Putting CO_2 back

CSIRO Atmospheric Research

Underground sequestration could be a long-term, high-volume greenhouse gas solution. Steve Davidson looks at the work of Australian scientists assessing its potential.

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AS THE WORLD comes to grips with the greenhouse challenge – that of reducing emissions of carbon dioxide (CO_2) to limit global warming – it seems unlikely that any single approach will prove a magic bullet. One of the options showing promise is to put CO_2, the main greenhouse gas, right back where most of it comes from – deep underground.

Underground storage sounds simple enough, but what are the pros and cons? Is it just a matter of pumping the gas deep underground and forgetting it? Is it wishful thinking? Or is it a cutting edge science that will solve a lot of our greenhouse problems?

Scientists of the GEODISC program at the Australian Petroleum Cooperative Research Centre (APCRC) have been looking into the potential for underground storage or geological sequestration of CO_2 in Australia since July 1999. This is a collaborative project which includes researchers from CSIRO, Geoscience Australia, Curtin University, The National Centre for Petroleum Geology and Geophysics and the University of New South Wales. Dr John Bradshaw, based at Geoscience Australia, and several colleagues, have now published their preliminary findings and have identified a number of sites that have potential for geological storage of CO_2.

Geological sequestration basically involves the capture, separation, injection and storage of CO_2 into underground geological formations, at least 800 metres below the surface. The geological formations may be saline aquifers (those too salty to be potable), unminable coal seams or depleted gas and oilfields. Some of these occur in geological formations under both land and sea.

Geological storage is applicable only to point sources of CO_2 such as power stations using fossil fuels to generate electricity or industrial sites like iron and steel plants, cement works, oil refineries and gas processing facilities. Capturing the emissions produced by millions of vehicles is currently impractical. If, however, hydrogen was to be used as a fuel for vehicles sometime in the future, CO_2 could be captured at the production plant.

This restriction to point sources is not a great problem as, contrary to what most of us think, the coal-burning power stations that generate electricity for the nation are overwhelmingly the leading source of CO_2 emissions in Australia. About half the nation's emissions of CO_2 (that is, 264 out of some 535 million tonnes of net emissions, using year 2000 figures) have the potential to be sequestered.

Storage science

The GEODISC program is conducting research into all aspects of geological storage of CO_2. Studies are being run over a portfolio of theoretical storage sites including the Barrow Sub-basin off Western Australia, a saline aquifer and hydrodynamic trap in the Gippsland Basin

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and other geological formations. This complements earlier work on deep coal seams and enhanced coal-bed methane alternatives. In the latter, CO_2 would be injected into coal seams, where it is adsorbed onto the coal, liberating the methane. The extracted methane then serves as an energy source for industry.

Scientists are modelling how CO_2 behaves deep below the surface. They are also investigating ways of monitoring storage sites, geomechanical effects, risk assessment and gas injection technology.

Drs Lincoln Paterson and Jonathan Ennis-King, of CSIRO Petroleum Resources, have been researching the migration of CO_2 over a time-frame of tens of thousands of years as it moves through the subsurface. While it moves, it combines with rocks and dissolves into water that then becomes heavier than the surrounding water, and hence falls to deeper levels.

In a comprehensive regional overview, Bradshaw and his colleagues screened some 300 sedimentary basins across Australia and – on the basis of their geological characteristics – reduced them down to 65 promising environmentally sustainable sites for CO_2 injection (ESSCIs, for short). Each of these sites was then subjected to a ranking which took into account factors including:

- adequate storage capacity – the chance that the reservoir would be able to store the volume of gas produced by neighbouring CO_2 sources
- injectivity potential – the chance that conditions will be viable for injecting CO_2
- site details – the chance of economical and technical viability
- containment – the chance that the seal and trap will work
- existing natural resources – the chance that there are no viable natural resources that may be compromised by CO_2 storage.

Further analysis, taking other considerations into account, led the researchers to conclude that, together, the ESSCI sites have an ultimate storage capacity equivalent to 1600 years worth of Australia's net emissions of CO_2. This is an impressive figure, but Bradshaw reckons even this is a conservative estimate given that sites were only selected from a part of each basin. The trapped CO_2 should be retained in these underground geological formations for more than 100 000 years. Some research from the CSIRO scientists indicates that there may be potential for virtually limitless storage capacity where there is dissolution of CO_2 into the salty underground water.

So the capacity for geological storage is vast, but it is also important to match CO_2 sources and sinks. Plenty of good storage sites occur along the North West Shelf, but there's a lack of suitable storage sites close to the major coal-fired power stations of eastern Australia, such as those around Sydney, Newcastle and Wollongong. Storage potential in the far south-east corner, near the Latrobe Valley power stations, is very good.

Cost Tier	Emission Node	% of 1998 NGGI CO_2 Emissions	Distance to viable ESSCI
1	Moomba	0.5	< 100 km
2	Burrup Peninsula	0.9	< 100 km
3	Latrobe Valley	12	< 100 km
4	Perth – Collie	2.9	< 100 km
5	Brisbane – Tarong	3	300–500 km
6	Gladstone – Rockhampton	6.4	300–500 km
7	Port Augusta – Adelaide	1.3	> 500 km
8	Newcastle – Sydney – Wollongong	15	> 500 km

A ranking of eight emission nodes – major sources of CO_2 – ranked according to estimated underground storage costs (from lowest to highest), their distance to a viable sink, and percentage contribution to Australia's total emissions.

Some economics

Scientists at the University of New South Wales have developed a computerised model to estimate the costs of CO_2 storage in onshore and offshore reservoirs. Early estimates have been updated to take into account the effects of both corrosive and non-corrosive impurities in the CO_2 stream, closer matching of sources and sinks, and different flow rates of the gas. For offshore storage, the main costs are: compression, pipeline transport, drilling of injection wells and installing platforms. The initial capital costs are high and difficult to predict, but are based on knowledge from identical infrastructure used in oil and gas exploration and production.

Taking the combined capital and operating costs over the full life of a CO_2 sequestration project, the APCRC scientists estimate that the net present value of the overall costs of injection might range from below US$10 to as high as US$25 per tonne of gas injected.

When the CO_2 emission points are ranked according to their geological storage costs per tonne, the Moomba, Burrup Peninsula and Latrobe Valley sites, in South Australia, Western Australia and Victoria, respectively, offer the most cost-effective opportunities for geological sequestration (see the table). Together, though, these produce less than 13.5% of national emissions.

In terms of volume, sequestration in the vicinity of the Latrobe Valley will have the greatest impact on CO_2 emissions, potentially accounting for 12% of national emissions. Electricity production in the Newcastle-Sydney-Wollongong area emits some 15% of Australia's total emissions. However, on current knowledge, the region has little prospect of viable geological sequestration to match the large emissions emitted in this area. Further research may identify viable sites, but if not, the closest large storage sites could be in the Gippsland Basin, more than 500 km away.

CO_2 injection wells have a small footprint, as demonstrated by the two wells (small brown sheds) at this Enhanced Oil Recovery operation in Canada.

John Bradshaw

Some storage projects

USA
In the United States, ambitious research programs, overseen by the US Department of Energy's Office of Fossil Fuel, have an ultimate goal of developing sequestration technologies that cost $10 or less per tonne of CO_2 stored. The program forms part of a long-term initiative that, beginning in 2015, would maintain US greenhouse gas emissions at the 2010 baseline.

Europe
The European Commission is funding a number of multi-partner projects to investigate sequestration issues. For example, the Commission is part-sponsoring a project assessing the European potential for geological storage of CO_2 produced by combustion of fossil fuels (GESTCO), and a monitoring project in Canada, based on activities at the Weyburn oilfield. The Sleipner gas field is a working demonstration of CO_2 storage in a deep saline aquifer in geological formations under the North Sea. It is a high-CO_2 gas field, which has been injecting 1MT of CO_2 per year since 1996. It produces gas from reservoirs about 3000 m deep, strips off the CO_2 and injects it into the Utsira Formation at a depth of 1000 m.

Canada
In Canada, it is anticipated that future developments of work now under way could produce designs for CO_2-neutral power plants, fuelled either by mined coal or by methane released from deep unminable coal. The CO_2 produced by the power plant would be injected into the coal beds to produce more methane, so continuing the cycle. A geological sink would also be established in the coal beds, 'virtually eliminating any release of CO_2 to the atmosphere.' Developments in the use of CO_2 for enhanced oil recovery are also ongoing in Canada, many centred on the above-mentioned Weyburn oil field. Projects are under way or preparing for operation there, both in an investigative role, and for commercial exploitation. Technology for enhanced coal bed methane recovery, involving injection of CO_2, is also being transferred from Canada to China.

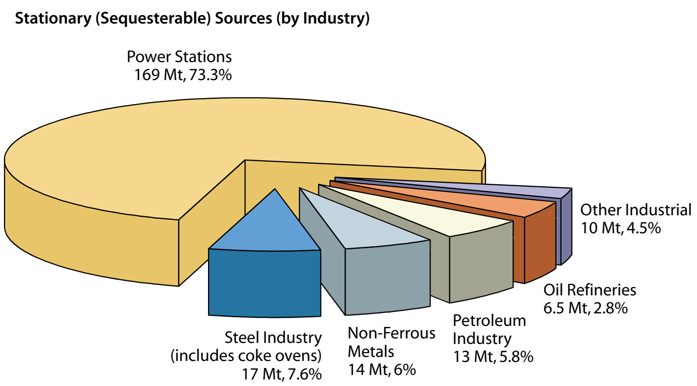
Algeria
In Algeria, a BP gas project with high CO_2 content is preparing to emulate the activities at Sleipner, but is injecting the CO_2 back into the same geological formation from which the gas comes. Unlike Sleipner, which was instigated on the basis of potential carbon emission taxes, the Algerian operation is associated with an internal BP carbon credits system, that is already up and running.

For more information:
http://script3.ftech.net/~ieagreen/research_programmes.htm

Pros and cons

Some scientists have reservations about the economics and safety of geological sequestration. Dr Mark Diesendorf, Director of the Sustainability Centre Pty Ltd, in a recent report, concluded that Australian decision-makers 'need to grasp the large number of uncertainties associated with these coal-based technologies'.

He argues that coal is the most polluting way to produce electricity and says it would be a mistake for Governments to continue to approve coal-fired power stations and to slow efforts to cut emissions in the hope that, in a few years, the most significant source of greenhouse gas pollution can be made completely benign.



Emissions from electricity consumed by each Industry included under Power Stations; eg Aluminium Industry = 15.4% of Australian electricity consumption

Data from 1998 NGGI & ABARE

John Bradshaw

An oil production well at an enhanced oil recovery field in Canada where CO_2 is being injected into the near depleted oil field. The CO_2 acts as a solvent and the injection process increases the pressure in the pressure depleted reservoirs thus helping the remaining oil to flow more freely to the surface via the production wells.

Diesendorf cites an International Energy Agency report that found that the process of collecting and storing the emissions from power stations reduces CO_2 emissions by about 80%, but also increases the costs of power stations and reduces their thermal efficiency. This is indisputable.

Pro-storage researchers agree that underground storage will not solve all our problems in a few short years but suggest that it may make a significant contribution. They say that the technique could be widely adopted without the need to completely change the energy supply infrastructure.

On economic and technical viability the APCRC scientists argue that the basis of their cost estimates are on the table and that current injection plants in several countries are demonstrating the technical feasibility of the technology (see the box).

The CRC scientists reckon that additional work on CO_2 capture, separation and storage, as well as ways to reduce the cost, is necessary if the method is to help us meet Kyoto targets. The group also believes that it will be well worth the effort considering the large tonnages of CO_2 that could be dealt with if full-scale underground storage gets going in Australia. Putting CO_2 back where it comes from will not be a cure-all but could prove an important element of a wide-ranging greenhouse reduction strategy.

MORE READING:

Bradshaw J, Bradshaw BE, Allinson G, Rigg AJ, Nguyen V and Spencer L (2002). The potential for geological sequestration of CO_2 in Australia: preliminary findings and implications for new gas field development. *APPEA Journal*, 42:25–46. This paper is also available at: **www.apcrc.com.au/Programs/GEODISC_APPEApaper2002.PDF**

Diesendorf M (2003). Australia's Polluting Power: Coal-fired electricity and its impact on global warming. WWF Discussion paper 03/02.