EFFECTIVE ENFORCEMENT OF UNDERGROUND STORAGE OF CARBON DIOXIDE

MEREDITH GIBBS

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Effective enforcement of underground storage of carbon dioxide

Dr Meredith Gibbs

30 June 2016

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The Fellowship

The Global CCS Institute (**Institute**) launched a CCS Fellowship program in 2016 designed to recruit industry experts to work with Institute specialists on important current issues facing the CCS industry. Fellowships are conducted over six months and Fellows undertake a program of work that aligns with the Institute's core strategic objectives of providing:

- fact-based influential advice and advocacy; and
- authoritative knowledge sharing on CCS,

and which will be effective in the context of the current public debate on climate change.

The Inaugural Legal Fellow (Asia-Pacific), Dr Meredith Gibbs

A prominent Australian environmental and climate change lawyer and a partner at HWL Ebsworth Lawyers in Melbourne, Dr Gibbs is a leading expert on Australia's CCS legal regimes. She is recognised in Australia's Best Lawyers for her expertise in Climate Change Law and has advised CCS proponents and government departments on CCS legal and regulatory issues.

I am honored to have been appointed as the inaugural Global CCS Institute Legal Fellow to deliver a research program focused on effective enforcement of the underground storage of carbon dioxide (**CO_2**). This issue is important because the perception of an effective enforcement regime that ensures the permanent and safe storage of CO_2 will be crucial in increasing public and industry confidence in CCS as a viable technology. The Fellowship has provided an invaluable opportunity to work with the Institute and contribute to the knowledge about the kind of legal regimes that will foster and promote CCS as part of a low-carbon future.

I have delivered the following research outputs during the Fellowship:

- publication of "Insights" on the Institute's website throughout the Fellowship tenure;
- facilitation of a collaborative workshop on monitoring and verification issues;
- this research report; and
- presentations of the research findings as part of the Fellowship program, as follows:
  - "Australia's offshore GHG storage regime", presentation to the APAC CCUS Legal and Regulatory Forum, Tokyo Meeting, 27 January 2016, Tokyo, Japan; and

- "Effective enforcement of CCUS obligations", presentation to the Asia Pacific CCS Forum, Global CCS Institute, Melbourne Meeting, 11 April 2016, Melbourne, Australia.

I also participated in a workshop discussion whilst at the APAC CCUS Legal and Regulatory Forum in Tokyo which was attended by a range of Japanese business people and government agencies. My participation at the Tokyo Forum was part-funded by the Institute and part-funded by my firm, HWL Ebsworth, and I wish to express my gratitude to each organisation for their support. While in Tokyo for this Forum, I also attended the International CCS Symposium for Low-Carbon Society, hosted by the Japanese Ministry of the Environment in cooperation with the Global CCS Institute, on 26 January 2016. These sessions, together with informal discussions with participants, provided invaluable information and insights into the Japanese regulatory framework for the underground storage of CO_2.

I will present my final research findings and recommendations at a webinar in August 2016.

I wish to thank the Institute for this opportunity to work collaboratively with other CCS experts. In particular, I wish to thank Mr Ian Havercroft, Senior Adviser – Legal and Regulatory at the Institute, who conceived of the Fellowship program and who has been the driving force behind it.

I wish to acknowledge the research assistance of Gabby MacMillan, Samantha Megenis and Ben Weintraub of HWL Ebsworth. The views and recommendations expressed in this report remain my own and do not necessarily represent either those of the Institute or HWL Ebsworth.

Dr Meredith Gibbs
30 June 2016

1. Executive summary

1.1 Rationale

The perception of an effective enforcement regime that ensures the secure and safe storage of CO_2 in underground geologic formations will be crucial in increasing public and industry confidence in carbon capture and storage (**CCS**) as a viable low-carbon technology.

1.2 Effective enforcement criteria

An effective enforcement regime for underground storage of CO_2 has the following key features:

- comprehensive obligations that address the key risks of underground storage of CO_2;
- comprehensive monitoring and verification (**M&V**) requirements, including baseline monitoring, M&V obligations during the injection phase and M&V obligations post-injection;
- enforcement mechanisms that are risk-based, layered and flexible, grounded in science and fact-based decision-making, and include the ability to deal with 'serious situations' (such as unintended releases and CO_2 not behaving as predicted)[1]; and
- a clear allocation of roles and responsibilities for enforcement.

1.3 The case studies

Five case studies were assessed and scored against criteria based on these key features. The following jurisdictions in the Asia-Pacific region were chosen for examination: Australian Commonwealth (offshore) (**Australian Offshore Regime**); the State of Victoria, Australia (onshore) (**Victorian Onshore Regime**); Japan (offshore) (**Japanese Offshore Regime**); Malaysia (offshore) (**Malaysia Offshore Regime**) and China (onshore) (**Chinese Onshore Regime**).

The two Australian regimes, the Australian Offshore and the Victorian Onshore Regimes, are very well developed and each provides the basis for an effective enforcement regime for the underground storage of CO_2. There is an extremely high level of detail included in all aspects of each of the regimes, which include detailed regulations and subordinate instruments, as well as extensive enforcement powers and a variety of enforcement tools. While aspects of the allocation of roles and responsibilities for enforcement could be improved, given that there are so few CCS projects in Australia there is little incentive or need for agencies to devote any resources to this at this point in time.

[1] See Appendix B for the definitions of "serious situation" in the Victorian Onshore and Australian Offshore Regimes.

The other case study jurisdictions will require further development if underground storage of CO_2 is to be deployed commercially and at scale in those countries. In particular, effective enforcement mechanisms appropriate to the CCS context will need to be developed.

The Japanese Offshore Regime represents a mid point with respect to the effectiveness of enforcement in the case studies. Japan's Marine Protection Law has CCS-specific provisions that permit storage of CO_2 in the sub-seabed. However, these provisions have significant limitations including that permits only have a five-year tenure and there is no closure regime. Despite this, the M&V requirements are detailed and CCS-appropriate, and although there are no specific powers to deal with serious situations, there are basic enforcement mechanisms in place. There is a clear allocation of roles and responsibilities.

Malaysia's Offshore Regime has no CCS-specific legislation. CCS projects could be largely dealt with under the current legal frameworks for offshore petroleum and environmental approvals. However, amendments to these existing regimes will be required in order to provide comprehensive obligations that address all relevant risks of the sub-seabed storage of CO_2. In particular, standards would need to be adopted for storage site characterisation and selection, as well as for the M&V of stored CO_2. Permitting regimes would need to be adapted for CCS and a closure regime developed. Malaysia's environmental legislation provides a solid basis for an effective enforcement regime and Malaysia has well-developed health and safety legislation. The allocation of roles and responsibilities is not clear.

As with Malaysia, China has no CCS-specific legislation. The existing regulatory framework for major project approvals could be adapted for CCS but for large-scale projects or industry deployment substantial reform would be required. In particular, there is a lack of technical and management standards including those required for adequate M&V and reporting. A number of problems with the Chinese environmental enforcement regime will need to be addressed if it is to provide a basis for effective, risked-based enforcement of underground storage obligations. These include a lack of clear allocation of enforcement roles and responsibilities, structural and resourcing issues, and attitudes towards enforcement.

1.4 Monitoring and verification (M&V)

Scientifically credible and robust M&V is required to support effective enforcement and to build public and industry confidence in the technology. Without access to adequate data, regulators will be unable to assess effectively the risk of non-compliance or a serious situation, and will be unable to base enforcement decision-making on credible and robust scientific evidence. These issues are important because industry participants need reassurance that underground storage activities will be enforced to a level commensurate with the risks involved. Moreover, if potential operators and investors are not confident that regulatory requirements can be met, the legislation itself may act as a barrier to development of the CCS industry.

Even in the well-developed regimes of Australia and Victoria, some critical unresolved issues around M&V remain. These include:

- what is a "leak" and what data will be required to prove (or disprove) that a leak has occurred;

- how can it be demonstrated that a CO_2 plume is or is not behaving as expected; and

- what will a regulator require a storage operator to do in a serious situation, such as a leak or the plume not behaving as predicted.

There is a need for greater clarity around the definition of "leak" in the Australian Offshore and the Victorian Onshore Regimes, the requirements for baseline monitoring and the appropriate regulator approach to determining when a CO_2 plume is behaving "as predicted". In addition, there needs to be further consideration of M&V capabilities and requirements, and how they interact with legal regimes, to ensure that industry operators are not subject to enforcement action in situations where CO_2 changes are a result of natural variations or other 'false positives' in M&V results.

1.5 Regulation or early mover projects: which comes first?

The tension between achieving certainty and flexibility pervades the legal and regulatory regimes for the underground storage of CO_2. Regulators and industry proponents argue for both attributes at different times and in different contexts. This tension underlies an important question for CCS globally. Which comes first: a comprehensive regulatory regime or demonstration and early mover projects? Industry experience suggests that while providing certainty, an overly prescriptive legal and regulatory framework can deter early mover projects. Equally, a regime that is not well developed may not provide a sufficiently certain project pathway for investment decisions to be made.

A balance must be struck, but the absence of a fully developed regime should not be used as an excuse for the lack of demonstration and early mover projects. For example, the Japanese Offshore Regime is sufficiently developed to provide a solid foundation for development of early mover projects. A public education campaign about the relative risks of the underground storage of CO_2 as compared to other industries is likely to assist to develop a social licence to operate for CCS.

1.6 Recommendations

My recommendations are set out throughout this report and collated in Chapter 8.

In respect of the Australian Offshore and Victorian Onshore Regimes, I have made recommendations regarding M&V related issues, including recommending that further research be undertaken into an appropriate definition for the parameters of what should be considered to be a "leak" and that consideration be given to the inclusion of such a definition in these legal regimes. In addition, I recommend that consideration be given to developing CCS-specific baseline monitoring guidelines to assist both storage proponents and regulators. Further, consideration should be given to recognising, formally, the iterative nature of M&V in terms of modelling and predicting CO_2 plume behaviour and the relevant legal tests.

All of these issues are crucial in addressing existing industry concerns about the ability and cost of meeting the detailed requirements of the Australian Offshore and the Victorian Onshore Regimes, while balancing the need for regulators to have adequate enforcement mechanisms available and ensuring that the public has confidence that the regimes can be effectively enforced. I recommend that these issues are addressed by other countries when developing their legal and regulatory frameworks, and more generally, that consideration be given to the establishment of regional baselines in areas where multiple storage sites could be established.

In respect of the Japanese Offshore, Malaysian Offshore and Chinese Onshore Regimes, I make a number of recommendations for adapting existing legal and regulatory frameworks, or developing CCS-specific provisions, to better provide for the effective enforcement of underground storage of CO_2, if CCS is to be deployed commercially and at scale in these countries.

2. Introduction

This report is the result of research I have undertaken as the inaugural Fellow (Asia-Pacific) of the Global CCS Institute (**Institute**) into the effective enforcement of underground storage of carbon dioxide (**CO_2**).

In 2005, the Intergovernmental Panel on Climate Change (**IPCC**) made the following findings in relation to the underground storage of CO_2 (IPCC 2005):

> *22. With appropriate site selection based on available subsurface information, a monitoring programme to detect problems, a regulatory system and the appropriate use of remediation methods to stop or control CO_2 releases if they arise, the local health, safety and environmental risks of geological storage would be comparable to the risks of current activities such as natural gas storage, EOR, and deep underground disposal of acid gas.*
>
> *…*
>
> *25. Observations from engineered and natural analogues as well as models suggest that the fraction [of CO_2] retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1000 years.*

In recent years, some national and regional governments have developed legal and regulatory frameworks to permit the deployment of CCS, and in particular, the long-term underground storage of CO_2.

In most countries, however, while existing legal and regulatory regimes could, with greater or lesser modification and adaptation, be used to regulate the underground storage of CO_2, they are not fit for purpose and some contain crucial gaps. While work has been done on regulatory models for CCS as a whole, little specific attention has been paid to effective enforcement of these regimes. This research seeks to address this gap.

The perception of an effective enforcement regime that ensures the secure and safe storage of CO_2 in underground geologic formations will be crucial in increasing public and industry confidence in CCS as a viable low-carbon technology. The public needs reassurance that the industry can be effectively regulated so that risks to public health and the environment are avoided, remedied or mitigated, and that appropriate mechanisms are available to regulators to deal with serious situations, such as potential or actual unintended escape of CO_2 into the environment.

Industry stakeholders also require confidence that enforcement regimes in which they will operate will be effective and reasonable. In particular, given the emerging state of the CCS industry, potential participants need reassurance that compliance is achievable and that underground storage activities will be regulated to a level commensurate with the risks involved. There is concern that overly prescriptive regulatory requirements may unnecessarily increase the costs of CCS, and may not allow for innovation and the improvements in technology that would be expected in an emerging technology. If potential operators and investors are not confident that regulatory requirements can be met, particularly in relation to site closure, the legislation itself will be a barrier to development of the CCS industry.

As experience with underground storage of CO_2 has increased over recent years, issues around M&V have arisen as operators seek to meet existing regulatory requirements. These issues include the type and extent of M&V that will enable operators to demonstrate compliance with legislation and how regulators will apply the various legal tests in relevant legislation. Particular concerns have been raised about unrealistically high expectations that every molecule of CO_2 injected can be accounted for. Further, given the uncertainties and tolerances of CO_2 plume modelling, there are concerns around when a CO_2 plume will be considered to be behaving as predicted, or not.

All of these issues feed directly into the effectiveness of enforcement regimes. Without appropriate and adequate data on which to base enforcement decisions, both regulator enforcement and operator compliance resources may be misallocated to unrealistic or low-risk situations, and significant risks may be ignored. In addition, operators need confidence that enforcement action will not be taken as a result of M&V inadequacies or failures, such as false positives.

After setting out the methodology for undertaking this research in the next chapter, this report goes on in Chapter 4 to examine the key features of an effective enforcement regime for underground storage of CO_2 and establishes the criteria against which five case study enforcement regimes will be assessed. The case studies are the Australian Offshore Regime; the Victorian Onshore Regime; the Japanese Offshore Regime; the Malaysia Offshore Regime; and the Chinese Onshore Regime. Chapter 5 presents the results of the five case study assessments and scoring process.

Chapter 6 focusses on M&V. It presents the discussions from the M&V workshop that I facilitated as part of the Fellowship research program and examines some critical unresolved issues in this area. These issues include: (a) what is a "leak" and what data will be required to prove (or disprove) that a leak has occurred; (b) how can it be demonstrated that a CO_2 plume is or is not behaving as expected; and (c) what will a regulator require a storage operator to do in a serious situation, such as a leak or the CO_2 plume not behaving as predicted.

Finally, Chapter 8 sets out my recommendations arising from the Fellowship research.

3. Case study methodology

3.1 Overview

The primary aim of this research was to identify the key features of an effective enforcement regime for the underground storage of CO_2. The key features identified were used to develop criteria to assess five national and sub-national legal and regulatory frameworks. Based on these assessments, I have recommended areas where these legal and regulatory frameworks could be improved to increase the effectiveness of enforcement. I have also identified areas where further research would be beneficial.

Given the importance of M&V in achieving effective enforcement, I hosted an M&V workshop as part of the Fellowship to provide an open forum for discussion of M&V issues between technical and industry experts and CCS legal and regulatory professionals.

The scope of this research is confined to issues related to the long-term, underground storage of CO_2 and accordingly, it does not address any aspects relating to capture and transportation of CO_2.

3.2 Case studies

(a) Choice of case study jurisdictions

The following jurisdictions in the Asia-Pacific region were chosen for examination: the Australian Offshore Regime; the Victorian Onshore Regime; the Japanese Offshore Regime; the Malaysia Offshore Regime and the Chinese Onshore Regime.

The choice of case studies was finalised in consultation with the Institute taking into account: (1) the nature of the legal regime (including CCS-specific or not) and the enforcement mechanisms available; (2) representative spread across the Asia-Pacific region and a balance of non-OECD and OECD countries; (3) the level of prospectivity of suitable geological reservoirs within the case study jurisdictions (onshore and offshore); and (4) the appetite for CCS deployment in the case study jurisdictions.

(b) Case study criteria

The case study criteria were developed after a targeted literature review which focussed on previous work done in relation to CCS regulatory models and best practice enforcement of environmental regulation (see Chapter 4). Each of the five national or sub-national legal and regulatory frameworks was assessed against these criteria.

(c) Case study scoring

An extensive review of each country's legal and regulatory regimes was conducted as a part of the assessment process. The scoring scale set out in Table 1 below was used to score each of the jurisdictions against the assessment criteria.[2]

Table 1: Scoring scale for assessment

Score	Indicator
3	The legal and regulatory framework is comprehensive with respect to the criterion
2	The legal and regulatory framework is moderately comprehensive with respect to the criterion
1	The legal and regulatory framework is not comprehensive with respect to the criterion but satisfies it in some minor respects
0	The legal and regulatory framework does not address the criterion

A final score for each case study jurisdiction was calculated based on the sum of scores awarded for each of the criteria.

3.3 The M&V workshop

Reflecting the importance of M&V for effective enforcement, I facilitated a collaborative workshop on legal and technical M&V issues.

The workshop brought together technical and legal experts to discuss legal and practical issues arising from two of the case study jurisdictions: the Australian Offshore Regime and the Victorian Onshore Regime. These two case study jurisdictions have well-developed legal and regulatory frameworks for underground storage of CO_2. As a result they provided an excellent basis for exploring some of the issues and difficulties that operators may face in seeking to comply with the regimes, as well as regulator perspectives on the same. The discussion was focussed on monitoring of CO_2 storage sites and CO_2 plume behaviour, and discussed the extent to which technical capacity exists to deliver the M&V required under those regimes. Some of the "grey" areas in the legislation were also explored at the workshop.

The workshop discussions are presented in detail in Chapter 6.

[2] Adapted from the scoring system used in the Global CCS Legal and Regulatory Indicator (Global CCS Institute, 2015).

4. Effective enforcement criteria

4.1 Effective enforcement of regulatory frameworks for the underground storage of CO_2

The principal aim of a CCS regulatory regime is to ensure the secure and safe storage of CO_2 in underground geologic formations, whether onshore or offshore. An effective enforcement regime will reflect this aim. At a high level, this means that the legal and regulatory framework must address the risks of CO_2 storage by providing relevant obligations for each aspect of storage activities and then provide effective enforcement mechanisms in respect of each obligation. In this way, where a storage operator fails to meet its obligations, there will be the means for the relevant regulator to act. Whether regulators use such mechanisms in a fair, effective and transparent manner is beyond the scope of this research.

In this chapter, the key features of an effective enforcement regime, which form the basis for the case study criteria, are discussed.

4.2 What are the key risks?

The principal risk of the underground storage of CO_2 is the unintended release of CO_2 from the storage site leading to:

- unacceptable human health impacts;
- adverse environmental impacts, including contamination of groundwater in the case of onshore storage sites or marine environment impacts in the case of offshore storage sites; and
- climate change impacts (defeating the purpose for which CCS is undertaken).

In addition, there are risks associated with stored CO_2 not behaving as predicted because this may signal an increase in the risk of an unintended release of CO_2.

The risk assessment for a storage site should focus on identifying potential leakage pathways such as faults, fractures and wells, and develop associated mitigation and contingency plans which would be implemented if the CO_2 plume moves in the direction of the identified pathways (WRI 2008). This risk analysis could indicate that the site is not suitable for long-term storage of CO_2.

The threat of a catastrophic, sudden escape of CO_2, with resulting adverse impacts on human health, including death, and the environment, is most often raised as the principal risk of the underground storage of CO_2. The probability of this occurring is actually extremely low with the risk of gradual release of small amounts of CO_2 being more likely, although still very low (Reisinger, 2009; Victorian Government, 2016). The IPCC in its 2005 Special Report on CCS (IPCC, 2005) found that:

> *Observations from engineered and natural analogues as well as models suggest that the fraction [of CO_2] retained in appropriately selected and*

> *managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1000 years.*[3]

Accordingly, the risk of leakage of stored CO_2 is very low.

In the unlikely event that a CO_2 leak did occur, because CO_2 is heavier than air, there is a risk that if undetected, CO_2 that is released into the atmosphere could accumulate in low-lying areas with a potential risk to humans and the environment (APEC, 2012), although again this risk is extremely low. Indeed, there are many areas where CO_2 is released naturally into the atmosphere, such as at natural spas, without danger to humans or the environment (Victorian Government, 2016). Further, CO_2 is currently managed safely in a range of industrial settings (APEC 2012). Recent research also indicates that even if there were an escape of CO_2 from the sub-seabed and into the marine environment, the impacts would be localised and minimal (Kano, 2010; Mori et al, 2015; Sato, 2016). A "more plausible risk" is that migrating CO_2 comes into contact with an underground aquifer and causes acidification of groundwater or pushes naturally occurring brine into groundwater used for drinking water or other beneficial uses (Reisinger, 2009). A further risk, also extremely low, is that of induced seismicity. Most geologists have concluded that this risk is an "improbable" result of the underground injection of CO_2.

Indeed, the IPCC in its 2005 Special Report on CCS found that (IPCC, 2005):

> *With appropriate site selection based on available subsurface information, a monitoring programme to detect problems, a regulatory system and the appropriate use of remediation methods to stop or control CO_2 releases if they arise, the local health, safety and environmental risks of geological storage would be comparable to the risks of current activities such as natural gas storage, EOR, and deep underground disposal of acid gas.*

Given that CO_2 is not flammable and that the potential impacts of any leak are far less serious than a leak or spill of petroleum or acid gas, the IPCC may well be overstating the risks of stored CO_2.

4.3 Effective regulation: key characteristics

As a general rule, when addressing the risks posed by the underground storage of CO_2 the legal obligations and enforcement mechanisms should reflect the likelihood of the occurrence of the relevant risk event and the magnitude of the impact should the event occur.

In addition, given that the principal aim of the regulation of the underground storage of CO_2 is to protect human health and environmental integrity, it will be essential that the regulatory requirements, and the enforcement mechanisms that back them up, are based on science and fact-based decision-making (APEC, 2012). This in turn relies on adequate data being available. The requirement to monitor regularly so as to detect any accidental release, or increased risk of accidental release, of CO_2 will be one of the key obligations involved. Further, regulators will need access to adequate data in order to inform enforcement decisions. Accordingly, it will be crucial that the regulatory

[3] "Very likely" is a probability between 90 and 99%. "Likely" is a probability between 66 and 90%.

regime provides for M&V, data collection and reporting requirements (APEC, 2012; IEA, 2010; US Department of Energy, 2012; WRI, 2008).

In practice, this means that it will be crucial that the regulatory framework, and in particular the storage permitting model, requires that adequate pre-application environmental assessments are undertaken to establish "environmental baselines" against which to assess any future impacts. This will also play out in the requirement that the geologic storage site is adequately characterised before an injection permit is granted and sufficient information is provided to the regulator with any injection permit application (APEC, 2012; IEA, 2010; US Department of Energy, 2012: WRI, 2008).

Once injection has commenced, such an approach will require ongoing M&V of the CO_2 plume movement and systems that ensure early detection of any leaks, or increased risks of leaks, coupled with regular reporting requirements. A comparison of actual plume characteristics against modelled behaviour should also be required. An iterative process that allows injection rates or operation of the facility to be modified in response to monitoring results in order to maintain the highest safety and environmental standards, and modelling updated to reflect actual knowledge of plume behaviour, will be most effective (APEC, 2012; US Department of Energy, 2012; WRI, 2008). The idea behind this iterative process is that the modelling is improved as actual data collected during the injection phase is taken into account with the ultimate aim that a robust and accurate model is achieved by the time injection ceases. The modelling of the long-term behaviour of the CO_2 plume can then be predicted with a high level of confidence and will guide the long-term monitoring required.

For those jurisdictions with site closure requirements or a transfer of long-term liability, these issues will be particularly important. In order to obtain site closure sign-off from the relevant regulator, an operator will have to demonstrate that the CO_2 plume is behaving as expected and does not pose a risk to human health or the environment. Ongoing monitoring responsibility may also be transferred but will be required to ensure the secure, safe storage of the injected CO_2.

While these principles will apply to all storage sites, each M&V plan will be site-specific and, as noted above, will change over the life of the project. The actual monitoring techniques used will depend on the purpose of the monitoring, with some techniques being more suited to monitoring for regulatory compliance and others are better suited to reservoir management (IEA, 2010; US Department of Energy, 2012; WRI, 2008). Accordingly, monitoring requirements need to be flexible and able to adapt to changing circumstances, including advances in monitoring technologies over time (APEC, 2012; IEA, 2014)

4.4 Enforcement mechanisms

In terms of the actual enforcement mechanisms available to regulators, there is a consensus of opinion that best practice enforcement regimes have a risk-based, layered and flexible approach that allows regulators discretion to use the most appropriate enforcement mechanism (Allens et al, 2013; Macrory, 2006; see for example, EPA Victoria, 2011). In practice, this means that the enforcement regime must include a range of sanctioning tools that allow regulators to apply the enforcement mechanism that best fits the risk profile of the situation and to provide a proportionate response. It is also important that sanctions should aim to change the behaviour of the offender, rather than being focused solely on punishment, and should aim to eliminate any financial gain or benefit from non-compliance. Ideally, sanctions should also aim to restore the harm caused by the regulatory non-compliance and aim to deter future non-compliance (Macrory, 2006).

These factors are particularly important in the context of the long-term storage of CO_2 where the regulatory priorities are safety and environmental integrity and where prevention is better than cure. At a minimum, the enforcement regime should empower the regulator to undertake necessary inspections and require the provision of monitoring data and other information collected by the operator so that the regulator can verify that the project is complying with all relevant obligations and that the CO_2 plume is behaving as expected (IEA, 2010).

A CCS enforcement regime should allow for early intervention and warnings before more formal action is taken, and be based on a cooperative relationship between the regulator and the regulated. This will be particularly important where there is an expertise asymmetry between the regulator and the regulated. However, equally important is that CCS regimes include high financial penalties and criminal sanctions, including for directors and officers of storage proponents, which could be used in the most serious situations where culpability and/or serious harm is involved.

It will be important that the regulator has the flexibility to act appropriately in serious situations where there is a leak or clear risk of a leak, so as to remedy or mitigate the harm to human health and the environment. While such powers need to contain a high degree of discretion so as to provide that flexibility, the legal tests for exercising such powers must be grounded in criteria that can be established on the data that the regulatory framework requires to be gathered. They must also allow the regulator to act in a timely manner and ensure that any adverse impacts are remedied (IEA, 2010). Further, an effective regime will empower the regulator to act where the operator fails, or is unable, to do so, and recover the costs of doing so (IEA, 2010).

In addition, the regulatory enforcement model should include a requirement for regulator transparency and accountability in a manner that promotes learning and information sharing with the regulated and the public more generally (Allens et al, 2013). This too will be particularly important in building the confidence of the public and industry in the early days of CCS deployment.

Another important factor will be a clear allocation of roles and responsibilities for enforcement. Unless regulatory roles and responsibilities are clearly set out in legislation and well understood, there is likely to be confusion and inaction on the part of regulators.

4.5 Case study criteria

Based on the above, the following primary and secondary criteria which address the critical elements of effective enforcement of the underground storage of CO_2 have been adopted for the case study assessments:

- The comprehensiveness of the obligations contained in the legal and regulatory framework for the underground storage of CO_2
  - The comprehensiveness of the obligations
  - The extent to which the obligations address the key risks
- The comprehensiveness of the M&V requirements
  - The extent to which baseline monitoring is required
  - The extent of M&V obligations during the injection phase
  - The extent of M&V obligations post-injection phase
- The comprehensiveness and range of enforcement mechanisms available
  - The extent to which the enforcement mechanisms are risk-based, layered and flexible
  - The extent to which the enforcement mechanisms are grounded in science and fact-based decision-making
  - The extent of mechanisms to deal with serious situations
- The extent to which there is a clear allocation of roles and responsibilities for enforcement

The case study results are presented in the next Chapter.

5. Case studies

5.1 Overview

The case studies are: the Australian Offshore Regime; the Victorian Onshore Regime; the Japanese Offshore Regime; the Malaysia Offshore Regime; and the Chinese Onshore Regime.

The Australian Offshore and the Victorian Onshore Regimes are very well developed, CCS-specific regimes, and each provides the basis for an effective enforcement regime for the underground storage of CO_2. There is an extremely high level of detail included in all aspects of each of the regulatory regimes, which include detailed regulations and subordinate instruments, as well as extensive enforcement powers and a variety of enforcement tools. While some aspects of the allocation of roles and responsibilities for enforcement could be improved, given that there are so few CCS projects in Australia there is little incentive or need for agencies to devote any resources to this at this point in time. The Australian Offshore Regime achieved a score of 25 out of a possible 27 and the Victorian Onshore Regime achieved slightly less, with 24.5 out of a possible 27, because the enforcement regime does not include any custodial penalties.

The Japanese Offshore Regime represents a mid point with respect to the effectiveness of enforcement in the case studies. Japan's Marine Protection Law has CCS-specific provisions that permit storage of CO_2 in the sub-seabed. However, these provisions have significant limitations including that permits only have a five-year tenure and there is no closure regime. Despite this, the M&V requirements are detailed and CCS-appropriate, and although there are no specific powers to deal with serious situations, there are basic enforcement mechanisms in place. There is a clear allocation of roles and responsibilities. The Japanese Offshore Regime scored 17 out of a possible 27.

Malaysia's Offshore Regime has no CCS-specific legislation. CCS projects could be largely dealt with under the current legal frameworks for offshore petroleum and environmental approvals. However, amendments to these existing regimes will be required in order to provide comprehensive obligations that address all relevant risks of the sub-seabed storage of CO_2. In particular, standards would need to be adopted for storage site characterisation and selection, as well as for the M&V of stored CO_2. Permitting regimes (pollution licences currently have a one year term) would need to be adapted for CCS and a closure regime developed. Malaysia's environmental legislation provides a solid basis for an effective enforcement regime and Malaysia has well-developed health and safety legislation. The allocation of roles and responsibilities is not clear. The Malaysian Offshore Regime scored 12 out of 27.

As with Malaysia, China has no CCS-specific legislation. The existing regulatory framework for major project approvals could be adapted for CCS but for large-scale projects or industry deployment substantial reform would be required. In particular, there is a lack of technical and management standards including those required for adequate M&V and reporting. A number of problems with the Chinese environmental enforcement regime will need to be addressed if it is to provide a basis for effective, risked-based enforcement of underground storage obligations. These include a lack of clear allocation of enforcement roles and responsibilities, structural and resourcing issues, and attitudes towards enforcement. The Chinese Onshore Regime scored 9 out of 27 indicating that significant reform is required.

Appendix A sets out the scoring for each case study.

5.2 Australian Offshore Regime

TOTAL SCORE: 25/27

(a) Comprehensiveness of obligations

Score: 6/6

The Australian Offshore Regime is comprehensive and its obligations and enforcement mechanisms address the key risks posed by underground storage of CO_2.[4]

There is an offence for almost all obligations. The maximum penalty is 10 years' imprisonment, with most offences attracting a penalty of approx. AUD$18,000.

In addition to detailed obligations, the Regime contains a broad catch-all obligation that a permit holder must not carry on CO_2 storage activities in a manner that interferes with: (a) navigation; (b) fishing; (c) conservation of the resources of the sea or seabed; (d) authorised activities relating to minerals (other than petroleum) or construction/operation of a pipeline; or (e) enjoyment of native title rights, to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties of the title holder. Further, it is an offence to carry out storage activities such as exploring for storage formations, testing and injecting CO_2, without the relevant approval.

The Australian Offshore Regime includes detailed regulations covering occupational health and safety (**OHS**), as well as risks to the environment. In addition, the requirements of Commonwealth environmental legislation must be complied with.

(b) Comprehensiveness of the M&V obligations

Score: 8/9

The Australian Offshore Regime has comprehensive M&V requirements that cover baseline monitoring and M&V obligations during the operational phase. Post-closure M&V will be the responsibility of the Australian government after an assurance period of at least 15 years. There are no detailed M&V requirements for the post-closure phase.

Under the Australian Offshore Regime, a storage operator is required to submit a raft of detailed plans as part of the permit application, including a site plan,

[4] For the purposes of this report, CO2 is synonymous with "greenhouse gas substance" as defined in the Australian Offshore Regime.

monitoring plan and an environmental management plan (**EMP**). The effect of these requirements is that storage operators will be required to undertake baseline monitoring prior to injection commencing and then to monitor against the established baselines up until the site is handed to the Australian government under detailed site closure requirements. The monitoring required in the pre-closure phase is comprehensive and addresses the key risks of long-term storage of CO_2 in the sub-seabed. Once site closure has been achieved and the site handed back to the Australian government, it is the responsibility of the Australian government to monitor the site, at the cost of the operator.

When granting a permit the relevant Commonwealth Minister must be satisfied that the monitoring plan is sufficient to detect significant events, including leakage, in a timely manner to enable any necessary mitigation and remediation activities to be initiated. The plan must also include monitoring for effects on the petroleum industry and effects on other resources. The plan must be reviewed regularly and updated to account for any significant changes to the management operations on site or a change in operations that would affect the behaviour of CO_2 in the storage formation.

A detailed site plan and an EMP are also required. The site plan must demonstrate that the site is safe for CO_2 storage, how risks have been eliminated or reduced, that the potential effects on living and non-living resources in the ocean (e.g. petroleum, groundwater, fishing industry) will be as low as is practicable, and contains sufficient monitoring, recording and reporting on compliance with the plan. The site plan must also contain predictions for how the CO_2 plume will behave over time, the related modelling, risk assessment and remediation strategies and so on.

The requirements for the EMP are equally detailed and include demonstrating that the environmental impacts and risks of the CO_2 storage will be reduced to as low as reasonably practicable and the environmental impacts and risks will be of an acceptable level, providing for appropriate environmental performance outcomes, environmental performance standards and measurement criteria, together with an appropriate implementation strategy and monitoring, recording and reporting arrangements.

In addition to the reporting requirements as part of the various plans required, the Regime also has a series of reporting requirements for incidents, the frequency or timeframe of which depends on the severity of the incident or importance of the information for example, the reporting requirements for leakages are: leakage of stored CO_2 into the seabed (2 hours) or leakage from a bore of a well (24 hours). Full incident reports are also required. There are also various detailed data collection and storage obligations, including power for the Minister to require permit holders to collect and retain records data, cores, cuttings and samples.

Failure to meet any of these requirements is an offence.

A storage operator is able to hand over the site and long-term monitoring to the Australian government provided that it meets all of the requirements of the two-step closure regime set out in the legislation. Once injection has ceased, the permit holder must apply for a Site Closure Certificate. The grant of this certificate will depend on the risk profile of the site and include consideration of whether: the licensee has complied with all laws and conditions of the licence; the wells have been plugged or closed off; the stored CO_2 is behaving, and will continue to behave, as predicted; the licensee has reduced all risks to as low a level as is reasonably practicable; stored CO_2 will not present a risk to public health or the environment; and the licensee has met various requirements for the provision of reports and information

At least 15 years after the Site Closure Certificate is issued, the permit holder may apply for a declaration stating that the "Closure Assurance Period" has come to an end. The relevant Commonwealth Minister can make this declaration if satisfied that the stored CO_2 does not pose any significant risks, is behaving as predicted and no further injection has taken place. At this point, the Australian government takes over liability for the stored CO_2 and the long-term monitoring of the storage site. The permit holder is required to provide security for the total costs and expenses of carrying out the post-Closure Assurance Period monitoring program. The long-term monitoring carried out by the government will be based on the post-closure monitoring plan prepared by the operator as part of the closure process. However, the frequency and term of the monitoring will ultimately be determined by the government at the time.

(c) Comprehensiveness and range of enforcement mechanisms

Score: 9/9

The Australian Offshore Regime contains a wide range of enforcement tools and powers. This range allows the regulator to take a risk-based approach and use an enforcement tool appropriate to the situation. The range of penalties allows a penalty to be imposed that fits the seriousness of the offence and the extent of harm to the environment or human health and safety. Although there is a high degree of regulator discretion, the enforcement regime requires legal tests to be met before the discretion is exercised. This means that enforcement decision making will generally be based on scientific evidence.

For each obligation under the Australian Offshore Regime there is a corresponding offence. Generally, these are criminal offences of strict liability. Penalties range from approx. AUD$9000, with the most serious offences attracting imprisonment of up to 10 years and up to AUD$340,000 (and sometimes both). In some situations, permit-holder property can be forfeited and where directions are not complied with, the relevant Commonwealth Minister can carry out the required activities and recoup the costs of doing so from the permit holder.

The responsible Commonwealth Minister has wide-raging powers to deal with serious situations, such as an unintended release of CO_2, where the CO_2 plume is behaving other than expected or predicted, and where there are significant risks to the geotechnical integrity of the storage formation. This power extends to the ability to require injection to cease, either temporarily or permanently.

The Minister also has a general power to issue directions to a permit holder in respect of CO_2 storage activities and to make remedial directions to permit holders regarding: (a) removal of property; (b) plugging or closing off wells; (c) conservation and protection of natural resources; and (d) making good damage to the seabed or subsoil. It is an offence to fail to comply with such a direction and the Minister can do any of the things required to be done under any of these directions and recover costs.

The Australian government may carry out operations to monitor the behaviour of CO_2 stored in a geological formation. Inspectors have powers of access, inspection and entry for the purposes of ensuring compliance with the Australian Offshore Regime, in particular, to inspect and test any equipment, enter relevant facilities and enter a vessel or place where documents might be held. Warrants to enter residential properties can be obtained. It is an offence to obstruct or fail to assist an inspector.

In addition, there are wide powers of inspection in relation to monitoring compliance with relevant OHS laws and concerning any accident or dangerous occurrence at or near a facility. They have a range of powers including to issue notices to remove an immediate threat to health and safety and OHS improvement notice.

There is no applicable statute of limitations period for the majority of these offences and proceedings may be brought at any time.

(d) Clear allocation of roles and responsibilities for enforcement

Score: 2/3

The Australian Offshore Regime sets out the responsibilities for enforcement.

The Commonwealth Minister responsible for the Australian Offshore Regime has the vast majority of powers to take enforcement action. In practice, these powers are administered by the National Offshore Petroleum Titles Administrator (**NOPTA**) and the National Offshore Petroleum Safety and Environmental Management Authority (**NOPSEMA**). NOPTA is generally responsible for GHG titles (ie resource allocation) and NOPSEMA is responsible for day-to-day operations, OHS, environmental laws and well integrity. NOPSEMA or an OHS inspector can institute proceedings for an offence against OHS law. Other parties can make a request to NOPSEMA that proceedings be instituted.

Prosecution of criminal offences is generally undertaken by the Department of Public Prosecutions.

While the allocation of responsibilities is set out in the legislation, how these will be carried out by relevant departments and government agencies is less clear. Inquiries of the relevant agencies did not always result in clear and unambiguous advice being provided. However, given that there are so few CCS projects in Australia there appears to be little incentive or need for departments and agencies to devote any resources to this at this point in time.

5.3 Victorian Onshore Regime

TOTAL SCORE: 24.5/27

(a) Comprehensiveness of obligations

Score: 6/6

The Victorian Onshore Regime is comprehensive and its obligations and enforcement mechanisms address the key risks posed by underground storage of CO_2.[5] There is an offence for almost all obligations and the majority of offences are strict liability. The maximum penalty under the Act is currently approx. AUD$88,500, with most offences attracting a penalty of approx. AUD$36,000.

It is an offence to carry out injection and storage activities without the relevant approval. A raft of approved plans, including a monitoring injection plan and operations plan, must also be in place before relevant activities are carried out. A permit holder must ensure that CO_2 storage operations are carried out in a manner that does not interfere with the activities of any other person who is using the land to a greater extent than is necessary for the reasonable exercise of its rights, and the performance of its duties, under the authority.

Unlike the Australian Offshore Regime which includes a raft of requirements covering OHS and environmental protection, the Victorian Onshore Regime relies on existing, separate regulatory frameworks that cover these matters. With the exception of certain planning approvals, the requirements of these separate acts would need to be met by a storage operator to the extent that they apply to the storage activities. Environmental assessments are included in the Victorian Onshore Regime through a referral process under which approval applications must be referred to the Ministers responsible for relevant environmental and water legislation, and the Victorian Environment Protection Authority (**EPA**), for an assessment of whether the relevant activity will present a risk to the environment, with each having a right of veto if the activity will present a risk to the environment or the applicable plan does not adequately address risks to the environment. In addition, a CCS project may need approval under the *Environment Effects Act 1978* (Vic), although the underground storage aspect, of itself, may not trigger this requirement.[6]

(b) Comprehensiveness of the M&V obligations

Score: 8/9

The Victorian Onshore Regime has comprehensive M&V requirements that cover baseline monitoring and M&V obligations during the operational phase. Post-closure M&V will be the responsibility of the Victorian government after an

[5] For the purposes of this report, CO2 is synonymous with "greenhouse gas substance" as defined in the Victorian Onshore Regime
[6] The total footprint of a CCS project may trigger the approvals process under the *Environment Effects Act 1978* (Vic) and the need to prepare an environment effects statement (EES), the development of an individual component, such as a storage site, may not trigger the approvals process (AECOM, 2013).

assurance period of at least 15 years. There are no detailed M&V requirements for the post-closure phase.

Similar to the Australian Offshore Regime, the Victorian Onshore Regime requires a storage operator to submit a raft of detailed plans as part of the permit application. Together these plans effectively require the establishment of baselines prior to injection and then monitoring against the relevant baseline during the injection phase. In contrast to the more prescriptive requirements for plans under the Australian Offshore Regime, the Victorian Onshore Regime is less prescriptive and more outcomes based in nature. In addition, if the *Environmental Effects Act 1978* (Vic) applies, a pre-commencement EIA will be required.

A key document is the operations plan, which will include a detailed injection and monitoring plan together with an EMP. The injection and monitoring plan must be detailed but the exact level of detail and requirements for monitoring and verification will be established on a case-by-case basis for each storage formation and area, taking a risk-based approach. The injection and monitoring plan must also include a comprehensive risk management plan.

The EMP must describe the existing environment that may be affected by the storage activities as well as any cultural, historical, aesthetic, social, recreational, ecological, biological and economic aspects of the existing environment that may be affected, and then identify the particular relevant values and sensitivities of those aspects of the environment. In addition, the EMP must include a risk assessment of operations and unintended incidents and an implementation plan to ensure the identified environmental performance objectives and standards are met. Before it is approved, the injection and monitoring plan needs to be referred to the EPA and Ministers administering the *Environment Protection Act 1970* (Vic) (**EP Act**) and the *Water Act 1989* (Vic) (**Water Act**) to assess the risk to the environment and water resources. The plan may also be referred to an independent panel for consideration and recommendations.

In addition, comprehensive record keeping and general reporting requirements are included.

The Victorian Onshore Regime allows a storage operator to surrender an injection permit and close the storage site. The Victorian government then takes over ownership of the stored CO_2 and the long-term monitoring of the site, at the operator's cost. However, unlike the Australian Offshore Regime, there is no transfer of long-term liability to the Victorian government.[7] A permit can only be surrendered where the Minister is satisfied that all requirements of the permit and the Act have been met and wells have been plugged. Significantly, the Minister must also be satisfied that: (i) the stored CO_2 is behaving and will continue to behave in a predictable manner; (ii) the permit holder has reduced the risks associated with the stored CO_2 to as low as is reasonably practicable; and (iii) the stored CO_2 will not present a risk to public health or the environment. For the purposes of assessing whether the CO_2 stored will

[7] For a discussion of the history of the legislative provisions and why this is the case see Gibbs (2011).

present a risk to the environment, the Minister must refer the application for surrender to the EPA and Ministers administering the EP Act and the Water Act. The Minister may also appoint an independent panel.

The storage operator must also provide a variety of information, including geological information, verifiable estimates of the capacity of the formation, details of the CO_2 injected, assessment of the processes and pathways for CO_2 migration and leakage, an assessment of the potential effects on environment health and a risk management plan in the event of a leak to the environment. The long-term monitoring and verification plan must also be approved.

As with the Australian Offshore Regime, the long-term monitoring will be based on the long-term monitoring plan approved as part of the closure process, but ultimately the actual monitoring that takes place will depend on the Victorian government at the time.

(c) Comprehensiveness and range of enforcement mechanisms

Score: 8.5/9

The Victorian Onshore Regime provides a range of enforcement mechanisms that include Ministerial directions, the ability to cancel or suspend an injection permit, improvement and prohibition notices, and to take criminal action for offences against the Act. In general, failure to comply with obligations, including failing to comply with directions and notices is a criminal offence. For example, failing to comply with an improvement notice attracts a maximum penalty of approx. AUD$36,400, and for failing to comply with a prohibition notice approx. AUD$91,000, and a further approx. AUD$3,000 for each day the offence continues after the notice takes effect. Failure to comply with a Ministerial direction to address a serious situation attracts a maximum penalty of approx. AUD$88,500. There are no custodial penalties.

This range of mechanisms allows the regulator to use one that reflects the risk and seriousness of the non-compliance. The power to issue directions is wide ranging and can include a requirement to take all reasonable steps to ensure the stored CO_2 does not leak, to stop or suspend injection, to take specified activities for the purpose of eliminating, mitigating, managing or remedying a serious situation and to undertake rehabilitation (e.g. to make good any damage to the surface of the land). Although the breadth of the powers has been criticised as causing uncertainty for operators, from a regulatory perspective it provides a high degree of flexibility and responsiveness to context that will allow the regulator to implement a layered, risk-based approach to enforcement.

In each case, the decision to take enforcement action must be based on relevant data that evidences that the specific tests under the legislation have been met. For example, the Minister has power to cancel an injection permit in certain circumstances, including where the authority holder has not complied with a work plan or conditions, where an activity has caused a risk to public health or the environment, or causes a serious situation. In the case of a "serious situation", the regulator will require evidence that the definition of this term has been met, for example, that "the stored CO_2" has behaved otherwise than as predicted in the approved injection and monitoring plan". Clearly, scientific data will be required and any decision to act will be open to challenge in the courts if not based on clear evidence. A further discussion on this issue is provided in Chapter 6.

In addition, if the EPA is not satisfied that a permit holder is not complying with a M&V plan, the EPA can issue an improvement notice. If the EPA is not satisfied that a permit holder is not complying with a M&V plan and that failure creates an immediate risk of injury, serious property damage or significant environmental damage, EPA can issue an prohibition notice (relating to that monitoring plan). In emergencies, inspectors have powers to intervene where the inspector believes that there is an immediate risk a person may be injured, property may be seriously damaged or significant damage could occur to the environment.

In addition to these enforcement mechanisms, where there has been a breach of OHS or environmental legislation, enforcement mechanisms under those Acts could also be used.

(d) Clear allocation of roles and responsibilities for enforcement

Score: 2/3

The Minister responsible for the Victorian Onshore Regime has the primary role for enforcement with the exception of monitoring compliance with any monitoring and verification plan forming part of an injection testing plan or an injection and monitoring plan approved under the Act which is the responsibility of the EPA.

The Minister may authorise inspectors to carry out inspections for the purposes of the Act and the EPA may authorise a person to be an inspector for the purposes of monitoring compliance with any M&V plan forming part of an injection testing plan or an injection and monitoring plan approved under the Act.

The Minister can also seek advice from an independent panel on some matters.

5.4 Japanese Offshore Regime

TOTAL SCORE: 17/27

(a) Comprehensiveness of obligations

Score: 3.5/6

In Japan, the permitting provisions for underground storage of CO_2 are found in the Marine Pollution Protection Law and only cover offshore, sub-seabed storage. There are no provisions covering onshore geosequestration.

Under the Marine Pollution Protection Law, the provisions applicable to the sub-seabed storage of CO_2 are focussed on protecting the marine environment from any adverse impacts of sub-seabed storage activities and are not specifically aimed at promoting CCS as a low-carbon technology. This reflects the fact that the CCS provisions were enacted in 2007 in order to comply with Japan's international obligations to implement the amendment to Annex I of the London Protocol that included CO_2 streams as wastes or other matter that may be considered for ocean dumping. For example, an application for sub-seabed CO_2 storage is made to the Minister of the Environment and is assessed, largely, from an environmental perspective.

Two of the key matters of which the Minister of the Environment must be satisfied before a permit will be granted directly reflect the requirements under the London Protocol, namely: (a) the storage site and the method for the storage will not harm conservation of the marine environment at the storage site; and (b) there is no other appropriate disposal method available (for example, the CO_2 stream cannot be disposed of onshore). Having noted this, it is likely that criterion (a) can be used to ensure that the storage site is suitable to provide safe and secure storage and will allow the key risks of CO_2 storage to be addressed. However, the criteria for approving a permit under the Japanese Offshore Regime do not specifically address the human health impacts of relevant risks, noting that those relating to injection activities would likely be addressed under Japanese existing OHS laws.

Accordingly, while key risks are addressed, such as a requirement to obtain a permit to store CO_2 in the sub-seabed, not to pollute or harm the marine environment and the requirements to take corrective action to address an unintended release of CO_2, together with corresponding offences, the Japanese Offshore Regime is considered to be only moderately comprehensive in addressing the range of issues that may arise in the injection and long-term storage phases.

(b) Comprehensiveness of the M&V obligations

Score: 6/9

The Japanese Offshore Regime is comprehensive in its M&V requirements in respect of establishing a baseline and operational phase M&V obligations. However, it does not address long-term M&V obligations.

Under the Japanese Offshore Regime, permit applications must include an array of information and plans including an implementation plan, monitoring plan, and an environmental impact assessment report.[8]

Applicants must submit the following monitoring plans with a permit application:

- *Routine monitoring* - this plan must include monitoring for a range of factors such as the quantity of stored CO_2, CO_2 characterisation and injection data (pressure, velocity and temperature), as well as site

[8] The Ministry for the Environment has developed a range of supporting documentation including specific application forms under the Marine Pollution Protection Law and 2008 Guidelines on the permitting process and requirements (MOE) and the 2009 a guideline for the safe operation of CCS demonstration projects has been released (METI) which sets out safety and environmental standards for large-scale demonstration projects.

characteristics including geological characteristics, location and range of stored CO_2, chemical characteristics of the seawater overlying the storage site, marine life and ecosystems, and utilisation of marine life, environmental and resources (eg fishing grounds).

- *Precautionary monitoring* - this plan must cover monitoring to detect any CO_2 release as soon as it occurs. Monitoring is required to cover time dependent changes in pressure in the storage formation, the location and range of stored CO_2 and chemical characteristics of the overlying seawater.

- *Emergency monitoring* - this plan covers the monitoring required if accidental release actually occurs and must include time dependent changes in pressure in the storage formation, detailed conditions of the CO_2, the location and range of stored CO_2, chemical characteristics of the seawater overlying the storage site, impacts on marine life and ecosystems, together with social impacts (including impacts on fishing grounds).

Applicants will also need to undertake an evaluation of the pre-storage marine environment of the disposal area, which will act as a baseline assessment, together with the expected impacts of the disposal of CO_2 at the site. The baseline assessments must be detailed and cover:

- the seawater and seabed overlying the storage site including water quality and benthic sediment;

- marine life including plankton, fish, seaweed and coral and benthic species;

- marine ecosystems including vulnerable and important ecosystems and ecosystems around hot springs; and

- social factors including recreation, parks, fishing grounds, cables on seabeds and mineral exploration.

Under the Japanese Offshore Regime, where an unintended release occurs the permit holder is required to take corrective action. The permit holder must report immediately to the Ministry of the Environment (**MOE**) any results outside the permitted ranges for CO_2 migration or seawater/marine ecosystem impacts, together with remediation plans for remedy the situation. Regular monitoring is then required until results settle within the expected range.

Under the Japanese Offshore Regime, a permit is only valid for five years, at which point the permit holder must renew the permit in order to have the right to continue to store the injected CO_2 in the seabed. It is not clear what would happen if a renewal was not granted. There are no site closure provisions and the Japanese regulatory framework is yet to deal with the issue of long-term liability. This means that, in theory, the permit holder must continue to monitor the site indefinitely and creates a liability for the operator in perpetuity.

(c) Comprehensiveness and range of enforcement mechanisms

Score: 4.5/9

The Japanese Offshore Regime has a limited range of enforcement mechanisms that cover the key breaches that are likely to occur. The ability to issue business improvement orders provides some flexibility to address non-compliance in a manner proportionate to the risks involved. However, there are no specific powers to address serious situations, which presumably would be addressed using a business improvement order, and there is no definition of what would be considered to be a serious situation.

The Minister of the Environment has powers to issue "business improvement orders" and "suspension orders", revoke a permit, or impose a monetary penalty, when:

- activities are conducted contrary to the permit conditions;
- there is a breach of the Marine Pollution Prevention Law; or
- when a permit is obtained based on false information or by fraud.

The MOE has powers to conduct inspections for the purpose of implementing the Marine Pollution Protection Law and can require the permit holder to submit various reports.

Penalties include:

- unlawful disposal - a fine not exceeding ¥10 million;
- obtaining a permit based on false information or fraud - a fine not exceeding ¥10 million; and
- failing to report monitoring results - a fine not exceeding ¥0.5 million.

Because the Japanese Offshore Regime relies on the general provisions under the Marine Pollution Protection Law, it is likely that an evidence-based approach to enforcement would be employed. Further, the range of monitoring requirements discussed in the previous section, in particular the requirement for the monitoring plan to include emergency monitoring if an accidental release of CO_2 actually occurs, supports the argument that the MOE would only act on the basis of scientific evidence. However, given that the regime does not have specific enforcement mechanisms for serious situations, and there are a limited range of enforcement tools available, the Japanese Offshore Regime is not comprehensive in this regard.

(d) Clear allocation of roles and responsibilities for enforcement

Score: 3/3

The Minister of the Environment, through the MOE is responsible for granting permits and enforcing the Marine Pollution Protection Law (see previous section). MOE would be responsible for enforcement of all relevant plans submitted as part of the permit process, including all monitoring plans.

Both Minister of the Environment and the Commandant of the Japan Coast Guard have the authority to inspect facilities of permitted operators for the purpose of investigating compliance with permit conditions.

Recommendations

If CCS is to be deployed commercially and at scale in Japan's offshore waters, a closure regime and the long-term M&V obligations need to be developed. The Japanese Offshore Regime would also benefit from a greater range of enforcement mechanisms, including mechanisms specifically designed to address the potential for serious situations such as leaks and unexpected migration of the CO_2 plume and to ensure adverse impacts of unintended releases are avoided, remedied or mitigated. Further civil and criminal liabilities should also be considered. Greater clarity around when the regulator would act, and what would be required of a storage operator, perhaps in the form of guidelines, would also be beneficial.

5.5 Malaysia Offshore Regime

TOTAL SCORE: 12/27

(a) Comprehensiveness of obligations

Score: 3/6

There is no dedicated CCS legislation in Malaysia. The sub-seabed storage of CO_2 could be governed under current legal frameworks for offshore petroleum developments and environmental approvals.[9] However, amendments to these existing regimes will be required in order to provide comprehensive obligations that address all relevant risks for the sub-seabed storage of CO_2. In particular, standards would need to be adopted for storage site characterisation and selection, as well as for the M&V of stored CO_2 (Global CCS Institute, 2013).

Although CO_2 has not been prescribed as a toxic or hazardous waste, the *Environmental Quality Act 1974* (**EQA**) may apply to the extent that CO_2 associated with sub-seabed storage activities causes "pollution", for example if CO_2 sub-seabed storage is shown to have an adverse effect on a beneficial use (such as fishing or petroleum activities) or is considered to be hazardous or

[9] The Environmental Quality Act 1974 (EQA), Merchant Shipping Ordinance 1952 (MSO), Exclusive Economic Zone Act 1984 (EEZA), Merchant Shipping (Liability and Compensation for Oil and Bunker Oil Pollution) Act 1994 (MSOP) and the Continental Shelf Act 1966 (CSA) are the main Acts governing the protection of the environment and the prevention of oil spills and pollution in Malaysian waters and its exclusive economic zone (EEZ). The EEZA and the CSA also govern petroleum operations in Malaysia’s EEZ and continental shelf.

potentially hazardous to human health or the environment. In that case, a pollution licence would be required. A pollution licence has a term of one year, but can be renewed by making application within three months of expiry. Accordingly, amendment to the EQA would be required for a pollution licence to be an appropriate mechanism to regulate the long-term storage of CO_2. Ongoing management or monitoring requirements could be made a condition of such a licence.

The EQA includes an EIA process which could apply to the sub-seabed storage of CO_2, but this would need to be clarified.[10] Generally, "prescribed activities" that have significant impacts on the environment are required to comply with the two-stage process, which requires a preliminary EIA and a detailed EIA. The EIA must contain an assessment of the impacts of the activity on the environment and the proposed measures that will be undertaken to prevent, reduce or control the adverse impacts on the environment. It must also include an EMP. The EMP could include appropriate M&V obligations. Approval of the EIA and associated EMP by the Malaysian Department of the Environment (**DOE**) must be obtained before other required approvals can be progressed.

Malaysia has comprehensive OHS laws that would apply to injection activities.

(b) Comprehensiveness of the M&V obligations

Score: 3.5/9

There are no CCS-specific M&V requirements. Malaysia's EIA process could apply to projects involving the sub-seabed storage of CO_2 to effectively require operators to establish an environmental baseline and monitor against that baseline. The EMP would likely contain obligations that require ongoing monitoring of the storage site and CO_2 plume.

To the extent that the EQA licencing requirements apply to the sub-seabed storage of CO_2, the Director General of Environmental Quality (**Director General**) has the power to impose licence conditions requiring the licence holder to install and maintain monitoring equipment, conduct monitoring programs to provide the Director General with information concerning "the characteristics, quantity or effects of the emission, discharge or deposit in respect of which the licence is issued". The Director General can specify the frequency and manner of monitoring and reporting required in the licence conditions. In addition, the EQA provides that the occupier of a licensed premises is required to maintain all equipment and control equipment (which could include monitoring equipment) in an efficient condition and shall operate the equipment in a proper and efficient manner.

[10] The DOE has designated 19 categories of activities as Prescribed Activities for which an EIA is required, including several activities could be relevant to the underground storage of CO2. These include industry, infrastructure, mining, petroleum, power generation and transportation. The Global CCS Institute (2013) notes that the construction of an off-site storage facility for toxic and hazardous waste are prescribed for this purpose and it could be argued that given the large quantities involve in storage of CO2 a storage site could be classed as a storage facility for toxic and hazardous waste. However, query whether use of a sub-seabed reservoir amounts to "construction" of a facility, although the drilling of wells etc may be classed as construction.

If pollution licenses were to be used to regulate CO_2 sub-seabed storage, the licence would need to be renewed annually in order to have the right to continue to store the injected CO_2 in the seabed. It is not clear what would happen if a renewal was not granted. There are no site closure provisions and the Malaysian regulatory framework does not address long-term liability. This means that, in theory, a pollution licence holder would be required to monitor the site indefinitely. Malaysia's PETRONAS[11] has guidelines applicable to the abandonment and decommissioning of oil and gas wells that could apply to CO_2 injection wells (APEC, 2012).

Accordingly, the Malaysian Offshore Regime's M&V obligations are not comprehensive but there are some M&V requirements that would apply to the underground storage of CO_2.

(c) Comprehensiveness and range of enforcement mechanisms

Score: 4.5/9

Malaysia's environmental legislation provides a solid basis for an effective enforcement regime because it contains a range of suitable enforcement tools, offering a risk-based, layered approach. However, it is not comprehensive and is not CCS-specific.

The EQA includes a range of enforcement mechanisms which include civil and criminal penalties for non-compliance with its provisions. For example, both non-compliance with a pollution licence or its conditions and failure to comply with the EIA process are offences attracting a maximum fine of 10,000 Ringgit, or imprisonment for a period not exceeding two years, or both, together with a further fine of one thousand Ringgit for every day that the offence continues. The DOE can require an environmental audit to be undertaken to ensure compliance with any applicable EMP.

In addition, the Director General has the power to require the occupier of any premises to provide information about any equipment, control equipment or industrial plant on that premises, or as to any wastes discharged within such period as may be specified. The Director General or a duly authorised officer can enter any premises (whether prescribed or not) to examine and inspect, take samples, examine books, records and documents, take photographs and so forth.

Although the EQA does not have any laws specifically dealing with serious situations, there are a number of provisions in the EQA that could be used. For example:

- the EQA provides for recovery of compensation for loss or damage to property and recovery of government costs for remediating any damage to the environment;

[11] Petroliam Nasional Berhad (PETRONAS) was established in 1974 and is owned by the Malaysian government. It is the custodian for Malaysia's national oil and gas resources, and regulates the oil and gas industry.

- even where a pollution licence has been issued under the EQA, if the DOE is satisfied that a CO_2 plume is likely to cause an adverse impact on the environment such as to affect the health, welfare or safety of human beings, or to threaten the existence of any animals, birds, wildlife, fish or other aquatic life, the Department may issue a notice requiring the licensee to abate such emission, discharge or deposit as specified in the notice;
- the Minister of Natural Resources and Environment can direct the Director General to issue an order requiring a person to cease all acts that have resulted in the release of environmentally hazardous substances, pollutants or wastes;
- the Minister may also direct the Director General to effect and render any machinery, equipment, plant or process to be inoperable where there is a threat to the environment, public health or safety;
- the Director General has power to issue a notice to the owner or occupier of land requiring the owner or occupier of the land to take steps to reduce, mitigate, disperse, remove, eliminate, destroy or dispose of pollution at a time specified under the notice. A similar power exists in respect of discharges to air, which could apply to a leak of CO_2 from an underground storage site.

(d) Clear allocation of roles and responsibilities for enforcement

Score: 1/3

Given the lack of CCS-specific legislation in Malaysia, there is no clarity around which regulatory agency would be responsible for regulating and enforcing sub-seabed storage of CO_2. Further, the Global CCS Institute's "Malaysian CCS Legal and Regulatory Workshop" in 2013 concluded that it was unclear who the potential regulatory candidates would be but noted that in the offshore environment PETRONAS would likely be the regulator, with appropriate checks and balances in place in the event that PETRONAS was itself the storage operator (Global CCS Institute, 2013).

In terms of the enforcement of any applicable obligations under the EQA, the Minister Natural Resources and Environment and the Director General have enforcement responsibilities. The Ministry of Domestic Trade, Co-operatives and Consumerism is responsible for overseeing the safety of the petroleum sector would likely oversee the OHS issues relating to the underground storage of CO_2, but this would need to be clarified.

Recommendations

If CCS is to be deployed commercially and at scale in Malaysia's offshore waters, a permitting regime for underground storage of CO_2 needs to be developed. In addition, relevant standards should be developed, including for M&V both during the injection and post-injection phase. Malaysia has some suitable enforcement mechanisms in its environmental legislation but these need to be expanded and adapted to address specifically the potential for serious situations such as leaks and unexpected migration of the CO_2 plume. Greater clarity around roles and responsibilities is required, together with guidance on how regulator discretions would be exercised in the event of a serious situation.

5.6 Chinese Onshore Regime

Total Score: 9/27

(a) Comprehensiveness of obligations

Score: 2/9

There is no dedicated CCS legislation in China. There are laws, including those applicable to the oil and gas sector, which could be adapted for demonstration projects, but if China is to move to wide-scale deployment or larger scale projects, then it is likely that CCS-specific laws will be required (ADB(a), 2015). The three major gaps that would need to be addressed are: (1) lack of technical and management standards; (2) lack of efficient policies for information disclosure and public engagement; and (3) financial barriers and lack of efficient economic incentivising policies to cover the commerciality gap (ADB(a), 2015). In terms of effective enforcement, the first of these will be crucial. Appropriate technical performance standards for CCS, including safety and environmental standards, are the necessary basis for an effective enforcement regime that ensures the secure and safe storage of CO_2 underground.

In general, a CCS project would require project approval from several government agencies including the National Development and Reform Commission and the Ministry of Land and Natural Resources. While China does have environmental impact assessment (**EIA**) requirements for major projects, it would need to be applied in the context of CCS to provide a suitable framework for assessing the risks of underground CO_2 storage. As part of the EIA process, an operator would be required to provide evidence of its mitigation and remediation systems and would be under an obligation to implement these. As part of these existing licensing frameworks for natural resource exploitation (oil and gas) and land use there would be the ability to impose conditions to address relevant risks of underground storage of CO_2.

China has a range of environmental laws that may apply. However, CO_2 is not designated as a "pollutant" for the purposes of requiring a licence to pollute under relevant laws. In addition, China has a range OHS laws that would apply. Numerous additional laws and regulations regarding oil, gas and chemical handling could also apply.

(b) Comprehensiveness of the M&V obligations

Score: 3/9

There are no CCS-specific M&V requirements, and as noted in the previous section, one of the fundamental areas that will need to be developed is the technical and management standards to apply to CCS. Specific monitoring requirements to address the risks of long-term storage of CO_2 will need to be developed.[12]

Environmental monitoring is likely to be required under China's EIA process which involves the submission and approval of an EMP for approved projects. Monitoring, verification and reporting may also be imposed as conditions of relevant permit approval processes. This will effectively require operators to establish an environmental baseline before any injection commences and to monitor impacts against the baseline in accordance with the approved EMP.

There are no CCS-specific closure or long-term monitoring requirements, other than which might be included in an EMP. Mining legislation, which could potentially apply, requires a mine closure report which includes information on operations, risks and environmental protection to be submitted when closing a mine.

(c) Comprehensiveness and range of enforcement mechanisms

Score: 3/9

Without the development of CCS-specific laws, enforcement will depend on the variety of other laws that will be applicable.

Legislation such as the Law of the People's Republic of China on Environmental Protection, the Law of the People's Republic of China on Prevention and Control of Water Pollution and the State Council Opinion on Managing Water Resources, and the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution (Order of the President No. 32) may apply to control the impacts of any leakage of CO_2 from a storage site, depending on the circumstances. These laws include financial penalties, which are often limited. Commentators report that it is almost always cheaper for companies to pollute and pay any fine, noting that such laws are not always enforced (Kelley, 2011).

The Chinese legal system has a variety of enforcement tools available, ranging from administrative tools such as the issuing of warnings in cases of lighter violations to suspension or termination of licences and fines if prescribed standards are not met. Other mechanisms include the seizure and transfer of property, the withdrawal of sites and the mandatory dismantling or shutdown of illegal constructions. Some violations may attract criminal sanctions of up to 10 years imprisonment. Non-criminal offences may also be dealt with by measures such as detention and re-education, and the confiscation of illegal income (Beyer, 2006; Kelley, 2011).

Under the Environmental Protection Law, a polluter is liable for the elimination and control of pollution. The range of enforcement tools available would enable relevant administrators to require the polluter to bring pollution under control

[12] See Li et al (2016) for a list of all CCS current projects in China and the monitoring techniques being used. While there is industry experience of monitoring for both hazardous wastes and radioactive pollution storage, they will provide limited guidance (Seligsohn et al, 2010).

within a specified timeframe. However, at this point in time CO_2 is not characterised as a "pollutant" and so it is unclear whether these enforcement mechanisms could be used in respect of any leak of stored CO_2 or other serious situation.

There has been much criticism of the enforcement of laws in China. It appears that enforcement of environmental laws in particular, is largely ineffective. There are a range of reasons for this including that Chinese laws do not always contain clear obligations with laws reading more like policy statements or ideals, key terms are not always defined and there are overlaps and gaps in China's environmental laws (Beyer, 2006; Kelley, 2011; Mu et al, 2014). In addition, mediation, rather than litigation, of disputes is favoured (Kelley, 2011). Academic journals have historically reported widespread local protectionism where enforcement authorities were often major shareholders of polluting enterprises creating inherent conflicts of interest (Beyer, 2006; Kelley, 2011), although recent reforms may have improved this (Mu et al, 2014).

In February 2016, China's Environmental Protection Minister, Mr. Chen Jining, acknowledged China's problems with "local protectionism and local interference with environmental monitoring, supervision and enforcement", describing interference from some local governments as a "serious problem" (Jining, 2016). The Minister referred to efforts in 2015 by the Chinese government to improve the enforcement of environmental laws, including increased numbers of environmental inspections, suspensions of project approvals for serious environmental breaches, supervision of the handling of law suits in an open manner, levying of fines for environmental breaches, administrative violation orders issued (with 2015 total penalties an increase of 34% over 2014 total penalties) and the number of violation cases made public. The Minister indicated that ongoing efforts would be made by the Chinese government to build on these improvements and endeavour to make compliance "the new normal". In addition, in relation to emergency measures on pollution matters, the Minister indicated that the Government will take "evidence-based, targeted and effective measures".

In addition, economic incentives for achieving environmental protection targets have been introduced, reportedly to good effect (Beyer, 2006). Heads of local governments and enterprises are held responsible for meeting certain environmental targets, and are rewarded with monetary grants, bonuses and awards, together with advantageous publicity of the high-achieving bureau or enterprise, for achieving targets. Failure to achieve targets can result in fines and often leads to criticism affecting personal careers.

China's Tort Liability Law provides avenues for individuals to enforce environmental laws, and which may apply to any loss or damage caused by the underground storage of CO_2. Remedies include cessation of infringement, removal of obstruction, elimination of danger, return of property, restoration to the original status, compensation for losses, apology, elimination of consequences, and restoration of reputation (Kelley, 2011).

(d) Clear allocation of roles and responsibilities for enforcement

Score: 1/3

A variety of government bodies would be involved in the enforcement of CCS activities in China, reflecting the range of laws that may apply. Roles and responsibilities would require clarification to avoid uncertainty and overlap.

Historically, effective enforcement of environmental laws has been undermined by technical and organisational shortcomings including overlapping responsibilities and lack of authority (Beyer, 2006). In particular, the national environmental agency, the Ministry of Environmental Protection, is reported to have limited resources and as a result, enforcement is left to local Environment Protection Bureaus. However, Environment Protection Bureaus are also understaffed and lack authority (Beyer, 2006; Kelley, 2011). Again, recent reforms may have improved this situation (Mu et. al. 2014; Jining, 2016). In addition, the Minister of Water Resources and Ministry of Land and Natural Resources will have a role enforcing respective laws with respect to regulating and monitoring surface, groundwater, and subsurface impacts. China's State Administration of Work Safety is the primary agency responsible for enforcing OHS regulations.

The Minister for Environmental Protection has acknowledged the problem of lack of resources and poor coordination among departments and has spoken of efforts being made to better coordinate administrative and criminal enforcement of environmental laws (Jining, 2016). He said:

> *… the Fifth Plenary Session of 18th CPC Central Committee decreed the implementation of a vertical accountability system for the monitoring, supervision and law enforcement agencies below provincial level. This is a significant reform aimed at fixing our existing fragmented accountabilities and establishing systemic and effective environmental monitoring. The local governments usually focus on economic development while ignoring environmental protection, and intervene in the monitoring, supervision and law enforcement, which leads to laws that are flouted and violators that go unpunished. I believe this vertical accountability system will help solve those problems.*

The Minister also referred the government's goal to strengthen the development of local monitoring and law enforcement teams.

Recommendations

If CCS is to be deployed commercially and at scale in China, a permitting regime for underground storage of CO_2 needs to be developed. In addition, relevant standards should be developed, including for M&V both during the injection and post-injection phase. Existing enforcement mechanisms should be either adapted to apply to the underground storage of CO_2 or new CCS-specific mechanisms developed. In particular, an enforcement mechanism to address the potential for serious situations such as leaks and unexpected migration of the CO_2 plume should be introduced. Greater clarity around roles and responsibilities is required, together with guidance on how regulator discretions would be exercised in the event of a serious situation. In addition, it appears likely that a shift in the attitude to enforcement and compliance will be required if the Chinese Onshore Regime is to operate effectively.

6. Monitoring and effective enforcement: some unresolved issues

6.1 Overview

Adequate and appropriate requirements for M&V of CO_2 stored underground will play a crucial role in an effective enforcement regime. Without access to adequate data, regulators will be unable to assess effectively the risk of non-compliance or a serious situation, and will be unable to base enforcement decision-making on credible and robust scientific evidence. As experience with underground storage of CO_2 has increased over recent years, issues around M&V have arisen as operators seek to meet existing regulatory requirements. These issues include the type and extent of M&V that will enable operators to demonstrate compliance with legislation and how regulators will apply the various legal tests in relevant legislation.

In order to better understand some of these concerns, I facilitated a M&V workshop as part of the Fellowship research. The workshop examined two scenarios, both focussed on "serious situations" under Australian underground storage legislation: the first, where there has been a leak of CO_2, and the second, where a CO_2 plume is not behaving as predicted. This examination raised related issues including the requirements for establishing a baseline against which to monitor a CO_2 storage site, regulator powers to act in serious situations, and the advantages and disadvantages of the well-developed, detailed Australian regimes in terms of early-mover project compliance. All of these issues were debated at the workshop.

This Chapter presents the results of the workshop discussions and further explores these issues with reference to relevant literature.

6.2 The monitoring workshop

The M&V workshop, held on 28 April 2016, provided a forum for an open discussion between Australian regulators, CCS technical experts and lawyers on issues relating to monitoring and enforcement of the legal and regulatory requirements for the underground storage of CO_2.

Prior to the workshop, my discussions within the broader CCS community had indicated a high level of concern about the ability of operators to meet the detailed M&V requirements found in the Australian regulatory frameworks. Concerns ranged from issues about the ability of technology to detect leaks or risks of leaks accurately and reliably, what regulators might require operators to do if a leak was detected, to how to meet legal tests set out in the legislation and how to achieve full compliance with detailed regulatory requirements. Many of the concerns focussed on being able to achieve full compliance with legal technicalities that may not relate to matters of substance or actual risks. These matters were seen by many as being particularly important from an industry perspective.

Accordingly, the workshop aimed to examine the following questions:

- With current technology, what can we monitor for and for what purpose? What are the limitations?

- How can a CO_2 plume be monitored? What are the limitations?
- What does it mean to say the CO_2 plume is "behaving as expected/predicted"?
- What is a leak, and if a leak is detected, what should/can the proponent be required to do to deal with the situation?
- How does what we can monitor for match up with legal requirements?

The workshop was attended by experts from the Cooperative Research Centre for Greenhouse Gas Technologies (**CO2CRC**), CSIRO, the CarbonNet project, the National Offshore Petroleum Titles Administrator (**NOPTA**), the National Offshore Petroleum Safety and Environmental Management Authority (**NOPSEMA**), the Commonwealth Department of Industry, Innovation and Science, the Victorian Government, the Victorian Environment Protection Authority (**EPA**), and the Institute. In order to facilitate an open forum discussion, the workshop was run under the Chatham House Rule.[13]

Workshop participants worked through two scenarios: one under the Victorian Onshore Regime (the *Greenhouse Gas Geological Sequestration Act 2009* (Vic) (**Victorian Act**)) and a second under the Australian Offshore Regime (the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) (**Commonwealth Act**)).

6.3 What is a serious situation?

The first scenario raised the question of when a "serious situation"[14] under the Victorian Act could be said to have occurred. If a serious situation occurs, the regulator can give directions requiring the holder of the injection licence to undertake a range of actions including to stop or suspend injection of CO_2 and to undertake activities specified in the direction for the purposes of eliminating, mitigating, managing or remedying the serious situation. It is a very wide discretion indeed.

Two of the situations that fall within the definition of a "serious situation" were discussed in detail, being where:

- CO_2 that has been injected into an underground geological storage formation has leaked or will leak; and
- CO_2 injected into an underground geological storage formation has behaved otherwise than as predicted in the approved injection and monitoring plan (**Approved Plan**).

Under Commonwealth Act, there is a similar power in relation to serious situations, which is defined in a similar manner.

[13] The Chatham House Rules allows participants of a meeting to report on what was said at the meeting, but neither the identity nor the affiliation of the speaker(s) may be revealed. See more at: https://www.chathamhouse.org/about/chatham-house-rule?gclid=CjwKEAjwu6a5BRC53sW0w9677RcSJABoFn4sGnfvRuUl0esZCdv-lvfm9CTsyFRiSq9bFJyjfth14hoCFZvw_wcB#sthash.hpfvvLPd.dpuf
[14] Full text of the definition of "serious situation" under the Victorian and Commonwealth Acts is provided in Annexure B.

6.4 Serious situations - what is a "leak"?

At one level, the question of what is a "leak" of CO_2 would seem to be a relatively easy question to answer. But consider the following:

- Where must the leak be detected?
  - If CO_2 is detected outside the area modelled and approved in the Approved Plan or outside the area licensed in the relevant approval, but still underground and poses no other risk, is it a leak?
  - Does the CO_2 need to escape to the atmosphere or to the surface of the seabed before it is a leak? Or would it be, for example, that CO_2 escapes beyond the layer of cap-rock that seals the approved storage site but is otherwise still underground? What about if CO_2 migrates into groundwater?
- How can it be proved that CO_2 is emanating from the storage site and not from elsewhere, or just part of the natural variability of CO_2 in that area?
- How much CO_2 must be detected? Is one molecule of CO_2 enough? If not, what is enough to be a leak?

The term "leak" is not defined in the Victorian Act. The Macquarie Dictionary defines a "leak" (verb) as:

> *to let a liquid, gas, etc., enter or escape, as through an unintended hole, crack, permeable material, or the like.*

Clearly, the movement or escape of the relevant substance must be *unintended*. Applying this definition, a leak of CO_2 could be said to have occurred when there is an unintended movement or escape of CO_2 from the approved storage site to another area which has not been approved. On this logic, it does not necessarily follow that for a "leak" to have occurred, that there must be an escape to the atmosphere, or in the case of sub-seabed storage, into the marine environment.

As a comparison, the definitions used in the IEA's *Carbon Capture and Storage Model Regulatory Framework*, a leak only refers to an escape on CO_2 into the atmosphere (IEA, 2010). In contrast, "unintended migration" is used to refer to unintended movements of the CO_2 plume outside of a storage site. If it is intended that only leaks to the atmosphere are to be covered by the term "leak" in the Victorian (or Commonwealth) Act, then this needs to be clarified.

Possible enforcement action for a serious situation under the Victorian Act includes:

- the Minister can issue a direction to the injection permit holder - this discretion is very wide and includes the ability to require the permit holder to undertake the activities specified in the direction for the purposes of eliminating, mitigating, managing or remedying the situation, to take or refrain from undertaking any action specified and to stop or suspend injection, amongst others. It is an offence to fail to comply with a direction; and

- the Minister may cancel the injection permit if any activity carried out under the permit has caused a serious situation.

Accordingly, the potential implications of a serious situation can be severe.

With these possible implications in mind, workshop participants discussed the circumstances that they believed *should* be classified as a "leak" for the purposes of enforcement action.

(a) The leak has to matter

At the workshop, it was argued that evidence of an escape of an amount of CO_2 alone should not be sufficient to amount to a "serious situation" under the legislation. Taking a risk-based approach, the escape or migration of CO_2 has to *matter*, that is, it must have an adverse impact on a sensitive receptor, or constitute a more than minor increase in the risk of such an adverse impact, before it should be a "leak". For example, is the CO_2 plume moving towards usable or environmentally significant groundwater or petroleum reserves? Alternatively, is the movement near a well or other leakage pathway? One comment at the workshop was that the regulator should view the behaviour of the CO_2 not by reference to its physical behaviour or movement, but by the *impact* that it has on the surrounding environment.

It is interesting to note that this type of approach is common in environmental regulation. In the context of determining whether pollution or contamination has occurred, a common definition in environmental legislation provides that the concentration of the relevant substance must be above the concentration normally present at that location ***and*** that the presence of the substance at that level presents a risk of harm to human health or any other aspect of the environment.

Further, the common law includes a principle known as *de minimis non curat lex*, or "the law does not concern itself with trifles". It is a common law defence to prosecution on the basis that the breach is so trivial or has such a minimal consequence that it should not be punished. In this respect it is noted that the IEA's *Carbon Capture and Storage Model Regulatory Framework* (EIA 2010) refers to "significant" leakages in a number of its model provisions. In particular, the obligations relating to corrective measures and remediation apply where there is a "*significant* leakage, unintended migration or other irregularity" (Model text 6.8.2, emphasis added).

However, the definition of "serious situation" under the Victorian Act in this respect does not include a requirement that the leak also pose a risk to human health or the environment. Nor does it require that the leak must be non-trivial or even significant. A regulator taking a risk-based approach to enforcement would consider this in deciding whether or not to take enforcement action and the type of enforcement action to take. However, this approach is not assured under the strict wording of the Victorian Act and it is this uncertainty that seemed to be at the heart of concerns around this issue. Taking this approach, if the unintended escape or movement of CO_2 was trivial or did not change the risk profile of the stored CO_2, then arguably it should not be considered to be a leak.

These types of issues are dealt with in many other areas of environmental enforcement. Comparative research in this area is likely to provide useful insights for CCS enforcement approaches and may indicate that legislative amendment is needed to introduce an appropriate definition of "leak" in the Commonwealth and Victorian Acts.

In the context of sub-seabed storage, there is current research being undertaken into the properties of CO_2 hydrate barrier layers which can act as a seal for CO_2 escapes (Sekiya, 2016; Sato, 2016). Research has shown that CO_2 exists in stable form as a gas hydrate with an icy structure under conditions of high pressure and low temperature present at certain depths below the seabed. Essentially, supercritical CO_2 which has escaped from an approved storage site (for example, through a cap-rock layer) will be trapped within the hydrate stability zone before it reaches the seabed, provided the pressure and temperature conditions are present. This means that the CO_2 will not continue to rise to the seabed surface and will not enter the marine environment.

In such a situation, which could occur in the Australian Offshore context under the Commonwealth Act (which has a similar test for a serious situation in relation to a leak as that contained in the Victorian Act and discussed above), there is no harm to human health or the marine environment. However, under the Commonwealth Act, this situation would likely be a "leak" and fall within the definition of a serious situation.

One factor not explored at the workshop at depth was the impact of a leak on the integrity of any emissions trading scheme or other market mechanism that might apply in the future and the need to account for carbon emissions under such a scheme. One participant mentioned that if an emissions trading scheme was in place, perhaps more attention would be given to M&V in order account for emissions, and the dollars attached. This sentiment is echoed in the IEA's *Carbon Capture and Storage Model Regulatory Framework* which notes that third party verification of monitoring results will be fundamental to support the integrity of any market-based scheme (IEA, 2010). However, the requirement to account (and pay) for unintended releases from storage sites could easily be dealt with separately, with serious situations being confined to those that 'matter' for the purposes of enforcement and potential offences against the relevant legislation.

In this context, a further, related concept that has been explored is that of "no detectable leakage". This term is used in the EU Directive in relation to closure of storage sites. In order to transfer responsibility for the storage site post-closure, an operator is required to demonstrate there is no detectable leakage from the storage site, amongst other things. The 6th IEA International CCS Regulatory Network Meeting, for example, found this term "problematic to define", particularly given the natural variability of CO_2 levels in soil, air and oceans, and the technological limits of monitoring (IEA, 2014). CO2CARE (2013) has focussed on this term in the context of closure requirements and noted that, "[a]ll leakage monitoring systems have a finite (and site-specific) CO_2 detection capability". It has argued that this term should be interpreted in the context of whether a site is meeting its emission reduction objective rather than as an absolute test, referring to a number of studies that have suggested that leakage rates of around 0.001% per year or less would ensure effective emission reduction performance. It recommends that regulators use the term "no detectable leakage" in the context of where a site is performing effectively in terms of emissions reductions, rather than for enforcement purposes.

Recommendations

- There is a need for greater clarification around the definition of a "leak" and when any resulting enforcement provisions could be invoked. Neither the Australian Offshore Regime nor the Victorian Onshore Regime includes a definition of the term "leak". Therefore, courts would look to the ordinary meaning of the word which does not include any consideration of the impact of the leak nor any requirement that the leak be of any particular magnitude or significance, noting however, that the courts may apply the *de minimis non curat lex* rule.

- I recommend that further research is undertaken on how best to define the term "leak". Reference should be made to analogous terms such as "pollution" and "contamination" in environmental law texts which require that the level of the relevant substance is higher than background levels *and* that this higher level presents a risk to human health or the environment, and to the IEA's *Carbon Capture and Storage Model Regulatory Framework* (2010) which requires that leaks be "significant" before relevant enforcement provisions apply.

- Consideration should be given to the inclusion of a definition of the term "leak" in the Victorian and Commonwealth Acts. This should include consideration of the inclusion of a requirement of "significance" and/or the addition of a requirement for human health or environmental impact. If "leak" is only intended to apply to an unintended release to the surface (that is, the atmosphere for onshore regimes and the marine environment for offshore regimes) this should be clarified.

(b) Establishing a baseline

The workshop participants explored the issue of how to determine when levels of CO_2 at a relevant monitoring location demonstrate that there is a "leak". The importance of establishing an environmental baseline was highlighted. Examples were provided where monitoring results indicating potential high levels of CO_2 could be explained by reference to baseline data showing that the results were within the range of natural variability, that is, ruling out false positives.

One example raised was that of soil gas monitoring where background monitoring over several years had revealed a high degree of variability due to natural drought cycles. This baseline data had enabled soil gas monitoring results to be explained as being within the natural variability of background levels rather then indicating a leak. However, if a shorter period of baseline monitoring had been undertaken, this option may not have been available until further data had been obtained.

The example of an appropriate baseline for seismicity at storage sites was also raised with the comment that the kind of baseline monitoring timeframes usually required will be very short in a geological context and that the longer the period of monitoring, the more likely seismic events will be detected. Thus, longer baseline monitoring periods may be advantageous.

The advantages of establishing a comprehensive baseline in order to have the capacity to demonstrate the range of natural variability must be balanced against the increase in costs and the potential to cause unacceptable delays to commencement of projects. Both of these factors could be barriers to deployment of CCS. Difficulties in establishing an appropriate baseline were also discussed, including the appropriate scope or parameters for the baseline monitoring.

These issues have been recognised by others in the field. Blackford et. al. (2015) stress that detailed baselines are essential to reduce the potential for false positive and false negative results and argue that the acquisition of baseline data more generally should be a high priority if CCS is to be progressed. They recommend:

> *As individual storage sites are not independent of their wider environmental setting, in regions where multiple storage operations are planned, a regionally conceived, potentially international baseline survey approach could either save costs and/or improve baseline quality.*

Blackford et. al. (2015) have developed a matrix of techniques and parameters for baseline monitoring in the offshore environment. This includes monitoring techniques such as active and passive acoustic monitoring, geochemical monitoring, biological monitoring and remote sensing, together with the temporal and spatial sampling intervals required.

Establishing an appropriate baseline is also crucial in proving causation. In most enforcement cases, it will be necessary to prove that an alleged offender has *caused* the relevant emission or discharge. In CCS enforcement, once it is established that there are higher than normal levels of CO_2, the regulator will need to prove that those higher than normal levels of CO_2 are as a result of CO_2 coming from the storage site. At the workshop, it was noted that because CO_2 is everywhere, it can be very difficult to prove that CO_2 is from a particular location. Comment was made at the workshop that if CO_2 is found three kilometers underground, for example, and the storage site is located at approximately the same level below the surface, then unless there is another plausible source, the CO_2 is probably from the storage site. However, if CO_2 is detected on the surface (onshore), then it may be very difficult to provide that it came from the storage site.

In the context of monitoring in the offshore environment, Blackford et. al (2015) recommend a multivariate, hierarchical approach, with monitoring for:

- detection of anomalies;
- attribution (i.e. to determine the source);
- quantification of leakage; and
- impact on the marine environment.

They argue that the greatest resources should be allocated to the monitoring type higher in the hierarchy. They suggest that given the large areas likely to require monitoring in the offshore environment, "a primary survey strategy to detect anomalies followed by more in depth surveys to confirm, attribute and assess impact for potential leakage is likely to be cost effective".

At the workshop, there was a suggestion that monitoring for CO_2 on the surface may be the wrong place to monitor if the purpose of monitoring is early detection of "leaks". Indeed there was a view that onshore, surface monitoring is not undertaken for detection of leaks at all, but rather for public assurance purposes.

Recommendation

- Greater clarity about the timeframes, scope and parameters for the monitoring required to establish a baseline should be developed. The tension between the benefits of a lengthy pre-commencement monitoring program to understand natural diurnal, seasonal, annual and other longer-term CO_2 variations on the one hand, and the costs and potential delays in project commencement on the other hand, should be recognised. Further, the requirements should be outcomes-based, rather than prescriptive.
- Consideration should be given to whether guidelines could be developed to assist both storage operators and regulators.
- Consideration should be given to the establishment of regional baselines in areas where multiple storage sites could be established, either through the collation of existing baseline data that includes processes that impact on the natural variability of CO_2 or new surveys, or both.

6.5 Serious situations - when is CO_2 behaving as predicted?

The question of what it means to say that a CO_2 plume is, or is not, behaving as predicted by the modelling contained in an Approved Plan led to much discussion at the workshop. Several key points emerged.

First, much will depend on the Approved Plan (which will contain the modelling). A draft Plan is required to be submitted as part of the injection permit approval process and this document will be generated by the storage proponent. The draft Plan should cater for appropriate levels of uncertainty and the workshop participants thought that the regulator should approve an envelope of parameters, or a range of acceptable impacts, which would be set out in the Approved Plan. The Approved Plan should represent best practice at the time, but much will depend on the geological context and the receptors relevant to the storage site. The IEA's *Carbon Capture and Storage Model Regulatory Framework* acknowledges this and the model rules provide that the relevant plans must be prepared and approved based on the specifics of each site (see for example Model text 6.3.2, 6.5.2 and 6.7.2: IEA, 2010).

Second, it is anticipated that the Approved Plan will be a living document that will, over the course of injection, be refined, updated and the modelling improved, as monitoring results are obtained and analysed. The process of refining the Approved Plan and its modelling should be risk-based, taking into account the significance of any potential impacts. Workshop participants stressed that there would need to be dialog between the licence holder and the regulator. Indeed, most accepted that there may be a need for industry players to educate regulators on at least some of the aspects of the Approved Plan.

There was support for the view that the behaviour of the plume needs to be assessed not solely at a physical level, for example, where the focus is on whether the current area of the plume is exactly the same as what was predicted in the modelling (particularly the initial modelling). The more important question, according to workshop participants, will be whether the impacts of the plume behaviour are consistent with what was approved in the Approved Plan. As with the question of "has there been a leak?", the filter of "does it matter?" should be applied. For example, even if the physical extent or location of the plume is not exactly as initially predicted, does it indicate that the risk profile has increased significantly from that predicted in the Approved Plan?

It must be stressed that this refining of the modelling and the Approved Plan over time is not a process to allow the operator to change, retrospectively, the Approved Plan to fit what is now happening at the storage site without reference to the risks posed by the plume movement. Any changes to the Approved Plan will need to be approved by the regulator. This point is acknowledged in the IEA's *Carbon Capture and Storage Model Regulatory Framework* which recognises the validation of modelled predictions of CO_2 plume behaviour by comparison with actual observations as part of best practice CO_2 storage management (IEA, 2010). The calibration of the model and re-casting of predictions of CO_2 behaviour, also known as "history-matching", is reflected in the IEA's model rules, which place an *obligation* on the operator to continue to refine and update the initial site model developed from the site characterisation process to reflect ongoing monitoring results and other operational data (Model text 6.5.2).

This is also reflected in the Australian Offshore Regime's requirement that site plans must be reviewed at least every five years and plume migration modelling updated having regard to experience gained about the modelling, the conduct of operations, and the observed behaviour of the plume.[15] The review must also include consideration of whether revisions are required due to the evolution of industry best practice. Further, an injection licence holder commits an offence if a revised site plan is not submitted to the regulator for approval where the technical knowledge relied on to formulate matters in the site plan, including plume migration paths and predictions for the behaviour of

[15] Offshore Petroleum and Greenhouse Gas Storage (Greenhouse Gas Injection and Storage) Regulations 2011 (Cth).

injected CO_2, becomes outdated to the extent that the site plan no longer contains the best available analysis of those matters.

A further key point acknowledged at the workshop was that one of the crucial objectives of this kind of iterative process is to develop modelling that can be used to achieve site closure. Provided that a risk-based approach is applied to the iterative process, the monitoring data obtained during the injection phase can be used to develop a model with high reliability and strong predictive power that can be used to achieve site closure and relied on in the post-closure monitoring period (see also IEA, 2010; IEA, 2014; WRI 2008). The site closure processes under both the Victorian and Commonwealth Acts require the operator to demonstrate, among other things, that the CO_2 plume is behaving as expected and to provide a long-term monitoring program for the site. Accordingly, the modelling of the plume behaviour will be crucial to site closure and to the transfer of long-term liability to the government, where available.

In this context, CO2CARE (2013) recommends that regulators should set conformance criteria at "realistic levels, focussing on progressive reduction of uncertainly with time and demonstration that the fundamental site-specific storage processes are understood". It warns against a purely technical approach, and recommends that operators and regulators agree in advance on the specific conditions under which deviations from predicted behaviour will trigger corrective measures, based on site-specific knowledge.

Another point raised, although not debated at length, was where the plume has moved beyond the area predicted in the Approved Plan (and, therefore, beyond the area approved under the relevant injection permit) but where this does not result in a higher risk profile for the site at a practical level. In other words, the answer to the "does it matter?" test for this scenario is "no". This would be a technical non-compliance with the Victorian or Commonwealth Acts because CO_2 would be stored in an area that does not have a relevant permit in place.

The obvious solution would be to request an amendment to the Approved Plan and the permit boundary. However, this may not be possible where the plume has migrated from, say, an area governed by the Australian Offshore Regime, that is Commonwealth offshore waters, to a contiguous area within Victorian coastal waters[16] which is governed by the Victorian *Offshore Petroleum and Greenhouse Gas Storage Act 2010* (Vic). This is a realistic scenario in the Bass Strait where suitable storage sites have been identified that cross the jurisdictional boundary between Commonwealth and Victorian (State) offshore areas. In these areas, CO_2 injected into the storage site within the Commonwealth offshore area is predicted to migrate northwards towards the coast and pass under Victorian coastal waters, and in some case, then to areas governed by the Victorian Onshore Regime (Gibbs, 2011). Because different governments have power to grant injection permits in the different areas, it is not possible for the Commonwealth Minister to grant a permit that extends over into Victorian coastal waters. This is an area that will need to be addressed in the future, most likely by appropriate administrative arrangements between the relevant government departments (Ibid). Certainly in terms of the approach to enforcement, this would need to be taken into account.

[16] That is, the area of water between the territorial sea baseline (commonly the low tide mark) and a line three nautical miles seaward of the territorial sea baseline.

Recommendations

- There should be a flexible and iterative process to allow the history-matching of models and actual plume monitoring results over the injection phase of projects, so that a robust model is achieved by the time of site closure.

- The regulatory regime should require the regulator to take a risk-based approach to this iterative process and the approval of changes to plume models and relevant injection and monitoring plans. It should also require the regulator to take a risk-based approach to any relevant enforcement action by requiring that technical breaches are not the subject of enforcement action but only where the unexpected behaviour also poses a significant risk (or significantly increased risk) to human health or the environment.

- In the Victorian Onshore Regime, consideration should be given to placing a requirement on the storage operator to update the Approved Plan throughout the injection phase to account for actual M&V data.

- Further, consideration should be given to a requirement that the regulator interpret "behaving as predicted" in the Approved Plan in light of best practice management of underground CO_2, including an iterative process for updating and history-matching the Approved Plan.

6.6 What can be done to address a serious situation?

Those at the workshop with technical expertise appeared confident that if a serious situation did occur appropriate measures could be taken to remedy the situation. Exactly what would be required would, of course, depend on the situation and the geological context of the site. The powers under the Victorian and Commonwealth Acts are very wide and would likely cover the range of remedial actions required to remedy a serious situation.

As a general rule, a CO_2 plume will travel upwards until it reaches an impervious cap-rock and will move away from a pressure source. Accordingly, remedial actions include:

- capping the plume in some way to stop it rising;

- removing the pressure source - for example, ceasing injection;

- creating another pressure source - for example, water injection to push back the plume; and

- adding a reagent (although this was questioned - it may be a technical possibility but it seemed unclear whether this was a practical option and it is likely to be extremely expensive).

It was pointed out that there are known risk scenarios or weak points for leaks. For example, the area around the injection well, if not constructed correctly, can provide a pathway between underground strata and, ultimately, to the surface. If a leak or movement of the plume not predicted occurs near a well, this issue can often be addressed by requiring the operator to fix the well. Well integrity issues are not uncommon in the oil and gas industry and there is existing expertise in well remediation techniques which could be used for CO_2 injection wells.

It was acknowledged that there is no precedent for the breach of a cap-rock layer (see also IEA, 2010). However, ceasing injection of CO_2 will remove the pressure source that would be forcing the plume upwards and some workshop members felt this would be sufficient to address the issue in many cases. Further, is extremely unlikely that there would ever be a massive eruption of CO_2 from an underground storage site. If a leak were to occur, it would more likely be a slow escape of small amounts of CO_2, and would likely be detected and dealt with before the CO_2 even reached the surface (Reisinger, 2009; Victorian Government, 2016).

In this respect, the IEA's *Carbon Capture and Storage Model Regulatory Framework* (IEA, 2010) provides the following suggested remediation techniques (in part based on the work of the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)):

Table 2: Potential leakage pathways and remedial measures

Potential leakage pathways	Remedial measures
CO_2 escapes from storage formation through a 'gap' in cap-rock into higher aquifer	Remove CO_2 and inject elsewhere
CO_2 gas pressure exceeds capillary pressure and passes through siltstone (upper layer of earth)	Extract and purify groundwater
Injected CO_2 migrates up dip, increases reservoir pressure and permeability of fault	Lower injection rates or pressures
CO_2 escapes via poorly plugged old abandoned well	Re-plug well with cement, well repair
Natural flow design of CO_2 dissolves CO_2 at CO_2/water interface and transports it out of closure	Intercept and re-inject CO_2
Dissolved CO_2 escapes to atmosphere or ocean	Intercept and re-inject CO_2

The practicality of removing injected CO_2 and re-injecting it elsewhere, suggested in Table 2, was discussed at the workshop. While possible, technical experts considered that this was not a practical solution because the CO_2 would have undergone mixing and/or chemical reactions after being injected.

Accordingly, the general conclusion of the workshop discussion was that the Victorian and Commonwealth Acts contain sufficient powers to deal with serious situations and that from a risk perspective, the technology is available to deal with such situations without causing any significant risk to human health or the environment.

6.7 Are the Minister's powers too wide?

The workshop participants discussed industry concern that the powers to issue such wide-ranging directions available under the Victorian and Commonwealth Acts, including in serious situations and other instances (for example as part of the site closure process under the Commonwealth Act), are too wide particularly considering that a direction can require an operator to cease injection. Some of the implications of this occurring were also discussed, such as the operator being permitted to vent CO_2 to the atmosphere if other storage sites were not readily available. With this option, and any leak, there would be a need to account for the emission in national greenhouse gas emissions accounts and if an emission trading scheme was in place, under such a scheme.

There was also discussion about whether the risk profile that this creates for an operator will be a barrier to development of the industry. However, it was acknowledged that storage proponents do need to be open to accepting a reasonable level of risk. It was also argued that the flexibility that this gives the regulator is crucial in enabling it to be responsive to a wide range of situations, changing circumstances, community expectations and improved technology. Taking a risk-based approach, the direction can be adapted to the risk posed by the serious situation.

7. Regulation or early mover projects: which comes first?

7.1 The tension between flexibility and certainty

As I reflect on the Fellowship research, one of the most pervasive themes has been the tension that exists between the desire for flexibility and certainty in CCS legal and regulatory frameworks. This tension permeated discussions at the various fora I attended as part of the Fellowship and is reflected in commentary on CCS regimes. Both regulators and industry argue for one or the other attribute at different times and in different contexts.

Industry, particularly when emerging, needs flexibility to allow for innovations and improvements in technologies, as well as for a 'learning phase'. Regulators need flexibility too, to respond appropriately to a range of situations and risk levels, and also to allow for innovations in technologies as well as their own learning phase. Flexibility is also needed because each storage site and its surrounding environment will be different. Generally, CO_2 plume behaviour will be known prior to injection. However, the exact behaviour of the plume will depend on the particular characteristics encountered underground, not all of which can be known before injection commences.

But certainty is equally important. Storage operators and investors need to know in advance what will be required to meet the relevant regulatory requirements. A clear project pathway, right through to site closure, is necessary to fully inform investment decisions. Certainty is also important to ensure that the legal and regulatory framework is enforced consistently and reasonably, and to ensure that all operators are on a level playing field. Regulators need clear legal tests to ensure that they have a solid foundation for the lawful exercise of powers and discretions, particularly when taking enforcement action. Further, certainty is required for the public to have confidence that public health and the environment are protected from any potential adverse effects of CO_2 storage activities.

7.2 Comprehensive regulation or early mover projects: which comes first?

This theme of flexibility and certainty also underlies a further question debated at the Melbourne M&V workshop and which was also discussed at the APAC CCUS Legal and Regulatory Forum in Tokyo. Which should come first, a comprehensive regulatory regime or demonstration projects? Is it is better to establish a full CCS regulatory framework and then start to carry out projects, including demonstration projects? Or is it better to undertake demonstration projects and use the lessons learned from these to inform the development of the regulatory framework.

At the Melbourne M&V workshop, where the vast majority (if not all) participants support measures that will promote CCS, there seemed to be a preference for the Victorian Onshore Regime's outcomes-based approach, over the Australian Offshore Regime's approach. The Australian Offshore Regime was seen as overly prescriptive. There was also an acknowledgement that while the Australian regimes provided a framework for the underground storage of CO_2 to progress, they may have been developed too early. The prescriptive nature of the Australian Offshore Regime, in particular, was seen as being a barrier to development of the industry due to the difficulties that early movers will face in meeting all requirements when the industry is still in a learning phase.

The issue of whether a lack of a fully developed regulatory regime would be a barrier to deployment of CCS, given the lack of regulatory uncertainty and therefore regulatory risk that this would throw up for project proponents was discussed. While this was acknowledged, some felt that project proponents would consider the risk of not being able to fully comply with a comprehensive regulatory regime as being greater than the risks of the uncertainty of an incomplete regulatory regime.

In other fora, including the Tokyo workshop, this tension between flexibility and certainty has been acknowledged. At the 6th IEA International CCS Regulatory Network Meeting, for example, participants concluded that one of the key challenges facing the development of CCS legal and regulatory regimes is (IEA, 2014):

> *… providing policy and regulatory certainty to investors and project proponents while retaining the necessary degree of flexibility in the regulatory regime. Governments must strike a balance between giving regulators the necessary flexibility, while ensuring projects have a clear view of the permitting pathway and reporting requirements.*

Several participants at the Melbourne M&V workshop favoured development of the industry by using project-specific legislation, as with the Western Australian Gorgon Project.[17] It was noted that various other major infrastructure projects, such as transport projects, are progressed under project-specific legislation. Workshop participants also stressed that project-specific legislation does not obviate the need to comply with environmental impact assessment processes and other relevant legislation, but provides certainty for significant projects to progress and allows government to address specific risk issues that may be an impediment to the project.

There were also some strong views expressed about the wisdom of transferring extremely high levels of risk to project proponents when the activity of CCS, or at least the storage aspect of it, is essentially a public good with no applicable market. It was felt by some that the public, through the government retaining a higher level of risk, should pay for this form of carbon emissions reductions. Of course, this view is always met with the counterview that the regulatory framework needs to maintain a balance so that project proponents have sufficient incentives to utilise best practice site selection and responsible operations and management practices.

7.3 A balance and a social licence to operate

A balance must be struck. As a lawyer, perhaps my disposition is to favour certainty and well-developed legal and regulatory frameworks. This approach has the advantage that rigorous requirements must be met before projects proceed, thereby ensuring public health and the environment are protected. But I do accept that without undertaking CCS, we will not gain the necessary experience and that our ability to develop and improve the technology will be severely limited. The lack of a fully developed regime should not necessarily deter deployment of demonstration and early mover projects, particularly if governments are willing to sponsor projects either through

[17] The *Barrow Island Act 2003* (WA).

project-specific legislation or financial incentives such as the transfer of long term liability (Gibbs, 2016). In my view, the Japanese Offshore Regime, for example, is sufficiently developed to provide a solid foundation for development of early mover projects.

In many situations, the balance that is struck is determined by the social licence to operate that exists for a particular project or technology. Certainly the mood at the Melbourne M&V workshop indicated that most believe that the social licence to operate for CCS does not yet exist, or if it exists, at best it is very weak. The public at large do not have a good knowledge about the technical ability to sequester CO_2. Nor do the vast majority of people understand that the risk of unintended releases of sequestered CO_2 is low, and that the potential impacts of any release are much lower than many industries we currently accept as being 'necessary' to our way of life today (such as the oil and gas industry) and certainty less than other technologies being suggested to address climate change (such as nuclear energy). A well-funded, broad-based public campaign would be required to disseminate these messages more widely, and therefore would require political will. But political will so often depends on public support, creating a 'catch 22'.

The work of the Institute is invaluable in overcoming this 'catch 22'. I trust that this report, and the Fellowship more generally, has contributed to authoritative knowledge sharing on CCS issues.

8. Recommendations

8.1 Australian Offshore and Victorian Onshore Regimes

(a) What is a leak?

There is a need for greater clarification around the definition of a "leak" and when any resulting enforcement provisions could be invoked.

Neither the Australian Offshore Regime nor the Victorian Onshore Regime includes a definition of the term "leak". Therefore, courts would look to the ordinary meaning of the word which does not include any consideration of the impact of the leak nor any requirement that the leak be of any particular magnitude or significance, noting however, that the courts may apply the *de minimis non curat lex* rule.

I recommend that further research is undertaken on how best to define the term "leak". Reference should be made to analogous terms such as "pollution" and "contamination" in environmental law texts which require that the level of the relevant substance is higher than background levels *and* that this higher level presents a risk to human health or the environment, and to the IEA's *Carbon Capture and Storage Model Regulatory Framework* (2010) which requires that leaks be "significant" before relevant enforcement provisions apply.

Consideration should be given to the inclusion of a definition of the term "leak" in the Victorian and Commonwealth Acts. This should include consideration of the inclusion of a requirement of "significance" and/or the addition of a requirement for human health or environmental impact. If "leak" is only intended to apply to an unintended release to the surface (that is, the atmosphere for onshore regimes and the marine environment for offshore regimes) this should be clarified.

(b) Establishing a monitoring baseline

Greater clarity about the timeframes, scope and parameters for the monitoring required to establish a baseline should be developed. The tension between the benefits of a lengthy pre-commencement monitoring program to understand natural diurnal, seasonal, annual and other longer-term CO_2 variations on the one hand, and the costs and potential delays in project commencement on the other hand, should be recognised. Further, the requirements should be outcomes-based, rather than prescriptive.

Consideration should be given to whether guidelines could be developed to assist both storage operators and regulators.

Consideration should be given to the establishment of regional baselines in areas where multiple storage sites could be established, either through the collation of existing baseline data that includes processes that impact on the natural variability of CO_2 or new surveys, or both.

(c) When is a CO_2 plume "behaving as expected"?

There should be a flexible and iterative process to allow the history-matching of models and actual plume monitoring results over the injection phase of projects so that a robust model is achieved by the time of site closure.

The regulatory regime should require the regulator to take a risk-based approach to this iterative process and the approval of changes to plume models and relevant injection and monitoring plans. It should also require the regulator to take a risk-based approach to any relevant enforcement action by requiring that technical breaches are not the subject of enforcement action but only where the unexpected behaviour also poses a significant risk (or significantly increased risk) to human health or the environment.

In the Victorian Onshore Regime, I recommend that consideration be given to placing a requirement on the storage operator to update the Approved Plan throughout the injection phase to account for actual M&V data.

Further, consideration should be given to a requirement that the regulator interpret "behaving as predicted" in the Approved Plan in light of best practice management of underground CO_2, including an iterative process for updating and history-matching the Approved Plan.

8.2 Japanese Offshore Regime

While the Japanese Offshore Regime provides a solid basis for demonstration and early mover projects, if CCS is to be deployed commercially and at scale in Japan's offshore waters, a closure regime needs to be developed. The detailed and appropriate operational phase M&V provisions could be easily adapted for the post-closure phase. The Japanese Offshore Regime would also benefit from a greater range of enforcement mechanisms to supplement those already in place under the Marine Protection Law. I recommend that enforcement mechanisms specifically designed to address the potential for serious situations, such as leaks and unexpected migration of the CO_2 plume, are introduced to ensure adverse impacts of unintended releases are avoided, remedied or mitigated. Further civil and criminal liabilities should also be considered. Greater clarity around when the regulator would act, and what would be required of a storage operator, perhaps in the form of guidelines, would also be beneficial.

8.3 Malaysian Offshore Regime

If CCS is to be deployed commercially and at scale in Malaysia's offshore waters, a permitting regime for underground storage of CO_2 needs to be developed. In addition, relevant standards should be developed, including for M&V both during the injection and post-injection phase. Malaysia has suitable enforcement mechanisms in its environmental legislation which should be used as a basis for developing CCS-specific enforcement mechanisms. I recommend that enforcement mechanisms specifically designed to address the potential for serious situations, such as leaks and unexpected migration of the CO_2 plume, are developed to ensure adverse impacts of unintended releases are avoided, remedied or mitigated. Greater clarity around roles and responsibilities is required, together with guidance on how regulator discretions would be exercised in the event of a serious situation.

8.4 Chinese Onshore Regime

If CCS is to be deployed commercially and at scale in China, a permitting regime for underground storage of CO_2 needs to be developed. In addition, relevant standards should be developed, including for M&V both during the injection and post-injection phase. Existing enforcement mechanisms should be either adapted to apply to the underground storage of CO_2 or new CCS-specific mechanisms developed. In particular, an enforcement mechanism to address the potential for serious situations such as leaks and unexpected migration of the CO_2 plume should be introduced. Greater clarity around roles and responsibilities is required, together with guidance on how regulator discretions would be exercised in the event of a serious situation. In addition, it appears likely that a shift in the attitude to enforcement and compliance will be required if the Chinese Onshore Regime is to operate effectively.

9. Glossary

Abbreviation	Defined term
Approved Plan	Approved monitoring and injection plan
CCS	Carbon, capture and storage
CO_2	Carbon dioxide
CO2CRC	Cooperative Research Centre for Greenhouse Gas Technologies
Director General	Director General of the Environmental Quality, Malaysia
DOE	Malaysian Department of Environment
EIA	Environmental impact assessment
EMP	Environmental management plan
EP Act	*Environment Protection Act 1970* (Vic)
EPA	Victorian Environment Protection Authority
EQA	*Environmental Quality Act 1974*, Malaysia
Institute	Global CCS Institute
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
M&V	Monitoring and verification
MOE	Japanese Ministry of Environment
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority, Australia
NOPTA	National Offshore Petroleum Titles Administrator, Australia
OHS	Occupational health and safety

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Appendix A: Case study scores

Criterion	Australian Offshore Regime	Victorian Onshore Regime	Japanese Offshore Regime	Malaysian Offshore Regime	Chinese Onshore Regime
The comprehensiveness of the obligations contained in the legal and regulatory framework for the underground storage of CO_2					
• The comprehensiveness of the obligations	3	3	1.5	1	1
• The extent to which the obligations address the key risks	3	3	2	2	1
The comprehensiveness and nature of the monitoring and verification (M&V) requirements					
• The extent to which baseline monitoring is required	3	3	3	2	2
• The extent of M&V obligations during the injection phase	3	3	3	1.5	1
• The extent of M&V obligations post-injection phase	2	2	0	0	0
The nature of enforcement mechanisms available					

Criterion	Australian Offshore Regime	Victorian Onshore Regime	Japanese Offshore Regime	Malaysian Offshore Regime	Chinese Onshore Regime
• The extent to which the enforcement mechanisms are risk-based, layered and flexible	3	2.5	2	2	2
• The extent to which the enforcement mechanisms are grounded in science and fact-based decision-making	3	3	1.5	1	0
• The extent of mechanisms to deal with serious situations	3	3	1	1.5	1
The extent to which there is a clear allocation of roles and responsibilities for enforcement					
• The extent to which there is a clear allocation of roles and responsibilities for enforcement	2	2	3	1	1
TOTAL SCORE	**25**	**24.5**	**17**	**12**	**9**

Annexure B: Serious situation definitions

Victorian Onshore Regime

Section 6 of the *Greenhouse Gas Geological Sequestration Act 2009* (Vic):

6 Meaning of serious situation

A serious situation exists in relation to an underground geological storage formation if:

(a) a greenhouse gas substance that has been injected into an underground geological storage formation has leaked or will leak; or

(b) a greenhouse gas substance has leaked or will leak in the course of being injected into an underground geological storage formation; or

(c) a greenhouse gas substance injected into an underground geological storage formation has behaved or will behave otherwise than as predicted in the approved injecting testing plan or the approved injection and monitoring plan applying to that underground geological storage formation; or

(d) the injection or storage of a greenhouse gas substance into an underground geological storage formation has had or will have a significant impact on the geotechnical integrity of the whole or a part of a geological formation or geological structure; or

(e) the underground geological storage formation is not suitable for the permanent storage of a greenhouse gas substance as set out in the approved injection and monitoring plan.

Australian Offshore Regime

Section 379 of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth):

379 Serious situation

(1) For the purposes of this Act, a ***serious situation*** exists in relation to an identified greenhouse gas storage formation specified in a greenhouse gas injection licence if:

(a) a greenhouse gas substance injected into the identified greenhouse gas storage formation:

(i) has leaked; or

(ii) is leaking;

from the identified greenhouse gas storage formation; or

(b) there is a significant risk that a greenhouse gas substance injected into the identified greenhouse gas storage formation will leak from the identified greenhouse gas storage formation; or

(c) a greenhouse gas substance:

(i) has leaked; or

(ii) is leaking;

in the course of being injected into the identified greenhouse gas storage formation; or

(d) there is a significant risk that a greenhouse gas substance will leak in the course of being injected into the identified greenhouse gas storage formation; or

(e) a greenhouse gas substance injected into the identified greenhouse gas storage formation:

(i) has behaved; or

(ii) is behaving;

otherwise than as predicted in Part A of the approved site plan for the identified greenhouse gas storage formation; or

(f) there is a significant risk that a greenhouse gas substance injected into the identified greenhouse gas storage formation will behave otherwise than as predicted in Part A of the approved site plan for the identified greenhouse gas storage formation; or

(g) either:

(i) the injection of a greenhouse gas substance into the identified greenhouse gas storage formation; or

(ii) the storage of a greenhouse gas substance in the identified greenhouse gas storage formation;

has had, or is having, a significant adverse impact on the geotechnical integrity of the whole or a part of a geological formation or geological structure; or

(h) there is a significant risk that:

(i) the injection of a greenhouse gas substance into the identified greenhouse gas storage formation; or

(ii) the storage of a greenhouse gas substance in an identified greenhouse gas storage formation;

will have a significant adverse impact on the geotechnical integrity of the whole or a part of a geological formation or geological structure; or

(i) the identified greenhouse gas storage formation is not suitable (with or without engineering enhancements) for the permanent storage of the relevant amount of the relevant greenhouse gas substance injected at the relevant point or points over the relevant period.

(2) For the purposes of paragraph (1)(i):

(a) the ***relevant amount*** is the total amount of greenhouse gas substance authorised to be injected into the identified greenhouse gas storage formation under the licence; and

(b) the ***relevant greenhouse gas substance*** is the kind of greenhouse gas substance that is authorised to be injected into the identified greenhouse gas storage formation under the licence; and

(c) the ***relevant point or points*** is the potential greenhouse gas injection site or sites at which the greenhouse gas substance is authorised to be injected into the identified greenhouse gas storage formation under the licence; and

(d) the ***relevant period*** is the period during which the greenhouse gas substance is authorised to be injected into the identified greenhouse gas storage formation under the licence.