Briefing on the Financial Liabilities associated with CO_2 Transport and Storage

3rd Report of the Thematic Working Group on:

CO_2 Transport, Storage, and Networks

Release Status: Final

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Date: 14th December 2020

Filename and version: TG3_Briefing-Financial-Liabilities-of-CO2-Transport-and-Storage.docx

EU CCUS PROJECTS NETWORK (No ENER/C2/2017-65/SI2.793333)

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Document History

Location

This document is stored in the following location:

Filename	Briefing on Liability Final.docx
Location	

Revision History

This document has been through the following revisions:

Version No.	Revision Date	Filename/Location stored:	Brief Summary of Changes
0.1	04/12/20	Briefing on Liability.docx	Initial formatted doc and drafting
0.2	08/12/20	Briefing on Liability QA.docx	First QA review
0.3	14/12/20	Briefing on Liability Final.docx	Final version Submission
Final	17/12/20	TG3_Briefing-Financial-Liabilities-of-CO2-Transport-and-Storage	

Authorisation

This document requires the following approvals:

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Consortium QA Manager	Jessica Yearwood		17/12/20

Distribution

This document has been distributed to:

Name	Title	Version Issued	Date of Issue

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Executive summary

Despite over twenty years of operations demonstrating that CO_2 storage can be done safely and securely, the investment and business case for CCS has yet to be fully realised in Europe. One of the highly debated topics surrounding CO_2 storage are the liabilities related to ensuring permanent storage throughout a project's lifetime.

At the CCUS Projects Network's Fourth Knowledge Sharing Event, Ian Havercroft from the Global CCS Institute provided an overview of the cross-chain liabilities associated with CCS and presented how a commercial approach could and should be taken to address these in the future. For CO_2 storage aspects specifically, the financial liability associated with CO_2 leakage, or so called 'climate and greenhouse gas liabilities' may potentially be an inhibiter for early-stage CCS projects under current EU regulation.

This briefing report reviews what is meant by liability and how obligations relating to ensuring permanent storage under the European ETS may impact CO_2 storage operators specifically. The implications of the EU CCS Directive are also reviewed to specifically highlight critical issues that remain for early-stage CCS project deployment in Europe. The liabilities associated with CO_2 storage will change throughout a project's lifetime and this is described in the two case studies, ROAD in The Netherlands and Peterhead in the UK, which have been included in this briefing report. Although a CO_2 storage project has not yet reached an operational phase under the European CCS Directive or ETS legislation, these projects were developed under the current regulatory framework and their early-stage insights highlight how issues surrounding liability has previously been addressed and processes developed.

Under the EU CCS Directive, storage operators currently have to provide evidence in their CO_2 storage permit application that they can set aside a budget for a 'worst-case scenario' i.e. to cover the costs of monitoring, remediation and to pay back ETS credits should a leakage occur. The requirement that funds be made available at the permitting stage for a worst-case scenario is not likely to be viable for many operators, especially given the low profit margins associated with current ETS price and subsidies for CCS in Europe. This liability is therefore explored further in this briefing.

A report by the Zero Emissions Platform (ZEP) recently reviewed the risk associated with potential leakage, with a focus on sites in the North Sea. It highlighted that given the very low risk of leakage the financial obligations made within the CCS Directive should take this into account and be associated with a "risked cost". This concept of risked cost and the implications for a CO_2 storage project are also reviewed in this briefing report.

This briefing report aims to summarise the critical issues that remain for future CCS project deployment and ascertain how potential uncertainties regarding liability may be impacting projects. In other industries (such as oil and gas operations) these sorts of risks would be absorbed by an existing insurance scheme system. However, given the early-stage of CCS development there are currently too few projects to contribute towards an insurance. Individual operators will find it a large financial burden to set aside funds for events such as leakage which are highly unlikely but would carry large financial labilities should they occur. This briefing therefore also summarises the potential way forward for early-stage CCS projects in Europe.

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Briefing on the Financial Liabilities associated with CO_2 Transport and Storage

1 Introduction

This briefing report follows from discussions at the CCUS Projects Network's fourth knowledge-sharing event for members, held online on 22nd October 2020. Discussions in the thematic working group on CO_2 transport, storage, and networks focused on commercial liability with Ian Havercroft from the Global CCS Institute (GCCSI) presenting on "Lessons and Perceptions: Adopting a Commercial Approach to CCS Liability". The presentation was based on the Global CCS Institute's report on liability published in 2019 (Havercroft, 2019).

Based on the work by I. Havercroft and the GCCSI, this thematic briefing report builds on how this review of liability can be utilised in CCS projects currently under development in Europe. For CO_2 storage operators specifically, even though risk of leakage is small, the financial liability should a release to atmosphere occur could be significant. This briefing report therefore focuses on the financial liabilities associated with greenhouse gas emissions and highlights the key areas of concern and future challenges to be overcome with regards to CO_2 transport and storage specifically.

1.1 Objective and scope

The aim of this briefing report is to outline the concept of commercial liability and investigate how CCS projects are currently approaching liability within European and national legislation and policy constraints. This briefing report will define different types of liability and how these relate to CO_2 transport and storage projects specifically.

The financial risks will also be outlined and the latest work by the Zero Emissions Platform (ZEP) on quantifying the risk of leakage and defining the financial risk associated with that under current EU regulation will be presented. Examples of how liability has been addressed in previous projects, namely ROAD and Peterhead, will also be outlined. The overall aim of this briefing report is to highlight where research is currently being undertaken to highlight where future projects in Europe may face challenges regarding liability and financial risks. The areas where future research should also be focused is discussed.

1.2 Defining Commercial Liability

The first point to be addressed in this briefing report, as highlighted by the work by Ian Havercroft, is that liability can mean different things in different contexts. Depending on the definitions of liability, and the type of liability being discussed, different concerns regarding liability need to be addressed. Three types of liability are defined (Havercroft, 2019) and presented in **Figure 1**.

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CIVIL	• May be owed by an operator where CCS activities harm the interests of third parties, with whom no contractual arrangement exists. • Termed 'tortious liability' in some common law jurisdictions. • Depending upon the jurisdiction, these liabilities are determined in legislation, or through principles developed through the decisions of the courts. • A claimant will likely seek compensatory damage for losses suffered, and/or an injunction where the damaging activity is continuing.
ADMINISTRATIVE	• Borne by an operator under both CCS-specific legislation and the broader body of national energy-related and environmental protection legislation. • Liabilities stem from a competent authority's statutory powers, which may compel an operator to undertake a specified action. • Designed to respond to a specific pollution problem and to secure practicable results, these powers are potentially broad in scope. • Wide-ranging obligations and potential for cost-recovery where an authority is compelled to act on an operator's behalf.

Figure 1 Definitions of civil and administrative liability as presented by I. Havercroft at the CCUS Project network's Knowledge Sharing Event (Taken from Havercroft, 2019)

Significant policy and regulatory intervention has been developed in recent years to address the issues concerning commercial liability and CCS hub developments. Despite this, liability still represents a critical issue.

This report will focus on the latter liabilities, which may have a significant impact on CO_2 storage and transport operators specifically. It has been highlighted that the greenhouse gas (GHG) emissions and climate change liabilities as defined in **Figure 1** often have the highest uncertainty and financial obligations associated with them, and therefore carry the largest risks for an operator. These GHG emission liabilities will influence CO_2 transport and storage operators specifically as credits will be sought in future CCS projects for emission avoided to atmosphere through the permanent geological storage of CO_2. Should a migration of CO_2 to the surface occur, this could have large financial consequences which need to be managed.

1.3 Report structure

Alongside this introduction, this briefing report consists of four more sections. Chapter 2 provides an overview of GHG emission liability, based on the introduction given at the 4th Knowledge sharing event. Chapter 3 focuses on financial risk and obligations on the CCS Directive. Chapter 4 uses two case studies in Europe to further assess how liability and financial risk have been handled in past projects in Europe. The role of future research is presented in Chapter 5.

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2 Greenhouse Gas Emission Liability

2.1 Definition of GHG Emission and Climate Change Liability

In the work by I. Havercroft (2019) two main types of liability are defined, civil (i.e. if a 3rd party were to seek compensation due to damages by CCS operations) and administrative (i.e. specific requirements imposed by an operator) as shown in Figure 1. 'Greenhouse gas emission' liabilities are a type of administrative liability, specifically relating to leakage, where the operator is required to account for any credits previously gained for greenhouse gas storage. The definition for greenhouse gas emission liabilities as given by Havercroft is:

- *In instances where some form of credit is secured for storing CO_2, a liability is borne by an operator in instances of subsequent leakage.*

Although a form of administrative liability, it is specific to CCS and present some distinct challenges. In order to address how significant the implications of this liability might be for a CO_2 transport and storage operator, the following questions are important (and can be found answered in blue text boxes throughout the report):

- Who will carry this liability, i.e. who will gain the credits for storing CO_2?
- What are the requirements to prove storage has occurred?
- What is defined as leakage and what are emissions?
- What are the requirements for emission quantification?
- Should leakage occur what are the financial ramifications?

This thematic briefing report will highlight where this information can be found within European legislative documents and provide case studies of European projects that have already addressed these questions during their storage permit applications. The following sections outline the legislation governing the credits gained for storing CO_2 (and the associated surrendering of allowances should leakage occur) and the associated challenges this poses both commercially and technically. The legislation surrounding what is defined as 'leakage' is also addressed in the following section.

2.2 Governing Legislation

European Union's Emission Trading Scheme

The European emissions trading scheme (EU ETS) is a 'cap and trade' system, setting a maximum amount of greenhouses gases that can be emitted by a participating installation. The allowances (EUAs) can also be auctioned off and subsequently traded. Installations that are covered by the EU ETS are not required to surrender credits for the CO_2 they have captured for subsequent transportation by pipelines and geological storage (European Union, 2020). CCS is included in Annex I of the revised EU ETS Directive (European Union, 2009). Therefore, the operators of the capture plant, transport network and storage facilities all require an emissions permit. Economic activities covered by the ETS (e.g. power stations and manufacturing facilities) that capture their CO_2 and reduce their direct emissions are eligible for ETS credits, currently valued at approximately €25 per ton of CO_2 (Ember, 2020). The liability for storage is therefore likely to be set up contractually to be with the storage operator to ensure permanent storage is achieved.

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In order to ensure permanent emissions reduction from these installations, the geological storage of CO_2 is required under the ETS, and is included as a sperate installation. The quantities of CO_2 must therefore be fully metered across the full CCS chain as the ETS liability moves from one operator to another. Each operator at the capture, transport or storage stage will be responsible for any emissions that occur. Installations undertaking CO_2 storage are eligible for ETS credits if the storage facility has a permit in force, in accordance with the CCS Directive[1]. (The European Commission, 2011).

Who will carry this liability, i.e. who will gain the credits for storing CO_2?

The ETS liability moves from one operator to another across the CCS chain. Each operator at the capture, transport or storage stage will be responsible for any emissions that occur.

The CCS Directive

The directive on the geological storage of CO_2 establishes a legal framework for the environmentally safe geological storage of CO_2 to contribute to the fight against climate change. It covers all CO_2 storage in geological formations in the EU and the entire lifetime of storage sites. For a CCS project to secure ETS credits it must comply with the directive. Four non-legally binding guidance documents have also been published. Guidance Document 4 is of particular significance regarding liability as it outlines the requirements for financial security. This is given in more detail in Section **Error! Reference source not found.** of this brief. The CCS Directive provides most of the administrative liabilities borne by the storage operator as it outlines the competent authority's powers and the actions an operator would be compelled to act on for specified problems e.g. leakage occurring.

What are the requirements to prove storage has occurred?

The requirements for storage to be proven are all outlined in the CCS Directive. The operator must monitor the CO_2 movement in the reservoir and the surrounding storage complex continuously. And should any leakages or "significant irregularities" occur the operator must both report and respond with corrective measures.

What counts as leakage?

Under the ETS, in the case of any CO_2 leakage, operators will have to surrender emissions allowances for any resulting emissions. This therefore raises the question of what would be considered leakage.

According to the CCS Directive, 'leakage' means any release of CO_2 from the storage complex. The storage complex is "*the storage site and surrounding geological domain which can have an effect on overall storage integrity and their safety*" (The European Commission, 2011). The CCS Directive states that in case of leakage 'corrective measures' must be taken.

The Monitoring and Reporting Guidelines (MRG) under the ETS Directive (European Union, 2010) provide monitoring and reporting guidelines for greenhouse gas emissions from the capture, transport and geological storage of CO_2. The ETS Guidelines state that "*where leakages from a storage complex pursuant to Directive 2009/31/EC are identified and lead to emissions, or release of CO_2 to the water column, they shall be considered as emission sources for the respective installation and shall be monitored in accordance with section 23 of Annex IV to this Regulation*" (The European Commission,

[1] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide

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2009). This means that any migration to ocean or atmosphere needs to be quantified and credits surrendered.

What is defined as leakage and what are emissions?

With regards to greenhouse gas emission liabilities, leakage refers to CO_2 reaching the water column and/or atmosphere. This will result in CO_2 emissions and will therefore require credits to be surrendered.

As discussed in Section 4.1, the ROAD CCS project concluded that only the ETS definition of emission, i.e. release into the water column or reaching the earth's surface, would result in the surrendering of allowances.

2.3 Challenges associated with Liability

Technical Challenges

The CO_2 storage operator will have to monitor and quantify the volumes of CO_2 emitted to ocean or atmosphere according to the ETS Directive. Combustion emissions at the injection site and fugitive emissions are likely to be minor and therefore carry relatively low risk with regard to financial liability.

There will be technical challenges associated with the techniques and technologies required for accurate monitoring and quantification of CO_2. The status of quantification monitoring techniques for potential CO_2 leakage are presented in a GHGT-10 paper (Korre et al., 2011). Overall technologies are already at a suitable readiness level for deployment on a project, but no CO_2 injection has yet been undertaken seeking ETS credits and therefore further development may be required once commercial-scale deployment begins.

The following emission sources at a storage site have to be monitored under the EU ETS (European Union, 2010):

- Combustion emissions at the injection site;
- Fugitive emissions and emissions from venting at the injection site;
- Emissions from vents and flaring at enhanced hydrocarbon recovery;
- Leakage from the storage reservoir into the water column or atmosphere;

Each CO_2 storage site will also inherently carry different challenges and risks due to varying geology, infrastructure and injection plans. This is discussed further with regards to types of storage sites and leakage risk in a report by the Zero Emissions platform (Zero Emissions Platform, 2019) which focuses on storage safety in the North Sea. The main risks focused on are those which may lead to emission of CO_2, such as through fractures or well leakage.

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What are the requirements for emission quantification?

*The **quantification** of emissions is specifically required by the ETS Directive. Guidance on the monitoring and reporting of emissions is provided by the ETS monitoring and reporting guidelines regulation: "COMMISSION REGULATION (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council"[2] Often referred to at the ETS MRGs.*

With regards to fugitive emissions from CO_2 injection, the ETS MRGs refer to the use of equipment specified in Annex II(1.1)(e) to (h) of the CCS Directive.

Commercial Challenges

Regarding the commercial aspects of a CO_2 storage project, i.e. the aim to make a profit, the greenhouse gas emission liabilities are associated with large financial risk. This is discussed further in Section 3.

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R0601

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3 Quantifying Financial Risk

Article 19 of the CCS Directive regards Financial Security and requires that:

"Member States shall ensure that proof that adequate provisions can be established, by way of financial security or any other equivalent, on the basis of arrangements to be decided by the Member States, is presented by the potential operator as part of the application for a storage permit."

Guidance Document 4 of the CCS Directive gives further details on Financial Security including definition, obligations that an operator are expected to cover and the amount that would be expected to be reserved. The guidance document also covers potential Financial Mechanisms. The aim of Guidance Document 4 is to strike the right balance between full coverage of obligations as required under Article 19 while at the same time not overpricing the risks in relation to these obligations for early movers.

An operator's CO_2 storage permit application will need to prove adequate provisions financially to cover unforeseen events such as CO_2 leakage and any related emissions, including the monitoring and remediation through all project phases.

3.1 Financial Security Requirements

Overall Article 19 and the Financial Security requirements of the CCS Directive, as they are currently written, give a high level of flexibility to the competent authorities of the Member States (but also in doing so create uncertainty for storage operators) in deciding when handover should occur and what Financial Security site operators should provide. The only legally binding aspect regarding financial liability is that stated in Article 19 of the CCS Directive.

The Financial Security requirements are outlined in more detail in Guidance Document 4 of the CCS Directive, although it should be noted the guidance document is not legally binding. The guidance document outlines how the amount of financial security could be calculated, and its current wording could be interpreted to require operators to set aside large funds for incidents with extremely low probabilities. These financial requirements may be considered a barrier for entrants into the CCS industry.

A report by the Zero Emissions Platform "CO_2 Storage Safety in the North Sea" has recently reviewed the implications of the CCS Directive and associated Guidance Document 4 with regards to financial security requirements and the burden this is currently placing on CCS projects in the early stages of development (Zero Emissions Platform, 2019).

The Financial Security requirements outlined in Guidance Document 4 discourage the use of "expected value" techniques:

The use of "expected value" techniques in determining amounts of FS coverage should be avoided. Such techniques apply probability weightings to costs of obligations that are uncertain to arise, such … surrender of allowances... A problem with applying such techniques to very low probability events is that the resulting expected values may be much too small to provide sufficient coverage via FS in the event that the obligation does arise. (Guidance Document 4, 2011)

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ZEP study proposes that the Financial Security should be based on "risked cost" which takes into account not only the cost of remediation but also the likelihood of that event happening. This concept is discussed further in Section 3.2.

The report investigated how financial security had been addressed in different countries and concluded that the focus on risk can lead to an extremely cautious approach concerning setting aside Financial Security. A key example of this is in the case of P18-4 field in the Netherlands where the regulators requested a Financial Security figure large enough to cover all events, routine or unplanned, regardless of probability, for a notional monitoring period of 50 years (Ministerie van Economische Zaken, 2013). This case is discussed further in Section 4.1 on the ROAD Project case study.

A review was conducted in the ZEP report regarding the magnitude of CO_2 storage risk using various risk assessment reports. For all currently operational projects, no geological release of CO_2 to the surface or the sea floor has been detected and the report concluded over 99,99% of injected CO_2 to remain in the subsurface for at least 500 years including during the operation phase and post closure (Zero Emissions Platform, 2019).

This ZEP report assesses ten theoretical CO_2 leakage scenarios (e.g. through faults, wells or fractures) in light of the containment risk, assessing their probability, impact, duration, and cost implications. As shown in Table 1, taken from the report, the probability of any of these ten scenarios occurring is extremely low.

The report states that following Guidance Document 4 the owners of a CO_2 storage site could be interpreted to be liable for the cost of leaked CO_2 equivalent to the carbon price under the EU Emissions Trading Scheme at the time of leakage multiplied by the volume of CO_2 released. This would require remediation costs in the order of 600 million euros. But the probability is so low (<1 in 10,000 projects in the ZEP report) that the risked costs are much lower:

"*Adding together the risked cost for all scenarios – and therefore assuming the possible simultaneous occurrence of mutually exclusive incidents – results in a total possible risked cost for one storage project of €840,650 – less than €1 million…. this is several orders of magnitude less than the defined worst-case scenario cost of €589 million, which owners and operators are required to set aside Financial Security to cover in the EU CO_2 Storage Directive*" (Zero Emissions Platform, 2019).

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Table 1 Remediation cost for given leakage scenarios or potential events applicable for a depleted field in the North Sea. (The probability quoted for leak event occurrence is over the project life time including post closure period). (Taken from Zero Emissions Platform, 2019).

Scenario	Probability over 500 years including lifetime of the project and post closure (%)	Peak leakage rate (t/d)	Duration of leak	Total mass leaked (tonnes)	Risked leaked mass (tonnes)	Total remediation cost (including ETS costs) (€m)	Risked cost (€)
Minor leakage; fault & fracture	0.2	100	50 years	1,825,000	3,800	97	194,000
Moderate leakage; fault & fracture	0.05	700	12 years	3,066,000	1,550	178	89,000
Severe leakage; fault & fracture	0.005	5,000	4 years	7,300,000	365	589	29,450
Active well leakage	0.5	50	250 days	12,500	62.5	10.4	52,000
Active well blowout	0.15	5,000	250 days	1,250,000	1,875	93	139,500
Abandoned well blowout	0.1	3,000	1 year	1,095,000	1,100	88	88,000
Seepage in abandoned well	0.5	7	100 years	255,500	1,250	34	170,000
Severe well problem, no repair successful	0.005	6,000	2 years	4,380,000	215	524	26,200
Leak from installation	0.25	100	5 days	500	1.25	15	37,500
Undesired plume spread	0.03	0	N/A	N/A	N/A	110	15,000
Total					10,219	1,838	**840,650**

3.2 Calculating 'risked cost'

The "risked cost", as proposed in the ZEP report (Zero Emissions Platform, 2019) is a methodology (often used by insurers and lenders) to measure the financial risk. In the case for CO_2 storage, the cost of the potential leakage is calculated but the risked cost also takes into account the probability of it occurring.

In the ZEP analysis, for example, the probability of an active well leak occurring was estimated to be 0.5% over 500 years (thus including the operational period and post-closure of the project). Taking into account leakage rate and duration, and therefore total mass leaked the total remediation cost (including ETS costs) would be 10.4 million euros. Therefore, the risked cost is 0.5% of 10.4 million which is 52,000 euros.

The ZEP report therefore proposes, that given a CO_2 permit will not be allocated under the CCS Directive unless there is no significant risk of leakage or damage to human health or the environment, this risk cost is more manageable. ZEP proposes that a fund held centrally with contributions according

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to the probability-weighted risk costs could be shared between the government and private sector whilst there are initially too few projects to set the scheme up privately.

The probabilities calculated in the ZEP assessment are consistent with the 2005 IPCC Special Report on CCS which found that "*the fraction* [of CO_2] *retained in appropriately selected and managed reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1000 years*" (IPCC, 2005).

Should leakage occur what are the financial ramifications?

The amount of financial security required will be decided by the Competent Authority at a Member State Level. The CCS Directive currently leaves a lot of flexibility on what is required but 'adequate' funds must be made available at the storage permit application stage.

Guidance Document 4 provides more details on financial security, but there is currently concern that it could be interpreted that full funds be made available for the paying back of emission credit allowances, rather than a more practical risk based approach.

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4 Case Studies: CCS & Financial Liability

Although no CCS projects have reached the operational phase since the CCS Directive has been in place, case studies are still available from early project developments. The ROAD project in the Netherlands and the Peterhead project in the UK are presented here to provide insight on how financial security was addressed in the early stages of the projects and how the issues surrounding liability were viewed in their risk assessments. Section 4.3 then reflects on these case studies to consider how the risk associated with liability and financial security may change throughout a project's full life time.

4.1 ROAD Case Study (The Netherlands)

Although the ROAD CCS[3] project in the Netherlands was cancelled in 2017, the project's application for a CO_2 storage permit under the CCS Directive provides useful insight into how liabilities were practically handled. Their project report detailing the permitting process for the CCS project (ROAD CCS, 2013) details the key issues they faced when it came to the CO_2 storage permitting process under the CCS Directive. Financial security is one of the 'key issues' relating to the storage permit outlined in their report. The legal liabilities for the transport and storage elements of the ROAD CCS project are outlined in **Table 2**.

Table 2 Overview of liabilities for transport and storage of CO_2 in ROAD CCS project (ROAD CCS, 2013)

	Liability regime	Potential grounds for liability	Law	EU law[1]	Dutch law	Applicable	Risk assessment[2]
Transport	Civil	Tort	6:162 Civil Code	No	Yes	Yes	+
	Civil	Superficies	6:174 Civil Code	No	Yes	Yes	+
	Civil	Hazardous substances	6:175 Civil Code	No	Yes	Probably not	+
	Environmental	Environment damage	Env. Liab. Dir. / Wm	Yes	Yes	Yes, but limited[3]	+
	Climate	Emissions	EU ETS / Wm	Yes	Yes	Yes	+
Storage	Civil	Tort	6:162 Civil Code	No	Yes	Yes	+
	Civil	Superficies	6:174 Civil Code	No	Yes	Yes	+
	Civil	Hazardous substances	6:175 Civil Code	No	Yes	Probably not	+
	Civil	Landfill	6:176 Civil Code	No	Yes	Maybe	+
	Civil	Mining works	6:177 Civil Code	No	Yes	Yes, but limited[4]	+
	Environmental	Environment damage	Env. Liab. Dir. / Wm	Yes	Yes	Yes, but limited[5]	+
	Climate	Emissions	EU ETS / Wm	Yes	Yes	Yes	-

[3] All ROAD Project close-out reports can be found on the Global CCS Institute website.

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Table 2 shows the ROAD project identified numerous civil liabilities and also environmental (relating to environmental damage) and climate (due to emissions). The civil aspects are only addressed in Dutch Law, and not a European level. Civil and environmental liabilities are also discussed in detail in the report but for the purpose of this brief the climate liabilities will be reviewed in more detail. As outlined in Section 2, this relates to the EU ETS and CCS Directive requirements regarding CO_2 leakage.

The transport and storage of CO_2 is regarded as a separate installation (from the capture plant) for the purposes of the Dutch Environmental Management Act and therefore in case of leakage at the transport or storage network, the operator must include these emissions in its reporting to the Dutch Emission Authority (NEa) and handover the associated EU emission allowances (EUAs). The ROAD project concluded that although the Directive and EU ETS Directive define leakage separately, *"the conclusion is that the operator has a major problem if CO_2 leaks from the reservoir / complex and the operator is required to take action, but as long as the CO_2 does not reach the surface, no allowances have to be surrendered."* (ROAD CCS, 2013). The financial security had to be secured and available from the start of injection until the site is transferred to the competent authority after closure.

The ROAD project faced three important questions regarding financial security which are presented and answered below:

(1) what are the exact activities that must be covered by the financial security?

ROAD concluded that the most important and financially significant activities to be covered by financial security were: monitoring; contingency monitoring in the event of a leakage; abandonment; financial contribution; and surrendering EUAs in the case of leakage.

(2) what is the amount of money that should guarantee these activities?

These associated costs assessed for ROAD are given in **Table 3**. They estimated that the cost of potential EU-ETS repayments would increase from 0 in Year 1 to 8 million in Year 9 to 29.

Table 3 Overview of financial security allocated for the ROAD project per year in million euros (taken from (ROAD CCS, 2013)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10 - 29
Monitoring	12	10	9	8	7	6	5	4	3	0,1
Contingency monitoring	10	10	10	10	10	10	10	10	10	10
Abandonment	15,5	15,5	15,5	15,5	15,5	15,5	15,5	15,5	15,5	0
FC	2	2	2	2	2	2	2	2	2	2
EU-ETS	0	1	2	3	4	5	6	7	8	8
Sub Total	***47***	***46***	***46***	***46***	***46***	***46***	***46***	***46***	***46***	***39,5***
Contingency 20%	9,4	9,2	9,2	9,2	9,2	9,2	9,2	9,2	9,2	7,9
Total	**56,4**	**55,2**	**55,2**	**55,2**	**55,2**	**55,2**	**55,2**	**55,2**	**55,2**	**47,4**

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Given these estimated costs ROAD highlighted the most serious risk to be the price of EU ETS allowance at any point in the future as this is unknown, estimations for the future ETS price used in the report differed from €15 per ton of CO_2 in 2020 to €140 in 2020. Finally, ROAD noted that since the financial security must be adjusted yearly it means that increases or reductions in the EU ETS price will impact upon the amount of financial security over time.

The Dutch authorities followed the CCS Directive's guidance Document 4 very closely and required that the financial security covered both high and low probability events. This resulted in large security amounts of more than €60 million over the initial five-year period as set out in the permits. Given the total capital investment of €30 million for the ROAD project this is a significant amount required for the financial security alone (Zero Emissions Platform, 2019).

(3) what kind of financial instrument is accepted by the competent authority?

Regarding the financial instrument, ROAD's storage permit application included several financial instruments that could be used to provide the financial security. ROAD successfully argued that a bank guarantee (that will impose higher costs than for example a balance sheet or parental guarantee) must not be demanded by the competent authority. The Dutch Competent Authority preferred a bank guarantee or escrow account, but may also have accepted a solid balance sheet of the proponents or its parent companies.

4.2 Peterhead Case Study

The Peterhead CCS project, led by Shell, published their 'Insurance Plan' in 2014 (Shell UK, 2014) before the project's funding was withdrawn by the UK Government in 2015 and the project was subsequently cancelled. The purpose of the report was to "*outline the insurance strategy…covering financial risk management and insurance aspects concerning hazard risks including liability*". The risks identified by the Peterhead CCS project are presented in **Table 4**.

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Table 4 Risk Matrix Overview for the Peterhead CCS Project (Shell UK, 2014); Red = not to be insured/ not insurable; Yellow = not applicable; Green = insurable/ to be insured

Risk	Design & Construction	Operations	Closure & Decommissioning	Post Closure
Liability				
Third Party Liability				
Seepage & Pollution (reservoir)				
Automobile Liability				
Employer's Liability				
Professional Liability				
Sub-surface Liabilities				
Physical Damage (PD)				
Damage to the Works				
Damage to existing assets				
Loss of well control				
Automobile Physical Damage				
Transits/Cargo				
Other				
Loss of Carbon Credits				
Business Interruption (caused by a PD event)				

The climate liabilities in this table are under 'Other', and named 'Loss of Carbon Credits'. The risk matrix presented in **Table 4** highlights how the risks vary throughout the lifecycle of the project, with the green/yellow/ red colours indicating the "insurability of the risk". The report concluded that "*coverage may be very expensive and/or restricted for the 'novel' aspects of the project (e.g. CCS liability, financial risks of repurchase of carbon credits, subsurface migration/pollution, etc.)*". Especially regarding the extent of liability for CO_2 release, it was concluded that repayment of carbon credits (EUAs) is currently uninsurable. This is due to the fact that the risk could not be defined or quantified given that the ETS depends on legal rules which may change over time. The monetization of risk associated with the Peterhead Project was not published in any publicly available reports.

4.3 Liability throughout a project's lifecycle

This section will provide a brief overview of what will change throughout a project's lifecycle with regards to liability and therefore how the risks associated with financial security may also change with time.

The project risk profile will change over the lifetime of a project as the risk of leakage from the storage profile fluctuates dependant on the injection period, as shown in **Figure 2**. The risk of leakage increases from the beginning of injection, but peaks shortly after injection stops and maximum reservoir pressures are reached. The risk of leakage therefore slowly decreases with time in the post-injection phase of a project.

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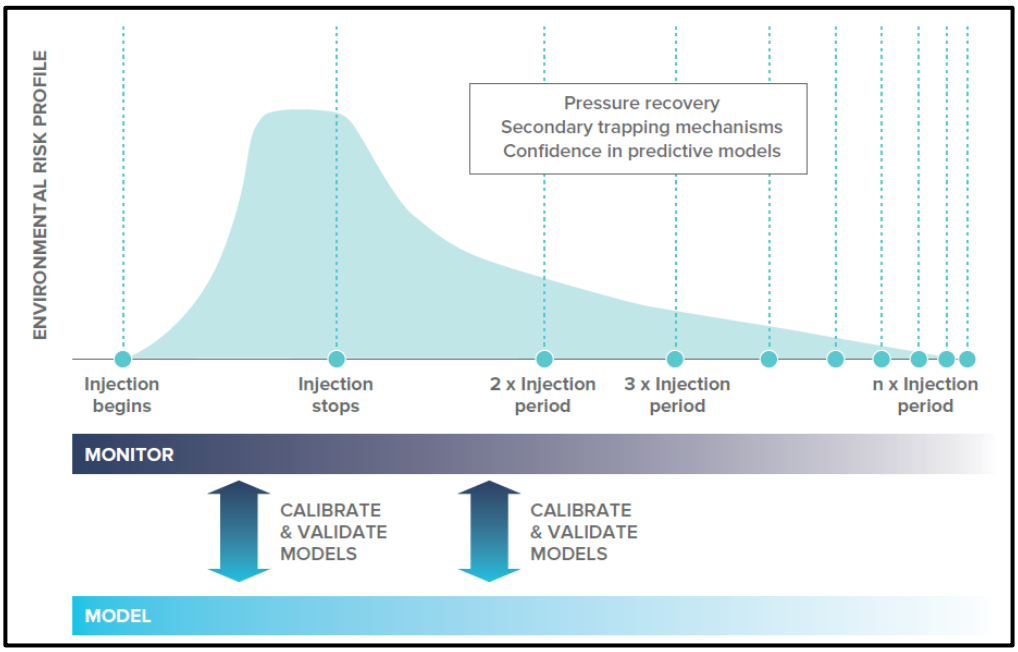

Figure 2 Lifecycle risk profile for CO_2 storage taken from (Havercroft, 2019).

This lifecycle model of a CCS project has distinct phases (e.g. site selection, injection, closure and post-closure) and has be adopted by many legal and regulatory models. The obligations of a CO_2 storage operator from the CCS Directive for example, have also divided between those during the operational phase and those in post-closure periods, and are stated as such in Guidance Document 4 of the CCS Directive (see **Table 5**)**Error! Reference source not found.**.

Table 5 Obligations under the permit that must be covered by Financial Security on the CCS Directive, (taken from Guidance Document 4)

Operations Period		Closure and Post-Closure Period	
1.A	monitoring, updates of monitoring plan, and required reports of monitoring results	1.B	monitoring, updates of monitoring plan, and required reports of monitoring results
2.A	updates of corrective measures plan, and implementing corrective measures, including measures related to the protection of human health	2.B	updates of corrective measures plan, and implementing corrective measures, including measures related to the protection of human health
3.A	surrender of allowances for any emissions from the site, including leakages, pursuant to ETS Directive	3.B	surrender of allowances for any emissions from the site, including leakages, pursuant to ETS Directive
4.A	update of provisional post closure plan	4.B	sealing the storage site and removing injection facilities
5.A	maintaining injection operations by the CA until new storage permit is issued, if storage permit is withdrawn, including CO_2 composition analysis, risk assessment and registration, and required reports of CO_2 streams delivered and injected.	5.B	making required financial contribution (FC) available to the CA

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Guidance Document 4 discusses the 'Timing of Potential FS Obligations over Storage Site Lifecycle' and states "*some of the obligations to be covered by financial security may become moot or decrease with the passage of time".* For example, after the site has been closed:

- the competent authority would have no need for financial security to cover temporary continuation of injection (i.e., operation of the site). It also wouldn't be required to cover closure (because the site already would have been closed);
- and once in the post-closure period, if the remaining time interval prior to site transfer decreases, the potential duration of monitoring obligations to be covered may also decrease.

Section 2.4(d) of Guidance Document 4 also discusses the CCS Directive requirement that financial security should be periodically adjusted to take account of the estimated costs of all obligations arising under the permit.

This system of assessing risk and liabilities throughout a project was also conducted by Shell for Peterhead as seen in **Table 4**. It is highlighted in the report by GCCSI (Havercroft, 2019) that the obligations regarding site selection, monitoring and verification 'front-load' the risks at the beginning of a project, minimising them at latter staged of the project lifecycle:

"From a regulatory and policy perspective the decision to 'front-load' legal and regulatory regimes, by placing considerable up-front requirements upon operators regarding site-selection and monitoring and verification, will also ensure government is adequately protected against any risks that may be transferred post-closure" (Havercroft, 2019).

Given that the risk of leakage is shown to decrease post-injection the risk of having to pay back ETS allowances also decreases over time. This concept is also presented in the ZEP report (Zero Emissions Platform, 2019) which concluded yearly risk in euros would start to increase once injection begins and would peak in the final year of injection and decreases dramatically in the first 50 years post-closure, shown in **Figure 3**.

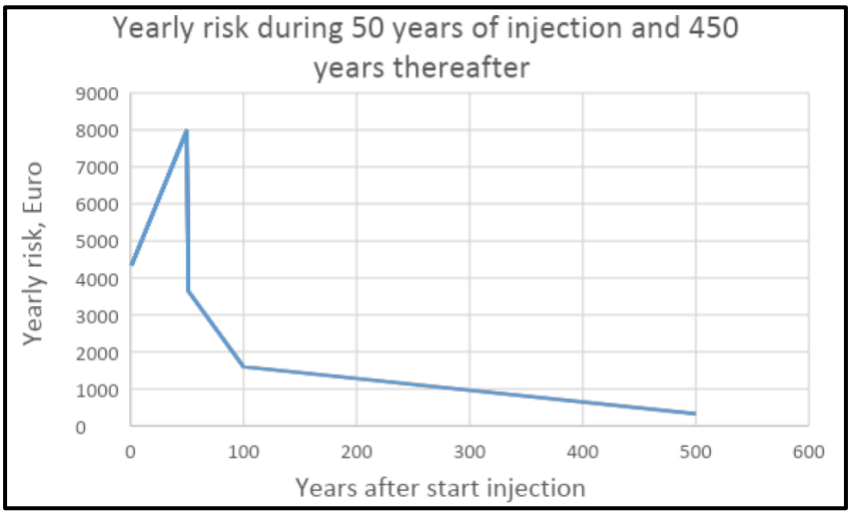

Figure 3 Yearly financial risk for a typical North Sea aquifer storage based on calculations for 50 years of injection and 450 years post-closure taken from (Zero Emissions Platform, 2019)

Overall, the risks associated with CO_2 transport and storage are likely to diminish throughout a CCS project's lifecycle, especially at the end of its operational phase. Financial security requirements are therefore also likely to diminish in the post-closure phase.

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5 Summary and conclusions

This report has provided a concise overview of the climate related financial liabilities currently associated with CO_2 transport and storage and the impact this may be having on early-stage CCS project development in Europe. The CCS Directive requirements regarding Financial Security may represent a potential hurdle to CCS deployment given the lack of insurance schemes currently available.

Although the risk of leakage has been estimated to be incredibly small, the financial liability associated with surrounding ETS allowances entails a requirement to provide large financial security funds for a project. There is also the added risk of these requirements changing over time, given the operational lifetime of a CCS project. The uncertainty associated with these risks makes them difficult to quantify and as a result they are therefore difficult to insure.

The risks associated with CO_2 storage are likely to decrease throughout a project, and decline significantly in the post-closure phase. This means that financial security requirements are likely to decrease after the operational phase, although the requirements at the beginning of the project may still pose a significant hurdle for projects in the early stages of development.

As more CCS projects develop in Europe, higher confidence will be developed in the technical feasibility and security of long-term CO_2 storage. Having more projects operational will also increase the insurance options available to operators.

5.1 Role of future research

For initial project development to overcome this initial hurdle more research is required on risk-based costing at a project specific level, to allow for a more balanced assessment of the financial security required by national competent authorities.

The current requirements of the CCS and ETS Directives regarding financial security leave great flexibility and openness for the local competent authority to decide how they would like to approach assessing the amount of funds required. This also flexibility also increases the uncertainty for project developers and therefore more guidance on how financial security can be assessed, for example using risked costs, is needed to provide clarity.

5.2 Next steps

This report will be provided to the Commission and the EU CCUS Projects Network intends to discuss the key viewpoints and remaining uncertainties during the forthcoming project review meeting. The responses from the Commission will then be shared with Network members where appropriate. Unresolved issues will remain on the agenda of the Thematic Group on CO_2 Transport, Storage, and Networks and the Network Secretariat will take efforts to address them.

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6 Glossary and abbreviations

CCS	carbon capture and storage
CCU	carbon capture and utilisation
CCUS	carbon capture utilisation and storage
CO_2	carbon dioxide
CCS Directive	Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide
ETS Directive	Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC
ETS MRG	Emissions Trading Scheme Monitoring and Reporting Guidelines
EU	European Union
EUA	European Union Allowance
FC	Financial contribution
FS	Financial security
GCCSI	Global CCS Institute
GHG	greenhouse gas
GHGT-10	The Greenhouse Gas Control Technologies Conference Series
IPCC	Intergovernmental Panel on Climate Change
ktpa	Kilo-tonnes per annum
€m	million Euros
Mtpa	Mega-tonnes per annum
N/A	not available or non-applicable
NEa	Dutch Emissions Authority (Nederlandse Emissieautoriteit)
PD	physical damage
t/d	ton/day
ZEP	Zero Emissions Platform

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