The regulation of geoengineering: A gathering storm for international climate change policy?

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ABSTRACT

Over the past decade geoengineering has steadily built momentum in academic and policy circles as a potential response to the risk of rapid climate change. Geoengineering has moved from a fringe idea to a serious topic of policy discussion. We argue that there are two reasons for the rise of interest in geoengineering. First, the international negotiations on reducing emissions have so far failed to provide a result that will likely prevent dangerous climate change occurring in coming decades. Second, geoengineering technologies have advanced to a stage where in the near future they might be attractive to countries facing significant climate impacts. Particularly, geoengineering holds out the possibility of a less costly short-term response to climate change than rapid de-carbonisation of stationary energy and transport systems. However, there are many considerable risks associated with geoengineering, including damage to environmental and social systems. At present, there are no international agreements that specifically regulate the testing and/or use of geoengineering technologies. It is currently possible for one country to unilaterally decide to use geoengineering technology to the detriment of others. This leads us to the conclusion that an international agreement should be urgently established to regulate decisions regarding the testing and use of geoengineering. Australia, as a country which is particularly vulnerable to climate change impacts, should prepare to participate in initiatives in this regard in order to protect our interests.

Keywords: geoengineering, climate change, international policy, Australia, technology

INTRODUCTION

> *The likelihood that geo-engineering could bring a safe, lasting, democratic and peaceful solution to the climate crisis is minuscule. The potential for unilateralism, private profiteering and disastrous, irreversible, unintended effects is great. Geo-engineering does not deserve serious consideration within climate policy circles. It should be banned.*
>
> (Mooney 2011)

> *Climate change is no longer something we can aim to do something about in a few decades' time, and that we must not only urgently reduce CO_2 emissions but must urgently examine other ways of slowing global warming, such as the various geo-engineering ideas that have been put forward.*
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> Wadhams cited in (Vidal 2012)

Geoengineering is a controversial topic emerging from the broader issue of climate change. It is the subject of widely conflicting opinions, from urgent calls for research and development, to strongly held arguments for an international ban on geoengineering technology. Geoengineering is the "deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change" (Royal Society 2009).[1] Developing technologies to control weather is not a new concept. As a result of the competitive scientific culture of the Cold War, the United States (US) and the Soviet Union invested in weather modification schemes during the 1950's and 1960's, such as 'cloud seeding', in order to be the first nation to gain an advantage through controlling weather (see Keith 2000). There was renewed interest in geoengineering during the 1990s as popular and scientific concern regarding global warming increased. In 1991, the United States National Academies Committee on Science, Engineering and Public Policy recommended that the US evaluate the benefits and side-effects of geoengineering as a potential method of reducing the greenhouse effect (COSEPUP 1991).

In 1996 Schelling also published a call to consider geoengineering in responding to climate change. In the same year Schneider (1996), while preferring a strategy of reducing greenhouse gas emissions, conceded that the further study of geoengineering was needed due to the growing potential seriousness of anthropogenic climate change. Over the past decade, geoengineering has moved from being a fringe idea, to a topic which is being discussed seriously within elite academic and policy circles, particularly in the US and United Kingdom (UK). An indication of this shift of attitude is that the UN Intergovernmental Panel on Climate Change (IPCC) has been requested to report on geoengineering options for climate policy in the fifth Assessment Report that is due in 2014. This article poses the following question: Why has the idea of geoengineering gained prominence in recent years?

We suggest that the answer to this question is two-fold. First, international negotiations on climate change have so far failed to reduce emissions sufficiently to put us on a path to keep the increase in global mean surface temperature below two degrees (Helm 2008), the current international position on the maximum warming that should occur (Cancun Agreement 2010). As global greenhouse gas emissions continue to rise, with an increase of more than 5% recorded in 2010 (Olivier *et al.* 2011), the need to consider alternative policy responses to anthropogenic climate change is becoming prominent in the minds of some influential scientists and policymakers. Second, scientific research has progressed to a point where large scale experimentation with geoengineering appears to be at least technically feasible (Royal Society 2009). This combination of rising emissions and technical feasibility has caused a number of influential scientists, academics and entrepreneurs in the US and UK to advocate geoengineering as a "plan B" response to anthropogenic climate change.

This article analyses the recent policy momentum behind geoengineering and highlights its growing importance as a concept in international policy discussion on climate change. We believe it is important for academics and policymakers within Australia to appreciate the growing significance of geoengineering in order to contribute to international policy debates which are developing around the issue. At the Australian National Committee for Earth System Science symposium in Canberra 2011, it was proposed a Southern Hemisphere perspective on geoengineering be developed and articulated

to provide balance to views coming from the North (NCESS 2011). Pearman *et al.* (2010) also argue that Australia needs to develop a strong, well-informed position on the development and governance of geoengineering. We agree with these statements, and argue that, as a country highly vulnerable to climate change (CSIRO 2011), Australia needs to seriously consider the risks and merits of geoengineering in order to play an active role in future international policy discussions.

The following section highlights the growing interest in geoengineering as an alternative to carbon emission reduction. The third section outlines proposed geoengineering methods and their claimed benefits for climate protection. Section four discusses the significant risks involved with attempting geoengineering. The fifth section details the growing advocacy of geoengineering in US and UK scientific and policy circles and the growing need to consider international regulation. The sixth makes the case for Australia to prepare to constructively engage in international policy discussion on the regulation of geoengineering.

THE FAILURE OF UN CLIMATE NEGOTATIONS AND THE ADVOCACY OF GEOENGINEERING

Since the 1990 IPCC First Assessment Report there has been widespread recognition of the problem of anthropogenic climate change (IPCC 1990). However, recognition of the problem has not generated sufficient political momentum at an international level to make significant reductions in the level of global greenhouse gas emissions. The 1992 United Nations Framework Convention on Climate Change (UNFCCC) failed to set binding emission reductions targets for countries, with developed countries providing only a non-binding commitment to reduce their emissions to 1990 levels by the year 2000 (UNFCCC 1992, Article 4).

In the following years it became clear this non-binding commitment by developed countries was unlikely to be kept, so binding emission reduction targets were negotiated for developed countries and formalised in the 1997 Kyoto Protocol (KP) to the UNFCCC. The US was the largest emitting country at the time but chose to not join the KP. Additionally, the KP contained no binding emission reduction targets for developing countries. The KP therefore could not constrain the greenhouse gas emissions of the world's two largest emitters, the US and China. The KP has arguably had a negligible impact on reducing global greenhouse emissions and the current trend is for emissions to continue to rise (Helm 2008). Major developed and developing countries continue to remain heavily reliant on fossil fuels to meet their stationary energy and transport needs and have rising emissions. Taking into further consideration the extraordinary 8-10% economic growth rates of China and India, the world's most populous countries, global consumption of fossil fuels appears destined to significantly increase over coming decades, along with rising global emissions and the associated risk of adverse climate change impacts (IPCC 2007b).

The international community and civil society groups hoped that the 2009 UNFCCC Copenhagen COP 15 meeting ("Copenhagen") would result in the international community negotiating a new international agreement to replace the KP, when its emission reduction targets expired at the end of 2012. It was hoped that parties to the UNFCCC would agree on deeper emission reduction targets that would bind developed countries and also influence large developing countries such as China and India to take on softer, albeit binding, commitments.

Unfortunately, Copenhagen failed to live up to these expectations. The agreement that emanated from that meeting, the 'Copenhagen Accord' (2009) is not binding on countries and fails to provide for an emission reduction pathway that will avoid two degrees warming. The best available estimates suggest that we are on track for in excess of three degrees warming above pre-industrial levels (Climate Action Tracker 2012). The current reality is that the international community has at least for the next decade eschewed any binding emission reduction commitments, instead again opting for voluntary political commitments similar to those that failed in the early 1990's under the UNFCCC.

Global cooperation is needed to successfully reduce emissions, but Copenhagen demonstrated that influential states, including the US and China, are reluctant to look beyond their national interests to reach an effective global agreement to reduce emissions (Christoff 2010). They did not want to commit to changes which, although having potential long-term environmental benefits, are likely to have significant negative economic effects in the short-term, particularly if not matched by major trade competitors (Barrett 2007).

The gridlock in the UNFCCC climate negotiations has brought forward a number of influential voices arguing alternative approaches are needed. In 2009, the UK Royal Society published a comprehensive report on geoengineering titled *Geoengineering the climate- Science, governance and uncertainty* ("Royal Society report"). The report concluded that "global efforts to reduce emissions have not yet been sufficiently successful to provide confidence that the reductions needed to avoid dangerous climate change will be achieved" (2009 p.ix). Concern is now growing not only for the advent of dangerous levels of anthropogenic climate change, but for the speed and severity of its onset. A prominent example is the rapid deterioration of summer sea ice in the Arctic observed over the past ten years. In its Fourth Assessment Report, the IPCC indicated that there is a risk of Arctic summer sea ice disappearing by the end of the 21st Century (IPCC 2007b). However, Wadhams now predicts that the Arctic sea ice will disappear as early as 2015-16 (cited in Vidal 2012). While this statement has received high publicity, it is not the first claim that the Arctic will suffer significant environmental damage sooner than expected. Modelling analysis conducted in 2006 also suggested that abrupt Arctic sea ice retreat could occur by 2015 (Holland *et al.* 2006). Moreover, recent observations of the Arctic ice sheets show that it is rapidly melting. According to NASA, the Arctic sea ice reached a record low of 3.41 million square kilometres on the 16th September 2012, half the average minimum recorded from 1979 to 2000 (NASA 2012).

Wadhams' voice has joined that of other experts calling for the investigation of geoengineering as an alternative response. Paul Crutzen, recipient of the Nobel Prize in Chemistry in 1995, published an examination of SRM aerosol technology in 2006, stating:

> *Given the grossly disappointing international political response to the required greenhouse gas emissions, and further considering some drastic results of recent studies… research on the feasibility and environmental consequences of climate engineering of the kind presented in this paper, which might need to be deployed in future, should not be tabooed. (2006 p.214).*

Furthermore, Wigley (2006) examined the potential benefits of geoengineering as a complementary measure to emission reduction. Lovelock and Rapley argued for geoengineering in the following terms:

> *…feedbacks, as well as the inertia of the Earth System- and that of our response- make it doubtful that any of the well-intentioned technical or social schemes for carbon dieting will restore the status quo. What is needed is a fundamental cure. (2007 p.403).*

Other notable advocates of geoengineering are Caldeira and Keith who argue it would be irresponsible to wait until a serious climate emergency before investing in geoengineering research and development (2010). Geoengineering has also attracted advocates from beyond the field of science. Prominent UK sociologist, Giddens, argues that because of political complexities within the UNFCCC system, we need to engage in other strategies, including geoengineering, to help control greenhouse gas emissions (Giddens, cited in Lee 2011). Bodansky, a leading US international lawyer on the climate change regime, advocates geoengineering research and governance, stating that despite the risks and fears associated with geoengineering "We are living in a world where we must prepare for the worst." (2011 p.31). Other prominent voices supporting geoengineering include US climate policy experts Victor (2011)

and Barrett (2007). These authors are part of a growing chorus of influential academics, advocating the investigation of geoengineering as a contingency plan to cool the planet in the event of rapid onset of negative climate change impacts. The following section provides an overview of current proposed geoengineering methods.

GEOENGINEERING SCHEMES: CURRENT SUGGESTIONS FOR THE 'PLAN B' SOLUTION

The Royal Society report (2009) divides geoengineering into two different "classes", Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR). SRM aims to provide a cooling effect by reflecting solar radiation away from the earth in order to counteract the rise in global temperatures caused by the greenhouse effect (Royal Society 2009). The Royal Society report discusses a variety of SRM techniques proposed to enhance the earth's ability to reflect solar radiation. One prominent idea is to inject aerosols into the stratosphere in an attempt to increase the amount of incoming solar radiation that is deflected back into space (Crutzen 2006). Another proposal is to create reflective clouds from seawater to enhance the albedo (*i.e.* level of reflectivity) of ocean clouds (Royal Society 2009). A more radical idea is to strategically place large mirrors in space orbits to shield the earth from incoming solar radiation (US National Academy of Sciences 1992).

The second class of geoengineering, CDR, involves deliberate human efforts to remove carbon dioxide from the atmosphere in order to stabilise the level of greenhouse gas concentration and reduce the greenhouse effect (Royal Society 2009). The Royal Society report discusses a number of possible land and ocean based CDR methods. Ocean fertilisation is one method under investigation and is promoted by the US geoengineering company Climos and the ISIS (In-Situ Iron Studies) Consortium of scientists. Ocean fertilization involves adding nutrients such as iron, nitrogen or phosphate to the ocean to stimulate algae growth, which will remove carbon dioxide from the atmosphere through photosynthesis (Royal Society 2009). Further CDR proposals include carbon sequestration methods such as biochar, which converts organic matter into a chemically stable from of carbon, thereby trapping carbon dioxide for a long period of time (CSIRO 2009). Research is also being conducted into large carbon filtering systems that would act in a similar manner to 'mechanical trees' in removing carbon dioxide directly from the atmosphere (Earth Institute).

However, the Royal Society stresses that while geoengineering schemes may be useful to supplement efforts to reduce greenhouse gas emissions, they should not supplant such efforts (2009). Although geoengineering schemes may be able to lessen the symptoms of climate change by removing carbon dioxide from the atmosphere, or by lowering global temperatures, they do not treat the cause of the problem. Developed and large developing countries are heavily reliant on fossil fuels and associated greenhouse gas emissions. Schneider compares this reliance on fossil fuels to drug addiction, stating that "it is better to cure heroin addiction by paced medical care that weans the victim slowly and surely from drug addiction than by massive substitution of methadone…" (1996 p.299). Schneider thus likened geoengineering to methadone treatment for heroin addiction in that it treats the symptom rather than the underlying problem. This is a salutary warning, as discussion of geoengineering does have the potential to weaken international resolve for reducing greenhouse emissions at source.

Nevertheless, compared to emission reduction schemes, geoengineering has a number of potential advantages. First, even if global greenhouse gas emissions are significantly reduced over coming decades, it is projected there would be considerable delay before global temperatures would start to decrease. The greenhouse gasses entering the atmosphere will continue to reside there for at least another hundred years (Morgan and Ricke 2010). While emission reduction may be the most obvious long run response to climate change, it is unlikely to produce a short term reduction in negative impacts.

On the other hand, if successful, SRM schemes hold the promise of rapidly increasing the earth's capacity to deflect solar radiation and thereby cause a swift reduction in global temperature. Natural SRM effects have been experienced in the recent past. For instance, particulates released into the stratosphere from the 1991 volcanic eruption of Mt Pinatubo in the Philippines caused an average reduction in global temperatures of 0.5^{o}C within a year following the eruption (see Crutzen 2006). SRM advocates argue that sulfate aerosol technology could achieve a comparable result (Morgan and Ricke 2010). Although slower in effect, CDR techniques could provide more than a short term cooling effect and could potentially address the root cause of anthropogenic climate change by drawing down greenhouse gases from the atmosphere to a safe level (Royal Society 2009).

Certain methods of geoengineering also hold out the promise of being relatively low-cost in dollar terms compared to the significant expense of de-carbonising stationary energy and transport systems. For example, according to Victor *et al.*, although most cost estimates for SRM geoengineering are unreliable, "there is general agreement that the strategies are cheap; the total expense of the most cost-effective options would amount to perhaps as little as a few billion dollars, just one percent (or less) of the cost of dramatically cutting emissions" (2009 p.3). Crutzen (2006) estimates that SRM solar aerosol techniques could costs considerably more, at least US $25-50 billon per annum globally, but points out that this is a relatively small sum compared to the estimated US$1000 billion spent annually on global military expenditure. Given the relatively low costs of attempting to implement a geoengineering strategy such as stratospheric aerosol injection, it may be possible for one country to unilaterally embark on this path. As Victor suggests:

> *Geoengineering may not require any collective international effort to have an impact on climate. One large nation might justify and fund an effort on its own. A lone Greenfinger, self-appointed protector of the planet and working with a small fraction of the Gates bank account, could force a lot of geoengineering on his own." (2008 p.324)*

Although, many proposed geoengineering techniques are only in the preliminary research phase, some have progressed to field-testing. For example, in 2009 ocean iron fertilisation experiments were carried out by German and Indian scientists in the Southern Ocean (Alfred-Wegener Institute 13 Jan 2009). Although the experiment stimulated the growth of ocean phytoplankton, the algae bloom was eaten by small crustaceans that were attracted to the experiment. Consequently, the experiment only resulted in a minor draw down of carbon dioxide from the atmosphere (Alfred-Wegener Institute 23 Jan 2009).

More recently, plans have been made by UK scientists to field-test SRM technology. The Stratospheric Particle Injection for Climate Engineering (SPICE) project is an SRM research initiative to investigate the feasibility of stratospheric aerosol technology (University of Bristol 2012). Field tests of a balloon and hose delivery system, which could be used in the future to inject aerosols into the stratosphere, had been planned for 2012, but were cancelled due conflicts of interest among the scientists regarding their involvement in similar commercial projects, as well as concerns regarding the lack of proper geoengineering governance mechanisms (Cressey 2012). Field tests represent an important scientific milestone. However, because they are conducted within the natural environment they blur the line between research and deployment, and raise issues regarding the risk and regulation of geoengineering technology as discussed below.

RISKS INHERENT IN GEOENGINEERING STRATEGIES

In light of these examples, the possibility that geoengineering will be attempted by a country in the future is real. This raises a number of issues that need to be considered by governments and the international community. For instance, geoengineering carries a number of potential risks including ozone depletion, unforeseen changes in global weather patterns, disproportional

regional weather impacts and ocean acidification (Royal Society 2009).
A further risk is that, once started, geoengineering may be too dangerous to stop (Bracmort *et al.* 2011). For example, if an SRM project was suddenly discontinued or broke down it could result in a rapid increase in temperature that may be very difficult to adapt to (Bracmort *et al.* 2011).

Furthermore, because geoengineering may involve the deployment of human created substances into the atmosphere and the oceans it runs the risk of triggering complex feedback mechanisms in climate systems that may cause unforseen changes. This raises a number of international governance concerns about geoengineering that need to be considered. For example; what right does one country or individual have to deploy geoengineering techniques?; Who decides what temperature goal should be targeted through the use of geoengineering?; How will accountability occur for any damage that may result from geoengineering? These are all serious questions that require thoughtful answers from the international community.

FUTURE INTERNATIONAL REGULATION OF GEOENGINEERING

There are currently no international agreements that specifically regulate geoengineering. Many critics argue that international regulation should not be encouraged as it may give legitimacy to geoengineering techniques and their attendant risks. However, advocates of geoengineering maintain that it is *because* of these risks that greater research and regulation is needed. Advocates claim that a greater understanding of the risks and benefits of geoengineering is important to create a strong international governance framework that can prevent the reckless, unilateral use of geoengineering technology (Blackstock and Long 2010). The argument goes that use of geoengineering technology should not be a hasty gamble. It should be based, if at all, on sound research and an international governance system that is established well in advance.

We agree that considering current projections for emission growth, there may in the future be a real need for a 'plan B' response to climate change. That being the case, it would be unwise to dismiss geoengineering on the basis of its risks without fully understanding it's potential. As stated by Virgoe, to ignore geoengineering now and only consider it at the last moment will lead to "bad, politics-led decision-making" (2009 p.117). We therefore agree with the Royal Society call for urgently establishing an international governance framework for geoengineering, which needs to be in place well before any large-scale field testing or deployment of geoengineering technology.

AUSTRALIA AND GEOENGINEERING

According to the IPCC, Australia is already experiencing climate change impacts such as a decrease in rainfall and an increase in the intensity of droughts (IPCC 2007a, chapter 11). Further, the 2011 Commonwealth State of the Environment Report (SoE 2011) states that as Australia is the driest inhabitable continent, climate change poses a serious threat. The SoE report indicates Australia is likely to experience an increase in average temperature of 1^{o}C above pre-industrial levels by 2030, which will have significant environmental impacts, including an increase in the severity and frequency of droughts and floods. The SoE report identifies geoengineering as an "emerging risk" to biodiversity which could have "unintended and disastrous effects" (2011 p.675). There is a significant risk that geoengineering efforts by another country may exacerbate climate change impacts or create new climate related problems. Therefore, Australia cannot ignore the growing likelihood of geoengineering schemes being attempted by some countries in the near future.

As discussed above, CCS aims to reduce Australia's greenhouse gas emissions at source by capturing carbon dioxide from stationary energy and/or industrial sources, such as coal-fired power plants, and storing it underground (see CO2CRC 2011). The purpose of CCS technology is to prevent carbon dioxide from being released *into* the atmosphere. The existing literature therefore treats CCS as different from CDR geoengineering technology which aims to remove carbon dioxide directly *from* the atmosphere (Kaldi 2011). However, CCS offers a useful example of Australia taking an international leadership role in climate change related technologies. Australia has developed a set of domestic regulatory principles and legislation regarding CCS (MCMPR 2005) and has also been an active contributor to leading international research initiatives, including hosting the Global CCS Institute. Australian support for CCS is consistent with our continued heavy reliance upon fossil fuels in our stationary energy systems.

For different reasons, it is also in Australia's interests to consider adopting a similar strong leadership role in relation to the governance of geoengineering. Geoengineering activities by other countries may have wide ranging impacts on Australia. Australia therefore needs to ensure that our interests are properly represented and protected in any international regulatory efforts. International regulatory structures on geoengineering are likely to evolve over the coming decades and to protect our national interest we need to be at the forefront of these discussions.

CONCLUSION

The need for alternative climate change action combined with technological feasibility has given rise to heightened interest into geoengineering over the past decade. Geoengineering is emerging a serious topic which is being given considerable attention by leading scientists, academics and policy makers in the US and UK. It is evident that as concern over climate change impacts increases, so will the risk that a state, or group of states, will attempt some form of geoengineering. The international governance of geoengineering is therefore an increasingly pressing issue. With the potential risks of geoengineering on the one hand, and the call for alternative action against climate change on the other, the development of an international regulatory system for geoengineering is likely to prove as controversial as the technology itself. It is therefore prudent for Australia to seriously research geoengineering technologies now and ensure that we are ready to participate in the formation of an international regulatory framework. Given the possible impacts geoengineering could have on our environment, Australia cannot afford to ignore geoengineering or be unprepared to face future developments in this area.

FOOTNOTES

1. For the purpose of this article, we follow the existing literature in not discussing carbon capture and storage (CCS) technology when using the term 'geoengineering'. CCS technologies capture greenhouse gases at source, such as from coal-fired power stations, thus preventing them from entering the atmosphere. The purpose of CCS technology is to prevent carbon dioxide from being released *into* the atmosphere. It is therefore different from Carbon Dioxide Removal (CDR) geoengineering technologies which aims to remove carbon dioxide directly *from* the atmosphere

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NATIONAL GEOSEQUESTRATION LABORATORY

The Australian Government has awarded CSIRO a massive $48.4 million to build a new research facility that will enable deep cuts to be made to Australia's greenhouse gas emissions. The National Geosequestration Laboratory (NGL) being developed in Perth will help to advance carbon storage technologies that play a crucial role in achieving a low-emission economy for Australia. The NGL will play a crucial role in achieving a low-emission future for Australia., by providing critical research to develop innovative solutions that will minimise risk and uncertainty regarding the long-term underground storage of carbon dioxide.

Geosequestration is a key technology that prevents large quantities of carbon dioxide from being released into the atmosphere. It does this by injecting captured carbon dioxide emissions into underground geological formations. The NGL will be equipped to develop and deploy highly specialised, targeted research and testing aimed at realising safe and secure carbon storage projects in Australia and around the world.

The world-class national facility is a collaboration between CSIRO, The University of Western Australia (UWA) and Curtin University, and builds on the successes of the Western Australian Energy Research Alliance. The NGL will operate as a 'hub and spoke' model and be centred at the Australian Resources Research Centre in Perth, with nodes at other Australian sites forming part of the overall facility. The first NGL research node will be built on the UWA campus to house a Carbon Capture and Storage (CCS) geophysics and geochemistry research facility.

'We believe we can provide the research and development needed to help enable commercial-scale carbon storage in Australia', NGL's Science Director, Linda Stalker, said. The facility will provide important research to underpin the South West Hub in Western Australia - Australia's first CCS Flagship project to demonstrate the feasibility and safety of large-scale geosequestration.

The Department of Industry, Innovation, Science, Research and Tertiary Education provided the funding through the Australian Government's Education Investment Fund to build the infrastructure and procure laboratory equipment. Minister for Science and Research, Senator the Hon Chris Evans, said the NGL will be one of the most significant international centres for research, training and technology development for the global resources sector.

Further information about the National Geosequestration Facility can be found at http://www.csiro.au/Outcomes/Energy/NGL.aspx..