The Parliament of the Commonwealth of Australia

Between a rock and a hard place

The science of geosequestration

House of Representatives
Standing Committee on Science and Innovation

August 2007
Canberra

ISBN 978-0-642-78908-2 (Printed version)

ISBN 978-0-642-78909 (HTML version)

Contents

DISSENTING REPORT

APPENDICES

LIST OF TABLES

LIST OF FIGURES

Foreword

There is now compelling evidence that human activity is changing the global climate. While Australia remains a relatively minor emitter of greenhouse gases, our emissions, particularly in the stationary energy and transport sector, have been rising since 1990. Geosequestration or carbon capture and storage (CCS) technology has the potential to play an important role in the global effort to reduce CO_2 emissions. It may also prove to be of particular importance to Australia.

Australia is between a rock and a hard place. For many years, Australia has benefited from being able to produce very cheap electricity from our vast reserves of both black and brown coal. Australia has approximately 8.6 per cent of world black coal reserves, which, at current production levels, would last 215 years. Australia also has enough brown coal to last for another 800 years at current production levels.

Australia's energy sector is heavily reliant on black and brown coal with over 83 per cent of total electricity generated from this source. Australia is also the largest exporter of coal in the world—in 2005, Australian coal exports were worth $24 billion, representing Australia's largest commodity export.

It is expected that Australia, and the world, will continue to rely on coal well into the future. This presents us with the challenge of reducing greenhouse gas emissions whilst remaining dependent on coal. CCS provides a possible solution to these competing demands. In a carbon-constrained world, if Australia is able to demonstrate and commercialise CCS technology it will protect both the environment and the coal industry.

Carbon capture and storage comprises three broadly defined stages: (i) CO_2 separation and capture at the source; (ii) transportation of CO_2 to the storage site; (iii) long-term storage of the CO_2, largely in an underground geological facility or a depleted oil or gas field, for thousands of years.

There are three possible ways to approach the first stage of the process, that of the separation and capture of CO_2: post-combustion, oxyfuel combustion and pre-combustion. Each process differs in either the way in which the CO_2 is separated from other gases or at which point in the process the CO_2 is captured. Whilst oxyfuel and pre-combustion technologies are viewed more favourably as their processes are more efficient, the current stock of Australia's power plants are most suited to be adapted to post-combustion technology.

In Australia and internationally there is currently a large stock of pulverised coal-fired power stations. Many of these plants are expected to operate for up to 40 more years. If serious cuts in emission are to be achieved by 2050, some form of post-combustion capture technology will need to be part of the CCS strategy.

Once the CO_2 has been separated and captured, it must be transported to a storage site. This is a relatively simple process and could occur via pipeline, road, ship or rail. Further research will be required, particularly to ascertain which distances make transport options economical. Storage options include: saline aquifers; depleted gas and oil fields; unmineable coal seams; or the injection of CO_2 into existing oil and gas reservoirs for enhanced recovery purposes.

In Australia, deep saline aquifers represent 94 per cent of our feasible geological storage capacity and have therefore become a key focus of storage research. However, all storage options need to be considered. In particular, the storage potential in the Wollongong-Sydney-Newcastle region needs to be further explored. The Committee recommends that the Australian Government provide funding to CSIRO to progress research into the storage potential for permanent CO_2 sequestration in sedimentary basins in New South Wales.

Once CO_2 has been stored underground, effective and accurate technologies to measure and monitor the CO_2 are essential for the purposes of regulation, carbon accounting and public safety. The greatest environmental risk associated with CCS concerns the potential for CO_2 leakage, which could have serious consequences for the environment and people's health. These risks can be mitigated through further research, rigorous site selection and post-injection management.

The extent of the environmental benefits of CCS continues to be debated. Some argue that CCS has the potential to reduce global CO_2 emissions by 7.8 per cent with potentially greater benefits to be seen in the later half of the 21st century. Others contend that, given the environmental risks, there are more viable options. The Committee concludes that there are substantial positive environmental benefits to be gained from the deployment of CCS, providing there is also appropriate regulation and scrutiny of environmental risks. The Committee recommends the implementation of a rigorous regulatory environmental risk mitigation framework for CCS.

While a great deal of confidence is being expressed about CCS technology, there are no major projects currently underway to demonstrate the integration of technologies with coal-fired power plants. In Australia, a number of smaller CCS demonstration projects are underway such as the Gorgon project, Hazelwood 2030 and ZeroGen. These and other projects will enhance our knowledge base.

However, the major challenge is to mount a project at the 500MW scale which demonstrates all stages in the process—from coal conversion, carbon capture, and transport, through to sequestration and long-term monitoring. This raises logistic coordination and environmental and technical challenges that are not tested or resolved by small-scale demonstrations. The Committee recommends that the Australian Government fund one or more large-scale CCS projects utilising a competitive tender process to ascertain which project will receive the funding. It is also expected that these demonstration projects will provide an ideal opportunity to subject CCS to rigorous environmental, health and safety regulations before any future long-term commercial operations are in place.

Alongside its investigation of the potential environmental benefits and risks associated with CCS, the Committee also examined the economic benefits and costs. It is difficult to accurately estimate the economic impact of CCS. The IPCC estimates that, in the long-term, including CCS in a range of mitigation strategies will reduce the cost of stabilising global CO_2 emissions by 30 per cent.

Equally as challenging is accurately measuring the economic cost of inaction. Available research indicates that the Australian economy may be more adversely affected by climate change than other developed countries.

The predicted actual costs of implementing CCS technology also vary. Capturing CO_2 is the most expensive aspect of the process, accounting for between 70 and 80 per cent of the total costs. The cost of capture will vary depending on a range of factors which are outlined in the report. Costs associated with the transport of CO_2 will also vary depending on the distance transported, the pressure used to transport the CO_2 through a pipeline and the terrain through which the pipeline passes. Storage and monitoring is expected to be the least costly component of the process and the total cost is expected to reduce over time.

There is also the question of what impact CCS deployment will have on electricity costs. Clean energy comes at a price but in the case of CCS, the size of a price increase is not clear. Available data suggests that CCS might double the cost of electricity generation from coal. However, as CSIRO notes, the cost of implementing capture technology is 'only a proportion of the costs consumers pay'.[1] Conversely, Robert Socolow has predicted that as 'the costs of distribution and transmission [of electricity] are hardly affected [by CCS] … the retail cost of electricity would increase by just 20 [per cent]'.[2]

1 CSIRO, *Supplementary Submission No. 10.1*, p. 2.

2 Robert Socolow quoted in, Quirin Schiermeier, *Putting the carbon back: the hundred billion tonne challenge*, Nature Vol. 442, Issue. 7103, (10 August 2006), p. 623.

It has been advised that the technological unknowns in cost estimates make industry investment in CCS on a wide-scale unlikely in the current environment. Industry has called for economic incentives, including a carbon price signal, to foster the development of CCS technology. The Committee recommends that the Australian Government employ financial incentives, both direct and tax based, in an effort to encourage science and industry to continue developing and testing CCS technology.

The Committee also maintains that the Australian and state governments must develop appropriate legal and regulatory frameworks covering the injection of CO_2 and subsequent operational monitoring, site closure and post-abandonment monitoring. This will provide confidence for investors to undertake large-scale CCS development. The issue of long-term liability is of particular concern. Regulations need to be flexible and robust enough to apply to the sequestration and storage of CO_2 which is intended to be in place for hundreds, if not thousands, of years. Regulations for financial liability need to be designed to cover both the period during which the CO_2 is being sequestered and the period after the injection process has ceased. Therefore, the Committee recommends that the Australian Government, following industry consultation, develop legislation to define the financial liability and ongoing monitoring responsibilities at geosequestration sites.

The Committee concludes its report with a discussion on how best to position Australian industry to capture possible market applications of CCS. Australia has a solid skills base in this area and a reputation as a world leader in the development of CCS science and technology. A number of programs administered by various universities and research centres are in place to ensure that our skill base keeps developing and expanding. Greater funding in this area will assist in retaining skilled people who may be attracted to more lucrative jobs. Nurturing and further developing a skills base will be key in further developing CCS technology and demonstrating it on a large scale. If Australia is successful in this regard, then it is expected that global marketing and export opportunities will arise.

Confidence in the potential environmental benefits of CCS technology is growing. Nevertheless, the technology underpinning this climate change strategy is yet to be fully proven. Modelling and general scientific optimism is not enough to guarantee the success of CCS. A great deal more demonstration work is needed for this technology to be part of the suite of options that will need to be rolled out if Australia, and the world, are to make serious inroads into significantly reducing the current levels of anthropogenic greenhouse gas emissions. Australia has the opportunity to play a key role in the development of this technology which could provide enormous environmental and economic benefits both domestically and internationally.

I would like to thank all those who contributed to this inquiry through submissions and discussion with the Committee. I would also like to thank Committee members and the Secretariat staff for their efforts throughout the inquiry process.

Petro Georgiou MP
Chair

Membership of the Committee

Chair	Mr Petro Georgiou MP	
Deputy Chair	Mr Harry Quick MP	
Members	Mr Harry Jenkins MP	Mr David Tollner MP
	Mr Chris Hayes MP	Hon Danna Vale MP
	Dr Dennis Jensen MP	Mr Roger Price MP (until 08/05/07)
	Hon Jackie Kelly MP	Mr Kelvin Thomson MP (from 08/05/07)
	Dr Mal Washer MP	

Terms of reference

The House of Representatives Standing Committee on Science and Innovation is to inquire into and report on the science and application of geosequestration technology in Australia, with particular reference to:

- The science underpinning geosequestration technology;
- The potential environment and economic benefits and risks of such technology;
- The skill base in Australia to advance the science of geosequestration technology;
- Regulatory and approval issues governing geosequestration technology and trials; and
- How to best position Australian industry to capture possible market applications.

List of abbreviations

ABARE	Australian Bureau of Agriculture and Resource Economics
ACA	Australian Coal Association
AGO	Australian Greenhouse Office
AP6	Asia Pacific Partnership on Clean Development and Climate
APCRC	Australian Petroleum Cooperative Research Centre
BIA	Barrow Island Act
CCS	Carbon Capture and Storage
CCSD	Cooperative Research Centre for Coal in Sustainable Development
cLET	Centre for Low Emission Technology
CO_2	Carbon Dioxide
CO2CRC	Cooperative Research Centre for Greenhouse Gas Technologies
CO_{2-e}	Carbon Dioxide Equivalent
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSLF	Carbon Sequestration Leadership Forum
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
GCEP	Global Climate and Energy Project

GDP	Gross Domestic Product
GEODISC	Geological Disposal of Carbon
GHG	Greenhouse Gas
GSL	Gas Storage Licenses
IDGCC	Integrated Drying and Gasification Combined Cycle
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
ISC	Industry Skills Council
LETDF	Low Emissions Technology Demonstration Fund
LVCSA	Latrobe Valley CO_2 Storage Assessment Project
MCMPR	Ministerial Council on Mineral and Petroleum Resources
MIT	Massachusetts Institute of Technology
MRET	Mandatory Renewal Energy Target
MW	Megawatts
PEL	Petroleum Exploration Licenses
PMSEIC	Prime Minister's Science, Engineering and Innovation Council
PPL	Petroleum Production Licenses
PPM	Parts Per Million
R&D	Research and Development
RIISC	Resources and Infrastructure Industry Skills Council
TAR	Third Assessment Report
ZCP	Zero Carbon Project

List of recommendations

3 Carbon capture and storage

Recommendation 1

The Committee recommends that the Australian Government provide funding to the CSIRO to progress research being conducted through the CO2CRC to assess the storage potential for permanent CO_2 geosequestration in sedimentary basins in New South Wales, particularly the off-shore Sydney Basin, and the economic viability of these sites.

4 Australian CCS demonstration projects

Recommendation 2

The Committee recommends that the Australian Government fund one or more large-scale projects which will demonstrate the operation and integration of the CCS—capture, transportation and sequestration and monitoring. The Government's assessment of which project(s) will receive funding will be based on a competitive tender process.

5 The environmental benefits and risks of CCS and public perception

Recommendation 3

The Committee recommends that the Australian Government implement a rigorous regulatory environmental risk mitigation framework for CCS which covers:

- Criteria for CCS site selection and an assessment of the environmental impact at selected sites;
- Assessment of the risk of abrupt or gradual leakage, and appropriate response strategies; and
- Requirements for long-term site monitoring and reporting.

6 The economic benefits and costs of CCS

Recommendation 4

The Committee recommends that the Australian Government, as part of its broader fiscal response to climate change, employ financial incentives, both direct and tax based, in an effort to encourage science and industry to continue developing and testing CCS technology.

7 Legislative and regulatory framework

Recommendation 5

The Committee recommends that the Australian Government, following industry consultation, develop legislation to define the financial liability and ongoing monitoring responsibilities at a geosequestration site.

The Committee recommends that financial liability and site responsibility should consist of three phases:

- Full financial liability and responsibility for site safety and monitoring should rest with industry operators for the injection phase and a subsequent length of time (this time to be determined by the Australian Government subject to specific site risk analysis);
- Following the above specified time, shared financial liability and responsibility for site safety and monitoring should rest equally with industry operators and state, territory and Australian governments in the longer term. The exact length of this shared responsibility and liability

phase should be determined by the governments subject to specific site risk analysis; and

- Following the determined phase of shared liability and responsibility, full financial liability and responsibility for site safety and monitoring should be transferred to the two spheres of government in perpetuity.

1

Introduction

Terms of reference

1.1 On 21 June 2006, the Minister for Science and Eduction, the Hon Julie Bishop, referred to the House of Representatives Standing Committee on Science and Innovation an inquiry into the science and application of geosequestration technology.

1.2 Under the terms of reference, the Committee was asked to inquire and report on:

- The science underpinning geosequestration technology;
- The potential environmental and economic benefits and risks of such technology;
- The skill base in Australia to advance the science of geosequestration technology;
- Regulatory and approval issues governing geosequestration technology and trials; and
- How to best position Australian industry to capture possible market applications.

Inquiry format

1.3 The inquiry was advertised in *The Australian* on 1 July 2006, *The Financial Review* on 5 July 2006, R&D*Info* Newsletter on 11 July 2006, Enviro*Info* Newsletter on 6 July 2006 and *New Scientist* on 22 July 2006. The Committee sought submissions from relevant Australian Government Ministers and from state and territory governments. In addition, invitations to make submissions were sent to a range of businesses, industry groups, academics and peak environmental bodies.

1.4 The Committee received 46 submissions. These are listed at Appendix A. Additional material relevant to the inquiry which was received as exhibits is listed at Appendix B.

1.5 The Committee held 10 public hearings in Canberra from 4 September 2006 to 26 March 2007. A list of hearings and witnesses is at Appendix C.

1.6 Appendix D lists principal power stations in Australia, noting their locations, operators, plant and fuel type, year of commissioning and capacity.

Terminology

1.7 The term geosequestration applies specifically to the injection of CO_2 into geological formations. For this reason, this inquiry has chosen to use the term Carbon Capture and Storage (CCS) instead of geosequestration. The term CCS has recently been widely adopted, as it encompasses all stages of the process, that is, the capture, transport, injection, storage and monitoring of carbon dioxide (CO_2).

1.8 Where possible, throughout the report, the Committee has endeavoured to refer to carbon dioxide (CO_2) or carbon dioxide equivalent ($CO_{2\text{-e}}$).

1.9 Throughout the report, mention is often made to a “carbon-constrained” world. This refers to a situation whereby there has been some intervention (voluntary or compulsory) to control or limit the amount of CO_2 released into the atmosphere. This constraint is referred to in terms of million tonnes of CO_2 or $CO_{2\text{-e}}$ avoided. The Kyoto Protocol is the most widely recognised example of a “carbon-constrained” intervention.

1.10 In this report, the following electricity units and terms have been used:

A unit of power is referred to as a watt (W). Domestic electricity usage is typically measured in kilowatts (kW). The output of electricity generators is typically measured in megawatts (MW). For example:

- 1 kW = 1000W
- 1 MW = 1000 kW
- 1 gigawatt (GW) = 1000 MW

The size of a generator is referred to as its capacity (measured in MW) - that is, the generator's maximum electrical output.

A generator with a capacity of 1MW will power 10 000 100W light globes simultaneously. A 500MW generator has sufficient capacity to service more than 150 000 domestic electricity customers.

The consumption or generation of electricity can be measured in kilowatt-hours (kWh). An average household in Australia uses approximately 7,400 kWh of electricity a year. In 2005, Australia's power stations produced
248 billion kWh of electricity.

Structure of the report

1.11 The report has briefly looked at where geosequestration or CCS fits into the bigger picture of climate change.

1.12 Chapter 2 generally outlines the issues relating to climate change, coal and CCS, while Chapters 3 and 4 provide an outline and analysis of all the component parts that make up CCS.

1.13 Chapter 5 considers the environmental issues and the level of public awareness and support for the geological storage of CO_2.

1.14 Chapter 6 examines the economic benefits and costs of CCS. In particular, it compares the various costs per tonne of CO_2 avoided that have been estimated for the various technologies as well as providing an analysis of the costs attributed to capture, transport, injection and storage, monitoring and verification.

1.15 Chapter 7 discusses the issues that must be taken into consideration when drafting the necessary legislative and regulatory framework to enable stakeholders to undertake CCS in Australia.

1.16 The final chapter looks at a range of issues that will help position Australian companies to exploit potential market applications arising from the establishment of a CCS industry in Australia.

2

Climate change, coal and CCS

2.1 There is now compelling evidence that human activity is changing the global climate. The majority of scientists, and the community at large, agree that global action is needed, otherwise we risk reaching a point where it is too late to reverse the damage.[1]

2.2 The leading international body investigating the impact of climate change, the Intergovernmental Panel on Climate Change (IPCC), has progressively hardened its view on the human contribution to climate change. Its most recent report stated that:

> Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* [>90 per cent] due to observed increase in anthropogenic greenhouse gas concentrations.[2]

2.3 The world's major greenhouse gas emitters are the United States (24.3%), China (15.3%), Russia (5.9%), India (5.1%), Japan (5.0%) and collectively, the countries of the European Union (15.3%).

---

1 For example see: House of Commons Science and Technolgy Committee, *Meeting UK Energy and Climate Change Needs: The Role of Carbon Capture and Storage*, First Report, Session 2006-06, vol. 1, p. 9; Mr A. Zapantis, *Transcript 26 February 2007*, p. 1; Centre for Energy and Environmental Markets, UNSW, *Submission No. 33*, p. 3; BP, *Submission No. 43*, p. 3.

2 IPCC, *Climate Change in 2007: The Physical Science Basis, Summary for Policy Makers*, February 2007, p.10.

2.4 In 2005, Australia contributed 1.4 per cent of global greenhouse gas emissions, or a total of 559 million tonnes of CO_{2-e}[3] (CO_{2-e} is the standard accounting provision for the measurement of greenhouse gas emissions). This was 102 per cent of 1990 emission levels. Between 1990 and 2005 Australia reduced its per capita emissions from 32.3 to 27.6 tonnes of CO_{2-e}.[4]

2.5 Six gases produced by human activity are commonly recognised as major contributors to climate change: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.[5] Of all anthropogenic (human induced) gases, carbon dioxide is the largest contributor to global warming. For example, 74.3 per cent of Australia's greenhouse gas emissions are made up of CO_2.[6]

2.6 Fossil fuels, which account for 75–80 per cent of the world's current energy use, are responsible for 75 per cent of manmade carbon dioxide emissions and the use of fossil fuels is expanding.[7]

2.7 The IPCC's Special Report on Carbon dioxide Capture and Storage concluded:

> Without specific actions to minimize our impact on the climate, carbon dioxide emissions from fossil-fuel energy are projected to swell over the course of 21st century. The consequences—a global temperature rise of 1.4 – 5.8°C and shifting patterns of weather and extreme events—could prove disastrous for future generations.[8]

---

3 Department of Environment and Water Resources, Australian Greenhouse Office, *National Greenhouse Gas Inventory 2005*, p. 1.

4 Department of Environment and Water Resources, Australian Greenhouse Office, *National Greenhouse Gas Inventory 2005*, p. 1; Australia is often regarded as having the highest per capita emissions. Among the world's 25 highest greenhouse gas emitting countries, Australia has the highest per capita emissions. Globally, however, Australia ranks fourth in per capita emissions. See, World Resources Institute, *Navigating the Numbers: Greenhouse gas data and international climate change policy*, pp. 21-22.

5 European Environment Agency, *Glossary*, <http://glossary.eea.europa.eu/EEAGlossary/G/greenhouse_gas>, accessed 30 May 2007.

6 Department of Environment and Water Resources, Australian Greenhouse Office, *National Greenhouse Gas Inventory 2005*, p. 3.

7 UNEP, *Can carbon dioxide storage help cut greenhouse emissions?*: *A simplified guide to the IPCC's "Special Report on Carbon Dioxide Capture and Storage"*, April 2006, p. 1; the other important source of manmade carbon dioxide emissions is land use and deforestation. See Department of Environment and Water Resources, Australian Greenhouse Office, *National Greenhouse Gas Inventory 2005*, p. 17.

8 UNEP, *Can carbon dioxide storage help cut greenhouse emissions?*: *A simplified guide to the IPCC's "Special Report on Carbon Dioxide Capture and Storage"*, April 2006, p. 1.

2.8 Between 1970 and 2004 there has been an 80 per cent growth in global CO_2 emissions, with 28 per cent of this growth occurring between 1990 and 2004. The largest growth in emissions has come from the energy supply sector with an increase of 145 per cent during this period.[9]

2.9 A recent study by the leaders of Princeton University's Carbon Mitigation Initiative, Robert Socolow and Stephen Pacala, estimated that if emissions continue to grow at the pace of the past 30 years, by 2056 the annual global rate of emissions would be approximately 14 billion tonnes of carbon per annum.[10]

2.10 To put these figures into an Australian context, Table 2.1 provides a breakdown of Australia's greenhouse gas emissions from 1990 to 2010. They show a substantial increase in emissions from the energy sector, particularly in stationary energy and transport.

9 IPCC, *Fourth Assessment Report, Working Group Three: Summary for Policy Makers*, May 2007, p. 3.

10 Robert Socolow and Stephen Pacala, *"A Plan to Keep Carbon in Check"*, Scientific American, September 2006, p. 50.

Table 2.1 Greenhouse Gas emissions: 1990, 2005 and 2010[11]

	1990	2005	2010 ('with Measures' best estimate)	
	MT $CO_{2\text{-}e}$	*MT $CO_{2\text{-}e}$*	*MT $CO_{2\text{-}e}$*	*% of 1990*
Energy	287	391	430	150
Stationary	196	279	306	156
Transport	62	80	86	140
Fugitive	30	31	38	127
Industrial Processes	25	30	38	150
Agriculture	91	88	96	105
Waste	19	17	16	81
Land use, land use change & forestry	129	34	24	18
Total	552	559	603	109

Source *Australian Greenhouse Office: Tracking to the Kyoto Target 2006, p. 4.*

Note: These projections are made under Kyoto Protocol accounting rules, which differ to those of the UNFCCC, notably in their treatment of forestry sinks. 2010 emissions projections are equivalent to the 2008-2012 average. Columns may not sum due to rounding.

Australia's reliance on coal

2.11 Australia's domestic and export energy sector is heavily reliant on low cost black and brown coal.[12]

2.12 Australia has 78 500 million tonnes of black coal reserves, or approximately 8.6 per cent of world reserves. At current production levels, these reserves would last 215 years.[13] Australia—specifically the La Trobe valley in Victoria—also has 53 000 million tonnes of

11 Stationary energy includes emissions from fuel consumption for electricity; Transport includes emissions from fuels by road, rail, domestic air transport and shipping; Fugitive includes methane, CO_2 and nitrous oxide emission that arise from the production, processing, transport, storage and distribution of raw fossil fuels; Industrial processes include all the non-energy emissions from all the industrial processes; Agriculture emissions include the methane and nitrous oxide produced by livestock, cereal production and other agricultural residues; Waste includes emissions from solid waste disposal to land fill and from the treatment of waste water; Land use, land use change and forestry emissions from activities including land clearing, decay of vegetation, disturbance of the soil. Reafforestation and revegetation provide offsets.

12 Department of Prime Minister and Cabinet, *Securing Australia's Energy Future*, 2004, p. 1.

13 AGL, *Submission No. 39*, p. 2.

brown coal reserves, enough to last for over 800 years at current rates of production.[14]

2.13 Australia is the largest exporter of coal in the world.[15] The Australian Coal Association (ACA) told the Committee that the black coal industry, in particular, is predominantly an export industry. In 2005, this export was worth $24 billion representing Australia's largest commodity export.[16]

2.14 Australia is the world's fourth largest coal producer (301 million tonnes) behind China (2226 million tonnes), the US (951 million tonnes) and India (398 million tonnes).[17]

2.15 Black coal-fired capacity provides over 58 per cent of Australia's electricity, brown coal 25.8 per cent, gas 6.6 per cent, hydro 7 per cent, with the remaining capacity being met by alternative technologies such as wind and solar.[18]

2.16 Coal-fired power stations emit nearly 170 million tonnes $CO_{2\text{-}e}$ per year, approximately 30 per cent of Australia's total greenhouse gas emissions.[19] The Australian Greenhouse Office (AGO) has forecast that, under a business as usual scenario (that is, emissions in the absence of mitigation measures), by 2020 Australia will be emitting approximately 837 million tonnes $CO_{2\text{-}e}$ annually. The stationary energy sector is forecast to account for over half these emissions (423 million tonnes).[20]

2.17 Internationally, CO_2 emissions are expected to grow by over 50 per cent from 24 to 37 billion tonnes per year in 2030.[21]

---

14 Department of Industry, Tourism and Resources, *Regional Minerals Program Report: Latrobe Valley 21000 Coal Resources Project*, <http://www.industry.gov.au/content/itrinternet/cmscontent.cfm?objectID=21523D51-0EE1-E185-7ABF7A995BE5A293>, accessed 8 May 2007.

15 Australian Coal Association, *Transcript of Evidence*, 27 November 2006, p. 1.

16 Australian Coal Association, *Transcript of Evidence*, 27 November 2006, p. 1.

17 Australian Coal Association, *Transcript of Evidence*, 27 November 2006, p. 1; Coal producing figures represent estimated 2005 figures and can be found at, World Coal Institute, Coal Facts 2006 Edition, <http://www.worldcoal.org/pages/content/index.asp?PageID=188>, accessed 6 June 2007.

18 Energy Supply Association of Australia, *Submission No. 16*, pp. 1-2.

19 Saddler, Riedy and Passey, "Geosequestration: What is it and how much can it contribute to a sustainable energy policy for Australia", *Discussion Paper No. 72*, Australia Institute, September 2004, p. ix.

20 AGO, *Tracking to the Kyoto Target 2006*, p. 19.

21 Centre for Low Emissions Technology, *Submission No. 7*, p. 1.

Responses to climate change

2.18 The challenge for the international community, including Australia, is to find ways to stabilise or reduce CO_2 emissions so that future generations are not faced with insurmountable climate change problems.

2.19 Many submissions to the Committee highlighted the global nature of climate change and the need to engage all countries.[22] Australia participates in numerous international activities and negotiations related to climate change, in addition to its domestic response.

Australia's participation in international initiatives

United Nations Framework Convention on Climate Change (Convention)

2.20 The Convention established an international framework to consider strategies to reduce global warming and measures to respond to temperature increases. It came into force on 21 March 1994 and has been ratified by 189 countries, including Australia.

2.21 The Convention recognises that the climate system is a shared resource and that its stability can be affected by anthropogenic emissions of carbon dioxide and other greenhouse gases. Under the Convention, governments:

- gather and share information on greenhouse gas emissions, national policies and best practices;
- launch national strategies for addressing greenhouse gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries; and
- cooperate in preparing for adaptation to the impacts of climate change.[23]

---

22 ExxonMobil, *Submission No. 19*, p. 5; Rio Tinto, *Submission No. 31*, p. 6; Australian Coal Association and Minerals Council of Australia, *Submission No. 40*, p. 3.

23 UNFCCC, <http://unfccc.int/essential_background/convention/items/2627.php>, 24 July 2006.

2.22 The Convention sets an ultimate objective of stabilising greenhouse gas emissions at 'a level that would prevent dangerous anthropogenic interference with the climate system.'[24] It states that:

- such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner;
- The Convention requires precise and regularly updated inventories of greenhouse gas emissions from industrialized countries ... With a few exceptions, the 'base year' for tabulating greenhouse gas emissions has been set as 1990. Developing countries also are encouraged to carry out inventories;
- Countries ratifying the treaty... agree to take climate change into account in such matters as agriculture, industry, energy, natural resources, and activities involving sea coasts. They agree to develop national programmes to slow climate change; and
- The Convention recognises that it is a 'framework' document -- something to be amended or augmented over time so that efforts to deal with global warming and climate change can be focused and made more effective.[25]

2.23 The Kyoto Protocol was the first addition to the Convention and was adopted in December 1997. The Kyoto Protocol:

> … strengthens the Convention by committing Annex I Parties to individual, legally-binding targets to limit or reduce their greenhouse gas emissions. Only Parties to the Convention that have also become Parties to the Protocol (i.e. by ratifying, accepting, approving, or acceding to it) will be bound by the Protocol's commitments. 173 countries have ratified the Protocol to date … The individual targets of the Annex 1 parties add up to a total cut in greenhouse-gas emissions of at least 5% from 1990 levels in the commitment period 2008-2012.[26]

---

24 UNFCCC, <http://unfccc.int/essential_background/feeling_the_heat/items/2914.php>, accessed 25 July 2006.

25 UNFCCC, <http://unfccc.int/essential_background/feeling_the_heat/items/2914.php>, accessed 25 July 2006.

26 UNFCCC, <http://unfccc.int/kyoto_protocol/items/2830.php>, accessed 30 April 2007.

2.24 The Australian Government supports the underlying objective of the Convention and has signed but not ratified the Kyoto Protocol, stating that:

> The Government has decided not to ratify the Kyoto Protocol because, while it has some positive elements, it does not provide a comprehensive or environmentally effective long-term response to climate change. There is no clear pathway for action by developing countries, and the United States has indicated that it will not ratify. Without commitments by all major emitters, the Protocol will deliver only about a 1% reduction in global greenhouse gas emissions.
>
> The Government is committed to Australia's internationally agreed target of limiting emissions to 108% of 1990 levels between 2008 and 2012. Due to strong action by the Australian Government, including around $1.8 billion domestic climate change programme, Australia is on track to meet this target.[27]

2.25 In May 2007, the Australian Government announced that the most recent emissions projections by the Australian Greenhouse Office show that Australia is within one percentage point of meeting its Kyoto target of 108 per cent of 1990 levels.[28] The latest figures show that Australia's greenhouse gas emissions in 2005 were 102 per cent above 1990 levels,[29] whereas under a "business as usual" scenario, Australia was projected to be 125 per cent above 1990 levels by 2010.[30]

Intergovernmental Panel on Climate Change

2.26 The IPCC assesses scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts, and options for adaptation and mitigation. It was set up by the World Meteorological Organization and the United Nations Environment Programme in 1988 and consists of scientists and researchers. It is acknowledged by governments around the

---

27 Department of Environment and Heritage, Australian Greenhouse Office, <http://www.greenhouse.gov.au/international/kyoto/index.html>, accessed 21 July 2006.

28 Australian Government Press Release, 2 May 2007; AGO, *National Greenhouse Gas Inventory 2005*, p. 1.

29 AGO, *National Greenhouse Gas Inventory 2005*, p. 1.

30 Australian Greenhouse Office, *2006 Tracking to the Kyoto Target*, December 2006, p. 4.

world, including the Australian Government, as the authoritative source of advice on climate change science.[31]

2.27 In January 2001, the IPCC approved the Third Assessment Report which updated the current level of understanding of the climate system and future challenges.[32] Its findings included:

- average global surface temperature has increased over the 20th century by about 0.6˚C;
- snow cover and ice extent has decreased;
- global average sea levels have increased and ocean temperatures have increased; and
- rainfall patterns have changed in various parts of the world.[33]

2.28 In September 2005, the IPCC released its Special Report on Carbon Dioxide Capture and Storage which assessed the scientific, technical, economic and policy dimensions of separating, capturing, transporting and storing the CO_2 that is produced in the combustion of fossil fuels. The Summary for Policymakers received line-by-line approval by governments at the IPCC Working Group III Session held in September 2005.[34]

2.29 The Australian Government submission notes Australia's significant contribution to the development of the report and also states that the report:

> ... 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.[35]

2.30 On 2 February 2007, the IPCC released its Fourth Assessment Report on climate change. This report painted a more pessimistic picture than its predecessor. It concluded that its earlier predictions understated

---

31 Australian Government, *Submission No. 41*, p. 8. Direct quote: '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'.

32 IPCC, *Third Assessment Report, Working Group I, The Scientific Basis: Summary for Policy Makers*, January 2001, p. 2.

33 IPCC, *Third Assessment Report, Working Group I, The Scientific Basis: Summary for Policy Makers*, January 2001, p. 2.

34 IPCC, *Special Report on Carbon Dioxide Capture and Storage*, pp. ix, 53-54.

35 Australian Government, *Submission No. 41*, p. 9.

the impact anthropogenic emissions were having on changes to the global climate:[36]

> Most of the observed increase in global average temperatures since the mid 20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. This is an advance since the TAR's conclusions ... Discernable human influences now extend to other aspects of climate including ocean warming, continental-average temperatures, temperature extremes and wind patterns.[37]

International Energy Agency

2.31 Since its inception in 1974, the International Energy Agency (IEA) has acted as an energy policy advisor to its 26 member countries. Its current focus is on climate change policies as well as energy technology collaboration and global outreach.[38]

2.32 The IEA biennial conference on Greenhouse Gas Technologies has become a major forum for knowledge transfer in relation to CCS technology and policy.[39] In addition, the IEA's Clean Coal Centre is a collaborative project to help members support the production, transportation and use of coal in an environmentally sustainable manner.

Asia Pacific Partnership on Clean Development and Climate

2.33 In 2006, the Australian Government hosted the launching of the Asia Pacific Partnership on Clean Development and Climate (AP6), announcing a commitment of $100 million to the partnership.[40] The member countries, Australia, China, India, Japan, Republic of Korea and the United States, account for nearly 50 per cent of global energy consumption and greenhouse gas emissions.[41] The principles

---

36 IPCC, *Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report, Summary for Policy Makers*, February 2007, p. 10.

37 IPCC, *Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report, Summary for Policy Makers*, February 2007, p. 10.

38 International Energy Agency, <http://www.iea.org/textbase/about/index.asp>, accessed 13 April 2007.

39 Australian Government, *Submission No. 41*, p. 9.

40 Australian Government, *Submission No. 41*, p. 7.

41 ABARE, *Report 06.6, Technology-its role in economic development and climate change*, July 2006, p. 5.

underpinning the work of AP6 include environmental effectiveness, economic efficiency and equity.[42]

2.34 The AP6 has established eight public-private sector taskforces to study and report on the cleaner use of fossil fuels, renewable energy and distributed generation, power generation and transmission, steel, aluminium, cement, coal mining as well as buildings and appliances. The clean fossil energy taskforce aims to promote an environment which will foster cleaner technologies and practices, including CCS.[43]

2.35 Evidence to the inquiry has indicated broad support for AP6.[44] According to the Australian Bureau of Agriculture and Resource Economics (ABARE):

> The partnership offers significant potential to reduce growth in greenhouse gas emissions because it includes key developing countries that are responsible for a significant proportion of global emissions, and also because it brings together considerable interregional expertise in a broad range of energy efficient and low emissions technologies.[45]

42 ABARE, *Report 06.6, Technology-its role in economic development and climate change*, July 2006, p. 7.

43 Australian Government, *Submission No. 41*, p. 7.

44 ExxonMobil, *Submission No. 19*, p. 5.

45 ABARE, *Report 06.6, Technology-its role in economic development and climate change*, July 2006, p. 5.

Carbon Sequestration Leadership Forum

2.36 In 2003, Australia became a founding member of the Carbon Sequestration Leadership Forum (CSLF)—a collaboration between governments, non-government organisations, industry and researchers on carbon dioxide capture and storage:[46]

> The Carbon Sequestration Leadership Forum is an international climate change initiative that is focused on 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 CSLF is to make these technologies broadly available internationally; and to identify and address wider issues relating to carbon capture and storage. This could include promoting the appropriate technical, political, and regulatory environments for the development of such technology.[47]

2.37 The CSLF Technical Group's technology roadmap outlines individual and technical issues that it wishes to address. These include:

- Achieving cost reduction for CO_2 capture, transport and storage technologies
- Developing an understanding of global storage potential
- Matching CO_2 sources with potential storage sites
- Demonstrating the effectiveness of CO_2 storage
- Building technical competence and confidence through multiple demonstrations.[48]

2.38 The roadmap, outlined in Table 2.2, identifies key milestones for the development of CO_2 capture, transport and storage that individual CSLF members can utilise.[49]

46 Australian Government, *Submission No. 41*, p. 5.

47 Carbon Sequestration Leadership Forum, <http://www.cslforum.org/about.htm>, accessed 25 July 2006.

48 Carbon Sequestration Leadership Forum, *CSLF Technology Roadmap*, p. 1.

49 Carbon Sequestration Leadership Forum, *CSLF Technology Roadmap*, p. 27.

Table 2.2 Carbon Sequestration Leadership Forum - ROAD MAP

Topic/timescale	**2004-2008**	**2009-2013**	**2014+**
Lower costs	Identify most promising pathways Set ultimate cost goals	Initiate pilot or demonstration projects for the promising pathways	Achieve cost goals
Secure Reservoirs	Initiate field experiments Identify most promising reservoir types	Develop reservoir selection criteria Estimate worldwide reservoir “reserves”	Large scale implementation
Monitoring and Verification Technologies	Identify needs Assess potential options	Commercially available technologies	

Source CSLF Technology Roadmap, p. 25.

Australia’s domestic response

2.39 Australia has established a wide ranging set of measures as its domestic response to climate change including:

- The AGO, an agency of the Department of Environment and Water Resources, was formed in 1998 and delivers the majority of programmes under the Australian Government’s climate change strategy; and
- The 2004 Australian Government White Paper, *Securing Australia’s Energy Future*, set out the Government’s approach to meeting Australia’s energy objectives of ‘prosperity, security and sustainability’.[50] The White Paper acknowledged the importance of addressing human-induced climate change, particularly those caused by greenhouse gas emissions.

50 Australian Government White Paper (2004), *Securing Australia’s Energy Future*, p. 2.

2.40 Government initiatives which have provided support for addressing CCS and climate change generally include:

- In 2001, Council of Australian Government (COAG) agreed to establish a National Energy Policy Framework;
- In 2001, funding provided for the Cooperative Research Centre (CRC) for Coal in Sustainable Development and CRC for Cleaner Power from Lignite (ceased in June 2006);
- In 2002, Prime Minister's Science, Engineering and Innovation Council (PMSEIC) released *Beyond Kyoto – Innovation and Adaptation*; Australia's National Research Priorities for 2002 also included *An Environmentally Sustainable Australia*;
- In 2003, $21.7 million funding for the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC);
- In 2004, Government announced $500 million for the Low Emissions Technology Demonstration Fund (LETDF), a fund intended to leverage at least $1 billion in additional private investment to demonstrate new low emissions technology (renewables and fossil fuel);
- On 25 November 2005, the Ministerial Council on Mineral and Petroleum Resources (MCMPR) endorsed a set of Regulatory Principles for CCS;
- In March 2007, the $200 million Global Initiative on Forests and Climate was launched by the Australian Government. This initiative promotes practical international action to help sustain the world's forests and reduce deforestation;
- Also in March this year, the Government allocated $52.8 million to assist households and small businesses in becoming carbon neutral through increased energy efficiency; and
- The 2007/08 Budget includes an allocation of $150 million for the installation of solar panels in Australian households and in schools and other community facilities.

Industry's response to greenhouse gas emissions

2.41 The response of the private sector to emission reduction, as outlined in the submissions, is proceeding across a broad front. A range of industry responses relating to existing and proposed CCS projects in

Australia is discussed at length in Chapter 4. The following are illustrative of industry responses both globally and locally.

2.42 ExxonMobil highlighted its involvement with Global Climate and Energy Project (GCEP) which was launched in the US in 2002. The project is:

> ... a major long-term research program designed to accelerate development of commercially viable energy technologies that can lower GHG [green house gas] emissions on a worldwide scale. Current GCEP research areas include CO_2 sequestration, hydrogen, solar energy, biomass, advanced combustion and advanced materials.[51]

2.43 ExxonMobil is also a major supporter of the University of Texas Geological CO_2 Storage Research Program which is 'carrying out state-of-the-art simulations to evaluate the feasibility and reliability of subsurface storage schemes'.[52]

2.44 In Australia, ExxonMobil is an advisory partner to CO2CRC in a feasibility study for the storage of emissions in the Gippsland Basin.[53]

2.45 In May 2006, Anglo American and Shell formed the Clean Coal Energy Alliance to address benefits from the emerging clean coal technologies.[54] In September 2006, the Alliance committed itself to progressing the Monash Energy Project, using Anglo's coal resources and Shell's proprietary coal gasification process. The Monash Energy Project is discussed in more detail in Chapter 4.

2.46 BP Australia, through its parent company, has been involved in several projects around the world. The In Salah project, located in Algeria, was commenced in 2004 to separate the CO_2 from natural gas and sequester it 1800 metres deep into a lower level of one of the gas reservoirs. One million tonnes of CO_2 is injected into the reservoir each year.[55]

2.47 In 2005, BP commenced planning the development of a clean energy plant at Peterhead in Scotland to split natural gas into hydrogen and CO_2. The hydrogen would fuel a 460MW (base load power) station.[56]

---

51 ExxonMobil, *Submission No. 19*, p. 4.
52 ExxonMobil, *Submission No. 19*, p. 4.
53 ExxonMobil, *Submission No. 19*, p. 7.
54 Anglo American, *Media Release*, 21 September 2006.
55 BP Australia, *Submission No. 43*, p. 5.
56 BP Australia, *Submission No. 43*, p. 5.

The CO_2 will be piped 240 kilometres to an oil reserve in the North Sea to be used for enhanced oil recovery (EOR) and ultimately for storage.[57] It is due to commence in 2009 and will require a capital investment of around US$600 million. The go-ahead depends upon public/government support, which is not yet guaranteed.[58] BP is also planning a similar hydrogen power and geosequestration project for California, albeit using petroleum coke, a refinery by-product, instead of natural gas.[59]

2.48 The FutureGen Alliance, a public-private partnership between twelve companies including BHP Billiton, Anglo American, China Huaneng Group, Rio Tinto, and Xstrata Coal, has been established to design, build and operate the world's first Integrated Gasification Combined Cycle (IGCC) plant with CCS in the US. It is estimated to cost around US$1 billion with construction due to commence in 2009 and the full-scale plant operational by 2012 /2013.[60]

2.49 The CO_2 Capture Project aims to find methods of reducing the cost of CO_2 capture technologies and improve methods of safely storing CO_2 underground.[61] The Project was created by eight of the world's largest energy companies, including BP, Chevron and Shell and in collaboration with governments, including the US Department of Energy, EU and Klimatek-Norway, NGOs and other stakeholders.

2.50 The ACA in March 2003 brought together representatives from the coal and electricity industries, unions, federal and state governments and the research community to form the COAL21 Partnership.[62] One of the aims of the partnership is to accelerate the demonstration and deployment of clean coal technologies. The Australian Government committed $500 000 to support the initial research.[63] This was followed up by the establishment of the COAL21 fund in March 2006 which will raise over $300 million over the next five years to support further research, development and demonstration (RD&D).[64]

57 BP, *Media Release, BP and Partners Plan Clean Energy Plant in Scotland*, 30 June 2005.

58 BP, *Media Release, BP and Partners Plan Clean Energy Plant in Scotland*, 30 June 2005; Rio Tinto, *Transcript*, 26 February 2007, p. 6.

59 BP Australia, *Submission No. 43*, p. 6.

60 The FutureGen Alliance, <http://www.futuregenalliance.org>, accessed 15 May 2007.

61 CO_2 Capture Project, <http://www.co2captureproject.org/overview/overview.htm>, accessed 15 May 2007.

62 Australian Coal Association, *Submission No. 40*, p. 5.

63 Australian Government, *Submission No. 41*, p. 5.

64 Australian Coal Association, *Submission No. 40*, p. 5.

2.51 The Centre for Low Emission Technology (cLET) is an unincorporated joint venture partnership between the State of Queensland through the Department of State Development Trade and Innovation, dthe Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australian Coal Research, Stanwell Corporation, Tarong Energy Corporation and the University of Queensland. Launched in November 2003, its aim is to advance 'the development of enabling technologies for the production of low emission electricity and hydrogen from coal'.[65]

CCS: one possibility in a suite of options

2.52 The international and national responses to reduce CO_2 emissions embrace a variety of participants and a wide array of mitigation strategies. The focus of this report, given the Committee's terms of reference, is on the science and the economic potential of CCS.

2.53 The Committee does not view CCS as a magic bullet for reducing global CO_2 emissions. The consensus of the submissions is that a suite of options will be needed to combat climate change and that this has to be a global endeavour. Nonetheless, as fossil fuels will play a major role in power generation worldwide in the 21st century, CCS has the potential to become an essential component of any future global CO_2 mitigation strategy.

2.54 The Australian Government submission to this inquiry notes that CCS has been supported both at a Federal and State level, as part of a suite of options to reduce CO_2 emissions from the energy sector.[66]

2.55 Socolow and Pacala offer another perspective on the role that CCS may play in reducing CO_2 emissions. Their model aims to show the extent of measures needed across a range of options in order to achieve equivalent levels of greenhouse gas emission reductions (see Figure 2.3). Each measure detailed in Socolow and Pacala's model, if phased in over the next 50 years, could potentially contain 25 billion tonnes of carbon.[67] CCS is one of 15 possible strategies, and would

65 Centre for Low Emission Technology, *Submission No. 7*, attachment p. 2.

66 Australian Government, *Submission No. 41*, p. 3.

67 Robert Socolow and Stephen Pacala, *"A Plan to Keep Carbon in Check"*, Scientific American, September 2006, p. 54.

require the installation of CCS at 800 coal-fired plants to capture 90 per cent of the CO_2.[68]

2.56 Other options in the Socolow and Pacala model include:

- increasing electricity efficiency;
- doubling nuclear power generation;
- a 700-fold increase in solar power;
- a 40-fold increase in wind power;
- the replacing of '1400 large coal-fired power plants with gas-fired plants';
- the widespread use of ethanol to power cars; and
- the end of deforestation.[69]

68 Robert Socolow and Stephen Pacala, *"A Plan to Keep Carbon in Check"*, Scientific American, September 2006, p. 54.

69 Robert Socolow and Stephen Pacala, *"A Plan to Keep Carbon in Check"*, Scientific American, September 2006, p. 54.

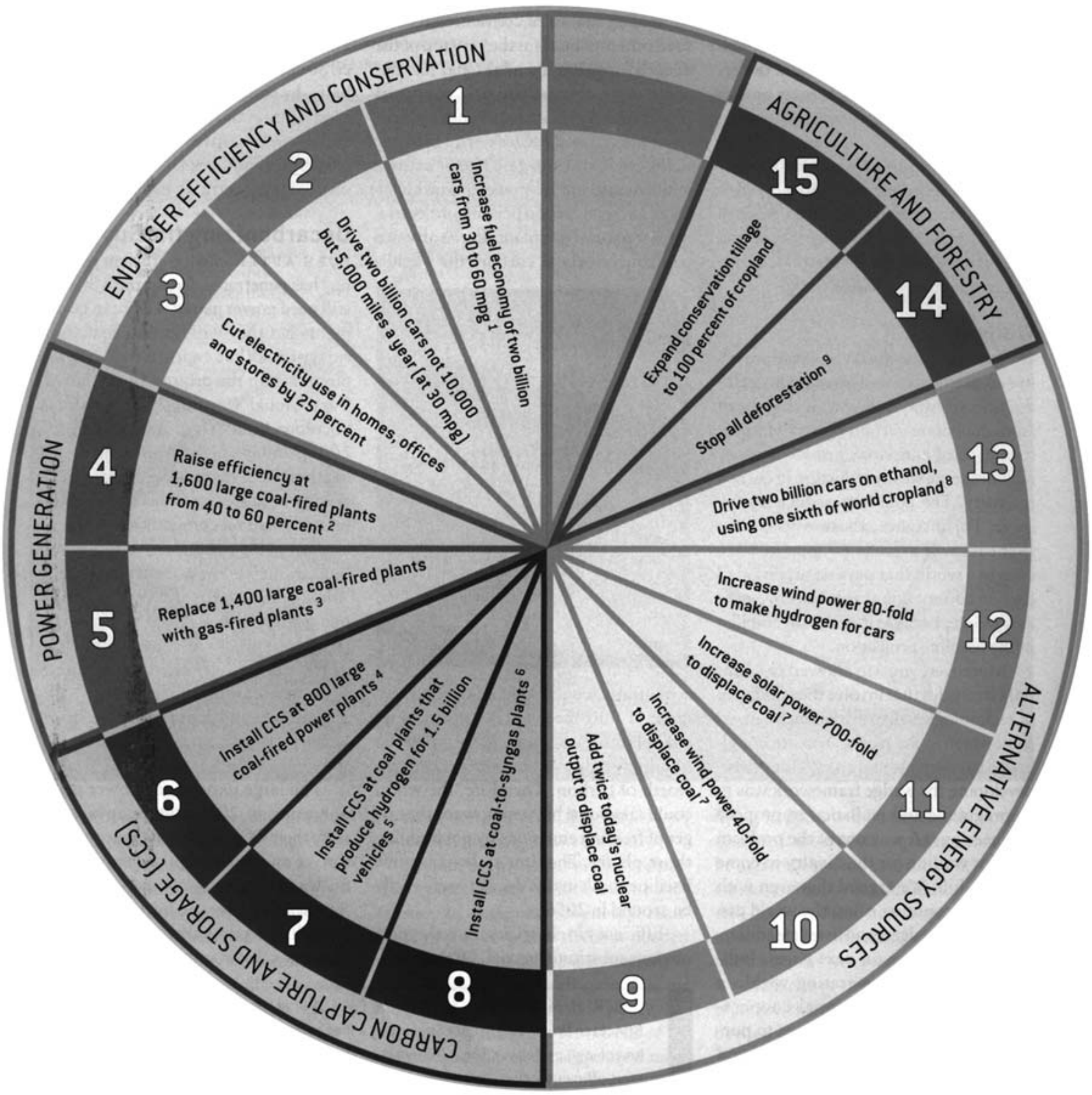

Figure 2.3 sourced from: Robert Socolow and Stephen Pacala, *"A Plan to Keep Carbon in Check"*, Scientific American, September 2006.

2.57 CSIRO suggests that it would be difficult for renewable energy sources to meet Australia's base-load demands.[70]

2.58 CCS is not a universally preferred option. Some evidence to the inquiry has expressed concern that while CCS has the potential to reduce CO_2, it does not address the other noxious emissions such as sulphur dioxide, nitrogen oxide, arsenic, mercury, dioxins, cadmium, radionucleotides and lead.[71]

2.59 Furthermore making coal 'cleaner' through the introduction of CCS will result in a continuing reliance on coal.[72] For example, Friends of the Earth Australia states:

> Choosing geosequestration and its associated 'clean coal' technologies is committing Australia to an emissions heavy coal-reliant future. It will mean further financial commitment to fossil fuels and the infrastructure that supports them at the cost of cleaner and less costly renewable energy choices. Renewable energy, energy efficiency and demand management remain the fastest, safest, most cost effective, environmentally and socially responsible ways to reduce greenhouse gas emissions. These technologies already exist, are proven, and could put Australia at the forefront of curbing greenhouse emissions.[73]

70 CSIRO, *Submission No. 10*, p. 7.

71 Friends of the Earth Australia, *Submission No. 13*, p. 6.

72 Friends of the Earth Australia, *Submission No. 13*, p. 5.

73 Friends of the Earth Australia, *Submission No. 13*, p. 5.

3

Carbon capture and storage

The science of CCS

3.1 Given that fossil fuels will continue to play a substantial role in power generation in the 21st century, CCS has the potential to be a significant component of global greenhouse gas mitigation strategies.

3.2 The principal source of anthropogenic CO_2 emissions is the burning of fossil fuels to produce energy in small sources, such as cars and residential furnaces, and in large stationary sources such as combustion for the production of electricity.

3.3 While the proposed primary application of CCS is power plants, CCS could also be applied to energy intensive industrial processes.[1] Globally, power stations emit 10.5 billion tonnes of CO_2 annually; industrial processes emit less than three billion tonnes.[2]

3.4 CCS comprises three broadly defined stages:

- CO_2 separation and capture at the source;
- transportation of CO_2 to the storage site; and
- long term storage of the CO_2, largely in an underground geological facility or a depleted oil or gas field, for thousands of years.

---

1 Energy intensive industrial processes include oil refining, steel and cement production.

2 IPCC, *Special Report on Carbon Dioxide Capture and Storage: Summary for Policy Makers and Technical Summary*, 2005, p. 20.

3.5 The science of separating, capturing and sequestering CO_2 is generally well understood. As the South Australian Government explained:

> While the capture of CO_2 for carbon geosequestration ... is a relatively new concept, CO_2 capture for commercial markets has been practi[s]ed here in Australia as well as overseas for many years. In Australia, CO_2 capture for commercial markets occurs at natural gas wells and ammonia manufacturing plants ... In North America, CO_2 capture at power plants ... has been practi[s]ed at some plants since the late 1970s, with the capturing of CO_2 being used for [EOR]. Furthermore, such is the confidence in the feasibility of this technology it is understood that a number of applications for Low Emission Technology Demonstration Fund (LETDF) grants have been submitted to the Federal Government for the capture and geosequestration of CO_2 gas.[3]

3.6 Some comparatively large scale separation, capture and sequestering systems are currently employed in the natural gas industry and for the purposes of EOR. EOR consists of injecting CO_2 into an oilfield where it mixes with the oil to bring more oil to the surface.

3.7 Norway's Sleipner natural gas project removes CO_2 in order to purify the gas stream for commercial sale. The project has injected a million tonnes of CO_2 a year since 1996 into a saline aquifer 900 metres below the North Sea. Project operators, Statoil, state that:

> It represents a relatively expensive approach. Generally speaking, a coal–or gas–fired power station which converted to this disposal method would see its costs rise by 50-80 per cent.
>
> However, the Sleipner West licensees would have to pay NOK 1 million [$203 000] per day in Norwegian carbon dioxide tax had they released the greenhouse gas to the air.
>
> Injecting the carbon dioxide costs about the same and the solution is more environmentally friendly.[4]

3.8 The Weyburn EOR project uses CO_2 captured from a coal gasification project in North Dakota and transports it by pipeline 330 kilometres

---

3 South Australian Government, *Submission No. 5*, p. 2.

4 Statoil: Topics, *Carbon Dioxide Storage Prized*, <www.statoil.com>, accessed 29 May 2007.

to Canada's Weyburn Field for EOR. The Weyburn project will store 30 million tonnes of CO_2 over its proposed 20 year lifetime.[5]

3.9 A great deal of confidence is being expressed about CCS technology. Some of this confidence is based on CCS operations in the natural gas sector with EOR. CCS has, however, not yet been applied at a large coal-based power plant.[6] Coal is the major fuel stock for power generation worldwide and the stationary energy sector is the major anthropogenic emitter of CO_2 into the atmosphere. The challenge is to demonstrate CCS technology in large coal-fired power stations.

Separation and capture

3.10 The first step of CCS is to separate and capture the CO_2 before it is emitted into the atmosphere. There are three available approaches to separate and capture CO_2:

- post-combustion;
- oxyfuel combustion; and
- pre-combustion.

Post-combustion

3.11 In post-combustion capture technology, CO_2 is separated from other flue gases by using a chemical solvent that reacts with CO_2 in an absorption process. Following absorption, the captured CO_2 is taken for transportation while the remaining gases, largely water vapour and nitrogen, are released into the atmosphere.

3.12 Post-combustion technology is commercially used to separate CO_2 for use in the food and beverage industry. It is also used in the natural gas industry to separate the CO_2 before the natural gas can be sold.

5 United States Department of Energy, *Successful Sequestration and Enhanced Oil Recovery Project Could Mean More Oil and Less CO2 Emissions*, Office of Public Affairs Media Release, 15 November 2005, <www.energy.gov/print/2673.htm>, accessed 29 May 2007.

6 A large power plant is generally defined as having a capacity of 500 megawatts (MW) or above. Mr A. Zapantis, Rio Tinto, *Transcript of Evidence*, 26 February 2007, p. 9.

The Sleipner Project, for example, uses post-combustion technology to remove CO_2 from a natural gas stream.[7]

3.13 Post-combustion capture has the potential to capture up to 95 per cent of CO_2. It requires considerable energy, which generates more CO_2. With current technology, it is estimated to reduce a generator's total electricity output by up to 30 per cent.[8]

3.14 Australia's existing power stations are fuelled by pulverised coal. There are three levels of air-blown coal generating technologies using pulverised coal combustion. These are subcritical; supercritical and ultra-supercritical.

3.15 The differences in the three technologies are associated with the difference in steam pressure and temperature used in the combustion process. The higher the pressure and temperature used, the greater the operating efficiency.

3.16 Subcritical technology operates at between 33 and 37 per cent efficiency for generating power, while supercritical operates at between 37 and 40 per cent efficiency. Current research in ultra-supercritical technology is targeting an increase in efficiency between 44 and 46 per cent. Some estimates are indicating efficiency of up to 55 per cent is achievable.[9]

Oxyfuel combustion

3.17 Oxyfuel combustion differs from post-combustion in that it separates the CO_2 by burning the fuel in pure oxygen, rather than air. This eliminates nitrogen from the resulting flue gas, and produces a high concentration of CO_2. The cleaned flue gas consists mainly of CO_2 and water vapour. Once the vapour condenses, an almost pure CO_2 stream is created.

---

7 House of Commons, Science and Technology Committee, *Meeting the UK Energy and Climate Needs: the Role of Carbon Capture and Storage*, First Report of Session 2005–06, Volume 1, p. 15.

8 CSIRO, *Submission No. 10*, p. 3; Mr T. Daly, Centre for Energy and Environmental Markets, *Transcript of Evidence*, 30 October 2006, p. 6.

9 Australian Coal Association, Clean Coal Technology in Australia, <http://www.australiancoal.com.au/cleantechAus.htm>, accessed 7 June 2007; ABARE research report 06.1, *Technical Development and Economic Growth: the Inaugural Ministerial Meeting of the Asia Pacific Partnership on Clean Development and Climate, Sydney*, January 2006, p. 51.

3.18 The oxyfuel combustion process is efficiency neutral, in that there is a comparable efficiency reduction to the other combustion capture technologies.

3.19 Oxyfuel combustion is relatively new and is yet to be fully demonstrated on a large scale. It has the potential to be retrofitted to existing coal-fired power stations, although the costs involved at present are substantial.[10]

3.20 The results from small scale demonstration projects are promising, with nearly all the CO_2 being captured. However, additional gas treatment systems are needed to produce the oxygen and to remove the sulphur and nitrogen oxides from the pulverised coal, which lowers the net capture of CO_2 to around 90 per cent.[11]

Pre-combustion

3.21 Pre-combustion separation and capture involves the removal of CO_2 from processed coal before the combustion stage. A gasifier converts solid fuel into a synthesis gas, which consists primarily of water and carbon monoxide. The synthesis gas is reacted with steam to produce CO_2 and hydrogen. The CO_2 is then separated through an absorption process and transported for storage. The hydrogen is combusted in a gas turbine to generate power, resulting in a flue gas consisting only of water vapour.

3.22 Pre-combustion capture technology is in the developmental stages for large scale application. It offers the potential for very clean fossil fuel use and a reduction in capture costs.[12] The reduction in capture costs is largely due to the production of a more concentrated stream of CO_2, making the capture process easier.[13]

3.23 Pre-combustion capture technology has the potential to capture up to 95 per cent of CO_2. It will require a new generation of IGCC power plants in which the fuel is first gasified.[14] IGCC has the capacity to be far more efficient than a conventional coal-fired (pulverised fuel boilers) power station.

---

10 Mr M. O'Neill, Australian Coal Association, *Transcript of Evidence* 27 November 2006, p. 6.

11 UNEP, *Can Carbon Dioxide Storage Help Cut Greenhouse Emissions? A Simplified Guide to the IPCC's "Special Report on Carbon dioxide Capture and Storage"*, April 2006, p. 4.

12 Australian Government, *Submission No. 41*, Attachment C, p. 2.

13 CO2CRC, *Submission No. 36*, p. 7.

14 CSIRO, *Submission No. 10*, p. 3.

3.24 At the present time, there are only four coal-based IGCC power plants in operation, located in Spain, the Netherlands and the United States. These IGCC plants are all using separation and capture technology, although not with CO_2.

Australia's coal-fired energy production

3.25 There are 30 coal-fired power stations operating in mainland Australia. The total capacity of these coal fired plants is close to 29 000 megawatts (MW). Twenty two of the plants have a capacity of 500 MW or more. The majority of the larger capacity plants are more than 20 years old.[15]

3.26 All but four of Australia's power stations operate using subcritical technology. The other four employ supercritical technology. The power stations using supercritical technology are all located in Queensland and were commissioned after 2000. [16]

3.27 The current stock of Australian and international pulverised coal-fired power plants can only make use of post-combustion capture technology. In some cases, post-combustion may be able to be combined with an oxyfuel process to produce a more concentrated stream of CO_2, facilitating more efficient capture.

3.28 Stanwell Corporation told the Committee that, unless there was an enormous breakthrough in science, the costs associated with retrofitting post-combustion capture technologies to existing plants would probably make it more attractive to build a new generation plant from scratch.[17]

3.29 BP stated that the only possible candidates for retrofitting would be those modern coal-fired power plants with supercritical technology that currently operate at in excess of 40 per cent efficiency. BP added that it would not be economically feasible to retrofit older plants operating at around 20 per cent. [18]

3.30 Coal-fired power stations are generally assumed to have a lifespan of 30 to 40 years, so Australia's power stations may be expected to have long economic lives.[19] If serious cuts in emissions are to be achieved

15 ESAA, *Electricity Gas Australia 2006*, Appendix 1, pp. 51–61.

16 ESAA, *Electricity Gas Australia 2006*, Appendix 1, pp. 51–61.

17 Stanwell Corporation, *Transcript of Evidence*, 11 September 2006, p. 17.

18 Dr T. Espie, BP United Kingdom, *Transcript of Evidence*, 30 October 2006, p. 16.

19 Clean Energy Future Group, *A Clean Energy Future for Australia*, March 2004, p. 151; and Australian Government, *Submission No. 41*, p. 13.

by 2050, some form of post-combustion capture technology will be necessary.

Transport

3.31 Once separated from other gases and compressed, the CO_2 can be transported to the site of storage by pipelines, road, ship or rail.

3.32 Evidence to the inquiry has indicated that transport of the captured CO_2 by pipeline is a relatively straightforward procedure. It is a well established practice in the chemical and petroleum industries and is analogous to the transportation of natural gas.[20]

3.33 However, CSIRO draws attention to the need for more research in the area of transportation:

> Materials research may show how costs can be reduced but at the moment, transport is receiving little attention in Australia and overseas compared to other aspects of geosequestration.[21]

3.34 Further research into the issue of transportation is required, particularly to ascertain which distances make transport options economical.

Storage and monitoring

Geological storage options

3.35 The options for long term geological storage include:

- saline aquifers;
- depleted gas and oil fields;
- unmineable coal seams;
- injecting into existing oil and gas reservoirs to enhance recovery;
- injecting into coal bed methane reserves to extract the methane; and

---

20 Australian Government, *Submission No. 41*, pp. 10-11.

21 CSIRO, *Submission No. 10*, p. 4.

- injecting into other geological formations such as basalts, oil shales and cavities. [22]

3.36 Commercial experience in the geological storage of CO_2, mostly for the purposes of EOR or gas recovery, is considerable.

3.37 According to the IPCC:

> The injection of CO_2 in deep geological formations involves many of the same technologies that have been developed in the oil and gas exploration and production industry. Well drilling technology, injection technology, computer simulation of storage reservoir dynamics and monitoring methods from existing applications are being developed further for design and operation of geological storage.[23]

3.38 BP told the Committee that around 35 million tonnes of CO_2 a year is injected into geological formations around the world.[24] Predominately this is for EOR. There are, for example, over 144 sites in the United States using this process. There are no EOR activities in Australia.[25]

3.39 The gas recovery plans of the Gorgon Project in Western Australia involve injecting CO_2 in a deep saline aquifer rather than back into the depleted gas reservoir.

3.40 While CO_2 storage in depleted oil and gas reservoirs is deployed overseas, CO_2 storage in saline formations, porous sandstone rocks, are considered to be the most promising location for long-term underground storage of CO_2. CSIRO, universities and other parties working through the CO2CRC are currently engaged in cooperative research on the use of saline aquifers for long-term, permanent storage.[26]

3.41 Studies indicate that deep saline aquifers represent 94 per cent of Australia's feasible geological storage capacity.[27]

---

22 CO2CRC, *Submission No. 36*, p. 10.

23 IPCC, *Special Report on Carbon Dioxide Capture and Storage: Summary for Policy Makers and Technical Summary*, 2005, p. 28.

24 Dr T. Espie, BP United Kingdom, *Transcript of Evidence*, 30th October 2006, pp. 13-14.

25 Australian Government, *Submission, No. 41*, Attachment B, p. 9; CSIRO, *Submission No. 10*, p. 5.

26 CSIRO, *Submission No. 10*, p. 4.

27 J. Bradshaw, *et al*, *Australia's CO_2 Geological Storage Potential and Matching of Emission Sources to Potential Sinks*, <www.co2crc.com.au/PRINTFRIENDLY/SciencePubsPrint.html>, accessed 29 May 2006.

3.42 Conservative estimates have put Australia's total capacity of all storage options at 740 billion tonnes of CO_2. The potential capacity of oil and gas fields in Australia has been estimated at 14 000 million tonnes CO_2.[28] At the same time, oil and gas field sites may be unsuitable or unavailable for many years to come, as high prices have extended the economic lives of the fields.[29]

3.43 Storage of CO_2 in unmineable coal deposits represents another alternative geological storage option. The CSIRO notes that there may be benefits associated with storage in unmineable coal seams—namely lower drilling costs as the CO_2 can be stored in shallower wells with the possibility of natural gas (methane) production in some cases to offset the cost.[30]

3.44 These benefits need to be put in the context of lower storage capacity as the ability to accept large volumes of CO_2 is reduced in comparison to porous sandstone.[31]

3.45 CO_2 can be adsorbed onto the extensive internal surface of coal.[32] This may be of importance in regions where there are not suitable deep saline reserves to store the CO_2. In New South Wales possibilities may exist to inject the CO_2 from black coal-fired power stations into nearby sites to recover methane gas.[33]

3.46 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.[34] The study produced three storage estimates:

- Total 'Theoretical' capacity of 740 Gt CO_2, equivalent to 1600 years of current emissions, but with no economic barriers considered;
- 'Realistic' capacity of 100–115 million tonnes CO_2 per year (or 25 per cent of our annual emissions), determined by matching sources with the closest viable storage sites and assuming economic incentives for storage; and

28 Australian Government, *Submission, No. 41,* p. 12; Attachment D, p. 9.

29 Australian Government, *Submission, No. 41*, Attachment D, p. 9.

30 CSIRO, *Submission No. 10,* p. 6.

31 CSIRO, *Submission No. 10*, p. 6.

32 CSIRO, *Submission No. 10*, p. 6.

33 CO2CRC, *Submission No. 36*, p. 11.

34 Australian Government, *Submission No. 41*, p. 11.

- 'Cost curve' capacity of 20-180 million tonnes CO_2 per year with increasing storage capacity depending on future CO_2 values.[35]

3.47 Theoretical capacity does not account for locality issues or critical economic and technical barriers. A more realistic approach is to consider the proximity of the sources of CO_2 to suitable storage sites. According to CO2CRC:

> …our preliminary assessments suggest that most existing emission "nodes", such as the Latrobe Valley, the Burrup Peninsula, Kwinana, southeast Queensland and Gladstone-Rockhampton, will have adequate storage capacity located within 200-500 km.[36]

3.48 The least explored state in terms of storage is NSW, partly because there has been little oil exploration in this state and little is understood about its deep geology.[37] The CO2CRC hopes to undertake a program of storage assessment in the Newcastle-Sydney region in the near future.[38]

3.49 Assessing sources of CO_2 with proximate sequestration sites, the Australian Government has submitted that:

> …the major emission sources (power plants) for Australia are located within the major coal provinces. Whilst the offshore Gippsland Basin has excellent reservoirs and is immediately adjacent to the potential major emissions from the brown coal sources in the Latrobe Valley (11% of Australia's total emissions), it will require significant capital investment to establish infrastructure and pipe CO_2 into an offshore environment. Similarly, whilst the North West Shelf has very good reservoirs, it is very distant from the largest emission sources which are on the east coast. The North West Shelf will however provide many opportunities for the potential emissions from the high CO_2 gas fields located in the Carnarvon and Browse Basins (potentially equivalent to 4% of Australia's total annual emissions). In southeast Queensland in the Bowen Basin the reservoirs are marginal due to the low permeability, but the sources (9% of Australia's total annual emissions) are within 250 km of

35 Australian Government, *Submission No. 41*, p. 12.

36 CO2CRC, *Submission No. 36*, pp. 18; 19.

37 CO2CRC, *Submission No. 36*, p. 18.

38 CO2CRC, *Submission No. 36*, p. 19.

> potential storage sites and they are both in an onshore environment. In the Sydney Basin region, despite having large emission sources (15% of Australia's total annual emissions), the geological characteristics of the reservoirs (no permeability) precludes any significant likelihood of large scale injection or storage of CO_2.[39]

3.50 Santos Limited raised the possibility of utilising a centralised storage site:

> …the Cooper Basin is centrally located between the major carbon dioxide emission sources of Gladstone-Rockhampton, Brisbane-Tarong, Newcastle-Sydney-Wollongong and Adelaide. The depleted oil and gas reservoirs of the Cooper Basin provide an effective means to develop a central geosequestration facility to service these centres, not withstanding transportation distances, the cost of which would be borne by a carbon price on emissions.[40]

3.51 A 2005 CO2CRC study, initiated by Monash Energy and funded by the Australian Government (Department of Transport and Regional Services) and the CO2CRC, proposed the establishment of a central CO_2 capture facility, or 'low emission hub', in the La Trobe Valley region. Compressed CO_2 from the facility would then be transported for storage by pipeline offshore to the nearby Gippsland oil fields.[41]

Committee comment

3.52 The viability of CCS depends on finding suitable long term and secure storage sites within reasonable distance from the major stationary energy hubs. One area warranting further examination is the Wollongong-Sydney-Newcastle region, particularly as there is limited knowledge about its deep geology.

3.53 It is encouraging that the CO2CRC plans to undertake a storage assessment of the Newcastle-Sydney region in the near future. Research being conducted by the CSIRO, through the CO2CRC, can also be expected to increase the number of sites suitable for permanent geosequestration in saline aquifers. [42]

---

39 Australian Government, *Submission No. 41*, Attachment D, p. 13.

40 Santos Limited, *Submission No. 25*, p. 4.

41 CO2CRC, *Submission No. 36*, p. 16; Anglo Coal Australia and Monash Energy, *Submission No. 24*, pp. 8, 12, 20.

42 CSIRO, *Submission No. 10*, pp.4–5; CO2CRC, *Submission No. 36*, p. 19.

3.54 Having found suitable sites, it is then incumbent on the Australian and State Governments to fully test these sites by undertaking storage demonstration trials similar to the one already underway in the Otway Basin, Victoria.

Recommendation 1

The Committee recommends that the Australian Government provide funding to the CSIRO to progress research being conducted through the CO2CRC to assess the storage potential for permanent CO_2 geosequestration in sedimentary basins in New South Wales, particularly the off-shore Sydney Basin, and the economic viability of these sites.

Other forms of storage

3.55 There are two other forms of storage that have been identified as potentially suitable to store CO_2, although both remain relatively untested.

3.56 Deep ocean storage may be an option as CO_2, when deposited into the sea floor below 3 000 metres, becomes denser than water and will remain *in situ* through geomechanical disturbances.[43] Another option is mineral carbonation, which occurs naturally when CO_2 combines with minerals to form solid carbonate.[44] The Carbon Safe Alliance proposed this alternative form based on turning CO_2 into carbonates which could then be used to manufacture a range of by-products.[45]

3.57 Both deep ocean storage and mineral carbonation are alternate storage options. However neither technology has been broadly demonstrated. Deep ocean storage is not regarded as ready to be applied, and doubts have also been raised about its environmental viability as a mitigation option. Similarly mineral carbonation is untested on a large scale and is widely regarded as not an economically viable option.[46]

---

43 IPCC, *Special Report on Carbon Dioxide Capture and Storage: Summary for Policy Makers and Technical Summary*, 2005, pp. 6–7; Docklands Science Park, *Submission No. 18*, pp. 2; 5

44 IPCC, *Special Report on Carbon Dioxide Capture and Storage: Summary for Policy Makers and Technical Summary*, 2005, p. 7.

45 The Carbonsafe Alliance, *Submission No. 38*, Appendix 1, pp. 11–12.

46 CO2CRC, *Submission No. 36*, p. 4.

Monitoring and verification

3.58 Effective and accurate technologies to measure and monitor CO_2 storage are essential for the purposes of regulation, carbon accounting and public safety.[47]

3.59 Most importantly, a risk assessment for all CCS sites must be carried out before storage can commence. This must apply to both engineered and natural storage systems. The criteria for selection will also need to be agreed in conjunction with the relevant regulatory authorities.[48]

3.60 Monitoring can be done by way of remote sensing, seismic, microseismic, petrophysical well logs and geophysical sampling.[49] In addition, prior to injecting, baseline surveys need to be done to assess any existing levels of CO_2.

3.61 Evidence to the Committee emphasised the importance of establishing good baseline data and knowledge of natural variation in CO_2 levels.[50] Additionally, the need for post injection regulation and monitoring was emphasised. There is currently no consistent national, nor international, regulatory framework for CO_2 injection and storage.[51]

3.62 Monitoring and verification is critical to the acceptability and success of any geosequestration operation. In particular, the public will need to be fully satisfied that the storage site is secure and safe and that any changes to those conditions can be immediately detected and acted on.

3.63 The IPCC special report on CCS concluded that for any given storage site, one could assume that there will be a 99 per cent probability the site will remain stable and safe for at least 1 000 years.[52] This view was supported by the CO2CRC which stated:

> Modelling has shown that with time, the CO_2-rich water becomes progressively denser which causes downward fingering of the denser CO_2-rich waters. Mineral trapping

47 CSIRO, *Submission No. 10*, p. 6.

48 CO2CRC, *Submission No. 36*, p. 11.

49 CO2CRC, *Submission No. 36*, p. 11.

50 CanSyd Australia and Auspace Limited, *Submission No. 9*, *passim.*

51 CanSyd Australia and Auspace Limited, *Submission No. 9*, p. 4; UNEP, *Can Carbon Dioxide Storage Help Cut Greenhouse Emissions? A Simplified Guide to the IPCC's "Special Report on Carbon dioxide Capture and Storage"*, April 2006, p. 16.

52 UNEP, *Can Carbon Dioxide Storage Help Cut Greenhouse Emissions? A Simplified Guide to the IPCC's "Special Report on Carbon dioxide Capture and Storage"*, April 2006, p. 16.

> involves the reaction of CO_2 with unstable minerals present in the host formation to form stable, solid compounds such as carbonates. Once the CO_2 has formed such minerals it is permanently locked. A key point about both of these mechanisms is that they ensure that over time the CO_2 becomes progressively more stable and even more unlikely to leak out of the storage formation.[53]

Conclusion

3.64 Much of the science which forms the basis for CCS is understood. It is being applied on a small scale at various sites around the world, including in Australia. The three stages of CCS (separation and capture, transportation, and storage) remain at different points of development and will require greater research and experimental application before CCS becomes a truly viable greenhouse gas mitigation strategy.

3.65 There is a consensus that all three technologies (post-combustion, oxyfuel and pre-combustion) should be pursued, to be applied in different circumstances. In particular, there is agreement that governments should not attempt to pick technology winners. As a recent Massachusetts Institute of Technology (MIT) report on the future of coal, notes:

> At present [IGCC] is the leading candidate for electricity production with CO_2 capture because it is estimated to have lower cost than pulverised coal with capture; however neither IGCC nor other coal technologies have been demonstrated with CCS…
>
> Approaches other than IGCC could prove attractive with further technology development, for example, oxygen fired pulverised coal combustion, especially with lower quality coals…The reality is that the diversity of coal type…imply different operating conditions for any application and multiple technologies will likely be deployed.[54]

---

53 CO2CRC, *Submission No. 36,* p. 11.

54 MIT, *Executive Summary, Future of Coal : Options for a Carbon Constrained World*, 2007, p. xiii, <web.mit.edu/coal/The_Future_of_Coal.pdf>, accessed 5 June 2007.

3.66 The 2006 UK House of Commons report on CCS similarly concludes that all three capture options offer potential advantages and should be pursued.[55]

3.67 There are a range of views on the suitability of each of these technologies, particularly in the Australian context. There is some agreement that post-combustion capture is the process most applicable to Australia's current stock of power stations. There is also general agreement that the focus of research and development should be on the technologies that can be applied to the existing power stations.

3.68 However, there are those who consider that IGCC would be a more viable option due to the high cost of post-combustion capture.[56] Some, such as Rio Tinto, expressed concern to the Committee that post-combustion capture can result in a loss of energy output and therefore could further reduce the efficiency of existing, low efficiency power plants.[57]

3.69 The transport of captured carbon raises another set of issues. As noted in this report, transporting captured CO_2 by pipeline should be relatively straightforward given previous experience in the chemical and petroleum industries. That being said, there is a need for greater research into the issues of transporting captured CO_2, especially economically viable options.

3.70 Commercial experience in the storage of captured CO_2 is considerable. CO_2 is injected into geological formations around the world each year. In particular, there is an existing body of knowledge about the injection and storage of CO_2 during, and as a consequence of, EOR; however, less is known about CO_2 storage in saline formations. These represent 94 per cent of Australia's feasible permanent geological storage capacity.

3.71 As with transport, issues relating to the storage of CO_2 in Australia will need to be more thoroughly researched, including to develop effective and accurate technologies to measure and monitor CO_2 storage.

55 House of Commons, Science and Technology Committee, *Meeting UK Energy and Climate Needs: The Role of Carbon Capture and Storage,* First Report, Session 2005-06, Volume 1, 2006, p. 16.

56 Mr J. Boshier, National Generators Forum (NGF), *Transcript of Evidence*, 4 December 2006, p. 4.

57 Mr A. Zantpantis, Rio Tinto, *Transcript of Evidence*, 26 February 2007, p. 7.

3.72 While a great deal of confidence is being expressed about CCS technology, there are no major projects currently underway to demonstrate the integration of technologies with coal-fired power plants. This integration of available technologies, to best suit the Australian context, needs to be demonstrated.

3.73 This observation was highlighted in the House of Commons report on the Role of Carbon Capture and Storage, published on 9 February 2006:

> Most of the technology is already known and available but there is a lack of experience in integrating the component technologies in single projects at the scale required. Multiple full scale demonstration projects using different types of capture technology and storage conditions are urgently needed. [58]

3.74 Much of the injection technology is already known and available but there is a lack of experience in integrating the component technologies in single projects at the commercial scale required, and in the Australian context. Multiple full scale demonstration projects using different types of capture technology and storage conditions are urgently needed.[59]

3.75 More research and development is required across a range of applications, under varying conditions and on a scale that would demonstrate commercial viability. There are projects underway in Australia, some of which are designed to address, in part, these concerns. The next chapter will discuss Australian projects in greater detail.

---

58 House of Commons, Science and Technology Committee, *Meeting UK Energy and Climate Needs: The Role of Carbon Capture and Storage*, First Report, Session 2005-06, Volume 1, 2006, Summary, p. 3.

59 Mr G. Humphrys, Stanwell Corporation Ltd, *Transcript of Evidence*, 11 September 2006, p. 3.

4

Australian CCS demonstration projects

Introduction

4.1 Although there are no large-scale projects encompassing capture, transport and storage of CO_2 generated by a coal-fired plant, there are a number of carbon capture and storage (CCS) demonstration projects underway or planned in Europe, Africa, the United States and Australia. These projects, some of which are discussed elsewhere in this report, will be crucial to the continued development and assessment of the technology.[1]

4.2 Figure 4.1 lists projects that are proposed to commence in various parts of Australia involving coal and natural gas.

---

1 Stanwell Corporation, *Submission No. 32*, p. 3; CSIRO, *Submission No. 10*, p. 8; Chevron Australia, *Submission No. 12*, p. 7; Anglo Coal, *Submission No. 24*, p. 21; Australian Government, *Submission No. 41*, pp. 32-33.

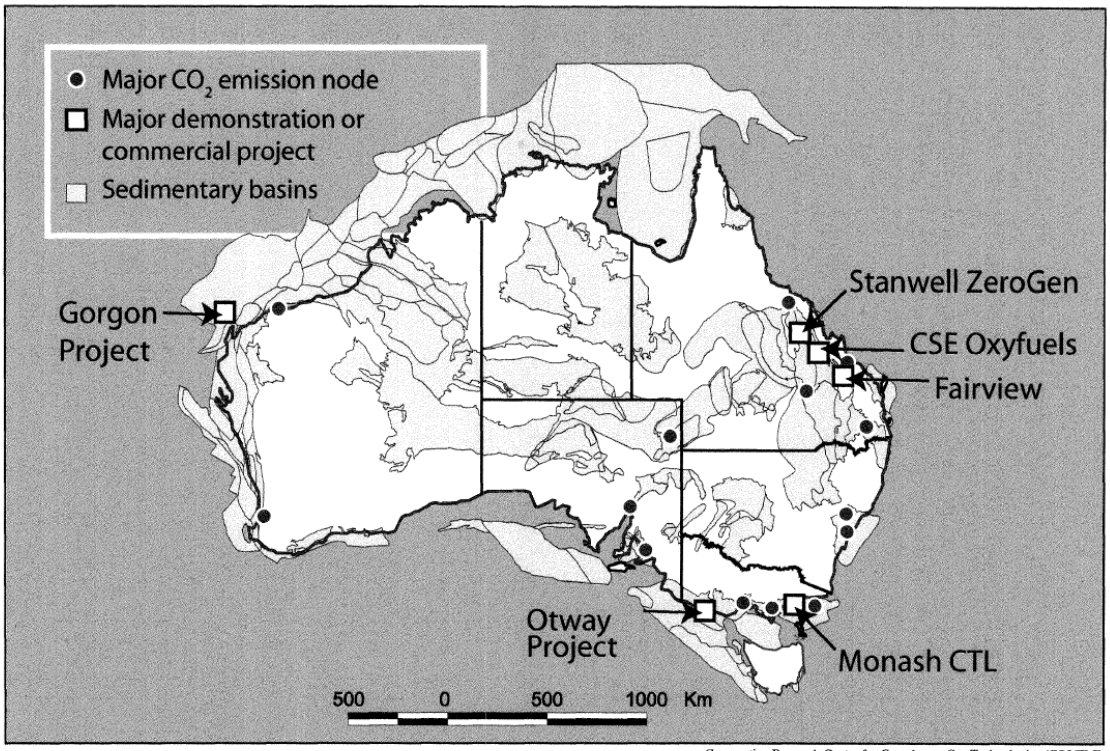

Figure 4.1 CO2CRC, Map of Australian CCS sites, Exhibit No. 3.

Latrobe Valley CO_2 Storage Assessment (LVCSA) Project

4.3 In 2005, with the assistance of a Commonwealth Government grant to Monash Energy and using the expertise of CO2CRC, the LVCSA Project evaluated the potential capacity for long-term and secure storage of compressed CO_2 in the Gippsland Basin.

4.4 The study found that the Gippsland Basin had an estimated storage capacity of 2 billion tonnes of CO_2, with some assessments as high as 6 billion tonnes. Acting as a large-scale injection facility, Gippsland Basin has the potential to store 50 million tonnes of CO_2 a year.[2] To put this in context, Australia's total emissions of CO_2 amount to 559.1

2 B. Hooper, L. Murray, and C. Gibson-Poole, (eds.), 2005. *The Latrobe Valley CO2 Storage Assessment*. Cooperative Research Centre for Greenhouse Gas Technologies, Canberra, CO2CRC Publication No. RPT05-0220, November 2005, p. 8-9.

million tonnes a year.[3] Victorian emissions total 99.5 million tonnes a year.[4]

4.5 The CO2CRC's assessment of the project concluded that:

> The LVCSA provides strong indications that the Gippsland Basin has sufficient capacity to safely and securely store large volumes of CO_2 and may provide a viable means of substantially reducing greenhouse gas emissions from coal-fired plants and other projects using brown coal in the Latrobe Valley.[5]

Otway Basin

4.6 CO2CRC is mounting a project in the Otway Basin to extract naturally occurring CO_2 and methane from the Buttress natural gas well,[6] located in Nirranda South, Victoria.[7]

4.7 The gases will be compressed to a supercritical fluid and piped 2-3 kilometres to the depleted Naylor Gas Field, where it will be injected and stored at least two kilometres below the earth's surface.[8] It is expected that up to 100 000 tonnes of CO_2 will be injected between 2007 and 2009 with monitoring to continue to mid 2010.[9]

4.8 The project will include an extensive programme monitoring the CO_2's behaviour, and new monitoring and verification technology will be developed and deployed with the aim of demonstrating that

3 Department of Environment and Water Resources, Australia Greenhouse Office, *National Greenhouse Gas Inventory 2005: Accounting for the 108% target*, p. 1.

4 Department of Sustainability and Environment, Victorian Greenhouse Strategy, *Victorian Greenhouse Gas Inventory 2004*, p. 1.

5 B. Hooper, L. Murray, and C. Gibson-Poole, (eds.), 2005, *The Latrobe Valley CO2 Storage Assessment*. Cooperative Research Centre for Greenhouse Gas Technologies, Canberra, CO2CRC Publication No. RPT05-0220, November 2005, p. 15.

6 The separation and capture of CO_2 from a gas well differs from a coal-fired power station, as the flue gases from coal fired power stations have a much higher CO_2 content compared to gas wells, which are approximately only 20% CO_2, CO2CRC, *Geosequestration Research Report Update, Issue 1*, June 2006, <http://www.co2crc.com.au/pilot/OBPPDL/ResearchProjectUpdate_01.pdf>, accessed 7 June 2007.

7 CO2CRC, *Submission No. 36*, p. 19.

8 CO2CRC, *Your Questions Answered*, <http://www.co2crc.com.au/pilot/OBPPDL/Q_A.pdf>, p. 5, accessed 8 June 2007.

9 CO2CRC, *Submission No. 36*, p. 19.

the injection and storage of CO_2 is safe and that any leakage of CO_2 can be detected.[10]

4.9 The project's sponsors report that extensive community consultation has taken place and will continue throughout the life of the project. The drilling of the injection well began in April 2007. [11]

Monash Energy Project – coal to liquids

4.10 The Monash Energy Project has been proposed by Anglo Coal as a 'world-scale coal-to-liquids plant' at a cost of $5 billion to convert brown coal to ultra-clean, synthetic diesel.[12]

4.11 Coal to liquid plants, along with natural gas processing plants, have the current advantage of being able to capture CO_2 from their respective processing at around $10 per tonne of CO_2 avoided. This compares very favourably with estimated capture costs of CO_2 from coal-fired power stations of around $20-100 per tonne of CO_2 avoided.[13]

4.12 The project as outlined would utilise pre-combustion separation and capture methods and would transport approximately 13 million tonnes of CO_2 from the Latrobe Valley to the potential storage facility beneath the depleting oil fields of the offshore Gippsland Basin.[14]

4.13 The plant is currently undergoing a pre-feasibility investigation with trials, evaluation and planning for adoption of the technology. Pending successful completion of these trials, the project will begin production in 2016.[15]

10 CO2CRC, *Geosequestration Research Report Update, Issue* 2, April 2007, <http://www.co2crc.com.au/pilot/OBPPDL/OBPP_NL/ResearchProjectUpdate_Issue02.pdf>, accessed 7 June 2007.

11 CO_2CRC, *Geosequestration Research Project Update,* Issue 2, April 2007, p. 1, <www.co2crc.com.au/pilot/OBPPDL/OBPP_NL/ResearchProjectUpdate_Issue02.pdf>, accessed 30 May 2007.

12 Anglo Coal, *Submission No. 24*, p. 3.

13 Anglo Coal, *Submission No. 24,* p. 9.

14 Anglo Coal, *Submission No. 24*, p. 12.

15 Anglo Coal, *Submission No. 24*, p. 12.

Gorgon Project (LNG processing and CCS)

4.14 Managed by Chevron Australia (on behalf of the Gorgon Joint Venturers), the Gorgon Project proposes to tap subsea natural gas reservoirs located 130 kilometres off the northwest coast of Australia. These reservoirs contain an estimated 1.1 trillion cubic metres of natural gases, approximately 25 per cent of Australia's known gas reserves.[16]

4.15 The CO_2 extracted from the liquid natural gas plant proposed for Barrow Island is to be disposed of in the Dupuy Formation, a saline aquifer located 2.5 kilometres beneath Barrow Island.[17]

4.16 Without sequestration, lifecycle greenhouse gas emissions from the Gorgon development are estimated to be 5.5 million tonnes *per annum*. With sequestration, emissions would be between 2.7 and 3.5 million tonnes per annum, a reduction of around 40 per cent.[18] Having considered alterative mitigation strategies, such as organic offsets, the operators of Gorgon found the proposed geosequestration project to be the most cost effective.[19]

4.17 The Gorgon Joint Venture has invested $1 billion on the project to date, and anticipate a total development investment of $11 billion.[20] They have received $60 million from the Australian Government's LETDF to help develop the geosequestration proposal.[21]

4.18 Detailed tests are being conducted to evaluate uncertainties in the injection operations and to identify any early signs of deviation from expected reservoir performance.[22]

---

16 Chevron Australia, *Submission No, 12,* p. 6.

17 Chevron Australia, *Submission No, 12,* p. 7.

18 Chevron Australia Pty Ltd, *Final environmental impact assessment and response to submission on the environmental review and management programme for the proposed Gorgon development,* May 2006, p. 358; Department of Industry and Resources (Western Australia), *Submission No. 26*, p. 2; Chevron, *Submission No. 12*, p. 7.

19 Chevron, *Submission No. 12*, p. 12.

20 Chevron Australia Pty Ltd, *Final environmental impact assessment and response to submission on the environmental review and management programme for the proposed Gorgon development,* May 2006, p. 10 & p. 67.

21 Senator Ian Campbell, Minister for Environment and Heritage, *$60 million for world's largest carbon capture and storage project*, Media Release, 23 November 2006, accessed 30 May 2007, <ausindustry.gov.au>.

22 Chevron, *Submission No. 12*, p. 9.

ZeroGen

4.19 The ZeroGen Project, managed by Stanwell Corporation (owned by the Queensland Government) proposes to build a 100 MW IGCC plant with capture technology adjacent to the existing Stanwell Power Station, 29 kilometres west of Rockhampton.

4.20 The project will convert pulverised coal into a synthesis gas (consisting of hydrogen and carbon dioxide), removing CO_2 and other gases to produce a hydrogen-rich fuel used to generate electricity.[23] It will combine coal gasification and CCS and the captured CO_2 will be piped approximately 220 kilometres to the Dennison Trough and stored in deep saline aquifers.[24]

4.21 A feasibility study is underway to assess the possible integration of a coal gasification plant with CCS facilities and to confirm the feasibility and capacity of the site for the safe storage of CO_2.[25]

4.22 The decision to proceed with the project is dependent on a number of factors, including the results of a test drilling program, the completion of the environmental impact statement and community consultation, successful cultural heritage and native title negotiations, obtaining the necessary funding, and Board and Shareholding Minister approval.

4.23 Subject to the above and the granting of final approval, the project expects that the demonstration program will commence in 2011 and run for 10 years. It is estimated that ZeroGen will result in a net saving of up to 420 000 tonnes of CO_2 a year once the plant is fully operational.[26]

4.24 The Queensland Government has earmarked $300 million from the Queensland Future Growth Fund to develop clean-coal technology, and has announced that it will provide funding support for the project from this fund, though the precise amount has not been disclosed. An application for LETDF funding was lodged in March 2006.[27]

---

23 Zerogen Gasification Fact Sheet, <http://www.zerogen.com.au/files/factsheetReviewOctober2006Gasification.pdf>, accessed 8 June 2007.

24 Queensland Government, *Submission No. 46,* p. 3.

25 Stanwell Corporation, *Transcript 11 September 2006*, p. 2.

26 Queensland Government, *Submission No. 46,* p. 3; Mr G. Humphries, Stanwell Corporation, *Transcript of Evidence,* 11 September 2006, p. 3.

27 Queensland Government, *Submission No. 46,* p. 3; Mr G. Humphries, Stanwell Corporation, *Transcript of Evidence,* 11 September 2006, p. 18-19.

Fairview Zero Carbon Project (ZCP)

4.25 The Fairview Zero Carbon Project (a subsidiary of Santos) will be located at Injune (near Roma), Queensland. The project will involve the extraction of methane from coal seams. The methane will be used to power a new 100 MW power station.[28]

4.26 At least 100 000 tonnes of CO_2 will be captured and injected back into the coal seam each year during the demonstration period. The project is due to commence in April 2007 and has received $75 million from the LETDF. The project will run until 2015 and is expected to cost around $445 million.[29]

HRL Limited – IDGCC technology

4.27 The HRL Limited project will build a new 400 MW demonstration power station at the Loy Yang Bench in the LaTrobe Valley that will incorporate integrated drying and gasification combined cycle (IDGCC) technology.[30]

4.28 Developed over the last 15 years, the IDGCC technology is specifically designed for brown coal and is currently at the stage of commercialisation.[31]

4.29 This new technology generates electricity at significantly higher efficiency rates by drying brown coal. As a result, CO_2 emissions from brown coal power generation are expected to be reduced by 30 per cent compared to the most efficient brown coal generation currently being produced in the LaTrobe Valley, and by approximately 50 per cent compared to older power stations.[32]

---

28 Hon I. Macfarlane MP, Minister for Industry and Resources, *$125 million to lower emissions in Queensland,* Media Release, 30 October 2006, <minister.industry.gov.au>, accessed 1 June 2007; Queensland Government, *Submission No. 46,* p. 4.

29 Hon I. Macfarlane MP, Minister for Industry and Resources, *$125 million to lower emissions in Queensland,* Media Release, 30 October 2006, <minister.industry.gov.au>, accessed 1 June 2007; Queensland Government, *Submission No. 46,* p. 4.

30 Ausindustry, *Low emissions technology demonstration fund grant offers,* March 2007, <ausindustry.gov.au/library/LEDTF_gratoffers_march0720070327095527.pdf>, accessed 5 June 2007.

31 Media Release, HRL Limited, *Australia's HRL and China's Harbin Power sign Global Clean Coal Power Generation Agreement*, 21 February 2006.

32 Media Release, HRL Limited, *Australia's HRL and China's Harbin Power sign Global Clean Coal Power Generation Agreement*, 21 February 2006.

4.30 Further conversion of the coal into clean-burning gases (e.g. methane) enables relatively pure CO_2 to be captured, enabling the application of CCS.

4.31 The project is expected to cost $750 million. In November 2006, the Victorian Government committed $50 million to the project and in March 2007, the Australian Government announced that the project would receive a $100 million grant through LETDF.[33] Private equity and debt finance will contribute $600 million.

4.32 Work on the IDGCC power plant is expected to begin in mid-2007, with completion set for the end of 2009.[34]

Hazelwood 2030

4.33 The Hazelwood 2030 project aims to develop a retrofit low emission technology project at the brown coal-fired Hazelwood Power Station in the LaTrobe Valley.

4.34 The Hazelwood plant is owned by International Power (Technologies Pty Ltd) which is a 100 per cent owned subsidiary of International Power (Australia) Holdings Pty Ltd.[35]

4.35 International Power will demonstrate internationally available technology (adapted to local conditions) to dry the brown coal used to feed one of eight 200 MW generating units at Hazelwood Power Station.[36]

4.36 The high moisture content (around 60 per cent) of brown coal means that the energy conversion efficiency is lower than black coal. The coal drying demonstration project will reduce the moisture content in the brown coal to approximately 12 per cent, and consequently less energy will be needed to convert the coal into electricity. It is expected

33 Ausindustry, *Low emissions technology demonstration fund grant offers,* March 2007, <ausindustry.gov.au/library/LEDTF_gratoffers_march0720070327095527.pdf>, accessed 5 June 2007.

34 Ausindustry, *Low emissions technology demonstration fund grant offers,* March 2007, <ausindustry.gov.au/library/LEDTF_gratoffers_march0720070327095527.pdf>, accessed 5 June 2007.

35 Ausindustry, *Low emissions technology demonstration fund grant offers,* March 2007, <ausindustry.gov.au/library/LEDTF_gratoffers_march0720070327095527.pdf>, accessed 5 June 2007.

36 Media Release, International Power Australia, *Clean Coal Project Awarded Funding,* 25 October 2006.

that this process will reduce greenhouse gas emissions by 30 per cent. This phase of the demonstration project is predicted to be completed by the end of 2009.[37]

4.37 The Hazelwood 2030 project will also include CCS facilities. By early 2008, it is expected that this phase of the project will demonstrate the capture and sequestration of up to 50 tonnes of CO_2 per day (18 250 tonnes per year). If successful, the technology being used at Hazelwood may be able to be retrofitted to other brown coal plants in the LaTrobe Valley.[38]

4.38 The Australian Government is contributing $50 million from the LETDF and the Victorian Government an additional $30 million.[39] Hazlewood is contributing $289 million, with the total cost of the project estimated at $369 million.

4.39 The demonstration project is expected to be fully operational by early 2008.[40]

CS Energy – Oxy-fuel retrofit

4.40 The CS Energy project will retrofit the 30 MW generator at the Callide A pulverised coal power station in Biloela in Queensland to allow oxyfuel combustion.[41]

4.41 Stage one of the project involves the conversion of a generator to apply oxyfuel combustion and the capture of CO_2. Stage two of the project will see the 'transport, injection and storage of liquefied CO_2 in deep geological formations in a site yet to be selected'. Construction and conversion of the plant is due to start in 2007 and power generation will commence in 2009.[42]

---

37 Media Release, International Power Australia, *Clean Coal Technology: Transforming the LaTrobe Valley, Fact Sheet*, 25 October 2006.

38 Media Release, International Power Australia, *Clean Coal Technology: Transforming the LaTrobe Valley, Fact Sheet*, 25 October 2006.

39 Ausindustry, *Low emissions technology demonstration fund grant offers,* March 2007, accessed 5 June 2007, <ausindustry.gov.au/library/LEDTF_gratoffers_march0720070327095527.pdf>

40 Ausindustry, *Low emissions technology demonstration fund grant offers,* March 2007, accessed 5 June 2007, <ausindustry.gov.au/library/LEDTF_gratoffers_march0720070327095527.pdf>

41 Queensland Government, *Submission No. 46*, p. 3.

42 CS Energy website, <www.csenergy.com.au/research_and_development/oxy_fuel.asp>, accessed 6 June 2007.

4.42 By 2010, it is expected that up to 150 000 tonnes of CO_2 will be transported and stored.[43]

4.43 The project will cost $188 million to which the LETDF has contributed $50 million.[44] The CS Energy retrofit project has been recognised as a project of significance by the AP6.[45]

4.44 Once it is fully operational, the demonstration project will continue for another five years. If successful, oxyfuel technology may be retrofitted to other stations in the Callide Group. These stations have an overall capacity to generate 1 720 MW of electricity.[46]

Conclusion

4.45 Australia has recognised the need to reduce greenhouse gas emissions from stationary sources. Major participants, supported by the Government through the LETDF and other initiatives have already committed to projects aimed at reducing CO_2 emissions.

4.46 The projects discussed in this chapter will add value and enhance our knowledge base. They do, however, have some limitations, with no demonstration of a large-scale CCS solution.

4.47 The Gorgon project, for example, proposes to sequester large amounts of CO_2, but does not involve the use of coal for electricity generation. It should, however, add enormously to our knowledge of higher volume sequestration in saline aquifers (subject to appropriate monitoring and verification. The Australian Government needs to ensure that this is the case).

4.48 The HRL project will incorporate drying technology into the gasification combined cycle technology, seeking to apply pre-combustion technology to brown coal. Hazelwood 2030 is retrofitting a brown-coal fired power station, but only on one 200 MW generator.

---

43 Queensland Government, *Submission No. 46*, p. 3.

44 Ausindustry, *Low emissions technology demonstration fund grant offers,* March 2007, <ausindustry.gov.au/library/LEDTF_gratoffers_march0720070327095527.pdf>, accessed 5 June 2007.

45 Australian Government, Asia-Pacific Partnership on Clean Development and Climate: Partnership for Action 2006, <http://www.dfat.gov.au/environment/climate/ap6/appcdc-booklet-06.pdf>, accessed 7 June 2007.

46 CS Energy website, <www.csenergy.com.au/research_and_development/oxy_fuel.asp>, accessed 6 June 2007.

CS Energy will retrofit a pulverised coal power station with oxyfuel technology, but this too will be small scale. ZeroGen's application of IGCC technology is to a small capacity power generator.[47]

4.49 The major challenge is to mount a project at the 500 MW scale which demonstrates all stages in the process—from coal conversion, carbon capture, treatment and transport through to sequestration and long-term monitoring. This raises environmental risks, logistic coordination and technical challenges that are not tested or resolved by small-scale demonstrations.

4.50 The British House of Commons report, *Meeting the UK Energy and Climate Needs: The Role of Carbon Capture and Storage*, observed that:

> Most of the technology is already proven and available but there is a lack of experience in integrating the component technologies in single projects at the scale required. Multiple full scale demonstration projects using different types of capture technology and storage conditions are urgently needed.[48]

4.51 As the MIT study notes, 'the demonstration of an integrated coal conversion, CO_2 capture, and sequestration capability is an enormous system engineering and integration challenge'.[49] The operating tempo of each individual power station raises particular challenges. As the pressurised, transport-ready CO_2 is produced, it needs to be transported via a pipeline network to an injection point at the rate of production, whilst accommodating any variation in the operating cycle of the production plant. In addition, the injection system must have the capacity to inject the arriving gas at the variable rates at which it is received.[50]

---

47 The Committee notes that BP and Rio Tinto have announced that they will begin feasibility studies and work on plans for the potential development of a coal-fired power generation project in WA, which would be a fully integrated CCS plant. A final decision to proceed will be taken in 2011. For further information see, BP/Rio Tinto press release, *BP and Rio Tinto plan clean coal project for Western Australia*, 21 May 2007.

48 House of Commons, Science and Technology Committee (United Kingdom), *Meeting UK energy and climate needs: The Role of carbon capture and storage.* First Report of Session 2005-06, p. 3.

49 Massachusetts Institute of Technology (MIT), *The Future of coal: Options for a carbon constrained world,* Cambridge MA, March 2007, p. 101.

50 MIT, *The Future of coal: Options for a carbon constrained world,* Cambridge MA, March 2007, p. 101.

4.52 The MIT study states that such a demonstration is important because it will:

> (1) give policy makers and the public confidence that this carbon mitigation control option is practical for broad application, (2) shorten the deployment time and reduce the cost for carbon capture and sequestration should a carbon emission control policy be adopted, and (3) maintain opportunities for the use of coal in a carbon constrained world in an environmentally acceptable manner.[51]

4.53 There is considerable support for the adoption of IGCC technology for CCS. The advantage of IGCC, with its precombustion capture, over the conversion of pulverised coal fired plants is largely due to the energy penalties that are inevitable with post-combustion techniques.

4.54 Nonetheless, it needs to be noted that a successful CCS operation on IGCC or any other type of large coal-fired power generating plant has yet to be demonstrated. More importantly, an IGCC solution does not address the reality of Australia's, and the world's, dependence on pulverised coal-fired power stations.

4.55 In the Australian context, the majority of coal-fired plants are old but will be relied upon for power generation for many years. Over half of Australia's coal fired power plants each have more than 500 MW capacity and notionally each emits 2.9 million tonnes of CO_2 per year.[52]

4.56 Moreover, the anticipated growth in the demand for electricity in Australia over the next 30 years will consume most of the output of new generating capacity. That means that most existing plants, although ageing and operating at various levels of efficiency, will remain in operation for the foreseeable future. Unless modifications are made, they will continue to release emissions at the current rate. There is no evidence to suggest that ageing and inefficient plants will be replaced by new technology cleaner plants, such as IGCC.

4.57 The Committee also heard evidence that, at this stage at least, the potential commercial risks of installing carbon capture technology in

---

51 MIT, *The Future of coal: Options for a carbon constrained world,* Cambridge MA, March 2007, p. 95.

52 For a breakdown of principal power stations in Australia, see Appendix D; Australian Government, *Submission No. 41*, p. 15.

large existing Australian plants do not justify the very major investments required (see Chapter 6).

4.58 Given the reality of Australian power generation, the priority needs to be the facilitation of commercial-scale projects at existing coal-fired power stations. It is important that these projects demonstrate CO_2 capture via:

- oxyfuel combustion;
- post-combustion technology at supercritical pulverised coal plants; and
- ultra-supercritical coal plants from subcritical coal plants.

4.59 Therefore, the Committee is recommending that the Australian Government fund one or more large-scale projects to demonstrate the three phases of CCS—capture, transportation and sequestration and monitoring.

4.60 The assessment of which projects should receive funding should be based on a competitive tender process that encourages submissions for projects which utilise different fuel sources and generating methods, including: sub-critical, supercritical, oxyfuel or IGCC.

4.61 The Committee is of the opinion that the advantages of this approach will be to:

- act as an incentive for current, operational, coal-fired power stations to develop carbon capture technologies;
- enable demonstration of desired technologies while minimizing government interference in commercial practice; and
- provide data in relation to the cost components to assist the government and the industry in its cost estimations.

4.62 The tender process should also include financing models. In view of the substantial amounts of capital required, financing arrangements would need to be varied and flexible, and structured so that each project could, after completion, operate grant-free as a profitable enterprise.

4.63 Initially, direct financial assistance may need to be provided at the capital intensive construction stage. Later, incentives may need to be offered in the form of payment per tonne of CO_2 sequestered.

4.64 It is the Committee's view that Australia must be technically equipped if and when formal carbon constraints become a reality. To this end, investment in research and development is needed now to implement CCS at a new or existing large coal-fired power station.

4.65 Australia's contribution to the worldwide understanding of the viability of CCS would contribute to addressing our greenhouse gas mitigation obligations and would materially enhance Australia's already significant contribution to responding to climate change.

Recommendation 2

The Committee recommends that the Australian Government fund one or more large-scale projects which will demonstrate the operation and integration of the CCS—capture, transportation and sequestration and monitoring. The Government's assessment of which project(s) will receive funding will be based on a competitive tender process.

5

The environmental benefits and risks of CCS and public perception

Introduction

5.1 The environmental impact of carbon capture and storage (CCS) is a critical issue in determining whether this technology should be part of the suite of options used to combat increasing greenhouse gas emissions, both nationally and internationally. As the purpose of CCS technology is to reduce the negative impact of anthropogenic greenhouse gas emissions on the environment, the environmental benefits of CCS need to outweigh the potential environmental risks.

5.2 The greatest environmental risk associated with CCS relates to the long term storage of the captured CO_2. Leakage of CO_2, either gradual or in a catastrophic leakage, could negate the initial environmental benefits of capturing and storing CO_2 emissions and may also have harmful effects on human health. On the other hand, CCS has the long term potential to make a substantial positive impact on the amount of CO_2 emitted into the atmosphere by the stationary energy sector. Therefore the potential risks need to be weighed against the potential benefits, and also the possible consequences of inactivity.

Environmental benefits

5.3 The major environmental benefit of CCS to both Australia and the world is its potential to reduce atmospheric levels of CO_2 while fossil fuels continue to be used to fuel the world's energy consumption.[1]

5.4 This potential, however, depends upon the amount of CO_2 captured and the amount (if any) of leakage from transport and long term storage of CO_2. The potential benefits needs also to be measured against the level of risk to the environment through CCS, compared to the risks if CCS is not used.

5.5 A recent ABARE study, which models the impact of the global deployment of CCS and non-CCS technology, indicates that CCS has the potential to substantially contribute to global greenhouse gas emission abatement.[2]

5.6 Commenting on the ABARE study, the Australian Government submission notes that:

> 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.[3]

5.7 The ABARE study models the emission level reductions likely to occur through the application of energy efficiency and low emission technologies, including and excluding the use of CCS.

5.8 In Australia, the benefit of emissions reduction from the uptake of CCS is better. If the use of CCS is excluded, just the application of energy efficiency and low technologies would see a global 18 per cent reduction in greenhouse gas emissions by 2050 against a business as usual scenario. With CCS, there would be a 25.8 per cent reduction in emission levels against a business as usual scenario. This suggests an

1 Australian Government, *Submission No. 41,* p. 13.

2 A. Matysek, M. Ford, G. Jakeman, A. Gurney, and B.S. Fisher, *Technology: Its role in economic development and climate change,* ABARE Research Report 06.6, Canberra, July 2006. Cited in ABARE, *Submission No. 28,* p. 1.

3 Australian Government, *Submission No. 41,* p. 14.

additional 7.8 per cent emission reduction benefit globally when CCS is used.[4]

5.9 In addition, ABARE notes that, while greenhouse gas emissions from electricity production will continue to rise until approximately 2020, if CCS technologies are applied to all new coal and gas fired electricity generation in combination with efficiency improvement and fuel switching, the result will be an absolute global reduction in electricity emissions.[5]

5.10 ABARE also notes that, while the uptake of CCS and more energy efficient and cleaner technologies is expected to markedly reduce greenhouse gas emissions by 2050, the impact on cumulative emissions is less significant. This is largely due to the time lag between these technologies becoming available and their widespread uptake.[6]

5.11 Despite this time lag, evidence to the House of Commons Science and Technology Committee's (UK) report on meeting UK energy stated that CCS technology should be thought about beyond 2020. The report concluded that 'CCS could play a vital role in helping the UK get back on track to meet its 2050 target to reduce CO_2 emissions by 60 per cent compared with 1990 levels.'[7]

5.12 MIT has also undertaken modelling on the take-up and effect of CCS. MIT modelling shows minimal uptake of CCS before 2030 and significant growth (albeit not universal) in the uptake of CCS from 2030 to 2050.[8] By 2050, MIT modelling predicts that, with universal simultaneous participation and high CO_2 prices, CCS technology is

4 A. Matysek, M. Ford, G. Jakeman, A. Gurney, and B. S. Fisher, *Technology: Its role in economic development and climate change,* ABARE Research Report 06.6, Canberra, July 2006, pp. 100-101.

5 A. Matysek, M. Ford, G. Jakeman, A. Gurney, and B. S. Fisher, *Technology: Its role in economic development and climate change,* ABARE Research Report 06.6, Canberra, July 2006, pp. 60-61

6 A. Matysek, M. Ford, G. Jakeman, A. Gurney, and B. S. Fisher, *Technology: Its role in economic development and climate change,* ABARE Research Report 06.6, Canberra, July 2006, p. 63.

7 House of Commons, Science and Technology Committee (United Kingdom), *Meeting UK energy and climate needs: The Role of carbon capture and storage.* First Report of Session 2005-06, p. 63 & p. 66.

8 Massachusetts Institute of Technology (MIT), *The Future of coal: Options for a carbon constrained world,* Cambridge MA, March 2007, p. 11.

likely to reduce global greenhouse gases by as much as 3-4 Gt per year compared to mitigation measures which do not include CCS.[9]

5.13 However, the IPCC states that current indications are that 'the majority of CCS deployment will occur in the second half of this century'.[10] The IPCC also states that, when this deployment does occur, 'the consensus of the literature shows that CCS could be an important component of the broad portfolio of energy technologies and emission reduction approaches.'[11]

5.14 From the IPCC report, the UK House of Commons report and MIT modelling, it appears likely that if even CCS technology is applied its impact on CO_2 emissions will only moderate by 2020. The significant impact of any CCS application is more likely to be in the later half of the 21st century.

5.15 According to the CO2CRC, the following is now required to achieve environmental benefits from lower CO_2 concentrations:

- a very intensive period of research, development and demonstration between now and 2015 to bring down the costs of geosequestration;
- from 2015 onwards all new power stations would be equipped with low emission technology including geosequestration. Over the subsequent 40 years all existing power stations would be phased out to be replaced with low emission power generation;
- additionally it is proposed that from 2035 onwards, low emission transportation, based on geosequestration-enabled hydrogen or electricity generation, would be progressively introduced over the subsequent 20 years; and
- by 2055, all electricity generation and transportation would be "geosequestration enabled".[12]

5.16 If such steps are taken in combination with other mitigation strategies, then atmospheric CO_2 concentrations could be stabilised.

5.17 While globally the predictions for the long term environmental benefits of CCS are positive, some evidence to the Committee

9 Massachusetts Institute of Technology (MIT), *The Future of coal: Options for a carbon constrained world,* Cambridge MA, March 2007, p. 15.

10 IPCC, *Carbon capture and storage: Summary for policy makers and technical summary,* 2005, pp. 41-42.

11 IPCC, *Carbon capture and storage: Summary for policy makers and technical summary,* 2005, pp. 41-42.

12 CO2CRC, *Submission No. 36,* pp. 12-13.

questioned the capacity for CCS to significantly impact on Australia's CO_2 emissions from stationary power sources. Greenpeace Australia Pacific (Greenpeace), for example, noted research undertaken by The Australia Institute in 2004 which found that:

> In Australia, the use of geosequestration would lead to, at best, a 9 per cent emission reduction in 2030, and a cumulative emissions reduction from 2005 to 2030 of only 2.4 percent.[13]

5.18 Greenpeace went on to claim that comparable and/or better reductions can be achieved through equivalent investment in gas-fired power generation and a doubling of Australia's Mandatory Renewal Energy Target (MRET).[14]

5.19 Similarly, Friends of the Earth Australia argued in their submission that not only is CCS technology expensive, essentially unproven and possibly highly dangerous, it only has the potential to provide an 8 per cent reduction in emissions from electricity production.[15]

5.20 If Australia and the world remain dependent on fossil fuels to produce electricity, as is predicted for the foreseeable future, CCS provides the greatest potential to reduce the greenhouse gases emitted by our stationary energy sector.[16]

Environmental risks

5.21 Carbon dioxide is part of the atmosphere we breathe and is essential to all life forms. It is odourless and non-toxic. However, as it is denser than air, if it accumulates in low-lying areas in high concentrations then it can prove harmful to humans and animals.[17]

5.22 The most substantial risk associated with CCS is the leakage of CO_2 from storage sites. While there is some experience with geological storage of CO_2 and natural gas for periods of approximately 10-20 years, long term storage over many hundreds or thousands of years

13 Greenpeace Australia Pacific, *Submission No. 15,* p. 12.

14 Greenpeace Australia Pacific, *Submission No. 15,* p. 12-13.

15 Friends of the Earth Australia, *Submission No. 13,* p. 4.

16 A. Matysek, M. Ford, G. Jakeman, A. Gurney, and B. S. Fisher, *Technology: Its role in economic development and climate change,* ABARE Research Report 06.6, Canberra, July 2006, pp. 100-101.

17 Australian Government, *Submission No. 41,* p. 28.

has not been proven.[18] However, as argued by CSIRO, the ongoing study of naturally occurring underground accumulations of CO_2 has increased knowledge and confidence in the viability of CO_2 storage.[19]

5.23 The IPCC Special Report on CCS suggests that the environmental risks associated with CO_2 capture and storage are low. As the IPCC stated:

> …well-selected geological formations are likely to retain over 99% of their storage over a period of 1,000 years. Overall, the risks of CO_2 storage are comparable to the risks in similar existing industrial operations such as underground natural-gas storage and [EOR].[20]

5.24 Furthermore, according to many submissions, the safety, health and environmental risks associated with CCS are similar to, or less than, those already experienced in the oil and gas industry.[21]

5.25 Nevertheless, concerns have been expressed regarding the long term storage of CO_2. Two types of CO_2 leakage that may occur are:

- abrupt leakage through injection well failure or leakage up an abandoned well; and
- gradual leakage, through undetected faults, fractures or wells. [22]

Abrupt leakage

5.26 Abrupt or catastrophic leaks of CO_2 could have serious consequences to the environment, potentially causing the death of humans and animals.[23] Leakages have been known to occur naturally, such as at Lake Nyos in Cameroon in 1986.[24]

---

18 TRUenergy, *Submission No. 17,* p. 1; Country Women's Association of NSW, *Submission No. 6,* p. 2; Friends of the Earth Australia, *Submission No. 13,* p. 7.

19 CSIRO, *Submission No. 10,* p. 2.

20 United Nations Environmental Programme (UNEP), *Can carbon dioxide storage help cut greenhouse emissions? A Simplified guide to the IPCC's 'Special report on carbon dioxide capture and storage',* April 2006, p. 15.

21 Anglo Coal, *Submission No. 24,* p. 21; Rio Tinto, *Submission No. 31,* p. 4; National Generators Forum, *Submission No. 35,* p. 4.

22 Australian Government, *Submission No. 41,* p. 15.

23 Friends of the Earth Australia, *Submission No. 13,* p. 6; Australian Government, *Submission No. 41,* p. 15.

24 Below Lake Nyos lies a pocket of magma that leaks CO_2 into the waters. In August 1986, a large amount of CO_2 was emitted from the lake, suffocating approximately 1 700 people and 3 500 livestock living within 25 kilometres of the site. Dr D. Maddison, *Submission No. 11*, p. 2.

5.27 There is the potential for CO_2 that is sequestered as part of the CCS processes to leak from storage points. Such leakage could occur if the well seal at the point of storage failed thereby resulting in the release of sequestered CO_2.

5.28 Evidence to the Committee from Greenpeace and the Australian Government also suggested that pressure built up by injected CO_2 could trigger small seismic events.[25]

5.29 In his submission Dr Maddison also raised potential risks associated with CCS, stating that:

> carbon dioxide sequestration is poorly conceived, cannot guarantee sequestration of gas forever as is necessary and has potential for great harm due to accidental or deliberate release.[26]

5.30 It has been suggested that CO_2 storage sites may become potential terrorist targets or that failure of the seal could result in catastrophic release. Greenpeace points out that concentration of CO_2 greater than 7-10 per cent by volume in the air puts the lives and health of people in the vicinity in immediate danger.[27]

5.31 However, evidence suggests that if storage sites are carefully selected, the chances of a catastrophic leak would be minimal. Current demonstration projects, such as the Otway Demonstration Project, extend understanding of the scientific processes and risk minimisation associated with the selection, sequestration and monitoring of CO_2 in an Australian context.

Gradual leakage

5.32 Gradual leakage could occur as a result of incorrect site selection and inadequate preparation.[28] This leakage would compromise the initial objective of removing the CO_2 from the atmosphere.

5.33 Other dangers associated with gradual leakage have also been highlighted. According to the International Association of Hydrogeologists, CCS is a potential environmental risk to overlying fresh groundwater resources and therefore CCS should only be

25 Greenpeace Australia Pacific, *Submission No. 15*, p. 16; Australian Government, *Submission No. 41*, p. 15.

26 Dr D. Maddison, *Submission No. 11*, p. 2.

27 Greenpeace Australia Pacific, *Submission No. 15*, p. 16

28 Greenpeace Australia Pacific, *Submission No. 15*, p. 16.

considered in geological formations which are not potential groundwater resources i.e. aquifers which are not connected with active groundwater flow systems.[29]

5.34 In terms of assessing the probability of leakage and escape of CO_2, Greenpeace points out that little is known about the behaviour of large quantities of CO_2. Greenpeace suggests that, because of the complex geology of each individual storage site, evaluation can only be conducted on a case by case basis.

5.35 Greenpeace states that storing CO_2 underground can dissolve the minerals that help stop the gas from escaping. The results from tests that injected CO_2 into saline aquifers in Texas showed that sequestration made aquifer water more acidic. This acidity attacked the surrounding rock formations, causing them to dissolve and thereby potentially allowing the gas to leak into the water table.[30]

5.36 In his evidence, Dr Maddison expresses similar concerns regarding potential leakage. He contends that there may be problems associated with the use of depleted gas fields, including rocks cracking as gas is removed causing structural changes which may result in the rock structure no longer being able to hold their contents for long periods of time. Furthermore, problems also exist in association with the re-pressurising of rocks when injecting CO_2 and the integrity of the well plug. Dr Maddison states that 'there is no proof that once a field is filled with carbon dioxide, the plug can or will remain intact over the rest of time.'[31]

Risk mitigation strategies

5.37 Rigorous risk mitigation strategies should be developed and implemented in order to reduce the risk of CO_2 leakage. For example, in evidence to the Committee it was noted that the risks of leakage during pipeline transportation can be reduced if care is taken that the water content of the CO_2 stream is kept low. This will avoid corrosion of the carbon manganese steel used in most pipe construction.[32]

29 International Association of Hydrogeologists, *Submission No. 8,* p. 1.

30 Greenpeace Australia Pacific, *Submission No. 15,* pp. 17-18.

31 Dr D. Maddison, *Submission No. 11*, p. 1.

32 Australian Government, *Submission No. 41,* p. 11.

5.38 Greenpeace raised concerns about the relative lack of experience with CCS risk mitigation strategies and the need for long term monitoring techniques.[33]

5.39 The CSIRO states that proper regulation is necessary to 'ensure that operators are competent, sites are appropriately chosen, and that wells are properly cemented.'[34]

5.40 CSIRO contends that catastrophic leakage is unlikely if sites are well selected, operators are competent and wells are properly sealed.[35] Rigorous site selection, diligent monitoring and management of the injection site are all critical factors and it is important that these activities are appropriately regulated.[36] Likewise, Chevron stated that 'the most effective way to mitigate the risk of containment failure is through rigorous site selection and management of injection operations'.[37]

The Gorgon Project and environmental issues

5.41 The Gorgon Project has highlighted some of the environmental challenges which arise from carbon sequestration projects. As discussed in Chapter 4, the Project plans to sequester around 2 million tonnes of CO_2 in a saline aquifer beneath Barrow Island, off the Northwest coast of Australia. Project operators, Chevron Australia, described it as, to the best of their knowledge, 'the first time a major geosequestration project has undergone such an exhaustive environmental impact assessment.'[38]

5.42 The environmental assessment, conducted by the Environmental Protection Authority (EPA), raised a range of environmental issues centred on dangers to Barrow Island's status as a Class A nature reserve. These included risk to a local population of flatback turtles, dredging, the introduction of non-indigenous species, and potential risks to rare subterranean and short-range invertebrate fauna.[39]

5.43 A submission from the Western Australian Government Department of the Environment elaborated on the risk CCS poses to these

33 Greenpeace Australia Pacific, *Submission No. 15,* p. 18.
34 CSIRO, *Submission No. 10,* p. 7.
35 CSIRO, *Submission No. 10,* p. 7
36 Chevron Australia, *Submission No. 12,* pp. 8-9.
37 Chevron Australia, *Submission No. 12,* p. 15.
38 Chevron Australia, *Submission No. 12,* p. 8.
39 Department of Environment (Western Australia), *Submission No. 3,* pp. 1-2.

subterranean fauna. The fauna are widely distributed in Western Australia, often in the sedimentary formations that are attractive for geosequestration.[40]

5.44 The Gorgon Project is based partly on positive comparisons with the successful Sleipner Project. Critics have noted, however, that the substantial differences between the sequestration sites raise further environmental questions in relation to Gorgon:

> At Gorgon, the annual volume of CO_2 to be stored is 5 times that of the Sleipner project. At Sleipner, a subsea aquifer is being used as the storage location but at Gorgon the proposed storage aquifer is under dry land. The storage location at Gorgon, some 2300 metres below the surface is 1500 metres deeper than at Sleipner. How will the CO_2 react to the temperature and pressures at this depth? Where will it migrate to? What effect will it have on subsurface geology? What effect will buoyancy have on the sequestered CO_2? Does the storage area have adequate seal integrity? Will previously drilled wellbores into the proposed storage area allow seepage back to the surface? What is the metallurgical integrity of those wells? CO_2 is highly corrosive, so what effect will there be on the well architecture? What effects could it have on fauna or flora if it does seep out? What happens to the sequestered CO_2 if there is a large earthquake in the immediate vicinity?[41]

5.45 In June 2006, the EPA recommended that the project not proceed based on potential environmental risks. The EPA stated that the joint venture had not been able to demonstrate that impacts from dredging, the introduction of non-indigenous species and the potential loss of fauna could be reduced to acceptable levels.

5.46 After further negotiations with the project partners, the Western Australian Government, on 12 December 2006, gave the approval for the Project to proceed.[42] The joint venturers agreed to allocate a further $60 million to address environmental concerns. Further EPA concerns were also addressed by a commitment from the Western

40 Department of Environment (Western Australia), *Submission No. 3,* p. 1.

41 M. Hastings, 'Australia: Gorgon Gas Project – Ugly by name', *Australian Energy Bulletin,* <energybulletin.net/5219.html>, accessed 14 May 2007.

42 M. McGowan MLA, Minister for Education and Training (Western Australia), Media Statement, *Tough conditions imposed on Gorgon gas project,* 12 December 2006, <mediastatements.wa.gov.au>, accessed 30 May 2007.

Australian Government to expand land and marine parks and reserves in the Pilbara and lower west Kimberley.

Committee conclusion

5.47 The Committee considers there are positive environmental benefits to be gained from the deployment of CCS, providing there is also the appropriate regulation and scrutiny of environmental risks.

5.48 A regulatory risk mitigation framework needs to address:

- Criteria for CCS site selection and an assessment of the environmental impact at selected sites;
- Assessment of the risk of abrupt or gradual leakage, and appropriate response strategies; and
- Requirements for long-term site monitoring and reporting.

Recommendation 3

The Committee recommends that the Australian Government implement a rigorous regulatory environmental risk mitigation framework for CCS which covers:

- **Criteria for CCS site selection and an assessment of the environmental impact at selected sites;**
- **Assessment of the risk of abrupt or gradual leakage, and appropriate response strategies; and**
- **Requirements for long-term site monitoring and reporting.**

Public perception and education

5.49 The Australian Government's submission notes research from Canada, the UK and Australia which indicates that the public is not well informed on CCS technology and its potential for climate change mitigation. The major public concern relates to potential leakage and consequent impact on ecosystems and the environment.[43]

43 Australian Government, *Submission No. 41*, p. 32.

5.50 The Australian Government has suggested that, based 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.[44]

5.51 Similarly, Chevron commented that:

> Community understanding of geosequestration as an appropriate greenhouse emissions reduction tool can be addressed by ongoing research and demonstration activities but widespread acceptance will only be achieved through securing successful, large scale projects and demonstrating the long-term integrity of this approach.[45]

5.52 To this aim, and as noted in the Australian Government submission, an important element of the Otway Basin Pilot Project is to inform and educate the community about CCS.[46] Public meetings held near the proposed storage site have been conducted, with further meetings scheduled in 2007. Newsletters are also to be circulated to everyone in the nearby Nirranda community. Stakeholder groups have also been formed and will meet on a regular basis to identify and deal with any issues that arise.[47]

5.53 Nevertheless, Friends of the Earth Australia suggests that public consultation for the Otway Basin Pilot Project has been inadequate[48] — a claim countered by CO2CRC who have alternatively claimed that extensive consultations preceded the announcement and these will continue to occur throughout the life of the project.[49]

5.54 Whatever decisions are made regarding the uptake of CCS, the community needs to be fully convinced about the long-term safety of

---

44 Australian Government, *Submission No. 41,* p. 32.

45 Chevron Australia, *Submission No. 12,* p. 5.

46 Australian Government, *Submission No. 41,* p. 32.

47 CO_2CRC, *Geosequestration Research Project Update,* Issue 2, April 2007, p. 1, <co2crc.com.au/pilot/OBPPDL/OBPP_NL/ResearchProjectUpdate_Issue02.pdf>, accessed 30 May 2007.

48 Friends of the Earth Australia, *Submission No. 13,* pp. 8- 9.

49 CO_2CRC, *Geosequestration Research Project Update,* Issue 2, April 2007, p. 1, <co2crc.com.au/pilot/OBPPDL/OBPP_NL/ResearchProjectUpdate_Issue02.pdf>, accessed 30 May 2007.

storing large volumes of CO_2 deep underground, particularly in areas located next to or nearby population centres.

Conclusion

5.55 The key goal of CCS is to achieve an environmental benefit by removing a large quantity of CO_2 from the earth's atmosphere and, in doing so, help redress some of the problems associated with climate change.

5.56 There are some potential environmental risks associated with CCS technology, most particularly in terms of potential leakage of CO_2 from storage sites. However, experience in monitoring the activity of naturally occurring deposits of CO_2, in transporting hydrocarbons via pipeline for many years and in the injection and storage of CO_2 over the past 10 years, means that the risk of adverse and harmful outcomes from CCS is minimal.

5.57 Furthermore, as the Australian Government submission points out, CO_2 is less reactive than other materials that are handled in a like manner and pipeline standards and operating conditions are well advanced the world over.[50]

5.58 Likewise, the Stern Review expressed the view that climate change, if unchecked, would have very serious impacts on the environment:

> The scientific evidence is now overwhelming: climate change is a serious global threat, and it demands an urgent global response … If no action is taken to reduce emissions, the concentration of greenhouse gases in the atmosphere could reach double its pre-industrial level as early 2035, virtually committing us to a global average temperature rise of over 2˚C. In the longer term, there would be more than a 50% chance that the temperature rise would exceed 5˚C. This would be very dangerous indeed; it is equivalent to the change in average temperatures from the last ice age to today.[51]

5.59 It is interesting to note comments by Rupert Murdoch who stated that:

---

50 Australian Government, *Submission No. 41*, p. 11.

51 United Kingdom Treasury, *Stern review on the economics of climate change,* 30 October 2006, p. vi.

> I am no scientist but … I do know how to assess a risk. Climate change poses clear catastrophic threats. We may not agree on the extent, but we certainly can't afford the risk of inaction.[52]

5.60 While recognising the risk of inaction, it is also important that one risk of environmental harm is not replaced with another. Therefore, CCS will need to be subjected to the same rigorous legislative and regulatory scrutiny as any other mining or petroleum venture. Such scrutiny will assist in reassuring the general public that sequestering CO_2 deep below the earth's surface will be safe and secure in the short, medium and long-term.

5.61 The Committee recognises that the desire to employ CCS in combating climate change must not overshadow the need to ensure that environmental risks are avoided. Specifically, it is important that CCS sites are carefully operated, maintained and monitored with this in mind. The Committee expects that the demonstration projects will provide an ideal opportunity to subject CCS to rigorous environmental, health and safety regulations before any future long-term commercial operations are put in place.

52 News Corporation, *Remarks by Rupert Murdoch, Chairman and Chief Executive Officer, News Corporation,* 9 May 2007, <newscorp.com/energy/full_speech.html>, accessed 30 May 2007.

6

The economic benefits and costs of CCS

Introduction

6.1 There is a consensus that taking action on climate change will have a cost impact on the global economy. The IPCC's Fourth Assessment Report estimates that if the world is to stabilise greenhouse gas emissions between 535-590 parts per million (ppm)[1] CO_{2-e}, this will result in a global median Gross Domestic Product (GDP) reduction of 0.6 per cent in 2030. [2] The Stern Review estimates the annual cost of reducing total greenhouse gas emissions, to a level consistent with a 550ppm CO_{2-e} stabilisation level by 2050, will range from between -1.0 to +3.5 per cent of GDP. That is, an average of around 1 per cent of GDP each year now and for the foreseeable future.[3]

6.2 There is also general agreement that the costs of addressing climate change will be less if CCS is included in the suite of mitigation strategies.[4] If CCS is not included in the mix, then other, potentially more expensive technologies will have to be utilised to reduce CO_2 emissions. The IPCC estimates that, in the long term, including CCS

---

1 Discussions about climate change tend to focus on the need to limit CO_{2-e} levels to 550ppm or less (approximately double pre-industrial levels) if human societies are to be safe-guarded from dangerous interference in the climate system that is limiting global temperature rises to 2˚C from current levels. However, the UN Framework Convention on Climate Change has avoided stating a desirable stabilisation level. Today's global CO_{2-e} levels stand at 380ppm, an increase of 100ppm since pre-industrial times.

2 IPCC Working Group III, Fourth Assessment Report, *Mitigation of Climate Change.*

3 The Stern Review, *The Economics of Climate Change,* 30 October 2006, pp. vi & 211.

4 ESAA, *Submission No. 16*, p. 2.

in the range of mitigation strategies will reduce the cost of stabilising CO_2 by upwards of 30 per cent.[5]

6.3 In the Australian context, ABARE estimates that if early action, including CCS, is taken to abate climate change, Australia's GDP in 2050 will be 2.5 per cent less than its projected GDP under a "business as usual" scenario. Without CCS in the mix, ABARE predicts that carbon abatement will reduce our 2050 GDP a further 0.7 per cent, falling to a total of 3.2 per cent.[6]

6.4 CO2CRC modelling suggests a similar scenario. Their findings indicate that, to achieve carbon mitigation without CCS, it will cost the Australian economy about $2 billion a year more than if CCS is deployed. This is premised on predictions that the cost of avoiding CO_2 emissions will reduce by 30 per cent over time and that CCS will be able to store 140 million tonnes (approximately half) of Australia's total stationary $CO_{2\text{-}e}$ emissions per year.[7]

6.5 By contrast, Greenpeace Australia notes that the cost CCS poses to Australian power stations is one of the major flaws of CCS technology. They state that 'there is no evidence available that indicates CCS is the most economical mitigation option'.[8]

6.6 At this stage, it is extremely difficult to accurately estimate the costs of CCS. The cost estimates for CCS that are made are marked by very wide variations.

---

5 IPCC quoted in cLET, *Submission No. 7*, p. 4.

6 Australian Government, *Submission No. 41*, p. 16.

7 CO2CRC, *Submission No. 36*, p. 17.

8 Greenpeace Australia Pacific, *Submission No. 15*, pp. 3-5.

6.7 As the Australian Government stated in its submission:

> 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… [Moreover] the sum of the costs of individual 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.[9]

6.8 These issues are compounded by the lack of commercial-scale, integrated CCS operations worldwide. In its *Special Report on Carbon dioxide Capture and Storage*, the IPCC noted that:

> There is still relatively little experience with the combination of CO_2 capture, transport and storage in a fully integrated CCS system …CCS has still not been used in large-scale power plants (the application with most potential).[10]

The economic cost of inaction

6.9 There are economic costs involved with the deployment of CCS, however, there are also significant economic costs associated with taking no action to address greenhouse gas emissions.

6.10 CO2CRC looked at risk from the point of view if no action was taken:

> Perhaps the greatest, but so far unquantified risk would arise if we took no action, or inadequate action, to limit greenhouse gas emissions, resulting in major (and expensive) consequences arising from climate change.[11]

9 Australian Government, *Submission No. 41*, p. 17.

10 IPCC, *Special Report On Carbon dioxide Capture and Storage, Summary for Policy Makers and Technical Summary*, p. 38.

11 CO2CRC, *Submission No. 36*, p. 18.

6.11 According to the Stern Review, continuing a "business as usual" approach will pose a major economic risk to the global economy, costing trillions of dollars:

> …the Review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of global GDP or more.[12]

6.12 The Prime Ministerial Task Group on Emissions Trading notes that 'without action, there are likely to be increasingly adverse economic, social and environmental consequences. These risks need to be managed. They require an economic solution.'[13]

6.13 Available research suggests that the Australian economy could be 'more adversely affected [by global warming] than other developed countries'.[14] This could be the result of a range of factors—Australia's agricultural production is often located in low lying, warm areas and would be adversely affected by even moderate increases in temperature. Additionally, Australia's high rainfall variability means that evaporation is relatively high, therefore large dam storage capacities are necessary.[15]

6.14 It should be noted, however, that conclusions such as these are based on a limited amount of research. The Australian Productivity Commission believes that there is a lack of research which 'systematically and comprehensively compares the costs and benefits of climate change impact in Australia with those in other developed countries.'[16]

6.15 Despite that paucity of research in this area, there are many who are of the opinion that inaction on climate change will have a detrimental impact on Australian industry.[17]

---

12 The Stern Review, *The Economics of Climate Change*, 30 October 2006, p. vi.

13 Prime Ministerial Task Group on Emissions Trading, *Report of the Task Group on Emissions Trading*, May 2007, p. 5.

14 Australian Productivity Commission, *Submission to the Prime Ministerial Task Group on Emissions Trading, No. 28*, p. 20.

15 Australian Productivity Commission, *Submission to the Prime Ministerial Task Group on Emissions Trading, No. 28*, p. 20.

16 Australian Productivity Commission, *Submission to the Prime Ministerial Task Group on Emissions Trading, No. 28*, p. 20.

17 Australian Business Roundtable on Climate Change, <http://www.businessroundtable.com.au/html/jointceo.html>, accessed 5 June 2007.

6.16 For example, the following economic impacts have been predicted as a result of climate change:

- Australia's $32 billion tourist industry is highly climate dependent. A 2-3°C temperature rise would bleach 97 per cent of the Great Barrier Reef, which supports a tourist industry valued at $1.5 billion;
- The livestock industry's $17 billion export trade would face risks from increased heat stress, disease and pests; and, if temperatures increase by 2°C, national livestock capacity in native pasture systems would drop by 40 per cent; and
- If, as a consequence of reduced water flows, Australian irrigation allocations were reduced by 20 per cent reduction, Australia's GDP would fall by around $750 million in 2009/10.[18]

Cost estimates

CCS: integrated system

6.17 The IPCC has estimated that the cost of producing a kWh of electricity from a coal-fired power plant (PC and IGCC) ranges from 4-6 US cent without CCS and from 5-10 US cents with CCS.[19] The IPCC estimates that the cost of electricity, with CCS at a pulverised coal station, would increase by between 43 and 91 per cent. At an IGCC power plant that increase would be between 21 and 78 per cent.[20]

18 CSIRO research cited in, Australian Business Roundtable on Climate Change, *The Business Case for Early Action*, April 2006, p. 4.

19 IPCC, *Special Report On Carbon dioxide Capture and Storage, Summary for Policy Makers and Technical Summary*, p. 9.

20 IPCC, *Special Report On Carbon dioxide Capture and Storage, Summary for Policy Makers and Technical Summary*, p. 28.

6.18 Table 6.1 sets out the range of cost estimates (in US$) for PC and IGCC plants with CCS.

Table 6.1 Cost Variations in Applying CCS to a Range of Power Plants

Plant performance & cost parameters	Pulverized Coal	IGCC
Reference plant without CCS	0.043 - 0.052	0.041 – 0.061
Cost of electricity (US$/kWh)		
Power plant with capture		
Increased fuel requirement (%)	24 – 40	14 – 25
CO_2 captured (kg/kWh)	0.82 -0.97	0.67 – 0.94
CO_2 avoided (kg/kWh)	00.62 – 0.70	0.59 – 0.73
%CO_2 avoided	81 – 88	81 – 91
Power with CCS		
Cost of electricity (US$/kWh)	0.063 – 0.099	0.055 – 0.091
Cost of CCS (US$/kWh)	0.019 – 0.047	0.010 – 0.032
% increase in COE	43 – 91	21 - 78
Mitigation cost (US$/tonne CO_2 avoided)	30 - 71	14 - 53

Source *Compiled from: IPCC, Special Report on Carbon Dioxide Capture and Storage, Technical Report*, p.40.

6.19 The British House of Commons report estimated that producing a kWh of electricity at a coal-fired power station (PC and IGCC) without CCS would be approximately 2.6 GB pence. With CCS it would cost approximately 3.7 GB pence.[21] On the basis of these cost estimates, the House of Commons report states that 'the cost of electricity generation using CCS seems to be comparable with, or even less than, published costs from other carbon abatement or low carbon technologies such as nuclear or renewables'.[22]

6.20 In Australia, the cost of a kWh of electricity from a coal-fired power station is between 3.1-4.0 Australian cents.[23] This is less than the cost of electricity production estimated by the IPCC and the British House of Commons report, (4-6 US cents and 2.6 GB pence) because coal is

21 House of Commons, Science and Technology Committee, *Meeting UK Energy and Climate Needs: The Role of Carbon Capture and Storage, First Report of Session 2005-06, Volume 1*, 1 February 2006, p. 51.

22 House of Commons, Science and Technology Committee, *Meeting UK Energy and Climate Needs: The Role of Carbon Capture and Storage, First Report of Session 2005-06, Volume 1*, 1 February 2006, p. 51.

23 Australian Government, *Submission No. 41*, p. 18.

cheaper in Australia.[24] Australian Government figures estimate that the cost of producing a kWh of electricity from a new pulverised coal power station with capture is between 8 Australian cents and 10.6 Australian cents,[25] and an average cost of between A$5 and A$45 per tonne of CO_2 transported. Table 6.2 illustrates the predicted costs for transporting CO_2 in US$.

Table 6.2 Indicative CO_2 Transport Costs in USD per tonne

Distance	**Average costs US$t/$CO_2$**
Under 50km	1
50 – 200km	4
200 – 500km	6
500 – 2000km	12
Over 2000km	35

Source *Compiled from:* ABARE, eReport 05.1, *Near Zero Emission Technologies*, January 2005, p. 20.

6.21 The Australian Government submission also notes that ABARE presents a general estimated cost for storage and on-going monitoring, calculating average costs to be anywhere between A$1 and A$17 per tonne of CO_2.[26]

6.22 Table 6.3 summarises the IPCC's cost estimates for storage under various conditions: those for ocean storage [that is CO_2 stored at an ocean depth of 3000m] include the cost of transport by pipeline, thereby accounting for some of the cost variations between the two sources. Such cost variables are discussed in greater detail later in the chapter.

24 Centre for Energy and Environmental Markets, *Submission No. 16*, p. 15.

25 Centre for Energy and Environmental Markets, *Submission No. 16*, p. 15. The submission converts a US$ figure sourced from ABARE (*Near Zero Emission Technologies*, p. 17) to Australian dollars using a conversion rate of US$1 = 75 Australian cents.

26 Australian Government, Submission No. 41, p. 18.

Table 6.3 CCS Cost Breakdown: Storage and Monitoring

CCS system components	Cost Range US$/tonne CO_2	
Storage		
Geological	0.5 – 8.0	Excludes EOR or ECBM*
Ocean storage – pipeline	6.0 – 31.0	Range represents 100-500km distance offshore and 3000m depth. **
Ocean storage – ship/platform	12 - 16	Range represents 100-500km distance offshore and 3000m depth. **
Geological Monitoring & Verification	0.10 – 0.30***	

Source Compiled from: IPCC Special Report on Carbon Dioxide Capture and Storage, p. 346.

** EOR refers to Enhanced Oil Recovery and ECBM refers to Enhanced Coal Bed Methane recovery*

*** Includes offshore transportation costs*

****Source IPCC Special Report on Carbon Dioxide Capture and Storage, Summary for Policy Makers and Technical Summary, p. 39.*

6.23 The IEA and ABARE estimate that the cost for electricity produced by an IGCC plant with the full range of CCS technology will range between A$ 51- 107 per MWh in 2010, with costs decreasing over time.[27] The Committee has not received an estimate for the total cost of CCS at a pulverised coal power station in Australia.

Cost variables: capture, transport, storage and monitoring

Capture

6.24 Capture is the most expensive component of CCS accounting for between 70 and 80 per cent of the total costs.[28]

6.25 The cost of capture will vary depending on:

- technology choice and design;
- the integration and flexibility of new technology;
- the type and quality of coal and its effect on generating efficiency;
- the energy demands of the capture process;

27 Australian Government, Submission No. 41, p. 19.

28 Saddler et al, The Australia Institute, *Geosequestration: What is it and how much can it contribute to sustainable energy policy for Australia?*, Discussion Paper No. 72, September 2004, p. 27; CO2CRC, *Submission No. 36*, p. 14.

- variant capital costs; and
- the overall performance of the plant with capture deployment.

6.26 As discussed in Chapter 3, there are three types of capture technology: pre-combustion, post-combustion and oxyfuel combustion.

6.27 Pre-combustion technology can only be applied to IGCC. Australia has no IGCC plant (though an IGCC demonstration plant is planned for QLD). IGCC is, however, the basis for many clean coal technology programmes worldwide, many of which envision IGCC as the first step to a hydrogen economy.[29] An MIT study notes that cost competitiveness has made IGCC plants the preferred candidate for electricity generation with CCS.[30]

6.28 The cost of generating electricity from an IGCC plant compared to a conventional pulverised coal plant is, however, considerably more expensive. The Cooperative Research Centre for Coal in Sustainable Development (CCSD) commissioned a techno-economic assessment of power generation options for Australia and concluded that IGCC 'is likely to remain significantly more expensive than advanced pf [pulverised fuel], even with CO_2 capture, for electricity generation'.[31] Yet the report also noted that 'learning rates from increased implementation, and the need for CO_2 capture and other emissions controls, will give the technology [IGCC] an overall cost advantage in the longer term'.[32]

6.29 The costs of pre-combustion capture may also be potentially offset by the considerable economic benefits of converting coal into a liquid fuel. The House of Commons inquiry concluded that 'for new a plant, pre-combustion capture offers a significant advantage, in a carbon constrained world, as a potential source of hydrogen'.[33]

29 Cooperative Research Centre for Coal in Sustainable Development, *Techno-economic assessment of power generation options in Australia*, Technology Assessment Report 52, April 2006 (parts updated August 2006), p. 26.

30 MIT, The Future of Coal, March 2007, p. xiii.

31 Cooperative Research Centre for Coal in Sustainable Development, *Techno-economic assessment of power generation options in Australia*, Technology Assessment Report 52, April 2006 (parts updated August 2006), p. ii.

32 Cooperative Research Centre for Coal in Sustainable Development, *Techno-economic assessment of power generation options in Australia*, Technology Assessment Report 52, April 2006 (parts updated August 2006), p. 26.

33 House of Commons, Science and Technology Committee, *Meeting UK Energy and Climate Needs: The Role of Carbon Capture and Storage, First Report of Session 2005-06, Volume 1*, 1 February 2006, p. 17.

6.30 In the case of current post-combustion technologies, the costs are substantial. Stanwell Corporation told the Committee that, without significant technological improvements, the cost of post-combustion capture would probably make it more attractive to build a new generation plant from scratch.[34] Terry Daly, researcher at the University of NSW's Centre for Energy and Environmental Markets, told the Committee that the high energy penalty of up to 30 per cent on a retrofitted power station makes the cost of retrofitting unviable.[35]

6.31 Whichever technology is chosen, the different operating conditions and diversity of coal type mean significant variability in cost.[36] For example, the Centre for Energy and Environmental Markets noted that the cost of CCS for Victorian brown coal based generators is likely to be higher because of the need for offshore storage and the high moisture content of Victoria's brown coal, which would require an additional coal drying process for IGCC and oxyfuel application.[37]

6.32 According to the MIT study, the effect of coal type on capture application means that 'multiple technologies will likely be deployed'.[38] The study notes, for example, that, with further technological developments, oxyfuel pulverised coal combustion could prove as attractive as IGCC, especially with lower quality coals.[39]

Transport

6.33 There are differences in views relating to the expenses involved in transportation, and these are primarily in terms of distance. The Centre for Energy and Environmental Markets at the University of NSW states that transporting CO_2 over distances greater than 500 km may not be economically viable.[40] CSIRO suggest that transport of CO_2 over distances of more than 100 kilometres can become expensive and uneconomical.[41]

6.34 Transport costs will be dependent on factors such as the method and pressure of the CO_2 to be transported, whether the pipeline has to

34 Stanwell Corporation, *Transcript, 11 September 2006*, p. 17.

35 Centre for Energy and Environmental Markets, *Transcript, 30 October 2006*, p. 6.

36 MIT, The Future of Coal, March 2007, p. 22.

37 Centre for Energy and Environmental Markets, *Submission No. 33*, p. 15.

38 MIT, The Future of Coal, March 2007, p. xiii.

39 MIT, The Future of Coal, March 2007, p. xiii.

40 Centre for Energy and Environmental Markets, *Submission No. 33*, p. 12.

41 CSIRO, *Submission No. 10*, p. 4.

pass through heavily populated areas, and the nature of the terrain over which the pipeline is constructed.

6.35 The pipeline costs will also vary depending on whether the pipeline is onshore or offshore. Onshore pipelines cost estimates are lower than offshore pipelines. If storage is to take place offshore, then shipping rather than pipeline becomes more economical for distances over 1 000 kilometres.[42] However, for the foreseeable future, transport of CO_2 by pipeline is the most practical and economic option.[43]

6.36 Another variable in the cost of transport is the fluctuating price of steel, which accounts for a major part of the total transport cost. Pipelines need to be constructed from special steel as any water that infiltrates the pipeline will turn the CO_2 into a corrosive carbonic acid.[44]

6.37 The other factor that will influence the final transport cost is the CO_2 mass flow rate.[45] The greater the flow rate and quantity transported the lower the overall unit cost.

Storage and monitoring

6.38 Storage, monitoring and verification costs are likely to be the least costly component in the CCS chain. Variation in storage costs will arise depending on the geological features of the storage site and whether there is a need to cap any potential leakage points.

Future cost reductions

6.39 While there is no real consensus about the costs of the separate components of CCS, it is widely anticipated that costs will decrease over time. Capture costs, currently by far the most expensive component of CCS technology, will experience the greatest decrease as the technology matures. The costs of transport and storage are less likely to dramatically fall because of the maturity of these technologies.

---

42 IPCC, *Special Report On Carbon dioxide Capture and Storage, Summary for Policy Makers and Technical Summary*, p. 28

43 CO2CRC, *Submission No. 36*, p. 9.

44 CSIRO, *Submission No. 10*, p. 4.

45 Mass flow rate, in this instance, refers to the movement of CO_2 through a pipeline per unit of time.

6.40 The IEA states that the current costs of capturing and storing CO_2 are likely to be reduced by around 50 per cent by 2030.[46] The IPCC states that over the next decade, 'the cost of capture could be reduced by 20-30 per cent and more should be achievable by new technologies still in the research or demonstration phase'.[47]

6.41 In addition to the development of new technologies, cost reductions in CCS may occur where it is possible to develop shared storage facilities. Australia does have natural regions where it may be possible to create transport and storage hubs. As the CO2CRC has stated, many of Australia's emissions point sources are located within 200-500 kilometres from adequate storage sites.[48]

6.42 There is a consensus that such hubs would substantially reduce costs by harnessing existing infrastructure, including storage reservoirs, as well as utilising existing skills and technical expertise.[49] The Western Australian Government believes that, based on the current costs of establishing CCS projects, CCS will only be economically viable when it is applied to sources of emissions in existing heavy industrial areas, which would allow it to utilise existing industrial infrastructure.[50]

6.43 Such an assessment is endorsed by Anglo Coal, which points out in its submission that one of Australia's biggest and most suitable storage resources is in the offshore Gippsland Basin, which is in relatively close proximity to the Latrobe Valley brown coal deposits of the onshore Gippsland Basin.[51] The closely bunched nature of the onshore Gippsland Basin coal deposits could, according to Anglo Coal, facilitate 'the development of a joint-use pipeline hub system to gather CO_2 from the Latrobe Valley sources and transport it to the storage sites for injection'.[52]

46 OECD/IEA, *Energy Technology Analysis: Prospects for CO2 Capture and Storage*, Paris: 2004, p. 17.

47 IPCC quoted in, CO2CRC, *Submission No. 36*, p. 16.

48 CO2CRC, *Submission No. 36*, p. 19.

49 Santos, *Submission No. 25*, p. 3.

50 Department of Industry and Resources, Government of Western Australia, *Submission No. 26*, p. 5.

51 Anglo Coal, *Submission No. 24*, p. 8.

52 Anglo Coal, *Submission No. 24*, p. 8.

Economic viability and government incentives

6.44 The difficulties in estimating realistic costs of CCS deployment, given the wide range of variables and the still untested nature of large-scale CCS application, are manifold. What is clear, however, is that CCS deployment significantly increases the cost of electricity production and that technological uncertainties and unknowns in cost estimation make industry investment in CCS on a wide scale unlikely in the current environment.

6.45 In evidence to the Committee, the National Generators Forum said that 'at this early stage of development, the investment risk of new coal based technology with carbon capture and storage is large'.[53] Stanwell Corporation's analysis indicated 'that the capture and storage of CO_2 produced in electricity generation is not economically viable in Australia at this time'.[54]

6.46 Industry submissions overall signalled that economic incentives need to be in place for CCS technology to be invested in by energy producers.[55] The Energy Supply Association of Australia (ESAA) notes that:

> … given CCS is at a clear cost disadvantage to existing generation technologies, carbon emission constraints are the only reason CCS technologies would be adopted by the energy supply industry.[56]

6.47 Members of the AP6 and the Australian coal industry are also 'calling for a carbon price signal to support the technology approach to abating and mitigating greenhouse gas emissions'.[57]

6.48 According to the IPCC:

> Most energy and economic modelling done to date suggests that the deployment of CCS systems starts to be significant when carbon prices begin to reach approximately 25-30 US$/t CO_2 … [this modelling suggests that] the large-scale deployment of CCS systems [will begin] within a few decades

53 National Generators Forum, *Transcript, 4 December 2006*, p. 2.

54 Stanwell Corporation, *Submission No. 32*, p. 4.

55 AGL, *Submission No. 39*, p. 3; BP Australia, *Submission No. 43*, pp. 14-15; CRC for Greenhouse Accounting, *Submission No. 14*, p. 1.

56 ESAA, *Submission No. 16*, p. 2.

57 Environment Business Australia, *Submission No. 37*, p. 2.

> from the start of any significant regime for mitigating global warming.[58]

6.49 The CO2CRC believes that a carbon price of A$20/tonne of CO_2 avoided would make CCS technology economically viable.[59] This would depend on a range of conditions including the concentration of the CO_2 stream and proximity to the storage site.[60] If such favourable conditions are not present, for example if the emissions stream is low in CO_2 and the storage site is hundreds of kilometres away, CCS deployment could cost a power station as much as A$100 or more a tonne per CO_2 avoided. As such, CCS deployment would become economically 'non-viable'.[61]

6.50 In terms of establishing the form a carbon price should take, the introduction of an emissions trading scheme has received the greatest support from industry. As Dr Peter Cook points out, such a scheme 'has the benefit of being technology neutral and is likely to produce the least cost outcome in the short term'.[62]

6.51 On the other hand, Chevron and BP give only qualified support to the introduction of an emissions trading scheme, arguing that such a scheme is dependent on government support and regulation.[63] Both suggest that the Australian Government's LETDF be extended beyond the demonstration phase either through the provision of direct grants, interest free funding or tax reform (for example allowing immediate capital deduction or accelerated depreciation).[64]

6.52 Rio Tinto expressed the view that CCS should be encouraged via a 'push' policy by which the government provides ongoing support to help achieve the public goal of reducing greenhouse gas emissions.[65]

> If the government would like these technologies to be deployed, the government is going to have to support their deployment. It really is as simple as that. The economics simply do not stack up without that support.[66]

---

58 IPCC, *Special Report On Carbon dioxide Capture and Storage,* p. 341.
59 CO2CRC, *Submission No. 36*, p. 14.
60 CO2CRC, *Submission No. 36*, p. 14.
61 CO2CRC, *Submission No. 36*, p. 14.
62 CO2CRC, *Supplementary Submission No. 36.1*, p. 9.
63 Chevron Australia, *Submission No. 12*, p. 14; BP Australia, *Submission No. 43*, p. 15.
64 Chevron Australia, *Submission No. 12*, p. 14; BP Australia, *Submission No. 43*, p. 15.
65 Rio Tinto, *Transcript, 26 February 2007*, pp. 4, 5 & 7.
66 Rio Tinto, *Transcript, 26 February 2007*, p. 8.

Emissions trading in Australia

6.53 On 10 December 2006, the Prime Minister announced the establishment of a joint government-business Task Group on Emissions Trading. The terms of reference were:

- To advise on the nature and design of a workable global emissions trading scheme in which Australia would be able to participate; and
- To advise and report on additional steps that might be taken, in Australia, consistent with the goal of establishing such a system.

6.54 The Task Group reported on 31 May 2007 and made a number of findings, Key findings include:

- Australia should not wait until a genuinely global agreement on emissions reduction has been reached. Therefore, Australia should adopt early emissions constraints;
- the most efficient way to manage risk is through market mechanisms. Therefore, an Australian emissions trading scheme would allow the nation to respond to future carbon constraints at least cost;
- the Australian Government should set a national framework for reducing greenhouse gases and then let the market set the carbon price;
- emissions trading enables the market—not the government—to decide which new or existing technologies will reduce emissions as least cost. Therefore, favouring particular technologies over others will increase the costs we impose on ourselves;
- an Australian emissions trading scheme should be as comprehensive as possible. However, it should not prejudice the competitiveness of Australia's trade-exposed, emissions-intensive industries;
- a long-term aspirational goal should be set for reducing Australia's production of greenhouse gases; and
- an emissions trading scheme should form the principal mechanism to achieve emissions-reduction goals. However, complementary

measures will be required as part of a comprehensive mitigation strategy.[67]

6.55 For the purpose of this report, it is important to note the Task Group's findings in relation to CCS. Specifically, it is the Task Group's conclusion that:

- the Government's role in supporting research and development (R&D) should be one of a technology 'push' through significant funding for basic and applied R&D, followed by a clear long-term price signal for carbon which will encourage market investment in the development of low-emission technology; and
- resource related technologies should be Australia's R&D priority. Therefore, given the importance of coal to Australia's economy, CCS technologies should be a primary focus of R&D.[68]

6.56 On 4 June 2007, the Prime Minister outlined his response to the Task Group's report. This response included four key points:

- Australia will move towards a domestic, cap and trade emissions trading system beginning no later than 2012;
- Australia will set a long-term aspirational goal for reducing carbon emissions, after carefully accessing with detailed economic modelling the impact any target will have on the Australian economy and Australian families. This target will be set in 2008;
- the scheme will be national in scope and as comprehensive as practicable, designed to take account of global developments and to preserve the competitiveness of Australia's trade exposed emissions intensive industries; and
- governments need to let the market sort out the most efficient means of lowering emission with all low emissions technologies on the table, including nuclear power.[69]

---

67 Prime Ministerial Task Group on Emissions Trading, *Report of the Task Group on Emissions Trading*, May 2007, pp. 6-7.

68 Prime Ministerial Task Group on Emissions Trading, *Report of the Task Group on Emissions Trading*, May 2007, pp. 127-29.

69 Prime Minister Howard, Address to the Liberal Party Federal Council, 4 June 2007, <http://www.pm.gov.au/media/Speech/2007/Speech24350.cfm>, accessed 6 June 2007.

Conclusion

6.57 Coal accounts for around 80 per cent of electricity generation in Australia. The comparatively inexpensive power derived from coal supports domestic and commercial users, as well as many large, energy intensive industries in Australia. The coal industry also provides employment. For example, in Queensland, 1 in 8 jobs depend on the resources industry; in Central Queensland the figure is 1 in 4.[70]

6.58 Given the impact that the coal industry has on the Australian economy and Australian families, any reduction in coal use would be detrimental to Australia. For example, modelling undertaken by MIT indicates that, without CCS and under carbon constraint, coal use in 2050 would fall by 28 per cent. It is therefore important that Australia consider the employment of CCS technology.

6.59 There is also international consensus on the importance of CCS technology, because fossil fuels will remain a significant part of the world energy mix well into the future. As noted in this Chapter's introduction, the IPCC argues that including CCS in the range of mitigation strategies adopted will reduce the cost of stabilising global CO_2 levels by at least a third.[71] The British House of Commons report found the cost of electricity generation using CCS to be comparable to, or less than, other forms of low carbon electricity generation.

6.60 In the Australian context, the ESAA, ABARE and CO2CRC all found that the deployment of CCS would reduce the cost of carbon abatement to the Australian economy.

6.61 However, the Committee notes the very real difficulty of putting a dollar value on the potential costs and ultimate economic benefits of CCS deployment.

6.62 Whatever the eventual costs of CCS, everyone accepts that the price of electricity will rise as the world attempts to combat global warming and reduce CO_2 emissions. Clean energy comes at a price, whether it will be from clean coal, renewables or nuclear,[72] but in the case of CCS, the size of the price increase is not clear. Available data suggests that CCS might double the cost of electricity generation from coal,

70 Queensland Resources Council, *Submission No. 20*, p. 3.

71 IPCC quoted in cLET, *Submission No. 7*, p. 4.

72 Friends of the Earth, *Submission No. 13*, p. 8; National Generators Forum, *Transcript, 4 December 2006*, p. 7; Australian Coal Association, *Transcript, 27 November 2006*, p. 17.

however, as CSIRO notes, the cost of implementing capture technology is 'only a proportion of the costs consumers pay.'[73] Robert Socolow has predicted that as 'the costs of distribution and transmission [of electricity] are hardly affected [by CCS] … the retail cost of electricity would increase by just 20%'.[74]

6.63 Despite the potential for rising electricity costs, CCS must be seriously considered. Given that Australia is the world's biggest coal exporter, a dramatic drop in coal consumption occasioned by international carbon constraint without CCS deployment, would have a significant detrimental impact on the Australian economy.

6.64 The future deployment of CCS globally, and its ramifications for the coal industry, will depend on an international research and demonstration effort now to which, as argued in Chapter 4, Australia has the ability to make a significant and leading contribution.

6.65 The Committee recognises that there is little economic incentive at present for the power generating sector to embrace CCS technology, as this technology which would add significantly to their operating costs and impact on their profitability. If a carbon price is introduced, and if the cost of CCS is at the lower end of the estimated range, then it is likely that incorporating CCS technology into the next generation of coal-fired power stations would be competitive with other forms of low emission power generation.

6.66 Initially additional support will be needed to facilitate the deployment of CCS at different sites and determine the total and ongoing costs of clean coal. Until more research and demonstration has been undertaken, there will continue to be speculation about the true costs of CCS technology.

6.67 The Committee considers that CCS should be viewed as a necessary component of a broader Australian Government response to the challenge of climate change. Within that broader response, there is a role for financial incentives, both direct and tax based, which the Government can use to encourage a range of measures targeting global warming. Previous recommendations in this report have stressed the need for further research and demonstration in the field of CCS. Therefore, the Committee recommends that the Australian Government, as part of its broader fiscal response to climate change,

73 CSIRO, *Supplementary Submission No. 10.1*, p. 2.

74 Robert Socolow quoted in, Quirin Schiermeier, *Putting the carbon back: the hundred billion tonne challenge*, Nature Vol. 442, Iss. 7103 (10 August 2006), p. 623.

employ financial incentives, both direct and tax based, in an effort to encourage science and industry to continue developing and testing CCS technology.

Recommendation 4

The Committee recommends that the Australian Government, as part of its broader fiscal response to climate change, employ financial incentives, both direct and tax based, in an effort to encourage science and industry to continue developing and testing CCS technology.

7

Legislative and regulatory framework

7.1 A large volume of evidence has highlighted the importance of establishing an appropriate legislative and regulatory framework for CCS.[1] While evidence was generally supportive of initiatives undertaken to date, the need for further development was recognised, and there were concerns regarding the translation of broad policy principles into a practical working model.[2]

7.2 In its submission, the Australian Government notes the key requirements that it sees as underpinning a CCS regulatory system, including the need for the system to 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; and
- consistent with obligations under international law.[3]

7.3 The regulatory framework will need to cover both onshore sequestration, which is primarily a state matter, and offshore sequestration, which is a federal matter. Currently state and federal legislation primarily covers access and property rights of sites. A

1 For example see ESAA, *Submission No. 16*, p. 3.

2 ExxonMobil, *Submission No. 19*, p. 10.

3 Australian Government, *Submission No. 41*, pp. 28-29.

nationally consistent framework is required which covers issues such as transport, injection, monitoring and financial liability through the stages of CCS.

International regulatory framework

7.4 Australia continues to play a key role in considering international regulatory, licensing and environmental issues concerning CCS within the IEA, the CSLF and the 1996 Protocol to the UN's London Convention of the Prevention of Marine Pollution by Dumping of Wastes and Other Matters.[4]

7.5 Australia is Chair of the IEA/CSLF Legal Issues Subcommittee which has been charged with examining legal and regulatory issues associated with the uptake of CCS on a global scale. In October 2006, a paper authored by the Australian representatives, entitled the National Legal and Regulatory Framework, was a key component of the IEA's workshop on the development and implementation of internationally agreed legal aspects of storing CO_2.[5]

7.6 Australia, together with France, Norway and the United Kingdom, has taken a leadership role in proposing amendments to the 1996 Protocol to the London Convention to address regulatory concerns regarding the sequestration of CO_2 in sub-sea geological formations.

7.7 On 10 February 2007, the International Maritime Organization approved the amendments to the London Convention which will enable the storage of CO_2 under the seabed.[6] These amendments affirm that CO_2 is not a pollutant and may be safely stored under the seabed.

4 Australian Government, *Submission No. 41*, p. 33.

5 Australian Government, *Submission No. 41*, p. 33.

6 Alistor Doyle, *Carbon, other pollutants to be stored beneath the sea to fight global warming*, <http://www.ocregister.com/ocregister/healthscience/abox/article_1575392.php>, accessed 12 February 2007.

7.8 The Australian Parliamentary Joint Standing Committee on Treaties inquired into these amendments and reported in March 2007. The committee endorsed the Annex I amendments to the London Convention.[7]

Domestic issues

7.9 There is currently no specific legislative or regulatory framework for CCS in Australia. There are, however, existing state and federal laws and regulations with relevance to various aspects of CCS.

7.10 At the state level, the *Queensland Petroleum and Gas (Protection and Safety) Act 2004* and the *South Australian Petroleum Act 2000*, for example, 'provide for the transport by pipeline and storage in natural reservoirs of substances including carbon dioxide'.[8]

7.11 At the Commonwealth level, environmental laws relevant to CCS include: the *Environment Protection and Biodiversity Conservation Act 1999*; the *Environment Protection (Sea Dumping) Act 1981*; and the *Offshore Petroleum Act 2006*.

7.12 Current legislative arrangements involve multiple jurisdictions and approvals. It is desirable to achieve consistent legislation across all states and territories. Similar sedimentary storage sites in different states should be treated in the same way as far as practicable. Co-operation should be extended so that CO_2 produced in one state may be able to be stored in another where long-term and secure storage is proximate and suitable.

7.13 The Australian Government is currently in the process of developing a nationally consistent regulatory framework.

7.14 In September 2003, the MCMPR[9] established a Geosequestration Regulatory Working Group (consisting of all federal, state and

---

7 Joint Standing Committee on Treaties, *CO_2 Sequestration in Sub-Seabed Formations: Amendment to Annex 1 to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972*, 26 March 2007.

8 Department of Industry, Tourism and Resources, Carbon Dioxide Capture and Geological Storage (CCS) Regulation (last reviewed 13/11/2006), <http://www.industry.gov.au/content/itrinternet/cmscontent.cfm?objectID=705E9B4B>, accessed 25 May 2007.

9 The MCMPR consists of the federal Minister for Industry, Tourism and Resources, State and Territory Ministers with responsibility for mineral and petroleum, with New

territory jurisdictions) to develop draft regulatory guiding principles for CCS.[10] In November 2004, the MCMPR charged its Contact Officers Group with reporting on how to implement a legislative framework to regulate CCS in Australia.

7.15 In November 2005, after consultation with relevant stakeholders including key industry peak association bodies, environmental representatives, research organisations and MCMPR representatives, a set of guiding principles for CCS was agreed upon.[11]

7.16 Six key issues were seen as fundamental to a CCS national regulatory framework:

- Assessment and approvals process;
- Access and property rights;
- Transportation issues;
- Monitoring and verification;
- Liability and post-closure responsibilities; and
- Financial issues.[12]

7.17 Although there is no CCS specific regulatory framework, it was suggested that legislation associated with the petroleum and mineral exploration industries covering approval 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 might provide a foundation.[13]

7.18 A significant volume of evidence to the inquiry was supportive of the MCMPR initiative and its recommendation for amendment to existing petroleum legislation rather than the development of totally new legislation where possible.[14]

7.19 Chevron, for example, stated that:

Zealand and Papua New Guinea having observer status. Its mandate is the promotion and development of Australia's mining and petroleum industries.

10 Australian Government, *Submission No. 41*, p. 27.

11 Australian Government, *Submission No. 41*, p. 27.

12 Australian Government, *Submission No. 41*, pp. 6-7.

13 Australian Government, *Submission No. 41*, p. 27.

14 CSIRO, *Submission No. 10*, p. 8; Chevron, *Submission No. 12*, p. 3 & 10; Australian Government, *Submission No. 41*, p. 27.

> While new or amended legislation may be required to allow the injection of carbon dioxide, many aspects of existing legislation, regulation or the principles behind existing regulation can be readily adapted to facilitate geosequestration projects.[15]

7.20 Chevron suggests using or adapting existing laws and regulations for areas such as:

- environmental impact assessment;
- the transportation of CO_2;
- the design, drilling and production regulations in relation to petroleum wells; and
- disposal management plans.[16]

7.21 According to Anglo Coal;

> On balance therefore we think incorporation into existing petroleum legislation is the most practicable route, given that there will be a vital need to promote co-development and to reconcile conflicts between overlapping tenements-both of which would be difficult to achieve if the respective tenements were housed in different regulatory structures with different regulators.[17]

7.22 Witnesses have stressed, however, the need to ensure that any future CCS legislation does not prejudice the existing rights of the oil and gas exploration and mining industry. Where there is likely to be an overlap of tenure, every effort will need to be made to ensure that co-development will not advantage one party at the expense of the other. As Anglo Coal cautions:

> While accepting that CCS is best dealt with by amending petroleum legislation administered by the petroleum regulator, care will need to be taken to ensure that in the process the rights of CCS tenement holders are not subordinated to those of petroleum tenement holders.[18]

7.23 The Australian Government submission notes that while existing petroleum legislation may provide the basis for regulation of CCS

15 Chevron, *Submission No. 12*, p. 3.

16 Chevron, *Submission No. 12*, pp. 10-11.

17 Anglo Coal, *Submission No. 24*, p. 24.

18 Anglo Coal, *Submission No. 24*, p. 24.

with regard to capture and transport, more legislation is required in relation to the injection and storage phases of the CCS process.[19] In particular, site selection criteria need to be determined and agreed upon, with a robust system of verification and monitoring to be developed and implemented to ensure compliance with any regulations.[20]

7.24 With regard to the regulation of monitoring and verification, the ESAA believed that it is important that the authorisation and compliance regime is not too onerous, otherwise there is a risk that the development of the technology will be stifled.[21]

Australian Government response to site access and property rights

7.25 In its May 2007 budget, the Australian Government committed itself to amending the *Offshore Petroleum Act 2006*.[22] The Government believes that amending the Act will 'facilitate access and property rights for offshore legislation' for CCS and encourage the states to 'introduce mirror legislation to facilitate [CCS legislation] within their own jurisdictions'.[23]

7.26 Specifically with regard to onshore legislation, a state jurisdiction, the Australian Government expects that the states will examine the CCS regulatory principles established by the MCMPR and 'seek to introduce their own legislation to facilitate carbon capture and storage projects'.[24]

19 Australian Government, *Submission No. 41*, p. 29.

20 Australian Government, *Submission No. 41*, p. 30.

21 ESAA, *Submission No. 16*, p. 3.

22 The Hon Ian Macfarlane, MP, Media Release, *Budget Boost for Carbon Capture and Storage*, 8 May 2007.

23 Ms Constable, *Transcript 9 October 2006*, p. 8.

24 Ms Constable, *Transcript 9 October 2006*, p. 8.

7.27 The Australian Government has announced that the amendment to the *Offshore Petroleum Act 2006* will be underpinned by a regulatory regime which is expected to 'establish the methods for selecting storage sites and then regulating and monitoring the storage activity'.[25] The regulatory system is expected to cover:

- assessment and approval of proposed activities;
- risk and site analysis; and
- the monitoring required for long-term storage and data analysis.[26]

Long-term liability

7.28 Given that CCS envisions the storage of CO_2 for potentially thousands of years, long-term storage poses important regulatory issues, in particular, responsibility and timeframe for liability post-closure.[27]

7.29 CSIRO suggests that operators could either make financial provision or equally insure for future remediation in a trust held by government.[28]

7.30 Chevron proposed that liability be shared by operators and responsibility handed to the government once the site has been closed.[29]

7.31 Against this, Greenpeace Australia Pacific argues strongly that the long-term liability for leakage should not be transferred to government, and by implication, to taxpayers and future generations. If, as proponents have stated, the risk of leakage is likely to be less than one per cent over 1000 years, then Greenpeace Australia Pacific argues that the operators should be able to carry that risk.[30]

7.32 The International Association of Hydrogeologists have pointed out that regulation needs to ensure the integrity of injection wells that

25 The Hon Ian Macfarlane, MP, Media Release, *Budget Boost for Carbon Capture and Storage*, 8 May 2007.

26 The Hon Ian Macfarlane, MP, Media Release, *Budget Boost for Carbon Capture and Storage*, 8 May 2007.

27 Greenpeace Australia Pacific, *Submission No. 15*, pp. 19-21.

28 CSIRO, *Submission No. 10*, p. 8.

29 Chevron, *Submission No. 12*, p. 14.

30 Greenpeace Australia Pacific, *Submission No. 15*, pp. 19-20.

pass through freshwater aquifers[31] and that national protocols and guidelines need to include a competent groundwater specialist.[32]

Legislative framework for CCS trial and demonstration projects

7.33 It is not intended that small-scale demonstration projects will be covered by the MCMPR framework. The small scale projects currently planned or under development will be subject to the requirements of their jurisdictions.[33]

7.34 Stanwell has proposed that the Australian Government should establish interim legislation in order to facilitate demonstration projects.[34] Once the technology is fully commercialised, the experiences gained could then be used to help structure a more durable legislative and regulatory environment.[35]

7.35 According to Anglo Coal, the most cost effective way forward would be to utilise existing Commonwealth and state petroleum and mining legislation by way of amendments to facilitate CCS development and demonstration.[36]

Australian experience to date

7.36 In Victoria, the Monash Energy project requires legislation to ensure access to sequestration sites in the Gippsland Basin in Bass Strait. This is complicated by the fact that the likely storage sites are already held by petroleum companies and the legislation will have to deal with overlapping interests.[37]

7.37 To date, the regulatory framework for transporting, injecting and monitoring is yet to be determined but will be informed by the MCMPR's Guiding Regulatory Principles.[38]

7.38 The experience of CO2CRC in taking forward the Otway Basin Project, also in Victoria, has been that there are far more legal and

---

31 International Association of Hydrogeologists, *Submission No. 8*, p. 1.

32 International Association of Hydrogeologists, *Submission No. 8*, p. 1.

33 Australian Government, *Submission No. 41*, p. 32.

34 Stanwell Corporation, *Submission No. 32*, p. 6.

35 Stanwell Corporation, *Submission No. 32*, p. 6.

36 Anglo Coal, *Submission No. 24*, p. 22; Stanwell Corporation, *Submission No. 32*, p. 6.

37 Government of Victoria, *Submission No. 42*, p. 6.

38 Government of Victoria, *Submission No. 42*, p. 6.

regulatory obstacles to overcome than originally anticipated.[39] The CO2CRC was not critical of these obstacles but it does highlight that in any jurisdiction there are many areas where it is unclear which regulation applies to CCS.[40]

7.39 Further delays have been incurred with the project following the local council's decision to ask the Victorian Planning Minister to make an amendment concerning the rezoning of land associated with the storage site.[41]

7.40 On Barrow Island in Western Australia, the Gorgon Project has raised numerous regulatory issues. Currently, the only legislation in WA that can approve CCS activities on Barrow Island is the *Barrow Island Act 2003* (BIA). In particular, the following procedures must be followed in relation to the Gorgon Joint Venture:

- Under section 13 of the BIA, a person must seek the BIA Minister's approval to dispose of the CO_2 by injection into a subsurface reservoir beneath Barrow island;
- Under Schedule 1 to the BIA (Gorgon Gas Processing and Infrastructure Agreement), requires the proponents to submit a CO_2 disposal proposal and a Closure Plan proposal which addresses the long term management of the injected CO_2;
- The proposed project will be regulated in line with existing relevant petroleum industry legislative requirements;
- In relation to injection, drilling and geophysical surveys, the joint venture will be required to comply with the petroleum Act 1967 and Onshore Schedule;
- BIA has amended the *Petroleum Pipeline Act 1969* to allow for transport of CO_2 by pipeline to Barrow Island; and
- Capture of CO_2 during the gas processing will be authorised and regulated under the State Agreement plant proposals and the Major Hazards Facility regulations for plant.[42]

7.41 However, to transport and inject CO_2 elsewhere in the state, amendments to existing legislation or new legislation would be required.

39 CO2CRC, *Submission No. 36.1*, p. 7.
40 CO2CRC, *Submission No. 36.1*, p. 7.
41 The Age, *Carbon Storage Plan Gains Momentum*, 19 February 2007.
42 WA Department of Industry and Resources, *Submission No. 26*, p. 9.

7.42 In South Australia, the Cooper Basin has been identified as a possibility for geosequestration projects. The SA Government, in line with the MCMPRs' Guiding Principles, has already amended the South Australian *Petroleum Act 2000* to facilitate geosequestration activities.[43] Further amendments are being drafted to take account of gas storage licences (GSL) (in relation to existing petroleum exploration licences (PEL)) and petroleum production licences (PPL). In particular, the amendments will ensure GSL rights continue where the PPL or PEL rights are distinguished. The amendments will:

- Allow the grant of exclusive gas storage exploration licences with compatible overlapping rights spatially coincident with pre-existing licences;
- Specify that no royalty payments will be introduced for gas storage, either for storage of gas for late sale or for geosequestration; and
- Make it clear both PPLs and GSLs provide entitlements to safely sequester carbon dioxide, as well as safely store gases for later sale.[44]

7.43 As demonstration projects are rolled out, these legal and regulatory complexities will be thoroughly examined and each project will add to the body of knowledge and help develop a more comprehensive set of rules and regulations that will govern future CCS projects.

Conclusion

7.44 It is important that both the Commonwealth and state governments develop appropriate legal and regulatory frameworks during the demonstration projects. While it is not possible to come up with a "one size fits all" approach, it will be important to establish clear and unambiguous procedures to enable future projects to proceed with full knowledge of the legal and regulatory requirements.

7.45 The recent changes to the London Convention, allowing the burial of CO_2 under the seabed, will go a long way to facilitating the advancement of CCS technology as many suitable storage sites are located offshore.

43 Government of South Australia, *Submission No. 5*, p. 5.

44 Government of South Australia, *Submission No. 5*, p. 5.

7.46 Currently, there are some regulations in relation to the capture and use of CO_2 for EOR in the petroleum and mining industries. There is no regulation, however, specific to either sequestration or monitoring, at either Commonwealth or state level.

7.47 Therefore, there is a need to establish a regulatory framework to cover the injection of CO_2 and, subsequently, operational monitoring, site closure and post abandonment monitoring, which will provide confidence for investors to undertake large scale development.

7.48 The mitigation of CO_2 emissions is a national responsibility and it follows that the federal government has primary responsibility to create the regulatory environment in which sequestration projects can proceed with safety and confidence.

7.49 The creation of a regulatory environment, together with successful demonstration projects, will go a long way to enhance public confidence, by assuring people that their interests and safety are properly protected.

7.50 To maintain public confidence, regulations should focus on defining financial responsibility in the event that liability due to environmental damage or public health issues might arise in the future.

7.51 The issue of long-term liability is of particular concern. Regulations need to be flexible and strong enough to apply to the sequestration and storage of CO_2 which is intended to be in place for hundreds, if not thousands, of years. Regulations for financial liability need to be designed to cover both the period during which the CO_2 is being sequestered and the period after the injection process has ceased.

7.52 Post-injection liability presents particular challenges, due to scale and timeframe. The Committee acknowledges that there needs to be greater understanding of the risks involved in long-term storage, in order to asses the liability of operators and other parties with legitimate interests who may be affected. The Committee also acknowledges that industry certainty is required for CCS to progress. Therefore, the Committee sees the development of legislation which addresses financial responsibility as essential.

7.53 The Committee suggests that is may be appropriate for any future legislation to look at this post-injection period as three separate phases.

7.54 The first would encompass the closure of sequestration sites and their monitoring and verification during the initial period after closure. The duration of this initial period would depend on the physical nature of the site.

7.55 The second and third components of the framework would define the responsibilities of government and industry relating to financial liability following post-closure monitoring and verification.

Recommendation 5

The Committee recommends that the Australian Government, following industry consultation, develop legislation to define the financial liability and ongoing monitoring responsibilities at a geosequestration site.

The Committee recommends that financial liability and site responsibility should consist of three phases:

- **Full financial liability and responsibility for site safety and monitoring should rest with industry operators for the injection phase and a subsequent length of time (this time to be determined by the Australian Government subject to specific site risk analysis);**

- **Following the above specified time, shared financial liability and responsibility for site safety and monitoring should rest equally with industry operators and state, territory and Australian governments in the longer term. The exact length of this shared responsibility and liability phase should be determined by the governments subject to specific site risk analysis; and**

- **Following the determined phase of shared liability and responsibility, full financial liability and responsibility for site safety and monitoring should be transferred to the two spheres of government in perpetuity.**

8

Positioning Australian industry to capture possible market applications

Utilising our science skills

8.1 Australia's strong skills base in earth sciences and engineering makes it well-placed to be a leader in CCS technology. Australia has already developed an enviable reputation as a world leader in CCS science and technology. This reputation has been earned as a result of the work done by CO2CRC, APCRC and Geoscience Australia.

8.2 As the Australian Government submission notes:

> 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…

> 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 CO2CRC 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.[1]

8.3 In relation to the skills base required, the Australian Government submission refers to the work of the CSLF policy group, which identified the following skill requirements:

- Geology, including geophysics;
- Geo-engineering, including reservoir engineering, and hydrogeology;
- Process engineering, including electrical & chemical engineering; and
- Power engineering.[2]

8.4 In its submission to the Committee, Chevron states that the strength of Australia's skills base in this area is dependent upon demonstration projects proceeding and the continuing support of the subjects of earth sciences and engineering in the tertiary education sector and through the CRC for Greenhouse Gas Technologies.[3]

8.5 The Australian Government submission suggests that while the current science and engineering skills base is adequate to support CCS in the developmental stage, should the technology reach a stage where it is to be deployed on a commercial scale then a more 'substantial' skills base will be required.[4]

8.6 In particular, Anglo Coal maintains that:

> The longer term adequacy of the supply of suitably trained young geoscientists will…need to be addressed. Whilst there are a number of positive initiatives in this area being undertaken by the CO2CRC, there appears to be a case for

1 Australian Government, *Submission No. 41*, p. 21.
2 Australian Government, *Submission No. 41*, p. 22.
3 Chevron Australia, *Submission No. 12*, pp. 11 & 15.
4 Australian Government, *Submission No. 41*, p. 20.

> establishing a new and more focussed initiative to develop centres of excellence for training petroleum and CCS scientists and technologists.[5]

8.7 With regard to capture technology, Australia is fortunate to already have a significant skill base within universities and CSIRO.[6] It is expected that accessing skills to advance storage technology will improve over time as domestic oil production falls and key technical personnel from the petroleum industry will be able to continue similar employment in the emerging CCS sector.[7]

8.8 Unfortunately, the opposite seems to be currently occurring with geoscientists being lured away from CCS research into the petroleum and mining industries by the offer of higher salaries. The current resources boom has made it very difficult for institutions such as CSIRO and CO2CRC to compete for the services of skilled scientists. According to Anglo Coal:

> This skills shortage arises initially from limited numbers of young geoscientists coming through our universities and being trained in petroleum and CCS expertise, but is currently being exacerbated by the competing demand for oil exploration geoscientists. The salaries available for young geoscientists for oil exploration are very much higher than they can earn as employees of CO2CRC organisations, or Geoscience Australia. As a consequence, there has recently been a steady drift of CCS geoscientists to the oil industry, making it difficult to maintain the schedules for established programs or to implement new programs.[8]

8.9 In addition to the shortage of scientists, it has also been suggested that there is a need for a greater number of professional engineers.[9]

8.10 Nevertheless, continued support for CCS technology is not expected to require new skill sets but will rely on continued support for the development of higher-level skills, particularly those associated with the resources sector.

---

5 Anglo Coal, *Submission No. 24*, p. 22.

6 Includes activities such as solvent scrubbing, various membrane separators, solid adsorbents, and cryogenic separations.

7 CSIRO, *Submission No. 10*, p. 7.

8 Anglo Coal, *Submission No. 24*, p. 22.

9 Engineers Australia, *Submission No. 21*, p. 4.

8.11 A recent report from the National Institute of Labour Studies[10] suggests that more than 7 000 extra professionals will be needed by the resources sector in Australia over the next 10 years, in addition to more than 22 000 skilled workers (e.g. operators) and 26 000 workers in the mechanical and electrical trades.[11]

8.12 To address these needs, the Australian Government submission identifies a number of initiatives intended to meet present and projected skills needs. These include the Industry Skills Councils (ISCs) which provide a way for industry skill needs to be identified, communicated and serviced, as well as having primary responsibility for developing and maintaining training packages. Specifically with regard to the development of skills in resources sector, the submission identifies the Manufacturing Industry Skills Council and the Resources and Infrastructure Industry Skills Council (RIISC).[12]

8.13 The submission also describes a number of initiatives intended to promote trades including $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 25 Australian Technical Colleges. This includes four regionally based colleges that will undertake mining related trade training and industry placements.[13]

8.14 Further support from the Australian Government is provided for the science, engineering and technology skills through a number of initiatives under *Backing Australia's Ability*.[14]

8.15 Australia has also taken a leading role in the development of national and international regulatory frameworks for CCS relying on 'expertise in policy analysis, legal and regulatory issues, and communication skills'.[15]

10 National Institute of Labour Studies, Flinders University on behalf of the Chamber of Minerals and Energy of Western Australia, *Labour Force Outlook in the Minerals Resource Sector, 2005-2015*, May 2006.

11 Australian Government, *Submission No. 41*, p. 23.

12 Australian Government, *Submission No. 41*, pp. 23-24.

13 Australian Government, *Submission No. 41*, p. 24.

14 Australian Government, *Submission No. 41*, pp. 25-26.

15 Australian Government, *Submission No. 41*, pp. 21-22.

Building and marketing our skill base

8.16 The Committee was advised of a number of initiatives taking place, which are designed to build and market Australia's skill base in this area:

- As part of its role in furthering the science of CCS, CO2CRC has 32 post-graduate students on placement in select universities. The development of capture technologies within these universities is being carried out within the CO2CRC program. These students will play a key role in shaping the future of CCS technology. However, given the likely size of the CCS industry, more specialists will be needed.[16]
- cLET is a joint venture partnership between the Queensland Government, CSIRO, University of Queensland, Australian Coal Research Limited, Stanwell Corporation and Tarong Energy Corporation. This centre has two main objectives; to develop technologies to produce low emission electricity and to produce hydrogen from coal.[17]
- CSIRO is building up skills through its work performed within the Energy Transformed National Research Flagship program. The focus of the CSIRO work is the application of capture technology to power generation systems utilising both the conventional pulverised fuel fired plants and the next generation IGCC plants. The pilot plant has been designed to be relocated to different power stations around Australia to test results of operational conditions.[18]
- The Centre for Energy and Environmental Markets, University of NSW, brings together the research skills of various faculties to undertake key research into operational and environmental issues in the relation to electricity markets.[19]

8.17 CO2CRC refer to a "Team Australia" approach which has enabled Australia to develop a significant body of CCS expertise in a relatively short period of time and this, in turn, has allowed Australia to "punch

---

16 CO2CRC, *Submission No. 36*, p. 21.

17 Centre for Low Emission Technology, *Submission No. 7, Position Paper*, p. 2.

18 CSIRO, *Submission No. 10*, p. 7.

19 The Centre for Energy and Environmental Markets, University of NSW, *Submission No. 33*, p. 2.

above its weight" in global CCS research, development and deployment.[20]

8.18 According to CO2CRC, such an approach must be retained and strengthened:

> Having a range of separate organisations in Australia all aspiring to develop their own expertise in geosequestration research and education would lead to loss of critical research mass and diminish Australia's standing in this crucial topic. It is also essential that a coordinated approach is taken to university education and training in the evolving area of geosequestration.
>
> Training in geosequestration is to be encouraged and supported, but it must be coordinated through a body such as CO2CRC, to ensure quality, leading edge, user-focussed education and training, not only for the benefit of Australia, but also for the benefit of other countries such as India and China, which face major challenges in addressing future energy and greenhouse gas issues.[21]

8.19 CO2CRC went on to assert that:

> if Australia is to maintain its world standing, it makes no sense to develop numbers of small, potentially non-viable geosequestration research groups. ….Australia's science base can only afford one major program focussed on geosequestration. CO2CRC and its Core Participants, working in collaboration with organisations such as [cLET] and with international partners, can meet national and industry CO_2 mitigation needs as well as make a major contribution to the resolution of international greenhouse gas issues.[22]

8.20 The skills base will develop further as a number of CCS demonstration projects commence over the coming years. The first hand experience gained from bringing these demonstration projects to fruition will further enhance our reputation in CCS science. However, a more critical obstacle needs to be addressed: that of the lack of students entering universities to study science. Currently this problem is being compounded due to the resources boom and the

20 CO2CRC, *Submission No. 36*, pp. 21-22.

21 CO2CRC, *Submission No. 36*, p. 22.

22 CO2CRC, *Submission No. 36*, p. 22.

ability of this sector to offer far more attractive salaries to the already scarce science labour market.

8.21 Both the Victorian and Western Australian Government submissions highlighted the skills base that has been developed in Australia and the need to ensure this is developed further to secure Australia's lead position in CCS technology and regulation.[23]

8.22 If Australia hopes to market the emerging technology to other major coal-using countries such as China and India then the commitment to develop and broaden the skills base must be given the same level of attention as the commitment to RD&D.

Developing and identifying CCS market opportunities

8.23 CCS technology is just one of a number of strategies that are presently under consideration throughout the world to combat the problem of greenhouse gas emissions. Realistically, if Australia were to just develop CCS to deal with its own CO_2 emissions then very little will be achieved in the fight against climate change. Therefore, in order to make significant inroads into greenhouse gas abatement, any CCS technology that is successfully developed and demonstrated in Australia should be on-sold to other countries that are still very dependent on fossil fuels.

8.24 BP Australia stated:

> With its world-class knowledge base, well-defined storage capacity and vast reserves of fossil fuels, Australia is exceptionally well-placed to become a world leader in CCS technology, both to secure the value of its own resources, and to export technology and know-how internationally.[24]

8.25 While noting that the main purpose for CCS is climate change mitigation, the Australian Government submission also notes that development of the technology presents possible market opportunities for Australian industry. Specifically, the submission notes Australia's expertise in site mapping may be valuable.[25]

23 WA Government, *Submission No. 26*, p. 7; Government of Victoria, *Submission No. 42*, p. 5.

24 BP Australia, *Submission No. 43*, p. 14.

25 Australian Government, *Submission No. 41*, p. 34.

8.26 CSIRO said that in order to position Australian industry to take advantage of market opportunities that will arise from CCS, it is necessary to undertake pilot or commercial demonstration projects to identify the key challenges and develop the technology.[26] If Australia develops the technology then it will be in a position to access a potentially very large international market including the provision of technical expertise, research, collaboration, bilateral agreements and technology transfer.[27] CSIRO is not just talking about the CCS industry but all the flow-on activities such as the development of CO_2 resistant cements for use in well sealing and tools for detecting and measuring CO_2 from within storage reservoirs.[28]

8.27 Chevron emphasised that projects such as the Gorgon Project have the potential to demonstrate Australia's position as a leading nation in the implementation of this technology as a greenhouse gas emission tool.[29] Chevron also highlighted its commitment to making the data from its monitoring activities publicly available.

8.28 Chevron noted the importance of Australia's involvement with international fora such as the CSLF and AP6 which will ultimately assist in the transfer of CCS technologies to developing countries.[30]

8.29 Anglo Coal also believes that Australia has made a good start in establishing a leadership position in CCS stating that:

> Australian industry will have a solid platform from which to capture new market applications arising from R&D and deployment, as well as to continuing derived value for a nation from our coal resources and markets.[31]

8.30 Anglo Coal noted that one of the key requirements for the widespread deployment of CCS technologies is a supportive skills base. As outlined above, this base has been somewhat eroded in recent years due to the offer of more attractive remuneration in the oil and gas sector and more generally in the booming resources sector.[32]

---

26 CSIRO, *Submission No. 10*, p. 8.

27 CSIRO, *Submission No. 10*, p. 8.

28 CSIRO, *Submission No. 10*, p. 8.

29 Chevron Australia, *Submission No. 12*, p. 3.

30 Chevron Australia, *Submission No. 12*, p. 3 & 15; Australian Government, *Submission No. 41*, pp. 32-33.

31 Anglo Coal, *Submission No. 24*, p. 26.

32 Anglo Coal, *Submission No. 24*, p. 26.

8.31 On the other hand, Greenpeace argues that market opportunities are being lost by Australia's continued lack of support for renewable energy options stating:

> Focusing on how to position industry to capture possible market applications of CCS is therefore betting on the wrong horse. By putting the majority of resources and capacities towards the development of geosequestration technology, Australia is setting the seal on its dependence on coal as the primary energy resource.[33]

8.32 The spin-off according to BP Australia is that the successful development and demonstration of CCS will provide global marketing opportunities and this will in turn help reduce the costs and increase its market competitiveness.[34]

Maintaining our international competitiveness

8.33 Central to the goal of achieving clean energy is the desire to maintain Australia's international competitiveness that is currently underpinned by its access to cheap energy. In the absence of any market incentives, the current cost of CCS would erode this competitiveness and put a number of industries at risk.

8.34 According to many submissions, a market driven carbon trading system would provide the necessary incentive in a technology-neutral manner. However, in order to maintain our competitiveness, many would argue that Australia should be part of a global emissions trading scheme.

8.35 The ACA stated in its submission that:

> Seeking to reduce greenhouse gases by establishing an Australian or other sub-regional carbon price in the current environment will simply act as a blunt and largely ineffective instrument of change and a tax impost. Moreover, in the absence of suitable step-change technologies, costs imposed in one zone will merely drive activity to a different zone that does not have the same restrictions.[35]

---

33 Greenpeace Australia Pacific, *Submission No. 15*, p. 23.

34 BP Australia, *Submission No. 43*, p. 14.

35 Australian Coal Association and Minerals Council of Australia, *Submission No. 40*, p. 6.

8.36 These issues were the subject of consideration by the Prime Minister's Task Group on Emissions Trading which reported on 31 May 2007 (see Chapter 6 for further discussion). In its Issues Paper, the Task Group re-iterated the position of the Australian Government's Energy White Paper, in which it identified emissions trading as a potentially least-cost approach to reducing emissions subject to an effective global approach being in prospect.[36]

8.37 The Task Group said:

> Emissions trading is a more flexible market-based policy tool than imposing a carbon tax on industry. It requires emitters to hold permits that provide the right to emit a certain amount of greenhouse gases and allows them to buy and sell permits in an open market. Such a system works because only enough permits are allocated to ensure total emissions are curtailed over time, and industry uses the open market to discover the lowest cost ways of reducing emissions. A tradeable permit market creates an explicit carbon signal which allows business greater certainty in taking long term investment decisions and allows for the development of financial instruments to manage risk.[37]

Conclusions

8.38 Australia can be rightly proud of the skill base it has built up over the years in a range of earth science and engineering disciplines. Fortunately, the skills set for CCS is not new, the challenge faced being one of applying these current skills to a new problem in order to realise the full commercialisation and economic viability of CCS.

8.39 However, the strong skill base in Australia has been under threat in recent years due to two key factors.

8.40 Firstly, the resources boom has placed a great deal of pressure on the recruitment of science and engineering personnel to fill jobs in the mining sector. This sector has been able to attract highly qualified people from important research areas by being able to offer far more attractive remuneration packages. This transfer of personnel is likely to continue in the near future as the industry continues to grow.

36 Task Group on Emissions Trading, *Issues Paper*, February 2007, p. 4.

37 Task Group on Emissions Trading, *Issues Paper*, February 2007, p. 4.

8.41 The second issue is a more generic problem and that is to do with a general lack of students undertaking undergraduate engineering and science courses.

8.42 The skills base in CCS technology will continue to be developed through CSIRO, CRC programs and Geoscience Australia provided they are given the appropriate levels of funding to attract and retain qualified people.

8.43 While most stakeholders have accepted the need for a price to be placed on carbon emissions, some have argued that the establishment of an emissions trading scheme should not be rushed.[38] Rather priority should be given to developing and demonstrating CCS technology so that industry will be in a better position to make decisions about future low-emission investments. At present the biggest impediment to the commercial uptake of CCS is its cost and this will only be reduced if sufficient time, money and effort is spent on further research, development, demonstration and deployment.

8.44 If this can be achieved, then notwithstanding the fact that this technology will primarily help address our greenhouse gas emissions and related climate change issues, other market opportunities may arise as the rest of the world also seeks ways to deal with its emissions. There is the potential that Australia's position as leaders in the development of these technologies may result in the capitalisation of major export and market prospects from this industry.

Petro Georgiou MP

Chair

13 August 2007

38 For example see, The Australian Coal Association and the Minerals Council of Australia, *Submission No. 40*, p. 13; Mr M. O'Neil, *Transcript 21 November 2007*, p. 8.

Dissenting report

Dr Dennis Jensen MP, Hon Jackie Kelly MP, Hon Danna Vale MP, Mr David Tollner MP

We do not believe the evidence unequivocally supports the hypothesis of anthropogenic global warming (AGW)

1.1 We dissent from some of the statements made in the report *Between a Rock and a Hard Place* by the Standing Committee on Science and Innovation on its investigation into the Geosequestration of Carbon Dioxide.

1.2 We disagree with the report's unequivocal support for the hypothesis that global warming is caused by man—so-called anthropogenic global warming (AGW).

1.3 We are concerned that the Committee's report strays well outside its terms of reference. In fact, the committee did not take any evidence relating to anthropogenic global warming.

1.4 We do agree with the report's examination of the various factors relating to the geosequestration of carbon dioxide. Its coverage of the five aspects required in the terms of reference is sound.

1.5 We believe that the document is valuable in providing a resource that is detailed and up-to-date on the science, technology and other issues related to carbon dioxide geosequestration in the Australian context. It is as good as any in the public domain.

The case for AGW based theoretical models and unproven economic assumptions

1.6 The science related to anthropogenic global warming is not, despite the assurances of some, settled in the scientific community.

1.7 There is a great deal of debate and uncertainty related to this science, yet the Committee's report, in dealing with those issues, uses one-sided language that does not in any way correspond with the level of uncertainty or the low level of scientific understanding of many of the disciplines involved in global warming research.

1.8 Furthermore, the critical area of the fallibility and shortcomings of computer modelling is not mentioned anywhere. These shortcomings are exacerbated by the need to base the theoretical models on assumptions which are in turn generated by complex and also theoretical economic projections.

Many eminent scientists say that AGW is far from proven

1.9 The very first discussion paragraph of Chapter 2 in the report sets the scene in a very unfortunate manner. The evidence that human beings are changing the global climate is certainly not compelling. Many, even within the Intergovernmental Panel on Climate Change (IPCC) itself, disagree with the claimed consensus view. Remember that it is the IPCC that is the international body to whom the policy makers and AGW fanatics have looked to for direction on this subject.

1.10 The following passages report the well founded views of some eminent scientists in fields related to climate change, some of whom have made significant contributions to the IPCC's investigations. They, with good reason, disagree with the IPCC's findings in relation to AGW.

- Yuri Israel, Vice Chairman of the IPCC has stated 'There is no proven link between human activity and global warming'.[1]
- Dr Chris Landsea, a hurricane researcher, quit the IPCC in disgust due to what he viewed as the politicisation of his work. In his resignation, among other things, he stated 'I personally cannot in good faith continue to contribute to a process that I view as both

1 <http://en.rian.ru/analysis/20050623/40748412.html>, accessed 23 August 2007.

being motivated by pre-conceived agendas and being scientifically unsound'.[2]

- IPCC reviewer and meteorologist Dr. Vincent Gray, after analysing the latest available temperature measurements from satellites and weather balloons, and determining that there was no significant warming in the lower troposphere, concluded that:

> The NOAA (2006) study does not remove discrepancies between surface and lower troposphere mean global temperature anomaly records, but, instead, confirms them. It shows that for temperature sequences comparatively free from the interference of natural influences **there is no detectable warming in the lower troposphere** (our emphasis), the place where the enhanced greenhouse effect is claimed to be evident. For six out of the seven lower troposphere temperature records there is no influence of greenhouse forcing for a period of nineteen years, and even the seventh one shows no warming for ten of those years. [3]

  Gray adds that the observed surface warming that is highlighted by the IPCC must therefore have a different cause, which is probably the biasing of the records by urban heat effects.[4]

- Climate scientist Dr. John Christy, specialising in satellite temperature measurements and formerly lead author of the IPCC has stated:

> I've often heard it said that there's a consensus of thousands of scientists on the global warming issue and that humans are causing a catastrophic change to the climate system. Well I am one scientist, and there are many that simply think that is not true.[5]

- Prof Richard Lindzen of MIT, a lead author of Chapter 7 of the scientific report of the IPCC TAR (2001) has also stated that the

2<http://sciencepolicy.colorado.edu/prometheus/archives/science_policy_general/000318chris_landsea_leaves.html>, accessed 23 August 2007.

3 V. Gray, *Temperature trends in the lower atmosphere*, Energy and Environment Vol. 17, no. 5, pp 707-14, 2006.

4 V. Gray, *Temperature trends in the lower atmosphere*, Energy and Environment Vol. 17, no. 5, pp 707-14, 2006.

5 Martin Durkin (director), *The Great Global Warming Swindle* [Documentary], United Kingdom: WAGtv Ltd. for Channel 4, aired 8 March 2007.

IPCC use the Summary for Policymakers to misrepresent what scientists say.[6] He has stated that:

> …the full IPCC report is an admirable description of research activities in climate science, but it is not specifically directed at policy. The "Summary for Policymakers" is, but it is also a very different document. It represents a consensus of government representatives (many of whom are also their nations' Kyoto representatives), rather than of scientists. The resulting document has a strong tendency to disguise uncertainty, and conjures up some scary scenarios for which there is no evidence.[7]

- Dr. Martin Manning, IPCC Vice Chair of IPCC Working Group II on Impacts until 2002, and currently Vice Chair of IPCC Working Group 1 on the Science of Climate Change stated:

> The process used to produce the Summary for Policymakers (SPM) is far from ideal and may be distorting the real messages from the available science. Some government delegates influencing the SPM do not understand the methodologies being used and misinterpret or contradict the lead authors. This may need to be addressed in future through tighter rules of procedure.[8]

- Prof. Paul Reiter of the Louis Pasteur Institute, a specialist in malarial diseases, has major issues with the IPCC's view of disease, and is very damning of the IPCC process itself. He stated that:

> These confident pronouncements, untrammelled by details of the complexity of the subject and the limitations of these models, were widely quoted as **"the consensus of 1,500 of the world's top scientists"** (occasionally the number quoted was 2,500). This clearly did not apply to the chapter on human health, yet at the time, eight out of nine major web sites that I checked placed these diseases at the top of the list of adverse impacts of climate change, quoting the IPCC. The issue of consensus is key to understanding the limitations of IPCC

---

6 R. Lindzen, *U.S. Scientists report doesn't support the Kyoto Treaty,* National Post, 16 June 2001.

7 C.R. de Freitas, *Are observed changes in the concentration of carbon dioxide in the atmosphere really dangerous?*, bulletin of Canadian Petroleum Geology, vol. 50, no. 2 (June 2002), p. 300.

8 M. Manning, *Report on IPCC Working Group II 6th Plenary Session*, Geneva, 13-16 February 2001.

> pronouncements. **Consensus is the stuff of politics, not of science**. Science proceeds by observation, hypothesis and experiment. Professional scientists rarely draw firm conclusions from a single article, but consider its contribution in the context of other publications and their own experience, knowledge, and speculations. The complexity of this process, and the uncertainties involved, are a major obstacle to meaningful understanding of scientific issues by non-scientists.[9]

Many others have also voiced their scepticism of the science.[10][11] In fact, according the IPCC itself, the level of understanding in six of the nine related disciplines is medium or low.[12] There are also other scientific factors that contribute to climate that are not even considered by the IPCC, such as the role of cosmic ray activity in cloud formation.[13]

Global warming observed on other planets

1.11 Another problem with the view that it is anthropogenic greenhouse gases that have caused warming is that warming has also been observed on Mars,[14] Jupiter,[15] Triton,[16] Pluto,[17] Neptune[18] and others.

9 <http://ff.org/centers/csspp/library/co$_2$weekly/2005-09-01/paul.htm>, accessed 23 August 2007.

10<http://en.wikipedia.org/wiki/List_of_scientists_opposing_global_warming_consensusm>, accessed 23 August 2007.

11 <http://www.tsaugust.org/Scientists%20Open%20Letter.htm>, accessed 23 August 2007.

12 IPCC Fourth Assessment Report, Working Group 1: *The physical basis of climate change Technical Summary,* p. 32.

13 H. Svensmark, J. O. P. Pedersen, N. D. Marsh, M. B. Enghoff, and U. I. Uggerhoj, *Experimental evidence for the role of ions in particle nucleation under atmospheric conditions*, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences DOI:10.1098/rspa.2006.1773, 2006.

14 <http://www.newscientist.com/article.ns?id=dn1660>; accessed 23 August 2007; <http://news.nationalgeographic.com/news/2007/02/070228-mars-warming.html>, accessed 23 August 2007.

15 <http://www.space.com/scienceastronomy/060504_red_jr.html>, accessed 23 August 2007.

16 <http://www.scienceagogo.com/news/19980526052143data_trunc_sys.shtml>; accessed 23 August 2007; <http://web.mit.edu/newsoffice/1998/triton.html>, accessed 23 August 2007; J. L. Elliot, et al “global Warming on triton”, Nature Vol. 393, p765-767, 25 June 1998.

17 <http://www.space.com/scienceastronomy/pluto_warming_021009.html>, accessed 23 August 2007.

It is the natural property of planets with fluid envelopes to have variability in climate. Thus, at any given time, we may expect about half the planets to be warming. This has nothing to do with human activities.

Science relies on testing hypotheses, not consensus

1.12 The issue of consensus in science is very much misunderstood; unfortunately, in dealing with the issue of anthropogenic global warming, the Committee's report adds to that misunderstanding.

1.13 Science is a discipline which relies on testing hypotheses and exposing flaws, (scientifically known as *falsification*), not on consensus, in order to further scientific understanding. Scientific fact is not a democracy. Scientific facts are not concerned with what the majority of people or scientists think or do not think. The laws of physics are not subject to the democratic vote of a group of scientists; they cannot be repealed by a popular vote. Albert Einstein, for example, when asked to comment on the book *One Hundred Authors Against Einstein* which denounced his Theory of Relativity, stated that ***'to defeat relativity one did not need the word of 100 scientists, just one fact'***.[19]

1.14 Many examples exist of erroneous scientific consensus in the history of science:

- The earth was found, via falsification, not to be the centre of the universe;
- Sir Isaac Newton's equations of motion were found, after having been accepted as a complete description of mechanics for two centuries, to represent only the special case where velocity was low relative to that of light. The special theory of relativity generalised the field of mechanics; and

18 H. B. Hammell and G. W. Lockwood, *Suggestive correlations between the brightness of Neptune, solar variability, and Earth's temperature,* GEOPHYSICAL RESEARCH LETTERS, VOL. 34, L08203, doi:10.1029/2006GL028764, 2007.

19 <http://www.britannica.com/nobelprize/article-256586>, accessed 23 August 2007.

- Indeed, even in the field of climatology, the consensus position in the mid 1970's was that the earth was cooling as a result of mankind's activities, and we were headed to another ice age.[20]

Committee does not apply scientific method

1.15 We view it as very disappointing that the Committee on Science and Innovation has put out a report that misunderstands the nature of scientific method.

1.16 For example, section 2.2 of the Committee's report mentions the IPCC Summary for Policymakers that there is a >90% certainty that human beings have affected the climate. The problem with this statement is that this ignores the fundamental fact that this figure is not the result of some detailed statistical or any other analysis.

1.17 It is based on, yet again, simply a consensus opinion arrived at by IPCC bureaucrats. This pseudo-quantitative figure is in the bureaucratic summary for policymakers, not in the actual technical reports, and has no material basis or justification in measured fact.

Evidence does not support AGW

1.18 This report on geosequestration also gives a false impression of the importance of carbon dioxide on the greenhouse effect. All of the gases mentioned in section 2.5 are minor contributors to greenhouse. Between 75%-95% of the greenhouse effect is the result of water vapour and cloud. The understanding of the influence of the latter is low, by the IPCC's own admission.

1.19 Doubling CO_2 will only increase the natural greenhouse effect less than 2%. This would produce warming of the order of 1 degree Celsius in the absence of negative feedbacks which are the norm in sustainable physical systems. To be sure, current model projections do depend on positive feedbacks from the ill-understood clouds and water vapour (primarily above 6km).[21]

1.20 Section 2.27 of the Committee's report relies heavily on the IPCC's third assessment report (TAR). The statements made in the Committee's report, summarised from the IPCC TAR Summary for

---

20 <http://www.realclearpolitics.com/articles/2006/04/cooler_heads_needed_on_warming.html>, accessed 23 August 2007.

21 R. S. Lindzen, *Private Communication*, July 2007.

Policymakers do not in any way address any of the complexities relating to the science underpinning these statements—they are simply bald statements made in an attempt to support the position taken on AGW in this report.

- IPCC states that average global surface temperatures have increased by 0.6 degrees Celsius, which is broadly correct. However, it does not explain how it is that most of this increase occurred in the first half of the 20th century, a time when increases in atmospheric carbon dioxide was not particularly rapid. The concentration of atmospheric carbon dioxide began increasing fairly rapidly following the Second World War, but the period between 1940 and 1975 was associated with a *reduction* in global surface temperatures.[22] Significantly, global surface temperatures peaked in 1998, and only NASA's Goddard Institute for Space Studies (GISS) shows any year other than 1998 as the hottest year on record. The Global Historical Climatology Network (GHCN), Hadley Centre and MSU satellite data sets show 1998 as the hottest on record.[23] In the nine years since 1998, global temperatures have been relatively stable despite rising carbon dioxide concentrations in the atmosphere.[24]
- IPCC states that snow cover and ice extent have decreased. The fact is there is some argument about the ice balance on Greenland,[25] and it is generally accepted that the main Antarctic ice cap is, in fact, both cooling and increasing its ice mass.[26] Indeed, a couple of the striking examples of the decrease in snow cover/ice extent given as examples of the effect of greenhouse gas induced global

22 IPCC Fourth Assessment Report, Working Group 1: *The physical basis of climate change,* Chapter 3, p. 242.

23 C. Idso, *A science-based rebuttal to the testimony of Al Gore before the United States Senate Environment and Public Works Committee*, p. 4, May 2007.

24 C. R. de Freitas, *Private Communication*, July 2007.

25 H. J. Zwally, M. B. Giovinetto, J. Li, H. G. Cornejo, M. A. Beckley, A. C. Brenner, J. L. Saba, and D. Yi, 2005; *Mass changes of the Greenland and Antarctic ice sheets and shelves and contributions to sea-level rise*: 1992-2002, Journal of Glaciology 51, pp. 509-527; R. B. Alley, P. U. Clark, P. Huybrechts, and I. Joughin, 2005. *Ice-sheet and sea-level changes.* Science 310, pp. 456-460.

26 D. J. Wingham, A. Shepherd, A. Muir, and G. J. Marshall, *Mass balance of the Antarctic ice sheet,* Philosophical Transactions of the Royal Society A 364, pp. 1627-35, 2006; D. H. Bromwich, Z. Guo, L. Bai, and Q. S. Chen, *Modeled Antarctic precipitation. Part I: Spatial and temporal variability,* Journal of Climate 17, pp. 427-47, 2004; W. J. Van de Berg, M.R. van den Broeke, C. H. Reijmer, and E. van Meijgaard, *Reassessment of the Antarctic surface mass balance using calibrated output of a regional atmospheric climate model,* Journal of Geophysical Research 111: 10.1029/2005JD006495, 2006.

warming by the proponents of anthropogenic global warming, such as Al Gore, are demonstrably wrong. For example, the glaciers of Kilimanjaro have been shrinking for over a century, but this is likely due to decreasing precipitation as a result of changed land use (deforestation).[27] The change of mass balance with glaciers is problematic: there are only 42 glaciers (out of 160 000 glaciers around the world) that have a fully detailed mass balance history extending more than 10 years.[28]

- Sea levels all over the globe have been rising for centuries; this is not due to anthropogenic global warming, but merely a recovery from the last ice age.[29] A recent analysis has found that no statistically significant ocean warming has occurred over the late 20th century.[30]

- Rainfall patterns have always changed around the world; this is nothing new. One needs merely examine the changes in precipitation in Australia over the last century to realise this;[31] there has been variation in Australian rainfall, but little change in long-term trends (see table below). The variations in this period are not proof that it is caused by human influence, as many populists claim. In fact, viewing history, the Mayan society collapsed due to a decrease in rainfall in the 9th century.[32]

---

27 G. Kaser, D. R. Hardy, T. Molg, R. S. Bradley, and T. M. Hyera, *Modern glacier retreat on Kilimanjaro as evidence of climate change: Observations and facts,* International Journal of Climatology 24, pp. 329-39, 2004.

28 R. J. Braithwaite, and Y. Zhang, *Relationships between interannual variability of glacier mass balance and climate*, Journal of Glaciology 45, pp. 456-462, 2000.

29 <http://www.giss.nasa.gov/research/briefs/gornitz_09/>, accessed 23 August 2007; S. Jevrejeva, A. Grinsted, J. C. Moore, and S. Holgate, *Nonlinear trends and multiyear cycles in sea level records*, Journal of Geophysical Research 111: 10.1029/2005JC003229, 2006; J. A. Church, N. J. White, R. Coleman, K. Lambert, and J. X. Mitrovica, *Estimates of the regional distribution of sea level rise over the 1950-2000 period,* Journal of Climate 17, pp. 2609-25, 2004; S. J. Holgate, *On the decadal rates of sea level change during the twentieth century,* Geophysical Research Letters 34: 10.1029/2006GL028492, 2007.

30 V. Gouretski and K. P. Koltermann, *How much is the ocean really warming?*, Geophysical Research Letters 34: 10.1029/2006GL027834, 2007.

31 <http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/timeseries.cgi>, accessed 23 August 2007.

32 *Intense droughts blamed for Mayan collapse*, New Scientist, 13 March 2003, <http://www.newscientist.com/article.ns?id=dn3502>, accessed 23 August 2007.

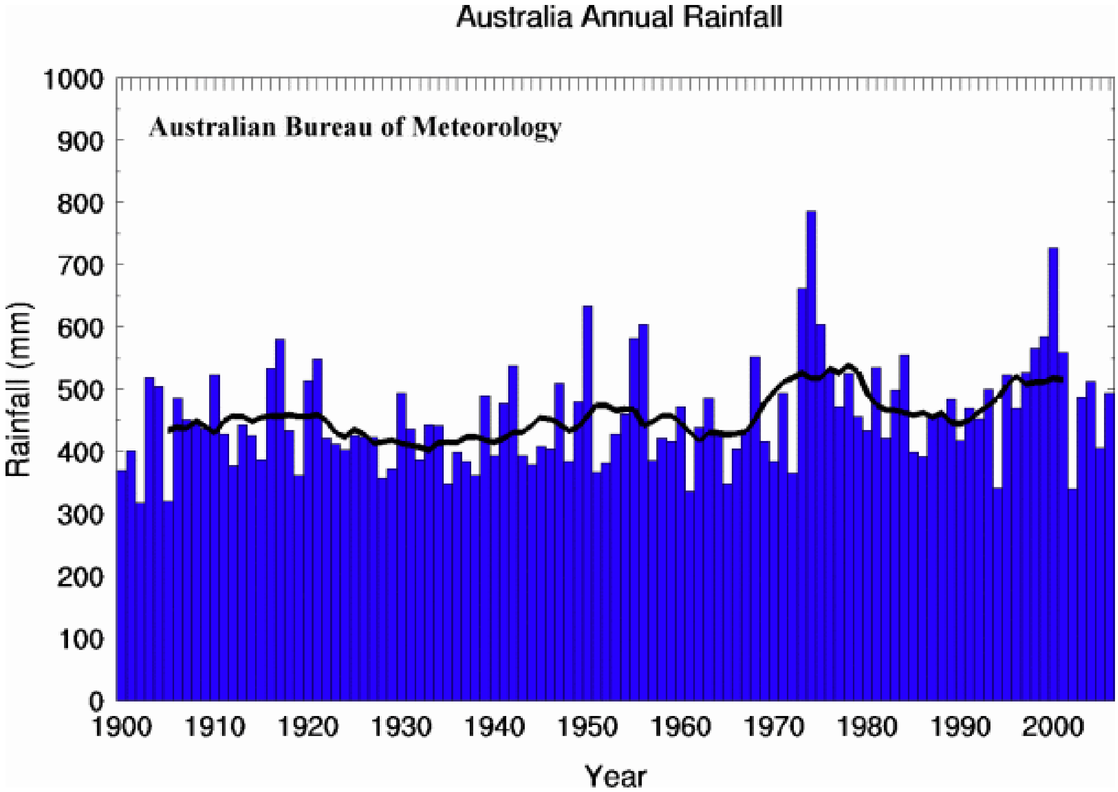

Table Graph showing the variability of aggregate rainfall in Australia

- It is a pity that the report uses the Stern Review as a basis for the scientific understanding of anthropogenic global warming. Not only has this report been thoroughly debunked in a scientific and economic sense,[33] but Stern acknowledges that he had zero understanding of the issue less than one year before the Stern Review. He stated that 'in August or July of last year (2005)… [he] had an idea what the greenhouse effect was but wasn't really sure'.[34]

  It is staggering that someone with essentially no scientific knowledge on greenhouse effect, within less than one year, had acquired the scientific knowledge to state that the 'scientific evidence is now overwhelming'. Furthermore, the Stern Review was commissioned because UK Prime Minister Blair and

33 *The Stern Review, a Dual Critique*, World Economics, Vol 7, No. 4, October-December 2006; <http://www.fnu.zmaw.de/fileadmin/fnu-files/reports/sternreview.pdf>, accessed 23 August 2007; W. Nordhaus, *The Stern Review on the Economics of Climate Change*, 2006 <http://nordhaus.econ.yale.edu/SternReviewD2.pdf>, accessed 23 August 2007; R. Tol and G. Yohe, *A review of the Stern Review*, World economics, 7 (4), Oct.-Dec. 2006.

34 <www.hm-treasury.gov.uk/media/695/8C/OXONIA_Oxford_31012006.pdf>, accessed 23 August 2007.

Chancellor of the Exchequer Brown did not like the findings of the House of Lords Report into climate change.[35]

Audit Process

1.21 The admissions and uncertainties quoted in this dissenting report demonstrate the clear need for better methods of auditing the science used for climate change policy advice.

1.22 In a recent discussion over the Stern report, Carter *et al*.[36] and Holland *et al*.[37] pointed out that the peer review process, on which the IPCC so heavily relies, is flawed. Ensuring the quality of advice on climate change also requires a comprehensive audit of the information on climate risk that is currently being used by governments to set public policy.

1.23 It is a matter of public record that some scientists have withdrawn from the IPCC process because of dissatisfaction with its probity and methods. Valuable though it might be for IPCC to continue to provide summaries of the science of climate change, it is simply not credible to see the IPCC as an adequate audit body.

Uncertainty in IPCC Summary for Policymaker's predictions based on computer models, and the use of unqualified "celebrities"

1.24 The references to anthropogenic climate change in this report do not in any way reflect the uncertainty in the science associated with climate change science, nor do they reflect the significant debate on the issue in the scientific community, including significant debate in the peer-reviewed scientific literature. Indeed, if one paragraph clearly illustrates the one sided nature of this report, it is paragraph 5.59. Here, we have a captain of industry (Rupert Murdoch), who, by his own admission is not a scientist, quoted regarding his view on anthropogenic global warming and the need to take action:

> I am no scientist but … I do know how to assess a risk. Climate change poses clear catastrophic threats. We may not agree on the extent, but we certainly can't afford the risk of inaction

35 House of Lords Select Committee on Economic Affairs, *Second Report of Session 2005-06, The Economics of Climate Change.*

36 *The Stern Review, a Dual Critique*, World Economics, Vol 7, No. 4, October-December 2006.

37 D. Holland et al., *Response to Simmonds and Steffen, Revised Draft Response to World Economics*, 27 June 2007.

1.25 This exemplifies the more general problem that most of the public statements that promote the dangerous human warming scare are made from a position of ignorance—by political leaders, press commentators and celebrities who share the characteristics of lack of scientific training and lack of an ability to differentiate between sound science and computer-based scaremongering.

1.26 On the issue of computer models used to predict (or project, the IPCC uses the terms interchangeably) future climate, Kevin Trenberth, coordinating lead author of IPCC 4th Assessment Report, WG1 Chapter 3, has made staggering admissions about the weaknesses inherent in the modelling process in the Nature Climate Change blogsite (a longer quote is to be found in Appendix 1):[38]

> **…in fact, since the last report it is also often stated that the science is settled or done and now is the time for action.**
>
> **In fact there are no predictions by IPCC at all…But they do not consider many things like the recovery of the ozone layer, for instance, or observed trends in forcing agents…**
>
> **…none of the climate states in the models correspond even remotely to the current observed climate. In particular, the state of the oceans, sea ice, and soil moisture has no relationship to the observed state at any recent time in any of the IPCC models.**
>
> **I postulate that regional climate change is impossible to deal with properly unless the models are initialized.**
>
> **Therefore the problem of overcoming this shortcoming, and facing up to initializing climate models means not only obtaining sufficient reliable observations of all aspects of the climate system, but also overcoming model biases. So this is a major challenge.**

Conclusion

1.27 Climate change is a natural phenomenon that has always been with us, and always will be. Whether human activities are disturbing the climate in dangerous ways has yet to be proven. It is for this reason that we strongly disagree with the absolute statements and position taken in this review regarding AGW. We have taken no evidence

38 <http://blogs.nature.com/climatefeedback/2007/06/predictions_of_climate.html>, accessed 23 August 2007.

regarding the science of AGW, yet a strong position has been taken regarding this. On the other hand, statements made about the cost competitiveness of renewable energy sources have been taken out of the report, despite the fact that evidence was taken on this.

1.28 We therefore conclude this dissenting opinion by appending a long quote from Carter *et al* (Appendix 2).[39]

Acknowledgements

We wish to thank the following people for reviewing the scientific accuracy of this report:

1. Professor R.S. Lindzen (Alfred P. Sloan Professor of Meteorology, Department of Earth, Atmospheric and Planetary Sciences, MIT)
2. Professor J.R. Christy (University of Alabama, Huntsville)
3. Professor G.W. Paltridge (Director of the Antarctic CRC and IASOS, University of Tasmania)
4. Professor R.M. Carter (James Cook University)
5. Associate Professor C.R. de Freitas (University of Auckland)
6. W. Kininmonth (Retired Head of the National Climate Centre, Australia)

Dr Dennis Jensen MP, Hon Jackie Kelly MP, Hon Danna Vale MP, Mr David Tollner MP

13 August 2007

39 R. Carter, et al., *Response to comments on Part 1 The Science of the Dual Critique of the Stern Review*, World Economics in press.

Appendix 1

'I have often seen references to predictions of future climate by the Intergovernmental Panel on Climate Change (IPCC), presumably through the IPCC assessments. In fact, since the last report it is also often stated that the science is settled or done and now is the time for action.

In fact there are no predictions by IPCC at all. And there never have been. The IPCC instead proffers "what if" projections of future climate that correspond to certain emissions scenarios. There are a number of assumptions that go into these emissions scenarios. They are intended to cover a range of possible self consistent "story lines" that then provide decision makers with information about which paths might be more desirable. But they do not consider many things like the recovery of the ozone layer, for instance, or observed trends in forcing agents. There is no estimate, even probabilistically, as to the likelihood of any emissions scenario and no best guess.

Even if there were, the projections are based on model results that provide differences of the future climate relative to that today. None of the models used by IPCC are initialized to the observed state and none of the climate states in the models correspond even remotely to the current observed climate. In particular, the state of the oceans, sea ice, and soil moisture has no relationship to the observed state at any recent time in any of the IPCC models. There is neither an El Niño sequence nor any Pacific Decadal Oscillation that replicates the recent past; yet these are critical modes of variability that affect Pacific Rim countries and beyond. The Atlantic Multidecadal Oscillation, that may depend on the thermohaline circulation and thus ocean currents in the Atlantic, is not set up to match today's state, but it is a critical component of the Atlantic hurricanes and it undoubtedly affects forecasts for the next decade from Brazil to Europe. Moreover, the starting climate state in several of the models may depart significantly from the real climate owing to model errors. I postulate that regional climate change is impossible to deal with properly unless the models are initialized.

The current projection method works to the extent it does because it utilizes differences from one time to another and the main model bias and systematic errors are thereby subtracted out. This assumes linearity. It works for global forced variations, but it can not work for many aspects of climate, especially those related to the water cycle. For instance, if the current state is one of drought then it is unlikely to get drier, but unrealistic model states and model biases can easily violate such constraints and project drier conditions. Of course one can initialize a climate model, but a biased model will immediately drift back to the model climate and the predicted trends will then be wrong.

Therefore the problem of overcoming this shortcoming, and facing up to initializing climate models means not only obtaining sufficient reliable observations of all aspects of the climate system, but also overcoming model biases. So this is a major challenge.'[40]

40 <http://blogs.nature.com/climatefeedback/2007/06/predictions_of_climate.html>, accessed 23 August 2007.

Appendix 2

'Climate changes naturally all the time. Human activities have an effect on the local climate, for example in the vicinity of cities (warming) or near large areas of changed land usage (warming or cooling, depending upon the changed albedo). Logically, therefore, humans must have an effect on global climate also. This notwithstanding, a distinct human signal has not yet been identified within the variations of the natural climate system, to the degree that we cannot even be certain whether the global human signal is one of warming or cooling. Though it is true that many scientists anticipate that human warming is the more likely, no strong evidence exists that any such warming would be dangerous.

The gentle global warming that probably occurred in the late 20th century falls within previous natural rates and magnitudes of warming and cooling, and is prima facie quite unalarming, especially when consideration is given to the likelihood that the historic ground temperature records used to delineate the warming are warm-biased by the urban heat island and other effects. Once corrected for non-greenhouse climate agents such as El Niños and volcanic eruptions, the radiosonde (since 1958) and satellite (since 1979) records show little if any recent warming and certainly none of untoward magnitude.

Atmospheric carbon dioxide is indeed a greenhouse gas, but the empirical evidence shows that the warming effect of its increase at the rates of modern industrial emission and accumulation is minor, given an assumed pre-industrial level of about 280 ppm and noting the established logarithmic relationship between gas concentration increases and warming. As one such empirical test, it can be noted too that no global increase in temperature has now occurred since 1998 despite an increase in carbon dioxide concentration over the same 8 years of about 15 ppm (4%).

Putative human influence aside, it is certain that natural climate change will continue, sometimes driven by unforced internal variations in the climate system and at other times forced by factors that we do not yet understand. The appropriate public policy response is, first, to monitor climate accurately in an ongoing way; and, second, to respond and adapt to any changes - both warmings and the likely more damaging coolings—in the same way that we cope with other natural events such as droughts, cyclones, earthquakes and volcanic eruptions.

Neither the Stern Review itself, nor the additional papers that our critique has stimulated, address the above cautious and widely held assessment of the situation. Instead, straw-man arguments are erected and attacked, detail is endlessly obfuscated and IPCC orthodoxy is relentlessly repeated.

In dealing with the certainties and uncertainties of climate change, the key issue is prudence. The main certainty is that natural climate change will continue, and that some of its likely manifestations—sea-level rise and coastal change in particular locations, for example—will be expensive to adapt to. But adapt we must and will. Moreover reducing vulnerability to today's climate-sensitive problems will also help the world cope with future challenges from climate change whether that is due to natural variability, anthropogenic greenhouse gas emissions or other human causes.[41] The most prudent way of ensuring that happens is to build wealth into the world economy and to be receptive to new technologies. This will not be achieved by irrational restructuring of the world's energy economy in pursuit of the chimera of "stopping" an alleged dangerous human-caused climate change that, in reality, can neither be demonstrated nor measured at this time.'[42]

41 M. Indur and Goklany, *A Climate Policy for the Short and Medium Term: Stabilization or Adaptation?*, Energy & Environment 16, pp. 667-680, 2005.

42 R. Carter, et al., *Response to comments on Part 1 The Science of the Dual Critique of the Stern Review,* World Economics in press.

A

Appendix A—List of submissions

1	Mr Grant Lockie
2	Mr Eriks Velins
3	Government of Western Australia
	Department of Environment and Conservation
4	Dr David Proctor
5	Government of South Australia
	Minister for Mineral Resources and Development
6	Country Women's Association of NSW
7	Centre for Low Emission Technology
8	International Association of Hydrogeologists
9	CANSYD Australia Pty Ltd & Auspace Ltd
10	CSIRO
10.1	Supplementary to submission 10
11	Dr David Maddison
12	Chevron Australia Pty Ltd
13	Friends of the Earth Australia
14	Cooperative Research Centre for Greenhouse Accounting

15	Greenpeace Australia Pacific
16	Energy Supply Association of Australia
17	TRUenergy Australia Pty Ltd
18	Docklands Science Park Pty Ltd
19	Exxon Mobil
20	Queensland Resources Council
21	Engineers Australia
22	Origin Energy
23	Renewable Energy Generators of Australia
24	Anglo Coal Australia Pty Ltd
25	Santos Ltd
26	Government of Western Australia
	Department of Industry and Resources
27	Climate Action Network Australia
28	Australian Bureau of Agricultural and Resource Economics
29	Australian Petroleum Production and Exploration Association
30	Hydro Tasmania
31	Rio Tinto Australia
32	Stanwell Corporation
33	UNSW Centre for Energy and Environmental Markets
34	Mr Luke Gale
35	National Generators Forum
36	Cooperative Research Centre for Greenhouse Gas Technologies
36.1	Supplementary to submission 36
37	Environment Business Australia
38	TecEco Pty Ltd & Greensols
39	AGL
40	Australian Coal Association & Minerals Council of Australia

41	Government of Australia:
	Department of Industry, Tourism and Resources
	Department of Education, Science and Training
	Department of Foreign Affairs and Trade
	Department of Environment and Water Resources
	Geoscience Australia
41.1	Supplementary to submission 41
42	Victorian Government
	Minister for Energy Industries and Resources
43	BP Australia
44	Ms Ilona Renwick
45	Mr Colin Dunstan
46	Queensland Government

B

Appendix B—List of exhibits

1 Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Carbon Dioxide capture and geological storage: research, development and application in Australia

2 Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Map of World CCS sites

3 Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Map of Australian CCS sites

4 Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Stage 1: Geosequestration Research Project (Otway Basin) Diagram

5 Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Stage 2: Geosequestration Research Project (Otway Basin) Diagram

6 Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Diagram of Proposed CCS hub

7 Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Diagram modelling a phased CCS uptake on shared increased cost of electricity to consumers

C

Appendix C—List of hearings, witnesses and inspections

Monday, 4 September 2006 - CANBERRA

CSIRO

Dr Greg Duffy, Stream Leader, Energy Technologies

Dr Lincoln Paterson, Stream Leader, CO2 Sequestration, CSIRO Petroleum Resources

Monday, 11 September 2006 - CANBERRA

Stanwell Corporation

Mr Gary Humphrys, Acting Chief Executive Officer

Mr Chai McConnell, Manager, Stakeholder Relations and Strategy

Mr Howard Morrison, Manager, Emerging Technologies

Monday, 9 October 2006 - CANBERRA

Department of Education, Science and Training

Mr Stephen Irwin, Branch Manager, Science and Technology Policy Branch

Department of Environment and Heritage

Mr Barry Sterland, First Assistant Secretary, Industry, Communities and Energy Division, Australian Greenhouse Office

Department of Foreign Affairs and Trade

Mr Robert Owen-Jones, Director, Environment Branch, Climate Change Section

Department of Industry Tourism & Resources

Ms Tania Constable, General Manager, Resources Development Branch/Resources Division

Geoscience Australia

Dr John Bradshaw, Chief Scientist, Carbon Dioxide Capture and Storage

Monday, 16 October 2006 - CANBERRA

Greenpeace Australia

Ms Yvonne Dierolf, Energy Campaigner Intern

Ms Helen Oakey, Political Advisor

Ms Gabriela Von Goerne, Energy Campaigner

Monday, 30 October 2006 - CANBERRA

BP Australia

Dr Tony Espie, Senior Advisor, CO2 Storage, BP Alternative Energy (UK)

Mr Ian Fliedner, Director Communications and External Affairs

Dr Fiona Wild, Evironmental Affairs Advisor, Communications and External Affairs

University of New South Wales

Dr Iain MacGill, Research Coordinator (Engineering), Centre for Energy and Environmental Markets

Mr Terry Daly, Researcher, Centre for Energy & Environmental Markets

Monday, 27 November 2006 - CANBERRA

Australian Coal Association

Ms Cassandra McCarthy, Director, Policy & International

Mr Mark O'Neill, Executive Director

Monday, 4 December 2006 - CANBERRA

National Generators Forum

Mr John Boshier, Executive Director

Dr Harry Schaap, Policy Advisor

Monday, 12 February 2007 - CANBERRA

Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Dr Peter Cook, Chief Executive Officer

Dr Dennis Van Puyvelde, Technical and International Projects Manager

Dr Ian Lavering, Manager, NSW QLD Projects

Monday, 26 February 2007 - CANBERRA

Rio Tinto - Australia

Mr Alex Zapantis, Manager, Energy and Sustainable Development

D

Appendix D—Principal power stations in Australia

1.1 See table on next page

Principal Power Stations in Australia

State	Name	Operator	Plant Type	Primary Fuel	Year of Commissioning	Capacity (MW)
NSW	Eraring	Eraring Energy	Steam	Black coal	1982-84	2,640.0
NSW	Bayswater	Macquarie Generation	Steam	Black coal	1982-84	2,640.0
NSW	Liddell	Macquarie Generation Macquarie Generation	Gas turbines Steam	Oil products Black coal	1988 1971-73	50.0 2,000.0
NSW	Vales Point B	Delta Electricity	Steam	Black coal	1978	1,320.0
NSW	Mt Piper	Delta Electricity	Steam	Black coal	1992-93	1,320.0
NSW	Wallerawang C	Delta Electricity	Steam	Black coal	1976-80	1,000.0
NSW	Munmorah	Delta Electricity	Steam	Black coal	1969	600.0
NSW	Shoalhaven	Eraring Energy	Pump storage	Water	1977	240.0
NSW	Smithfield	Sithe Energies	Combined cycle	Natural gas	1997	160.0
NSW	Redbank	National Power	Steam	Black coal	2001	150.0
NSW	Blowering	Snowy Hydro	Hydro	Water	1969	80.0

NSW	Hume NSW	Eraring Energy	Hydro	Water	1957	29.0
NSW	Tumut 1	Snowy Hydro	Hydro	Water	1973	1,500.0
NSW	Murray 1	Snowy Hydro	Hydro	Water	1967	950.0
NSW	Murray 2	Snowy Hydro	Hydro	Water	1969	550.0
NSW	Tumut 2	Snowy Hydro	Hydro	Water	1959	329.6
NSW	Tumut 3	Snowy Hydro	Hydro	Water	1962	286.4
NSW	Guthega	Snowy Hydro	Hydro	Water	1955	60.0
VIC	Loy Yang A	Loy Yang Power	Steam	Brown coal	1984-87	2,120.0
VIC	Hazelwood	Hazelwood Power Partnership	Steam	Brown coal	1964-71	1,600.0
VIC	Yallourn W	TRU Energy	Steam	Brown coal	1973-75 1981-82	1,480.0
VIC	Loy Yang B	IPM Eagle	Steam	Brown coal	1993-96	1,000.0
VIC	Newport	Ecogen Energy	Steam	Natural gas	1980	510.0
VIC	Jeeralang A and B	Ecogen Energy	Gas turbines	Natural gas	1979 1980	449.0
VIC	Valley Power	Snowy Hydro	Gas turbines	Natural gas	2002	300.0

VIC	Morwell	Energy Brix	Steam	Brown coal	1958 1962 1958-59	195.0
VIC	Anglesea	Alcoa	Steam	Brown coal	1969	160.0
VIC	Somerton	AGL	Gas turbines	Natural gas	2002	150.0
VIC	McKay Creek	AGL	Hydro	Water	1960	150.0
VIC	Dartmouth	AGL	Hydro	Water	1980	150.0
VIC	Eildon	AGL	Hydro	Water	1956-57	120.0
VIC	Bairnsdale	Alinta	Gas turbines	Natural gas	2001	92.0
VIC	West Kiewa	AGL	Hydro	Water	1955-56	62.0
VIC	Hume VIC	Eraring Energy	Hydro	Water	1957	29.0
QLD	Gladstone	Comalco/NRG	Steam	Black coal	1976-82	1,680.0
QLD	Tarong	Tarong Energy	Steam	Black coal	1984-86	1,400.0
QLD	Stanwell	Stanwell Corporation	Steam	Black coal	1993-96	1,400.0
QLD	Callide C	CS Energy	Steam	Black coal	2001	900.0
QLD	Millmerran	Intergen	Steam	Black coal	2002	852.0

QLD	Callide B	CS Energy	Steam	Black coal	1988-89	700.0
QLD	Swanbank B	CS Energy	Steam	Black coal	1970-73	500.0
QLD	Wivenhoe	Tarong Energy	Pump storage	Water	1984	500.0
QLD	Tarong North	Tarong Energy	Steam	Black coal	2002	443.0
QLD	Swanback E	CS Energy	Combined cycle	Natural gas	2002	385.0
QLD	Mt Stuart	Origin Energy	Gas turbines	Oil products	1998	304.0
QLD	Oakey	Oakey Power Holdings	Gas turbines	Natural gas	2000	288.0
QLD	Yabulu	Transfield Holdings	Combined cycle	Natural gas	2005	240.0
QLD	Collinsville	Transfield Holdings	Steam	Black coal	1998	188.0
QLD	Mica Creek	CS Energy	Combined cycle	Natural gas	1997-2001	158.0
		CS Energy	Steam	Natural gas	1998	132.0
		CS Energy	Gas turbines	Natural gas	1997	35.0
QLD	Kareeya	Stanwell Corporation	Hydro	Water	1957-59	84.0
QLD	Roma	Origin Energy	Gas turbines	Natural gas	1999	80.0
QLD	Barron Gorge	Stanwell Corporation	Hydro	Water	1963	60.0
QLD	Barcaldine	Enertrade	Combined cycle	Natural gas	1996	57.0

QLD	Mackay	Stanwell Corporation	Gas turbines	Oil products	1976	34.0
SA	Torrens Island	TRU Energy	Steam	Natural gas	1977 1967	1,280.0
SA	Northern	NRG Flinders	Steam	Brown coal	1985	530.0
SA	Pelican Point	International Power	Combined cycle	Natural gas	2000	478.0
SA	Thomas Playford B	NRG Flinders	Steam	Brown coal	1960	240.0
SA	Osborne	ATCO Energy	Combined cycle	Natural gas	1998	185.0
SA	Hallet	AGL	Gas turbines	Natural gas	2002	183.0
SA	Dry Creek	International Power	Gas turbines	Natural gas	1973	156.0
SA	Quarantine	Origin Energy	Gas turbines	Natural gas	2002	92.0
SA	Mintaro	International Power	Gas turbines	Natural gas	1984	90.0
SA	Ladbroke Grove	Origin Energy	Gas turbines	Natural gas	2000	84.0
SA	Snuggery	International Power	Gas turbines	Oil products	1978-97	63.0
SA	Port Lincoln	International Power	Gas turbines	Oil products	1998-00	50.0
SA	Angaston	Infratil Energy Australia	Internal combustion	Oil products	2005	40.0

WA	Muja	Verve Energy	Steam	Black coal	1985-86 1981 1965	1040.0
WA	Kwinana WPC	Verve Energy	Gas turbines Steam	Natural gas Multi-fuel	1972 1976 1970	21.0 880.0
WA	Pinjar	Verve Energy	Gas turbines	Multi-fuel	1990-92 1996	586.0
WA	Collie	Verve Energy	Steam	Black coal	1999	330.0
WA	Cockburn	Verve Energy	Combined cycle	Natural gas	2003	240.0
WA	Worsley WPC	Verve Energy	Gas turbines	Natural gas	2000	120.0
WA	Mungarra	Verve Energy	Gas turbines	Natural gas	1990-91	112.0
WA	Kalgoorlie	Verve Energy	Gas turbines	Natural gas	1984-90	62.0
WA	Tiwest	Verve Energy	Gas turbines	Natural gas	1999	36.0
WA	Albany	Verve Energy	Wind	Wind	2001	22.0
WA	Geraldton	Verve Energy	Gas turbines	Natural gas	1973	21.0
WA	Wellington Dam	Verve Energy	Hydro	Water	1992	2.0

WA	Bremer Bay	Verve Energy	Wind	Wind	2005	0.6
TAS	Gordon	Hydro Tasmania	Hydro	Water	1978	432.0
TAS	Poatina	Hydro Tasmania	Hydro	Water	1964	300.0
TAS	Bell Bay	Hydro Tasmania	Steam	Natural gas	1971	240.0
TAS	Reece	Hydro Tasmania	Hydro	Water	1986	231.2
TAS	John Butters	Hydro Tasmania	Hydro	Water	1992	144.0
TAS	Tungatinah	Hydro Tasmania	Hydro	Water	1953	132.5
TAS	Tarraleah	Hydro Tasmania	Hydro	Water	1938	90.0
TAS	Cethana	Hydro Tasmania	Hydro	Water	1971	85.0
TAS	Liapootah	Hydro Tasmania	Hydro	Water	1960	83.7
TAS	Tribute	Hydro Tasmania	Hydro	Water	1994	82.8
TAS	Trevallyn	Hydro Tasmania	Hydro	Water	1955	80.0
TAS	Bastyan	Hydro Tasmania	Hydro	Water	1983	79.9
TAS	Mackintosh	Hydro Tasmania	Hydro	Water	1982	79.9
TAS	Woolnorth	Hydro Tasmania	Wind	Wind	2002-04	64.5
TAS	Devils Gate	Hydro Tasmania	Hydro	Water	1969	60.0

TAS	Lemonthyme	Hydro Tasmania	Hydro	Water	1969	51.0
TAS	Catagunyah	Hydro Tasmania	Hydro	Water	1962	48.0
TAS	Fisher	Hydro Tasmania	Hydro	Water	1973	42.0
TAS	Wayatinah	Hydro Tasmania	Hydro	Water	1957	42.0
TAS	Meadowbank	Hydro Tasmania	Hydro	Water	1967	40.0
TAS	Lake Echo	Hydro Tasmania	Hydro	Water	1956	32.4
TAS	Wilmot	Hydro Tasmania	Hydro	Water	1971	30.6
TAS	Paloona	Hydro Tasmania	Hydro	Water	1972	28.0
TAS	Repulse	Hydro Tasmania	Hydro	Water	1968	28.0
TAS	Currie	Hydro Tasmania	Reciprocating Engine	Oil Products	1952	20.0
TAS	Cluny	Hydro Tasmania	Hydro	Water	1968	17.0
TAS	Butlers Gorge	Hydro Tasmania	Hydro	Water	1951	12.2
TAS	Rowallan	Hydro Tasmania	Hydro	Water	1968	10.4
TAS	Lake Margaret	Hydro Tasmania	Hydro	Water	1995	8.4
TAS	Whitemark	Hydro Tasmania	Reciprocating Engine	Oil Products		6.0

TAS	Tods Corner	Hydro Tasmania	Hydro	Water		1.6
TAS	Currie	Hydro Tasmania	Wind	Wind	1998	0.8