Evaluation of the Coal Innovation NSW Program

February 2016

This publication is part of a series summarising program evaluations to enhance the accountability and transparency of NSW Department of Industry activities. The completed program evaluation template is attached.

Ex-ante versus ex-post evaluation

The NSW Department of Industry Program Evaluation Framework is designed to evaluate new or ongoing programs ex-ante (i.e. into the future) by identifying the program objective, mapping how program activities contribute to the attainment of that objective and identifying alternative options for pursuing the objective.

The unanticipated withdrawal in 2014 of Australian Government funding for a NSW Carbon Capture and Storage Demonstration Project has required the Coal Innovation NSW Program to be redesigned. The Minister has approved broad budget allocations and will receive detailed program options as they are developed. Considering the changing nature of the Program, an ex-ante evaluation was considered impractical. Consequently, an evaluation of the performance of the Coal Innovation NSW Program ex-post (i.e. to date) has been undertaken.

The Coal Innovation NSW Program

Coal Innovation NSW (CINSW) is a Ministerial advisory council, established under the Coal Innovation Administration Act 2008 (the Act), which brings together representatives of industry (coal and energy sectors), research institutions and the NSW Government to consider how best to support low emissions coal technologies research, development and demonstration (RD&D) in NSW.

The Act outlines that the significant function of CINSW is to provide advice and make recommendations to the Government concerning the funding of projects that encourage the development of low emissions coal technologies. The Minister, in accordance with the Act, delegates that the Department project manages these programs to encourage commercial deployment outcomes and to communicate to the public the importance of low emissions coal technologies in reducing greenhouse gas emissions.

Since its establishment in 2008, CINSW has made a number of recommendations to the Government. These recommendations have formed the following three main streams of program activity:

1. NSW Carbon Capture and Storage (CCS) Demonstration – to demonstrate the post combustion capture of carbon dioxide (CO₂) at a Delta Electricity power plant, for transport and injection at a suitable NSW site for permanent geological storage;
2. NSW CO₂ Storage Assessment Program– to identify and assess potential NSW sites for CO₂ storage; and
3. Research and Development - to support research in innovation, proof-of-concept, demonstration and commercialisation of low emissions coal technologies.

Objective

The NSW Government recognises the economic benefits that coal provides to NSW, including: investment stability; jobs in regional NSW as well as manufacturing areas of Sydney; a reliable and cost effective source of electricity to NSW households and industries; NSW’s largest export commodity; and paying $1.3 billion a year in mineral royalties.

In the last few years coal fired electricity generation in NSW accounted for 80 to 90 per cent of NSW electricity generation, however this form of generation emits relatively high levels of greenhouse gases. The implementation of low emissions coal technologies with CCS can result in substantially lower greenhouse gas emissions, enabling coal to be a more sustainable fuel source in a likely future carbon-constrained world. Low emissions coal technologies refer to the various approaches used to reduce emissions from coal powered electricity generation, and/or increase the efficiency with which coal is utilised for electricity generation. CCS utilising CO₂ or greenhouse gas geosequestration is a collective
group of technologies and techniques that enable the capture of CO₂ from fuel combustion or industrial processes, for transport via ships, pipelines, or trucks to be permanently stored by injection into deep geological porous rock formations (i.e. underground). However, market barriers and/or insufficient incentives mean that private firms are not investing enough into the research, development and demonstration to make these technologies financially viable.

A future greenhouse gas related policy or price signal that makes existing coal fired electricity generation uncompetitive relative to other forms of electricity generation would result in significant costs to the NSW economy, including shutting down NSW coal fired power stations and coal mines. The adoption of low emissions coal technologies would likely avoid or mitigate some of these costs and the wider impacts on the NSW economy.

Most innovations pass along a chain from research, development and demonstration to commercialisation. For low emissions coal technologies that have not been demonstrated at commercial scale, there is less private investment than is socially optimal. This is due to the positive externalities (spillovers) that come from knowledge generation, especially where businesses are involved in the research and development (R&D), and that R&D spills over cheaply to others or triggers cycles of innovation by the business or their rivals.

The objective of the CINSW Program is, therefore, to encourage the research, development and demonstration of low emissions coal technologies to reduce greenhouse gas emissions cost effectively, and improve the sustainability of the NSW coal-fired electricity generation and coal mining industries. This objective is a direct outcome of goal 22 of the NSW2021 plan (require and support NSW coal mines to reduce dust emissions and invest $100 million in the NSW Government’s Clean Coal Fund for the research, development and demonstration of clean coal technologies). The program’s objective is also consistent with the Department of Industry Corporate Plan 2015-2019 goals to: Support government decision-making for infrastructure, regulation and priorities with information about economic opportunities and challenges; Reach out to Industry, the community and other parts of government, to deepen understanding and strengthen collaboration; and Be a responsive and engaged department driven by a culture of innovation and collaboration.

Projects

CINSW funded projects have targeted research, development and demonstration of technologies that can reduce greenhouse gas emissions at all stages of the coal life cycle, including into CCS. As such, CINSW funded RD&D projects have been targeted in the following areas:

- At the coal extraction point, a project is trialling a prototype plant to mitigate fugitive emissions from underground mines;
- At the coal fired power station where the coal is burned, a project has demonstrated a novel air separation technology for producing oxygen for use in the efficient burning of coal, potentially lowering production costs and energy requirements;
- To demonstrate an alternative form of electricity generation with much higher thermal efficiencies than conventional coal combustion in steam boilers and turbines, a project is developing a prototype direct carbon fuel cell;
- Proving alternative forms of separating the CO₂ from the other emissions of a coal fired power station in order to reduce the energy penalty:
  - a project has successfully demonstrated a novel approach to capturing CO₂ from real flue gas of a power station using an absorbent material for dry CO₂ capture at room temperature and atmospheric pressure in dusty environments; and
  - a project relocated and refurbished the post-combustion capture (PCC) pilot plant from Munmorah to Vales Point power station for use in further trials and campaigns to evaluate a range of innovative technologies utilising real flue gas from coal combustion.
- To investigate the NSW potential for large scale geological CO₂ storage for its power stations emissions, drilling campaigns have been carried out in the Sydney Basin and Darling Basin. Preliminary results from the Darling Basin have been encouraging, with modelling showing the potential to permanently store 50 years of emissions from a single large NSW coal fired power station. However further drilling is required to verify and build upon the results;
- To investigate alternative methods for permanently storing CO₂, a project is trialling a new technology to transform captured CO₂ emissions by the conversion of silica / magnesium based rocks into forms of carbonate rocks for potential use as new green building materials in the construction industry; and
To increase public awareness on the importance of low emissions coal technologies in the energy context, a project used an innovative approach to understand social networks and their potential impacts on developing low emissions projects.

**Evaluation**

This evaluation considers the costs and benefits of the CINSW Program relative to a base case of ‘no program’. The total cost of all completed projects (since 2008) under the program is approximately $34 million (of which CINSW contributed $13.5 million or approximately 40%). From this, CINSW projects have generated significant outcomes for the benefit of NSW, including:

- progressing NSW towards being ‘storage ready’ by the identification of large scale CO₂ geological storage potential in the Darling Basin due to prospective geological conditions that permit CO₂ storage, and existing easements for pipeline infrastructure to emission sources;
- developing a novel chemical looping based air separation process technology that moves industry a step closer to commercial-scale deployment of low emissions electricity generation;
- demonstrating the technological stability of a novel CO₂ capture adsorbent under industrial conditions;
- gaining new intelligence on public engagement with low emissions coal technologies;
- ensuring the continued use of a key post-combustion capture pilot plant for ongoing industry-funded research, demonstration and evaluation of innovative post-combustion CO₂ capture technologies on NSW coals; and
- facilitating PhD and post-doctoral research into low emissions coal technologies and advancing the body of knowledge on low emissions coal technologies.

By leveraging CINSW funds with Commonwealth and industry investment, these outcomes have been achieved at significantly lower cost to the NSW Government than would have otherwise been the case. Relative to the comparable Queensland ZeroGen project and its search for viable CO₂ storage, the CINSW Program represents value for money and is expected to verify the ‘storage readiness’ of NSW at a considerably lower cost, in order to enable a sustainable future for coal fired power generation.

**Cost recovery**

The evaluation assessed the existing program pricing arrangements relative to the cost recovery principles outlined by the Productivity Commission in its 2001 Inquiry Report on Cost Recovery by Government Agencies. The evaluation found that the program primarily produces private benefits to electricity producers, and as such, should continue to be funded via a levy on distribution network service providers (at avoidable cost). This funding was achieved through a four-year levy and is now placed within the Coal Innovation NSW Fund.

**Future Evaluations**

This is the first evaluation of the CINSW Program as part of the regular Departmental cycle of evaluations informed by the NSW Government Evaluation Framework. As such, the evaluation concentrated on the qualitative aspects of a ‘formative’ evaluation (considering problem identification, program logic and cost recovery arrangements). To build the capacity of program management and to monitor program’s performance in the future, it would be useful to be able to identify appropriate performance measures and to conduct a more comprehensive ‘summative’ evaluation when this program is next scheduled for evaluation.

**More information**

Further information on the CINSW Program can be obtained from:

**Resources & Energy NSW**

NSW Department of Industry, Division of Resources & Energy  
Postal address: GPO Box 7060, Sydney NSW 2001  
Phone: 1300 736 122  
Email: rick.fowler@industry.nsw.gov.au  
Attachment: Program Evaluation Template

<table>
<thead>
<tr>
<th>Division:</th>
<th>Resources &amp; Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program (Current):</td>
<td>Coal Innovation NSW</td>
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</table>

### Step 1 - Issue or Challenge and Objectives

a. *Describe the issue or challenge that the program aims to address. That is, why should the department intervene? What would happen in the absence of the program?*

At present over 89%\(^1\) of all electricity produced in NSW is from coal. Coal is also NSW’s largest export commodity, valued at $15 billion.\(^2\) In NSW, the abundance of available and mineable coal, the certainty of a safe energy supply, and the low cost of energy compared to most other countries, all contribute to the State’s productivity, comparative advantage and prosperity. NSW has 15,311 Mt of known recoverable reserves.\(^3\) If mined at current production rates, that is a reserve for approximately 60 years.

However, coal fired power generation produces higher CO\(_2\) emissions than other electricity generation options and accounted for 37% of the State’s total greenhouse gas (GHG) emissions in 2013. Another source of GHG emissions is fugitive emissions from coal mining. This source of emissions is growing with high export demand for NSW black coal, and together with emissions from coal fired power generation, accounted for 47% or nearly half of the State’s total GHG emissions in 2013.

Australia looks to face a carbon constrained future as GHG emissions are likely to be regulated:

- initially with the current Australian Government’s target of reducing emissions by 5% by 2020 on 2000 levels; and then 26 to 28% below 2005 levels by 2030 (Intended Nationally Determined Contributions commitment)

The Paris Agreement, adopted by the Conference of Parties plenary on 12 December 2015, defined the implementation and long term climate goal as holding the increase in the global average temperature to well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. This climate goal can only be achieved through an aggressive expansion of renewable energy generation together with an accelerated scale up of CCS mitigation.

In a carbon constrained future, coal mining and electricity generated from current (high emissions) coal technology would become less financially viable, and lower emissions technology would be needed to generate proportionally more electricity.

Electricity generated from non-fossil fuel low emissions technologies such as solar; require more capacity (more plants) to offset the intermittency, are currently significantly more expensive than electricity generated using current coal technology, and may well be more expensive than electricity generated using low emissions coal technology.

A future GHG emissions related policy or price signal that makes existing coal fired electricity generation uncompetitive, relative to other forms of electricity generation, may lead to the shutting

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\(^1\) NSW Department of Industry, *National Electricity Market Draft Annual Report 2014/15*

\(^2\) NSW Trade and Investment, *New South Wales Coal Industry Profile 2014*, p.1

\(^3\) Ibid p.1
down of NSW power stations and coal mines resulting in significant costs to the NSW economy. Currently, the market forces of a decline in demand without a carbon price are pushing down the cost of wholesale energy, and making older and less efficient generators unviable. Examples of this in the last two years include the coal fired power stations at Wallerawang (1,000 MW) in NSW, and Northern (544 MW) and Playford B (240 MW) in South Australia.

The use of low emissions coal technologies can lower GHG emissions from the mining and combustion of coal. CO₂ emissions can also be captured from fuel combustion or industrial processes, to be transported via pipeline, ship, road or rail, to be injected deep underground and permanently stored in a geological formation. This is a process known as CCS, which according to the International Energy Agency (IEA) can make a significant contribution to reducing CO₂ emissions globally, contributing one-sixth of total global CO₂ emission reductions required in 2050 or making 14% of the cumulative emission reductions to 2050. In a carbon constrained future, the use of low emissions coal technologies would likely avoid or reduce some of the costs of mitigation.

The issue is that not all CCS-related technologies have not been trialled at industrial scale, nor fully integrated with coal fired power generation at industrial scale (capturing > 1 Mt CO₂-equivalent (CO₂-e)per year). Consequently research, development and deployment of low emissions coal technologies and demonstration of CCS projects is pivotal to the continued use of coal for power generation in NSW.

b. **Identify the groups that would be affected by the issue or challenge without departmental involvement (individuals, industry or community).**

- Fossil fuel-fired electricity generators through reduced demand for the electricity they generate over time, potentially resulting in the closure of NSW coal fired power stations.
- Coal miners and gas industry supplying electricity generators through reduced demand for their products over time, potentially resulting in the closure of NSW coal mines.
- Electricity consumers, industry and domestic users through higher prices and energy costs over time.
- Equipment manufacturers and services supplying the coal mining industry and coal fired power stations.
- Regional communities and community groups being supported by the coal mining industry and coal fired power stations.
- Research community, universities and organisations focused on low emissions coal technologies.
- NSW Government through reduced mineral royalty revenue over time as coal mines either close or reduce coal production.

c. **Quantify the impact of the issue in the absence of departmental involvement - the severity of the issue should be demonstrated with quantitative data where possible on the significance and consequences of the issue or challenge in the absence of departmental involvement. If no such 'cost' estimate exists, proxy information can be provided to give an indication of potential 'scale', such as industry value of production.**

As a consequence of future GHG emission regulation, electricity generated from high emissions coal technology will become less financially viable due to the cost imposts of a price on carbon or statutory regulations on emission levels. The may lead to the closure of some or all coal fired power stations. Electricity will then need to be generated from more expensive low emissions technologies in order to meet the shortfall in electricity demand. Whilst NSW is part of the National Electricity Market, it should be noted that the capacity of the interconnectors between

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4 IEA, Energy Technology Perspectives 2014, Paris, OECD
States would limit any sizeable import of electricity to make up the shortfall of electricity from coal fired generation.

Approximately 70,000 Gigawatt hours (GWh) of electricity is generated in NSW each year, with over 89% of this coming from coal-fired electricity generators. Assuming this level of generation is constant and meets the required level of demand, the replacement cost of coal fired power generation could be approximated using the proxy of levelised cost of electricity (LCOE).

LCOE is the present value of costs per unit of electricity generated over the life of a particular plant. It may be interpreted as the price of output the plant must receive over its lifetime to break even, using a common unit expressed in $/MWh so as to be comparable to other plants that have different lifetimes and cost profiles. Costs include fixed capital costs as well as ongoing fuel and maintenance, in addition to a commercial rate of return paid to owners and financiers of the plant. Other parameters in the calculation of the LCOE include: how many hours a year the generator can run; fuel costs and fuel efficiency; plant life and construction time.

Table 1 below has been developed from the latest available datasets for LCOE. It extrapolates the replacement cost for the NSW coal fired power generation fleet, based on an assumption of 62 GWh per year (89% of total generation coming from coal), with alternate technologies. As a comparison, three sets of figures are provided in US and AUD to reflect the source of the reports and maintain consistency in interpretation.

Table 1: Estimated replacement cost of alternative technologies

<table>
<thead>
<tr>
<th>Total Electricity supply to NSW is approx. 70,000,000 MWh/y, ~89% (62,300,000 MWh/y) of</th>
<th>LCOE data cost range</th>
<th>Replacement cost</th>
<th>LCOE data cost range</th>
<th>Replacement cost</th>
<th>LCOE data cost range</th>
<th>Replacement cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Onshore</td>
<td>66-94</td>
<td>4.1 - 5.9</td>
<td>103-105</td>
<td>6.4-6.5</td>
<td>55-120</td>
<td>3.4 - 7.5</td>
</tr>
<tr>
<td>Black coal</td>
<td>80</td>
<td>5</td>
<td>80</td>
<td>5</td>
<td>60-108</td>
<td>3.7 - 6.7</td>
</tr>
<tr>
<td>CCS (gas)</td>
<td>83-93</td>
<td>5.1 - 5.8</td>
<td>105</td>
<td>12.2</td>
<td>110-210*</td>
<td>6.9 - 13.1</td>
</tr>
<tr>
<td>Nuclear</td>
<td>86-102</td>
<td>5.4 - 6.4</td>
<td>180</td>
<td>11.2</td>
<td>85-175</td>
<td>5.3 - 10.9</td>
</tr>
<tr>
<td>CCS (coal)</td>
<td>115-160</td>
<td>7.2 - 10</td>
<td>169</td>
<td>10.5</td>
<td>110-195*</td>
<td>6.9 - 12.1</td>
</tr>
<tr>
<td>Wind Offshore</td>
<td>158-224</td>
<td>9.8 - 14</td>
<td>n/a</td>
<td>n/a</td>
<td>120-240</td>
<td>7.5 - 15</td>
</tr>
<tr>
<td>Solar PV</td>
<td>162-264</td>
<td>10.1 - 16.5</td>
<td>134-150</td>
<td>8.4-9.3</td>
<td>65-205*</td>
<td>4 - 12.8</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>168-228</td>
<td>10.5 - 14.2</td>
<td>246</td>
<td>15.3</td>
<td>75-260**</td>
<td>4.7 - 16.2</td>
</tr>
</tbody>
</table>

Notes:
- Technological development over the next decade is forecast to reduce the lower-bound cost, thus the difference between GCCSII 2014 and AETA 2025 cost ranges. The CO2CRC costs represent a plant built overnight and its operation in the first half of 2015.
- * refers to CCS retrofit to existing subcritical Pulverised Coal boiler of existing NSW fleet
- ** refers to Solar Thermal with central receiver and no storage

Source:

As illustrated in Table 1, the cost of replacing coal with any alternate form of energy will be more in all cases. For example, the replacement cost with solar photovoltaic systems if built in 2015 to replace coal fired power generation is AUD $8.4-9.3 billion, however in reality the constraints of this would be intermittency, available storage for 24hr power supply, transmission upgrade costs, and land siting for solar fields, which would likely increase this cost.

A transition to low emissions technologies from current high emissions coal fired electricity is inevitable. This transition will need to be managed as:
- coal production in NSW contributes over $16.7 billion (2013/14) to NSW Gross State Product;
- approximately 90% of total NSW coal production from the 60 or so coal mines is exported and generates an estimated $15 billion in revenue (greater than the combined value of NSW tourism and education exports); and
Without departmental involvement and the work of Coal Innovation NSW in accelerating low emissions coal technologies RD&D and CCS and bringing down the costs, the switch to most alternate forms energy production would significantly and negatively impact on fossil fuel-fired electricity generators (including gas generators), coal miners and the gas industry supplying electricity generators, electricity consumers, and the NSW Government.

d. Describe who or what created the issue or challenge. Examples include specific industry participants (such as producers or consumers) and environmental factors (such as the effect of climate change).

The Intergovernmental Panel on Climate Change (IPCC) Climate Change 2014 Synthesis Report Basis (Summary for Policy Makers) makes the following statements:

- “Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.” SPM 1
- “Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.” SPM 1.1
- “Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century.” SPM 1.
- Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks. SPM 2
- There are multiple mitigation pathways that are likely to limit warming to below 2°C relative to pre-industrial levels. These pathways would require substantial emissions reductions over the next few decades and near zero emissions of CO₂ and other long-lived greenhouse gases by the end of the century. Implementing such reductions poses substantial technological, economic, social and institutional challenges, which increase with delays in additional mitigation and if key technologies are not available. Limiting warming to lower or higher levels involves similar challenges but on different timescales. SPM 3.4

In 2013, Australia was responsible for about 1.1% of the world’s GHG emissions; however, Australia had the highest per capita emissions of all developed countries, around 16.9 tonnes of CO₂-e per person. Our per person emissions are very high because: we use coal to produce most of our electricity; coal is our second biggest export commodity; we are a geographically dispersed country and rely on GHG emitting modes of transport; and our other major overseas export goods include agricultural products, meaning we have large numbers of methane-emitting sheep and cattle to supply Australian animal products to the rest of the world.

In NSW, the energy sector, which includes stationary energy, transport, and fugitive emissions from fuels, makes the largest contribution to NSW GHG emissions, accounting for a combined 79% or (111.7 Mt) of NSW emissions in 2013 (see Figure 1 below).

- Coal-fired electricity generation accounted for 47% (52.3 Mt) of the emissions from the...
energy sector." In NSW about 89% of electricity needs are currently met from coal fired power stations. NSW coal fired power stations are located in the Sydney Basin close to significant coal resources in the Hunter, Central Coast and Western coalfield.

- Transport and agriculture accounted for 19% (26.9 Mt) and 13% (18.8 Mt) respectively, of the total 2013 emissions from NSW inventory total (including LULUCF).\(^5\)

**Figure 1: NSW GHG emissions per sector (% of total 141.8 MtCO\(_2\)-e)**

Table 2 highlights the major sources of emissions in NSW in 2013 and their contribution to national emissions.

**Table 2: Major sources of emissions in NSW 2013**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Major contributor</th>
<th>Contribution to 2013 national emissions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary energy</td>
<td>Coal-fired electricity generation</td>
<td>25</td>
</tr>
<tr>
<td>Transport</td>
<td>Road transport</td>
<td>29</td>
</tr>
<tr>
<td>Fugitive</td>
<td>Coal mine methane</td>
<td>39.2</td>
</tr>
<tr>
<td>Industrial processes</td>
<td>Iron and steel production</td>
<td>36.3</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Cattle and sheep enteric fermentation</td>
<td>22.1</td>
</tr>
<tr>
<td>Land use / Land use change and Forestry</td>
<td>Land clearing</td>
<td>-19.8</td>
</tr>
<tr>
<td>Waste</td>
<td>Landfill methane</td>
<td>32.6</td>
</tr>
</tbody>
</table>

Data Source: State and Territory Greenhouse Inventories 2013, Australia’s National Greenhouse Accounts, DOE, Canberra


\(^6\) Department of the Environment, State and Territory Inventories 2013, Commonwealth of Australia, Canberra, May 2015, p.19
Emission reduction policies and strategies within Australia and NSW will significantly impact electricity generation using current high emissions coal technologies due to their relatively high levels of GHG emitted.

The Commonwealth Government proposes to achieve its international commitment for emissions reductions of 5% by 2020 on 2000 levels through the Direct Action Plan. The $2.55 billion Emissions Reduction Fund (ERF) is the centrepiece of the Australian Government's Direct Action Plan. The ERF will operate alongside existing programs, such as the Renewable Energy Target and energy efficiency standards on appliances, equipment and buildings.

Commonwealth funding of CCS programs continues through the CCS Flagship Program and National Low Emissions Coal Initiative (NLECI) Fund, where there is no doubling up under ERF.

The Australian Government has announced its Intended Nationally Determined Contributions commitment of 26 to 28% below 2005 levels by 2030. The potential for higher targets exists if the world agrees to ambitious targets and/or potential mandatory future actions.

<table>
<thead>
<tr>
<th>Other Programs</th>
<th>Able to be altered?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCS Flagships program ($1.18 billion)</strong></td>
<td><strong>No</strong>, the shortlist of projects has been determined and process is underway in assessing shortlisted projects to final investment decision.</td>
</tr>
<tr>
<td>The CCS Flagships Program is an Australian Government program to fund a portfolio of between two and four large-scale integrated CCS projects across a range of capture technologies under consideration in Australia. Project funding under the program was subject to a competitive process, in consultation with state governments and industry bodies. The program is expected to leverage contributory funding from State Governments and industry in order to limit Australian Government funding to one third of total funding required for the non-commercial aspects of the selected CCS Flagships projects. The program includes funding of $100 million from the Education Investment Fund (EIF) to support research infrastructure partnerships between the Flagship’s projects and eligible research institutions for collaborative research into CCS.</td>
<td></td>
</tr>
<tr>
<td><strong>NLECI ($265 million)</strong></td>
<td><strong>Yes</strong>, there is potential to request recently withdrawn funds to be reconsidered.</td>
</tr>
<tr>
<td>The National Low Emissions Coal Initiative (NLECI) Fund was established in 2008 with a $370 million budget over eight years until 2015 to accelerate the development and deployment of technologies to reduce emissions from coal use. The focus of NLECI is research, demonstration and deployment of low-emission coal technologies involving CCS. After successive budget cuts the remaining NLECI budget is $265 million. Implementation of the NLECI is supported by a variety of stakeholders, including NSW. The Commonwealth Government decided to reduce funding for NLECI in the 2014-15 Budget, withdrawing $17.145 million previously allocated to NSW.</td>
<td></td>
</tr>
<tr>
<td><strong>Coal Mining Abatement Technology Support Package (CMATSP) – approximately $35 million (2012/13 to 2016/17)</strong></td>
<td><strong>No</strong>, CMATSP is only assessing projects focussed on reducing fugitive emissions from the mining of coal. This selection process is now complete with projects selected and Funding</td>
</tr>
</tbody>
</table>
### Evaluation of the Coal Innovation NSW Program

1) **RD&D** – Support the research, development and field trials of methane abatement and related technologies
2) **Mine Safety** – Work on safety and regulatory issues associated with the introduction of coal sector abatement technologies; and
3) **Mine Abatement Plans** – Assistance for small and medium coal sector participants to prepare abatement plans.

Funding is on a 1:1 basis (Federal Government: Industry + State Government)

<table>
<thead>
<tr>
<th>Carbon Capture and Storage Research and Development Fund $25 million, Expression of Interests closed 16 November 2015.</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Australian Government fund is to provide up to $25 million for CCS research, development and demonstration activities. Grants are available to industry and research organisations and will provide support for research, development and demonstration, particularly for the transport and storage of CO₂.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COAL21 Fund</th>
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<tbody>
<tr>
<td>COAL21 is a voluntary fund dedicated to the demonstration and deployment of low emissions coal technologies such as CCS. So far, the COAL21 Fund has committed more than $300 million to demonstration projects.7 Funding is focussed on large (commercial scale) demonstration of integrated CCS.</td>
</tr>
</tbody>
</table>

f. **Identify who might benefit if action [such as the program being evaluated] is taken by the department.**

Who are the primary beneficiaries?
- Coal-fired electricity generators would benefit from the development of technologies that would enable them to reduce GHG emissions while still remaining financially viable. AGL recently announced its new GHG policy and its intended shift away from coal fired power generation unless it utilises CCS technologies to reduce GHG emissions. Origin has also stated it will close coal fired generation at life expectancy dates if there are no technology improvements, specifically mentioning CCS.
- Coal miners supplying electricity generators would benefit from the continued demand for coal by electricity generators in NSW.
- Electricity consumers would benefit from cheaper electricity when it was generated from financially viable low emissions coal technology relative to alternative (i.e. non-coal) technologies.
- Equipment manufacturers and services supplying the coal mining industry and coal fired power stations would benefit from continued local demand for their goods and services.
- Regional communities and local businesses supported by employment in coal mining and/or coal fired power generation would benefit from the continued availability of employment.
- Regional communities if new industries are established around low emission coal technologies (in the future), and community groups being supported by the coal mining and coal fired power station.
- The NSW Government would benefit from continued mineral royalties from coal as electricity generators would continue to use coal.

Who else might benefit?
- Researchers involved in the research and development of low emissions coal technology and the overall increase in NSW skill base within these technologies.
- Other jurisdictions (within Australia and overseas) who may benefit from the wider development of financially viable low emissions coal technologies.

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g. **Statement of Objectives:** Determine whether there might be a role for the department in addressing the perceived issue or challenge – i.e. what high-level objectives might a potential program achieve?

**Objective:** To encourage the research, development and demonstration of low emissions coal technologies to reduce greenhouse gas emissions cost effectively, and improve the sustainability of the NSW coal-fired electricity generation and coal mining industries.

**Policy Alignment:**
- a NSW 2021 goal⁸.
  A Priority Action in NSW2021 under Goal 22 to: *require and support NSW coal mines to reduce dust emissions and invest $100 million in the NSW Government’s Clean Coal Fund for the research, development and demonstration of clean coal technologies.*
- a NSW Department of Industry Strategic Plan (2015 – 2019) outcome:
  The Division of Resources and Energy outcomes of:
  - economic growth by ensuring sustainable use of and access to natural resources;
  - ensuring energy security for NSW through better balancing of the energy mix; and
  - support and promote new exploration and innovative approaches to the exploration and production of resources and energy in NSW.

**Market Failure:**
Most innovations pass along the 'innovation chain' from concept to research and development (R&D) to commercialisation. There is less market pull for low emissions coal technologies that have not been demonstrated at commercial scale in electricity generation and/or the industrial sector. This demand is limited as:
- the positive externality of reducing emissions is not fully reflected in the price that consumers pay for energy;
- the positive externalities (spillovers) from research and development cannot be captured (solely) by the innovator and cannot be realised without support; and
- there are technical risks associated with moving to ‘proof of concept’ and demonstration.

The inadequate levels of investment by private firms in low emission coal technologies indicate that there are market barriers and risks that arise from being an ‘early mover’ in researching, demonstrating and commercialising low emission coal technologies. Industry has also shown a predisposition for co-investment of its COAL21 Fund with both State and Commonwealth Governments to spread this level of risk.

To address the lack of incentives to conduct RD&D in low emissions coal technologies, government can play a role in removing barriers in the market that is not currently delivering outcomes that are socially optimal. There is a case for public support for RD&D where knowledge generated spills over cheaply to others or triggers a cycle of innovation by rivals.⁹ Government can play a major role in the early stages of the technology innovation life cycle in providing support in research and development for a new idea through preliminary funding.

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⁸ NSW State Priorities (NSW Making it Happen) have since replaced NSW 2021
Ex-ante versus ex-post evaluation

The NSW Department of Industry Program Evaluation Framework is designed to evaluate new or ongoing programs ex-ante (i.e. into the future) by identifying the program objective, mapping how program activities contribute to the attainment of that objective and identifying alternative options for pursuing the objective.

The withdrawal in mid-2014 of Australian Government funding for a NSW Carbon Capture and Storage Demonstration Project has required the CINSW Program to be redesigned, with program options currently the subject of interdepartmental discussion. Considering the changing nature of the Program, an ex-ante evaluation was considered impractical. Consequently, an evaluation of the performance of the Program ex-post (i.e. to date) has been undertaken.

While Step 1 (issue or challenge identification and program objectives) of this evaluation is consistent with the NSW Department of Industry Program Evaluation Framework, Step 2 (options identification and program design) only includes the option of the Coal Innovation NSW Program as it existed prior to being redesigned. Some aspects of program design, including governance, consultation and key performance measures are not included due to the program redesign.

Step 3 (option assessment) assesses the Program ex-post relative to the base case of no program. No comparative assessment of alternative options was included due to the program redesign. This ‘outcome evaluation’ remains consistent with the NSW Government Evaluation Framework and reports on the outcomes attributable to the program.
Step 2 – Program Design

Identify all potential options for achieving the objective, including those that least impede business activity.

<table>
<thead>
<tr>
<th>Option 1</th>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Innovation NSW Program</td>
<td>Coal Innovation NSW (CINSW) is a Ministerial Advisory Council that brings together representatives of industry (coal and energy sectors), research institutions and the NSW Government to consider how best to support low emissions coal technologies research and development in NSW. A significant function of CINSW is to provide advice and make recommendations to the Government concerning the funding of projects under Coal Innovation NSW that encourage the development of low emissions coal technologies. The purpose of CINSW is to drive RD&amp;D in low emissions coal technologies to enable these technologies to be commercially viable and cost effective for early deployment. As these technologies have the potential to significantly reduce GHG emissions, their broad-based uptake can greatly improve the sustainability of coal fired electricity generation and the coal mining industry in a carbon constrained future. CINSW has a proven track record of leveraging investment for R&amp;D from the Commonwealth government and industry in joint initiatives. CINSW funds projects through the technological and commercialisation ‘valley of death’ by shortening the time taken for technological development and reducing resource requirements for market penetration. CINSW grants attempt to reshape the ‘valley of death’ by making it narrower, allowing successful technologies to progress to the market sooner (see Figure 2). This, in effect, will support and drive innovation opportunities for low emissions coal technology research projects in order to help them become commercialised sooner and better compete with incumbent energy sources.</td>
</tr>
</tbody>
</table>

Figure 2: Bridging the clean energy valleys of death (Jenkins and Mansur, 2011)

CINSW brings together research bodies and industrial stakeholders, aligning them to many common goals in order to promote collaboration, which is crucial for driving innovation and reducing the severity of the valley of death.

The overriding objective of CINSW is to maintain the future viability and international competitiveness of the NSW coal industry in a carbon constrained...
future by supporting industry efforts to develop and demonstrate technologies that will provide future solutions to reduce GHG emissions from coal.

Since first established in 2008, Coal Innovation NSW has made a number of recommendations to the Government. These recommendations have formed the following three streams of program activity:

1. NSW Carbon Capture and Storage (CCS) Demonstration – to demonstrate the whole CCS chain from a power station, transport and geological storage;
2. NSW CO₂ Storage Assessment – to determine the availability of large scale geological CO₂ storage in NSW; and
3. Research, Development and Demonstration – targeting all aspects of the coal life cycle and coal-related GHG emissions.

Changing nature of the program:

Australian Government funding of the CCS Flagships and the National Low Emissions Coal Initiative (NLECI) was reduced in the 2014-15 Federal Budget (May 2014). Funding ceased for committed but non-contracted projects, and also for some existing contracted projects.

The lead project of the CINSW Program was to be the **NSW CCS Demonstration**. This project had the objective of demonstrating the whole CCS value chain by integrating post-combustion capture, transport and permanent geological storage of CO₂ from a black coal fired power station.

Stage 1 of this project (pre-feasibility, planning and approvals) was contracted and jointly funded by the Australian Government, Australian Coal Association Low Emission Technology Ltd and the Coal Innovation NSW Fund. Work on this project had commenced, however, Australian Government funding for this project was withdrawn in the 2014-15 Federal Budget, making this project financially unviable. Stage 1 of the project was subsequently terminated by agreement of all funding partners in accordance with the Funding Agreement. Approximately $760,000 of CINSW Funds was spent and work undertaken resulted in initial analysis of CO₂ transport options, a procurement and community engagement strategy, and development of a preliminary pathway process for approvals and legal framework for GHG injection and demonstration.

Stage 2 of the project (construction and operation) formed a major component of the future work of the CINSW Program. Australian Government funding for this project was also withdrawn in the 2014-15 Federal Budget, and as a result Stage 2 of the project was not commenced.

The minutes of the Steering Committee’s termination meeting stated that “the Commonwealth Department of Industry [representative] expressed his appreciation of Delta’s management of the CCS Demonstration project. He noted that the decision to withdraw Commonwealth funding was not a reflection on the management of the project but was made in the context of budget pressures which resulted in the government reducing funding across a number of government programs, including the National Low Emissions Coal Initiative.”

In light of the withdrawal of Australian Government funding, and the termination of the CCS demonstration project, the future nature of the CINSW Program is being redesigned with options currently the subject of interdepartmental discussion.
The **NSW CO₂ Storage Assessment** aims to develop an understanding of and confirm NSW’s potential for geological storage of CO₂. Compared to most other States in Australia, NSW’s deep sedimentary basins are virtually unexplored. This program aims to address this gap in knowledge.

Potential CO₂ storage sites in NSW have been identified and referenced from the commissioned reports of the *Sydney Basin Reservoir Prediction Study* (September 2007) and *Darling Basin Reservoir Prediction Study* (June 2007). Prioritising these as target basins was also corroborated by the National Carbon Storage Taskforce (Taskforce), established under the National Low Emissions Coal Initiative to drive prioritisation of, and access to, a national geological storage capacity to accelerate the deployment of CCS technologies in Australia.

The Taskforce developed a Technical pre-exploration program that ranked the Clarence-Moreton, Sydney and Darling Basins as number 1 in priority with options of further drilling pending results obtained. The Taskforce also noted that New South Wales basins were relatively unexplored, and that exploration drilling was a priority.

Having already explored the Sydney Basin, the program is focused on the Darling Basin due to the identification of potentially large storage formations and its proximity to easement infrastructure that could potentially carry all of the GHG emissions from NSW east coast power stations to the Darling Basin.

The **RD&D** program has targeted all aspects of the coal life cycle and coal related GHG emissions, with the specific aim of reducing GHG emissions at each stage.

**Projects:**
The CINSW Program has funded six completed projects (see Appendix A) with another three projects ongoing (see Appendix B). A description of terminated programs is provided in Appendix C.

**Resourcing requirements:**
The $100m Coal Innovation NSW Fund (the fund that pays for Program activities and administration) was generated from a levy on electricity distribution network service providers in NSW (ultimately paid for by electricity consumers).

**Existing or proposed program pricing strategy:**
Application of the Productivity Commission’s cost recovery principles to the existing program indicates that it is appropriate that cost recovery be pursued from the electricity distribution network via a levy at avoidable cost. The pathway through the Cost Recovery Decision Framework (Appendix D) is as follows: 1, 2, 3, 9a, 10a, 10b, 11, 12, 13b, 14, 16 = avoidable cost.
CNSW OBJECTIVE: to encourage the research, development and demonstration of low emissions coal technologies to reduce greenhouse gas emissions cost effectively, and improve the sustainability of the NSW coal-fired electricity generation and coal mining industries.

Carbon Capture and Storage (CCS) could be achieved by removing and storing CO2 before it enters the atmosphere. It is a technology that can help reduce the amount of CO2 emitted by power plants and industrial processes. CCS can be achieved through various methods, including pre-combustion capture, post-combustion capture, and oxy-fuel combustion. These technologies involve different steps, such as capturing CO2 from the stack gases, transporting the CO2 to a storage site, and finally storing it underground. The use of CCS is expected to play a significant role in achieving climate change mitigation goals.
Step 3 – Program Assessment

Costs

The total cost of completed projects is around $34 million, of which CINSW contributed $13.5 million, or approximately 40% (see Table 3 for costs by project). Leveraging CINSW funds with contributions from the Commonwealth Government and the Australian Coal industry has allowed the CINSW Program to achieve outcomes far above what it could have without these contributions.

Ongoing CINSW research projects have also been able to leverage CINSW funding with in-kind contributions from research institutions to generate significantly more research activity, and associated research findings, than would have been possible without these in-kind contributions. CINSW has contracted commitments of nearly $6 million to ongoing projects, which has leveraged over $8 million in additional contributions including in-kind.

<table>
<thead>
<tr>
<th>Completed Projects</th>
<th>CINSW Contribution ($m)</th>
<th>Other Contributions including in-kind ($m)</th>
<th>Total Project Expenditure ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW CO2 Storage Assessment Project - Stage 1A</td>
<td>7.6</td>
<td>2.8*</td>
<td>7.6</td>
</tr>
<tr>
<td>NSW CO2 Storage Assessment Project - Stage 1B</td>
<td>2.2</td>
<td>15.2</td>
<td>20.2</td>
</tr>
<tr>
<td>Post Combustion Capture pilot plant relocation Project</td>
<td>1.6</td>
<td>1.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Solid Sorbent Prototype Test Unit, Trials of Novel CO2 Capture Technology</td>
<td>0.6</td>
<td>0.3</td>
<td>0.9</td>
</tr>
<tr>
<td>A Novel Chemical Looping Based Air Separation (CLAS) Technology for Oxy-Fuel Combustion of Coal</td>
<td>0.9</td>
<td>1.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Managing Low Emissions Coal Technology Project Risk: The Role of Public Awareness</td>
<td>0.7</td>
<td>-</td>
<td>0.7</td>
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<tr>
<td>Total completed projects cost ($m)</td>
<td>13.5</td>
<td>20.5</td>
<td>34.6</td>
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</tbody>
</table>

<table>
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<tr>
<th>Ongoing Projects</th>
<th>CINSW Contribution ($m)</th>
<th>Other Contributions including in-kind ($m)</th>
<th>Total Project Cost ($m)</th>
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</thead>
<tbody>
<tr>
<td>Demonstration of VAM-RAB Technology</td>
<td>2.2</td>
<td>2.1</td>
<td>4.3</td>
</tr>
<tr>
<td>Mineral Carbonation International</td>
<td>3</td>
<td>6.1</td>
<td>9.1</td>
</tr>
<tr>
<td>Development and Optimisation of Direct Carbon Fuel Cell</td>
<td>0.6</td>
<td>-</td>
<td>0.6</td>
</tr>
<tr>
<td>Total ongoing projects cost ($m)</td>
<td>5.8</td>
<td>8.2</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Terminated Projects</th>
<th>CINSW Contribution ($m)</th>
<th>Other Contributions including in-kind ($m)</th>
<th>Total Project Cost ($m)</th>
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</thead>
<tbody>
<tr>
<td>Data CCS Demonstration Project</td>
<td>0.76</td>
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<tr>
<td>UCCe</td>
<td>0.04</td>
<td>0</td>
<td>0.04</td>
</tr>
<tr>
<td>CSIRO Cornell Project</td>
<td>0.04</td>
<td>0</td>
<td>0.04</td>
</tr>
<tr>
<td>Terminated projects cost ($m)</td>
<td>0.83</td>
<td>2.35</td>
<td></td>
</tr>
</tbody>
</table>

* This contribution was rolled into Stage 1B expenditure.

Table 3: Summary of project costs and CINSW contributions
**Benefits**  
The completed CINSW projects have generated significant outcomes for the benefit of NSW, including:

- **Progressing NSW towards being 'storage ready'** by the identification of large scale CO\textsubscript{2} geological storage potential in the Darling Basin and existing easements for pipeline infrastructure to emissions sources -
  
  - Modelling estimates have found formations in one well that could be capable of storing approximately 650 million tonnes of CO\textsubscript{2}. This one site could therefore permanently store 50 years emissions captured from a major NSW coal-fired power station. To put it another way, the site could potentially store one-fifth of the CO\textsubscript{2} emitted over a 50 year period by the State’s coal power sector. There are 16 separate sub-basins in the Darling Basin with similar, but currently unknown, potential for large scale CO\textsubscript{2} storage, which could potentially mitigate emissions from all current NSW coal fired power generation;
  
  - At this stage, this one well makes the Darling Basin the only verifiable CO\textsubscript{2} geological storage location in NSW, due to prospective geological conditions that permit CO\textsubscript{2} storage. Case study results from the recent CO2CRC report\textsuperscript{10} found that the total plant costs for CO\textsubscript{2} transport, injection and monitoring from power stations in the Hunter Valley to the Darling Basin, is likely to be on average around $22/t CO\textsubscript{2} injected. With average costs of other national case studies varying from $5-$68/t CO\textsubscript{2} injected, the case of transporting CO\textsubscript{2} a 915km from the emission sources in the Hunter Valley to the Darling Basin is a viable mid range cost option.

- **Developing a novel chemical looping based air separation (CLAS) process technology** that moves industry a step closer to commercial-scale deployment of low emissions electricity generation and a more cost effective separation process available to wider industry -
  
  - It found the normalised capital cost of a chemical looping based oxy-fuel retrofit in NSW can be as low as $2,300/kW while the corresponding levelised cost of electricity and the cost of CO\textsubscript{2} abatement were $92/MWh and $41/tCO\textsubscript{2}, respectively. With a future carbon price signal, the application of this technology in retrofitting NSW coal fired power stations makes for a financially and sustainably viable electricity generation from coal.

- **Demonstrating the technological stability of a novel CO\textsubscript{2} capture adsorbent under industrial conditions** with real flue gas -
  
  - The benefit of this innovation provides for an alternative form of medium to capture CO\textsubscript{2} particularly in dry dusty conditions. The solid sorbents also have the potential to serve another use as a two-in-one process of pre-cleaning and pre-treatment capture technology.

- **Gaining new intelligence on public engagement with low emissions coal technologies**, with new insights into the use of new social media to share information -
  
  - The benefit of which is enabling government to be more effective and efficient at communicating to industry and general public on the development of low emissions coal technologies.

- **Ensuring the continued use of a key post-combustion capture pilot plant** for

\textsuperscript{10} CO2CRC, The Australian Power Generation Technology Report, November 2015, p.287 and 312
### Qualitative assessment of net impact

<table>
<thead>
<tr>
<th>CINSW funded project outcomes provide significant value in positioning NSW with options to manage a carbon constrained future. The CINSW Fund is enabling NSW to effectively become CO₂ ‘storage ready’ by providing the technological and infrastructure foundation for commercial scale demonstration of CCS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>By leveraging CINSW funds against Commonwealth and industry funding, these outcomes have been achieved at significantly lower cost to the NSW Government and community than would have otherwise been the case. Of the six completed projects, which were approximately $34 million in total project cost, CINSW contributed $13.5 million, or just 40%.</td>
</tr>
<tr>
<td>In this emerging field of technological development, shared learnings from other states and countries have also contributed to the effectiveness of CINSW programs. Becoming storage ready in NSW has come at a significantly lower cost than a similar attempt by the Queensland Government in the ZeroGen project. This project involved developing a 500 MW Integrated Gasification Combined Cycle (IGCC) power plant with CCS of 60–90 million tonnes of CO₂ over a 30 year period in central Queensland.¹¹</td>
</tr>
<tr>
<td>The cost of the ZeroGen prefeasibility study, including CO₂ storage exploration and appraisal activities was approximately $138 million. Over 70% of this (around $100 million) was related to CO₂ storage exploration drilling (12 wells), testing and studies. What the prefeasibility study found was that the sub–surface resource was unsuitable for large scale CO₂ storage. Primarily, insufficient storage capacity was available for the expected emissions from the proposed power plant in Queensland.</td>
</tr>
<tr>
<td>By comparison, and from these learnings, total project costs for the NSW CO₂ Storage Assessment project Stage 1 are around $28 million (of which CINSW contributed $9.8 million). This project has so far identified one site with the potential to store 13 million tonnes of CO₂ per year over a 50 year period, and there are further sub-basins of interests in the area that could potentially store similar volumes of CO₂.</td>
</tr>
</tbody>
</table>
| Relative to the ZeroGen project in Queensland, CINSW efforts to make NSW

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storage ready have been more cost-effective. By this comparison, CINSW represents very good value for money by moving NSW towards storage readiness at a much lower cost than the comparable ZeroGen project in Queensland.

In addition to helping NSW to become storage ready, CINSW projects target technologies that reduce greenhouse gas emissions at all stages of the coal life cycle. CINSW continues to contribute towards significant and valuable advancements in these technologies, reducing the cost of separating CO₂ emissions from flue gas, piloting a process of transforming captured CO₂ emissions into carbonate rock, and trialling the treatment of methane in the ventilation air of underground coal mines by an oxidation process.
Appendix A: Description of Completed Projects

NSW CO₂ Storage Assessment Project - Stage 1A
This project involved seismic surveys and stratigraphic drilling in the Sydney-Gunnedah Basin, undertaken to fill gaps in knowledge of the deeper geology of the NSW sedimentary basins to assess the geological CO₂ storage potential and uncover the reservoir and sealing characteristics of the strata.

Stage 1A in the Sydney-Gunnedah Basin achieved its aims and objectives. The prospectivity of targeted areas was previously largely unknown due to the lack of available deep stratigraphic information. Stage 1A greatly assisted in addressing this data gap and by testing the porosity and permeability of intersected sandstones has classified them as unlikely to be suitable as CO₂ storage reservoirs.

A great number of learnings were acquired that will assist in enhancing the outcomes of further exploration undertaken as part of the NSW CO₂ Storage Assessment Program. An enhanced understanding of the geology of the basin has been gained, and a large volume of subsurface data and drill core (5303m) was acquired. These data and cores are now available for continued assessment and study by government agencies, academia and industry involved in CCS and mineral/petroleum exploration activities.

NSW CO₂ Storage Assessment Project - Stage 1B (Darling Basin)
This project involved a drilling and testing program of two wells in the Darling Basin. These were undertaken to fill gaps in knowledge of the deeper geology of the NSW sedimentary basins, and to assess the geological CO₂ storage potential of these basins and uncover the reservoir and sealing characteristics of these strata. The geothermal potential of the Darling Basin was also explored as part of the program.

Stage 1B in the Darling Basin achieved its aims and objectives, and provided preliminary positive results of geological CO₂ storage potential. Modelling conducted by the CO2CRC has indicated a potential storage site with a capacity of 650 Mt of CO₂ at an injection rate of between 11 and 14 Mt per annum. In other words, the potential to permanently store approximately 50 years of emissions from one of NSW’s largest power stations.

An enhanced understanding of the geology of the Darling Basin has been gained, and a large volume of subsurface data and drill core (114.39 m) acquired. The data and cores are now available for continued assessment and study by government agencies, academia and industry involved in CCS and mineral/petroleum exploration activities. Key learnings were acquired that will assist in enhancing the outcomes of further exploration required to ascertain the storage potential of the Darling Basin as part of a Stage 2 of the NSW CO₂ Storage Assessment Program, subject to the consideration of Government. This data will also serve to improve knowledge of the state’s geothermal potential and increase the accuracy of existing heat flow mapping.

The total expenditure on Stage 1A and Stage 1B is $30 million, of which CINSW contributed $9.8 million.

Post Combustion Capture (PCC) pilot plant relocation Project, by CSIRO
This two year project aimed to enable further development of a process, based on aqueous ammonia and possibly other solvents, for post combustion capture of CO₂ from power station flue gases for application in NSW in preparation of a larger scale demonstration of the
technology. The project involved relocating the PCC pilot plant facility from Munmorah power station to Vales Point power station. At Vales Point the pilot plant has undergone further refurbishment to enable its effective operation. The total cost of the project was approximately $2.6 million, of which CINSW contributed $1.6 million.

The project has enabled the consolidation and extension of technical infrastructure for the evaluation of PCC technologies for application in coal fired power plants in NSW. The PCC pilot plant at Vales Point is unique in that it is the only facility in NSW that can actually evaluate technologies utilising real flue gases from coal combustion.

The infrastructure is now available to be utilised to address issues that are pertinent to the development and deployment of environmentally benign and cost-effective PCC technologies. A project funded by the Australian Renewable Energy Agency (ARENA) aimed at the demonstration of solar thermal energy for regeneration of the liquid absorbents has also recently started using this refurbished pilot plant.

**Solid Sorbent Prototype Test Unit, Trials of Novel CO₂ Capture Technology, by CSIRO**

The aim of this two and half year project was to investigate the ability of a novel, patented technology to physically separate out the CO₂ from the flue gas emitted from NSW coal-fired power stations. The technology uses a type of nano-structured Monolithic Carbon Fibre Composite adsorbent material fabricated in a Honeycomb structure. The technology enables dry CO₂ capture at room temperature and atmospheric pressure and in dusty environments with low pressure drop, reducing the operational and maintenance cost of the post-combustion capture process. In addition, the heat in the flue gas can be utilised in the process thereby further reducing the electricity requirements of capturing CO₂. This new technology has potential to play a key role in the cost effective and environmentally responsible generation of electricity in the future. The total cost of the project was approximately $0.9 million, of which CINSW contributed $0.6 million.

With the CO₂ capture performance of the solid sorbents maintained after more than 200 tests, this is a world first demonstration of these solid sorbents and their stability with real flue gas without any noticeable impact of SOx and NOx on their CO₂ capture performance. The solid sorbents also have the potential to serve another use as a two-in-one process of pre-cleaning and pre-treatment CO₂ capture technology.

All project objectives were successfully accomplished through this study. The important experimental data and site operational experience obtained at the power station form a basis for further development of this carbon composite adsorbent CO₂ capture technology towards its industrial application at fossil fuel fired power stations.

**A Novel Chemical Looping Based Air Separation (CLAS) Technology for Oxy-Fuel Combustion of Coal, by the University of Newcastle**

This two year project was concerned with the development of a novel chemical looping based air separation process named CLAS (and its variant named ICLAS) to facilitate the commercial-scale deployment of oxy-fuel combustion across the power generation sector in NSW. The emphasis of the project was mainly on fundamental studies at bench-scale and pilot-scale under controlled laboratory settings. The total cost of the project was $1.5 million, of which CINSW contributed $0.9 million.
The project reached all its milestones and successfully met its key targets. More importantly, the project produced the scientific evidence that confirms the viability of the CLAS process from both technical and economic points of view.

The specific power requirements of the CLAS system were estimated to be about 11% (including heat losses to the ambient) of that of the most advanced cryogenic air separation unit. As a significant reduction in the energy and CO₂ emissions footprints of oxygen production, the CLAS technology could accelerate the commercial-scale deployment to low emissions electricity generation utilising cost effective highly advanced coal technologies such as Oxy-Fuel Combustion.

**Managing Low Emissions Coal Technology Project Risk: The Role of Public Awareness, by the University of Newcastle**

This two year study completed an investigation of public engagement with Low Emissions Coal Technologies. The purpose of this study was to understand the network of relations between industry, community and government that impact on public awareness of Low Emissions Coal Technologies. It investigated the organisational dynamics within the CCS and Coal Seam Gas (CSG) industries (due to commonality of technologies and as the research was at the height of the CSG debate) and the question of how and why the public form opinions around issues related to them. The total cost of the project was $0.7 million, fully funded by CINSW.

The project is a valuable piece of research on public engagement with low emissions coal technologies and draws attention to the many complex social dimensions of the policies and practices associated with these technologies. It has provided valuable insights into how and why users choose to join and use new social media to share information. Importantly it points out that scientific facts alone may not be sufficient to address public opposition, which is valuable insight for future public engagement in CCS.

The report incorporates all the different stages of research to outline a Network Solutions Model that suggest methods to manage public risk by monitoring and responding to public concerns in the development of the technology. This model establishes key tasks for policy-makers, civil society and project proponents in the form of recommendations, which are non-controversial and deemed acceptable.
Appendix B: Description of Ongoing Projects

Demonstration of VAM-RAB Technology at Mandalong with Centennial Coal

The aim of this three year project is to trial a new technology termed a Ventilation Air Methane Regenerative After Burner (VAM-RAB). A VAM RAB unit treats methane in the ventilation air of underground coal mines by a process of oxidation. This safely converts the methane into CO₂, thereby reducing the GHG impact of fugitive methane emissions from an underground coal mine. These emissions are notoriously difficult to abate because the naturally-occurring gas becomes diluted in the large volumes of ventilation air that are flushed through the mine during standard mining operations. As methane typically constitutes less than 1% of the ventilation air expelled from the mine, the gas is in too low in concentration to either burn-off (often referred to as flaring) or process to generate electricity. Total costs are budgeted to be $4.3 million, with a budgeted commitment of $2.2 million from CINSW.

Mineral Carbonation International

A CO₂ mineral carbonation pilot plant is being established at the University of Newcastle to trial a new technology that transforms captured CO₂ emissions into forms of carbonate rock for potential use as new green building materials in the construction industry. The mineral carbonation technology mimics and accelerates the Earth's own carbon sink mechanism by combining CO₂ with low grade minerals to make inert carbonates, which are similar to common baking soda. The solid products can be used in various applications, including building materials, and its storage potential is on the same scale as global CO₂ emissions. The project is being conducted by a multi-disciplinary team of researchers, chemical and industrial engineers. Total costs are budgeted to be $9.1 million, with CINSW contributing $3.0 million.

Development and Optimisation of the Direct Carbon Fuel Cell

This four year project is researching and developing a Direct Carbon Fuel Cell (DCFC) prototype. In a DCFC, electricity is generated directly from coal through the chemical oxidation of coal, which has been ground and purified of ash and other contaminants. This technology is yet to be commercialised but is widely promoted as being the ‘holy grail’ of coal-fuelled electricity generation, as it has the capacity to generate electricity with much higher thermal efficiencies (~70-80%) than engines and turbines (~35-55%). The higher efficiencies equate to substantial reductions in GHG emissions as less fuel is used per unit of electricity generated. In addition, the fuel cell emissions are almost entirely pure CO₂ which is therefore ready for capture and storage without the need to firstly separate out other gases, such as nitrogen, which are present in flue gases of existing power plants. Total costs are budgeted to be $0.6 million, with all costs covered by CINSW.
Appendix C: Description of Terminated Projects

**Delta CCS Demonstration Project**

The lead project of the CINSW Program was to be the NSW CCS Demonstration. This project had the objective of demonstrating the whole CCS value chain by integrating post-combustion capture, transport and permanent geological storage of CO₂ from a black coal fired power station.

Stage 1 of this project (pre-feasibility, planning and approvals) was contracted and jointly funded by the Australian Government, Australian Coal Association Low Emission Technology Ltd and the Coal Innovation NSW Fund. Work on this project had commenced, however, Australian Government funding for this project was withdrawn in the 2014-15 Federal Budget, making this project financially unviable.

Stage 1 of the project was subsequently terminated by agreement of all funding partners in accordance with the Funding Agreement. Approximately $760,000 of CINSW Funds was spent and work undertaken resulted in initial analysis of CO₂ transport options, a procurement and community engagement strategy, and development of a preliminary pathway process for approvals and legal framework for GHG injection and demonstration.

Stage 2 of the project (construction and operation) formed a major component of the future work of the CINSW Program. Australian Government funding for this project was also withdrawn in the 2014-15 Federal Budget, and as a result Stage 2 of the project was terminated.

The minutes of the Steering Committee’s termination meeting stated that “the Commonwealth Department of Industry [representative] expressed his appreciation of Delta’s management of the CCS Demonstration project. He noted that the decision to withdraw Commonwealth funding was not a reflection on the management of the project but was made in the context of budget pressures which resulted in the government reducing funding across a number of government programs, including the National Low Emissions Coal Initiative.”

Approximately $760,000 of CINSW Funds was spent and work undertaken resulted in initial analysis of carbon dioxide transport options, a procurement and community engagement strategy, and development of a preliminary pathway process for approvals and legal framework for greenhouse gas injection and demonstration. The return of committed monies back to the CINSW Fund has enabled the program to reprioritise on a scaled up drilling program, future energy generation study, and smaller additional allocation for continued research and development into low emissions coal efficiency measures.

**UCC Energy Pty Ltd - Demonstration of Ultra Clean Coal in a Diesel Engine.**

This project was awarded grant funding through a two stage gated process. Stage 1 was to provide partial funding (50% funding up to $50,000) of the GHG life cycle assessment (GHG LCA) and use the results as a strong decision gate (i.e. LCA verifies that the UCCE project has the potential to lead to significant, measurable, monitored and verifiable reductions in GHG emissions) to consider further funding of this project.

The proponent completed Stage 1 in Q1 2011 and CINSW Secretariat assessment concluded the LCA as providing the most accurate and up-to-date analysis of UCCE technology, and therefore it can be considered that the UCC Energy project may be able to demonstrate the potential of achieving significant reductions in GHG emissions.
In accordance with the funding deed agreement the results of the LCA were to be assessed by the Clean Coal Council’s Technical Working Group; and a recommendation from the Clean Coal Council will be made to the Minister.

At the time, the membership terms for the majority of Clean Coal Council members had expired and so Council did not meet until at the newly reformed Coal Innovation NSW in March 2012. During this time, from the completion of the LCA to CINSW reviewing this project, there was no contact between both parties as:

- The key personnel at UCCE had changed as the new owners Yancoal put in place more of its management team; and
- The Secretariat had no Council to refer the matter for decision.

The CINSW, through its subcommittee reviewed this project in July 2012 and raised further queries to the LCA report to be responded to by UCCE. After making contact with UCCE, the Secretariat learnt the UCCE had been restructured and that the project had continued on without any CINSW funding beyond Stage 1 to the point of near completion, and possibly beyond the scope of Stage 2 funding sought in the original application. A recommendation was then endorsed by CINSW to terminate the project.

CSIRO Project to perform a field trial to demonstrate enhanced gas drainage in order to lower fugitive emissions from open cut coal mining

This project experienced significant delays from not having contractual arrangements in place with the industry host to carry out the project and experienced a fire at the proposed site (Xstrata Blakefield South mine site in January 2011, which affected the availability of key technical staff which were focusing their efforts on the recovery of the Blakefield site. Additional time was given to Project leader to seek a contractual commitment and provided a revised project plan, and source another industry partner. After an initial report of an unsuccessful approach to a NSW mine, there were no further reports provided. The advisory body for CINSW recommended terminating this project at the last meeting in December 2012, which was acted on.
Appendix D: Cost Recovery Decision Framework

1. ACTION: Identify the nature of the issue that may potentially involve government intervention
   Then conduct a "market failure"/"welfare" test as below:

   2 (a) Market Power: Are there participants in the market that have sufficient market power so as to artificially influence trade or price? (See Notes)
   No

   2 (b) Externality: Are participants in the market imposing an unwanted cost on others not involved in the market transaction? (See Notes)
   No

   2 (c) Public Goods: If left unassisted, would the market fail to provide an adequate level of investment to address the issue identified above? (See Notes)
   No

   2 (d) Asymmetric Information: Does one party to a transaction have more or better information than the other party, thus creating an imbalance of power? (See Notes)
   No

   2 (e) Welfare Objective: Does the Government wish to pursue a welfare or distributional objective? (See Notes)
   No

   Market failure present – Government action may be justified (See Notes)

3. ACTION: Devise a Proposed Government Program or Activity if one does not already exist
   The proposed intervention should be designed to overcome the specific market failure identified above. (See Notes) the component parts of each activity/program should be considered separately through the remaining part of this diagram.

4. Is it for what it would be necessary to regulate for the provision of this activity/program?
   (eg, to pursue impaction, establish industry levy, enforce compliance certification, etc)
   Yes

5. Does would the activity/program involve "registration/ approvals" or "compliance/enforcement"?
   Compliance/Enforcement
   Yes

6. Are the identifiable minor beneficiaries capture enough benefits to warrant paying for the provision? (sufficiency principle)
   Yes

7. Is it appropriate to recover costs from the individual risk creator or individuals/firms? (through a fee or fine, as opposed to recovering costs from an entire industry through a levy)
   Yes

8. Are the other individuals/firms be able to free-riders on the approval of the first applicant?
   Yes

9. Are the affected parties identifiable, i.e. are the affected parties identifiable, is there (or could there be a fee collection mechanism in place and would the amount of money collected be likely to significantly outweigh the administrative costs of doing so?
   Yes

10. Is it would "group-based" cost recovery be both efficient and cost effective? i.e. are the affected parties identifiable, is there (or could there be) a levy collection mechanism in place, and would the amount of money collected be likely to significantly outweigh the administrative costs of doing so?
    Yes

11. ACTION: Conduct a Benefit Cost Analysis
    (Only proceed with options in which benefits are greater than costs)

12. If the impacts of the issue in question lie solely within one sector or industry, the responsible funding party (government/levy in industry) may decide for the proposed activity/program not to be provided. Otherwise...

13. Cost Recovery fee or levy set to achieve fully distributed cost recovery

   Cost Recovery Components
   A - Salaries & O&M Costs
   B - Operating Expenses
   C - Overheads
   D - Returns on Assets
   E - Profit Margin

14. Would there be actual or potential competition for the provision of this activity/program?
    Yes

15. Would the provision of this activity/program involve additional data collection, analysis or research beyond what is already taxpayer funded?
    Yes

16. Provisions of this activity/program involves the further dissemination of a basic product.
    No