Submission to The House of Representatives Standing Committee on Science and Innovation

Inquiry into geosequestration technology

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Executive Summary

Scientists say that global greenhouse gas emissions must be reduced by at least 60 percent below 1990 levels by 2050 and the average global temperature rise must remain below 2 degree Celsius, if the worst impacts of climate change are to be avoided. The latest evidence suggests that the scale and speed of climate change might have been underestimated and that its consequences are likely to be more severe than previously thought.

Australia is the world's driest inhabited continent and so will suffer drastically from worsening climate change. Scientists predict massive species loss, an increase in severe weather events, damage to agricultural production and worsening water shortages. Climate change also threatens Australia's natural treasures, the Great Barrier Reef, the snow country and Kakadu. Aside from domestic impacts, regional security issues will also arise with our near neighbours feeling the pressures of overpopulation, changing land use and climate change.

Governments have been slow to implement effective climate change mitigation strategies and, without significant action, greenhouse gas emissions are predicted to rise significantly over the next 30 years. In Australia, where coal-fired power stations provide over 80 percent of our electricity and emit approximately one third of our total greenhouse gas emissions, geo-sequestration of carbon dioxide is now being considered as a primary means to reduce emissions from burning fossil fuels.

Carbon capture and storage technology reveals three major flaws:

- Too costly: Costly and unsuitable for a significant proportion of coal fired power generation in Australia;
- Too little: Ineffective at delivering significant emission reductions and could even jeopardise emissions stabilisation in the future; and
- Too risky: Carries significant financial, health and environmental risks.

Scientific research clearly shows that CCS is a risky enterprise. Not only is the technology itself inherently risky, but **the overly optimistic perception and the deceptive reliance on its viability has the potential to detract from the development of other technologies**. In Australia, CCS is often viewed as an entire *strategy* for climate mitigation, rather as an emerging *technology* which has not yet been proven as safe, feasible or effective. This is a risky over-evaluation.

CCS is a complex system whose major steps include carbon capture from large point sources (eg. coal fired power plants), compression, transport and storage. The potential risks associated with CCS have not yet been resolved. These include both **continuous and sudden leakage of CO_2**, the former of which has the potential to render climate mitigation efforts ineffective, while the latter can jeopardise life and health of exposed individuals.

Transport of CO_2 over large distances is energy intensive, yet while suitable geo-sequestration sites have been found in Queensland, Victoria and Western Australia, **there are no identified sites within 500km** of coal-fired power stations in the Newcastle-Sydney-Wollongong area of New South Wales, nor at Port Augusta in South Australia. These regions produce 39 percent of Australia's current net CO_2 emissions from electricity generation.

While still susceptible to uncertainties, **cost** calculations in relation to CCS are estimated to almost **triple the price of coal power**, resulting in it being even more expensive than proven existing renewable energy technologies such as wind and geothermal power. Yet this does not include costs to monitor and maintain storage sites for up to 100,000 years to ensure they remain secure against CO_2 escape.

Analysis indicates more **cost-efficient abatement** could be achieved through a combination of energy efficiency measures, demand management and renewable energy between now and 2030 than from CCS.

The use of geo-sequestration in Australia would result in, **at best, a cumulative emissions reduction from 2005 to 2030 of only 2.4 percent.** Modestly increased energy efficiency, based on the efficiency potential assumed in the Government's 2004 *Energy White Paper*, could - at zero or even negative cost - decrease cumulative emissions by twice as much.

The limited potential for CCS to deliver emission reductions does not justify large-scale public investments in research and development of the technology. Such a **premature reliance on unproven technologies such as CCS** runs the risk of diverting investments and research funding away from more sustainable technologies and mitigation options.

Time is important in the context of the rapidly emerging impacts of climate change. Even technology optimists consider 2014-2015 as the earliest possible date for a pilot-scale coal-fired electricity generation project in Australia. Others regard this as too optimistic in the face of the technological and risk-related challenges that have yet to be resolved. It is predicted that it will be at **least 25 years before CCS** may make a contribution to climate change mitigation.

Liability for leakage and other environmental harm through CCS is a major issue that is unresolved in regard to regulation. It is unreasonable to expect tax-payers and future generations to accept responsibility for a geo-sequestration site after a corporation has created it and financially benefited from it. However, this is exactly what recent draft legislation proposes.

Overall **investment in technology** claiming to make coal 'cleaner' in Australia, including proposed private industry spending, is expected to tip AUS$20 billion in the next ten years – investment that should be redirected to energy efficiency, renewable energy and demand management. The environmental and social costs of fossil fuels combustion are also not internalised into electricity tariffs. This and the removal of direct and indirect **subsidies** to fossil fuel power-generation technologies are essential policy strategies for stimulating the development of renewable energy technologies.

Renewable energy generates **local jobs and investment**. In Australia, wind power has been shown to create more than six times as many manufacturing and installation jobs as equivalent coal generation. In contrast, employment in the Australian coal mining industry has declined by 45 percent since the mid 1980s and since the 1990s employment in electricity generating has fallen by 50 percent, while production in both industries has continuously risen.

Greenpeace believes carbon capture and storage technology is:

- too costly: There is no evidence available that indicates CCS is the most economical mitigation option. Research indicates it is cheaper *and* more effective to reduce the amount of carbon dioxide produced in the first place. In Australia more carbon dioxide emissions from electricity generation could be **reduced at lower cost** from a combination of energy efficiency measures, natural gas and renewable energy between now and 2030 than from CCS. Focusing on CCS also diverts financing away from truly sustainable mitigation options.
- too little: CCS would deliver too little emissions reductions and could even jeopardise stabilisation in the future. More effective and rapid mitigation options include energy efficiency improvements, the switch to less carbon-

intensive fuels and renewable energy technologies. These are safe, technologically mature, economically feasible and presently available.

- too risky: Climate change requires immediate action and a coherent response that can be implemented today. CCS is a technology whose large scale commercial application cannot be realised within the next twenty years, if at all. The IPCC confirms that for a widespread application of CCS "technical maturity, costs, overall potential, diffusion and transfer of the technology to developing countries and their capacity to apply the technology, regulatory aspects, environmental issues and public perception" are still to be proven.

Recommendations

In order to respond effectively to the challenge of climate change, **Greenpeace** recommends that the Australian Government:

- Set a target to reduce the nation's greenhouse emissions by 60-80 percent below 1990 levels by 2050 with a target of at least 20 percent by 2020. A roadmap also needs to be developed to set out the measures necessary for these targets to be achieved.
- Give immediate and top priority to rapidly expanding renewable energy, energy efficiency and reducing energy demand to achieve the deep cuts in emissions that are required to prevent dangerous climate change.
- Direct public research funding towards renewable energy and energy efficiency. Recognising the polluter pays principle: research in areas advocated by the fossil fuel industry, including geosequestration, should be funded by the fossil fuel industry and should be subject to independent scientific evaluation.
- Develop and implement appropriate stimuli and regulatory frameworks for emissions reductions through the implementation of a carbon levy.
- Establish a stringent legal framework for regulating current geosequestration facilities that ensures that the proponents assume complete legal liability for the full economic, environmental and social costs of leakage over the lifetime of the storage (ie. in perpetuity).
- Ensure that no geo-sequestration projects are approved until risks and uncertainties are resolved through independent analysis.
- Increase the Mandatory Renewable Energy Target (MRET) so that 10% of electricity is supplied by renewable energy by 2010, and 25% by 2020, to increase thereafter.

1. Introduction

There is strong evidence that most of the global warming observed over the last 50 years is attributable to human activities.[1] Carbon dioxide (CO_2) emissions are responsible for over 60 per cent of the anthropogenic greenhouse effect and the main driver of climate change. The burning of fossil fuels such as coal, oil, and natural gas is releasing the carbon stored in the fuels into the atmosphere and affects the global carbon cycle, a balanced system of carbon exchange between the air, the oceans and land vegetation. At present atmospheric levels of carbon dioxide are rising by over 10 per cent every 20 years[2], while greenhouse gas emissions from electricity generation have increased by 90 percent since 1990.

Scientists say that global greenhouse emissions need to be reduced by at least 60% below 1990 levels by 2050 and the average global temperature rise must remain below 2 degree celsius, if the worst impacts of climate change are to be be avoided.[3] But even then, as greenhouse gases are long-lived and remain in the atmosphere for hundreds or even thousands of years, global warming will continue to affect the earth's natural systems for hundreds of years. Estimates of upcoming changes are wide-ranging, however, even the best case predictions of future climate impacts say that the consequences will significantly affect our lives in the very near future.[4]

Australia is the world's driest inhabited continent and so will suffer drastically from worsening climate change. Australia could lose half its native species to global warming by 2050[5]. Scientists warn that if no progress is made more severe weather events are in store, including more frequent and severe droughts, storms, bushfires and floods. Australia's agriculture will suffer serious damage and its already severe water shortages will worsen. For instance, loss of arable farmland could cause loses to the Australian wheat industry of $1 billion per year within 30 years.[6] Climate change also threatens

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[1] IPCC, *Carbon Dioxide Capture and Storage*: *Special Report of the Intergovernmental Panel on Climate Change*, IPCC, Geneva, 2005, http://arch.rivm.nl/env/int/ipcc/pages_media/SRCCS-final/SRCCS_WholeReport.pdf.

[2] UNFCCC, *The greenhouse effect and the carbon cycle*, UNFCCC, Bonn, 2006, http://unfccc.int/essential_background/feeling_the_heat/items/2903.php

[3] The Climate Institute, *Top ten tipping points on climate change: An analysis of how the fundamental trends of climate change have shifted and why Australia is adrift*, The Climate Institute Australia, Sydney, 2006.

[4] UNFCCC 2006

[5] C D Thomas et al. (2004), 'Extinction risk from climate change, *Nature*, Vol. 427, pp. 145 - 148 , http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v427/n6970/full/nature02121_fs.html

[6] The Climate Institute 2006

Australia's natural treasures, the Great Barrier Reef, the snow country and Kakadu.[7]

A risk and vulnerability report for the Australian Greenhouse Office confirms that over the next 30 to 50 years Australia is likely to experience severe consequences of climate change such as[8]:

- annual average temperature increases between 0.4° and 2.0°C by 2030 and 1.0° and 6.0°C by 2070 (with significantly larger increases in the most affected regions);
- more heatwaves and fewer frosts, along with higher propensity for bushfires;
- rising sea levels and storm surges;
- more severe storms and wind speeds in cyclones;
- more frequent El Nino Southern Oscillation (ENSO) events;
- reductions in average rainfall and run–off in Southern and much of Eastern Australia with rainfall increases across much of the Tropical North (this includes a further 20 per cent rainfall reduction in Southwest Australia, and a 20 per cent reduction in run–off in the Murray Darling Basin by 2030); and
- change in ocean currents, affecting Australia's coastal waters.

Apart from posing risks to the Australian environment and economy new research suggests climate change also challenges its security and political stability. Climate change is predicted to impact on Australia's security because of extreme food, water and energy scarcities in a relatively short timeframe. The density of coastal populations in Asia and the Pacific increases the likelihood of their displacement through predicted sea level rise. Resulting regional destabilisation and unregulated population movements are likely to be felt across borders. Consequences of severe weather events will increase the demand for resources and coping ability for developed countries in the region. But they will also lead to longer term health security consequences as infectious diseases are more likely to spread in the course of global warming. In general, the overall effects of global warming might push some of Australia's neighbouring states above their carrying capacity, undermine the legitimacy and response capacity of their elected governments

[7] IPCC, *The regional impacts of climate change: An assessment of vulnerability*. A Special Report of IPCC Working group II, IPCC, Geneva, 1997, http://www.ipcc.ch/pub/regional(E).pdf

[8] Australian Greenhouse Office, *Climate change: Risk and vulnerability*, Commonwealth of Australia, Canberra, 2005b.

and threaten the security of their citizens. This will place new and additional demands on Australian resources and capacities.[9]

Latest evidence suggests that the scale and speed of climate change impacts might have even been underestimated and that its consequences are likely to be more severe than previously thought.[10] All human and natural systems are strongly dependent on stable climate patterns and extremely vulnerable to climate change. Rapid climate change puts extreme pressure on people, species and habitats and, at present levels, is likely to exceed the overall natural adaptive capacities. For many, effective adaptation options such as relocation, developing migratory corridors or relieving other environmental pressures are extremely limited not available at all. A risk and vulnerability study by the Australian Greenhouse Office concludes: “Greenhouse gas emissions since the industrial revolution make some climate change inevitable, but adaptation is likely to be a progressively imperfect substitute for reducing global greenhouse gas emissions because the more greenhouse gas concentrations in the atmosphere rise, the greater the risk of ‘dangerous’ anthropogenic interference with the world’s climate system that cannot be readily absorbed or prepared for”.[11] The most appropriate and most effective strategy against climate change - to mitigate, to immediately begin to reduce the production and emission of greenhouse gases into the atmosphere - has not been put into action quickly enough.

In Australia, and other coal producing countries, geosequestration is being put forward as the primary means to reduce greenhouse gas emissions (GHG) from burning fossil fuels, especially from burning coal to generate electricity. Geosequestration of carbon dioxide means injecting it into deep underground geological formations, where the carbon dioxide will be kept from rising into the atmosphere for hundreds or even thousands of years. Outside Australia, the term ‘carbon capture and storage’ (CCS) is more common to describe the whole process the CO_2 has to go through before finally being sequestrated. Coal-fired power stations provide around 80 percent of Australia’s electricity and emit nearly 170 Mt CO_2-e per year, which is approximately one third of Australia’s total emissions.[12] Therefore it comes as no surprise that CCS is presented and promoted as a cost effective solution to climate change by major Australian industries such as the coal sector.

[9] A Dupont & G Pearman, *Heating up the planet: Climate change and security*, Lowy Institute for International Policy, Sydney, 2006.
[10] The Climate Institute 2006
[11] Australian Greenhouse Office 2005b, p. iii.

Greenpeace does not share this vision of carbon capture and storage as the silver bullet to climate change mitigation. The IPCC clearly states that no single technology option will be able to achieve the emission reductions needed to stabilise greenhouse gas concentrations in the atmosphere.[13] As further outlined in this report, research suggests that geosequestration will not even be a crucial part of it.

In order to respond effectively to the challenge of climate change, **Greenpeace** recommends:

- The government should set a target to reduce the nation's greenhouse emissions by 60-80 percent below 1990 levels by 2050 with a target of at least 20 percent by 2020. A roadmap needs to be developed to set out the measures necessary for these targets to be achieved.
- Australia must give immediate and top priority to rapidly expanding renewable energy, energy efficiency and reducing energy demand to achieve the deep cuts in emissions that are required to prevent dangerous climate change.

2. Science underpinning geosequestration technology

In theory, CCS is a complex system that involves three main steps:

1. Carbon capture: Fossil fuels are converted to a gas before combustion and CO_2 is extracted in the power plant. Alternatively, the CO_2 is captured from the stream of combustion gases.
2. Carbon transport: A system or mechanism (e.g. pipeline) transports the CO_2 from the production to the storage site.
3. Carbon storage: The CO_2 is injected into the storage site. In the case of geosequestration these are geological formations such as deep saline aquifers, depleted oil and gas fields or unmineable coal seems.

The cost of carbon capture and compression is the major cost driver in most CCS systems. Generally, individual costs for the single components vary widely depending on the reference plant, the CO_2 source, transport requirements and storage situation. While carbon capture is also the most complex step, the carbon storage step is the most uncertain one due to

[12] H Saddler, C Riedy, C & R Passey, *Geosequestration: What is it and how much can it contribute to a sustainable energy policy for Australia?*, The Australia Institute, Anu, 2004.
[13] IPCC 2005, p. 3

limited experience and knowledge about storage sites, sequestration technology and long-term behaviour of injected CO_2.[14]

2.1 Technology status

Commercial power stations that integrate geosequestration technology have not been realised anywhere in the world. This is mainly due to the immaturity of the technology, the energy penalty, the high cost of CO_2 capture and the currently unquantified risk of leakage from underground storage.[15] COAL21, an initiative of the Australian Coal Association, states 2014-15 as the earliest possible date for operation of a pilot-scale coal-fired electricity generation project with geosequestration in Australia, but behind the backdrop of technological and risk-related challenges yet to overcome this is considered as too optimistic by non-industry experts.[16]

Components of CCS systems are in various stages of development, but a complete CCS system is more than the sum of its parts. Even if all individual components prove to be mature it cannot be concluded that an overall system is mature. Little experience exists with combining CO_2 capture, transport and storage into a fully integrated system. Well-drilling and injection technology, computer simulation of storage reservoir performance and monitoring methods still have to be developed further to be used for geosequestration. While standard monitoring methods are available, higher monitoring standards are needed for improved risk management, but are a major cost-driver and not factored into present cost calculations. Even with improved monitoring methods small leakage and displacement of brine cannot be detected, but can cause significant environmental problems. Additionally, the application of CCS to large-scale power plants remains to be implemented.[17]

To capture CO_2 from existing power stations would significantly reduce overall power station efficiency due to the need for large and expensive equipment as well as the use of large amounts of energy. For this reason retrofitting existing plants with CCS is regarded as more costly than equipping newly built power plants with CCS and therefore not considered as cost-effective by both the Australian coal industry and research communities.[18] Accordingly, research efforts are focusing on the development of new coal utilisation technologies

[14] IPCC 2005; Saddler, Riedy & Passey 2004
[15] M Diesendorf, 'Can geosequestration save the coal industry?', in J Byrne, L Glvoer & N Toly (eds), *Transforming power: Energy as a social project*, Energy and Environmental Policy Series vol. 9, 2006, p.14.
[16] Saddler, Riedy & Passey 2004
[17] IPCC 2005, p. 8
[18] IPCC 2005; Saddler, Riedy & Passey 2004

that could be applied directly to electricity generation. They include oxy-fuel combustion, hydrogen or liquid fuel production plants and integrated gasification combined cycle (IGCC) power stations. IGCC is the most advanced of these, but it is still much more expensive than conventional coal-fired generation. IGCC requires further technical improvements and is presently not used in Australia.[19]

Transport of CO_2 over long distances is less complex but very energy intensive. Pipelines are the most feasible transportation methods for large amounts of CO_2 for distances up to around 1,000 km but there is always the potential for leakage. CO_2 can also be transported by rail and road tankers, but it is unlikely to become an attractive option for large-scale CO_2 transportation.[20] In addition to the energy penalty this will also require large investments in pipeline infrastructure. In Queensland, Victoria and Western Australia suitable geosequestration sites have been found within a reasonable distance of coal-fired power stations (and associated coal mines). But there are no identified sites within 500km of the coal-fired power stations in the Newcastle-Sydney-Wollongong area of New South Wales and at Port Augusta in South Australia, which together produce about 39 percent of Australia's current net CO_2 emissions from electricity generation. This lack of suitable sites presents an enormous cost barrier for the use of CCS in these areas.[21]

2.2 Effectiveness

The overall potential of CCS to reduce emissions depends on the fraction of CO_2 captured, the level of increased CO_2 production required by CCS, and levels of leakage from transport and storage sites in the long term.[22]

In Australia, the use of geosequestration would lead to, at best, a 9 percent emission reduction in 2030, and a cumulative emissions reduction from 2005 to 2030 of only 2.4 percent.[23] Modestly increased energy efficiency based on the efficiency potential assumed in the Government's Energy White Paper, could - at zero or even negative cost - decrease emissions in 2030 by about the same amount, and cumulative emissions by twice as much. Gas-fired generation and renewable energy, built instead of new coal-fired generation, would achieve the same cumulative abatement by 2030 as geosequestration

[19] Saddler, Riedy & Passey 2004
[20] IPCC 2005, p. 181
[21] Saddler, Riedy & Passey 2004
[22] IPCC 2005, p. 4
[23] Saddler, Riedy & Passey 2004, p. xii

through only a doubling of the current very modest Mandatory Renewable Energy Target (MRET) as well as doubling of additional gas-fired generation. If these technologies were combined with even more extensive energy efficiency improvements, which are still well within identified technical potential, emissions in 2030 could be reduced by more than five times and cumulative emissions by ten times as much as geosequestration alone.[24]

Furthermore, a power plant with a CCS system would use about 10–40 percent more energy than without CCS and a CCS system with storage as mineral carbonates would need 60–180 percent more energy than an equivalent plant without CCS.[25] **In other words CCS technology, developed to reduce the amount of greenhouse gas concentrations, will lead to a higher amount of greenhouse gases produced.**

2.3 Timeframes

In order to meet the deep emission cuts of at least 60% by 2050 that scientists and Federal Environment Minister Ian Campbell say are necessary major cuts need to be taken quickly. The next 10 to 15 years offer a crucial but fast-closing window of opportunity to prevent runaway climate change. Yet CCS, if it can be proven to work, will not be commercially available for years. CCS would take at least 25 years to even start to make a significant contribution to climate change mitigation, if at all.[26] The IPCC estimates the bulk of this technology's deployment would take place in the second half of this century. That is nearly 50 years away.[27] Even then, it would only capture a small proportion of global greenhouse pollution, at high cost.

2.4 Costs

Cost calculations in regard to CCS contain a high level of uncertainties. Generally, absolute and relative costs vary considerably from country to country. Regarding general cost assessments, the United Nation's international scientific expert panel, the IPCC, concludes: "Since neither Natural Gas Combined Cycle, Pulverized Coal nor Integrated Gasification Combined Cycle systems have yet been built at a full scale with CCS, the costs of these systems cannot be stated with a high degree of confidence at this time".[28] The IPCC estimates the technology would raise costs of coal

[24] Saddler, Riedy & Passey 2004
[25] IPCC 2005, p. 321.
[26] Diesendorf 2006, p. 19
[27] IPCC 2005, p. 41
[28] IPCC 2005, p. 10

generation by up to 5 US cents per kWh (almost 7 Australian cents).[29] This could almost triple the price of coal power, currently about 4 AUS cents per kWh in eastern Australia, making it more expensive than renewable energy such as wind and geothermal power[30].

Given its higher cost, investors and industry are unlikely to deploy geosequestration in the absence of policies that put a price on greenhouse gas pollution. In 2006, Origin Energy's CEO Gary King confirmed "the absence of a clearly defined framework for applying a carbon cost is a major impediment to investment decisions, particularly in power generation"[31]. As the IPCC notes "in the absence of measures for limiting CO_2 emissions, there are only small, niche opportunities for CCS technologies"[32]. In fact, the IPCC states that only when the price of CO_2 reaches approximately US$ 25-30 per tonne of CO2 captured (an equivalent of AUS$33-40) will CCS be deployed to a significant extent by the electricity sector.[33]

In Australia, a recent CSIRO study emphasised that "existing renewable energy resources are capable of substituting for coal-fired power stations, in spite of claims to the contrary. Further, they show that combinations of energy efficiency, renewable energy, and gas as an interim bridging fuel, may be less expensive than continuing to build coal-fired plants, even without considering the environmental and health costs of burning coal"[34]. Taking into account the large uncertainty in the future cost of geosequestration, models show that coal-fired electricity generation with geosequestration must be expected to cost more than other low-emission electricity generation options including wind and solar energy and biomass.[35] All these technologies are far more mature than geosequestration; they are proven, safe, already in widespread commercial use, but also, particularly in the case of wind, likely to fall considerably in cost over time. Furthermore, more efficient energy use is much more cost-effective than any electricity supply technology, having negative costs with a much shorter payback time.

If the costs of abatement are taken into account (measured by $/tonne CO_2-e of abatement), energy efficiency, natural gas, and renewable energy are again more economically attractive options than CCS. Coal-fired power

[29] IPCC 2005, pp. 9-10
[30] M Diesendorf, 'Why Australia needs wind power', *Dissent*, no. 13, Summer 2004, pp.43-48. Australian wind power costs in 2003 were 8-10 c/kWh and are predicted to drop to 6-8 c/kWh by 2010
[31] The Climate Institute 2006, p. 41
[32] IPCC 2005, p. 41
[33] IPCC 2005, p. 10
[34] CSIRO Sustainability, *Sustainability Network Update No. 54E*, 2005, p.1.
[35] Saddler, Riedy & Passey 2004

stations with the additional cost of CCS are unlikely to be competitive with the alternative means of cutting emissions for at least some decades.[36] This applies not only to the period between now and 2020, the earliest year geosequestration technology could be ready for commercial use, but also for a significant period beyond. These assessments take no account of the risk that one or more of the technologies involved in a complete CCS system could turn out to operate at a much higher than expected level of costs. They also take no account of environmental risks and associated costs, particularly the risk of leakage.[37] In other words, in Australia more carbon dioxide emissions from electricity generation could be reduced at lower cost from a combination of energy efficiency measures, natural gas and renewable energy between now and 2030 than from CCS.[38]

Greenpeace believes that research into carbon capture and storage technology reveals three major flaws of it:

- it is too costly;
- it delivers too little emission stabilisation and could even jeopardise stabilisation in the future;
- it is too risky.

Relying on CCS would both introduce new risks (which are outlined below) and add to existing environmental, health or social hazards of coal-fired electricity generation such as air and water pollution, high water usage and land degradation. Alternative options such as energy efficiency improvements and renewable energy technologies are already commercially available, proven to be safe and will reduce emissions sooner at lower cost. **Greenpeace** recommends:

- Australia's public research funding should be directed towards renewable energy and energy efficiency. Recognising the polluter pays principle, research in areas advocated by the fossil fuel industry, including geosequestration, should be funded by the fossil fuel industry and should be subject to independent scientific evaluation.
- The government should develop and implement appropriate stimuli and regulatory frameworks for emissions reductions - either a carbon levy or tradeable emission permits with cap and trade.

[36] Saddler, Riedy & Passey 2004
[37] Saddler, Riedy & Passey 2004
[38] Diesendorf 2006, p. 20

3. Risks and benefits of geosequestration technology

The technology of geosequestration and the overtly optimistic perceptions of it, pushed by industry and governments, pose significant environmental, economic, legal, political, technological and sustainability risks, while its benefits remain uncertain.

3.1 Environmental risks of geosequestration

Environmental risks of geosequestration include but are not limited to:

- Reservoir leakage: the slow, long-term release of CO_2 from storage sites, for instance through faults;
- Sudden leakage: the large-scale release of CO_2 from storage sites, for instance through failures of active or abandoned injection wells ;
- Escape of CO_2 into shallow groundwater;
- Displacement of deep brine and mobilisation of toxic metals and organics moving upwards leading to contamination of potable water;
- Escape of other hazardous captured flue gases.

On global scale continuous leakage of CO_2 has the potential to offset climate change mitigation efforts. Despite different results, all studies to date agree that leakage can only be tolerated within certain limits.[39] From the environmental point of view no leakage is tolerable. On a local scale, release of CO_2 leading to concentrations of CO_2 greater than 7–10 percent by volume in the air can immediately jeopardise life and health of exposed individuals. This potential risk also applies to pipeline transport of CO_2 through populated areas raising critical issues in regard to route selection, overpressure protection and leak detection.[40] A natural example of a sudden emergence of a large volume of CO_2 occurred in a volcanic active area at Lake Nyos in Cameroon in 1986. Large quantities of CO_2 accumulated on the bottom of Lake Nyos were suddenly released. The released CO_2 poured an invisible cloud over the valleys below, killing 1700 people and thousands of cattle in a range of 25 km.[41]

CO_2 rising to the shallow subsurface could have lethal effects on plants and subsoil animals and contaminate groundwater. CO_2 injection could build up pressure and cause seismic activities.[42] Greater environmental damage due to increased fossil fuel extraction is another risk. The higher power demands

[39] IPCC 2005, p. 15
[40] IPCC 2005, p. 12
[41] Diesendorf 2006, p. 16
[42] IPCC 2005, p. 13

of plants using geosequestration mean a higher coal and other fossil fuel use for given power output. Thus the major localised environmental problems associated with fossil fuels including habitat destruction**,** damage to rivers and waterways (from subsidence due to longwall mining), and air pollution will also increase.

The risk probability of leakage and escape of CO_2 is uncertain because little knowledge about the geology of the majority of proposed storage sites such as deep saline aquifers and the behaviour of injected CO_2 is available. Furthermore, because of the complex geology every single storage is uniform and must be evaluated case by case. No conclusion can be drawn from one storage site to another. In Australia deep saline aquifers account for 94 percent of all feasible geological storage capacity, while depleted oil and gas fields account for four percent and unmineable coal seems for less than one percent.[43] While scientific knowledge of CO_2 storage in saline aquifers and deep coal mines is limited, oil and gas fields are well studied. However, on sites where lots of drilling has taken place well bore failure poses a great risk for leakage as the well filling cement can corrode. Present rates of reservoir leakage are uncertain due to lack of experience and the lack of capacity of current technology to accurately monitor and verify leakage.[44] Due to economic considerations storage sites to be chosen for future CO_2 storage are likely to be quite large, so the leakage risk is significant. Generally, it cannot be taken for granted that injected CO_2 will stay underground securely for long periods of time. Safe storage depends on the integrity of the storage site, its potential damage through wells drilled into it, and structural changes in the walls of the storage site through extraction of oil or gas.[45]

In the past storage sites with highly impermeable caprocks, geological stability, absence of leakage paths and effective trapping mechanisms have been assumed to have a low risk of leakage. However, the latest research from the US reveals that burying carbon dioxide underground can dissolve the minerals that help keep the greenhouse gas from escaping. In a US Government field test in Texas, scientists tested the viability of injecting CO_2 into saline sedimentary aquifers. The results showed that the injected carbon

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[43] J Bradshaw, G Allinson, B E Bradshaw, V Ngyen, A J Rigg, L Spencer & P Wilson, *Australia's CO_2 geological storage potential and matching of emission sources to potential sinks*, Sixth International Conference on Greenhouse Gas Control Technologies, Kyoto, 2002.

[44] Saddler, Riedy & Passey 2004

[45] Diesendorf 2006, p. 15

dioxide caused carbonates and other minerals to dissolve rapidly, which could allow CO_2 and brine to leak into the water table.[46]

To minimise health, safety and environmental (HSE) risks the IPCC suggests careful site selection based on geological information, a monitoring programme, a regulatory system and the availability and use of remediation methods to stop or control CO_2 releases.[47] However, at the same time the IPCC says that due to limited experience with geological storage, risk management and remediation is expected to be based on "closely related industrial experience and scientific knowledge"[48], even though "effectiveness of the available risk management methods still needs to be demonstrated for use with CO_2 storage"[49]. The lack of reliable risk management methods at hand is even more significant as the risks of CCS will not cease to exist with the closure of an injection site. Geosequestration operates on a virtually infinite timeframe. Site monitoring may therefore be required for very long periods.

3.2 Other risks of geosequestration

CCS technology also poses considerable financial risks for states or private investors in regard to its absolute and relative costs. As further outlined in paragraph 2.2 and 2.3, economic analysis of absolute costs of CCS is characterised by a high level of insecurity, with present studies estimating the cost of geosequestration at \$36 to \$157 per tonne of CO_2 avoided. Related to the risk that costs will turn out to be higher than anticipated, there is a significant risk that the required conditions for commercial viability will never be met.[50] Regarding relative costs current research already shows that electricity generated from coal with geosequestration will be more expensive than other less polluting sources, such as gas, wind power and many types of biomass. It is clearly more expensive than increasing energy efficiency.[51] Even assuming that geosequestration is technically feasible, capable of long-term storage, and environmentally safe and commercially viable (which is yet to be proven) research shows it would only reduce Australia's greenhouse emissions by less than 2.5% from 2005 to 2030.[52] Such a low level of effectiveness neither justifies large scale public investments in research and

[46] Y K Kharaka, D R Cole, S D Hovorka, W D Gunter, K G Knauss & B M Freifeld, 'Gas-water-rock interactions in frio formation following CO_2 injection: Implications for the storage of greenhouse gases in sedimentary basins', *Geology,* vol. 34, no. 7, 2006, pp. 577–580.
[47] IPCC 2005, p. 12
[48] IPCC 2005, p. 13
[49] IPCC 2005, pp.13-14
[50] Saddler, Riedy & Passey 2004
[51] Saddler, Riedy & Passey 2004
[52] Saddler, Riedy & Passey 2004

development of the technology nor can it achieve the levels of emission stabilisations required within the next 15 to 20 years to prevent the most severe consequences of climate change.

Large-scale application of CCS also poses significant liability risks. Fossil fuel projects normally have lifetimes of 30-40 years. Yet to effectively reduce greenhouse emissions, the sequestered emissions from these projects would have to remain underground for at least 100,000 years. This raises the significant question of who is liable for the sequestered greenhouse emissions particularly once the respective CCS project is no longer operational. A recent US report concludes: “Companies that build coal-fired power plants today knowingly and significantly contribute to the public health, environmental and property damage that will result from global warming. Such companies face potential legal risks, similar to the lawsuits filed against the tobacco industry in the last decade”.[53]

Furthermore, premature reliance on unproven technologies such as CCS bears the risk of taking investments and research funding away from technologies and mitigation options such as renewable energy, energy efficiency and demand management. Present public energy policy supports geosequestration with very large amounts of government funding and premature endorsement, while minimal resources and attention are spent on energy efficiency and renewable energy. Australia has three cooperative Research Centres for fossil fuels, one particularly committed to geosequestration, while there is none for renewable energy technology.[54].

Greenpeace believes that scientific research clearly shows that CCS is a risky enterprise. Greenpeace also believes that an additional risk in regard to CCS is not found in the technology itself, but in the overly optimistic perception and the deceptive reliance on its viability. In the present political discourse in Australia, CCS is too often presented as a *strategy* for climate change mitigation, not as an emerging *technology* which has yet to proven safe, feasible and effective. This is a risky overvaluation.

Greenpeace is convinced that an insufficient and unsustainable response to climate change worsens the problem for generations to come. Geosequestration in particular shifts the responsibility to manage our waste to

[53] T Madsen & R Sargent, *Making sense of the “coal rush”: The consequences of expanding America’s dependence on coal*, U.S. PIRG, July 2006, http://uspirg.org/reports/CoalRushUS.pdf

[54] Diesendorf 2006, p. 13

future generations. Geosequestration means postponing and increasing the climate problem by creating more greenhouse gas emissions instead of committing to real emission reductions now. **Greenpeace** recommends:

- No geosequestration projects should be approved at this stage given the range of risks and uncertainties.

4. Regulatory and approval issues governing geosequestration technology and trials

While some Australian states have legislation or regulations that touch on aspects of CCS, at present efforts are being made by the Australian Government to achieve a nationally consistent framework for CCS activities in each Australian jurisdiction. As a first step, on 25 November 2005, the Ministerial Council on Mineral and Petroleum Resources (MCMPR) agreed on the Regulatory Guiding Principles for Carbon Dioxide Capture and Geological Storage. The council identified six issues as fundamental for a regulatory framework, namely assessment and approvals process; access and property rights; transportation issues; monitoring and verification; liability and post-closure responsibilities; and financial issues.[55]

In July 2006, a Legislation and Draft Discussion Paper by the Government about Implementing the Australian Regulatory Principles for Carbon Capture and Geological Storage[56] has been circulated. The draft paper confirms that a regulatory framework for CCS in Australia might turn out to be insufficient to reduce or dismiss the risks associated with CCS. At present, the flaws of the proposed legislation for carbon capture and storage are significant:

- Post-closure liability: The proposed legislation shifts all responsibility for the long-term risks from the private sector proponents of CCS to the public. It does not allow for the possibility of long-term failure, once the regulator has determined that the site is in the post-closure phase. Apart from possibly covering some of the long-term monitoring costs, private operators are not required to contribute to a government or pooled private fund that would cover long-term remediation (and/or the costs of escaped CO2) if there is leakage in the post-closure phase. The claim that these provisions correspond to regulatory arrangements for disposal of other

[55] Department of Industry, Tourism and Resources, *Carbon dioxide capture and geological storage (CCS) regulation*, 2006, http://www.industry.gov.au/content/itrinternet/cmscontent.cfm?objectID=705E9B4B-65BF-4956-B7729E096286852A.

[56] Department of Industry, Tourism and Resources, *Implementing the Australian Regulatory Guiding Principles for Carbon Capture and Geological Storage*, Draft V1.2, July 2006b.

wastes is incorrect. Operators in the nuclear industry usually have to pay a substantial levy into some national insurance scheme. There is no refund not even after closure and remediation or a site.

- Liability timeframes: The proposed legislation fails to specify time frames for the post-injection period. Once the relevant regulator believes there is no serious risk of leakage, the private operators could be relieved of legal liability and have their bond returned very soon after the injection phase has finished - even within one or two years!
- Monitoring timeframes: The proposed legislation does not specify a minimum time frame for post-injection monitoring. While timeframes must be decided individually on a case per case basis, a minimum of 50 years post-injection monitoring with open extension should be mandatory. This is not unreasonable, given the carbon dioxide needs to be stored safely for at least 100,000 years.
- Third party insurance requirements: The proposed draft legislation claims that “the risks associated with separation, capture and transport technologies are well understood and there is no (initially apparent) reason as to why normal insurance processes should not apply”[57]. It also speculates, with no evidence, that "it is highly likely that natural leakage is something that will attract such a high insurance cost that project proponents will self-insure to the extent of any costs not covered by public indemnity"[58]. In other words, there are no third party insurance requirements aside from general public liability, which will probably exclude specific CCS liabilities. This is an equivalent to no insurance at all from a community perspective if the operator does not have sufficient assets to cover any liabilities.

Greenpeace believes that the question of liability for leakage and other environmental harm through CCS is one of the major unresolved issues in regard to legislation and regulation. It is unacceptable to expect governments, and therefore tax-payers and future generations, to assume responsibility for a geosequestration site after a corporation has created it. However, this is exactly what the most recent draft legislation proposes. **Greenpeace** recommends:

- No geosequestration projects should be approved at this stage given the range of risks and uncertainties.

[57] Department of Industry, Tourism and Resources 2006b, p. 19
[58] Department of Industry, Tourism and Resources 2006b, p. 19

5. Positioning Australian industry to capture possible market applications

Continued fossil fuel use in the Asia Pacific region would see greenhouse gas pollution rise by over 70 percent by 2050 even if geosequestration captured 85 percent of emissions[59]. The IPCC's CCS report further found that up to 70 percent of emissions from electricity generation in 2050 may not even be technically suited to geosequestration.[60]

Outside Australia, this does not go unnoticed. Within the last one and a half years a significant shift has occurred in the US, where action on a national, state and city level is being taken. US President Bush recently confirmed his confidence in renewable energy as a major energy source for Americans and stated that "areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States"[61]. At present the US Department of Energy is collaborating with the American Wind Energy Association and the National Renewable Energy Laboratory to develop an action plan focused on providing up to 20 percent of the nation's electricity from wind energy.[62] With a US Congress more and more pushing for a mandatory emissions cap and carbon trading, Australia may soon be left isolated in its denial of renewable energy options. "Australia has already lost solar thermal technology to China because there were no funds for its commercialisation", says University Professor Dr Phillip Jennings, "It would have created an industry worth at least $1billion, but that's gone now".[63] China, one of the largest coal producers worldwide, announced to spend US$200 billion (almost AUS$266 billion) on renewable energy over the next 15 years because it wants one tenth of its energy to come from environmentally friendly sources by 2010. Credit Suisse puts the compound annual growth rate of China's wind power capacity at 39 per cent in 2004 to 2010 and at 20 per cent in 2010 to 2020, which represents a significant growth potential for wind turbine manufacturers.[64] In Sweden a green tax shift

[59] Transition Institute, *Excess focus on geosequestration in Asia Pacific would lead to major increase in greenhouse emissions*, 2005

[60] IPCC 2005, p. 9

[61] American Wind Energy Association, *Annual industry rankings demonstrate continued growth of wind energy in the United States*, Press Release 20 March 2006b, http://www.awea.org/news/Annual_Industry_Rankings_Continued_Growth_031506.html.

[62] American Wind Energy Association, *Energy department, wind industry join to create action plan to realize national vision of 20% electricity from wind*, Press Release 5 June 2006, http://www.awea.org/newsroom/releases/Energy_Dept_Wind_Industry_Action_Plan_060506.html.

[63] The Climate Institute 2006, p. 56

[64] A Leung, *Analysis - Cashing in on China's Renewable Energy Boom*, Reuters News Service 17 July 2006 / Planet Ark, http://www.planetark.org/dailynewsstory.cfm?newsid=37280&newsdate=17-Jul-2006.

is under way to end oil use by 2020 and make that country the first entirely powered by renewable energy.[65]

Governments around the world and global business have recognised climate change as a strategic business driver for the development of new markets, renewable technologies and investment. In April 2006 US Senate Committee members were told by General Electric, Wal-Mart, Shell, Exelon and Duke Energy they would welcome or accept mandatory greenhouse gas emission caps. In the UK companies such as Vodafone, ABN Amro, Tesco and Shell argued for higher greenhouse gas emission curbs in June 2006 as these would encourage innovation and be good for business. In Australia, despite recent economic analysis by some major companies that confirms today's technologies to be cheaper, faster and completely feasible to deeply cut greenhouse gas emissions, government and some businesses are lagging behind.[66]

Focusing on how to position industry to capture possible market applications of CCS is therefore betting on the wrong horse. By putting the majority of resources and capacities towards the development of geosequestration technology, Australia is setting the seal on its dependence on coal as the primary energy resource. Overall investment in technology claiming to make coal 'cleaner' in Australia is, including proposed private industry spending, expected to tip AUS$20 billion in the next ten years – investments renewable energy technologies can only dream of.[67] This entails significant political, economic, security and health risks and consequences. In the likely event that international greenhouse gas emissions become more constrained over the next decade a high dependence on coal could become a major economic and environmental liability. At the current EU carbon trading price of about A$35 per tonne of CO_2 over its 40 year operation time a 1000 MW coal-fired power station could incur a liability of about A$7.7 billion dollars. Alternatively, by directing investments towards improvements in energy efficiency and expansion of renewable energy, Australia could take action against climate change, strengthen its economy and improve public health together.

[65] 'Sweden plans to be world's first oil-free economy', *The Guardian*, 8 February 2006, http://www.guardian.co.uk/oil/story/0,,1704954,00.html.

[66] The Climate Institute 2006; Australian Business Roundtable on Climate Change, *The business case for early action*, 2006, http://www.businessroundtable.com.au/pdf/FO78-RT-WS.pdf.

[67] A Hodge, 'Cleaning up a costly problem', *The Australian*, 8 June 2006, http://www.theaustralian.news.com.au/story/0,20876,19398445-28737,00.html

5.1 Creating jobs and investment through renewable energy

Renewable energy generates local jobs and investment. In Australia, wind power has been shown to create more than six times as many manufacturing and installation jobs as equivalent coal generation.[68] There are 1.7 million jobs in the renewable energy sector worldwide, 400,000 jobs alone in the ethanol sector in Brazil and 250,000 jobs in the Chinese solar hot water industry.[69] In Germany, the renewable sector has created 150,000 jobs by 2005 and now provides more electricity in the country than does nuclear power.[70] In contrast, employment in the Australian coal mining industry has declined by 45 percent since the mid 1980s, while the amount of coal mined has increased steadily over the same period of time. Since the 1990s employment in electricity generating has fallen by 50 percent while the amount of electricity produced has significantly risen.[71]

Low-cost renewable energy power such as wind or biomass, operate at a much more distributed scale and can often be financed or partly manufactured locally. Renewable energy delivers much greater local control over technologies and much greater local job creation potential. Furthermore, benefits immediately benefit the regions where these technologies are manufactured or installed. At present wind farms built in Australia have a 50 percent Australian content (in dollars) and presumably 80 percent in the future if the Mandatory Renewable Energy Target (MRET) is increased. Coal electricity only has an Australian content (in dollars) of about 26 percent. Even if the economic efficiency of wind power over the next years led to an equal number of global jobs in wind power compared to coal electricity on a per MWh base, the smaller scale of wind power would ensure that small economies such as Australia will gain more local employment per MWh from wind power than from coal.[72]

5.2 Need for new market structures and policies

The transition to a sustainable energy future cannot be driven by the existing market structure and policies. If local, regional and global environmental and social damage costs resulting from combustion of fossil fuels were internalised into the electricity tariff a number of renewable energy technologies would immediately be competitive with coal-fired electricity

[68] R Passey, *Driving investment, generating jobs: Wind energy as a powerhouse for rural and regional development in Australia*, Australian Wind Energy Association, Melbourne, 2004.
[69] The Climate Institute 2006
[70] Bundesverband Wind Energie (eds) (2005), 'Energy news: German renewables producing more power than nukes', *New Energy*, No. 5, October 2005, p. 10.
[71] Diesendorf 2006
[72] Diesendorf 2006, pp. 9-10

generation. The appropriate pricing of fossil fuels and electricity produced from burning fossil fuels plus the removal of both direct and indirect subsidies to power-generation technologies are essential policy strategies for stimulating the development of renewable energy technologies.[73]

Greenpeace recommends:

- the current Mandatory Renewable Energy Target (MRET) should be increased so that 10 percent of electricity is supplied by renewable energy by 2010 and 25 percent by 2020, with increasing targets beyond 2020.
- states and the federal government should not allow any new coal plants to be built in order to meet rising energy demands. Apart from the fact that coal plants are Australia's biggest single source of greenhouse gas emissions, their construction undermines substantial programs for efficient energy use.
- Develop and implement appropriate stimuli and regulatory frameworks for emissions reductions through the implementation of a carbon levy.

6. Conclusion

Effective climate change mitigation requires to *reduce* greenhouse pollution by at least 60 per cent by 2050 worldwide. CCS leads to burning *more* coal with all its negative environmental impacts and trying to get rid of the waste underground, instead of reducing the amount of waste produced in the first place.

In summary, **Greenpeace** believes carbon capture and storage technology is

- too costly: There is no evidence available that CCS is the most economical mitigation option. Research indicates it is cheaper *and* more effective to reduce the amount of carbon dioxide produced in the first place.
- too little: By far more effective mitigation options are energy efficiency improvements, the switch to less carbon-intensive fuels and renewable energy technologies. These are safe, technologically mature, economically feasible and presently available.
- too risky: Climate change requires immediate action and a coherent response that can be implemented today. CCS is a technology whose large scale commercial application cannot be realised within the next

[73] A D Owen, 'Renewable energy: Externality costs as market barriers', *Energy Policy*, no. 34, 2006, pp. 632–642.

twenty years, if at all. In general, CCS is a technology whose feasibility, merit and safety are still undecided. The IPCC confirms that for a widespread application of CCS "technical maturity, costs, overall potential, diffusion and transfer of the technology to developing countries and their capacity to apply the technology, regulatory aspects, environmental issues and public perception" are still to be proven.[74]

[74] IPCC 2005, p. 3

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