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Comments on the geosequestration tenure discussion paper

Some views on how geosequestration will work with the private sector

August 2007

Executive Summary

It must be acknowledged that the Queensland Government has taken a leadership role in recognising the need for geosequestration and is in the process of implementing a regulatory system ahead of most other jurisdictions globally.

After reading the *Carbon dioxide geosequestration tenure administration discussion paper* released by the Queensland Department of Mines and Energy in June 2007, it was apparent that many readers may not fully understand how geosequestration works, who the parties involved are, and most importantly how government can best work with the private sector to ensure the most rapid adoption of it.

If geosequestration is considered to be a desired activity by society then everything possible must be done to facilitate its early adoption. That means ensuring that the right economic incentives are in place.

The main stationary sources of carbon dioxide (CO2) are electricity generators, smelters and refineries, general industry and manufacturing, natural gas producers, and oil companies.

The coal miners and petrochemical industry also have an interest in the development of geosequestration.

The development of geosequestration is a complex and long term task that involves the discovery, appraisal and development of fields. The operators will be required to quantify and model the behaviour of the CO2 to the satisfaction of government and other stakeholders. During and after field operations the amount of CO2 injected will need to be verified and the behaviour of the CO2 monitored.

The activities required to explore, appraise, develop and operate sequestration fields are squarely in the domain of the oil and gas companies. These companies have an economic incentive to undertake the geological exploration necessary to find oil and gas simply because they can make a profit.

From a commercial perspective there are no incentives for geosequestration. The risks are high, there is no reward for taking that risk, there is uncertainty on regulations, and there is a skills shortage. The potential for clashing tenement types is high, and there is a need to encourage large fields that take CO_2 from multiple sources.

It is mainly large multinational oil and gas production and service companies that have sufficient profits to invest in the early development of the industry. The power sector is fragmented, small scale and lacks a decent cash flow to invest too heavily, but wants to be involved in the development of new technologies. The coal industry is interested in contributing to some research on clean coal technologies, including geosequestration, due to the potential decrease in demand for coal after 2020.

Normal private sector investors, however, would likely have no interest in high risk geosequestration projects with high liabilities and no rewards for the foreseeable decade or so. Consequently, every effort must be made to leverage funds currently being invested in oil and gas exploration by allowing those companies to have geosequestration rights as well as oil and gas rights.

In a regime with insufficient financial incentives and developing technologies, demonstration projects will dominate for the next 15 to 20 years as this industry is commercialised.

These demonstration projects will require considerable support from Government over and above the cap and trade system the Australian Government is indicating that will be introduced.

In economic terms the cost of demonstration projects that will establish the viability or not of geosequestration should be outweighed by the benefits of learning by doing and putting in place a good foundation of regulations and oversight on the industry to allow its earliest possible adoption.

Initially, the oil and gas industry and service companies will be the natural owners of the geosequestration industry. They have the skills, technologies, resources and needs to geosequester. Allowing oil and gas companies to have automatic rights to geosequester, or at a minimum, first rights of refusal will be an important step to encourage the rapid adoption of the technology.

Once the technology is commercialised the oil and gas industry, electricity generators and coal companies will seek geosequestration as a means of reducing emissions from their operations. The boundaries between these industries will blur as the emphasis becomes more on providing low cost, low emission energy and fuels.

The legal issues associated with the implementation of this new industry should not be underestimated. There are a number of industries with vested industries who will not agree on all issues. For example, coal seam methane producers, geosequestration companies and oil and gas companies may have irreconcilable views on priority of rights.

There may be delays to the implementation of geosequestration due to legal issues such as uncertainty over liability, resources law, native title, overly conservative regulation, lack of compatibility between jurisdictions, lack of compatibility with carbon trading regimes, and inflexibility of the system.

These legal issues must be clearly identified and sorted out as quickly as possible. In parallel considerable policy framework should be developed, likely with the involvement of the private sector, environmental groups and other interested stakeholders.

To address some of the above issues it is suggested that a system based on statutory leases and licences, such as already exist under the *Petroleum and Gas (Production and Safety) Act 2004*, is the best form of tenure system. It is based on existing well understood processes which provide much needed certainty to industry. In addition it is compatible with oil and gas exploration and production tenure which is important as the oil and gas industry will be the natural owners of geosequestration for the next two decades.

The overarching emphasis of all policy should be on encouraging private sector involvement in the most rapid adoption of geosequestration. After all, we need to act now if we want to reduce our contribution to global warming.

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Preface

Author of this paper

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Eris O'Brien – Director of Lazuli Enterprises Pty Ltd – has been involved in business development in the mining and energy industry for over 12 years. He started his career as an exploration geologist before moving to the disciplines of economics and finance.

He was first involved in geosequestration as part of the initiative taken by Stanwell Corporation Limited in 2002 and was involved full time in that project – now called ZeroGen – in 2005 and 2006. In 2006 he was the CO2 Project Manager for geosequestration and found himself confronted daily with the challenge of taking the academic and policy theory of geosequestration and trying to deliver an actual project.

While in this role he found that the perceptions of what was needed for the introduction of geosequestration within the public system diverged from the real world commercial drivers that the private sector face in delivering a solution which is in effect a socially desirable outcome.

As well as working on clean coal and geosequestration, he also has worked on wind farms, biomass fuelled electricity generation and other forms of electricity generation. His interests are in practical and cost effective means of reducing greenhouse gas emissions.

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Chapter 01 Purpose of submission

The release of the Carbon dioxide geosequestration tenure administration discussion paper by the Queensland Department of Mines and Energy in June 2007 is an important step towards bringing geosequestration as a commercially possible method for reducing carbon dioxide (CO2) emissions into reality.

It must be acknowledged that the Queensland Government has taken a leadership role in recognising the need for geosequestration and is in the process of implementing a regulatory system ahead of most other jurisdictions globally.

After reading the discussion paper, however, it was apparent that many readers may not fully understand how geosequestration works, who the parties involved are, and most importantly how government can best work with the private sector to ensure the most rapid adoption of it.

The development of a geosequestration tenure system is an interesting challenge. There are social issues, potential safety issues, requirements for economic incentives, the need to provide certainty to project sponsors, as well as the likely structure of the industry.

Consequently the purpose of this submission is to provide an overview of how the industry will work and how the tenure system will interact with industry.

The submission covers

- Who wants to sequester CO2
- The activities associated with geosequestration
- The skills and knowledge required for the establishment of a geosequestration industry and who has those skills.
- The commercial issues and incentives, or lack thereof, in the development of a geosequestration industry
- A prediction on how the geosequestration industry will evolve over the next 20 years

The report then links all the above points into the requirements for a tenure system and how that compares to the discussion paper with the emphasis being on the rapid development of a geosequestration industry.

In writing the submission, the viewpoints and commercial drivers of power companies, oil and gas companies, and coal companies were considered.

This paper is not a detailed consideration of the minutiae of legal issues associated with tenure systems. It is intended as a high level overview of geosequestration, the industry that will deliver it and what is needed of government to facilitate the rapid adoption of geosequestration.

Chapter 02 Who wants to sequester CO2

The following mostly private sector parties understand the potential need for geosequestration as a potential solution to their levels of carbon emissions.

Figure 01: Major sources of CO2

Major Sources of CO2	Motivations
Electricity generators	▪ Mostly coal fired as it is likely to remain the cheapest form of fossil fuel based electricity. ▪ Easy for government to regulate ▪ Supplying a critical commodity to a society that wants a cleaner product at the lowest possible price. ▪ Power plants are expensive long-life assets, so any solution that can be retrofitted to existing plants is good. ▪ Carbon permits may cover all of the costs in the long term. ▪ Geosequestration may allow the creation of a major hydrogen source.
Smelters/ Refineries/ Cement kilns, etc.	▪ Users of both CO2 intensive electricity and CO2 emitting processes. ▪ A relatively small change in production prices can dramatically affect profits and competitiveness – so wary of paying for CO2 unless they can be assured all their competitors are likewise affected. ▪ Unless all countries introduce carbon trading these industries will relocate to the jurisdictions offering the lowest cost electricity.
General industry and manufacturing	▪ Can produce CO2 during its operations. ▪ Will pay penalties under either a carbon trading scheme or carbon tax scheme. ▪ Looking for least cost answer to reduce CO2 emissions.
Natural Gas Producers	▪ Natural gas fields can contain unacceptably high levels of CO2, which has to be removed from the gas before it can be sold. ▪ Without geosequestration this CO2 is simply vented into the atmosphere and indications are that many new fields will face this issue.
Oil companies	▪ Peak oil issues mean that tar sands, oil shales and coal gasification must be looked at as sources of petroleum products. ▪ All these sources of petroleum products require CO2 emission reductions in order to be socially acceptable alternatives to existing oil.

Figure 02: Other parties concerned about geosequestration

Other concerned parties	Motivations
Coal miners	▪ Provide the source of CO2 to major users. ▪ Future survival will depend on cleaning up the emissions from coal.
Petrochemical industry	▪ Worried about the price of oil. ▪ Looking for alternative sources of feedstock for their processes which without geosequestration will be dirtier than current oil derivative products.

Of the industries listed here, only the oil and gas industry has any expertise in the discovery, development and operations of fields suitable for geosequestration.

The electricity generators are good at creating highly reliable power plants that convert coal to electricity, but have little understanding of the processes associated with carbon capture and are mostly uneasy with geosequestration as they have no existing frame of reference to understand the risks associated with it.

The petrochemical industry understands processes such as carbon capture well, but like the electricity generators they mostly have little understanding of the risks associated with geosequestration.

Chapter 03 Geosequestration explained

Stages of geosequestration

Figure 03: Description of stages of geosequestration

Stage of geosequestration	Description
Regional Exploration	▪ Selection of large scale geological features that may be suitable for the long term sequestration of carbon dioxide. This kind of geological survey is typically carried out by government, perhaps in partnership with the private sector and universities. ▪ The type of work may involve aerial geophysical surveys, regional scale seismic surveys, drilling and laboratory analysis.
Location Specific Exploration	▪ A smaller area is chosen as the targeted exploration area. Exploration is typically carried out in several suitable locations to test which has the best characteristics in terms of both the potential to store CO2, and to keep it there. ▪ This work will likely involve detailed analysis of publicly available data, the compilation of computerized reservoir models, local scale seismic surveys, drilling, sample analysis (geophysical, petrological and geochemical) and test injection. ▪ The private sector would typically carry out such work, in conjunction with oil and gas service companies.
Field appraisal	▪ Once the site has been chosen detailed work to prove up reserves, prove the suitability of the cap rock and plan the development of the field is required. ▪ This stage is about gathering sufficient data to provide the confidence required to develop the field. This data is typically gathered by detailed seismic surveys and additional drilling. ▪ The data gathered at this stage will also provide the baseline data for the monitoring program.
Detailed computer based reservoir simulations	▪ While part of the field appraisal and development, for geosequestration this will be a major exercise as this is a computerized simulation of the subsurface behaviour of the carbon dioxide over time. ▪ The model will be used by regulating authorities to certify that the proposed location for sequestration meets the required standards. ▪ This stage is a desktop study using proprietary oil and gas industry software.
Field development	▪ The number and type of CO2 injection wells have to be optimized, planned and constructed. ▪ The cost of using CO2 resistant materials (pipes, cement, etc) has to be included.

Stage of geosequestration	Description
	▪ In-field infrastructure requirements for transporting CO_2 around the sequestration site also require design and construction. ▪ Monitoring requirements are also finalized, and depending on the characteristics of the reservoir rocks, may require wells to be drilled. ▪ The timing of field development is optimized to match the start of supply, the amount of supply and the changing injection rate of the wells over time. ▪ The costs of field development are considerably lower when using existing infrastructure in depleted oil and gas fields.
Injection	▪ The field operator takes the CO_2 supplied by the pipeline operator and injects it down the injection wells into the chosen reservoir rocks. ▪ Wells need to be monitored for rate of injection and maintained to both safely maximize the rate of injection and reduce the potential for leaks. ▪ The in-field CO_2 distribution system (pipes and pumps) also need to be maintained and constructed as needed.
Verification	▪ An independent certification on the amount of CO_2 injected and the likelihood of it staying in storage for the minimum required times will be required. ▪ This kind of work can be carried out either by government or by the global organisations that typically carry out such work.
Monitoring	▪ During the operation of the sequestration field, monitoring for leakage both at the well heads and other locations will take place. This would typically be carried out by the field operator, working to an agreed plan with the regulators. ▪ Post-closure monitoring will be required to check that the CO_2 is still behaving as predicted.
Closure	▪ At the end of the life of the field, injection wells will be suitably plugged or sealed, and testing will be required to show that the CO_2 is behaving in the manner predicted by the computer reservoir models before handover to the government. ▪ Due to the potential long life of injection fields (40 years or more) it is possible that individual wells may be decommissioned rather than the whole field.
Post-closure	▪ Once the sequestration field, or parts thereof, are handed back to government, they will be responsible for monitoring the fields, in conjunction of long term maintenance on decommissioned infrastructure that may be a source of leakage. ▪ The field operator may be required to cover the costs of full decommissioning in a manner that maximizes the long term storage of CO_2. ▪ Of particular interest will be the potential for long term

Stage of geosequestration	Description
	leakage from oil and gas exploration wells that may become a problem after the decommissioning of the sequestration fields. ▪ Another important role of the regulators would be to ensure that additional CO2 sequestration projects in the area of the decommissioned field do not reduce the integrity of the sequestration plan of the original field.

Suitable locations for geosequestration

A number of suitable geological conditions have been identified as good for long term geosequestration. These are listed in the table below.

Figure 04: Locations for geosequestration

Geosequestration Location	Description
Deep saline aquifers	▪ Porous and permeable rock layers that contain, as the name suggests, water too salty for normal usage for livestock or industrial use. ▪ May be the same reservoir rocks as oil and gas fields. ▪ Thought to have the highest global potential for overall capacity to store CO2.
Depleted oil and gas fields	▪ Similar to deep saline aquifers, but with the advantage that the trapping mechanisms for the CO2 are well understood. ▪ The characteristics of the reservoir are very well understood, and the use of existing infrastructure may cut the costs of field appraisal and development dramatically. ▪ Such fields will likely be the locations for most early developments, however there are complications related to potential leakage from existing oil and gas wells.
Unmineable deep coal formations	▪ Coal reserves so deep underground that they are unlikely to ever be mineable. ▪ Such rocks may, with a little bit of assistance, have good storage characteristics. Sequestration locations will be dependent on the existence of cap rocks. ▪ Queensland has a number of deep coal deposits that may be suitable.
Coal seams for enhanced coal bed methane production	▪ Carbon dioxide displaces methane molecules from the coal and effectively sticks to the surface of the coal. This will both enhance the

Geosequestration Location	Description
coal bed methane production	production of methane and store carbon dioxide. ▪ For economic reasons the use of this type of location will depend on the close proximity of the CO2 source to the coal bed methane fields in question.
Oil reservoirs for enhanced oil recovery	▪ As an oil production field ages the rate of extraction of oil becomes lower and lower. Carbon dioxide can be used to enhance the recovery of the remaining oil as it both provides additional pressure to the oil field, and through its chemical properties also helps release the oil. ▪ This technology has been used by the oil industry for many years and forms the basis of sequestration technology. ▪ The lack of suitable oil fields in Queensland mean this is not as attractive a solution, but the proximity to Cooper Basin may lead to the development of CO2 pipelines to facilitate this solution.

All of these require the CO2 to be injected in a compressed semi-liquid state – termed supercritical phase – to a depth generally greater than 800 m below surface. At these depths, the CO2 should stay in its compressed state, requiring less volume of rock for storing the CO2 than if it was allowed to re-expand back to a gas phase.

Ensuring the CO2 remains stored

A layer of impermeable sedimentary rock, termed a seal or cap rock overlying the storage reservoir is required to prevent the carbon dioxide from moving back to the surface.

The ability of the seal rock to both contain the CO2 and not be degraded by either the storage processes or the CO2 itself will need to be adequately proved prior to injection of CO2.

The integrity of such a seal over existing oil and gas fields is largely proven in the sense that in order to contain oil and gas they have most of the desired characteristics for a CO2 sequestration project.

If areas without oil and gas fields are chosen as sequestration sites, then the integrity of the seal rocks will need to be proved, which is a relatively new science.

Consequently, depleted oil and gas fields, or the margins of existing oil and gas fields will be the best locations to start geosequestration.

It should be noted that it may be acceptable to have known locations for leakage of CO_2 through cap rocks as long as the CO_2 is subsequently trapped by other seals higher up, or is turned into a mineral form that permanently stores the CO_2. The Weyburn project in Canada is testing such mechanisms.

While seals prevent geological leakage upwards, the CO_2 may migrate over time in a lateral movement. Where the CO_2 will migrate to and the rate at which it will do so needs to be understood.

If during its lateral migration the CO_2 meets a natural geological barrier then the system is called a constrained field. A good analogy for constrained systems would be streams draining into dam. The water is trapped (constrained) by the dam. And just as a dam can overflow, a constrained system can receive too much CO_2, meaning that some will bypass it.

Where there is no natural geological barrier to lateral migration of the CO_2 then it is called an unconstrained field. The lack of a geological constraint does not mean that geosequestration is not possible. The suitability of unconstrained fields will depend on the distance the CO_2 has to travel and the rate at which it travels. If the CO_2 will take tens of thousands of years before leakage is possible then unconstrained fields will be suitable.

Finally, the integrity of the injection wells and other infrastructure that penetrates the sequestration reservoirs needs to be ensured by careful design and usage of materials that both maintain their characteristics over long periods of time and can resist the corrosive properties of concentrated CO_2.

How CO2 behaves in the long term

CO2 is injected in a compressed semi-liquid state into the pores of the reservoir rock.

Over a period of thousands of years, the CO2 dissolves slowly into the water in the reservoir. This CO2 rich water then migrates slowly along its normal path.

The rate of migration can be very slow, measured in terms such as metres per thousand years, or it can be relatively fast, depending on the location.

As the CO2 rich water migrates through the reservoir rocks it interacts with those rocks and the other minerals in the water to form minerals that permanently trap some or all of the CO2. This process will likely take tens of thousands of years.

Because of the potential migration of CO2 over time (both vertical and lateral migration) it is important to understand sequestration fields as whole systems rather than discrete locations. To use another water based analogy, sequestration systems are similar to water catchments in that over very long periods of time the CO2 may migrate, link up with other CO2 streams and ultimately either run into a geological constraint or run up to the surface.

While such migration will happen over many thousands, if not millions of years, it is incumbent on the government to ensure that the system is used wisely and that not so much CO2 is put into the system that it is overloaded and leakage occurs.

Initially projects will likely occur in or at the margins of existing oil and gas fields as the likely migration paths for CO2 are well understood.

Chapter 04 Skills/knowledge required to sequester CO2

The history of the technology

The technology and knowledge base behind geosequestration comes from the oil and gas industry.

The industry developed techniques for the identification of suitable oil and gas reservoirs, and the characterization and development of those fields. When enhanced oil recovery using CO2 became necessary the industry adapted existing technologies and knowledge to inject CO2 into existing oil fields.

The oil and gas industry has the right knowledge and skills

Successful geosequestration depends on using geology, geophysics and geochemistry as tools to understand the suitability of the reservoir for sequestration. These scientific disciplines are complex and measure results in terms of probabilities.

The operation of geosequestration fields relies on the technology and knowledge of the operation of oil and gas fields. Much of the know-how and technology was developed by the oil and gas service companies working for private oil companies and also for national oil companies which control the majority of the world's known reserves.

Power generators and other industries are good at building and operating machines and processes. The costs of construction can be quantified, the risks are related to either machines or men and the emphasis is on reliability at the lowest possible cost. In other words, there is little comprehension of the variability of the subsurface as this mode of thinking and analysis is not a discipline of those industries.

In business terms, the barriers to entry to the geosequestration business are very high, and only highly skilled oil and gas companies will likely be able to deliver this business. This will be true at leas for the next 15 to 20 years.

Consequently, the existing oil and gas industry and oil and gas service companies will be the natural owners of geosequestration fields, with power stations and their like providing CO2 to the field operators.

A more comprehensive breakdown of the skills of the various industries are as follows.

Figure 05: Ability to deliver on geosequestration

Stage of geosequestration	Government/ Public Sector	Power Generators	Oil & Gas Industry	Oil & Gas Service Companies	Petrochemical industry	Pipeline companies	Smelters/ Refineries/ cement kilns, etc.	General industry	Independent certification companies
CO_2 capture	-	✓	✓	✓	✓	-	-	-	-
CO_2 transport	-	-	✓	✓	✓	✓	-	-	-
Regional exploration	✓	-	✓	✓	-	-	-	-	-
Location specific Exploration	-	-	✓	✓	-	-	-	-	-
Field appraisal	-	-	✓	✓	-	-	-	-	-
Detailed computer based reservoir simulations	-	-	✓	✓	-	-	-	-	-
Field development	-	-	✓	✓	-	-	-	-	-
Injection	-	-	✓	✓	-	-	-	-	-
Verification	✓	-	✓	✓	-	-	-	-	✓
Monitoring	✓	-	✓	✓	-	-	-	-	-
Closure	-	-	✓	✓	-	✓	-	-	-
Post-closure	✓	-	✓	✓	-	-	-	-	-

In short, the oil and gas industry, and service companies, have the technology and knowledge, and also have a decision making framework that specifically takes into account the kinds of risks that will be involved in geosequestration.

It is unlikely that power generators or other major sources of CO_2 will be able to afford to purchase these skills for individual projects and implement geosequestration in a field dedicated to that single project.

Chapter 05 Commercial issues for geosequestration

Lack of rewards

Right now there are no financial benefits for any organisation to implement geosequestration in Australia. Nor is there any legal requirement for geosequestration.

Those few demonstration projects that are known in the media are partially funded by companies that recognise something should be done and are hopeful that some kind of carbon credit trading regime or carbon tax will become reality sooner rather than later.

Even with carbon credits (similar to Kyoto Protocol based trading regimes), the price of credits will be unlikely to support the industry on a commercial basis in the immediate future for two main reasons.

1) The full suite of low cost carbon capture technologies touted as the way forward are unlikely to make the transition from the laboratory to commercial plants until at least 2020.

2) To lower the costs of sequestration to acceptable levels will require the creation of CO2 field operators who can take advantage of economies of scale by taking CO2 from multiple sources. It is hard to imagine any private sector party or consortium developing a CO2 field out of the goodness of their hearts. The availability of CO2 sources and a suitable pricing mechanism will precede the development of such fields.

In other words, companies will only geosequester if it is a cheaper option than paying the costs of a carbon penalty.

As it seems exceedingly difficult to reach the touted CO2 emission cut targets without geosequestration as part of the solution, Government will likely take a role in developing this industry over and above simply introducing a carbon trading regime and leaving it to the market.

Finding and developing CO2 fields – who will front up the cash?

If you search for oil and gas there is a potential big pay off if you succeed. As they say, there can be a pot of gold at the bottom of the well. However, the chances of success may be as little as one in one thousand or even less.

The low probability of success does not deter people from buying shares in speculative oil and gas exploration companies. In a broad sense, investing in oil and gas exploration is like taking a bet on a horse. The horse might win, but in case it doesn't you don't bet all your savings on it.

When it comes to geosequestration there are currently no rewards or incentives available for investors.

To compound matters, the cost of exploring for and developing CO2 fields is likely to be much higher than exploring for oil and gas. For example, the presence of oil and gas means that the seal rocks overlying the field are intact. This is not the case in geosequestration where the suitability of those seal rocks will still have to be proved. More expensive materials need to be used, and more comprehensive data may be required to develop predictive geological models.

The volatility and behaviour of prices of credits in a future CO2 trading regime are also completely unknown. Only sufficiently high prices will encourage investment in the risky long term activities associated with the exploration for, appraisal and development of geosequestration fields.

Consequently, it is unlikely that investors will put their own money at risk in the search for geosequestration fields until it is clear that there are potential rewards.

Additionally, there is only so much money investors are willing to put at risk at any time, and it would be naïve to assume that as much money will be available for the geosequestration industry as there is for the oil and gas industry for many years to come.

What this means for this nascent industry is:

- Oil and gas companies will continue exploration efforts using mostly the same techniques as required for geosequestration.

- No additional funds will be released to the private sector by shareholders and investors for geosequestration exploration and development until at least 2020.

- To develop this industry, oil and gas explorers should be given rights to convert discovery of potential geosequestration fields to a geosequestration tenure.

- The government may require the lodgement of additional information from exploration and production activities which are pertinent to geosequestration.

- A focus on existing oil and gas fields which have already been explored and developed as the first locations for geosequestration.

Indicative cash flow profiles for a CO2 field operator

When looking at potential regulations and policy for the geosequestration industry it is important to consider the likely cash flow profiles of an operator. Cash flows are linked to a number of considerations, including;

- The industry will likely consist of stand alone CO2 field operators who are supplied by CO2 pipeline operators, who in turn transport the CO2 from multiple sources.

- The exploration phase may take up to five years, during which time significant losses will be incurred which will not have much of a revenue stream to be offset against.

- Appraisal and development of a field will be costly due both to the amount of data required to satisfy regulatory processes and also due to the high cost of the CO2 resistant materials (high grade steels, new polymers, specialist cement, etc.) that are required for infrastructure.

- CO2 pipelines will also take several years to pass through regulatory processes and the very high capital costs of building the pipelines will be timed to meet the beginning of geosequestration. There is a risk that pipeline construction will commence prior to the final approvals of the geosequestration field in order to meet the timetables required.

- CO_2 injection wells can take a higher rate of CO_2 injection in the early years of operation, decreasing over time. This will mean a staged investment in injection wells and distribution pipeline infrastructure.

- The useful life of individual wells is highly variable, and it is likely that over time some wells will be closed and new ones drilled, all in the same field of operations.

- The size of sequestration fields may be quite compact (several square kilometres) where highly permeable rocks are available or very large (maybe a hundred linear kilometres) where permeability is low.

- Revenues are only earned for CO_2 that is actually considered sequestered. The timing of full payment of these revenues is vital. It is also important that injected CO_2 is accepted as successfully geosequestered and that there is no later recourse on credits allocated, otherwise there may be uncertainty on the value of the CO_2, and the potential revenue streams will be discounted reducing the economic viability of the industry.

- The amount CO_2 available for geosequestration, and the potential revenues from it, will depend on the development of pipelines that can collect CO_2 from multiple sources to provide the economies of scale required for commercially viable geosequestration.

In short, there is a lot of risk, a long lead time prior to production, high capital costs during that lead time, and uncertain and potentially volatile revenue sources.

The need for a risk based regulatory approach

While enhanced oil recovery using CO_2 has been occurring for several decades, the large volume storage of CO_2 that comes with geosequestration is still a new activity.

While it is true that each location will be unique, the variation between sites will occur within the parameters of existing science and engineering knowledge.

The next decade or so will be very much a period of ‘learning by doing’ for the geosequestration industry. New materials will be developed, new methods and tools for exploration and appraisal will be developed, and a better understanding of the locations for storage and the retention of CO2 will also be developed.

Consequently, there is not yet enough information available for regulators to provide proscriptive rules. What is best practice on one day will likely be superseded the next.

There is a fear within industry that government, despite published guidelines, will put proscriptive rules in place that will fossilise the technology available for geosequestration, be overly conservative and drive the costs of building and operating fields up so high that it will never be economic.

To put Queensland at the forefront of this industry it will be necessary to adopt an approach that will enable this process of learning.

A properly implemented risk based approach will allow for the recognition of the specific risks associated with each project, and cater to the needs of each project while addressing safety and environmental issues.

The skill sets required for a risk based approach exist either in oil and gas service companies, or in the few independent international certification companies.

Government, despite best intentions, rarely has the knowledge base or resources available to closely oversee industry and geosequestration will likely be little different. The Government's role in a risk based approach should be to set the right framework and incorporate global best practices in setting the required principles by which the industry can be judged.

Such a risk based approach should also be compatible with other jurisdictions in Australia, and be similar enough to international regimes to allow for mutual recognition of carbon credits in any trading regimes.

Skills shortage as a barrier to entry

As previously discussed, the skills and knowledge for the establishment of geosequestration reside almost entirely in the oil and gas sector. With the current oil and gas boom the effects of a skills shortage can be felt in a number of ways.

- The oil and gas industry is willing to pay top dollar to attract and retain their staff. These are the same people required for geosequestration. With the lack of economic incentives, why would anyone quit their oil and gas job for a lower paying geosequestration job.

- Oil and gas producers will not willingly allocate their staff to geosequestration projects unless there is a compelling economic benefit that outweighs the benefits that could be obtained by having them work on oil and gas projects.

- Oil and gas service companies are able to deploy all their staff on high paying oil and gas work, meaning there is little if any incentive to work with geosequestration projects, especially if they are asking for discounts due to the lack of economic incentives.

- The only oil and gas companies that will put their own earnings at risk by involving themselves with geosequestration are those so large that they can afford to make a small loss in return for future benefits in terms of increased knowledge and experience. In other words, only large multinationals are likely to invest in geosequestration skills development, and not many of these are based in Queensland, let alone Australia.

- The power industry and similar will have a hard time trying to buy the required skills for geosequestration on the open market.

In the short term, there is no easy answer to the skills shortage. In the medium to long term the implementation of geosequestration will require the development of an industry which is essentially a duplicate copy of the oil and gas industry. Such an industry will not develop until there is clarity on legal issues and certainty of economic incentives in places.

Carbon capture costs delaying industry development

The current approach to geosequestration is that only relatively high purity CO2 is transported and sequestered.

The costs of separating CO2 from the emissions of a power plant or other plant are very high, and increase in a non-linear fashion the higher the purity you are trying to reach.

To ensure the rapid adoption of geosequestration as a means of reducing human induced global warming, then it will be necessary to examine the geosequestration of less pure gas streams, possibly even essentially untreated emissions from power stations.

To be sure, there will be problems with this, including but not limited to:

- Increased capital costs for pipeline infrastructure to transport a mixture of gases (although operating and safety regulations should be similar),

- A more complicated approach to measuring and allocating credits for greenhouse gases stored, and

- The need to better understand the interaction of these gases with the subsurface. This is something that can be modelled, but will depend on the composition of the gas mixture and the characteristics of the rocks that will both store the gas and seal it in.

The flipside of this is that there could be an opportunity to make deep cuts to greenhouse gas emissions from existing power stations in a short period of time as the costs are much lower.

It should be remembered that existing natural gas sources have a variable composition with high levels of CO2 and other gases. If these gases already exist in the kind of locations that are being considered for sequestration then the question needs to be asked why we are focusing on such high purity CO2.

At a minimum, the definition of gases suitable for geosequestration should be as broad as possible and not restricted to high purity CO2.

Kick starting the industry

In the short term, the availability of comprehensive data sets and existing useable infrastructure make it likely that existing or nearly depleted oil and gas fields, and flanking areas will be the first locations for geosequestration.

Such locations, however, will not likely provide sufficient storage space for the volumes of CO2 that need to be geosequestered to make a difference in Queensland in the long term. Therefore new suitable locations will have to be found.

To date, the effort by government agencies to identify potential locations for geosequestration has relied on data made available by the oil and gas industry. Such data, by its very nature, is focussed on areas with paying oil and gas fields.

While there is data available from other locations the industry would have spent the least amount of money possible to try and figure out if there was oil or gas present. This means that the seismic surveys were done either years ago when the technology was less advanced or were done on a minimum adequate basis. Likewise exploration drilling would have been done on a basis where very little information was gathered as they were only interested to know if they hit oil or gas, little else.

What all this means is that the information currently available is inadequate for the required rapid growth of the industry. Historically, it has been considered a net benefit to government to undertake regional exploration to establish enough high quality baseline geological data to enable industry to come in and exploit any opportunities.

The Queensland Government's recent announcements on funding such work in the Galilee basin is a good start, but represents just the first step in a much longer journey. Such work will form the foundation of the geosequestration industry.

Building economies of scale

In order to establish sufficient economies of scale for the geosequestration industry to be economically viable it is likely that there will be a limited number of large geosequestration fields connected by long distance pipelines.

In the case of highly permeable offshore sequestration locations, then there may also be the development of short distance pipelines connecting CO_2 sources to the coast, where the gas can be loaded onto tankers similar to existing LNG tankers, and be transported by ship to offshore geosequestration fields.

As pipelines are expensive, they will likely transport gas from multiple sources.

Field operations are likely to be carried out by single entities, whether owned by individual corporations or other consortium type arrangements.

The tenure system should recognise that these economies of scale will be necessary and not unnecessarily carve up sequestration systems into small pieces in the name of preventing speculative land banking.

The need for coexisting tenement types

In the short term it is hard to understand how carbon sequestration tenements can be sensibly treated as completely independent of the oil and gas tenure system.

If geosequestration is considered to be a desired activity by society then everything possible must be done to facilitate its early adoption. That means ensuring that the right economic incentives are in place.

The activities required to explore, appraise, develop and operate sequestration fields are squarely in the domain of the oil and gas companies. These companies have an economic incentive to undertake the geological exploration necessary to find oil and gas simply because they can make a profit.

A number of scenarios illustrate the need to allow overlap and portability between tenement types. These are more complicated than those anticipated for offshore sequestration as onshore activities overlap with more resource types than oil and gas.

Scenario 1

A major oil company spends tens of millions of dollars surveying and drilling a potential large oil and gas field. If they discover that there is little paying oil and gas in the field, then they will write off the expense of exploration, shelve the data gathered and provide the minimum amount of data required by government.

In this scenario a potentially large and valuable geosequestration field is abandoned and if ultimately developed, may be subject to long delays as a not only will a future company need to replicate most of the work, but the tenements themselves may not be released by the exploration company for a number of years.

Scenario 2

A geosequestration company obtains exploration rights, spends the tens of millions of dollars necessary to prove up geosequestration and finds oil and gas, which they are not able to exploit.

In this scenario the geosequestration company faces potential bankruptcy. Even though they are undertaking the same work, using the same equipment and technology, in the same potential reservoirs as the oil and gas industry, they are not allowed to exploit any discoveries. If geosequestration companies are to survive recognition of rights to discovered resources is important.

Scenario 3

A natural gas company finds out that its gas contains too much carbon dioxide which must be removed prior to the gas becoming considered saleable. The ability to inject the CO2 is important as it will provide the opportunity to decrease penalties associated with carbon emissions and potentially provide a means to improve the operations of the gas field through reinjecting into the same field.

It will be not only necessary to allow such companies to sequester the CO2 into their own fields, but also to allow them a sensible amount of space around their producing fields to find a suitable location for sequestration if the gas field itself is not suitable.

This is what has happened in the development of the North West Shelf, as well as at least one of the Queensland fields

Scenario 4

An oil company is using CO2 for enhanced oil recovery to prolong the economic life of their field. They cannot claim the CO2 injected is geosequestered as the rights to sequestration belong to another company.

This scenario will deny the oil company the ability to earn some revenues from geosequestration, and will also remove potentially valuable carbon credits from the carbon trading scheme.

Scenario 5

A coal seam methane (CSM) company undertakes the expensive process of identifying and exploring a deep coal seam for its potential as a source of coal seam methane. The methane resource requires the injection of CO2 to stimulate economic levels of production.

The CO2 will need to be purchased from another company at a high price due to the costs of transport. The CSM producer doesn't have the rights to sequester in that area as they belong to another party who will not cooperate. Consequently, the CSM company is denied the potential revenues from carbon sequestration which would otherwise offset the cost of the CO2. This renders the field uneconomic.

The above scenarios illustrate just a few examples of where there is need for overlap in rights to sequester and rights to exploit oil and gas.

While governments understandably wish to keep different tenure types separate, the mindless application of such principles will handicap the development of geosequestration to the point that it will not be a useful means of combating human induced global warming.

For example, a common example given is someone drilling for water cannot claim any mineral resources they discover while drilling. Consequently, there is a separation of water extraction rights attached to a property and the mineral resources which belong to the Crown. This is not a suitable analogy for the complete separation of geosequestration and other rights.

To similarly claim that someone exploring for a geosequestration tenement should not be able to take advantage of oil and gas, or CSM discovered, and vice versa does not stand scrutiny for the following basic reasons.

- Oil and gas, and CSM exploration activities are very costly, take a long time and rely on sophisticated technologies and knowledge.
- The reservoir rocks are often the same. That is, you don't accidentally discover something else in a different layer of rock. You are generally looking at the same pore space in the same layer of rock.

- If overlap and automatic tenure rights are not available then the commercial incentives for the exploration and development of geosequestration tenements are almost non-existent.

In other words, to most effectively deploy the skills and money required to rapidly develop the industry the oil and gas industry must be allowed to automatically convert oil and gas tenements to geosequestration tenements, and vice versa.

This could be achieved by staging the implementation of tenure rights. For example, for the first 20 or 30 years the right to automatically have first rights for geosequestration on an oil and gas tenement or coal seam methane tenement could exist. Likewise, companies that expend the resources and money to try and find a geosequestration field should have the automatic right to exploit oil and gas found.

This latter point is especially relevant as it could also encourage exploration in more areas and prompt the discovery of new oil and gas provinces and their development. Considering the implications of the Peak Oil theory and current high oil prices, this may be a sensible measure.

As greater certainty on the suitable locations for geosequestration through the gathering of more complete geological data sets for the State, then over time, the separation of tenement conversion rights could be phased in.

Chapter 06 A sneak peak at the future geosequestration industry

The industry as it exists now

As of this moment the only geosequestration projects that are in commercial operation around the world are in the oil and gas industry where excess carbon dioxide is reinjected directly into, or adjacent to producing fields.

There are a couple of smaller scale demonstration projects such as Weyburn, but there is no geosequestration industry yet.

The next 15 to 20 years

In a regime with insufficient financial incentives and developing technologies, demonstration projects will dominate for the next 15 to 20 years as this industry is commercialised.

The major carbon producers will be keenly interested in, and participate in the demonstration of new technologies that either reduce emissions or capture carbon. The required technological advances for more cost effective carbon capture are well understood and will migrate from the laboratory scale to commercial demonstration over the next 20 years.

Geosequestration demonstration projects will occur, likely with considerable support from Government over and above the cap and trade system the Australian Government is indicating that will be introduced. In economic terms the cost of demonstration projects that will establish the viability, or not, of geosequestration should be outweighed by the benefits of geosequestration.

The benefits of geosequestration demonstration projects are:

- Road testing of ambitious, but largely academic plans on the viability of the industry.
- Early development of a suitable regulatory framework.
- It allows for learning by doing.

- Development of appropriate skill sets in Government and the private sector.
- Creation of both jobs and companies specialising in geosequestration.
- Education of the public on the geosequestration and the risks associated with it.

There are those that argue demonstration projects are economically inefficient as they represent picking winning technologies. This argument is flawed. The following are some of the reasons why.

- It is recognised that human induced global warming needs to be combated by reduced emissions. The long lead times for the development and regulation of an industry mean that if we want this as a potential solution, then we need to start now.
- While there may be some as yet undiscovered cheap source of clean energy the lead time of bringing technologies from a laboratory bench to commercialisation is ten to twenty years. We know what these technologies are and while some of them may play a role, indications are that they will not be as important as geosequestration.
- Of the currently available technologies, industry experts consider that geosequestration is practical, achievable and likely cost effective provided the technology improves as expected over the next 15 years.
- Geosequestration is one of several major ways to help achieve the deep cuts touted as being required by 2050. Without it that target looks to be in jeopardy.
- Fossil fuelled electricity generation plants are high cost and long life assets. They cannot simply be replaced by renewable technologies in the near term. The ability to clean up existing power plants, and reduce the emissions from new power plants through the use of geosequestration is vital.

To put that into a simple financial argument, we have a real option available to us now. The cost of the option is demonstration projects to ensure that we can implement geosequestration as a solution if it is found viable and cost effective. If demonstration projects do not go ahead then there may be considerable delays to the implementation of geosequestration as part of Australia's contribution to combating climate change.

In other words, if we think that cutting carbon emissions is necessary then the penalties associated with delays and obfuscation are likely to be higher than the costs associated with demonstration projects now. This isn't about picking one winner above others. It is about taking what we know is an actual answer and likely to provide one of the lowest cost paths to reducing Australia's greenhouse gas emissions and ensuring that it can be fully commercialised when it is needed.

The future

The natural owners of the skill sets and risk management expertise associated with geosequestration are the existing oil and gas industry – including exploration, production and services companies.

As economic incentives are realised the oil and gas industry will foster the development of the geosequestration expertise within their own companies. Over time, new companies will be formed that are solely in the business of being CO2 field operators and will eventually become independent of their parent companies.

The initial fields used for geosequestration will be existing oil and gas fields or their surrounding areas. Oil and gas producers will be best placed to understand the impacts of that geosequestration may have on their oil and gas production and are the natural operators of such fields.

In parallel, exploration efforts in under explored areas will identify new potential geosequestration fields that contain limited or no oil and gas. The Government will play a strong role in identifying potential basins or other suitable locations. These fields will then be assessed and put into operation by specialist CO2 field operators.

The energy industry of the future will force a blurring between the roles of existing energy sector companies.

Oil and gas companies will look to get into the business of producing synthetic petroleum and diesel products from coal. They will also be interested in producing hydrogen gas from coal as a transport fuel.

The coal companies, facing takeovers from the oil and gas industry as well as decreased demand for their product after 2020 will also look to add value to their product. However, being commodity producers without much ability to process, refine and distribute these other products, they are facing competition from the oil and gas companies.

Electricity companies will also metamorphose. Future coal fired power plants will turn coal into hydrogen, capturing the carbon dioxide and sending it off to CO_2 fields for geosequestration. These plants could run on hydrogen tolerant gas turbines or on fuel cells to generate electricity. The excess hydrogen produced could be on sold as a fuel source for transport use as well as other uses within the hydrogen economy.

It is even possible, if not likely that electricity generators will buy their hydrogen from large coal gasification plants that are developed by the oil and gas industry as the refinery of the future.

Natural gas pipeline operators will at first be the natural owners and operators of a backbone of CO_2 pipeline infrastructure that connects major sources of CO_2 to the major CO_2 fields. A number of large pipelines servicing national requirements will likely be developed as key national infrastructure. As CO_2 pipelining becomes a larger and more stable industry then other owners and operators will come in, as seen in the natural gas pipeline industry.

Summary of the future

This future vision of the energy sector will come into existence over the next 20 to 30 years. In the short term the oil and gas industry will play the major role by taking CO_2 from existing sources and sequestering in their existing fields. As economic incentives are realised an independent CO_2 geosequestration industry will form, however, this will not occur without strong involvement of the public sector in the short term.

Chapter 07 Legal issues in geosequestration

Legal risk arises from uncertainty in the regulations and legislation that govern an activity. Such uncertainty can arise from unresolved issues or lack of clarity, as well as from future potential changes to law.

While the legal issues associated with geosequestration have been considered in detail by other forums, it was thought necessary to stress the following legal issues as potential impediments to the commercial implementation of geosequestration.

Clashing tenements and the need for regulatory oversight

The potential for conflict between the oil and gas industries, and the geosequestration industry should not be underestimated. The following discussion should keep in mind the above discussion of overlapping tenements and co-existing rights.

Oil and gas producers will not simply allow geosequestration activities to occur either at the same location as their paying fields, or even near them. The act of injecting CO2 can change the pressure of fluids in the reservoir rocks, and could affect producing oil and gas fields several kilometres distant.

The economic benefits of oil and gas versus geosequestration rights are also unclear. For example, if there is an oil and gas resource in the same place as a geosequestration location, then which will have priority?

If the oil and gas resource is demonstrably small then it well may be clear cut that a larger potential geosequestration field will be of more benefit to society. However, in real life, matters are rarely so clear cut.

- A small company could make a decent profit out of a small oil and gas field.
- The oil and gas industry will likely be of the view that it would not like to ‘sterilise’ land by allocating it to geosequestration if that land has been under explored for oil and gas.
- Existing oil and gas producers may have as yet unrealised exploration plans for areas adjacent to producing fields.

- The potential benefits of both types of activities may be roughly equivalent.

Delays and uncertainty in resolving such issues will affect both industries. For geosequestration companies, there is a strong need for a decision making process that will provide an answer in the shortest period possible. This is especially important for the first few projects Australia wide that will likely be near existing oil and gas fields, the operators of which may vehemently object to geosequestration activities.

Similar issues exist where there is interaction with coal resources, coal seam methane resources and also with underground water resources.

Government should take a lead in establishing guiding principles and a method of settling such disagreements in order to provide certainty to both industries. This would ensure both industries can have alternative to a negotiated outcome when parties can't agree and the matter may be dragged into the courts for years.

The need for uniform principles of legislation across jurisdictions

The natural world does not respect political boundaries.

- Oil and gas fields may overlap State boundaries.
- Onshore fields under State control may be connected in the subsurface to offshore fields which are under Commonwealth control.
- Pipelines cross state borders.

These issues apply equally to the geosequestration industry and the infrastructure needed for it.

It is vital that the States and Commonwealth provide compatible legislation to encourage the geosequestration industry. The Ministerial Council on Mineral and Petroleum Resources (MCMPR) *Carbon capture and geological storage Regulator Guiding Principles* form a great foundation, however, apart from Corporations Law, when has there been complete agreement between jurisdictions?

The common good of all of Australia should be the overriding principle, rather than benefits to an individual jurisdiction.

The unpredictability of predictive models

It is accepted that a robust predictive model on the behaviour of sequestered CO2 is a requirement in the approvals process for a geosequestration project.

By their very nature such models are based on limited information and are predictive, not precise. CO2 can and will move away from the predicted migration paths.

As long as the CO2 remains sequestered and is unlikely to escape, then the objectives of geosequestration have been achieved. This highlights the need to:

- Treat geosequestration tenements as a part of a larger system and allow for the CO2 to move outside of the tenements allocated for that activity, at no penalty.
- Ensure that any future accreditation and certification system recognises this uncertainty and does not seek any form of refund of carbon credits or other form of penalty, as long as the CO2 will remain in storage.
- Transfer liability for monitoring and managing the CO2 to government after closure of the field as long as the CO2 is still sequestered, albeit in not exactly the way as predicted during the approvals process.

Native title

It is understood that there is some uncertainty over whether or not geosequestration activities are eligible for the same processes as already negotiated for other resource projects under the *Native Title Act 1993 (Cth)*.

For example, a question at law is whether or not geosequestration constitutes a mining activity, which oil and gas do. If it is not a mining activity then other means are available under the Act through which project proponents can negotiate under Indigenous Land User Agreements (ILUAs) or similar. However, such a process will take a longer time than the existing agreed mechanisms for mining activities. Government assistance, either financial or in-kind, may be appropriate to help on Native Title matters.

This is not an issue that can be solved through simple measures, and may require test cases as we go forward. If not resolved this may lead to delays in implementing geosequestration.

Uncertainty over the definition of a natural resource

Geosequestration will occur in the pores of rocks. These pores are empty spaces, except where there is a substance that will be displaced by the stored CO2.

Under law, natural resources belong to the Crown which grants rights of exploitation. Things that do not constitute a natural resource belong to the owner of the land, from the centre of the Earth up into the atmosphere.

Is pore space – the holes in the rock – a natural resource? These pores normally contain the natural resource – a container for the natural resource and not the natural resource in and of themselves.

As this situation was not contemplated in the formulation of existing resources laws, and will likely require PhD level studies on the issue, it will not be solved in a short time.

The legal risk here is that a company's tenure for geosequestration right could be reversed if it is considered that the pore space belongs to the land owner and not the Crown. While such a situation will surely be resolved over time, any delays will again mitigate against the early adoption of geosequestration as a tool to help combat human induced climate change.

Interaction with water

In Queensland the availability of ground water is a pertinent issue.

As a guiding principle, currently contemplated geosequestration projects are staying away from the Great Artesian Basin.

This is because geosequestration activities may penetrate the aquifers of the Great Artesian Basin. While such activities may well be conducted in a technically safe manner that will neither damage the water supply nor create a source of leakage, to be conservative, it is currently being avoided where possible.

The definition of saline for deep saline aquifers is another issue that bears scrutiny. For example, if a source of water is found at depths of a kilometre or so, does this mean that it should be reserved for use by humans, agriculture, livestock or industry?

It is entirely sensible to argue that as the costs of exploiting such a deep water resource are so high, no reasonable man would expect that water to be quarantined from usage as a location for geosequestration. For example, would a farmer be willing to pay one and half million dollars for a one kilometre deep water well that only supplies a slow trickle of water?

Likewise, the situation where someone seeking to exploit underground water accidentally inducing the movement or escape of CO2 is a low probability event as common sense economics (the above mentioned one and half million dollars) would dictate that the depths of geosequestration activities are such that this kind of interaction is unlikely.

While there is potential interaction between geosequestration activities and water resources, it should be managed in such a way that the risks of adversely affecting water supplies are minimised, and should take into account common sense principles about the ability to exploit potable water that is at depths that will likely never be exploited by any other party. Regulations and the approvals process should take this into account and not be unnecessarily cautious in their application.

The need to allow for learning by doing

In granting approval for geosequestration projects the need to recognise learning by doing is important. We need to test the boundaries of what is acceptable for the long term storage of CO2 rather than always taking an overly conservative, and potentially more costly path which will limit the usefulness of geosequestration as a tool to mitigate human-induced climate change.

For example, to test the viability of non-conventional geology, or to test techniques for monitoring CO_2, it may be a requirement to allow for the potential small scale escape of CO_2 from storage locations.

The approvals process for these projects should provide enough flexibility to allow for learning by doing over the coming two decades.

Financial assurances

Companies are required to put up financial assurances that can be used by the Government to repair or remediate damage when a company either can not or will not assume its responsibilities to the environment. Such financial assurances are part of the environmental approvals process in Queensland.

Likewise, financial assurances will be sought from the geosequestration industry. The question in this case is more along the lines of timing.

It is currently proposed that geosequestration tenure be held for 50 years. This is a long time for a company to undertake an economic activity.

For example, if a CO_2 storage field is closed after 20 years, will it be eligible to claim back the bond when it does the right thing when closing the field? If not and it has to wait until the 50 years are up, then the economics of the business case are adversely affected.

Similarly, it may be that individual wells are closed after a decade or two and correctly abandoned while the rest of the field remains in operation. Should the company be able to claim back part of the financial assurances paid to the government?

The mining industry can close down their production tenements earlier than scheduled and claim back their financial assurances. This does not absolve them of all long term liabilities, but allows them to effectively drop the tenement. Such principles should also apply to geosequestration.

Paying for long term monitoring

Geosequestration is a long term activity. An entity will store a large volume of CO_2 underground over the space of a few decades. After they close the field, and an appropriate period of post-closure monitoring, the field will be handed over to government.

The CO_2 will stay sequestered for thousands, if not many tens of thousands to millions years.

Who will watch the CO_2 to make sure it is staying down there, and not heading towards a situation where it can escape? Such a role is best suited to government.

The natural question that arises from this is who will pay for such activities.

Given the long time periods involved the question is how much is it reasonable to expect the entity that injects the CO_2 to contribute towards long term monitoring costs.

- It may be reasonable to require operating companies to close the fields using materials and techniques that sensibly minimise the potential for CO_2 to escape.

- It may be reasonable to require operating companies to install infrastructure to allow for long term monitoring as part of the closure process.

- There may even be argument for a small contribution by the company based on revenues earned to contribute to long term monitoring, similar to resource rent taxes paid by other resource industries. The setting of such a tax should be based on an *ad valorem* approach and linked to revenues earned rather than as a flat tax per unit of carbon dioxide sequestered. South Australia is proposing amendments to the *Petroleum Act 2000* that put in place provisions that ensure no royalty payments are put on geosequestration or gas storage.

- As the activity of geosequestration will provide society with the ability to continue with their existing lifestyle while minimising their contribution to human-induced global warming, it is also reasonable to assert that society should contribute to the costs of long term monitoring of CO_2.

- It is not reasonable to expect a company to cover all the costs of long term monitoring for long periods of time. Future work will be subject to inflation, and will be best paid for at the time rather than added to the costs of a project now.

CO_2 ownership and liability

When seeking to attribute liability, the ownership of the CO_2 will be an issue.

In principle it seems sensible that the person who injects the CO_2 should own it in terms of liability. While ownership represents only a small part of the overall issue of liability, it is one that could adversely affect freehold title land owners.

Under normal legal principles any improvements or modification made to land are the property of the owner of the land and not the person who made the improvement. Pipelines are one exception to this rule. However, for geosequestration it is arguable that the owner of the land (e.g. a farmer) may become liable for the behaviour of the CO_2. In the case of freehold title, uncertainty in this area could hand liability for another's actions to an innocent party, and could adversely affect property prices.

As part of the effort to bid for involvement in the FutureGen project in the United States, two states have raised alternatives to deal with the issue of ownership.

- The State of Illinois is in the process of passing a bill which transfers ownership of the CO_2, and consequently liability to the state.

- The State of Texas has introduced a bill that provides indemnities to the owners and operators of clean coal plants with geosequestration.

Clearly, there is need for greater certainty on liability both during sequestration and after closure both for the development of the industry and to help prevent innocent parties from being liable.

Recognising the evolving nature of the industry over time

The next twenty years represents the birth of a new and vital industry – geosequestration.

The first projects will be demonstration projects with no financial rewards for the participants for undertaking the projects, and definitely no compensation for managing the risks and taking on the liabilities of the activities.

Consequently, the regulations, legislation and approvals process should recognise this.

Additionally, the government should consider taking part or all of the liability associated with such demonstration projects during their operation.

If governments maintain the current expectation that liability will not be transferred until after a certain period after closure of the field, then demonstration projects vital to the development of geosequestration will either be delayed or cancelled.

Given how vital geosequestration is, some bold vision is required in this area. Government is better placed to take on these risks than any other party and should do so.

When geosequestration becomes a standard commercial activity then governments could ensure that liability stays with the private sector until after closure of the field, as already proposed in the MCMPR regulatory guiding principles.

Legal structuring

While the geosequestration tenure regulations under consideration do not explicitly deal with potential carbon credit regimes or carbon taxes, the need to put in place a tenure system that is likely compatible with such future regimes is important.

Industry typically tries to quarantine activities that are risky and carry either the potential for bankruptcy or legal liability.

For example, unincorporated joint ventures will typically appoint operating companies separate to the ownership of the joint venture. In such a case who will own the sequestered CO2, and be able to claim credits and be liable for any future issues.

Similarly, industry will use special purpose vehicles which will be wound up at the end of the life of a project, or quarantined from commercial operations if there is unexpected legal action.

The key point here is that legal structures for the operation and ownership of CO2 Geosequestration fields are by their very nature likely to be transitory arrangements set up specifically for the geosequestration activities undertaken. This lifespan may well be shorter than the currently mooted 50 years for sequestration tenements and will definitely be shorter than the potential for longer term, so called 'long-tail liabilities'.

The regulatory framework should be drafted with these issues in mind.

Chapter 08 Principles for a tenure system

Based on the above discussion on the makeup of the geosequestration industry and the commercial drivers required for the rapid development of geosequestration by the private sector the following key principles should be recognised in the formulation of policy and regulations.

1. As geosequestration is one of the major potential technological pathways to mitigating the human induced global warming, it is critical that a framework that promotes and fosters the early development of the industry is put in place.

2. The private sector has the skills but not the commercial incentive to act on geosequestration. Consequently, Government needs to take a leadership role in establishing and fostering this industry.

3. Even with the introduction of a carbon trading scheme, without government leading the way in terms of capping liability and promoting demonstration projects geosequestration will be limited in its application.

4. The oil and gas industry, and not the power industry are the natural owners of the geosequestration industry for its first 15 to 20 years. Indeed many of the required technologies may be partially proved up by enhanced oil recovery using CO_2.

5. Oil and gas tenement owners should have automatic first right of refusal on CO_2 sequestration tenements both on their own tenements and in adjacent areas.

6. A flexible system is required that allows for the many permutations of CO_2 sources and CO_2 sequestration sinks.

7. The legislative framework should provide certainty to project proponents and operators.

8. Policy, legislation and approvals processes should recognise the slow movement of CO_2 outside tenement boundaries and manage the potential reservoir rock as an interconnected system rather than isolated blocks that do not interact.

9. There will be conflict over tenements and a mechanism should be put in place that allows for an arbitrated outcome where a negotiated outcome does not occur.

10. Establish a private sector and government working group to work through the underlying principles of tenement conflict issues.

11. Allow for a risk based approach and encourage learning by doing through active government sponsorship, for example in taking liability for demonstration projects.

12. Seek to provide a one-stop-shop approach for project proponents that tie together all relevant government departments and processes.

13. Actively engage with the broader community on the reasons for geosequestration and the potential benefits of the activity. It is the role of government to promote geosequestration and it is the role of project proponents to promote their project and pass the legislative hurdles required. The early and ongoing involvement of environmental groups in the debate over geosequestration should be encouraged by government and the government should take a leadership role in this area.

14. While it is understandable that the first few projects will be exceedingly conservative to help build public confidence in geosequestration, this initial overly conservative approach should not become enshrined as standard for government approval processes.

15. Promote some economic incentives for the private sector and its investors to enter the geosequestration industry by allowing sequestration tenement holders the right to exploit oil and gas found, and allowing oil and gas explorers to take advantage of geosequestration reservoirs found. To not do so would be to waste large sums of money and expertise and materially delay the introduction of geosequestration. In other words, the overzealous application of separation of rights in the name of equity to promote a market in the absence of such a market will cause significant delays to the implementation of geosequestration.

16. Recognise that the discovery, appraisal and development of geosequestration fields will be a long term and costly process, and

provide as much incentive as possible to the creation and promotion of such an industry.

17. Recognise the need to promote large CO_2 fields so operators can take advantage of economies of scale to bring the costs down to a level that make geosequestration a commercially viable activity. This means that tenements should be large and not unnecessarily carved up into small pieces.

18. Recognise that safe long term geosequestration is the desired outcome and not exact adherence to a predictive model that by definition can never be completely accurate.

Chapter 09 Comments specific to the discussion paper

Based on the above principles and previous discussion, the following comments relate specifically to the *Carbon dioxide geosequestration tenure administration discussion paper* released by the Queensland Department of Mines and Energy in June 2007.

1. Support the use of the *Petroleum and Gas (Production and Safety) Act 2004* as a vehicle for tenure administration.

2. Disagree with the mooted tenure mechanisms of Profit a Prendre and volumetric subdivisions. These will not provide effective and legitimate legislative support for CCS tenure administration and carbon trading.

3. The use of such mechanisms will be confusing and provide too much uncertainty to proponents of geosequestration. The use of statutory lease and licence arrangements such as already exist under the *Petroleum and Gas (Production and Safety) Act 2004* is suggested.

4. The tenure system should not only recognise the sequestration rights as granted to the private sector, but the need for government and its agents to monitor the CO2 for long periods of time – potentially hundreds of years.

5. Provide a common sense framework based on sound science to water management rather than blindly applying the precautionary principle. Appropriate amendment to water regulations should be sought to ensure that geosequestration activities are not automatically classified as interfering with the water and providing authorisation for geosequestration activities.

6. At least for the first 20 years give CO2 geosequestration companies the rights to petroleum resources discovered, and conversely give oil and gas companies the rights to CO2 geosequestration reservoirs discovered. This is not to say that priority should always be given to oil and gas tenure holders, especially where they are obstructing geosequestration, but it is intended as recognition that they in many ways are the most likely to rapidly develop geosequestration as an industry.

7. Remove uncertainty on ownership of injected CO2 and provide indemnity to otherwise innocent landholders that may by default become liable for the actions they had no control over or economic interest in. This is especially important in the case of freehold title over the land.

8. On a case by case basis accept liability for CO2 geosequestration demonstration projects, or accept ownership of the CO2, during the operation of the project and not wait until after the project has been closed and monitored for several years. Failure to do this will hamstring the development of this much needed industry which is trying to provide a social outcome with no commercial incentives or reward for taking on such risk.

9. Provide a broad definition of the gas stream to be geosequestered in recognition of the punitive costs of capturing a relatively high purity CO2 stream from the emissions of polluters. The sequestration of mixed gas streams can monitored by government as the science has long existed to understand the interaction of different gas streams with the minerals within a reservoir.

10. Where compensation is due to landowners for the use of subsurface rights then provide a regime that allows for this and provides a sensible economic outcome in relation to a resource that a freehold land owner would otherwise not be able to use. This is a separate issue to compensation requirements for the use of land at surface, for which existing practices should suffice.

11. While third party access to facilities such as pipelines is an issue that the government should consider, it is also important to recognise that pipelines for commercial operators will likely have multiple sources of CO2 and thus already provide access to multiple users. Unlike natural gas, gas for geosequestration is not a fungible commodity with a set composition. The composition of geosequestration gases transported can have a deleterious effect on the pipeline and its infrastructure requirements and care should be taken not to allow third party access for gas types that would damage the pipeline.

12. Provide a regime that provides irrevocable and full recognition of geosequestration of CO2 at the time it is stored to provide compatibility

with carbon trading or carbon market mechanisms that will provide the revenues that will underpin the operation of this industry.

13. Recognise that the use of CO_2 in enhanced oil recovery can be a form of geosequestration and authorize it as such. This is particularly important as enhanced oil recovery will likely be the first commercial form of geosequestration and the recognition of sequestration will provide access to carbon trading and markets to provide revenues offsetting the high costs of transporting and injecting CO_2 for enhanced oil recovery.

14. Seek greater quantities of, and better quality data from oil and gas exploration and production activities. While the compulsory provision of such data is controversial within the oil and gas industry due to claims of commercial sensitivity, for the rapid implementation of geosequestration it is in the best interests of society that such data at a minimum be available to government. This will enable the rapid identification of the geosequestration potential of regions within Australia.

Disclaimer

The views expressed are solely those of the author and represent his view of what is needed to most rapidly implement geosequestration as a mechanism to mitigate human induced global warming.

At the time of writing this paper, the author has no working relationship with any geosequestration related project or company.