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Best Practice for Transitioning from Carbon Dioxide (CO_2) Enhanced Oil Recovery EOR to CO_2 Storage

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Abstract

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. One issue is that projects to enhance oil production are primarily implemented to increase oil production with (tertiary recovery methods and any long term storage of CO_2 is considered 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. In EOR, the formation where CO_2 would be stored is predetermined by the existing oil bearing reservoir, raising potential questions about monitoring, long-term CO_2 storage liabilities, potential, leakage, permanence and other issues that must be addressed in CCS projects but may fall outside the boundaries of a typical EOR project. Finally, although this paper is premised on historical and current experiences with enhanced oil recovery projects, similar considerations could also be given to enhanced recovery of natural gas.

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There are no specific technological barriers or challenges in transitioning and converting a pure CO_2-EOR operation into a CO_2 storage operation but there are a number of legal, regulatory and economic differences which must be addressed if an EOR project is to serve as a CCS project. Lack of experience or unresolved issues related to EOR becoming CCS could create barriers unless the issues are fully understood and managed to the satisfaction of regulators. Understanding best practice and the policy and regulatory frameworks affecting CCS from 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 recognised as a mitigation activity under local legislation/carbon market schemes and in national GHG inventories which support monitoring progress under the COP21 Paris Agreement.

The paper provides an overview of the key issues in the USA, Canada, EU, Australia, and Brazil and provides recommendations for what companies need to do should they wish to transition from EOR to CCS for existing or future operations.

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Keywords: CO_2 enhanced oil recovery; carbon capture and geological storage; long term CO_2 storage liability; storage capacity; leakage; monitoring; legal and regulatory review; GHG emissions accounting

1. Introduction

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 paper 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 in Table 1:

Table 1. Fundamental Differences between CO2/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-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". [2]

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 behaviour 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 Underground Injection Control (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 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:

Regulations/process in place
Regulations/guidance in development
Policy discussions under way
No information available

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

Type of Regulation	USA	Canada			European Union	Australia	Brazil
		Alberta	Saskatchewan	British Columbia			
EOR							
Transition							
CCS							

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". [3]

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.

References

[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.

[2] 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.

[3] 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.