OPENING STATEMENT TO THE HOUSE OF REPRESENTATIVES INQUIRY BY DR PETER J COOK, CHIEF EXECUTIVE, COOPERATIVE RESEARCH CENTRE FOR GREENHOUSE GAS TECHNOLOGIES. (CO2CRC)

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By way of introduction I should mention that the points I will make and the responses I will provide are based on the collective work of the CO2CRC, one of the world's leading collaborative research bodies; involving 100 researchers, 25 organisations (industry, government, universities, research). It also draws on the work of many international collaborators.

Based on the question posed by the Inquiry and some recent debate, I propose to touch on a number of key issues relating to carbon dioxide capture and geological storage (geosequestration) otherwise known as CCS:

1. Can CCS make deep cuts in emission?
2. Is there enough geological storage capacity and is it where we need it?
3. How much does CCS cost now, how much will it cost in the future, and how much will electricity cost if we apply CCS?
4. If CCS can make deep cuts in emissions, why is it taking so long to get it deployed in Australia and elsewhere?
5. Would deployment of CCS occur faster if we had a carbon tax, emissions trading or some other price signal?

1. <u>CCS and its mitigation potential</u>

The committee has already heard a great deal about the science and technology of CCS and therefore I do not propose to spend any time explaining how CCS "works", although I am of course more than happy to address any questions. Suffice to say CO_2 can be effectively captured from emissions using various pre and post combustion techniques; it can be readily transported by pipeline and it can be injected into suitable rocks where it will remain safely and effectively sequestrated for thousands of years and longer.

CO_2 is currently injected into geological formations in many parts of the world for enhanced oil recovery (EOR) and to avoid emitting CO_2 derived from natural gas production and processing. One plant in the USA injects the CO_2 derived from coal gasification as part of the Canadian Weyburn EOR project. A number of coal-based CCS projects are proposed for North America and Europe.

In Australia a number of LETDF projects will progress CCS in a commercially significant environment. These include the Hazelwood Project (innovative coal drying plus a small scale post combustion plant), the Fairview Project (post combustion capture plus CO_2 –enhanced coal bed methane), the Oxyfuel Project (oxy-firing to produce concentrated CO_2 and medium scale storage), and the Gorgon Project (large scale CO_2 storage). In addition the proposed Zerogen Project (coal gasification to produce concentrated CO_2, then storage) and the Monash Project (production of liquid hydrocarbon from coal and storage of by-

product CO_2) could involved future large scale CCS. Most of these projects are unlikely to commence injection of CO_2 until 2010 or later.
CO_2 storage at a pilot or demonstration scale is being undertaken in Australia for the first time by CO2CRC in the Otway Basin in Western Victoria, where we will start drilling in the next few days and commence CO_2 injection in mid-2007. Approximately 100,000 tonnes of CO_2 will be injected to a depth of around 2000m. We will undertake several years of highly sophisticated monitoring of the CO_2 plume, to demonstrate that CO_2 can be safely stored and effectively monitored under Australian conditions.

CCS has the potential to make deeps cuts in emissions from major stationary sources (power stations, industrial plants, gas separation facilities) but this cannot happen overnight, with a lead time of five years or more being likely for a new power station with CCS. In the long term, moves to the hydrogen economy are likely to based initially at least at least on fossil fuels and there too, CCS has the potential to plan a key enabling role.

CO2CRC has modelled the possible role of CCS in limiting global emission. The concept in the modelling (based on IPCC emission scenarios such as IS92 a) was to test the temporal boundaries of CCS deployment and in particular to determine if it could significantly decrease the likely concentration of CO_2 by the year 2100. Without going into detail our model indicated that under the IS92a model for example, without CCS, the atmospheric concentration of CO_2 would be 721 parts per million by 2100, whereas if CCS was deployed globally (commencing in 2015 and ramping up over the subsequent 40 yeas to 2055) then the atmospheric concentration of CO_2 would be 556 parts per million, a very significant decrease by any measure. Could the concentration be decreased even more by more rapid deployment of CCS. Yes, but the cost appears to rise quite significantly if deployment commenced earlier than 2015 or if it was ramped up over say 20 years rather than over 40 years. The deployment of post combustion capture on a "retro fit" basin could also further decrease atmospheric concentration.

In conclusion, CO2CRC has a high level of confidence that CCS works now and will be used on a wide scale in the future to make deep cuts in CO_2 emissions. Having said that, CO2CRC also wishes to emphasis that it sees CCS as part of a portfolio including energy efficiency, increased use of renewable, switching to low carbon fuels and CCS. But for as long as we use fossil fuels for power generation and transport CCS is likely to be a very significant part of that portfolio.

2. Is there enough storage capacity in Australia and globally?

The IPCC Special Volume on carbon dioxide capture and storage examined the question of global storage capacity and concluded "while there are uncertainties, the global capacity to store CO_2 deep underground is large": and also "Available evidence suggests that world wide it is likely that there is a technical potential of at least 2000 Gt CO_2 (545Gtc) of storage capacity in geological formations". The IPCC Report also states "The economic potential of CCS would amount to 220-2200 Gt CO_2 (60-600Gtc) cumulatively, which would mean that CCS contributes 15-55% to the cumulative mitigation effort world wide until 2100".

Therefore overall the global storage capacity appears to be large and in many though not all cases the major stationary sources of CO_2 are located near the potential storage sites. Work by CO2CRC on behalf of APEC, examined the storage capacity of East Asia and concluded that storage potential existed in many countries including China (an increasingly significant CO_2 emitter). However not all countries or regions are regarded as prospective for storage of CO_2 in deep saline aquifers (one of the most important storage options) with India appearing to have limited opportunities for "conventional" geological storage. However it in important to stress that in many area there is poor knowledge of the deep geology and many areas still require comprehensive assessment of their geological storage opportunities.

The storage potential Australia is better known than that of most other countries but even here, more work needs to be done. In 1999-2003 APCRC (the precursor of CO2CRC) undertook a large scale assessment of Australia's storage resources and identified it as likely to very large able to take Australia's stationery CO_2 emissions for hundreds of years. That outcome provided the basis for the more detailed assessments of storage potential that CO2CRC is now undertaking. Those studies in areas such as the Gippsland Basin of Victoria, the Perth Basin of WA and some of the Central Queensland Basins, provide further grounds for optimism that in high emission areas such as the Latrobe Valley, central and southern Queensland and Kwinana adequate useable storage capacity exits. Our knowledge of the storage potential of South Australia and the Northern Territory is quite limited at this time, as is our level of knowledge of NSW.

The Inquiry has previous discussed the opportunities for applying CCS in New South Wales and therefore it is worth outlining the current level of knowledge in that State and take the opportunity to address a quite misleading impression that NSW is a "lost cause" for CCS. NSW (particularly in the Wollongong-Sydney-Newcastle region), produces more CO_2 emissions than any other State and therefore from that perspective it is a prime candidate for CCS. There are also large sedimentary basins in NSW. But the basins in the vicinity of the major emission sources such as the Sydney and Gunnedah Basins are geologically complex and their rocks are "tight" i.e. they appear to have limited pore space and low permeability. However, in fact we know very little about the deep rocks in NSW i.e. below 1000 metres as there has been very little deep drilling in the state. A key area, the offshore Sydney Basin, which is geographically ideally sited close to the Newcastle area is hardly known and has never been drilled. It may or may not be suitable for geosequestration. In other words we know so little about the deep geology of the Sydney-Gunnedah Basins that we are in no position to jump to conclusions about their storage potential. CO2CRC is now working with New South Wales to undertake a comprehensive and definitive assessment for the storage potential of the State and views on the applicability of CCS to NSW must wait until that assessment is made.

In conclusion the global storage capacity is large and overall is likely to be able to meet anticipated needs to 2100. However there are regions where this may not be the case and more work is needed to assess such areas and perhaps develop new, more innovative geological storage models. Australia is fortunate in having a large storage potential, but there is a need to convert that potential to useable storage space. This requires detailed site specific work and whilst some work is underway more needs to be done. Parts of Victoria, Queensland and WA have high storage potential; the capacity of SA and the NT is poorly known. New South Wales requires detailed onshore and offshore studies of the deep geology (below 1000m) of its sedimentary basins before a definitive statement can be made on the potential of CCS in the state, but CO2CRC is cautiously optimistic that suitable rocks will be found.

3. <u>How much does CCS cost?</u>

The Inquiry has on a number of previous occasions sought to address the question of how much does CCS cost, how much will it cost, and what will this mean to the cost of electricity or the future viability of Australian industries? No doubt like others asking this question it has been frustrated by the lack of a clear answer. However the question and the difficulties in giving a simple answer can be compared to the difficulties in responding to the questions. How much does a house cost? One immediately has to ask where is the house, what is the area of the house (and garden), is a poorly built house or is it a high quality home that is built to last, what are the fitments and so on. Even more difficult, what will an Australian house cost in 2030?

Nonetheless despite the difficulties it is important to attempt to answer the question of what will CCS cost? Obviously could have a profound impact on future mitigation measures.

The IPCC Special Volume looked at this issue in some detail and (Chapter 8) provides a wealth of information on this issue. The costs provided by the IPCC and other studies are in $US and are based mainly on northern hemisphere capital and operating costs, which can be quite different to Australian costs. Nonetheless our experience suggests that CCS costs converted on the basis of the dollar number (i.e. do not apply a rate of exchange and operate on the basis that a $US cost is equivalent to a $A cost) is a reasonable approximation. The costs per tonne CO_2 avoided cited by the IPCC (in the SPM) for new power plants with CCS are:

Pulverized coal plant $29-51 tonne CO_2 avoided
Natural gas combined cycle $37-74 tonne CO_2 avoided
Integrated coal gasification combined cycle $13-37 tonne CO_2 avoided

However as stressed earlier it would be dangerous to take these figures and attempt to extrapolate them everywhere as CCS costs are highly project specific. Additionally these costs relate to “new build” and it is important to recognise that many of the existing power stations will still be operating in 20, 30 or even 40 years time. We cannot therefore ignore the option of retro fitting CCS to existing power stations. Will this be “economical”? This is perhaps the wrong question – the question should be “Would this significantly decrease CO_2 emission to the atmosphere?” And to this question, the answer is a definite yes!

CO2CRC has sought to address the issue of costs in an Australian context and is involved in a number of technological developments that it believes will bring down the price of CO_2 capture. This would suggest that under some circumstances retrofitting of post combustion capture will be a cost effective measure in terms of cost of CO_2 avoided. The work also indicated that a regional approach to CCS (bringing a number of emitters together to combine facilities and share costs) may be a cost effective option. For example modelling of a regional CCS project with multiple power stations in the Latrobe Valley based on the proposition of 50 million tonnes CO_2 stored per annum, with a project life of 40 years and storage in the offshore Gippsland basin indicated a cost of AU$38 per tonne CO_2 avoided. Mitigation costs will decrease further if the CO_2 is derived from a coal to liquids project for example.

As pointed out by many others, the majority of the cost of CCS is in the capture process and many of the criticism based on CCS costs relate to present day costs.

- Low carbon power with CCS is at the start of the cost curve
- Low carbon power with CCS already appears to be competitive with some other forms or carbon free or low carbon energy,
- Costs for low carbon power with CCS are site specific and fuel specific and will vary from country to country
- The estimated costs of nuclear appear to vary from around US$/MWh $30 in Europe to $40-60 in Canada to $60-70 in the USA. In other words the lower end of nuclear costs appears to be cheaper than CCS; the upper appears to be more expensive.
- A range of publicly available studies indicate that the cost of electricity from plants with CCS can be significantly reduced, with IEA, DOE, EC and our own studies suggesting cost reduction of 20-30% over the next 10-20 years.
- As emphasised elsewhere, Australian response to climate change will require a portfolio of technology options.

If the world is going to continue to use fossil fuels (as indicated by the International Energy Agency and IPCC projections) then we have no alternative but to apply CCS on a massive scale and as soon as we reasonably can. As pointed out by the IPCC, "…inclusion of CCS in a mitigation portfolio is found to reduce the cost of stabilising CO_2 concentrations (in the atmosphere) by 30% is more". It will take time and more research to get better CCS economics. But the developments that need to be progressed are well-trodden ground for process engineering companies and chemical engineers in general. There is considerable confidence that the improvements that will underpin the low-cost projection for CCS can and will be made.

However what needs to be remembered is that

In other words there are well founded grounds for expecting costs to reduce, these reductions will come from:-

- Economic of scale
  - engineering literature suggests a 20% cost reduction for a doubling of the unit capacity
- Standardization
- Innovation and application of advanced technologies

Deployment of CCS will result in increased costs for electricity, just as deployment of renewable energy under MRET costs a total of around $380 million per annum to mitigate approximately 6 million tonnes of CO_2 per annum i.e. a cost of approximately $60 a tonne CO_2. Obviously if all the costs of CCS fall into one electricity producer or one group of customers then the economic impact would be severe. However spread across the entire community, the cost on the average electricity bill would not be significant. To put the cost increase for electricity in perspective, a decision by an electricity generator to deploy CCS at a cost of A$20 per tonne CO_2 avoided would increase the cost at the generator by around 50% whereas the cost increase to the domestic customer, would be in of the order of 15%. If however the cost was spread across the entire grid then the cost would be one or two percent to the consumer. CO2CRC has recently priced the impact on electricity prices for a hypothetical scenario of introducing one new 1000 MW power station with CCS into the grid every two years and then average the extra cost of that "clean" electricity across the grid. The average cost increase over the entire grid is less than two percent for each new CCS generator brought on line. Would this be acceptable to the community? The response to the MRET cost increase suggest that it would be, if it was clearly demonstrated to the community that this was a cost effective way of making real cuts in emissions.

In conclusion CCS costs are relatively high at the moment but they are at the start of the cost curve and will decrease. CO2CRC and other organisations have suggested a target mitigation cost of around $20 tonne CO_2 avoided and this is seen as an attainable target in the larger term. Cost decreases of 20-30% are feasible over the next 10-20 years. There will be an increase in electricity costs but provided CCS implemented over a number of years, the cost is likely to bearable to the domestic users and to the economy as a whole.

4. <u>Why is CCS taking so long to deploy?</u>

In fact the concept has only received real consideration as a viable technology in the past decade. Therefore the uptake from concept to "mainstream" has been remarkably fast. By comparison wind mills have been used to produce electricity for 100 years and solar cells for 50 years. Nonetheless many of the components for CCS are in fact mature in that they have been deployed by the petroleum industry for many years. What is new is bringing all those components together to produce low emission fossil fuel based power generation systems.

Therefore if much of the technology is mature why is it not being more rapidly deployed? The single most important reason is cost and the lack of a frame within which to spread that cost. As indicated in the previous discussion on electricity costs, unless there is government assistance or a mechanism for spreading the cost, the first power company to deploy large scale CCS would produce uneconomic electricity and would rapidly go broke!

This clearly is presently a barrier; the LETDF scheme will help to meet some CCS costs but the only coal-based LEFDF Project that is proposing to deploy CCS, the Oxyfuels Project, whilst a highly innovative and very important project for Australia but will have no impact on Australia's CO_2 emissions for many years. This will only happen when CCS is deployed on full scale power stations and this is unlikely to happen this decade. Overseas the US FutureGen Project is planned for about 2012 and a number of the European projects are expected to have similar time lines. Therefore by comparison with other countries, Australia is not being unduly slow to deploy CCS.

Are there technologies barriers to deployment of CCS? The need to confirm storage capacity in some areas has been previously discussed and until this is done, this will be an inhibition in some areas. Obviously there is a need to bring costs down significantly and we are confident that this will happen and in doing so will speed up deployment. Are there regulatory or licensing barriers to deployment of CCS? The experience of CO2CRC in taking forward the Otway Basin Geosequestration Project has been that there are far more legal and regulatory obstacles to overcome than originally anticipated. These include land holder issues uncertainties over which regulatory bodies have responsibilities, lack of knowledge of CCS, multiple layers of regulations etcetera. This is not in any way to criticise the regulatory regime in Victoria, for the Government and the Authorities in that State have been extremely supportive of the project. Rather it is to point out that in any jurisdiction there are many areas where it is very unclear which regulation apply to CCS.

The lack of clarity on the issue of long term liability for geologically sequestration CO_2 is also a potential inhibition. Many proponents of CCS projects are willing to accept the need to accept liability for the operational and closer phases of a CO_2 storage project but few if any are willing to accept responsibility for stored CO_2 for hundreds of years or longer. In fact the risk of leakage from a well characterised geological storage site in very low and therefore the liability to be carried is similarly low. But it is impossible to obtain insurance extending out for hundreds of years and few if any of the companies presently in existence are likely to exist on say 500 years time.

There appears to be no option other than government taking on long term liability for geological storage of CO_2 , given the long time scales and the fact that the community in unlikely to accept any organisation other than government as appropriate to take on such a long term responsibility. Given that there is a major community benefit in decreasing CO_2 emissions to the atmosphere this would seem to be a reasonable trade off of roles between the short term responsibilities of industry and the long term responsibility of government. However there is a need for clarity in this liability role.

Finally there is also a need to ensure clarity on the issue of licensing of offshore geological storage. This matter is under active consideration by government at the present time, it is important that momentum in maintained as no CCS proponent in likely to make the necessary massive investments to take offshore CCS forward unless there is absolute clarity on the terms of any offshore CCS licence.

In conclusion, there are no major technical impediments to the uptake of CCS but there is a need to more definitely determine storage potential and bring costs down. This will happen as CCS is deployed and it is important to stress that we cannot wait until; CCS can be deployed at a particular (and arbitrary) cost threshold of $20, $30 or $40 a tonne CO_2 avoided. We need to now get CCS underway and make deep cuts in emission.

There are some potential licensing, regulatory and liability issues that need to be resolved to ensure that they do not unduly slow CCS implementation. But at the present time one of the biggest single impediment to CCS uptake is an inability of any generator deploying CCS to get a fair return on their investment and their willingness to take on the risk of being the first to deploy the technology. Government measures will be essential to overcome this barrier, whether through direct financial assistance, or through the opportunity to average the extra cost of CCS over the entire electricity grid or perhaps through some price signal.

5. <u>What is the potential impact of emission trading on CCS deployment?</u>
This question has clearly come into focus with the recent release of the report of the governments' task force on emissions trading. As previously pointed out, the biggest impediment to the uptake of CCS is the cost of the implementation of the technology and the current inability to receive an adequate commercial return on that investment. It can reasonably be argued that any company that is a major emitter of CO_2 (such as a power company) carries a significant risk of being adversely impacted by future measures that puts a high cost of carbon emissions. A decision to decrease that risk by implementing CCS at a new-build power station would be one option, but in the absence of any clarity on a future carbon price, the cost incurred in offsetting the risk could be greater than the cost of buying carbon credits for example.

The lack of a long term policy or market setting for carbon inhibiting the capacity of industry to make longer terms investment decisions regarding the implementation of CCS? Probably. Would an emission trading regime remove this impediment to deployment? Possibly, but effectiveness would depend on the manner in which the trading regime was defined. If too many credits were issued then the price of carbon might be too low to encourage anybody to take up CCS (or maybe other mitigation measures). If the time frame within which the ETS was expected to function was too short, then most companies would probably avoid a long term investment in CCS. Further, if the geographic boundaries of the ETs were limited to a state or a country then a high technology mitigation responses such as CCS may not be taken up to the extent that it would be in a global scheme.

Australia might be well placed to benefit from a global ETS that incorporated CCS in that it does have a large geological storage resource; it is one of the leading countries in development of the technology and its energy infrastructure is readily amenable to the deployment of CCS. There may also be added benefits such as the export of technology, support for the coal industry (Australia's biggest export)

As pointed out earlier there are a number of steps that can be taken to accelerate the deployment of CCS in addition to emissions trading. The opportunity to spread the cost of technology deployment whether through an MRET-type scheme for low emission technologies or an "averaging" mechanism. Alternatively Government could decide to support CCS through public funds or through a levy on the electricity sector, to meet the cost of first movers in the implementation of CCS through an expanded or modified LETDF-type scheme. There is no question that this would in turn have the added benefit of helping to position Australia to be a service provider in the CCS industry that is already developing. It will also help to protect Australia's coal exports from the ill-considered criticism that they are adding to global emission (and should therefore be halted), by taking forward CCS as a mechanism for minimising those emissions in the user country.

In conclusion there are a range of options for accelerating the uptake of CCS and undoubtedly emissions trading are one such mechanism. It has the benefit that it is technology neutral and is likely to produce the least cost outcome in the short term. However tackling the greenhouse problem is a long term issue that requires global action. Therefore any emissions trading scheme must be within the right frame of being long term, global and structured to reflect the cost of CO_2 emission on the environment and the economy. Nor should it be structured in a way that sets the price at a level that is ineffective in producing the necessary changes in industry and the community. CO2CRC has always indicated that CCS has to be part of a mitigation portfolio and to the extent that an ETS is technology will facilitate the development of the most effective portfolio mix, it is to be welcomed.

It must be accepted that whilst some may see the greenhouse problem as being a consequence of technology and the massive increase in the demands of society for electricity transport etc, it must also be recognised that technologies such as CCS, are likely to provide part of the solution. The Australian Government and the Opposition have indicated a wish to see Australia play its part in developing an effective global response to climate change whilst at the same time recognising the need to maintain energy exports CCS, can help to achieve this.

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This submission should not be taken to necessarily present the views of CO2CRC Participants, the CO2CRC Board or individual researchers. It has been developed by the CEO and members of the Senior Executive Team as a contribution to the Inquiry.

ADDITIONAL EVIDENCE PRESENTED TO THE HOUSE OF REPRESENTATIVES INQUIRY INTO GEOSEQUESTRATION BY THE COOPERATIVE RESEARCH CENTRE FOR GREENHOUSE GAS TECHNOLOGIES

Background

The Cooperative Research Centre on Greenhouse Gas Technologies (CO2CRC) is a world leader in geosequestration research, and in the development and demonstration of key CO_2 technologies.

CO_2 can be captured from flue gases using a range of pre- and post-combustion systems and a variety of separation techniques (solvents, membranes). But application of these techniques to stationary sources such as power stations is expensive (currently 70-80% of the total cost of geosequestration). Therefore, research by CO2CRC and other organisations in Australia and overseas is focused on bringing down these costs. In the case of geological storage, the technology is more mature and cost is less of an issue, but it is important to demonstrate to the community that geological storage is safe and effective, and to identify adequate CO_2 storage capacity to meet Australia's current and future needs.

As part of a portfolio of technologies to address greenhouse concerns, geosequestration has the potential to enable us to make deep cuts in CO_2 from stationary emissions. Given that the International Energy Agency considers there will be an increasing use of fossil fuels in the future, geosequestration will be an essential component of the global mitigation strategy. Australia is fortunate in having abundant coal and gas resources and extensive geological storage opportunities; it is therefore well-positioned to include geosequestration in its portfolio of low-emission technologies.

Geosequestration will benefit the environment, but there will be an increase in the cost of electricity.

CO2CRC has previously provided written evidence to the House of Representatives Inquiry into Geosequestration. The Inquiry has now requested responses to five specific questions and these are addressed below.

Responses to Questions

1. ***One of the arguments put forward by witnesses is that we should wait a bit longer because as with every new technological development, costs will fall over time. Isn't this argument a bit "chicken and egg"? How can we expect prices to fall if the technology is not fully tested commercially?***

As previously acknowledged, the deployment of carbon dioxide capture and storage (CCS) will initially be costly and, unless there are appropriate price signals, government assistance, or price differentials for low-emission electricity, then no electricity company will deploy CCS. Indeed, if we were to wait until electricity derived from clean coal is the same price as electricity from a conventional coalfuelled power station, then we will wait for ever! The deployment of advanced technologies such as CCS in order to mitigate CO_2 emissions will inevitably result in increased costs for electricity. However, those costs will decrease over time, with the Intergovernmental Panel on Climate Change (IPCC) suggesting a decrease of 20-30% over the next decade. Our research supports that prognosis.

2. ***Is there still a lot of work to be done on the selection of suitable long-term storage sites? A lot of publicity has been given to the vast amounts of potential storage sites in Australia but when it comes down to an actual commitment to use a site, concerns are expressed by various experts about fault line/fractures, acidity problems as well as wider environmental impacts. Concerns have been expressed about the Gorgon project on the NW Shelf using the Barrow Island storage and even ExxonMobil has expressed concerns about the suitability of its Bass Strait field for the proposed Monash Energy Project in Gippsland.***

The selection of sites for long-term storage of CO_2 is a process that is analogous to petroleum or mineral exploration, which starts by establishing a "resource" that may be economically exploitable, before progressing to definition of a "reserve" that can be exploited at a specific cost. For storage sites, this involves first the broad identification of sedimentary basins that are likely to be prospective for storage, then the more-detailed assessment of smaller areas or particular geological units to confirm their likely suitability as a drilling target, and finally undertaking the actual drilling and associated testing of the site to confirm that rocks are indeed suitable for the injection and long-term storage of a specified volume of CO_2.

We have established over the past seven years that Australia does have a large storage resource, and we have also determined that a number of areas are prospective for long-term CO_2 storage. However, as yet we have confirmed in only a limited number of areas that the storage potential is an exploitable storage "reserve". The most prospective areas are now fairly well known and include areas such as offshore Western Australia, offshore Victoria and central Queensland. Our research indicated that issues such as "fault/line fractures" require careful consideration but do not constitute major constraints in most areas, either because they are unlikely to become conduits for movement of fluids such as CO_2, or because the injection program can be conducted in a manner that ensures that there is no impact on the faults.

In the specific example of Gorgon, our work to date does not indicate technical issues that would adversely impact on the use of Barrow Island for the deep storage of CO_2. In the case of the Bass Strait area, CO2CRC research indicated that the geology is suitable for the long-term storage of large volumes of CO_2. Obviously any storage activity would need to be conducted in such a way as to ensure that it did not adversely impact on oil or gas resources, and CO2CRC modelling supports the view that this can be done.

There are some important areas where we have yet to acquire the necessary geological information to enable us to determine the storage prospectivity. One of the least known areas in this respect is New South Wales, where there is little information currently available on the deep geology (i.e. below 1000m). The argument has been advanced that the rocks of the Sydney basin are impermeable and therefore unsuitable for geological storage of CO_2 . This may or may not ultimately prove to be correct, but it is far too early to jump to such a conclusion. CO2CRC has commenced a storage assessment program for New South Wales and is in discussions with various bodies on extending the scope of that work both onshore and offshore.

In conclusion, a great deal of work has been undertaken to assess the long-term storage potential of Australia and more needs to be done. We are confident that in many areas there is indeed considerable storage potential. But identification of actual storage sites is a costly exercise that requires more detailed work which is undertaken once the impetus to store CO_2 has been clearly defined. This detailed work has been undertaken by CO2CRC in a small number of areas but a great deal more work will need to be done as the need for CCS increases.

3. ***If CCS is the way ahead for continued use of fossil fuels in a carbon-constrained world then what implications does this have with respect to the level of CO_2 emissions post 2010 if most of the commercialisation is not likely to be realised until the second half of the 21^{st} century.***

If there is no significant application of CCS to fossil-fuel based electricity until the second half of the 21^{st} century then the concentration of CO_2 in the atmosphere will continue to rise steeply throughout the century. Depending on the model used, the concentration by 2100 in this circumstance, is likely to be at least double present-day concentrations and perhaps considerably higher. CO2CRC has undertaken modelling of the consequences of various delays in the uptake of CCS. The optimum outcome in terms of atmospheric concentration of CO_2 and cost was achieved in the model by commencing wide-scale deployment of CCS in 2015. There is no technical or economic reason to delay CCS deployment until the second half of the 21^{st} century. Indeed any such delay would almost certainly result in a far greater overall cost of mitigation.

4. ***Your Cooperative Research Centre has had the benefit of focusing solely on carbon capture and storage and would be across all international developments in this area. From your experience, what do you believe would be the key driver to get more commercial scale operations up and running? Does it simply come down for the need to put a price on carbon or are there still some aspects of carbon capture and storage that require further development and demonstration?***

There are no fundamental technical impediments to the deployment of CCS, but there is a clear need to achieve greater efficiencies and bring down costs, particularly in the areas of CO_2 capture. It is a normal feature of any new technology uptake that costs come down and efficiencies improve as deployment increases. Therefore it is essential that deployment does not wait until costs come down to some arbitrary level. The important thing now is to start to bring down emissions by deploying CCS.

Will this be facilitated by putting a price on carbon? This depends on the nature of the price signal. For example, application of carbon tax may do little more than result in a short-term response or in creative carbon accounting, or the tax could merely become another revenue-raising exercise. If, on the other hand, it is applied to facilitate the long-term development of low-emission technologies such as CCS then the outcome could be beneficial. As the recent IPCC Fourth Assessment report points out, tackling the greenhouse issues will require long-term action. Therefore governments must accept the need for long-term mitigation strategies, including ensuring that long-term technologies have the opportunity to mature and reach their full mitigation potential. This includes CCS. Ultimately, CCS must be able to compete on the basis of cost-effectiveness in an open emissions trading scheme. But it, along with renewables, will need intervention for some time to come. The Australian Government's Mandatory Renewable Energy Target scheme (MRET) is an example of government intervention to facilitate uptake of renewable-energy technology, and it is necessary that other technologies are appropriately assisted to enable them also to achieve their long-term mitigation potential.

In the specific case of CCS, if the world is going to continue to use fossil fuels (as indicated by the International Energy Agency and IPCC projections) then we have no alternative but to apply CCS on a massive scale and as soon as we reasonably can. As pointed out by the IPCC, ". . . inclusion of CCS in a mitigation portfolio is found to reduce the cost of stabilizing CO_2 concentrations (in the atmosphere) by 30% or more".[1] Nonetheless, a number of measures will be required to ensure deployment of CCS, of which an emissions trading scheme will be one. It will take time and more research to get better CCS economics. But the developments that need to be progressed are well-trodden ground for process engineering companies and chemical engineers in general. There is considerable confidence that the improvements that will underpin the lower-cost projection for CCS can and will be made. Despite this, the price of electricity will increase, with the increase in cost initially falling unduly on any electricity producers that deploy CCS.

Ensuring this does not inhibit the uptake of CCS will require a policy regime that gives electricity producers confidence that the necessary investment will make them more, rather than less, competitive over the long term. Similar long-term confidence will be required to encourage industry to make the substantial investments needed in research to reduce the cost of CCS technology. A policy regime which gives clear long-term price signals (through a cost on emissions and/or subsidies for reducing emissions, particularly by the early movers) will be necessary to stimulate the investment needed to ensure that CCS, and other low-emission technologies, reach their potential.

CO2CRC always emphasises that a portfolio of technologies will be required to address greenhouse concerns. CCS will be part of the portfolio mix that will ultimately be based on a balance between technology cost and emission rate (or mitigation effectiveness). CO2CRC believes it is unfortunate that on occasions one technology or another is seen as providing all the answers. Polarisation of the debate is not helpful, any more than it is helpful to try to address the long-term issue of greenhouse by taking short-term measures.

The magnitude of the task of addressing greenhouse issues is highlighted by consideration of the scale of the infrastructure that will be required for CCS. This

[1] *Carbon Dioxide Capture and Storage: Summary for Policymakers and Technical Summary,* Intergovernmental Panel on Climate Change, p11

could be on the scale of the electricity industry itself or the petroleum industry, for example. In the past some of the major infrastructures (such as water) were built by governments because of the public good that they endowed. It could be argued that a high level of government intervention may similarly be needed to address greenhouse concerns, but equally well the private sector may be able to meet the need, perhaps in response to appropriate carbon pricing signals coupled with some early support mechanisms. In either case, it will take some time to get the necessary financial and physical infrastructure in place, providing once again a reason why we should move speedily to implement CCS at scale.

5. ***Carbon dioxide has been around from time immemorial and many sceptics would argue that the CO_2 emissions from man-made activities still only account for around four percent of the total CO_2 in the atmosphere (refer submission no.1). Is this a valid assessment and if so, then why is such a small percentage causing so much concern? Is this the "straw" that is going to break our back or is it simply recognition that this small percentage is the only amount that we can have some control over?***

CO2CRC is not involved in atmospheric research but based on a general understanding of the issues it points out that carbon dioxide concentrations in the atmosphere at the present day are approximately 380 parts per million compared to approximately 280 parts per million at the start of industrial revolution. It is likely that most (and probably all) of this increase is due to anthropogenic emissions over the past 200 years resulting primarily from the use of fossil fuels but with significant contribution from increased burning of wood and clearing of forests.

This suggests that of the order of 30% of the CO_2 in the present day atmosphere is the result of man-made activities. CO_2 constitutes only 0.04% pf the atmosphere, but its presence is of critical importance. It keeps the earth at a comfortable temperature (without it the world would virtually be an ice ball), thereby ensuring that it is habitable. CO_2 is essential to virtually all forms of life, either directly or indirectly.

Given that carbon dioxide is a gas of such crucial importance to life on planet Earth, it is not surprising that an increase of 30% in its atmospheric concentration should pose a threat to many aspects of the earth system.

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