Australian Government

# AUSTRALIAN GOVERNMENT SUBMISSION

into the
House of Representatives Inquiry
on
Geosequestration

On Friday 30 June 2006 the House of Representatives Standing Committee on Science and Innovation announced an inquiry into the science and application of geosequestration technology in Australia, with particular reference to:

1. The science underpinning geosequestration technology;
2. the potential environmental and economic benefits and risks of such technology;
3. the skill base in Australia to advance the science of geosequestration technology and trials;
4. regulatory and approvals issues governing geosequestration technology and trials; and,
5. how to best position Australian industry to capture possible market applications.

This submission constitutes the Australian Government's submission to the inquiry from the following contributing agencies:

- Department of the Environment and Heritage
- Department of Education, Science and Training
- Department of Foreign Affairs and Trade
- Department of Industry Tourism and Resources and Geoscience Australia

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*Attachments affixed*:

# INTRODUCTION

## Role of CCS in Australia’s energy future

Australia's domestic and export energy sector relies heavily on large scale carbon intensive fossil fuel based energy. The competitively priced and reliable energy services derived from these energy resources are a key part of our international competitiveness and economic prosperity. This prosperity in turn provides Australia with the means to realise important national goals of economic prosperity, energy security and sustainability. Continuation of Australia's economic growth and standard of living requires a secure, economically viable, and long term source of energy.

In 2004 the Australian Government released its national energy policy and announced its commitment to meeting the three major goals. In meeting these goals, the Australian Government is supporting and encouraging public and private investment in leading-edge low emissions technologies (LET) including both fossil fuels and renewables.

The Australian Government in its Energy White Paper (EWP) assessed a broad range of energy related technologies, using criteria related to technical feasibility, likely development costs, strategic benefits, the role of government and methods for effective support. As a result, the EWP classified technologies into three broad categories (market leader, fast follower, reserve). Geosequestration, more commonly known and hereafter referred to as Carbon Capture and Storage (CCS) was evaluated as being in the market leader category, or more simply, it was considered to be in Australia’s interest to take a lead role in international efforts to develop and implement CCS.

In light of the need to respond to the challenge of climate change, the key issue is to provide a secure source of energy and at the same time achieve lower greenhouse gas emissions. Given that fossil based energy will remain a primary baseload provider, CCS is one of a suite of technologies which will provide low emission energy sources.

CCS is an opportunity to reduce $CO_2$ emissions while taking advantage of the world's resources of fossil fuels to meet development predictions and energy requirements across the globe.

## Australia's Positioning

The Australian Government is supporting a suite of options to reduce greenhouse emissions from the energy sector. CCS technology has been supported by both the Federal and State governments since 2001 and Australia is now considered a world leader in the development of CCS technologies and regulation. The support for CCS technology is demonstrated through the following summary list of actions:

- In June 2001 the Council of Australian Government’s announced “A National Energy Policy Framework” which sought (among other things) to address greenhouse issues by embracing a policy principle that encouraged "the efficient economic development and increased application of less carbon-intensive (including renewable) energy sources and technologies[1]…".

- In August 2002 the Australian Government announced that the US and Australia had agreed on 19 projects under the US-Australia Climate Action Partnership, which included exchanging experience on the research and development of clean coal technologies and CCS[2].

- In November 2002, the Prime Minister in an address to the Committee for Economic Development of Australia (CEDA), stated that Australia must ensure that its energy policy continues to support economic growth and development while also contributing to reduced air pollution and greenhouse gases. At the same time, Australian industry and researchers should continue to develop new technology[3].

- In December 2002 the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) released the publication, *Beyond Kyoto – Innovation and Adaptation*. It concluded that the principal challenge for CCS is to develop cost effective methods of capturing carbon emissions and testing the geosequestration process on a large scale. It also recommended that Australia "establish a national program to scope, develop, demonstrate and implement near zero emissions coal-based electricity generation"[4].

- Also in late 2002 the Prime Minister announced Australia's four national research priorities to inform Government support for research. The priority, *An Environmentally Sustainable Australia*, contained the goal of reducing and capturing emissions in energy generation. This included encouraging clean combustion and efficient new power generation systems and CCS.

- In July 2003 the Australian Government announced A$21.7m support for the CRC for Greenhouse Gas Technologies ($CO_2$CRC) to establish a critical mass of total resources (cash and in-kind) of $123 million, to undertake research into CCS technologies for their potential application to decrease Australia's levels of $CO_2$ emissions. The $CO_2$CRC was developed from the GEODISC Project in the Australian Petroleum CRC [5].

- The CSIRO and Geoscience Australia has partnered with the $CO_2$CRC to assess the feasibility of geological storage of carbon dioxide. Funding for CSIRO under the Australian Government's A$8.3 billion Backing Australia's Ability packages to 2010-11 included an additional $305 million over seven years to support a new Flagships programme to enable the development of large-scale collaborative research partnerships which reflect the National

[1] Council of Australian Governments' Communique, 2001. *Attachment 2 - A National Energy Policy Framework*. http://www.coag.gov.au/meetings/080601/energy.htm (24 August 2006)
[2] US Department of State, 2002. *The U.S.-Australia Climate Action Partnership Moves Forward,* http://www.state.gov/r/pa/prs/ps/2002/11744.htm (29 August 2006).
[3] HOWARD, John, 2002. *Strategic Leadership For Australia Policy Directions In A Complex World,* http://www.pm.gov.au/news/speeches/2002/speech1996.htm (24 August 2006).
[4] PMSEIC, 2002. *Beyond Kyoto – Innovation and Adaptation,* Australia *pg 33*
[5] www.apcrc.com.au.

Research Priorities. CSIRO's energy research is now principally supported through its Energy Transformed Flagship and the Division of Energy Technology. The CSIRO is also partnering with the A$26 million Centre for Low Emission Technology (cLET) in Queensland which includes a focus on CCS technology.

- The Australian Government also committed funding to two other key CRCs in the research and development of clean coal technologies, including: the CRC for Coal in Sustainable Development (which was established in 2001 replacing its predecessor, the CRC for Black Coal Utilisation) which is undertaking research into existing and potential new $CO_2$ capture technologies to evaluate the cost and their potential for integration with Australian power stations; and the CRC for Cleaner Power from Lignite which ceased on 30 June 2006, and developed technology for removing water from lignite (brown coal) to improve the efficiency of lignite utilisation in power generation and the prospect for application of carbon capture technology.

- In mid-2003 the Australian Government became a founding member of the Carbon Sequestration Leadership Forum (CSLF), as well as co-Chair of the Policy Working Group, and is now also co-Chair of the Project Initiation and Review Team. The CSLF was established to facilitate collaboration between governments, industry, researchers, and non-government organisations on carbon dioxide capture and geological storage. In the three years since commencement, the CSLF has marshalled 17 research, development and demonstration projects selected to advance the technologies of CCS. Australia hosted a Regulatory Workshop in Brisbane in 2003, as well as the 2nd Ministerial Meeting of the CSLF in Melbourne in September 2004. The key outcomes of the CSLF to date include:
    - CSLF Strategic Plan
    - Acceptance of a CSLF Technical Roadmap;
    - Recognition of CSLF projects – international collaboration efforts;
    - Acceptance and release of a CSLF international regulatory issues report; and
    - Agreement on a CSLF Stakeholder Engagement Strategy
    - Public Awareness Strategy
    - Capacity building in emerging economies strategy
    - Taskforces on; Monitoring, Measurement and Verification; Geological Storage Capacity Estimation; and Capture and Transport

- In March 2004 the Australian Government committed A$500,000 to support initial research under the industry-government partnership COAL21. COAL21 has subsequently launched a National Action Plan which is a comprehensive industry-led response to the need to curtail greenhouse gas emissions associated with the sector. In March 2006 COAL21 announced a A$300 million Fund (over five years) to develop clean technology in the Australian black coal industry[6].

[6] HOWARD, John, 2006. *$300 Million Investment In Clean Coal Welcomed*, http://www.pm.gov.au/News/media_releases/media_Release1823.html (24 August 2006)

- In June 2004 the Prime Minister released a white paper on energy policy, *Securing Australia's Energy Future*. The paper represented a comprehensive examination of Australian energy policy covering (among other things) stationary energy markets; energy and climate change; energy and the environment; and energy innovation[7].

  In it, the Australian Government committed to a long-term greenhouse response acknowledging that significant changes needed to be realised in the way Australia supplied and used energy. It recognised the need to increase the range and lower the cost of low-emission technologies to bring the achievement of long-term emission reductions within reach.

  A major flagship measure, the $500 million Low Emission Technology Demonstration Fund, was established to competitively promote low-emissions technology. The aim was to leverage at least $1 billion in private investment to demonstrate breakthrough low-emission technologies (including both renewables and fossil fuel) with significant long-term abatement potential. This programme is in the final assessment phase of the first of three rounds and has been very successful in attracting a broad range of low emissions technology projects, including CCS.

- In September 2005 the Australian Government welcomed the Intergovernmental Panel on Climate Change Special Report on Carbon Dioxide Capture and Storage (the first summary of the global state of knowledge on CCS) by stating that CCS is an "important and potentially significant abatement option"[8]. As for all IPCC reports, the Special Report is policy relevant rather than policy prescriptive, and represents an increasing global consensus between researchers and governments on the integrity of CCS as a mitigation option to address climate change. As an indication of Australia's world class research capacity in this area, it had three lead authors contributing to the drafting of four chapters within the report and two were co-ordinating lead authors. Many Australian researchers also acted as reviewers of the Special Report.

- On 25 November 2005, the Ministerial Council on Mineral and Petroleum Resources (MCMPR) endorsed a set of Regulatory Guiding Principles for CCS. The aim was to achieve a nationally consistent framework for CCS activities in Australian jurisdictions. Six key issues were seen as fundamental to a CCS regulatory framework:

  - Assessment and approvals process;
  - Access and property rights;
  - Transportation issues;
  - Monitoring and verification;
  - Liability and post-closure responsibilities; and

[7] Department of Prime Minister and Cabinet, 2004. *Securing Australia's Energy Future*, Canberra.
[8] Campbell, Ian, 2005. *International report on technological opportunities to reduce greenhouse gases*, http://www.deh.gov.au/minister/env/2005/mr27sep05.html (29 August 2006)

- Financial issues[9].

- In January 2006, the Australian Government hosted the launching of the Asia-Pacific Partnership on Clean Development and Climate (including Australia, China, India, Japan, Republic of Korea and the United States) and announced a commitment of A$100 million to the partnership (AP6)[10]. The AP6 has established a number of taskforces, and one of those is the clean fossil energy taskforce. Its aim is to collaborate to promote and create an enabling environment for the development, diffusion, deployment and transfer of existing and emerging cost-effective, cleaner technologies and practices. Areas for collaboration include (among others) CCS.

- In 2006, the Australian Government committed to support a geosequestration pilot project based in the Otway Basin in western Victoria.

These announcements underpin the current policy environment of how Australia is tackling its environmental and energy concerns in a way that ensures policies satisfy both objectives of sustaining the environment and continuing economic growth. Such an environment embraces the rapid advances in technology in cleaner fossil fuels as well as growing scope for renewable technology.

[9] The issues covered under the MCMPR work are examined in greater detail in section 6 of the publication. This is useful in addressing *Regulatory and Approvals Issues Governing Geosequestration Technology and Trials* in further detail.

[10] Macfarlane, Ian, 2006. *$100 million Energy fund for all new technologies,* http://minister.industry.gov.au/index.cfm?event=object.showContent&objectID=BC956990-A8E5-F0D4-9B89DC86E537888D (29 August 2006)

# 1. THE SCIENCE UNDERPINNING GEOSEQUESTRATION TECHNOLOGY

## Recent history of CCS technology development and knowledge transfer

Carbon dioxide Capture and Storage (CCS) is a technology that has significant potential to prevent emission of carbon dioxide ($CO_2$) to the atmosphere by capturing, transporting, injecting and storing the $CO_2$ into deep geological subsurface formations. The science and technology involved is readily available from the industrial, chemical and petroleum industries. Some aspects of the technology such as enhanced oil recovery with transport and geological injection of $CO_2$ into depleted oil fields have been operating for four decades[11]. At the Sleipner gas field in the North Sea (a commercial site), $CO_2$ natural gas production operations have been injecting 1 Million tonnes (MT) of captured and separated $CO_2$ per year since 1996.

As a science, CCS has rapidly expanded over the last five years to the stage where it is considered an emerging, but mainstream science based on many existing mature technologies. As documented below, the science has now reached a prominent position in terms of its recognition as a significant technology to achieve large scale $CO_2$ emission reduction. The technical acceptance of CCS is evidenced through the programmes and activities of some of the international agencies supporting and investigating CCS, such as the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA).

### Intergovernmental Panel on Climate Change

In September 2005, the Intergovernmental Panel on Climate Change (IPCC) released a Special Report on Carbon Dioxide Capture and Storage (SRCCS). The IPCC collates scientific advice on climate change and the conclusions of the IPCC are generally accepted by the Australian Government as being the most authoritative science available. The Australian Government contributed substantially to the development of the SRCCS by submitting a substantial whole of government review on the various drafts (also soliciting and considering key stakeholders' views) and negotiating the Summary Report for Policy Makers (SPM).

The welcoming of the SPM and the SRCCS by the United Nations Framework Convention on Climate Change (UNFCCC) signifies increasing global consensus between researchers and policy makers on the integrity of CCS as a mitigation option to address climate change. The SRCCS also provides a legitimate basis for a closer dialogue between policy makers and industry/community on the range and complexity of CCS issues needing consideration and provides a platform in which industry can better engage on, and partner with, the research community on CCS.

[11] Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press. Metz B, Davidson O, De Coninck H, Loos M and Meyer L (Eds.) 2005.

The SRCCS offers an expert survey of peer reviewed scientific literature that essentially underpins the current knowledge base on CCS science. It includes a technical status of capturing, transporting and storing $CO_2$ as well as identifying the maturity (or nascency) of related technologies. The SRCCS is an important and potentially long lived document that not only reinforces the strategic direction of CCS in Australia as outlined in *Securing Australia's Energy Future* but also gives further technical legitimacy to its future application in Australia as a large scale mitigation option for fossil fuel energy supply.

An abridged Summary for Policy Makers and Technical Summary is provided in **Attachment A**. The simplified guide to the IPCC's "Special Report on Carbon Dioxide Capture & Storage" is provided as **Attachment B**.

## International Energy Agency

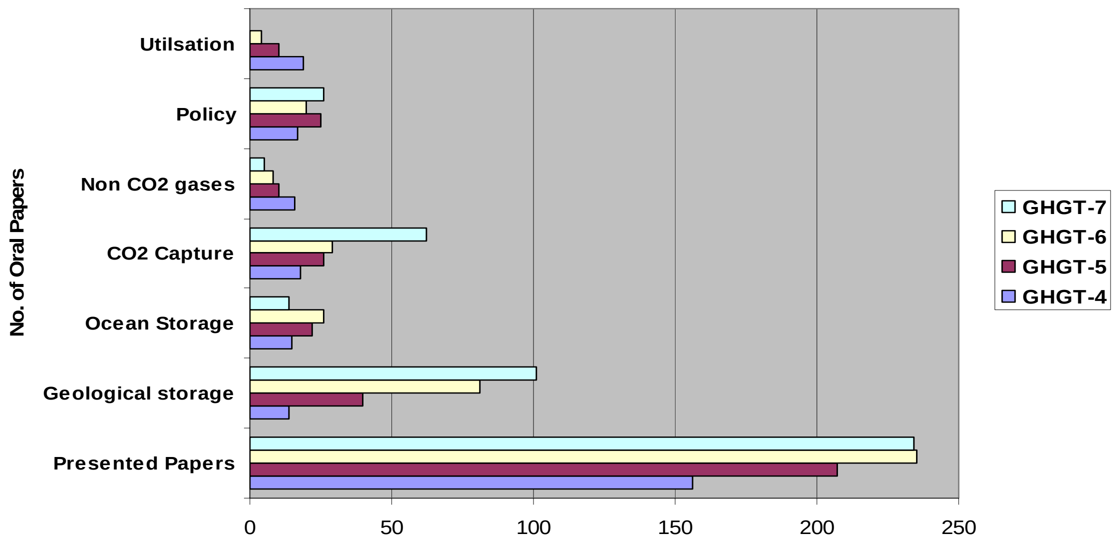
Fourteen years ago the International Energy Agency (IEA) established a Greenhouse Gas R&D Programme which has since produced over 100 studies on greenhouse gas reduction technologies and has a website of CCS RD&D activities, which includes 135 projects with links to their individual project websites (http://www.co2captureandstorage.info./). It also established an international conference on greenhouse gas technologies (GHGT) which has been held every two years and has grown to be the principal forum for knowledge transfer of CCS matters at both a technical and a policy level (http://www.ieagreen.org.uk/ghgt.html ). Table 1 below shows the growth in the conference since 1998.

**Table 1 : The International Energy Agency Greenhouse Gas Technology Conference (GHGT) statistics since 1998.**

| Date | Location | Confernce No. | Papers | Posters | Attendees |
|---|---|---|---|---|---|
| September 1998 | Interlaken, Switzerland | GHGT4 | 160 | 40 | 530 (49 countries) |
| August 2000 | Cairns, Australia | GHGT5 | 210 | ? | 400 (35 countries) |
| October 2002 | Kyoto, Japan | GHGT6 | 246 | 90 | 530 (34 countries) |
| September 2004 | Vancouver, Canada | GHGT7 | 220 | 170 | 650 (35 countries) |
| June 2006 | Trondheim, Norway | GHGT8 | 235 | 225 | 986 (45 countries) |

Over that time there has been a marked increase in the number of papers focussed on geological storage and capture, whilst there have been decreases in other aspects such as $CO_2$ utilisation, and a marked shift in trends in ocean storage as shown in Table 2.

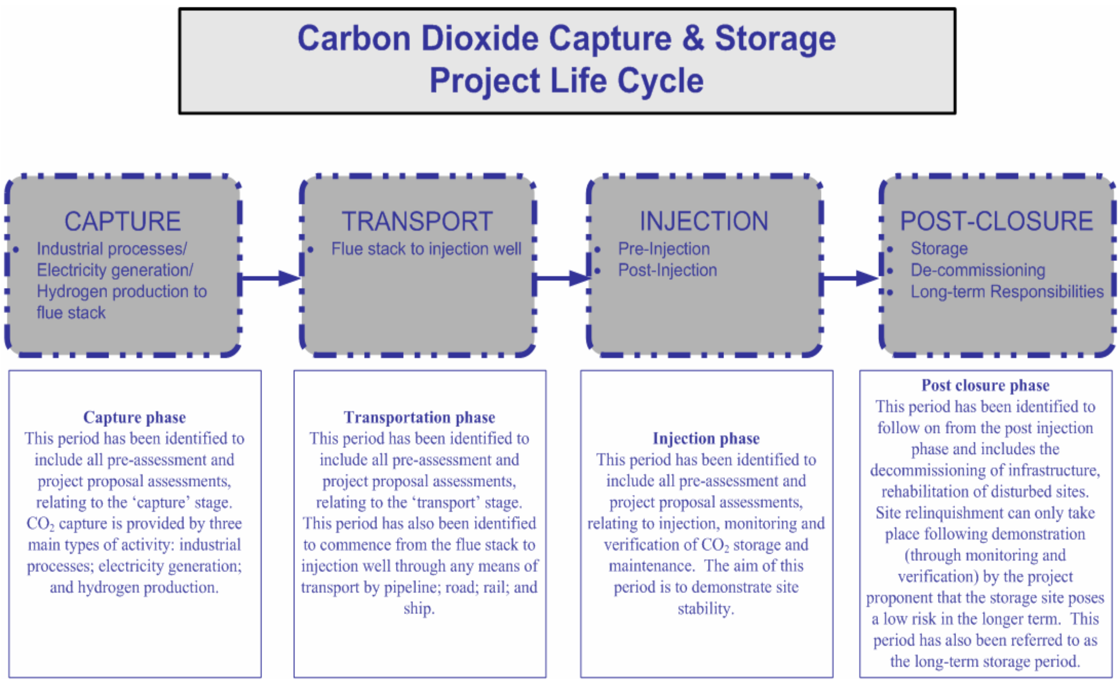
**Table 2: Graph of the changes in the number of papers delivered at the International Energy Agency conference on Greenhouse Gas Technologies (GHGT) between 1998 and 2006. Courtesy IEA GHG programme.**



Recently at GHGT8 in June 2006 in Norway, nearly 1000 delegates attended with 235 papers and 225 posters presented in five concurrent sessions over four days; including geological storage (20 sessions), capture and transport (20 sessions) and policy and economics (12 sessions) http://www.ghgt8.no/.

## Key Stages of CCS

CCS is essentially an integrated system comprising of four major components: Capture, Transportation, Injection, and long term geological Storage as outlined in the diagram below.




### Carbon Dioxide Capture

To capture the $CO_2$ before it can be emitted into the atmosphere, the $CO_2$ must first be separated from other gases resulting from combustion or processing. It is then compressed and purified to make it easier to transport and store. Some gas streams resulting from industrial processes, such as natural-gas purification and ammonia production, are very pure to begin with, whilst others may not be.

Three major options are available for the capture of carbon dioxide; post-combustion; oxygen-fired; and pre-combustion. **Attachment C** discusses capture technology in further detail.

### Transportation

In general, CCS storage sites are unlikely to be situated at the same location as the sources of CO2 and transportation of CO2 will be necessary.

The transport of captured carbon dioxide is a relatively straight forward process being a well established practice in the chemical and petroleum industries. Pipeline transportation of $CO_2$ operates as a mature market overseas and is analogous to the transportation of natural gas.

Pipeline standards and operating conditions are well developed on a worldwide basis and carbon dioxide is less reactive than other materials handled in a similar manner. The pressurised condition of the carbon dioxide stream is the main issue in relation to this part of the CCS process. Pipeline costs are a major element of any proposed CCS project. A range of carbon dioxide handling facilities and pipelines exist in North America and elsewhere where they have been used for enhanced oil recovery operations as well as CCS handling. These pipeline systems extend over a distance of 2500 km and handle 50 $MtCO_2$ per year in North America[12].

Other issues are associated with transportation which reflects upon the issues unique to CCS. The water content of the CCS stream in the pipeline must remain as low as possible to avoid corrosion, due to any minute amounts of sulphur dioxide and nitrogen dioxide, both of which are capable of corroding carbon-manganese steels used in pipelines. If required the carbon dioxide stream can be liquefied and transported in ships, similar to the process used in transporting liquefied petroleum gas.

**Injection**

During oil and gas production operations, it has been common practice for many decades to inject fluids (water and gas) to help maintain the pressure in the deep subsurface geological reservoirs to enhance oil and gas production rates and commercial return. Typically, only about 30-40% of the oil in a reservoir is recovered without such processes. Such activities occur in both the onshore and offshore environments, with offshore drilling now routinely occurring in several kilometres of water depth if required. In addition, it is common throughout the world to inject gas (methane) for storage purposes, either in depleted oil or gas fields, or in aquifers, for later recovery at a time of increased gas demand.

**Geological Storage of $CO_2$**

At the geotechnical level, many of the fundamental aspects of CCS are reliant on proven and mature technologies that have been widely implemented for many decades in the oil and gas exploration and production industry and the groundwater industry at both a domestic and global scale. This includes the disciplines of geology, geophysics, reservoir engineering and hydrogeology. The fundamental key for successful storage of $CO_2$ is the identification of appropriate sites and appropriate risk analysis.

**Attachment D** is a Geoscience Australia summary of potentially acceptable storage options and describes the science underpinning geological storage.

[12] Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press. Metz B, Davidson O, De Coninck H, Loos M and Meyer L (Eds.) 2005.

**Australia's potential for CO2 storage**

A regional study, GEODISC[13], was undertaken of our continent to identify a range of geological storage sites. The initial assessment screened 300 sedimentary basins down to 48 basins and 65 potential injection sites. Methodology was developed for ranking storage sites (technical and economic risks) and proximity of large $CO_2$ emission sites. Region-wide solutions were sought, incorporating an economic model to assess full project economics over 20 to 30 years, including costs of transport, storage, monitoring and Monte Carlo analysis. The study produced three storage estimates (See **Attachment D –** Geological Storage Capacity):

- Total 'Theoretical'capacity of 740 $GtCO_2$, equivalent to 1600 years of current emissions, but with no economic barriers considered;
- 'Realistic' capacity of 100–115 $MtCO_2$ yr-1 or 25% of our annual emissions, determined by matching sources with the closest viable storage sites and assuming economic incentives for storage;
- 'Cost curve' capacity of 20–180 $MtCO_2$ /y, with increasing storage capacity depending on future $CO_2$ values.

[13] The Geological Disposal of Carbon (GEODISC) programme (1999-2003) established under the Australian Petroleum Cooperative Research Centre (APCRC) reviewed all of the Australian sedimentary basins for their geological sequestration options. The programme was also designed to address key technical, commercial, and environmental issues associated with geological sequestration of $CO_2$ in Australia.

## 2. THE POTENTIAL ENVIRONMENTAL AND ECONOMIC BENEFITS AND RISKS OF SUCH TECHNOLOGY

### Environmental Benefits

The International Energy Agency (IEA) considers that the world will be dependent on fossil fuels for the foreseeable future, and that CCS will be an extremely important technology option to make its use cleaner. As a major coal and gas user and exporter, Australia has an important role to play in developing and demonstrating the environmental benefits of CCS.

The World Meteorological Organization and the United Nations Environment Programme established the Intergovernmental Panel on Climate Change (IPCC) in 1988 to assess the available scientific information on climate change. In its 2001 Third Assessment Report[14] (TAR) the IPCC made a number of conclusions including:

- there is new and stronger evidence that most of the warming of the Earth's surface over the last 50 years is attributable to the increase in greenhouse gas concentrations in the atmosphere resulting from human activities; and
- climate models project the globally averaged surface temperature increasing by between 1.4 to 5.8 degrees Celsius by the end of this century.

Australia contributes around 1.4 per cent of global greenhouse gas emissions, while supplying a significant percentage of the world's energy-intensive products such as aluminium, iron and steel and liquefied natural gas. The Australian Government is committed to implementing an effective global response to managing emissions.

In this regard, the major environmental benefit to Australia (and the world) - is that CCS offers the largest single opportunity to reduce stationary energy emissions while continuing to use fossil fuels (especially in the electricity sector). This is because CCS is most suited to large point sources of emissions (see Table 3), which in 2004, were responsible for about 51% of Australia's carbon dioxide ($CO_2$) emissions (including the electricity generation sector which alone generated some 36% of Australia's total net greenhouse emissions[15]).

Most of Australia's power stations have very long economic lives. Success in reducing greenhouse emissions in the power sector can make a significant contribution to overall emission reduction in Australia. CCS allows for a realistic option of continued use of fossil fuels while avoiding the $CO_2$ emissions embodied in them and within the context of existing national reserves and infrastructure, amid concerns over energy security.

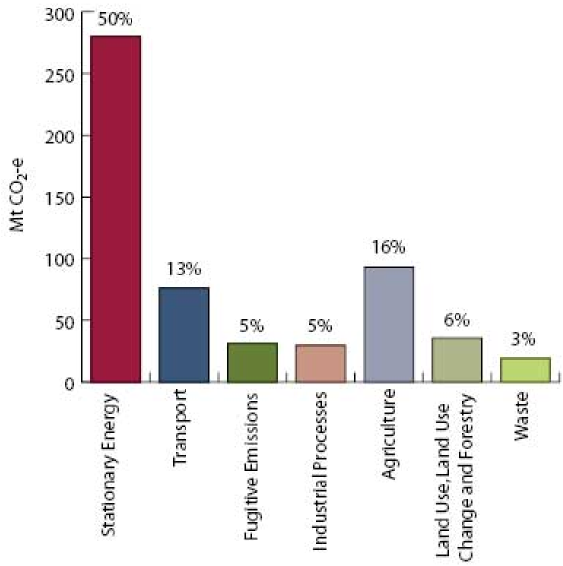
While plant efficiency improvements assist in reducing the amount of emissions (as well as offset any energy penalties associated with $CO_2$ capture), integrated CCS systems offer the only large scale opportunity to significantly cut emissions from existing plants. Any other change of this scale to the generation sector could require retiring existing plants prematurely and constructing new ones. This is neither

[14] IPCC, 2001. *Third Assessment Report – Climate Change 2001*, Geneva
[15] DEH 2004 National Greenhouse Gas Inventory

economically feasible nor practical given Australia's rapidly growing demand for energy.

CCS technology R&D can also foster the development of further energy breakthroughs. The production of synthetic fuels (gas to liquids, coal to liquids) and the efficient separation of non-$CO_2$ elements such as hydrogen will be important steps towards increased energy security (especially given current high global oil prices) and 'the hydrogen economy'.

**Table 3: Australia's emissions profile, source: 2004 NGGI (DEH-AGO)**




The Australian Bureau of Agricultural and Resource Economics (ABARE) have undertaken modelling on the impact of global deployment of CCS and non CCS technology based emission reduction scenarios. These scenarios suggest inclusion of CCS technologies has the potential to substantially increase the opportunities for greenhouse gas abatement.[16]

While CCS technology has the potential to contribute to emission reductions in Australia, it is the broader deployment of CCS, particularly in large economies such as the United States, China and India, (which account for 41% of global greenhouse emissions) that could potentially deliver significant global environmental benefits through a substantive reduction in greenhouse gas emissions above what could be achieved without CCS technologies.

In the study referred to above, a scenario involving energy efficiency and low emission technologies excluding CCS reduced emissions by 18% by 2050 against a business as usual scenario (BAU). The same scenario with CCS technology deployed would result in a 26% reduction against BAU, that is, an additional 8% emission reduction benefit globally when CCS is deployed.

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[16] ABARE, 2006. *Technology: its role in economic development and climate change.* Canberra, http://www.abare.gov.au/publications_html/climate/climate_06/cc_technology_nu.pdf (24 August 2006)

**Project example of $CO_2$ avoided**

When examining $CO_2$ emission reductions, comparisons need to be made with baseline estimates of plant with and without capture technology. As an example, a conventional coal fired 500 MW electricity generating power plant would emit about 2.9Mt of carbon dioxide per year into the atmosphere[17]. A similar plant with carbon dioxide capture and geological storage which produces a similar amount of electricity would emit only 0.6Mt $CO_2$ per year, if 85% of all the carbon dioxide produced were captured, allowing 3.4 Mt $CO_2$ per year to be injected and stored. The greater volume of carbon dioxide generated by the plant with CCS is due to the additional carbon dioxide produced by the capture and storage processes; including emissions resulting from the energy requirements of the capture plant and energy used in the compression of the carbon dioxide for transport and injection.

## Environmental Risks

The IPCC SRCCS indicates that the environmental risks of capture are generally considered low and can be largely governed by existing industrial regimes. There is some risk of fugitive emissions from plant and $CO_2$ transport pipelines, however this risk is expected to be minimised as there is substantial experience (especially in the US) of managing such emissions.

The environmental risks of the geological storage stage of CCS can be divided into local and global impacts from the release of stored $CO_2$ to the atmosphere. There are two types of leakage scenarios: abrupt leakage through injection well failure or leakage up an abandoned well; and gradual leakage, through undetected faults, fractures or wells.

The local impacts of leakage to the subsurface could include adverse affects for plants and subsoil animals; and the contamination of ground water. Large amounts of leakage to the atmosphere during stable atmospheric conditions could lead to local high $CO_2$ concentrations in the air, which could harm animals or people. Pressure build-up caused by $CO_2$ injection could trigger small seismic events. However, the risks are extremely low if CCS is planned and managed well.

Appropriate site selection, combined with robust monitoring (measurement and verification), and regulation that provides for remediation if required, would make the local environmental risks comparable to industrial activities such as natural gas storage and enhanced oil recovery. Any CCS project would need to comply with Commonwealth and State legislation and regulation regarding environmental impacts and risk management.

CCS sites that are well-selected, designed and managed could over the very long term become even more secure as most of the $CO_2$ will gradually be immobilised by

[17] Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press. Metz B, Davidson O, De Coninck H, Loos M and Meyer L (Eds.) 2005. p 61

various trapping mechanisms. The management of these environmental risks are further discussed in 'Management of Carbon Dioxide in CCS projects', pg 28.

## Economic Benefits

The economic benefits to Australia from the wide scale deployment of CCS include the potential to reduce the overall cost of meeting any future and increasing emission constraints and to provide a realistic option to continue using and exporting its fossil fuels while managing the associated CO2 emissions. The broad benefits are outlined in more detail below.

1. CCS has the potential to provide Australia with a technological capability to reduce the economic costs imposed on the national economy of an emission constrained global economy.

   Analysis done by ABARE on meeting future global emission constraints yields a lower cost to global and national economies when CCS is deployed internationally as part of a portfolio of available technologies.

   Table 4 below summarises key findings of the ABARE report into climate change policy options that make CCS available or unavailable[18].

2. The second CCS benefit, when available to our major energy export markets, will be to provide these countries with the capacity to continue to use fossil fuel based energy sources, in turn preserving our significant energy export markets.

   ABARE modelling again shows the negative impacts on key Australian energy intensive sectors such as energy and nonferrous metals are lessened by the availability of CCS. This benefit is largely derived through the lessening of international impacts on the Australian economy of the contraction in demand for our major commodity exports, such as coal and aluminium that would result from different emission reduction strategies.

**Table 4: Impact on the Australian Economy and sectors - 2050[19]**

| Key Sectors | Early action, full range of technologies including CCS | Early action, full range of technologies without CCS |
|---|---|---|
| Agriculture | -2% | -3% |
| Coal | -22% | -38% |
| Electricity | -14% | -22% |
| Other energy (oil and gas) | -14% | -29% |
| Nonferrous metals | -24% | -39% |
| Other manufacturing | 1 | 2 |
| Services | -1% | -1% |
| Total GDP | -2.50% | -3.20% |

[18] ABARE, 2006. *Economic impact of climate change policy: the role of technology and economic instruments*. Canberra

[19] Energy prices are calculated by ITR using information supplied in the ABARE report, Economic Impact of Climate Change Policy.

In addition to these broad benefits Australia, as one of the leading nations for the development of CCS technology, has the potential to benefit from the export of goods and services related to the development of CCS projects in the oil, gas and coal sectors. Australia has already demonstrated considerable expertise in mapping and analysis of CCS storage sites and has considerable research expertise in low emission technology research on CCS. Australia is an active international contributor to CCS technology developments through the CSLF, Asia Pacific Partnership on Clean Development and Climate (AP6) and the IEA.

The UNEP's simplified guide to the IPCC's 'Special report on Carbon Dioxide' found that CCS could lower the cost of mitigating climate change over the next 100 years by 30% or more, and that they would also be competitive with other large-scale technologies, such as nuclear power and renewable energy technologies[20].

The IEA, in a recent report, *Energy Technology Perspectives 2006*, found that CCS could play a large role. The report states that "one of the key findings of this analysis is that carbon capture and storage technologies enable coal to play a significant role even in a carbon constrained world"[21].

Australia appears to have a significant number of potential storage sites and its industrial/power profile and geographic distribution would be amenable to the application of the zero-emission hub concept. This could provide an impetus to Australia in respect of capacity building in partnership with developing countries such as China and India, future large emitters.

**Costs associated with CCS application**

There is no simple answer to the question of how much CCS costs or what its net economic impact will be (either now or in the future). This is due to the heterogeneous nature of the technical options available (including capture and compression; transport; storage), the variability of its application (e.g. industry sectors and markets; technical options; policy and regulatory environments); the technical and financial complexity of integration; and the still largely speculative nature of the risk profiles being attached to the deployment of these nascent systems by governments and markets. Ultimately it will be market conditions that determine the cost of delivered energy, which in turn will be driven by market demand for a diverse range of energy supply options.

The IPCC SRCCS notes that many of the technologies that make up integrated CCS systems are well understood and/or already in operation or being demonstrated.

There seems to be little global consensus on the methodologies and models that should be used to determine and aggregate the individual cost components and economic impacts of CCS systems and their deployment. For example, the sum of the costs of individual CCS components does not necessarily add up to the overall system cost (mainly due to the energy penalties of $CO_2$ capture). This suggests that each CCS project will have its own unique set of cost estimates and economic impacts.

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[20] United Nations Environment Programme, 2006. *Can carbon dioxide storage help cut greenhouse emissions?*, Geneva, pg 14.
[21] OECD/International Energy Agency, 2006. *Energy Technology Perspectives* 2006, Paris, pp 121

ABARE has undertaken research on the impact of installation costs of electricity generation plants (with and without $CO_2$ capture) on Australian electricity prices.[22] The emphasis of the analysis is on the global reduction of $CO_2$ by encouraging a suite of technology options in the electricity generation sector (including CCS). The adoption of technologies is assumed to occur at a cost equal to or less than the marginal value of $CO_2$ as determined by a specific global $CO_2$ abatement task to 2050[23]. The following estimates exclude the costs associated with $CO_2$ storage.

- The current cost of coal fired power generation plants operating in Australia range from $31-$40 per MWh[24].
- The current costs estimated for a new Pulverised Coal (PC) generation plant with $CO_2$ capture is between $80-$106 per MWh[25].
- Over the near term in Australia, an Integrated coal Gasification Combined Cycle (IGCC) plant with 75% $CO_2$ capture could be expected to generate electricity at around A$61 per MWh. This estimate is consistent with that estimated by the Cooperative Research Centre for Coal and Sustainable Development.[26] ABARE predict these costs will fall to around $35 per MWh in 2030[27].

Additional costs for $CO_2$ transport must also be integrated into the cost of capture. ABARE has estimated the average transport costs to range between $5 - $45 per $tCO_2$. depending on such factors as the method and pressure of the carbon dioxide to be transported and distance to and type of storage site[28].

  - The IEA estimates that pipeline based transportation cost range from $1.3 - $6.6 $tCO_2$ per 100 kilometres[29].
  - The IPCC estimates pipeline transportation costs to also range from $1.3 - $10.6 tCO2 per 250 kilometres, with the price falling with a higher carbon dioxide flow rate.

Similarly, storage and on-going monitoring costs need to be factored into the total cost of CCS. ABARE estimate these costs range from between $1 - $17 $tCO_2$ depending on the geological characteristics of the storage sites and the geographical location of the carbon dioxide source. On-going costs of monitoring and verification are estimated to be marginal as compared to total capture and storage costs[30].

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[22] ABARE, 2005. *Near Zero Emission Technologies*, Canberra
[23] These results depend on (among other things) a cost of US$25-30 per tonne of $CO_2$ in 1997 US dollars.
[24] Ministerial Council on Energy Standing Committee of Officials 2006, *Discussion Paper on the Impediments to the Uptake of Renewable and Distributed Energy*, pp 21
[25] ABARE, 2005, *Near Zero Emission Technologies*, Canberra, pp 17
[26] Cooperative Research Centre for Coal and Sustainable Development, 2006. Techno-economic assessment of power generation options for Australia – technology assessment report 52, Brisbane.
[27] ABARE, 2005. *Near Zero Emission Technologies*, pp. 19. Canberra
[28] Ibid. pp. 21. Canberra.
[29] International Energy Agency, 2006. *Energy Technology Perspectives; scenarios and strategies to 2050, pp 197*
[30] Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press. Metz B, Davidson O, De Coninck H, Loos M and Meyer L (Eds.) 2005. p11 table SPM.5

Forecast cost estimates provided by the IEA and ABARE show electricity produced from an IGCC generator with complete CCS stages range from A$51 - $107 per MWh in 2010 and from A$41 - $97 MWh in 2030[31]. However, the wide range in these price estimates is an indication of the difficulty of predicting specific project level costs and the emerging technology nature of power generation with CCS and the site specific variations associated with transportation and storage of carbon dioxide. Both IEA and ABARE forecast figures discussed above indicate that costs would decrease over time.

The major cost of CCS lies in the capture processes. The gaps in knowledge of capture processes are mainly in the practical and demonstration aspects of applying such integrated systems, e.g. learning how to integrate and operate both a power and chemical plant side by side. Many of the technical systems which are proposed for advanced CCS are an adaptation of existing technology, all of which are well practiced with long-standing safety and control practice histories. The cost of each option varies according to a range of factors which include the type of carbon dioxide source, technology employed, the scale of the operation and a range of economic and financial factors. The methods proposed at present are likely to be altered as new or improved methods are developed and implemented. It is expected that the capture costs will be reduced by 20-30% over the next decade and beyond[32].

[31] This figure is a composite derived from the discussion in the previous paragraphs. The two sources are the *ABARE Zero Emission Technology* and the *IEA Energy Technology Perspectives*.

[32] Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press. Metz B, Davidson O, De Coninck H, Loos M and Meyer L (Eds.) 2005. p107

## 3. THE SKILL BASE IN AUSTRALIA TO ADVANCE THE SCIENCE OF GEOSEQUESTRATION TECHNOLOGY AND TRIALS

### Skills and Training

The Australia Government has built up a skill base in CCS technology through investment in research, principally through the CSIRO, the CRC programme and Geoscience Australia.

The Australian industry and research community is currently well placed to play a key role in facilitating excellence in the demonstration and domestic application of CCS technology. In performing this role, Australia is also creating opportunities to export this technology to key resource markets overseas, as well as the associated intellectual property, expertise and skills.

By encouraging leadership, innovation, and investment to develop and deploy the next generation of CCS technologies, the Australian Government aims to enhance the scope for emerging new industries and jobs, economic growth, together with improved energy security and protection for our environment.

### CCS funding

Government funding of major programs of research and development into CCS, which also features collaboration with international research bodies, has positioned Australia as a world leader in CCS research and therefore as an internationally recognised skills source

The technology is at the trial stage with scientific and engineering expertise playing the major role. Should CCS technology move beyond the trial phase to full commercial application, a more substantial skills base will be required to underpin this industry.

The Government has provided $50 million through the Cooperative Research Centres programme to foster collaborative research on CCS, which has resulted in a total investment of cash and in-kind support, including the CSIRO and all other partners, of around $240 million in the following three CRCs: The Cooperative Research Centre for Greenhouse Gas Technologies ($CO_2$CRC); The Cooperative Research Centre for Clean Power from Lignite; and The Cooperative Research Centre for Coal in Sustainable Development (CCSD).

**Table 5: Breakdown of CRC Programme funding for the CRCs over the next three years.**

| CRC | 2006/07<br>$ million | 2007/08<br>$ million | 2008/09<br>$ million | 2009-10<br>$ million |
|---|---|---|---|---|
| CCSD | 2.000 | 1.684 | | |
| $CO_2$CRC | 3.500 | 3.500 | 3.000 | 2.300 |

The Cooperative Research Centres have proven to be an effective mechanism for developing Australia’s CCS technology expertise. CRCs bring together researchers from universities, CSIRO and other government laboratories, and private industry or public sector agencies, in long-term collaborative arrangements emphasising commercialisation and technology transfer. The CRC programme also has a strong education component with a focus on producing graduates with skills relevant to industry needs (including a PhD programme).

The $CO_2$CRC is internationally recognised as one of the world's leading collaborative research organisations focussed on CCS. It leverages the collaborative talent of more than 100 researchers in Australia and New Zealand to develop safe and economical technologies. The $CO_2$CRC also collaborates with universities and (other) research institutions in Australia, New Zealand, the United States, Canada, Europe and Asia.

The $CO_2$CRC has been focused on storage activity, addressing a range of basic and applied issues relating to the behaviour of $CO_2$ in deep geological environments. This will enable Australia to identify and appropriately utilise its $CO_2$ storage capacity in the most effective manner. The CRC is undertaking a CCS pilot project in the Otway Basin, Victoria, to trial carbon capture, transport, injection, storage, and monitoring and verification technologies under Australian conditions. The CRC is also engaged in collaboration with the USA in a CSLF project involving a pilot field experiment in the FRIO Formation – Texas to explore the potential for storage of $CO_2$ in saline formations.

The CSIRO has also been a key contributor of CCS technology expertise and is involved in all the above CRCs. In addition, it is a core partner of the Centre for Low Emissions Technology in Queensland and has strong links and operations with COAL21. These partnerships - resulting from spin-off activity of CSIRO research in coal gasification technology, capture of greenhouse gases and carbon dioxide geological sequestration - continue to be supported in CSIRO energy research priorities involving the Energy Transformed Flagship, the Division of Health and Molecular Science (modelling the behaviour of liquid carbon dioxide) and the Division of Energy Technology.

Research into gasification by the Centre for Low Emissions Technologies (cLET) and the Cooperative Research Centre for Coal in Sustainable Development (CCSD), coupled with pre- and post-combustion research by the $CO_2$CRC and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), is providing a strong basis for a future program of demonstration of oxy-fuel, integrated gasification combined-cycle (IGCC) and post-combustion capture options.

Another important facet of CCS technology is the work on regulatory issues over the last two years. Australia has led an international taskforce under the CSLF to develop internationally agreed principles for storage of carbon dioxide. In late 2005, Australia developed a set of guiding regulatory principles for CCS, in consultation with industry, research groups and community groups to enable the uptake of CCS technology for commercial projects in Australia. These principles are currently being used to guide the development of legislation and to support the appropriate management of proposed, large-scale commercial CCS projects in Australia.

Australia has also taken a leading role in seeking to amend relevant international legislative frameworks such as the 1996 Protocol to the *London Convention on the*

*Prevention of Marine Pollution by Dumping of Wastes and Other Matter*. Australia has lodged a formal submission proposing the Protocol be amended to allow for the sequestration of $CO_2$ produced onshore into sub-seabed geological structures. See also 'Australia's International Engagement' p32.

This work, along with collaborative international efforts to enhance CCS technologies, including the AP6 Clean Fossil Energy Taskforce and CSLF are important for the development of a number of important CCS projects being proposed in Australia. These already very publicly known projects include the Gorgon Project in Western Australia, the Monash Energy Project in the Gippsland Basin and the Stanwell Project (ZeroGen) in Queensland.

## Skill Base for CCS industry

The practical application of CCS technology could lead to an industry primarily covering $CO_2$ capture technology associated with coal fired power stations, natural gas production and $CO_2$ storage in a limited number of sites. It is expected to be a capital intensive industry with requirements for skilled labour.

The Policy Group of CSLF in the publication *Capacity Building for Carbon Sequestration in Emerging Economies* identified the following skills required for undertaking CCS projects:

- Geology, including geophysics
- Geo-engineering, including reservoir engineering, and hydrogeology
- Process engineering, including electrical & chemical engineering
- Power engineering

In addition, regulatory expertise is needed to set the necessary government framework governing commercial application of CCS. Within the regulatory sphere, this will more specifically involve expertise in policy analysis, legal and regulatory issues, and communication skills.

The required skills for CCS are matched with the type of institution involved in Table 6. Expertise for CCS projects will be sought principally from the “power generation and process” sector, the “oil and gas” sector and academic and research institutions.

**Table 6: Expertise Required for Involved Institutions**

| Type of Expertise | Type of Institution | | | | |
|---|---|---|---|---|---|
| | Power Generation and Process | Oil and Gas | Financial | Academic and Research | Government |
| Geology | | X | | X | I |
| Geoengineering | | X | | X | I |
| Process Engineering | X | X | | X | I |
| Power Engineering | X | | | X | I |
| Policy Analysis | | | | X | X |
| Legal/Regulatory | | | X | X | X |
| Communication | X | X | | X | X |

Key: X – Required for Institution, I – input required from this expertise.

## Future availability of skills

The future development of CCS technology as a commercial activity will be reliant on scientific and engineering capability as well as skilled labour. However, it is not expected to require the development of significant new skill sets, being able to rely on application of higher level skills developed via existing courses in universities and technical colleges and skilled labour already available in the resources sector.

In utilising an existing range of skills, a CCS industry will have to compete for skilled labour within the resources sector more generally. Some indication of the future demand for such skills was provided in a recent report by the National Institute of Labour Studies[33] which suggested that 7,659 additional professionals will be required by the resources sector in Australia over the next ten years. Other priorities for the resources sector are competencies associated with mechanical and electrical trades and skills associated with skilled workers such as operators. It suggested that 22,058 additional skilled workers will be required in the resources sector nationally and 26,983 additional workers in the mechanical and electrical trades (with the emphasis on the former).

The Government is addressing the availability of skilled labour through Industry Skills Councils (ISCs) which provide an avenue for dialogue over skills requirements between industry and the vocational and technical education system. ISCs provide a way for industry skills needs to be identified, communicated and serviced, and ISCs have primary responsibility for developing and maintaining Training Packages, which comprise nationally endorsed components for training and assessment for specific industries, industry sectors or enterprises that are used for developing and recognising people's competencies.

[33] Labour Force Outlook in the Minerals Resource Sector, 2005 – 2015 (May 2006) by National Institute of Labour Studies at Flinders University carried out for the Chamber of Minerals and Energy of Western Australia for a project under the National Skills Shortages Strategy

The Manufacturing Industry Skills Council has developed and maintains the Chemical, Hydrocarbons and Oil Refining Training Package. The Training Package is currently under review to bring it up to date with emerging technologies and industry needs. The Resources and Infrastructure Industry Skills Council (RIISC) has coverage of all of the industries involved in the resources supply chain from exploration, extraction, and primary processing to the civil construction sector.

RIISC has been working actively with the resources industry to address the industry's critical skills needs and to project future skills needs through workforce planning that identifies the future impact on skills needs of key drivers such as the effect of new technologies, processes and systems, and changing workforce demographics. This includes a greater emphasis on upgrading the skills of existing and semi-skilled employees in order to capitalise on the existing skills and knowledge base employed in the industry and retain workers in the industry.

Meeting the skills needs of CCS will also be assisted by a COAG initiative where States and Territories have agreed to put in place arrangements that will allow apprentices and trainees to work as qualified trades men and women as soon as they have demonstrated competency to industry standards, without having to wait out a set time period or make special application.

In addition, the 'Fast Track Apprenticeship Project' will recognise candidates' current skills and industrial experience. The project targets mature candidates such as trades' assistants to formally achieve a trade certificate through flexible delivery strategies and "on-the-job" support. This gives mature aged and semi-skilled workers an express route through an apprenticeship in areas of skills shortages.

The Australian Government has committed $351 million over the next five years from 2004-05 to 2008-09 to assist more young Australians entering traditional trades through the establishment of twenty five Australian Technical Colleges.

The Australian Technical Colleges provide young Australians with the opportunity to commence their training in a traditional trade through an Australian School Based Apprenticeship while at the same time completing academic subjects leading to a Year 12 certificate.

Funding agreements have been signed by the Hon Gary Hardgrave MP, Minister for Vocational and Technical Education, for several Australian Technical Colleges throughout regional Australia. Four of these colleges (Northern Tasmania, Gladstone, Townsville and the Pilbara region) will undertake mining related trade training and industry placements as part of an Australian School Based Apprenticeship. Colleges located in the Hunter, Illawarra and Spencer Gulf regions will also be developing linkages with relevant industries. The apprenticeships offered, or will be in the future, include metals and engineering and mining and plant process operations.

For example, the establishment of the Australian Technical College Pilbara was announced by the Prime Minister on 31 May 2006. The College will be a collaborative initiative involving the Chamber of Minerals and Energy of Western Australia, BHP (Billiton) Iron Ore, Pilbara Iron, Woodside Energy, the Australian Petroleum Production and Exploration Association and the Australian Government.

The availability of higher level skills in the business sector is addressed by the Business, Industry and Higher Education Collaboration Council (BIHECC) set up by the Australian Government in July 2004 to help industry to interact with the higher education system. BIHECC fosters greater collaboration between higher education providers, industry, business, other education providers and communities. The Council is addressing issues such as skills mapping, re-skilling and educational responsiveness, and graduate skills formation for employers.

Recently, industry and science research organisations have expressed concern that the supply of skills from the education and training system may not be adequate to meet current or future demand for skills. In response, the Australian Government undertook a Science, Engineering and Technology Skills Audit with the aim to develop a comprehensive picture of SET skills issues in Australia. The summary report[34] released in July 2006 provides information on enrolment trends in the areas identified by the CSLF and these are shown in Tables 7 and 8.

The Government has already taken action to address shortages in engineering skills by adding a number of engineering occupations to the Migration Occupations Demand List (MODL) in 2005 and by providing additional engineering university places. On 24 July 2006, the Government announced the allocation of 510 new engineering places to higher education providers.

**Table 7: Enrolments in undergraduate programmes by domestic and overseas students**

| | | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Earth sciences | Domestic | 1,708 | 984 | 898 | 934 |
| | Overseas | 126 | 27 | 28 | 30 |
| Process, resources engineering | Domestic | 3,270 | 3,665 | 3,579 | 3,761 |
| | Overseas | 567 | 748 | 906 | 1,099 |
| Geomatic engineering | Domestic | 1,540 | 1,488 | 1,518 | 1,458 |
| | Overseas | 47 | 62 | 65 | 77 |

**Table 8: Enrolments in post-graduate programmes by domestic and overseas students**

| | | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Earth sciences | Domestic | 881 | 810 | 801 | 748 |
| | Overseas | 163 | 147 | 144 | 168 |
| Process, resources engineering | Domestic | 1,002 | 1,128 | 1,189 | 1,246 |
| | Overseas | 261 | 313 | 385 | 497 |
| Geomatic engineering | Domestic | 247 | 250 | 240 | 256 |
| | Overseas | 46 | 68 | 71 | 80 |

To support the development of these skills, action is also being taken to strengthen science and engineering capabilities in schools. In the 2004-05 Budget, the Australian Government committed an estimated $373 million over the next four years through *Backing Australia's Ability* to continue building stronger scientific, mathematical and technological skills of Australian school students.

[34] Department of Education, Science and Training, *Audit of Science, Engineering & Technology Skills*, Summary Report, July 2006

The Australian Government has implemented a range of initiatives calculated to increase the number of teachers in areas of shortage, and especially in the fields of mathematics, science and technology. These include: providing an additional $109.2 million in practicum funding for 2005–08; placing a cap on the maximum student contribution in education units of study to 2004 Higher Education Contribution Scheme levels to attract students to teaching; allocating over 4,000 extra places in teacher education courses to higher education providers between 2005 and 2008; allocating nearly 770 new, fully-funded places to teacher education programmes focusing on maths, science and information technology for the years 2001 to 2006; and contributing to an independent Review of Teaching and Teacher Education.

The programme, Boosting Innovation, Science, Mathematics and Technology Teaching (BISMTT), worth $38.8 million over 7 years from 2004–05, will strengthen science, mathematics and technology education, increase the number of talented people attracted to teach in the fields of science, technology and mathematics and build a culture of continuous innovation in Australia.

# 4. REGULATORY AND APPROVALS ISSUES GOVERNING GEOSEQUESTRATION TECHNOLOGY AND TRIALS

## Development of Nationally Consistent Australian Regulatory Guiding Principles

There has been considerable effort between all Australian jurisdictions and stakeholders to examine regulatory and approvals issues in relation to CCS. In September 2003 the Ministerial Council on Mineral and Petroleum Resources (MCMPR) established a Regulatory Working Group (consisting of all jurisdictions) to develop draft regulatory guiding principles for CCS.

A key focus was to ensure that the views of all relevant stakeholders were examined and addressed in formulating the draft guiding principles. A Regulatory Reference Group and subsequently a CCS Stakeholder Group were established to facilitate this process. Membership of the CCS stakeholder Group consisted of key industry peak association bodies, environmental representatives, research organisations and MCMPR representatives. The membership was representative of relevant stakeholders groups with individual members bringing together the views of their individual constituents.

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

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

The general finding was that while there is not yet a CCS-specific regulatory regime in place in Australia, technical understanding of the individual elements of CCS is advanced. This is mainly through experience developed by the petroleum and minerals exploration and production industries. These industries have longstanding, comprehensive regulatory frameworks, covering approvals processes, environmental protection, transport of gases by pipeline (although not specifically $CO_2$), a legislative regime for storage and injection of gases as part of a petroleum recovery operation, and considerable technical, legislative and regulatory know-how for industry operations. One of the Principles' express recommendations is that wherever possible, these existing frameworks should act as a basis for the development of a regulatory system for CCS. This recommendation is supported by the International Energy Agency document, *Legal Aspects of Storing* $CO_2$ which makes a similar recommendation[35].

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[35] Specifically, the document recommended that: *In the short-term, governments should ensure that there is an appropriate national legal and regulatory framework for more storage demonstration projects. In the interest of time, and given the diversity of institutional setups and policy processes between States, working at the national and/or provincial/state level using existing legal frameworks*

## Management of Carbon Dioxide in CCS Projects

There has been significant research that has been carried out on the interactions between carbon dioxide and the atmosphere, soils, water and the biota, from a modelling perspective. Carbon dioxide, a naturally-occurring constituent of air that is essential to all life forms, is a non-toxic, relatively inert gas and is generally regarded as safe. At elevated concentrations, however, carbon dioxide can cause harm to oxygen breathing organisms. A hazard can arise if carbon dioxide, which is denser than air and odourless, is allowed to accumulate in low-lying, confined or poorly ventilated spaces or if there is a significant gas cloud release. However, these risks can be significantly reduced with adequate management and monitoring.

Carbon dioxide and numerous other gases/substances are managed on a regular basis as part of current petroleum and resource-extraction activities. Specifically:

- Large quantities of CCS streams are transported by pipeline every day without any adverse consequences;
- Immense quantities of extracted natural gas are stored in the subsurface in many parts of the world;
- There are massive quantities of gas (including carbon dioxide) trapped naturally in the subsurface under parts of Australia which are not regarded as constituting a safety hazard to the general public; and
- Fluids (including hazardous materials) are injected into the subsurface every day throughout the world. These waste disposal projects have provided a knowledge base for the regulatory control of the injection of fluids into the subsurface.

While many of the pieces of a CCS regulatory regime are already in place and long-standing within the Australian petroleum and minerals industry, the development of an Australian regulatory and approvals system for CCS will be underpinned by key requirements. These are that the regulatory system should be:

- focussed on safeguarding public interest, particularly to minimise risks to health, safety, environment, economic consequences and government accountabilities;
- based on sound risk management principles, be 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 leverage experience in future developments in technologies, markets and institutional arrangements;
- flexible to allow for future government decisions regarding possible greenhouse policy measures; and

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*might be the preferred route. Longer term national frameworks should be formulated on the basis of adequate empirical knowledge about the conditions and risks of long-term storage.*

- consistent with obligations under international law[36].

Adherence to these key guidelines in the development of a regulatory and approvals framework for CCS will help gain community confidence and also provide a sound basis for industry investment. Such a framework will need to take into account the entire life cycle of a CCS project. As indicated in the introduction, there are four distinct phases in a CCS project:

1. Capture and separation – involves the separation of carbon dioxide from other gases such as flue gas emissions from a power plant or gases from a petroleum production well. Separation is necessary to ensure an acceptable mixture of $CO_2$ and other gases is stored[37];
2. Transportation – this involves moving large volumes of $CO_2$ from the collection source to a site where the $CO_2$ can be injected and stored underground. Transportation could be by way of a pipeline, rail, road or ship;
3. Injection – this involves the injection of the $CO_2$ into deep underground geological formations and ongoing management and monitoring of the storage site; and,
4. Storage – this involves the decommissioning of infrastructure, rehabilitation of disturbed sites and potentially ongoing management and monitoring of the storage site.

Capture and transport of $CO_2$ is not a new technology or idea. It has been practiced and regulated in the petroleum exploration and development industries for many decades. Some changes will be required to the national petroleum legislative regimes to enable these activities to be undertaken for CCS.

However, petroleum legislation was not developed with CCS activities in mind, and thus CCS requires the development of new regulatory practices in particular for phases three and four (injection and storage) of a CCS project. Within these two phases of a CCS project, the science suggests the key mitigation measure is site selection for injection and storage, involving assessment methodologies and appropriate risk analysis as outlined below.

## Site Selection for CCS

CCS projects will have their own unique safety issues including operational risk and other technical risks associated with the specific storage site chosen. The selection of an appropriate site has been identified as the most effective means of reducing to as low as reasonably practicable any risks over the long-term.

[36] These key principles were developed from the document, *Principles and Guidelines for National Standard Setting and Regulatory Action by Ministerial Councils and Standard Setting Bodies.* Council of Australian Governments, 1985

[37] The required purity of any CCS stream is likely to be a sensitive issue. It has already been raised in discussions regarding the amendment of the London Protocol to allow sub-seabed CCS storage. Some Protocol Parties have indicated a preference for a very high proportion of $CO_2$. The introduction of prescriptive international standards could impact on the development of Australia's national regulatory framework governing CCS.

The highest perceived operational risks associated with CCS projects result from the combination of different or newly applied technologies and lack of experience of combined operations.

The technical risk associated with each storage site will be unique and must be determined at the beginning of a project and subsequently managed.

Overall, near term challenges for site risk evaluation for CCS activities will be to:

- Continue to improve and standardise modelling techniques enabling accurate predictions of injected CCS stream movements at sites;
- Determine and agree on site selection criteria to ensure low leakage rates;
- Obtain and/or establish processes that provide up to date, accurate and comprehensive geological and hydrodynamic data to determine the suitability of proposed storage sites;
- Continuously improve technology to accurately monitor the mass and movement of CCS streams in the deep sub-surface in different geological structures; and
- Develop an adequately robust verification system.

## Monitoring and Verification

The monitoring and verification of stored $CO_2$ is fundamental to managing CCS resources, project risks and compliance obligations (such as reporting requirements). Project risk assessments will be crucial to defining the monitoring systems (and may have to be continuously revised after developing the monitoring protocols).

The objectives for CCS monitoring systems include: protecting health, safety and the environment; satisfying accounting requirements within national emission inventories (including transboundary issues); providing public assurance of storage site performance; assisting the management of CCS resources; and providing a basis for predicting the $CO_2$ behaviour in the very long term.

In addition to monitoring the behaviour of stored $CO_2$, it is important that a robust verification regime is in place to ensure that an appropriate amount of $CO_2$ remains isolated from the atmosphere. This is a key issue for $CO_2$ accounting and for providing assurance to the investment community and governments alike that claimed CCS emission reductions are legitimate reductions. Also, monitoring techniques and equipment would likely require certification as being safe, accurate and reliable by an independent verifier.

The Australian Government is also supporting the CO2CRC's Otway Basin Pilot Project, including providing funds to enhance the monitoring and verification component of the pilot. This project will enable the trialling and comparison of a range of monitoring techniques. The results will also be significant internationally as other monitoring trials around the world should be able to build on them (and vice versa).

## Legislation and regulation

As discussed in previous sections, there is at this stage no specific or comprehensive legislative and regulatory regime in place. Thus the establishment of legislation and regulation to bring forward the use of low emissions technology which will enable development of a sustainable energy industry is an essential first step.

The Australian Government is currently developing a legislative model for access and property rights which will provide investors with the confidence to participate in CCS activity in Commonwealth offshore waters. The model will provide industry with the opportunity to take up offshore acreage to identify potential storage sites, and provide a mechanism for long term injection and storage.

In line with the recommendations of the *Carbon Dioxide Capture and Geological Storage - Australian Regulatory Guiding Principles* (2005), a consistent management approach, which builds on the existing legislative framework, should be applied to the assessment and approval of projects in a manner similar to existing comparable industries. Such a regulatory system needs to apply the principles of ecologically sustainable development as agreed by COAG in 1992.

At present there are a number of Commonwealth and state environmental laws and regulatory process that have relevance and application to CCS projects (including trial projects). The applicability of the various laws will depend on the scale, environmental risks and location of the project. Commonwealth legislative arrangements that may apply to environmental regulation of CCS include:

- the *Environment Protection and Biodiversity Conservation Act 1999* – applicable nationally but focussed on matters of national environmental significance and the Commonwealth jurisdictional area.
- the *Environment Protection (Sea Dumping) Act 1981* – regulates dumping of wastes at sea including injection of material into the sub-seabed[38];
- the *Offshore Petroleum Act 2006* – potential for regulating day to day management of operations as well as regulating and facilitating access and property rights for offshore areas.

Current legislative arrangements would involve multiple jurisdictions and approvals.

Enhancement and improvement of the legislative framework should be considered to ensure an efficient and consistent regulatory system is applied. Specifically, existing and/or future regulatory systems should be amended or developed to include: streamlined environmental regulation; co-existence arrangements with the petroleum industry incorporating technical and administrative options for risk mitigation; development of objective monitoring and verification techniques; national protocols and guidelines; cross jurisdictional issues; long-term responsibility management options; use of financial instruments including insurance and performance bonds; CO2 stream access and property rights issues; deployment of technology; and, third party access issues

[38] The *Environment Protection (Sea Dumping) Act 1981* implements Australian's obligations to the London Protocol which currently prohibits sea bed sequestration of $CO_2$ – refer to section on "Australia's International Engagement" for further details.

## Public awareness

Findings from work done in Canada, UK and Australia show that in general, the public is not well informed on CCS technologies and the issues connected to its implementation and potential for mitigating global climate change. The main concerns are about probability of leakage and impacts thereof on ecosystems and the environment. A transparent, inclusive and open decision-making process would enhance information about CCS to the public, and help gain public acceptance of the basic underlying science of climate change and provide context around CCS as a tool to mitigate climate change.

Based on the above elaboration on public concerns about CCS, liability of leakage and the linkage between CCS and other regulations on climate change, guidelines to secure public involvement through consultation processes when developing legislation and assessing CCS projects should promote a transparent process in all stages of the carbon capture and storage life cycle.

Involving the public, relevant Government agencies, NGOs and industry in consultation regarding regulation and legislation should be emphasised and secured through guidelines and regulations for CCS.

Furthermore, an important focus for the Otway Basin Pilot Project is to inform and educate the community about geosequestration, and demonstrate its safe and effective storage of emissions.

## CCS trial projects

The MCMPR work was only directed at developing guidelines for large scale demonstration and commercial projects and was not intended to apply to small scale research and development CCS projects, such as the Otway Basin CCS project.

Australia currently has a number of projects either in the development or planning stages, including the demonstration project at Stanwell (ZeroGen) in Queensland and the planned Gorgon Project on Barrow Island in Western Australia. These projects would also be subject to specific requirements relating to their respective jurisdictions.

## Australia's International Engagement

Through our establishment of the Asia Pacific Partnership on Clean Development and Climate, Australia has established itself as a world leader in the pursuit of wide-ranging, practical and collaborative partnerships to advance clean energy technology.

Australia has gained a world class reputation on regulatory related CCS issues through its policy and technical work in the Carbon Sequestration Leadership Forum (CSLF) and in particular its role as vice-chair of the CSLF's policy group. Australia also contributes to international literature on the technology and its application, as exemplified by its valuable contribution to the International Panel on Climate Change's *Special Report on Carbon dioxide Capture and Storage*.

Australia is chair of the International Energy Agency/CSLF (IEA/CSLF) Legal Issues Subcommittee, which has been charged with examining the legal and regulatory impediments to the uptake of CCS technology on a world-wide scale. In 2004 and 2005, Australia was involved in the IEA Workshop on Legal Aspects of Storing $CO_2$ and the associated report which concentrated on legal issues surrounding $CO_2$ storage in both domestic and international law. Australia has a lead role as co-Chair of the Project Initiation and Review Team of the CSLF which has recognised 17 CCS projects, and leads the Taskforce on $CO_2$ Storage Capacity Estimation Methodologies which is documenting guidelines to give greater certainty and reliability to such estimates.

Australia is well advanced in leading the development of a regulatory regime for CCS. A paper authored by Australia, entitled *National Legal and Regulatory Frameworks*, will be a key component of the 2nd IEA Workshop on Legal Aspects of Storing $CO_2$ to be held in Paris on 17 October 2006 that will look to further develop and refine the development of an internationally accepted and consistent CCS regulatory framework. Other issues that will be discussed at the workshop in the context of legal and regulatory impediments to CCS include intellectual property, creating a level playing field for CCS, international marine environment instruments and public awareness. The outcomes of the workshop will be documented in the IEA's second publication on *Legal Aspects of Storing* $CO_2$ which is expected to be released in early 2007.

In addition, Australia is taking a leading role in seeking to amend the 1996 Protocol to the *London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*. In April 2006, Australia lodged a formal submission, co-sponsored by France, Norway and the United Kingdom, proposing the Protocol be amended to allow for the sequestration of carbon dioxide produced onshore into sub-seabed geological structures. Consideration of the amendment will occur in October 2006.

Other international fora Australia is involved in to further the development and deployment of CCS include the IEA's Greenhouse Gas R&D Programme and international conference on greenhouse gas technologies; IEA Working Party on Fossil Fuels; India-Australia Technical Workshop on CCS held 3 February 2006; Global Climate Energy Project - Exploring the Opportunities for Research to Integrate Advanced Coal Technologies with CCS in China on 22-23 August 2005; and the International Workshop on Near Zero Emissions Coal-Power Generation with Carbon Capture and Storage in China on 5-6 July 2006.

Australia's involvement in international fora ensures that it can learn from other countries' experiences and enhance its views on CCS technical and legal issues. One such example of learning from others is the similar way in which Australia and Norway have approached regulation of CCS projects.

# 5. HOW TO BEST POSITION AUSTRALIAN INDUSTRY TO CAPTURE POSSIBLE MARKET APPLICATIONS

## Creating possible market applications

While mitigating dangerous climate change is the driving force behind advancing CCS technologies, the development and implementation of these technologies also present opportunities to Australian industry.

The IPCC SRCCS estimates that for ‘most scenarios for stabilisation of atmospheric greenhouse gas concentrations between 450 and 750ppmv $CO_2$ and in a least-cost portfolio of mitigation options, the economic potential of CCS would amount to 220-2,200 $GtCO_2$ cumulatively’. Clearly, to achieve such an outcome requires considerable industrial activity. Please see **Attachment D** under 'scale of injection required'.

Australian industry is well positioned to play a significant role. For example, Geoscience Australia, working with Australian industry and academics, has undertaken sophisticated mapping of potential Australia storage reservoirs. Several other countries are now endeavouring to produce similar maps, and Australian expertise can make a valuable contribution to these efforts.

In addition, the Australian electricity generation sector is also well placed to take advantage of CCS technologies. With around 50 percent of net national greenhouse gas emissions attributable to that sector, and it being dominated by relatively few large emission sources, CCS represents an excellent medium term solution to the sector’s $CO_2$ emissions. Success in reducing greenhouse emissions in the energy sector – especially the electricity sector can make a significant contribution to overall emission reduction in Australia.

Some of Australia's major natural gas reserves contain significant proportions of carbon dioxide and developers may also be well placed to utilise CCS technology, given that carbon dioxide capture and separation is part of the gas processing system.

Other industry sectors, including some forms of chemical manufacture, natural gas processing, renewable energy sources such as biomass, the cement industry and aluminium production are all large point source emitters of carbon dioxide and may also be able to apply CCS technologies to reduce their greenhouse gas emissions.

Developing an environment in which investment in CCS can be made involves a number of closely inter-related aspects: legislation and regulation (including well developed systems for monitoring, reporting and verification and 'carbon accounting' systems) and public awareness. Continued development of the knowledge base in relation to CCS also has an important role to play.

## Final Observation

A key challenge for government is balancing the time it affords to answering outstanding critical scientific and technical questions on CCS and having to respond to the need to proceed to wide-scale deployment of CCS (particularly in the context of new coal fired power stations) in order to mitigate the impacts of anthropogenic climate change.

Regulators increasingly face community demand (from both industry and civil society) to make approval decisions on CCS projects (i.e. pilot, demonstration and commercial scale projects). This often involves having to stipulate regulatory conditions today that may or may not have relevance within the context of a projects changing risk profile over time (which is expected to firm with more information).

This means that monitoring and verification and reporting protocols (and other areas of CCS regulation) must remain flexible enough to embrace improved standards and technical knowledge. Also, CCS processes and equipment need to be able to deliver on changing data requirements as community preferences also change.

In summary, Australia's strong CCS science credentials and increasing CCS project experience place us at the forefront of this developing industry.