DEPARTMENT OF
PRIMARY INDUSTRIES

Geosequestration

Putting the carbon back

A paper to discuss current issues and opportunities to reduce greenhouse gas emissions through geosequestration

Victoria
The Place To Be

ISBN: 174146 9147

The Department of Primary Industries acknowledges contributions by the Cooperative Research Centre for Greenhouse Gas Technologies. Acceptance of these contributions, however, does not endorse or imply endorsement by the Department of Primary Industries of any product or service offered by the contributors.

Revised edition September 2004

Website: www.dpi.vic.gov.au/minpet

Foreword

Victoria's abundant, affordable and secure electricity and gas supplies have not only helped make Melbourne the manufacturing centre of Australia, but have also enhanced our reputation as the most liveable city in the world.

As the Minister responsible for energy industries and resources, I want to ensure that we can all continue to enjoy these benefits.

However, producing electricity by burning fossil fuels like coal and gas generates large amounts of carbon dioxide (CO_2), a greenhouse gas which contributes to global warming. Recognising that greenhouse induced climate change is one of the biggest environmental challenges we face, I also want to ensure that our continued economic development goes hand in hand with greenhouse gas abatement.

This will be achieved through a number of methods such as the development of renewable energy sources and more efficient energy use.

The Victorian Government has already prepared a comprehensive Victorian Greenhouse Strategy, and is undertaking a major review of energy and greenhouse issues through its 'Greenhouse Challenge for Energy' initiative.

We are investing $8.45 million in the Renewable Energy Support Fund, and $3 million in a solar energy retrofit scheme for schools, kindergartens, childcare centres and community health centres.

We have set a target to increase the share of Victoria's electricity expected from renewable energy sources from the current 4% to 10% by the year 2010. We will also continue to push for the Commonwealth Government to ratify the Kyoto Protocol on reducing greenhouse gases.

However, Victoria has huge reserves of coal and this, along with gas, will remain our major source of electricity for many years. Therefore, alongside our support for the development of renewable energy, we must also support research into finding technologies to reduce greenhouse emissions from power stations and natural gas wells. One such technology may be geosequestration.

Geosequestration aims to permanently store CO_2 in deep underground rock structures. In other words, it puts the carbon from the coal and gas back underground.

Like all new technologies, there are some who say that it will never work. Others say that geosequestration will solve the world's greenhouse issues.

We know that geosequestration offers the potential to reduce CO_2 emissions from power stations and natural gas wells to almost zero. However, research is needed before it is proven to be safe, secure and affordable.

The Victorian Government supports the growth of this technology but wants an open and informed debate on its development.

To encourage this discussion, this paper gives an overview of how geosequestration could work and the challenges that need to be addressed.

It also acknowledges the benefits to the world if this technology can be successfully developed.

With proper debate, and further investigation of new technologies, I am confident that we can move forward and continue to support both Victoria's economy and the environment.

Theo Theophanous
Minister for Energy Industries and Resources

Victorian Energy Supply and Greenhouse Gases

Across the world the fossil fuels of coal and gas are the principal energy sources used to produce electricity. This is no different in Victoria.

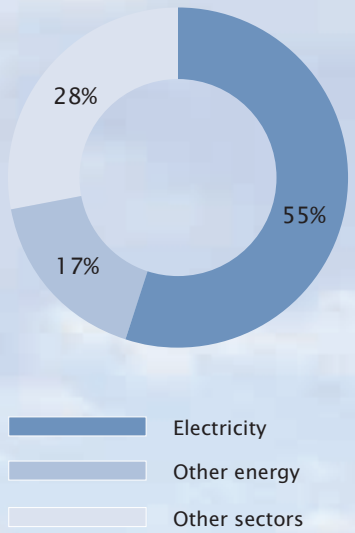
In fact, over 85% of electricity generated in Victoria comes from brown coal, with gas providing additional peak load capacity.

Victoria's coal reserves are vast and cheap to extract. Their scale and accessibility provides abundant, secure and affordable electricity for Victoria – electricity that supports our whole economy.

The vast reserves of coal also make it the State's largest natural resource and an important asset for our continued economic development, particularly as new uses for coal are discovered, such as producing clean diesel fuel, fertilisers and even hydrogen.

However, the burning of any fossil fuel, particularly coal, produces large amounts of CO_2. In Victoria 55% of our greenhouse gas emissions come from the burning of coal to generate electricity.

FIGURE 1: SHARE OF VICTORIAN GREENHOUSE GAS EMISSIONS BY SECTOR – 1999 (FROM GREENHOUSE CHALLENGE FOR ENERGY)



Greenhouse Gas and Climate Change

Carbon dioxide and a range of other gases referred to as greenhouse gas are produced by a number of human and natural processes, such as from agriculture, land clearance and motor vehicles.

Over the last 100 years or more, as human activity has increased, more and more greenhouse gases are emitted. Some of these gases rise into the atmosphere, forming a blanket around the earth, trapping heat and causing the earth's temperature to rise gradually.

This rise in temperature causes changes to our climate and a rise in sea levels. Climate changes may alter rainfall rates and change local climate patterns, which may impact on agriculture and native flora and fauna. It may also cause an increase in the frequency of damaging storms across the world.

Australia may be particularly affected if climate change results in a decrease in rainfall in areas that already have low rainfall levels.

The Greenhouse Challenge for Energy

There is clearly a need to balance the environmental, social and economic imperatives facing the energy sector.

One of the Victorian Government's responses to this has been to launch **The Greenhouse Challenge for Energy** discussion paper in June 2003. This has encouraged discussion between government, industry and other interested parties, and will lead to a Victorian policy framework for energy and reducing greenhouse gases.

Victoria is also developing renewable forms of energy such as solar and wind power, as well as looking at the potential to obtain energy from the heat in the earth's crust (geothermal energy).

However, while these are important, they are currently unable to provide the quantity of power our society needs. They are also currently unable to provide electricity at a competitive price compared to fossil fuel energy sources.

Victoria must therefore look at all technologies that have the potential to reduce greenhouse emissions from fossil fuels.

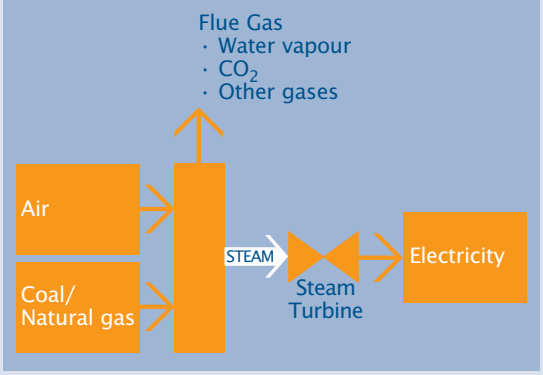
This includes ensuring that technologies such as geosequestration are actively pursued through informed and open debate. This paper on geosequestration has been prepared to encourage this debate and supports the objectives of the Greenhouse Challenge for Energy.

Where does CO_2 come from?

Fossil fuels such as coal and gas contain high levels of carbon. When they are burnt, the carbon in the fuel combines with oxygen and produces heat. This heat is used to generate steam, which drives generators and produces electricity for our homes, factories, shops, streetlights, computers and televisions.

However, when carbon and oxygen combine, they produce carbon dioxide (CO_2). The emissions coming from the flue of a power station (Figure 2) therefore contain significant amounts of CO_2, as well as nitrogen (from the air) and water vapour.

FIGURE 2:
A FOSSIL FUEL FIRED POWER STATION



What is Geosequestration?

"sequester: seclude, isolate, set apart … bind so that it cannot react … commit for safe keeping" – from the *Concise Oxford Dictionary*

Approximately 20,000 years ago, volcanoes erupted across what is now south-western Victoria. As well as transforming the landscape around the Western Otway Basin, they also generated large amounts of CO_2.

In some parts of this region, the CO_2 was trapped deeply underground where it has remained for thousands of years (Figure 3). We now pump some of this gas out to use in our soft drinks and dry ice.

Scientists believe that we can copy this natural process and put large amounts of greenhouse gas back underground. This process is called geosequestration.

LADBROKE GROVE NATURAL CO_2 GAS ACCUMULATION, OTWAY BASIN

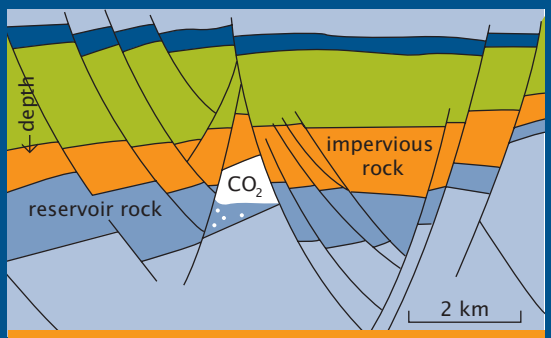


FIGURE 3: A SECTION OF THE EARTH'S CRUST SHOWING CO_2 STORAGE IN THE OTWAY BASIN AT A DEPTH OF OVER 2000 METRES.

Types of sequestration

Ocean sequestration

Ocean sequestration involves mixing the CO_2 in the ocean. Although the ocean already stores huge amounts of CO_2 naturally, this technology is not supported by the Victorian Government as it appears to be moving the CO_2 from one environment (the atmosphere) to another (the ocean).

Chemical sequestration

Chemical sequestration is forming the CO_2 into a solid, usually by combining it with another material. While this is a possible option for small amounts of CO_2, it is unlikely to be suitable for the large volumes of gas from a power station. It could also create significant landfill issues.

Biological sequestration

Biological sequestration is the natural absorption of CO_2 into plants. For example, trees absorb carbon dioxide from the air and release oxygen. As a corollary, when trees are burnt, they release the stored CO_2. And as land is cleared for agriculture or other uses, the natural ability of the environment to store CO_2 is reduced.

Geological sequestration (geosequestration)

Geosequestration is a technology that puts CO_2 into deep, secure underground geological storage, including in deep geological structures underneath the ocean.

Stages of Geosequestration

Capture and separation of CO_2

In most cases coal and gas are burnt in air. This means that the flue gas from power stations mostly contain nitrogen. (The air we breathe is nearly 80% nitrogen and 20% oxygen). Therefore before CO_2 can be geosequestered, it must be separated from this nitrogen and any other gases. Capturing CO_2 from mixed gas streams is a major technological and economic challenge.

The challenge is to separate the CO_2 quickly and effectively. One technology being developed is membrane technology. This uses a material (membrane) that allows only CO_2 to pass through it. Other technologies may absorb the CO_2 into liquid or even solid materials or burn fossil fuels in oxygen instead of air.

Some of these technologies are already being used to separate CO_2 from natural gas. Others have been successfully trialed in laboratories, with various gas mixtures but these technologies are not yet able to economically manage the very high volumes of gas that would come from a major power station.

Research into these technologies is being carried out around the world, with Victoria and Australia playing an important role in their development. This includes major work at both Melbourne and Monash universities.

Transport of CO_2

Once the CO_2 has been captured it will be compressed to a liquid condition (supercritical) and transported, under pressure, by pipeline to a site where it can be injected.

CO_2 is already transported directly over long distances using the skills and experience gained from the construction and operation of natural gas and oil pipelines. However, CO_2 being non-flammable, is inherently safer to transport.

Despite this experience, research is being conducted to reduce the cost of transport and to develop appropriate standards relating to issues such as pressure, materials and pipeline corridors. In Australia much of this research is being coordinated by the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC).

Injection of CO_2

CO_2 must be injected into deep underground storage, at depths of at least 800 metres. At this depth the CO_2 will remain as a liquid.

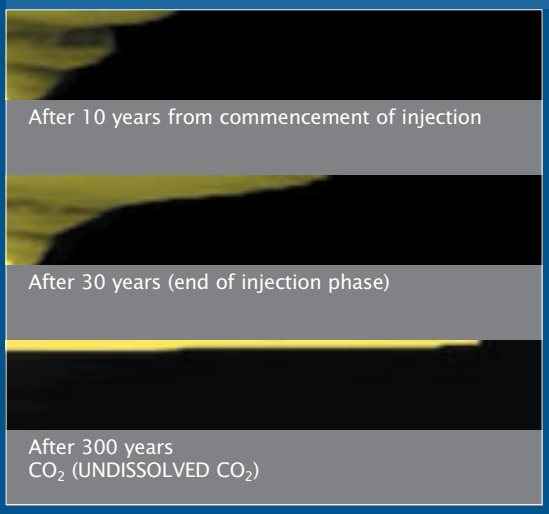
Proven technologies are available to inject CO_2 deeply underground. However, scientists are continuing to increase their understanding of factors such as injection rates and the development of accurate models to predict and monitor the movement of CO_2.

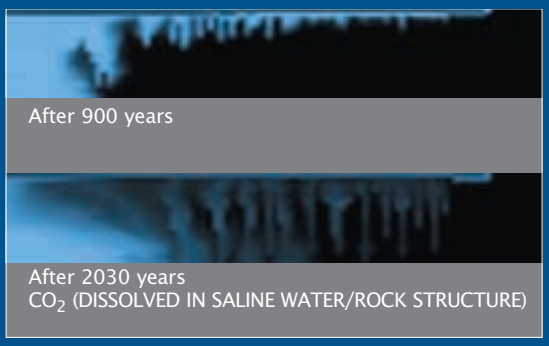
This process has analogies in nature, including in the Western Otway Basin, (as shown in Figure 3). where an impervious rock layer has formed a natural storage space.

Without natural formations such as this, the world's oil, gas and CO_2 reservoirs would have long since evaporated.

Modelling by CO2CRC, a world leader in geosequestration research, has shown that CO_2 will initially move slowly away from the injection site, rising towards the bottom of the impervious rock layer (Figure 4). After 30 years, much of it will have spread out over the bottom of the layer. After that, the CO_2 will gradually dissolve and start to migrate downwards and in 2000 years will be spread throughout the rock.

FIGURE 4: COMPUTER SIMULATION SHOWING THE MOVEMENT OF CO_2 BENEATH AN IMPERVIOUS ROCK LAYER [THE RIGHT HAND CROSS SECTION IS SHOWN WITH CO_2 BEING INJECTED AT THE BOTTOM LEFT HAND CORNER]





Modelling assumptions

- depth of the impervious rock layer from the earth's surface is 1100m
- depth of the computer simulation is 150m
- carbon dioxide injected at 50 kg/s for 30 years
- formation shown is 150m thick and 5000m from left to right
- average pressure prior to injection is 12 MPa
- temperature is around 60°C
- porosity of the formation is 15%
- average permeability is 100 mD horizontally and 10 mD vertically

Victorian Geosequestration Potential

FIGURE 5: MAP SHOWING LOCATIONS OF POTENTIAL CO_2 INJECTION SITES IN VICTORIA (BRADSHAW ET AL; CO2CRC)

A detailed study of the geology of the Australian continent over several years, under the GeoDisk program, has identified a number of potential suitable geosequestration sites across Australia based on:

- seismic stability of the area
- porosity of the impervious cap
- potential storage volume
- proximity to a large source of CO_2.

Some of the most suitable sites are in, or adjacent to, Victoria and those located in Bass Strait have been identified as having some of the highest potential worldwide and are conveniently located close to the major Latrobe Valley Power stations and Victoria's huge reserves of coal.

The CO2CRC is proposing to undertake further detailed studies into Victoria's potential, possibly leading to a future trial.

Does Geosequestration Work?

The Sleipner natural gas well is operated by the Norwegian company, Statoil.

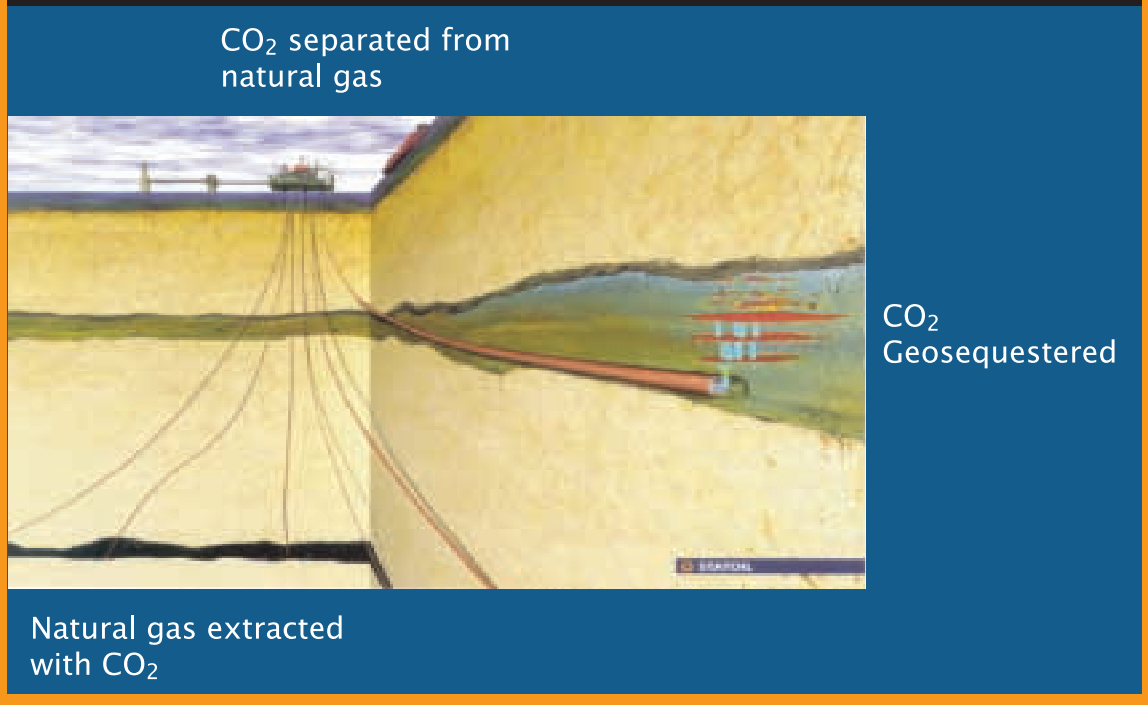
The natural gas extracted from that well contains a high proportion of CO_2 which must be removed before the natural gas can be liquefied.

To prevent this CO_2 being released into the atmosphere, Statoil capture it and inject it into sandstone, 1000 metres beneath the North Sea. Since the gas field was established in 1996, Statoil have geosequestered in the order of 1 million tonnes of CO_2 per annum.

The Sleipner site is the world's first commercial CO_2 storage program. It successful operation over eight years gives a strong indication that geosequestration holds significant potential to achieve large cuts in greenhouse gas emissions.

Also, about 70 firms worldwide inject CO_2 into deep underground structures to enhance oil recovery. An example of this is the Weyburn project in Canada. This project transports CO_2 from a North Dakota coal gasification plant through a 320 km pipeline to an oil field in southern Saskatchewan. The CO_2 is then injected deeply underground at a rate of 5000 tonnes per day to enhance the rate of oil recovery.

FIGURE 6: GEOSEQUESTRATION AT THE SLEIPNER GAS FIELD IN THE NORTH SEA



Current Research into Geosequestration

Carbon Sequestration Leadership Forum (CSLF)

Reducing greenhouse emissions from energy is a global issue and research into geosequestration is being conducted throughout the world. In June 2003, Victorian Energy Industries and Resources Minister Theo Theophanous and Federal Energy Minister Peter McGauran led a team of Australian scientists, industry and policy makers to the inaugural International Carbon Sequestration Leadership Forum.

At this meeting, 14 countries and the European Union signed a charter agreeing to co-operate in the development of geosequestration policy and research. This international co-operation recognises the potential benefits of pursuing this technology.

Since that first meeting several other countries have also joined.

Victoria is a major supporter of the CSLF and is jointly hosting the 2nd ministerial meeting in Melbourne in September 2004, along with the Commonwealth Government. This meeting is bringing government ministers and the world's leading scientists to Melbourne, and will set the direction for future international cooperation.

Cooperative Research Centres (CRC's)

Several Cooperative Research Centres have been established with funding from government, industry and research institutes. CRCs work in partnership with their members to research new technologies leading to commercialisation.

The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) is a world leader in identifying suitable geosequestration sites and in understanding the movement of CO_2 deep underground. Through its own research and in partnership with research agencies around the world, it will be the leader in developing Australia's geosequestration technologies. Victoria is a member of the CRC and the only Government represented on its Board.

Universities

Melbourne and Monash universities conduct significant research into geosequestration technologies, particularly related to the capture and separation of CO_2. Both these universities work in partnership with the CO2CRC.

Centre for Energy and Greenhouse Technologies (CEGT)

The Victorian Government recognises that research must be co-ordinated in the area of energy and greenhouse. It has also recognised that the outcomes of that research must be supported through development and commercialisation stages.

The CEGT has been established to work in partnership with industry and research bodies to support development and ensure that Victoria benefits from energy and greenhouse research. The Government has provided $14 million to establish this Centre.

CSIRO

The CSIRO's Energy Flagship Project is working to support greenhouse gas abatement. As just one part of this important initiative, the CSIRO is working with the CO2CRC in areas such as the movement of CO_2 in the subsurface.

Coal21

The Australian coal industry has formed a partnership with government, industry and the research community to support projects which demonstrate that greenhouse gas can be abated. These would include high-efficiency gasification generating plants and geosequestration injection plants.

APEL

APEL is a private company that has been awarded an exploration licence to some of the vast Latrobe Valley brown coal reserves. This licence was issued to allow APEL to develop a proposal to construct a coal-to-liquids (low sulphur diesel) plant that will produce near zero emissions through geosequestration.

International Power Limited (IPRH)

International Power, operators of the Hazelwood Power Station, have formed an alliance with other companies to develop a high-efficiency plant that could produce liquid fuels or electricity. They believe that they can reduce CO_2 emissions by a significant amount and that the flue gas would be readily geosequesterable.

Investigation into associated technologies

CRC for Clean Power from Lignite

This CRC is based in Victoria and is conducting research into coal drying to address the inefficiencies caused by the very high moisture content of Victorian coal. These processes could lead to significant reductions in greenhouse emissions from existing power stations as well as provide a technology that will benefit new power stations, including in countries such as China.

The CRC is also researching technologies to increase the efficiencies of combustion, particularly through coal gasification.

Universities

Monash and Swinburne universities work with the CRC for Clean Power from Lignite in the development of coal drying technologies. They also work with the CRC in areas associated with gasification and other combustion efficiency technologies.

HRL

HRL is a private firm of consultants specialising in issues relating to coal and was formed from the research arm of the now privatised State Electricity Commission of Victoria. HRL is working towards an 800MW high-efficiency (low greenhouse emissions) power station by integrating coal drying and gasification to produce electricity. Heat from the gasification process and the gas turbine is also used to generate steam to drive steam turbines and produce additional electricity.

Other research

A number of other companies are also researching technologies which would support low greenhouse emissions and future geosequestration.

These companies are also developing technologies to use the massive reserves of Victorian coal in new greenhouse friendly ways. New technologies could support the development of liquid fuels, chemicals, fertilisers and hydrogen. They may also support the development of new export opportunities for coal.

The Victorian Government commends the efforts of these organisations and their willingness to work towards projects that support our economic development and address our greenhouse issues.

The Challenge

Through the Carbon Sequestration Leadership Forum, co-operative research centres, CSIRO and a range of other research and industry bodies, Victoria and Australia are playing a key role in developing greenhouse abatement technologies, including geosequestration.

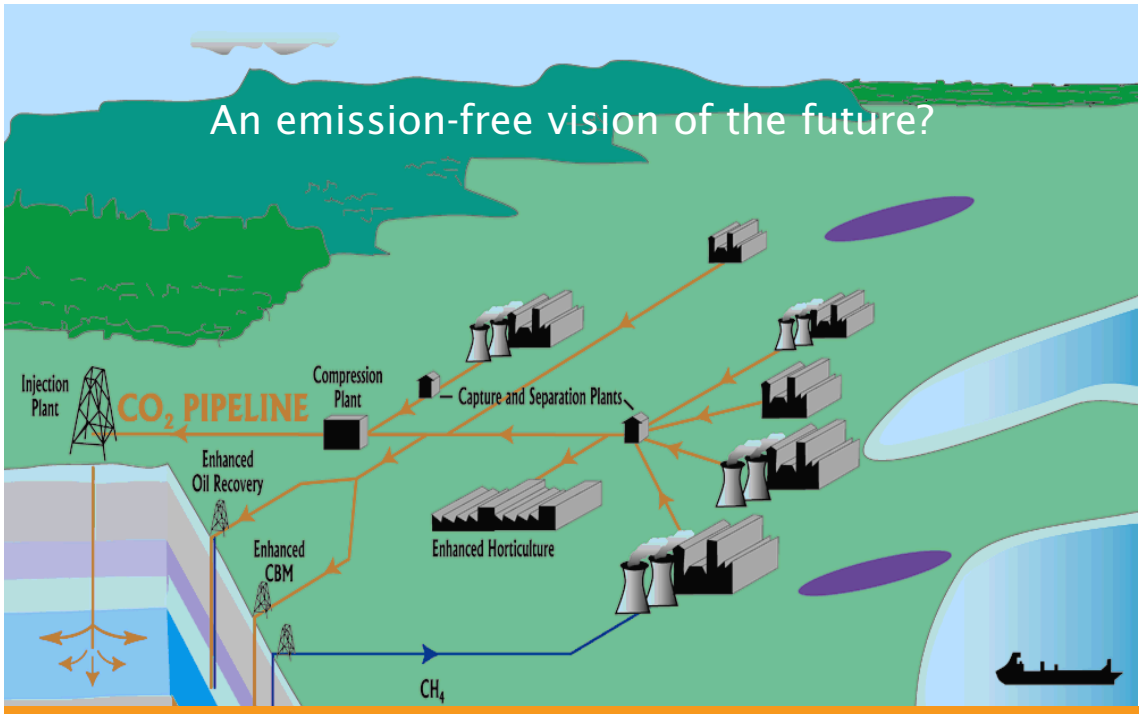
The challenge for Victoria and the world is to support the development of geosequestration given its potential to achieve near zero emissions.

However, we must recognise that there are still issues to be resolved before geosequestration is accepted as an appropriate greenhouse abatement strategy.

In particular, research must prove that geosequestration technologies:

- can manage the large volumes of gas from a power station;
- can reduce greenhouse gases at a reasonable economic cost;
- are safe, secure and permanent.

The future



REFERENCE CO2CRC
FIGURE 7: A POSSIBLE FUTURE USING A CENTRAL HUB TO TRANSPORT ALL STATIONARY CO_2 EMISSIONS TO A GEOSEQUESTRATION SITE.

The Victorian Government is committed to retaining our secure, reliable and affordable supply of electric energy. It is equally committed to reducing greenhouse gas emissions.

It therefore strongly supports the development of greenhouse gas abatement technologies from fossil fuels alongside the development of renewable energy and energy efficiencies.

Geosequestration has the potential to achieve near zero emissions from major power stations and gas production wells. It may therefore become a very important part of a future where we can have abundant supplies of electric energy as well as low greenhouse gas emissions.

Victoria recognises that we must plan for alternative futures where energy sources will be vastly different to the present.

For example, many scientists believe that we are moving towards an economy where hydrogen is the primary fuel. Already, hydrogen buses are being trialed in Australia using fuel cells and automotive companies are developing hydrogen cars. If this occurs, the most likely source of hydrogen will be our abundant supply of coal.

Our coal may therefore continue to be our most significant energy source if we can address our greenhouse issues.

THE VICTORIAN GOVERNMENT WELCOMES YOUR COMMENTS ON GEOSEQUESTRATION

Please direct comments to:
John Lambert
Manager, Science and Technology Development
Email: customer.service@dpi.vic.gov.au

Or write to:
Department of Primary Industries
Minerals and Petroleum Division
Level 16
1 Spring Street
Melbourne Vic 3000

Contacts
www.dpi.vic.gov.au

CO2CRC – for Greenhouse Gas Technologies
www.co2crc.com.au

CRC Clean Power for Lignite
www.cleanpower.com.au

Greenhouse Challenge for Energy
www.greenhouse.vic.gov.au

Department of Sustainability and Environment
Greenhouse Policy Unit
www.greenhouse.com.au