth, States and Territories provide an adequate starting point for developing a framework. In view of the long-term storage requirement for carbon dioxide geosequestration however, specific regulations may need to be developed.

It is therefore recommended that government regulation (a combination of Commonwealth, State and Territory legislation and of new and existing regulation) be used to manage the capture, transport, storage and post-closure phases of carbon dioxide geosequestration. As described in the recommendations under each issue, in the context of this Council of Australian Government Regulatory Impact Statement, government regulation is not limited to regulation. In some areas, it may be appropriate to consider co-regulation as a more efficient and cost effective alternative.

7. CONSULTATION

Ongoing consultation is occurring with relevant stakeholders including Commonwealth agencies, State Governments, industry and research organisations, relevant international agencies and environmental non government organisations. This consultation takes place within the following groups:

- Commonwealth Inter-departmental Committee – established in February 2003 and consists of eleven Commonwealth government agencies.
- Carbon Dioxide Geosequestration Regulatory Reference Group – established in September 2003 and consists of twenty two member agencies including State and Commonwealth government agencies and industry representatives.
- Carbon Sequestration Leadership Forum – established in June 2003 and consists of sixteen member countries.
- Australian Carbon Sequestration Leadership Forum Reference Group – established in February 2003 and consists of twenty nine member agencies including State and Commonwealth government agencies and industry representatives.

Through these various groups and associated consultation with government agencies and industry, consensus has been reached on the proposed draft principles that is intended to form the basis of government regulation in each jurisdiction. Additional consultation subject to public consultation with non government organisations and the community is currently being progressed.

Targeted consultation meetings with relevant non-government organisations were conducted with the following groups:

- Climate Action Network Australia

- Australian Conservation Foundation
- Western Australian Conservation Council
- Environment Victoria
- Greens Party Western Australia

While only a small number of relevant non-government organisations have been consulted in the first stage in establishing a regulatory framework, the five organisations above are key non-government organisations on carbon dioxide geosequestration. Climate Action Network Australia is the peak non-government organisations body with responsibility for climate change issues. The Western Australia Conservation Council is an umbrella organisation of nearly seventy affiliated conservation groups from throughout Western Australia, and Environment Victoria is the State's peak non-government environment organisation.

These sessions included:

- Brief explanation of carbon dioxide geosequestration technologies;
- Overview of Ministerial Council on Minerals and Petroleum Resources Regulatory Working Group work to date
- Explanation of proposed regulatory principles;
- Next steps, including continued consultation when implementing regulation/legislation; Comments and questions.

The main comments and concerns raised at the non-government organisations consultations are as follows:

- Generally, non-government organisations are not totally opposed to carbon dioxide geosequestration, but have issues with the use of sequestration versus renewables.
- Carbon dioxide geosequestration is not being discussed enough in the community. The government representatives explained the information/consultation sessions that have been proposed and will take place in the near future.
- Cost of carbon dioxide geosequestration as compared to sources of renewable energy and how the draft principles fit with Australia's international obligations. Both of these issues are currently being addressed by Commonwealth government agencies.
- Non-government organisations recommended that guidelines be implemented before carbon dioxide geosequestration projects go ahead.
- Need for early establishment of science to ensure carbon dioxide geosequestration works. Need for transparency in the carbon dioxide geosequestration process. This view was shared by the government representatives present.
- Long term liability issues and which government would be responsible post closure. The draft principles as they stand however do not go into that level of detail as they are only at the first draft initial stage. Further consideration is needed regarding specific details of principles.
- Questions about the life cycles of projects and leakage rates were raised. The length of the life cycle of a project would be determined on a case by case basis; however work is still being done on how long the carbon dioxide can be contained in a formation. The draft principles do not go into enough detail to state the specific leakage rate that may be allowable. However, existing regulations will be considered as a starting point.

8. IMPLEMENTATION AND REVIEW

- Implementation of principles and future consideration of government regulation will be left to the discretion of each jurisdiction;
- Processes for amendment of regulation will be outlined; and
- The Ministerial Council on Minerals and Petroleum Resources should review the regulatory framework to ensure that it is effective and efficient in practice and the principles are being interpreted consistently.

<u>**ATTACHMENT A**</u>

Draft Regulatory Guiding Principles

- The Carbon dioxide Geosequestration Regulatory Reference Group has compiled a broad document titled Draft Regulatory Guiding Principles for Carbon Dioxide Geosequestration. This document focuses on seven key areas relevant to of carbon dioxide geosequestration. These are the principles that MCMPR have agreed to and they will be considered by stakeholders during consultation sessions.

The principles are as follows:

Access and Property Rights

Access to suitable geological structures for carbon dioxide geosequestration and to surface injection sites should:

- *be based on established legislative and regulatory arrangements, custom and practice;*
- *recognise and adequately account for the interests of other stakeholders, including existing and future surface and subsurface rights-holders; and*
- *accommodate the likely evolution of multi-user geosequestration infrastructure and facilities.*

Legislation granting surface and subsurface rights for carbon dioxide geosequestration should:

- *provide certainty to rights-holders of their entitlements and obligations;*
- *guarantee security of access over time and in relation to the volume of gas that may be stored; and*
- *define the "geosequestration gas" so that it can be legally injected into the storage site.*

In granting rights to inject carbon dioxide into subsurface formations, governments should give due consideration to land use planning issues likely to arise as a consequence of having carbon dioxide injected into that part of the subsurface.

Long Term Responsibilities

Responsibility and associated liabilities should remain with the project proponent until the relevant government is satisfied to a high degree of certainty that:

- *future land-use objectives defined at the time of project approval have been met; the residual risks of leakage and liability are acceptably low; and*
- *the ongoing costs associated with the site are acceptably low or are otherwise appropriately managed (for example through financial assurances, instruments and trust funds).*

Following closure, primary responsibility for the site will lie with government, although some residual liability may remain with the proponent.

The scope and nature of these residual responsibilities should be resolved upfront to the extent possible, recognising that responsibility depends on individual circumstances of each case. These liabilities should be determined and negotiated with the proponent on a project-by-project basis.

There may be a need to manage any residual liability that remains with the proponent e.g. through means such as ongoing indemnities, insurance policies or trust funds.

Environmental Issues

Regulation of carbon dioxide geosequestration should be based on a science-based assessment of the environmental risk, be based on best practice, be nationally consistent and be subject to regular review as new information becomes available.

Regulation of carbon dioxide geosequestration should aim to instil community confidence that the environment will be protected, provide industry with the certainty required to undertake projects, avoid overregulation that would unnecessarily impinge on project viability and be based as far as possible on existing regulatory frameworks.

Authorisation and Compliance

Existing legislation (Acts, Regulations, guidelines) such as those for chemical manufacturing, electricity generation, pipeline transportation, petroleum and mining exploration and development, environmental aspects, operational health and safety, storage of hazardous waste, that relate to activities under carbon dioxide geosequestration should be identified along with the parts of that legislation that applies to carbon dioxide geosequestration; and this existing legislation could be modified and augmented as needed to achieve an integrated carbon dioxide geosequestration framework.

National consistency should be aimed for in Commonwealth and State legislation relating to carbon dioxide geosequestration. There should be agreed national protocols and guidelines to be used by all jurisdictions. Commonwealth and State agencies should authorise carbon dioxide geosequestration activities and ensure compliance in their jurisdictions. A single industry code of conduct throughout Australia should be investigated.

Monitoring and Verification

For the purposes of monitoring and verification, a regulatory framework should:

- *Provide for the generation of clear, comprehensive, publicly accessible, timely and accurate information that is used to effectively and responsibly manage environmental, health, safety and economic risks and to ensure that set performance standards are being met; and*
- *Determine to an appropriate level of accuracy the quantity, composition and location of gas captured, transported, injected and stored and the net abatement of emissions. This should include identification and accounting of fugitive emissions.*

Transportation

The transport of carbon dioxide in pipelines has many similarities to the pipeline transport of chemical and petroleum products and therefore the same regulatory principles relating to access, safety and environment should apply. However where there are differences these must be recognised.

Similarly existing legislation should be applied and if necessary modified for the transport of carbon dioxide by road, rail and sea.

Financial Issues

Consistent with the need to create and maintain public confidence, all fiscal and regulatory measures must be subject to a least cost approach:

- *regulatory processes should preserve the international competitiveness of Australian industry;*
- *wherever practicable established regulatory principles and procedures should be used in preference to introducing new ones; and*
- *fiscal burdens imposed on any jurisdiction or industry as a result of regulatory processes or outcomes should be avoided wherever possible.*

Recognition should be made (e.g. via a policy statement) that the capital and operating costs of capture and storage can be substantially incorporated into the existing fiscal system and accounting principles framework on the same basis as existing business expenditure. Where changes need to be made, they should not discriminate against this form of investment.

It should be recognised that capture and storage technologies enable the generation of national, global and intergenerational public goods. Given that these technologies in their early stages are likely to be marginally commercially viable, consideration may need to be given to how these public goods are incorporated into commercial decision making so as to arrive at nationally optimal levels of investment and timing of new investment.

ATTACHMENT B

Environmental impacts and risks of CO_2 geosequestration

The environmental issues and risks associated with CO_2 and its interaction with the atmosphere, soils, water and the biota are relatively well understood. However further research and monitoring is required to fully understand the issues that may be associated with long term geological storage.

CO_2 is a naturally occurring constituent of the biosphere that is essential to all life forms. It is generally regarded as safe, however environmental impacts, including biological toxicity, may arise where CO_2 is present in unnaturally high concentrations. The degree of potential environmental impact depends on the degree of concentration and the characteristics of the receiving environment, including the composition of the biota in that environment.

Apart from climate change impacts, a CO_2 release to the atmosphere poses little environmental danger provided that it is able to disperse quickly to relatively normal concentrations. A hazard can arise if CO_2, which is denser than air, is allowed to accumulate in low-lying, confined or poorly ventilated spaces.

The environmental impacts of CO_2 in-situ in geological formations will depend on the chemistry of the formations and the integrity of the encapsulating structures. Potential chemical interactions between the CO_2 and the surrounding geology are the subject of ongoing research. However negative environmental impacts of CO_2 may not arise unless it migrates beyond the anticipated containment zone. Potential environmental impacts associated with migration beyond the containment zone would depend on where the CO_2 migrates to, over what time-frame and in what quantities. The possible impact on deep sub-surface nanobes has been raised as an issue and should be the focus of future research. Environmental issues requiring further clarification include:

- the potential implications of mixed gas streams (i.e. in the event of an unplanned release from either the capture, transport or injection stages of a CCS project);
- the long-term implications of CO_2 in-situ in geological structures;
- the environmental implications of CO_2 migration or escape from containment zones and the risk of these events occuring; and,
- the environmental implications of the storage of non-pure CO_2.

CO_2 capture stage

The technologies used for CO_2 separation or capture are well understood and used in a range of industrial processes. Although the Subgroup was unable to identify any issues that would differentiate the environmental risks of CO_2 separation/ capture for geosequestration purposes from gas separation for other purposes, a number of issues require further investigation. Issues requiring further investigation include the risks that might be posed by leaks at the capture point, the effect of mixed gases at the capture point and the impact of chemicals used in capture. The issue that may differentiate any risks at the capture stage of CCS projects from CO_2 capture/separation for other purposes is that of scale. However it is probable that plant safety rather than environment would be the primary issue at the capture stage.

CO_2 transport stage

The environmental risks associated with transport of CO_2 via pipeline construction activities would be similar for any pipeline carrying compressed gases (e.g. natural gas). Because CO_2 is heavier than air and toxic in high concentrations, the specific dispersion characteristics of CO_2 would require separate modelling to evaluate the pattern of potential impacts in the event of pipeline failure. The overall risks from pipeline transport are not significantly different from a range of pipelines already in operation. The environmental risks of transport of CO_2 by road, rail or ship would be similar or less than those arising from the movement of other compressed and liquefied gases.

CO_2 injection stage
The potential environmental impacts of wells drilled for CCS projects would be similar to those for oil and gas wells. There may be subtle differences in the requirements for compressor stations and related infrastructure. The potential for gas cloud releases to be undetected if injection fails may be increased for CO_2 due to its non-odorous nature, however this risk can be easily managed with adequate monitoring at the injection point.

CO_2 storage stage
Potential impacts of CO_2 storage in a geological structure are related primarily to the potential for it to escape over time. The leakage of CO_2 may possibly occur via pre-existing faults and fissures or as a result of pressurisation of the structures. It is currently difficult to quantify with confidence the likelihood of unplanned releases of CO_2 from geosequestration sites. This is due to the lack of detailed research and field trials into CO_2 geosequestration and the difficulty of assigning generic risks to situations that are likely to vary considerably from site to site. Further research combined with test work and trials of specific reservoirs will need to be conducted to enable risk profiles, and eventually quantitative risk estimates, to be made.

There is a slight risk of CO_2 migrating out of the storage reservoir and into one or more surrounding geologic formations. This in turn could result in the contamination of freshwater aquifers, and/or interference with the activities at producing oil/gas reservoirs or coal mines. In the case of CO_2 injection into deep saline formations, there is also the small possibility that displaced brine could contaminate groundwater. The contamination of freshwater aquifers could be caused by vertical migration of stored CO_2. Buoyancy forces, caused by the density difference between the injected supercritical CO_2 and the formation waters, will tend to drive stored CO_2 upward. If the formation is not a geologic trap or not adequately sealed by an impermeable caprock, CO_2 could leak from the storage reservoir.

There is then the potential for the vertically migrating CO_2 to dissolve in shallow aquifer waters, form carbonic acid and lower the aquifer water pH, which in turn could result in the mobilization of heavy metals and/or the leaching of nutrients. In a worst-case scenario, the contamination of a freshwater aquifer could exclude its use for drinking or irrigation supplies. CO_2 migration within the subsurface also has the potential to contaminate energy and mineral resources as well as pose an occupational safety hazard for mining and exploration activities. While there are still uncertainties with regards to CO_2 migration, significant advances in understanding fluid behaviour and formation integrity have been made. Further, enhanced oil recovery (EOR) operations using CO_2 floods have experienced no significant losses of CO_2 to other subsurface zones and as such give us some confidence that CO_2 migration risks may be low. At the same time, however, it is to be noted that EOR activities cannot simulate the movement of CO_2 over the time frames required for effective storage.

Groundwater contamination could also result from the displacement of brine in the case of CO_2 injection into deep saline formations. Brines displaced from deep saline formations by injected CO_2 could, potentially, contaminate shallower freshwater aquifers by increasing their salinity and thereby make them unsuitable as a source of potable water. In the worst case, infiltration of brine into groundwater or the shallow subsurface could also restrict or eliminate agricultural use of land and/or impact wildlife habitat. It is to be stressed, however, that North American experience with deep well injection of fluids, at rates roughly comparable to the rates at which CO_2 would be injected if geosequestration was widely adopted, has found that groundwater contamination from brine displacement is rare, and that one may therefore expect that contamination arising from large-scale CO_2 storage activities would also be rare.

Health and Safety Risks

The risk to humans from the pipeline transport, injection and storage of CO_2 as part of geosequestration projects would be minimal. The transport of CO_2 by pipeline and the injection of CO_2 into geologic reservoirs has been occurring for many years in the United States, as well as in some other countries, as part of enhanced oil recovery (EOR) and acid gas injection (AGI) operations. This experience has led to the tools and expertise needed for CO_2 pipeline transport and CO_2 injection to be managed safely.

The health and safety risks associated with CO_2 storage, although considered small, are characterised by a greater degree of uncertainty. This is first due to the fact that once the CO_2 enters the geologic reservoir, its fate is transferred from largely human control to a natural system. Second, unlike for CO_2 pipeline transport and CO_2 injection, EOR using CO_2 floods and AGI do not provide a great level of understanding or expertise in safe and effective management of CO_2 storage; the quantities of CO_2 stored are smaller and the time periods involved are shorter than required for geologic carbon sequestration.

Through the development of improved models of the long-term behaviour of CO_2 in reservoirs and the study of analogues such as natural CO_2 deposits, scientists are however gaining a better understanding and further minimizing the risks of CO_2 storage. It should be noted that the potential health and safety impacts associated with a CO_2 leak from the offshore CO_2 pipeline transport, injection and storage will be negligible, although there is the possibility of minimal damage to the local marine environment.

Carbon dioxide (CO_2), a naturally-occurring constituent of air that is essential to all life forms, is a non-toxic, inert gas and is generally regarded as safe. At elevated concentrations, however, CO_2 can cause harm to humans. The effects of elevated CO_2 levels depend not only on the concentration but also the duration of exposure. The ambient concentration of CO_2 in the atmosphere is currently about 370 parts per million (ppm) or less than 0.04%. For humans, there are no adverse health effects for CO_2 concentrations up to 3%. While some discomfort occurs for concentrations between 3% and 5%, it is only for concentrations above 5% that there are serious, possibly fatal, consequences. At concentrations above 25% to 30%, loss of consciousness occurs within several breaths and death quickly thereafter.

The risk of a CO_2 leak from a pipeline and then humans being exposed to harmful levels of CO_2 is very minimal. According to the United States Department of Transportation's Office of Pipeline Safety, onshore pipeline failure most often occurs as a result of external activities such as construction and farming. In the case of onshore pipeline failure, the amount of CO_2 escaping will be limited by the use of gas detection and pressure monitoring systems, and automated shutdown valves. Typically, the escaping CO_2 will then be diluted to safe levels by entraining air within minutes of the release. It is to be noted that, since 1990, there have been no injuries or fatalities associated with incidents involving CO_2 pipelines in the United States.

The potential risk to human health and safety from CO_2 injection is primarily of an occupational nature. The most common cause of CO_2 exposure during the operational phase is well-head failure that results in CO_2 leakage. In the majority of cases, the problem is quickly identified and the well promptly repaired or plugged. A threat to worker safety would occur where the leak went undetected and CO_2 was allowed to accumulate in a confined space. While such incidents may pose a safety risk to workers in the immediate vicinity of the well, the risk to the general public should be considered negligible. Well failure of this type is most often caused by poor engineering practices.

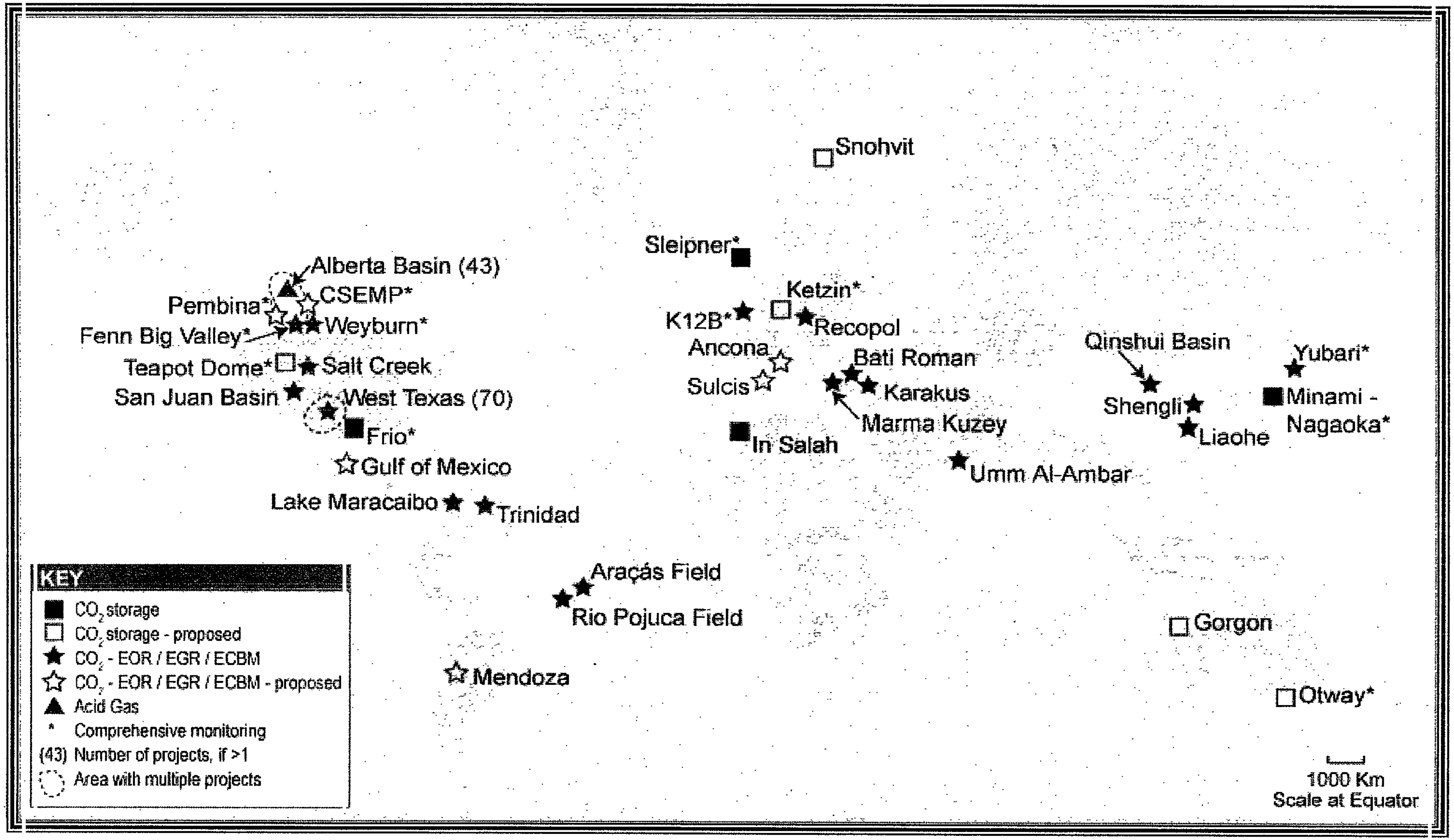
It is possible, though quite unlikely, that slow releases of CO_2 from a geologic CO_2 storage site could pose a safety threat. Potential sources of slow CO_2 leaks include transmissive faults or fractures, poorly sealed injection wells and incompletely plugged abandoned wells.

The majority of leaks such as these are likely to go unnoticed as they diffuse in the atmosphere in similar fashion to CO_2 fluxes from natural earth degassing, biological respiration and organic matter decomposition. Nonetheless, there is the slight possibility that certain topographies or confined structures may act to concentrate the CO_2 to dangerous levels.

There are three main concerns associated with geosequestration in terms of health and safety:

1. The transport of CO_2 by pipeline presents a potential safety hazard to workers and the general public (negative externality).
2. The injection of CO_2 into a geologic reservoir presents a potential safety hazard to workers (negative externality).
3. The storage of CO_2 in a geologic reservoir presents a potential safety hazard to the general public (negative externality).

CO_2 CAPTURE AND STORAGE ACTIVITIES



Courtesy of the CO2CRC

THE AMERICAS

CO_2 capture commercial projects		
Shady Point Power Plant	The plant generates electricity and produces food-grade CO_2 from flue gases	Oklahoma Currently in use
Warrior Run Power Plant	The plant generates electricity and produces food-grade CO_2 from flue gases	Cumberland, Maryland Currently in use
Bellingham Cogeneration Facility	The plant generates electricity and produces food-grade CO_2 from flue gases	Bellingham, Massachusetts Currently in use
Prosint Methanol Production Plant	The plant uses an MEA-based scrubber to capture CO_2 from boiler flue gas for use in beverage production	Rio de Janeiro, Brazil Currently in use
IMC Global Inc. Soda Ash plant, Trona	Part of this large soda ash production plant comprises a coal-fired power generation plant featuring CO_2 capture from the flue gas. The CO_2 is used for the carbonisation of brine	Trona, California Currently in use
Great Plains Synfuels Plant (GPSP) CO_2 Capture and Compression	The GPSP is the only commercial-scale coal gasification plant in the United States that manufactures natural gas. Located five miles northwest of Beulah, North Dakota, the GPSP has been owned and operated by Dakota Gasification Company (DGC), a subsidiary of Basin Electric Power Cooperative, Bismarck, North Dakota, since 1988. This $2.1-billion plant began operating in 1984. Using the Lurgi process, the GPSP gasifies lignite coal to produce valuable gases, liquids, and by products (including CO_2). Delivers CO_2 to the Weyburn Unit in Canada	Five miles northwest of Beulah, North Dakota Currently in use
Demonstration Projects		
Weyburn Enhanced Oil Recovery Project	The location of the project is the Weyburn oilfield in Canada, first discovered in 1954. In October 2000, EnCana began injecting significant amounts of carbon dioxide into a Williston Basin oilfield (Weyburn) in order to boost oil production. Overall, it is anticipated that some 20 Mt of carbon dioxide will be permanently sequestered over the lifespan of the project. The gas is being supplied via a 205 mile long pipeline (costing 100 million US$) from the lignite-fired Dakota Gasification Company synfuels plant site in North Dakota.	Williston Basin, North America Currently in use
Acid Gas Injection Projects in Canada	Sour natural gas contains hydrogen sulphide (H2S) and carbon dioxide (CO_2); both require removal prior to transportation and sale. The high capital and operating costs of sulphur conversion plants and restrictions on flaring of acid gases has resulted in the development of an alternative process for their disposal termed acid gas re-injection.	Canada Currently in use
FutureGen	A US$1 billion, 10 year research project to build the world's first coal-fuelled plant to produce electricity and hydrogen with zero emissions. The FutureGen plant will establish the technical and economic feasibility of producing electricity and hydrogen from coal while capturing and storing CO_2 generated in the process (approximately 1-2 million metric tons/year).	U.S.A. Proposed

Weyburn II CO_2 Storage Project	This is a commercial-scale project that will utilize CO_2 for enhanced oil recovery at a Canadian oil field. The first phase began in 2000 and is scheduled to conclude in June 2004. Phase II will involve transport of 95 million cubic feet per day of 95% pure CO_2 from a North Dakota coal gasification facility through a 320-kilometer pipeline to an oil field in southern Saskatchewan, where it will be injected into the field for enhanced oil recovery. CSLF Endorsed Project	The Weyburn oil field in southern Saskatchewan, Canada Currently in Phase II
CO_2 Capture R&D Projects and Research Areas		
International Test Centre (ITC) for CO_2 Capture	The project is examining improvements to the chemical absorption process (using a variety of solvents) as well as developing new technology and carrying out technology screening studies. CSLF Endorsed Project	Boundary Dam Power Plant University of Regina Currently Underway
Advanced CO_2 Separation and Geologic Storage Technologies	The project will demonstrate the feasibility of capturing CO_2 from a variety of fuel types and combustion sources and storing it in un-minable coal seams and saline aquifers	North America Proposed as at May 2004
CO_2 Separation Using Thermally Optimized Membranes	Los Alamos National Laboratory and Idaho National Engineering and Environmental Laboratory are collaborating with the University of Colorado, Pall Corp. and Shell Oil Co, in a 3-year project to develop an improved high-temperature polymer membrane for separating carbon dioxide from methane and nitrogen gas streams.	Los Alamos Project should be completed
Dry Redeemable CO_2 Sorbets	The project will investigate and develop a separation technology that uses a redeemable, sodium-based sorbet to capture CO_2 from flue gas	North America Currently underway
CO_2 Dioxide Process for Gas Separation from Shifted Singes	The project will develop a process that captures CO_2 by combining it with water at low temperature and high pressure, thus forming CO_2/water hydrates	North America. Project in preparation
Physics and Chemistry of Coal-Seam CO_2 Sequestration and Coaled Methane Production	The goals of the research are to ultimately provide guidelines for drilling of new CBM production wells and enable field engineers to determine if cases of poor CO_2 sequestration and/or low methane productivity can be attributed to non-ideal coaled temperatures/depths or, perhaps, to other factors.	North America Currently being researched
A Novel CO2 Separation System	The project aims to develop a novel electricity generation and CO_2 separation system based on the reduction of a metal oxide	North America. Project in preparation
Vortex Tube Design and Demonstration for the Removal of Carbon Dioxide from Natural and Flue Gas	The project is studying CO_2-liquid absorption kinetics, solvent generation requirements, and scale up parameters for Vortex Tube contactors	North America. Project is currently being undertaken
Carbon Dioxide Capture by Absorption with Potassium Carbonate	The project will develop an alternative solvent that captures more CO_2 whilst using 25-50% less energy than conventional, state-of-the-art MEA (monoethanol amine) scrubbing	Austin, Texas Project in preparation

Development of oxy-fuel boiler concept	The project will develop a novel oxy-fuel boiler - a new design that incorporates a membrane to separate oxygen from the air which is then used for combustion	Tonowanda, New York Project in preparation
Development of inorganic palladium-based membranes	The project is developing an advanced palladium-based membrane for the reforming of hydrocarbon fuels	North America. Project is currently underway
Development of a computer model for the evaluation of different CO_2 capture from power plant options	The project is developing a model for the systematic evaluation and comparison of different technological options for CO_2 capture from power plant	Pittsburgh Project is currently underway
Detailed cost analysis of three options for CO_2 capture from an existing coal-fired power plant	The project is examining several technological options for the capture of CO_2 from coal-fired power plants	North America Project completed
Clean Energy Systems (CES), Kimberlina demonstration plant	CES is a privately funded company based in California that is developing an oxy-combustion process based on rocket propulsion technology. The company is conducting a series of developments aimed at demonstrating a complete oxy-combustion, zero-emissions power generation system. The first step involved the development of a high-pressure gas generator (burner) that burns natural gas with pure oxygen in the presence of a large water recycle to control flame temperature. The gas generator produces a mixture of high-pressure steam and CO_2 that drives an expansion turbine to generate power. The second part of the development is to demonstrate the complete power cycle by adding the turbine, condensing the steam, recycling the condensate, and capturing the CO_2. The final stages of development will involve developing turbines capable of operating at higher temperatures and pressures in order to maximise the efficiency of the power cycle. Successful tests in December 2004 of up to three hours duration have been achieved on a gas generator of 20 MW thermal capacity. Work continues to test the long term operation of the gas generator and the full recirculation of the water.	CES Base at Rancho Cordova CA, USA. Demonstration facility at Kimberlina Power Plant, near Bakersfield, CA, USA. Project is currently underway
U.S. Department of Energy Carbon Sequestration Regional Partnerships	On November 21, 2002, U.S. Secretary of Energy Spencer Abraham announced plans to create a national network of public-private sector partnerships that would determine the most suitable technologies, regulations, and infrastructure needs for carbon capture, storage and sequestration in different areas of the country. CSLF Endorsed Project	North America Project is currently underway

CANMET Energy Technology Centre (CETC) R&D Oxyfuel Combustion for CO_2 Capture	The CANMET Energy Technology Centre's (CETC's) pre-competitive collaborative R&D program in Ottawa, tackles the development of combustion and pollution abatement technologies for fossil fuels in oxygen (O_2) and recycled flue gas (RFG) atmospheres for the purpose of producing high purity CO_2 streams that are capture ready for transport and storage. The technique, often called oxyfuel combustion, has been shown to be a promising approach that can be used in both retrofit and new applications to process heaters, furnaces and power plants that burn fossil fuels for energy or power production. Oxyfuel combustion has the capability of generating flue gas with purity that ranges from 95-98 vol% (dry basis) of CO_2 at the expense primarily of oxygen generation and use in a combustion application. CSLF Endorsed Project	Near Ottawa Canada Project is currently underway
CO_2 Separation from Pressurized Gas Stream	This is a small-scale project that will evaluate processes and economics for CO_2 separation from pressurized gas streams. Testing will utilize membranes developed in Japan at a test facility near Pittsburgh, Pennsylvania. The proposed project, which began in 2003 and is scheduled for completion in 2006, will evaluate primary promising new membranes under atmospheric pressure. The next stage is to improve the performance of the membranes for CO_2 removal from the fuel gas product of coal gasification and other gas streams under high pressure. CSLF Endorsed Project	Test facility near Pittsburgh, Pennsylvania, United States. Project is currently underway
Sorbent Development for Carbon Dioxide Separation and Removal – Pressure Swing Adsorption & Temperature Swing Adsorption	Selective separation of CO_2 can be achieved by the preferential adsorption of the gas on high-surface area solids. Conventional physical adsorption systems are operated in pressure swing adsorption (PSA) and temperature swing adsorption (TSA) modes. In PSA, the gas is absorbed at a higher pressure. Then pressure is reduced to desorb the gas. In TSA, the gas is absorbed at a lower temperature. Then, the temperature is raised to desorb the gas. PSA and TSA are some of the potential techniques that could be applicable for removal of CO_2 from high-pressure gas streams, such as those encountered in Integrated Gasification Combined Cycles (IGCC).	North America. Project status not available
Fuel-Flexible Gasification-Combustion Technology for Production of H_2 and Sequestration-Ready CO_2	GE-EER has developed an innovative, fuel-flexible advanced gasification-combustion (AGC) concept that produces three product streams: H_2, CO_2, and O_2-depleted air.	North America Project completed
Greenhouse Gas Emissions Control by Oxygen Firing in Circulating Fluidized Bed Boilers	The overall project goal is to determine if carbon dioxide can be recovered at an avoided cost of $10/ton (or less) of carbon avoided, using an existing or newly constructed circulating fluidised-bed (CFB) combustor while burning petroleum coke, coal or biomass fuels with a mixture of oxygen and recycled flue gas, instead of air.	North America Project completed
Recovery & Sequestration of CO_2 from Stationary Combustion	Physical Sciences Inc. (PSI), Aquasearch, and the Hawaii Natural Energy Institute at the University of Hawaii are jointly developing technologies for recovery and sequestration of	North America Project completed

Systems by Photosynthesis of Microalgae	CO_2 from stationary combustion systems by photosynthesis of microalgae.	
Canadian Clean Power Coalition	An association of Canadian utilities and coal producers, Basin Electric Power Cooperative from the state of North Dakota and the US Electric Power Research Institute, the Coalition is implementing a program focused on "securing a future for coal-fired electricity generation."	North America Project is underway
CO_2 Capture for PC-Boiler Using Flue-Gas Recirculation: Evaluation of CO_2 Capture/Utilization/Disposal Options	This project will provide the power industry with a low-cost retrofit system that could remain in service during future upgrades at the power plant. The captured CO_2 can be used for EOR or sequestered. Overall, this project addresses both design and full energy-cycle issues pertaining to our current coal-fired power plants.	North America Project status not available
CO_2-Enhanced Coal Bed Methane Recovery Project (Alberta ECBM)	The project aims to reduce greenhouse gas emissions by sub-surface injection of CO_2 into deep coal beds and to enhance methane recovery factors and production rates as a result of CO_2 injection. CSLF Endorsed Project	Various Locations, North America Project is underway
Field Test of CO_2 sequestration into the Frio Formation, Texas, U.S.A. – Component of the GEO-SEQ project	The project demonstrated the process of sequestration in a brine formation setting in Texas; where very large scale sequestration may be needed to significantly offset anthropogenic CO_2 releases. CSLF Endorsed Project	Liberty County, Texas, U.S.A. Project is underway

EUROPE

CO_2 capture commercial projects		
Sleipner Project	The storage in underground geological formations is an attractive option for the removal, essentially permanently, of very large quantities of CO_2 generated from a variety of industrial operations. One promising technological option is that of capturing CO_2 and injecting it into deep underground saline aquifers, found in many parts of the world. One such formation is located above the Sleipner field, one of the larger natural gas producers in the North Sea.	North Sea, Norway Project is underway
Hammerfest Natural Gas Power Plant with CO_2 and NOx capture	Gas fired power plant with CO_2 capture. Energy efficient capture of CO_2 takes place in a high pressure environment with high CO_2 concentration. The power plant technology is based on well proven and commercially available components.	Hammerfest, Norway Project is in preparation
	Demonstration Projects	
Various Worldwide CO_2-Enhanced Oil Recovery Operations	This entry provides information on existing CO_2-EOR operations in North America and Worldwide.	Texas, Colorado, Oklahoma, Louisiana Project Status is not available

Sleipner Project	The storage in underground geological formations is an attractive option for the removal, essentially permanently, of very large quantities of CO_2 generated from a variety of industrial operations. One promising technological option is that of capturing CO_2 and injecting it into deep underground saline aquifers, found in many parts of the world. One such formation is located above the Sleipner field, one of the larger natural gas producers in the North Sea.	North Sea Project is underway
Snohvit (Snow White) LNG Project	In October 2001, Statoil and its partners filed a formal development plan for the Snøhvit Field, the first offshore gas field found in the Barents Sea and the point of supply for Europe's first LNG export project.	Snohvit Field, near Norway Project is underway
CO_2 Re-use through Underground Storage (CRUST)	The project is examining issues leading to the creation of an underground CO_2 buffer facility, capable of providing subsequently the stored CO_2 for commercial application	Netherlands, government is primary financial supporter. Project completed
CO2STORE	The CO2STORE Project will utilise the knowledge gained from the SACS project to study new CO_2 storage opportunities in Europe. It is planned to investigate the properties of new storage reservoirs in Denmark, Germany, Norway, and the UK. The project will also predict the long term fate of CO2 at Sleipner (Utsira reservoir) and do further work on seismic and gravimetry as monitoring techniques. CSLF Endorsed Project	Denmark, Germany, Norway, and the UK Project is underway
Offshore re-injection of CO_2 into a depleted gas field in the North Sea	Gaz de France Production Nederland B.V. (GPN) currently produces natural gas from various gas production installations on the Dutch continental shelf of the North Sea. The gas produced at one of GPN's existing offshore platforms contains a relatively large percentage of CO_2. This CO_2 is currently separated from produced natural gas and is released in the atmosphere. This project focuses on re-injecting this CO_2 for storage and Enhanced Gas Recovery.	North Sea, Netherlands. CO_2 is injected on one of GNP's offshore platforms. This platform, K12-B (operational since 1987) is situated at about 100 km from the coast NW Den Helder. Project is underway.
CO_2 Capture R&D Projects		
CO_2 Capture Project (CCP)	The project is a joint initiative carrying out a development programme leading to the reduction in the cost of CO_2 capture from combustion sources, followed by its safe, economical underground storage	Various Locations, Europe. Project underway
NorCap Project	The project is developing and testing promising technologies for reducing the costs of separating and capturing CO_2 from fossil fuel combustion sources, plus its transport and storage	Norway. Project underway
Power Generation with CO_2 Capture	The project aims to improve the energy conversion of natural gas in power cycles that significantly reduce CO_2 emissions.	Norway. Project underway
Future Energy Plants	The project is developing and testing a concept for co-production of power and hydrogen from natural gas with integrated CO_2 capture.	Norway. Project underway

Separation of CO_2 Using Membrane Gas/Liquid Contactors	N/A	Norway. Project status not available
Advanced Zero Emissions Power Plant (AZEP)	This multi-partner project is developing an advanced, gas turbine-based power generation system that will produce no emissions to atmosphere	Europe – exact country unclear. Project underway
Development of the HiOx Technology	The project is developing a power generation technology whereby oxygen if firstly separated from the air, followed by the combustion of natural gas and concentrated oxygen in an atmosphere of recirculated exhaust gases. A concentrated CO_2 stream is produced	Norway Project underway
Grangemouth Advanced CO_2 Capture Project (GRACE)	Cost effective environmental abatement technologies for power production.	UK and Europe – exact countries unclear. Project completed
CO_2 Capture, Transport and Storage in the Netherlands (CATO)	Several institutions in the Netherlands have worked on a number of aspects or components of Clean Fossil Fuel (CFF) systems. Often these institutions have very different perspectives but CATO aims to streamline the objectives and perspectives of these activities and integrate them into a comprehensive programme and network, closely connected to international networks in which the partners of CATO participate.	Netherlands Project underway
CASTOR, "CO_2 from Capture to Storage"	The project's objective is to make possible the capture and geological storage of 10% of European CO_2 emissions, or 30% of the emissions of large industrial facilities (mainly conventional power stations). To accomplish this, two types of approach must be validated and developed: new technologies for the capture and separation of CO_2 from flue gases and its geological storage, and tools and methods to quantify and minimize the uncertainties and risks linked to the storage of CO_2. In this context, the Castor project program is aimed more specifically at reducing the costs of capture and separation of CO_2 (from 40-60€/ton CO_2 to 20-30€/ton), improving the performance, safety, and environmental impact of geological storage concepts, and, finally, validating the concept at actual sites. CSLF Endorsed Project	Europe – various including Denmark. Project underway
Enhanced Capture of CO_2 (ENCAP)	The ENCAP project is a research project for the development of Pre-combustion technologies for Enhanced Capture of CO_2 in large power plants. CSLF Endorsed Project	Sweden. Project underway
Carbon sequestration in Sotacarbo project on hydrogen and energy production from Sulcis coal (SEPCA)	Sotacarbo project involves the design, construction and experimentation of a test facility for production of clean fuel gas such, hydrogen, energy from Sulcis coal and as well as CO_2 capture and storage.	Italy. Sotacarbo Research Centre, which is under construction in Carbonia, South East Sardinia. Project in preparation

Innovative In Situ CO_2 Capture Technology for Solid Fuel Gasification	The proposed project aims on exploiting this potential to produce a gas stream in the re-generation process consisting of >95% CO_2.	Germany, Poland, Greece, Finland, Northern Ireland, Spain, Austria Project underway
CO2NET	CO2NET is the European Network of researchers, developers and users of CO_2 technology, facilitating co-operation between these organisations and the European projects on CO_2 geological storage, CO_2 capture and zero emissions technologies.	Europe – exact location unknown. Project underway
CO_2 Capture Project (CCP) – Phase 2	The CO_2 Capture Project is an international effort funded by eight of the world's leading energy companies. This project intends to address the issue of reducing emissions in a manner that will contribute to an environmentally acceptable and competitively priced continuous energy supply for the world. The project seeks to develop new technologies to reduce the cost of capturing CO_2 from combustion sources and safely store it underground. These technologies will be applicable to a large fraction of CO_2 sources around the world - such as power plants and other industrial processes. Implementing these new technologies during this decade will reduce the impact of continued fossil energy use while cleaner energy sources are being developed. CSLF Endorsed Project	Europe (EU Commission and Norway) and North America Project underway
CO2SINK	This project is located at Ketzin some 25 km West of Berlin, Germany. It is planned to inject approximately 30,000 tons of CO_2 injected into an aquifer which underlies a redundant gas storage reservoir. The target reservoir lies between 600and 700m. A variety of techniques will be deployed to characterise the site prior to CO_2 injection and some novel down-hole monitoring techniques will be developed and tested. A detailed risk assessment will be carried out prior to start of the experiment as well as a process of full consultation with local authorities, residents and other interested stakeholders. CSLF Endorsed Project	Ketzin near Potsdam, Brandenburg, Germany Project underway
CO2GeoNet	The Network focus is on the geological storage of CO_2 as a greenhouse gas mitigation option. It has several objectives over the 5 year period of EC funding for integration. CSLF Approved	Europe (EU Commission) Project underway

ASIA

CO_2 capture commercial projects		
Sumitomo Chemicals Plant, Chiba, Japan/Kokusai Carbon Dioxide	The plant generates electricity and produces food-grade CO_2 from flue gases	Chiba, Japan. Project is ongoing
Petronas Fertilizer Co, Malaysia	The plant features an amine-based scrubbing system, operating with a novel solvent, as part of its operations producing ammonia and urea for the fertiliser market	Malaysia Project underway

The Indo Gulf Fertilizer Company Plant, India	The fertiliser plant incorporates a CO_2 capture facility that feeds a urea manufacturing unit	Jagdishpur, Uttar Pradesh Project underway
Luzhou Natural Gas Chemicals (Group)	The plant produces urea and ammonia for the fertiliser industry in China. Part of the plant features a scrubber system that captures CO_2 from the process for urea production	Luzhou City Project underway
	Demonstration Projects	
JODCO EOR Project	JODCO, in collaboration with by Mitsubishi Heavy Industries, has developed what is claimed to be a novel technique based on CO_2 injection for boosting oil production from wells characterised by diminishing output. This is to be tried for the first time by JODCO as part of its operations on the Upper Zakum Field in the United Arab Emirates.	Japan. Project status not available
	CO_2 Capture R&D Projects	
Research on Physical Adsorption Method for CO2 Recovery	The present project forms part of an on-going programme examining the Pressure Temperature Swing Adsorption technique for CO_2 capture	Yokosuka, Japan Project active
Development of Coal bed Methane Technology/Carbon Dioxide Sequestration Project (CCCDP)	The project is addressing a number of issues leading to an ECBM/CO_2 sequestration demonstration project in China via transfer of Canadian technology CSLF Endorsed Project	Qinshui Basin, China Project in preparation
Demonstration of Capture, Injection and Geologic Sequestration of CO2 in Basalt Formations of India	Evaluation of Basalt Formation in India (Deccan Trap) for environmentally safe and irreversible storage of CO_2 CSLF Endorsed Project	India Project in preparation

AUSTRALIA

	CO_2 capture commercial projects	
Gorgon Gas Development	ChevronTexaco as operator of the Gorgon gas development is planning one of the largest geological CO_2 sequestration projects in the world. The development will be based on the Gorgon gas field in Australia which is one of the world's premier hydrocarbon resources. The gas field is situated 130 km off the north-west coast of Western Australia.	Gorgon gas field, 130km off the north-west coast of Western Australia. Project underway
	Demonstration Projects	
Otway Basin Pilot Project (OBPP)	The CO2CRC has developed a research project which involves extracting CO_2 and methane gas from an existing well, separating these gases in a temporary surface separation plant and compressing the CO_2 to a supercritical state in a compressor/refrigeration unit. This condensed CO_2 will then be transported and injected into a depleted natural gas field where it will be monitored by the CO2CRC. A comprehensive monitoring program across the atmospheric, near surface and subsurface domains is being planned. It is estimated that 100,000 t of CO_2 will be injected over 1 –2 years and monitoring and modelling activities will continue post injection for several years.	Otway Basin – South West Victoria, Australia Project active

CO_2 Capture R&D Projects		
Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)	In December 2002, the Australian Minister for Science announced the approval of a new Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC). CO2CRC will undertake research into existing and new capture technologies to reduce the cost of capture and to assess and enhance their suitability for industrial and power generation activities.	Australia Project active

AFRICA

Demonstration Projects		
In Salah Project	The field is being developed by In Salah Gas, a 50:50 joint venture between BP and state energy company Sonatrach, and is scheduled to come on stream in 2003-4. Ultimately, In Salah Gas aims to supply 9 billion m3/y of gas to the southern European market. A component part of the project will include the facility to remove CO_2 from the gas produced, followed by large-scale reinjection into an underground formation. CSLF Endorsed Project	Algeria Project active

MIDDLE EAST

Demonstration Projects		
The Sour Gas Injection Project of the Abu Dhabi Oil Company	In October 2000, final commissioning of the Sour Gas Injection Project was completed and the project became operational. In parallel to the Sour Gas Injection Project, ADOC implemented has a second project known as the Zero Gas Flaring Project.	Undertaken in the Middle East by a Japanese Group Project status is not available

Complied from: International Energy Agency (IEA), Intergovernmental Panel On climate Change (IPCC), World Energy Council (WEC), Carbon Sequestration Leadership Forum (CSLF), Co-operative Research Centre for Greenhouse Gas Technologies (CO2CRC), CRC for Coal in Sustainable Development (CCSD), Centre for Low Emissions Technology (cLET)

Low Emissions Technology Demonstration Fund (LETDF)

Fairview Power Pty Ltd:
Zero Carbon Power from Coal Seams

Proponent
The proponent of the Zero Carbon Power (ZCP) project is Fairview Power Pty Limited, a wholly owned subsidiary of Santos Limited. With Santos in the ZCP initiative is GE Energy, BHP Billiton, Ergon Energy, the AJ Lucas Group, Commonwealth Scientific and Industrial Research Organisation (through its Energy Transformed Flagship), Innovative Carbon Technologies Pty Limited (the commercialization arm of CO_2CRC) and Leasing Corporation Pty Limited (collectively named the ZCP Consortium).

Location
The project will be located at the Fairview CBM Project site in Injune near Roma, in southwest Queensland.

Project description
The project will construct a 100MW power station fuelled by coal seam methane. The gas turbine used in the project will be an open cycle General Electric LMS100. The project will have a 10 year demonstration period.

The project will capture and store one-third of the carbon dioxide emissions from the power station. Over 100,000 tonnes of carbon dioxide will be captured and stored each year.

The project will demonstrate the use of coal beds as a source of fuel for power generation and as a storage site for the carbon dioxide emitted from the power station.

The Fairview coal seams are unlikely to be mined as they have significantly adverse features for use in the coal market. These include depth of seams (600-1000m), high ash, longer distance from the coast than other deposits, low volatiles hence unsuitable for the coking coal market.

Deep coal beds in Australia have the potential to be storage for large quantities of carbon dioxide. By 2030 over five per cent of Australia's carbon dioxide emissions could be stored in deep coal beds. In some parts of Australia deep coal beds may be the only economic storage sites for carbon dioxide.

Cost and funding
The total project cost is $445 million. The Australian Government is contributing $75 million.

Low Emissions Technology Demonstration Fund (LETDF)

CS Energy:
Oxy-firing demonstration and carbon sequestration project

Proponent
CS Energy's partners in the oxy-firing project are a Japanese consortium comprising JCoal, JPower and IHI; the Australian Coal Association and Xstrata Coal; Schlumberger – a world leader in geosequestration technology; the CO_2CRC and the CRC for Coal in Sustainable Development.

Location
The project will be implemented using the Callide A power station at Biloela in central Queensland.

Project description
CS Energy Ltd. will retrofit a set of new technologies into an existing coal-fired power station in Queensland. The project involves four processes:

- oxygen production;
- the use of that oxygen in the oxy-firing of pulverised black coal;
- capture of all the gases resulting from combustion; and
- CO_2 separation, liquefaction, transport and geological storage.

The project will store 30,000 tonnes of carbon dioxide per year for the life of the demonstration project. As a result of the oxy-firing combustion process, the technology will also reduce emissions of sulphur oxides and nitrogen oxides.

This project has already attracted several international partners since it provides an efficient way to deal with emissions from existing coal-fired plants.

Construction at Callide A will commence in April 2007, followed by a five-year technology demonstration starting in late 2008.

Cost and funding
The total cost of the project is $188 million. The Australian Government is contributing $ 50 million.

Low Emissions Technology Demonstration Fund (LETDF)

Chevron (TAPL) Pty Ltd:
Gorgon carbon dioxide (CO_2) Injection Project

Proponent
Chevron will be working with Shell Development Australia Pty Ltd and Mobil Australia Resources Company Pty Ltd as joint venture partners.

Location
The project is part of the Gorgon development off the northwest coast of Western Australia. It includes the injection of carbon dioxide into the Dupuy Formation saline aquifer underneath Barrow Island.

Project description

The Gorgon CO_2 Injection Project is a commercial-scale demonstration project comprising three components:

- the capture of carbon dioxide from reservoir gas from the gas stream of the Gorgon development, compression and dehydration of the CO_2 and its transportation by pipeline to the injection site;
- injection of the CO_2 into the Dupuy Formation saline aquifer under Barrow Island; and
- monitoring of the injected CO_2 to ensure it is safe in terms of health, safety and the environment.

Carbon sequestration technology is being applied by the oil and gas industry worldwide. However, an unusual feature of this project is that CO_2 will be injected into a low permeability saline aquifer, rather than into an existing depleted oil or gas reservoir.

The project will be the world's largest geological sequestration project of this type. The injection of CO2 is expected to start in 2009. Over its 40 year lifetime, the project anticipates removing about 3 million tonnes per annum of reservoir CO_2.

Cost and funding
The total project cost is $1500 million. The Australian Government is contributing $60 million.

Low Emissions Technology Demonstration Fund (LETDF)

International Power:
Hazelwood 2030

Proponent
International Power (Technologies) Pty Ltd was formed in March 2006 and is a 100% owned subsidiary of International Power (Australia) Holdings Pty Ltd. International Power is a global power generation and desalination company. Its headquarters are in the UK and it trades on the London and New York stock exchanges.

Location
The demonstration project will occur at the Hazelwood power station in the Latrobe Valley, Victoria.

Project description
International Power will introduce and demonstrate technology to dry brown coal that is used as the feedstock for one of the boilers at the Hazelwood power station. The use of dried brown coal will significantly reduce CO_2 emitted by the generating unit. Hazelwood has eight generating units and the company will consider applying the new technology to all units, if the demonstration project is successful.

The project will also include carbon capture and sequestration facilities. CO_2 will be utilised for ash water treatment and be sequestered into calcium carbonate. Excess CO_2 will be processed for industrial gas markets.

International Power will adapt internationally available technology for brown coal drying and carbon capture to local conditions. This technology can also be retrofitted to other brown coal plants in the LaTrobe Valley.

The coal drying demonstration phase of the project will be completed by the end of 2009. The carbon dioxide capture scheme is expected to be operational by early 2008.

Cost and funding
The total project cost is $369 million. The Australian Government is contributing $50 million and the Victorian Government an additional $30 million.

Stanwell ZeroGen Project

Subject to the outcomes of a feasibility study currently underway, the ZeroGen proposal aims to demonstrate an Integrated Gasification Combined Cycle (IGCC) power plant with carbon capture and storage (CCS) technology.

- Coal-based gasification is a process that converts coal into a synthesis gas (syngas), which can be used as a fuel to generate power.
- Carbon capture and storage is a process to capture carbon dioxide (CO_2) from the syngas, compress, transport and safely store it underground in deep saline aquifers.

The project will be the first in the world to combine both IGCC and CCS for power generation, making it an initiative of national and international importance. It is intended that the facility will be located adjacent to the existing Stanwell Power Station, 29km west of Rockhampton, in Central Queensland. Carbon dioxide would be captured at the site and transported by pipeline for safe storage in deep underground saline aquifers in the Northern Denison Trough, approximately 220km west, near Emerald.

Stanwell, a Queensland Government owned corporation, is the primary contractor to the ZeroGen project and is responsible for the management of the project, in conjunction with external advisors.

IMPACT OF CARBON CAPTURE AND STORAGE ON GLOBAL GREENHOUSE GAS EMISSIONS

ABARE ANALYSIS

Source: *ABARE, Technology: its role in economic development and climate change, Research Report 06.6, July 2006, pp.2-4, 100-101.*

To assess the energy consumption and emissions impacts of new technology and methods such as carbon capture and storage (CCS), ABARE analysed a number of alternative scenarios for the development and transfer of more energy efficient and low emissions technologies.

ABARE modelling has shown, that if CCS is excluded from a suite of global measures to reduce greenhouse emissions, a reduction of 18 per cent of greenhouse gas emissions is possible by 2050. However, if CCS is included, a reduction of nearly 26 per cent can occur. This represents an eight per cent decline in global emissions from business as usual resulting from CCS.

<u>ABARE Scenarios</u>

Scenario 1: global technology

In this scenario, the development and availability of more energy efficient and advanced technologies are assumed to be fully diffused throughout the world. The electricity, transport and key energy intensive industries — aluminium, non-metallic minerals (cement), mining, iron and steel, and wood, pulp and paper products — are considered to be the focus sectors for technological development. Cost declines for nuclear power and non-hydro renewables are also assumed in this scenario, to reflect possible gains associated with enhanced research and development and learning by doing.

Scenario 2: global technology plus CCS

In this scenario, the development and availability of more energy efficient and advanced technologies is assumed to be the same as in Scenario 1. In addition, CCS technologies are assumed to be used in all new coal and gas fired electricity generation plants from 2015 in countries that are in Annex B to the Kyoto Protocol (EU25, Russian Federation, CIS, Canada and Japan) and the United States and Australia. From 2020, all other countries are assumed to utilise carbon capture and storage technologies in all new coal and gas fired electricity generation plants.

D3 regional greenhouse gas emissions – global technology scenario

	greenhouse gas emissions			percentage change from reference case		
	2010	2030	2050	2010	2030	2050
	Mt Ce	Mt Ce	Mt Ce	%	%	%
Australia	151.3	180.1	196.2	-1.0	-7.7	-14.1
China	2 329.2	3 365.2	3 966.0	-1.4	-14.8	-23.7
India	606.1	1 008.8	1617.0	-0.9	-11.1	-22.6
Japan	345.2	344.5	340.1	-1.4	-9.1	-17.9
Rep. of Korea	174.6	185.7	184.9	-1.6	-11.9	-20.5
United States	2 119.4	2 566.3	2 802.9	-1.3	-10.1	-18.5
Brazil	229.9	323.6	429.5	-1.9	-9.5	-15.4
Canada	202.3	229.9	238.7	-1.8	-11.1	-18.1
Chinese Taipei	77.8	93.0	92.3	-1.5	-10.4	-20.4
European Union 25	1 371.4	1 498.6	1 512.5	-1.3	-8.6	-15.1
Indonesia	162.4	267.4	408.4	-1.0	-8.7	-16.7
Mexico	161.9	236.4	328.5	-1.1	-9.2	-17.0
Other ASEAN	262.9	405.3	570.5	-0.9	-8.7	-16.2
Other CIS	315.4	388.7	433.9	-1.2	-10.0	-15.4
Rest of OPEC	568.1	1 008.2	1 676.2	-0.8	-7.5	-14.1
Rest of World	1 082.3	1 724.5	2 707.8	-0.7	-5.7	-10.7
Russian Federation	558.0	548.1	526.6	-1.1	-9.3	-15.8
South Africa	134.4	162.9	208.0	-0.8	-10.6	-18.9
International bunkers	248.7	324.3	412.6	-1.9	-10.6	-17.9
CFCs	169.7	14.8	1.3	0.0	0.0	0.0
World total	11 270.9	14 876.4	18 653.8	-1.2	-10.3	-18.0

D4 regional greenhouse gas emissions – global technology + CCS scenario

	greenhouse gas emissions			percentage change from reference case		
	2010	2030	2050	2010	2030	2050
	Mt Ce	Mt Ce	Mt Ce	%	%	%
Australia	151.3	158.7	156.1	-1.0	-18.7	-31.7
China	2 329.2	3 086.4	3 412.7	-1.4	-21.8	-34.3
India	606.1	911.2	1311.5	-0.9	-19.7	-37.2
Japan	345.2	321.1	297.9	-1.4	-15.3	-28.1
Rep. of Korea	174.6	186.0	185.3	-1.6	-11.8	-20.3
United States	2 119.4	2 274.0	2 293.9	-1.3	-20.4	-33.3
Brazil	229.9	323.6	429.2	-1.9	-9.4	-15.5
Canada	202.3	218.8	224.7	-1.8	-15.4	-22.9
Chinese Taipei	77.8	93.3	92.7	-1.5	-10.1	-20.0
European Union 25	1 371.4	1 370.6	1 307.8	-1.3	-16.4	-26.6
Indonesia	162.4	267.6	409.0	-1.0	-8.6	-16.6
Mexico	161.9	236.7	329.0	-1.1	-9.1	-16.9
Other ASEAN	262.9	405.9	571.6	-0.9	-8.6	-16.0
Other CIS	315.4	360.2	383.9	-1.2	-16.6	-25.1
Other OPEC	568.1	1 009.5	1 679.2	-0.8	-7.3	-14.0
Rest of world	1 082.3	1 731.9	2 719.6	-0.7	-5.3	-10.3
Russian Federation	558.0	506.9	454.1	-1.1	-16.1	-27.4
South Africa	134.4	164.0	209.7	-0.8	-10.1	-18.2
International bunkers	248.7	323.6	411.3	-1.9	-10.8	-18.2
CFCs	169.7	14.8	1.3	0.0	0.0	0.0
World Total	11 270.9	13 964.8	16 880.3	-1.2	-15.8	-25.8