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Western Australia

GREENHOUSE GAS CAPTURE AND STORAGE A tale of two projects

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Western Australia - A Tale of Two Projects

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Abstract

Carbon Capture and Storage (CCS) is the only option that allows the world's existing investment in the fossil fuel infrastructure to be used whilst at the same time bringing about a major reduction in CO₂ emissions.

Two CCS projects are planned in Western Australia. Both projects are supported by collaborative partnerships between the Australian and the Western Australian governments. One will store CO₂ from a Liquefied Natural Gas (LNG) plant and the other CO₂ from coal fired industry and power generation. They differ in their social and environment impact and reservoir geology. One is in an uninhabited location with high fauna conservation value; the other in a populated agricultural district. One has a conventional seal for storage while the other depends on several trapping mechanisms. Together these projects have the potential to store 11 percent of the Western Australia's CO₂ emissions.

The first and most advanced is a proposal to capture the CO₂ which occurs naturally in the Greater Gorgon Area natural gas field 130 km off the north west coast of WA. This is known as the Gorgon Carbon Dioxide Injection Project and is an integral component of the much larger Gorgon Project to recover and export natural gas from the northwest shelf.

The joint venture operator Chevron is in the process of developing the Gorgon and Jansz fields to supply a 15.4 million tonne/annum liquefied natural gas (LNG) plant on Barrow Island and a domestic supply pipeline with a capacity of 300 Terajoules/day to the mainland.

In most existing gas processing plants carbon dioxide extracted from the natural gas during the processing operations is vented to the atmosphere, but Chevron propose to inject this into strata over 2 km below the surface of Barrow Island. This is estimated to reduce CO₂ emissions from the LNG plant by 40 percent.

The Collie-South West CO₂ Geosequestration Hub project is a proposal by a consortium of electrical power generators and industrial users of coal to extract carbon dioxide from flue gasses and coal gasification processes in Collie and Kwinana. Participants include coal miners, electricity generators, alumina refiners and fertiliser manufacturers.

The captured CO₂ will be transported by a common user pipeline to the proposed injection site in the Shire of Harvey where it will be injected into deep sandstone strata.

This paper explores the differences and similarities between these two leading projects.

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A Euro on Barrow Island



Stirling Cottage in Harvey

Background

Australia is governed under a federal system through a constitution that binds six states and two territories. The state of Western Australia takes up about one third of the Australian land mass, with some 10 percent of the population and a buoyant, resources based economy that provided over 35 percent of Australia's exports in 2010.

Western Australia (WA) emits around 72 million tonnes of carbon dioxide equivalent (CO₂-eq) a year. About 27 million tonnes comes from energy industries and 14 million tonnes from the manufacturing and construction industries. Agriculture at 13 million tonnes and transport at 9 million tonnes are the other major contributors.

The Australian Government is committed to reducing Australia's carbon emissions by 80 percent of year 2000 levels by 2050. The government has also committed to an unconditional five percent reduction in carbon pollution below 2000 levels by 2020.

This cannot be achieved in the time available by a single strategy. In the long run the world will have to convert to a low carbon economy, but for the immediate future existing technologies based on coal and hydrocarbons can be adapted to reduce emissions.

Carbon Capture and Storage

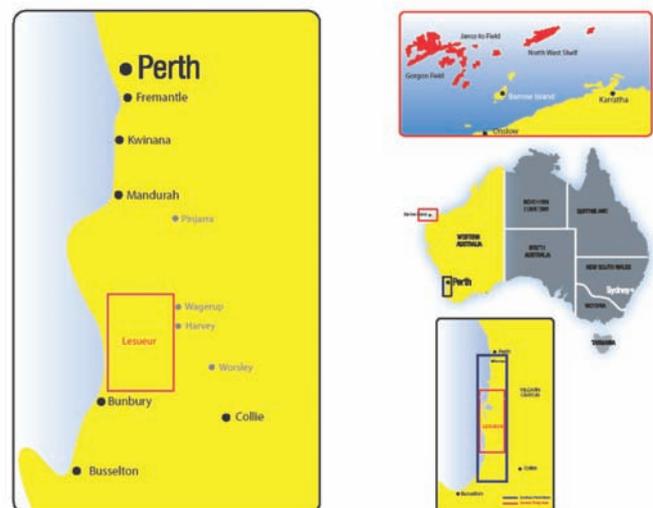
Natural gas (mainly methane) can be seen as a transition fuel. When burnt to produce heat or generate electricity it releases approximately half as much carbon dioxide (450-500g CO₂/kwh) as coal (900-950g CO₂/kwh). [1] This range can vary depending on the efficiency of the power stations and the type of coal. Collie coal

is sub bituminous and generates more CO₂ than other black coals, but less than brown coals.

According to the International Energy Agency (IEA) Blue Map, Carbon Capture and Storage (CCS) is expected to contribute nearly 20 percent of the reduction in greenhouse gas emissions required in Australia by 2050. This will come from capturing CO₂ from large stationary sources. [2 & 3]

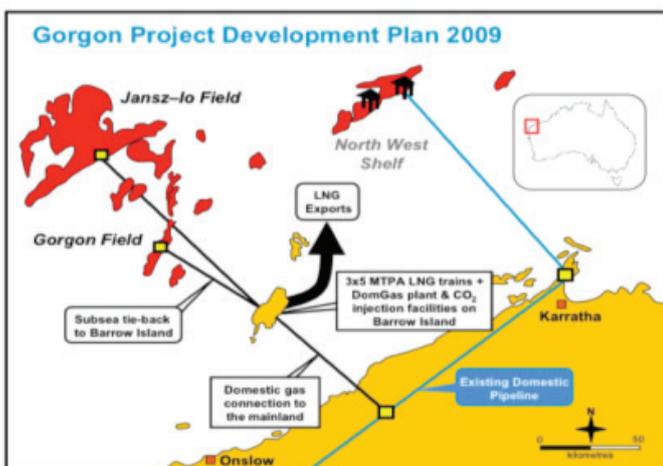
CCS is the only option that allows the world's existing investment in the fossil fuel infrastructure to be used whilst at the same time bringing about a major reduction in CO₂ emissions.

Two CCS projects are currently at different stages of development in WA.



Barrow Island and the Lesueur in Western Australia

The first and most advanced is a proposal to capture the carbon dioxide which occurs naturally in the Greater Gorgon Area natural gas fields and must be removed as part of the gas processing operations. This is known as the Gorgon Carbon Dioxide Injection Project and is an integral component of the much larger Gorgon Project to recover and export natural gas from the northwest shelf. The joint venture operator Chevron² is in the process of developing the Gorgon and Jansz fields to supply a 15.4 million tonne/annum liquefied natural gas (LNG) plant on Barrow Island, condensate and a domestic supply pipeline with a capacity of 300 Terajoules/day to the mainland.



Barrow Island

In most existing gas processing plants carbon dioxide is vented to the atmosphere, but Chevron propose to inject this into strata over 2 km below the surface of Barrow Island. This is estimated to reduce CO₂ emissions from the Project by approximately 40 percent.

The other project is a proposal by a consortium of electrical power generators and industrial users of coal (Collie-South West CO₂ Geosequestration Hub) to store carbon dioxide from emitters in Collie and Kwinana. Participants include two coal miners, two alumina refineries, two power generators and a coal to urea project at Collie.

The four year research and evaluation project proposes that CO₂ will be transported by a common user pipeline to an injection site within the Shire of Harvey where it will be injected into deep Lesueur sandstone strata.

The major industrial areas of WA lie between Kwinana and Collie. They generate about 25 million tonnes of CO₂ per annum. Of this somewhat more than 25 percent is available for capture. This amount should increase as older generating plants are replaced in the next decade. A unique feature of this project is the sequestration of 300,000 tonnes per annum of CO₂ in bauxite residue at Pinjarra and Wagerup, where the CO₂ chemically combines with the residue and reduces the Ph and provides a more easily handleable material with potential by-product use.



South West Hub

Both proposals are driven by industry. The Chevron-led Gorgon Project is furthest developed having received its final approvals in September 2009. The project is well into a five year construction program with first gas scheduled for 2014. The Australian Government has committed \$60 million towards the cost of the carbon dioxide injection project as part of the Low Emissions Technology Demonstration Fund. The State Government commitment has been through the Department of Mines and Petroleum towards independent reviews and technical analysis of the Gorgon carbon dioxide injection project.

²The Gorgon Joint Venture consists of Chevron as operator and 47% owner, Exxon Mobil 25%, Shell 25%, Osaka gas 1.25% and Osaka Electrical Power 0.417%.

The proposed Federal and State government commitment to the South West Hub CCS project is \$350m with the bulk of this funding coming from the Australian Government through the CCS Flagships Program and the Department of Mines and Petroleum playing a significant facilitating role for the early part of the project.

Carbon Capture

Natural gas as found usually contains some percentage of carbon dioxide –the Gorgon gas field contains around 14 percent carbon dioxide while the Jansz gas field has less than 1 percent. In order to liquefy natural gas to enable its efficient transport it is necessary to cool the natural gas to around 162 oC below zero. However at this temperature any retained carbon dioxide will freeze into a solid potentially plugging or damaging the liquefaction equipment. For this reason it is necessary to remove any carbon dioxide before the natural gas is cooled. The technologies for removing the reservoir carbon dioxide is well understood and has been used in gas processing plants worldwide for many decades.

In contrast, separation of carbon dioxide from flue gas is a less developed technology. Four techniques are available: absorption on amines, solid physical absorption, low temperature distillation and selective membranes. Of these only amine absorption has been extensively used on flue gases. Finding the optimum separation techniques for the emissions from each plant is a subject of research. In addition, coal gasification as a pre-combustion technology, and oxyfiring technologies are also available for commercial decision making.

A further option is pre-combustion capture where CO₂ is removed in a chemical process yielding hydrogen, prior to combustion. Hydrogen rich gas provides a lower emission fuel.

Both proposals incorporate other mitigation methods to reduce greenhouse gas emissions, including increasing the thermal efficiency of generation and refrigeration plants and in the case of Alcoa's Wagerup and Pinjarra refineries industrial carbonation of bauxite residue (commonly called red mud) which is currently a by product of no value. The carbonation process locks away the CO₂ through chemical bonding and improves the pH and handling characteristics of the residue to the point that it can be used for soil amendment, road base or the manufacture of building products.

Transport

Both proposals require construction of pipelines and injection wells drilled into storage strata. The Gorgon project will utilise a 7km pipeline to transport carbon dioxide from the gas processing plant to the injection well sites. It is anticipated that nine injection wells will be drilled directionally from three drill pads to minimise disturbance of the environment.

The proposed Collie-Harvey pipeline is about 80km long and the Kwinana-Harvey pipeline 100km long. Where possible it is planned to utilise existing easements but the pipelines will still traverse industrial and populated areas, farmlands and land used in other ways.

Geology And Trapping Mechanisms

The geology of the proposed injection sites is also very different. The Gorgon Carbon Dioxide Injection Project proposes to inject CO₂ into the Dupuy Formation at a depth of some 2300 metres. The Dupuy formation is a sandstone saturated with brackish water. It is overlaid by several layers of shale and siltstone that should act as effective seals. Much nearer the surface is the Windalia Sandstone Member, which contains Australia's largest onshore oil field and is itself sealed by thick layers of Gearle siltstone. That oil has been contained in the Windalia reservoir for millions of years indicates that the seal is effective.

The proposed injection strata in Harvey are the Lesueur Sandstone measures at a depth of between 1800 and 3,000 metres in the southern Perth Basin. The Perth Basin strata consist of basement Precambrian rock overlain by Permian Sue Group strata – mainly consolidated sandstone and siltstone with some coal measures. Overlying this is a thin belt of Sabina Sandstone and a much thicker (1600m) layer of Lesueur Sandstone. A coarse grained sandstone laid down during the Triassic period, the Lesueur Sandstone contains highly saline water.



Spectacle Haired Wallaby, Barrow Island

Overlying the Lesueur Sandstone is the Jurassic Cockleshell Gully Formation consisting of river-borne deposits of fine to coarse-grained sands interbedded with shale and silt. It is between 600m and 2000 metres thick.

The Yarragadee Formation, which is an important fresh-water aquifer in the south-west of Western Australia, salinity less than 1000mg/L, is present in parts of the southern Perth Basin but is absent in the target area. Avoiding any potential impacts on the Yarragadee is extremely important as potable water supplies are a major community and political issue.

Groundwater salinity typically rises rapidly with depth. In the storage target area the formation salinity rises to in excess of 15000mg/L.

The Lesueur Measures are deep saline formations, which may be one of the best potential options for CO₂ geological storage. However it does not have a proven continuous effective seal, so retention of CO₂ will depend on other trapping mechanisms.

Carbon dioxide can be trapped within permeable strata by a range of different mechanisms including structural seals, solubility, residual gas and mineral trapping.

Solubility trapping occurs because CO₂ is weakly soluble in water. When it is exposed to the ground water it will gradually dissolve and be held in solution within the aquifer.

In residual gas trapping, tiny bubbles of CO₂ become trapped in the pore spaces by capillary pressure. CO₂ may move through the reservoir rock, as a non-wetting phase, while the saline formation water acts as a wetting phase. Once the main CO₂ 'cloud' has passed through the rock, a small droplet of CO₂ remains trapped in the centre of the pores. This droplet of CO₂ is immobilised by the capillary pressure exerted by the wetting phase across the pore throats.

Solubility and residual gas trapping should occur at both Barrow Island and Lesueur. However, unlike the Dupuy Formation, the Lesueur lacks the assurance of a continuous impermeable seal. The discontinuous layers of shale in the Cockleshell Gully formation act as baffles, increasing the length of the passage the CO₂ plume must take towards the surface. It is calculated that this process, together with the trapping mechanisms outlined, will ensure that CO₂ is permanently retained in the Lesueur Formation.

Modelling for the South West Hub project indicates that approximately 60 percent of CO₂ will be trapped in the Lesueur sandstone, 30 percent will be dissolved in the saline water and 10 percent will percolate to the shale baffles.

The Lesueur reservoir is calculated to be capable of receiving six million tonnes of CO₂ annually for 40 years.

Injection operations at the Gorgon Carbon Dioxide Injection Project are anticipated to occur for approximately 40 years, but in this case termination will be due to depletion of the natural gas reserves, the source of the carbon dioxide.

Existing wells that penetrate into the reservoir formations are possible sources of leakage. Only four wells are known to penetrate the Lesueur formation and they are at a considerable distance from the proposed injection site. On Barrow Island only 28 of more than 1000 existing wells penetrate the Dupuy formation. It is planned that those that are anticipated to come into contact with the injected carbon dioxide will be studied and if required remediated to ensure they do not provide potential leakage pathways.

None of the known geological faults at either Barrow Island or the Southern Perth Basin are active. However they have been active in the past and could become active again. Geophysical tests carried out on core samples from wells in the South Perth Basin showed faults there were able to withstand a pressure increase of up to 10000 kPa without leakage. Modelling of the Barrow Island proposal showed that the CO₂ plume is unlikely to come in contact with the main Barrow Island Fault.



Perentie, Barrow Island

The Community

Barrow Island has no population apart from the fly-in fly-out workers associated with the existing oil field operations and construction activities of the Gorgon Project. There is no indigenous population, although there are ethnographic sites suggesting the island was inhabited 20-40,000 years ago when sea levels were lower and the island was connected to the mainland. There are no native title claims over the island.



Oil production on Barrow Island

The Island is however an A Class nature conservation reserve in recognition of the diverse fauna present on the Island. Chevron has undertaken exhaustive work to ensure the preservation of these conservation values primarily through the implementation of a world leading quarantine management system.



Nesting Turtle on Barrow Island

In contrast the area surrounding the Harvey location is occupied by a large residential population of approximately 30,000 people within a broader area of 150,000 people. Major industry, service industries and agriculture, principally dairying are the drivers for a dynamic and diverse economy. The area itself and the broader South West region is also a major tourist destination.

No native title claims are expected at the injection site, but they may affect the transport pipeline.

The local population in the Harvey and surrounding shires have been kept informed of the progress of the project for the past three years. Communication activity was stepped up in 2011. A community workshop was held in February 2011 following extensive advertising. Publications include a project outline and an explanation of the seismic survey which was conducted in March 2011. A Lesueur Common Consultative Committee was established in August 2011 and this will keep the public informed about future stages of the project through the local media. The community is vital to this four year evaluation and research project to allow commercial decisions to be made in 2015.



Harvey Dairy Farmer (source: *The West Australian*)

The Environment

Barrow Island is an A class reserve³ with populations of 17 native animal species, seven of which are endangered. These species are threatened on the mainland by predation from foxes, feral cats and black rats. Mice might also compete for limited food resources. Rats were introduced to Barrow Island by pearlers in the 19th Century but these were eradicated in the 1990s. The Gorgon Joint Venture has adopted protocols to prevent unnecessary disturbance of native animals, removal of populations prior to land clearing and quarantine measure to prevent the introduction of non-native animals. Where accidental breaches occur vigorous measures are taken to prevent the establishment of pest populations on the island.

In order to limit the impacts on the conservation values of Barrow Island the Gorgon Project is only permitted to disturb 300Ha of uncleared land or less than 3 percent of the total island land mass. This requires innovative approaches to limit surface disturbance. For example the CO2 Baseline 3D seismic survey used helicopters to transport drilling rigs and other equipment so

as to avoid clearing access tracks. This resulted in the surface disturbance of 10 percent of what would have been the case without these constraints.

The Lesueur project does not appear to pose any threats to native fauna or flora, but the pipeline route is being mapped as a precautionary measure. However, economic and social considerations such as dairy farming routines and farming infrastructure become critical to the project.

The Gorgon Project includes on-going monitoring including near surface CO2 monitoring, observations wells and repeated seismic investigations to plot the CO2 plume and to confirm or modify the modelling.

The Lesueur project has not yet reached that stage of development but it will necessarily include extensive monitoring procedures, providing baseline data prior to the commencement of injection and verification that the CO2 is remaining in place after the project gets under way.



Orange Orchard, Harvey

³An A Class Reserve is the most highly protected class of crown land in Australia. They are created under an Act of Parliament for a specific purpose usually related to conservation.

Conculsion

When completed these two projects have the potential to store more than eight million tonnes of CO₂ annually, approximately 11 percent of the State's annual current emissions.

Gorgon is a single project (although involving joint venture partners) remote from population in an environmentally sensitive area. The Lesueur project is a multi party project involving different sources of CO₂ and industrial use in a highly populated area of the state.

The Gorgon project operates under a State Agreement Act as there was no green house gas storage legislation at the time of its development. The Lesueur project will be the first project operating under Western Australia's new Green House Gas legislation, amendments to the Petroleum and Geothermal Energy Resources Act 1967 and the Petroleum Pipelines Act 1969.

There are many differences, but there are also similarities and there is a sharing of knowledge and experience. Together these two projects place Australia and Western Australia at the forefront of CCS projects, CCS knowledge sharing and CCS research and development capability.

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