Chapter 2

Science and economics of offshore CO_2 storage

2.1 Geological sequestration (geosequestration), or carbon capture and storage (CCS), involves capturing the carbon dioxide (CO_2) that would otherwise be emitted into the atmosphere, compressing it, transporting it to a suitable site, and injecting it into deep geological formations, where it will be trapped for thousands or millions of years.[1]

2.2 Typically, carbon capture and storage has three stages:

- *capturing* CO_2 from fuel and industrial processing and electricity generation plants and compressing into a fluid or supercritical state;
- *transporting* the CO_2 by pipeline or tanker; and,
- *injecting* the CO_2 into a suitable geological formation for long-term isolation from the atmosphere.

2.3 CO_2 can be stored underground in geological formations (onshore and under seabeds) such as deep saline aquifers, depleted oil and gas reservoirs or unminable coal seams. 85 per cent of the world's storage potential is said to be in deep saline aquifers.[2] However, in Australia, oil and gas basins are also considered to have substantial potential for geological storage.

2.4 For most applications, the CO_2 has to be captured and separated, then transported from its source to a compression plant in preparation for injection and storage. The CO_2 is then injected as a dense, liquid-like, supercritical fluid into reservoirs. The CO_2 sits in the microscopic spaces between grains in the sandstone and is trapped by the impermeable rock, or mudstone, which acts as a seal or 'lid'. Generally, the storage needs to be at least one kilometre below the surface so that the pressure, and temperature, is sufficient to maintain the CO_2 as a supercritical fluid.

2.5 Woodside Energy explained to the committee its CCS process differed for liquid natural gas (LNG). The LNG is taken from offshore gas fields and brought onshore by pipeline; the CO_2 is then separated, before being prepared for injection back offshore, several kilometres below sea level:

> Before we can make the LNG, we have to remove (the) CO_2 from the gas stream. When we make LNG, we largely take methane and cool it down to about minus 160 degrees Celsius. In cooling the methane down, the CO_2 will freeze before getting to that level, so we have to take it out of the system before we freeze the methane or it plugs up the system. We do that

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1 It may also be referred to as 'clean-coal technology'.

2 Monash Energy, *Submission 3*, fact sheet.

> using what are called acid gas removal units. What happens when we remove this gas is that we are left with a relatively pure stream of reservoir related CO_2 potentially available for geosequestration.[3]

Viability of CCS technology

2.6 While the concept of geosequestration of CO_2, as a means of reducing greenhouse gas emissions, has arisen in the past decade, geosequestration utilises technologies that have been widely practiced in different industries for many years.

2.7 The committee heard evidence suggesting that every element of the technology required for CCS is already in operation: capture, separation, transportation, injection and storage. While the large-scale integrated performance of these components in CCS application is yet to be fully demonstrated, a number of local companies have technological experience with each of the component technologies.[4]

2.8 Dr Geoffrey Ingram, Schlumberger Carbon Services, offered the following assessment of where he believed the industry was at:

> …technologically we believe carbon capture and storage is ready to go. What the industry is waiting on is for the legislation and economic drivers to materialise. We believe the federal government's commitment to a price on carbon in the amended legislation going through Parliament House at the moment is the start of this process.[5]

2.9 Internationally, the Sleipner Project is the longest running commercial application of carbon dioxide storage in the world.[6] It has been operating since 1996 when CO_2 separated from natural gas produced from the Sleipner West gas field has been injected into a large, deep saline formation some 800 metres below the bed of the North Sea in Norway. The project is expected to store a total of 20 million tonnes of CO_2 over its lifetime. ExxonMobil explained to the committee that through the project, over 1 million metric tonnes of CO_2 have been stored each year since 1998.[7] There has been no escape of CO_2 in that time.

2.10 The Norwegian government has not created separate legislation for CCS projects and the Sleipner project operates purely under Norway's existing petroleum law. While there are no requirements within this legislation relating to monitoring, remediation or site closure provisions, the Norwegian government considers that

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3 Mr Francis Cumming, Woodside Energy, *Proof Committee Hansard*, 1 September 2008, p. 3.

4 See, for example, Mr Mark Nolan, ExxonMobil, *Proof Committee Hansard*, 29 August 2008, p. 27 and Mr Paul Toni, World Wildlife Fund, *Proof Committee Hansard*, 29 August 2008, p. 19.

5 Dr Geoffrey Ingram, *Proof Committee Hansard*, 29 August 2008, p. 40.

6 This is being undertaken by Statoil, the Norwegian state owned oil company.

7 Mr Robert Young, ExxonMobil, *Proof Committee Hansard*, 29 August 2008, p. 27.

regulation is now required in regard to safety issues, risk analysis and long term monitoring.[8]

2.11 The committee received submissions from a number of companies currently involved in the development of CCS technologies in Australia. These submissions suggested that while CCS technology is well advanced, it is at an early stage of commercialisation.

2.12 ExxonMobil Australia, with partner Chevron, is currently involved in the largest commercial scale CCS project in Australia. Located off the northwest coast of Western Australia, the Gorgon Project involves a CCS project on Barrow Island. The Greater Gorgon gas fields contain resources of about 40 trillion cubic feet of gas, Australia's largest-known gas resource. The project includes research into greenhouse gas management via injection of CO_2 into deep formations beneath Barrow Island. ExxonMobil describes it as 'the biggest single investment contemplated solely for the management of greenhouse gas emissions'. The Gorgon Project has the potential to be the first project in Australia to reduce significantly greenhouse gas emissions by the injection of carbon dioxide underground.[9]

2.13 Monash Energy, a joint development of Anglo American and Shell Gas and Power, is involved in developing CCS in the Latrobe Valley (Gippsland), through a 'coal-to-liquid' project and through investigating the storage potential of the Offshore Gippsland Basin.[10]

2.14 Schlumberger Carbon Services, who has been involved in providing services for subsurface characterisation and monitoring since the mid 1990s, is currently involved in the large scale CCS demonstration Callide Oxyfuel Project in Queensland and has contributed to a pilot project in the Otway Basin.[11]

2.15 For a full list of Australian carbon capture projects with storage, and with potential storage, see tables at the end of this chapter.

2.16 In its submission to the committee, the Victorian government argued that Victoria also has world-class greenhouse gas storage facilities in the Latrobe Valley/ Gippsland Basin, 160 km west of Melbourne:

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8 Department of Resources, Energy and Tourism, answer to questions on notice 1, 29 August 2008.

9 Exxon Mobil Corporation is the largest publicly traded oil and gas company in the world and is the parent company of ExxonMobil Australia. The Exxon Mobil Corporation has a 32 per cent working interest in the abovementioned Sleipner Project. In Australia, ExxonMobil is also involved in CCS projects in the Bass Strait fields. See *Submission 1*, pp. 2–4; Mr Robert Young, ExxonMobil, *Proof Committee Hansard*, 29 August 2008, p. 27.

10 Monash Energy, *Submission 3*, p. 1.

11 Schlumberger is also involved in the Illinois Project (USA) as part of the Midwest Geological Sequestration Consortium; see *Submission 5*, p. 2.

> The offshore Gippsland Basin in Commonwealth waters is estimated to have the state's largest potential greenhouse gas storage capacity: roughly 35,000 million tonnes or approximately 285 years of Victorian emissions at current emission rates. The Gippsland Basin is also estimated to be the lowest cost storage site, as it is geographically proximate to Victoria's main emissions source, the coal-powered electricity sector in Gippsland's Latrobe Valley.[12]

2.17 Victoria is also home to the CO2CRC (Cooperative Research Centre for Greenhouse Gas Technologies) project in the Otway Basin. CO2CRC is Australia's premier collaborative research organisation focusing on the development and application of technologies for the mitigation of greenhouse gases.[13] The CO2CRC Otway Project is the world's most advanced demonstration project based solely on storage without associated CO_2 production. The project 'aims to demonstrate that up to 100 000 tonnes of CO_2, extracted from a nearby natural accumulation, can be safely transported via pipeline and injected and stored while trialling a significant number of potential monitoring and verification techniques'.[14] CO2CRC has also assessed the storage potential of a number of sedimentary basins including the offshore Gippsland, Otway Perth, Browse and Canarvon basins and a number of offshore basins in Victoria, Western Australia, New South Wales and Queensland.[15]

2.18 CCS technology is likely to be of particular relevance to Victoria because the state is heavily dependent upon brown coal for electricity generation. As the above quotation suggests, Victoria has the benefit of having its large emitters located near a geologically suitable storage site. This is frequently not the case and, in its evidence to the committee, Greenpeace suggested that there was no identified suitable site within 500 kilometres of coal-fired power stations in the Newcastle, Sydney and Wollongong area of New South Wales, nor at Port Augusta in South Australia. These regions alone produce 39 per cent of Australia's current net CO_2 emissions.[16]

Possible environmental risks associated with CCS

2.19 While Greenpeace proposed that CCS is a dangerous gamble and therefore 'that the legislation in fact should not proceed and that the proposed activity of burying carbon dioxide underground, either offshore or onshore, should be curtailed',

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12 Mr Dale Seymour, Department of Primary Industries, Victorian Government, *Proof Committee Hansard*, 29 August 2008, p. 20.

13 CO2CRC is a joint venture comprising participants from Australian and global industry, universities and other research bodies from Australia and New Zealand, and Australian Commonwealth, State and international government agencies.

14 Department of Resources, Energy and Tourism, answer to questions on notice 9, 29 August 2008.

15 Cooperative Research Centre for Greenhouse Gas Technologies, *Submission 15*, p. 2.

16 Greenpeace Australia, *Proof Committee Hansard*, 29 August 2008, p. 3.

the committee heard little evidence from other environmental groups suggesting that there were serious environmental risks associated with CCS.[17]

2.20 With respect to the environmental risks of CCS, the House of Representatives Standing Committee on Science and Innovation concluded last year that:

> …the desire to employ CCS in combating climate change must not overshadow the need to ensure that environmental risks are avoided…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.[18]

2.21 While the report suggests that the benefits of CCS need to outweigh the potential environmental risks, the 'potential benefits need also to be measured against the level of risk to the environment through CCS, compared to the risks if CCS is not used'.[19]

2.22 The Cooperative Research Centre for Greenhouse Gas Technologies similarly argued that the 'low risk of leakage from a storage site should be compared to the fact that 100% of all CO_2 emitted at the present day enters the atmosphere!'.[20]

2.23 The greatest environmental risk associated with CCS appears to relate to the long term storage of captured CO_2. However, at this point in time, the long term consequences of subterranean and submarine storage of CO_2 are not known, and are unlikely to be known until the process has been tested in actual operation, over a considerable period of time.

2.24 Some submitters to the inquiry suggested that an independent committee of experts be established to advise the minister on a range of issues including environmental protection. This is given further consideration in Chapter 3 which considers provisions for regulating the market.

Provisions contained within the bill for the long-term monitoring

2.25 Section 249CZGAA sets out conditions relating to arrangements for long-term monitoring which are required before a closing certificate can be issued. These arrangements include the programme of long-term monitoring and other operations proposed to be carried out by the Commonwealth following closure and an estimate of the costs.

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17 Greenpeace Australia, *Submission 10*, p. 2. The World Wildlife Fund, while making some caveats, called for 'accelerated approval of demonstration projects'; *Submission 4*, p. 2.

18 House of Representatives Standing Committee on Science and Innovation, *Between a Rock and a Hard Place: the Science of Geosequestration*, August 2007, p. 68.

19 House of Representatives Standing Committee on Science and Innovation, *Between a Rock and a Hard Place: the Science of Geosequestration*, August 2007, p. 56.

20 Cooperative Research Centre for Greenhouse Gas Technologies, *Submission 15*, p. 4.

2.26 Prior to the issuing of a closure certificate, the security commensurate with the finalised program of monitoring activities must be paid to the Commonwealth. Once the closure certificate is issued it is intended that the Commonwealth takes over the agreed work programme of monitoring and other activities, funded through the lodged security.[21]

Environment Protection and Biodiversity Conservation Act

2.27 The World Wildlife Fund suggested that the proposed bill be amended to provide an environmental impact assessment to be undertaken prior to the issuing of any approval for exploration, injection and storage operations. Further, it suggested that the bill be amended to include 'no-go zones' around sensitive natural and heritage areas and provide large environmental buffers around protected or vulnerable marine and offshore areas.

2.28 However, evidence from the Department of Resources, Energy and Tourism suggested that the *Environment Protection and Biodiversity Conservation Act* provides a legal framework to protect and manage important flora, fauna, ecological communities and heritage places—defined in the Act as matters of national environmental significance. The Act provides that any activity needs to be referred under the Act if the proponent is of the view that the activity will significantly affect any matter of national environmental significance. This includes Commonwealth marine areas and would apply to CCS projects.[22]

Amounts of energy used for CCS

2.29 Evidence was received suggesting that CCS technology uses large amounts of energy and that the wide scale adoption of CCS would increase resource consumption by 30 per cent. The World Wildlife Fund claimed:

> It is believed that CCS operating in that whole system will reduce the efficiency of power stations by about 30 per cent. But that takes them down to about the level of efficiency of a nuclear power station, without the hundreds of thousands of years of toxic waste. Coal is cheap. This technology may in fact not be as expensive as people are saying, but we will not know until we find out, and that is the stage that we would argue should be accelerated [23]

2.30 Evidence from Greenpeace claimed the technology itself uses between 10 and 40 per cent of the energy produced by a power station, and further that, 'wide scale

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21 Department of Resources, Energy and Tourism, answer to questions on notice 3, 29 August 2008.

22 Department of Resources, Energy and Tourism, answer to questions on notice 2, 29 August 2008.

23 Mr Paul Toni, World Wildlife Fund, *Proof Committee Hansard*, 29 August 2008, p. 19.

adoption of CCS is expected to erase the efficiency gains of the last 50 years and increase resource consumption by one-third'.[24]

CCS versus alternatives

2.31 The committee received several submissions in which it was claimed that CCS storage is a 'distraction from undertaking real action on reducing greenhouse gas emissions' or that CCS is an 'end of pipe' response that attempts to manage the effects of a system reliant on fossil fuel consumption.[25] That is, that CCS allows for nations to continue their reliance upon fossil fuels.

2.32 This notion of CCS being a distraction from undertaking real action on climate change raises the question of opportunity cost. Environmental groups suggest that, 'Money spent on CCS will divert investments from sustainable solutions to climate change'.[26] In turn, they argue that if the substantial investment in CCS projects was diverted to renewables then Australia could achieve its necessary emission reductions without developing CCS.[27]

2.33 This would involve Australia shifting its energy base away from coal and oil to a diverse portfolio of renewable energy technologies.

The economics of carbon capture and storage

2.34 Under an emissions trading scheme, or a carbon tax, polluters must pay for the damage done to the environment by their activities. A company will therefore be willing to pay for CCS if the cost of storing CO_2 in this way is less than the cost of purchasing a permit to emit CO_2 into the atmosphere.

2.35 The committee heard a wide range of estimates of the carbon price necessary for CCS to be commercially viable, from $20 to $100 per tonne. However, the majority view seems to be that a price of around $40–$50 would represent a breakeven point:

> …[the International Energy Agency's] figures were in the order of US$45 a tonne to US$70 to US$80 a tonne, depending on the technology.[28]
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> For the offshore injection of CO_2, which is very expensive in terms of the technology around the special steel pipelines and the injection wells and the special corrosion-resistant alloys required for that, some estimates have

24 Greenpeace Australia, *Submission 10*, p. 2.

25 Greenpeace Australia, *Submission 10*, p. 2; Australian Network of Environmental Defenders' Offices, *Submission 2*, p. 2.

26 Ms Helen Oakey, Greenpeace Australia, *Proof Committee Hansard*, 29 August 2008, p. 3.

27 Ms Emily Rochon, Greenpeace Australia, *Proof Committee Hansard*, 29 August 2008, p. 4.

28 Mr Dale Seymour, Victorian Department of Primary Industries, *Proof Committee Hansard*, 29 August 2008, p. 25.

> been made that a carbon price between $50 and $100 will be needed to make that economically viable.[29]
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> It would be above $20 a tonne.[30]
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> …but it has got to be over $40 or $50 a tonne to get people to start thinking about this sort of technology, or any of the other technologies. At the moment, the renewables are being given the incentive of the MRETS (Midwest Renewable Energy Tracking System) and a potential extension to that scheme. But if you remove that sort of thing you are looking at a carbon price up at about $50 or $60.[31]

2.36 The breakeven price will vary for different kinds of CCS projects. A large proportion of the cost of CCS projects for coal-fired power stations will comprise building and operating the plants to capture and liquify the carbon, and building pipes to transport it to the coast, even before the process of storing it offshore begins. Storage of CO_2 generated by offshore oil drilling will therefore be viable at much lower carbon prices than would CCS of CO_2 generated by coal-fired power stations. It will also be considerably more expensive to retrofit carbon capture facilities to existing power stations than to build it into new power stations.

2.37 Both sides of the debate agreed that CCS would be a costly process:

> The technology itself uses between 10 and 40 per cent of the energy produced by a power station...CCS is expensive. It could lead to a doubling of plant costs and an electricity price increase of 21 to 91 per cent.[32]
>
> …the storage cost is not the big part…The big cost is at the power station, building a massive plant on the front end for oxyfuel or on the back end for post-combustion capture…and also the enormous amount of energy you need to drive that. You are looking at between 20 and 30 per cent of the power station's output to drive the capture. It is costly.[33]

2.38 However, the Cooperative Research Centre for Greenhouse Gas Technologies claimed that while the cost of deploying the technology is likely to be high:

> …the economies of scale that could be achieved through deployment will probably make the technology cheaper than some renewable energy generation resources currently being deployed.[34]

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29 Mr Mark Nolan, ExxonMobil, *Proof Committee Hansard*, 29 August 2008, p. 32.

30 Dr Geoffrey Ingram, Schlumberger Carbon Services, *Proof Committee Hansard*, 29 August 2008, p. 41. Dr Ingram cited the IPCC as saying around $10 for the storage component alone.

31 Mr Ralph Hillman, Australian Coal Association, *Proof Committee Hansard*, 29 August 2008, p. 51.

32 Ms Helen Oakey, Greenpeace Australia, *Proof Committee Hansard*, 29 August 2008, pp. 2–3.

33 Mr Ralph Hillman, Australian Coal Association, *Proof Committee Hansard*, 29 August 2008, p. 50.

34 Cooperative Research Centre for Greenhouse Gas Technologies, *Submission 15*, p. 1.

2.39 A high (expected) carbon price does not necessarily mean the widespread adoption of CCS. A high price will reduce the overall demand for energy and encourage greater efficiency. It will also make renewable energy producers, which do not need to purchase permits or pay for CCS, more competitive in selling energy.

2.40 Commercial CCS projects will operate on a very large scale and cost hundreds of millions if not billions of dollars. Only very large companies, or consortia, will be in a position to undertake them, and they will need to be confident before starting them. Having clear rules in place, and preferably with bipartisan support, will be important in creating an investment climate conducive to undertaking CCS projects.

2.41 The Victorian Government wants a competitive market:

> …greenhouse gas storage formations are a new resource and should be treated as separate and distinct from petroleum resources, which are commonly co-located. An equitable and competitive market for access to CCS resources is therefore essential. The rights of CCS proponents should not be treated as subordinate to those of existing petroleum titleholders or of the petroleum industry generally...Areas should not be excluded solely because there are existing petroleum titles over them.[35]

2.42 A challenge for CCS is what one witness termed 'reputational risk':

> These projects are so reliant on public confidence that they really have to be done properly…It would only take one CCS project going wrong, leaking or having someone cut corners somewhere for CCS to be off the public agenda and going the same way as genetically modified crops. The science may be good but, if public confidence turns against it, we will lose out.[36]

Current public expenditure on CCS projects

2.43 Under the Low Emissions Technology Demonstration Fund (LETDF), a total of $410 million has been offered to applicants involved in developing low emissions technologies.[37]

2.44 CSS projects currently receiving funding under this scheme include:

- *Chervon Gorgon carbon dioxide (CO_2) Injection Project*—the project is part of the Gorgon development off the northwest coast of Western Australia. It includes the injection of carbon dioxide into the Dupuy Formation saline

35 Mr Dale Seymour, Victorian Department of Primary Industries, *Proof Committee Hansard,* 29 August 2008, pp. 20–1.

36 Dr Geoffrey Ingram, Schlumberger Carbon Services, *Proof Committee Hansard,* 29 August 2008, p. 43.

37 For a complete list of funded projects under LETDF Round 1 see: http://www.ret.gov.au/energy/Documents/2008%2007%2029%20LETDF_Round_1_Funded_projects.pdf (accessed: 4 September2008).

aquifer underneath Barrow Island. Total cost of the project: $841 million; Australian government contribution: $60 million.

- *CS Energy: Oxy-firing demonstration and carbon sequestration project*—the project will be implemented using the Callide A power station at Biloela in central Queensland. The total cost of project: $188 million; Australian government contribution: $50 million.

- *HRL Limited: Clean Coal Demonstration Project*—the project demonstration will be implemented at the Loy Yang Bench in the Latrobe Valley, Victoria. The total cost of the project: $750 million; Australian government contribution: $100 million; Victorian government contribution: $50 million.

- *International Power: Hazelwood 2030*—the demonstration project will occur at the Hazelwood power station in the Latrobe Valley, Victoria. Total project cost: $369 million; Australian government contribution: $50 million; Victorian government: $30 million.

Australian Capture Projects with Storage

Name, state	Lead	Description	CO_2 Source	Injection Rate	Start-up
Otway Project VIC	CO2CRC	Storage demonstration project	Natural Gas / CO_2 well	100 kt total	April 2008
Moomba CO_2 Storage Project SA	Santos	Regional CO_2 Storage Hub. Initial demonstration through EOR	Natural Gas	1mt total	2010
Gorgon LNG Project WA	Chevron	15mtpa Gas field development with CO_2 Capture and Storage	Natural Gas	Up to 4mtpa	2012–2013
Callide Oxyfuel Project QLD	CS Energy Ltd	30MW Coal fired boiler Oxyfuel retrofitting Capture and CO_2 Storage	Black coal	Up to 50 kt	2010–2011
ZeroGen Project QLD	Stanwell Corp.	100MW IGCC and CO_2 Capture and Storage	Black Coal	Up to 400 ktpa	2011–2012
Monash CTL Project VIC	Monash Energy	Coal to liquids CO_2 Capture and Storage	Brown Coal	Up to 15 mtpa over 40 years	2015
Fairview Project QLD	GE Santos	100MW CSM post combustion capture and CO_2 re-injection	Enhanced CSM	100 ktpa	TBD
Browse Project	Woodside	18tcf Gas field development with possible CO_2 Capture and Storage	Natural Gas	ytbd	2013–2015

Australian Capture Projects with Potential Storage

Name	Lead	Description	CO2 Source	Injection Rate	Start-up
HRL Project VIC	HRL	400MW IDHCC Pilot Scale CO_2 Capture	Brown Coal	Future potential storage	Post 2009
Hazelwood 2030 PCC Project VIC	International Power	200MW Boiler re-fit. 10-20ktpa solvent based capture	Brown Coal	Future potential storage	Late 2008
Loy Yang PCC Project VIC	Loy Yang Power	5,000 tpa mobile PCC facility trials	Brown Coal	Future potential storage	2008–2009
Munmorah PCC Project NSW	Delta Electricity	5,000 tpa mobile PCC facility trials		Future potential storage	Mid 2008
FutureGas Project SA	Hybrid Energy	150–300MW Lignite CFB Combustion and Gasification CO_2 Capture and Storage	Brown Coal	ytbd	2015
Collimbah Power Project WA	Aviva Corp.	2x200MW Oxyfuel with conversion for CO_2 capture and storage	Black Coal	ytbd	2012

Source: Department of Resources, Energy and Tourism