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.

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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

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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.

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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.

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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]

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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]

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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.

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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.

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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.