Best Practice in Transitioning from CO_2 EOR to CO_2 Storage

Report for CCP4 Policies and Incentives Working Group

30 March 2016

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The CO_2 Capture Project Phase 4

Best Practice in Transitioning from CO_2 EOR to CO_2 Storage

Final Report for CCP4 Policies and Incentives Working Group

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For and on behalf of
Environmental Resources Management

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Position:	Partner
Date:	30 March 2016

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EXECUTIVE SUMMARY

The purpose of Carbon Capture and Storage (CCS) is to reduce emissions of greenhouse gases to the atmosphere as a climate change mitigation activity. However, given the relatively high costs currently associated with CCS, coupling CCS with Enhanced Oil Recovery (EOR) could provide a critical financial incentive to facilitate development of CCS projects in the near term.

EOR projects are primarily implemented to increase oil and gas production (tertiary recovery) with any long term storage of CO_2 a potential ancillary benefit. When projects are designed as CCS from the start, there is typically a site evaluation process to review the storage formation according to best practice criteria for CCS.

CO_2 EOR regulations were not written to cover long-term underground storage of CO_2 as a CCS project. In oil and gas producing countries, there will be a body of laws, policies, rules and regulations for hydrocarbon extraction including EOR activities. The legal/regulatory framework governing EOR anticipates that CO_2 injection will end and producing wells will be decommissioned, plugged and abandoned after CO_2 EOR has ceased. Typically, EOR regulations do not account for what happens to the injected CO_2 after EOR activities have ceased.

An EOR project seeking to be treated as a CCS project presents a special case which must satisfy both oil and gas production rules and the rules for CCS storage sites. Regulations that govern CCS projects typically assume that the project was designed for the purpose of CCS from the beginning on the basis of site selection criteria that emphasize permanence in underground CO_2 retention. Since the underground reservoir in an EOR project is pre-determined by the location of the existing oil and gas producing formation – i.e., not selected from the beginning for CO_2 storage purposes – then a separate process will likely be required to evaluate the oil and gas reservoir undergoing EOR to determine its viability for long-term underground storage of CO_2 under CCS rules and regulations.

EOR operators who focus on the commercial benefit of EOR and not on any additional environmental benefit, have their own concerns over any new legal requirements that they perceive could impose cost or impede their ability to continue to grow their EOR portfolios in line with traditional oil and gas activities. In order to encourage EOR, any proposed changes to policy and legal frameworks in relation to transitioning to CO_2 storage should take these concerns into account, provide clear legal guidance addressing uncertainties, and recommend cost-effective solutions.

Thus, the key question addressed in this report is:

> *'How should best practices and regulatory frameworks for CCS project site evaluation and monitoring be taken into account in cases where the underground pore space has been pre-determined as an existing oil and gas reservoir where CO_2 will be or is being injected for purposes of CO_2 EOR?'*

CHALLENGES FOR TRANSITIONING CO_2 EOR TO CCS

Most of the CO_2 injected into the reservoir for EOR remains permanently trapped under ground. It is this characteristic of EOR operations which makes them potential candidates for CCS project designation. Also, CO_2 costs are offset by revenues generated from the sale of recovered hydrocarbons. This is especially beneficial when comparing against the higher cost of standalone CCS projects that do not have an associated revenue stream.

As a basis for understanding the key practical challenges for a transition, it is helpful to identify the main fundamental differences between CO_2 EOR and CCS projects, as set out below:

Table E1 Fundamental Differences between CO_2/ EOR and CCS Projects

Aspect	*CO_2 EOR*	*CCS*
Purpose	Increase oil and gas production efficiency (tertiary recovery) to optimise the hydrocarbon-bearing reservoir.	Reduce greenhouse gases (GHG) emissions to the atmosphere in support of climate change mitigation activities/obligations.
CO_2 Lifecycle	Captured from a natural or anthropogenic source, transported, injected into the hydrocarbon-bearing formation and recycled through a closed circuit process [(1)].	Captured from an anthropogenic source, transported and injected into the depleted hydrocarbon formation for safe and permanent sequestration.
Primary Regulatory Framework	Oil and gas or petroleum legislation.	Ranges between: • CCS/GHG storage-specific legislation; • Mining and mineral Legislation; • General environmental management/ impact assessment legislation.
Competent Authority	Oil & Gas or Energy Regulator	Oil and gas or energy regulator; mineral resources regulatory; and/or environmental management regulator.

Site Evaluation, Integrity and Monitoring

CO_2 EOR projects are not required to investigate the structure of the oil and gas producing fields in which they operate to the same extent required by CCS site evaluation rules because the oil and gas producing formation was not originally developed for the stated purpose of CCS.

As such, CO_2 EOR operations wishing to transition to CCS are not likely to have undertaken the technical analysis and site evaluation called for in a built-

(1) Consensus on the incidental retention rate of the injected CO_2 ranges from 50-60% sequestration to 99%. See further *n.24* in '*Bridging the Gap: An Analysis and Comparison of Legal and Regulatory Frameworks for CO_2–EOR and CO_2–CCS*', Global CCS Institute (October 2013).

for-purpose CCS project. Therefore, claiming credit for the CO_2 which has been stored underground from CO_2 EOR presents a special case.

The appropriateness of a potential CO_2 storage site needs to be carefully assessed in order to ensure safe and permanent storage of CO_2. This is determined primarily by three principal requirements:

- ***Capacity*** - whether there is sufficient storage volume and whether it can be accessed;
- ***Injectivity*** - whether suitable reservoir properties exist for sustained injection of CO_2 at economical industrial supply rates; and
- ***Integrity*** - whether the site is secure with negligible risk of unintended migration or leakage.

Given that depleted oil and gas fields are considered promising storage site options for CCS, capacity and injectivity are unlikely to be an issue in the transition from CO_2 EOR to CCS.

Integrity, on the other hand, could be a challenge given the need to ensure permanent storage of CO_2 in order to achieve climate change mitigation aims. Although the original geological traps that allowed the hydrocarbon to accumulate in the first place are still there, CO_2 EOR activities result in the drilling of numerous injection wells across an oil field in order to enhance production. Therefore, '*injection wells and abandoned wells have been identified as one of the most probable leakage pathways for CO_2 storage projects*'[(1)].

(1) Intergovernmental Panel on Climate Change (IPCC) Special Report (IPCC, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B.,O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp.); 2015 p 244.

A key element related to the long-term nature of CCS projects is monitoring. The long-term monitoring of CO_2 storage sites required by CCS regulations go beyond the post-closure and decommissioning requirements for CO_2 EOR projects. CO_2 EOR/CCS projects will need to ensure that appropriately robust monitoring regimes are in place to detect leakage, to account for losses in the projects over all emissions inventory and to ensure that measures are put in place to stop leaks when detected. Maintaining well integrity is important throughout the well's life cycle, from drilling to plugging and abandonment.

An issue that could affect well integrity is the potential impact of acidic fluids migration. While the acidic fluids migration issue is still being researched, the uncertainties, potential future regulatory changes, and risk context should be considered when addressing the transition from CO_2 EOR to CCS.

Any CO_2 EOR project seeking to transition to a CCS project will have to address the long-term monitoring requirements for CCS storage sites.

Pore Space Issues Likely to Arise in CO_2 EOR Transition to CCS

A CO_2 EOR project ends when oil production ceases, the production facilities are decommissioned, wells are plugged and abandoned and the lease to produce oil from that field is terminated. Any CO_2 EOR operation seeking to transition to a CCS project and receive credit for long-term underground storage of CO_2 as a GHG mitigation activity will likely need to address issues regarding the use of the pore space for CO_2 storage purposes beyond decommissioning of oil production.

The challenges associated with pore space ownership in a CO_2 EOR project are not insurmountable barriers to claiming credit for long-term underground storage of CO_2 from EOR. But the success of a CO_2 EOR project transitioning to a CCS project will likely require addressing these issues in the broader context of a clear, legal framework and possibly including engagement with the pore space owner to assess and deal with concerns.

Post-Closure Liability and CO_2 Ownership

Given the nature of CCS projects and the long term need to remove CO_2 permanently from the atmosphere, the issue of liability and ownership of CO_2 over time is important in ensuring that effective measures are put in place to ensure the efficacy of the projects. Liability issues arise with respect to any impacts that might occur to persons or property from operation of a CO_2 underground storage facility and in the worst (but highly unlikely) case of catastrophic release of CO_2 from the site.

Aspects which have been considered by government authorities in the context of a liability framework for CCS include:

- Management of leakage and permanence
- Stewardship of the storage site
- Costs and financial provision(s)

GHG emissions accounting considerations

For a CO_2 EOR/CCS project, the GHG emissions during the production stage of the project have added complexity due to the nature of the EOR operations. In CO_2 EOR operations, a minority fraction of the injected CO_2 becomes miscible with the oil and will eventually be recovered in production wells when the oil is produced – sometimes referred to as 'break through' of CO_2.

The process of recovering, separating, recompressing, and reinjecting the CO_2 in an EOR operation is often referred to as 'CO_2 recycle'. Because there are energy requirements and potential losses of CO_2 during the CO_2 recycle process, the GHG emissions associated with CO_2 EOR/CCS need to account for the energy use and fugitive emissions inherent in the operation.

A number of GHG accounting guidelines addressing CCS and specifically, CCS with EOR, have been published in the last several years. Most of these guidelines do address accounting for emissions associated with CO_2 EOR, especially in the recycle phase of production. The *IPCC Guidelines for National GHG Inventories* (2006) address the geological storage of CO_2 within emission inventories. CCS projects have requirements to assess the potential for CO_2 to be emitted via leakage pathways, as follows:

- Properly and thoroughly characterize the geology of the storage site and surrounding strata;
- Model the injection of CO_2 into the storage reservoir and the future behavior of the storage system;
- Monitor the storage system; and
- Use the results of the monitoring to validate and/or update the models of the storage system.

LEGAL AND REGULATORY REVIEW AND GAPS ANALYSIS

Over the course of the past 40 years, the application of CO_2 EOR has proven to be an effective technology for the purposes of maximising the oil-bearing reservoir output and incidentally, through project lifecycle, sequestering the majority of the injected CO_2. Experience has been gained from over 130 commercial CO_2 EOR operations globally. Based on a mature regulatory regime and decades of industry practice, active CO_2 EOR projects exist primarily in the United States and Canada, with further commercial and demonstration projects, operating in Asia, Middle-East and the North Sea.

The legal and regulatory review focused on the regimes in the USA, Canada, EU, Australia and Brazil. The regions presented varying degrees of stakeholder attention and progression to potentially enable the transition process from a CO_2 EOR operation to the long-term sequestration of CO_2 as a CCS project.

There is currently widespread CO_2 EOR activity in North America, underpinned by decades of technical and regulatory experience in the oil and gas sector. In the US, the Environment Protection Agency (EPA) has produced a series of guidance document pertaining to the Underground Injection Control (UIC) Well Programme and a memorandum with key implementation principles to this effect. CO_2 EOR and CCS projects are currently feasible in terms of existing regulatory framework in the US (Federal); Canada (Alberta and Saskatchewan) and the EU (including the UK). However, further regulatory direction is required in terms of an efficient and legitimate approval pathway for transitioning from one to the other. This relates both to the primary laws for oil, gas and CO_2 injection and sequestration activities such as the U.S. EPA's UIC Well Programme, but also secondary or 'incidental' environmental, health and safety regulations.

In Australia, petroleum and GHG storage legislation exists at a federal and state level, with specific provision for CO_2 EOR. However, there is minimal evidence of any current or planned CO_2 EOR activity in the country and no explicit guidance for the prospective transition to long-term CO_2 storage.

In Brazil, CO_2 EOR activities occur under oil and gas regulations enforced under federal and state level institutions. The current National Climate Change Policy allows for technological processes such as CCS/EOR to be considered as GHG 'sinks' in the National GHG Inventory, but no further aspects are regulated under a CCS-specific legislative framework.

Table E0.2 summarizes the CO_2 EOR and CCS regulations and the potential (theoretical at least) for a transition between these projects, to the extent these exist, across focus regions. The indicator key is as follows:

(green)	Regulations/process in place
(yellow)	Regulations/guidance in development
(orange)	Policy discussions under way
(red)	No information available

Table E0.2 Overview of regulatory status of each country/region

Type of Regulation	USA	Canada			European Union	Australia	Brazil
		Alberta	Saskatchewan	British Columbia			
EOR	(green)	(green)	(green)	(orange)	(green)	(green)	(green)
Transition	(yellow)	(orange)	(orange)	(red)	(green)	(red)	(orange)
CCS	(green)	(green)	(yellow)	(yellow)	(green)	(green)	(orange)

KEY FINDINGS

The analysis conducted and the information compiled in this report regarding the transition of CO_2 EOR to CCS support the 2013 CSLF finding that:

> *"There are no specific technological barriers or challenges* per se *in transitioning and converting a pure CO_2 EOR operation into a CO_2 storage operation.*

The main differences between the two types of operations stem from legal, regulatory and economic differences between the two."[1]

There is a clear regulatory framework for CO_2 EOR and for CCS in most regions but there are insufficient provisions that would allow a CO_2 EOR operator to follow a clear transition pathway for legal and regulatory approval of a CCS project. Permitting requirements for design, commissioning, operational management, decommissioning and post-closure site stewardship, if any, differ for CO_2 EOR and CCS projects.

It is important to note that no existing policies or regulatory provisions in the regions studied explicitly prohibit the prospect of CO_2 EOR projects transitioning to CCS projects.

The main differences that require particular attention from regulators, policy makers and relevant legal authorities for CO_2 EOR transitioning to CCS are:

1. Storage site evaluation and geological modelling;
2. Monitoring of the storage site, reporting and verification;
3. Site closure conditions and post-closure stewardship and liability;
4. Conformance with national GHG inventory guidelines for CCS.

Practically, these areas of difference are likely to have greater implications for existing CO_2 EOR projects that have been operating in accordance with the applicable oil and gas legislative framework before any attention was placed on CO_2 EOR becoming a candidate for transition to CCS. The legal and technical provisions for CCS projects to meet the requirements of the issues outlined above are such that an existing CO_2 EOR project may have difficulty complying – particularly in relation to well monitoring requirements.

In theory, and if incentivized, a proponent of a *new* CO_2 EOR project should be in a better position to design and plan for such a project to transition to CCS based on the evaluation of issues such as site evaluation and monitoring requirements in the design of the entire project life (i.e., planning for both the CO_2 EOR and CCS phases).

It is recommended that specific guidance or regulation be provided setting out the specific requirements on new and existing CO_2 EOR projects which may wish to transition to CCS.

[1] Carbon Sequestration Leadership Forum (CSLF) Task Force on CCS Technology Opportunities and Gaps, Final Report (https://www.cslforum.org/sites/cslf/publications/documents/Washington2013/Bachu-TechnicalChallengesConversionCO$_2$EORtoCCSTaskForceRepor.pdf); November 2013. p 3.

1 INTRODUCTION

Carbon Capture and Storage (CCS) – the long-term underground sequestration of Carbon Dioxide (CO_2) – is a proven technology recognized as a key response option for mitigating the release of CO_2 into the atmosphere. The International Energy Agency has suggested that CCS may need to contribute as much as 20% of the emissions reductions needed by 2050 to achieve the limitation of global warming to 2°C[1].

Enhanced Oil Recovery (EOR) is a long-standing practice in the oil and gas industry. In a CO_2 EOR project, the operator injects CO_2 into an oil and gas reservoir to produce resources through what is considered tertiary recovery. The application of EOR techniques becomes increasingly important as production declines from existing oil and gas fields over time while significant volumes of hydrocarbons remain. These additional hydrocarbons can be extracted if pressure can be increased in the pore space to push out additional oil and gas using tertiary recovery methods. Although this paper is premised on historical and current experiences with EOR projects, similar considerations could also be given to enhanced recovery of natural gas (EGR).

It is a relatively recent concept for EOR projects to look beyond the increased production of oil and gas in an existing hydrocarbon field to consider the added prospect of the EOR activity being treated as a CCS project, which provides for the secure long-term underground storage of CO_2 in the oil and gas field after the EOR operation has ended.

CO_2 EOR-CCS is potentially attractive as a near-term option to accelerate CCS project development because CO_2 has a commercial value when supplied to an EOR operation, hence reducing the net incremental capture cost portion of a CCS project due to the use or sale of the CO_2 for EOR as well as CCS.

Thus, the Policy and Incentives Team of the fourth phase of the CO_2 Capture and Storage (CCP4) has commissioned ERM to work with them to produce this report on '*Best Practice for Transitioning CO_2 Enhanced Oil Recovery (EOR) to CO_2 Storage (CCS)*'.

At the September 2011 Carbon Sequestration Leadership Forum (CSLF) Ministerial Meeting in Beijing, a task force was formed to address the "Technical Challenges for Conversion of CO_2 EOR to CCS". The report from this CSLF CO_2 EOR Task Force concluded that:

> '*there are no specific technological barriers or challenges* per se *in transitioning and converting a pure CO_2 EOR operation into a CO_2 storage operation. The main differences between the two types of operations stem from legal, regulatory and economic differences between the two*'.[2]

(1) "Energy Technology Perspectives 2014", International Energy Agency (IEA/OECD), Paris, 2015

(2) Carbon Sequestration Leadership Forum (CSLF) Task Force on CCS Technology Opportunities and Gaps, Final Report (https://www.cslforum.org/sites/cslf/publications/documents/Washington2013/Bachu-TechnicalChallengesConversionCO2EORtoCCSTaskForceRepor.pdf); November 2013. p 3.

Why the need to study policies and regulations for CO_2 EOR-CCS projects in particular?

EOR regulations were not written to cover long-term underground storage of CO_2 as a CCS project. In oil and gas producing countries, there will be a body of laws, policies, rules and regulations for hydrocarbon extraction including EOR activities. The legal/regulatory framework governing EOR anticipates that CO_2 injection will end and producing wells will be decommissioned, plugged and abandoned after CO_2 EOR has ceased. Typically, EOR regulations do not account for what happens to the injected CO_2 after EOR activities have ceased.

An EOR project seeking to be treated as a CCS project presents a special case which must satisfy both oil and gas production rules and the rules for CCS storage sites. Regulations that govern CCS projects typically assume that the project was designed for the purpose of CCS from the beginning on the basis of site selection criteria that emphasize permanence in underground CO_2 retention. Since the underground reservoir in an EOR project is pre-determined by the location of the existing oil and gas producing formation – i.e., not selected from the beginning for CO_2 storage purposes – then a separate process will likely be required to evaluate the oil and gas reservoir undergoing EOR to determine its viability for long-term underground storage of CO_2 under CCS rules and regulations.

The United States Department of Energy (DOE) Fossil Energy Office EOR website[1] states that:

> "Several tertiary, or enhanced oil recovery (EOR), techniques offer prospects for ultimately producing 30 to 60 percent, or more, of [a] reservoir's original oil in place. **The EOR technique that is attracting the most new market interest is CO_2 EOR** *(emphasis added).*
>
> First tried in 1972 in Scurry County, Texas, CO_2 injection has been used successfully throughout the Permian Basin of West Texas and eastern New Mexico, and is now being pursued to a limited extent in Kansas, Mississippi, Wyoming, Oklahoma, Colorado, Utah, Montana, Alaska, and Pennsylvania.
>
> DOE's R&D program is moving into new areas, researching novel techniques that could significantly improve the economic performance and expand the applicability of CO_2 injection to a broader group of reservoirs; expanding the technique out of the Permian Basin of West Texas and Eastern New Mexico into basins much closer to the major sources of man-made CO_2. **Next generation CO_2 EOR has the potential to produce over 60 billion barrels of oil [in the United States]** *(emphasis added),* using new techniques including injection of much larger volumes of CO_2, innovative flood design to deliver CO_2 to un-swept areas of a reservoir, and improved mobility control of the injected CO_2."

Clearly, there is commercial interest in CO_2 EOR because it can extend the producing life of oil and gas fields. When the US DOE estimates that

(1) http://energy.gov/fe/science-innovation/oil-gas-research/enhanced-oil-recovery

innovative CO_2 EOR techniques could produce an additional 60 billion barrels of oil in the US alone, the magnitude of this issue warrants attention.

The huge volumes of CO_2 slated for EOR could present a significant opportunity for emissions mitigation if it can be shown that the CO_2 used in EOR can satisfy CCS rules for permanence.

Yet, EOR operators who focus on the commercial benefit of EOR and not on any additional environmental benefit, have their own concerns over any new legal requirements that they perceive could impose cost or impede their ability to continue to grow their EOR portfolios in line with traditional oil and gas activities. In order to encourage EOR, any proposed changes to policy and legal frameworks should take these concerns into account, provide clear legal guidance addressing uncertainties, and recommend cost-effective solutions.

Understanding best practice and the policy and regulatory frameworks affecting CCS with EOR is an important driver for ensuring that CO_2 EOR projects are developed in a manner which will enable the carbon stored to be recognized as a mitigation activity under local legislation/carbon market schemes and in national greenhouse gas (GHG) inventories which form the basis for monitoring progress in countries' commitments under the *Paris Agreement*(1).

Thus, the key question addressed in this report prepared for CCP4 is:

> '*How should best practices and regulatory frameworks for CCS project site evaluation and monitoring be taken into account in cases where the underground pore space has been pre-determined as an existing oil and gas reservoir where CO_2 will be or is being injected for purposes of EOR?*'

(1) https://unfccc.int/documentation/documents/advanced_search/items/6911.php?priref=600008831

2 *CHALLENGES FOR TRANSITIONING CO_2 EOR TO CCS*

In a CO_2 EOR project, the operator injects CO_2 into a declining oil and gas reservoir to produce resources through what is considered tertiary recovery. The process produces a mixture of hydrocarbons, CO_2, and water. As the wells produce, the operator does a pressure step down; uses a three phase separator (free water knock out) to separate oil, gas and water; captures and purifies the CO_2 (typically using an amine or similar gas treatment/ capture system); and re-injects or "recycles" the captured CO_2 back into the formation to continue the process.

Most of the CO_2 injected into the reservoir for EOR remains permanently trapped under ground. It is this characteristic of EOR operations which makes them potential candidates for CCS project designation. Also, CO_2 costs are offset by revenues generated from the sale of recovered hydrocarbons. This is especially beneficial when comparing against the higher cost of standalone CCS projects that do not have an associated revenue stream.

There are a number of issues that are important in the context of CCS but are not considered in great detail during typical EOR activities. In order for CO_2 EOR to transition to EOR-CCS and the emission reductions to count towards national GHG inventories, the following challenges need to be addressed:

- CO_2 storage site evaluation, integrity, and monitoring;
- Ownership/long-term stewardship of underground pore space;
- Post-closure liability and CO_2 ownership at storage sites; and
- Ambiguities in GHG emissions accounting rules dealing with EOR-CCS for national inventories.

2.1 *SITE EVALUATION, INTEGRITY AND MONITORING*

CO_2 EOR projects are not required to investigate the structure of the oil and gas producing fields in which they operate to the same extent required by CCS site evaluation rules because the oil and gas producing formation was not originally developed for the stated purpose of CCS.

As such, CO_2 EOR operations wishing to transition to CCS are not likely to have done the technical analysis and site evaluation called for in a built-for-purpose CCS project. Therefore, claiming credit for the CO_2 which has been stored underground thanks to CO_2 EOR presents a special case.

CCS guidelines and regulations have specific requirements in relation to storage site evaluation and the need to undertake significant geological and geotechnical assessments to obtain a detailed picture of the storage location and to ensure that the geological structure will facilitate permanent capture of CO_2 through, for example, the presence of a non-porous cap rock and minimal fracturing and faulting in the structure of the formation.

The appropriateness of a potential CO_2 storage site needs to be carefully assessed in order to ensure safe and permanent storage of CO_2. This is determined primarily by three principal requirements:

- ***Capacity*** - whether there is sufficient storage volume and whether it can be accessed;
- ***Injectivity*** - whether suitable reservoir properties exist for sustained injection of CO_2 at economical industrial supply rates; and
- ***Integrity*** - whether the site is secure with negligible risk of unintended migration or leakage.

Given that depleted oil and gas fields are considered promising storage site options for CCS, capacity and injectivity are unlikely to be an issue in the transition from CO_2 EOR to CCS.

Integrity, on the other hand, could be a challenge given the need to ensure permanent storage of CO_2 in order to achieve climate change mitigation aims. Although the original geological traps that allowed the hydrocarbon to accumulate in the first place are still there, EOR activities result in the drilling of numerous injection wells across an oil field in order to enhance production. Therefore, '*injection wells and abandoned wells have been identified as one of the most probable leakage pathways for CO_2 storage projects'*[(1)]. Maintaining well integrity means to prevent leakage in/along wells and geological fractures**.** This is important throughout the well's life cycle, from drilling to plugging and abandonment.

EOR-CCS projects will need to ensure that appropriately robust monitoring regimes are in place to detect leakage, to account for losses in the projects over all emissions inventory and to ensure that measures are put in place to stop leaks when detected.

While the large number of man-made injection wells might increase monitoring requirements, their location is at least well understood. Leaks from geological fractures are less easy to find and leakage emissions less easy to measure. Detailed geotechnical assessments of sites ought to identify geological faults across the formation but this may not have been done at the start of EOR operations and therefore this work will need to be done in advance of transitioning to CCS – the associated costs depend on the scale of the EOR operations. An advantage to an EOR site is that years of production history have given geotechnical staff and reservoir engineers large amounts of real data to work with as compared to a green field CCS site.

A key element related to the long-term nature of CCS projects is monitoring. The long-term monitoring of CO_2 storage sites required by CCS regulations go beyond the post-closure and decommissioning requirements for EOR projects. Any CO_2 EOR project seeking to transition to a CCS project will have to address the long-term monitoring requirements for CCS storage sites.

[(1)]Intergovernmental Panel on Climate Change (IPCC) Special Report (IPCC, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B.,O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp.); 2015 p 244.

An issue that could affect well integrity is the potential impact of acidic fluids migration. While the acidic fluids migration issue is still being researched, the uncertainties, potential future regulatory changes, and risk context should be considered when addressing the transition from CO_2 EOR to CCS.

2.2 *Pore Space Issues Likely to Arise in CO_2 EOR Transition to CCS*

A CO_2 EOR project ends when oil production ceases, the production facilities are decommissioned, wells are plugged and abandoned and the lease to produce oil from that field is terminated. Any CO_2 EOR operation seeking to transition to a CCS project and receive credit for long-term underground storage of CO_2 as a GHG mitigation activity will likely need to address issues regarding the use of the pore space for CO_2 storage purposes beyond decommissioning of oil production.

Key issues that could arise about the pore space where CO_2 was injected for EOR purposes include the following:

- Can the CO_2 EOR operator apply for permits that would recognize the transition of their operation to become a 'CCS project' without the express permission and prior agreement of the pore space owner since the CO_2 was originally injected for the purpose of EOR but not for the purpose of 'CCS'?

- Will the owner of the underground pore space (could be a government or private party) accept the long-term 'stewardship' responsibilities of managing that pore space as a 'CCS project'?

- What **monitoring** responsibilities accrue to this pore space becoming a 'CCS project'?

- What **liability** from the 'CCS project' after the EOR operator leaves rests with the pore space owner or the surface land owner if mineral rights are owned separate from the land?

- What recourse would the pore space owner and land or mineral rights owner (if minerals rights are owned separately) have against the EOR operator if that operator claims credit for the CO_2 injected as a 'CCS project' and some liability arises after oil production ended and the EOR operator left?

- Can the CO_2 EOR operator claim credit for the CO_2 emissions avoided if they do not own the CO_2 in the pore space post decommissioning? Since ownership of any unproduced oil or gas left in the reservoir reverts to the pore space owner after an oil producer's lease terminates, does that mean ownership of CO_2 left in the pore space after EOR ceases also reverts to the pore space owner?

- Presumably the pore space owner could decide not to assert ownership of the CO_2 injected by the EOR operator or could sign over the ownership of the CO_2 to the EOR operator, but what liability and responsibilities, if any, could fall on the pore space owner if they take either of these approaches?

These examples of issues that could arise with respect to the pore space owner in a CO_2 EOR project are not presented as insurmountable barriers to claiming credit for long-term underground storage of CO_2 from EOR. But they do suggest that the success of a CO_2 EOR project transitioning to a CCS project will likely require addressing these issues in the broader context of a clear, legal framework and possibly including engagement with the pore space owner to assess and deal with concerns.

2.3 *POST-CLOSURE LIABILITY AND CO_2 OWNERSHIP*

Given the nature of CCS projects and the long term need to remove CO_2 permanently from the atmosphere, the issue of liability and ownership of CO_2 over time is important in ensuring that effective measures are put in place to ensure the efficacy of the projects.

Liability issues arise with respect to any impacts that might occur to persons or property from operation of a CO_2 underground storage facility and in the worst (but highly unlikely) case of catastrophic release of CO_2 from the site.

Liabilities for ensuring that the GHG emissions avoided from CCS projects as a GHG mitigation activity are of a different nature. When a national GHG inventory deducts CO_2 emissions attributable to a CCS project, such deductions to the national inventory are treated as permanent. Should CO_2 from the CCS project counted in the national inventory as avoided emissions be found later to have been released, the CCS storage site owner who took credit originally for storing the CO_2 would be liable for the later release.

Regulatory frameworks for CCS identify how liability is allocated in relation to attaching responsibility of the risks posed by CCS over the short, medium, and long-term across the CCS chain (i.e. creating a *chain of custody / responsibility* for captured CO_2)[(1)] .

Aspects which have been considered by government authorities in the context of a liability framework for CCS include:

- Management of leakage and permanence – causing both "global" and "local" damages – and the means for possible redress and compensation for the global atmosphere (due to the CO_2 release) and any affected communities/persons in the event of local damages caused by CO_2 leakage. This may include the need for emergency response plans in the event of leakage;

- Stewardship of the storage site in the context of these aspects over the long-term, and the possibility of transferring liability from operator to State; and

[(1)] The CO_2 Capture Project has undertaken a number of studies covering post-closure liability and ownership in reference to regulatory frameworks. See http://www.co2captureproject.org/allresults.php?pubcategory=policies

- Costs and financial provision(s) – this can act to reduce the potential moral hazard for operators that can arise where a liability transfer occurs. This type of mechanism can also limit the exposure of the State in remediating, closing and managing poorly performing projects, and costs for long-term stewardship, where appropriate.

2.4 GHG EMISSIONS ACCOUNTING CONSIDERATIONS

2.4.1 *IPCC Guidelines for National GHG Inventories*

The UNFCCC reporting guidelines for nations to submit their national GHG inventories require Parties to use the 2006 IPCC Guidelines for monitoring and reporting national GHG emissions. The *IPCC Guidelines for National GHG Inventories* (2006 version adopted at the Durban COP in 2011) include a chapter (5) on how to address the geological storage of CO_2 within emission inventories. Importantly, the proponents of CCS projects, including project operators who want to earn credit for the CO_2 emissions avoided as a result of CO_2 EOR, will only be recognized by the competent 'inventory compiler' where the project is located, if that country captures the site-specific CO_2 storage project in the National GHG Inventory in accordance with Chapter 5.

The IPCC Inventory Guidelines for CCS are divided in to four 'systems' along the CCS chain, from capture and compression through to the storage phase. The geological sequestration guidelines do specifically include depleted or partially depleted oil and gas fields with EOR. However, the guidelines indicate that all CCS projects have necessary requirements to assess the potential for CO_2 to be emitted via leakage pathways, as follows:

- Properly and thoroughly characterize the geology of the storage site and surrounding strata;
- Model the injection of CO_2 into the storage reservoir and the future behavior of the storage system;
- Monitor the storage system; and
- Use the results of the monitoring to validate and/or update the models of the storage system.

Implications for the CO_2 EOR to CCS Transition

There are several potential regulatory ambiguities for CO_2 EOR projects to be accounted for as CCS projects in national GHG inventories under the 2006 IPCC Guidelines for National GHG Inventories:

- While the guidelines are extensive, no prescriptive monitoring and reporting guidelines are provided. Rather, the guidelines indicate a Tier 3 site-specific methodology is required. While this allows for flexibility, the onus is on the reporter to develop the appropriate approach.
- No exceptions in the 'site evaluation' guidelines are specified explicitly for CO_2 –EOR projects, thus raising the quandary of what to do when CO_2 –EOR projects are not subjected to an appropriate CO_2 storage site selection and evaluation process, since the injection site was already determined by the location of the oil or gas production operation;

- No exceptions or special considerations for CO_2 – EOR injection and reservoir modeling and monitoring requirements are provided. Monitoring is required after EOR injection has ceased and the well is no longer in production;

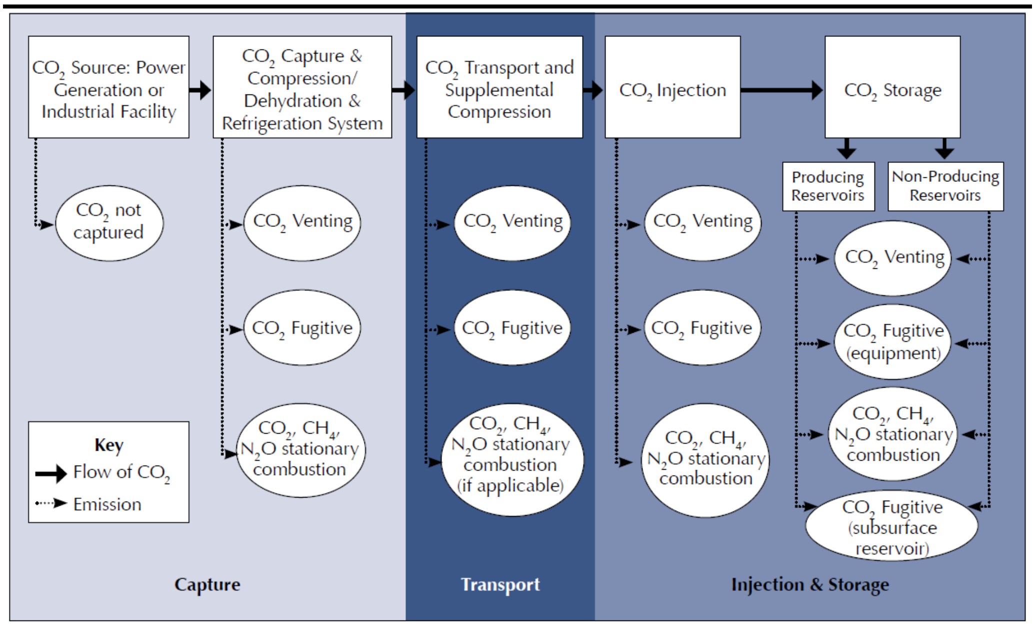
- The precedent for countries including CCS in their national GHG inventories submitted to the UNFCCC, and how inventory review teams convened by the UNFCCC react to the handling of CCS in those inventories, is not clear for all CCS projects, much less for the specific issues related to CO_2 - EOR projects.

2.4.2 *Other GHG Accounting Guidelines for CCS*

Other GHG accounting guidelines have been developed for CCS projects, some of which address EOR projects specifically. Unlike the IPCC Guidelines for national inventories, most of the other accounting guidelines address CCS project emission reductions as offset projects and are therefore subject to project-based accounting guidelines. GHG emission reductions are expressed as the difference between baseline and project emissions, and may or may not include emissions outside the EOR operators' control. These guidelines are important for quantifying GHG offsets that may be traded in voluntary carbon markets, or potentially used for compliance in existing or future cap-and-trade or carbon tax systems. For example, the Specified Gas Emitters regulatory regime in Alberta Canada allows for EOR - CCS projects as offsets to meet regulatory targets.

The GHG emissions during the typical stages of a CCS project are shown in *Figure 2.1*. The basic CCS project schematic and the associated GHG calculation methods from this reference do not distinguish between CCS and EOR-CCS, although both are addressed.

Figure 2.1 GHG Emissions during the Basic Stages of a CCS project (1)



(1) Source: McCormack, Mike. Center for Climate and Energy Solutions (C2ES), A Greenhouse Gas Accounting Framework for Carbon Capture and Storage Projects, February 2012.

For a CO_2 EOR/CCS project, the GHG emissions during the production stage of the project have added complexity due to the nature of the EOR operations. In EOR operations, a minority fraction of the injected CO_2 becomes miscible with the oil and will eventually be recovered in production wells when the oil is produced – sometimes referred to as 'break through' of CO_2.

At the producing wells, oil mixed with water and gas is pumped to the surface, where it flows to a centralized collection facility. The produced fluid containing oil, water, gas, and CO_2 is separated at the surface. Any produced CO_2 is recovered from the gas stream (typically in an acid gas removal system), re-compressed and re-injected along with additional volumes of newly purchased CO_2. The separated produced water is treated and re-injected, often alternating with CO_2 injection, in a water-alternating-gas (WAG) process. The process of recovering, separating, recompressing, and reinjecting the CO_2 in an EOR operation is often referred to as 'CO_2 recycle'. Because there are energy requirements and potential losses of CO_2 during the CO_2 recycle process, the GHG emissions associated with EOR-CCS need to account for the energy use and fugitive emissions inherent in the operation.

The accounting framework developed by the Centre for Climate and Energy Solutions (C2ES) categorizes EOR operations as CO_2 injection in producing formations. The following GHG accounting considerations identified by C2ES are unique to CO_2 injection in hydrocarbon producing formations, compared to CO_2 injection into non-hydrocarbon producing formations.

- **Energy Use - CO_2 Recycle**: During the production stage for CO_2 injection into a producing formation, the recycle operations to recover, recompress and reinject CO_2 into the reservoir consume energy in the form of electricity and/or fuel gas. While there is potential for CO_2 to be released directly from recycle operations from unintentional venting, flaring, or fugitive losses which are difficult (but not impossible) to quantify, the primary contribution of CO_2 recycle operations to GHG emissions comes from the energy used in the surface equipment.

- **CO_2 Losses – CO_2 Recycle**: The unintentional release of CO_2 during surface recycle activities must also be included in GHG emissions accounting. CO_2 EOR may include CO_2 fugitive losses from surface facility equipment components, as well as venting and flaring losses. But the contribution of these losses is expected to be minimal during normal operations because the CO_2 recycle operations are a closed loop system. The EOR operator is motivated to conserve as much CO_2 on surface as possible since the purchase of new CO_2 is an operating expense.

- **CO_2 Losses Outside Project Boundary**: Any CO_2 that is transported or lost outside the project boundary must also be addressed in GHG accounting.

In addition to the direct emissions during CO_2 EOR production operations, indirect emissions referred to in some GHG accounting regimes as 'leakage' outside the project boundary may also need to be addressed. (Note: In this context of GHG accounting, 'leakage' is not referring to the emissions from

CO_2 migration from the storage site to the surface or atmosphere.) Leakage emissions are defined as: '*potential for net changes in emissions to occur outside the boundaries and operational control of a particular policy and/or activity, but arising as a consequence of the policy and/or activity*.'[1] For a CO_2 EOR project, the emissions from increased oil production from EOR operations may need to be taken into consideration when accounting for lifecycle emissions. In most cases, such calculations of 'leakage' arise when the emissions avoided from a mitigation activity like CCS are to be traded as carbon credits in an emissions trading regime. The IPCC accounting rules for national GHG inventories do not ascribe the emissions from combusting the oil produced by EOR to a CCS project, because the responsibility for emissions is always ascribed to the point of combustion.

A number of GHG accounting guidelines addressing CCS and specifically, CCS with EOR, have been published in the last several years. *Table 2.1* shows recent documents that are in the public domain. Most of these guidelines do address accounting for emissions associated with EOR, especially in the recycle phase of production.

(1) Modalities and Procedures for the Clean Development Mechanism, UNFCCC, 2010.

Table 2.1 GHG Accounting Guidelines Addressing CCS and EOR-CCS

Date	Organization	Title of Guidance Document	GHG Accounting for EOR Addressed?	Differences in Accounting between CCS and EOR?	Emissions from Increased Oil Production Accounted for?
2015	IEA	Storing CO_2 through Enhanced Oil Recovery	Yes, indicative only	Only EOR is addressed	Yes, in lifecycle assessment
June 23, 2015	Alberta Government	Quantification Protocol for CO_2 Capture and Permanent Storage in Deep Saline Aquifers	No, only applies to deep saline aquifer storage	NA	NA
April 2015	American Carbon Registry	Methodology for GHG Emission Reductions from Carbon Capture and Storage Projects, Version 1.0	Yes	None; the same equations are used to account for energy use and CO_2 losses during recycle operations.	No
January 2015	California Council on Science and Technology	Electricity from Natural Gas with CO_2 Capture for Enhanced Oil Reduction Emissions Accounting under Cap and Trade and LCFS	No; discussion paper on lifecycle considerations	NA	No
January 2013	ICO2N	Net Greenhouse Gas Impact of Storing CO_2 Through Enhanced Oil Recovery (EOR)	Yes, high level carbon intensity figures presented	Yes, carbon intensity of CCS versus EOR-CCS are presented	Yes
October 2012	DOE, NETL	Best Practices for Monitoring, Verification and Accounting of CO_2 Stored in Deep Geologic Formations, Second Edition	No	Monitoring is addressed, but no methodology to determine GHG emission reductions	No
February 2012	Centre for Climate and Energy Solutions	GHG Accounting Framework for Carbon Capture and Storage Project	Yes	CCS in producing formations are addressed separately, but no major differences	No
October 2007	Alberta Environment	Quantification Protocol for Enhanced Oil Recovery (Specified Gas Emitters Regulation)	Yes	Only EOR is addressed	No
December 2006 (adopted December 2011)	United Nations Framework Convention on Climate Change (UNFCCC)	United Nations Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories	Yes	No distinction between CCS and EOR-CCS	No

3 OVERVIEW OF EXISTING PRACTICES

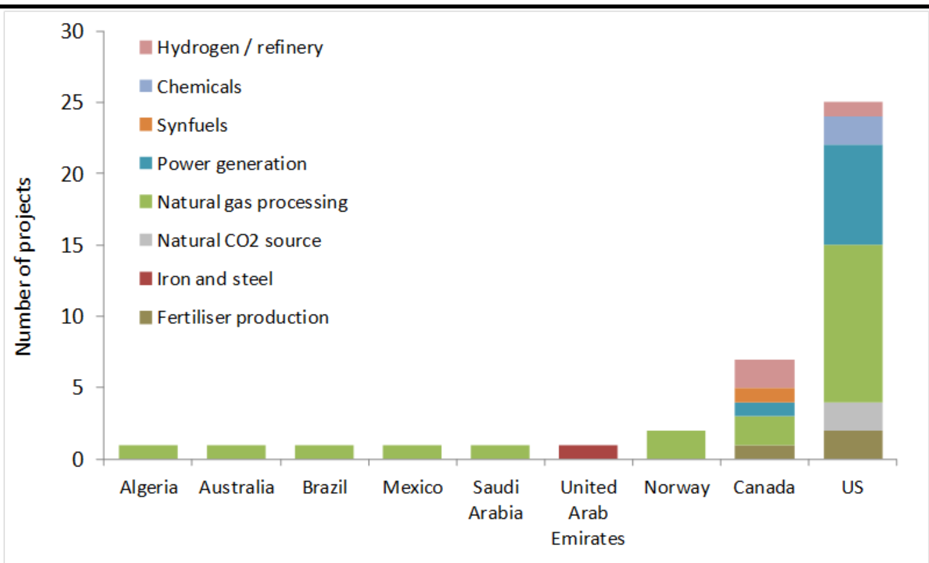
There is significant experience with EOR globally and an increasing body of expertise in relation to CCS. This section provides a high level overview of existing EOR projects and the perspectives of industry and academic experts in relation to the transition from CO_2 EOR to CCS.

3.1 GLOBAL STATUS OF EOR

Over the course of the past 40 years, the application of CO_2 EOR has proven to be an effective technology for the purposes of maximising the oil-bearing reservoir output and incidentally sequestering the majority[1] of the injected CO_2. *Figure 3.1* illustrates the global distribution of CO_2 injection projects by sector (for EOR and CCS purposes) and *Figure 3.2* provides a summary of large scale EOR and CCS CO_2 injection projects and their timeframe for development.

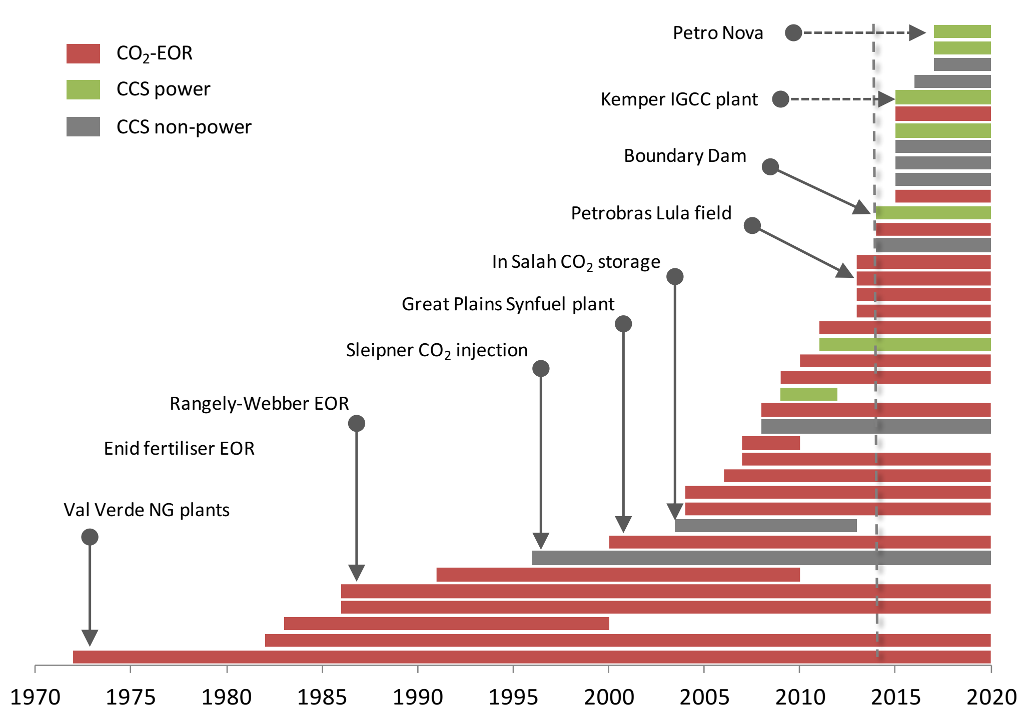
Experience has been gained from over 130 commercial CO_2 EOR operations globally. Based on a mature regulatory regime and decades of industry practice, active CO_2 EOR projects exist primarily in the United States and Canada, with further commercial and demonstration projects, operating in Asia[2], Middle-East and the North Sea[3]. The CO_2 sources utilised by these projects includes conventional anthropogenic sources (power and industrial installations) and naturally occurring reservoirs, such as the McElmo Dome in Colorado, Jackson Dome, in Mississippi, and Bravo Dome in New Mexico, US.

Figure 3.1 Global Distribution of Large-scale CO_2 Injection by Sector



[1] Expert opinion varies on the average percentage of CO_2 that remain incidentally stored, with the potential for a 95-99% retention rate if the reservoir contains appropriate natural trapping mechanisms.
[2] There are a number of CO_2 EOR projects scheduled to be commissioned between 2017 – 2020 in China. See further http://www.globalccsinstitute.com/projects/large-scale-ccs-projects
[3] *'Bridging the Gap: An Analysis and Comparison of Legal and Regulatory Frameworks for CO_2–EOR and CO_2–CCS'*, Global CCS Institute (October 2013), pp 13.

Figure 3.2 Timeline of large-scale CO_2 injection project deployment



Notes: Data current as of September 2014 (dashed line); dashed arrows show projects currently in construction/execution. Source: Carbon Counts.

3.2 CASE STUDIES OF EOR-CCS PROJECTS

The following high-level case studies were selected on the basis that the locations are representative of the focus regions under review and the project findings offer practical insights[(1)]. The Weyburn CO_2 Storage project is based in Saskatchewan, Canada, and monitored CO_2 behaviour in an onshore reservoir. The Weyburn project was developed under the regulations in place at the time in Saskatchewan (*Section 4.2.2* provides an overview of the regulatory framework in Saskatchewan).

The Lula Oilfield project is located offshore in Brazil, under the regulatory framework summarized in *Section 4.5*. It in fact represents the deepest CO_2 injection well in the world. Enabled by a more advanced policy and regulatory framework, the Weyburn CO_2 Storage project demonstrated that based on the appropriate geological evaluation and with effective modelling it has ensured the long-term permanent storage of approximately 22 million tonnes of CO_2. In contrast, the Lula Oilfield project is operational within a lesser developed and fragmented regulatory regime, yet, in accordance with best available technology and practice the CO_2 EOR activities are both effective and economic, at exceptional depths.

(1) Further CO_2 EOR/CCS projects to monitor include The Alberta Carbon Trunk Line (ACTL), the first large-scale CO_2 EOR and storage project in Alberta available at http://www.enhanceenergy.com/actl and The Uthmaniyah CO_2 EOR Demonstration Project in Saudi Arabia available at http://www.cslforum.org/publications/documents/riyadh2015/AlBuraik-UthmaniyahCO2EORProject-Ministerial-Riyadh1115.pdf

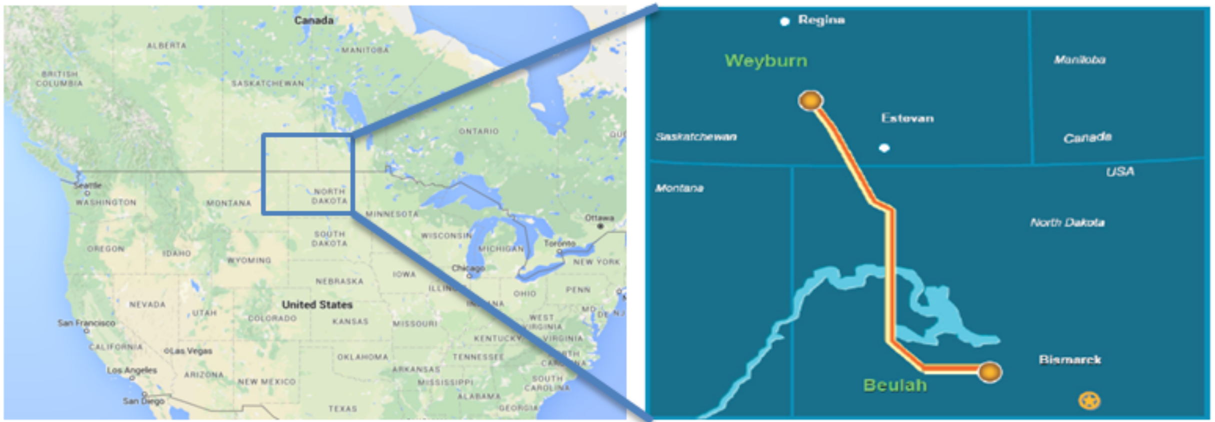
IEA GHG WEYBURN CO_2 STORAGE AND MONITORING PROJECT

The Weyburn oilfield is located in the Williston Basin, 16 km south-east of Weyburn, Saskatchewan. The oilfield operation began in 1957 and in order to remain viable, commenced with EOR in 2000, sourcing the CO_2 from a synfuels plant based in North Dakota[(1)]. The operator, Encana Resources, agreed to the commercial oilfield serving as a demonstration project for CO_2 injection, under the management of the Petroleum Technology Research Centre. The key overall objective of this project was to predict and verify and the ability of an oil reservoir to securely store and economically contain CO_2[(2)]

The monitoring and modelling of the sequestered CO_2 was conducted over the period 2000-2012, resulting in two research study reports:
Phase 1: IEA GHG Weyburn CO_2 Storage and Monitoring Project (2000-2004)[(3)];
Phase 2: Best Practices for Validating CO_2 Geological Storage: Observations and Guidance from the IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project [(4)].

Project Sponsors

Government	Industry
Alberta Energy Research Institute	BP
European Community	Chevron Texaco
Natural Resources Canada	Dakota Gasification Co.
Saskatchewan Industry & Resources	Encana Corporation
US Department of Energy	Nexan Inc.
	SaskPower
	Total
	Transalta Utilities



Location of Weyburn project in USA and Canada [(5)]

Geological characterisation of Geosphere and Biosphere	Geological setting of Weyburn was deemed to be highly suitable for the long-term storage of CO_2. The geology provides multiple containment zones should the CO_2 plume leak through the primary caprock.
Prediction, Monitoring & Verification of CO_2 Movement	Demonstrated the ability of seismic and geochemical sampling methods to monitor physical and chemical changes in the target reservoir, induced by injected CO_2. The exercise confirmed that both monitoring methods can determine the distribution of the CO_2 plume.
CO_2 Storage Capacity and Distribution Predictions	Reservoir simulation model was successfully used to predict the storage capacity and distribution of the CO_2 plume. Reservoir storage capacity was estimated to be 45.15 million tonnes of CO_2.
Long-term Risk Assessment of the Storage Site	Numerical simulations showed that over 5000 years, in the extreme and unlikely case of well failure, essentially 100 % of the CO_2 plume will remain underground. Only 0.2% will seep to the overhead biosphere. By the end of this period, the CO_2 would have dissolved precluding further migration. Therefore, the project found that the CO_2 will be safely stored and the operation economic. By project closure in 2012, 22 million tonnes of CO_2 was injected into the deep formation.

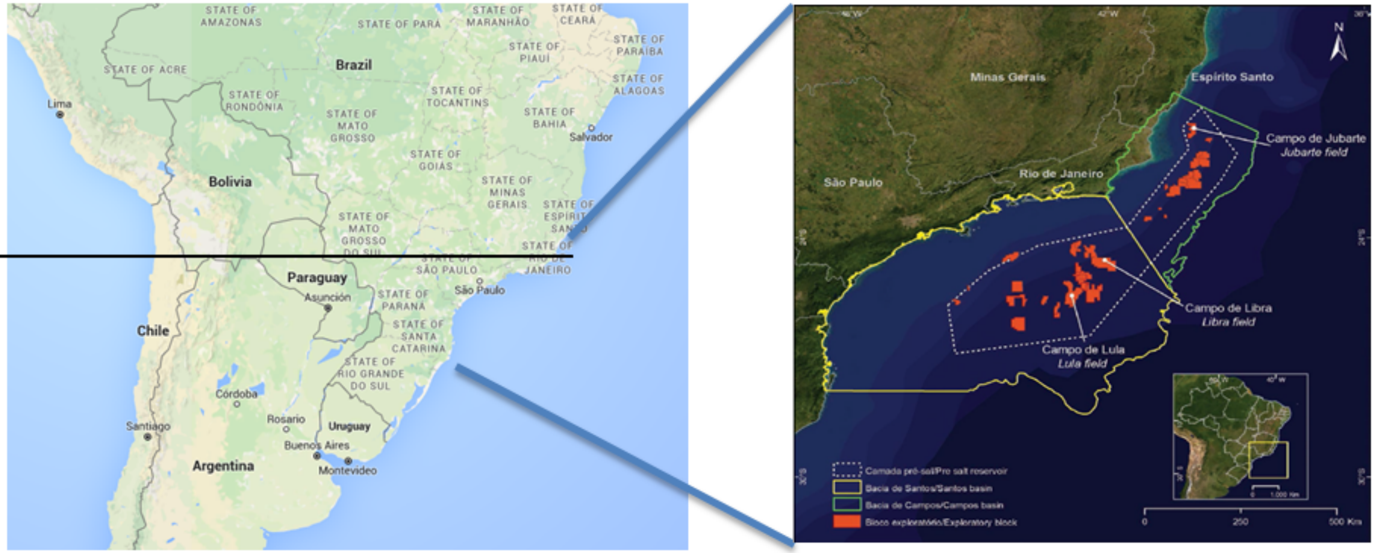
(1) IEA GHG R&D Programme, *'Weyburn CO2 Storage and Monitoring Project'*. Available at http://www.ieaghg.org/docs/general_publications/weyburn.pdf
(2) Wilson, M. and M. Monea. Eds. *IEAGHG Weyburn CO2 Monitoring and Storage Project Summary Report*, 2000- 2004. Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies (September 2004). Pp 1.
(3) Report available at http://ptrc.ca/+pub/document/Summary_Report_2000_2004.pdf
(4) Report available for purchase at www.geosciencepublishing.ca
(5) IEA GHG R&D Programme: Weyburn CO2 Storage and Monitoring Project Presentation, pp 7.
(6) IEA GHG R&D Programme, *'Weyburn CO2 Storage and Monitoring Project'*. Available at http://www.ieaghg.org/docs/general_publications/weyburn.pdf. Pp 19-23.

PETROBRAS LULA OILFIELD CCUS PROJECT

Located 300 km off the coast of Rio de Janeiro, the Lula Oilfield CCUS Project is the only offshore CO_2-EOR project, operating since 2013. Using EOR, hydrocarbons are extracted from carbonate reservoirs in the Santos Basin, which lies between 5,000 -7,000 metres below sea level. The injected CO_2 captured and recycled for injection back into producing reservoir. The produced oil is subsequently offloaded into tankers and transported to shore.[1]

Project Sponsors

Industry Project Sponsors
Petrobras
BG E&P Brasil Ltd
Petrogal Brasil SA



Location of the Lula Oilfield project in Brazil [2]

Geological characterisation	The efficiency and behaviour of the CO_2 injection has been continually modelled by Petrobras over a period of time. The pre-salt fields particular characteristics such as elevated pressures, high carbonate diversity present in the reservoir, fluid-rock interactions, inter alia, have been gradually compiled since 2009 from experimental data obtained from R&D projects and from the field (Lula and Sapinhoá fields).
Prediction, Monitoring & Verification of CO2 Movement Distribution	Petrobras has developed 4D seismic evaluations and chemical tracers to follow the CO_2 mobility in the Lula Oil Field. Conventional monitoring wells are not economically feasible in the offshore environment.
Long-term Risk Assessment of the Storage Site	Despite the fragmented regulatory framework, Petrobras has applied best international practice and evolved its technical experience, specific to Santos Basin geology and offshore location. This existing body of data should form a reliable basis for assessing the long-term viability for permanent CO_2 storage.

[1] Global CCS Institute 'Global Status of CCS 2014' available at https://hub.globalccsinstitute.com/publications/global-status-ccs-2014/64-brazil-deployment-success; http://www.globalccsinstitute.com/projects/petrobras-lula-oil-field-ccs-project ; and http://www.globalccsinstitute.com/sites/www.globalccsinstitute.com/files/content/page/92241/files/Fact%20sheet%20-%20CCS%20in%20The%20Americas_US%20letter_December%202015_0.pdf
[2] Source: CEPAC 'Brazilian Atlas of CO2 Capture and Geological Storage'. (April 2015). Pp 43
See 'Pioneering Technologies for the Pre-Salt at http://presal.hotsitespetrobras.com.br/pioneering-technologies/#0

3.3 *Perspective from the Bureau of Economic Geology*

The Bureau of Economic Geology (BEG) at the University of Texas at Austin's Gulf Coast Carbon Center has been heavily involved with both EOR and CCS research and analysis for many years and provided an alternative view to consider in this assessment[1]. While these comments do not necessarily represent BEG's official views, they are helpful in highlighting potential issues around EOR and CCS. The interviewee felt that many of the perceived issues about the viability of EOR for long-term storage of CO_2 are due to a knowledge or communication gap, versus significant technical barriers to be addressed, supporting the 2013 CSLF finding mentioned previously. Several key points were raised: [(2)]

Injection withdrawal ratio

- If EOR CCS is to be encouraged, one item that is missing in both the the U.S. EPA's Underground Injection Control (UIC) Class II and Class VI permit process (See *Section 4.1*) is assessing the injection/withdrawal ratio. The reasoning is that production wells act to prevent underground CO_2 from migrating beyond intended boundaries. The assessment should confirm that the injection volumes should equate to withdrawal volumes (i.e., an injection/withdrawal ratio = 1).
- In current EOR practice, there is no financial incentive to inject more CO_2 beyond what is required for efficient hydrocarbon recovery. However, a scenario where EOR CCS operators receive new sources of revenue from CO_2 volumes stored may create incentives for the operator to store additional volumes of CO_2 beyond what is required for EOR. Thereby, the additional CO_2 injection could create a situation where injected CO_2 volumes are migrating beyond their intended areas. While this may be unlikely, assessing the injection/withdrawal ratio can be a beneficial test to confirm that this practice is not happening – and would be relatively straightforward to implement.

Area of Review (AoR)

- The way that the AoR is defined is really different for Class II (EOR) vs. a Class VI (CCS) well.
- The AoR is a key concept in Class VI – regulators need to know how large the area of CO_2 migration is going to get over time. Class VI requires a robust demonstration that CO_2 is contained in the intended zone and does not migrate.
- Class II has a 1/4 mile AoR (because the existence of injection and withdrawal patterns – the CO_2 will not migrate beyond the withdrawal/production wells).
- The EU method of a "storage complex", which includes all the area the CO_2 "might" migrate to, is a more robust concept for guarding against CO_2 migration/leakage. For Class VI wells, determining the AoR and

(1) Interview with Sue Hovorka, BEG Stratigrapher, held on 11/23/2015. Gulf Coast Carbon Center, Bureau of Economic Geology. Jackson School of Geosciences. The University of Texas at Austin. Website is http://www.beg.utexas.edu/

(2)Carbon Sequestration Leadership Forum (CSLF) Task Force on CCS Technology Opportunities and Gaps, Final Report (https://www.cslforum.org/sites/cslf/publications/documents/Washington2013/Bachu-TechnicalChallengesConversionCO2EORtoCCSTaskForceRepor.pdf); November 2013.

modeling the CO_2 migration is a challenge and the EU concept might be more appropriate.

The review focused on the legal and regulatory regimes in the USA, Canada, EU, Australia and Brazil. The regions presented varying degrees of stakeholder attention and progression to potentially enable the transition process from a CO_2 EOR operation to the long-term sequestration of CO_2 as a CCS project. *Table 4.1* summarizes the four categories of CO_2 EOR to CCS regulatory transition of the focus regions.

Table 4.1 EOR – CCS Regulatory Transition

CO_2 EOR regulatory transition	Countries
Comprehensive EOR and CCS-specific regulations;	US, EU, Alberta - Canada, Australia
EOR regulations and fragmented CCS - specific regulations;	Saskatchewan - Canada
Partial coverage of EOR and CCS activities	British Columbia - Canada
Oil and gas legislation with no CCS-specific regulation.	Brazil

There is currently widespread CO_2 EOR activity in North America, underpinned by decades of technical and regulatory experience in the oil and gas sector. In the US, the Environment Protection Agency (EPA) has produced a produced a series of guidance document pertaining to the Underground Injection Control (UIC) Well Programme and a memorandum with key implementation principles to this effect. This arguably serves as a comparative model for the subject matter under review. CO_2 EOR and CCS projects are currently feasible in terms of existing regulatory framework in the US (Federal); Canada (Alberta and Saskatchewan) and the EU (including the UK). However, further regulatory direction is required in terms of an efficient and legitimate approval pathway. This relates both to the primary laws for oil, gas and CO_2 injection and sequestration activities such as the U.S. EPA's Underground Injection Control (UIC) Well Programme, but also secondary or 'incidental' environmental, health and safety regulations.

In Australia, petroleum and greenhouse gas storage legislation exists at a federal and state level, with specific provision for EOR. However, there is minimal evidence of any current or planned CO_2 EOR activity in the country and no explicit guidance for the prospective transition to long-term CO_2 storage.

Brazil forms the fourth category above, with oil and gas regulations enforced under the Ministry of Mines and Energy´s National Petroleum Agency and other governmental agencies. The National Climate Change Policy allows for technological processes such as CCS/EOR to be considered as GHG 'sinks' in the National GHG Inventory, but no further aspects are regulated under a CCS-specific legislative framework. Notwithstanding this current status, it boasts the deepest CO_2 EOR injection well in the world and is assessed to be in a favourable situation regarding the potential for CO_2 geological storage.

Based on available resources, the following sections provide a high-level analysis of the CO_2 EOR/CCS framework in each of the five regions. Note the analysis is restricted to primary laws of application (oil and gas and CCS) for the purposes of CO_2 injection, storage and long-term stewardship. Therefore, secondary environmental, health and safety laws and the regulatory implications for CO_2 capture, compression and transportation are not specifically considered in this scope of work.

The analysis includes a summary of EOR and CCS regulations, to the extent these exist, across the project lifecycle and a traffic light indicator summarizing status of the current EOR regulations, CCS-specific regulations and the potential (theoretical at least) for a transition between these projects, at present[1]. The key for the indicator table is as follows:

(green)	Regulations in place
(yellow)	Regulations/guidance in development
(orange)	Policy discussions under way
(red)	No information available

4.1 *UNITED STATES*

The United States has experience in CO_2 EOR that expands over the last 40 years, with annual injections estimated to be around 65 million metric tonnes per year in more than 7,200 injection wells[(2)]. This has been sustained by a robust regulatory framework: the U.S. EPA's Underground Injection Control (UIC) Class II well requirements, under either Section 1422 or 1425 of the 1974 Safe Drinking Water Act. In 2010, under the UIC Programme, the EPA established the Class VI regulations for wells used to inject CO_2 into deep rock formations.

4.1.1 *US EPA Guidance on Transitioning from Class II to Class VI Wells*

In December 2013, the EPA released a Draft Guidance Document on transitioning Class II wells for oil and gas operations, to Class VI wells for geologic carbon storage. According to the draft guidance[(3)]:

"Owners or operators that are injecting carbon dioxide for the primary purpose of long-term storage into an oil and gas reservoir must apply for and obtain a Class VI permit when there is an increased risk to Underground Sources of Drinking Water (USDWs) compared to Class II operations [40 CFR 144.19(a)]".

"EPA identified several factors that indicate a change in project operations that may increase risks to USDWs. These factors are to be considered by owners or operators and Class VI UIC Program Directors when determining whether a Class VI permit is required for carbon dioxide injection in wells currently permitted as Class II wells.

(1) Colour Scheme: Green – regulations exist; Orange – regulations/official guidance in the process of development; yellow – policy discussions or no available information.
(2) 2012 Worldwide EOR Survey 2012 Oil and Gas Journal 110 (4); See further Global Carbon Capture and Storage Institute 'The Global Status of CCS 2014' (2014), available at https://hub.globalccsinstitute.com/publications/global-status-ccs-2014/54-regional-policy-legal-and-regulatory-developments ;
Professor Richard Macrory, et al '*SCCS CO_2 EOR JIP Legal Status of CO_2 – Enhanced Oil Recovery*', UCL Carbon Capture Legal Programme *(*2013).
(3) Available at http://www.epa.gov/sites/production/files/2015-07/documents/epa816p13004.pdf

Considering these factors ahead of time may also ease the transition process at a later point in time. These factors are established in the Class VI Rule at 40 CFR 144.19(b), and include:

- *increase in reservoir pressure;*
- *increase in carbon dioxide injection rates;*
- *decrease in reservoir production rates;*
- *distance between injection zone and USDWs;*
- *suitability of Class II Area of Review (AoR) delineation;*
- *quality of abandoned well plugs;*
- *anticipated recovery of injected carbon dioxide at cessation of injection;*
- *source and properties of injected carbon dioxide; and*
- *additional factors determined by the EPA's UIC Program Director."*

It was anticipated that The EPA would publish its final rule towards the end of 2014. However in its absence, the EPA issued a 2-page memorandum specifying the 'Key Principles in EPA's Underground Injection Control Program Class VI Rule Related to Transition of Class II Enhanced Oil or Gas Recovery Wells to Class VI', which are as follows[(1)]:

1. Geologic storage of CO_2 can continue to be permitted under the EPA's UIC Class II program;
2. Use of anthropogenic CO_2 in EOR operations does not necessitate a Class VI permit;
3. Class VI site closure requirements are not required for Class II CO_2 injection operations;
4. EOR operations that are focused on oil or gas production will be managed under the Class II program;
5. The Class II and Class VI directors should work together to address the potential need for transition of any individual operation from a Class II to a Class VI permit;
6. The best implementation approach is for states to administer both the Class II and the Class VI EPA's UIC programs.

4.1.2 *Greenhouse Gas Reporting Programme*[2]

In December 2010, the EPA finalised a rule under the authority of the Clean Air Act requiring all facilities that conduct geologic sequestration of CO_2 and all other facilities that inject CO_2 underground to report greenhouse gas data to the EPA on an annual basis. The Reporting Rule is complementary to and builds on EPA's UIC programme, allowing any well or group of wells that inject a CO_2 stream for long-term containment in subsurface geologic formations to report. Facilities that conduct enhanced oil and gas recovery are not required to report geologic sequestration under Subpart RR unless:

- The owner or operator chooses to opt-in to subpart RR; or
- The facility holds an EPA's UIC Class VI permit for the well or group of wells used to enhance oil and gas recovery and reports under Subpart UU.

(1) Available at http://www.epa.gov/sites/production/files/2015-07/documents/class2eorclass6memo_1.pdf
(2) EPA Guidance available at http://www.epa.gov/sites/production/files/2015-07/documents/subpartrrruletraining2012.pdf

Furthermore, CO_2 EOR facilities may be required to report under Subpart RR if they are seeking to gain federal tax credits for the use of anthropogenic CO_2 for EOR under IRS 45Q.[(1)].

4.1.3 *Overview of US Regulation*

An overview of the Federal regulations relevant to EOR, CCS and considerations for transition can be found in *Table 4.3*.

A key potential gap in this transition guidance is the requirement to apply for a Class VI permit *'when there is an increased risk to Underground Sources of Drinking Water'*. It may not, therefore, cover CCS operations where there is no risk to USGW and given the increased monitoring and verification requirements, operators may well choose the cheaper option of Class II if given the choice.

In summary, the regulatory framework is in place for EOR and CCS, however the transition between the two is still under development and the challenges outlined in *Section 2* will need to be considered at a technical level and during permitting as summarized in *Table 4.2* (see key above).

Table 4.2 USA Federal Law – status of EOR to CCS regulatory transition

Type of Regulation	Project Lifecycle Stage		
	Commissioning	Operation	Closure / Stewardship
EOR			
Enabling transition			
CCS - specific			

(1) 26 USC Section 45Q – Credit for carbon dioxide sequestration. http://uscode.house.gov/uscode-cgi

Table 4.3 United States Legal and Regulatory Review Summary

		Project Commissioning	*Operation*	*Closure/Stewardship*
Enhanced Oil/Gas Recovery Regulation	**EPA's UIC Class II Oil and Gas Related Injection Wells**	(40 CFR 146.22/24): Permit information; (40 CFR 146.6): Area of review (AoR) and corrective action; (40 CFR 146.24): Financial responsibility (abandonment); (40 CFR 146.22): Injection well construction requirements	(40 CFR 146.22 (f)): Logging, sampling and testing; (40 CFR 146.23): Prohibitions during operation; (40 CFR 146.23): Mechanical integrity testing; (40 CFR 146.23(b): Injection fluid monitoring; (40 CFR 146.23(c): Annual Reporting.	(40 CFR 146.10(a)(1): Well plugging to prevent migration; (40 CFR 146.24(b)(4): Contingency plans (well failures). *No Post-injection site care and site closure.*
	Greenhouse Gas Reporting Programme (GHG RP) - Subpart UU		- Monitoring: CO_2 received; - Reporting: Mass of CO_2 received	- A facility must continue to report unless the mass of CO_2 received meets specified thresholds.
Potential Transition Pathway/Considerations	**Project continues to operate in terms of Class II Permit**	- Operators of EOR Facilities may opt-in to Subpart RR / instructed to report in accordance with Subpart RR Class II and Class VI Directors; - Additional risk assessments, authorizations or variations to existing permits maybe required for either pathway, in terms of the following Federal legislation, listed below (non-inclusive): 1) National Environmental Policy Act: undertaking an environmental assessment to determine if the activity would significantly affect the environment; 2) Clean Air Act: Title V Operating Permits for point source emitters; 3) Clean Water Act: Title VI Permits and Licenses; 4) Resource Conservation and Recovery Act: Waste storage or disposal Permits; - Consequences and/or uncertainty of State level primacy for Well II and Well VI authorizations(1)		
	If the transition to a CCS project would increase the risk profile in relation to USDW	**<u>Key additional Permit VI Requirements:</u>** 40 CFR 146.82 /83: Permit information (Site evaluation and baseline history); 40 CFR 146.84: AoR modelling; 40 CFR 146.85: Financial Responsibility (full lifecycle); 40 CFR 146.86: Injection well construction requirements;	**<u>Key additional Permit VI Requirements:</u>** 40 CFR 146.87: Logging, sampling and testing; 40 CFR 146.88: Injection well operating requirements; 40 CFR 146.89: Mechanical integrity testing; 40 CFR 146.90: Testing and monitoring requirements; 40 CFR 146.91: Reporting requirements (three types).	**<u>Key additional Permit VI Requirements:</u>** 40 CFR 146.92: Injection well plugging to prevent migration; 40 CFR 146.93: Closure and Post-injection site care; 40 CFR 146.94: Emergency and remedial response.
CCS Regulation	**EPA's UIC Class VI - Wells used for Geologic Sequestration of CO_2** **Greenhouse Gas Reporting Programme (GHG RP) – Subpart RR**		**<u>Key additional Greenhouse Gas Reporting Information (*inter alia*):</u>** - Mass of CO_2 received; injected; produced; emitted by surface leakage; equipment leakage and vented CO_2; - Approved monitoring, verification and reporting (MRV) plan; and - Quarterly records	**<u>Key additional Greenhouse Gas Reporting Information:</u>** - Plug and abandon all well(s); - Submit a request for site closure authorization.

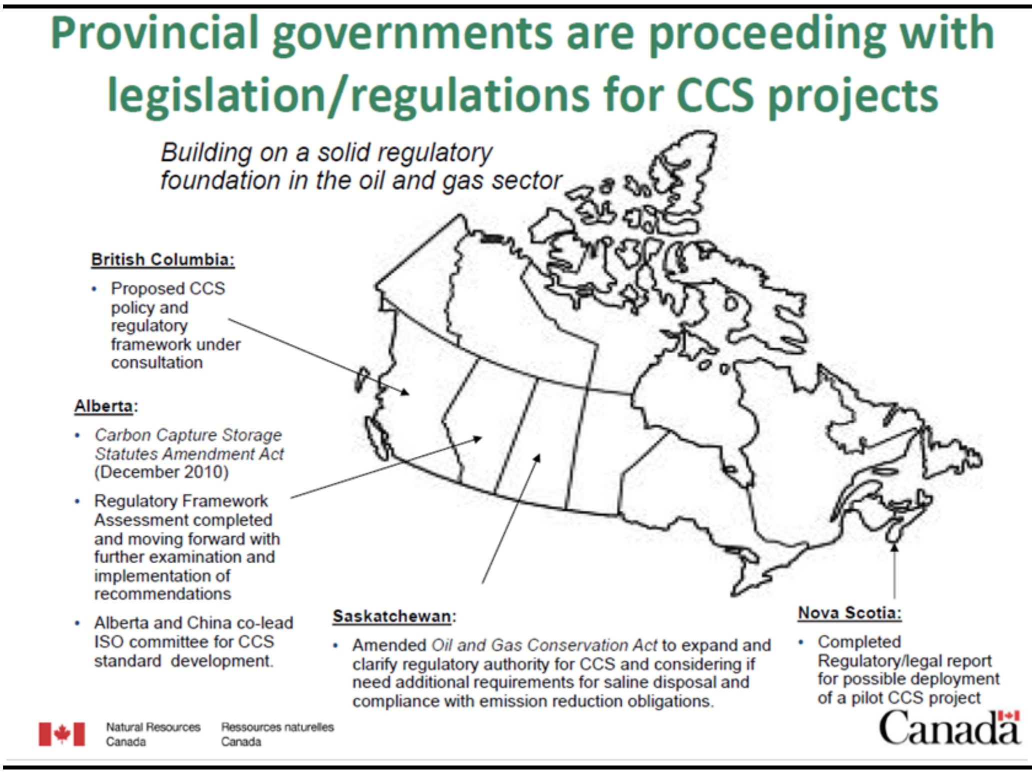
(1) Currently, at least 34 states have primacy for Class II wells, while seven states share Class II permitting authority with the EPA. For the remaining states, EPA retains primacy. A state's oil and gas development agency is likely to retain the regulatory authority with primacy to issue Class II permits. No state has applied for primacy to administer Class VI wells, but several states are understood to be communicating with the EPA and could apply for Class VI primacy in the future. Given the technical similarities in injecting CO_2 for enhanced oil recovery and for long-term geologic sequestration, states are likely to have the agency that administers Class II wells also administer Class VI wells. See further http://www.c2es.org/publications/state-policy-actions-overcome-barriers-carbon-capture-sequestration-enhanced-oil-recove

4.2 CANADA

CO_2 EOR is a primary policy, regulatory and legal driver for carbon capture, utilisation and storage (CCUS) in Canada. Regulating resource development is the responsibility of the provinces, while the federal government is responsible for the regulation of cross-border issues such as climate change. Therefore, the physical injection of CO_2 in a single province is under the purview of that particular province, while setting standards for what can or cannot be counted under provincial and federal CO_2 reduction targets will be a shared responsibility.

The Government of Canada and the provinces have been engaged in updating their existing oil and gas regulatory and CCS – specific frameworks [1]. *Figure 4.1* provides an overview of the current provincial CCS policy and regulatory development activity in Canada.

Figure 4.1 *CCS Policy and Regulatory Development in Canada*[2]



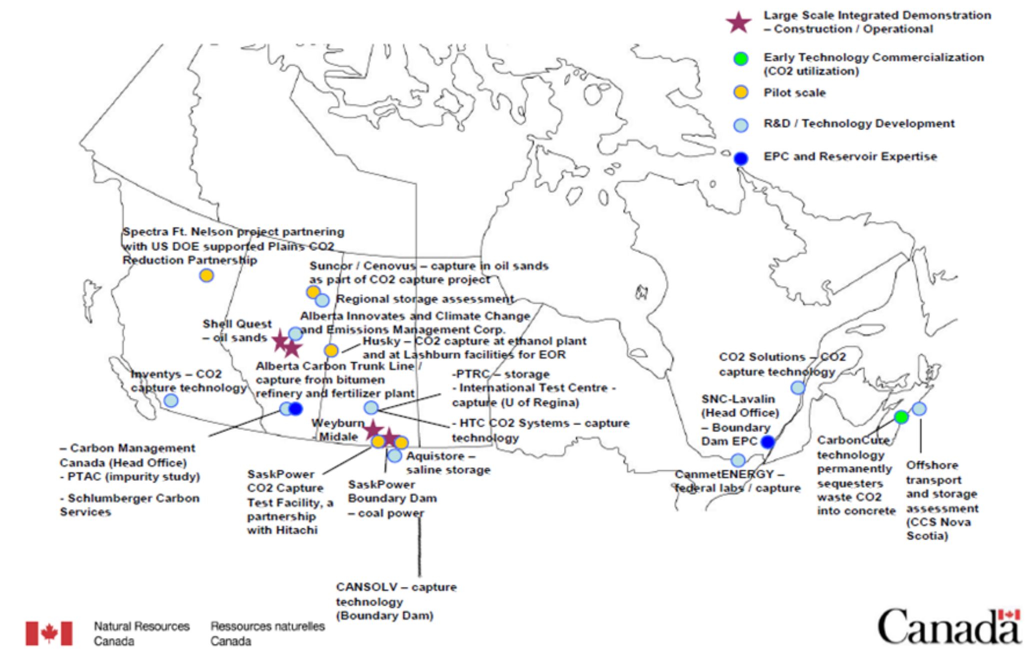
Building on the technical and regulatory experience developed CO_2 EOR in the oil and gas sector over three decades, a number of related large CCS demonstration projects and pilot-scale research projects have been commissioned across the country. Specific to CO_2 EOR, it is understood that at least 195 CO_2 injection wells are reported to be active, the majority of which

(1) Global Carbon Capture and Storage Institute '*The Global Status of CCS 2014*' (2014). Available at https://hub.globalccsinstitute.com/publications/global-status-ccs-2014/54-regional-policy-legal-and-regulatory-developments

(2) Kathryn Gagnon 'Canada Update: Select CCS Regulatory Developments' Presentation at the IEA 6th CCS Regulatory Network Meeting (2014). Available at https://www.iea.org/media/workshops/2014/ccsregnet/3.3_Gagnon.pdf

are associated with the Weyburn project in Saskatchewan[1]. *Figure 4.2* provides an overview of CCS development projects in Canada at the moment.

Figure 4.2 ***CCS Development Projects in Canada***[2]



4.2.1 *Alberta*

Alberta presents a comprehensive regulatory framework for the oil and gas sector, administered by the Energy Resources Conservation Board (ERCB), under the Oil and Gas Conservation Act. In addition, Alberta has a history of injecting substantial quantities of CO_2 into deep geological formations as part of acid gas disposal (AGD) in order to reduce atmospheric emissions of hydrogen sulphide (H_2S). The acid gas can contain up to 95% CO_2 [3] .

CCS – specific legislation has been developed in the form of the Carbon Capture and Storage Statutes Amendment Act 2010. Although this amends legislation that applies to certain types of oil and gas activities, CO_2 EOR is not explicitly addressed.

The Report compiled in 2013 by the UCL Carbon Capture Legal Programme considering the '*Legal Status of CO_2 – Enhanced Oil Recovery*', provides an effective summary of the key transition issues in the province of Alberta:

- "All sub-surface injection of CO_2 has been classified as AGD under the ERCB's Directive 065, but the introduction of the Carbon Sequestration Lease will allow the alternative option of 'CO_2 sequestration'. As things stand, new operators could choose either registration;

[1] 2012 Oil & Gas Survey. See further Global CCS Institute '*Bridging the Gap: An Analysis and Comparison of Legal and Regulatory Frameworks for CO_2–EOR and CO_2–CCS*', (October 2013), pp 47.
[2] Kathryn Gagnon 'Canada Update: Select CCS Regulatory Developments' Presentation at the IEA 6th CCS Regulatory Network Meeting (2014). Available at https://www.iea.org/media/workshops/2014/ccsregnet/3.3_Gagnon.pdf
[3] Professor Richard Macrory, et al 'SCCS CO_2 EOR JIP Legal Status of CO_2 – Enhanced Oil Recovery', UCL Carbon Capture Legal Programme (2013), pp 37.

- Carbon offset credits can be obtained for any new CO_2 that is verified as injected and contained within the geological formation, for either resource recovery or sequestration purposes;
- There is currently no regulation enabling a project operating as CO_2 EOR for most of its active life to change its registration to CO_2 sequestration as it nears the end of the injection period. Among other things, such a change could allow the operator to transfer liability to the state after closure, a protection that is not currently offered to oil and gas producers, or to AGD; and
- The hydrocarbon reservoir developed by EOR would not necessarily have met the site selection criteria for sequestration; minimum depth; or tenure requirements; the monitoring, measurement and verification (MMV) practices would have been different; and different requirements would have existed in relation to financial security and contributions to cover post-closure care."

For the purposes of addressing these and other regulatory issues, the Government of Alberta initiated a process called the Regulatory Framework Assessment (RFA) in March 2011. This process considered regulations that currently apply to CCS in Alberta as well as regulations and best practices in other parts of the world. The consultative process culminated in 71 individual recommendations and nine conclusions. *Table 4.4* summarizes key recommendations from Section 15 for the RFA which are of direct relevance to CO_2 EOR/CCS activities[(1)].

Table 4.4 Key Recommendations in the Alberta Regulatory Framework Assessment

Recommendation 68 The Government of Alberta should define what qualifies as CO_2 sequestration, CO_2 EOR and acid gas disposal, with particular attention to the distinction between CO_2 sequestration and acid gas disposal.	**Recommendation 70** The regulator should align and/or amend its regulations and requirements to explicitly cover CO_2 sequestration, as deemed appropriate (e.g. Directive 065).
Recommendation 69 The Government of Alberta should identify differences in how CO_2 injection and storage activities are regulated as CO_2 sequestration, CO_2 enhanced oil recovery and acid gas disposal, and address them appropriately to ensure regulatory consistency and/or that regulatory differences can be justified.	**Recommendation 71** The Government of Alberta should review the requirements for CO_2 EOR projects requesting to transition to CO_2 sequestration to ensure that they meet the same objectives as the requirements for CO_2 sequestration projects.129

Although recent developments have focused on the regulatory framework as it applies to CCS projects, there is widespread recognition of opportunities stemming from the use of industrial CO_2 in EOR in Alberta, and the importance of encouraging their development. Opportunities stem from the dual benefits of CO_2 - EOR[(2)] projects: increased oil production, and the potential benefit of geological sequestration of anthropogenic CO_2. In Alberta, CO_2 EOR projects can gain recognition for CO_2 sequestration activities in the form of CO_2 offset credits under the Alberta Specified Gas Emitters Regulation

(1) Report available at http://www.energy.alberta.ca/CCS/pdfs/CCSrfaNoAppD.pdf
(2) CO_2 EOR in this context refers to CO_2 EOR projects using CO_2 generated from industrial sources.

(SGER)(1). Projects wishing to gain credit for sequestered CO_2 must meet specific Measurement, Monitoring and Verification (MMV) requirements set out in the CO_2 EOR protocol for eligibility for CO_2 credits to ensure the viability of the long-term storage of CO_2(2). *Table 4.6* summarizes the regulations relating to each stage of the project lifecycle in Alberta.

4.2.2 *Saskatchewan*

As is the case in the Province of Alberta, Saskatchewan has over three decades of experience in the injection of CO_2 into the subsurface. There are reported to be in excess of 6000 wells injecting various substances into subsurface reservoirs, all regulated under existing legislation: Saskatchewan Oil and Gas Conservation Act RSS 1978 (O&G Act).[3] Current CO_2 storage operations in Saskatchewan were developed under the pre-existing oil and gas framework, amended in 2011, including the Weyburn project detailed in Section 3 . *Table 4.7* summarizes the regulations relating to each stage of the project lifecycle in Saskatchewan.

4.2.3 *British Columbia*

Complementing its neighbouring provinces, British Columbia has a comprehensive oil and gas regulatory regime: the Petroleum and Natural Gas Act (P&NG Act) and the Oil and Gas Activities Act (OGAA). The more common activities occurring in this jurisdiction is the temporary storage of marketable natural gas and disposal of acid gas. Importantly, there are currently no explicit authorization provisions for CO_2 EOR projects, although it is not to say that the current regime is not sufficient to enable such an activity.[4] Furthermore, the Ministry of Natural Gas Development is developing a regulatory policy framework for CCS. The proposed framework developed for CCS would apply to the use of underground storage reservoirs for any substance. The key purposes of developing such a framework is to[5]:

- Identify and address any regulatory gaps;
- Ensure that CCS is done safely to protect the public and the environment; and
- Provide transparency in CCS development.

Table 4.8 summarizes the policies relating to each stage of the project lifecycle in British Columbia based on the '*Carbon Capture and Storage Regulatory Policy Discussion and Comment Paper*'.

(1) Alberta Regulation 139/2007 Climate Change and Emissions Management Act – Specified Gas Emitters Regulation. http://www.canlii.org/en/ab/laws/regu/alta-reg-139-2007/latest/alta-reg-139-2007.html. Under the SGER, large industrial emitters in Alberta are required to meet emissions intensity reduction targets of 12% per year from an approved baseline emission intensity. Facilities in Alberta that are able to reduce their GHG emissions according to a government approved protocol are eligible to generate CO_2 offset credits that can be bought and sold in the Alberta offset market. This offers a compliance option to facilities subject to SGER emissions intensity reduction targets.
(2) Alberta Environment - Specified Gas Emitters Regulation: Quantification Protocol for Enhanced Oil Recovery, 2007. http://environment.alberta.ca/02291.html
(3) 2015 SaskPower CCS Symposium Presentation, available at http://www.saskpowerccs.com/2015-symposium/event-recap/Floyd%20Wist%20-%20Regulat%20of%20CCS%20in%20Saskatchewan.pdf ; See further regulatory analysis http://www.iea.org/ccsdatabase/ccs/canada/name-40237-en.html#13
(4) See legal and regulatory index page at http://www.iea.org/ccsdatabase/ccs/canada/
(5) Province of British Columbia '*Carbon Capture and Storage Regulatory Policy Discussion and Comment Paper*' (2014) available at http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-gas-oil/uploads/ccs_rpf_discussion_paper_final_2014.pdf

4.2.4 *Overview of Canadian Regulation*

In summary, the regulatory framework is in place for EOR and CCS in Alberta and Saskatchewan and is being developed in British Columbia as summarized in *Table 4.5* (see key above). There are no guidelines or regulations relating to the transition from EOR to CCS and the challenges outlined in *Section 2* will need to be considered at a technical level and during permitting but the broad framework is in existence or development.

Table 4.5 Status of EOR to CCS regulatory transition in Canada

Canadian Province	Type of Regulation	Project Lifecycle Stage		
		Commissioning	Operation	Closure / Stewardship
Alberta	EOR			
	Enabling transition			
	CCS - specific			
Saskatchewan	EOR			
	Enabling transition			
	CCS - specific			
British Columbia	EOR			
	Enabling transition			
	CCS - specific			

Table 4.6 Alberta Canada Legal and Regulatory Review Summary

		Project Commissioning	***Operation***	***Closure/Stewardship***
Enhanced Oil/Gas Recovery Regulation	**Enhanced Oil Recovery Program Guidelines;**	- Application under *Enhanced Oil Recovery Royalty Regulation AR156/2014* (Alberta Energy); - Scheme must also be approved by the Alberta Energy Regulator (AER) under Section 39 of the *Oil and Gas Conservation Act (*applications submitted simultaneously).	- Operate in accordance with applicable regulations under the Oil and Gas Conservation Act; - Measurement, Monitoring and Verification requirements set out in the CO_2 EOR Protocol; - Contributions to Orphan Well Fund - Alberta Energy may conduct periodic reviews of the scheme and ask for additional information.	- An operator may request termination or suspension of the EORP approval; - The operator must specify the date they want the EORP approval to be suspended or terminated; - Abandonment requirements in accordance with the *Oil and Gas Conservation Act*.
Potential Transition Pathway/Considerations	- Evaluation of geophysical properties in terms of the Mines and Minerals Act; - Obtain new or amended well licence and approval of the Alberta Energy Regulator; - Comply with the additional monitoring, measurement and verification requirements in the sequestration approval received from the Energy Regulator		**Regulatory Framework Assessment Report:** *Recommendation 71*: The Government of Alberta should review the requirements for CO_2 EOR projects requesting to transition to CO_2 sequestration to ensure that they meet the same objectives as the requirements for CO_2 sequestration projects. Policymakers may rely on the Canada's first CCS Standard (CSA Z741) which lays out broad operational requirements for CCS. CSA Z741 establishes a standardized approach to CCS projects consistent with industry best practices and regulatory requirements.	
CCS Regulation	**Carbon Capture and Storage Statutes Amendment Act 2010**	- Mines and Minerals Act: Agreement to evaluate the geological or geophysical properties of a subsurface reservoir and/or right to inject captured carbon dioxide into a subsurface reservoir for sequestration; - Carbon Sequestration Lease in terms of the Carbon Sequestration Tenure Regulation (68/2011); - Obtain a well licence and approval of the Regulator under the Oil and Gas Conservation Act;	A lessee of an agreement under this Act shall in accordance with the applicable Regulations: - Comply with a monitoring, measurement and verification plan that has been approved; - Provide reports with respect to the lessee's compliance with the monitoring, measurement and verification plan (Section 17 of Carbon Sequestration Tenure Regulation); - Contribute to the Post Closure Stewardship Fund	- Apply to the Minister for a closure certificate in accordance with the Regulations and the lessee has complied with the agreement and associated legislation; - The Crown becomes the owner of the captured carbon dioxide injected pursuant to the agreement and assumes all obligations of the lessee.

Table 4.7 Saskatchewan Canada Legal and Regulatory Review Summary

		Project Commissioning	*Operation*	*Closure/Stewardship*
Enhanced Oil/Gas Recovery Regulation	**Enhanced Oil Recovery Project Guidance**[1]	- Section 54 of The *O&G Regulations 2012* approval from the Minister of the Economy before beginning any work on wells for the purpose of an EOR project (*Section 17 of the O&G Act*).	- Reporting requirements are detailed in the project authorization. Minimum requirements provided in the Guidance; - Requirements in terms of *Section 17.01 of the O&G Act;* - Operator contributes to the Oil and Gas Orphan Fund.	- Licence to abandon wells and facility in terms of *Section 8 and 8.01 of the O&G Act*, - Responsibility of the licensee will continue with respect to any obligations of the licensee under the Act or the regulations.
Potential Transition Pathway/Considerations	- CO_2 EOR and permanent sequestration activities all captured under existing oil and gas regulatory framework (as amended); - No explicit guidance currently exists on the transition from a CO_2- EOR project to permanent CO_2 sequestration; - Assumed that Ministry of Energy and Resources remains as the competent authority for the transition application which should benefit the process		**Reported Regulatory Considerations in Saskatchewan:** - Government to consider what additional policy/regulatory requirements may be necessary to ensure sufficient measurement, monitoring, and verification is undertaken of the subsurface CO_2 injection to demonstrate compliance with emission reduction obligations; - If additional policy/regulatory requirements are necessary for large saline aquifer disposal projects; - Reviewing the policies and regulations established by other jurisdictions to determine if any desirable revisions should be made to the policies and regulations currently applied to CCS field activity.	
CCS Regulation	**Saskatchewan Oil and gas Conservation Act & Regulations.**[2]	- Section 53 of the *O&G Regulations 2012* (Disposal of waste and other substances); - Section 17 of the Oil and gas Conservation Act states - the minister may make orders approving plans for injecting, storing or disposing of oil and gas wastes or non-oil-and-gas substances in subsurface formations.	- Reporting requirements are detailed in the project authorization. Minimum requirements provided in the Guidance; - Requirements in terms of *Section 17.01 of the O&G Act;* - Operator contributes to the Oil and Gas Orphan Fund.	- Licence to abandon wells and facility in terms of *Section 8 and 8.01 of the O&G Act* and the well facility decommissioning and reclamation requirements under Regulation 56 of the Oil and Gas Conservation Regulations 2012; - Responsibility of the licensee will continue (i.e., licensee will remain liable) with respect to any obligations of the licensee under the Act or the regulations. (3)

(1) Government website guidance: https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/oil-and-gas/oil-and-gas-licensing-operations-and-requirements/oil-and-gas-drilling-and-operations/enhanced-oil-recovery-projects

(2) See legal and regulatory index page at http://www.iea.org/ccsdatabase/ccs/canada/

(3) The existing Oil and Gas legislation was amendment (extended) to include CCS activities. As the legislation and its regulations largely apply to more conventional oil and gas activities, there is no explicit provision in terms of "long-term" liability or stewardship. As mentioned above, it is reported that the Saskatchewan Government are reviewing the policies and regulations established by other jurisdictions to determine if any desirable revisions should be made to the policies and regulations currently applied to CCS field activity – therefore it is reasonable to expect further guidance to be issued in time to come. Section 8 and Regulation 56 do also appear to allow the authorities to exercise discretionary power in terms of the requirements and content of a licence to abandon wells the undertake facility reclamation.

Table 4.8 British Columbia Canada Legal and Regulatory Review Summary

		Project Commissioning	*Operation*	*Closure/Stewardship*
CO_2 Sequestration	**CCS Regulatory and Policy Framework**	- Proposing the creation of three categories of storage reservoir lease based on a project's development stage: developmental, operational, and post-closure. Each lease category would have a different purpose, term-length and right of extension. The Minister would have discretion over whether a project moves from one category of storage reservoir lease to the next; - The Ministry is proposing to clarify and strengthen the lease application process for underground storage reservoirs to be used for CCS and to include the establishment of a rigorous site evaluation and selection process.[1]	- The core obligations of operators under OGAA would apply to CCS operations as per current legislation, which includes CCS as an oil and gas activity. CCS operators would follow the regulatory process for acid gas disposal projects and therefore be required to obtain OGC approvals; - Operators would also submit an application to operate a CO_2 injection plan; - CCS project proponents would develop a monitoring plan that is results-based and informed by site-specific risk assessments.	- Once the CCS project is complete, the Ministry is proposing the creation of a post-closure assurance phase during which the operator would continue to maintain all project liability, monitoring, maintenance and remediation responsibilities; - The Ministry is considering the establishment of a Storage Reservoir Stewardship Board; - It is proposed that a minimum of 15 years must pass post-injection before an operator could submit an application to the Board; - The Ministry is considering the transfer of long-term liability for storage reservoirs back to the Crown following the completion of the Post Closure Assurance period.

(1) See further 'Resource Management considerations' on page 8 of the Discussion Paper.

4.3 *EUROPE*

CCS activities in Europe are regulated under the 2009 EU Directive on the geological storage of carbon dioxide ('CCS Directive') [(1)], an instrument that is commonly understood to be one of the most comprehensive examples of CCS-specific legislation in the world. In support of the implementation process, delayed by lagged transposition by a number of Member States, The European Commission published four Guidance Documents in 2011:

- Guidance Document 1: CO_2 Storage Life Cycle Risk Management Framework;
- Guidance Document 2: Characterization of the Storage Complex, CO_2 Stream Composition, Monitoring and Corrective Measures;
- Guidance Document 3: Criteria for Transfer of Responsibility to the Competent Authority;
- Guidance Document 4: Financial Security (Art. 19) and Financial Mechanism (Art. 20).

CCS Directive 2009/31/EC Review[(2)]

In May 2014, the European Commission launched a consultative review process in order to assess the CCS Directive's effectiveness, relevance, efficiency, coherence and EU-added value.

With respect to the Directive itself, the following specific issues were highlighted:

- the feasibility of retrofitting power plants for CO_2 capture;
- Emissions Performance Standards (EPS) for the role played by integrated transport and storage infrastructure in Europe ahead of establishing capture projects to maximize social benefits; and
- – the definition of 'permanent' in the case of storage, transfer of responsibility for a storage site, financial security, financial mechanisms and the criteria for establishing and updating the monitoring plan.

More recently, Member States were required to submit an Implementation Report to the European Parliament (EP) and European Council by 31 March 2015.

Application to CO_2 EOR and the EU ETS Directive

For the purposes of this study, the following points should be noted:

1) The EU Emissions Trading System (EU ETS Directive 2003/87/EC) has been amended by the European Commission to include the capture of GHGs from installations covered by this Directive for the purpose of transport and geological storage in a storage site permitted under

(1) Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0031:EN:NOT
(2) Global Carbon Capture and Storage Institute 'The Global Status of CCS 2014' (2014). Available at https://hub.globalccsinstitute.com/publications/global-status-ccs-2014/54-regional-policy-legal-and-regulatory-developments

Directive 2009/31/EC (CCS Directive). This effectively means that installations undertaking a *pure* CO_2 storage activity must acquire an EU ETS permit and comply with the monitoring and reporting requirements, in accordance with the Directive[1];

2) There are not substantive provisions in relation to CO_2 EOR (Enhanced Hydrocarbon Recovery or 'EHR') in the CCS Directive, however Recital 20 in the Preamble states the following:

> *"EHR is not in itself included in the scope of this Directive. However, where EHR is combined with geological storage of CO_2, the provisions of this Directive for the environmentally safe storage of CO_2 should apply. In that case, the provisions of this Directive concerning leakage are not intended to apply to quantities of CO_2 released from surface installations which do not exceed what is necessary in the normal process of extraction of hydrocarbons, and which do not compromise the security of the geological storage or adversely affect the surrounding environment.*

Although the legal status of the Preamble text is debatable[2], there appears to be a consensus amongst commentators that the CCS Directive will apply to a CO2 EOR project, provided that the CO_2 for the purposes of 'permanent storage' (i.e. incidental CO_2 storage during a conventional EOR operation) would be considered to be beyond the remit of the CCS Directive, and therefore, the EU ETS Directive. An existing EOR project wishing to obtain credit for the CO_2 stored would therefore have to retrospectively undertake the geotechnical assessments required for site evaluation and other activities in order to comply with the CCS Directive.

United Kingdom

The CCS Directive has been transposed under the Energy Act 2008, providing clear implementation guidance through the following supporting regulations:

1) The Storage of Carbon Dioxide (Amendment of the Energy Act 2008 etc.) Regulations 2011;
2) The Storage of Carbon Dioxide (Licensing etc.) Regulations 2010;
3) 2012 Regulations (amending the 2010 Regulations), which implement Article 15 of the CCS Directive on the inspection of carbon dioxide storage complexes
4) Storage of Carbon Dioxide (Access to Infrastructure) Regulations 2011, which implement Articles 21 and 22 of the CCS Directive, on third party access to carbon dioxide storage sites and transport networks; and
5) The Storage of Carbon Dioxide (Termination of Licences) Regulations 2011, which implement Articles 18 and 20 on the transfer of responsibility for a closed storage site and the associated financial mechanism.[3]

In terms of Section 17 of the Act, a licence is required for the use of a controlled place for the storage of carbon dioxide (*with a view to its permanent*

(1) Professor Richard Macrory, et al 'SCCS CO_2 EOR JIP Legal Status of CO_2 – Enhanced Oil Recovery', UCL Carbon Capture Legal Programme (2013), pp 17.
(2) Further legal interpretation and analysis see Professor Richard Macrory, et al 'SCCS CO_2 EOR JIP Legal Status of CO_2 – Enhanced Oil Recovery' , UCL Carbon Capture Legal Programme (2013), pp 12; *'Bridging the Gap: An Analysis and Comparison of Legal and Regulatory Frameworks for CO_2–EOR and CO_2–CCS'*, Global CCS Institute (October 2013), pp 64.
(3) Available at http://www.legislation.gov.uk/ukpga/2008/32/contents

disposal, or as an interim measure prior to its permanent disposal); or the conversion of any natural feature in a controlled place for the purpose of storing carbon dioxide (with a view to its permanent disposal, *or as an interim measure prior to its permanent disposal*). Importantly, the wording of this section appears to be consistent with the CCS Directive, only including a CO_2 EOR project for the purpose of permanent storage, following the depletion of the oil-bearing reservoir[(1)]. Furthermore, in relation to the UK context, the UCL CCS Programme Report referenced here, offers the following remark:

> *"In practice, at present at least, it seems likely that any proposed sites for UK EHR operations will in fact be already selected as CCS storage sites in accordance with the Directive, and these transitional issues or the need to secure exemption from the Directive are not an immediate issue"*[(2)].

Finally, Section 33 of the Energy Act makes provision for the following discretionary authority:

> *(1) The use of carbon dioxide, in a controlled place, for a purpose ancillary to getting petroleum is to be regarded as –*
>
> > *(a) an activity within section 17(2); or*
> >
> > *(b) the storage of gas for the purposes of section 1(3)(b), only in the circumstances specified by the Secretary of State by order;*
>
> *(2) Orders made under this section are without prejudice to Part 1 of the Petroleum Act 1998;*
>
> *(3) An order under this subsection may provide that the use of carbon dioxide, in a designated place, for a purpose ancillary to getting petroleum is to be regarded, for the purposes of this Chapter, as the use of carbon dioxide in a controlled place for such a purpose.*

On the basis of the Explanatory Notes that accompany the Act and respective Regulations, it is understood that the intention is to use this power, for example, to ensure that the requirements extend to operators undertaking an EOR activity if those operators wish to claim credits under the EU ETS. This being said, the pursuit of emission credits is not the sole reason on which the CCS Directive may be considered to apply to a particular project [(3)].

4.3.1 Overview of EU Regulation

The requirement to comply with the CCS Directive means that the regulatory framework is in place for a transition from EOR to CCS in the EU as summarized in *Table 4.9* (see key above). An overview of the EU regulations can be found in *Table 4.10*.

Table 4.9 EU – status of EOR to CCS regulatory transition

Type of Regulation	Project Lifecycle Stage		
	Commissioning	Operation	Closure / Stewardship
EOR			
Enabling transition			
CCS - specific			

(1) Professor Richard Macrory, et al 'SCCS CO_2 EOR JIP Legal Status of CO_2 – Enhanced Oil Recovery', UCL Carbon Capture Legal Programme (2013), pp 14.
(2) *Ibid.*
(3) *Ibid*, pp 24.

Table 4.10 European Union Legal and Regulatory Review Summary

<table>
<tr><th colspan="2"></th><th>Project Commissioning</th><th>Operation</th><th>Closure/Stewardship</th></tr>
<tr><td rowspan="2">Potential Transition Pathway/Considerations</td><td>Pure CO_2 EOR Activities: National Oil and gas Regulatory Frameworks</td><td colspan="3">Pure CO_2 EOR projects licenced under national regulatory regimes to the extent that enabling provisions exist, for example:
- UK: Petroleum Act 1998 – no clear guidance for exploration and appraisal for CO_2 injection (Competent Authority is The Energy Development Unit within the DECC)[(1)];
- Norway: Petroleum Activities Act 1996 (Competent Authority is Ministry of Petroleum and Energy).</td></tr>
<tr><td>CO_2 EOR to Permanent Sequestration: CCS Directive/EU ETS Directive</td><td colspan="3">Potential issues in regulating CO_2 EOR projects under the CCS Directive:
- Member State transposition and consistency in national implementation;
- Capacity to administer the transition; and
- Further substantive guidance would still be necessary for a pure CO_2 EOR project opting/required to make the transition duration operation.</td></tr>
<tr><td>CCS Regulation</td><td>CCS Directive 2009 / EU ETS Directive 2003</td><td>Article 4: Selection of Storage Site (Annex I);
Article 5: Exploration Permit
Article 6: Storage Permits;
Article 8: Conditions for storage permits - Prescribed operating requirements.

EU ETS Directive
Article 4: Greenhouse gas emissions permits;
Article 6: Conditions for and contents of the greenhouse gas emissions permit.</td><td>Article 12: CO_2 stream acceptance criteria and procedure;
Article 13: Monitoring
Monitoring plan designed by the operator pursuant to the requirements Annex II;
Article 14: Reporting
Monitoring report submitted at least once a year.

EU ETS Directive
Article 7: Changes relating to installations;
Article 14: Guidelines for monitoring and reporting of emissions (read with Annex IV);
Article 15: Verification (read with Annex V).</td><td>Article 17: Closure and post-closure obligations
A storage site shall be closed if the relevant conditions stated in the permit;
Article 18: Transfer of responsibility
All legal obligations relating to monitoring and corrective measures, shall be transferred to the competent authority;
Article 20: Financial mechanism
Covers at least the anticipated cost of monitoring for a period of 30 year.</td></tr>
</table>

(1) Available at http://www.legislation.gov.uk/ukpga/1998/17/pdfs/ukpga_19980017_en.pdf ; Professor Richard Macrory, et al 'SCCS CO_2 EOR JIP Legal Status of CO_2 – Enhanced Oil Recovery', UCL Carbon Capture Legal Programme (2013), pp 24.

4.4 AUSTRALIA

In Australia, states and territories have jurisdiction over CCS activities onshore and up to three nautical miles offshore, beyond which jurisdiction is with the federal government. At the federal level, offshore storage of CO_2 is regulated through the 2006 Offshore Petroleum and Greenhouse Gas Storage Act (OPGGS Act), as amended by the Offshore Petroleum and Greenhouse Gas Storage Legislation Amendment Act 2010. In 2011, the development of a set of Regulations under the OPGGS Act was finalised with the publication of the Resource Management and Administration Regulations 2011, and the Gas Injection and Storage Regulations 2011. These regulations consolidate and streamline the various resources, administration, injection and storage-related requirements set out under the OPGGS Act.

Furthermore, dedicated CCS legislation exists onshore in the States of Victoria, Queensland, and South Australia. New South Wales and Western Australia are in the process of developing CCS legislation that is likely to be based on existing oil and gas regulations, as well as federal offshore CCS legislation.

A review of the available resources produced minimal content pertaining to CO_2 EOR activities in Australia and no best-practice guidance development for the subject matter under review. Referenced a number of times in the preceding section of this Report, the UCL Carbon Capture Legal Programme Report provides an effective summary of the relevant legislative provisions, as they apply in this context. This summary has been compiled into *Table 4.11*, including additional commentary and current policy and regulatory developments of note [1]:

The regulatory framework is in place CCS but given the lack of EOR activities in Australia no explicit provisions for EOR or transition to CCS have been identified as summarized in *Table 4.12* (see key above).

Table 4.11 Australia – status of EOR to CCS regulatory transition

Type of Regulation	**Project Lifecycle**		
	Commissioning	**Operation**	**Closure / Stewardship**
EOR			
Enabling transition			
CCS - specific			

[1] Professor Richard Macrory, et al 'SCCS CO2 EOR JIP Legal Status of CO2 – Enhanced Oil Recovery', UCL Carbon Capture Legal Programme (2013), pp 33-35.

Table 4.12 Australia Legal and Regulatory Review Summary

Jurisdiction	CO_2 Storage	CO_2 EOR/EHR	Regulatory Transitional Guidance Available	Policy Development
Commonwealth	Offshore Petroleum and Greenhouse Gas Storage Act 2006 – Section 98.	Offshore Petroleum and Greenhouse Gas Storage Act 2006 – Section 161.	None	None
Queensland	Greenhouse Gas Storage Act 2009.	Greenhouse Gas Storage Act 2009 - Section 14; Petroleum Act 1923 and Petroleum and Gas (Production and Safety) Act 2004.	None	The Modernising Queensland Resources Acts (MQRA) Program until 2016-17: Progressively modernise, simplify and harmonise the resources legislation. See https://www.dnrm.qld.gov.au/our-department/policies-initiatives/mining-resources/legislative-reforms/mqra/why-new-resources-act
Victoria	Onshore Victoria Greenhouse Gas Geological Sequestration Act & 2009 Regulations; Offshore Petroleum and Greenhouse Gas Storage Act & 2012 Regulations (up to three nautical miles offshore).	Petroleum Act 1998 – Sections 6,8,46.	None	First State to have finalised its CCS regulatory framework for both onshore and offshore CO_2 storage.
South Australia	Petroleum and Geothermal Energy Act 2000 - Section 10.	Petroleum and Geothermal Energy Act 2000 - Sections 21, 34.	None	None

4.5 *BRAZIL*

The state-owned oil company, Petrobras[(1)], has been conducting EOR activities for over two decades in accordance with Brazil's general environmental and oil and gas regulations. This has enabled the development of technological and geo-physical experience in CO_2 injection into offshore oil-bearing reservoirs. The commercial Lula Oilfield operation in the Santos Basin is such an example, and is further described in Section 4 of this Report. Oil and gas related activities are generally required to comply with specific resolutions issued by competent governmental agencies, including, the *Agência Nacional de Petroleo, Gas e Biocombustiveis* (oil sector regulating agency). Resolution provisions include local content requirements or conditions and gas flaring reduction targets. It is understood that there are currently no Ministerial Resolutions providing specific guidance for a CO_2 EOR project to transition to permanent storage.

Furthermore, there is currently no legal or regulatory framework specific to CCS operations. However, the following developments are worth noting:

1) Brazil is a member of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and the 1996 London Protocol, as well as, Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal;
2) CCS is mentioned as a potential technology being developed by the oil and gas industry in the 2008 National Climate Change Plan (Plano Nacional de Mudança do Clima);
3) The 2009 National Climate Change Policy (Política Nacional sobre Mudança do Clima) does not refer to specific technologies, but aims to incentivize the strengthening of emission reduction technologies and the promotion of carbon sinks;
4) CCS is mentioned in the research and development plans under the Ministry of Science, Technology and Innovation (Petrobras research informs these plans);
5) CCS is not explicitly mentioned in the 2015 Intended Nationally Determined Contribution to the UNFCCC and Brazil has opposed the adoption of CCS technology as a CDM modality. The country has, however, previously advocated for another framework using specific financial/funding mechanisms under the UNFCCC.

In advancing the agenda for potential CO_2 sequestration in Brazil, the Center of Excellence in Research and Innovation in Petroleum, Mineral Resources and Carbon Storage (CEPAC) produced the *'Brazilian Atlas of CO_2 Capture and Geological Storage'*. With the assistance of Petrobras and the Global CCS Institute, the Atlas Report represents the consolidation of nearly a decade of research and data gathering undertaken by specialist professionals /organizations since 2007. The research areas that have informed the content include the following:

(1) Petrobras is a member of the CO_2 Capture Project Phase 4.

- Geological and mineralogical evaluation of storage reservoirs and reservoir interaction with CO_2;
- Investigation of the integrity and reliability of different materials and procedures applied to the injection of CO_2 through injection wells, in order to maximize the safety and feasibility of geological carbon storage;
- Studies of the geochemical interactions and flow mechanisms in the CO_2-water-rock system with focus on Brazil's pre-salt reservoirs; and
- Development of a Geographic Information System (GIS) containing data on CO_2 emissions resulting from stationary sources, transport infrastructure, and potential geological reservoirs.

The Atlas Report contains a number of constructive findings and it represents an initial step to inform further regulatory development and future CCS demonstration projects. For the purposes of this study, the following conclusions have been identified(1):

1) Overall, Brazil has a favorable situation regarding the potential for CO_2 geological storage. The country has a large area covered with sedimentary basins, both onshore and offshore. Most of the stationary emitting sources, especially in the Southeast region, are located in proximity to these basins;
2) The continental margin basins stand out as the main producers of hydrocarbons (Figure 40; Figure 41). The continental margin basins stand out as the main producers of hydrocarbons (Atlas Report, Figure 40; Figure 41). The Campos Basin is one of the major producing fields. The Santos Basin will possibly continue to be a major area of hydrocarbon production in Brazil from 2025 when exploitation of pre-salt reservoirs will increase substantially;
3) Further case reference is made to the Lula Oilfield Project located in the ultra-deep waters off Brazil's south-eastern coast.

4.5.1 *Overview of Brazilian Regulation*

CO_2 EOR is currently undertaken within existing petroleum legislation in Brazil. There is currently no CCS regulatory framework and therefore no structure in place for a transition from EOR to CCS in Brazil as summarized in *Table 4.13* (see key above).

Table 4.13 Brazil – status of EOR to CCS regulatory transition

Type of Regulation	Project Lifecycle Stage		
	Commissioning	Operation	Closure / Stewardship
EOR			
Enabling transition			
CCS - specific			

(1) CEPAC, *'Brazilian Atlas of CO_2 Capture and Geological Storage'*. (April 2015). Pp 27, 39 and 43.

The legal, regulatory and economic differences between CO_2 EOR and CCS inform the discussion of how CO_2 injected underground from CO_2 EOR might be recognized as mitigation of carbon emissions in line with the long-term storage of CO_2 in CCS projects.

The analysis conducted and the information compiled in this report regarding the transition of CO_2 EOR to CCS support the 2013 CSLF finding that:

> "*There are no specific technological barriers or challenges* per se *in transitioning and converting a pure* CO_2 *EOR operation into a* CO_2 *storage operation. The main differences between the two types of operations stem from legal, regulatory and economic differences between the two."*(1)

As a basis for understanding the key practical challenges for such a transition, it is helpful to identify the main fundamental differences between CO_2 EOR and CCS projects, as set out in *Table 5.1* below:

Table 5.1 ***Fundamental Differences between CO_2 EOR and CCS Projects***

Aspect	*CO_2 EOR*	*CCS*
Purpose	Increase oil and gas production efficiency (tertiary recovery) to optimise the hydrocarbon-bearing reservoir.	Reduce greenhouse gases (GHG) emissions to the atmosphere in support of climate change mitigation activities/obligations.
CO_2 Lifecycle	Captured from a natural or anthropogenic source, transported, injected into the hydrocarbon-bearing formation and recycled through a closed circuit process (2).	Captured from an anthropogenic source, transported and injected into the depleted hydrocarbon formation for safe and permanent sequestration.
Primary Regulatory Framework	Oil and gas or petroleum legislation.	Ranges between: • CCS/GHG storage-specific legislation; • Mining and mineral Legislation; • General environmental management/ impact assessment legislation.
Competent Authority	Oil & Gas or Energy Regulator	Oil and gas or energy regulator; mineral resources regulatory; and/or environmental management regulator.

(1)Carbon Sequestration Leadership Forum (CSLF) Task Force on CCS Technology Opportunities and Gaps, Final Report (https://www.cslforum.org/sites/cslf/publications/documents/Washington2013/Bachu-TechnicalChallengesConversionCO2EORtoCCSTaskForceRepor.pdf); November 2013. p 3.

(2) Consensus on the incidental retention rate of the injected CO_2 ranges from 50-60% sequestration to 99%. See further *n.24* in '*Bridging the Gap: An Analysis and Comparison of Legal and Regulatory Frameworks for CO_2–EOR and CO_2–CCS*', Global CCS Institute (October 2013).

For CO_2 EOR/CCS to count as progress in meeting national commitments in the Paris Agreement, projects must be included in national GHG inventories. Since parties interested in transitioning a CO_2 EOR project to a CCS project will presumably be interested in that project receiving recognition for emissions avoided, it will be necessary to address and resolve the ambiguities identified in Section 2.1 of this report with respect to the Chapter 5 CCS provisions in the 2006 IPCC Guidelines for National GHG Inventories.

There is a clear regulatory framework for CO_2 EOR and for CCS in most regions but there are insufficient provisions that would allow a CO_2 EOR operator to follow a clear transition pathway for legal and regulatory approval of a CCS project. Permitting requirements for design, commissioning, operational management, decommissioning and post-closure site stewardship, if any, differ for CO_2 EOR and CCS projects.

It is important to note no existing policies or regulatory provisions in the regions studied explicitly prohibit the prospect of CO_2 EOR projects transitioning to CCS projects.

The main differences, identified by this study, that require particular attention from regulators, policy makers and relevant legal authorities for CO_2 EOR transitioning to CCS are:

5. Storage site evaluation and geological modelling;
6. Monitoring of the storage site, reporting and verification;
7. Site closure conditions and post-closure stewardship and liability;
8. Conformance with national GHG inventory guidelines for CCS.

Practically, these areas of difference are likely to have greater implications for existing CO_2 EOR projects that have been operating in accordance with the applicable oil and gas legislative framework before any attention was placed on CO_2 EOR becoming a candidate for transition to CCS. The legal and technical provisions for CCS projects to meet the requirements of the issues outlined above are such that an existing CO_2 EOR project may have difficulty complying – particularly in relation to well monitoring requirements.

In theory, and if incentivized, a proponent of a *new* CO_2 EOR project should be in a better position to design and plan for such a project to transition to CCS based on the evaluation of issues such as site evaluation and monitoring requirements in the design of the entire project life (i.e., planning for both the CO_2 EOR and CCS phases).

CO_2 EOR projects present a special case with particular circumstances for the long-term underground storage of CO_2 and it is the view of the authors that a set of legal and regulatory provisions unique to this special case are required to ensure smooth transition.

Europe and Australia do not have significant EOR/EHR operations at present and any new projects can therefore be developed and designed in a manner which is consistent with the CCS Directive. Similarly in Brazil, CCS Regulation can be developed which enables the transition from EOR.

In the USA and Canada, existing regulation exists for EOR and CCS but the process for transition is less clear. Guidance has been produced by the US EPA for transitioning from Class II (EOR) to Class VI (CCS) wells but the requirements for more detailed monitoring for Class VI wells relates primarily to risks to underground drinking water and therefore issues of permanence and liability from a GHG accounting perspective are not necessarily sufficiently covered.

It is recommended that specific guidance or regulation be provided setting out the specific requirements on new and existing CO_2 EOR projects which may wish to transition to CCS covering the challenges discussed in *Section 2*.

In addition, industry concerns (e.g., from EOR operators focused on the commercial benefit of EOR and not pursing environmental benefits) should be further explored and addressed. In order to encourage EOR, any proposed changes to policy and legal frameworks with respect to CCS project eligibility should take industry concerns into account, provide clear legal guidance addressing uncertainties, and recommend cost-effective solutions.

In the absence of comprehensive guidance or regulations specific to CO_2 EOR transitioning to CCS in different regions, a developer planning both the EOR and CCS phases from the start will have to anticipate what could pass for 'best practice' handling of CCS aspects post-EOR. Two good sources of 'best practice' in CCS projects are the CO_2 Capture Project's 2009 report *A Technical Basis For Carbon Dioxide Storage*[1] and the CCS section in Chapter 5 of the 2006 'IPCC Guidelines for National GHG Inventories'

In sum, a clear pathway for legal and regulatory approval of a CO_2 EOR project transitioning to a CCS project will remain elusive until the gaps in regulatory and legal provisions that have been identified in this report are resolved.

(1) See: http://www.co2captureproject.org/viewresult.php?downid=123

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