# CO2CRC response to NSW inquiry into the economics of energy generation

Gustavo Fimbres Weihs, Minh Ho and Dianne Wiley

*June 2012| CO2CRC Report No: RPT12-3537*


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**Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)**

GPO Box 463
Ground Floor NFF House, 14-16 Brisbane Avenue, Barton ACT 2600
CANBERRA ACT 2601
Phone: +61 2 6120 1600
Fax: +61 2 6273 7181
Email: info@co2crc.com.au
Web: www.co2crc.com.au

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# Executive summary

This report presents high-level scoping study estimates of the cost of transporting $CO_2$ from New South Wales emission sources to several potential storage basins in eastern Australia. The estimated transport costs range from about A$10 per tonne of $CO_2$ transported to the nearest basin, to A$32 per tonne transported to the furthest basin. Transport costs are mainly driven by the distance between the emission sources and the storage basin location. Using a pipeline network is important for reducing costs.

The pipeline cost estimates reported here do not include the costs of capture or storage and, therefore, are only one component of the total cost of capturing, transporting, injecting and storing the $CO_2$ for each of the basins considered. So these pipeline cost estimates should not be used as the sole basis for selecting either the pipeline network configuration or the $CO_2$ storage location. For sites with favourable characteristics, storage costs may only be a small component of the total cost, but this could increase by up to 3 orders of magnitude for sites with unfavourable characteristics. In addition, the capture costs currently constitute about 60 – 80 % of the total costs and therefore have a significant impact on a decision to progress with an integrated CCS project.

The estimates presented in this report are subject to large uncertainties, are only indicative and could change substantially over time as technologies, 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. More detailed and extensive feasibility studies, based on more data, need to be undertaken before an investment decision in a $CO_2$ transport project could be made.

This report also summarises publicly available cost data for global CCS projects currently under operation as well as those in the execution, define and evaluation phases. The capital costs for 23 projects are summarised; however, the CCS operating costs for only one project are available in the public domain. The capital costs reported for the projects in the operation stage reflect the actual implementation costs for these projects. The values reported for projects in the execution, define and evaluation stages are based on feasibility studies, and as such are only indicative and could change substantially over time. It should also be noted that because operating costs are not available for the projects, it is not possible to evaluate total project costs per tonne of $CO_2$ captured over the lifetime of the project, which would be essential for making more direct comparisons between these and other projects. Furthermore, because the projects involve different emission sources, types of capture and storage locations, comparisons must be made cautiously, even for similar amounts of $CO_2$ captured or stored.

For the summarised projects, capital costs vary from as low as US$100 million to over US$3 billion for amounts of $CO_2$ from 0.1 million to almost 6 million tonnes per year. The projects cover $CO_2$ capture from natural gas processing, chemical plants, other industrial process and power plants. Note that some of the projects only report costs for some components in the CCS chain (capture, transport and/or storage) while others report the cost for the full chain.

Given that capture and storage of $CO_2$ from coal and natural gas fired power plants is essential for ensuring a reliable, low cost and low emission energy supply, governments need to be active in supporting CCS demonstration projects as well as developing the required legislative and regulatory frameworks. They also need to play a key role alongside industry and research organisations in reducing technical, financial and social risks.

# 1. Introduction

The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) thanks the NSW Public Accounts Committee for this opportunity to provide responses to two questions on notice from the NSW Inquiry into Economics of Energy Generation in May 2012. The questions are:

- Can you provide the Committee with economic modelling on the costs of transporting $CO_2$ from New South Wales to other states?

- In projects currently underway around the world what does it cost to capture, transport and store a tonne of carbon dioxide?

This report provides estimates of the costs of pipeline transportation of carbon dioxide ($CO_2$) from emission sources in New South Wales to storage locations in New South Wales and other states. Data for the emission sources and geological basin locations was obtained from the National Greenhouse Gas Inventory [1] and the Carbon Storage Taskforce reports [2, 3, 4], respectively. While this data provides a good starting point for a comparative analysis, it is likely that this data will be modified as more detailed investigations progress, such as the NSW Storage Capacity Project [5]. This report provides data from a first-pass scoping study that does not attempt to design the pipelines in detail such as would be completed during a full project feasibility study. Because the study focuses on pipelines, we have not conducted any geological or reservoir engineering analysis of the storage sites and we have not completed any engineering optimisation of the capture technology for the emissions sources. The cost estimates presented in this report are subject to large uncertainties, are only indicative and could change substantially over time as technologies, equipment costs and other variables change. The assessment has been completed by the CO2CRC economics group based at the University of New South Wales (UNSW).

This report also provides a summary of large-scale carbon capture and storage (CCS) projects under active operation or in the planning stages. The projects were identified from the Global Carbon Capture and Storage Institute's (GCCSI) list of large-scale projects. We report the publicly available details and capital cost data but do not report the operating costs, as these are not publicly available except for one project. Where possible we have broken the capital cost down into the separate components for capture, transport and storage; otherwise, we have reported the total project costs.

# 2. $CO_2$ pipeline transport costs in NSW

## 2.1. Background

The Carbon Storage Taskforce, established under the National Low Emissions Coal Initiative, identified the location of the main $CO_2$ emission sources in Australia and the most likely storage basins for those emissions [2] (see Figure 1). An estimate of the cost to transport the $CO_2$ from each emission hub and to inject it in to several nearby basins was also provided [3]. However, not every emission hub-storage basin combination was evaluated.

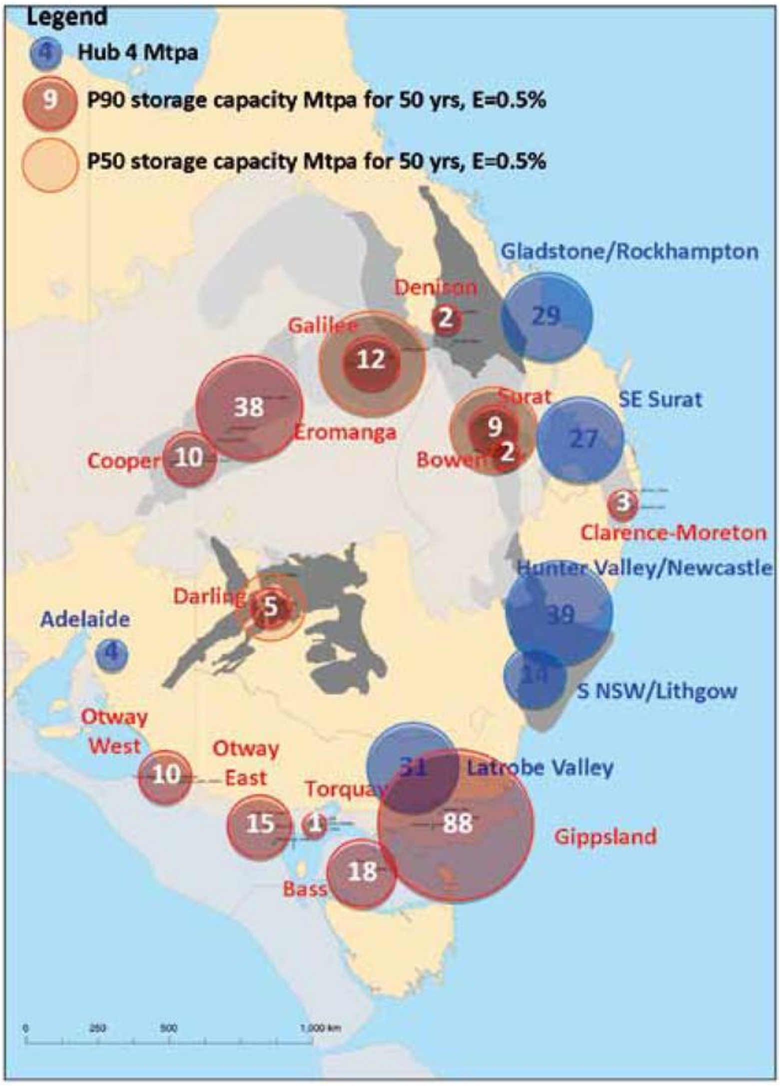


**Figure 1: Hub emission levels and basin storage capacity for Australia's eastern seaboard, as in [2]**

The analysis by the Carbon Storage Taskforce [2] concluded that, based on data available at the time, most of the storage basins in New South Wales have very low storage capacity. The taskforce suggested that a possible exception is the Darling basin, located in central west New South Wales (Figure 1). This means that in order to transport $CO_2$ from emission sources in New South Wales to potential storage locations, up to 1,700 kilometres of large diameter pipelines would be required.

The analysis presented in this report extends our work on $CO_2$ transport costs completed for the Carbon Storage Taskforce. We estimate the costs of independent transport of $CO_2$ from each individual source in New South Wales to each of the potential storage basins ("independent transport"). These costs are then compared to the cost of transporting the combined emissions to each of the potential storage basins using a pipeline network ("network transport"). The potential storage basins cover on-shore locations in Queensland, New South Wales, Victoria and South Australia as well as off-shore locations in Victoria.

## 2.2. Assumptions and methods

For each case we estimate the equipment size, the capital, operating and decommissioning costs to obtain the cost of $CO_2$ transport per tonne per kilometre. The costs are reported as Australian dollars in 2011. These costs are based on limited data and have a margin of error typical of a scoping study of ± 30%. This reflects the high degree of uncertainty in estimating individual cost items. The effects of financing, taxation and carbon price are not considered.

The main methods and assumptions used for the analysis are as follows and are standard conditions used in our comparative analyses [6]. Where possible, recommended IEA assumptions [7] are used. These may not be the same as those used in actual CCS projects.

1. Data for $CO_2$ emission sources and storage locations is taken from the National Greenhouse Gas Inventory [1] and Carbon Storage Taskforce reports [2, 3, 4], respectively. The $CO_2$ is delivered ready for transport at 25 °C and 8 MPa.
2. Additional energy for recompression is provided from a newly built, natural gas-fired power plant. This new power plant does not have capture facilities.
3. The $CO_2$ is recompressed to a sufficiently high pressure (at least 8 MPa) to keep it in a supercritical state along the pipeline. The maximum pipeline pressure is 15 MPa.
4. The pipelines used to transport $CO_2$ are made from X65 carbon-steel line pipe. The maximum nominal pipeline diameter considered is 1,050 mm (42 inches). The effects of terrain and land use on pipeline construction costs are not considered. As in our earlier study [8], the pipelines follow the shortest possible routes.
5. We calculate the present value of the costs using a real discount rate of 7%, a project construction period of 3 years and an operation period of 25 years after which the project is decommissioned. The total cost of $CO_2$ transported in A$ per tonne is calculated by dividing the present value of all costs by the present value of $CO_2$ transported.
6. In each case, we assume that all of the $CO_2$ is transported to one basin. In practice, it may be more cost effective to take the $CO_2$ to different basins.

Only transport economics are reported here. The economics of capture, compression to transport-ready conditions and storage are not included.

## 2.3. Results and discussion

For pipeline transport of $CO_2$, Figure 2 shows that lower costs can be achieved by transporting larger amounts of $CO_2$ [9]. For example, for a flow rate of 0.3 million tonnes per year of $CO_2$, transport costs are approximately 10 cents per tonne per kilometre. However, if this flow rate is tripled, then the transport cost per tonne per kilometre is reduced ten-fold. Consequently, a large trunkline pipeline network transporting $CO_2$ from multiple emission sources has the potential to improve the cost-effectiveness of transport.

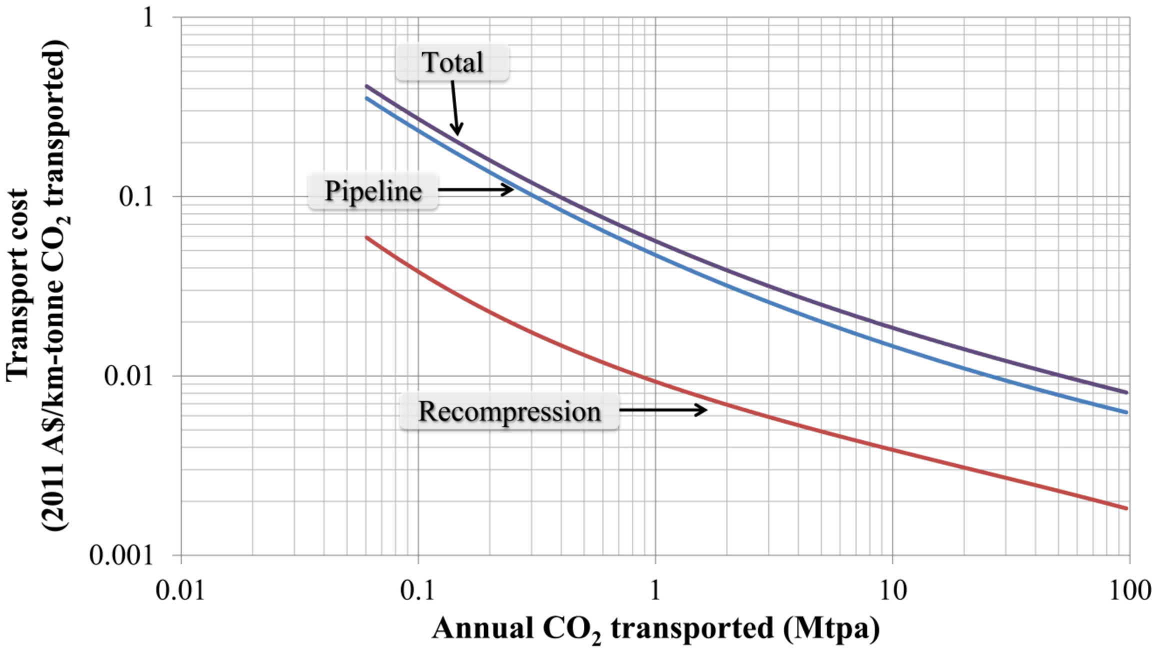


**Figure 2: Relationship between the cost of onshore $CO_2$ transport and the amount of $CO_2$ transported.**

The estimated costs for transporting $CO_2$ from the New South Wales emission sources to each of the potential storage basins are reported in Table 1. Figure 3 and Figure 4 depict illustrative examples of independent and network transport, respectively.

Because the cost estimates do not include the costs of capture or storage, they are only a part of the total cost of CCS for each of the basins considered. Given that capture costs vary greatly with emission source and capture technology and that storage costs can vary greatly from one storage basin to another, these estimates should not be used as the sole basis for selecting the $CO_2$ storage location. Moreover, the capture costs typically constitute 60 to 80 percent of the total costs at this point in time [8, 10, 11] and have a significant impact on a decision to progress with an integrated CCS project. In addition, it is important to note that some of the basins shown in Table 1 are not currently considered as being prospective for large-scale storage of $CO_2$. This may be because the basins are small or because of their geological properties. Such issues are outside of the scope of this report and must be considered in selecting the $CO_2$ storage location.

The estimated present value of the cost of independent transport ranges from A$8 billion to A$16 billion, or about A$15 to A$32 per tonne of $CO_2$ transported. In contrast, the present value of the cost of network transport ranges from A$5 billion to A$9 billion, or about A$10 to A$19 per tonne of $CO_2$ transported. Thus, for New South Wales emissions, the cost of independent transport is significantly higher than for network transport (around 65 % higher). The difference in costs is larger for basins that are located further away from the emission sources.

**Table 1: Estimates of the cost for transporting $CO_2$ from major emission sources in NSW to potential storage basins in eastern Australia.**

| Storage basin | Present value cost (2011 A$ billion) | | Unit cost (2011A$/tonne $CO_2$ transported) | |
|---|---|---|---|---|
| | Independent transport | Network transport | Independent transport | Network transport |
| Clarence-Moreton* (NSW) | 8 | 5 | 15 | 10 |
| Bowen* (Qld) | 9 | 6 | 18 | 12 |
| Surat† (Qld) | 10 | 6 | 19 | 12 |
| Gippsland (Vic-offshore) | 10 | 7 | 20 | 14 |
| Darling† (NSW) | 11 | 7 | 22 | 14 |
| Otway-East (Vic-onshore) | 14 | 8 | 27 | 16 |
| Torquay* (Vic-offshore) | 13 | 8 | 26 | 16 |
| Denison (Qld) | 14 | 8 | 28 | 17 |
| Galilee† (Qld) | 15 | 9 | 29 | 17 |
| Otway-West (Vic-onshore) | 15 | 9 | 30 | 17 |
| Bass (Vic-offshore) | 14 | 9 | 28 | 18 |
| Cooper (SA) | 16 | 9 | 32 | 18 |
| Eromanga (Qld) | 16 | 9 | 32 | 19 |

(*) Basins with a capacity of less than 25 % of NSW emissions over 50 years [2].
(†) Basins with capacity likely to be less than 25 % of NSW emissions over 50 years [2].

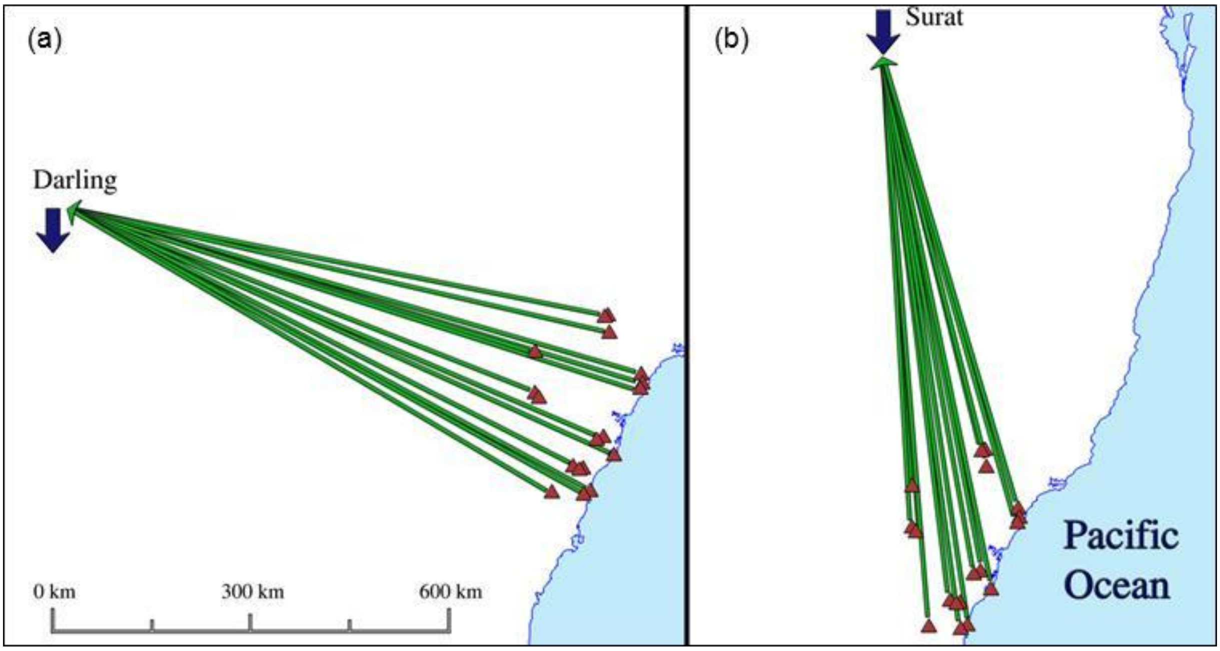


**Figure 3: Examples of independent transport to (a) the Darling basin (A$22/tonne $CO_2$ transported) and (b) the Surat basin (A$19/tonne $CO_2$ transported).**

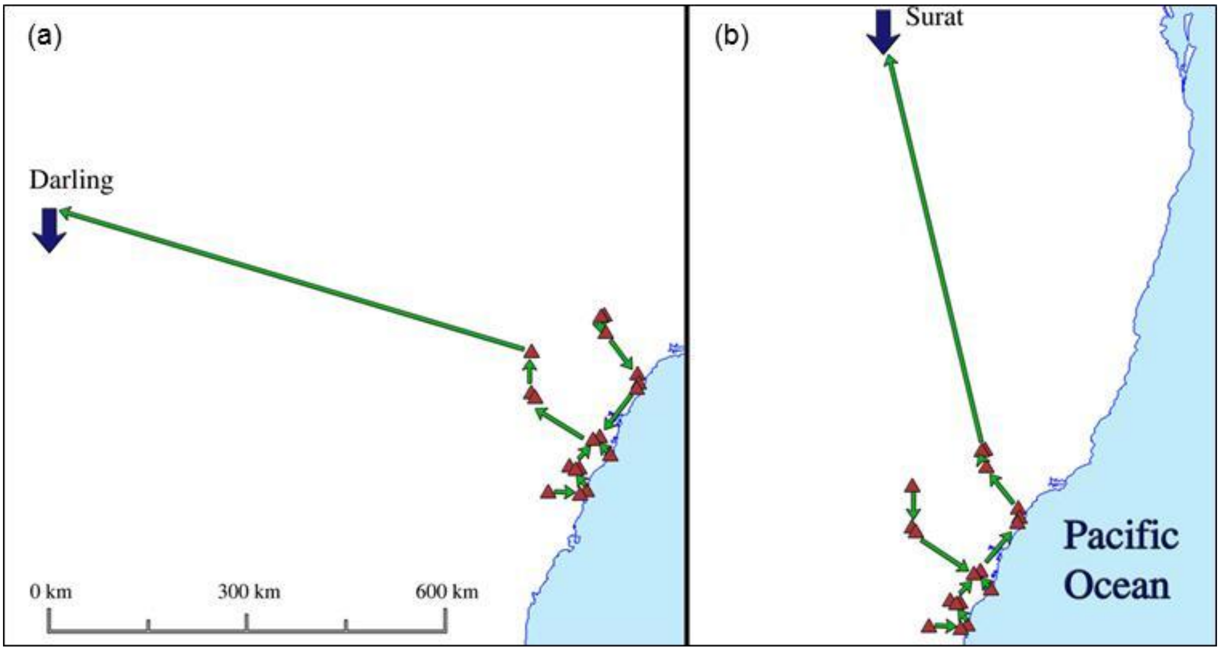


**Figure 4: Examples of network transport to (a) the Darling basin (A$14/ tonne $CO_2$ transported) and (b) the Surat basin (A$12/ tonne $CO_2$ transported).**

Figure 5 shows the relationship between estimated $CO_2$ transport costs and the distance between emission sources and each of the storage basins considered. Because transport costs are almost linearly related to distance, the transport distance is one of the main drivers of costs. Note that transport costs to offshore basins are higher than those for onshore basins at the same distance from the emission sources because of the higher cost of construction of offshore pipelines.

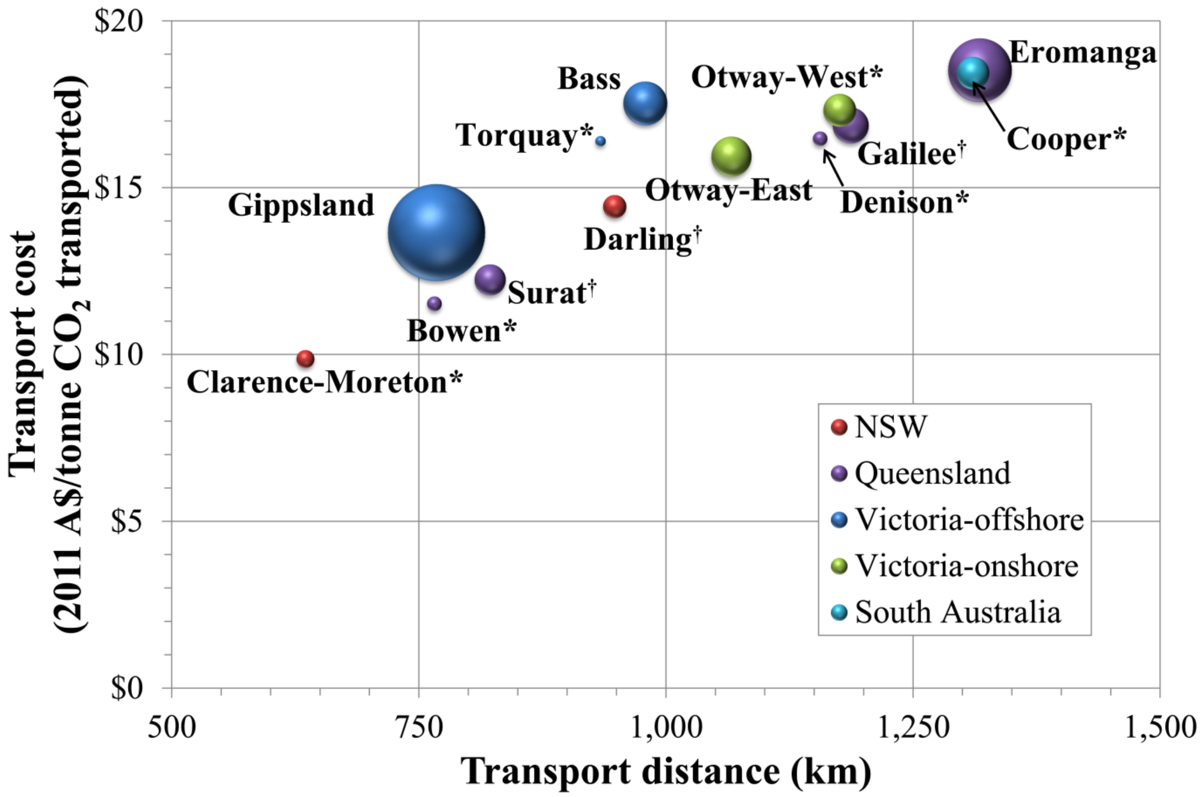


**Figure 5: Relationship between network transport costs and distance for NSW emission sources. Bubble sizes indicate storage capacity. Basins indicated with (*) or (†) are unlikely to have capacity for 25 % of NSW emissions over 50 years [2].**

# 3. Cost of CCS projects

According to the GCCSI, there are 76 planned or active large-scale (over 0.6 million tonnes of $CO_2$) CCS projects world-wide. The GCCSI reports that 16 of these projects are currently under operation while the remainder are in (1) the execution stage where the project is under construction, (2) the define stage where the project is undergoing a feasibility study, or, (3) the evaluation stage where the project is under investigation. This report summarises data for projects in the GCCSI database where costs are publicly available. In addition we have included data available for projects that have recently been cancelled and for three small pilot projects. Data was obtained from public domain sources including front-end engineering design (FEED) studies, company websites, public reports, conference and journal articles.

Tables 2 to 5 show the capital costs, the amount of $CO_2$ stored and other details of the projects. The capital costs shown in Table 2 are the actual reported capital costs of operational projects. Tables 3 and 4 show the estimated capital costs of projects under planning, while Table 5 shows the estimated capital costs for the recently cancelled projects. Yearly operating costs have not been reported except for the ROAD project (Table 4). In most cases, there is insufficient data to permit us to calculate the costs in dollars per tonne of $CO_2$ on a captured, transported, stored or avoided basis[a].

In Table 2, for the four projects where the amount of $CO_2$ stored is approximately 1 million tonnes or larger, capture (or separation) is an inherent part of the process. This applies to natural gas processing and the production of certain chemicals. Hence, the cost data shown is only for the $CO_2$ pipeline and storage facilities. For these projects, the capital costs range from US$100 million to approximately US$200 million. According to Torp and Brown [12], this translates to US$17 to US$20 per tonne of $CO_2$ stored for the Sleipner and Weyburn projects.

Table 2 also summarises capital cost data for three pilot scale oxyfiring power generation plants. For the Vattenfall and Callide Oxyfuel Project where the amount of $CO_2$ stored is 0.3 million tonnes, the costs for just the oxyfiring retrofit (i.e. without the pipeline or storage) are €90 million and A$200 million respectively. For the Lacq pilot project, which has a smaller volume of $CO_2$ stored of 0.1 million tonnes per year, the capital costs for the oxyfiring together with the pipeline and storage facilities are €60 million.

For three of the seven projects under execution shown in Table 3, $CO_2$ capture or separation is an inherent part of the process. The reported costs for the pipeline and storage are US$200 million for the ADM Illinois Industrial CCS Project, US$400 million for the Lost Cabin Gas Plant, and over A$1 billion for the Gorgon project. The cost reported for the Gorgon project is much higher than the others because of the significantly larger volume of $CO_2$ stored (3 to 4 million tonnes per year compared to approximately 1 million tonnes). In Table 3, there are three CCS projects incorporating capture, transport and storage. The capital costs for the projects located at Boundary Dam and the Alberta Carbon Trunk Line, each involving the storage of about 1 million tonne per year of $CO_2$, are of the order of C$1 billion. For the project at Kemper County involving the storage of approximately 3.5 million tonnes of $CO_2$, the capital cost is over US$2.4 billion.

[a] To enable the cost per tonne of $CO_2$ to be calculated, the capital and operating costs are required. Further, project specific data such as the length of the project life, the discount rate and the energy penalty are also needed. It is incorrect to divide the capital costs by the amount of $CO_2$. Full details of the methodology are available in the CO2CRC Economic Methodology Report [6].

The projects under the define or evaluation phase (Table 4) all have estimated capital costs of over US$1 billion. Most of these projects are for power generation. In contrast to the operating projects, the costs include capture as well as transport and storage. Note that because these projects are in the preliminary phases of development, the costs will have a high degree of uncertainty.

Table 5 summarises costs for three large-scale CCS projects that were under evaluation but have recently been cancelled: the AEP Mountaineer CCS Project, ZeroGen and Project Pioneer. Reported costs for these projects appear to fall within the range of other projects under development.

While it is not possible to estimate the cost per tonne of $CO_2$ for the majority of projects in Tables 2 to 5, there have been a number of recent generic engineering studies that have estimated total project costs for capturing, transporting and storing $CO_2$ [8,13,14]. From these studies, the indicative cost for fully integrated CCS projects range from A$80 to A$200 per tonne of $CO_2$ avoided. The levelised cost of electricity (LCOE) for CCS added to coal fired power plants falls in the range of A$100 to A$220 per MWh, which is similar to the range of costs for other low emission energy sources [15, 16]. These estimates are yet to be verified with real operating data.

From the data presented in the tables, it is clear that costs are high, variable and project specific. In general, costs are affected by:

1. $CO_2$ emission source and capture technology;
2. Degree of integration between the process plant and the capture plant;
3. Transport distance and network structure;
4. Storage site characteristics; and
5. Economic parameters such as the discount rate, project life, carbon price and fuel cost.

It is important to note that the costs shown in the tables may reflect the relatively early stage of development of CCS projects. As such, costs may decrease over time as technologies develop, project experience is gained and uncertainties reduce.

**Table 2: Summary of operating CCS projects and capital cost data**

| Asset Lifecycle Stage | Project Name | Country | Volume $CO_2$ | Start Date | Facility Details | Capture Type | Transport Length | Transport Type | Storage Type | Capital costs and inclusions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Operate | Weyburn-Midale Project [12] | Canada | 3 Mtpa | 2000 | Synthetic Natural Gas | Pre-Combustion | 315 km | Onshore pipeline | Enhanced Oil Recovery | US$100m | Cap ✗<br>Pipe ✓<br>Stor ✓ |
| Operate | In Salah $CO_2$ Storage [17] | Algeria | 1 Mtpa | 2004 | Natural Gas Processing | Pre-Combustion | 14 km | Onshore pipeline | Onshore Deep Saline Formation | US$100m | Cap ✗<br>Pipe ✓<br>Stor ✓ |
| Operate | Sleipner $CO_2$ Injection [12] | Norway | 1 Mtpa + 0.2 Mtpa | 1996 | Natural Gas Processing | Pre-Combustion | 0 km (capture same as storage location) | Offshore pipeline | Offshore Deep Saline Formation | US$100m | Cap ✗<br>Pipe ✓<br>Stor ✓ |
| Operate | Snøhvit $CO_2$ Injection [18] | Norway | 0.7 Mtpa | 2008 | Natural Gas Processing | Pre-Combustion | 150 km | Onshore pipeline | Offshore Deep Saline Formation | €150m | Cap ✗<br>Pipe ✓<br>Stor ✓ |
| Operate | Lacq [19] | France | 0.12 Mtpa | 2010 | 30 MW Power Generation | Oxyfuel | 27 km | Onshore pipeline | Depleted Onshore Gas Reservoir | €60m including power plant | Cap ✓<br>Pipe ✓<br>Stor ✓ |
| Operate | Callide Oxyfuel Project [20] | Australia | 0.3 Mtpa | 2012 (oxyfiring mode) | 30 MW Power Generation | Oxyfuel | Under consideration | Under consideration | Under consideration | A$206m including retrofit | Cap ✓<br>Pipe ✗<br>Stor ✗ |
| Operate | Vattenfall [17] | Germany | 0.3 Mtpa | 2008 | 30 MW Power Generation | Oxyfuel | Under consideration | Under consideration | Under consideration | €90m including retrofit | Cap ✓<br>Pipe ✗<br>Stor ✗ |

**Table 3 Summary of CCS projects under execution and the estimated capital cost**

| Asset Lifecycle Stage | Project Name | Country | Volume $CO_2$ | Start Date | Facility Details | Capture Type | Transport Length | Transport Type | Storage Type | Capital costs and inclusions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Execute | Port Arthur Air Products Steam Methane Reformer EOR Project [17] | United States | 1 Mtpa | 2013 | Hydrogen production | Pre-Combustion | Not specified | Onshore pipeline | Enhanced Oil Recovery | US$431m | Cap ✓<br>Pipe ✗<br>Stor ✗ |
| Execute | ADM Illinois Industrial CCS Project [17] | United States | Up to 1 Mtpa | 2013 | Chemical Production | Industrial Separation | 1.6 km | Onshore pipeline | Onshore Deep Saline Formations | US$208m | Cap ✗<br>Pipe ✓<br>Stor ✓ |
| Execute | Alberta Carbon Trunk Line with Agrium $CO_2$ Stream [21] | Canada | 0.585 Mtpa | 2014 | Fertiliser Production | Pre-Combustion | 234 km | Onshore pipeline | Enhanced Oil Recovery | C$1.2bn | Cap ✓<br>Pipe ✓<br>Stor ✓ |
| Execute | Boundary Dam Integrated CCS Demonstration Project [17] | Canada | 1 Mtpa | 2014 | Power Generation | Post-Combustion | 100 km | Onshore pipeline | Enhanced Oil Recovery | C$1.24bn | Cap ✓<br>Pipe ✓<br>Stor ✓ |
| Execute | Kemper County [17] | United States | 3.5 Mtpa | 2014 | Power Generation | Pre-Combustion | 75 km | Onshore to onshore pipeline | Enhanced Oil Recovery | US$2.4bn | Cap ✓<br>Pipe ✓<br>Stor ✓ |
| Execute | Gorgon Carbon Dioxide Injection Project [21] | Australia | 3.4 - 4 Mtpa | 2015 | Natural Gas Processing | Pre-Combustion | 10 km | Onshore pipeline | Onshore Deep Saline Formations | A$1-2bn | Cap ✗<br>Pipe ✓<br>Stor ✓ |
| Execute | Lost Cabin Gas Plant [17] | United States | 1 Mtpa | 2013 | Natural Gas Processing | Pre-Combustion | 370 km | Onshore pipeline | Enhanced Oil Recovery | US$400m | Cap ✗<br>Pipe ✓<br>Stor ✗ |

**Table 4 Summary of CCS projects under design and the estimated capital cost**

| Asset Lifecycle Stage | Project Name | Country | Volume $CO_2$ | Start Date | Facility Details | Capture Type | Transport Length | Transport Type | Storage Type | Capital costs and inclusions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Define | Hydrogen Energy California Project (HECA) [17] | United States | 2 Mtpa | 2017 | Power Generation | Pre-Combustion | 6.4 km | Onshore pipeline | Enhanced Oil Recovery | US$2.3bn | Cap✓<br>Pipe✓<br>Stor✓ |
| Define | Tenaska Trailblazer Energy Center [32] | United States | 5.75 Mtpa | Not specified | Power Generation | Post-Combustion | 201 – 250 km | Onshore pipeline | Enhanced Oil Recovery | US$1.25bn | Cap✓<br>Pipe ✘<br>Stor ✘ |
| Define | Rotterdam Opslag en Afvang Demonstratieproject (ROAD) [24] | Zuid-Holland | 1.1 Mtpa | 2015 | Power Generation | Post-Combustion | ≤50 km | Onshore to offshore pipeline | Offshore Depleted Oil and Gas Reservoirs | €210m<br><br>(€25-31/yr operating costs) | Cap✓<br>Pipe ✘<br>Stor ✘ |
| Evaluate | Full-scale $CO_2$ Capture Mongstad (CCM) [17] | Norway | 1 Mtpa | Not specified | Power Generation | Post-Combustion | Not specified | Onshore to offshore pipeline | Not specified | NOK6bn | Cap✓<br>Pipe✓<br>Stor✓ |
| Evaluate | Peterhead Gas CCS Project [25] | United Kingdom | 1 Mtpa | 2016 | Power Generation | Post-Combustion | Not specified | Onshore to offshore pipeline | Offshore Depleted Oil and Gas Reservoirs | £840m capture £125m pipeline £220m storage | Cap✓<br>Pipe✓<br>Stor✓ |
| Evaluate | Wandoan CCS Project [26] | Australia | Up to 2.5 Mtpa | 2017 | Power Generation | Pre-Combustion | ≤50 km | Onshore pipeline | Onshore Deep Saline Formations | A$3.8bn for IGCC power plant with capture | Cap✓<br>Pipe✘<br>Stor✘ |

**Table 5 Summary of recently cancelled CCS projects**

| Asset Lifecycle Stage | Project Name | Country | Volume $CO_2$ | Start Date | Facility Details | Capture Type | Transport Length | Transport Type | Storage Type | Capital costs and inclusions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| On hold/ Cancelled | AEP Moutaineer [27] | United States | 1.5 Mtpa | N/A | Power Generation | Post-Combustion | 19 km | Onshore pipeline | Onshore Deep Saline Formations | US$665m capture US$160m transport and storage | Cap ✓<br>Pipe ✓<br>Stor ✓ |
| Cancelled | ZeroGen [28] | Australia | 2 Mtpa | N/A | Power Generation | Pre-Combustion | 350 km | Onshore pipeline | Onshore Deep Saline Formations | US$3.3bn IGCC with capture US$736 m transport and storage | Cap ✓<br>Pipe ✓<br>Stor ✓ |
| Cancelled | Project Pioneer [29] | Canada | 1 Mtpa | N/A | Power Generation | Post-Combustion | 90 km | Onshore pipeline | Enhanced Oil Recovery | C$640m capture C$79m pipeline | Cap ✓<br>Pipe ✓<br>Stor ✗ |

# 4. Conclusions

Our analysis of the cost of pipeline networks suggests that using a network (or networks) for transport for $CO_2$ would reduce the cost by about a third compared to building pipelines for each emission source. Costs could be of the order of A$10 to A$20 per tonne of $CO_2$ transported from major emission sources in New South Wales to suitable storage sites in eastern Australia. These cost estimates are preliminary and may vary significantly as more detailed engineering and design is undertaken on specific networks. For example, in each scenario in this report, we assumed that all of the major $CO_2$ emissions from New South Wales were stored at one location. More work on optimisation of the whole system including the process plant and capture plant design and operations together with the pipeline network and potential storage locations may achieve further cost reductions. The objective of further studies should be to identify opportunities for development of state and national pipeline infrastructure to link major emissions sources from all states to the largest and most cost effective storage location(s) in any state.

As with all large-scale infrastructure projects, no individual company could justify the expenditure for a large-scale CCS project on their own, particularly at this stage of the technology development. For this reason there is a role for government in facilitating the infrastructure development. This includes supporting demonstration projects, developing the appropriate legislative and regulatory framework to stimulate CCS deployment, as well as supporting the reduction of technical, financial and social risks.

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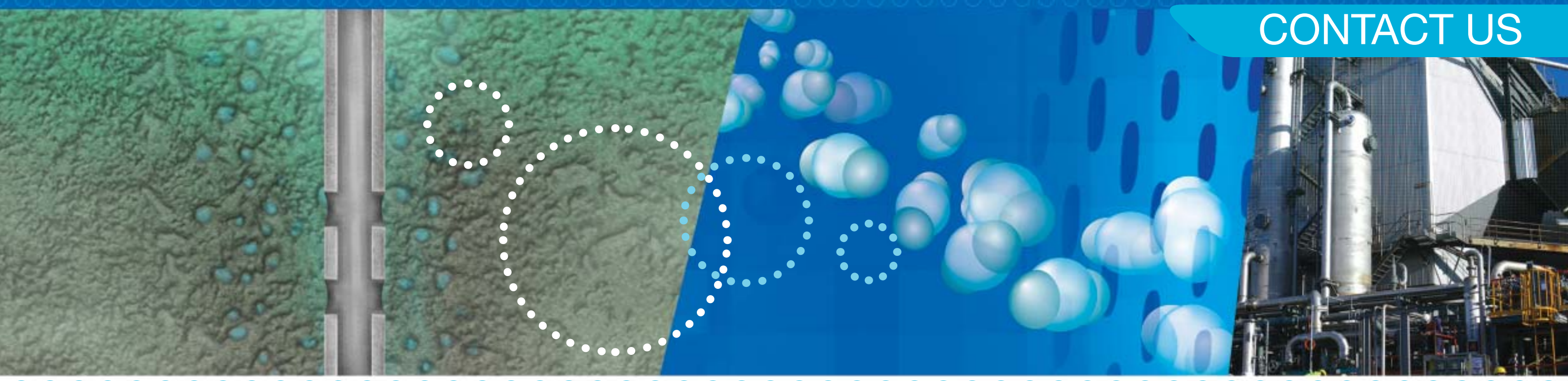
# CONTACT US



## Canberra

**Dr Richard Aldous**
*Chief Executive*
GPO Box 463, Canberra, ACT 2601
Ph: + 61 2 6120 1600
Fax: + 61 2 6273 7181
Email: raldous@co2crc.com.au

**Ms Carole Peacock**
*Business Manager*
GPO Box 463, Canberra, ACT 2601
Ph: + 61 2 6120 1605
Fax: + 61 2 6273 7181
Email: cpeacock@co2crc.com.au

## Melbourne

**Dr Matthias Raab**
*Program Manager for $CO_2$ Storage*
School of Earth Science
The University of Melbourne
VIC 3010
Ph: +61 3 8344 4309
Fax: +61 3 8344 7761
Email: mraab@co2crc.com.au

**Mr Barry Hooper**
*Chief Technologist*
Room 232/Level 2
School of Electrical & Electronic
Engineering, The University
of Melbourne, VIC 3010
Ph: + 61 3 8344 6622
Fax: + 61 3 9347 7438
Email: bhooper@co2crc.com.au

**Mr Rajindar Singh**
*Otway Project Manager*
School of Earth Science
The University of Melbourne
VIC 3010
Ph: + 61 3 8344 9007
Fax: + 61 3 8344 7761
Email: rssingh@co2crc.com.au

## Sydney

**Prof Dianne Wiley**
*Program Manager for $CO_2$ Capture*
The University of New South Wales
UNSW Sydney, 2052
Ph: + 61 2 9385 4755
Email: dwiley@co2crc.com.au

## Adelaide

**Prof John Kaldi**
*Chief Scientist*
Australian School of Petroleum
The University of Adelaide, SA 5005
Ph: + 61 8 8303 4291
Fax: + 61 8 8303 4345
Email: jkaldi@co2crc.com.au

## Perth

**Mr David Hilditch**
*Commercial Manager (CO2TECH)*
PO Box 1130, Bentley
Western Australia 6102
Ph: + 61 8 6436 8655
Fax: + 61 8 6436 8555
Email: dhilditch@co2crc.com.au

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