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Can geosequestration save the coal industry?

Mark Diesendorf

1. Introduction

There is archaeological evidence that coal was used in the Bronze Age, 3,000-4,000 years ago, in ancient China and in Roman Britain. But over the millennia, while human and animal labour and wood burning were the principal energy sources, coal played a minor role. In the pre-industrial age, reflected in the novels of Thomas Hardy and the paintings of the Old Masters, energy supply was local and distributed over land and waterways.

The growth of coal mining and use was driven by the growth of technology. Steam powered machines were introduced around 1770, commercial revolving wheel cutters in 1868, and the longwall cutter, originally driven by compressed air, in 1891. Bulldozers, mechanical shovels and eventually giant dredges, for open-cut coal-mining, were introduced in the 20th century, when coal became the principal fuel for electricity generation. The use of large coal-fired power stations, rated at 1000 megawatts or more and located in coal-mining areas, has shaped a centralized electricity grid based on high-voltage transmission lines that transport high-grade energy from mine to city.

Associated with coal’s large contributions to energy supply and the economy are very large impacts on the natural environment, health and society. The coal industry also wields great political power. It is perceived to have a strong influence on the policies and processes of many governments, international organisations and local communities.

This chapter reviews briefly the environmental, health and social impacts of the coal industry and its political power. It then examines critically the potential role of a new technology that offers the possibility of entrenching coal for the next several centuries allowed by coal reserves. If successful, the technology would do this by reducing coal’s biggest impact, its major contribution to global climate change resulting from the emission of the greenhouse gas, carbon dioxide (CO_2), when coal is combusted. The technology involves the capture of CO_2 and its injection into geological formations deep underground, where it would be sequestered from the atmosphere for thousands of years. This is called ‘geosequestration’ or ‘CO_2 capture and storage’ (CCS). Our critical examination asks:

- What are the environmental, health and social impacts of geosequestration?
- What is it likely to cost?
- When could it feasibly make a large contribution to electricity generation?
- What is its role in diverting resources away from existing technologies for the efficient use of energy and renewable sources of energy?
- Is the prospect of geosequestration drawing attention away from ongoing programs to build many more conventional, dirty, coal-fired power stations.

In this chapter Australia, the world’s largest coal exporter and the fourth largest coal producer, is treated as a case study.

2. Coal production and consumption

In 2002 total global production of coal of all types amounted to 4.78 billion tonnes with energy content of 102 x 10^{18} joules. Coal consumption, which was approximately the same as production, was responsible for the emission of 9.1 billion tonnes of carbon dioxide (CO_2), the principal greenhouse gas. (US EIA, 2004)

Globally the main coal producers in 2002 were China, USA, India, Australia, Russia, South Africa, Germany and Poland, in that order (see Table 1). The biggest coal exporter was Australia. These are the countries where we expect the coal industry to be the most politically powerful. This is certainly the case for Australia, as discussed in Section 4.

Table 1: The world's largest coal producing and consuming countries, 2002

Country	**Coal production** (million tonnes)	**Coal consumption** (million tonnes)
China	1430	1060
USA	996	818
India	358	247
Australia	344	98
Russia	236	No data (former USSR 612)
South Africa	223	130
Germany	210	371
Poland	162	136

Source: US EIA (2004), Tables 25 and 14. We have converted the EIA data from short tons to tonnes.

Coal is the leading source of electricity generation in both the groups of OECD and non-OECD countries. Table 2 shows the high dependence upon coal for electricity generation in several countries. Coal is also combusted directly in the smelting of aluminium and other metals, and in steel and cement works. In cities in several developing countries, coal is still widely used as a fuel for residential heating.

Table 2: Percentage of electricity generated from coal in selected countries

Country	**Year**	**Percent of electricity from coal**	**Trend since 1990**
Poland	2000	96	steady at saturation
South Africa	2000	92	steady
Australia	2000	78	steady
P.R. China	1999	75	small increase
India	1999	75	increase
Czech Republic	2000	73	steady
Germany	2000	53	fallen slightly
USA	2000	52	steady
Denmark	2000	47	fallen greatly as use of gas & wind increase
Korea	2000	42	big increase
UK	2001	37	fallen rapidly since 1986

Sources: International Energy Agency reports; US EIA (2004).

3. Impacts of coal use

Coal is one of the most damaging sources of environmental pollutants used by humankind. Every stage of coal use – from mining, to washing, to transportation, to burning and to disposing of the wastes – brings substantial environmental and health damage, and social impacts:

- Greenhouse gases are emitted from combustion and mining.
- Air is polluted from combustion, mining and transportation.
- Water is diverted from drinking, agricultural and ecological uses.
- Water is polluted from mining, coal washing and combustion.
- Land is degraded from mining, pollution from combustion, and the disposal of solid wastes.
- Coal mining is still one of the most dangerous occupations, even in industrialized countries.
- Coal mining and coal-fired electricity foster centralized energy production and use, thus supporting a system that is vulnerable to disruption from natural causes, electrical instabilities and sabotage.
- The industry is losing jobs rapidly and, in particular, local jobs in regional centers and rural areas.

In the early 1990s the coal industry's public relations arm coined the phrase 'clean coal', creating the false impression in the public mind that existing sources of coal and coal-burning technologies produce little pollution. When challenged, the coal industry in Australia explained that 'clean coal' was used to describe Australian coals, because they are low in sulfur and hence lower in air pollution than coals burnt in several other parts of the world. In the late 1990s the term 'clean coal' was extended to hypothetical coal-burning processes in which carbon dioxide is captured and buried, glossing over the situation that this may take several decades to implement on a commercial scale, if ever (see below). 'Clean coal' lobbies tend to ignore all except the first two impacts listed in the previous paragraph.

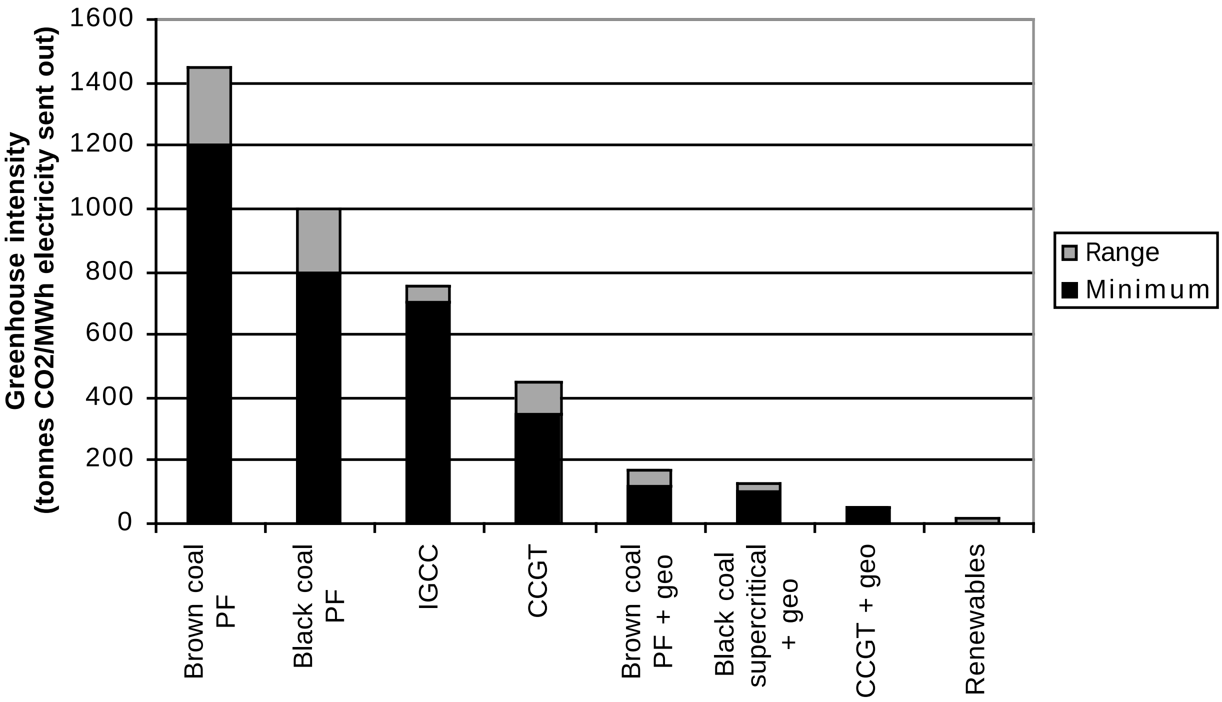
3.1 Greenhouse gas emissions

Carbon dioxide emissions from various types of power station and fuel are shown in Figure 1. Coal is the highest CO_2 emitter per unit of electricity sent out. Of the various types of coal, brown coal or lignite is the worst in this respect. Black coal power stations, with ordinary boilers burning pulverized fuel, emit about 1000 tonnes CO_2/MWh sent out, while those with supercritical boilers emit about 800 tonnes CO_2/MWh sent out. The power stations with geosequestration are all hypothetical.

3.2 Air pollution

Over the past two centuries, many communities in coal mining and coal burning regions have suffered from extreme air pollution. The infamous London smogs of the 19th and 20th century killed many thousands of people until domestic coal burning was banned in the 1950s. Similar zones of great danger existed in eastern Europe until some years after the fall of communism in the 1980s. Beijing was one of the most polluted cities in the world until it was awarded the 2008 Olympics. Then coal burning was banned inside the third ring road and within two years citizens were saying in wonder that they could see the stars at night. But several other regions of China, India and other Third World countries are still shrouded in the poisonous veils produced by extracting and burning coal.

Figure 1: CO_2 emissions from various power stations with various fuels



Sources: This author's results. Emissions from some specific Australian power stations were either obtained directly from annual or environmental reports of electricity generation utilities or, in cases where coal consumption data are published, by calculation using CO_2 emission factors of Australian fuels and point-source energy content of fuel (Australian Government, 2004c, Table 1). Emissions from hypothetical power stations with geosequestration from Freund and Davison (2002) and other published desktop studies assuming capture of 80-90% of CO_2 emissions.

Notes:

'PF' denotes 'pulverized fuel', the standard type of coal-fired power station.

IGCC is 'Integrated Gasification Combined Cycle', a new type of coal-fired power station that is not currently competitive with PF types;

CCGT denotes Combined Cycle Gas Turbine, the most efficient existing type of base-load gas-fired power station.

'Geo' denotes geosequestration.

'Renewables' in this figure comprise wind power and certain types of bioenergy. Renewable energy has been assigned nominal CO_2 emissions under assumption that energy use for manufacturing power plant comes from predominantly fossil fuels.

Even in highly developed countries, such as the USA and Australia, coal burning is still a big emitter of sulfur dioxide, nitrogen oxides, fluoride, hydrochloric acid, boron, particulate matter, mercury and sulfuric acid. Nitrogen oxides or NOx are toxic to humans and other animals, are one of the main contributors to the production of ozone and hence smog, and are an important source of acid rain. Sulfur dioxide is toxic to humans and other animals and is an important source of acid rain. For details of the hazards of chemicals in the environment, see the IPCS INCHEM web site, http://www.inchem.org/ (accessed 3 January 2005). This is a web-based gateway to internationally peer reviewed information on chemicals commonly used throughout the world, which may also occur as contaminants in the environment and food. Coal-fired power stations also emit low-level ionizing radiation, which is potential cause of small numbers of cancers, genetic defects and possibly heart disease each year (UNSCEAR, 2000).

3.3 Water pollution and water take

The production, transportation, washing, storage and burning of coal can have significant effects on surface and underground water bodies.

In particular, coal washery waste discharge, amounting to tens of millions of tonnes per year, pollutes water as well as the area of land used for storage in tailings dams. A little of this waste, which is about 40% coal, is beginning to be used as a fuel source (e.g. Redbank power station in the Hunter Valley of Australia), but this is hardly a solution to a massive problem.

Some large coal-fired power stations take tens of millions of tonnes per year of fresh water from rivers and lakes for cooling purposes. This competes with drinking and agricultural uses and ecological flow requirements of rivers. It is technically possible and in some cases economically feasible to design any new coal-fired power stations to be either air-cooled, like one of Queensland's newest power stations, Millmerran, or, in the case of coastal power stations, cooled with sea water.

Discharging warm cooling water from power stations into rivers and lakes lifts the ambient water temperature and so is a hazard to ecosystems.

3.4 Land degradation and impacts on biodiversity

Contrary to the notion that 'out of sight is out of mind', modern underground coal mining is collapsing the land surface, opening up large cracks in stream beds, and draining rock pools and wetlands. Creeks and rivers that were once pristine and supported healthy ecosystems, are now dry, dead zones. Underground mining is also releasing pollution in the form of methane gas to the surface and cracking key water supply structures (Colong Foundation for Wilderness, 2004).

Open cut coal mining takes even larger areas of land. The land area used per kilowatt-hour of electricity generated is much larger than that used by wind power or rooftop solar photovoltaics or bioenergy based on agricultural crop residues rather than dedicated energy crops. If open cut mining takes place in land that was previously pasture or open woodland, it is possible to restore it after mining has been completed to something superficially resembling a pasture or open woodland. In practice land rehabilitation costs money, and some coal mining corporations are failing to fulfill their contracts by undertaking the necessary rehabilitation. In Queensland, Australia, the situation was exposed by a whistleblower, Jim Leggate, who revealed that his State Government Department, charged with the regulation of the mining industry, had adopted a policy of non-enforcement of those regulations (Whistleblowers Australia, 2004). The result was a potential taxpayer bill, now about $2 billion, to avoid environmental harm that mining companies were being allowed to impose on Queenslanders.

Open cut coal mines also may release vast quantities of dust, some of which comprises fine particles. Although this is normally controlled to some extent by water sprays, it is still an environmental and health problem. In the mid-1990s epidemiological research (e.g. Pope et. al., 1995) revealed that the health hazards of inhaling fine particles may be much greater than previously thought and that there may be no safe threshold. Particles of more than 10 micrometre (millionth of a metre) in diameter are mostly stopped in the nose and throat and appear less harmful. Between 2.5 and 10 micrometre, the particles penetrate into the bronchi and bronchioles of the lungs and are regarded as more harmul. Particles smaller than 2.5 micrometre (known as PM2.5 or fine particles) penetrate so deeply into the lungs that they reach the alveoli and so could be even more dangerous. Many national pollution inventories report on PM10 (particles up to 10 micrometre in diameter), but very few report on PM2.5.

The adverse health effects of fine particles include:

- Toxic effects by absorption of the dust into the blood (eg from lead, cadmium, zinc).
- Allergic or hypersensitivity effects (eg from some woods, flour grains, chemicals).
- Bacterial and fungal infections (from live organisms)
- Fibrosis (eg from asbestos, quartz).
- Cancer (eg from asbestos, chromates).
- Irritation of mucous membranes (eg from acids and alkalis).
- Long term deleterious effect on lung function causing marginally increased death rates and sickness in sensitive people.

Local communities in coal-burning regions are becoming increasing concerned about fly ash, which is both toxic and carcinogenic, containing fine particles, heavy metals, arsenic, fluoride, boron, molybdenum and low-level radioactivity. Current practice is to dump it in unlined landfills, such as depleted open-cut coal mines, instead of ensuring the prevention of leaching and wind-blown escapes. Fly ash is sometimes used in concrete, but since it is radioactive, it may be a low-level health hazard when the concrete is used for homes and offices.

3.5 Occupational health and safety

Despite the advances of modern technology, underground coal mining is still one of the most dangerous and unhealthy of all occupations. Coal miners are at high risk of suffering from several different types of respiratory disease, from explosions and fires caused by methane gas, from collapse of underground tunnels, and from poisonous fumes and noise.

In Australia. a study by the National Occupational Health and Safety Commission (1998) found that in 1989-92 the mining industry had the third highest rate of traumatic deaths, after the forestry and fishing industries. The mining death rate was 36 deaths per 100,000 people per year, which was 7 times that of all industries taken together. The box offers an abridged extract from a description of one tragic event:

Prosecutions over Australian mine disaster fail to address underlying safety issues
by Terry Cook
26 April 2000

Two years after a judicial inquiry into the deaths of four miners at the Gretley coal mine, the government in the Australian state of New South Wales has begun prosecuting the mine operator Newcastle Wallsend Coal Company, its parent company Oakbridge Pty Ltd and several of its managerial staff.

The four men—John Hunter, 36, Edward Batterham, 48, Mark Kaiser, 29, and Damon Murray, 19—were killed on November 14, 1996, when the mining machine they were operating cut into an adjacent disused mine shaft that was filled with water. They had no way of escaping the powerful inrush of water and were drowned….

Even if found guilty, the [managers] only face fines and the loss of their mining licenses. The company could also be fined. The government has not brought criminal charges despite evidence at the previous inquiry showing that a series of company decisions had severely compromised safety in the mine and led directly to the disaster which claimed the four lives.

Justice James … Staunton was compelled to admit that there was evidence of “widespread and serious shortcomings at every level of management of the Newcastle Coal Company....”

Source: http://www.wsws.org/sections/category/workers/au-mines.shtml

In China, where Dickensian conditions are still prevalent, tens of thousands of coal miners are killed in ‘accidents’ every year.

3.6 Assessing the public health impact

The public health impacts of coal burning depend on the concentrations, daily doses, periods of exposure, and environmental and lifestyle factors such as smoking, alcohol consumption and exercise. Not every individual reacts in the same way to hazardous chemical and physical agents. Even a few heavy smokers and drinkers live to a ripe old age, however statistically their chances are much worse than those of non-smokers and moderate drinkers. It must be recognized that there is generally insufficient data on the effects of low levels of exposure received over long periods of time. Rigorous epidemiological studies are few and far between. It is the rare acute cases of illness and environmental disaster that tend to be reported in the medical literature and the media.

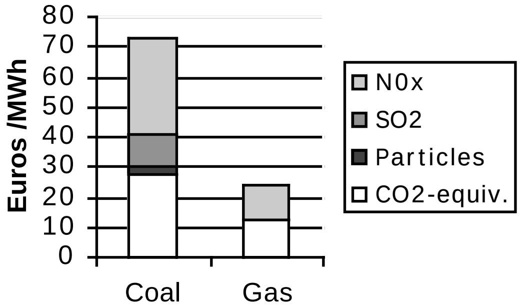
Nevertheless, in recent years there has been progress in the analysis of the health impacts and *external* costs (costs of environmental and health damage that are not taken into account in the market prices) of energy supply in the US and EU. These costs are based on the full fuel cycles, e.g. from the mining of coal through to the disposal of fly ash from a coal-fired power station. The calculations use Life Cycle Assessment and trace the main pathways of the pollutants from the points of emission to the various receptors (people, soils, crops, forests, buildings, etc.). The most comprehensive set of studies to date is the ExterneE project carried out in the late 1990s on behalf of the European Commission (ExternE, 1998; Rabl and Spadaro, 2000). There is of course much uncertainty in such calculations and the 1998 ExternE studies can be considered to be very cautious and conservative, because:

- They focus on the impacts of the well-known air pollutants, oxides of nitrogen and sulfur, to which they add the impacts of fine particles and aerosols which became pollutants of concern in the mid-1990s. They omit health hazards that they cannot quantify, such as those of heavy metals, volatile organic compounds (VOCs), fluoride, land degradation and waste management.[1]
- They consider only the impacts of the most modern combined-cycle power stations, with flue gas desulfurization (i.e. collection of SO_2 emissions from smokestacks), electrostatic precipitators (to collect dust from smokestacks) and low NO_x emissions. They point out that, for many existing power stations, the emissions of NO_2 and SO_2 can be several times higher.
- They calculate the monetary value of deaths from air pollution by multiplying the reduction of life expectancy by the monetary value of life per year. Most earlier studies obtained much higher values by multiplying the number of deaths by the monetary value of a statistical life.
- The air pollution results are calculated for an average population density of 80 persons/km^2 and should be rescaled according to average population of the region of interest.

With these assumptions, ExternE's calculated external costs of new European fossil-fuelled power stations, as reviewed by Rabl and Spadaro (2000), are shown in Figure 2. The range of typical retail electricity prices in Europe is 4-8 Euro cents/kWh and so including the calculated external cost in the price of coal electricity could double or even triple the current retail price.

[1] Impacts of ozone are included in those of nitrogen dioxide. The impacts of mercury and lead have not yet been quantified.

Figure 2: Typical damage costs of new baseload coal and gas-fired power stations assuming average European conditions.



Source: Rabl and Spadaro (2000).
Note: These external costs are additional to the economic costs of generation. 1 Euro = 1.23 US$ on 1 October 2004.

The ExternE studies found that the external costs of wind power, photovoltaic electricity and some types of biomass energy are negligible compared with those of fossil fuels. However, some other forms of biomass energy may have impacts up to about half those of natural gas.

3.7 Scale, centralisation and job creation

Throughout the 20th century coal-fired electricity has driven an increasing centralization of the electricity grid, with economies of scale driving the construction of ever larger power stations at coal fields, the largest rated at several thousand megawatts. From these power stations electricity is transported via high-voltage transmission lines to cities and large industrial electricity consumers. Such a centralized network is very vulnerable to disruption resulting from natural causes (storms, lightning, wildfires, floods), instabilities in the transmission system and sabotage.

The construction of modern coal mining equipment and major components of power station, such as 660 MW turbogenerators, has also become highly centralised. With the rise of automation, there have been substantial job losses in both coal mining and electricity generation in several industrialised countries.

> "Worldwide, only about 10 million coal mining jobs remain, making up one-third of all mining jobs and accounting for one-third of 1 percent of the global workforce. In industrial nations, the coal mining industry is no longer a major employer, and employment is falling even where production or exports are rising." (Dunn, 1999).

As a specific example, in Australia employment in coal mining has decreased by 45% since its peak in the mid-1980s, although the quantity of coal mined has increased substantially. Employment in electricity generation has fallen by 50% since the early 1990s, although the quantity of electricity generated has increased substantially (Diesendorf, 2004a).

In contrast, the lowest cost renewable energy power stations, powered by wind and biomass, are typically rated at 1-200 MW and require a much more distributed grid network. The scale of these renewable energy technologies means that in some cases they can be financed locally and that many components can be manufactured locally. Thus there is more local control over the technologies, more local employment creation and more benefits flow to the regions where they are manufactured and installed. For instance, wind farms currently being built in Australia have an Australian content (in dollar terms) of about 50% and this is expected to increase to about 80% if the Mandatory Renewable Energy Target is increased. With this level of local content wind power creates 4-6 times the number of local jobs per MWh generated compared with coal electricity, which has an Australian content (in dollar terms) of about 26% (MacGill, Watt and Passey, 2002; Diesendorf, 2004a).

Some economists argue that coal electricity has fewer jobs because it is more economically efficient and that this is the reason why coal-fired electricity is cheaper than wind power. However, even if wind power becomes much more economically efficient over the next 10-20 years, to that the extent that the number of *global* jobs in wind power per MWh declines to that of coal electricity, the point is that the smaller scale of wind power entails that small economies, such as those of Denmark and Australia, will always gain more *local* employment per MWh from wind power. Furthermore, the low price of coal electricity is in large measure due to the fact that it does not include the environmental and health costs that it imposes. If these are taken into account, they can lift the price of coal electricity to a level far above that of wind power and bioelectricity, as discussed in Section 3.6.

4. Political influence of the coal industry

One measure of the political power of the coal industry is the magnitude of subsidies it receives. De Moor (2001) has estimated that the global energy sector receives over $240 billion per annum in subsidies to fossil fuels. Of this coal receives $53 billion per annum. This estimate includes coal's share in the subsidies for electricity generation in OECD countries, but not in non-OECD countries. In Western Europe and Japan, Anderson (1995) has estimated that subsidies to coal production in 1991-92 were equivalent to providing a domestic producer price that is more than three times the import price in Belgium, Germany and Japan, two times in Spain and 40% higher in France and the UK. Furthermore, assistance per coal miner was about $90,000 per year in Belgium and West Germany, $38,000 per year in UK and over $100,000 in France (expressed in US 1990$). In the USA, Senate Energy Bills S.597 and S.14 provided coal subsidies in the fiscal year 2003 of $4.8 billion, comprising $2.2 billion for tax breaks and $2.8 billion for direct subsidies (Roder, 2003). This does not include R and D funding which is also measured in billions.

Why does such a large and wealthy industry receive such large subsidies? The literature on subsidies and distortionary trade policies commences with the premise that governments behave in ways to maximise their chances of remaining in office. They can deliver large and concentrated benefits to well organized groups and impose costs on other less organized groups in a dispersed way, so that each loser loses only a little (Anderson, 1995). The coal industry and its allies can afford to make large political donations and to foster links with publishers and journalists that gain them extensive, positive, media coverage. The community at large is often unaware of the magnitude of the subsidies. Coal mining unions are often found to be in alliance with management on issues that do not involve occupational health and safety. In coal mining regions, this alliance can be translated into strong political influence at both State/Provincial and Federal Government levels.

In Australia coal is so cheap to mine that producer subsidies are less important than subsidies to large consumers, such as aluminum smelting (Riedy and Diesendorf, 2003).

Instead of receiving producer subsidies, the coal industry is given a dominant role in the formulation of national energy policy. For instance, in June 2004 the Australian Government (2004) released its Energy White Paper, which supported a big investment in geosequestration and little for renewable energy. At the launch of the White Paper, the Industry Minister set the context:

> “The coal industry produces 80 per cent of our energy and the reality is that Australia will continue to rely on fossil fuels for the bulk of its expanding power requirements, for as long as the reserves last.”

Subsequently the Australian Broadcasting Corporation’s Investigative Unit obtained leaked meeting minutes, emails and memos which suggest that, behind the scenes, the fossil fuels industry influenced strongly the content of that White Paper (ABC, 2004). The ABC reported that the Industry Minister had formed a secret advisory group to assist him on the development of policy. The group of 12 companies, known as the Lower Emissions Technical Advisory Group (LETAG), comprised among others the major fossil fuel producers – Exxon Mobil, Rio Tinto, BHP Billiton – and big fossil fuel users and generators – Alcoa, Holden, Boral, Amcor, Energex, Edison Mission and Origin Energy. They worked directly with the Government to develop the energy plan. It was something that the Government was not keen to publicise. According to notes taken by one of the executives during a LETAG meeting. the Minister stressed the need for absolute confidentiality, saying that if the renewable energy industry found out, there would be a huge outcry. The ABC also obtained the minutes of a LETAG meeting during which the General Manager of the Energy Futures branch of Federal Government’s Department of the Industry stated that the government was seeking to adjust policy so that it supports and accommodates industry's direction. (ABC, 2004)

In a big coal producing country as Australia, such apparent collusion between the fossil fuel industry and government is not new. In the 1990s I was one of the representatives of the environmental NGOs on a group convened by the Australian Government to (nominally) advise on the development of a macro-economic model of greenhouse response called MEGABARE. Our advice was ignored and the structure of the completed model and the presentation of the results of the modelling were biased so that it exaggerated the costs of reducing greenhouse gas emissions and ignored the benefits (Diesendorf, 1998). MEGABARE was used widely by the Australian Government in international fora, for example during negotiations on the Kyoto Protocol to support the government’s position in opposition to international greenhouse abatement targets and especially the Kyoto Protocol. In particular, MEGABARE and its successor GIGABARE were used as a basis for special pleading by the Australian Government that, as a ‘fossil fuel dependent country’, Australia’s target should involve an increase in emissions.

Subsequently, it was revealed that our advisory group was a sham and that there was a secret Steering Committee convened by the Australian Bureau of Agricultural and Resource Economics (ABARE) comprising mainly representatives of large fossil fuel producers and consumers, including Rio Tinto, BHP, Australian Coal Association, Australian Aluminium Council, Texaco, Mobil and Exxon. The fee for membership of this inner group was A$50,000 and ABARE did not reveal the source of the funding for its modelling in the publications of the results (Commonwealth Ombudsman, 1998). In recruiting members of the Steering Committee, ABARE explicitly stated that “the benefit to your organisation of participating in this project” includes “influencing policy debate”.

There were international links. According to RJ Smith from the Competitive Enterprise Institute of Washington DC, the head of ABARE presented the MEGABARE model at a conference in Washington DC on 15 July 1997 that was designed to develop strategies to oppose the Kyoto Protocol (Interview with RJ Smith cited in Burton, 1997, p.1).

Nowadays the ongoing work of lobbying the Australia Government to oppose ratification of the Kyoto Protocol and any substantial actions to reduce greenhouse gas emissions is conducted *inter alia* by the Australian Industry Greenhouse Network, www.aign.net. Its membership is drawn mainly from the big greenhouse gas emitting industries: coal, oil, motor vehicles, cement and minerals. In the USA, AIGN has a wide range of counterparts – a sample is included in Table 3.

Table 3: Some organizations promoting coal and growth in energy consumption in the USA and Australia

Organisation	Web address	Mission (from Website) & comments
USA		
Center for Energy and Economic Development (CEED)	www.ceednet.org/index.asp	"To foster the long-term viability of coal-based electricity generation in America"
American Coal Foundation	www.teachcoal.org/aboutus.html	"To develop, produce, and disseminate coal-related educational materials and programs designed for teachers and students."
Americans for Balanced Energy Choices (ABEC)	www.balancedenergy.org/about_abec.asp	"To promote a dialogue with community leaders across the U.S. on issues involving America's growing demand for electricity"
Coalition for Affordable and Reliable Energy (CARE)	www.careenergy.com/about/index.asp	(To ensure) "the availability of affordable and reliable supplies of energy for America's families and businesses"
Global Climate Coalition	www.globalclimate.org	Deactivated since it has achieved its mission to stop the USA from ratifying Kyoto Protocol and accepting mandatory cuts in greenhouse gas emissions.

Australia		
Australian Coal Assocation	www.australiancoal.com.au	"representing the interests of the black coal producers in New South Wales and Queensland, the states that produce 98 per cent of Australia's black coal."
Australian Industry Greenhouse Network	www.aign.net	Even this is obscure: e.g. "(members) have an interest in better understanding the climate change issue; contributing to the climate change policy debate; and see value in collaborative industry action on climate change policy issues."
Australian Aluminium Council	www.aluminium.org.au	One aim is "to encourage the growth of the aluminium industry in Australia and in the use of aluminium in Australia and overseas". In practice the council is one of the principal campaigners against Australia ratifying the Kyoto Protocol. (In Australia, unlike the rest of the world, most aluminium is manufactured using coal-fired electricity.)

Based on their own websites and media reports, the methods used by these organizations include:

- lobbying politicians, public officials and decision-makers in business;
- media campaigns; dissemination of other information and educational materials;
- commissioning computer modelling of greenhouse response;
- conference presentations;
- organization of conferences, workshops, seminars and public meetings;
- funding of scientific research, 'think tanks' and public opinion 'surveys';
- creation and ongoing funding of 'NGOs'.

Outcomes of the political influence of the coal industry, together with its allies among the other fossil fuel and coal-based aluminium industries, in both USA and Australia have been substantial. As of 10 March 2005, USA and Australia are the only two Annex 1 countries (apart from Monaco and Liechtenstein) to refuse to ratify the Kyoto Protocol. Energy policy, backed up with very large amounts of government funding, is targeted at geosequestration in both countries, with minimal funding for efficient energy use and renewable energy. The US FutureGEN project has allocated $1 billion to build a pilot coal-fired power station of 275 MW with separation and geosequestration of at least 90% of the CO_2 produced. In Australia there are three Cooperative Research Centres for fossil fuels, one of which is devoted to geosequestration, but none for renewable energy.

So, despite the environmental, health and social problems of coal use outlined in Section 3, the coal industry is enjoying strong support from energy sector lobbyists, public officials and politicians, especially in the USA and Australia. An important technical element in this support is the possibility that the separation and geosequestration of CO_2 may become a commercial reality in the future. Therefore, the next section of this chapter reviews the technology, impacts, costs and development timescale of this technology.

5. Geosequestration

5.1 Science and technology of geosequestration

For several years the oil and gas industry has been investigating the potential of geosequestration to reduce CO_2 emissions in many natural gas fields where CO_2 occurs naturally mixed with methane, the main constituent of natural gas. Several scenarios for future energy systems, with much lower rates of CO_2 emissions than existing energy supply mixes, assign an important role to natural gas as a transitional fuel to a sustainable energy future based primarily upon renewable energy sources used efficiently (e.g. Saddler, Diesendorf and Denniss, 2004, for Australia; Torrie, Parfett and Steenhof, 2002, for Canada). Natural gas is a much cleaner fuel than coal, in terms of greenhouse gas emissions, air and water pollution, land degradation, and occupational health and safety. But the emission of CO_2 from some gas fields offsets a significant part of the greenhouse benefit of burning the natural gas extracted from those fields, compared with coal. So, we recognise that geosequestration may be essential at some natural gas fields .

Fortunately, it is generally simpler and cheaper to implement geosequestration at natural gas fields than at coal-fired power stations. The latter case involves either converting coal to a gas before combustion and then extracting the CO_2, or capturing the CO_2 from the stream of combustion gases in the smokestack of a conventional power station that burns pulverized coal. Then the CO_2 must be compressed, requiring much energy, piped from the point of production to the geosequestration site, and then injected into a suitable geological formation at least 800 metres deep underground. The capture of CO_2 is the most complex and difficult step. On the other hand, it is the security of the final geosequestration step that is most uncertain and risky over the long term.

Capturing CO_2 from *existing* power stations requires the use of expensive equipment and large quantities of energy, thus reducing overall power station efficiency. For these reasons, retrofitting existing power stations to capture CO_2 is not considered by the industry and research communities to be the lowest cost route to geosequestration. A very large research effort is therefore being committed to new coal utilisation technologies that would reduce the cost and complexity of capturing CO_2. Technologies that could be applied directly to electricity generation include integrated gasification combined cycle (IGCC) and oxy-fuel combustion. The production of hydrogen or liquid fuels from coal could also be associated with CO_2 capture. IGCC is perhaps the most advanced of these, but it is still much more expensive than conventional (pulverized fuel) coal-fired generation and requires further technical improvements.

In general, the main barriers to large-scale application of geosequestration are the immaturity of the technology, the energy penalty, the costs of capture, and the currently unquantified risks of the escape of CO_2 from underground stores. Reducing those risks to a very low level may entail substantial costs.

In Australia a technology road-mapping exercise set 2014-15 as the earliest possible date for operation of the first pilot-scale coal-fired electricity generation project with geosequestration in the Southern Hemisphere. Given the size and complexity of the technology development task required, this may be optimistic. With larger financial resources, the US $1 billion FutureGEN project is likely to be the global first.

For future commercial operation much scientific and engineering research is still required on the long-term containment of CO_2, the consequences of breaching of containment, and the reduction of costs of the capture and burial of CO_2. This means that a wide range of disciplines and specific areas of expert knowledge are required, such as ecology, chemistry, geology, physical geography, various branches of engineering, risk analysis and economics. It is suggested that research topics include:

- Conditions favoring natural containment of CO_2 and breaches of natural stores.
- How to assess suitability of potential stores for injected CO_2.
- Leakage pathways from underground stores to the surface.
- Risk of large releases from all types of underground stores.
- Mechanisms of storage and release of CO_2 in saline aquifers and deep coal seams. In particular, conditions under which CO_2 forms stable solids in these stores.
- Methods of monitoring containment in all types of underground stores.
- Impacts of CO_2 on fresh water and shallow sea ecosystems, and soil and subsoil micro-organisms.
- For geosequestration under the ocean bed, research on seamount ecosystems: species, ecosystems structure and function.

5.2 Environmental, health and social impacts of geosequestration

There is quite a large body of experience in transporting gases in pipelines or large tankers and storing them underground. CO_2 is easier to handle than methane, the major constituent of natural gas, because CO_2 does not burn or explode. The main dangers of geosequestration (summarized in Table 4) would result from escapes of large volumes from underground stores. For economic reasons, stores are likely to be quite large and so the possibility of large escapes is a real concern. Presumably stores where CO_2 becomes bound underground as limestone or other minerals would have negligible risk of large releases. But such stores may be hard to find. The majority of stores, where CO_2 would be stored as a liquid under pressure, are likely to be much less secure.

Since oil and gas fields are quite well understood, proponents of geosequestration argue that large escapes from these stores will be rare, provided sensible procedures are established. For example, if a store was previously a gas well, the CO_2 pressure in the store would have to be constrained to remain below the previous gas pressure in the store. However, just because oil and gas (and the CO_2 that is often found associated with them) have been contained for millions of years, it cannot be assumed that reinjected CO_2 will be securely contained. This will depend upon whether the integrity of the store has been damaged by the large number of wells drilled into it and by structural changes in the walls of the store resulting from the extraction of oil or gas.

Table 4: Summary of potential environmental and health impacts of geosequestration

Risk	Impact
Escape of CO_2 into the atmosphere	Contribution to global climate change via greenhouse effect. Asphyxiation of humans & animals in low-lying areas
Escape of CO_2 into waterways	Acidification of waterways and impacts on biodiversity
Escape of CO_2 into soils	Damage to soil ecosystems
Escape of CO_2 from under sea-bed	Damage to seamount ecosystems
Pushing brine from saline aquifers to the surface	Contamination of drinking water; dryland salinity of soil

A sufficiently large release of CO_2 from a store into the atmosphere would increase the anthropogenic greenhouse effect and hence increase global climate change. Furthermore, since CO_2 is heavier than air, the sudden emergence of a large volume of CO_2 at a point on the Earth's surface at could result in low-lying areas near the breach filling with CO_2 and people becoming asphyxiated. A natural example occurred at Lake Nyos in Cameroons in 1986, when the volcanic crater lake suddenly emitted very large quantities of CO_2. An invisible cloud, estimated at 50 m thick, poured over the rim of the crater, filled the valleys below to a range of 25 km, and killed 1700 people and thousands of cattle.

On a smaller scale, this kind of event could occur more commonly as a result of breaching of an above-ground or near-surface store or a pipeline. Both slow leaks and sudden escapes resulting from (say) earth tremors or sabotage could be a problem. The siting and protection of above-ground and near-surface CO_2 stores and pipelines would be a key factor in minimizing the occurrence such events. As always, developers will be tempted to cut corners in order to reduce costs. In practice, industry in general and the energy industry in particular has tended to locate hazardous installations near low-income and minority communities (Byrne et al., 2002, chapters 1,4,5,6,7,11,).

Because scientific knowledge of CO_2 storage in saline aquifers and deep coal mines is quite rudimentary at present, a premature rush into their use could be much more risky than using oil and gas wells. The only large trial conducted to date in the USA, of pumping CO_2 down into deep coal deposits for the purpose of Enhanced Coal Bed Methane Recovery (ECBMR), caused swelling of the coal matrix (Wildenborg and Van der Meer, 2002). This could result in cracks developing in the coal and surrounding rock and hence the release both CO_2 and coal-bed methane into the atmosphere.

Even before CO_2 reaches the atmosphere, sudden escapes and slow leakage could impact on ground water, surface waterways, soils, subsoil and biodiversity. In water, CO_2 dissolves partially to form carbonic acid and the resulting decrease in pH could have a wide range of adverse impacts on living organisms. Impacts on soil microbes and soil ecosystems in general could be profound. Even less well understood are subsoil microbial systems and their possible responses to CO_2 (Johnston and Santillo, 2002).

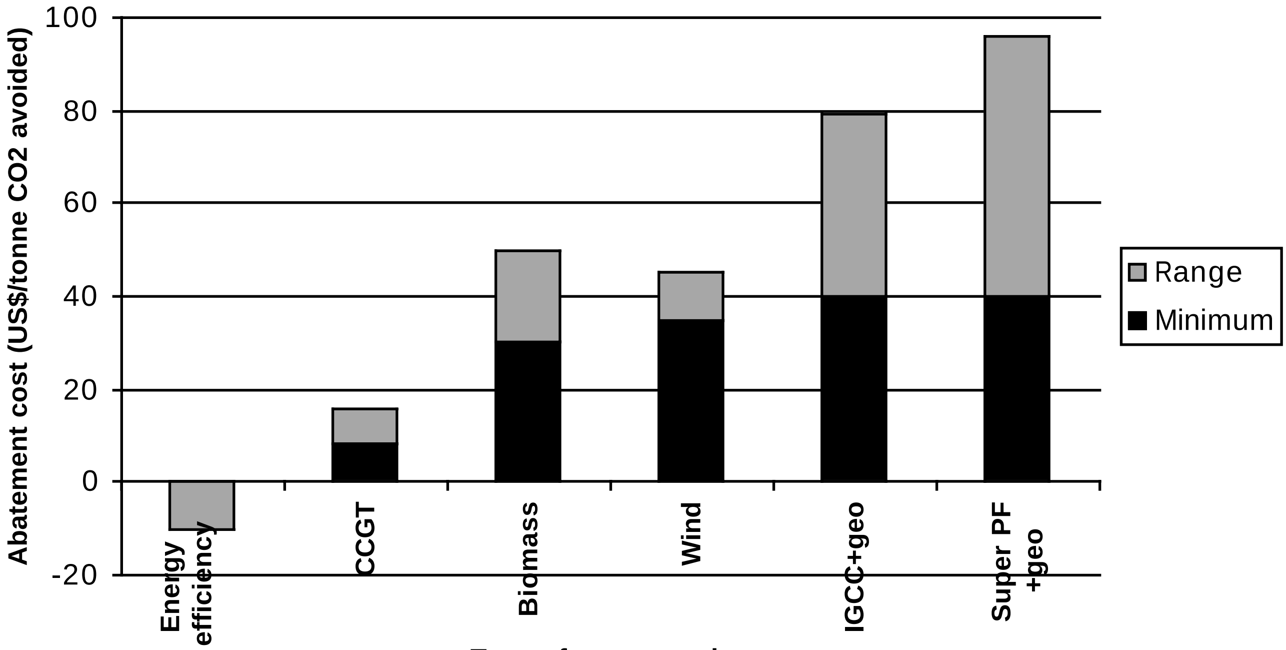
The breaching of CO_2 reservoirs under the sea-bed could impact strongly on seamount ecosystems. Previously it was thought that the ocean bed was low in biodiversity. But, recently, seamounts rising 1000 metres or more above the ocean bottom have begun to be studied. They are rich in biodiversity, containing many species new to science, highly productive, and highly vulnerable to disturbance (Johnston and Santillo, 2002). Storage in international territory under the sea-bed is presumably restricted by the London Convention.

Theoretically it may be possible that, with detailed investigation of potential stores, well-designed technologies, management systems, laws and policing of those laws, the risks of severe adverse environmental and health hazards of geosequestration could be reduced to very low levels. Then, the principal hazards remaining would be those of coal mining and the non-greenhouse impacts of coal burning discussed in Sections 3.2-3.5. However, safety may come at a high economic cost.

5.3 Cost of geosequestration

Figure 3 shows the current costs of avoiding emission of a tonne of CO_2 from an existing best-practice pulverized fuel coal-fired power station, and by using several existing commercial technologies (efficient energy use, combined cycle gas turbine (CCGT), biomass and wind) and by using two different types of hypothetical coal-fired power stations with geosequestration. The black bars give minimum values and the gray bars give the approximate range of uncertainty.

Fig. 3: Typical costs of avoiding emission of a tonne of CO_2



Sources: See text.
Note: It is assumed that the avoided CO_2 emission is from a new conventional, pulverised fuel, black coal power station without geosequestration. This power station has a greenhouse intensity of 80 kg CO_2/MWh electricity sent out and a generation cost of US $25/MWh. The abatement costs shown in Fig. 3 are *additional* to the cost of the conventional coal power station. 'Geo' denotes geosequestration. 'Super PF' denotes a conventional pulverized fuel coal-fired power station with a supercritical boiler.

In practice, costs of both fossil and renewable power vary significantly between countries and between regions of countries and so Figure 3 can only be considered to be a rough guide. More precise costs, including those of transmission, must be calculated for particular regions. For the existing technologies in Fig. 3, cost estimates come from Saddler, Diesendorf and Denniss (2004) for Australia, with 1 AUD = 0.7 x 1 USD. For existing technologies the uncertainty range reflects mainly the range of scales and sites. For instance, a 100 MW wind farm at an excellent site could generate electricity at US$35-40/MWh (US 3.5-4.0 c/kWh). However, a 20 MW wind farm at a medium wind site may generate at US$50/MWh (US 5 c/kWh). The minimum bioelectricity costs come from landfill gas and biomass residues, while the maximum come from dedicated energy crops without other economically viable products (e.g. activated charcoal, eucalyptus oil). At the time of writing there are large differences between countries and regions in the costs of generating electricity from natural gas and coal. The CCGT values in Fig. 3 reflect Australian natural gas prices in September 2004 which were far below those in the USA at the same time. For efficient energy use, we assume that costs vary between negative and zero, depending upon the degree of implementation.

For the two hypothetical coal-fired power stations with geosequestration in Fig. 3, one is an integrated gasification combined cycle (IGCC) power station and the other is a new supercritical pulverized fuel power station. Since there is no commercial geosequestration, the large uncertainty bands represent genuine uncertainty in costs rather than variation resulting from scale or site. At the present level of uncertainty, it is unclear which of the two geosequestration options shown here will be cheaper. IGCC is currently the option most favoured by geosequestration researchers. Its power station is expected to be more expensive than the supercritical pulverized fuel power station, but its cost of separating CO_2 is expected to be less. It is assumed that CO_2 is transported only 100 km by pipeline from production point to store. Cost estimates are taken from Freund and Davison (2002) supplemented with other international sources. For geosequestration in oil fields that are almost exhausted, there may be some economic value in injecting CO_2 for enhanced oil recovery that would offset at least part of the costs.

Figure 3 represents *actual* costs for the existing technologies (efficient energy use, CCGT, biomass and wind) and *current estimates* of future costs for the two coal technologies with geosequestration. All these costs can be expected to decline over the next two decades. However, the costs of renewable energy technologies have been declining steadily over the past two decades and this trend is expected to continue as the scale of production continues to increase and improvements already achieved in R and D are commercialized. For instance, projections by both a government-owned corporation (Short and Dickson, 2003) and industry (Mallon and Reardon, 2004) researchers suggest that wind power at excellent sites may be competitive with conventional coal-fired electricity in eastern Australia costing about US $25/MWh by 2020. On the other hand coal-fired electricity with geosequestration is likely to cost *at least* US$40/MWh above that of conventional coal-fired electricity and even the $40/MWh minimum level shown in Fig. 3 is unlikely to be achieved by 2020.

5.4 What could geosequestration achieve and when?

Geosequestration offers the possibility of capturing and storing 80-90% of CO_2 emitted from new coal-fired power stations in the long term. However, it would not reduce significantly any of the other environmental, health or social impacts of coal-fired electricity discussed in Section 3, namely air and water pollution, high water use, land degradation, occupation health and safety hazards, vulnerability to disruption and job losses from automation.

Geosequestration would take several decades to make a significant reduction in CO_2 emissions. Saddler, Riedy and Passey (2004) have developed a spreadsheet model to estimate the potential for geosequestration to reduce emissions from coal-fired electricity generation in Australia. The model assumes that geosequestration is technically feasible, capable of long-term storage, environmentally safe and commercially viable. Demonstration power stations are assumed to be built between 2016 and 2020, with 'commercial viability' (whatever that means) being achieved in 2020. Geosequestration is applied only to new plant, in States where large underground storage sites are known to exist, and modeling is extended out to 2030. The remainder of this section quotes directly the results from the executive summary of Saddler, Riedy and Passey (2004), with some shortening, and with references and parentheses added.

> "It was found that use of CCS (CO_2 capture and storage) alone would reduce emissions by about 9 % in 2030, and cumulative emissions from 2005 to 2030 by only 2.4%. A scenario with modestly increased energy efficiency, corresponding to the efficiency potential assumed in the Australian Energy White Paper (Australian Government, 2004a), could reduce emissions in 2030 by about the same amount, and cumulative emissions by twice as much. This would be achieved at zero or even negative cost."
>
> "If gas-fired generation and renewable energy were built instead of new coal-fired generation, to achieve the same cumulative abatement by 2030 as CCS would require only a doubling of the current very modest MRET (Mandatory Renewable Energy Target, currently only 9500 GWh/year) target, and double that of additional gas-fired generation."
>
> "Scenarios that include more extensive energy efficiency improvements, though still well within identified technical potential, combined with use of gas-fired generation and renewables instead of new coal-fired plant, could reduce emissions in 2030 by more than five times as much as CCS alone, and cumulative emissions by ten times as much."
>
> "The key to these results is that end-use efficiency, gas-fired generation, wind power and some types of bioenergy are currently commercially available, and so do not have to wait until 2020. While it is possible CCS may be an effective abatement option after 2030, use of currently available technologies will reduce emissions much sooner and at lower cost, and make any abatement task for CCS easier."

In practice, in countries that have placed strong emphasis on geosequestration in their energy policies, plans for new, conventional, dirty, coal-fired power stations are proceeding apace. In the USA about 100 such power stations are in various stages of development. Assuming that 72 of these projects survive public opposition, the USA would emit an additional 209-275 million tonnes of CO_2 per year from coal by 2012 (Clayton, 2004). This corresponds to an increase of 9-12 percent in the U.S. 2002 CO_2-equivalent emissions from electricity generation (US EPA, 2004). In four out of Australia's six States there are proposals for a total of three new conventional black coal-fired power stations and one major refurbishment of a very old and dirty brown coal station (Diesendorf 2005 a,b,c; 2004b) amounting to an additional 32 million tonnes per year of CO_2 emissions by 2010. This corresponds to a 17.6 percent increase in the Australian 2002 CO_2 emissions from electricity generation (Australian Government, 2004b).

This situation suggests that that the possibility of large-scale geosequestration, three or more decades in the future, is being used to deflect attention away from the current reality of business-as-usual. Thus, geosequestration is less about sustainable development and more about sustaining the coal industry by greening its image

6. Conclusion

The coal industry has strong political influence and has built up a network of supporting organizations that lobby government and other decision-makers, gain extensive positive media coverage, disseminate information in schools, obtain grants and subsidies, perform R and D, and present a high profile at professional and other conferences (Section 4). With its substantial human and financial resources the coal industry is promoting geosequestration as a means of ensuring that future electricity generation systems will still be highly dependent upon coal.

Geosequestration of CO_2 emissions from coal-fired power stations could possibly begin to make a significant contribution to greenhouse gas abatement after 2030. But, even then, it cannot reduce any of the other environmental and health impacts of coal use: air and water pollution, large water use, land degradation, biodiversity loss and occupational health and safety hazards (Section 3). Furthermore, geosequestration introduces new environmental and health hazards (Section 5.2). If the coal industry is successful in establishing large-scale geosequestration, people will continue to suffer these impacts and the citizens of countries with high coal use may be forced to pay very large subsidies for geosequestration, either through the taxation system or through high electricity prices.

Geosequestration may never become economically competitive with a mix of efficient energy use, natural gas and lower cost renewable energy sources such wind power and bioenergy from crop residues. Despite that situation, the *possibility* of geosequestration in the future is being used to divert funding away from cleaner technologies that are more cost effective now, notably efficient energy use and renewable energy, and to deflect attention away from current proposals to build many more conventional dirty coal-fired power stations.

Between now and 2030 (Saddler, Riedy and Passey, 2004) and possibly by 2050 (Saddler, Diesendorf and Denniss, 2004), much greater reductions in CO_2 emissions from electricity generation could be achieved in Australia more cheaply from a combination of efficient energy use, solar hot water, natural gas, wind power and bioenergy based on crop residues. In Canada, which currently generates only about 15% of its electricity from coal, an 86% reduction on CO_2-equivalent greenhouse gas emissions from electricity generation could be achieved by 2030, using existing technologies (Torrie, Parfett and Steenhof, 2002, pp.109-110).

Efficient energy use in particular offers a myriad of technologies that can reduce energy wastage and emissions at no net cost and with very low environmental and health impacts. Wind and bioenergy require a more distributed energy supply system than the current highly centralized system based on large coal-fired power stations and, in some countries, nuclear power stations. In the age of terrorism, a distributed system is more secure and resilient than a centralized system. Distributed energy systems also create much more local employment than centralized.

While there are future potential roles for geosequestration, especially for reducing CO_2 emissions at gas fields, it is unwise for governments to allocate to geosequestration the major part of their funding for future energy supply and demand management systems. Efficient energy use and several renewable energy technologies could make large contributions in the short and medium term (by 2020). Indeed, it has been argued that the additional costs of renewable energy sources could be funded from the savings from efficient energy use, so that the transition to a sustainable energy future could possibly be made at no net cost (Saddler, Diesendorf and Denniss, 2004; Torrie, Parfett and Steenhof, 2002). Current proposals for new or refurbished conventional coal-fired power stations in Australia could be cost-effectively replaced with a mix of efficient energy use, renewable energy and natural gas stations by 2010 (Diesendorf, 2005a,b,c; 2004b).

Some government action and up-front funding is required to facilitate the transition process under current circumstances where the environmental and health costs of burning fossil fuels have not been internalised in prices. It is unfortunate that the two industrialised countries that are refusing to ratify the Kyoto Protocol, the USA and Australia, are directing very large resources into geosequestration while doing very little to reduce their greenhouse gas emissions. The USA has the world's highest total emissions and Australia has the world's highest per capita emissions. The US Government and Congress delayed extension of the production tax credit for wind power for almost all of 2004, thus undermining the US wind power industry. The Australian Government has refused to expand the tiny Mandatory Renewable Energy Target (MRET), which gives a subsidy of a small fraction of 1 c/kWh to accredited renewable energy sources.

The pathway to a sustainable energy future must involve such initial stimuli and more: either a carbon levy or tradeable emission permits with cap and trade. This would be an economically rational means of allocating resources between coal plus geosequestration on one hand and efficient energy use plus renewable energy plus natural gas on the other hand.

7. References

ABC. 2004. Story broadcast on Australian Broadcasting Corporation national radio, 7 September 2004, available on http://www.abc.net.au/pm/content/2004/s1194166.htm (accessed Sept 2004).

Anderson, K. 1995. "The political economy of coal subsidies in Europe." *Energy Policy*. Volume 23: 485-96.

Australia: National Occupational Health and Safety Commission. 1998. *Work-related traumatic fatalities in Australia, 1989 to 1992*, http://www.nohsc.gov.au/Statistics/publications/#relatedfatalaties/ (accessed 3 January 2005).

Australian Government. 2004a. *Securing Australia's Energy Future*. Canberra: Department of Prime Minister and Cabinet. http://www.pmc.gov.au/publications/energy_future/index.htm, accessed 2 January 2005.

Australian Government. 2004b. *National Greenhouse Gas Inventory 2002*, Canberra: Australian Greenhouse Office. Table 4. http://www.greenhouse.gov.au/inventory/2002/pubs/inventory2002parta.pdf (accessed 2 January 2005).

Australian Government. 2004c. *AGO Factors and Methods Workbook*. Canberra: Australian Greenhouse Office, Table 1. www.greenhouse.gov.au/workbook/ (accessed 3 January 2005).

Burton, B. 1997. "WMC's campaign to scuttle binding targets." *Mining Monitor* Volume 2, Number 4:1. Australia: Mineral Policy Institute, www.mpi.org.au/ (accessed October 2004).

Byrne, J., Glover, L. & Martinez, C. (eds) 2002. *Environmental Justice: Discourses in International Political Econom*y. Series on Energy and Environment Policy, Volume 8. New Brunswick USA and London UK: Transaction Publishers.

Clayton, M. 2004. "New coal plants 'bury' Kyoto." *Christian Science Monitor* 23 December. http://www.csmonitor.com/2004/1223/p01s04-sten.html/ (accessed 2 January 2005).

Colong Foundation for Wilderness. 2004. website www.colongwilderness.org.au, (accessed September 2004).

Commonwealth Ombudsman. 1998. "Ombudsman releases ABARE investigation report." Media release, Canberra, 4 February.

De Moor, A. 2001. "Towards a grand deal on subsidies and climate change." *Natural Resources Forum* Volume25, Number 2: 167-76.

Diesendorf, M. 2005a (in press). "Towards Queensland's clean energy future." A report for the Clean Energy Future Group in collaboration with Queensland Conservation Council. November. To be published on www.wwf.org.au/.

___________. 2005b (in press). "Towards Western Australia's clean energy future." A report for the Clean Energy Future Group in collaboration with the Conservation Council of Western Australia. To be published on www.wwf.org.au/.

___________. 2005c (in press). "Towards New South Wales' clean energy future." A report for the Clean Energy Future Group. To be published on www.wwf.org.au/.

___________. 2004a. "Comparison of Employment Potential of the Coal and Wind Power Industries." *International Journal of Environment, Workplace and Employment* Volume 1: 82-90.

___________. 2004b. "Towards Victoria's clean energy future." A report for the Clean Energy Future Group in collaboration with Environment Victoria. November. See www.wwf.org.au/.

___________. 1998. "Australian economic models of greenhouse abatement." *Environmental Science and Policy* Volume1: 1-12.

ExternE. 1998. *ExternE: Externalities of Energy. New results 1998*. Luxembourg & Belgium: European Commission, Directorate-General XII, Sci. Res. & Dev.. See also http://ExternE.jrc.es/.

Freund, P. and J, Davison. 2002. *General overview of costs*. IPCC workshop on carbon dioxide capture and storage. Regina, Canada, November. (www.climatepolicy.info/ipcc/index.html).

Johnston, P. and D. Santillo. 2002. *Carbon capture and sequestration: potential environmental impacts*. IPCC workshop on carbon dioxide capture and storage, Regina, Canada, November. (www.climatepolicy.info/ipcc/index.html).

MacGill, I., M. Watt and R. Passey. 2002. *The economic development potential and job creation potential of renewable energy: Australian case studies*. Commissioned by Australian Cooperative Research Centre for Renewable Energy Policy Group, Australian Ecogeneration Association and Renewable Energy Generators Association.

Mallon, K. and J. Reardon. 2004. *Cost convergence of wind power and conventional generation in Australia*. Melbourne: Australian Wind Energy Association (www.auswea.org.au)

Pope, C.A., M.J. Thun, M.M. Namboodri, et al.1995. "Particulate air pollution as a predictor of mortality in a prospective study of US adults." *Am. J. Respir. Crit Care Med*. Volume 151:669-74.

Rabl, A. and J.V. Spadaro. 2000. "Public health impact of air pollution and implications for the energy system." *Annual Review of Energy & Environment* Volume 25:601-27.

Riedy, C. and M. Diesendorf. 2003. "Financial subsidies to the Australian fossil fuel industry." *Energy Policy* Volume 31: 125-37.

Saddler, H., M. Diesendorf and R. Denniss. 2004. *A Clean Energy Future for Australia*, Sydney: Clean Energy Future Group. (May be downloaded from www.wwf.org.au)

Saddler, H., C. Riedy and R. Passey. 2004. *Geosequestration: What is it and how much can it contribute to a sustainable energy policy for Australia?* Discussion Paper No. 72, Canberra: Australia Institute.

Short, C. and A. Dickson. 2003. *Excluding technologies from the Mandatory Renewable Energy Target*. ABARE eReport 03.12, Canberra: AbareEconomics, June, Table 10.

Torrie, R., R. Parfett and P. Steenhof. 2002. *Kyoto and Beyond: The low-emission path to innovation and efficiency*. Canada, www.torriesmith.com.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000, *Sources and Effects of Ionizing Radiation*, Vol. 1: Sources. Annex B: Exposures from natural radiation sources. Pp.109-10; 136-8. http://www.unscear.org/reports/2000_1.html

U.S. EIA. 2004. Energy Information Administration of US Department of Energy. www.eia.doe.gov/emeu/iea/coal.html (accessed 1 October 2004).

U.S. Environmental Protection Agency, 2004. *Inventory of U.S. Greenhouse Gas Emissions and sinks: 1990-2002*. Washington DC: Environmental Protection Agency, Table 3.6. www.epa.gov/globalwarming/publications/emissions/ accessed 2 January 2005.

Whistleblowers Australia, http://www.uow.edu.au/arts/sts/bmartin/dissent/contacts/au_wba/, see 'Whistleblower cases of national significance' and then case of Mr Jim Leggate.

Wildenborg, A.F.B. and L.G.H. Van der Meer 2002. *The use of oil, gas and coal fields as CO_2 sinks*. IPCC Workshop on carbon dioxide capture and storage, Regina, Canada, November. (see www.climatepolicy.info/ipcc/index.html, accessed 1 October 2004).