NATIONAL LOW EMISSIONS COAL STRATEGY

ACCELERATING CARBON CAPTURE AND STORAGE IN AUSTRALIA

NATIONAL LOW EMISSIONS COAL COUNCIL

SEPTEMBER 2009

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ISBN 978-1-921516-59-7 National Low Emissions Coal Strategy (paperback)
ISBN 978-1-921516-60-3 National Low Emissions Coal Strategy (PDF)

National Low Emissions Coal Strategy: Accelerating Carbon Capture and Storage in Australia

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INTRODUCTORY LETTER

The Hon Martin Ferguson AM MP
Minister for Resources and Energy
Parliament House
CANBERRA ACT 2600

Dear Minister,

On behalf of the National Low Emissions Coal Council (Council), it is with pleasure that I present you with the *National Low Emissions Coal Strategy: Accelerating Carbon Capture and Storage (CCS) in Australia*.

As set out in our Terms of Reference (ToR), a key task for the Council is to advise you on the development and implementation of a national low emissions coal strategy (the strategy) to ensure that the coal sector makes a substantial contribution to greenhouse gas abatement, whilst enhancing the contribution that coal makes to Australia's energy security and economic well being.

In particular, the Council was asked to address the goal of ensuring that low emissions technologies for coal, including CCS, are demonstrated at a commercial scale from 2015, are available for commercial deployment by 2020 and are deployed as they become commercially available.

This strategy builds on the preliminary report and other advice that the Council has provided to you previously, including proposed eligibility and selection criteria for the CCS Flagships Program and advice on the technological priorities for demonstration in Australia.

In developing the strategy, the Council considered a range of issues including:

- the strategic impetus for CCS both in Australia and globally
- current policy and operating environment for investors
- barriers to investment in CCS
- the magnitude of the challenge if CCS is to become a commercial reality in the timeframe that has been set.

Key findings include that CCS applied to the stationary energy sector will enable a significant proportion (more than 20 per cent) of Australia's CO_2 emissions to be captured, transported and stored safely, and that the target timeframe for the commercial availability of CCS is ambitious but feasible if a range of actions are undertaken in key strategic areas.

Key areas for recommended action are:

- community acceptance
- a coherent and cost-effective demonstration portfolio
- research support
- a conducive Carbon Pollution Reduction Scheme (CPRS) and taxation policy settings
- transitional support measures for CCS projects and storage hubs
- a supportive regulatory framework
- storage availability
- the streamlining of project approvals
- the necessary skills base.

Delivery of this strategic framework is essential if CCS is to deliver on its strong potential to significantly reduce greenhouse gas emissions.

In relation to the national research program, the Council has established the Australian National Low Emissions Coal (ANLEC) R&D organisation to lead and enhance the coordination of Australia's research effort. The Council, in conjunction with ANLEC R&D, will provide you with advice on the initial priorities for a national low emissions coal research program in the first quarter of next year.

The strategy was prepared in close consultation with the Carbon Storage Taskforce. I would like to thank the Chairman, Mr Keith Spence, and the Taskforce for their cooperation. I also commend the commitment and cooperation of all participants in bringing this report together, including my colleagues on the Council and its working groups.

I look forward to meeting with you to discuss the findings and recommendations contained in this report, with a view to fast-tracking early action where possible.

Yours sincerely

Dick Wells
Chairman
National Low Emissions Coal Council
September 2009

Chair: Mr Dick Wells

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National Low Emissions Coal Council

Delivering a coordinated Australian approach to low emissions coal technology research, development and demonstration to support accelerated deployment

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EXECUTIVE SUMMARY

IMPERATIVES FOR ACTION

Australia is facing an unprecedented economic challenge in reducing greenhouse gas (GHG) emissions by 60 per cent of 2000 levels by 2050 while maintaining secure, reliable and affordable energy supplies for Australian households and industry.

With over 95 per cent of fuel use for Australia's electricity currently sourced from coal and natural gas, Australia will not make meaningful progress towards our emissions reduction targets without addressing emissions reductions from fossil fuel use.

The International Energy Agency (IEA) assesses that carbon capture and storage (CCS) is the only technology available to reduce emissions from large-scale fossil fuel use. CCS will also significantly reduce the cost of reducing global emissions, with the IEA finding that CO_2 mitigation costs will be much higher – around 70 per cent – without CCS. The IEA estimates that globally, CCS will need to contribute nearly one-fifth of emission reductions to reduce GHG emissions by 50 per cent by 2050.

In Australia, CCS is expected to be a larger part of the solution given our reliance on fossil fuels. The successful deployment of CCS technologies in Australia will also allow us to capitalise on the continuing use of Australia's abundant black coal, brown coal and natural gas resources. Black coal was Australia's single largest export in 2008–09, worth around $55 billion, and the coal industry is a major regional employer. These are compelling reasons for ensuring that CCS is taken up domestically and by our major coal export customers.

The Council recognises that the challenges of reducing emissions while meeting growing energy demand are such that all fuels and all technologies will be required. Investment in CCS must complement and form part of a broader technology response alongside energy efficiency and greater uptake of renewable energy.

Consistent with the Council's Terms of Reference, the focus of this report is on the coal-fired power generation sector. In particular, the Council has been asked to address the goal of ensuring that low emissions technologies for coal in Australia, including CCS, are demonstrated at a commercial-scale from 2015, are available for commercial deployment by 2020, and are deployed as they become commercially available.

However, CCS is not exclusively a coal technology and the Council recognises the broader application of CCS in Australia. The Council's recommendations to support early deployment of CCS for coal-fired power generation will ultimately underpin the application of CCS to other high emitting industries, such as steel, cement, and gas-fired power generation.

Action has commenced in Australia to support accelerated demonstration and deployment of CCS. The Australian Government has also taken a leading role in establishing and supporting the Global Carbon Capture and Storage Institute to facilitate and drive global cooperation on CCS deployment.

The international community is increasingly focusing on ways to mobilise necessary financing for CCS demonstration and deployment. Measures being proposed in this report by the National Low Emissions Coal Council are of direct relevance to Australia's engagement in these issues.

CO_2 CAPTURE, TRANSPORT AND STORAGE IN AUSTRALIA

The implementation of CCS requires the capture of the CO_2 emissions at the source, their processing and compression for pipeline transportation, their injection underground for permanent geological storage, and confirmation of ongoing storage integrity.

Notwithstanding the significant technical, timeline and financial challenges ahead, it is the view of the Council and the Carbon Storage Taskforce (CSTF) that CCS applied to the stationary energy sector will enable a significant proportion (more than 20 per cent) of Australia's future CO_2 emissions to be captured, transported and safely stored deep underground.

For the capture element, post-combustion capture (PCC), pre-combustion capture (including integrated gasification combined cycle – IGCC) and oxyfuelling are the three main technology options identified internationally for CO_2 capture in fossil-fuel electricity generation and a range of large-scale industrial processes. While the technologies are at different stages of development, they are all considered prospective for application in Australia and it is the Council's view that they should be developed in parallel.

CO_2 transport in supercritical phase through pipelines is a relatively mature technology internationally. There will be some technical challenges with initial CO_2 pipelines built in Australia, and the regulatory regime to support the rollout of networks will require attention. These challenges are manageable.

The CSTF has conducted an extensive analysis of the potential for large-scale, long-term storage of Australia's CO_2 emissions from power stations and major industrial plants and concluded that:

- there is a high confidence that the east of Australia has aquifer storage capacity for 70–450 years at a storage rate of 200 Mtpa (million tonnes per annum), and that the west of Australia has capacity for 260–1120 years at 100 Mtpa, with the possibility that far greater capacity will be defined as basins and their CO_2 storage behaviour become better known
- developing adequate confidence in storage capacity and likely total costs is now recognised as the critical driver of CCS project timelines
- the timeframes for commercial deployment of geological storage sites are long. For large basins, the earliest time that aquifer storage could be available for use by demonstration capture projects is 2018. Depleted gas and oil fields, where there is usually abundant seismic data, wells and production history, could be evaluated and understood in a relatively short timeframe, that is by 2016.

INTEGRATED CCS DEMONSTRATION AND DEPLOYMENT IN AUSTRALIA

Although the individual components of CCS have been demonstrated at commercial-scale in the oil and gas industries for over a decade, CCS for power generation plants has not been demonstrated yet at commercial-scale anywhere in the world.

Demonstration at commercial-scale is an essential prerequisite for broader commercial deployment. While each CCS element is feasible in its own right, CCS technologies will need to be demonstrated on a fully integrated basis under industrial operating conditions. That is, the generation, capture, transport and storage elements must be shown to successfully work together as an overall system, at commercial-scale and at high utilisation. Until this happens, a rational investor will not accept that commercial deployment of CCS is 'bankable'.

To be demonstrated at a commercial-scale from 2015 and be available for commercial deployment by 2020, CCS must overcome deployment challenges in:

- accelerating the generational deployment path. Each generation of a major new power technology typically takes 10–15 years to design, construct, commission and operate for learning experience. The timeline for CCS commercial-scale first-of-a-kind (FOAK) project commitment decisions in Australia is being compressed, and associated higher risks moderated, through government-industry grant funding support and through staged decision-making on project selection under the CCS Flagships Program
- progressing a coherent and cost-effective national portfolio of CCS demonstration projects with appropriate research foundations and support, and with a focus now on commercial-scale integrated demonstration projects
- coordinating the development of multi-user capture and storage hubs, over and above technology deployment through individual CCS projects. Significant penetration of CCS technologies will require realisation of economies of scale from multi-user hub-and-spoke CO_2 transport and storage infrastructure
- financing commercial-scale demonstration projects and early deployment plants.

Australia has taken a leading role in developing CCS, including world leadership on geological storage and innovations in adapting existing technology to undertake trials of capture technologies in Australia. At the same time, Australia needs to be fully attuned to international technology developments and have full access to international learning from FOAK commercial-scale demonstration projects in other countries. It is important to ensure the opportunities provided under the Global CCS Institute are fully realised so that Australia can draw on and use other international experiences to address some of the regulatory, policy, technical and financial hurdles to CCS development, demonstration and deployment.

INVESTING FOR LOW EMISSIONS ELECTRICITY IN AUSTRALIA

It is anticipated that Australia's future electricity supply will be provided through a diversified technology portfolio. Achieving Australia's targeted GHG emissions will require the average emission intensity of Australia's electricity generation to drop to less than a fifth of current levels by 2050.

Different technologies will be competitive in different situations, depending on factors such as carbon permit prices, geography, geology, fuel input prices and intermittency. The capacity of each technology to come down its cost curve and deliver performance improvements will also be critical to the mix of technologies in the future energy market.

Comparative assessments of energy technologies currently incorporate a high degree of uncertainty. Within the range of current estimates, it is plausible that CCS technologies can be competitive with a range of renewable energy technologies, and also with conventional generation technologies (that is fossil-fuel-fired generation without emissions abatement, that pays for emission permits) at future higher levels of CO_2 emission prices.

Building and operating commercial-scale CCS demonstration projects is an essential prerequisite to more fully determine the cost and performance characteristics of this technology, and to begin delivering material future cost reductions. Investment is urgently needed in the next stages of CCS demonstration and early deployment to keep open the option of CCS making a vital contribution to cost-effective emissions abatement in Australia.

It is the Council's view, however, that the barriers to investment in such FOAK projects are too great for the market alone to overcome in the required timeframe. Competitive electricity markets in Australia have performed well over the last decade to deliver sound investment and electricity supply outcomes in response to growing demand. In practice, however, there are barriers and limitations to the market's ability to respond fast enough and deeply enough to GHG mitigation imperatives based solely on price signals and commercial investment decisions.

Key investment limitations are:

- disincentives for early-mover investment in large capital-outlay projects in immature technologies
- uncompetitive operating costs against incumbents until CO_2 emission prices reflect the full costs of GHG mitigation
- the availability of finance.

In the face of these major risks and uncertainties around climate change and financing, electricity market investors have responded rationally by deferring large, baseload capacity investment decisions and instead have invested in peak and shoulder plants (generally gas) that have a lower capital exposure but are inherently unsuitable to baseload generation. The longer the delays, the larger the potential capacity shortages become.

Policy interventions are required to ensure rapid deployment of initial CCS demonstration plants and to accelerate subsequent early pre-commercial plants in the required timeframes. This will include the need for special transitional financial assistance in addition to the early CPRS price levels to bridge the commercial gap that will occur in the early deployment of low emission plants. These interventions should phase out as the underlying market failures decrease.

STRATEGIC FRAMEWORK FOR CCS DEMONSTRATION AND DEPLOYMENT IN AUSTRALIA

In considering the objective of commercial-scale demonstration of CCS from 2015 and commercial deployment from 2020, concurrent action is needed by industry and governments in the following nine areas. Recommendations in each of these strategic areas are set out in the report and listed at the end of the Executive Summary.

1. Gaining the support of communities located near CCS demonstrations, and the Australian public more broadly, will be as essential for the deployment of CCS as addressing the technical and economic challenges.

2. A portfolio of demonstration projects required in the timeframe to 2020 would include at least one commercial-scale IGCC, several medium-scale PCC and oxyfuel plants and at least one commercial-scale combustion-based plant. The total cost of this program is in the range of $10–17 billion. This cost includes only the next phase of demonstration-scale (30–100 MW) and commercial-scale (250 MW+) projects. It does not include funding shortfalls on existing demonstration projects, or funding requirements for new pilot demonstration projects, recognising that there will be a number of these in the years to come particularly for new CO_2 capture technologies.

3. Australia has a number of R&D programs applicable to low emissions coal utilisation, although two major programs—the Cooperative Research Centre for Coal in Sustainable Development (CCSD), and the Centre for Low Emission Technologies (cLET)—have concluded in the last two years. Australian National Low Emissions Coal R&D (ANLEC R&D) will play a key role in rebuilding, leading and enhancing the coordination of Australia's research effort associated with CCS demonstration projects.

4. General Carbon Pollution Reduction Scheme (CPRS) and taxation policy settings are working against established and emerging CCS demonstration projects. CPRS liabilities on CCS demonstration projects will add a major cost impost on projects and will reduce the likelihood of some projects proceeding. General taxation provisions tend to result in taxation loss of direct grant funding for project proponents.

5. Investment in commercial-scale CCS demonstration projects will not proceed without significant, targeted support and incentives. Substantial market failures that are blocking private investment are the innovation risks around early, commercial-scale demonstration of CCS technology, and a carbon pricing trajectory in Australia that will not fully reflect the costs of emissions abatement for many years. Project support models should be weighted towards achieving long operating lives of commercial-scale CCS demonstration projects.

6. There are considerable uncertainties on a range of regulatory elements including CO_2 pipeline regulation, and network and economic regulation of transport and storage infrastructure. Nationally consistent approaches, and preferably single national regulation, should be adopted.

7. Immediate actions are needed to allow rapid access to the most prospective large storage basins for early CCS demonstration and to better characterise and prioritise other basins for potential future use.

8. Lengthy, complex and uncertain approvals processes present significant impediments and risks for CCS projects.

9. The development, demonstration and deployment of these technologies will increase the demand for a range of technical skills. The ability of the tertiary education system to satisfy this demand in the timeframes required needs to be confirmed.

PRIORITY ACTIONS TO UNDERPIN THE STRATEGIC FRAMEWORK

Priority action is needed over the next two years to:

- develop and commence implementation of a comprehensive national CCS communications strategy
- progress initial priorities under the national Research Program for low emissions coal R&D, including research support for medium-to-large scale CCS demonstration projects, and addressing funding gaps for existing and future small-to-medium scale demonstrations
- exempt CCS demonstration projects from CPRS liabilities
- undertake a detailed assessment of and commitment to transitional support options for CCS deployment, to increase investment certainty
- commence a prioritised, pre-competitive exploration program to assess CO_2 storage basins of strategic importance
- complete establishment of onshore and offshore CO_2 storage legislative and regulatory frameworks
- establish consistent national regulatory frameworks and support for multi user CO_2 transport and storage hub infrastructure
- establish clear approval guidelines and licensing pathways for CCS projects in Australia.

RECOMMENDATIONS

COMMUNITY ACCEPTANCE

1. A comprehensive national CCS communications strategy should be developed by the Council, in consultation with key stakeholders, by the first quarter of 2010. This includes:

    - A dedicated CCS Communications Manager should be engaged to develop the communications strategy and should report to the Council.
    - The Communications Manager should establish and work closely with a CCS communications network comprised of key communications officers across industry, governments, research agencies and project owners/proponents to inform the development of the strategy and to improve coordination of CCS communications efforts.
    - Adequate funding over five years should be allocated from the National Low Emissions Coal Fund for this purpose.

2. Australian demonstration projects funded under the CCS Flagships Program should have comprehensive and well-resourced communications strategies as part of public funding requirements.

3. The Australian Government, through the Energy White Paper, should take a leadership role in developing a far-reaching national communications and media campaign to promote awareness of *all* low emissions technologies and their role in Australia's response to climate change.

DEMONSTRATION PORTFOLIO

4. The Australian Government's Clean Energy Initiative should be considered as the first tranche of funding required over the next 10–15 years for implementation of a portfolio of commercial-scale demonstration CCS projects in Australia.

    - The Council urges the Government to commit to expanding the current CCS Flagships Program to include further selection rounds with additional funding in 2012 and 2014.

5. In developing funding agreements for the CCS Flagships Program, the Australian Government should liaise with ANLEC R&D, the Global CCS Institute, state governments and Australian Coal Association Low Emissions Technologies Ltd (ACALET) to develop model contract clauses enabling suitable access to project performance and economic data across Australian CCS Flagship projects and all global commercial-scale CCS demonstration projects.

6. Data access arrangements for commercial-scale CCS demonstration projects should include a focus on obtaining early, robust indicators of long-term integrity of CO_2 storage in Australian geological formations.

RESEARCH SUPPORT

7. The Council will provide advice to the Minister for Resources and Energy by the first quarter of 2010 on the initial priorities for a national research program for low emissions coal research and development that:

    - focuses on applied R&D, performance data, and research priorities to support medium- to large-scale CCS demonstration projects and accelerated commercial deployment, through ANLEC R&D
    - identifies technological priorities and portfolio gaps in small- to medium-scale CCS demonstration projects, and assesses associated funding requirements and funding availability for existing and future projects

- ensures coordination through ANLEC R&D of Australian R&D with international research programs at a detailed program and project level. The coordination should focus at the operating level by defining Australian research programs that are complementary to international efforts and/or programs that adapt international R&D to Australian conditions
- ensures coordination of the national low emissions coal demonstration project portfolio with demonstration of CCS application to gas-fired electricity generation and industrial processes such as steel-making and LNG production.

GENERAL CPRS AND TAXATION POLICY SETTINGS

8. As an urgent priority, CCS demonstration projects should be exempted from CPRS liabilities.

9. Direct grant funding for CCS demonstration projects should be non-taxable.

TRANSITIONAL SUPPORT FOR CCS PROJECTS AND HUBS

10. The Australian Government, in consultation with the Council, should urgently undertake a detailed assessment of transitional support options for CCS deployment.

    - Consideration should include market-based support mechanisms such as clean energy targets, as well as a range of incentives such as tax, capital and operating subsidies, loan guarantees, and insurance.

11. Flexible approaches should be adopted in the progressive selection and implementation of commercial-scale CCS demonstration projects in order to:

    - ensure that Australia's CCS demonstration portfolio includes cornerstone projects that have long CCS operational lives and that anchor hub development
    - allow scope for adjustment to project or portfolio parameters in response to changes in information (for example, large storage basin availability) and policy developments (for example, electricity market-based support measures).

A SUPPORTIVE REGULATORY FRAMEWORK

12. Nationally consistent onshore and offshore CO_2 storage legislative and regulatory frameworks should be established as an urgent priority. In particular:

    - the New South Wales and Western Australian Governments must urgently introduce storage legislation
    - regulations must be in place for explorers to take up acreage from 2010, particularly for the Gippsland, Surat and Perth basins
    - the Australian Government approach on long-term liability should be adopted nationally, with state and territory governments assuming long-term liability for CO_2 storage from 20 years after injection ceases, provided pre-conditions are met.

13. Nationally consistent approaches, and preferably single national regulation, should be adopted for other aspects of the regulation of CO_2 transport and storage infrastructure where required, including:

    - retaining easement options for potential future strategic pipeline corridors
    - CO_2 pipeline technical regulation
    - the potential need for network and economic (access) regulation of common user regional CO_2 transport and storage infrastructure in view of natural monopoly aspects. A national, dedicated regulator may be warranted.

STORAGE AVAILABILITY

14. A phased, gated, pre-competitive exploration program should be conducted, totalling $254 million as 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. As pre-exploration proceeds, there may be a need for further pre-competitive exploration investment.

15. A Review Committee should be established to consider the pre-competitive exploration programs across the jurisdictions and be 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
    - reporting back to Government through the Ministerial Council on Mineral and Petroleum Resources (MCMPR) on the results, their implications and expenditure.

16. CO_2 storage exploration incentives that could be applied over the period 2010–2017 should be identified and evaluated, with the CSTF to provide a recommendation on appropriate incentives policy to the Minister for Resources and Energy in the first quarter of 2010.

STREAMLINING PROJECT APPROVALS

17. Options should be developed to improve regulatory certainty and consistency for CCS project approvals:

    - Consideration should include transitional licensing provisions; setting time frames for granting approvals; specific transitional regulations and legislation; establishing a dedicated cross-agency coordinating team on an as-required basis to manage the regulatory approval process for commercial-scale projects; and resolving conflicts and overlaps between different bodies of regulation and different jurisdictions
    - Implementation of the preferred options should be overseen through the MCMPR.

SKILLS DEVELOPMENT

18. The Council, in association with relevant professional institutes, should develop a skills gap analysis to assess the requirements for skilled personnel to support the rollout of CCS technology over the next 20 years. This could potentially link with the recently announced National Resource Sector Employment Taskforce.

1 INTRODUCTION

Under the Australian Government's National Low Emissions Coal Initiative (NLECI), the National Low Emissions Coal Council (NLECC or the Council) has been established to bring together key stakeholders from government, industry, and the coal research community. The Council's Terms of Reference are provided at Attachment A. Council members at July 2009 are listed at Attachment B.

A key task for the Council is to advise Australian governments and industry on development and implementation of a national low emissions coal strategy to ensure that the coal sector makes a substantial contribution to Australian greenhouse gas (GHG) abatement, while enhancing the contribution that coal makes to Australia's energy security and economic well being.

In particular, the Council has been asked to address the goal of ensuring that low emissions technologies for coal, including carbon capture and storage (CCS), are demonstrated at a commercial-scale from 2015, are available for commercial deployment by 2020, and are deployed as they become commercially available.

CCS technologies are aimed at achieving near-zero emissions of carbon dioxide (CO_2) from industrial use of fossil fuels for energy. CCS involves capturing the CO_2 at the industrial source point, transporting it to the point of storage and injecting it into suitable geological rock formations that provide long-term, safe containment deep underground.

The first part of this report sets outs the strategic impetus for CCS. Chapter 2 focuses on the drivers for CCS uptake for energy-related GHG abatement, as part of a broad transformation of the energy sector. The imperatives for Australia resonate strongly with wider global goals. CCS coal-fired power generation is suited to anchoring the provision of a reliable and affordable electricity supply as part of a broader, low emissions energy technology mix in a carbon constrained world. Linkages and interdependencies with Australia's significant coal resource endowment are highlighted. Strategic links are also drawn with the wider uptake of CCS needed for emissions abatement in a range of industries. Australia is not on its own in this area, and major policy and support measures currently being developed by governments around the world should inform the Australian experience.

The second part of the report explores the realities of the challenges. Chapter 3 assesses the current state of technological development for CO_2 capture, transport and storage, and the innovation and deployment hurdles which lie ahead for CCS, similar to other commercial-scale, emerging low emissions technologies. The target timeframe for CCS availability for commercial deployment for low emissions power generation in Australia from the early 2020s is confirmed as feasible but ambitious, driven by the overall urgency to mitigate adverse climate change impacts. In Australia and elsewhere, coal-fired power generation will lead the early deployment path for commercial-scale industrial plants integrated with CCS.

Chapter 4 provides insights into the key factors affecting investment decisions by power generation businesses in Australia, in particular the National Electricity Market (NEM). These decisions lie at the heart of how the power sector will adjust to a carbon-constrained future, and how the roles of various power generation technologies, including coal with CCS, will unfold in a low emissions, energy-secure future.

The final part of the report provides structured recommendations on the combined actions needed from industry, government and the community in order for CCS to deliver on its strong potential contribution to GHG mitigation and energy security. Chapter 5 identifies and prioritises required actions, and broadly indicates the scale of investments required. A number of areas are flagged for further investigation and consideration. Chapter 6 outlines recommended implementation and reporting arrangements.

2 THE CLIMATE CHANGE IMPERATIVE

THE CHALLENGE

- Securing reliable and affordable energy supplies and reducing associated carbon dioxide (CO_2) emissions is a major economic challenge.
- There is clear scientific evidence that there is a high risk of damaging climate change if the world does not move quickly to significantly reduce GHG emissions.
- Australia has a stronger interest than most other developed countries in finding a way to address climate change due to our hot, dry climate and the structure of our economy.
- The energy sector is a major source of GHG emissions, both globally and in Australia. The energy sector was the source of 75 per cent of Australia's GHG emissions in 2007. This includes electricity generation, which was the source of 37 per cent of Australia's GHG emissions.
- All options for reducing GHG emissions from the energy sector, including energy efficiency and greater uptake of renewable energy, need to be explored to prevent the most serious impacts of climate change and to determine the most cost-effective measures for prevention.
- CCS must also be part of any GHG abatement solution as it is assessed, by the IEA, as the only technology available to mitigate GHG emissions from large-scale fossil fuel usage and is therefore essential to achieve significant emission cuts.
- The IEA estimates that CCS will need to contribute nearly one-fifth of the necessary emission reductions to reduce global GHG emissions by 50 per cent by 2050 at a reasonable cost. Without CCS, the IEA estimates that the annual cost for halving emissions in 2050 would be 71 per cent higher.
- CCS will need to be an even bigger part of the solution in Australia due to our abundance of fossil fuels and our high reliance on coal for baseload electricity supply.
- The successful deployment of CCS technologies in Australia will allow us to capitalise on the continuing use of Australia's abundant black coal, brown coal and natural gas resources. The black and brown coal industries are major regional employers.
- Australia has a strong interest in facilitating CCS uptake by our major coal export customers. Black coal is Australia's largest export commodity, with exports valued at nearly $55 billion for the twelve months ending April 2009.
- CCS will have broader application in Australia beyond coal-fired power generation, including as part of the proposed Gorgon Liquefied Natural Gas (LNG) project. Support for early deployment of CCS for coal-fired power generation will ultimately underpin the application of CCS to other high emitting industries, such as steel, cement, and gas-fired power generation.
- Action has commenced in Australia to support R&D, small- to medium-scale demonstration, and first-of-a-kind (FOAK) commercial-scale demonstration of CCS.
- The Australian Government has taken a lead role in establishing and supporting the Global Carbon Capture and Storage Institute (Global CCS Institute), which aims to accelerate commercial deployment of CCS projects and to facilitate and drive global cooperation on CCS.
- Most of the major world economies have recognised the fundamental importance of accelerated deployment of CCS, with a focus on commercial deployment of CCS for power generation. Ways to mobilise necessary financing will be addressed at the Carbon Sequestration Leadership Forum Ministerial (CSLF) meeting in October 2009, and at the Conference of the Parties meeting in Copenhagen in December 2009.

2.1 THE MITIGATION CHALLENGE

There is clear scientific evidence that there is a high risk of climate change if the world does not move quickly to significantly reduce GHG emissions. A recent report of the international *Breaking the Climate Deadlock* initiative between former UK Prime Minister Tony Blair and The Climate Group notes that:

> It is now almost universally accepted that, in order to minimise the risk of irreversible damage to our planet and our livelihoods, we need to strive to keep the average global temperature increase below 2°C. It is also widely recognised that, to achieve this, we will need to peak global emissions before 2020 and then reduce them by 50–85% below 2000 levels, setting interim targets along the way.[1]

The Climate Group report also acknowledges that the political will to tackle climate change is in place:

> Heads of government from all parts of the world have declared their willingness to adopt ambitious emissions targets, both individually and collectively, but have wanted to be sure that such goals, while certainly challenging, are practically achievable.[2]

As Garnaut and others have stated, Australia has a stronger interest than most other developed countries in addressing climate change. We are already a hot, dry country and the structure of our economy means that our terms of trade would be damaged more by the effects of climate change than those of other countries.[3]

2.2 THE DRIVERS FOR CCS GLOBALLY

The energy sector is the major source of global GHG emissions, accounting for approximately 69 per cent of global CO_2 and 60 per cent of total GHG emissions.[4] Further, in the absence of new policies or supply constraints, the IEA projects that CO_2 emissions from the energy sector will increase by 45 per cent by 2030 compared to 2006 levels[5], and by up to 130 per cent by 2050 compared to 2005 levels[6]. These increases, if they occurred, would be driven by continuing rises in the use of fossil fuels (coal, oil and natural gas) to meet expected world demand for energy, with the bulk of the new CO_2 emissions and increased demand for energy occurring in developing countries.

In its *Fourth Assessment Report*, the Intergovernmental Panel on Climate Change (IPCC) indicates that such a rise in greenhouse emissions could lead to a temperature increase in the range of 4° C to 7° C, whereas achieving a halving of energy-related CO_2 emissions by 2050 could limit the expected temperature increase to less than 3° C. However, the IEA has commented that achieving such reductions in energy sector emissions will require an 'energy technology revolution involving increased energy efficiency, increased renewable energies and nuclear power, and the decarbonisation of power generation from fossil fuels.'[7]

1 Climate Group 2009: The Climate Group and the Office of Tony Blair: *Breaking the Climate Deadlock, Technology for a Low Carbon Future,* July 2009 (available at www.theclimategroup.org).

2 Climate Group 2009.

3 Garnaut 2008: R. Garnaut, *The Garnaut Climate Change Review*, Cambridge University Press, September 2008.

4 IPCC 2007: Intergovernmental Panel on Climate Change, *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report*, B. Metz et al, Eds., Cambridge University Press, 2007.

5 IEA WEO 2008: International Energy Agency, *World Energy Outlook 2008*, November 2008.

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

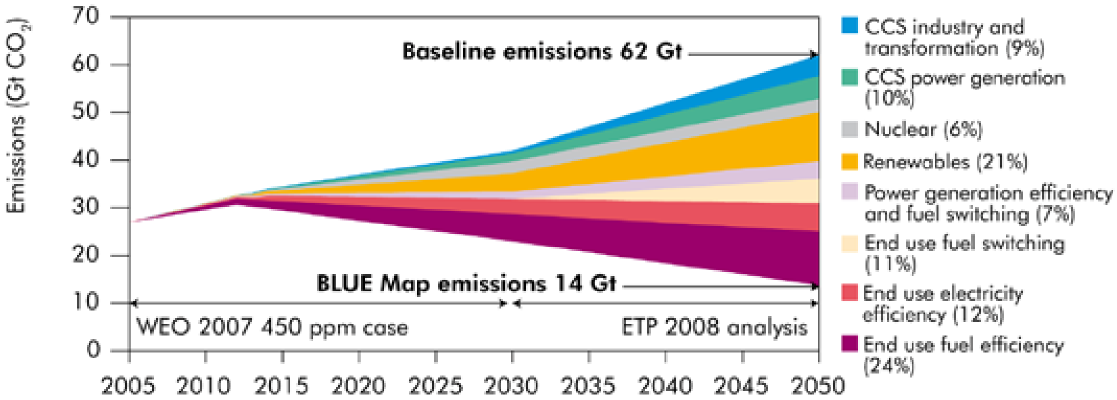
7 IEA CCS 2008: International Energy Agency, *CO_2 Capture and Storage: A key carbon abatement option*, October 2008.

To achieve the required decarbonisation of fossil fuel power generation, the IEA assesses that CCS is the only technology available to mitigate GHG emissions from large-scale fossil fuel usage.

The Council agrees that all options for reducing GHG emissions need to be explored if serious inroads are to be made within the required timeframes. In particular, if the world's large reserves of fossil fuels are to continue to be a part of the future energy supply mix, CCS must be part of any GHG abatement solution and is essential to achieving significant emission cuts.

The IEA's Energy Technology Perspectives (ETP) scenarios demonstrate that to achieve significant reductions **at a reasonable cost**, CCS will need to contribute nearly one-sixth of emissions reductions necessary to reduce global GHG emissions by 2030 and one-fifth of emissions reductions necessary to reduce global GHG emissions by 50 per cent by 2050. As demonstrated in Figure 2.1, about half of all CCS would be in power generation and half in other industrial processes (cement, iron and steel and chemicals) and the fuel transformation sector.

Figure 2.1: Technologies for reducing global energy-related CO_2 emissions by 2050[8]



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

The IEA has also found that deployment of CCS will significantly lessen the cost of reducing global GHG emissions:

> Without CCS, the annual cost for emissions halving in 2050 is USD1.28 trillion per year higher…this is an increase of about 71%[9].

CCS is therefore essential to the achievement of deep emission cuts by 2050 particularly—but not solely —in the strategically important coal sector.

8 IEA 2009: International Energy Agency, *Ensuring Green Growth in a Time of Economic Crisis: The Role of Energy Technology*, Paper for G8 Environment Ministers Meeting, Siracusa, 22–24 April 2009.

9 IEA ETP 2008, p17.

The 2008 *IEA World Energy Outlook* forecasts that in the absence of new policies or supply constraints, coal-fired electricity generation's share of global electricity production is projected to rise from 41 per cent to 44 per cent in the two decades to 2030. Countries such as China and India—which together account for 46.8 per cent of world coal production—will continue to rely on coal to meet rapidly growing energy demand and to improve living standards. The following table from the Australian Bureau of Agricultural and Resource Economics (ABARE) indicates substantial planned additions to coal-fired electricity generation capacity in Asia.

Table 2.1: Planned additions to coal-fired electricity generation capacity in Asia to 2020[10]

	MW	implementation phase
India	77 770	2008 – 2017
Pakistan	19 710	2006 – 2030
Sri Lanka	4 100	2007 – 2016
Bangladesh	2 400	2008 – 2016
Thailand	4 000	2008 – 2018
Laos	1 800	2008 – 2014
Cambodia	4 510	2008 – 2020
Viet Nam	116 000	2007 – 2025
Malaysia	2 670	2007 – 2014
Indonesia	50 000	2007 – 2026
Philippines	4 360	2008 – 2016
China	280 500	2009 – 2020
Korea, Rep. of	8 450	2005 – 2020
Japan	2 940	2006 – 2016

Most of the major world economies recognise the fundamental importance of CCS to achieving deep emissions cuts, and have implemented CCS technology development programs designed to achieve commercial deployment, with a focus on CCS for power generation.

Although the individual components of CCS have been demonstrated at commercial-scale in the oil and gas industries for over a decade, CCS integrated with power generation plants has not been demonstrated yet at commercial-scale anywhere in the world. CCS demonstration and deployment challenges are discussed further in the next chapter.

2.3 THE DRIVERS FOR CCS IN AUSTRALIA

The Council accepts the imperative of substantially reshaping and significantly reducing Australia's energy-related GHG emissions, in line with the Australian Government's commitment to reduce emissions in Australia by 60 per cent of 2000 levels by 2050. The Council notes that a continuing licence to operate for fossil fuels generally, and brown and black coals specifically, will be contingent on the ability to significantly reduce their CO_2 emission profiles in order to meet growing community expectations and mandated emissions reductions targets in Australia and key export markets.

10 ABARE 2009: Australian Bureau of Agricultural and Resource Economics, *Australian commodities*, Vol 16 No 1, March 2009.

2.3.1 Reducing Australian energy-related GHG emissions

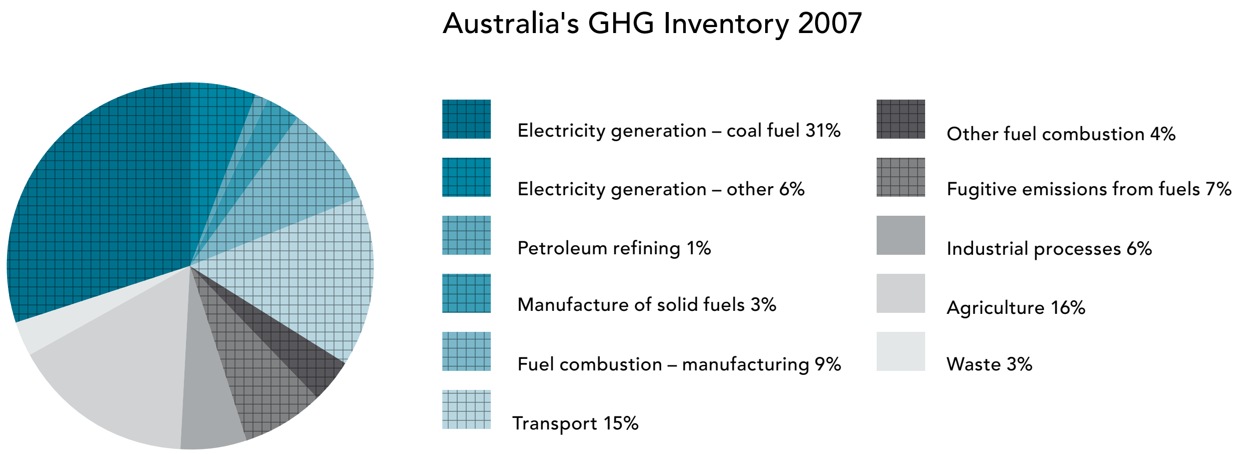
The Australian Greenhouse Gas Inventory reports that Australia's energy sector was the source of 408.2 million tonnes (Mt) CO_2-equivalent (CO_2-e) of GHG emissions in 2007, or 75.4 per cent of Australia's total GHG inventory emissions of 541.2 Mt CO_2-e that year.[11,12]

Figure 2.2 shows the major sources contributing to Australia's GHG emissions in 2007. Within the energy sector, electricity generation was the largest source of GHG emissions, with 199.5 Mt CO_2-e, or 36.8 per cent of Australia's total emissions. Other energy sector contributors included:

- transport 78.8 Mt CO_2-e, or 14.6 per cent of total emissions
- fuel combustion in manufacturing and construction 48.7 Mt CO_2-e, or 9.0 per cent of total emissions
- fugitive emissions 37.7 MT CO_2-e, or 7.0 per cent of total emissions.

GHG emissions from coal-fired electricity generation for 2007 are estimated at 168.4 Mt, or 31.1 per cent of Australia's total GHG inventory emissions that year. Of this, black coal-fired electricity generation contributed 112.1 Mt, and brown coal-fired electricity generation contributed 56.3 Mt.

Figure 2.2: Proportions of GHG emissions in Australia in 2007. Energy sector shares are hashed.[13]



The IEA analysis depicted in Figure 2.1 indicates that significant emissions reductions globally will be achieved most cost-effectively through a range of measures including energy efficiency, uptake of renewables, and the application of CCS technologies.

The same mix of measures is equally applicable to Australia, but the role of CCS will be far more dominant due to our reliance on fossil fuels. Figure 2.3 shows a projection by CSIRO of Australia's electricity generation portfolio to 2050. Coal-fired power generation with CCS is projected to provide more than 40 per cent of Australia's electricity in 2050[14].

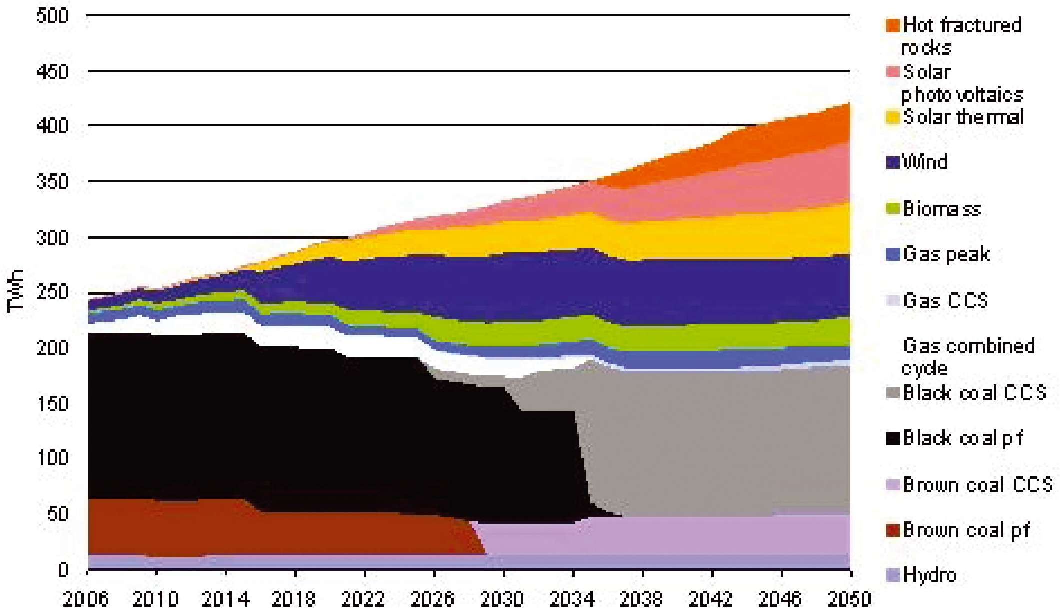
11 DCC 2009: Department of Climate Change, *Australia's National Greenhouse Accounts: National Greenhouse Inventory accounting for the KYOTO target*, May 2009.

12 Australia's total greenhouse gas emissions in 2007 were estimated at 541.2 MT CO_2-e before accounting for Land Use, Land Use Change and Forestry Activities. After accounting for these activities, the estimated total was 597.2 MT CO_2-e.

13 DCC 2009; derived.

14 CSIRO 2009, *Dealing with carbon – what is Australia's carbon balance & footprint and how do we deal with the cost of adaption?*, presentation by Dr Megan Clark, Chief Executive CSIRO, at the Australia-Israel Chamber of Commerce, June 22 2009.

Figure 2.3: Projected Australian electricity generation portfolio under CPRS-5[15]



The carbon emissions intensity of Australia's electricity production will be dramatically reduced under future diversified electricity generation portfolios with CCS and renewables. The average carbon intensity of National Electricity Market (NEM) sent-out electricity in 2008 was estimated at around 0.98 tonnes of CO_2 per MWh.[16] By 2050, to meet the targeted emissions reductions for the Australian economy, this will need to drop to projected carbon intensity levels between 0.1 and 0.2 tonnes of CO_2 per MWh[17].

Early deployment of CCS for coal-fired power generation will help underpin the application of CCS to other high emitting industries in Australia, such as steel, cement, and gas-fired power generation. Internationally, the steel industry has identified the need for CCS uptake as part of the industry's strategies for ultra-low CO_2 steelmaking, and this has been included in the CSLF's latest global CCS Technology Roadmap.

The fuel transformation sector in Australia, as internationally, has the potential to play an important role in reducing energy emissions intensity, and to be a commercial driver to deploy CCS. In Australia there are numerous projects being considered for coal to liquids such as Dimethyl Ether (DME), methanol and synthetic natural gas to LNG. In some cases there may be better commercial drivers for these projects to deploy CCS than for power projects with CCS. A demonstration coal to liquids project has recently been announced in Victoria.

The Gorgon LNG project in Australia's North West Shelf is expected to commence storing 3.5 Mtpa of reservoir[18] CO_2 from around 2015. In terms of CO_2 storage volumes, this will be the world's largest CCS project.

15 CSIRO 2009

16 ACIL Tasman 2009: *Fuel Resource, New Entry and Generation Costs in the NEM*, ACIL Tasman, April 2009.

17 Treasury 2008: *Australia's Low Pollution Future: The economics of climate change mitigation*, Australian Government Department of the Treasury, Canberra 2008; P175.

18 Emissions associated with LNG production come from two main sources – reservoir CO_2 that naturally occurs associated with hydrocarbon gases in the geological reservoir, and CO_2 generated by combustion of fuel in the production and liquefaction of LNG. Reservoir CO_2 can be captured by well established chemical processes.

2.3.2 Energy security considerations

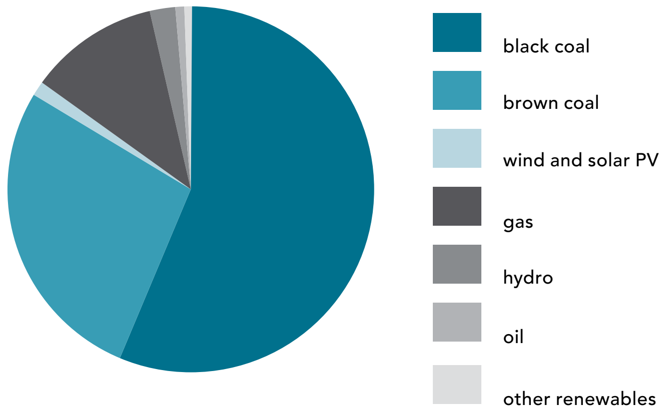
Energy security in the Australian context is defined[19] as the adequate, reliable and affordable supply of energy to support the functioning of the economy and social development, where:

- *adequacy* is the provision of sufficient energy to support economic and social activity
- *reliability* is the provision of energy with minimal disruptions to supply
- *affordability* is the provision of energy at a price which does not adversely impact on the competitiveness of the economy and which supports continued investment in the energy sector.

Australia's energy security has historically been enhanced by the physical availability of energy in the form of abundant fossil fuel resources (both coal and more recently gas) and relatively low electricity prices.

In 2006–07, coal accounted for 84 per cent of all fuels consumed by generators (in energy content terms), and gas a further 12 per cent (Figure 2.4). Notwithstanding the introduction of policies designed to encourage the development of alternative energy supplies, the dominance of coal in Australia's energy mix is projected to remain for some time.

Figure 2.4: Fuel inputs into Australian electricity generation, 2006–07[20]



As illustrated in Figure 2.3, modelling of how Australia may transition to a future low emissions economy anticipates a continuing foundation role for fossil fuel power generation to anchor the electricity supply over coming decades. Conventional fossil fuel generation (coal and gas fired power without emissions abatement) will progressively phase out, as CCS fossil fuel generation and increased renewables phase in.

Australia's reliable and affordable energy supply has also made it an attractive investment destination for a range of large energy intensive industries including aluminium, cement, steel and paper. Conversely, interruptions to energy supply can cause major financial losses and create havoc in economic centres, as well as causing potential damage to the health and wellbeing of the country.

Governments face a number of key challenges if Australia's energy security position is to be improved or at least maintained while Australia transitions to a low emissions economy. The Australian Government's National Energy Security Assessment highlights that policies aimed at achieving emissions reductions—discussed further in Section 2.4—will have a negative impact on the reliability and affordability of electricity to 2023.

19 DRET 2009: Department of Resources, Energy and Tourism, *National Energy Security Assessment 2009*, Commonwealth of Australia, 2009.

20 ABARE 2009: Australian Bureau of Agricultural and Resource Economics, *Energy in Australia* Resources, Energy and Tourism, Commonwealth of Australia, 2009. Note that this ABARE publication advises (p21) that the latest (2006–07) data is presented on the basis of *fuel inputs* into electricity generation, and that this cannot be compared with previous ABARE publications reporting *electricity generation output* by fuel.

2.3.3 Coal's contribution to the Australian economy

The successful deployment of CCS technologies in Australia will also allow us to capitalise on continuing use of Australia's abundant black coal, brown coal and natural gas resources.

In addition to providing 84 per cent of fuel used for Australia's electricity, coal makes a direct contribution to the Australian economy. With the value of coal exports approaching $55 billion (approximately 24 per cent of all merchandise exports) for the twelve months ending June 2009[21], black coal was Australia's largest export commodity in 2008–09. Each year the Australian black coal industry injects around $20 billion into the Australian economy—almost $15 billion is spent annually in wages, salaries, payments to contractors and on goods and services; up to $4 billion was paid in royalties to state governments in 2008–09; and around $2.5 billion paid in direct and indirect taxes.

The black and brown coal industries are also major employers, employing over 30,000 people, with a further estimated 100,000 jobs dependent on the industry. Many of these jobs are in regional areas—the coal sector underpins the prosperity of regions including the Latrobe Valley, Hunter Valley and the Bowen basin.

Australia therefore has a compelling strategic and economic interest in ensuring a sustainable future for the coal industry, including by demonstrating CCS domestically and facilitating CCS uptake by our major coal export customers.

2.4 AUSTRALIAN POLICIES FOR CCS SUPPORT

2.4.1 Climate change policies and the CPRS

In February 2008, the Australian Government announced its approach to climate change policy based on three pillars. The first pillar is reducing Australia's GHG emissions, marked by a commitment to reduce Australia's emissions by 60 per cent of 2000 levels by 2050. The second pillar is adapting to climate change that we cannot avoid. The third pillar is helping to shape a global solution to this global problem.

The foundation elements for reducing Australia's GHG emissions—the first pillar of the Government's climate change policy—are the Carbon Pollution Reduction Scheme (CPRS), investment in CCS demonstration, an expanded renewable energy target (RET), and action on energy efficiency.[22] These foundation elements will work in parallel to support the development and deployment of technologies, improvements in energy efficiency and structural changes that are needed to move to a low-carbon economy.

The CPRS will develop a price on carbon in the Australian economy through a 'cap and trade' mechanism. The Australian Government's CPRS White Paper framework recognises that complementary measures will need to work in parallel with the CPRS to build Australia's capacity to respond to a carbon price and to reduce the average cost of GHG abatement across the economy. Complementary measures may also be designed to address market failures that cannot be addressed by a carbon price alone. For instance, complementary measures may include measures where price signals provided by the CPRS are insufficient to overcome other market failures that prevent the uptake of otherwise cost-effective abatement measures. Such measures may only need to be transitional to address specific failures in the short- to medium-term and will not be required in the longer-term.

The NLEC strategy will make a key contribution to the second of the foundation elements for reducing GHG emissions—namely, investment in CCS. Public sector investment in CCS technology is needed to accelerate the timeframe for developing and deploying this technology. To reduce Australia's long-term GHG emissions by 60 per cent below 2000 levels by 2050, CCS technologies need to be available for deployment from 2020. These technologies will not be available for widespread deployment in Australia until they are demonstrated at an industrial-scale. This is explored more fully in Chapter 3.

21 ABS 2009: Australian Bureau of Statistics, *5302.0 Balance of Payments and International Investment Position, Australia, TABLE 9. GOODS CREDITS: Seasonally adjusted*. Released 01 September 2009.

22 Treasury 2008: Chapter 19

Commercial deployment will not automatically follow demonstration at industrial-scale. Carbon prices generated in the earlier stages of the CPRS are not expected to provide sufficient inducement on their own to justify widespread deployment of CCS. The Council notes that it will be some time until emission permit prices rise to levels that fully address this underlying market failure, and that this will weigh against investment in rapid deployment of all low emissions technologies in the early stages of the CPRS.

A major focus of the low emissions coal strategy (see Chapter 5) is therefore on additional measures that may be needed to ensure the level of short-term investment in the deployment of CCS technology reflects levels that are needed to support longer-term national interests. This range of measures needs to complement the CPRS by addressing market failures that act to delay the deployment of CCS technologies and to reduce the prices that would otherwise be needed under the CPRS to bring about effective changes in technology deployment.

This range of measures together with the overall strategy also needs to take account of, and feed into, wider energy policies being developed under the Energy White Paper by the Australian Government. The Energy White Paper will provide a comprehensive, integrated policy framework of long-term policies and actions to ensure cleaner, adequate, reliable and affordable energy through to 2030.

2.4.2 Progressing low emissions technologies in Australia

Targeted assistance

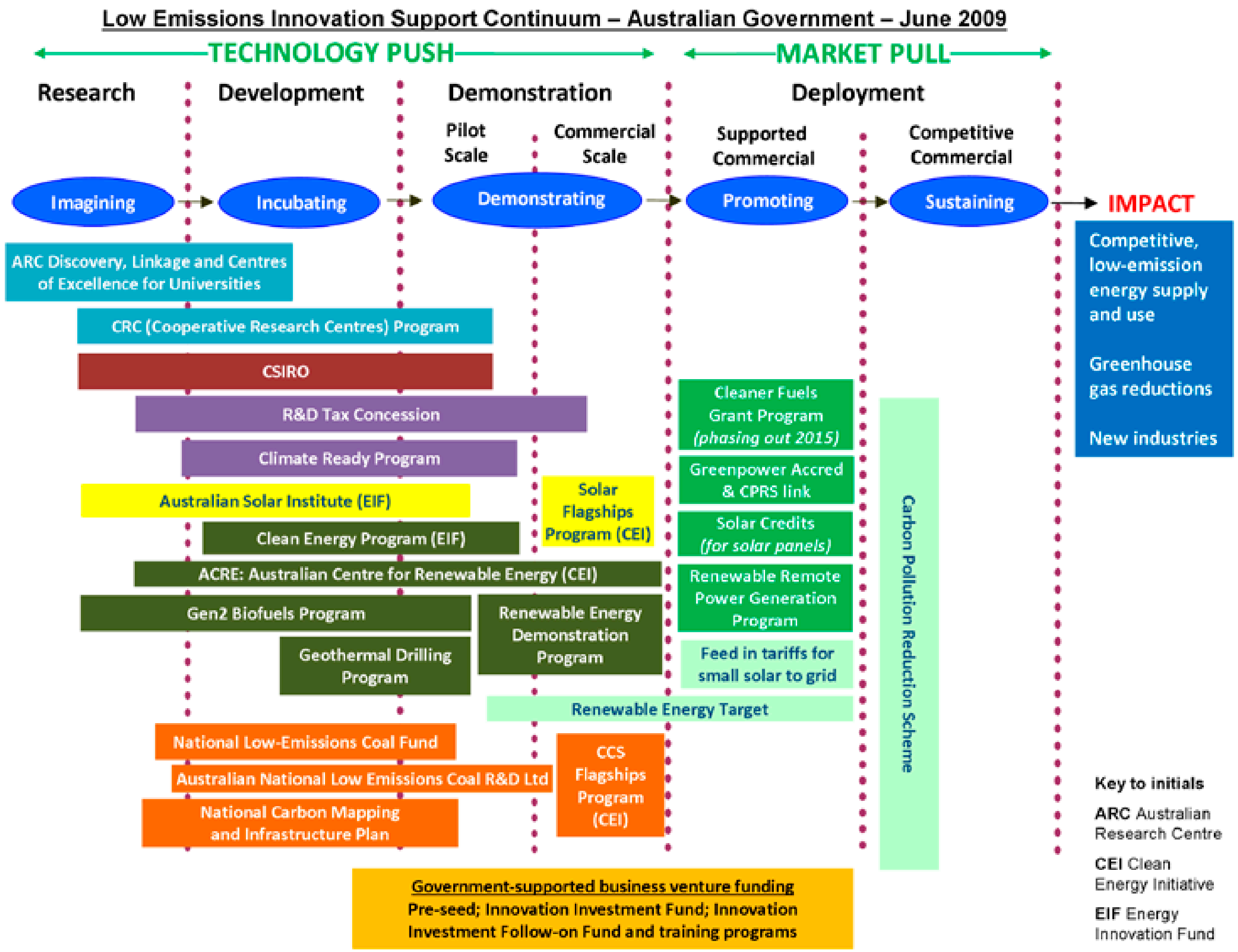
The Australian Government has a range of measures (see Figure 2.5) in place to progress the commercial deployment of low emissions energy technologies. Those relevant to CCS include:

- Clean Energy Initiative – CCS Flagships Program, which includes:
  - > funding to support construction and demonstration of commercial-scale, integrated CCS projects in Australia
  - > $2 billion Australian Government funding plus leveraged state government and industry contributions.
- National Low Emissions Coal Initiative, which includes:
  - > $400 million Australian Government funding plus leveraged state government and industry contributions to accelerate development and demonstration of low emissions technologies for coal, with a focus on medium-scale demonstration and research and development
  - > this includes $75 million to establish Australian National Low Emissions Coal Research and Development Ltd (ANLEC R&D).
- strong links with the Global Carbon Capture and Storage Institute (Global CCS Institute):
  - > the Australian Government is providing $100 million annual funding
  - > Australia's efforts to accelerate CCS demonstration and deployment, both domestically and for uptake by our key coal export customers, are expected to strongly benefit from the work of the Global CCS Institute.

These initiatives are complemented by state government funding programs and the Australian black coal industry's $1 billion COAL21 Fund, which is a world-first voluntary industry fund to support low emissions coal technologies.

The Council welcomes these initiatives and recognises the important role they are playing in R&D and early demonstration activities and the role they will play in FOAK commercial-scale demonstration. As highlighted in Figure 2.5, however, the Council notes a particular gap in support programs in Australia for early CCS deployment at the *supported-commercial* stage where costs typically are significantly higher for new technologies than mature, widely-deployed plants in the final *competitive-commercial* stage. Options for bridging this gap are discussed in Chapter 5.

Figure 2.5: Innovation support initiatives of the Australian Government for low emissions technologies – June 2009.



Source: Extended from B Godfrey 2009: *Delivering the externality benefits of renewables for Australia*, presentation to the Australian Academy of Technological Sciences and Engineering, March 2009. Available from www.atse.org.au. Used by permission.

Research and Development

At this relatively early stage in the development of CCS, there is still a vital role for further research and development (R&D), which is needed to:

- bring down capture costs
- more cost effectively identify and use storage space
- provide confidence in capacity values and storage integrity in a range of geological settings
- improve monitoring and verification
- enhance community confidence in CCS technology.

Australia has a range of R&D activities applicable to low emissions coal utilisation that are supported by government programs and by industry, including through the COAL21 Fund. State government activities in CCS research, development and demonstration are outlined at Attachment C.

Current major providers for low emissions coal R&D in Australia are listed below[23].

Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) – capture and storage research. The CO2CRC is also running a demonstration program which includes the Otway Project, the first Australian demonstration of geological storage of CO_2.

CSIRO – research for coal-fired power generation activities focus on gasification, post-combustion capture and CO_2 storage.

University of Newcastle – specialises in oxyfuel, chemical looping, fundamental chemistry and CO_2 storage.

University of Queensland – focuses on oxygen separation, hydrogen separation and CO_2 storage.

Monash University – coal research activities are focused on servicing Victorian brown coal interests. Research priorities are oxyfuel combustion, novel gasification methods and improved efficiency.

University of Western Australia – focus areas are coal combustion, petroleum geoscience and geotechnical engineering.

Curtin University of Technology – low emissions coal-fired power generation and coal to liquids processes.

University of Melbourne – coal research activities are focused on membrane separation, solvents, geopolymers, carbon storage and coal deposits.

Two leading CCS R&D Programs, namely the CRC for Coal in Sustainable Development (CCSD) and the Centre for Low Emission Technologies (cLET), which represented a strong collaboration between researchers, the coal industry and electricity generators, have been concluded within the last two years.

The Council has established the Australian National Low Emissions Coal (ANLEC) R&D organisation to rebuild, lead and enhance coordination of Australia's research effort associated with CCS demonstration projects.

Australia's CCS research priorities and ANLEC R&D's forward work program are discussed in Chapter 5.

23 Lowe A and Simento N 2009: *Considerations for Research Supporting Low Emissions Coal Technology Demonstration*, Allen Lowe and Noel Simento, January 2009; report prepared for the National Low Emissions Coal Council; Department of Resources, Energy and Tourism, Canberra.

The Australian low emissions coal R&D effort should be seen within the context of a much larger overseas R&D expenditure and Australia's position as a technology taker, particularly in generation, capture and pipeline technologies. The Australian effort must be integrated with overseas programs where possible. An important role for ANLEC R&D will be in developing international research linkages to support technology development and the dissemination of information.

2.5 CURRENT INTERNATIONAL DEVELOPMENTS IN CCS

Although the focus of the national low emissions coal strategy is on the work that must be done in Australia to support the further development and deployment of low emissions coal technologies domestically, the importance of the international dimension cannot be underestimated. Australia has taken a leading role in developing CCS. This includes world leadership on geological storage and innovations in adapting existing technology to undertake trials of capture technologies in Australia.

Ultimately though, Australia is reliant on the world's major equipment suppliers to undertake the multi-billion dollar programs that are needed to develop and manufacture CCS equipment. The work being done by Australia will influence the further development of CCS technologies and deliver important innovations and engineering services. Importantly, the commercial-scale demonstration projects in Australia and the work that we do to encourage other countries down a similar path are providing the initial drivers that are needed by equipment suppliers to refocus their development priorities on CCS. At the same time, Australia needs to be fully attuned to international technology developments and have full access to international learnings from FOAK industrial-scale demonstration projects in other countries.

The initiative by the Australian Government to establish and support the Global CCS Institute supports these objectives. The Global CCS Institute's central objective is to accelerate the commercial deployment of CCS projects to ensure their valuable contribution to reducing CO_2 emissions, and to facilitate and promote global cooperation on CCS. The G8 countries have committed to the development of 20 commercial-scale CCS projects to be in operation by 2020, and a particular focus of the Global CCS Institute is to develop the partnerships needed to achieve this.

The Global CCS Institute is undertaking a comprehensive audit of the world's current CCS projects. This aims to take stock of aspects of global deployment of CCS, including:

- project status
- costs
- the impact of the global financial crisis
- policy and regulatory frameworks
- research and development efforts
- commercial and non-commercial gaps.

The international community increasingly recognises that the accelerated deployment of CCS is vital to achieving GHG mitigation objectives.

This is reflected in major statements of support and calls for action by the G8 and G20 Leaders and by Leaders at the Major Economies Forum (MEF). Leaders including the Prime Minister of Australia, the Hon Kevin Rudd MP, at the MEF Meeting in L'Aquila Italy in July 2009 noted the need to develop a broad set of principles to guide the design of a financial system that will support the deployment of new technologies to promote energy security, lower GHG emissions, and facilitate adaptation to climate change.

MEF leaders agreed, among other things, that financing needs to:

- be scaled up substantially
- come from a variety of sources, both public and private
- be more predictable
- draw upon the expertise of existing institutions
- be subject to balanced governance and clear accountability.

Ways to mobilise necessary financing to support deployment of new energy technologies will be considered at the Conference of Parties meeting in Copenhagen in December 2009, under the United Nations Climate Change Conference.

The October 2009 Ministerial meeting of the CSLF is also anticipated to focus on the roles of government and industry in moving CCS to commercialisation. The CSLF has developed an international register of CCS incentives being put in place around the world[24].

Further, the IEA is expected to release a detailed global CCS technology roadmap by the end of 2009.

The roadmap[25] is being developed in partnership with the CSLF and the Global CCS Institute and aims to provide actions and milestones on the full spectrum of issues that must be addressed if CCS is to deliver the necessary GHG emissions reductions in time for global climate stabilisation by 2050. These issues include:

- appropriate financing mechanisms for CCS, both for near-term full-scale demonstration and for medium-term commercialisation
- adequate legal and regulatory frameworks that protect public health and safety and facilitate rapid CCS demonstration
- full engagement of the public to understand their questions and design projects to meet their informational and risk mitigation needs
- active involvement of emerging economies that rely heavily on fossil fuels, to create a shared goal of CCS information sharing and truly global demonstration.

The roadmap is intended to facilitate international collaboration and information sharing around these issues, with a goal to speed up demonstration, learning and successful deployment of this important GHG mitigation technology.

The measures being proposed in this report by the National Low Emissions Coal Council are of direct relevance to Australia's participation in these international initiatives.

The December 2009 meeting of the United Nations Conference of Parties will include consideration of whether CCS projects should be included under the Clean Development Mechanism (CDM). Under the CDM, eligible projects in developing countries generate CO_2 credits that correspond to the GHG reduction achieved by the project, and the project's host country can sell the credits to companies or industrialised countries.

Australia supports the inclusion of CCS as an eligible project activity under the CDM, acknowledging that this will require credible and scientifically robust methodologies for verifying safe and secure geological storage of greenhouse gases, and noting Australia's world leadership in this area[26]. In November 2008, Australia passed legislation for a comprehensive regulatory framework to facilitate the geological storage of greenhouse gases in offshore areas.

24 Available at http://www.cslforum.org/incentivesregistry/index.html

25 IEA 2009: International Energy Agency, *IEA CCS Roadmap Meeting 2–3 February 2009*, Summary Statement.

26 DCC 2008 SBSTA: *Views on issues relevant to the consideration of CCS as CDM project activities*; Australian submission to the Subsidiary Body on Scientific and Technical Advice (SBSTA) to the UN Framework Convention on Climate Change; Department of Climate Change, November 2008.

3 CAPTURE, TRANSPORT AND STORAGE OF CO_2

KEY FINDINGS

Implementing CCS requires capture of CO_2 emissions at the source, their processing and compression for pipeline transport, their injection underground for permanent geological storage and confirmation of ongoing storage integrity.

Notwithstanding the significant technical, timeline and financial challenges ahead, it is the view of the Council and the CSTF that a significant proportion (over 20 per cent) of Australia's future CO_2 emissions can be captured, transported and safely stored deep underground.

Capture

- There are three main technology options—post-combustion capture (PCC), pre-combustion capture (including Integrated Gasification Combined Cycle – IGCC), and oxyfuelling—for CO_2 capture in fossil-fuel electricity generation and for utilisation in a range of large-scale industrial processes.
- While the technologies are at different stages of development, they are all considered prospective for application in Australia, and it is the Council's view that they should be developed in parallel.
- Construction and operating costs estimates for CCS integrated with power generation plants are currently uncertain, as no commercial-scale plant has yet been built. Within the current high levels of uncertainties, a recent study estimated that for early capture plants while the technologies are immature, the cost of electricity produced from a new commercial-scale, coal-fired power plant in Australia with a high CO_2 capture function is expected to be approximately double the cost without capture (excluding emission permit costs). CO_2 transport and storage costs also need to be included.
- Looking ahead to when the capture technologies are assumed to be more mature, the study estimated that the capture function costs will have been reduced but will still be higher in real terms than coal-fired generation without capture (excluding emission permit costs).

Transport

- The CSTF has extensively analysed CO_2 transport and storage issues in the Australian context.
- There is long-term, international, commercial experience in CO_2 pipeline transportation.
- Transport of CO_2 in supercritical phase over long distances will typically require recompression en route, with associated power requirements for that recompression.
- Specifications for the composition of streams to be carried in pipeline networks should be set by each hub network based on the source emissions profile and requirements at the storage sites. It is likely to be most economic to specify high purity CO_2 streams.
- If CCS deployment proceeds at a significant scale in Australia, the capacity of pipeline manufacturers to construct sufficient large-diameter pipes – greater than 34" – could be a deployment constraint, particularly if other countries are also deploying CCS. However, pipeline manufacturers would be expected to develop capacity to increase supply in response to sustained increased demand.

Storage

- There is high confidence that the east of Australia has storage capacity for 70–450 years of emissions, and the west of Australia has storage capacity for 260–1120 years of emissions, with the possibility for a far greater capacity as basins and their CO_2 storage behaviour become better known.
- Developing adequate confidence in storage capacity and likely total costs is now recognised as the critical driver of CCS project timelines.
- The timeframes for commercial deployment of geological storage sites and technology are long.
- For large basins, 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, or that are using smaller sites (that is smaller annual storage capacity) may be able to achieve results sooner.
- Depleted gas and oil fields, where there is usually abundant seismic data, wells and production history, could be evaluated and understood in a relatively short time frame, that is by 2016.
- 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.
- 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 Surat and Perth basins are also likely to develop as early capture and storage hubs.

Integrated CCS demonstration and deployment

- Although the individual components of CCS have been demonstrated at commercial-scale in the oil and gas industries for over a decade, CCS for a power generation plant has not been demonstrated yet at commercial-scale anywhere in the world.
- Integrated, commercial-scale demonstration projects, that link the generation, capture, transport and storage elements, are now needed to make rigorous technical, economic and risk assessments of the overall system operating at high utilisation factors and at scale.
- Until this happens, a rational investor will not accept that commercial deployment of CCS is 'bankable'.
- In an integrated CCS project, the main timing driver is expected to be the alignment of key decision points for the capture and storage components.
- Feasibility, design, permitting, construction and commissioning of such FOAK projects, either for new-build plants or for retrofitting existing plants, are expected to total 8 to 10 years.
- Significant penetration of CCS technologies will require realisation of economies of scale from multi-user hub-and-spoke CO_2 transport and storage infrastructure.
- Successful demonstration of such CCS regional hubs is needed to build confidence to make large-scale investments in multi-user infrastructure.

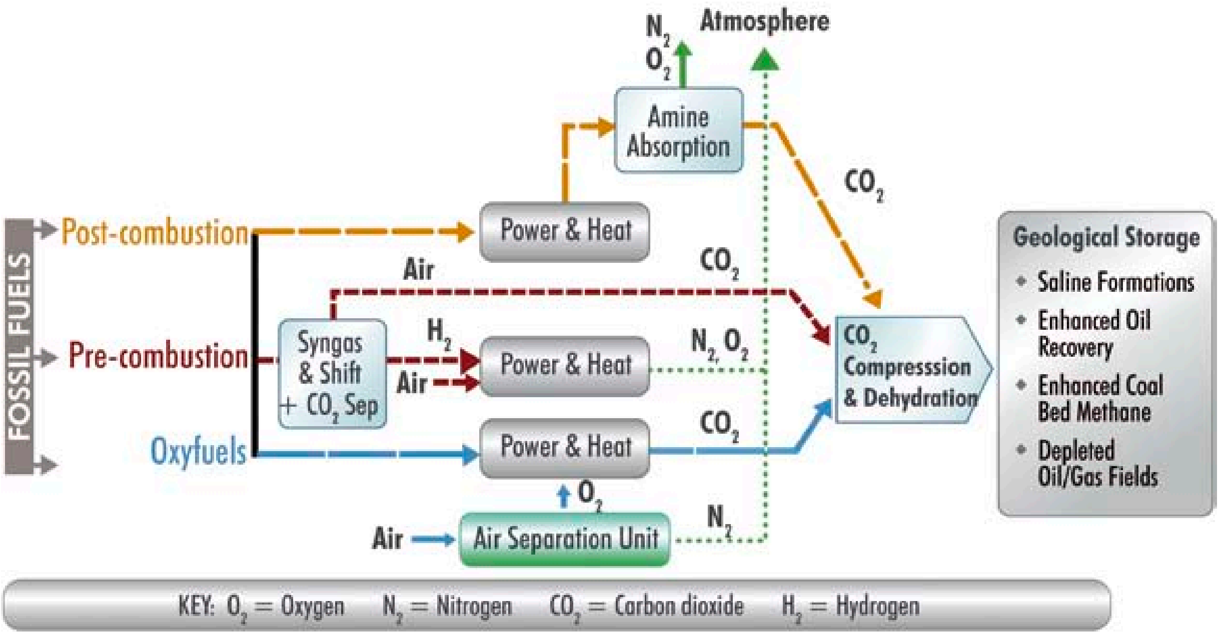
- The progress of stand-alone, FOAK, capture-transport-storage demonstration projects therefore should be aligned with development of capture-transport-storage demonstration hubs.
- If CCS is to be demonstrated at a commercial-scale from 2015 and available for commercial deployment by 2020, CCS must overcome the following deployment challenges. Strategies to address these challenges are considered in Chapters 4 and 5, and include:
  - > accelerating the generational deployment path. Each generation of a major new power technology typically takes 10–15 years to design, construct, commission and operate for learning experience
  - > progressing a coherent and cost-effective national portfolio of CCS demonstration projects with appropriate research foundations and support, and with a focus now on commercial-scale integrated demonstration projects
  - > coordinating the development of multi-user capture and storage hubs, over and above technology deployment through individual CCS projects
  - > financing commercial-scale demonstration projects and early deployment plants.

3.1 CO_2 CAPTURE

3.1.1 Overview

The main approaches for CO_2 capture, in particular for electricity generation, are depicted in Figure 3.1.

Figure 3.1: CCS processes for fossil fuel utilisation[27]



27 Source and copyright: CO2CRC http://www.co2crc.com.au/images/imagelibrary/cap_diag/Captureapplications_IEA.png, accessed 05 December 2008.

Post-combustion capture (PCC), pre-combustion capture, and oxyfuelling are the three main technology options for CO_2 capture in fossil-fuel electricity generation and for utilisation in a range of large-scale industrial processes (for example, steel, cement and fertiliser production).

In the PCC, CO_2 is captured from flue gases that contain 4 per cent to 8 per cent of CO_2 by volume for natural gas-fired power plants, and 12 per cent to 15 per cent by volume for coal-fired power plants. The CO_2 is captured typically through the use of solvents and subsequent solvent regeneration, sometimes in combination with membrane separation. The basic technology (using amine-based solvents) has been used on an industrial-scale on non-coal-fired emissions for decades, but the challenge is to recover the CO_2 with a minimum energy penalty and at an acceptable cost. A particular issue in the Australian market is cost and efficiency trade-offs on treatment of SO_x and NO_x gas elements[28].

Pre-combustion capture processes such as integrated gasification combined cycle (IGCC) can also be used in coal- or natural gas-based plant. The fuel is reacted first with oxygen and/or steam and then further processed in a shift reactor to produce a mixture of hydrogen and CO_2. The CO_2 is captured from a high-pressure (up to 70 bars) gas mixture that contains between 15 per cent and 40 per cent CO_2. The hydrogen is used to generate electricity and heat in a combined-cycle gas turbine. Critical elements that need further development are the coal gasifiers and, where the hydrogen is used for electricity generation, the hydrogen turbines. Further work is also needed to demonstrate operation in integrated systems.

The oxyfuel process involves the removal of nitrogen from the air in the oxidant stream using an air separation unit or, potentially in the future, membranes. The fossil fuel is then combusted with near-pure oxygen using recycled flue gas to control the combustion temperature. The efficiency of oxyfuelled power plants and their associated CO_2 capture system depends heavily on the energy required for oxygen production—so new air separation systems would enhance the prospects of oxygen-based CO_2 capture strategies significantly. The oxyfuel process is a promising enabling technology for CCS from coal-fired power plants.

As well as being applicable to new-build plants, both PCC and the oxyfuel process may be used to retrofit existing steam cycle plants, and thus offer retrofit options for the vast installed base of power generation plants.

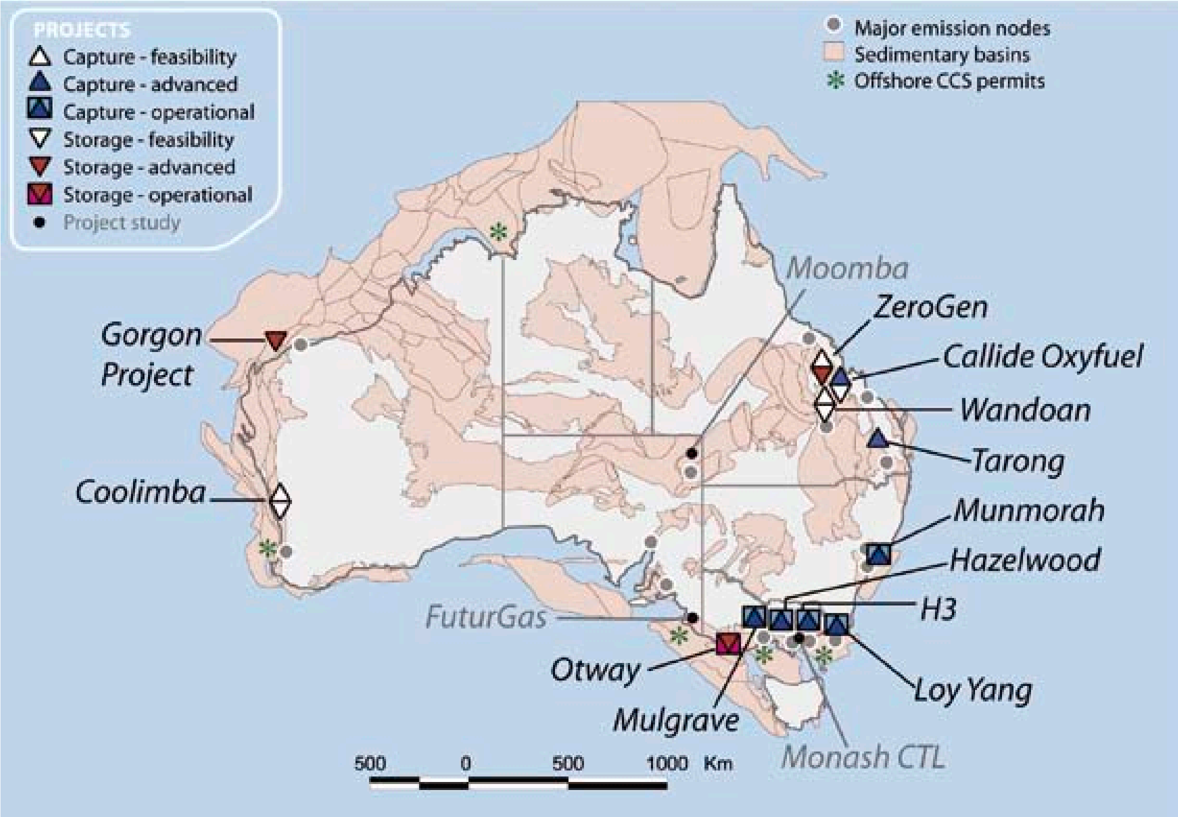
3.1.2 The Australian context

As for most industrial plant technologies, a few large multinational companies are emerging as dominant players in the global market for supply of CO_2 capture equipment.

The Australian power sector has substantial previous experience with transfer and uptake of vendor-driven technologies. A key lesson from this experience is that strong local R&D support and local expertise (preferably in-house) is needed for ongoing optimisation of the technologies for local conditions (for example, local coal characteristics and scarcity of water in Australia) after the vendor has completed its installation and handover, and has left.

28 SO_x refers to oxides of sulphur; NO_x refers to oxides of nitrogen. SO_x and NO_x do not generally need to be removed from flue gas prior to release from coal-fired power plants in Australia, in contrast to many overseas plants, as Australian coals release low levels of these elements. An area of investigation in application of PCC technologies in Australia is whether it is optimal to remove SO_x and NO_x prior to the flue gas entering the PCC process, versus applying the PCC process to flue gas still containing SO_x and NO_x elements.

Figure 3.2: Major CCS development and demonstration activities underway or proposed in Australia[29]



Australian companies and research organisations are currently active in partnering with a range of multinational capture technology companies in small- and medium-scale capture demonstration projects and in early-stage feasibility work on larger project proposals (Figure 3.2).

These projects include:

- a medium-sized oxyfuel combustion demonstration project (1 x 30 MW unit) at CS Energy's Callide power station in Queensland
- two medium-sized PCC demonstrations in New South Wales (at Munmorah Power Station) and Victoria (at Hazelwood Power Station), each around 50,000–100,000 tonnes per year of CO_2 capture
- pre-combustion CO_2 capture trials by the CO2CRC on HRL's IDGCC gasifier in Mulgrave, Victoria to identify the most cost-effective technologies for application to brown coal gasification power-generation technology
- post-combustion CO_2 capture trials in Victoria at Hazelwood power station in conjunction with the CO2CRC (the 'H3' project) and at Loy Yang power station in conjunction with CSIRO to better understand the performance of various CO_2 capture technologies with Australian brown coal flue gases and to evaluate the performance of three technologies for larger-scale capture
- post-combustion CO_2 capture trial in Queensland at Tarong power station in conjunction with CSIRO to assist the selection of PCC technology for a commercial-scale application
- a feasibility study in Queensland to inform the development of a commercial-scale (≈500 MW gross) IGCC plant with pre-combustion capture and storage (the 'ZeroGen' project) that could be deployed as early as 2017, capable of capturing up to 90 per cent of carbon dioxide emissions

29 Source and copyright: CO2CRC http://www.co2crc.com.au/images/imagelibrary/gen_diag/aus_projects_media.jpg, accessed 21 July 2009.

- a feasibility study (including evaluation of storage sites) by Aviva Energy in Western Australia for the Coolimba power station project that will be constructed to be CCS ready.

Other projects not shown on the map include the Perdaman Chemicals and Fertilisers project at Collie in the south west of Western Australia and the Wandoan project in the Surat basin.

Some of these projects have in-principle funding commitments from governments and industry, including the $400m National Low Emissions Coal Fund, state government programs and the COAL21 Fund. However, many projects face funding shortfalls (some as a direct result of CPRS cost impositions, as well as the recent global financial situation) and will require additional support, including at the pre-feasibility stage, to ensure the projects can proceed. Chapter 5 examines these issues in more detail.

3.1.3 Economics of CO_2 capture

CO_2 capture costs can be considered in terms of construction costs and operating costs.

Construction costs relate to the additional costs of including a capture function in a new build plant, or the costs of retrofitting capture technology to an existing plant.

Operating costs centre on the additional energy requirements to run CO_2 capture processes, and on required chemical engineering process costs and materials. The additional energy required for CO_2 capture for a power plant is called the parasitic load, and impacts as additional in-house generation capacity (and costs) required to achieve a given amount of electricity sent-out to the grid compared with a non-CCS power plant, and/or a reduction in sent-out electricity delivered from a given amount of generating capacity. The parasitic load may be a substantial driver of capture costs. For example, for early post-combustion capture for coal-fired power plants, it is estimated that the parasitic load will be in the order of 20–30 per cent; a key goal is to bring this down to around 15 per cent in the longer-term.

Costs of CO_2 capture technology for commercial-scale industrial processes are currently uncertain. In particular, CCS integrated with power generation plants has not yet been demonstrated at commercial-scale anywhere in the world, so that both construction costs and operating costs estimates are uncertain. Current international estimates are based on inferences from pilot-scale work and on preliminary design studies for commercial-scale demonstration plants.

Within these uncertainties, a recent study commissioned from the Electric Power Research Institute (EPRI)[30] for the Australian Government's Energy White Paper examined construction and operating cost premiums for adding an 85–90 per cent capture function into a range of new-build coal-fired power plants.

Costs for early capture plants, while the technology is immature, are estimated to be very high. For example, for a supercritical pulverised coal plant operating with black coal from 2015, adding an 85–90 per cent capture function is estimated to approximately double the levelised cost of electricity (LCOE), from around $70–90/MWh without capture (excluding emission permit costs) to around $110–200/MWh with capture. Transport and storage costs must additionally be covered, as considered below.

Looking ahead to 2030 when the capture technologies are assumed to be more mature, the study estimates reductions in capture costs relative to the first generation technologies. However, the LCOE for electricity produced with CCS in new plants from 2030 is still estimated to be higher in real terms than the current most competitive coal-fired generation technologies in Australia (excluding emission permit costs).

30 EPRI 2009: Electric Power Research Institute (EPRI), *Assessment of Low Emissions Technologies in Australia*, 2009

3.2 CO_2 TRANSPORT

The discussion in the following sections on CO_2 transport and storage draws extensively on the recent report and National Carbon Mapping Infrastructure Plan prepared by the CSTF.

The Australian Government established the CSTF, in parallel with establishing the National Low Emissions Coal Council, in 2008. The CSTF includes representives from all key industry sectors with an interest and expertise in CO_2 storage including coal, power generation, oil and gas, and pipeline operators, as well as representatives from geological survey agencies, unions, non-government organisations, and the Australian and state governments.

The CSTF's National Carbon Mapping and Infrastructure Plan aims to prioritise and drive access to national geological storage capacity, and so help to accelerate the deployment of CCS technologies in Australia.

3.2.1 Overview

CO_2 pipelines have been in operation internationally for over three decades.[31] 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.[32] The major use has been in transporting CO_2 streams for enhanced oil recovery.

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 evaluation of risks under Australian Standard AS2885. 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 focused on cost reduction, without compromising safety.

3.2.2 The Australian context

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.

Transport of CO_2 in the 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. CSTF 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.

31 Canyon Reef Carriers pipeline, constructed in 1972, extends 140 miles from McCamey, Texas, to Kinder Morgan CO_2's SACROC oil field.

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

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 CSTF has estimated that 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.

The CSTF estimates that there is currently only approximately 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 1250 km, 1198 km of which is the Moomba to Sydney gas pipeline. This contrasts rather starkly with the projected future pipeline requirements for CO_2 transport. There is a future need for more than 5000 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 5000 km of smaller diameter pipe.

While there is likely sufficient industry capacity to construct this transport and distribution network, the capacity of pipeline manufacturers to construct sufficient large diameter—greater than 34"— pipeline 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.

3.3 CO_2 STORAGE

3.3.1 Overview

Underground geological storage of CO_2 involves injecting it in a supercritical state via wellbores into suitable geological strata. The IEA[33] considers that the sub-surface storage of CO_2 in aquifers and depleted oil and gas fields, together with the use of CO_2 for enhanced oil recovery (EOR), are proven storage options.

The principal risks associated with CCS arise during CO_2 storage site injection and immediately after site closure. The main risks of CO_2 geological storage arise from:

- inadequate (poorly designed and/or ageing) injection wells
- unidentified and/or poorly abandoned wells
- inadequate cap rock characterisation
- seismic events and migration via natural fractures or hydrologic flow.

However, provided that geological reservoirs are appropriately selected and managed, the IEA has concluded that storage integrity can be effectively assured[34].

33 IEA CCS 2008, p81

34 IEA CCS 2008, p125

3.3.2 Australia's geological storage capacity

To determine the potential for geological storage of CO_2 in Australia, the CSTF has evaluated the carbon storage capacity of depleted oil and gas fields and aquifers. Capacity estimates derived by the CSTF were based on an extensive, high level, 'topdown' analysis using publicly available data. Ultimately though, the capacity and characteristics of each storage reservoir will require a comprehensive, 'bottom-up' assessment, calibrated over time against the monitored behaviour of injected CO_2.

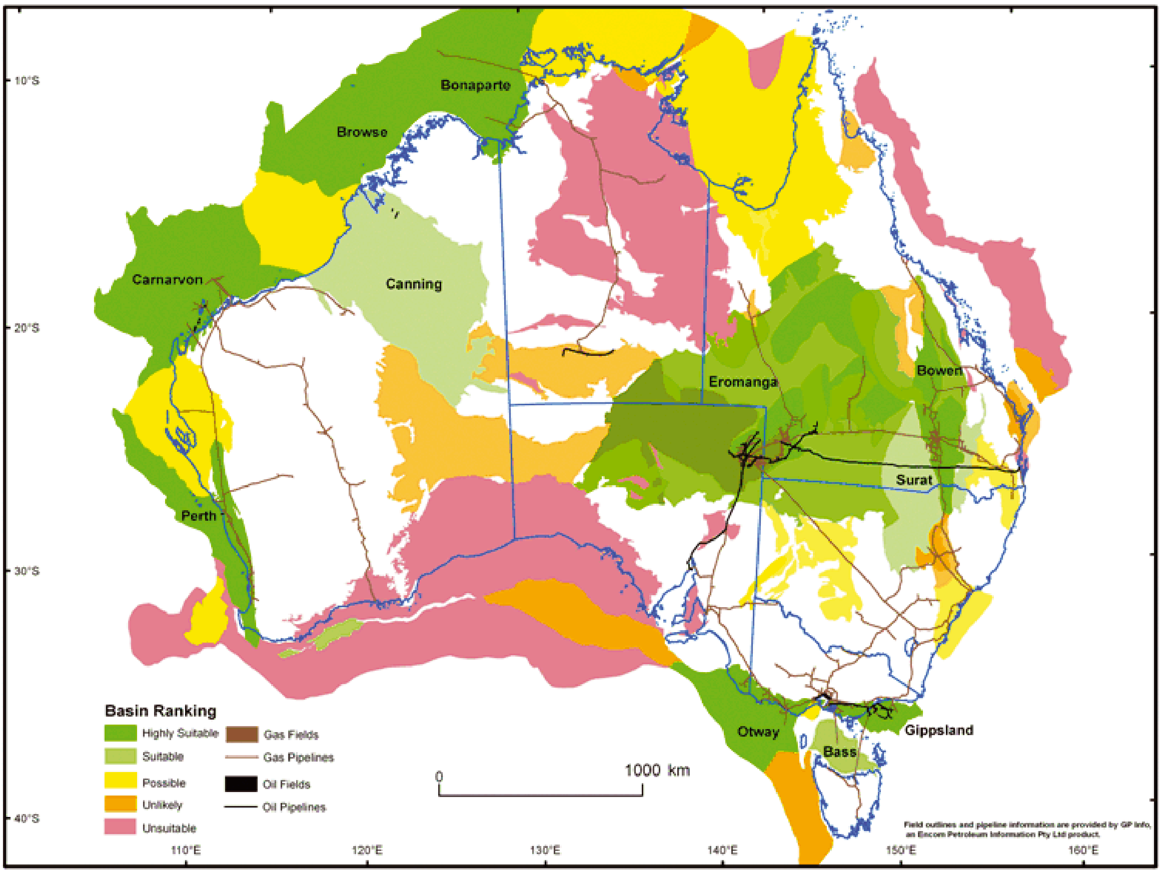
The CSTF has concluded that (see Figure 3.3):

- the majority of Australia's storage potential lies in aquifers. There is high confidence that the east of Australia has aquifer storage capacity for at least 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 for a far greater capacity as basins and their CO_2 storage behaviour become better known
- 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.

3.3.3 Developing storage sites in Australia

The CSTF 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. Basins that are well known geologically can be developed more quickly than those with poorly known characteristics.

Figure 3.3: Australia's basins ranked for CO_2 storage potential



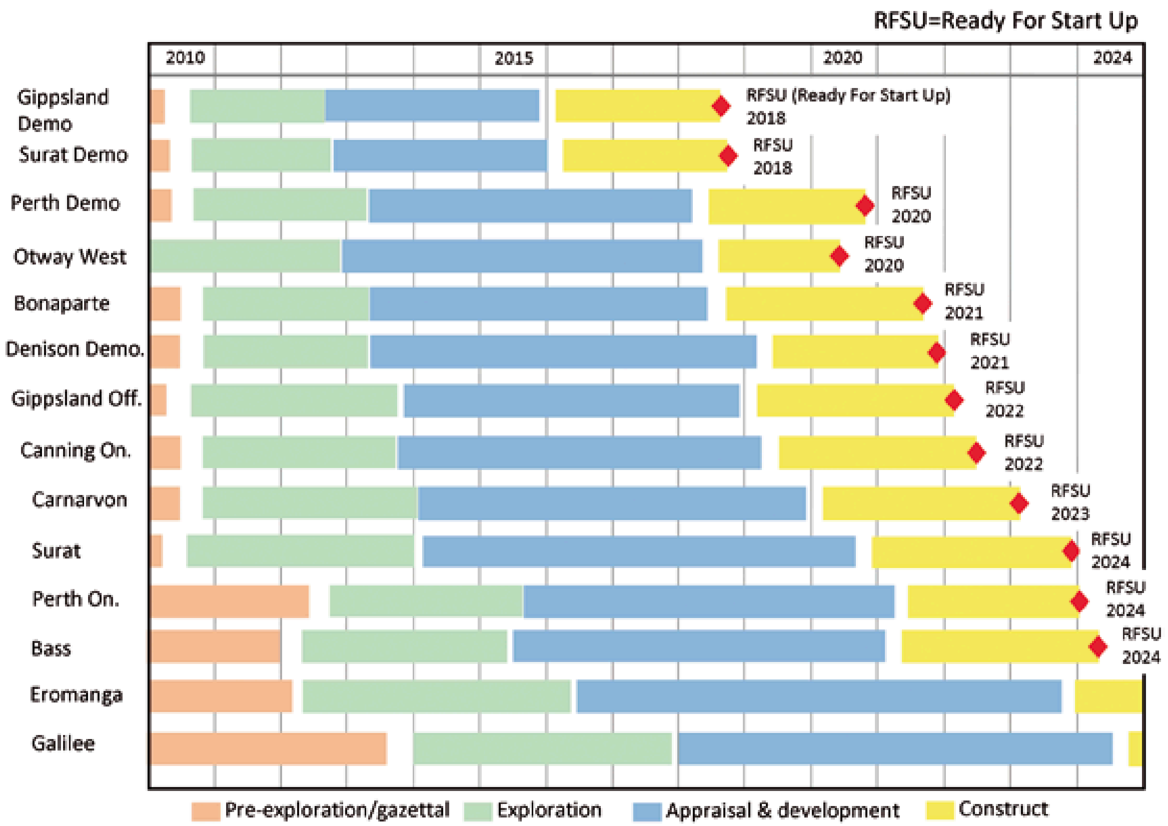
The CSTF has examined the time required to mature a site for storage. If it is assumed that the storage construction phase is 2–3 years, and that legislation is in place by the end of 2009 in order to allow release and award of acreage to storage explorers by Q3 2010, then the elapsed time to mature 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 3.4).

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 timeframe, that is 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. 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.

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

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 CCS project timelines.

Figure 3.4: Timing from pre-exploration to commencement of storage operations for likely storage basins and demonstration areas (RFSU=Ready For Start-Up)



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. It is noted that this could potentially delay power generation CCS projects for many years.

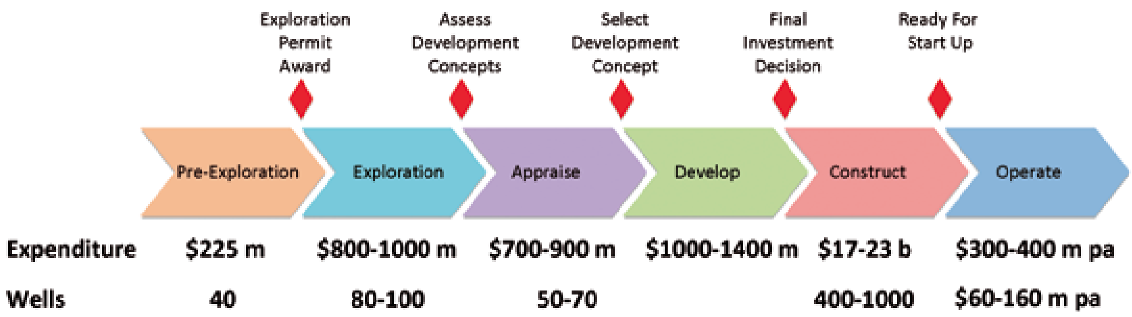
The deployment of CCS technology in Australia, at large scale, could first be achieved by the Gorgon Project in north-western Australia. The Gorgon LNG Project, which aims to store some 3.5 Mtpa of CO_2 in reservoirs under Barrow Island, would be the largest storage project in the world and would represent a critical step towards large-scale commercial storage of CO_2. The project is expected to be sanctioned in Quarter 4 2009.

3.3.4 Cost drivers for storage

The full storage 'value chain' is shown in Figure 3.5 below, together with eastern Australian lifecycle investment costs as estimated by the CSTF.

The pre-exploration costs represent about 25 per cent of exploration costs. Investment in storage prior to Final Investment Decision (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 per cent of the final transport and storage capital investment.

Figure 3.5: Value chain for storage development – eastern seaboard



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.

3.4 CCS AS AN INTEGRATED SYSTEM

The previous sections examined issues relating to the separate CCS technology components — capture, transport and storage. The knowledge and confidence from the analyses of these separate components and the activities in Australia in each are necessary, but by no means sufficient, to support CCS commercial deployment.

Integrated, commercial-scale demonstration projects, that link the generation, capture, transport and storage elements, are now needed to make rigorous technical, economic and risk assessments of the overall system operating at high utilisation factors and at scale. Until this happens, a rational investor will not accept that commercial deployment of CCS is 'bankable'.

CCS faces technology integration challenges at two levels—standalone projects, and multi-user hub infrastructure.

3.4.1 CCS project timeline and coordination

Coordination challenges in the *development phase* (scoping, planning and design) of an integrated CCS commercial-scale project centre on managing the interdependencies and timing links between decisions on the capture, transport and storage aspects of the project.

A key point is that geological knowledge for CO_2 storage is critically important to the overall project development timing because final site selection is required for completion of engineering studies for the power plant. Permitting issues also impact critically on the timeline, and final site selection is also necessary to progress permitting applications.

For a decision on committing to a power plant investment of possibly several billion dollars, detailed FEED studies of $100 million or more would typically be undertaken. The greater the level of uncertainty on the final site location when FEED studies are commenced, the greater the risk that the site decision may change and a new FEED study will have to be undertaken. The overall project development cannot be completed until the storage site is finalised and the power plant FEED study is completed.

Aligning key decision points for the capture and storage components is expected to be the main timing driver for development of the overall CCS project. Transport infrastructure (pipeline) investment and construction could be accommodated within the overall project envelope determined by the capture and storage elements.

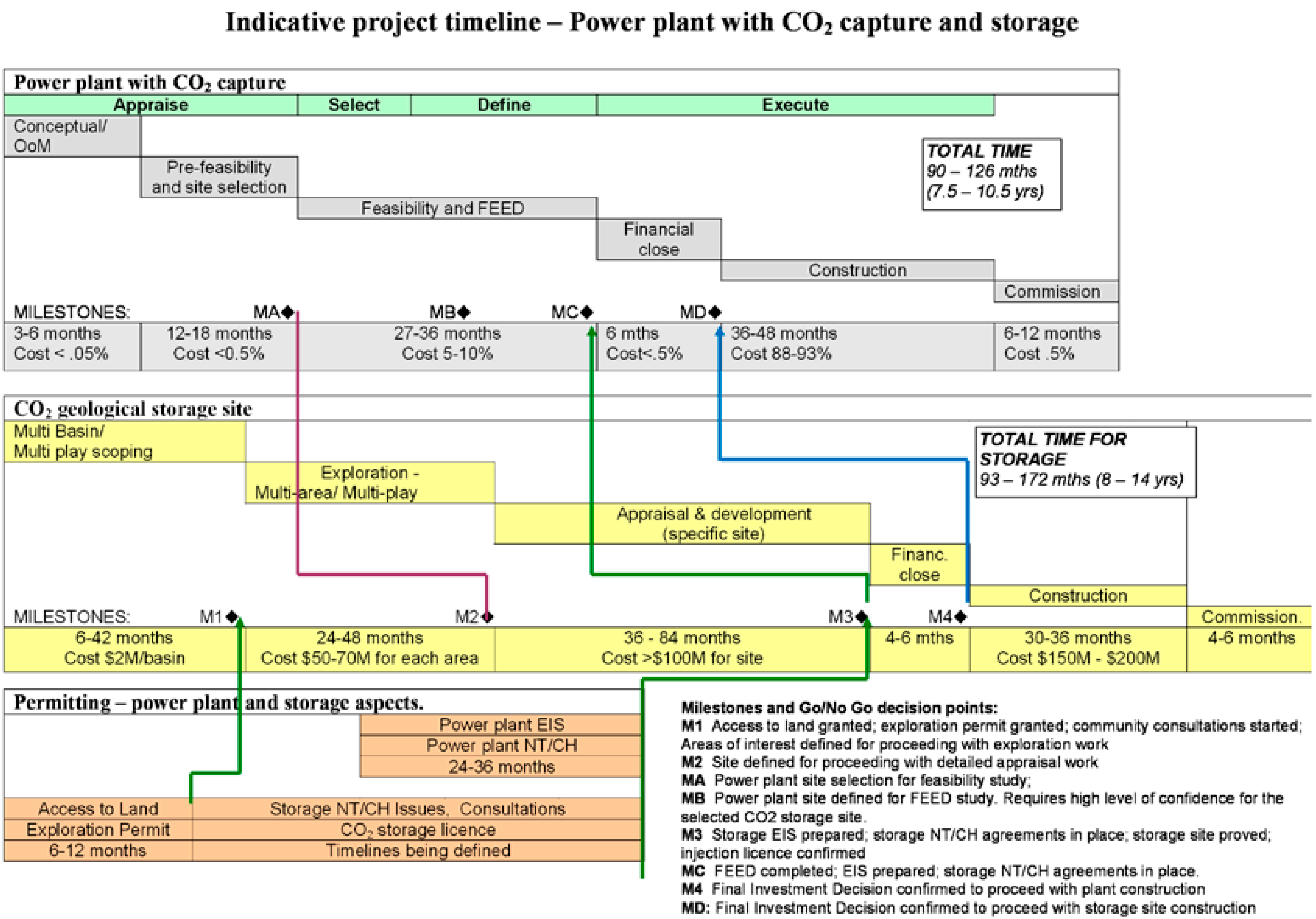
The project timeline and coordination challenges for a single, integrated project can be illustrated in more detail by considering a hypothetical commercial-scale (≈400 MW) coal-fired power plant with capture, with a proximal (within 200 km) storage facility. Figure 3.6 indicates timelines for this hypothetical project. The top section of the diagram covers the capture project component, the middle section covers the storage project component, and the lower section covers permitting issues across both the capture and storage components.

The capture timeline was developed following discussions with developers of commercial power plant projects in all parts of the world. Capture elements of such a FOAK project, either for new-build plants or for retrofitting existing plants, are expected to take 8 to 10 years. Note that these times will compress by approximately half for smaller (approximately 50 MW) projects.

The storage timelines indicated reflect indicative findings from the CSTF on the time to develop a large storage basin in Australia. As illustrated earlier in Figure 3.4, the earliest and best sites for demonstration will not be ready for storage start-up until around 2018. Note that if the project used a small, dedicated storage site, storage lead times and costs could be significantly reduced.

Coordination challenges in the *operational phase* of these FOAK plants are also significant. For example, for post-combustion capture technology-fitted plants, the power plant operator is expected to seek the flexibility to turn the capture function on and off depending on prevailing electricity and carbon permit prices. This could adversely affect transport and storage operators, who will be seeking stable volumes and revenue streams to service their investment outlays.

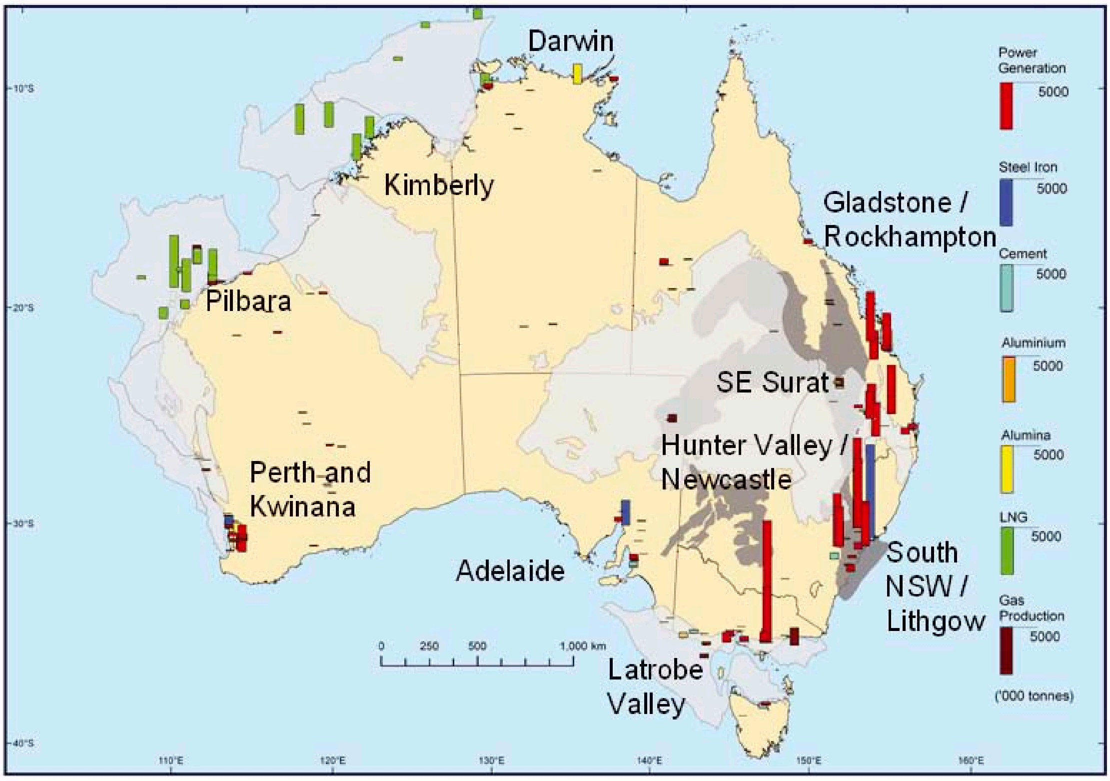
Figure 3.6: Industry-standard timeline for delivery of a FOAK commercial-scale demonstration of a CCS coal-fired power plant



3.4.2 CCS network coordination: source-sink matching

The CSTF has identified 10 concentrations of stationary emitters across Australia, where emitters are located sufficiently close together to allow the gathering of captured CO_2 through a hub (Figure 3.7). A hub provides economies of scale leading to efficient transport to, and storage in, large CO_2 geological storage sites. Indicative modelling[35] commissioned by the CSTF projects that by 2020, 123 Mt of emissions from the 10 hubs could feasibly be captured. This quantity represents 21 per cent of total Australian greenhouse gas emissions in 2006.

Figure 3.7: Geographical distribution of emissions by industry in Australia



The Gippsland basin has the greatest capacity of the eastern basins. It is also very close (150 km) to the Latrobe Valley hub (Figure 3.8(b)). 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. 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 (EOR) 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 1200 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.

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

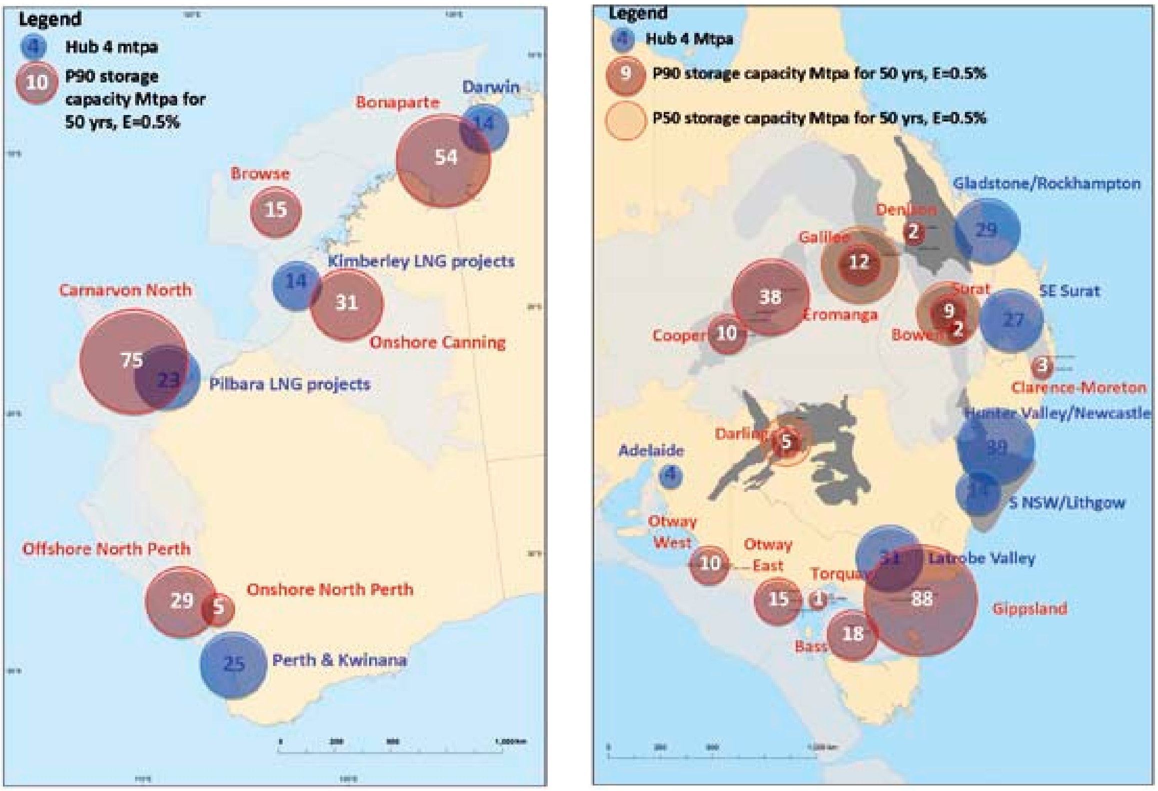
The New South Wales basins are relatively unexplored, but on current data the majority of the basins have low storage capacity. The one possible exception is the Darling basin, which is a very large basin located in central west New South Wales. Data is very limited given the extent of the basin, but 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 NSW 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.

For the Perth/Kwinana hub on Australia's west coast, the most likely storage basins are the onshore and offshore North Perth basin (Figure 3.8(a)). 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 3.8: Hub emission levels and basin storage capacity
– (a) western seaboard and (b) eastern seaboard



(a) (b)

3.4.3 Economic comparisons of hub-basin combinations

The CSTF commissioned an estimation of CO_2 transport and storage tariffs[36] for a number of hub-basin combinations[37] in Australia, noting that these estimates:

- are subject to large uncertainties—they 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
- do not include either the cost of capture or the capital charges associated with the new power generation technologies—they refer to transport and storage only[38]
- 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 utilisation risk (considered further in Chapter 5).

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). These factors cause the calculated transport and storage tariffs to vary considerably, as evident in Figure 3.9.

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[39]. 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.

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 per cent to 12 per cent increases the cost of CO_2 avoided by about 40 per cent. 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 per cent to tariffs.

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.

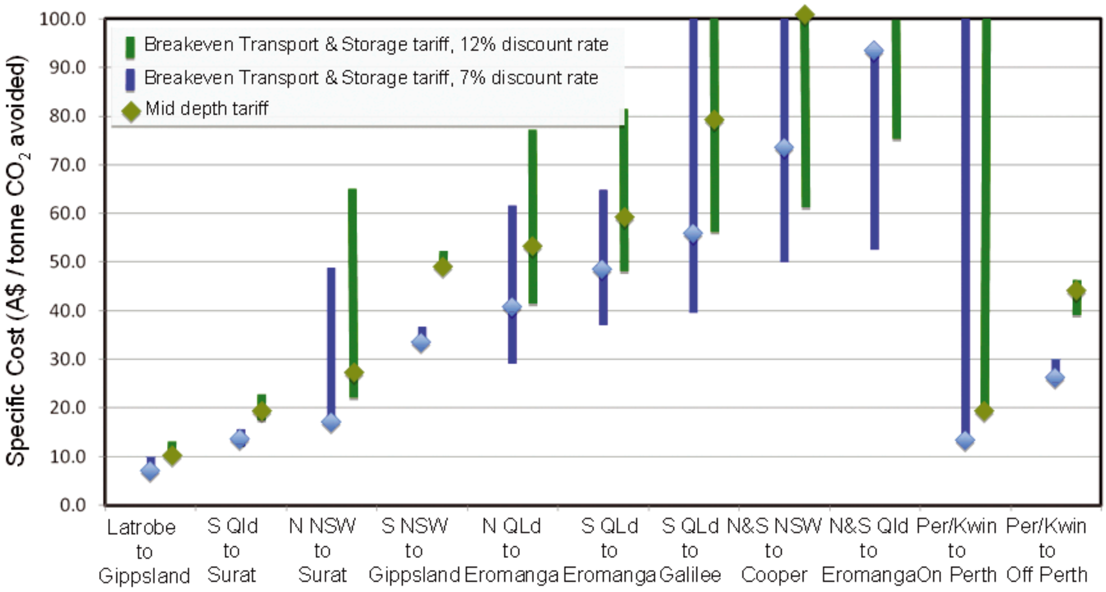
36 Cost per tonne of CO_2 avoided, calculated using the net present value of cash flows over a 25 year asset life.

37 Allinson 2009: Allinson G, Cinar Y, Hou W & Neal P, *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, 2009.

38 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.

39 Calculated using 962kg CO_2/MWh for Gippsland basin and 906kg CO_2/MWh for Eromanga basin; 95 per cent capture rate; shallow, mid and deep transport and storage tariffs.

Figure 3.9: Break-even transport and storage tariffs for hub-basin combinations in Australia



3.4.4 Transport and storage efficiencies through hubs

The CSTF has determined that the economies of scale offered by combining multiple sources for CO_2 transport in a large size pipeline are significant and could potentially reduce CCS deployment costs 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 CSTF recommends, and the Council concurs, that support is provided 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[40].

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 cannot 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 CSTF recommends, and the Council agrees, 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).

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

3.4.5 Economics of CCS as an integrated system

The overall economics of CCS are determined by the total costs and performance of the capture, transport and storage integrated system.

As outlined earlier, the integrated CCS system may operate at the level of a standalone project (for example, a capture-fitted power plant piping compressed CO_2 to a nearby dedicated storage site), or potentially in the longer-term, at a regional network level with economies of scale achieved through large-scale multi-user transport and storage infrastructure.

For CCS applied to power generation, estimation of CCS costs and performance data is only at a very early stage worldwide. Key aspects to keep in mind in interpreting CCS cost estimates are that:

- there are high levels of uncertainty. Until detailed engineering studies are progressed for commercial-scale CCS demonstration projects, there is inherently high uncertainty in construction cost estimates. Operating cost estimates are also uncertain, as no commercial-scale CCS power plant has yet been built
- costs are highly localised. The cost drivers for the transport and storage components of a CCS project or hub are strongly dependent on geography (pipeline distances and terrain) and site-specific storage geology
- improvements are expected in CCS economics over time. CCS economics are expected to improve as subsequent generations of the technology are deployed, and as regional CCS hubs emerge. It is important to distinguish between cost estimates for FOAK commercial-scale demonstration projects, where the technology is being tested at industrial-scale for the first time, and cost estimates for later deployment projects and hubs. In development of major industrial technologies, FOAK costs are typically much higher than subsequent projects. The CCS technology deployment path in Australia is discussed further in the next section
- CCS electricity must be competitive for dispatch, if the overall CCS project is to be viable. The expected savings to the CCS power generator from avoided carbon emission permits, and the expected revenues earned from electricity sales, must underpin investment decisions for the overall CCS project – capture, transport and storage. Conversely, the costs from transport and storage operations must be passed through to the CCS power generator, and may be a major determinant of the competitiveness (or lack of competitiveness) of CCS electricity generation at a particular location.

The next chapter examines CCS competitiveness and investment issues in the electricity market in more detail.

3.5 CCS TECHNOLOGY DEPLOYMENT PATH IN AUSTRALIA

In the experience of the power industry worldwide, the uptake of major new technological developments progresses through a generational development and deployment path.

Foundation research and development is needed to provide an initial level of confidence that the technology is prospective enough to progress to pilot-scale demonstration stage. FOAK projects then are essential for commercial-scale demonstration of the technology at high utilisation over a sustained period, to test and further develop the technology under industrial conditions. The first generation of commercial projects aims to leverage lessons and experience from the previous FOAK demonstrations—and typically quite widespread deployment and technology refinement is required to achieve fully-commercial levels of operating and cost performance.

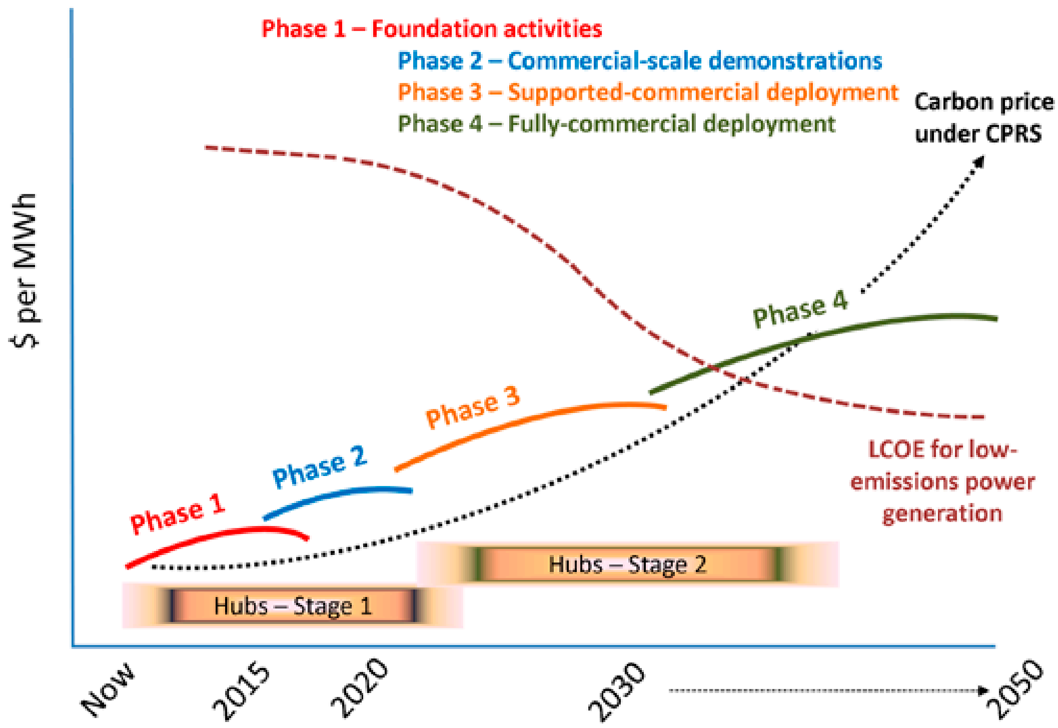
CCS is following this technology deployment path and currently is poised to enter commercial-scale FOAK demonstrations of integrated systems. However, if CCS is to be a significant option for mitigation of greenhouse gas emissions from the 2020s, it faces additional deployment challenges in:

- progressing a coherent and cost-effective national portfolio of CCS demonstration projects, with appropriate research foundations and support
- coordinating the development of multi-user capture and storage hubs, over and above technology deployment through individual CCS projects
  - > CCS economics will vary from case to case, and in some instances a stand-alone capture source with nearby dedicated storage with sufficient capacity for the life of the single project may be viable
  - > significant penetration of CCS technologies, however, will require realisation of economies of scale from multi-user hub-and-spoke CO_2 transport and storage infrastructure.
- accelerating the generational deployment path
  - > typically, each generation of a major new power technology takes 10–15 years, given the 5–8 year lead time to build and construct a commercial-scale power plant project, and the desirability of five years or more experience with high plant utilisation
  - > risk management and parallel development approaches will be needed to compress the early phases of CCS technology deployment.

These CCS technology deployment challenges are examined in the rest of this section. Strategies to overcome these challenges and the associated financing challenges for commercial-scale demonstration projects and early deployment plants are considered in Chapters 4 and 5.

Figure 3.10 broadly outlines the envisaged phases of CCS technology commercial-scale demonstration and deployment in Australia that, over time, are expected to yield reduced costs through learning by doing and technology refinement and breakthroughs. Deployment is also plotted against the rate at which the carbon price rises, as this will be a critical driver of investment in CCS projects and hub development. Wider commercial deployment factors, over and above technology deployment challenges, are explored more fully in later chapters.

Figure 3.10: CCS technology deployment path in Australia



3.5.1 Managing a national portfolio of CCS research, development and demonstration

CCS covers a wide breadth of technology issues. For example, various capture technologies are being investigated for application in various settings (power generation, LNG production, industrial thermal contexts, fuel transformation sector). Increased knowledge of Australia's geological storage capacity is another priority. And as previously outlined, demonstration of commercial-scale integrated CCS projects and hubs is essential to underpin investor confidence in the technology under industrial conditions.

The breadth of the associated R&D and demonstration issues presents complex challenges for managing a coherent and cost-effective national portfolio of activity. This is illustrated below with respect to demonstration of CCS technologies in coal-fired power generation.

An effective demonstration portfolio for CCS technologies in power generation

A portfolio of demonstration projects will be a critical precursor to broad commercial deployment of low emissions coal technologies in Australia. Demonstrations at appropriate scale (30-250^{+}MW, depending on the technology) will increase understanding of the technologies, and reduce technological risks. Importantly, the demonstrations will assist original equipment manufacturers (OEMs) and engineering procurement construction (EPC) companies to gain sufficient confidence in their technologies to offer performance and process guarantees for an integrated plant that in turn will underpin investor confidence in CCS technologies and project economics.

Demonstration plants will range from pilot-scale up to commercial-scale. The optimal scale of a demonstration plant is a complex function of:

1. The maturity of the technology, and hence the technical and integration risks being addressed. Is the project size a reasonable next step?
2. The engineering and financial scalability of the technology—that is, whether project costs are correlated with utility size. Could equivalent benefits be obtained from a smaller, less expensive project? These issues are discussed further below.
3. The need to generate sufficient tonnages of CO_2 to allow demonstration at scale of geological storage.
4. The potential for larger demonstrations to retain residual value after the demonstration phase as they transform into commercially-operated plant.

DEMONSTRATION OF PRIORITY CAPTURE TECHNOLOGIES: SCALE

- Oxyfuel – Oxyfuel combustion demonstrations are likely to be based on individual boilers being fitted to run as oxy-fired units. The scale is subject to the economic size of boilers, which can vary markedly between the east coast NEM and the stand-alone market in Western Australia, but should be of sufficient size to address scale-up to larger sized boilers and oxy-firing's application to both supercritical and sub-critical boilers.
- PCC – PCC demonstrations are likely to be based on industrial-scale modules that either can continue to operate as an integral part of ongoing commercial operations or can be replicated to accommodate expansions in emissions-abatement operations at the power station. The standard size of industrial-scale modules will vary between equipment suppliers and the PCC technology that each supplier utilises.
- IGCC – IGCC power plants, utilising either black or brown coal, are highly non-linear in scaling. The Council's Research Working Group and industry sources have advised that the capital cost of a 50 MW IGCC demonstration plant is (indicatively) about half the cost of a 400 MW demonstration—and that only the latter would be capable of significant post-demonstration commercial operation with or without CO_2 capture. Modular pre-combustion CO_2 capture with an IGCC power plant is an option for commercial-scale demonstration, with replication of modules covering expansions in emissions-abatement operations at the power station.

In the case of oxyfuel and PCC, there are compelling technical reasons why they can be demonstrated initially at smaller scale—unlike IGCC with pre-combustion capture. These are:

1. The costs of smaller oxyfuel and PCC plants are roughly scalable, while the learning benefits apply to full-scale plant.
    - It therefore makes sense to build and operate smaller demonstrations at an indicative capital cost of several hundred million dollars before moving to commercial-scale at a cost of several billion dollars.
2. PCC and oxyfuel technologies are not yet ready for commercial-scale deployment.
    - Oxyfiring technology – Several small oxyfuel demonstration plants have recently been commissioned, including the Vattenfall (10 MW) plant in Cottbus Germany, and the Total (10 MW) plant now operating in Lacq (France). The Callide Oxyfuel Project (30 MW) is under construction in Queensland and will be commissioned in 2011. The next step in the technological development and demonstration of this technology will be at around 200-250 MW, either as a retrofit or new build.
    - PCC requires two orders of magnitude scale-up from existing plant. The logical demonstration process is to trial different technologies at sub-commercial scales (for example, first on a plant flue gas slipstream and then a single line of a multi-unit utility).
3. Any full-scale plant build of an immature technology runs the risk of constraining medium to long-term commercial viability of the plant.

3.5.2 Aligning demonstration projects with demonstration hubs

A key dimension of the targeted overall CCS technology deployment path in Australia is that the development of FOAK capture-transport-storage demonstration projects preferably should be aligned with development of capture-transport-storage demonstration hubs. The captured emissions stream from a FOAK demonstration project will anchor development of the storage facility, allowing attraction of other capture-source projects and early demonstration of hub operation. This has important implications:

1. Site selection for demonstration projects should be linked with storage site confirmation for the most prospective, early large basins.

    On currently available information, the CSTF has identified the Gippsland, Surat and Perth basins as the strongest candidates for early access for demonstration projects and for progression to large storage facilities. Finalising site selection for the capture project component, and hence finalising relevant FEED and feasibility studies, depends on finalising the appraisal and development results for a specific storage site. Project risks will increase if FEED and feasibility studies are completed before full storage-site appraisal is completed, but this risk may have to be accepted if the target timeframe for CCS demonstration from 2015 is to be achieved.

2. The FOAK project's operation should preferably be optimised against longer-term hub development, not just the operations of the stand-alone project.

    In particular, for a power plant-based capture demonstration project, long-term operation (that is ongoing sales of generated electricity) and sustained high capture rates offer the best platform for realising economies of scale for the transport and storage hub infrastructure. This could potentially contrast with more immediate dynamics for a FOAK capture project to operate for an initial demonstration period only, or to operate its capture function intermittently rather than continuously.

3. The technical and economic feasibility of CCS in a region will depend on its uptake by multiple emissions sources accessing common-user transport and storage infrastructure.

    Where an initial, commercial-scale CCS demonstration project (for example, CCS applied to a commercial-scale power plant) anchors development of a hub, the longer-term success of the demonstration project will be tied to the successful demonstration and uptake of CCS in other industrial applications in the same region.

Alternatively, if multiple capture technology projects can be encouraged to at least commercial modular scale across a range of industrial applications in a geographic area, this potentially allows for a regionally-focused learning network comparing CCS results and testing, and the emissions from these demonstrations may feed development of a hub-and-spoke model for transport and storage.

Successful demonstration of a CCS hub-and-spoke cluster will need to include effective operational integration of CO_2 emission streams from disparate industrial sources. For example, the purity of CO_2 emission streams from different sources will need to be optimised or controlled for entry to common user trunk pipeline that is constructed to a given standard. Variability of CO_2 volumes from different sources (by time of day, by season or by market conditions) will also need to be managed.

3.5.3 Parallel preparation for second generation deployment

To meet target timeframes for CCS technology deployment, priority action is also needed to prepare for second generation deployment, in advance of full results from first generation projects.

The timeline for CCS FOAK project commitment decisions in Australia is being compressed, and associated higher risks moderated, through government-industry grant funding support and through staged decision making on project selection under the CCS Flagships Program.

There are other clear threshold requirements to allow the option of second generation CCS deployment from the 2020s, which will not be met unless preparations commence soon. In particular, immediate action is required to:

- better characterise large storage basins to identify the best prospects for suitable storage availability from 2020
- ensure that robust information on lessons and insights from commercial-scale CCS demonstration projects around the world is available as early as possible—a key role for the Global Carbon Capture and Storage Institute.

4 INVESTMENT CHALLENGES FOR LOW EMISSIONS ELECTRICITY IN AUSTRALIA

KEY FINDINGS

Understanding key drivers and constraints to investor decision-making in the power generation industry is fundamental to framing effective strategies for achieving a near-zero emissions, secure energy future, and to realistically assess the role of CCS-mitigated fossil fuels in this future.

It is anticipated that Australia's future electricity supply will be provided through a diversified technology portfolio. Achieving Australia's targeted GHG emissions will require the average emission intensity of Australia's electricity generation to drop to less than a fifth of current levels by 2050.

Different technologies will be competitive in different situations, depending on factors such as carbon permit prices, geography, geology, fuel input prices, and intermittency. The capacity of each technology to come down its cost curve and deliver performance improvements will also be critical to the mix of technologies in the future energy market.

There is currently a high degree of uncertainty on comparative assessments of energy technologies. Within the range of current estimates, it is plausible that CCS technologies can be competitive with a range of renewable energy technologies, and also with conventional generation technologies (that is fossil-fuel-fired generation without emissions abatement, that pays for emission permits) at future higher levels of CO_2 emission prices.

Building and operating commercial-scale CCS demonstration projects is an essential prerequisite to more fully determine the cost and performance characteristics of this technology, and to begin to deliver material future cost reductions. Investment must urgently proceed in the next stages of CCS demonstration and early deployment to keep open the option for CCS to make a vital contribution to cost-effective emissions abatement in Australia.

Competitive electricity markets in Australia have performed well over the last decade to deliver sound investment and electricity supply outcomes in response to growing demand. However, existing market structures will struggle with the challenge of energy market adjustment and restructuring for climate change.

Key limitations to rapid change are:

- disincentives for early-mover investment in large capital-outlay projects in immature technologies
- uncompetitive operating costs against incumbents until CO_2 emission prices reflect the full costs of GHG mitigation
- availability of finance.

In the face of these major risks and uncertainties around climate change and financing, electricity market investors have responded rationally by deferring large, baseload capacity investment decisions and instead have invested in peak and shoulder plants (generally gas) that have a lower capital exposure but are inherently unsuitable to baseload generation. The longer the delays, the larger the potential capacity shortages become.

'Early mover' investors in CCS technologies could reap the benefits of early positioning in expanding new global markets for low emissions power generation technologies, but FOAK capital costs will be much higher than for later, more mature CCS plants—and the larger the capital outlays, the higher the financial risk exposure from FOAK plant obsolescence. Even if the capital cost of coal-based plant with CCS is substantially subsidised to quite a high level, similarly to renewables, this plant also faces the challenge of competing, that is being 'dispatched', in electricity markets. A CCS plant has much higher operating costs compared to a conventional coal-fired plant, and carbon permit prices are unlikely to offset this cost disadvantage for many years.

Targeted interventions should be considered to guard against the market failing to investigate technology options that may prove the most useful in the longer-term. These interventions should phase out as the underlying market failures decrease.

Given the uncertainty in the future cost and performance of all low-carbon, baseload technologies, it is important that all options are pursued, including CCS. In the case of CCS, this will require policy interventions to ensure rapid deployment of initial demonstration plants and subsequent early pre-commercial plants.

This will include the need for special transitional financial assistance in addition to the CPRS to bridge the commercial gap that will be experienced by early deployment of low emissions plants. These measures will be essential to deliver sufficient CCS deployment to ensure material future cost reductions.

Options for the use of a revenue mechanism to support low emissions technologies include:

- direct funding support for projects, based on competitive tendering or other processes
- price support for the electricity produced at the wholesale or retail level
- technology portfolio standard, including a national low emissions technology target.

On balance, a national low emissions technology target scheme (as part of a technology portfolio standard) is ultimately likely to provide the best market-pull mechanism, although it is recognised that the value of a targeted mandate is likely to be of limited value up to at least 2020, while low emissions coal-based CCS technologies are in the development stage.

The detailed design of targeted interventions will require further investigation and analysis, and is further considered in Chapter 5.

4.1 THE AUSTRALIAN ELECTRICITY MARKET

Commercial investment decisions on power generation capacity—new capacity, upgrading existing plant, or retiring plant—lie at the heart of how the power sector will adjust to climate change mitigation around the world and in Australia. This will involve transformation of the electricity supply sector, which must be managed alongside the need to maintain adequate, affordable and reliable supply.

Understanding key drivers and constraints to investor decision-making in the power generation industry is fundamental to framing effective strategies for achieving a near-zero emissions, secure energy future, and to realistically assess the role of CCS-mitigated fossil fuels in this future.

Australia has long enjoyed, and continues to enjoy, residential, commercial and industrial electricity prices that are among the lowest in the world, as illustrated in Figure 4.1. Further, Australia's electricity supply also operates at high levels of reliability.

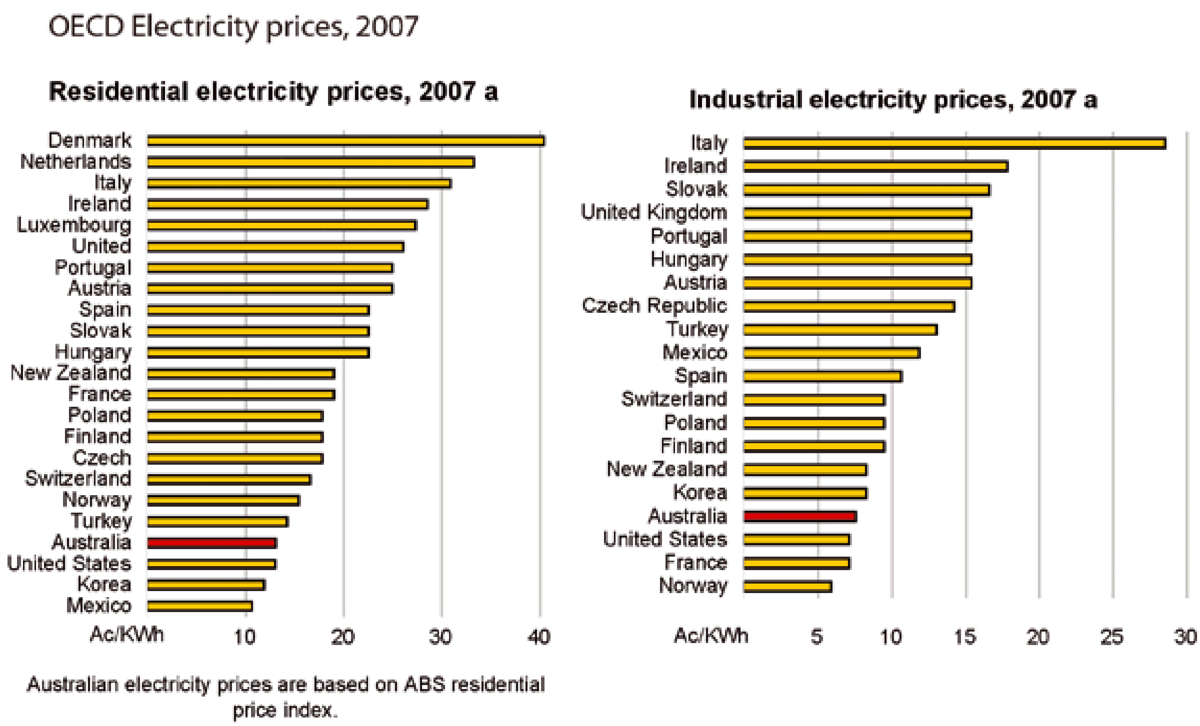
Electricity demand varies depending on the time of day and the season and electricity supply (generation) characteristics adjust to instantaneously meet this varying demand from residential, commercial and industrial customers.

Black and brown coal-based generation, together with hydro in Tasmania, provide the baseload power in Australia, augmented by gas-based plant and hydro plant to provide intermediate and peaking loads. Other renewables, such as wind power, are not firm (that is are intermittent) and are generally dispatched as available.

From the 1990s, Australia's energy sector has undergone an extensive competition reform process and progressive privatisation, which is still being completed. In essence, the aim has been to harness the potential efficiencies of a competitive, market-based approach to optimise prices, investment and consumer benefit.

There are two main electricity markets in Australia—the large east-coast National Electricity Market (NEM) covering Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia and Tasmania, and the much smaller South West Interconnected System (SWIS) serving the south-west of Western Australia. The NEM is an 'energy only' market where the aggregated clearing price in each half-hour sets the pool price paid to all generators. The SWIS is essentially a 'payment for capacity' market with 'bilateral contracts' for energy supply.

Figure 4.1: Comparison of year 2007 electricity prices in OECD countries[41]



41 ABARE 2009, p29

4.2 THE INVESTMENT CHALLENGES FOR AUSTRALIA'S ELECTRICITY SUPPLY SYSTEMS

Baseload power generation provides the foundation of the electricity supply, and the dynamics of investment in baseload capacity underpin provision of secure and affordable energy. Investment in any commercial-scale, baseload electricity generation plant is complex, but the underlying economics are quite well understood. The fundamental risks and challenges facing these investments include:

- capital intensity. Capital costs for a new coal-fired power plant of typical size (500 MW) in Australia can easily exceed $2 billion[42]. No revenues are generated to offset outlays during the planning and construction period, which may be 5–8 years
- long payback periods. After a power plant is built, it is usually expected to operate over many decades (typically 30–40 years) to earn returns on the investment. Typically, a significant part of the capital costs is covered through project finance (debt funding from financial institutions) rather than equity or internal funds, and reliable revenues to service the debt are particularly critical during the first two decades of operation. Therefore, a materially changing regulatory regime will stifle investment due to perceived increased financial risk
- technology obsolescence. Typically, within a few years of a new power plant's construction, the technology in the plant is overtaken by newer, more efficient technology available to later competitors. The competitiveness of an existing plant will generally fall over time relative to new entrants. The risk of early retirement due to technology obsolescence can be mitigated by seeking a strongly competitive start position on entry to the market, and by upgrades and refurbishments where this is economically feasible over the life of the asset
- electricity price risks. More broadly, the performance of the investment depends on the revenue stream from competitively selling the generated electricity. Uncertainty on future electricity price trends, and volatility within these trends, affects investment risk
- fuel cost risks. The return on investment is heavily influenced by fuel input costs over the operating life of the generation plant. In turn, the level of uncertainty on future fuel costs impacts on investment risk. Risk mitigation strategies include vertically integrating fuel supply with power generation in a single business, or by locking in long-term fuel supply contracts
- transmission access. Conveying the generated electricity from the power plant to the point of consumption requires use of transmission and distribution infrastructure. The level of uncertainty on reliable access to this infrastructure over the life of the project, particularly in the face of rising congestion on the network, impacts on investment risk[43].

Investment in intermediate and peaking plant tends to be less capital intensive, but has similar risks to baseload investment.

Australia's current fleet of power generation plants is ageing. By 2020—the goal year for global availability of commercial, integrated CCS power plants—over 40 per cent of this generation capacity (mostly coal-fuelled) will be more than 40 years old. This figure will increase to nearly 75 per cent by 2025.

In order to meet growing demand, generation capacity will need to increase by about 20 per cent over the next 10 years, in addition to existing plant replacement.

42 Base generic estimates provided in ACIL Tasman 2009: *Fuel Resource, New Entry and Generation Costs in the NEM*, ACIL Tasman, April 2009, Tables 33 and 35. Site-specific factors increase costs.

43 NGF 2009: National Generators Forum, *Submission to Energy White Paper Discussion Paper on Investment, Competitive Markets and Structural Reform*, June 2009.

4.3 CPRS IMPACTS ON ELECTRICITY PRICES: A SIGNAL FOR INVESTMENT

The impact of carbon pricing via the Carbon Pollution Reduction Scheme (CPRS) will occur at several levels.

In relation to the investment climate, uncertainty about the carbon price and emissions reduction trajectory will be priced into the projected revenue requirements of investment proposals. The Council notes that in recent years, in view of uncertainties on directions and settings of climate change policies, there has been a general hesitancy to invest in new power generation assets[44].

Further, international investors compare merchant generator investment opportunities in Australia alongside other global investment opportunities. Some investors in the NEM have not achieved reasonable returns on their investment and have exited Australia, while others are in the process of scrutinising their Australian positions[45].

The introduction of a cost on carbon will affect the relative merit order of dispatch and impact on technologies in the capital stock. The more carbon-intensive coal businesses will be able to recover fewer costs in general than lower carbon generators.

The impact of carbon prices will also affect the price of electricity and result in higher costs on the broader economy.

In light of these investment risks and uncertainties, investors and generators currently are deferring large, baseload capacity investment decisions.

While some fuel-switching with increased penetration of gas-based generation will occur under the CPRS, the complete absence of investment in coal-fired baseload generation in Australia is not sustainable.

Further, if there is too abrupt a retirement of existing coal-fired generation plant, there will be significant adverse impacts on Australia's energy security over the near- to medium-term.

4.4 MARKET-DRIVEN INVESTMENT NOT ENOUGH

4.4.1 Capital disincentives to invest in immature technologies

A limited portfolio of technologies is currently identified[46] as potentially suitable for contributing to zero or low emissions baseload power generation. These include fossil fuel with CCS; geothermal; hydro; nuclear; and intermittent renewables. In Australia, government policy prohibits nuclear energy, and there are limited prospects for further deployment of hydro electricity due to water scarcity. The remaining options—fossil fuel with CCS, geothermal and intermittent renewables—all need major development before reaching mature technical and cost performance for commercial deployment.

A prudent risk management approach at this stage, for the electricity market as a whole, is to pursue investigation of all available technology options.

Fossil fuel with CCS and geothermal technologies are both currently at pilot demonstration stage. They face the major innovation challenge of now needing large capital investment to demonstrate the technology at commercial-scale and under industrial operating conditions.

Although 'early mover' investors in these technologies could reap the benefits of early positioning, there is a significant disincentive for investment in commercial-scale demonstration, or FOAK, projects. As discussed in Chapter 3, FOAK capital costs will be higher than for mature plants—the larger the capital outlays, the higher the financial risk exposure from FOAK plant obsolescence.

44 Garnaut 2008, p472.

45 NGF 2009.

46 ATSE 2009: Australian Academy of Technological Sciences and Engineering (ATSE), *Electricity Generation: Accelerating Technological Change*, International Workshop, 2009.

For these reasons, direct support from the public sector is needed to augment private sector investment in FOAK, commercial-scale demonstration plants, in Australia and globally. Chapter 5 examines currently committed public support for fossil fuel with CCS FOAKs and recommends additional actions and models.

4.4.2 Operating disincentives to invest in immature technologies

All new entrant technologies will face competition with incumbents to be placed high enough on the merit order for dispatch into the NEM as determined solely by short-run marginal costs (that is fuel and variable operation and maintenance costs), to earn sufficient revenue at suitable margins.

The incumbent competition benchmark for baseload power generation will be set by a combination of the most efficient coal-fired power generator without emissions abatement[47], and the price of CO_2 emissions permits that the unabated coal-fired power station will have to purchase.

That is, early movers in new entrant technologies face a prohibitive competitive disadvantage against market incumbents, until carbon prices rise substantially to more fully reflect the costs of GHG mitigation measures. This could apply over an extended, uncertain period (perhaps a decade or more).

4.4.3 Comparing new low emissions electricity technologies

The emerging indicators in Australia suggest that, at likely prevailing carbon prices, all new entrant electricity technologies will be deeply uncompetitive over a large part or most of their asset life.

Coal-based generation with CCS is an emerging technology, so it is very difficult to accurately estimate ultimate costs using traditional engineering studies and factored estimates.

Given that no fully integrated CCS power plant has been built and operated anywhere in the world, it is very difficult to forecast the ultimate cost of CCS with any certainty. In addition, CO_2 pipeline and disposal costs vary widely depending on location and geology (see Figure 3.9 as an example), making it difficult to produce a generic CCS cost estimate.

The EPRI study[48] commissioned for the Energy White Paper estimated the LCOE for a range of power generation technologies in Australia. The EPRI study examined costs within the generation site only. Off-site costs such as carbon transport and storage for CCS and transmission costs for remote renewables are site-specific and highly variable, and so are excluded. Within this band of uncertainty, the estimated cost premium for FOAK generation of low-carbon electricity with CCS is similar to the cost premiums for generating baseload, low-carbon electricity by other means, such as nuclear and renewables.

Across a wide range of zero and low emissions technologies, including low-carbon power with CCS, the estimated LCOE for FOAK generation is approximately double that of new conventional power generation (excluding emission permit prices).

The cost premiums for all of these technologies are expected to decline in future. However, *the extent of these cost reductions is highly uncertain* and will depend on the amount of pre-commercial deployment and future technology breakthroughs. Consequently, there is significant uncertainty about the likely timeframe in which FOAK plant can successfully transition to early commercial deployment.

4.4.4 Supporting new low emissions technologies to fully-commercial deployment

Given the uncertainty in the future cost and performance of all low-carbon, baseload technologies, it is important that all options are pursued, including CCS. In the case of CCS, this will require policy interventions to ensure rapid deployment of initial demonstration plants and subsequent early pre-commercial plants.

47 This could be either existing plant built over the last couple of decades in Australia with thermal efficiency rates up to around 30 per cent or, potentially, a new-build plant incorporating the latest coal-fuelled power generation technologies such as ultra-supercritical coal or Integrated Combined Cycle Gasification, with thermal efficiencies up to 45 to 55 per cent.

48 EPRI 2009.

This will include the need for special transitional financial assistance in addition to the CPRS to bridge the commercial gap that will be experienced by early deployment of low emission plants. These measures will be essential to deliver sufficient CCS deployment to ensure material future cost reductions through learning, scale and technology design/integration step-change.

Further, the challenge for coal-based generation plants with CCS is to compete, that is be 'dispatched', in the NEM or SWIS markets, even if the capital cost of coal-based plant with CCS is substantially subsidised, like renewables, to a quite high level. This is due to higher operating costs compared to conventional coal-fired plant, including much higher levels of in-station electricity requirements to drive the carbon capture process. Carbon permit prices are unlikely to offset this cost disadvantage for many years.

This challenge becomes ever greater if these newly emerging coal plants with CCS generators have to purchase emissions permits in the market place for any residual emissions or emissions due to breakdowns of the capture plant.

Government has a range of policy instruments available to advance the commercial uptake of low emissions coal-based technologies. Ideally, such policies should be based on the accepted principles of being technology neutral, and incentive and market focused.

While direct grants and other financial assistance are of significant value at the R&D and early commercialisation stage, they are likely to be inadequate in pulling through the full commercialisation of more expensive zero or low emissions technology, even in the presence of an emissions trading scheme, unless the carbon price becomes unacceptably high.

This is clearly recognised in the Renewable Energy Target (RET) scheme where public funding support is likely to be around $30–$40 billion[49] between 2010 and 2030 in order to achieve the 45,000 GWh target. The price of emissions permits will have to be high (in excess of $60/tonne in 2020[50]) for renewable electricity generators to compete in the NEM without the retail subsidy. For early deployment, the price of emissions permits will need to be even greater for coal-based generators using new technologies and CCS to compete in the NEM.

There are several options for the use of a revenue mechanism to support low emissions technologies, including:

- direct funding support for projects, based on competitive tendering or other processes
- price support for the electricity produced at the wholesale or retail level
- technology portfolio standard, including a national low emissions technology target.

Ultimately the Council accepts that a single national emissions trading scheme, linked internationally, should be the primary, long-term mechanism to meet emissions targets because such a scheme reduces emissions in a least-cost manner, without picking winners. While such CO_2-e emission pricing schemes are maturing, a case for further market intervention can be made for low emissions coal-based generation because, like renewables, low emissions coal-based generation will have to be part of a global solution to reducing emissions.

On balance, a national low emissions technology target scheme (as part of a technology portfolio standard) is ultimately likely to provide the best market-pull mechanism. However, unlike a number of renewable energy technologies (mainly wind), low emissions coal-based CCS technologies are very much in the development stage and the value of a targeted mandate as part of a portfolio standard is likely to be limited up to at least 2020.

49 Prima facie total cost of mandated annual RET targets times average annual Renewable Energy Certificate costs, as modelled in: Access Economics 2009: *Scoping impediments and policy initiatives for early deployment of carbon capture and storage technologies*, August 2009; report prepared for the National Low Emissions Coal Council, Department of Resources, Energy and Tourism; Canberra.

50 Source: IES modelling for the National Generators Forum (2009)

The Council observes though that in the longer-term, and assuming appropriate policy interventions are made, the range of estimated costs for Nth-of-a-kind (NOAK) mature-technology plants is within the range of plausible future carbon prices, implying that mature technology can be competitive with conventional fossil fuel plants at future prevailing carbon prices.

In the transformation of the energy market in response to climate change, it is important to highlight and contrast the investment dynamics during the initial transitional phase and later commercial phases.

The Australian Energy Market Commission (AEMC) is currently reviewing energy market frameworks in light of climate change policies[51], and is due to report to the Ministerial Council on Energy by September 2009. The review focuses on identifying potential stress points as the market adjusts to the CPRS and expanded RET over the short- to medium-term (that is up to 2020). Within this context the AEMC has found NEM market settings to be broadly robust.

However, as outlined above, the Council is taking a wider strategic perspective on the emergence of major new entrant technologies over the period to 2030 and beyond. From this viewpoint there are significant market failures that will act as barriers to rational investment in new entrant technologies during the initial transitional period when the technologies and the carbon price signals are immature. These barriers are:

- early mover disadvantage, mitigating against investment in commercial-scale demonstration projects with very high capital costs and very high risk of early obsolescence, with competitors able to capture the benefits of subsequent improvements in technology
- the critical gap in the business case for new low emissions technologies during the extended transitional period (perhaps a decade or more) while carbon prices are progressively raised in line with increasing abatement needs. Until this happens, the higher operating costs of the new technologies mean that they cannot compete with incumbent technologies and will not be able to sell the electricity generated.

Without significant investment to develop new entrant technologies through the critical commercial-scale demonstration phase and sufficient early deployment to drive material future cost reductions, these technologies will not be available as options for later commercial investment.

Targeted interventions should therefore be considered to guard against the market failing to investigate technology options that may prove the most useful in the longer-term. These interventions should phase out as the underlying market failures decrease.

The detailed design of targeted interventions in electricity markets will require further investigation and analysis.

51 AEMC 2009: Australian Energy Market Commission (AEMC), *Review of Energy Market Frameworks in light of climate change policies: 2nd interim report*, June 2009.

5 A STRATEGIC FRAMEWORK FOR CCS DEPLOYMENT IN AUSTRALIA

KEY FINDINGS

In considering the objective of commercial-scale demonstration of CCS from 2015 and commercial deployment from 2020, concurrent action is needed by industry and governments in the following nine areas. Recommendations in each of these strategic areas are set out in the report and are listed in the Executive Summary.

1. Gaining the support of communities located near CCS demonstrations, and the Australian public more broadly, will be as essential for the deployment of CCS as addressing the technical and economic challenges.

2. A portfolio of demonstration projects required in the timeframe to 2020 would include at least one commercial-scale IGCC, several medium-scale PCC and oxyfuel plants, and at least one commercial-scale combustion-based plant. The total cost of this program is in the range of $10–17 billion. This cost includes only the next phase of demonstration-scale (30–100 MW) and commercial-scale (250 MW+) projects. It does not include funding shortfalls on existing demonstration projects, or funding requirements for new pilot demonstration projects, recognising that there will be a number of these in the years to come, particularly for new CO_2 capture technologies.

3. Australia has a number of R&D programs applicable to low emissions coal utilisation, although two major programs—the CRC for Coal in Sustainable Development (CCSD) and the Centre for Low Emission Technologies (cLET)—have concluded in the last two years. Australian National Low Emissions Coal R&D (ANLEC R&D) will play a key role in rebuilding, leading and enhancing the coordination of Australia's research effort associated with CCS demonstration projects.

4. General CPRS and taxation policy settings are working against the establishment of CCS demonstration projects. CPRS liabilities on CCS demonstration projects will add a major cost impost on projects and will reduce the likelihood of some projects proceeding. General taxation provisions tend to result in taxation loss of direct grant funding for project proponents.

5. Investment in commercial-scale CCS demonstration projects will not proceed without significant targeted support and incentives. Substantial market failures blocking private investment are innovation risks around early commercial-scale demonstration of CCS technology and a carbon pricing trajectory in Australia that will not fully reflect the costs of emissions abatement for many years. Project support models should be weighted towards achieving long operating lives of commercial-scale CCS demonstration projects.

6. There are considerable uncertainties on a range of regulatory elements including CO_2 pipeline regulation, and network and economic regulation of transport and storage infrastructure. Nationally consistent approaches, and preferably single national regulation, should be adopted.

7. Immediate actions are needed to allow rapid access to the most prospective large storage basins for early CCS demonstration and to better characterise and prioritise other basins for potential future use.

8. Lengthy, complex and uncertain approvals processes present significant impediments and risks for CCS projects.

9. The development, demonstration and deployment of these technologies will increase the demand for a range of technical skills. The ability of the tertiary education system to satisfy this demand in the timeframes required needs to be confirmed.

Previous chapters have set out the accelerated CCS technology deployment path required if CCS is to be available to make a significant contribution to GHG mitigation from the 2020s, and have highlighted the substantive barriers preventing the market responding in the required timeframes.

This chapter identifies immediate priorities for policy and regulatory frameworks and for targeted, transitional interventions to enable progress on commercial-scale CCS demonstration projects and demonstration hubs. Early, parallel action is recommended in key areas needed to position for rapid subsequent deployment. Further detailed investigation is recommended in many areas. The most appropriate stance at this stage is to keep strategies as open and flexible as possible. Uncertainties are currently high on many fundamental factors that will shape strategies for Australia's low emissions energy future. These uncertainties include Australian and international carbon trading regimes, and assessment at scale of the emerging technologies.

The following analysis highlights areas for action in:

- community acceptance
- demonstration portfolio
- research support
- general CPRS and taxation policy settings
- transitional support for CCS projects
- regulatory frameworks
- storage availability
- streamlining project approvals
- skills development.

5.1 COMMUNITY ACCEPTANCE

The Council recognises that lack of community awareness and acceptance of CCS is likely to be the single most significant barrier to CCS deployment in Australia. The CSTF has also highlighted the importance of community acceptance and managing interactions with stakeholders in the successful deployment of CCS projects.

Gaining the support of communities located near CCS demonstrations, and the Australian public more broadly, will be as essential for the deployment of CCS as addressing the technical and economic challenges. This has already been demonstrated internationally; for example, a recent Shell CCS project in the Netherlands where community opposition ultimately led to the project being shelved.

A well coordinated and resourced national CCS communications strategy will be critical to the successful deployment of CCS Flagship demonstration projects from 2015 and for commercial deployment from 2020.

Current communications efforts in Australia are uncoordinated and, in the main, poorly resourced. This has resulted in a low level of public understanding of CCS technologies and low levels of acceptance of the technology. Common perceptions include that CCS is too expensive, will take too long to be deployed commercially, is not technically feasible and that investment in CCS is occurring at the expense of renewable energy. However, studies by the CSIRO and others show that acceptance of CCS improves significantly with provision of technical information in an open and transparent manner.

Recent efforts by industry, research agencies, governments and project proponents are contributing to the improved availability of high-quality, public information on CCS. The Australian Coal Association (ACA) launched the NewGenCoal website in 2008 and an associated media campaign. The website builds on the communications efforts of CSIRO, CO2CRC and state governments as well as demonstration projects such as Otway, CS Energy Oxyfuel and ZeroGen, which have clearly defined local communications strategies and web-based information. Improved coordination of these existing efforts and the targeted dissemination of this information will need to be a central part of a national CCS communications strategy.

In framing a national communications strategy, the Council has regard to the following key lessons from recent international communication efforts, as highlighted by the IEA:

- Public perception will be heavily influenced by early CCS demonstration projects. It is therefore essential to ensure that projects are well-designed and operated, that they are monitored thoroughly by credible independent authorities, that they strive toward continuous improvement and that they provide transparent information about their results to policy makers and the public.
- Governments must take a leading role in improving the perception of risks associated with CCS by establishing clear regulatory responsibility for CCS project evaluation, approval and monitoring.
- Governments (and project developers) must use effective communication techniques to engage and educate different audiences including the public, the NGO community, local environmental groups and media, with special attention paid to developing guidelines for local community consultation for proposed CCS projects
- For long-term stewardship, the public acceptance of this long-term responsibility will only come if CCS is clearly communicated as an essential, long-term, climate-change-mitigation technology that is being deployed along with other important technologies, including renewable energy, energy efficiency and other solutions[52].

A National CCS Communications Strategy

A national CCS communications strategy should be carried out as part of a broader strategy to communicate that a fundamental transformation of the energy system will be required to address the climate change challenge. The CCS component of this strategy will be based around three major components:

1. A public awareness and education campaign targeted at the general community:

   A far-reaching communications campaign will be essential to raise public awareness of CCS technologies and their role as part of a portfolio for addressing climate change. The campaign could involve initiatives such as:

   - a comprehensive, technology-focused website with links to other key sites
   - a media campaign including print media, web-based advertising and television.

2. Targeted engagement of opinion-makers and influential figures:

   A comprehensive strategy of targeted engagement of key opinion-makers is considered the most effective way of stimulating public discussion and building support for CCS technologies. For example, targeted engagement may include:

   - workshops for politicians and their researchers
   - one-on-one briefings for key individuals and stakeholder groups
   - briefings for journalists and preparation of media briefing packs
   - targeted workshops for environmental NGOs and other identified stakeholders
   - hosted site visits to Flagship demonstration projects.

3. Local community engagement around CCS demonstration projects:

   As public perceptions are heavily influenced by early projects, it is essential that the first Australian commercial-scale demonstration projects are successful, and that they engage effectively with local communities throughout all stages of the project. This may involve:

   - project-specific community briefings and workshops
   - targeted workshops for local councils and local community groups
   - opportunities to showcase the project to local communities
   - project performance monitored thoroughly and reported by credible independent authorities.

52 IEA CCS 2008, p37.

Recommendations

1. A comprehensive national CCS communications strategy should be developed by the Council, in consultation with key stakeholders, by the first quarter of 2010. This includes:
   - a dedicated CCS Communications Manager should be engaged to develop the communications strategy and should report to the Council
   - the Communications Manager should establish and work closely with a CCS communications network comprised of key communications officers across industry, governments, research agencies and project owners/proponents to inform the development of the strategy and to improve coordination of CCS communications efforts
   - adequate funding over five years should be allocated from the National Low Emissions Coal Fund for this purpose.
2. Australian demonstration projects funded under the CCS Flagships Program should have comprehensive and well-resourced communications strategies as part of public funding requirements.
3. The Australian Government, through the Energy White Paper, should take a leadership role in developing a far-reaching national communications and media campaign to promote awareness of *all* low emissions technologies and their role in Australia's response to climate change.

5.2 DEMONSTRATION PORTFOLIO

A coherent and cost-effective national portfolio of low emissions coal demonstration projects operating from 2015 is needed to support commercial deployment from 2020. The portfolio should:

- build on current and planned demonstrations
- address gaps in the existing demonstration portfolio
- demonstrate priority technologies (for both black and brown coal) at the most efficient and cost-effective scale
- support development of commercial-scale storage facilities, with demonstration projects of significant scale (greater than 1 Mtpa CO_2) preferably evolving into demonstration hubs. The Gippsland, Surat and Perth basins are identified by the CSTF as the most likely to develop as the first capture and storage hubs.

A broader national demonstration portfolio for CCS needs to include application of CCS to gas-fired electricity generation as well as to industrial processes, including steel manufacturing and LNG production.

Pilot and medium-scale demonstrations of PCC are anticipated to cost around $200–500 million per project depending on the scale (that is capacity of the plant), the technology being demonstrated and the storage location. Commercial-scale IGCC projects with integrated CCS are estimated to cost over $4 billion[53] per plant.

A suggested portfolio of demonstration projects required in the timeframe to 2020 would include at least one commercial-scale IGCC, several medium-scale PCC and oxyfuel plants, and at least one commercial-scale combustion-based plant. The total cost of this program would be in the range of $10–17 billion. This cost includes only the next phase of demonstration-scale (30–100 MW) and commercial-scale (250 MW+) projects. It does not include pilot demonstration projects, recognising that there will be a number of these in the years to come, particularly for new CO_2 capture technologies.

53 For example: ZeroGen Fact Sheet – *Project Overview*. Downloaded from www.zerogen.com.au on 1 September 2009. The outlined project proposal is for a 530 MW (gross) IGCC power plant, with 90 per cent carbon capture and sequestration of all captured CO_2. These cost estimates are preliminary, with pre-feasibility studies proceeding on several potentially suitable storage sites.

The Council emphasises that the national demonstration portfolio will need to be underpinned by a comprehensive storage program, including an accelerated pre-competitive exploration program as recommended by the CSTF.

CCS Flagships: A key part of the national demonstration portfolio

The Australian Government's $2 billion CCS Flagships Program has been established to support two to four commercial-scale CCS demonstration projects. These Flagship projects will be Australia's contribution to the G8 target of 20 integrated, industrial-scale, CCS projects operating by 2020—and also a key part of a national demonstration portfolio that ideally will be complemented by the range of pilot and medium-scale demonstrations across the key technologies discussed above. Given the anticipated cost of commercial-scale CCS demonstrations, the Flagships Program as currently allocated will make a major contribution to CCS development in Australia, but will not be able to deliver all demonstration priorities.

Recommendation

4. The Australian Government's Clean Energy Initiative should be considered as the first tranche of funding required over the next 10–15 years for implementation of a portfolio of commercial-scale demonstration CCS projects in Australia.

    - The Council urges the Government to commit to expanding the current CCS Flagships Program to include further selection rounds with additional funding in 2012 and 2014.

Selection of commercial-scale demonstration projects

The Council notes that, given the significant uncertainty surrounding storage availability and the long lead times for project development, reaching a final investment decision on a commercial-scale project is likely to take several years. Staged project decision processes enable project funders to assess risks step-by-step at each 'gate' and, if satisfied, authorise the next stage. Failure to follow this process for CCS demonstrations would involve unacceptable financial risks for both governments and industry, particularly given the size and cost of the projects under consideration.

An implication of this is that it will not be possible to definitively select projects for the national demonstration portfolio, including CCS Flagship Projects, until after project feasibility studies have concluded.

This point is illustrated by international and domestic experience which often has shown that commercial-scale CCS projects will not move beyond conceptual or pre-feasibility studies because they have identified issues related to, for example, storage availability, regulatory barriers or significant cost increases.

Accelerating Data Access

The Council notes the importance of ensuring that robust information on lessons and insights from CCS demonstration projects is available as early as possible to prepare for the next generation of projects.

Recommendations

5. In developing funding agreements for the CCS Flagships Program, the Australian Government should liaise with ANLEC R&D, the Global CCS Institute, state governments and Australian Coal Association Low Emissions Technologies Ltd (ACALET) to develop model contract clauses enabling suitable access to project performance and economic data across Australian CCS Flagship projects and all global commercial-scale CCS demonstration projects.

6. Data access arrangements for commercial-scale CCS demonstration projects should include a focus on obtaining early, robust indicators of long-term integrity of CO_2 storage in Australian geological formations.

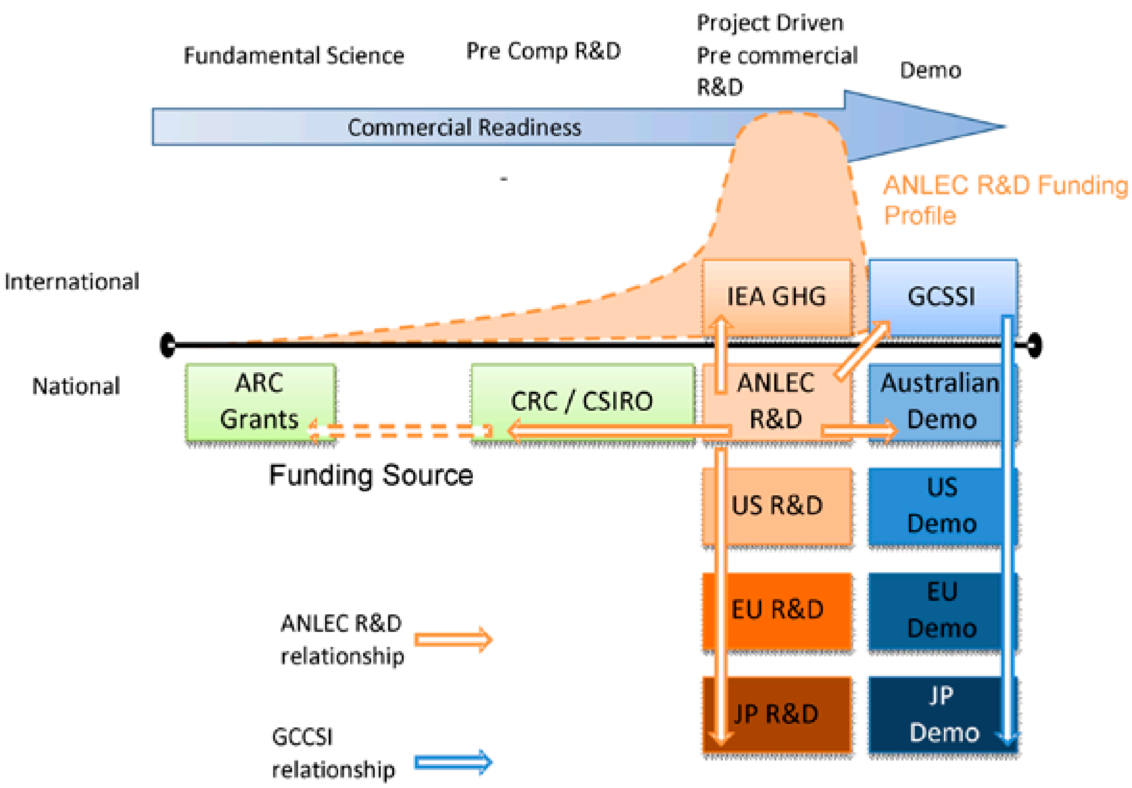
5.3 RESEARCH SUPPORT

Australia has a number of significant and considered R&D programs applicable to low emissions coal utilisation, each with high quality leadership but with quite different foci. Fundamental research into second and later generation technologies is being conducted by a range of research providers. These R&D programs appear reasonably robust, although as mentioned in Chapter 2, a number of major CCS research-industry collaborative R&D programs have concluded in recent years.

There is a need to focus on applied R&D in support of the demonstration projects and to increase total R&D funding. The Australian medium-scale and commercial-scale demonstration projects offer the opportunity to identify and conduct useful R&D directed towards reducing project risk and providing independently validated, consistently reported information on the capital cost, technical performance and operating cost structure of these demonstration projects. This cost and performance information will be essential for accelerated commercial deployment and the formation of robust energy and climate policy.

Using the R&D funding available under the Australian Government's NLECI, the Australian Coal Association's COAL21 Fund and various other initiatives, the Council has established ANLEC R&D Limited to manage the Council's R&D investments as part of its national strategy. The relationships of ANLEC R&D with other R&D support programs in Australia, the Global CCS Institute and international R&D activities are illustrated in Figure 5.1.

Figure 5.1: ANLEC R&D's relationships with key organisations and activities nationally and internationally



ANLEC R&D will be a coordinating organisation with a small Board of Directors focused on governance, a small management team focused on execution, and a number of R&D managers integrated with the demonstration projects. All will concentrate on developing and delivering a needs-based, demonstration-project-focussed R&D program. Activities will be conducted in technically-aligned nodes in the fields of:

- post-combustion capture (PCC)
- integrated gasification combined cycle (IGCC)
- oxyfuel combustion
- geo-sequestration
- brown coal fundamentals
- economics and modelling.

Each node will become the focus for Australian R&D in its area of responsibility.

Within each activity area, ANLEC R&D will attract the best researchers in the field to form virtual teams, regardless of where these researchers are based. Work will be focused on applied R&D to help reduce the risks inherent in the demonstration projects, provide mechanisms for reporting independently-validated cost and performance data, and use demonstration project experience to identify research priorities to accelerate future commercial deployment. The R&D will be carefully coordinated with international programs and will focus on world-leading expertise and unique Australian issues such as reducing the water demand associated with capture and alternative sequestration options.

Recommendation

7. The Council will provide advice to the Minister for Resources and Energy by the first quarter of 2010 on the initial priorities for a national research program for low emissions coal research and development that:

    - focuses on applied R&D, performance data, and research priorities to support medium- to large-scale CCS demonstration projects and accelerated commercial deployment, through ANLEC R&D
    - identifies technological priorities and portfolio gaps in small- to medium-scale CCS demonstration projects, and assesses associated funding requirements and funding availability for existing and future projects
    - ensures coordination through ANLEC R&D of Australian R&D with international research programs at a detailed program and project level. The coordination should focus at the operating level by defining Australian research programs that are complementary to international efforts and/or programs that adapt international R&D to Australian conditions
    - ensures coordination of the national low emissions coal demonstration project portfolio with demonstration of CCS application to gas-fired electricity generation and industrial processes such as steel-making and LNG production.

5.4 GENERAL CPRS AND TAXATION POLICY SETTINGS

The Council observes that current general CPRS and taxation policy settings are working in the opposite direction to targeted interventions and are effectively reducing assistance to CCS demonstration projects.

The CPRS White Paper framework takes the position that assistance for CCS technology development should be delivered outside the CPRS scheme. However, industry members of the Council are concerned that the lack of relief from CPRS liabilities threatens the viability of current pilot-scale CCS demonstration projects emitting over the 25,000 tpa CPRS threshold. These pilot projects, such as Callide A, Munmorah and the Latrobe Valley projects, are attached to older, less efficient plants, and will operate intermittently and at relatively low capture rates. They now face high anticipated liabilities under the CPRS.

Further, CPRS liabilities potentially will add major costs to future medium- and large-scale demonstration projects. FOAK commercial-scale CCS projects may not be able to achieve emission levels below the CPRS threshold, and in any case will likely take a number of years to ramp up capture rates. CPRS liabilities will reduce the likelihood of some projects proceeding.

General taxation provisions tend to result in taxation loss of direct grant funding received by CCS research, development and demonstration projects, with the effect that less funding is available to apply to the project. The general deductibility of expenditure on CCS demonstration projects (by project sponsors) will likely provide insufficient inducement for project sponsors to contribute to those projects. There is a need to consider enhanced deductions for CCS demonstration projects. Removing uncertainties about the application of R&D tax concessions for CSS demonstration projects would help speed up the development of project funding agreements.

Recommendations

8. As an urgent priority, CCS demonstration projects should be exempted from CPRS liabilities.

9. Direct grant funding for CCS demonstration projects should be non-taxable.

5.5 TRANSITIONAL SUPPORT FOR CCS PROJECTS AND HUBS

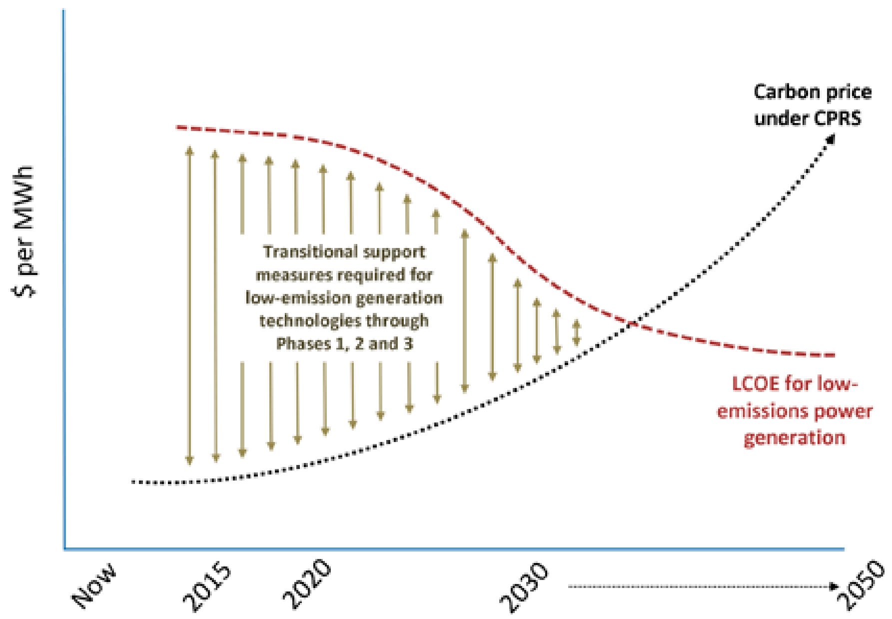
This section considers the case for targeted, transitional support for CCS uptake. Many aspects of the case for intervention apply for CCS uptake across all industry sectors. Challenges for CCS uptake for power generation are specifically considered.

5.5.1 The commercial gap

As discussed in previous chapters, innovation risk and high technology costs for commercial-scale demonstration projects, coupled with capping of carbon prices to initially low levels expected to rise only moderately over time, represent significant barriers to commercial investment in all emerging commercial-scale zero and low emissions technologies including CCS.

This 'commercial gap', where transitional support may be warranted, is conceptually illustrated in the context of electricity markets in Figure 5.2. The commercial gap is most severe in the early stages of deploying new technologies, where power generation costs from these technologies are high and carbon prices are low.

Figure 5.2: Conceptual illustration of the commercial gap for emerging low emissions technologies including CCS



5.5.2 Risk barriers

From a commercial perspective, barriers to investment also manifest as prohibitively high risks that block progression towards prospective longer-term technologies.

Risk profiles for integrated CCS projects are currently well beyond what plant owners and equity/debt investors will bear for the envisaged levels of return. A project finance workshop conducted by the CSTF, with stakeholders including financiers, government and industry, indicated that returns would need to be at venture capital levels to attract CCS project investment at current risk levels. Access Economics, commissioned on behalf of the Council, conducted consultations with power generators, financiers, government agencies, pipeline owners, researchers and CCS project proponents. This study also found that the magnitude of assessed risks on CCS technology, integration and regulatory uncertainties were identified as major impediments to current CCS investment[54].

Risk levels must be decreased or offsetting support offered if investment in commercial-scale CCS demonstration projects is to proceed soon, as required to meet the government's target timelines for CCS demonstration and deployment.

Australian and international carbon permit trading arrangements and prices are currently one area of very high project risk. Greater certainty is needed on Australia's CPRS legislation and regulations, and on international emissions permit trading as soon as possible.

Other broad areas currently contributing to high project risk include uncertainties in relation to community acceptance and regulations for GHG storage exploration and site operation. Actions outlined elsewhere in this chapter will help to reduce these uncertainties and risks.

Other high risk factors for CCS coal-fired power generation projects include:

- capital hurdles. The power plant capture component will typically be the largest element of capital outlays in an integrated CCS demonstration project. New build or whole-of-plant refurbishment projects face high capital hurdles. Retrofit and/or modular projects at a smaller scale, with lower capital outlays, may be feasible for some technologies (for example, post-combustion capture)
- technical risks. These mainly depend on the nature and scale of capture technology used, and the nature and scale of the storage sites to be developed
- counterparties. Unless a single entity will own and operate the generation/capture, transport and storage components of an integrated CCS project, each project component is exposed to risks outside their control that the other components may not be available in time or at required performance. To a degree, counterparty risks can be mitigated through commercial negotiations in project consortia agreements or through service contract agreements
- electricity revenue stream. Returns on power generation investment rely on electricity sales over the life of the asset. As outlined in Chapter 4, it is likely to be some time before CCS generated electricity can compete on price for dispatch into the NEM against incumbents (non-CCS fossil fuel generators paying for emission permits). In the absence of ongoing electricity market support measures, it is likely that CCS demonstration projects will seek to capitalise the expected operating losses from an initial CCS demonstration period into upfront grant support, then switch to more competitive plant operation (for example, turn off the capture function, or fuel-switch to gas)
- hub economics. Potentially, the longer-term business case for a CCS demonstration project could link with development of a future hub. Revenue streams and returns on investment for the transport and storage operators could then be spread over a larger base of users, reducing the transport and storage tariff faced by the initial capture source. However, reliance on potential future hub development introduces greater project uncertainties and risks.

54 Access Economics 2009: Access Economics, *Scoping impediments and policy initiatives for early deployment of carbon capture and storage technologies*; report prepared for the National Low Emissions Coal Council; Department of Resources, Energy and Tourism; Canberra, 2009.

5.5.3 Transitional support measures for CCS projects and hubs

Commercial-scale CCS demonstration projects are substantive, high-risk investments that will require risk sharing between the private and public sectors if CCS technologies are to be available for commercial deployment in target timeframes. The choice of appropriate support measures will vary according to the specific risks involved, and the interventions should phase out as the underlying market failures decrease[55].

Public sector investment in CCS projects, like private investment, will need to be managed in the context of significant uncertainties. Prudent risk management approaches should be adopted. This could include staging progressive decision points towards final funding commitment as more information is obtained and uncertainty reduced, and using contingency support mechanisms where possible.

Broad options for CCS transitional support mechanisms are[56]:

- up-front funding support—options include grants, concessional debt finance (for example, income contingent loans), and equity injections
- medium-term operational support—for CCS electricity generation projects, the core issue here is to provide assurance that CCS generated electricity will have a market
- underwriting early CCS coordination risks—underwriting early counterparty risks requires particular consideration for early CCS integrated projects and hubs.

These approaches are discussed further below. An overview of the advantages and disadvantages of various support models as compiled by Access Economics is provided at *Attachment D*.

An overarching objective in Australia, as highlighted earlier in consideration of the CCS technology deployment path and the optimal national CCS demonstration portfolio, is for commercial-scale CCS demonstration projects to evolve into and anchor CCS demonstration hubs. It follows that project support models should be weighted towards achieving long-lived CCS operating lives of commercial-scale demonstration projects.

Up-front funding support

Grant funding can be calibrated to weight private/public risk sharing to match project risk profiles. It can also be structured with different weightings across unconditional funding and approaches allowing more risk sharing with the proponent, such as equity funding or income-contingent repayable funding. Competitive selection processes with criteria including a requirement for a significant private sector funding contribution are desirable.

Flexibility may be needed to accommodate project risk profiles on a case-by-case basis. In particular, the current CCS Flagships Program caps the Australian Government funding contribution at one third of a project's total budget. It is the Council's view that it will be difficult for some early, high-risk CCS demonstration projects to secure sufficient private sector or other funding contributions to cover the balance.

Medium-term operational support

As considered in Chapter 4, electricity market-based support could be provided through mechanisms such as feed-in tariffs (price support for the electricity produced at a wholesale or retail level), or a technology portfolio standard including a national low emissions technology target.

55 COAG 2008: Council of Australian Governments, *COAG (Complementarity) Principles for Jurisdictions to review and streamline their existing climate change mitigation measures.*

56 Access Economics 2009.

On balance, a national low emissions technology target scheme (as part of a technology portfolio standard) is considered ultimately likely to provide the best market-pull mechanism, although it is recognised that the value of a targeted mandate is likely to be of limited value up to at least 2020, while low emissions coal-based CCS technologies are in the development stage.

Phase out could be linked, for example, with achievement of CCS technology maturity benchmarks, a carbon price threshold, or a sunset date.

Alternatively, within a Government budget context, other options for ongoing support for CCS projects include tax incentives (for example, tax credits, accelerated depreciation) and financial guarantees.

Underwriting early CCS coordination risks

Options for partially underwriting cross-sector CCS start-up risks include:

- up-front government guarantees to conditionally void CPRS liabilities for vented emissions if a capture project component is ready but the storage project component is delayed
- up-front government guarantees to provide conditional funding support to a storage facility if the capture source is delayed

or

- initial public ownership of critical infrastructure; for example, backbone pipelines.

In relation to development of a large-scale storage hub, if storage facility development cannot be readily staged to match capture sources progressively coming on stream, then initial funding support for the most strategic and prospective storage demonstration sites may be warranted. Risk sharing arrangements through 'take or pay' contracts may be feasible and should be further assessed.

As recommended by the CSTF, CO_2 pipeline networks should be built sequentially and optimally designed to capture economies of scale from future volumes. Support should be provided for oversizing of pipelines, following careful analysis of likely future loads on a hub basis. It is well established that private sector investment in pipeline assets will tend to size the pipeline to accommodate near-term volumes from secure customers, rather than face the risk of underutilised capacity.

Recommendations

10. The Australian Government, in consultation with the Council, should urgently undertake a detailed assessment of transitional support options for CCS deployment.
    - Consideration should include market-based support mechanisms such as clean energy targets, as well as a range of incentives such as tax, capital and operating subsidies, loan guarantees and insurance.
11. Flexible approaches should be adopted in the progressive selection and implementation of commercial-scale CCS demonstration projects in order to:
    - ensure that Australia's CCS demonstration portfolio includes cornerstone projects that have long CCS operational lives and that anchor hub development
    - allow scope for adjustment to project or portfolio parameters in response to changes in information (for example, large storage basin availability) and policy developments (for example, electricity market-based support measures).

5.6 A SUPPORTIVE REGULATORY FRAMEWORK

5.6.1 CO_2 storage regulations

The accelerated deployment of CCS in Australia will depend on the implementation of comprehensive regulatory frameworks for CO_2 storage. Commercial-scale CCS demonstration projects cannot proceed before proponents can secure storage tenure and this will require regulatory frameworks to be in place urgently, particularly if 2015 demonstration targets are to be met.

The Council acknowledges that Australia is leading the world in the development of storage regulations, with the Australian Government, Queensland, Victoria and South Australia passing CO_2 storage legislation in 2008 and 2009. Western Australia and New South Wales must now move urgently to implement appropriate regulatory frameworks to support CCS deployment in these states.

In implementing these regulatory frameworks, the Council emphasises the importance of promoting national consistency and cooperation across governments. Some early demonstration and FOAK projects are likely to operate across jurisdictional boundaries—consistent regulations and active cooperation between different levels of government and industry will be critical for their accelerated deployment.

Long-term liability

The level of uncertainty surrounding the issue of long-term liability is a significant impediment to investment in CCS projects. While the risks of CO_2 leakage after site closure are considered low, it is a risk that private industry cannot effectively or realistically manage over periods of hundreds of years. The Australian Government has recognised this in its offshore storage legislation and has explicitly agreed to take on long-term liability 20 years from when injection ceases, provided that the Minister is satisfied that the stored gas is behaving as expected and the site poses no significant risk.

The Council believes this is an effective way to address the investment hurdle that long-term liability poses for CCS deployment.

Management of resource conflicts

Accelerated and widespread deployment of CCS will depend on regulatory frameworks providing an effective and transparent mechanism to manage potential resource/land use conflicts with CO_2 storage operations. A commonly-cited example of a potential resource conflict is in the highly prospective Gippsland basin, where existing petroleum titleholders have expressed concern that CO_2 storage activities will have a detrimental impact on their operations. However, the CSTF has identified that storage operations could begin progressively in the Gippsland basin in a manner that is unlikely to affect petroleum operations.

It is important that the development of storage facilities in these areas is not vetoed without a robust and transparent assessment of the impact of storage operations on other activities or uses.

The Council recommends that state and federal regulatory frameworks provide for ministers to seek independent, expert advice in cases where CO_2 storage is asserted to have a detrimental impact on other activities. This will ensure ministers are able to make a fully informed resource management decision based on public interest considerations.

Recommendation

12. Nationally consistent onshore and offshore CO_2 storage legislative and regulatory frameworks should be established as an urgent priority. In particular:

    - the New South Wales and Western Australian governments must urgently introduce storage legislation
    - regulations must be in place for explorers to take up acreage from 2010, particularly for the Gippsland, Surat and Perth basins
    - the Australian Government approach on long-term liability should be adopted nationally, with state and territory governments assuming long-term liability for CO_2 storage from 20 years after injection ceases, provided pre-conditions are met.

5.6.2 Reducing other regulatory uncertainty

In line with recommendations of the CSTF and analysis commissioned by the Council from Access Economics, the priority areas that should be addressed to reduce regulatory uncertainties for CCS project proponents are:

- corridors for strategic pipelines. National and local planning should be coordinated to retain easement options for strategic pipeline corridors for potential future use
- CO_2 pipeline regulation – *technical*. A nationally consistent approach to CO_2 pipeline regulation is required, and levels of assurance provided for regulators and the public that pipeline operations will be safe
- CO_2 infrastructure – *network and economic regulation*. Natural monopoly aspects may apply to regional storage sites and pipeline networks. The need to sequence access to a storage basin to ensure optimal filling to its full capacity, and the likelihood of a single backbone pipeline to the storage site, may mean that a capture source has effectively only one choice for transport/storage services in their region. Network design, coordination and access may need to be regulated, perhaps including through a dedicated storage regulator. In line with recent reforms to infrastructure regulation in other sectors such as energy and land transport, regulation should be at a national level. Further detailed assessment of the costs and benefits of regulation in this area is required[57].

Recommendation

13. Nationally consistent approaches, and preferably single national regulation, should be adopted for other aspects of the regulation of CO_2 transport and storage infrastructure where required, including:
    - retaining easement options for potential future strategic pipeline corridors
    - CO_2 pipeline technical regulation
    - the potential need for network and economic (access) regulation of common user regional CO_2 transport and storage infrastructure in view of natural monopoly aspects. A national, dedicated regulator may be warranted.

5.7 STORAGE AVAILABILITY

The CSTF has recommended the following key actions that are needed to allow rapid access to the most prospective large basins for early CCS demonstration (namely the Gippsland, Surat and Perth basins), and in parallel, to better characterise and prioritise other basins for potential longer term use. The Council concurs with the CSTF's recommendations.

Recommendations

Pre-exploration

14. A phased, gated, pre-competitive exploration program should be conducted, totalling $254 million as 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. As pre-exploration proceeds, there may be a need for further pre-competitive exploration investment.

15. A Review Committee should be established to consider the pre-competitive exploration programs across the jurisdictions and be 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
    - reporting back to government through the Ministerial Council on Mineral and Petroleum Resources (MCMPR) on the results, their implications and expenditure.

57 Access Economics 2009.

Exploration

16. CO_2 storage exploration incentives that could be applied over the period 2010–2017 should be identified and evaluated with the CSTF to provide a recommendation on appropriate incentives policy to the Minister for Resources and Energy in the first quarter of 2010.

5.8 STREAMLINING PROJECT APPROVALS

The overarching objective of regulation should be to achieve desired policy outcomes more efficiently than would be achieved by alternatives, including no regulation[58]. The six principles of good regulatory practice as endorsed by the Australian Government[59] have been considered in the review of the current regulatory approvals that will be required to undertake CCS projects and in the development of suggested remedial practices where they are required.

A simulation exercise was undertaken where three representative CCS power plant project proposals were submitted to relevant project approval processes. The project profiles for a pre-combustion capture project, a post-combustion capture project and an oxyfuel project were developed and peer reviewed by technical experts within Queensland Mines & Energy and by industry experts.

It was evident from the simulation exercise undertaken using these project profiles that the approval process will be similar for each variant of CCS technology. What is likely to change is the degree of detail that will be required in the various approvals. It was noted that the more detailed and prescriptive approval requirements tended to influence technology selection for a project (that is the proponent will select technology on the basis of what will satisfy the regulation versus what would otherwise be the best technology choice for the project). It was also evident that environmental approvals were more complex and difficult to obtain.

Some of the key outcomes from this process were:

- the approvals required to undertake a CCS project should fundamentally be the same as are already required to undertake a conventional power plant project without CCS. The notable differences to be dealt with are:
  - there are overarching energy policy criteria on GHG emissions, rather than mandated GHG emission levels/targets (for example, prohibiting/limiting carbon dioxide emissions). These policy criteria vary between jurisdictions, and may be open to interpretation regarding the sort of developments which will or won't be approved by the regulators.
  - even though Greenhouse Gas Storage legislation has been enacted in some jurisdictions, there are as yet no regulations in place for issuing the necessary permits and approvals for the storage of carbon dioxide. It was also noted that the development, enactment and implementation of GHG transport and storage legislation varies between jurisdictions, and that a national, coordinated approach would result in less complexity and provide more certainty through a uniform approach.
- the declaration of a greenfield CCS project as a 'significant project' by a central coordinating agency will probably be the most appropriate and effective way to obtain the necessary approvals. This has the advantage of whole-of-government coordination, but can be cumbersome and time-consuming where public notification stages are required (as in the case of significant project status for which an environmental impact study is required under the *State Development and Public Works Organisation Act 1971* in Queensland).

58 OBPR 2007: Office of Best Practice Regulation, *Best Practice Regulation Handbook*, Department of Finance and Deregulation, Canberra, 2007.

59 Treasury 2006: Department of the Treasury, *Rethinking Regulation: Report of the Taskforce on Reducing Regulatory Burdens on Business – Australian Government's Response*; Canberra, 2006.

- a potential disconnect was identified between the desired greenhouse policy goals and the maturity of the relevant technologies
  > in order for a CCS project to be constructed in parallel with technology development, some approval conditions may need to be relaxed in the early years of operation while the technology is bedded down (for example, an unintended release of carbon dioxide). This could result in less incentive to develop new technologies if their deployment is constrained by stringent approval conditions and enforcement of the same.
- FOAK and Early Deployment projects will most likely be providing a training role for the approval agencies. This has become more noticeable in recent times with other projects and is possibly a result of the regionalisation of approval activities by the regulators. This extensive approvals learning curve will delay the commencement of the projects and add substantial costs to the project through the lost opportunities (and the present value and cash flow of an early project start).

Lengthy and complex approval processes are a significant project cost both in terms of actual dollars spent on the approvals and the present value of project revenue if the project were able to operate earlier. The monetary cost of the actual approvals is often less than the present value of the cost of the delays.

In addition, companies, financiers and investors will take account of the costs and risks associated with obtaining the necessary regulatory approvals when considering a CCS project. Project proponents require certainty around the time and process required to obtain the necessary approvals. Financiers have indeed indicated that the vagaries of the plethora of approvals represent a major impediment to their investment in CCS projects.

Further, presently a CCS project will encounter different approval processes in different jurisdictions. This often introduces another level of complexity for proponents, financiers and investors to consider, particularly where a project may cross adjoining jurisdictions.

There also is a risk of arbitrary, inconsistent decisions—often as a result of approvers introducing extra requirements above and beyond that which is required under the relevant legislation/regulation. The capability and capacity of staff in the approving body is a critical determinant of the cost and efficiency of the approval process.

A major impediment for proponents considering significant investment commitments relates to the inflexibility in licensing and environmental approvals pertaining to the performance of the early deployed low emissions plant. In addition, the commercial implications of rigidly applying regulations (in particular environmental regulations) act as a disincentive to investment.

These impediments and risks could be mitigated through the use of transitional licensing provisions; for example, in the event that a CCS power plant was required to vent carbon dioxide, it would not be penalised or required to pay for the carbon emissions. This measure would be available to FOAK and Early Deployment plants for a transitional period of between 5 and 10 years (situational dependent), during which time the plant would be bedded down.

The creation of a coordinating team comprised of skilled and experienced officers from the relevant approval agency (on a part time basis; for example, a number of hours a week dedicated to processing the approval) would assist in mitigating a number of the issues that have been identified with the current approval processes. The team would operate under a 'central agency mandate' that would provide it with the capability to coordinate the approval process across multiple agencies. This functionality would be similar to the role of project officers under the powers of a Coordinator General. However, the team would coordinate all major regulatory approvals and not just approvals relating to an environmental impact statement.

Overall, the regulatory approval process could be improved through targeted initiatives such as:

- increasing certainty in the approval process
- reducing approval timeline—this could be achieved through the use of statutory timeframes to make a decision (for example, similar structure to FIRB approval process), with allowance for ministerial discretion to be declared where significant/complex issues arise, resulting in an extension of the approval timeframe
- simplifying (coordinating) the approval process.

Recommendation

17. Options should be developed to improve regulatory certainty and consistency for CCS project approvals:

    - Consideration should include transitional licensing provisions, setting timeframes for granting approvals, specific transitional regulations and legislation, establishing a dedicated cross-agency coordinating team on an as-required basis to manage the regulatory approval process for commercial-scale projects, and resolving conflicts and overlaps between different bodies of regulation and different jurisdictions
    - Implementation of the preferred options should be overseen through the MCMPR.

5.9 SKILLS DEVELOPMENT

The power industry has traditionally been dominated by the power, mechanical and electrical engineering disciplines. As power stations transition to CCS, there will be an increased need for trained staff to operate capture equipment, particularly from the chemical engineering sector.

The role of staff with chemistry training is generally limited to water management in boiler operations and perhaps some environmental oversight. Staffing levels at a standard power station may include 2–4 chemists and perhaps 6–8 sub-professional chemical staff. It is rare for a chemical engineer to be directly employed.

Given the long lead times to develop skilled practitioners in engineering disciplines and the fact that the shortfall of chemical engineers is likely to be replicated on a worldwide basis, there is an urgent need to conduct a skills gap analysis in this area.

In relation to the exploration and development phases for geological storage, the CSTF has undertaken an assessment of the people and skills required. The CSTF found that geoscientists, petroleum engineers and engineers could largely be drawn from the oil and gas sector, but that reservoir engineers, inorganic geochemists, geomechanics/structural geologists and production technologists/ completions engineers are in short supply.

Building capacity to provide a skilled workforce takes many years in the TAFE, technical education and university sectors. The pipeline of trained graduates needs to be planned and mapped to identify gaps. The tertiary education and training sector will need to be engaged with a view to building up capacity in the specific areas identified, and also in the more generic technologically-oriented underpinning disciplines—such as engineering, maths, computing/IT, physics, materials, and chemistry. In many parts of Australia, these critical skills have been depleted or have naturally run down, and planning will be required to build capacity.

On 1 September 2009, the Prime Minister announced the establishment of a National Resource Sector Employment Taskforce to help ensure the availability of the skilled workers required to build and operate major resource sector projects over the next decade. The Taskforce will include representation from state and territory governments, the resource sector, Skills Australia, universities, and the vocational education and group training sectors. The Australian Government will also appoint a Major Project Employment Coordinator to work with the Gorgon joint venture partners and the Western Australian Government.

Recommendation

18. The Council, in association with relevant professional institutes, should develop a skills gap analysis to assess the requirements for skilled personnel to support the rollout of CCS technology over the next 20 years. This could potentially link with the recently announced National Resource Sector Employment Taskforce.

6 IMPLEMENTATION AND REPORTING

Under its Terms of Reference, key activities for the Council are to:

- ensure that low emissions technologies for coal are demonstrated at a commercial-scale from 2015 and are available for commercial deployment by 2020
- advise the Minister on the development and implementation of the NLEC strategy
- develop a national program for low emissions coal research and development (Research Program) and oversee the implementation and operation of the Research Program.

IMPLEMENTATION OF THE STRATEGY

The Council will monitor progress with implementing the NLEC strategy, including developments in:

- establishing a national portfolio of pilot, medium-scale and industrial-scale demonstration projects
- the research program, including assessing that it is supporting the needs of CCS demonstration projects
- the Carbon Mapping and Infrastructure Plan
- the wider energy and greenhouse policy framework, including the EWP and CPRS
- international CCS policies and initiatives.

Anticipated key dates that will need to be considered in implementing the strategy include:

- September 2009 – final results from Global CCS Institute baseline study
- September/October 2009 – public release of NLEC Strategy (tbc)
- Fourth quarter 2009 – Government to announce short list of projects under CCS Flagships Program
- Late 2009 – release of Energy Green Paper (tbc)
- First quarter 2010 – CSTF concludes its work
- First quarter 2010 – Release of Energy White Paper (tbc)
- First quarter 2010 – Government response to NLEC strategy (tbc)
- August 2010 – target date for Government to announce CCS Flagship projects.

Following the above, the Council will consider an appropriate implementation schedule and further prioritise key actions.

REPORTING

The Council will report annually to the Minister for Resources and Energy and other stakeholder groups represented on the Council on issues associated with the implementation of the NLEC strategy, including issues affecting the development and deployment of low emissions technologies that stakeholders may need to address.

The report to the Minister will include consideration of:

- the effectiveness of the NLEC strategy
- the appropriateness (currency) of the NLEC strategy
- whether current project portfolios and research and development efforts are delivering required results
- the identification of any gaps in the strategic framework
- a review of broader policy frameworks and international linkages
- recommendations for adjustments where necessary.

GLOSSARY

ABARE	Australian Bureau of Agricultural and Resource Economics
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Markets Operator
ANLEC R&D	Australian National Low Emissions Coal Research and Development Ltd
CCS	Carbon Dioxide Capture and Storage
CGI	Carbon GeoStorage Initiative
CO_2	Carbon Dioxide
CO2CRC	Cooperative Research Centre for Greenhouse Gas Technologies
CPRS	Carbon Pollution Reduction Scheme
CSLF	Carbon Sequestration Leadership Forum
CSM	Coal Seam Methane
CSTF	Carbon Storage Taskforce
EOR	Enhanced Oil Recovery
EWP	Energy White Paper
FEED	Front End Engineering Design
FID	Final Investment Decision
FOAK	First-of-a-Kind
Global CCS Institute	Global Carbon Capture and Storage Institute
GHG	Greenhouse Gas
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IPCC	Inter-governmental Panel on Climate Change
LCOE	Levelised Cost of Electricity
MCMPR	Ministerial Council on Mineral and Petroleum Resources
MEF	Major Economies Forum
Mt	Megatonne; 1 million tonnes
Mtpa	Megatonnes per annum (year)
MW	Megawatt; 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.
NEM	The National Electricity Market covering Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia and Tasmania.
NGO	Non-Government Organisation

NLEC Council	National Low Emissions Coal Council
NLECI	National Low Emissions Coal Initiative
NOAK	Nth-of-a-Kind. That is, a number of plants have been built and operated subsequent to First of a Kind plants.
PCC	Post–combustion capture
PDCG	Petroleum Data Consultative Group
RET	Renewable Energy Target
SWIS	South West Interconnected System electricity market covering the south-west of Western Australia
UPGS	Upstream Petroleum and Geothermal Subcommittee

ATTACHMENT A – COUNCIL'S TERMS OF REFERENCE

The National Low Emissions Coal Council (the Council) will bring together key stakeholders to develop and implement a national low emissions coal strategy (the strategy) that is aimed at ensuring the coal sector makes a major contribution to greenhouse abatement whilst enhancing coal's contribution to energy security and economic well being. The national strategy will cover the research and development, accelerated demonstration and early commercial deployment of low emissions coal technologies, including carbon capture and storage.

The Council will be made up of high level representatives appointed by the Minister for Resources and Energy, based on nominations from key stakeholder groups representing the Australian Government, coal producing states, coal and power producers, and the research community.

The Council will advise the Minister for Resources and Energy and other key stakeholder groups represented on the Council on the development and implementation of the national low emissions coal strategy. The Council will represent the interests and the commitment of its stakeholder groups in developing and implementing the strategy.

The strategy developed by the Council will:

- aim to ensure low emissions technologies for coal, including carbon capture and storage are demonstrated at a commercial-scale from 2015 and are available for commercial deployment by 2020
- aim to ensure these technologies are deployed as they become commercially available
- identify research priorities to support this strategy and develop a national research program
- identify technological priorities and gaps in the development and demonstration of these technologies that need to be addressed as part of the strategy
- provide input into the development of and take account of the National Carbon Mapping and Infrastructure Plan to ensure the availability of commercial carbon storage sites by 2011
- take account of wider energy and greenhouse policies and initiatives and domestic GHG abatement measures, such as the proposed Energy White Paper, the Carbon Pollution Reduction Scheme, the Global CCS Initiative, renewable energy targets and national GHG reduction targets, and provide advice on policy mechanisms needed to support the deployment of low emissions coal technologies. It will also take account of international abatement policies and measures
- provide for regular reports (at least annually) to the Minister for Resources and Energy and other stakeholder groups represented on the Council on issues associated with the implementation of the strategy, including issues affecting the development and deployment of low emissions technologies that stakeholders may need to address.

To address research priorities identified in the strategy, the Council will develop a national program for low emissions coal research and development (the Research Program) and oversee the implementation and operation of the Research Program. In doing this, the Council will:

- identify research nodes based on existing research centres or support the development of new centres to undertake programs of work under the Research Program
- recruit a Research Coordinator to report to the Council and be responsible for managing and coordinating the implementation of the Research Program
- create a National Low Emissions Coal Research Centre as a small separate agency to support the work of the Research Coordinator and to administer the receipt of research funds by contributors and the allocation of these funds to research nodes and approved research activities
- secure financial resources needed to implement this program and provide parameters that the Research Coordinator will follow in allocating funds to research nodes, approved research activities and the costs associated with administering the Research Program including an annual budget for the Research Centre

- monitor and report to the Minister for Resources and Energy and stakeholder groups represented on the Council on the implementation and outcomes of the Research Program
- review research priorities and the implementation of the Research Program on an ongoing basis to ensure full consideration is given to developments impacting on technological requirements and breakthrough technologies.

The Council may draw on its stakeholders to develop expert panels that the Council and the Research Coordinator can use to obtain guidance and advice on the development and implementation of the Research Program.

An important priority to be addressed by the Research Program is to support existing and prospective demonstration projects; innovation and the identification of prospective new low emissions coal technologies; and the widespread deployment of low emissions coal technologies through the contribution that the Research Program makes to the ongoing development of expertise and skills.

The Research Program will need to be endorsed by the Minister for Resources and Energy and other stakeholder groups represented on the Council.

The Council's report to the Minister for Resources and Energy identifying technological priorities and demonstration gaps will be used by the Australian Government to develop selection criteria for demonstration projects to be supported under the National Low Emissions Coal Initiative. As such the Council's report on technological priorities will need to be coordinated with and consider support for activities of the Queensland Clean Coal Council, the New South Wales Clean Coal Council and Victorian brown coal initiatives.

The Council will also identify and promote opportunities for international collaboration on research, development and demonstration of low emissions coal technologies.

ATTACHMENT B – COUNCIL MEMBERS (JULY 2009)

Chair	**Mr Dick Wells** **Secretariat support** Department of Resources, Energy and Tourism

Stakeholder Group	Representative
Queensland Government	Mr Dan Hunt Director General, Qld Department of Mines and Energy
New South Wales Government	Mr Brad Mullard Executive Director NSW Department of Primary Industries
Victorian Government	Dr Richard Aldous Acting Deputy Secretary Victorian Department of Primary Industries
Western Australian Government	Mr Dominique Van Gent Manager, Regional Programs WA Department of Mines and Petroleum
Coal Producers	Mr Peter Freyberg Chief Executive, Xstrata Coal Australia Mr Bill Champion Managing Director, Rio Tinto Coal Australia
COAL21 Fund	Mr Ross Willims Chair, Australian Coal Association Low Emissions Technologies Ltd (ACALET)
Power Generators	Mr Ian Nethercote Chief Executive, Loy Yang Power Mr David Brown Chief Executive, CS Energy
Researcher	Dr Beverley Ronalds Group Executive, Energy Chief, Petroleum Resources
Universities Low Emission Coal Consortium (ULECC)	Professor Les Field Deputy Vice-Chancellor (Research) University of New South Wales
Australian Coal Association	Mr Ralph Hillman Executive Director, ACA
Australian Government	Mr John Hartwell Head, Resources Division Department of Resources, Energy and Tourism

ATTACHMENT C – RD&D ACTIVITIES IN QUEENSLAND, NEW SOUTH WALES, VICTORIA AND WESTERN AUSTRALIA

QUEENSLAND

The Queensland Government enacted the *Queensland Clean Coal Technology Special Agreement Act 2007* (the Act) in June 2007. The Act established the Clean Coal Council, which comprises representatives from Government and the coal industry, to advise the Premier on priorities for funding from the $900 million government/industry clean coal commitment and other issues to achieve the objectives of accelerating the development and deployment of clean coal technologies. The $900 million comprises a $300 million commitment by the Queensland Government and the black coal mining industry's voluntary fund of $600 million over the next 10 years through the Coal21 Fund.

Queensland hosts a series of low emissions coal technology development and demonstration projects:

- ZeroGen Pty Ltd (ZeroGen) is currently developing a two-stage IGCC with carbon capture and storage project, with Stage One involving an 80 Megawatt (MW) net demonstration project, and Stage Two involving a commercial-scale project of approximately 300 MW net capacity. ZeroGen is currently considering a reconfiguration of the facility into a single-stage 530 MW commercial-scale demonstration project.
- The Callide Oxyfuel Project involves the addition of oxy-firing technology to an existing 30 MW unit, capture and liquefaction of up to 75 tonnes of CO_2 per day and transport and geological storage of approximately 50,000 tonnes of CO_2 over a 3 to 4 year period.
- The CSIRO recently entered into a collaboration agreement with Tarong Energy to host a Post Combustion Capture (PCC) pilot plant based on amine technology at the Tarong Energy power station.
- The Queensland Gasification Consortium involving GE Energy (GE) and Stanwell Corporation Limited (Stanwell) is developing a proposal for the construction of a commercial-scale integrated gasification combined cycle (IGCC) plant of 700 to 750 MW capacity near Wandoan, in the Surat basin, which is located about 400 km (by road) northwest of Brisbane. The proposal aims to capture up to 90 per cent of its CO_2 emissions for storage in depleting oil and gas reservoirs. The Consortium proposes this project could be operational by 2015. The Consortium has also established an alliance with Xstrata Coal to secure supplies of coal from Xstrata's proposed Wandoan Coal Project.

Clean coal R&D activities in Queensland are currently undertaken by CSIRO at the Queensland Centre of Advanced Technology and the University of Queensland (UQ) through the Centre for Coal Energy Technologies. CSIRO and UQ research includes the coal gasification research commenced by the Centre for Low Emission Technology (cLET) that closed on 31 July 2009 and by the Cooperative Research Centre for Coal in Sustainable Development (CCSD). The Queensland Government is exploring the scope for a National Low Emissions Coal Gasification Research Program that would include the current research and the Australian Government commitment of $50 million towards a new research gasifier in Queensland.

The Queensland Government recently announced commencement of Stage 1 of a Carbon Geostorage Initiative (CGI) to provide a state-wide assessment of prospective geological sites as potential storage for carbon dioxide. The CGI is a two-stage program aimed at collecting pre-competitive geoscience data comprising Basinal Assessment of Queensland (Stage 1) and evaluation of selected basins or portions of basins to identify suitable sites and collection of new data (Stage 2).

The Queensland Government has passed new Carbon Capture and Storage legislation.

NEW SOUTH WALES

The NSW Government is active in reducing CO_2 emissions through a number of projects and the establishment of the NSW Clean Coal Council and Clean Coal Fund.

The first project is a joint initiative by Delta Electricity and the CSIRO. This post-combustion capture pilot facility is currently being commissioned and will trial capture technology at the Munmorah Power Station on the State's Central Coast. A number of experimental trials are being undertaken to determine the potential to adapt the technology to NSW coal and power station conditions and capturing up to 5,000 tonnes of CO_2 a year.

Drilling is complete on the first hole at Munmorah Power Station. Sealing of the borehole and rehabilitation work has commenced. A detailed analysis of the core is underway to determine the site's geosequestration potential. Drilling of a second hole near Vales Point power station to determine the reservoir potential of that area commenced in July 2009; drilling will continue for a short period prior to core analysis commencing.

In addition, the Department of Industry and Investment is undertaking a regional stratigraphic drilling program aimed at identifying high potential reservoirs for long-term CO_2 storage.

It is anticipated that these projects will provide the foundation for a large-scale $200 million post-combustion capture and storage demonstration project in NSW. The project should be operational by 2014, capturing more than 100,000 tonnes of CO_2 each year and pumping it into deep underground rock formations for permanent disposal. Funding for this project will be jointly shared by the NSW Government, the Australian Coal Association Low Emissions Technologies and the Australian Government, with the NSW portion announced as part of the recent NSW budget. NSW has committed $16.5 million for the 2009/10 budget year out of a total $100 million over 4 years.

The NSW Government is currently finalising a White Paper on carbon capture and storage for public consultation prior to drafting legislation.

VICTORIA

The Victorian Government announced the following brown coal related projects as part of its Energy Technology Innovation Strategy:

- $110 million fund to establish new large-scale, pre-commercial Carbon Capture Storage (CCS) demonstration projects, as part of $127.4 million to secure Victoria's clean coal future
- $50 million for a 400 MW $750 million power generation plant that will demonstrate a Victorian owned and developed 'integrated drying and gasification combined cycle' (IDGCC) technology. The Australian Government has also committed up to $100 million to this project
- $30 million for a $369 million coal drying and carbon capture project at Hazelwood Power Station. The Australian Government has also committed up to $50 million to this project
- $12 million R&D grants program; 10 projects funded and currently under way including projects on coal drying, oxyfuel, pre-combustion, boiler optimisation, gasification and post-combustion capture in association with CSIRO's pilot plant at Loy Yang A. All are strongly supported by industry participants
- $6 million has been allocated to a trial of carbon dioxide capture and storage in the Otway basin
- $2.2 million has been allocated to support construction of a pre-commercial plant demonstrating coal drying technology known as Mechanical Thermal Expression (MTE)
- $5.2 million towards investigating carbon storage sites in the Gippsland basin to better understand carbon storage potential through research and modelling of the region's geology.

WESTERN AUSTRALIA

The Gorgon Project in Western Australia involves Chevron (as operator), Shell and Exxon. The separated CO_2 will be injected under Barrow Island to a depth of about 2,500 m, with injection of 3 Mt CO_2 to 4 Mt CO_2 per year beginning in around 2012, and a total of 125 Mt injected over the life of the project. A test well has been drilled and a study of the subsurface is underway.

A regional study on potential CO_2 geological storage in the Collie basin and the Perth basin of Western Australia was completed by CO2CRC in 2007, with important contributions from the Australian School of Petroleum, CSIRO.

Aviva Corporation Ltd is proposing to develop two 200 MW oxyfuel coal-fired base-load power stations in its Coolimba Power project, with subsequent conversion to capture CO_2 for storage expected to begin in 2012.

A recent study by the CO2CRC has identified the Lower Lesueur Measures in the Southern Perth basin, an area south of Lake Clifton, as having the best potential for future carbon dioxide geological storage in south-west Western Australia. The study, commissioned by the State Government's Coal Futures Group as part of its push towards clean coal technology, assessed the potential for storage in the Collie and Perth basins.

This project aims to assess carbon dioxide storage potential of the Calliance and Torosa fields in the Browse basin, Offshore, Western Australia.

ATTACHMENT D – OVERVIEW OF FINANCIAL SUPPORT MODELS[60]

SUPPORT OPTION	ADVANTAGES	DISADVANTAGES
Direct grant funding	Risk can be shared with private proponents, thereby providing an element of self-selection of viable projects. Transparent funding arrangements.	Can be problems with selection bias. Good program design is required.
Debt finance	Limits long-term contribution for the budget.	Would need to be offered on very concessional terms to be effective.
Equity contributions	Risk can be shared with private proponents, contributing to self-selection of viable projects. Limits long- term contribution for the budget.	PPP-type arrangements can be contractually complicated. High administrative and legal costs.
Income contingent loans	Provides income insurance for project proponents. Self-selection of viable projects.	Government holds default risks.
Industry levies	Can have efficiency advantages. Low budget impact.	Can be difficult to determine an appropriate level of the levy and how it should be apportioned across industry/s.
Matched funding	Risk can be shared with private proponents, leading to self-selection of viable projects.	Level of capital sharing may be insufficient, especially for larger or risky projects.
Operating subsidies	Can provide effective risk-sharing until project reaches a commercially viable scale.	Can lack transparency. Possible market distortions. May be difficult to withdraw support over longer term.
Regulatory support	Low budget impact.	May be difficult to design and ensure that support is withdrawn over longer term.
Taxation concessions	Little or no upfront outlays by government. Can promote operational flexibility.	Lacks transparency. Can have serious distortions for the operation of the tax system.

60 Access 2009: Access Economics, *Scoping impediments and policy initiatives for early deployment of carbon capture and storage technologies*; report prepared for the National Low Emissions Coal Council; Department of Resources, Energy and Tourism; Canberra, 2009