NATIONAL CARBON MAPPING AND INFRASTRUCTURE PLAN – AUSTRALIA

CONCISE REPORT

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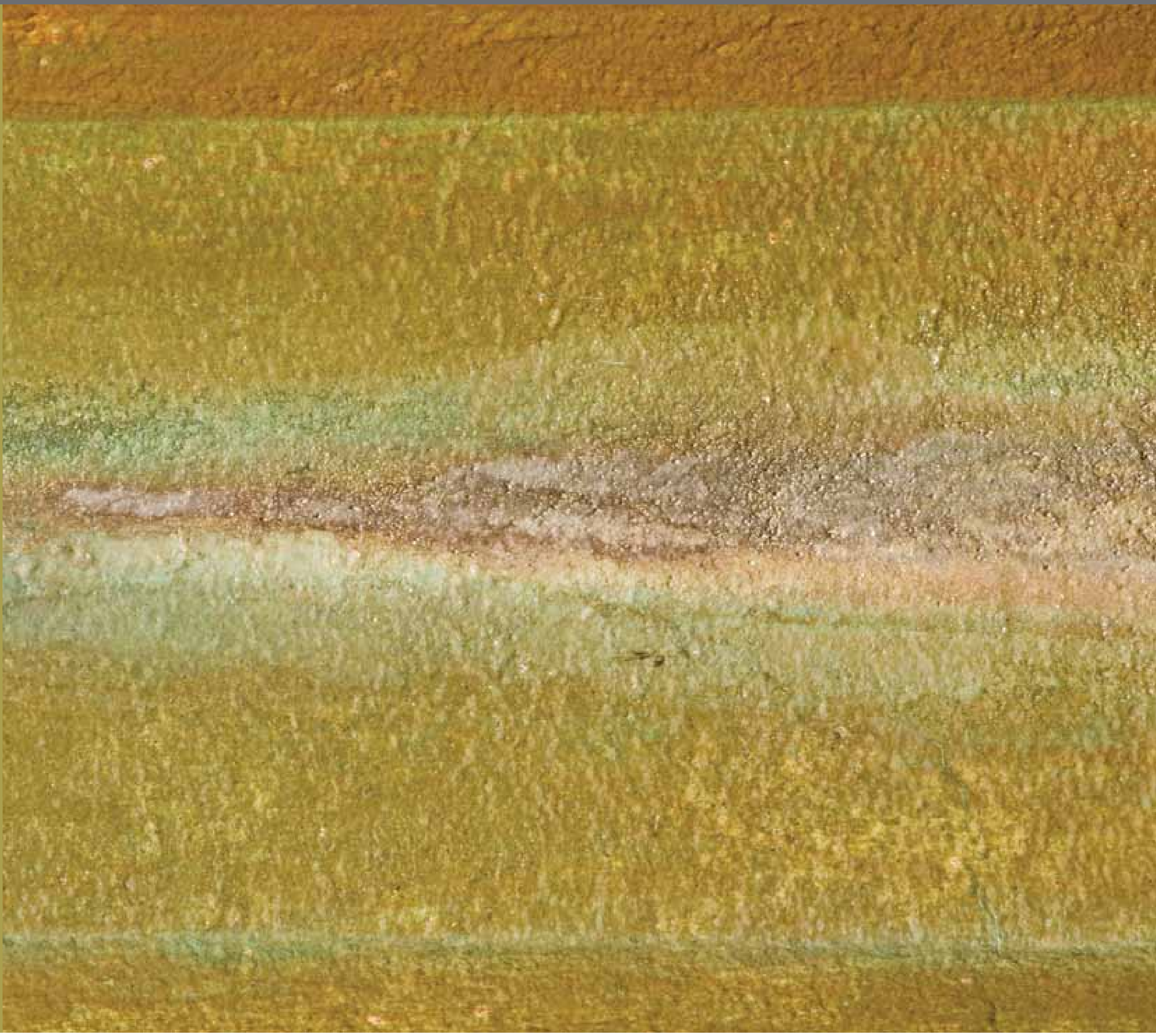

CARBON STORAGE TASKFORCE

SEPTEMBER 2009

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ISBN 978-1-921516-61-0 (paperback)
ISBN 978-1-921516-62-7 (PDF)

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REFERENCE

Carbon Storage Taskforce 2009, *National Carbon Mapping and Infrastructure Plan – Australia: Concise Report*, Department of Resources, Energy and Tourism, Canberra.

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The Hon Martin Ferguson AM MP

Minister for Resources and Energy

Parliament House

Canberra ACT 2600

Dear Minister,

The Carbon Storage Taskforce was established under the National Low Emissions Coal Initiative to develop a National Carbon Mapping and Infrastructure Plan. I have pleasure in submitting the Taskforce's report to you.

Carbon Dioxide Capture and Geological Storage (CCS) could play a key role in the portfolio of responses necessary to reduce greenhouse gas emissions in Australia at a substantial level. It is currently the only technology recognised as being capable of dealing with large quantities of emissions from stationary point sources. The availability of suitable geological storage sites underpins deployment of CCS. In the National Carbon Mapping and Infrastructure Plan, Australia now has a roadmap prioritising the development of suitable storage sites and the necessary pipeline infrastructure.

The Taskforce sought to take a measured and balanced approach in its investigation of the risks and opportunities presented by transport and storage of carbon dioxide. This included consideration of CCS on an integrated basis. Issues arising from carbon dioxide capture with energy generation and hydrocarbon extraction were considered to the extent they impacted on transport and storage issues.

The broad membership of the Taskforce provided a unique opportunity to consider the diverse, and sometimes conflicting, views of stakeholders regarding deployment of CCS in Australia. Stakeholders were drawn from all key industry sectors with an interest and expertise in carbon dioxide storage including coal, power generation, oil and gas, pipeline operators, geological survey agencies, unions and non-government organisations as well as representatives from the Commonwealth and state governments.

I would like to express my gratitude to my colleagues on the Taskforce who have worked with me to develop the National Carbon Mapping and Infrastructure Plan, as well as those who have provided support to us during this process. As noted in the report, the development of the Plan is just the first step. The challenge now is to maintain the momentum generated by stakeholders and implement the Taskforce's recommendations.

I commend this report to you.

Yours sincerely,

Keith Spence
Chair, Carbon Storage Taskforce

7 September 2009

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KEY OUTCOMES

Mitigating greenhouse gas emissions requires the development and application of a portfolio of technologies. The technology identified as having the greatest potential to mitigate greenhouse gas emissions from large-scale fossil fuel usage is carbon dioxide capture and geological storage (CCS).

CCS combined with power generation and gas processing is expected to play a significant role in Australia. The first capture hub could be commercially viable as early as 2020–25.

Deployment of carbon dioxide (CO_2) transport and storage in Australia is technically viable and, under appropriate management regimes, safe.

Current geological and engineering activities must be accelerated and maintained over the next decade if the nation is to be in a position to capture the opportunity for commercial deployment beyond 2020.

Demonstration of the technology at significant scale is essential for investor confidence. Several demonstration storage sites could be ready by 2018. The Gorgon LNG project will be the world's largest CCS project (3.5 Mtpa) when sanctioned.

Apart from gas processing projects, commercial investment is highly unlikely until a carbon regime is introduced that is perceived to introduce costs, incentives or mandated outcomes that will persist in the medium to long term.

A significant proportion (more than 120 Mtpa) of Australia's future CO_2 emissions can be avoided by the capture of CO_2 from ten emissions hubs.

There is a high confidence that the east of Australia has aquifer storage capacity for 70 – 450 years at an injection rate of 200 Mtpa, and that the west of Australia has capacity for 260 -1120 years at an injection rate of 100 Mtpa. These capacities have been estimated using a probabilistic analysis similar to that used for petroleum resource estimation. Assumptions on storage efficiency were highly conservative. It is possible that far greater capacity will be defined as basins and their CO_2 storage behaviour become better known.

The critical path for large scale deployment is now recognised to be the identification and development of suitable storage reservoirs. For aquifers, this is estimated to be 11-13 years for a focussed program that is actively pursued and adequately funded. This time period assumes typical levels of investment, activity, and resource availability, and importantly, the activities are sequential (e.g. drilling takes place once seismic is acquired and interpreted). The time could be shortened by using multiple drilling rigs for example, or by overlapping activities (e.g. seismic and drilling). However, this incurs greater risk. The time would also be shortened if smaller scale injection was anticipated.

Carbon dioxide storage operations may be located in basins where other resources are, or will be, developed. The impact of the CCS activity on other resources and operations will need to be assessed for each case.

Transport and storage tariffs vary widely for hub/basin combinations. Preliminary cost indications for transport of large quantities of CO_2 from the Latrobe Valley to Gippsland basin storage sites range around 10 \$/t CO_2 avoided, compared to around 30-60 \$/t CO_2 avoided for CO_2 transported from central east Queensland to the Eromanga basin. For the power generation sector, this translates to an additional 1-10 \$/MWh for electricity generation costs, depending on location. This does not include the costs for the new upstream generating and capture capacity.

It is essential that modelling of CCS as an element of energy futures in Australia should differentiate CCS costs by location.

The first capture hub is likely to be located in the Latrobe Valley in 2020–2025, due to its significant competitive advantage, arising from relatively low carbon transport and storage costs.

The different CO_2 transport and storage costs will become a factor in considering the optimal location of new plant, and new energy generation hubs may emerge. For example, locating new generating plant close to the Surat Basin storage areas would reduce the transport and storage tariff by more than 50%, to levels comparable with the Latrobe Valley to Gippsland costs.

The level of exploration, development and infrastructure activity needed to create Australia's transport and storage capacity appears manageable. The projected level of exploration and development activity benchmarks favourably with current levels of oil and gas activity. However, this petroleum activity is likely to continue or increase. Full scale deployment of CCS could at least duplicate the demand for similar resources. More than 5,000 km of large diameter pipeline infrastructure is needed to transport CO_2. This is a three-fold increase in Australia's current large diameter steel pipeline.

While CO_2 transport and storage has many parallels with oil and gas, it poses challenges that require a different approach and mix of skills and knowledge for industry and authorities.

There is a need for further research and development on CO_2 pipelines to develop assurance for the Australian community and its regulators that pipeline leaks can be avoided and that operational venting can be managed safely.

Public acceptance is essential for deployment, particularly onshore, and particularly for pipelines. The Taskforce has identified key concerns and suggests strategies to address them.

RECOMMENDATIONS

NATIONAL CARBON MAPPING AND INFRASTRUCTURE PLAN

The Taskforce recommends the following six element plan:

1. Implement a $254m, strategically phased, pre-competitive exploration program.
2. Release exploration acreage in the onshore Surat and Perth basins as soon as possible in addition to those offshore areas released in March 2009.
3. Develop several transport and storage demonstration projects at a significant scale of 1 Mtpa CO_2 or more, which are integrated with CO_2 capture demonstration projects.
4. Support pipeline infrastructure development that is designed to incorporate economies of scale, competitive long term costs and uncompromising safety standards.
5. Identify and recommend incentives to drive competitive CO_2 storage exploration over the period 2010–2017, in concert with other policy and fiscal settings established to support deployment of low emissions technologies, including CCS.
6. Develop and implement a Communication Strategy.

These plan elements incorporate the following recommendations:

PLAN ELEMENT 1: PRE-EXPLORATION

1a) Conduct the phased, gated, pre-competitive exploration program totalling $254 million developed by the state government geological surveys and Geoscience Australia to assess basins of strategic importance. Programs specific to each basin need to be conducted concurrently, and commence now. The estimated cost is significantly in excess of the $50 million provided by the Commonwealth. As pre-exploration proceeds, there may be a need for further pre-competitive exploration investment.

1b) Establish a Review Committee to consider the pre-competitive exploration programs across the jurisdictions, charged with:

- optimising the expenditure on the programs by aligning them in timing and location;
- updating the priorities of the program in light of near term results from exploration programs and tendering of areas; and
- reporting back to Government through the Ministerial Council on Mineral and Petroleum Resources (MCMPR) on the results, their implications and expenditure.

1c) Form a clear understanding of the data types and sources relevant to basin management for CO_2 storage, and government policy and requirements in relation to provision of this data by industry operators.

The Taskforce recommends that this process is managed by the Upstream Petroleum and Geothermal Subcommittee (UPGS), reporting to the MCMPR in the first half of 2010.

PLAN ELEMENT 2: EXPLORATION

2a) Place a high priority on acreage release over the onshore Surat and Perth basins (in addition to the offshore areas already released). Acreage release in these basins in the near term is essential if timeline targets for significant CCS deployment are to be met.

2b) Enact legislation enabling CO_2 storage in onshore Western Australia and New South Wales at the earliest opportunity.

2c) Encourage consistency of exploration and storage legislation in different jurisdictions to facilitate investment.

PLAN ELEMENT 3: DEMONSTRATION PROJECTS

3a) Build demonstration projects at significant scale (greater than 1 Mtpa CO_2) linking capture, transport and storage elements so that the risks associated with the operability of the overall integrated system can be understood and addressed. This is crucial for investor confidence.

3b) Support development of demonstration capture plants and storage reservoirs that are able to evolve into demonstration hubs, to show viability of systems at the scale necessary for wide spread deployment, and to capture economies of scale. This recommendation does not preclude development of 'stand alone' CCS systems, if a particular system can demonstrate competitive benefits.

3c) Place priority on proposals for significant-scale, linked demonstration projects in the Gippsland, Surat and Perth basins as these are the most likely to develop as the first capture and storage hubs.

3d) Design demonstration projects to develop a better understanding of storage, including storage efficiency, migration behaviour and monitoring techniques.

PLAN ELEMENT 4: INFRASTRUCTURE

4a) Develop a nationally consistent approach to CO_2 pipeline regulation.

4b) Undertake activities designed to build capacity for regulators, industry operators and the public, and that develop awareness that CO_2 transport and injection infrastructure can be developed and operated safely in Australia. The program should primarily draw on existing international experience in CO_2 pipeline construction and operations, supplemented by a targeted R&D program designed to complement international programs.

4c) Prioritise investment in emissions hub-storage basin combinations that are lowest cost, and optimise initial infrastructure design for anticipated future loads.

4d) Coordinate national and local planning to ensure options for strategic pipeline corridors for potential future use are retained.

4e) Prioritise deployment of lowest cost options that are more likely to remain economically competitive against other energy generation options in the longer term (30-40 years). Use early learning to demonstrate proof of concept and identify opportunities for cost reduction, before committing to longer distance pipelines.

PLAN ELEMENT 5: POLICY AND FISCAL SETTINGS

5) Identify and evaluate CO_2 storage exploration incentives that could be applied over the period 2010–2017. The Taskforce should provide a recommendation on appropriate incentives policy to the Minister for Resources and Energy in the first quarter of 2010.

PLAN ELEMENT 6: COMMUNICATION

6) The Taskforce should consult with its members and other CCS stakeholders with a view to the development of a CCS communicators' forum, or similar structure, which will provide a coordination node for CCS in Australia to:

- develop credible, verified and consistent messages in the context of the whole portfolio of responses to climate change, and liaise with relevant groups developing other responses;
- create a reference source to avoid duplication; and
- on occasions, and if agreed, coordinate a response to a specific event.

1 INTRODUCTION

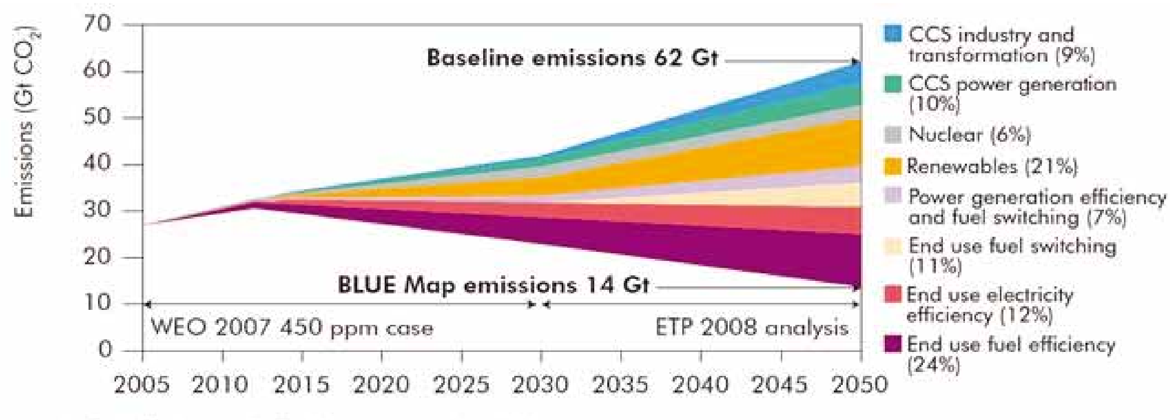
Governments in Australia, Europe and the United States are taking action to mitigate the impact of greenhouse gas emissions on climate change. Australia is one of the nations likely to be affected by climate change earliest and hardest. Postponing action to mitigate greenhouse gas emissions is considered likely to result in substantially greater costs, and impacts[1]. There is an urgent need to mitigate greenhouse gas emissions globally and Australia has an opportunity to contribute to this action at many levels.

Currently, about 69% of all carbon dioxide (CO_2) emissions and 60% of all greenhouse gas emissions are "stationary energy"-related. The International Energy Agency[2] (IEA) projects that without policy change, world energy demand will grow by 45% between 2006 and 2030. Even with the growth in renewable energy sources, fossil fuels are expected to remain major sources of the world's energy in the coming decades.

The IEA[3] projects that CO_2 emissions from energy use will increase by 130% by 2050, largely due to increased fossil fuel usage, in the absence of new policies or supply constraints. The Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report[4] found that such a rise could lead to a temperature increase in the range of 4–7°C, with major impacts on the environment and human activity. The IPCC concluded that Australia's water resources, coastal communities, natural ecosystems, energy security, health, agriculture and tourism would all be vulnerable to climate change impacts if global temperatures rise by 3°C or more.

It is widely agreed that a halving of "stationary energy"-related CO_2 emissions is needed by 2050 to limit the expected temperature increase to less than 3°C. To achieve this will require an energy sector transformation on a massive scale. The IEA projections of global responses include increased energy efficiency, increased renewable energies and nuclear power, and the decarbonisation of power generation from fossil fuels (Figure 1). At present, the technology identified as having the greatest potential to mitigate greenhouse gas emissions from large-scale fossil fuel usage is CO_2 capture and geological storage (CCS).

Figure 1: Technologies for reducing global "stationary energy"-related CO_2 emissions by 2050



Source: IEA (2008), *Energy Technology Perspectives 2008.*

1 Garnaut, R. 2008, *The Garnaut climate change review: final report / Ross Garnaut*, Cambridge University Press, Port Melbourne, Vic.

2 International Energy Agency 2008, *Energy Outlook 2008*

3 International Energy Agency 2008, *Energy Technology Perspectives 2008*

4 Intergovernmental Panel on Climate Change (IPCC) 2007, *IPCC 4th Assessment Report*

CCS will need to contribute nearly 20% of the necessary emissions reductions to reduce global greenhouse gas emissions by 50% by 2050 at a reasonable cost[5], and so CCS is essential to the achievement of deep emission cuts.

The IEA also found that deployment of CCS would significantly reduce the cost of reducing global emissions. It estimated that without CCS, the annual cost for emissions halving in 2050 is USD1.28 trillion per year higher, an increase of 71%[6]. In July 2008, the G8 countries acknowledged the important role of CCS by setting a target of 20 large-scale CCS demonstration projects to be committed by 2010, with a view to beginning broad deployment by 2020.

1.1 AUSTRALIAN CONTEXT

Australia's net greenhouse gas emissions in 2006 were 576 Mt CO2-equivalent (CO2 -e)[7,8]. The energy sector ("stationary energy", transport and fugitive emissions) was the largest source of greenhouse gas emissions at 70%. The largest contributor to the energy sector is "stationary energy", which made up 50% of Australia's emissions in 2006. "Stationary energy" includes power generation, gas liquefaction and processing, alumina, aluminium, cement, steel and iron manufacturing, and petroleum refining. ABARE projects that Australia's energy demand will grow by 54% between 2005 and 2030[9]. Around 80% of Australia's electricity currently comes from coal-fired power generation.

The Australian Government's Carbon Pollution Reduction Scheme (CPRS) is planned to come into effect in July 2011. The CPRS will be the primary mechanism through which Australia will seek to meet its emissions reduction objectives. Under this scheme, a carbon permit price increases the costs of emissions from coal and gas-fired power over time, thereby increasing the competitiveness of the higher cost, lower emission alternatives such as renewables and CCS. The other major elements of the Government's mitigation strategy are: the expanded Renewable Energy Target; investment in renewables and carbon capture and storage; and action on energy efficiency.

The electricity sector is expected to make a substantial contribution to abatement and is very important for achieving national emission reduction. Figure 2 shows CSIRO's national projection for the power generation sector under the CPRS. In CSIRO's projection, wind and natural gas electricity generation are projected to be the main new power plant investment in the first decade after CPRS is introduced, as these are the two lowest cost electricity abatement opportunities initially and other technologies are in the demonstration stages.

Solar thermal and solar photovoltaics are expected to be the next technologies to emerge as economically viable emission abatement technologies. Solar thermal power is expected to be in the form of high temperature concentrating towers. Hot fractured rocks and fossil fuel power generation with CCS are projected to be economically viable in the period from 2025.

Coal-fired power generation with CCS is projected to play a significant future role, being more than 40% of projected power generation capacity in 2050[10].

5 International Energy Agency 2008, *CO_2 Capture and Storage – A key carbon abatement option*

6 International Energy Agency 2008, *Energy Technology Perspectives 2008 – Scenarios and Strategies to 2050*, July 2008.

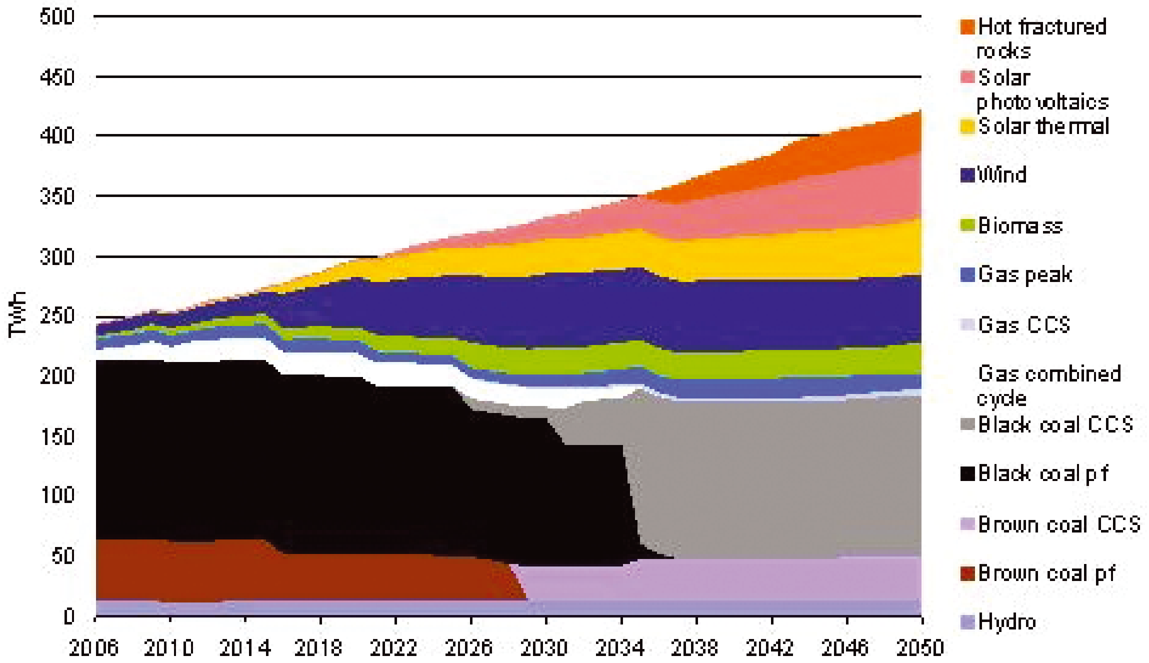
7 Department of Climate Change 2006, *National Greenhouse Gas Inventory 2006*, Department of Climate Change, Canberra

8 CO_2-e: A standard measure that takes account of the different global warming potential of different greenhouse gases and expresses the cumulative effect in a common unit.

9 ABARE 2007, *Australian energy – national and state projections to 2029–30*, ABARE Research Report 07.24, Canberra

10 CSIRO 2009, *Dealing with carbon – what is Australia's carbon balance & footprint and how do we deal with the cost of adaption?*, presented at the AICC June 22 2009

Figure 2: Projected Australian electricity generation portfolio under CPRS-5



Source: CSIRO.

There is a wide range of possible future energy-mix scenarios, and the timing and level of contribution of different technologies could vary significantly. It is important, therefore, that a wide range of scenarios are considered when developing policy responses.

The Australian Academy of Technological Sciences and Engineering (ATSE) recently reported[11] that for a typical energy demand growth scenario of 1.4% per annum (similar to ABARE projections) and a portfolio of new technologies installed, around $250 billion in new technology investment will be required by 2050. The investment cost is dependent on the portfolio of technologies adopted, especially the higher cost and lower capacity-factor technologies such as wind and solar. ATSE's results for projected investment costs are consistent with recent studies, including the IEA study and the recent Australian Government Treasury report[12].

ATSE concludes that it is unlikely that any single technology will achieve the CO_2 reduction outcome targets now being proposed. Rather, the response will require the development and application of a portfolio of technologies.

1.2 CARBON DIOXIDE CAPTURE AND GEOLOGICAL STORAGE IN AUSTRALIA

Australia has an active research effort underway. The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) and CSIRO are leading research into CCS. A number of small-scale CCS demonstration projects have commenced at Australian power stations. A pilot carbon storage project is currently underway in south western Victoria, with 65,000 tonnes of CO_2 injected and stored to date. Carbon capture technologies to entrap CO_2 emitted as flue gas have also progressed.

The Australian Government has established the National Low Emissions Coal Initiative (NLECI), a $400 million program to accelerate the development and deployment of technologies that will reduce emissions from coal use. It includes funding for research and to support the trial of different technologies. An allocation of $50 million has been provided to progress CO2 storage initiatives.

11 Australian Academy of Technological Sciences and Engineering (ATSE) 2008, *Energy Technology for Climate Change, Accelerating the Technology Response*, ATSE, Melbourne

12 Department of the Treasury 2008, *Australia's Low Pollution Future – The Economics of Climate Change Mitigation*, Department of the Treasury, Canberra

In September 2008, the Australian Government announced the establishment of the Global Carbon Capture and Storage Institute (GCCSI) to help coordinate and drive the concerted global effort called for by global leaders. The Government is also supporting a range of CCS-related projects with key international partners, including China, through the Asia–Pacific Partnership on Clean Development and Climate and through its membership of the Carbon Sequestration Leadership Forum (CSLF).

The Federal Government amended the *Offshore Petroleum Act 2006* in November 2008 to introduce a regulatory regime for CCS activities in Commonwealth offshore waters. In March 2009, ten offshore areas were released for the exploration of greenhouse gas storage. Victoria, Queensland and South Australia have also passed legislation for the conduct of CCS activities onshore.

The 2009 Budget included $4.5 billion for the Clean Energy Initiative, of which $2 billion will go to building two to four industrial-scale CCS projects in Australia, in pursuit of the G8 goal to develop at least 20 large scale integrated CCS projects globally by 2020. The remainder will support the construction and demonstration of large-scale solar power stations in Australia through the Solar Flagships Program, and establish a new body, the Australian Centre for Renewable Energy (ACRE), to promote the development, commercialisation and deployment of renewable technologies, through a commercial investment approach.

In August 2009, the Australian Government announced an additional five years of funding for the CO2CRC to take forward its CCS research and development, including further work on pilot scale capture and storage. A five year funding package was also provided for the newly created Energy Pipelines CRC, which has a work program which includes pipelines carrying CO_2 emissions.

Through a voluntary industry levy, the Australian coal industry has committed over $1 billion to accelerate the deployment of low emission coal technologies, at commercial scale, in Australia, in order to reduce CO_2 emissions from coal-fuelled power generation and manufacturing through the development of low emissions demonstration projects including CCS.

1.3 CARBON STORAGE TASKFORCE

The Australian Government established the Carbon Storage Taskforce (the Taskforce) in October 2008 to bring together key industry sectors with an interest and expertise in carbon storage including coal, power generation, oil and gas, pipeline operators, geological survey agencies, unions and non-government organisations as well as representatives from the Commonwealth and state governments to develop a National Carbon Mapping and Infrastructure Plan (the Plan).

The primary aim of the Plan is to develop a road map to drive prioritisation of, and access to, a national geological storage capacity to accelerate the deployment of CCS technologies in Australia. The full Terms of Reference for the Taskforce are included at Appendix A.

2 TASKFORCE ACTIVITIES

The Taskforce identified ten hubs or concentrations of Australia's stationary emissions that are expected to account for 210.8 Mt or 76% of stationary emissions in 2020[13].

The Taskforce identified a priority list of potential storage basins and determined indicative estimates of their storage capacities and injection characteristics[14]. These sites were matched with emissions hubs, to generate estimates of transport and storage tariffs[15].

The study identified that transport and storage costs vary significantly for different hub/basin combinations. This cost range was included in a model examining energy futures for the National Electricity Market (NEM) under different scenarios.

A range of technical matters relating to pipeline transport and storage were investigated in detail. The Taskforce also investigated the opportunity for commercial deployment of CCS in Australia, and community opinions relating to CCS.

13 The modelling included stationary emissions only, not total emissions forecast to 2020 in Australia.

14 A montage of geological information and characteristics was developed for each basin. The montage of the Gippsland basin is shown as an example in Appendix E.

15 Tariff: the cost per tonne of CO_2 avoided, calculated using the net present value of cash flows and avoided CO_2 over a 25 year asset life.

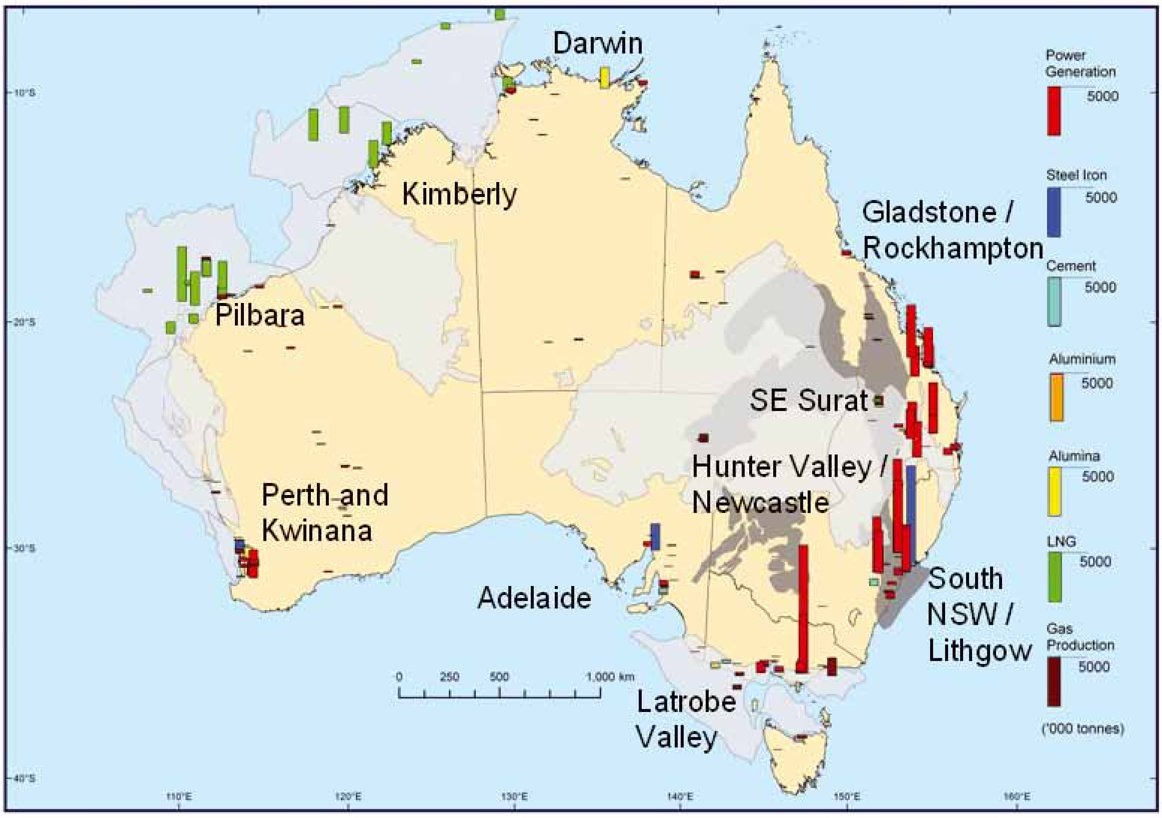
3 TECHNICAL FEASIBILITY

It is the view of the Taskforce that a significant proportion (more than 20%) of Australia's future CO_2 emissions can be avoided by the capture, transport and geological storage of CO_2 from Australia's stationary emission sources.

3.1 EMISSIONS

Ten concentrations of stationary emitters have been identified across Australia, where emitters are located sufficiently close together to allow the gathering of captured CO_2 through a hub (Figure 3)[16]. A hub provides economies of scale leading to efficient transport to, and storage in, large CO_2 geological storage sites. Complex commercial agreements will be required, however, and government could consider its role in facilitating these.

Figure 3: Geographical distribution of emissions by industry estimated for 2020



Projected emissions from stationary emitters, assuming a 10% emissions reduction target, are 277 Mt CO_2 in 2010. Electricity generation from black coal, brown coal, and gas are projected to make up 70% of this total. Emissions from power generation are projected to decrease by 2020 due to fuel switching from coal to gas and increased use of renewable energy under the Mandatory Renewable Energy Target (MRET) scheme. However, total emissions are projected to be steady to 2020, largely due to increasing LNG-related emissions from new LNG developments.

16 ACIL Tasman 2009, *Australian stationary energy emissions: an assessment of stationary energy emissions by location suitable for capture and storage*, report prepared for the Carbon Storage Taskforce, Department of Resources, Energy and Tourism, Canberra.

Emissions associated with LNG production come from two main sources – reservoir CO_2 that naturally occurs associated with hydrocarbon gasses in the geological reservoir, and CO_2 generated by combustion of fuel in the production and liquefaction of LNG. Reservoir CO_2 emissions are projected to increase from 2.8 to 20.5 Mtpa from 2010-2020. Reservoir CO_2 can be captured by well established chemical processes. The Gorgon Project[17] is expected to commence storing 3.5 Mtpa of reservoir CO_2 from around 2015.

CO_2 emissions from the production and liquefaction of LNG are projected to increase from 6.6 to 29.9 Mtpa in 2020. However, capturing CO_2 associated with upstream processing and liquefaction is more problematic as LNG liquefaction plants have many sources of emissions making capture difficult. Therefore, it is likely that the most effective way to reduce emissions from liquefaction of LNG is through improving the energy efficiency of the process, rather than capturing its emissions.

Technologically, it is reasonable to assume that 90% of coal-fired power emissions and nearly 100% of LNG-related reservoir gas could be captured, although individual project economics will need to be considered. On this basis, some 58% (or 123 Mt in 2020) of emissions from the ten hubs could be captured for transport and underground storage. This quantity represents 21% of total Australian greenhouse gas emissions in 2006[18]. Other single point sources, such as those generated in the manufacture of steel, cement, and fertiliser, may also be able to contribute to the available emissions at each hub.

3.2 AUSTRALIA'S STORAGE POTENTIAL

The IEA[19] considers that the storage of CO_2 in aquifers, depleted oil and gas fields, and the use of CO_2 for enhanced oil recovery (EOR) are proven storage options. The Taskforce has therefore evaluated the carbon storage potential of depleted oil and gas fields and aquifers in Australia.

Given the timeframe set by the Terms of Reference and wide scope of the assessment, capacity estimates derived by the Taskforce were based on an extensive, high level, 'top down' analysis using publicly available data. Ultimately, the capacity and characteristics of each storage reservoir will require a comprehensive, 'bottom up' assessment, which will be calibrated against the monitored behaviour of injected CO_2.

3.2.1 Oil and gas field storage

While the majority of the storage potential lies in aquifer storage, the CO_2 storage capacity of oil and gas fields in Australia was investigated, and has been estimated to be approximately 16.5 gigatonne (Gt)[20]. The vast majority of this storage is offshore (~15.6 Gt). The northwest of Australia contains ~13.4 Gt of storage capacity, but these fields are distant from the emitters in southwest western Australia and eastern Australia and depletion is many years away.

The Bowen and Surat Basin gas and oil reservoirs in Queensland are well placed to match local small volume CO_2 sources. Most oil and gas reservoirs in this area are in an advanced stage of depletion so a CO_2 storage project could have progressive access to a series of depleted reservoirs over time. There may be competing interests where depleted reservoirs would also form an ideal storage buffer for coal seam gas (not CO_2) extracted for use in the proposed LNG projects.

There is significant storage potential in the Gippsland Basin where several oil fields appear to be at or near the end of their productive life. These have potential to hold significant volumes of CO_2 but the transition from petroleum recovery to storage activities needs to be carefully managed. The larger gas fields have productive lives that could extend beyond 2050.

17 www.gorgon.com.au

18 Department of Climate Change, 2008, *National Greenhouse Inventory 2006*

19 International Energy Agency, 2008, *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050, OECD/IEA*

20 Geoscience Australia (Petroleum and Greenhouse Gas Advice Group) 2009, *Australian Carbon Dioxide Storage Potential in Oil and Gas Reservoirs*, report prepared for the Carbon Storage Taskforce, Department of Resources, Energy and Tourism, Canberra.

There appears to be only limited potential for the use of CO_2 to enhance oil recovery in Australia, and this activity appears unlikely to result in significant storage. However, it could be an important driver of early projects since it generates revenue through the sale of the additional hydrocarbons recovered, thereby offsetting costs. The net impact on emissions after considering the end use of the additional fossil fuels recovered needs to be also taken into account.

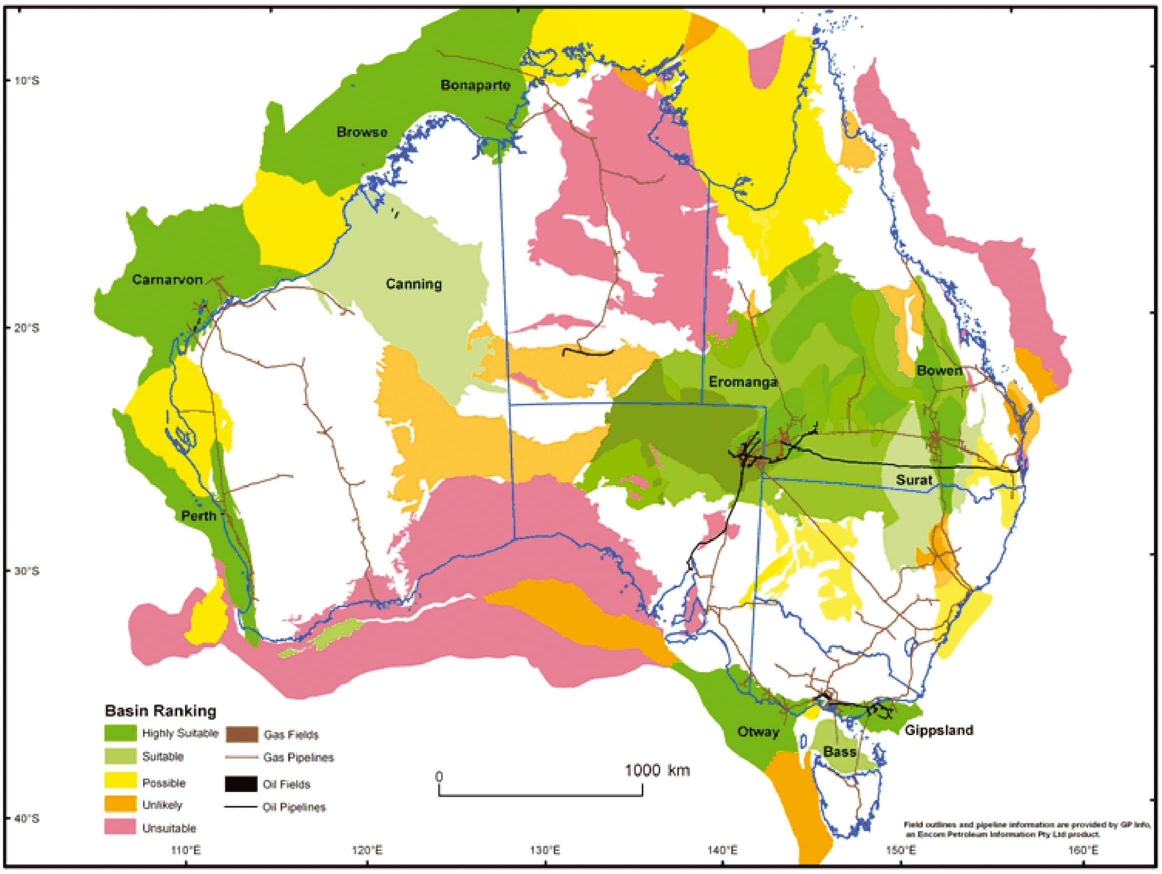
> The depleted and near-depleted gas and oil fields of the Bowen and Surat Basins are well placed to match local small volume CO_2 sources. There is significant storage potential in the Gippsland Basin where some oil fields appear to be near the end of their productive life.

3.2.2 Aquifer storage

Some of Australia's many basins are well explored and knowledge of the basin's geology is high. Others are relatively unexplored and there is little knowledge and data.

The Taskforce has used a high-level, qualitative approach to ranking the basins to account for this diversity. Eleven basins are regarded as having the best potential for storage – Gippsland (Vic), Bass (Vic/Tas), Bowen (Qld), Surat (Qld), Eromanga (SA/Qld), Otway (Vic/SA), Perth (WA), Carnarvon (WA), Browse (WA), Canning (WA), and Bonaparte (WA/NT). A further series of basins have been identified as having possible storage potential or are of strategic importance (Figure 4: Australia's basins ranked for CO_2 storage potential).

Figure 4: Australia's basins ranked for CO_2 storage potential[21]



21 The mismatch of colours in the basin ranking map (Figure 4) with the basin ranking classes in the map legend in the Eromanga and Surat basin's region, is due to the presence of underlying sedimentary basins.

Using a probabilistic approach, the parameters describing each basin's storage characteristics have been combined in Monte Carlo simulations to derive probabilistic estimates of each basin's storage capacity. Australia's CO_2 storage capacity (50% confidence[22]) is estimated to be 417 Gt, assuming a storage efficiency factor (E) of 4%. The storage efficiency factor is not well known, and it may vary considerably depending on geology. Estimates for aquifers tend to be in the range 0.5%–4%, which is almost an order of magnitude of uncertainty. The "proven" (90% confidence[23]) cumulative storage capacity is between 33 Gt (E=0.5%) and 226 Gt (E=4%).

Some 40% of Australia's storage capacity is located on the east coast, where most of the CO_2 emission hubs are located. Figure 5 and Figure 6 show that there is high confidence that the east of Australia has aquifer storage capacity for 70–450 years at a storage rate of 200 Mtpa, and that the west of Australia has capacity for 260–1120 years at a rate of 100 Mtpa.

Figure 5: Eastern seaboard Australia – risked CO_2 storage capacity

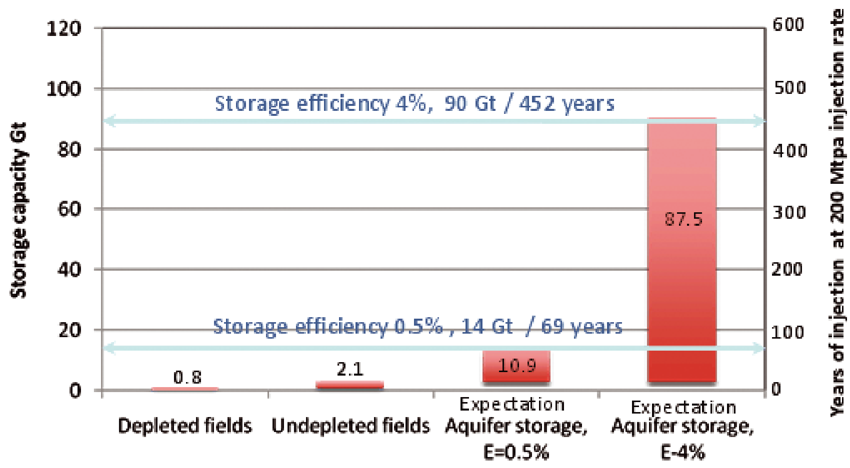
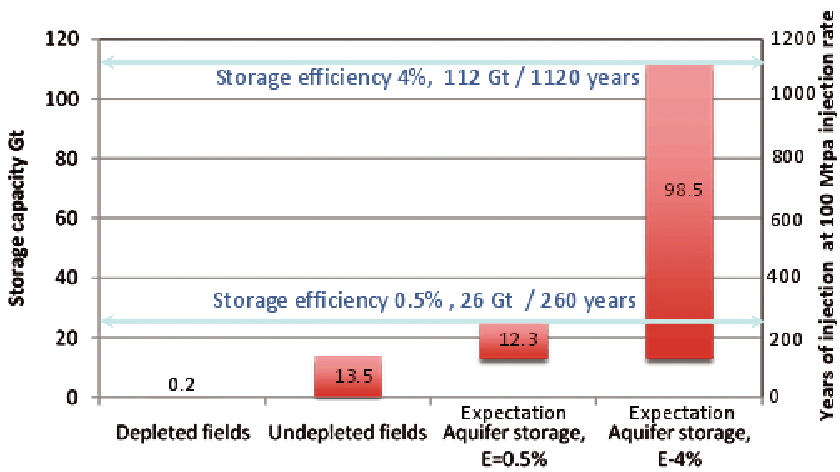


Figure 6: Western seaboard Australia – risked CO_2 storage capacity



22 Storage capacity estimated using a probabilistic approach as used in petroleum resource estimation. '50% confidence' indicates that there is at least a 50% probability that the storage capacity actually able to be utilised will equal or exceed the estimate.

23 'Proven' used where there is at least a 90% probability that the storage capacity is actually able to be utilised will equal or exceed the estimate.

There is high confidence that the east of Australia has aquifer storage capacity for 70–450 years at a storage rate of 200 Mtpa, and that the west of Australia has capacity for 260–1120 years at 100 Mtpa, with the possibility that a far greater capacity will be defined as basins and their CO_2 storage behaviour become better known.

3.3 SOURCE-SINK MATCHING

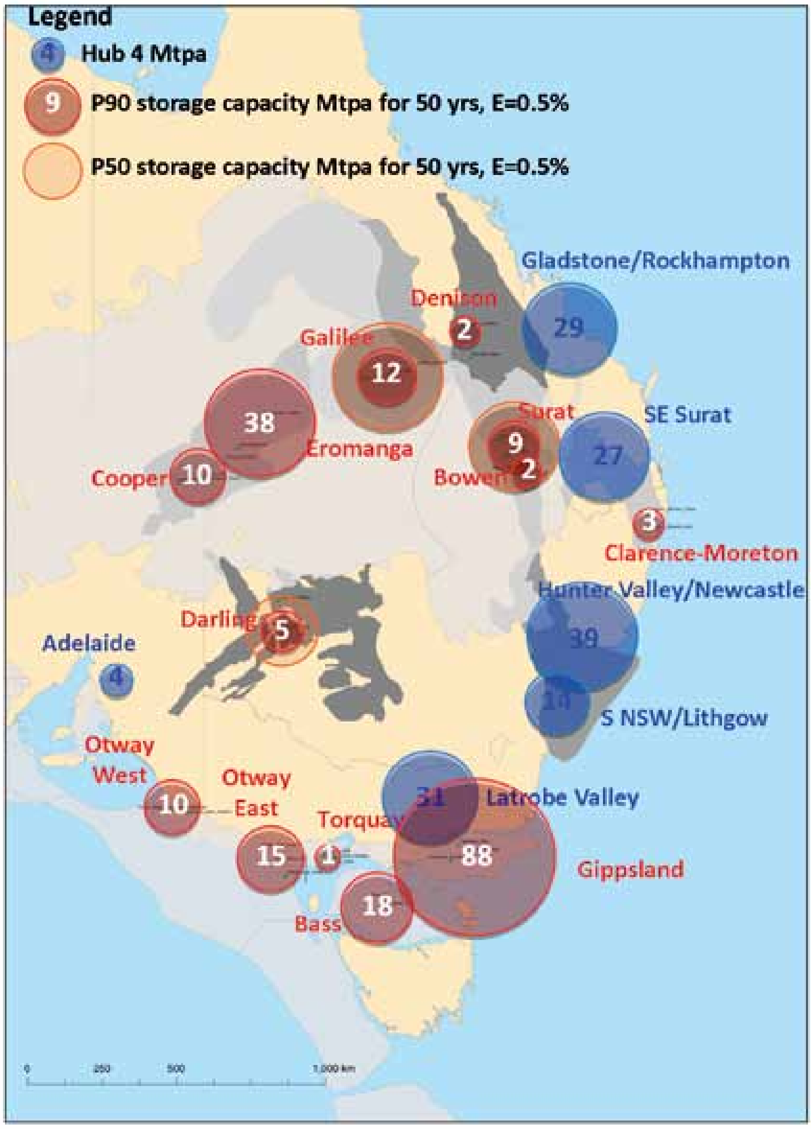
The Gippsland Basin has the greatest capacity of the eastern basins (Figure 7). It is also very close to the Latrobe Valley hub (150 km). From a purely technical point of view, it is the first choice for the development of a long-term storage basin in Victoria.

In South Australia, the Otway West Basin is the likely storage site for the Adelaide hub (Figure 7). The Cooper Basin could be used for the storage of reservoir CO_2 associated with the production of domestic gas from the Cooper and Eromanga basins. There is potential for use of CO_2 in the Cooper basin to enhance oil recovery with oil sales offsetting some of the costs associated with geological storage.

In Queensland, the Eromanga Basin has the greatest capacity, but is more than 1,200 km from the emissions hubs. Storage in this basin would incur significant transportation costs. The closer Surat and Galilee basins (400–600 km) have storage capacity that could be used for the first 25 years as a stepping stone to Eromanga.

The New South Wales basins are relatively unexplored, but on current data the majority of the basins have low storage capacity. The one possible exception is the Darling basin which is a very large basin located in central west New South Wales (Figure 7). Data is very limited given the extent of the basin, but there are some indications of suitable porosity and permeability, which suggests potential for storage of CO_2. If these characteristics extend more widely, there is potential for larger scale storage, but considerable additional data will be required to confirm this potential. If the pre-exploration activities fail to prove up potential, it is likely that major pipelines will need to be constructed to transport CO_2 from the Hunter Valley northwards to the Surat and Eromanga basins (up to 1700 km) and from the southern New South Wales hub southwards to the Gippsland Basin (1000 km). The New South Wales Government is also conducting preliminary investigations into the potential for mineral carbonation as an alternative to long distance transport to aquifer storage sites.

Figure 7: Hub emission levels and basin storage capacity – eastern seaboard

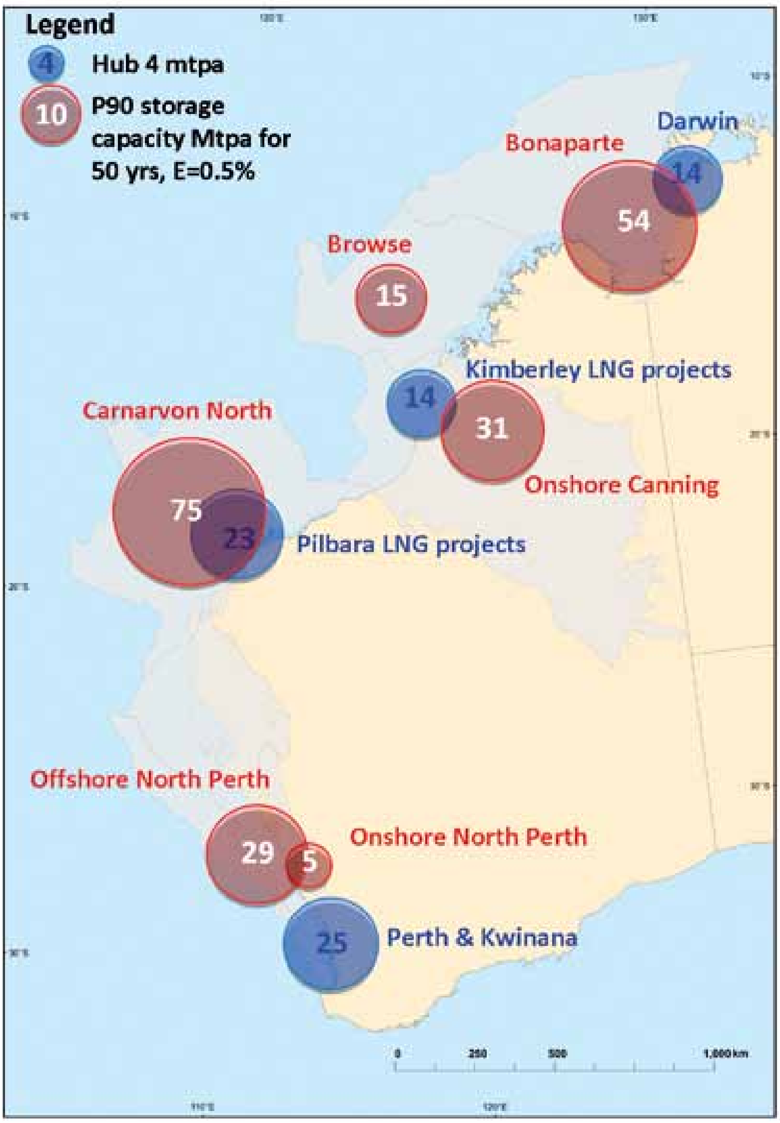


For the Perth/Kwinana hub on Australia's west coast (Figure 8), the most likely storage basins are the onshore and offshore North Perth Basin. In addition to aquifer storage, the onshore North Perth Basin is attractive as the initial storage location because it has a number of depleted, but small volume, gas fields as storage locations. The offshore North Perth Basin is the likely longer term storage location.

CO_2 emissions in the Pilbara region are projected to increase as new LNG and domestic gas projects come on line. The Carnarvon Basin is expected to be the storage location. Significant emissions are projected for the Kimberley region as a result of the possible development of a LNG hub to the north of Broome. The onshore Canning Basin may be preferred.

The majority of emissions from the Darwin Hub are also associated with LNG production. Reservoir CO_2 could be transported to the nearby offshore Bonaparte Basin for storage.

Figure 8: Hub emission levels and basin storage capacity – western seaboard



3.4 INFRASTRUCTURE

Pipeline engineering technology is advanced, and subject to cost, many fluids can be transported using pipelines. CO_2 pipelines have been in operation internationally for over three decades.[24] Today in the United States, more than 40 Mtpa of CO_2 from natural and anthropogenic sources is transported through over 5,800 km of pipeline.[25] The major use has been in transporting CO_2 streams for enhanced oil recovery. CO_2 contents in this network are typically > 95% and contain a range of other substances. Most of the network is situated in non-urban areas. In Australia, there is extensive operational and regulatory experience in managing hydrocarbon (gas and oil) pipelines under the standard, AS2885. The knowledge base for hydrocarbon pipeline management has been developed both in Australia and internationally over decades, and has been able to be applied to the evaluation of risks under AS2885.

24 Canyon Reef Carriers pipeline, constructed in 1972, extends 225 km from McCamey, Texas, USA to Kinder Morgan CO_2's SACROC oil field.

25 ICF International, 2009, *Developing a Pipeline Infrastructure for CO_2 Capture and Storage: Issues and Challenges*; Report prepared for INGAA Foundation.

Deployment of large scale, high pressure CO_2 pipeline systems will benefit from a similar development of a knowledge base that addresses both risk and economics. From a risk perspective, industry operators and regulators will consider in detail the impact of CO_2 pipeline leakage, rupture or controlled release ("blowdown") at every section of a proposed pipeline route. Given that many CCS pipelines will be relatively long distance, it is also important that development work is focussed on cost reduction, without compromising safety. This area of work would focus on optimal design, and consider factors such as fracture control, thermodynamics, and materials selection and design. All of these factors are currently covered for hydrocarbon pipelines under AS2885. The knowledge developed through this process will assist design and regulatory assessment of CO_2 pipeline proposals under AS2885 and any other relevant codes. It will also help to identify if the risk analysis process for hydrocarbon pipelines, which is incorporated into this standard, needs any modification when it is applied to risk analysis for CO_2 pipelines.

There is an increasing body of work both in Australia and internationally providing insights into the construction and operation of CO_2 pipelines. Significant work has already been undertaken by industry operators and CCS organisations in designing CO_2 infrastructure for specific projects. It is important that Australian activities are coordinated with these international efforts. Knowledge of CO_2 behaviours and pipeline performance developed by project proponents to satisfy regulatory requirements is expensive to obtain, and so may be held as intellectual property. Release of this information into the public domain will be a decision for individual project proponents in their community engagement program. A need therefore exists to develop publicly accessible technical information from credible sources that can be used by communities and individuals to form their own judgements about CO_2 pipeline transport (refer Plan Element 4: Infrastructure).

Australia's extensive high pressure gas transmission pipeline infrastructure is privately owned and currently in use conveying hydrocarbons. The Taskforce has assessed these pipelines as unsuitable for transport of CO_2, as the cost associated with converting these pipelines for CO_2 transport would be similar to the construction costs of a new pipeline. The 1,375 km Moomba – Botany (Sydney) pipeline, completed in 1996, transports ethane at similar pressure ranges to those required for transport of CO_2 in supercritical phase. Technically, this pipeline could be used for CO_2 transport, but at rates less than those anticipated for large scale deployment.

Pipeline construction will be a key element of CCS project timelines. There are multiple factors affecting pipeline project timeframes and each project is unique. In general, without incurring exceptional costs, the timeframe for a 300–450mm (12–18 inch) pipeline between 300 and 700 km in length is 24–36 months after Final Investment Decision (FID) is reached. Prior to reaching FID, an extra 12–24 months of feasibility and environmental assessments and front end engineering design (FEED) will need to have been undertaken. In the case of the first CO_2 pipelines to be built in Australia, it is expected that the process to reach FID including environmental assessment, land access and native title issues, will be more protracted, and could extend up to 36 months in duration. This suggests that development could take 3–6 years.

Transport of CO_2 in supercritical phase over long distances will typically require recompression en route and hence a substantial power source. For larger pipelines, the demand will need a supply independent from the electrical grid. This requirement adds a cost constraint to route design, as either a gas supply or a transmission line will be required to power the compressor stations.

Some pipeline networks specify the composition of the streams to be carried. A common Australian specification for the streams to be transported in CO_2 pipelines in Australia is not needed because each power generation facility could have a different CO_2 gas composition, depending on the technology deployed and the mode of capture. Individual transport systems or networks should set their own specifications for hubs based on the source emissions profile and requirements at the storage sites. Taskforce investigations suggest that for long distance transport systems, the economic driver to reduce pipeline material and recompression costs is likely to result in specifications that seek high concentrations of CO_2 with minimal impurities.

4 IMPACT OF CARBON DIOXIDE STORAGE ON OTHER RESOURCES

Carbon dioxide storage operations may be located in basins where other resources are, or will be, exploited. The impact of the CCS activity on other resources and operations will need to be assessed for each case.

For instance, the highest ranked storage basins are also hydrocarbon producing basins. Other resources such as fresh water, geothermal heat, coal seam methane, coal, and underground coal gasification could also be potentially impacted by CO_2 storage operations. The nature of the impact may be, for example, that production of hydrocarbons is adversely affected due to CO_2 migrating into hydrocarbon producing fields, resulting in increased corrosion and variation of product quality. Conversely, hydrocarbon production may in some instances be improved due to increased reservoir pressure resulting from CO_2 injection.

The Taskforce has identified and undertaken preliminary assessments of the two most strategically significant areas of potential resource impact: firstly, the availability of the prolific oil and gas producing Gippsland Basin for storage operations; and secondly, the risk of impact of storage operations on the freshwater aquifers of the Surat and Eromanga basins.

4.1 TIMING OF GIPPSLAND BASIN STORAGE AVAILABILITY

The offshore Gippsland is the highest technically ranked storage basin and it has the lowest transport and storage cost per tonne of CO_2 avoided (refer Section 5). It is of strategic importance because it is the preferred storage site for Latrobe Valley emissions. It would also be the preferred storage basin for some or all of NSW's emissions, should the current pre-exploration program prove to be unsuccessful. This would require major pipeline infrastructure to be established.

However, it is also an oil and gas-producing basin with many currently productive fields. While some oil fields are nearing depletion, the large northern gas fields are expected to be producing well into the future.

The Taskforce has examined whether parts of Gippsland could be available for storage contemporaneously with petroleum operations. This has been assessed by estimating the timing of depletion of individual fields[26], and by examining their proximity to petroleum operations and CO_2 migration pathways. The Taskforce's estimates do not take account of any future discoveries. The evidence of how the basin filled with hydrocarbons indicates that the fields are connected along common systems. In order to maximise the depleted field and aquifer storage capacity, the location and sequence of injection sites needs to be carefully managed to prevent early projects filling structures that could preclude future storage capacity.

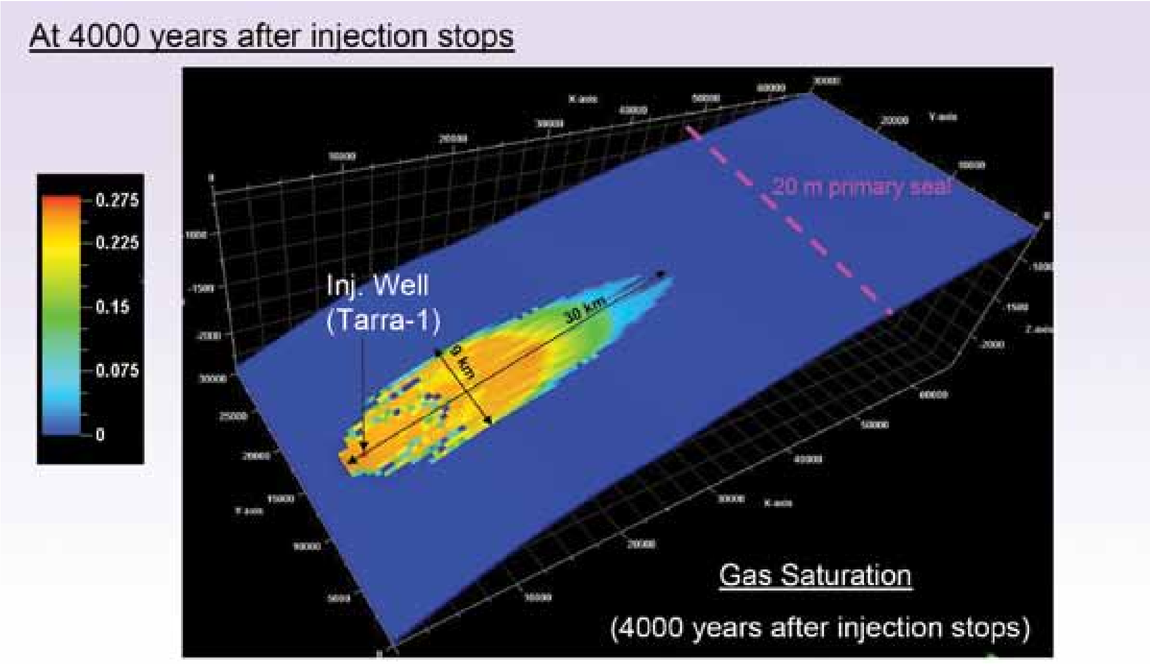
The conclusion is that storage operations could begin progressively, in a manner that is unlikely to impact on petroleum operations.

The first storage area would be located on the southern margin (contained by the areas that were released for storage exploration in March 2009). Reservoir simulations indicate that this area has potential CO_2 injection capacity for 50 Mtpa for 25 years[27]. Figure 9 shows the maximum extension of the CO_2 plume in the reservoir 4,000 years after injection ceases. The Taskforce estimates indicate that if exploration commenced in 2010, a storage site could be ready to commence operations by around 2022.

26 RISC 2009, *Gippsland Basin – Availability Projections for Carbon Storage*, report prepared for the Carbon Storage Taskforce, Department of Resources, Energy and Tourism, Canberra.

27 Department of Primary Industries 2009, *Plume Migration in Gippsland Offshore*, report prepared by Schlumberger Carbon Services, for the DPI, Melbourne

Figure 9: Size of plume extension for 50 Mt



Source: Schlumberger, provided by the Department of Primary Industries, Victoria.

The second storage area would be located under depleted southern oil fields, which could be available for storage by 2020–2025. These fields have significant in-field storage capacity, but due to the degree of interconnectedness of the basin, their use needs to be aligned with the plans for the aquifer storage to ensure that the much larger aquifer capacity is not sterilised.

The third and final northern storage area would become available after 2050, once the northern gas fields are depleted. It is also highly connected and would also require careful management of the sequence and location of injection to ensure use of storage capacity is optimised.

It is recommended that a more detailed assessment, utilising reservoir simulation techniques, be made to examine CO_2 migration pathways and aquifer pressure implications associated with injection in the southern oilfields area.

4.2 GREAT ARTESIAN BASIN

The Surat and Eromanga basins form the larger part of the Great Artesian Basin in Queensland, South Australia, New South Wales and the Northern Territory. These two basins contain vast quantities of fresh groundwater and significant hydrocarbon wealth. In the absence of newly identified storage capacity closer to sources, they have also been identified in this Taskforce study as being potential storage locations for emissions generated from the northern New South Wales and Queensland hubs.

The Taskforce commissioned a study to examine the potential impact of storage operations on freshwater aquifers[28], primarily focused on the distribution of groundwater types spatially and with depth, the mineralogy of reservoirs and seals, and the hydrochemical and geochemical reactions associated with the injection of CO_2 into the freshwater aquifers of the Surat and Eromanga basins.

28 Queensland Department of Mines and Energy (Queensland Carbon Geostorage Initiative) 2009, *The Potential Impact of Carbon Dioxide Injection on Freshwater Aquifers: The Surat and Eromanga Basins in Queensland*, report prepared by: J Hodgkinson, M Preda, M McKillop, O Dixon, Queensland Carbon Geostorage Initiative; A Hortle, CSIRO Petroleum, ARRC, Perth; and L Foster, Queensland Department of the Environment and Resource Management

The main conclusion of this preliminary study is that CO_2 storage can potentially operate without significantly impacting the freshwater aquifers.

Water chemistry and hydrodynamic data indicate that vertical mixing between the overlying and underlying units appears nominal and modelling indicates that the acid buffering capacity of the groundwater is large. Simulation results also suggest that the groundwater systems have the capacity to naturally remediate the induced acidified conditions resulting from CO_2 injection. Mineralogical data shows favourable mineral stability characteristics in the sandstones of the principal storage targets.

The location of carbon storage injection sites relative to existing resource and environmentally sensitive areas is critical to the mitigation of any detrimental contamination effects. The prevailing hydrodynamic regime will dictate the volume of CO_2 that can be safely stored in the long term, without negative impacts on groundwater resources, hydrocarbon production, mining operations and groundwater-dependent ecosystems.

Additional data and further interpretations are required in both basins to more clearly define potential impacts. Clearly, it would be desirable to identify storage locations that are closer to emissions sources, and that remove or reduce the potential for resource conflict. This work forms part of existing programs in New South Wales and Queensland, and the exploration program recommended subsequently in this report.

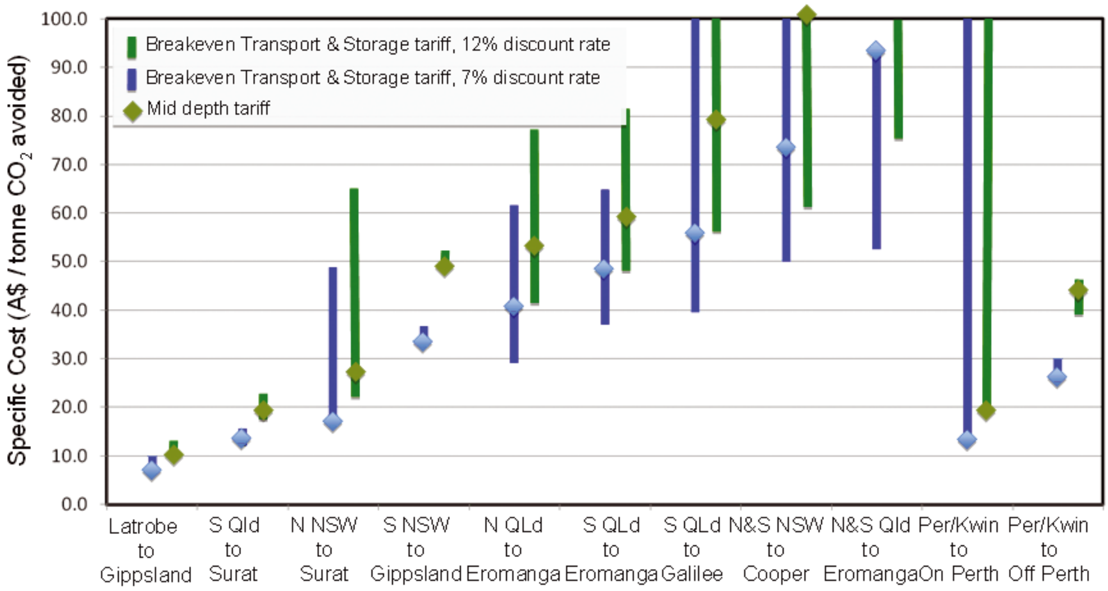
> It is recommended that pre-competitive exploration of the Surat and Eromanga basins includes the collection of new data as part of a deep well drilling program and re-sampling of existing groundwater bores. Also, observation wells at the new drilling sites are recommended to provide data to establish the vertical relationships between the aquifers/reservoirs and aquitards/seals.

5 ECONOMIC COMPARISONS OF HUB-BASIN COMBINATIONS

Transport and storage tariffs[29] have been calculated for large scale source-sink combinations[30 31] (Figure 10). The estimates are subject to large uncertainties and are only indicative and could change substantially over time as technologies, storage capacities, equipment costs and other variables change. They are based on rule-of-thumb techniques for estimating equipment sizes and the costs of individual items of equipment and associated services, and on assessment of subsurface potential at a screening level only. More detailed and extensive feasibility studies, based on more data, need to be undertaken as part of initial scoping work by project proponents before investment in any CO_2 storage projects could be considered.

Neither the cost of capture nor the capital charges associated with the new power generation technologies are included in these tariff estimates. They refer to transport and storage only.[32]

Figure 10: Break-even transport and storage tariffs for hub-basin combinations



The main factors affecting the economics of carbon storage are the location (the distance from the CO_2 source to the storage location determines pipeline costs), reservoir depth (influencing well costs) and injectivity parameters (notably permeability and differential pressure, which determine the number of wells needed).

29 Cost per tonne of CO_2 avoided, calculated using the net present value of cash flows and avoided emissions over a 25 year asset life.

30 Allinson W.G., Cinar Y., Hou W. & Neal P.R. 2009. *The Costs of CO_2 Storage in Australia*, School of Petroleum Engineering, The University of New South Wales, Sydney, Australia. CO2TECH Report Number RPT09-1536, prepared for the Carbon Storage Taskforce, Department of Resources, Energy and Tourism, Canberra.

31 Allinson, W.G., Ho, M.T., Neal, P.R., Wiley D.E., "The methodology used for estimating the costs of CCS", in *Proceedings of the 8th International Conference on Greenhouse Gas Control Technology (GHGT-8)*, Trondheim, Norway, 19–22 June 2006, Paper #0191

32 Estimates of the projected cost of power generation technologies, including CO_2 capture, from the range of technologies currently proposed vary widely, and are subject to large assumptions on learning curves and capital costs for different technologies over the next decades. It is also important to note that the tariff figures provided should not be combined with capture unit costs by simple addition. The emissions not avoided need to be also taken into account, as well as assumptions on compression costs.

These factors cause the calculated transport and storage tariffs to vary considerably (Figure 10). The Gippsland Basin in Bass Strait is Australia's most suitable storage basin, and it has the greatest storage capacity of the east coast basins. Because of its proximity to the Latrobe Valley and its excellent reservoir properties, its break-even tariff for CO_2 avoided is $7-10/t CO_2 or about $7–10/MWh[33].

In contrast, the Gladstone/Rockhampton hub with storage in the Eromanga Basin has a break-even tariff for CO_2 avoided of $29-62/t CO_2 or about $25–83/MWh[33].

The tariff calculation did not include historical exploration costs, which were considered in sensitivity analyses. These analyses included assessment of the impact of monitoring, drilling extra wells, well workovers, and the cost of exploration, appraisal and development planning and discount rate on the calculated tariffs for the Surat Basin. Of these factors, the discount rate has by far the biggest impact. Changing the real discount rate from 7% to 12% increases the cost of CO_2 avoided by about 40% (Figure 10). Oil and gas companies use higher discount rates as a means of accommodating exploration and sovereign risk. The other sensitivities add typically less than 10% to tariffs.

It is also important to note that the analysis considered only large scale deployment and utilisation, which yields substantial economies of scale. In practice this will not apply to 'early mover' projects. Installing infrastructure with a capacity to meet future demand is unlikely unless governments play a central role in large-scale infrastructure development and mitigation of the initial utilization risk.

33 Calculated using 962kg CO_2/MWhr for Gippsland basin and 906kg CO_2/MWhr for Eromanga basin; 95% capture rate; shallow, mid and deep transport and storage tariffs.

6 IMPACT OF TRANSPORT AND STORAGE TARIFFS ON ENERGY FUTURES AND FUTURE EMISSIONS

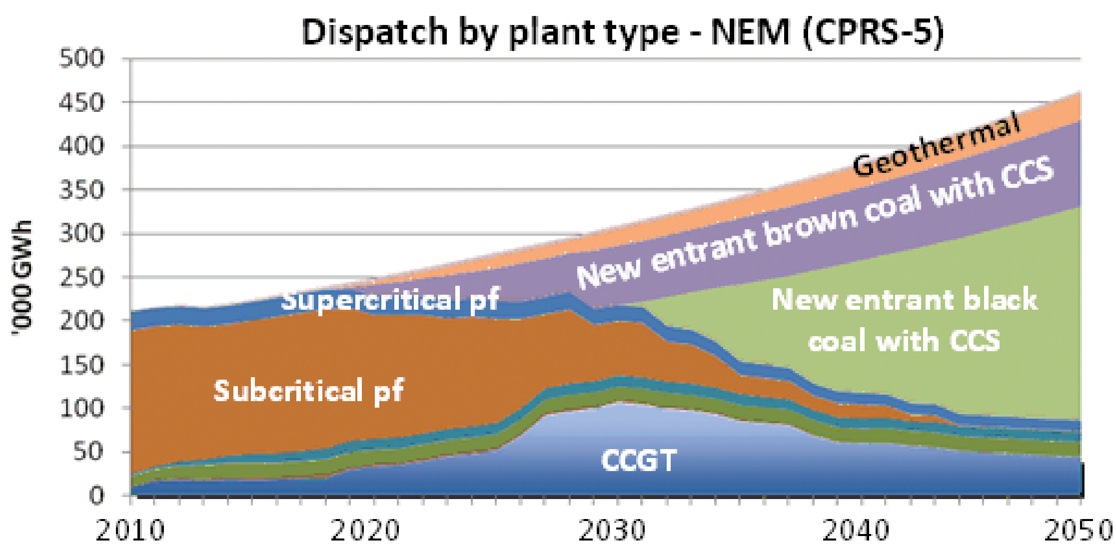
For the CPRS-5 regime, it is projected that by 2050, almost 250 Mtpa of CO_2 will be captured and stored from power generation operations.

The first capture hub is likely to be located in the Latrobe Valley in 2020-2025, due to its significant competitive advantage, arising from relatively low carbon transport and storage costs.

The impact of variable carbon transport and storage costs on the National Energy Market (NEM) has been modelled[34] (Figure 11).

Under a CPRS-5 regime[35], the modelling suggests that generation from existing plant is expected to peak in 2020 and then progressively decline as new power generation plants enter the market. New entrants are projected to provide 73% of generation in 2050.

Figure 11: Impact of variable carbon transport and storage costs on the National Energy Market



Initially, new entrants are likely to locate in the Latrobe Valley, due to its lower cost of carbon transport and storage. The first commercial capture and storage from power generation is modelled to occur in 2020 in the Latrobe Valley. By 2030, some 50 Mtpa of CO_2 from the Latrobe Valley could be avoided using CCS technology with storage in the Gippsland Basin.

34 ACIL Tasman 2009, *Carbon Capture and Storage Projections to 2050*, report prepared for the Carbon Storage Taskforce, Department of Resources, Energy and Tourism, Canberra. The analysis used power generation and capture costs provided in: ACIL Tasman, *Fuel resource, new entry and generation costs in the NEM*, Final report, April 2009.

35 CPRS-5 regime: Application of the Carbon Pollution Reduction Scheme (CPRS) using an emissions reduction target of 5% by 2020.

New generators also come on line around 2020 in Queensland and New South Wales, but growth in new generation with CCS is initially slow due the higher carbon transport and storage costs in Queensland. After 2030, CCS is projected to be commercially attractive to New South Wales and Queensland generators as carbon and electricity prices increase.

The scenario modelled suggests that almost 250 Mtpa of CO_2 could be captured and stored from power generation operations by 2050.

This modelling assumes that alternative energies such as geothermal and solar thermal are not successful in competing economically at the scale required to meet projected energy demand. If these, or another form of energy, were able to compete at carbon prices of around $57/tonne CO_2-e, then the new power generation plants with CCS in the Latrobe Valley are expected to go ahead, but power in Queensland and New South Wales could be sourced from these different technologies. Australian Government policy does not support nuclear power as part of Australia's energy mix.

The level of uncertainty in future outcomes directly affects the location and extent of infrastructure developed in anticipation of future demand. The modelling indicated that varying transport and storage tariffs may have a significant impact on the competitiveness of different types of energy generation technologies.

In future, transport and storage costs are expected to become a factor in selecting optimal plant location. In particular, locating plant close to storage locations may become important. A good illustration is the southeast Surat emissions hub, which is located some 400-450 km from the potential Surat Basin storage areas. If the hub was located closer to the Surat Basin storage areas (i.e. within 50 km), the transport and storage tariff reduces by A$8-10/t CO_2, to a level comparable with the low Latrobe Valley to Gippsland tariff, and the net present value of capital costs are reduced by around $1.5 billion. The majority of the savings are a result of the shorter transport distance. Clearly, this benefit would have to be assessed together with all the other costs and benefits determined by the plant location.[36]

The Taskforce recommends that any future modelling of energy futures in Australia differentiates CCS costs by location.

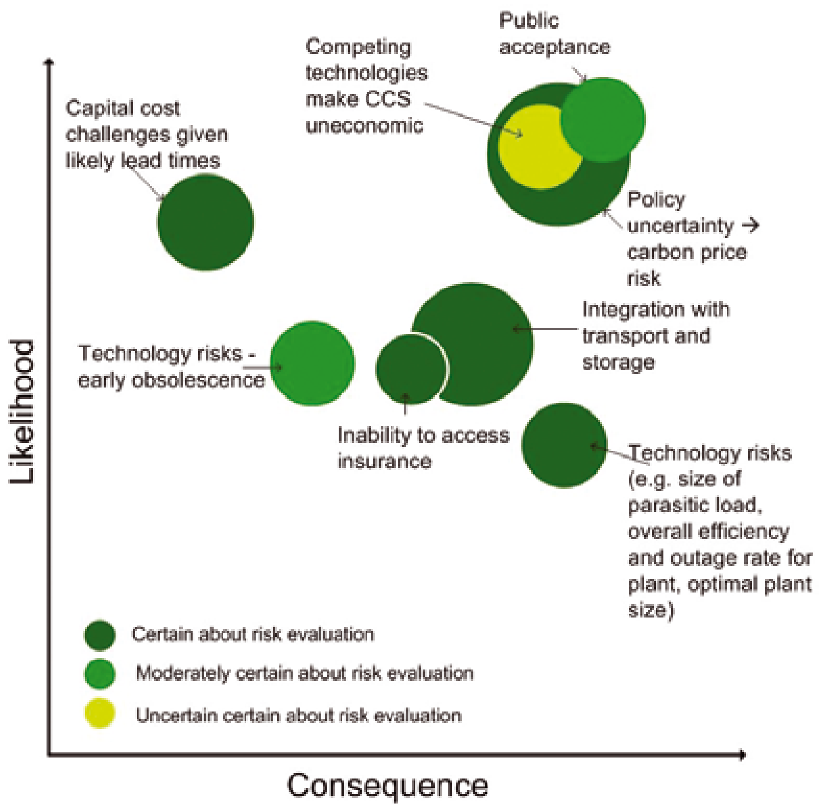
The different CO_2 transport and storage costs will become a factor in considering the optimal location of new plant and new energy generation hubs may emerge.

36 Other factors include access to transmission networks, water, infrastructure, a skilled population, coal, start up fuel, and the regulatory environment.

7 INVESTMENT RISK

The commercial risks associated with carbon dioxide capture, transport and storage have been examined by a broad spectrum of stakeholders including financiers, government and industry[37]. The identified risks have been ranked using a risk consequence / probability matrix (Figure 12, Figure 13 and Figure 14). Policy uncertainty and carbon price risk was identified as a key factor in investors' perceptions of project risk.

Figure 12: Risk Analysis – Generation and Capture



Deployment of any low emissions energy technology, using renewable energy or fossil fuels, at the scale required to reliably satisfy demand, will require investments of very large amounts of capital. At present, the investment return is typically recovered over three to four decades. Larger scale investments normally generate significant economies of scale, and make costs more competitive.

Future energy costs from any currently available generation technology appear likely to be higher than those generated currently using coal fired power with no emissions abatement, depending on the future carbon price. Therefore, the cost and viability of various generation options could change significantly over the coming decades[38]. This creates the risk that an asset might be stranded during its expected life, thereby substantially reducing the return on investment or generating a loss.

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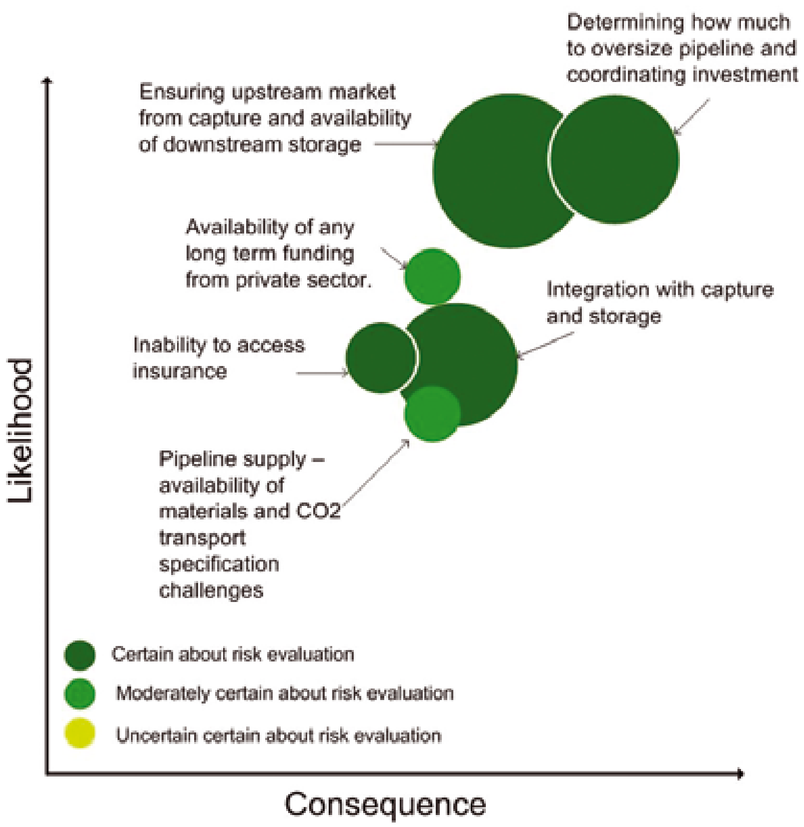
37 Deloitte Touche Tohmatsu 2009, *Project Finance Workshop Facilitation Report*, report prepared for the Carbon Storage Taskforce, Department of Resources, Energy and Tourism, Canberra.

38 A wide range of factors affect the cost and viability of technologies over time, including cost reduction through development of more efficient process designs and technologies, improved material capacities, and economies of scale. Conversely, competing use for raw materials or fuels may increase costs. In energy technologies in Australia, transport infrastructure – transmission of electricity, pipelines for CO_2 and gas, railways for coal – could have a particularly significant impact. For processes requiring geological storage capacity or exploitation of a hydrocarbon fuel reserve, changes in competitiveness are primarily determined by the discovery and development of more economically attractive resources.

Investments made to reduce emissions in response to the CPRS are, on average, unlikely to reap early cash flow benefits. There is no revenue stream, but rather an avoided cost and/or a social licence to operate. Under the CPRS, the avoided cost is likely to increase with time, rather than in the earlier stages of the project. Against this benefit profile, substantial investment is required for CCS projects many years in advance of a start-up date to define storage reservoirs adequately. This typically involves higher levels of risk than construction of plant, as exploration / appraisal can involve expenditure of many millions of dollars with no return. This cash flow pattern is not unique to CCS. Other energy technology responses to the CPRS at a scale capable of matching energy demand face the same challenges of large scale investment in relatively high risk projects without significant early returns.

Figure 13: Risk Analysis – Transport



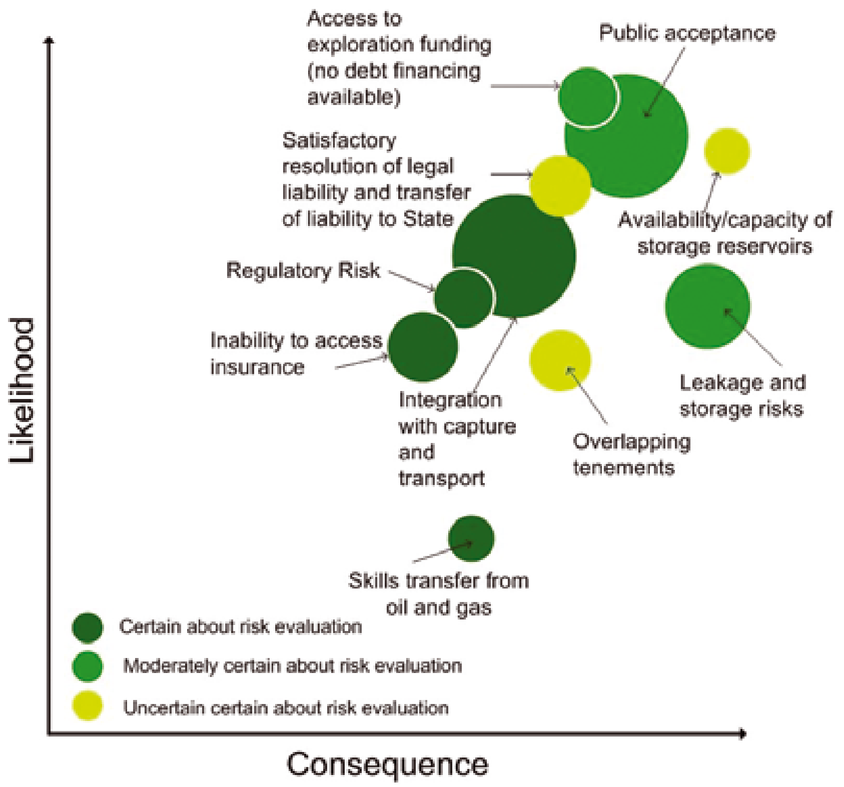
Continuing liability for the impact of the injected substances for a lengthy period following cessation of injection has also been frequently raised by project proponents as an issue of great concern.

To reduce risk in responding to this uncertain future, it follows that if investment is to be made at large scale, it should be made in those assets most likely to remain low cost and competitive in any future energy generation cost portfolio. This applies to the combination of both capital and operating costs per unit of energy delivered, not just the cost for the peak power rating of the facility[39]. It is also important for electrical system stability reasons to ensure that most of the new generating capacity has a high utilisation rate so that it provides adequate base-load energy delivery.

39 For example, a coal-fired power plant with a 1000 MW (megawatt) nameplate capacity that delivered energy to the grid 90% of the time would deliver ~7.9 GWh (gigawatt hours) of electrical energy in a year. Solar or wind power plants would need a 3000 – 5000 MW capacity to match this output of delivered energy. Solar or wind power plants can only generate power between ~20% to ~30% of the time (on average throughout the year) because the renewable fuel source (the sun or wind) is variable or intermittent. Delivering the same amount of energy annually as the coal-fired plant will require ~3 to ~5 times the nameplate capacity of wind turbines or solar power plant to be installed, with back-up energy generators covering times when the renewable fuel source isn't available. Adding energy storage into a solar or wind power plant significantly improves the capacity factor of these plants, but this requires additional capital investment for the storage sub-system and additional energy to compensate for efficiency losses in the storage system.

Project financiers attach high levels of risk to untested integration of process elements, and also to scale up to new capacity levels. In the case of CCS, there are several elements that need to come together technically for future commercial deployment at large scale. For electrical power generation, these are the power generator, the CO_2 capture facility, the pipeline, and the storage facility. The risks associated with the operability of this overall process stream at high utilisation factor and scale are at present too high for commercial investment at reasonable rates of return.

Figure 14: Risk Analysis – Storage



Capture, transport and storage will also need to be integrated contractually. Similar levels of complexity are dealt with in other industries such as petroleum, where suppliers, transporters and distributors interact. However, these relationships are based on experience that can be reasonably risked and accounted for contractually. To accelerate deployment of CCS, it is important that any differences presented by CCS are explored in the near term by industry and government so that opportunities for mitigation of risk are identified, and the contractual relationships and exposures are mapped and understood by all stakeholders.

These risks will diminish with the first successful commercial-scale demonstrations of the integrated CCS process for power generation. There is currently very little appetite, if any, for commitment of private funds to first-of-a-kind, integrated CCS operations.

Policy uncertainty and carbon price risk were identified as a key factor in investors' perception of risk for projects that required returns on assets over several decades.

Large scale investments are required to reduce costs through economies of scale, but this creates an exposure to the risk of technological obsolescence during the life of the project.

If investment is to be made at large scale, it should be made in those assets most likely to remain low cost and competitive in any future energy generation cost portfolio.

Successful operation of a fully integrated CCS process at large scale will have the greatest beneficial impact on investors' perception of risk for CCS projects.

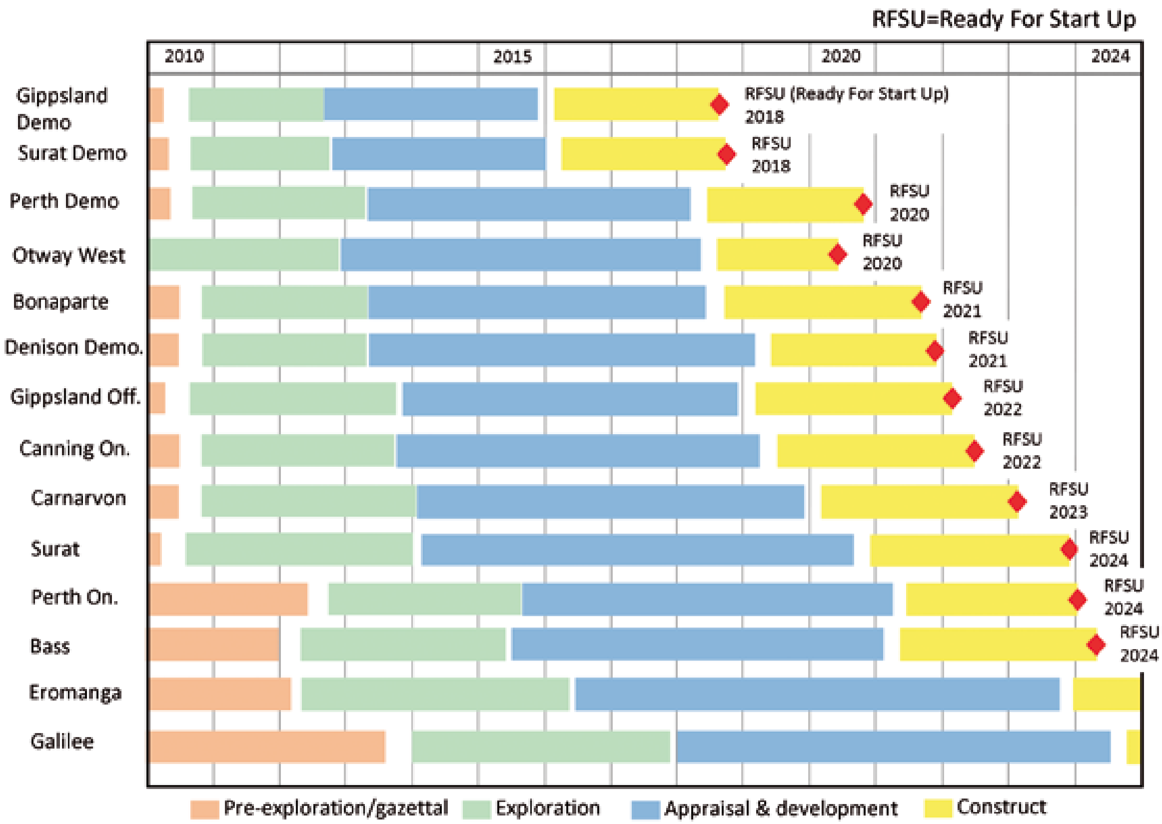
8 TIMING

It is the experience of the pipeline industry that the projects at either end of the pipeline are more consequential to the overall project timeline than the pipeline itself. For CCS projects, it is considered the geological storage sites will need the longest preparation time in terms of extensive exploration effort.

Overall, the Taskforce has determined that the timeframes for commercial deployment of CCS technology are long and significantly depend on the exploration and appraisal phases of the development timeline[40]. Basins that are well known geologically can be developed more quickly than those with poorly known characteristics. However, in those basins with insufficient information to allow the release of acreage for competitive exploration, a pre-exploration phase of 2–3 years could be needed.

The Taskforce has examined the time required to mature a site for storage (Figure 15). If it is assumed that the storage construction phase is 2–3 years, and that legislation is in place by end-2009 in order to allow release and award of acreage to storage explorers by Q3 2010, then the elapsed time to mature an aquifer storage site from commencement of exploration to commencement of CO_2 storage at large scale could be 10–13 years, i.e. 2020 to 2023.

Figure 15: Timing from pre-exploration to commencement of storage operations for likely storage basins and demonstration areas



40 Accelerating broader commercial deployment of CCS will require reductions in the cost of capture through technological development, and this involves similarly long timelines.

For depleted gas and oil fields, where there is usually abundant seismic data, wells and production history, the risks associated with storage can be evaluated and understood in a relatively short time frame, i.e. by 2016. The earliest time that aquifer storage could be available for use by demonstration capture projects is 2018. Projects that have already started an evaluation process may be able to achieve an earlier result.

Smaller sites (i.e. with smaller annual storage capacity) are relatively quick to develop (e.g. demonstration sites, Otway West, and Bonaparte) while large storage sites take considerably longer (e.g. Surat, Eromanga). Exploration and appraisal of offshore basins is accelerated by the early acquisition of 3D seismic (which is relatively low cost and fast offshore).

The pre-exploration phase could take 2–3 years to complete in those basins with insufficient information to allow the release of acreage for competitive exploration. To prove up storage reservoirs to match future needs, work therefore needs to begin immediately. It is now generally recognised within industry that developing adequate confidence in storage capacity and the resulting total cost for capture, transportation and storage is the critical driver of timelines for the proposed 'early mover' 'flagship' projects. However, acceleration of broader commercial deployment of CCS will require parallel activity to establish and improve the economics of capture technologies.

Parallel activity is also required to develop assurance and expertise for decision makers determining the design, and approval criteria, for CO_2 pipelines. This work needs to begin today, so that when firm pipeline proposals are developed later in the CCS project development process, regulatory decisions can be made efficiently and effectively.

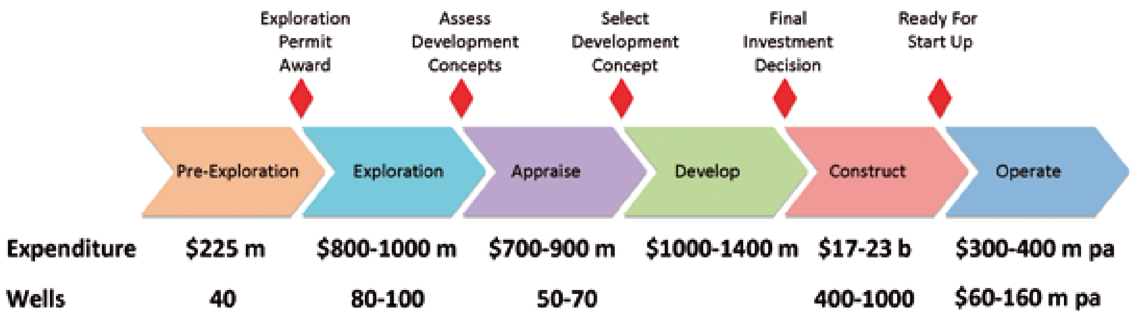
The availability and cost of services and materials are influenced by both domestic and international activities and markets, which are typically cyclic. Competition for resources could come from widespread international deployment of CCS, increased petroleum industry activity, or more locally, extensive development of the coal seam methane (CSM) industry in Queensland. This could potentially delay power generation CCS projects for many years.

9 COST AND SCALE OF THE CHALLENGE

The cost associated with the explore, appraise and develop phases for CCS is estimated to be in the order of $6 billion, split roughly equally over the three phases. This level of investment would be required to explore and develop storage sites for Australia's major hubs and to also progress up to four demonstration sites. The level of drilling and seismic activity is estimated to be in the order of 130 exploration wells, 100 appraisal wells, and acquisition of 60,000 km of 2D seismic and 14,000 km^2 of 3D seismic.

The full storage "value chain" from the eastern seaboard is shown in Figure 16 below.

Figure 16: Value Chain for Storage Development – Eastern Seaboard[41]



The pre-exploration costs represent about 25% of exploration costs. Investment in storage prior to FID (the point at which a storage and transport operator decides to invest in building facilities) is $2.5 billion, which is equivalent to about 15% of the final transport and storage capital investment. This pre-investment has not been included in the estimates of storage tariffs. However, sensitivity analyses show that these costs increase the tariff by approximately 12%.

Benchmarking this activity against the Australian oil and gas industry activity level suggests that this is generally achievable in a reasonable timeframe, with the exception of onshore seismic acquisition, which would represent a dramatic increase over current levels. It is important to note that CCS activity would be in addition to ongoing oil and gas industry activity, and so increase demand for similar resources.

An assessment of the people and skills required during the exploration to development phases indicates a sustained requirement for around 200 geoscientists, petroleum engineers and engineers over the period from 2011–2020. This ramp-up of staff cannot be built from the new graduate market, but will need to be attracted largely from the oil and gas industry. Some skills such as reservoir engineering, inorganic geochemists, geomechanics / structural geologists and production technologists / completions engineers are in short supply. This estimate does not include drilling, seismic and other contractor services staff.

There is currently only ~300 km of steel pipeline greater than 36" in Australia, comprising five pipelines, two of which are 104 km long. They are all proprietary pipelines, either being large trunklines for the North West Shelf project, or essentially short pipelines that act as long storage vessels for gas power stations. Including 34" pipeline, there is an additional 1,250 km, 1,198 km of which is the Moomba to Sydney gas pipeline. Periods of pipeline construction are evenly spread from 1969 to present.

This contrasts rather starkly with the projected future pipeline requirements for CO_2 transport. There is a future need for more than 5,000 km of 34–42" transport pipeline to be constructed on the eastern seaboard alone, from 2020–2035. This estimate does not include flowlines within the storage sites, which are estimated to be almost 5,000 km of smaller diameter pipe.

41 For explanation of elements of value chain, refer Glossary under 'Storage Development'

While there is likely sufficient industry capacity to construct this transport and distribution network, the capacity of pipeline manufacturers to construct sufficient large diameter (>34”) is a major concern and is likely to be a constraint, particularly if other countries are also deploying CCS. Currently there are many smaller scale manufacturers internationally, but their quality standards do not match Australian standards. However, they could be brought up to adequate standards and capacity with appropriate investment, and thereby meet demand earlier than relying entirely on greenfield construction.

The projected level of exploration and development activity associated with storage of CO_2 is achievable and benchmarks favourably with current levels of oil and gas activity.

The generally long distances between emissions hubs and storage basins means that more than 5,000 km of large diameter pipeline infrastructure is needed to transport CO_2. This is more than three times greater than Australia’s current inventory of large diameter steel pipeline.

10 ROLE OF GOVERNMENT IN SUPPORT OF GEOLOGICAL STORAGE OF CO_2

The geological storage of CO_2 is different from extractive resources in that it involves injecting, rather than removing, fluids into the subsurface to store them over geological time. This fundamental difference leads to important considerations in making areas available for CO_2 storage exploration and development.

Firstly, there is no custody transfer of the resource i.e. storage capacity. The pore space remains the Crown's, unlike minerals or petroleum where ownership is transferred at some stage of production. Secondly, there is a significant public benefit from reducing CO_2 emissions. Thirdly, there will be an ongoing need for regional geological oversight or monitoring in areas where there is injection, particularly where one or more parties are involved. Finally, the sequencing of access to the pore space may require additional consideration.

The evaluation of CO_2 storage must consider three major technical factors. The first and by far most important factor is containment of CO_2 i.e. that injected CO_2 remains stored and is not likely to leak back to the surface or into other subsurface resource areas. The second factor is the storage capacity of the area. The final factor is the injectivity or the rate at which CO_2 can be injected without impacting on the containment.

10.1 PRE-TENEMENT GRANT

When issuing rights for the first time in an area for conventional extractive resources, the primary considerations are the cost of extraction, offset of investment risk, and the environmental impact of development. By contrast, in CO_2 storage, there must be a broad and clear understanding of the parameters for optimisation of the resource. The pore spaces and their spatial distribution and "interconnectedness" need to be understood to ensure that the site sequencing for injection does not substantially reduce the ultimate storage potential of the basin. It is typical in most resource exploration that the best or largest resource is explored first. For CO_2 storage, however, meeting threshold criteria (e.g. proximity to sources, access, etc.) may take precedence over accessing the best storage.

Prior to release of areas, existing and potentially new geological data needs to be assessed to determine fundamental questions associated with the presence and distribution of seal and porous (reservoir) rock. Secondary parameters to be evaluated include the existence of suitable trapping mechanisms, such as in aquifers or depleted oil or gas fields. There is an expectation that areas will not be made available that have little or no prospect of effectively storing CO_2.

Non-geological factors will also need to be taken into account including community stakeholders, source sink matching, infrastructure, land use, existing tenements, and other resource occurrences. Additional work is also required in jurisdictions where there is a potential for resource conflict. This includes understanding the fluid dynamics of potential storage basins involving oil, gas, potable and saline waters.

Simulation modelling of the CO_2 plume would assist in defining minimum acceptable size of tenement where the basin geometry or structure does not define the limits of migration. Alternatively, large sized initial tenements may be defined that will reasonably contain the anticipated volume of CO_2.

10.2 POST-TENEMENT GRANT

There is a strong need for ongoing regional geological assessment of the impacts of injection during the course of the life of an injection program, as well as for an area that has been retired from injection. This need again differentiates carbon storage from the hazard and safety oversight in more conventional extractive resource exploitation which largely requires engineering expertise to ensure public and worker safety.

The cumulative impacts of injection will need to be considered from one or more injection sites, particularly if more than one injecting party is involved. Identifying the CO_2 source, as has been advised by previous research, will also be important in ensuring "accountability" for CO_2.

Monitoring areas near the limits of basins should mitigate against seal break-through. Geoscience data captured at the exploration, development and injection stages will inform future projects and long term risk assessments.

Skills development is required within the authorities, particularly in engineering, fluid migration modelling, and seismic techniques and interpretation. These skills need to be enhanced and accelerated to ensure the nation is storage ready.

10.3 ACCESS TO DATA

The impact of large scale injection of CO_2 needs to be understood across the whole of the basin. The ability to forecast and monitor the impact of injection is greatly enhanced by having the fullest possible information on a range of factors. In basins with multiple operators, information can be obtained from existing wells on a range of relevant factors. This is particularly the case for wells that extend to the same depths as those used for CO_2 storage, e.g. petroleum and geothermal wells.

While existing permit holders typically have advanced knowledge of their reservoirs, the available or publicly available basin data beneficial for CCS assessment and implementation is limited. This data is essential to the regulator, given the need for the regulator to develop a deep knowledge of the basin's geological framework, reservoir and seal distributions and connectivity, and hydrology, in order to optimise the basin's storage capacity. This is an issue faced internationally, not just in Australia.

It is important that both the new, increased need in the requirement for data for CO_2 storage management, and the commercial sensitivity of some of this data, is recognised. Data reporting and regulations need to be reviewed to ensure that CCS regulators are able to consult relevant data. The degree of release of data into the public domain should also be reviewed separately, as part of this discussion. It is essential that this review takes place in close consultation between industry and governments.

The Taskforce recommends that the Upstream Petroleum and Geothermal Subcommittee (UPGS) prepares a report on issues related to data management for regulators specifically relating to injection and storage of CO2, by the first quarter of 2010. Industry should be consulted a part of the report process. Recommendations should be made by the UPGSto the MCMPR in the first half of 2010.

The objective is that both governments and industry form a clear understanding of the data types and sources relevant to basin management for CO_2 storage, and government policy and requirements in relation to provision of this data.

11 COMMUNITY ACCEPTANCE

The Taskforce examined potential community concerns about carbon storage issues, and investigated potential approaches for addressing them.

11.1 POTENTIAL COMMUNITY CONCERNS

A workshop was convened with environmental NGOs (eNGOs), which sought to identify their position in relation to CCS. The participants expressed support for a portfolio approach to climate change mitigation, and not treating CCS as a 'silver bullet' or a competitor of renewable energy. Participants also expressed a need for government and industry to promote the urgency of climate change, and a portfolio approach to mitigation as the solution. This would help to also raise awareness of the need for action at the general public level. There was concern that some stakeholders would not appreciate the scale of infrastructure required for CCS, or the timelines involved in CCS projects. The findings suggest that information about CCS should be increased to reduce concerns about the technology, in a form that is accessible and easy to understand.

Media reporting of CCS since 2007 in most major newspapers, radio and television media was analysed. There was a fairly even balance of positive, negative, and balanced/neutral articles, but they rarely contained technical explanations. Recurring themes include: the importance of coal to Australia's economy and the consequential importance of CCS; that CCS is technically possible but needs financial support from government; that CCS investment diverts important funds from other mitigation strategies; and that CCS should be funded by industry and not by taxpayers. The findings suggest that a more proactive approach should be taken, by engaging journalists and mainstream media. CCS should be promoted as 'low emission' instead of 'clean coal', because of its far-reaching applications in non-coal industries.

The Taskforce also reviewed the increasing body of analyses and experiences relating to community concerns and communications in Australia and internationally. Opinions, concerns and awareness vary widely, between opposite extremes. In some instances, landholders have welcomed the potential for construction of CCS-related infrastructure for the economic benefits it provides. Conversely, some parties only consider investment in renewable energies, and appear unwilling to even consider any information describing a role for fossil fuels. More generally, the level of understanding of CCS technologies, or of any other energy generation technology, or response to climate change, is superficial. Ashworth[42] et al. found that acceptance grew strongly following provision of technical information in an open and transparent manner.

Some key issues or concerns that emerged from this review, which need to be addressed include:

Funding: There is concern that allocation of funding to develop low emissions energy technologies is disproportionately supporting coal-fired power, rather than renewable energy technologies. The Australian Government's announcement of the Clean Energy Initiative went some way towards addressing this concern.

Technology: Many people hold a belief in the efficacy of solar power and renewables as a solution for Australia, which is not matched by an understanding of the current capacity of these technologies to meet energy demand, and the full costs and risks of deploying these technologies, relative to alternatives. There is a need to convey information on the costs of any proposed technology, including CCS, relative to the costs of pursuing other alternatives. The evaluations currently being undertaken as part of the development of the Energy White Paper may provide useful data for dissemination.

Impact on power costs: Generally, there is limited understanding that introduction of low emissions energy technologies will make power costs in Australia more expensive. There has been widespread reporting of the view that the CPRS will have a negative impact on the economy and cause job losses.

42 Ashworth P et al. 2007, *An integrated roadmap of communication activities around carbon capture and storage (CCS) in Australia and beyond*, Report no. P2007/975, Centre for Low Emission Technology, Pullenvale

Factual, verifiable information on best estimates of costs forecasts need to be made available in a transparent manner as part of the debate.

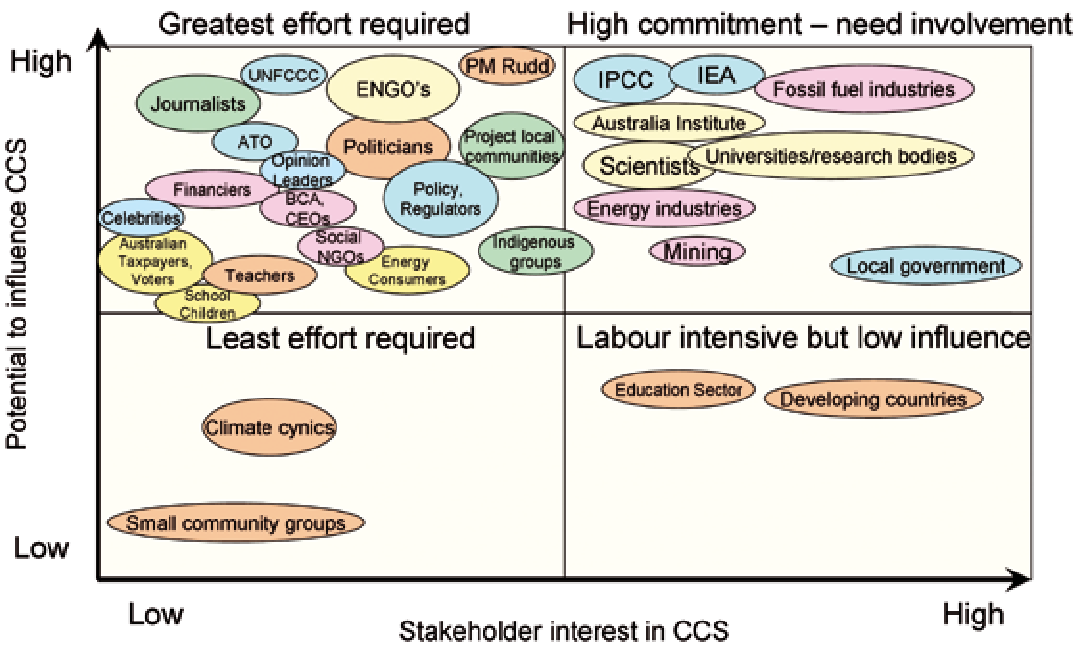
NIMBY (Not In My Back Yard): To date, project proponents in Australia have been successful in engaging with stakeholders that might be affected specifically by a project. In some instances, the project was welcomed for the economic welfare it provided. However, there are some instances overseas where projects onshore are meeting strong local resistance. There is a need for transparency on the risks relating to CO_2 pipeline construction and operation, and how these can be adequately and safely managed. Storage onshore will require a similar level of assurance. Storage offshore will not directly affect landholders, apart from the transport infrastructure.

11.2 RESPONSE

11.2.1 Stakeholder Engagement

The Taskforce investigated potential approaches to engage with influential stakeholders, as well as actions that would address community concerns more widely if required. A map and categorisation of stakeholders is identified in Figure 17. A more detailed breakdown of influential individuals or groups is provided in Appendix B. This table also specifies a suggested program for engagement for each stakeholder.

Figure 17: Map of key stakeholders for developing a communication strategy



11.2.2 Coordination

An engagement strategy needs sponsorship, funding and management to be implemented. A centrally controlled strategy for CCS communications in Australia seems unlikely, given the disparate and conflicted range of CCS stakeholders, and the need of each stakeholder to control its engagement with its audience. To date, individual project proponents have managed their interaction with their stakeholder group successfully. At the wider community level, statements on CCS have been made independently by, amongst others, governments, politicians, environmental NGOs, prominent individuals, the CSIRO and the CO2CRC. The Australian Coal Association (ACA) has invested substantially in developing a website and schools curriculum program. The CO2CRC has provided information on CCS in many forums for some years. The intention is also that the GCCSI plays an increasingly important role in CCS communications.

This *ad hoc* model might continue to be adequate, but the opportunity for coordination should also be evaluated, particularly if more widespread campaigns opposing low emissions fossil fuel technologies are introduced. It is therefore proposed that the Taskforce consult with its members and other CCS stakeholders to obtain their views on the development of a CCS communicators' forum, or similar structure, which will provide a coordination node for CCS in Australia. There is an opportunity to develop credible, verified and consistent messages; create a reference source to avoid duplication; and on occasions, and if agreed, coordinate a response to a specific event (announcement, overseas event etc). One of the key tasks of this group would be to develop CCS messages in the context of the whole portfolio of responses to climate change, and liaise with relevant groups developing other responses.

It should be emphasised that the proposal is to consult with CCS industry stakeholders on an optimal structure, not to recommend any particular outcome at this stage. The objective is to ensure all stakeholders are aware of the resources already available, and to provide an opportunity to discuss the effectiveness of different approaches and actions, both actual and proposed.

12 KNOWLEDGE GAPS AND PRIORITY RESEARCH AND DEVELOPMENT

R&D priorities have been developed in discussions with industry. Alignment of research efforts will be required across all Australian projects and activities (CO2CRC, ANLEC R&D, Energy Pipelines CRC), and international activities noted and involved as appropriate.

Pipelines: Research areas to be addressed prior to constructing a pipeline network for CO_2 transport include determining the state diagrams[43] for supercritical CO_2 mixtures from different capture plants; the modelling of the transport pipeline requirements for different pipeline scenarios and CO_2 properties in Australia; examining materials compatibility with the CO_2 mixtures expected in Australia; pipeline design and full scale burst tests.

Storage Efficiency Factor: Uncertainty in the storage efficiency factor results in a very wide range of carbon storage capacity estimates for Australia of 50 to 400 years. This uncertainty outweighs geological uncertainty by an order of magnitude. For the improved planning of national infrastructure, this uncertainty needs to be reduced through research into the individual storage efficiency factors of Australia's key basins.

Migration of CO_2 in the subsurface: Further research is needed on the migration and trapping of CO_2 in the reservoir over time. It is essential for public acceptance that a deep understanding of the CO_2 movement in reservoirs is demonstrated to allow reliable risk assessment. Current models need to be improved and more detailed and sophisticated methods need to be developed.

It should be noted that most of the understanding regarding storage efficiency and migration will come from calibration of modelling using site-specific project development experience.

Freshwater Aquifers: Further research is needed to assess the possible impact of CO_2 injection on fresh water resources and how the increase in pressure from injection may influence the overall basin both at the point of injection and regionally.

Monitoring, Measurement & Verification: Cost effective, reliable tools and technologies for CO_2 monitoring in different environments and conditions, particularly non-seismic methods, are needed. Research is needed to determine the best use of monitoring wells, especially for pressure measurement. Frameworks for environmental assessments of CCS activities are considered to be adequate[44], but may need to be reviewed as the knowledge base expands.

Operational issues: Some operational issues are already apparent that could be considered for R&D, such as the operability of the integrated capture, transport and storage system.

Outreach: There is clear scope for further social research on community attitudes to CCS.

43 Diagrams showing in what phase a substance or mixture of substances exists for any given temperature and pressure. If a substance changes phase, it may dramatically affect the operation of a pipeline.

44 The Environment Protection and Heritage Committee (EPHC), which reports to the MCMPR, adopted Environmental Guidelines for CCS in May 2009 which acknowledge that a new legal framework is not needed and that existing environmental assessment legislation and procedures are suitable for addressing CCS.

13 NATIONAL CARBON MAPPING AND INFRASTRUCTURE PLAN

The Taskforce has developed the National Carbon Mapping and Infrastructure Plan in order to drive the prioritisation of, and access to, a national geological storage capacity to accelerate the deployment of carbon capture and storage technologies in Australia.

There are six main elements to the Plan:

1. Implement a $254m, strategically phased, pre-competitive exploration program.
2. Release exploration acreage in the onshore Surat and Perth basins as soon as possible in addition to those offshore areas released in March 2009.
3. Develop several transport and storage demonstration projects at a significant scale of 1 Mtpa CO_2 or more, which are integrated with CO_2 capture demonstration projects.
4. Support pipeline infrastructure development that is designed to incorporate economies of scale, competitive long term costs and uncompromising safety standards.
5. Identify and recommend incentives to drive competitive CO_2 storage exploration over the period 2010–2017, in concert with other policy and fiscal settings established to support deployment of low emissions technologies, including CCS.
6. Develop and implement a Communication Strategy.

13.1 PLAN ELEMENT 1: PRE-COMPETITIVE EXPLORATION PROGRAM

The Taskforce has defined a coherent, three phase pre-competitive exploration technical work program that is required to make the decisions needed for acreage release. Outcomes of earlier phases will potentially modify specific elements of subsequent phases. The Phase 1 program costs $84 million. Phase 2 would cost a further $46 million, and the Phase 3 activities would cost $124 million. The total pre-competitive exploration program of $254 million is far in excess of the original $50 million provided by the Commonwealth. It should be noted that this funding was proposed by the Commonwealth on the basis that both industry and state governments would also make financial and other contributions to the program.

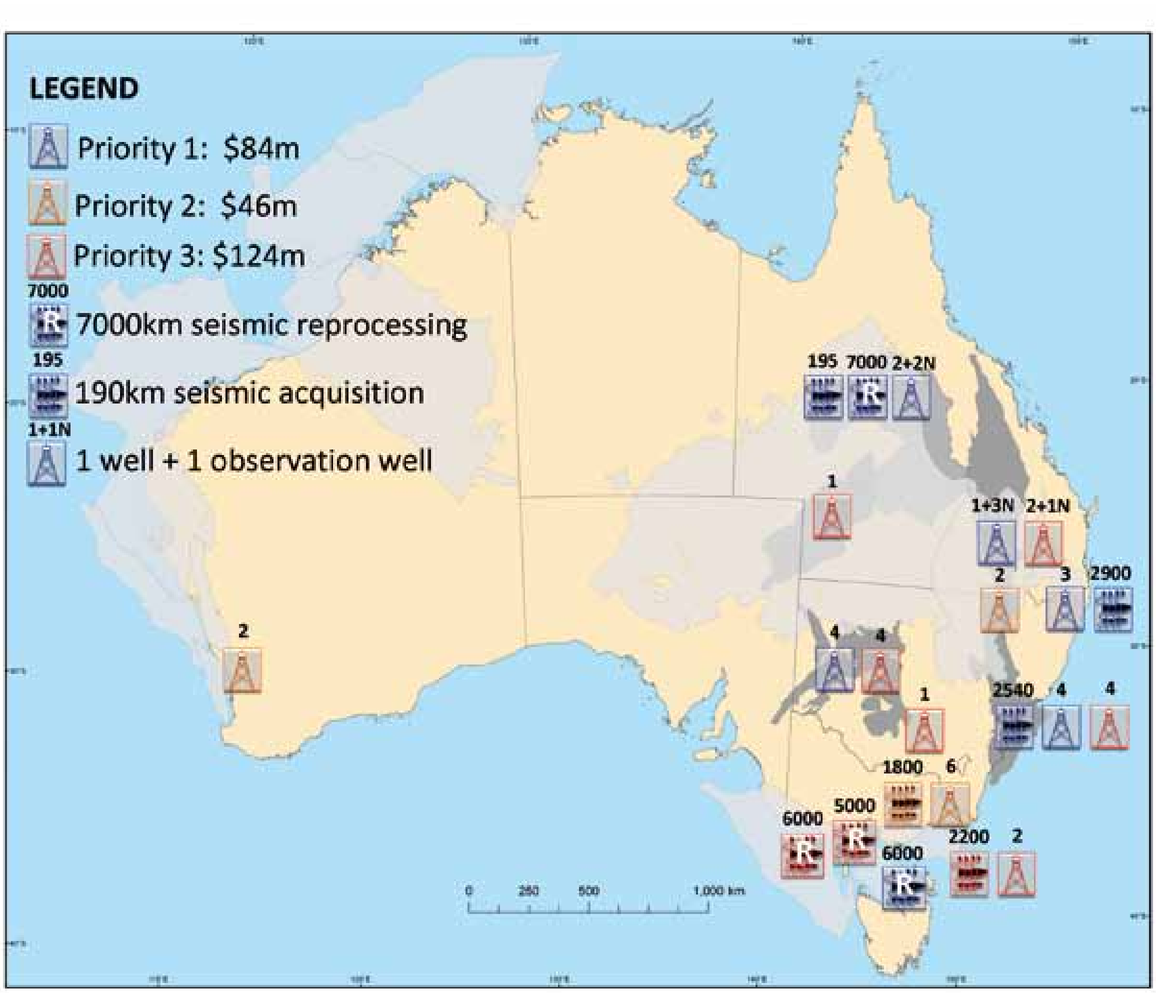
The program, which has already commenced in some jurisdictions, is expected to be implemented over five years.

The objective of pre-competitive exploration is to establish that a basin is likely to have sufficient storage potential to justify release for efficient commercial exploration and development, and to ensure that enough is known about the basin to release acreage in a way that optimises the storage potential of the basin.

In terms of storage capacity, Australian basins have been ranked as suitable to possible. The amount of available data and knowledge of these basins is variable. In basins with oil and gas production, data and knowledge of the basin's architecture and geology is generally much better, although even in these basins, the focus of the oil and gas industry is on the structural high trends and not in the deeper parts of the basin that may be attractive for CO_2 storage.

There are significant differences between CO_2 storage and oil and gas operations. CO_2 storage areas are expected to be large and the effects of pressures produced by injection of CO_2 will occur over even greater areas. CO_2 is likely to be mobile for some time during the storage process and in order to release acreage, authorities will need to have a much greater understanding of the basin's architecture than would be required for oil and gas activities. Pore space is the main asset in a basin. Authorities will need sufficient information to create basin-scale reservoir models and simulations to understand each basin's storage capacity and to inform strategies for maximising the CO_2 storage asset. The containment of CO_2 will need to be well understood. Also, the potential impact of carbon storage operations on other resources needs to be understood (e.g. basin use for extraction of other hydrocarbons, storage of gas, fresh water, geothermal heat, coal seam methane extraction, underground coal gasification, etc).

Figure 18: Pre-exploration program



Data quality from pre-competitive work needs to be sufficient for informed decision-making in all of these issues, with a balance between adequate knowledge and regulatory and legal requirements. There needs to be a focus on pre-competitive work at the regional scale level by governments. The "prospect" scale is where private industry operates.

Future work includes developing a comprehensive GIS (Geographic Information System) database with a standard format to ensure that ongoing work is sustainable and usable in the future. Existing geological data needs to be accessible through a national basins database that is established through the participation of the Commonwealth (Geoscience Australia), state and NT governments. Funding (~$3 million) is recommended to develop this distributed database. A key output of this work will be national GIS coverage. GIS themes will include seismic data, well data, rock properties, and fluid properties. Such a database will have application for resources of an entire basin, from potable water at shallow depths, to oil, gas and geothermal sources at increasing depths. This holistic approach is necessary to anticipate and manage any resource conflict.

New work programs totalling around $250 million, designed to provide pre-competitive data for both industry and resource management by jurisdictions, should either commence as soon as is possible, or be accelerated, to make Australia storage ready. The pre-competitive exploration program has been determined and prioritised by the state government geological surveys and the Geoscience Australia using both the strategic and technical criteria i.e. the basin is likely to be required for storage in the near to medium term; there are strategic infrastructure decisions (e.g. pipeline decisions) that depend on the basin's storage potential; there are potential resource conflicts where pre competitive information is required to understand better the basin's viability; and, the basin may be suitable for carbon storage but there is insufficient data and knowledge of the basin to allow an informed release of acreage. The work programs identified should be undertaken more or less concurrently, and be coordinated to achieve economies of scale: for example land seismic acquisition programs and/or onshore drilling programs.

Basins that are relatively well known and already under consideration for large scale demonstration are not considered for first rank pre-competitive exploration, unless market testing reveals that they do not attract private investment. Basins currently under release for tender were ranked lower, but may be re-evaluated once the response of the market to the tender is known.

The Phase 1 program costs $84 million. Phase 2 would cost a further $46 million, and the Phase 3 activities would cost $124 million. The later phases will be modified according to the results obtained from earlier programs. The total pre-competitive exploration program of $254 million is far in excess of the original $50 million provided by the Commonwealth and would need to be augmented by additional funding from other sources.

The Taskforce recommends that a Review Committee be established to consider the pre-competitive exploration programs across the jurisdictions, charged with:

- optimising the expenditure on the programs by aligning them in timing and location (i.e. reducing the mobilisation costs and possible obtaining savings through multi-project programs);
- updating the priorities of the program in light of near term results from exploration programs and tendering of areas; and
- reporting back to Government (through the Ministerial Council) on the results, their implications and expenditure.

It is important that in reaching its decisions, the Review Committee continues the consultation process with CCS stakeholders, which has been a key element of the work of the Taskforce. Further work is required to determine the most suitable structure and process by which effective consultation with stakeholders, and non-government funding participants, can take place.

The Taskforce also recommends that high risk projects should be "gated" and additional expenditure be released subject to the results from the initial exploration projects.

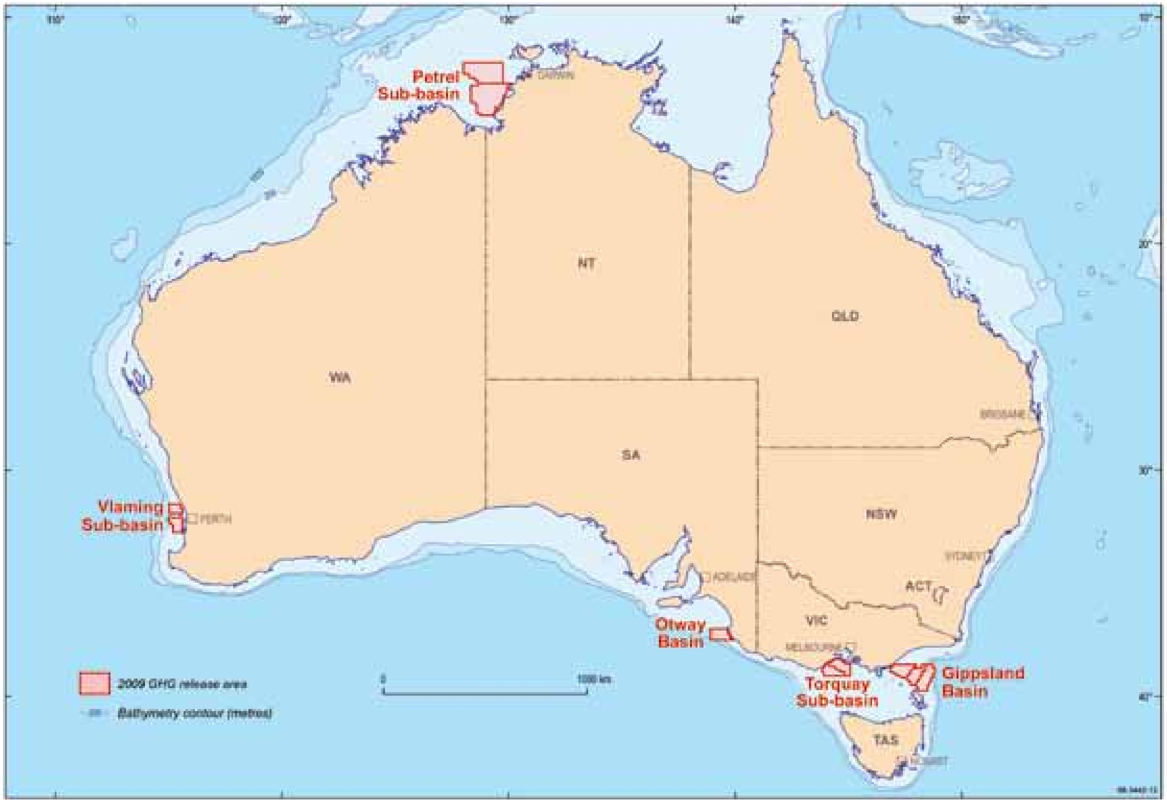
Geological emissions data and emissions data has been generated by the Taskforce and will be generated by the exploration program. It is very important that this data be captured in a database.

13.2 PLAN ELEMENT 2: EXPLORATION

Large-scale, commercial carbon storage capacity may be needed as early as 2020. However, the lead time to develop a large capacity, aquifer storage site from commencement of exploration to commencement of CO_2 storage at large scale has been estimated to be 10-13 years. Hence exploration needs to start by 2010 if timeline targets for significant CCS deployment are to be met.

In March 2009, the Commonwealth Minister for Resources and Energy announced the release of ten offshore areas for the exploration of greenhouse gas storage areas in the Gippsland (Vic), Torquay (Vic), Otway (SA), Vlaming (WA) and Petrel (NT) basins (Figure 19).

Figure 19: Greenhouse gas assessment areas – acreage release



The capacity estimates for the Gippsland, Otway and Petrel basins and their proximity to emissions hubs make these important exploration prospects. The Gippsland Basin has the highest technical rank for storage basins and the lowest transport and storage cost of all the basins examined by the Taskforce and the commencement of exploration here is essential if the Latrobe Valley hub is to evolve successfully. Storage capacity estimates for the Vlaming and Torquay basins suggest that they are small and more suited to pairing with single source emitters (in the order of 1-5 Mtpa).

In considering the need for exploration, the Taskforce has identified that the release of acreage is required urgently if large-scale storage capacity is to be available by 2020-25. Acreage release is required over the Surat for emissions from the Eastern Surat, and potentially from the Hunter Valley, if closer storage reservoirs are not identified. Acreage release is also required over the onshore Perth basin for the Perth / Kwinana hub.

There are several challenges facing the commencement of exploration in 2010. The first is having legislation in place to allow exploration and development to proceed. Jurisdictions covering the offshore Commonwealth waters and onshore Victoria, Queensland, and South Australia have established legislation. Regulations and guidelines to support this new legislation are under development and are expected to come into force during 2009/10. Western Australia and New South Wales are yet to put legislation in place. The Northern Territory and Tasmanian Governments do not anticipate any storage requirement within their jurisdictions (onshore), and so are taking no action.

The second and bigger challenge is the incentive for explorers to take up acreage when the nature and degree of volatility in any future carbon regime is uncertain. Deployment of CCS will be accelerated by early complementary investment by industry and government, rather than reliance solely on government 'pre-competitive' programs.

The CPRS is intended to start in mid 2011 (after exploration should have started) and a carbon price of $10/tonne will apply between 1 July 2011 and 30 June 2012. From 1 July 2012, businesses covered by the scheme will need to purchase permits at the prevailing market price. Under CPRS-5, the cost of carbon is not projected to reach levels that support commercial storage operations until around 2020–2025.

This means that the explorers taking up acreage in 2010 would be risking hundreds of millions of dollars to explore for storage in a carbon regime that is not proven, nor commercially attractive. Conversely, if the explorer waits until there is confidence in the carbon regime and pricing (potentially until around 2017 or five years after the market opens), storage would not be available until 2025–2030.

It is likely that commercial exploration for carbon storage must take place over the period 2010–2017, if timeline targets for significant CCS deployment are to be met.

To this end, the Taskforce have begun to examine options that could incentivise exploration. The *Petroleum Search Subsidy Act* (PSSA), which was active from 1957 to 1974, has been examined to see whether a similar scheme would be suitable to promote the exploration for the deployment of carbon storage exploration. The research shows that the PSSA was effective in that it stimulated exploration activity, reduced the cost for explorers, and gave the government rights to data and samples. Any such scheme would need to look carefully at what activities are actually subsidised and how government ensures that its money is being spent on useful exploration without getting into the business of the explorers.

There are alternative options that could also assist in narrowing this financial gap. For example, immediate depreciation write off for capital investment in low emissions technology could make the upfront investment decisions in these projects more attractive.

> The Taskforce considers that the release of acreage over the onshore Surat and Perth basins is a high priority if timeline targets for significant CCS deployment are to be met.
>
> Legislation to allow exploration in onshore Western Australia, New South Wales and Northern Territory needs to be established. Consistency of exploration and storage legislation in different jurisdictions to facilitate investment should be encouraged.
>
> The Taskforce recommends that options for carbon storage exploration incentives over the period 2010–2017 be further explored and evaluated by the Taskforce with a firm recommendation to be made to the Minister for Resources and Energy by the end of the first quarter, 2010.

13.3 PLAN ELEMENT 3: DEMONSTRATION

The volumes to be stored annually in Australia are large (~200 Mtpa) and some storage basins may need to store up to 50 Mtpa. If further demonstration of storage is to be successful, it needs to prove that the technology can be applied at a significant scale (greater than 1 Mtpa). A range of CCS projects associated with petroleum projects now exist internationally at this level, some operating for over a decade[45]. A portfolio of demonstrations is required to demonstrate different aspects of CCS technologies, and this could involve smaller scale projects according to the specific target of the demonstration project. However, the Taskforce was given a strong message from potential investors and

45 Sleipner 1 Mtpa since 1996; Snohvit 0.7 Mtpa since 2008; In Salah 1.2 Mtpa since 2004; Weyburn Midale 1.8 Mtpa since 2004

the financial community that only demonstration at large scale will be sufficient to build the confidence and knowledge needed to invest in full scale storage.

The aversion of the investment and financial community to the first-of-a-kind risks associated with initial power-related CCS demonstration projects indicates clearly that these projects will require large amounts of public funding to proceed. It is also clear that the amount of public funding required is closely related to the perceived risks for private investment, and that governments can potentially reduce the requirement for public funding by actively striving to manage and reduce first-of-a-kind project risks.

It is also important for community acceptance that the first demonstrations of storage technology are a success i.e. that CO_2 is successfully and safely stored, and that it does not leak. The best prospect for this is in depleted oil and gas fields, where the geological trap integrity is more likely. The depleted gas and oil fields of the Surat and onshore Perth basins are potentially the most attractive candidates, although they have low storage capacity. Storage sites in existing fields have added attractiveness in that they could be developed relatively quickly (possibly by 2015–16), due to the high existing knowledge of the reservoir characteristics. Site development in these areas would, however, need to include thorough investigation of the integrity of existing wells.

Aquifers in basins with high carbon dioxide storage potential present an attractive alternative. The Taskforce considers that storage sites of ~3 Mtpa capacity could be available in the Gippsland, Surat and onshore Perth basins by around 2018. These locations have the advantage of being onshore (or close to shore) and they are proximal to potential capture demonstration sites, hence the transport and storage costs are low.

The demonstration projects need to link capture, transport and storage elements so that the risks associated with the operability of the overall integrated system at high utilisation factor and scale can be understood and mitigated. This is a significant aspect that needs to be resolved to support future successful financing of commercial projects.

The deployment of CCS technology in Australia, at large scale, could first be achieved by the Gorgon Project in north-western Australia. The Gorgon LNG Project, which aims to store some 3.5 Mtpa of CO_2 in reservoirs under Barrow Island would be the largest storage project in the world and would represent a critical step towards large-scale commercial storage of CO_2. The project is expected to be sanctioned in Q4 2009.

Aquifer storage sites of ~3 Mtpa capacity could be available for demonstration projects by 2018. Projects that have already started an evaluation process may be able to achieve an earlier result.

> Demonstration projects need to be of a significant scale (greater than 1 Mtpa) and they should link capture, transport and storage elements so that the risks associated with the operability of the overall integrated system can be understood and addressed.
>
> The Taskforce recommends that proposals for integrated demonstration projects at a scale greater than 1 Mtpa (i.e. capture, transport and storage) in the Gippsland, Surat and Perth basins should have highest priority for funding, given the expected importance of these basins in establishing Australia’s first storage sites and hubs.
>
> Demonstration projects should be designed to develop a better understanding of storage, including storage efficiency, migration behaviour and monitoring techniques.

13.4 PLAN ELEMENT 4: INFRASTRUCTURE

Capturing economies of scale: The economies of scale offered by combining multiple sources for transport in a large size pipeline are significant and could potentially reduce deployment costs for CCS substantially. However, investing today in an 'oversized' pipeline involves significant risk, as the asset may ultimately be underutilised, or worse, stranded, during its working life. The Taskforce therefore recommends provision of support for 'oversizing' of pipelines, following careful analysis of likely future loads. This analysis needs to be conducted at a 'hub' level, which considers all likely sources of demand for transport. There are a range of infrastructure support models already in place. The mechanism would need to be considered on a case by case basis. Government support has been common in the development of Australian pipeline infrastructure[46].

Retaining easement options: Successful deployment of CCS in demonstration hubs will enable investors and governments to consider substantial capital investments in long distance 'backbone' pipelines. If more local storage is unable to be identified, these pipelines could link a range of emissions sources to distant storage reservoirs. Delaying a decision on construction of large scale pipelines will also provide more certainty in relation to competitive technologies and the operation of the carbon pricing regime, which drive the projected location and quantity of emissions requiring transport. In the interim, it is vital that the easements or pipeline routes that could be used in the future are not compromised by uninformed planning and development. The Taskforce therefore recommends that governments consider in detail potential pipeline routes and easements for future CO_2 pipelines, and incorporate these routes into their planning and approval processes. This will require integration across several levels of government, and liaison with the Australian Energy Markets Operator (AEMO).

Building confidence: Australian communities need to be confident that CO_2 pipelines will be safely managed. This confidence is built at several levels, including development of: i) an accurate and reasoned understanding of the risks and how they can be managed, ii) confidence in the capacity of regulators, and iii) confidence that industry standards provide suitable risk management requirements. These elements will need to be developed in an Australian setting, drawing on the substantial experience and knowledge developed globally and through existing Australian practice.

The Taskforce recommends that a report detailing Australian legislation, regulations and codes affecting deployment of CO_2 pipelines be commissioned by the Taskforce for completion by the end of the first quarter, 2010. This report will also seek to identify any actions required to ensure regulatory management systems relating to deployment of CO_2 pipelines are in place in time to match the requirements of project proponents. This report will complement the report commissioned by the Australian Pipeline Industry Association (APIA) Research and Standards Committee[47] providing a gap analysis for the AS2885. The Taskforce recommends that these reports then be considered by the relevant regulators from each jurisdiction, and that a work program of actions and milestones for outcomes be confirmed by the end of the second quarter, 2010. The MCMPR CCS Working Group[48] is likely to be a suitable vehicle for this coordinated action by governments.

46 Kimber M.J. 2009, *Development of Australia's Natural Gas Resources: A Possible Model for Carbon Capture Transportation and Storage*, report prepared for the Carbon Storage Taskforce, Department of Resources, Energy and Tourism, Canberra.

47 APIA Research and Standards Committee, 2009, *Gap Analysis for Use of AS2885 for CO_2 Pipelines, Research Project APIA 08–09* report prepared by Venton and Associates, Peter Tuft and Associates.

48 The MCMPR CCS Working Group provides a forum for discussions between jurisdictions within Australia on CCS policy, in order to support consistency in regulatory frameworks.

13.5 PLAN ELEMENT 5: POLICY AND FISCAL SETTINGS

The Taskforce considered the nature of any market failure and the level and nature of any required government intervention to address such matters.

Market Drivers

Carbon dioxide capture, transport and geological storage adds a cost to operations currently venting the carbon dioxide into the atmosphere. The activity does not generate a revenue stream, but instead imposes very substantial costs and potential liabilities.[49] The only current commercial incentive to deploy CCS is the perception that it will form part of a company's social licence to operate. That is, that development approval, or a continuing licence to operate, may not in future be granted for plants emitting CO_2 without (or even with) some form of offsetting activity. Many companies seek to operate in a manner that minimises their environmental impact, but the scale of investment required for CCS is typically too great for individual companies to make unilaterally. This is particularly the case for electricity generators, which operate on tight marginal returns in a highly competitive market.

Current Policy Status

The Australian Government recognises the potential future cost of the impacts of climate change, and the scale and timelines of the required response. The most significant current policy setting is the introduction of a system that creates a price for emissions and simultaneously enables trading of emissions exposures, using emission permits. The intent of the CPRS is to create a market mechanism that leads to the deployment of the lowest cost mechanisms for reducing emissions. Other important policy settings include the continuing imposition of a mandatory technology target for renewable energies (MRET), which spreads the resulting increased costs of energy generation across the NEM, and capital grants for developing 'first-of-a-kind' low emissions technologies under the Clean Energy Initiative, announced in the 2009 budget. This includes allocation of capital grants for demonstration 'flagship' projects, including CCS operations. The Government has also created and funded the Global Carbon Capture and Storage Institute (GCCSI) which is mandated to facilitate the G8 development goal of 20 'commercial scale' CCS flagship projects internationally by 2020.

Investment Appetite

Investors seek certainty regarding the factors that put their investment at risk, and the mechanisms for risk mitigation or avoidance. CCS projects at commercial scale will require commitments of many billions of dollars to plants expected to generate profitable returns for 30 to 40+ years. Currently, these investments face two primary and interrelated risks – an unknown future carbon regime and cost, and technological obsolescence. In this environment, there is little, if any, incentive for most companies to individually allocate a significant proportion of their capital to developing CCS projects today.

Nevertheless, investment can still take place when risks are high, if the return is considered adequate. This is clearly the case for CCS, where deployment of this technology could contribute significantly to reduction of global emissions, while continuing to use coal and gas to generate energy without generating significant emissions. The potential industry size is huge, and thus presents an attractive target for companies supplying goods and services to the industry. These factors drive the composition of the current investor group, which comprises governments, very large corporations, fossil fuel industry groups, generator equipment suppliers, and oil and gas operators and service providers.

49 In Australia, it appears likely that there will be only limited opportunity to use captured CO_2 to enhance oil recovery and so generate revenue. There are some processes that utilise CO_2 to generate other products, but these do not typically contribute ultimately to the avoidance of emissions.

Accelerating Australian deployment of CCS

Given these current policy settings, and the investment climate, the following actions are recommended:

Create a consistent 'carbon regime': 'Carbon regime' refers to the portfolio of policy instruments that seek to modify behaviour in relation to carbon dioxide emissions. The key driver for lowest cost price discovery will be the CPRS, but its impact will be modified if other instruments are retained or introduced, such as mandated technology targets (e.g. MRET), or emissions controls specified in licensing processes. Investors are seeking certainty regarding the total regime, not just one element of it. It is important to also note that it is the perception of what the carbon regime will be over the next 2 – 3 decades that affects investment decisions, not just the carbon regime anticipated in the near term.

Fund demonstrations: Fund and identify opportunities to mitigate risk of 'first-of-a-kind' demonstrations that are at commercial scale and that integrate capture, transport and storage. This is a very effective use of government funds as it builds confidence with community stakeholders and investors in the technology and operability of CCS, which potentially leads to commercial deployment.

Select lowest cost, large scale hubs first: Direct support to hubs that appear likely to yield lowest cost outcomes for long term, large scale deployment of CCS. This gives the hub the highest chance of surviving any future competition and so reduces investment risk. This approach is more likely to accelerate larger scale deployment of CCS, as it concentrates limited resources to a solution that supports a larger outcome. The form of support requires more detailed investigation. Provision of capital grants and the introduction of the CPRS will be the key drivers.

Seek economies of scale: Support hub design that accommodates expected future load. For example, a government could act as a "foundation customer" to underwrite large diameter pipeline investments with a take or pay contract (as governments have done for gas pipelines).

Build on success: Successful demonstration of lower cost hubs will build confidence to make large scale investments such as long distance 'backbone' pipelines to link distant emissions hubs. Investment in these pipelines prior to demonstration using lower cost alternatives is not recommended at this stage.

Place highest priority on developing storage reservoirs: The CCS industry recognises that without confidence that a suitable storage reservoir can be utilised, investment in capture or transport facilities is of limited or no purpose. It is also recognised that developing adequate levels of confidence in a storage formation is likely to consume the largest amount of time in typical CCS project development. **Exploration programs must therefore commence immediately to meet the Government's deployment timeline targets**. Despite this imperative, there is little, if any, commercial incentive today to invest the substantial capital required. In the absence of a strong market signal, governments therefore have a key role in accelerating exploration activity. This may take two forms:

i) Increase funding for acquisition of 'pre-competitive'[50] data. The Taskforce has identified a prioritised program that supports a portfolio development approach in Australia. Importantly, this program is 'gated', that is, the program of activities proposed in the initial program will be confirmed, amended, or cancelled according to the interpretation of the results of earlier activities as they are received.

ii) Stimulate and accelerate exploration activity by private operators. This action needs to be put in place from around 2012 to around 2017, by which time investors should start to have confidence in the carbon market and future prices. There are a number of mechanisms that could be used to achieve this outcome[51]. The Taskforce recommends that the specific mechanisms for supporting private sector exploration be examined in more detail.

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50 Data acquired for public dissemination, issued to encourage bidding by exploration companies for land over which they will be granted an exclusive exploration right.

51 For example, the *Petroleum Search Subsidy Act 1959* enabled subsidies for exploration well costs until 1973, by which time the private sector had strong interest in Australia as an exploration target. The drilling cores obtained from this program form the basis of Geoscience Australia's geological database for Australia.

13.6 PLAN ELEMENT 6: COMMUNICATION

Deployment of CCS in Australia relies on community acceptance. It is important that information on CCS is presented in an open and transparent manner through trusted channels. It is equally important that communications on alternative responses to climate change and low emissions energy sources provide similarly full information on what each response can deliver, the risks and likelihood of successful deployment and what it will cost. Any CCS communications activity needs to be delivered in this context.

The CCS industry comprises a disparate group of stakeholders. To date, communications have been on a mostly independent, *ad hoc* basis. This may remain the most appropriate model, but there may also be an opportunity to avoid delivery of conflicting or erroneous information, and to avoid duplication of effort. A highly centralised coordinating body directing a single message is not recommended, as it is unlikely to satisfy the requirements of every stakeholder.

The Taskforce proposes instead that CCS industry stakeholders are consulted for their views on the most effective structure to enhance communications for CCS deployment in Australia. Consideration could be given to a network, such as a CCS Communicators' Forum, but no particular structure is being recommended prior to wider consultation. The Taskforce would deliver the outcomes of this consultation to its members and stakeholders prior to year end 2009, with the intention that a recommended structure and management plan be put in place in the first quarter of 2010.

A need for assurance that CCS deployment will be safe and secure is the community concern most often heard. Pipeline transport and storage are the activities to which most people will be exposed. As noted in the infrastructure discussion, the Taskforce recommends that a program of research and development activities be defined and implemented which will provide further assurance to regulators and the community that infrastructure and storage can be managed to produce safe outcomes in Australia.

14 IMPLEMENTATION

Work programs supporting each recommendation will be further developed by the Taskforce to be presented to the Minister for Resources and Energy by year-end. These identify the tasks required for each activity, and the resources and timelines necessary to achieve suitable outcomes.

When the Australian Government established the Carbon Storage Taskforce, it was envisaged that the Taskforce would spend six months developing the National Carbon Mapping and Infrastructure Plan and then a further six months overseeing the initial implementation of the Plan. Responsibility for oversight of the Plan beyond initial implementation was not addressed.

The Plan and the Taskforce's other recommendations cover a wide range of activities and subject areas over the next ten years to 2020. If Australia is to maintain CCS as a carbon pollution reduction option, then the Taskforce considers it is important that clear accountability is established for the strategic oversight and coordination of the implementation of the Plan and Taskforce recommendations. Successful implementation will require coordinated, focussed programs, with the priorities set from a national perspective to achieve maximum effectiveness. Deployment of CCS in Australia at a meaningful level will entail the development of a major new Australian industrial activity, of a size similar to that of the existing petroleum industry. A CCS Council, or some similar entity, could be used to support and accelerate this level of deployment.

The composition of the CCS Council should represent the diverse range of stakeholders in the CCS area including industry (power generators, coal producers, oil and gas producers, pipeline industry, cement, alumina, aluminium, steel/iron manufacturers and petroleum refiners), government (federal and state), eNGOs and employee representatives. A reporting relationship with the MCMPR through the Minister for Resources and Energy would assist with national coordination and prioritisation.

The Council would only exist for as long as is needed to ensure the successful implementation of the Plan.

Australia is one of the nations likely to be affected by climate change earliest and hardest. Delaying action to mitigate greenhouse gas emissions is considered likely to result in substantially greater costs, and impacts. The technology identified as having the greatest potential to mitigate greenhouse gas emissions from large-scale fossil fuel usage is carbon dioxide capture and geological storage.

The Taskforce has assessed that the deployment of CO_2 transport and storage in Australia is technically viable and could be safely implemented. However, CCS-related activities must be accelerated and maintained over the next decade if the nation is to be in a position to capture the opportunity for commercial deployment beyond 2020. While there are many challenges to be overcome, the Taskforce believes that, through the implementation of the Plan and Taskforce recommendations, they are manageable.

15 ACKNOWLEDGEMENTS

Geoscience Australia, and in particular the CCS Storage Section, took the lead in drawing together disparate information to facilitate the assessment of basin and oil field storage potential and capacity.

The Geosequestration Mapping Taskforce (the Chief Geoscientists from the national and state geological surveys) played a pivotal role in ranking Australia's basins storage potential and in creating the pre-exploration component of the National Mapping Plan. They maintained a national perspective throughout the process.

A strong feature of the Taskforce report is the depth of understanding of pipeline issues. This work was very ably led by the Australian Pipeline Industry Association (APIA) with input from many of their members. APIA also facilitated a meeting with Dr Julia Race, an internationally recognised expert on pipelines for CO_2 transport.

CO2Tech, the commercial arm of CO2CRC, estimated carbon dioxide storage tariffs. Economics relies on inputs from many others and, as a consequence, the work is often under schedule pressure. Dr Guy Allinson and Dr Peter Neal with their team at the University of New South Wales absorbed this pressure and were very comprehensive in their analysis of tariffs.

The Queensland Department of Mines and Energy conducted a thorough review of the potential impact of carbon storage operations on the Great Artesian Basin.

CSIRO is acknowledged for allowing Peta Ashworth to help the Taskforce to understand potential community concerns and possible responses about carbon storage and transport issues.

There was close cooperation and communication with the National Low Emissions Coal Council, and its Strategy Working Group, and comments from Council members enhanced the report considerably.

A more detailed report has been developed in parallel to this Concise Report. Dr John Burgess drafted and adapted much of the more comprehensive and technically specific report.

Finally, but by no means least, the Taskforce wishes to acknowledge the excellent support provided by the Taskforce Secretariat.

APPENDIX A

CARBON STORAGE TASKFORCE

TERMS OF REFERENCE

INTRODUCTION

The Carbon Storage Taskforce will bring together key stakeholders to develop a National Carbon Mapping and Infrastructure Plan ("the Plan"). The primary aim of the Plan is to develop a road map to drive prioritisation of, and access to, a national geological storage capacity to accelerate the deployment of carbon capture and storage (CCS) technologies in Australia.

MEMBERSHIP

Membership of the Taskforce will include all key industry sectors with an interest and expertise in carbon storage including coal, power generation, oil and gas, pipeline operators, geological survey agencies, unions and non-government organisations as well as representatives from the Commonwealth and state governments.

KEY TASKS

The Taskforce will develop a National Carbon Mapping and Infrastructure Plan which will provide a roadmap for geological storage to support significant penetration of CCS technologies into the Australian electricity, oil and gas, and industrial sectors. Specifically, the Taskforce will:

- examine existing ongoing work across jurisdictions on identifying potential carbon storage sites and their proximity to carbon sources;
- identify a priority list of potential storage sites taking into account major sources of CO_2;
- identify broad infrastructure requirements to facilitate CO_2 storage based on current knowledge of source/sink matches;
- identify gaps in existing knowledge in the areas outlined above and any priority areas for future work and/or research;
- identify main priorities for industry;
- identify the potential for the market to develop an adequate national carbon storage and infrastructure capacity, the nature of any market failure and the level and nature of any required government intervention to address such matters;
- examine potential community concerns about carbon storage issues, and make recommendations on potential approaches for addressing them; and
- make recommendations on a forward work program to address issues arising from consideration of the above issues.

Following consideration by the Australian Government and the approval of a forward work program, the Taskforce will oversee the initial implementation arrangements for the Plan which will draw on a coordinated approach between geological survey agencies from the Commonwealth and the States.

TIMING

The intention is for the Taskforce to operate for 12 months, with the final Plan being submitted to the Commonwealth Minister for Resources and Energy within six months. Following endorsement of the Plan by the Government, the Taskforce will oversee initial implementation arrangements, including in relation to the approved forward work program.

WORKING ARRANGEMENTS

The Taskforce will determine its own operating arrangements, including the need to establish specialised working groups to examine issues of specific interest for the development of the Plan. These could include for example, geological storage and monitoring; pipelines and infrastructure; and health and safety, and community issues.

The Taskforce will also work closely with the National Low Emissions Coal Council ('the Council') including providing regular progress reports of its work and seeking and taking into account any comments that the Council may have on its work. Specifically the Taskforce will provide the Council with an opportunity to comment on its plan before it is finalised and submitted to the Minister for Resources and Energy.

APPENDIX B

Table 1: Summary of Communication Activities[52]

STAKEHOLDER GROUP		NOTE	SUGGESTED ACTIVITY	FREQUENCY (PER YEAR)
INFLUENTIAL OTHERS				
Policy Makers	Federal; State	Includes environmental, health, minerals, energy, science, technology and innovation portfolios.	**Presentations to Government Departments** – understanding by key government figures is integral to the success of the project and this group will need to be proactively targeted.	4
Politicians	Federal; State	Should be extended to all parties.	**Workshops for politicians and their researchers** – politicians have expressed an appetite for information on the topic of climate change and energy technologies. Need to run short sharp workshops to allow them time to ask questions and understand the complexity of the carbon issue.	2
Financial, Insurance, Legal	International; National		**Personal Invitations CEO Breakfast Meetings** – host a series of breakfast meetings to target key stakeholders in this group. Small groups will allow for more interactive discussion and dialogue.	4
			Individual presentations to stakeholder group – similar to government, these groups will require specific information around which to base their decisions.	4
			Keynote speaker roles at international conferences – interest in the development of these technologies is global and therefore investment should not be limited to Australian waters.	Ad hoc
Media	National; State; Local		**Workshops for journalists across Australia** – proactive communication with this group is essential to ward against opportunities for misinformation. Small groups will be more effective and offers to transport them to the project site while it is being developed will be essential.	4

52 Adapted from Ashworth, P. 2008 *Social and Economic Integration: Managing Stakeholder Dialogue for Low Emission Coal Gasification.* Presentation for Centre for Low Emission Technology,. Brisbane, Qld. 8th April, 2008

STAKEHOLDER GROUP		NOTE	SUGGESTED ACTIVITY	FREQUENCY (PER YEAR)
Environmental NGO's	International; National; State; Local	New Zealand and nearby Asian countries should be considered in this approach.	**Workshops for eNGOs across Australia** – proactive communication with this group is essential to ward against opportunities for misinformation. Need to develop energy champions.	1
			Engage an NGO representative – research has shown that engaging an NGO group will help to build trust in the project. Funds should be allocated to buy this person's time as a representative from a not-for-profit organisation.	4
			Individual presentations to representatives – it will be important to ascertain individual representative's views on the project to elicit concerns and their respective positions about the project.	4
Other Industry Peak Bodies	National		**Personal Invitations CEO Breakfast Meetings** – host a series of breakfast meetings in various states to raise awareness of the project and possibly identify alternative funding opportunities. Up to 20 people should be invited, more intimate setting allows for more interactive discussion and dialogue.	2
EDUCATION				
Materials Development	International; National	Global community is beginning. Coordination is the key.	**Coordinated approach to the development of education and information materials for society.**	Ongoing
Media Press Packs	National		**Media packs** – although media will be engaged as influential others, materials to support any media releases will be required.	Ongoing
Curriculum Development	International; National	Coordination with other groups working in this area will minimise duplication.	**Coordination of classroom materials to enable easy delivery for teachers.**	Ongoing
Science Week	State			7
Local Education Initiatives	State; Local		**Time and travel.**	7
School Talks	State; Local		**Time and travel.**	7
GENERAL PUBLIC				

STAKEHOLDER GROUP		NOTE	SUGGESTED ACTIVITY	FREQUENCY (PER YEAR)
Energymark (CSIRO's community education and awareness program)	National	Should buy a seat on the steering committee to be key recipient of information and feedback.	**Engages community groups around the topic of climate change and energy technologies.**	4
Local community conferences	National; State; Local	Community groups such as CWA, ICLEI, LGA	**Presentations on request.**	Ad hoc
PROJECT SPECIFIC				
Local government	Local		**Workshops for local councils in the area** – this group is key to project success at the local level and requires ongoing dialogue activities at project inception through to deployment.	4
Landholders			**Individual meetings as required. Time and travel.**	Ad hoc
Local community groups	Health; Infrastructure; Natural Resources; Local NGO's		**Workshops for local stakeholder groups** – these groups have the influential roles within the local community and acceptance of the project at this level is crucial for deployment. May not always be the same groups of individuals.	4
General Public	Local		**Public meetings** – Open discussion forums allow local community representatives to have their say if they are not accessed through formal dialogue channels. Important at the beginning of the project, a community liaison group can take up the role going forward once issues have been overcome.	2
Schools	Local		**Target local schools** – provision of materials, talks, site visits.	Ad hoc
Community Liaison group			**Meetings every six weeks or as required** – minimal cost because it is local volunteers.	7
Community Liaison Person			**Part-time person** – on the ground near demonstration project site.	Ongoing
OTHER CONSIDERATIONS				
Website				
Communications Person				

APPENDIX C

CONSULTATION

The Taskforce sought to consult widely in acquiring information and forming its recommendations. Listed below are the various individuals, organisations and companies that contributed to various aspects of the Taskforce's activities.

Carbon Storage Taskforce

Chair	Keith Spence
Australian Coal Association	Bill Koppe
Australian Petroleum Production and Exploration Association	Bob Griffith
Australian Pipeline Industry Association	Cheryl Cartwright
Australian Pipeline Industry Association	Steve Davies
Construction, Forestry, Mining, Energy Union	Tony Maher
Cooperative Research Centre for Greenhouse Gas Technologies	Peter Cook
Department of Employment, Economic Development and Innovation, Queensland	John Draper
Department of Primary Industries, N.S.W.	Brad Mullard
Department of Primary Industries, Victoria	Richard Aldous
Department of Primary Industries and Resources, S.A.	Barry Goldstein
Department of Resources, Energy and Tourism (RET)	Margaret Sewell
Geoscience Australia	Clinton Foster
National Generators Forum	Tony Concannon
National Generators Forum	Patrick Gibbons
National Geosequestration Mapping Working Group	Kathy Hill
WWF-Australia	Greg Bourne

Observers

Australian Coal Association	Thomas Berly
Australian Petroleum Production and Exploration Association	John Torkington
Cooperative Research Centre for Greenhouse Gas Technologies	Ed Gaykema
Cooperative Research Centre for Greenhouse Gas Technologies	Gerry Morvell
Department of Employment, Economic Development and Innovation, Queensland	David Mason
Department of Environment, Water, Heritage and the Arts	Chris Baker
Department of Primary Industries, N.S.W	Rick Fowler
Department of Primary Industries, N.S.W.	Robert Larkings
Department of Primary Industries, Victoria	Fiona Clarke
Department of Primary Industries, Victoria	Belinda Close
Department of Mines and Petroleum, W. A.	Jeff Haworth
M. J. Kimber Consultants	Max Kimber
National Low Emissions Coal Council	Dick Wells
Niche Tasks	John Burgess

National Geosequestration Mapping Working Group

Department of Primary Industries, Victoria	Kathy Hill (Chair)
Geoscience Australia	Clinton Foster (Chair)
Carbon Storage Taskforce Secretariat, RET	Peter Wilson
Department of Employment, Economic Development and Innovation, Queensland	John Draper
Department of Employment, Economic Development and Innovation, Queensland	Jonathan Hodgkinson
Department of Employment, Economic Development and Innovation, Queensland	David Mason
Department of Mines and Petroleum, W.A.	Carol Bacon
Department of Mines and Petroleum, W.A.	Jeff Haworth
Department of Primary Industries, N.S.W.	Brad Mullard
Department of Primary Industries and Resources, S.A.	Barry Goldstein
Geoscience Australia	Andrew Barrett
Geoscience Australia	Rick Causebrook

MCMPR CCS Working Group

Department of Employment, Economic Development and Innovation, Queensland	Ruth Marshall
Department of Environment, Water, Heritage and the Arts	Matt Johnson
Department of Environment, Water, Heritage and the Arts	Terry McKinley
Department of Mines and Petroleum, W.A.	Carol Bacon
Department of Mines and Petroleum, W.A.	Ian Briggs
Department of Primary Industries, N.S.W.	Brad Mullard
Department of Primary Industries, N.S.W.	Shirley Hibbs
Department of Primary Industries, Victoria	Grant Arnold
Department of Primary Industries, Victoria	Colin Harvey
Department of Primary Industries and Resources, S.A.	Michael Malavazos
Department of Regional Development, Primary Industry, Fisheries and Resources, N.T.	Bob Adams
Geoscience Australia	Andrew Barrett
Geoscience Australia	Rick Causebrook
Geoscience Australia	Clinton Foster

WORKSHOPS

Mapping Workshop – 16 March 2009

Carbon Storage Taskforce (Chair)	Keith Spence
Carbon Storage Taskforce	John Burgess
Carbon Storage Taskforce Secretariat, RET	Steve Adamson
Carbon Storage Taskforce Secretariat, RET	Larissa Cassidy
Carbon Storage Taskforce Secretariat, RET	Meredith Dinneen
Carbon Storage Taskforce Secretariat, RET	Peter Wilson
Department of Employment, Economic Development and Innovation, Queensland	John Draper

Department of Mines and Petroleum, W.A.	Jeff Haworth
Department of Primary Industries, N.S.W.	Robert Larkings
Department of Primary Industries, N.S.W.	Ricky Mantaring
Department of Primary Industries, Victoria	Kathy Hill
Department of Primary Industries, Victoria	Geoff O'Brien
Department of Primary Industries and Resources, S.A.	Elinor Alexander
Department of Resources, Energy and Tourism	Steve Tantala
Geoscience Australia	Andrew Barrett
Geoscience Australia	Rick Causebrook
Geoscience Australia	Clinton Foster

Project Finance Workshop – 14 May 2009

Access Economics	Ric Simes
Anglo Coal	Bill Koppe
ANZ Bank	VJ Satkunasingam
Australian Coal Association	Burt Beasley
Callide Oxyfuel	Chris Spero
Carbon Storage Taskforce (Chair)	Keith Spence
Carbon Storage Taskforce Secretariat, RET	Larissa Cassidy
Carbon Storage Taskforce Secretariat, RET	Meredith Dinneen
Carbon Storage Taskforce Secretariat, RET	Peter Wilson
Chevron Australia	John Torkington
Clinton Foundation	Tony Wood
CS Energy	John Harten
CSIRO	Peta Ashworth
Department of Employment, Economic Development and Innovation, Queensland	Stuart Booker
Department of Employment, Economic Development and Innovation, Queensland	Rob Metcalfe
Department of Primary Industries, N.S.W.	Brad Mullard
Department of Primary Industries, Victoria	Fiona Clarke
International Power	Chris Kendall
Macquarie Capital Advisers	Sally Aitken
Monash Energy	Scott Hargreaves
National Low Emissions Coal Council	Bruce Godfrey
Niche Tasks	John Burgess
PriceWaterhouseCoopers	Brian Johnson
PriceWaterhouseCoopers	Simon Parbery
Santos	Mike Congreve
Schlumberger Carbon Services	Andrew Garnett
UBS	Angela Karl
Westpac Institutional Bank	Nick Cleary
Worley Parsons	Peter Brooks
ZeroGen	Chris Greig

Scenarios Workshop –15 May 2009

Access Economics	Cameron O'Neill
Australian Coal Association	Burt Beasley
Australian Coal Association	Thomas Berly
AngloCoal	Bill Koppe
Australian Pipeline Industry Association	Steve Davies
Carbon Storage Taskforce	Andy Rigg
Carbon Storage Taskforce (Chair)	Keith Spence
Carbon Storage Taskforce Secretariat, RET	Larissa Cassidy
Carbon Storage Taskforce Secretariat, RET	Peter Wilson
Chevron Australia	John Torkington
Clinton Foundation	Tony Wood
Greenhouse Gas Storage Solutions	John Bradshaw
Construction, Forestry, Mining, Energy Union	Tony Maher
Cooperative Research Centre for Greenhouse Gas Technologies	Guy Allinson
Cooperative Research Centre for Greenhouse Gas Technologies	Peter Cook
Cooperative Research Centre for Greenhouse Gas Technologies	Barry Hooper
Cooperative Research Centre for Greenhouse Gas Technologies	Peter Neal
CSIRO	Peta Ashworth
Department of Employment, Economic Development and Innovation, Queensland	John Draper
Department of Employment, Economic Development and Innovation, Queensland	Rob Metcalfe
Department of Primary Industries, N.S.W.	Rick Fowler
Department of Primary Industries, N.S.W.	Brad Mullard
Department of Primary Industries and Resources, S.A.	Barry Goldstein
Department of Primary Industries, Victoria	Fiona Clarke
Exxon Mobil	Bob Griffith
Geoscience Australia	Rick Causebrook
Geoscience Australia	Rob Langford
Hydrogen Energy	Lewis Jeffery
International Power	Patrick Gibbons
National Low Emissions Coal Council	Bruce Godfrey
Niche Tasks	John Burgess
Santos	Mike Congreve
Schlumberger Carbon Services	Alf Garnett
Worley Parsons	Peter Brooks
WWF-Australia	Greg Bourne
Xstrata	Barry Isherwood
ZeroGen	Rod Brown
ZeroGen	Howard Morrison

Pipelines Workshop – 5 June 2009

Australian Coal Association	Thomas Berly
Australian Pipeline Industry Association	Steve Davies
Carbon Storage Taskforce (Chair)	Keith Spence
Carbon Storage Taskforce Secretariat, RET	Jenessa Rabone
Carbon Storage Taskforce Secretariat, RET	Peter Wilson
Cooperative Research Centre for Greenhouse Gas Technologies	Guy Allinson
Cooperative Research Centre for Greenhouse Gas Technologies	Peter Neal
Cooperative Research Centre for Greenhouse Gas Technologies	Denis Van Puyvelde
Department of Primary Industries and Resources, S.A.	Belinda Hayter
Department of Resources, Energy and Tourism	Lindsay Gamble
M. J. Kimber Consultants	Max Kimber
Niche Tasks	John Burgess
University of Newcastle, U.K.	Julia Race
Worley Parsons	Peter Cox

Environmental NGO Workshop

Six environmental NGO representatives participated in this workshop.
To facilitate open dialogue, this workshop was conducted on an anonymous basis.

Technical assistance:

Greenhouse Gas Storage Solutions	John Bradshaw
Cooperative Research Centre for Greenhouse Gas Technologies	Barry Hooper

GROUPS PROVIDING SERVICES		
Geoscience Australia	Rick Causebrook, Rob Langford, Michelle Spooner, Chris Consoli, Chris Southby, Kane Rawsthorn, Duy Nguyen, Chris Lawson, Steve le Poidevin, Richard Dunsmore, Andrew Barret	Preparation of montages, ranking of basins, and substantial support on a range of matters for the Taskforce.
APIA Research and Standards Committee		Research project: APIA08-09 Gap analysis for use of AS2885 for CO_2 pipelines – 16 Mar 09
Geoscience Australia – Petroleum and Greenhouse Gas Advice Group		Australian carbon dioxide storage potential in oil and gas reservoirs – May 2009
Queensland Government	Jonathan Hodgkinson, Micaela Preda, Allison Hortle, Mike McKillop, Owen Dixon and Linda Foster	The Potential Impact of Carbon Dioxide Injection on Freshwater Aquifers: The Surat and Eromanga Basins in Queensland
Other	Andy Rigg, ACA Low Emissions Technologies Ltd Andrew Garnett, Schlumberger Carbon Services John Torkington, Chevron Australia	Provided comments on work relating to exploration and project development.
COMMISSIONED WORK		
ACIL Tasman	Paul Hyslop, Owen Kelp	Australian stationary energy emissions: an assessment of stationary energy emissions by location suitable for capture and storage – 27 Feb 09
ACIL Tasman	Paul Hyslop, Owen Kelp, Martin Pavelka	Carbon Capture and Storage projections to 2050
CO2CRC Technologies	Dr Guy Allinson, Dr Peter Neal, Felix Booth, Yildiray Cinar, Val Pinczewski	The Costs of CO_2 Storage in Australia – 24 Dec 08
CO2CRC Technologies	Dr Guy Allinson, Dr Peter Neal, Wanwan Hou, Yildiray Cinar	The Costs of CO_2 Storage in Australia – 2009
CSIRO	Peta Ashworth, George Quezada	Who's Talking CCS? – Media Analysis – 8 May 2009
CSIRO	Peta Ashworth, Richard Parsons	Australian eNGO views on CCS – 1 May 2009
CSIRO	Peta Ashworth	A strategic approach for communication and outreach activities for CCS
M.J.Kimber Consultants	Max Kimber	Development of Australia's natural gas resources: a possible model for carbon capture, transportation and storage – 4 May 2009

COMMISSIONED WORK		
Niche Tasks	John Burgess	Completion of detailed Taskforce Report
RISC	Graham Jeffery, Dogan Seyyar	CO_2 injection well cost estimation – March 2009
RISC	Graham Jeffery, Dogan Seyyar, Stuart Weston	Gippsland Basin – availability projections for carbon storage – May 2009
Worley Parsons	Peter Cox	Carbon dioxide specification study - 401001-00514 – 401001-00514-00-PR-REP-0002 – 1 June 2009
Worley Parsons	Peter Cox	CO_2 injection and pumping study - 401001-00514-00-PL-REP-0001 – 1 June 2009
Worley Parsons	Peter Cox	Summary of pipeline sizing study - 401001-00507 – 401001-00507-00-PR-REP-0001 – 16 April 09
Worley Parsons	Peter Cox	CO_2 small diameter pipelines: total installed cost budget estimates - 401001-00514-PM-EST-0001 – 2009
Worley Parsons	Peter Cox	Impacts of Interruptions to Supply for Carbon Dioxide Pipeline Transport Flow report - 401001-00514-00-PL-REP-0002 – 2009
Worley Parsons	Peter Cox	Compression Configuration Study report - 401001-00514-00-PR-REP-0003 – 2009
Deloitte Touche Tohmatsu	Rod Marsh, Govert Mellink, David Charles	Project Finance Workshop and Report
Sinclair Knight Mercz	Jane Lawson	Schematic pipeline diagram
KPMG	Jennifer Westacott, Jack Holden	Scenarios workshop outcomes

APPENDIX D – GLOSSARY OF TERMS

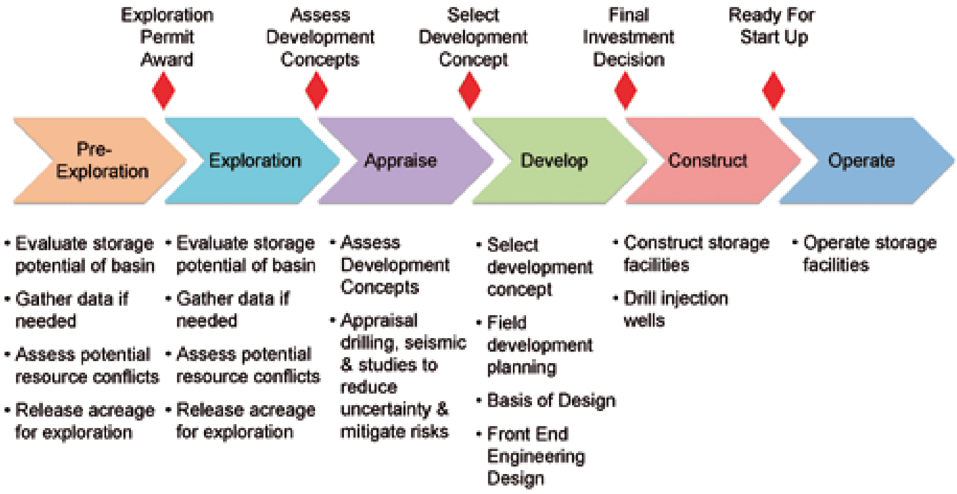
acid buffer	A chemical system that resists a change in pH.
ACIL Tasman	ACIL Tasman Ltd, a consulting company.
acreage	An area that is released for competitive exploration.
ANLECR&D	Australian National Low Emissions Coal – Research and Development Ltd.
APIA	Australian Pipeline Industry Association.
aquifer	A body of rock saturated with water that is capable of allowing the subsurface water to be stored or transmitted and is capable of absorbing recharge water.
aquitard	A body of rock that is not capable of allowing the subsurface water to be stored or transmitted and is not capable of absorbing recharge water.
AS2885	The overarching Standard that applies to the pipeline industry in Australia. This series of standards specify requirements for the design, construction, testing, operation and maintenance of pipelines.
basin	A geological depression filled with sediments.
black coal	Bituminous, anthracite and sub-bituminous coal of higher carbon and energy content and lower moisture content than brown coal. Used generally for power generation in States other than Victoria.
brown coal	Lignitic coal with lower energy and high moisture content than black coal. Used for power generation in Victoria.
carbon capture	Removal of carbon dioxide from a gas stream using chemical engineering methods.
carbon price	Price of CO_2e under the CPRS (\$/t CO_2e)
CCS	Carbon Capture and Storage.
CO_2	Carbon dioxide, a colourless gas at ambient conditions. Heavier than air. Can be converted to a supercritical fluid at high pressures (>74 atmospheres at ambient conditions) and temperatures greater than 31°C. Product of the combustion of carbon.
CO_2-e	A standard measure that takes account of the different global warming potential of different greenhouse gases and expresses the cumulative effect in a common unit.
CO	Carbon monoxide, a colourless gas at ambient conditions; toxic at low concentrations in gas mixtures. Product of the partial combustion of carbon.
CO2CRC	The Australian Cooperative Research Centre focused on CO_2 capture and storage.
coal	Combustible black or brownish organic-rich rock; a fossil fuel.
coal gasification	The process of transforming coal into fuel through the reaction of coal, water and heat.

completions engineer	An engineer trained to finish a well, which is either sealed off or prepared for production.
core	A cylindrical sample of geologic formation, usually reservoir rock, taken during or after drilling a well.
CPRS	Carbon Pollution Reduction Scheme.
CPRS -5	One scenario for future carbon reduction under the CPRS.
E	Storage efficiency of CO_2 in sedimentary rock; expressed as a percentage of the pore volume eventually occupied by CO_2.
ENGO	Environmental Non-Government Organisation.
EOR	Enhanced Oil Recovery. A technique whereby the efficiency of oil extraction is improved through the injection of CO_2 and water into the reservoir.
FEED	Front End Engineering Design
FID	Final Investment Decision
GCCSI	Global Carbon Capture and Storage Institute.
geochemistry	The study of the chemistry of the Earth, including the distribution, circulation and abundance of elements (and their ions and isotopes), molecules, minerals, rocks and fluids.
geothermal energy	Energy obtained from beneath the earth, either from dry hot rocks with water injection to create steam, or from steam brought to the surface from hydrothermal areas.
geochemist	A scientist trained in the study of the chemistry of the Earth, including the distribution, circulation and abundance of elements (and their ions and isotopes), molecules, minerals, rocks and fluids.
geomechanics	The study of structural geology and the knowledge of the response of natural materials to deformation or changes due to the application of stress or strain energy.
geoscientist; geoscience	A scientist trained in the study of the Earth; the study of the Earth and Earth systems.
Geoscience Australia	A prescribed agency within the Resources, Energy and Tourism portfolio; the Minister is the Hon Martin Ferguson AM MP.
GIS	Geographic Information System.
greenfield construction	Creating a new plant where no existing plant exists. "Brownfield" refers to adaptation or expansion of the capacity of existing plant.
greenhouse gas	A gas with global warming properties due to infra-red radiation absorption. Generally refers to CO_2 for CCS.

groundwater	Water in the subsurface below the water table. Groundwater is held in the pores of rocks.
Gt	Gigatonnes (1000 million tonnes)
GW	Gigawatts; a measure of power being generated at a given point in time. 1 GW equals 1000 MW.
GWh	Gigawatt hours; a measure of energy. 1 GWh of power being produced for 1 hour equals 1 GWh; 1 GWh is equivalent to 1000 MWh.
hub	A concentration of CO_2 emitters in a geographic region.
hydrochemistry	The study of chemical processes and conditions in groundwater.
hydrodynamics	The study of flow of liquids and forces which influence this movement.
IEA	International Energy Agency.
injectivity	Ability to be injected; high injectivity implies high permeability of the reservoir rock strata, and low differential pressure for a given injection rate.
LNG	Liquefied Natural Gas.
MCMPR	Ministerial Council on Mineral and Petroleum Resources.
mD	milli-Darcy, a measure of reservoir permeability.
Monte Carlo simulation	A statistical risk analysis technique to estimate the most probable outcomes of a model.
Mt	Millions of tonnes.
Mtpa	Millions of tonnes per year (annum).
MW	Megawatts; a measure of power being generated at a given point in time.
MWh	Megawatt hours; a measure of energy. 1 MW of power being produced for 1 hour equals 1 MWh.
natural gas	A combustible colourless gas at ambient conditions, mainly comprising methane (CH_4); a fossil fuel. May be liquefied at low temperatures to form LNG.
NEM; NEMMCO	National Electricity Market.
NGO	Non-Government Organisation.
NLECC	National Low Emissions Coal Council.
OECD	Organisation for Economic Cooperation and Development.
oil	A combustible liquid comprising a mixture of hydrocarbons; a fossil fuel.

petroleum engineer	An engineer trained in various aspects in the production of hydrocarbons.
Plume; (CO_2 plume)	The dispersing volume of CO_2 in a geological formation.
pore; porosity	A discrete void within a rock, which can contain air, water, hydrocarbons or other fluids; in a body of rock, the percentage of pore space is the porosity.
pre-competitive data	Data acquired for public dissemination, issued to encourage bidding by exploration companies for land over which they will be granted an exclusive exploration right.
pressure (differential)	The change in force per unit area between the reservoir pore pressure and the wellbore fluid pressure.
PSSA	Petroleum Search Subsidy Act.
reservoir	Sub-surface geological formation comprising porous rock that could contain oil, natural gas, CO_2 or other fluids.
reservoir engineering; reservoir engineer	A branch of engineering dealing with the behaviour of fluids in reservoirs.
saline formation; saline reservoir; saline aquifer	Sediment or rock body containing brackish water or brine.
seal	An impermeable rock that forms a barrier above and around a reservoir such that fluids are held in the reservoir.
seismic: 2D, 3D, 4D.	Seismic – geophysical technique involving the transmission of sound waves and their reflection and refraction of this energy off subsurface geological boundaries. This data can be interpreted to produce geological cross-sections, i.e. extent and geometry of rocks sequences and their composition and fluid properties; 2D – a group of seismic lines acquired individually to produce a series of 2 dimensional cross-sections; 3D – a set of multiple, closely-spaced seismic lines that provide a 3 dimensional image of subsurface geology; 4D – a 3D seismic data set acquired at different times over the same area to assess changes in a reservoir with time.
storage	Injection of carbon dioxide into a suitable geological basin comprising porous sandstone for long term storage.

storage development	Elements include: pre-exploration, exploration, appraisal, development, construction and operation, described in the diagram below.



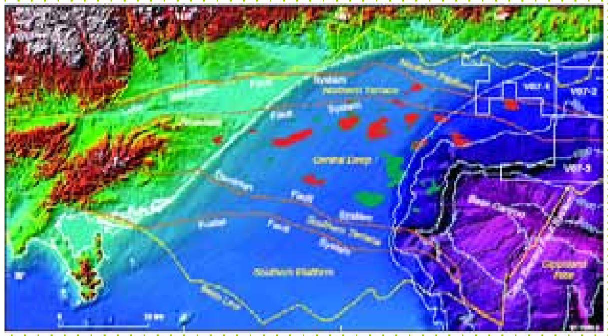
structural geologist	A geoscientist trained in the study of structural geology.
sandstone	A clastic sedimentary rock composed of fragments of sand.
sequestration; geo-sequestration	Long term storage of CO_2 in geological formations.
stationary emissions	Emissions of CO_2 from industrial processes and power generation facilities that operate at a fixed location.
supercritical phase	At a temperature and pressure above the critical temperature and pressure of the substance concerned. The critical point represents the highest temperature and pressure at which the substance can exist as a vapour and liquid in equilibrium
Taskforce	The Carbon Capture and Storage Taskforce (see Appendix A).
tenement	A licence granted to allow exploration or production of a commodity.
Treasury	Australian Government Department of the Treasury.
UNFCCC	United Nations Framework Convention on Climate Change.
well	Man-made hole drilled into the earth to produce liquids or gases, or to allow the injection of fluids.

APPENDIX E

Offshore Gippsland Basin

Southeastern Victoria, offshore
Reservoir:
Top Latrobe, Curlip, Admiral formations, Golden Beech, Intra-Latrobe, Intra-Strzelecki, Intra-Seaspray groups, and Intra-Golden Beach Subgroup.
Seal:
Lakes Entrance Formation, basal Halibut Group, and Kipper Shale.

Structural elements

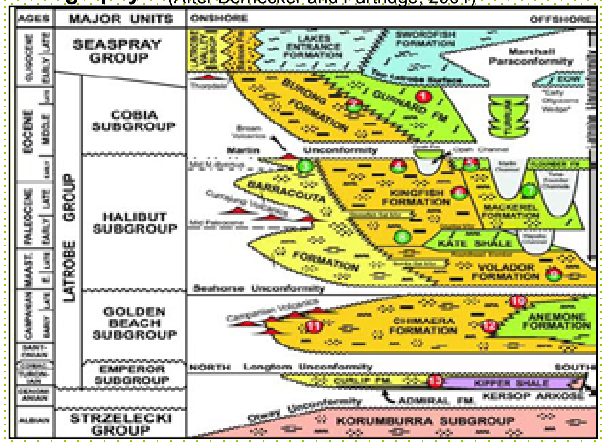


Hydrocarbon potential

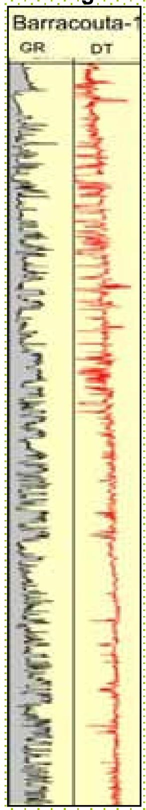
Category 1 and 2 (OGRA 2005)		
Crude oil	MMBL	278.28
Condensate	MMBL	130.92
LPG	MMBL	174.85
Sales gas	Tcf	7.35

*data from entire basin

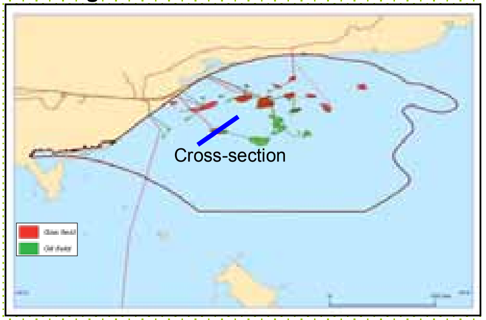
Stratigraphy (After Bernecker and Partridge, 2001)



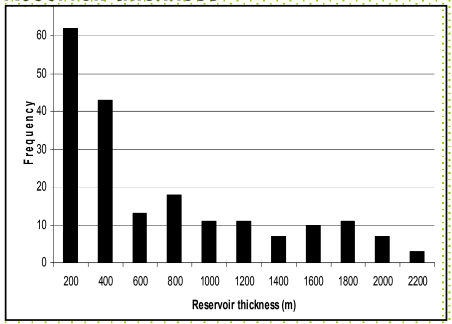
Well log



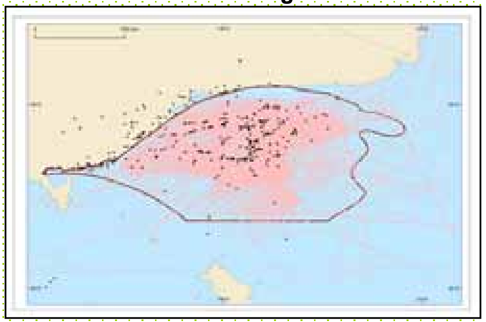
Oil and gas fields



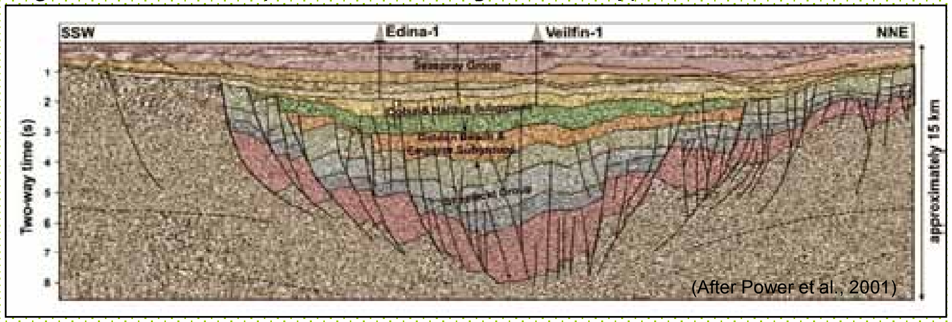
Reservoir thickness



Wells and seismic coverage



Regional cross section (location in Oil and gas fields map)



(After Power et al., 2001)

The purpose of these montages is to aid a high level evaluation of the geological storage potential of Australia's sedimentary basins for future CO2 emissions. The evaluations are based on core analysis and other data derived from Geoscience Australia and other sources. However due to time constraints, it has not been possible to carry out the detailed evaluation of the data, which will be required for the next phase of analysis.

In this exercise, we sought to recognise a range of characteristics within each basin by identifying three sets of parameters at different locations and depths in the basin. The intent is to generate an indication of a range of storage capacity and potential injection rates. These capacities and rates are being used in high level reservoir modelling work to generate injection tariffs* and capacity estimates. All of this work feeds into a process that provides indicative, conceptual transport and storage tariffs for CO2 emissions captured in various parts of Australia.

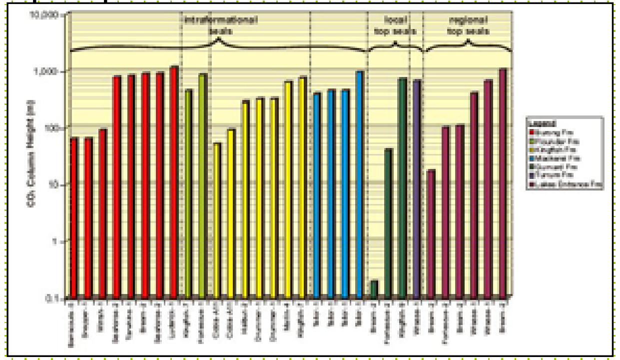
This 'top down', simplistic approach seeks to describe the magnitude and range of potential costs for transport and storage in Australia, at a 'conceptual' level of accuracy. Clearly, any final investment decision would call on an increased understanding and level of accuracy through the usual project development process.

* Cost per tonne of CO2 avoided, calculated using the net present value of cash flows over a 25 year asset life.

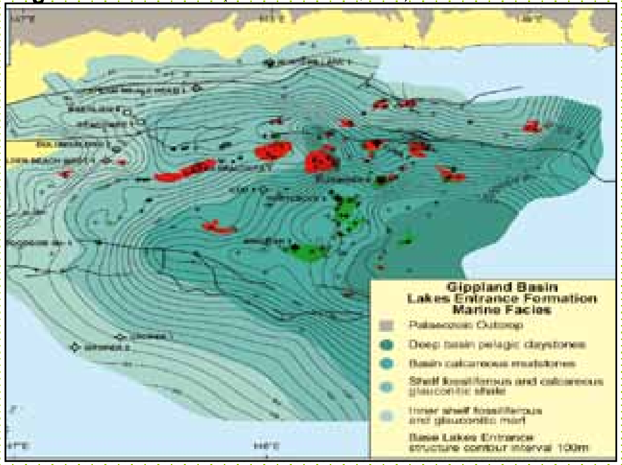
Basin ranking

Category	Description	Score	Weighting
Tectonics (Seismicity)	Medium/Low	4	0.00
Size	Large	3	0.06
Depth	Intermediate	3	0.10
Type	Non-marine and Marine	2	0.04
Faulting intensity	Limited	3	0.14
Hydrogeology	Good	3	0.04
Geothermal	Moderate	2	0.05
Hydrocarbon potential	Giant	5	0.05
Maturity	Over-mature	5	0.05
Coal and CBM	Deep	3	0.00
Reservoir	Excellent	5	0.16
Seal	Excellent	5	0.18
Reservoir/Seal Pairs	Excellent	4	0.03
Onshore/Offshore	Shallow Offshore	2	0.00
Climate	Temperate	5	0.00
Accessibility	Acceptable	3	0.00
Infrastructure	Extensive	4	0.00
CO2 sources	Major	4	0.00
Knowledge level	Extensive	4	0.05
Data availability	Excellent	4	0.05
Overall Ranking			**1**

Top seal potential (After Gibson-Poole et al., 2006)



Regional seal area (After O'Brien et al., 2008)



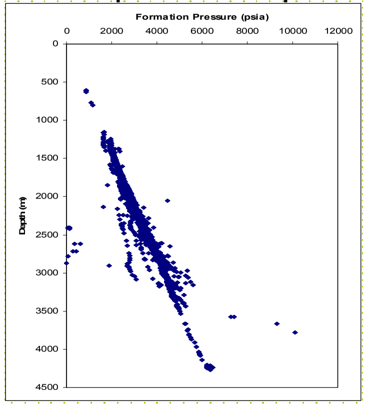
Potential injection parameters

Parameter	Unit	Shallow	Mid Depth	Deep
Depth base seal	m	1600	2000	2400
Formation thickness	m	500	700	900
Injection depth	m	2100	2700	3300
Porosity	%	24	22	20.5
Absolute perm	mD	1400	400	125
Form pressure	psia	3030	3900	4760
Fract pressure	psia	5460	7010	8570

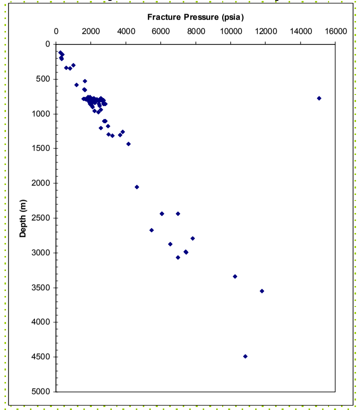
Storage capacity estimate

Parameter	Unit	Score (P90)	Score (P50)	Score (P10)	Distribution
Area of storage region	km^2	10000	16000	30000	Triangular
Gross thickness of saline formation	m	200	500	900	Triangular
Average porosity of saline formation over thickness interval	%	19	22	25	Triangular
Density of CO_2 at average reservoir conditions	t/m3	0.5	0.6	0.7	Triangular
E-storage efficiency factor (% of total pore volume)	%	4	4	4	
Calculated storage potential	gigatons	31.0	48.8	78.3	

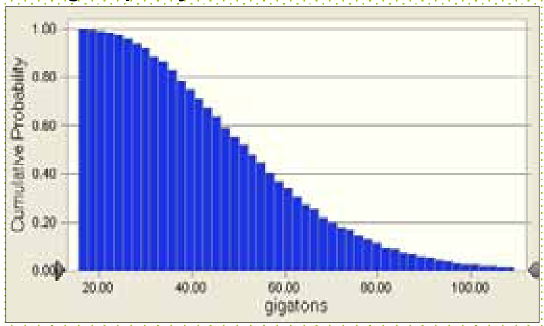
Reservoir pressure vs. depth



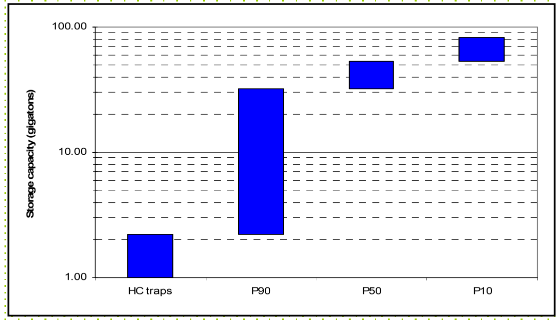
Fracture pressure vs. depth



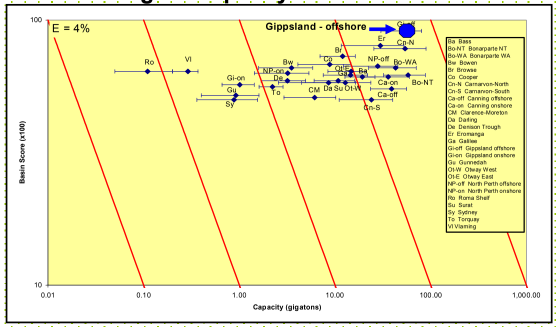
Storage capacity curve



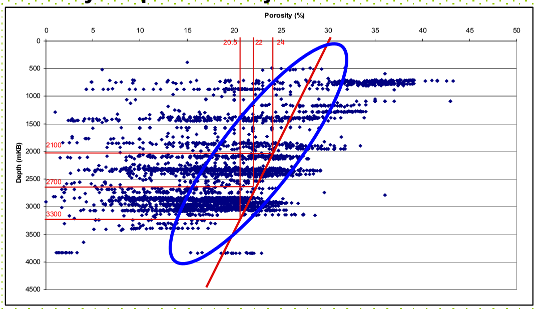
Storage capacity



Basin ranking vs. capacity

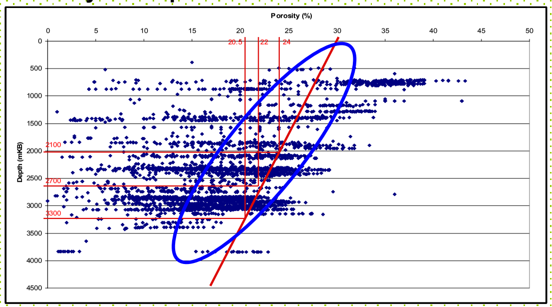


Porosity vs. permeability



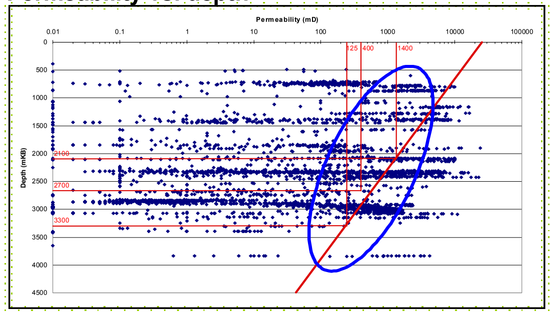
*data from all formations within the Gippsland Basin

Porosity vs. depth



*data from all formations within the Gippsland Basin

Permeability vs. depth



*data from all formations within the Gippsland Basin

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