A CO_2GeoNet Initiative

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Approaches to Regulating CO_2 with EHR in Selected Member States

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Contents

Executive summary

The ENOS (ENabling Onshore CO_2 Storage) project (www.enos-project.eu), addresses the challenges to apply Carbon Capture and Storage (CCS) technology onshore in Europe, with its unique geological and socio-economic context. The advantages of local onshore storage include empowering communities to steer the process, supporting local jobs and industries and enabling sustainable development. Onshore storage is needed to meet climate targets and offer opportunities for EU Member States that do not have easy access to storage potential in the North Sea (where CO_2 storage has been demonstrated for over two decades). In addition, the costs for transport and storage onshore are much lower than offshore.

The ENOS consortium includes more than 100 professionals (scientists and engineers, experts in geology, monitoring and social sciences and many others) from 29 organisations based in 17 European countries. The main objective of the ENOS project is to enable the development of CO_2 storage onshore in Europe by:

- Developing, testing and demonstrating in the field, under “real-life conditions”, key technologies specifically adapted to onshore contexts (for example tools to monitor CO_2 storage sites);
- Involving local communities in CO_2 geological storage development (e.g. establishing dialogue groups with researchers, citizens and civil society representatives);
- Sharing experience and knowledge across Europe to contribute to the creation of a favourable environment for onshore storage.

ENOS Work Package 4 focuses on the integration of CO_2 storage with local economic activities, for example, hydrocarbon production. This report reviews potential barriers to integrating CCS alongside enhanced hydrocarbon recovery (EHR) or temporary storage (buffering) for re-use purposes, using the injection of CO_2 under current European regulations. A review of the current legal framework in the EU regarding EHR and CCS activities is provided and any amendments currently required to legislation to remove potential barriers are summarised.

The current legal framework for CO_2 storage in the EU, specifically the EU Directive on the geological storage of CO_2 (henceforth referred to as the ‘CCS Directive’), and the amendments allowing CO_2 storage as a permitted mitigation activity under the EU ETS, does not prohibit the combination of CO_2 storage with enhanced hydrocarbon recovery and/or the buffering of CO_2. Despite this, certain Member States, for instance the Netherlands, have previously enacted legislation that prevents operators holding a license for both permanent CO_2 storage and CO_2 EHR or buffering, although this has now been resolved. The injection of anthropogenic CO_2 into the subsurface at a commercial scale either for enhanced hydrocarbon recovery, buffering (temporary storage), or permanent storage, has yet to take place in Europe, hence the review in this report is based on an interpretation of current legislation. The report is directed to the regulatory assessment of several combinations of injection including temporary storage (buffering), hydrocarbon production and temporary storage/hydrocarbon production followed by permanent storage. The report includes case studies from the North Sea with a focus on Dutch legislation but also including UK, Irish and Norwegian case studies.

Potential barriers have been highlighted at a national level with no overarching EU requirements having been found to provide a barrier to the integration of permanent CO_2 storage alongside hydrocarbon production or buffering activities. Although some elements of the European regulations remain ambiguous regarding CO_2 storage associated with enhanced hydrocarbon or buffering activities it is widely interpreted that these activities, if combined with permanent storage, can be conducted under the CCS Directive and therefore qualify for the EU Emission Trading Scheme accreditation. Recommendations for removing any potential regulatory and technical barriers have also been provided.

1 Introduction

The aim of this report is to provide an overview of the regulatory framework in the EU and its Member States regarding the injection of CO_2 for a combination of purposes including enhanced hydrocarbon recovery (EHR), temporary storage (buffering) and permanent storage and to identify potential barriers for implementation. This report is focused on European regulations and references current regulatory frameworks, mainly in the North Sea, in specific member states such as the Netherlands and the UK.

The main purpose of CCS is to reduce CO_2 emissions and mitigate climate change due to greenhouse gas emissions. Enhanced hydrocarbon recovery (EHR) is an important topic within CCS development, as CO_2-EHR as a technique can serve two purposes (CSLF EOR Task Force, 2017):

- Recover additional oil or gas, thus supplying affordable energy and increasing revenues.
- Mitigate climate change by reducing CO_2 emissions to the atmosphere.

Enhanced hydrocarbon recovery is predicted to play a major role in the development of full-scale CCS as for many project developers it can provide an additional revenue stream providing a financial incentive for storing CO_2. It is thought that promoting CO_2 storage alongside EHR will facilitate the development of various CCS technologies and allows projects to move from demonstration to commercial scale.

EHR has already been undertaken extensively in North America, with the first CO_2-EHR projects having begun in the 1970s in Texas (US DOE, 2019). To date, a majority of CO_2-EHR has been undertaken onshore but the first offshore site, the Lula project off the coast of Brazil, which commenced in 2013, has conducted CO_2-EHR offshore at a commercial scale. Many studies have concluded that there are no technical barriers to permanently storing CO_2 alongside EHR both on- and offshore (CCP, 2016) but regulatory barriers may exist. This review discusses the current regulations surrounding both EHR and CO_2 storage and the potential regulatory constraints that may arise transitioning between the two.

The current legal framework for CO_2 storage in Europe is given by the EU Directive on the geological storage of CO_2 (2009/31/EC) which will henceforth be referred to as the 'CCS Directive' in this report. Amendments to EU Emissions Trading Scheme (ETS Directive) have allowed for CO_2 storage as a permitted mitigation activity under the regulation and the transfer of CO_2 across the CCS chain. Despite this, certain Member States may have enacted both directives through national legislation, which, depending on their own interpretations, could prevent CO_2 storage alongside EHR or make transitioning from an EHR project to permanent storage difficult.

Injection of anthropogenic CO_2 into the subsurface either for EHR, buffering (temporary storage), or large-scale permanent storage, has yet to take place in an EU Member State. The permitting process for regulating a CO_2 storage site, where (part of) the storage volume may act as a CO_2 buffer, has also yet to be approached by any European Member State. Therefore the review of legislation in this report is based on interpretations in published literature on how implementing these regulations may be done, as no operational experience exists under the EU CCS Directive.

Case studies have been included in this report where appropriate to highlight legislation relating to EHR and CO_2 storage at a national level within specific EU member states. International examples of current CO_2-EOR (CO_2-Enhanced Oil Recovery) and storage projects have also been included for comparison.

This report has been completed through specific legal and regulations research in order to describe the legality of combining the activities of CO_2 buffering, CO_2-EHR and permanent CO_2 storage,.

2 Current CO_2-EHR and CO_2 Storage Regulations

2.1 CO_2-EHR Legislation

There is no unifying legislation or policy for CO_2-EHR with permanent storage at a European level but CO_2-EHR is mentioned in a variety of directives such as those on the Emission Trading Scheme (ETS Directive) (2003/87/EC), Offshore Safety (2013/30/EU), and Carbon Capture and Storage (CCS Directive) (2009/31/EC). Extensive regulation and policy already exists in the oil and gas sector regarding EHR at a national level, which also covers the injection of CO_2 for tertiary recovery purposes such as in the UK and the Netherlands. If an operator is planning to seek financial credit under the ETS Directive for the associated CO_2 storage during an EHR project, they must first qualify for a storage permit in conformance with the CCS Directive. A summary of the legal and regulatory documents regarding both CCS and pure EHR in the European Union are summarized in Table 1 (page 9).

European Union member states do not have any significant EHR operations at present and it is therefore thought that any new projects planning to permanently store CO_2 should be developed and designed in a manner which is consistent with the CCS Directive from the start. It is thought that offshore CO_2-EOR activities can be regulated under existing national oil and gas regulation, and current regulations in Europe are not predicted to constitute a barrier to EHR projects being undertaken (CSLF EOR taskforce, 2017). However, if the intention is for the CO_2-EHR to demonstrate long-term storage and it is seeking participation in the EU ETS, additional CCS regulatory requirements will need to be met.

The “dumping” of CO_2 in the seabed is also protected by the London Protocol and the OSPAR convention. These are both discussed in detail in relation to CCS and EHR in a report by the GCCSI, 2012. In summary, neither the London Protocol nor the OSPAR convention prohibit EHR as both documents include exemptions for EHR activities.

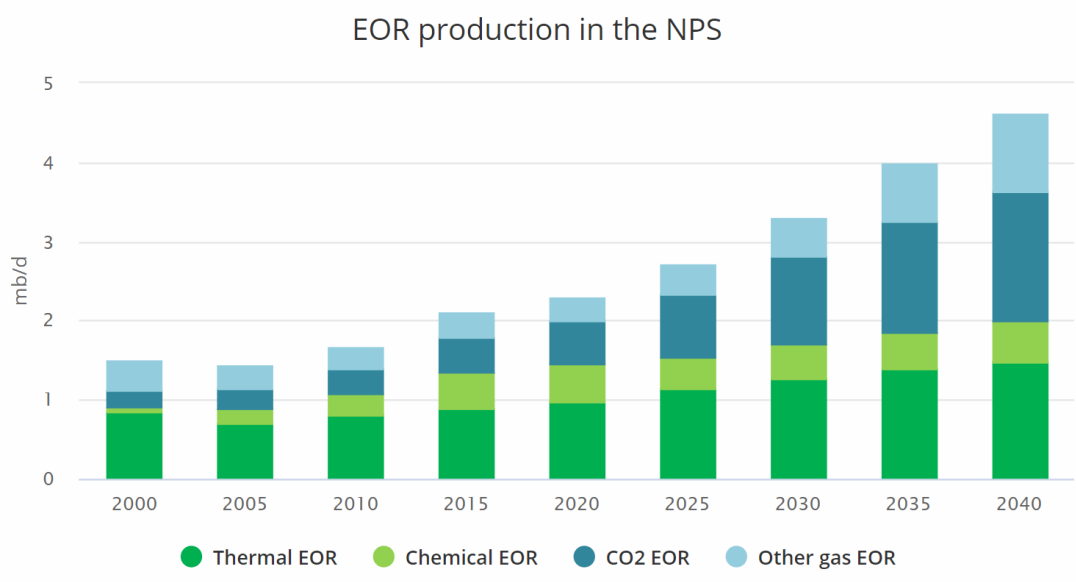

Figure 1: EOR Production in the New Policies Scenario (IEA Website, 2018)

EHR, and primarily EOR, is currently undertaken most extensively in North America. In the U.S., there are about 114 active commercial CO_2 injection projects that together inject over 2 billion cubic feet (0.1Mt[1]) of CO_2 per day and produce over 280,000 BOPD (Oil and Gas Journal, 2010). Large-scale CCS and CO_2-EHR is currently taking place in a couple of projects such as Petra Nova and the Shute Creek Gas Processing Plant. Although there have been considerable onshore EHR developments in the U.S and especially the Gulf States, there have been very few offshore projects. Five pilot projects were undertaken in the 1980s in Louisiana coastal waters, these were generally successful but did not lead to commercial developments (SCCS, 2015).

The International Energy Agency (IEA) attributes the success of EOR in the US to good policy incentives. In the 1980s the Crude Oil Windfall Profit Tax kick-started the US EOR industry by significantly reducing its tax burden. More recently, the US section 45Q tax credit has been amended to provide a tax reduction of \$35/tCO_2 for 12 years for CO_2 stored in EOR operations (IEA, 2018). The majority of CO_2 injected in current EOR projects is produced from naturally occurring sources. This is due to economic factors and natural CO_2 reservoirs often being available close to oil fields, but using natural sources provides no benefit in terms of the emissions intensity of the produced oil. In the US, more than 70% of the CO_2 injected today for CO_2-EOR is from natural sources (IEA Website, 2018). However, for a CO_2-EHR storage project to be accredited by the ETS Directive (and also the 45Q tax credit in the US), the CO_2 must come from an industrial (anthropogenic) source, as required by the CCS Directive.

2.1.1 Petrobras Lula Project, Brazil

The CSLF 2017 Report by the CO_2-EOR taskforce includes a detailed case study of the LULA project in Brazil, the world's first commercial scale offshore CO_2-EOR project. Injection started in 2011 injecting around 1 million m^3. No major operational or reservoir problems had been detected by the time of the CSLF report in 2017.

The CSLF reported that some of the key drivers enabling the LULA field development included:

- *Phased development, dynamic data acquisition and actions to add robustness/flexibility to the production system and manage uncertainties. Phased development concept aimed at risk mitigation, optimization of production systems and also expenditure versus revenue balancing, coupling information acquisition with cash flow acceleration.*
- *Multi-well production pilots. The early operation of pilot projects provided valuable information not just for conventional waterflood recovery, but also for future EOR by WAG injection.*
- *Comprehensive analysis of the existing uncertainties, such as: reservoir characterization, early water and gas breakthroughs, bypassed oil saturation, flow assurance in deep water flow lines, $CaCO_3$ scale possibility in production wells.*
- *Definitive systems incorporating the knowledge acquired through the previous phases and prioritizing the standardization of wells and production systems.*
- *CO_2-EOR planned in advance. As offshore projects need to be planned well in advance, due to the lack of room on the platforms and prohibitive costs for future expansions, the pioneer application of EOR methods needs to be considered from the conceptual stage of the development.*

As highlighted above the project was designed for CO_2-EOR from conception which greatly aided the project in its successful development. Although technically possible, transitioning to CO_2-EOR

[1] Using US DOE conversion: 1 metric ton of CO_2 =19.25 thousand cubic feet (Mcf) at standard conditions, 14.7 psi and 70 °F

(especially for permanent storage) once production has begun can be difficult both due to design and infrastructural changes but also in regards to the policy and legislation the project would then fall under.

2.1.2 CO_2-EOR ISO Standard

An international standard was published in January 2019 regarding “Carbon dioxide storage using enhanced oil recovery (CO_2-EOR)” (ISO 27916:2019). The Standard applies to demonstrating and documenting the quantity of anthropogenic CO_2 that is stored in association with CO_2-EOR. The standard does not apply to or supersede any regulations otherwise applicable to oil or gas drilling, production, and other activities, including permitting and implementation of enhanced recovery operations and CO_2 injections in enhanced recovery operations.

ISO standards are not legally binding but most regulating bodies of individual countries refer to ISO standards as an example of good practice. Many regulators require businesses and manufacturers to comply with applicable ISO standards, in addition to local regulations. The publication of this ISO will be beneficial for operators in Europe planning EHR projects as reference for good practice in combining EHR and CO_2 storage.

The ISO standard includes sections on monitoring and quantification which outline how to calculate the amount of CO_2 that has been permanently stored as part of the EHR processes. It highlights that potential errors can occur with regards to ‘double counting’’ and two extremes should be avoided:

1. Recycled and re-injected volumes must not be counted multiple times, which is to say that no matter how many times the same molecule is injected and produced, it is counted as only one molecule stored;
2. Closed loop recycle must not be confused with loss from storage and discounted. Quantification of recycled CO_2 may be difficult if mixed gasses (CO_2 plus light hydrocarbons and other gases) are metered. The volume-to-mass conversions are complex for mixed gasses and can lead to measurement errors. Since repeated measurement of the large volumes extracted, separated and re-injected during the recycle process may lead to an accumulation of potentially large errors, the direct measurement of losses from the system may be more accurate.

A standard for the quantification of CO_2 stored is given in the ISO which is beneficial for European projects seeking to gain ETS accreditation. The calculations include leakage from surface facilities, venting from production operations and entrained CO_2.

More details are provided in ENOS Deliverable 4.11 (Rycroft, 2019) on how a site can be monitored, following best practices such as those given in the ISO, to meet ETS Directive requirements regarding CO_2 quantification in CO_2-EHR.

<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><u>Pure CO_2 EOR Activities:</u>
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><u>CO_2 EOR to Permanent Sequestration</u>:
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.

<u>EU ETS Directive</u>
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.

<u>EU ETS Directive</u>
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>

Table 1: European Legal and Regulatory Review Summary (CCP4 Report 2016)

2.2 CO_2 Storage Legislation

CO_2-EHR regulations were not developed to cover long-term underground storage of CO_2 as a permanent storage project. Typically, EHR regulations do not account for what happens to the injected CO_2 after EHR activities have ceased (CPP, 2016). Legislation for the injection of CO_2 for permanent storage is covered by the CCS Directive 2009/31/EC and then implemented at national level.

CO_2 injection for permanent storage in addition to EHR is not explicitly dictated in EU regulation. Regarding enhanced hydrocarbon recovery the EU CCS directive (2009/31/EC) states that:

> *"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. Such releases are covered by the inclusion of storage sites in Directive 2003/87/EC[2] of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community, which requires surrender of emissions trading allowances for any leaked emissions."*

The CCS Directive would therefore cover CO_2-EHR operations should the operator choose to acknowledge the "geological storage of CO_2" associated with the project rather than just classifying the CO_2 as a working fluid under conventional oil and gas regulations. The main incentive for an operator to do this is to be accredited under the ETS Directive to provide a financial incentive for demonstrating the CO_2 is stored permanently. If a project secures a CO_2 storage permit under the CCS Directive it will then qualify for accreditation under the ETS Directive.

The ETS Directive works on the 'cap and trade' principle where a cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that total emissions fall. Up to the cap, companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available ensures that they have a value. The ETS Directive includes fossil-fuel energy production installations (>20 MWth), industrial installations and aviation, 2013 the ETS Directive's scope was amended to also cover installations undertaking CCS:

- *Capture of greenhouse gases from installations covered by this Directive for the purpose of transport and geological storage in a storage site permitted under Directive 2009/31/EC.*
- *Transport of greenhouse gases by pipelines for geological storage in a storage site permitted under Directive 2009/31/EC.*
- *Geological storage of greenhouse gases in a storage site permitted under Directive 2009/31/EC.*

The EU ETS is supported by the Monitoring and Reporting Guidelines (MRGs -Commission Implementing Regulation (EU) 2018/2066) which outline how to implement the ETS and allow for the effective monitoring and reporting of greenhouse gas emissions. Within the MRGs, guidance is provided on a number of activities covered by the EU ETS. 'Activity Specific Guidelines' are present for CO_2 capture, transport and

[2] i.e. the ETS Directive. So CO_2 generation associated with normal EHR procedures, e.g. fuel required for compressors would not be covered by the CCS Directive but would be included in quantification required under the ETS Directive.

storage activities conducted in line with the provisions of the CCS Directive. As part of the Activity Specific Guidelines for CO_2 storage, there are some provisions for accounting for emissions from EHR operations. Operators must take into account emissions from:

- *the oil-gas separation units and gas recycling plant, where fugitive emissions of CO_2 could occur,*
- *the flare stack, where emissions might occur due to the application of continuous positive purge systems and during depressurisation of the hydrocarbon production installation,*
- *the CO_2 purge system, to avoid that high concentrations of CO_2 extinguish the flare*

Therefore even though the CCS Directive states that EHR alone is not included in its scope, the ETS Directive MRGs do contain provisions, albeit minimal, to include the process in accounting systems for CO_2 storage sites permitted under the CCS Directive. Therefore it can be confidently assumed that EU legislation does not prohibit the combination of CO_2 storage and EHR. However, there is no specific legislation that can assist operators in the transition between CO_2-EHR and CO_2 storage (only) operations.

The CO_2 Capture Project (CPP) published a report in 2016 which highlighted 4 key areas which should be focused on regarding the main differences between CCS projects and EHR without permanent storage for policy and legislation:

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.

CO_2-EHR projects without permanent storage are not required to investigate the structure of the reservoirs in which they operate to the same extent required by CCS. Site characterization will vary between the two types of projects, especially regarding proving the integrity of a depleted hydrocarbon field for the purpose of permanent CO_2 storage as the pressure cycling effects during production must be evaluated. The long-term aspect of permanent storage compared to EHR projects also means the liability of the operator and monitoring requirements post-closure will also be more extensive. This could provide difficulties when transitioning from EHR to permanent storage as different standards of site characterisation, MRV planning and post-closure liabilities have to be met.

There are only two large-scale CCS facilities currently operating in Europe, both in Norway, but many are in early stages of development (e.g. Acorn in the UK, Ervia in Ireland and Porthos in the Netherlands). All of these countries have CO_2 storage regulations and policy in place at a national level (more details in section 3.3). The CSLF 2017 Policy Group taskforce concluded that in order to make regulations practical:

1. CO_2 storage regulations should be established under the principle of promotion of safe CCS. In the establishment of the regulations, the timely involvement of industry is important.
2. Existing CO_2 storage regulations can be improved through a review by diversified stakeholders.
3. CO_2 storage regulations should be flexible enough for various CCS projects with different characteristics to move forward.
4. New or amended CO_2 storage regulations should be flexible with transitional provisions where necessary for continuation of existing valid projects, if any.
5. The definitions of key terms should be made with consideration of technical constraints and should have consistency with those in other related laws and regulations.

Although the CCS Directive does not prevent the combination of EHR activities with permanent storage, national regulation and policy may be in place that could provide potential barriers for operators planning

to transition between the two, see Section 3.1.3 regarding Dutch National policy for more details. Member States should therefore focus on the recommendations above regarding developing new CCS regulation.

2.2.1 Interpretations of the CCS Directive and EHR

The legal status of EHR in the CCS Directive (see quote on page 10) is still debated. Generally, there appears to be a consensus amongst experts that the CCS Directive will apply to an EHR project, provided that the CO_2 is for the purposes of 'permanent storage' (CCP, 2014).

The CCS Directive is focused on the scenario where long-term CO_2 storage is conducted for emission reduction purposes. Given the current wording of the CCS Directive regarding EHR, which states that EHR falls under the CCS Directive "*where EHR is combined with geological storage of CO_2"* different interpretations in literature currently exist regarding whether all CO_2-storage projects qualify.

During a majority of CO_2-EOR operations currently undertaken, a large volume of CO_2 is permanently stored, even though these projects are focused on oil production economics rather than climate mitigation. A review of eight North American case studies found approximately 72% of injected CO_2 was permanently stored; the cumulative gross CO_2 injected for all eight case studies was 67.5Mt and cumulative net stored was 49.2Mt (Faltinson, 2011). This demonstrates that regardless of the project motivation, it is still a logical conclusion that as CO_2-EHR activities have a large proportion of associated permanent CO_2 storage, they would qualify for permanent storage under the CCS Directive, provided that the CO_2 has an anthropogenic source.

This interpretation has been disputed though, for example by a SCCS publication in 2013 which concluded (regarding the above interpretation):

> *"We are not convinced that this interpretation is convincing when looking at the overall aims and context of the Directive. It would deprive the Preamble[3] of any effective meaning since all EHR operations are accompanied by storage in this broad sense. It would mean that all pure EHR operations become storage sites under the Directive, are eligible for inclusion with the emissions trading regime, and those capturing do not have to surrender allowances. It seems unlikely that it was the intention of the legislature to subsidise pure EHR operations in this way"*

The report then categorises four scenarios in which CO_2 storage may occur (SCCS, 2013):

(a) **Incidental storage of CO_2 during EHR operations.** EHR operators recycle as much CO_2 as possible for further injection, but estimates are that typically between 30% and 50% may be permanently stored in the strata following initial injection (for hydrocarbon extraction purposes).

(b) **Incremental storage during EHR operations**. With improved incentives, EHR techniques could deliberately maximize the quantity of CO_2 injected for a given amount of oil production (for emission mitigation purposes).

(c) **Incremental storage following termination of EHR operations.** CO_2 can be injected in a depleted hydrocarbon site for emission reduction purposes. (Where the eventual use of the site for CCS storage is planned from the beginning of the EHR project it is referred to as a "combined" EHR/CCS operation.)

(d) **Storage during buffering or balancing operations.** This refers to the storage undertaken to accommodate variations between CO_2 supply and injection operations.

[3] The preamble is the text in the CCS Directive as quoted on page 10 of this report.

The report concludes that pure EHR projects with incidental storage (category a) fall outside the scope of the CCS Directive given that no CO_2 is being stored for beyond that required for oil production.

This is one interpretation of the text in the CCS Directive and does not represent all views. This interpretation does require some conjecture given the limited text and slightly ambiguous nature of the CCS Directive regarding EHR. It is worth noting in this report though that not all legal interpretations of the CCS Directive regarding EHR have come to the same conclusions regarding incidental storage.

2.3 Transitioning from Hydrocarbon Production to CO_2-Storage Licensing

In the case where a CO_2-EHR project did not initially have the intention to apply for accreditation under the ETS Directive, a transition from oil and gas licensing to permanent storage licensing will then be required. To gain ETS credits the CO_2-storage project must be included in national GHG inventories and receive recognition for the emissions avoided, as will the capture and transport installations. In order for this to happen, the project will need to meet the requirements of the CCS Directive. An existing EHR project wishing to obtain credits 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 (CCP, 2014).

Numerous GHG accounting guidelines exist that include CCS and EHR activities. At an international level the IPCC Guidelines for National GHG Inventories include a chapter on how to address the geological storage of CO_2 within emission inventories. As highlighted in the CCP4 2016 report, there are several potential regulatory ambiguities for CO_2-EHR projects to be accounted for under the 2006 IPCC Guidelines for National GHG Inventories, e.g:

- *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 modelling 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.*

A 2016 IEAGHG report outlines current carbon accounting standards in CCS and highlights that although standards are clear for CCS projects, there are some knowledge gaps regarding 'special cases' such as those associated storage alongside CO_2-EOR (Table 2). This is due to a 'leakage' effect of emissions coming from outside the defined GHG accounting boundary (this does not refer to physical leakage in the report but rather 'leakage' is used to refer to changes in GHG emissions that can occur outside the specific boundaries of a project/programme/policy or activity). These 'leakages' can be from onsite emissions of production sources or downstream emission from the end-use of the crude oil produced. On an international-scale this should not be an issue as CO_2-EOR emissions from site-level operations would be included in GHG inventories under the 2006 guidelines.
Table 2 (taken from the IEAGHG 2016 report) summarises current MRV/Accounting rules and their applications to CCS.

Accounting/ MRV rules		Special cases: CO_2-EOR
Economy-wide	2006 IPCC Guidelines	MRV of all emissions from CO_2-EOR site-level operations must be included in the national GHG inventory; mid-and downstream sources covered elsewhere.
Sector-based	EU Monitoring and Reporting Regulation (MRR)	Site-level emissions reported by qualifying installations within oil and gas sector. Potential for leakage outside of the EU ETS boundary (other sectors and/or countries).
	US EPA GHG Reporting Program (GHGRP)	EOR operators may report under subpart UU (*Injection of Carbon Dioxide*) or subpart RR (*Geologic Sequestration of Carbon Dioxide*). However, to qualify for support for purposes of long-term storage (CCS), all operators (Class II and VI) must report under RR; RR requires reporting of site-level emissions (under subparts C+W). Downstream leakage potential.
	Canada GHG Reporting Program (Canada GHGRP)	CO_2-EOR site level operational emissions monitored and reported following IPCC Guidelines (see above). Downstream leakage potential.
	Australia National Greenhouse and Energy Reporting Act (NGER)	Government has developed MRV guidance covering CO_2-EOR site emissions based on the API Compendium, with effect from July 2015. Downstream (transport) leakage potential.
Project-based	Kyoto Protocol clean development mechanism (CDM)	Any CO_2-EOR CDM methodology would require monitoring to include all emissions from CO_2-EOR site level operations. Mid- and downstream sources should also be identified as 'leakage emissions'.
	Alberta-based Offset Credits scheme	The EOR Protocol (based on gas processing only) includes MRV of site-level emissions. Mid- and downstream emissions not considered because "No Leakage" is an eligibility criterion for projects.
	American Carbon Registry (ACR)	Operators required to monitor and report all site-level GHG emission sources; also required to take into account "leakage emissions" although exact methods are not specified.

Table 2: CCS Requirements and GHG Accounting and MRV Rules Worldwide (Extract from IEAGHG, 2016)

Note: Green indicates where the requirement is adequately addressed. Yellow is where there are areas of uncertainty or where only minor issues exist.

Problems are predicted to arise when considering accounting rules across both national-level and project-level schemes (IEAGHG, 2016). In Europe, under the ETS, the scheme boundaries are defined under 'the physical limits of the installation' which means all downstream emissions could potentially lead to emissions occurring outside the specified accounting boundary.

Another potential barrier to the transition of a hydrocarbon production site to permanent storage is that the CCS Directive states that there should be a level playing field for parties interested in CCS. This means when an application for a storage exploration permit is made, it is public so others are able to apply at the same time. Therefore, the operator of the production phase cannot be guaranteed to also receive the storage license. These uncertainties complicate the transition from production to EOR/EHR and eventually storage. (CATO2, 2013).

Alongside this, there are some potential barriers to a depleted hydrocarbon field operator repurposing and reusing the same infrastructure for the injection of CO_2. National policy covering production licenses usually come with obligations for closure and removal of the equipment. This potential barrier is highlighted in the Netherlands Case Study, Section 3.1.3. A detailed assessment of the re-use of infrastructure in the UK North Sea was conducted in an IEAGHG 2018 report which highlighted the case-by-case nature of the suitability of infrastructure for reuse.

3 European Case Studies

3.1.1 UK

Numerous CCS investments and initiatives by the UK government have failed to materialise into any CO_2 injection for storage occurring at present. Yet, in June 2019 the government announced their plans to reach net-zero emissions by 2050, an ambitious goal in line with their Paris agreement targets. UK advisors have demonstrated a necessity for future policy to support CCUS if this target is to be met (Committee on Climate Change, 2019).

In the UK, the CCS Directive was implemented primarily through amendments to the 2008 Energy Act (Chapter 3) but these regulations do not apply to CO_2-EHR. Pure EHR operations are covered by licenses under the Petroleum Act 1998 and there appear to be no major inconsistencies between the regimes. (SCCS, 2013). The UK Oil and Gas Authority (OGA) included CO_2-EOR alongside CCS as an ambition in their latest Enhanced Oil Recovery (EOR) Strategy Delivery Report (Oil and Gas Authority, 2016). In 2016 powers were transferred from the government's energy department (BEIS) to the Oil and Gas Authority (OGA). This means it is now the OGA that regulates offshore CO_2 storage and issues storage permits. Current legislation allows for operators to move from CO_2-EOR to permanent CO_2 storage by applying for a new storage license allowing the storage activities to become ETS compliant. The Petroleum Act 1998 allows the use of CO_2 as an ancillary purpose to getting petroleum. If the operator wishes to store CO_2 permanently and gain credits under the EU ETS Directive, the operator would then have to apply for a storage license under the Storage of Carbon Dioxide from the OGA. Until a storage permit is granted (or not), this does not prevent the operator continuing to use CO_2 for the purpose of getting petroleum (CATO2, 2013).

A detailed evaluation of UK policy regarding EOR and storage was undertaken by the SCCS in 2013. The report stated:

> *"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"*

Any legislative barriers to CO_2-EHR being undertaken in the UK and being accredited under both the CCS and ETS Directives are therefore unlikely.

There are no CO_2-EHR or storage projects currently taking place in the UK but the OGA have recently awarded the UK's first CO_2 appraisal and storage license, to the Acorn CCS project in Scotland. Under the terms of the OGA licence, Pale Blue Dot (the project developers) are required to submit and be awarded a Storage Permit before CO_2 injection could begin at the Acorn CO_2 Storage Site. In addition to the Acorn project, there are 4 other CCS projects in early development stages (Caledonia Clean Energy, HyNet, H21 and the Teeside Collective) (GCCSI Database, 2019).

3.1.2 Ireland

Ireland is currently undertaking feasibility studies to assess the potential for a large-scale CCS project in Cork to capture the CO_2 from a number of gas-fired CCGT power plants to provide low-carbon electricity. An offshore pipeline, that first carried natural gas to Ireland, is being assessed to potentially be reutilised to carry CO_2 (Ervia website, 2019).

Ireland transposed the CCS Directive into Irish Law through the European Communities (Geological Storage Of Carbon Dioxide) Regulations 2011. Within this legislation CO_2 storage is currently prohibited

in Ireland with no permitting allowed except for research with less than 100 Ktonnes of CO_2 injection (Shogenova et al., 2014).

The Government of Ireland published their "National Marine Planning Framework Baseline Report" in 2018 to which Ervia provided a consultation response in December 2018. Ervia's response stated that, regarding legislation, 'The Marine Spatial Plan' needs to address:

- The legislation concerning CCS, S.I. No 575 of 2011, needs to be amended to provide for large-scale transportation and storage of CO_2 in suitable reservoirs in Ireland, or offshore Ireland.
- Ireland needs to ratify the 2009 amendment to the London Protocol to allow for the cross-border export of CO_2 for storage.
- A permitting regime for the exploration, establishment and operation of CCS facilities is required.
- The safety legislative regime, which applies to petroleum exploration and extraction, needs to be extended to other offshore activities, such as CCS, to ensure CCS can be delivered.

The public review period closed at the end of 2018 and a finalised National Marine Plan is expected in March 2021 following further revisions and review processes.

3.1.3 Netherlands

Activities relating to the exploration or production of minerals and oil and gas in the Netherlands are governed by the Mining Act (Mijnbouwwet). This was amended in 2011 to incorporate the EU CCS Directive. To undertake CO_2-storage (including exploration) a storage licence is required under the Mining Act and must be applied for with The Dutch Ministry of Economic Affairs and Climate.

The Dutch government set an objective for 2009-2015 to carry out large-scale demonstration projects for CO_2 CCS both onshore and offshore. The ROAD pilot project (Rotterdam Storage and Capture Demonstration Project) was launched in 2009. The preparatory studies were completed and the permit for storage was issued in July 2013. The project experienced delays due to the business case no longer being sound (as a result of the low CO_2 price within the ETS). The ROAD project was cancelled in 2017 (The Dutch Ministry of Infrastructure and the Environment 2015). A new CCS project is currently underway; the Port of Rotterdam CCUS Backbone Initiative (PORTHOS) which completed feasibility studies in 2018 and is currently working towards technical and financial validation for an investment decision in 2020.

In the Netherlands CO2 storage activities focus on storage in depleted hydrocarbon fields. In the event of storage activities in former production fields, the production licence shall lapse the moment the storage licence becomes irrevocable (Global Legal Group, 2016).

At present, the Mining Act requires the decommissioning of depleted fields and the removal of platforms not in use. In a CCS vision under development, the Central Government is assessing whether policy changes would be desirable in this respect (The Dutch Ministry of Infrastructure and the Environment, 2015). Amendments are currently underway which include an exemption from decommissioning obligations which has been proposed to allow for the extended use of mining infrastructure, e.g. for electrification, transport or storage of hydrogen or CO_2. These amendments were under public review until June 2019, and if accepted will allow for decommissioned oil and gas fields to be more easily re-used for CCS purposes (Overheid.nl, 2019).

The Netherlands have previously altered the Mining Act to meet the requirements for CO_2 storage. Legislation was enacted that initially prevented operators from holding a license for both permanent CO_2 storage and CO_2-EHR, however this has since been altered.

4 CO_2 Seasonal Storage and Buffering

Chapter 2 and 3 focused on the combination of CO_2-EHR and permanent storage. Another way to utilize CO_2 is to use a reservoir as a temporary buffer to tackle the mismatch in supply and demand for industrial use. This concept has been proposed in the Netherlands as a potential scenario for the horticultural sector which requires large amounts of CO_2 in summer and only small amounts in winter. The CO_2 storage 'buffer' concept may also be applicable for varying CO_2 supply requirements in EHR operations, or any other type or re-use for which a mismatch between supply and demand has a monthly or seasonal character.

Agricultural greenhouses in the Rotterdam area currently secure part of their CO_2 demand through OCAP (the Organic Carbon-dioxide for Assimilation of Plants) which supplies pure CO_2 by pipeline from industry in the Rotterdam port area to greenhouses North of the port. The CO_2 demand of the greenhouses has a highly seasonal character, with much higher demand in the summer. Currently, the OCAP system is supply-limited and cannot be expanded as the supply of CO_2 cannot be increased to meet the existing peak summer demand (Ros et al., 2014). It has therefore been proposed to store some of the surplus CO_2 produced in winter and produce it during higher demand in the summer.

In this scenario the operator might not seek ETS credits as a revenue stream as most of the CO_2 will only be 'stored' temporarily and will eventually be extracted and sold to make profit, permanent storage is not the goal in buffering scenarios. If focusing on temporary storage the operator might not seek EU ETS credits and will not require the project to be permitted under the CCS Directive but instead under more general gas storage laws. If, however, the operator plans to use the reservoir for permanent storage at the end of the buffering project they would have to meet the more stringent ETS requirements and apply for a storage permit in line with the CCS Directive requirements. Although neither the CCS or ETS directives refer to a buffer style scenario it can be considered to be a similar concept to CO_2-EHR with permanent storage and it is thought the directives will therefore apply in similar ways.

Chapter 3 of the Dutch Mining Act covers "Permits for the storage of substances and for the detection of CO_2 storage complexes", with the first part including *temporary* storage of substances. This chapter is separated into two parts:

3.1 General Rules
3.2 Supplemental provisions with respect to the permanent storage of CO_2

Chapter 3.1 outlines the 'general provisions' for the 'storage of substances' which would be the main focus for buffering projects. The permanent storage of CO_2 has more stringent 'supplementary' requirements (e.g. finding proof of the projects financial feasibility) but these are covered separately later in Chapter 3.2. A buffering project would not need to meet these more stringent requirements for permanent storage if ETS credits are not required and hence the project does not need to fulfill the CCS Directive requirements. The project would only need to meet the more generalized CO_2 storage requirements in Chapter 3.1 regarding the storage of any gas in the subsurface.

The 'General Rules' in Chapter 3.1 are extensive and still provide some difficult requirements such as "As soon as an application for a storage license has been submitted, other parties shall be afforded the opportunity to submit an application for a storage license for the same area" meaning the operator of a hydrocarbon field cannot guarantee securing the license to temporarily store the CO_2.

The more stringent requirements for permanent storage that a buffering project would **not** need to fulfill, unless the operator is seeking credits under EU ETS, include addressing the following subjects:

a. the period of injection of CO_2 and the area,

b. the location and the delimitation of the storage reservoir and the area of the storage complex,
c. data with respect to the hydraulic unit,
d. conditions for the storage process,
e. the total maximum volume of CO_2 that can be stored in accordance with the license,
f. the value limits of the pressure of the stored CO_2,
g. the maximum allowable velocity and pressure at injection of CO_2 and the maximum allowable pressure of the stored CO_2,
h. risk management,
i. monitoring,
j. sealing,
k. corrective measures,
l. soil movement,
m. the composition of the CO_2 stream that will be stored, inclusive of substances that are added for the purpose of the monitoring and the control of CO_2 migration, and
n. the amount of financial security or an equivalent arrangement.

In the Netherlands the Mining Act is supported by the Mining Decree (Mijnbouwbesluit) which lays down the rules for implementing the Mining Act. The Mining Decree states that for any storage of substances, both permanent and temporary, a relevant plan must contain:

a. a description of the quantity and composition of the substances that are stored;

b. a statement of the data with regard to the structure of the occurrence and the location of the occurrence in relation to other earth layers, with associated geological, geophysical and petrophysical studies and the uncertainty analyzes used for that purpose

c. a specification of the substances used for the subsidence of the substances;

d. an inventory of the risks with regard to the distribution of the substances stored in the subsoil, the occurrence of chemical processes in the subsoil and the degradation of the mineral reservoirs present in the subsoil or the composition of these minerals;

e. an inventory of measures taken to prevent the risks referred to in point d;

f. a description of how the occurrence is left after the storage has ended, and

g. a risk analysis regarding soil movement as a result of the storage.

The Mining Decree then states that if the storage of substances is of a *temporary* nature, the plan for the storage of substances shall **also** contain:

- A description of the manner in which the substances that are stored are retrieved and of the substances that are used thereby, and

- A specification of the composition and quantities of the substances other than the stored substances that are inevitably extracted from the soil with the retrieval of the stored substances.

Within the ENOS project these two aspects are investigated for the buffer concept in Q16-Maas, and reported in deliverables D4.3 (Koenen and Hofstee, 2017) and D4.4 (Koenen et al., 2018).

The distinction between temporary storage of substances and the permanent storage of CO_2 in Dutch law implies that legislation should support the use of temporary CO_2 storage in a buffering scenario. In case the project would not apply for storage credits, the permanent storage commitments are not applicable and hence it should be easier and less restrictive for the project to meet the legislative requirements.

5 Key Findings and Recommendations for Removing Existing Regulatory Barriers

The CCS Directive does not directly prohibit the combination of CO_2 storage with hydrocarbon production activities. Any EU Member States undertaking new combined CCS/EHR projects have the opportunity to design the projects to meet CCS Directive requirements already in place in order to become accredited under the EU ETS. Any new EHR projects starting in Europe should therefore be encouraged to design a CO_2-EHR project with permanent storage considered from the proposal stage. This will allow the operator to incorporate the CCS Directive requirements within the project design and no regulatory or policy barriers are foreseen in this scenario.

Potential barriers may exist should a CO_2-EHR project want to transition to incremental storage (see definition on page 12). This is possible under current European legislation but potential barriers currently exist which may make the permit application process difficult. There are also more specific barriers at a national Member State level, which are country specific. As no EHR projects are currently being undertaken at a commercial scale in Europe, the potential barriers in transitioning from EHR to permanent storage can be avoided if the CCS Directive is taken into account from the project proposal stage. If a hydrocarbon field operator does want to transition from initial production operations to EOR with permanent storage and gain ETS credits for the CO_2 stored during EOR operations, potential barriers to securing a storage permit include:

1. Storing enough CO_2 to qualify for ETS credits:
   - It is still debated as to whether the storage should have to demonstrate a climate mitigation focus and store as much CO_2 as possible rather than focusing on maximum CO_2 recovery for re-injection. The limited text in the Directive regarding EHR implies that all CO_2 storage associated with EHR activities would qualify. But different interpretations of the CCS Directive currently exist with a some claiming further storage, beyond the minimum required for oil production may be required.

2. Quantifying CO_2 stored for ETS Credits:
   - In comparison with pure CO_2 storage projects, combined CCS/EHR projects will also need to quantify the CO_2 produced and calculate the amount of CO_2 permanently stored. This is not a barrier but an element of legislation that makes the associated storage of CO_2 more complicated.

3. Meeting CCS Directive requirements retrospectively:
   - Site characterisation for CO_2 storage will have to be undertaken retrospectively in line with the CSS Directive's requirements.
   - Site characterisation will have been undertaken for hydrocarbon activities but the more stringent CCS Directive requirements will also have to be met.
   - When hydrocarbon production is still ongoing this may be difficult to achieve e.g. undertaking well integrity assessments.

4. Country specific barriers:
   - The Netherlands is currently in the process of updating legislation regarding the decommissioning of oil and gas infrastructure being required at the end of production preventing the re-use for CO_2 storage purposes.
   - Ireland currently has restriction on the amount of CO_2 that can be stored. Injection is currently only allowed for research purposes, which will have to be revised to allow commercial CCS projects.

5. Buffering activities:
    - CO_2 buffering activities alone do not fall under the regulations of the CCS Directive, but under national laws for subsurface storage of substances (i.e. in the Netherlands). For CO_2 buffering projects aiming to transition to permanent storage, the site would then have to comply with the additional requirements of the Directive. Quantifying the mass balance of amount stored versus reproduced to meet ETS Directive requirements may add elements of complexity though, but is similar to CO_2-EHR projects.

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