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A solution to climate change?

The objective of the CRC for Greenhouse Gas Technologies is to develop cost-effective technologies to reduce carbon dioxide emissions to the atmosphere. A closer look at global warming and the methods being developed to capture carbon dioxide are presented here.

Atmospheric concentrations of greenhouse gas are increasing and have been linked to global warming, rising sea levels and severe weather conditions. This is arguably the leading environmental issue the world currently faces. Anthropogenic emissions of carbon dioxide contribute significantly to global warming. Figure 1 shows a close correlation between Antarctic temperature and atmospheric CO_2 concentrations. Model projections from the Intergovernmental Panel on Climate Change show that if we continue on our current course, the average global temperature will increase by a catastrophic 3–6°C as a result of increasing CO_2 levels.[1]

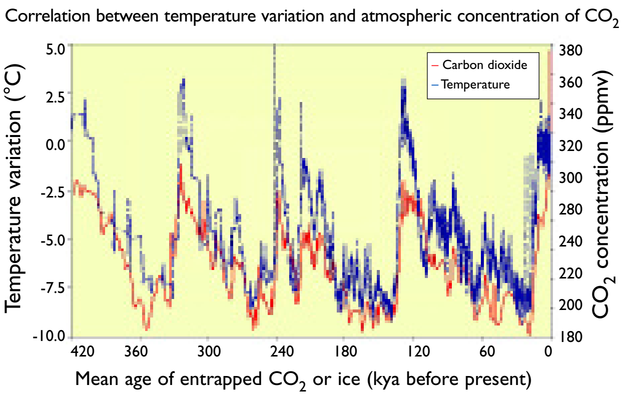

Figure 1. Ice core data from the Russian Vostok station in East Antarctica. The data extend through four climate cycles. (Data adapted from reference[2,3].)

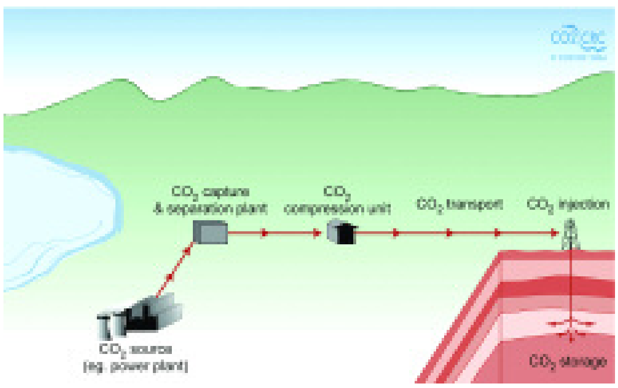

Figure 2. Flow diagram of the CCS process.

Although Australia did not ratify the Kyoto Protocol, the Australian Government acknowledges the threat of global warming and is seeking a way to reduce CO_2 emissions. Globally, implementation of a portfolio of solutions including reducing energy consumption, switching to lower carbon fuels, increased use of renewable energies, increased use of nuclear energies and CO_2 capture and storage will be required.

The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) was commissioned by the Australian Government in July 2003 to develop a sustainable future for our power and manufacturing industries. The program has been funded for 7 years with total resources of $120 million and aims to significantly contribute to reducing CO_2 emissions over the next decade. To ensure Australia's access to leading edge technology, research is being carried out in collaboration with universities and research institutes, government organisations and companies worldwide. The aim of CO2CRC is to help Australia decrease its greenhouse gas emissions while maintaining the competitiveness of its industries through the development of CO_2 sequestration (carbon capture and storage – CCS) technologies. The idea is to capture CO_2 from industrial sources that would otherwise be released to the atmosphere and inject it deep underground for long-term storage in geological formations (Fig. 2). CO_2 could be injected into depleted oil and gas fields, deep saline reservoirs or deep unmineable coal deposits. A spin-off company, Innovative Carbon Technologies Pty Ltd, will commercialise CCS technologies that have been developed by CO2CRC.

Half of Australia's CO_2 emissions could potentially be sequestered (Fig. 3). The majority of these emissions are from coal or gas-fired power generation.

Technology for CCS is currently prohibitively expensive. Separation of the CO_2 from other flue gases is the most significant factor in this expense, contributing up to 80% of the overall cost. Compression and transportation to a storage site (10%) and storage in geological formations (10%) contribute the remaining costs. In a model developed by the International Energy Agency,[5] the cost of electricity is projected to increase by 4–8 cents per kWh with currently available CCS technology. An increase of 1–1.5 cents per kWh (or a 75–80% decrease from currently projected CCS costs) is the aim of CO2CRC.

Capture options being considered are outlined in Table 1. Studies are also being conducted to project the cost associated with these technologies. The University of Melbourne is focused on the development of absorption and membrane gas separation systems.

Absorption processes have been established for 60 years for the removal of H_2S and CO_2 from gas streams in chemical and oil industries.[6] The gas stream is fed into a packed column where it comes into contact with a solvent that chemically reacts to form an intermediate product with CO_2 (Fig. 4). Application of heat removes the carbon dioxide and allows the regenerated solvent to be recycled. This method is best suited to the treatment of low-pressure flue gas. However, a large quantity of energy is required to release the CO_2 and research is being carried out to minimise this energy requirement. Also, a new efficient packing material, the 'Plum Flower Mini Ring' developed by Tsinghua University (Beijing) is being tested on a pilot scale. This innovative design promises to increase the contact area between gas and liquid phases and thereby reduce capital costs.

A hybrid process combining absorption and membrane technology is also emerging as an alternative. This approach was first demonstrated on a pilot scale (a 2610 kg/h feed stream of 85% CO_2 purity) by Falk-Pedersen of Kvaerner.[7] CO_2 diffuses through a hollow fibre membrane where it is absorbed into a solvent. This process has many advantages over conventional absorption; most notably, membrane contactors offer a reduction in equipment size (and therefore capital cost) and the ability to operate in any orientation. This would be particularly useful for offshore applications where space and mass constraints apply. However, for optimal performance it is important to ensure that solvent–membrane systems are chosen so that the pores of the membrane remain gas-filled. Research is focused on modifying membrane properties so that this constraint can be maintained when operating with commercially available solvents.

Gas separation membranes rely on a pressure differential as a driving force for separation. CO_2 selectively dissolves into the membrane, diffuses through the membrane bulk and dissociates at the permeate side. This technology is already commercially proven for the removal of CO_2 from natural gas. However, there are a number of technical barriers to its implementation as a CCS technique. First, the low membrane flux rates at typical flue gas pressures will probably prevent its application on a large scale in standard combustion processes. Membrane processes may be more suited to the higher gas pressures associated with CO_2 separation from coal gasification and syngas streams (pre-combustion capture). The commercial polymeric membranes are useful only for low temperature applications (<300°C). Further, extended exposure to CO_2 causes membrane plasticisation and compaction, which can lead to reduced selectivity for CO_2 and shortened membrane lifetimes. Research is being carried out to increase membrane temperature tolerance and reduce plasticisation using polyimide/epoxy blend membranes. The polyimide component provides the selectivity towards CO_2 while the epoxy component adds strength and reduces plasticisation effects.

Carbon nanoporous membranes impart selectivity for CO_2 separation on the basis of both molecule size and surface absorbtivity. They are particularly suited for high temperature applications. The two types of nanoporous structures that are being tested are nanoporous carbon membranes and carbon nanotubes. Nanoporous carbon membranes are made by coating a polymer onto a porous stainless steel support and heating it in a furnace with an argon

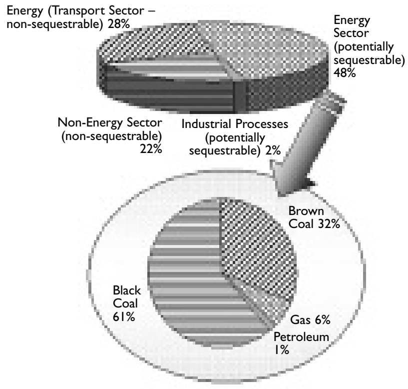

Figure 3. Sources of Australia's CO_2 emissions where C&S technologies can be applied. (Data adapted from reference.[4])

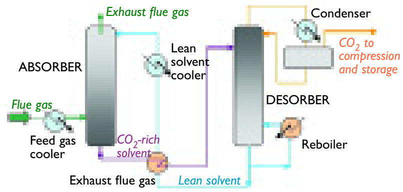

Figure 4. Flow diagram of an absorption process used to remove CO_2 from power plant flue gas.

Figure 5. Clare Anderson manufacturing nanoporous carbon membranes at The University of Melbourne.

Table 1. Carbon dioxide capture research projects being carried out within CO2CRC. The shaded projects are those being conducted at The University of Melbourne

Project title	Description	Constraint	Major problem
Solvent-based systems			
Solvent absorption	Test new packing material and reduce energy requirements on a pilot scale	Minimal impurities in feed	Energy required for regeneration of solvent
Membranes in gas absorption	Modify membranes and test in laboratory scale membrane gas absorption modules		Wetting of membrane pores by solvent
Innovative membrane systems			
Polyimide membranes	Test polyimide gas separation membranes on a laboratory scale and at higher temperatures	Low temperature, high pressure feed	Membrane plasticisation and ageing
New membranes	Develop superior gas separation membranes		
Nanoporous membrane	Test carbon nanoporous structures on a laboratory scale	Currently expensive	Selectivity for carbon dioxide
Module design; The University of New South Wales	Optimise membrane module hollow fibre designs	Pressure drop across module	Laminar flow inside fibres
Inorganic membranes; The University of Queensland	Development of inorganic membranes to selectively	Potentially expensive	Selectivity for carbon dioxide
Innovative pressure swing adsorption (PSA) systems			
Novel adsorption cycles; Monash University	Develop novel adsorption cycles and contactor design on a laboratory and pilot scale	Adsorptive capacity of solids	Large equipment sizes
New materials with better selectivity and tolerance to impurities; Monash University	Test nanocomposite mesoporous solids		
	Test inorganic–organic hybrid membranes		
	Test electrically regenerable monolithic adsorbent carbons		
Hydrate formation and cryogenic capture systems			
Cryogenics; Curtin University	Optimise hydrate formation and decomposition processes	High CO_2 concentration	High energy requirements

atmosphere (Fig. 5). The high temperatures used (300–800°C) result in the formation of nano-sized pores. This technology is in an early stage of its development so its potential is largely unknown.

In summary, global warming is being accelerated by increasing CO_2 emissions. If we wish to stabilise CO_2 concentrations at twice pre-industrial levels by the end of this century, we will have to reduce our emissions to at least half of 1990 levels.[8] Cost-effective CSS technologies being developed by CO2CRC will contribute significantly to this solution, particularly in the short to medium term. A range of capture technologies is being developed and applied. Each technology is likely to be implemented commercially in different areas and on different scales, depending on the source and condition of the gas stream that must be purified.

References

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