ClimateWise
REDUCING THE RISK FOR TOMORROW

MANAGING LIABILITIES OF EUROPEAN CARBON CAPTURE AND STORAGE

A CLIMATEWISE REPORT ON DEVELOPING COMMERCIALLY VIABLE INSURANCE SOLUTIONS

UNIVERSITY OF CAMBRIDGE
PROGRAMME FOR SUSTAINABILITY LEADERSHIP

CLIMATEWISE IS A GLOBAL INSURANCE INDUSTRY LEADERSHIP GROUP TO DRIVE ACTION ON CLIMATE CHANGE RISK, FACILITATED BY THE CAMBRIDGE PROGRAMME FOR SUSTAINABILITY LEADERSHIP

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About ClimateWise

ClimateWise is a global insurance industry leadership group to drive action on climate change risk. It was conceived of and launched by insurance industry Chief Executives in 2007 and our international membership now covers Asia, Europe, North America and Southern Africa. The group leverages the insurance industry's expertise to better understand, communicate and act on climate risks. ClimateWise members undertake collaborations to support the ClimateWise Principles where action needs to be taken at the industry or system level. Collaborations may involve insurers, other industries, policymakers and academics. ClimateWise's secretariat is provided by the University of Cambridge Programme for Sustainability Leadership (CPSL). Further information is at www.climatewise.org.uk and www.cpsl.cam.ac.uk.

Acknowledgements

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Cover image: Dag Myrestrand / Statoil. The full report is available at:

www.climatewise.org.uk

Contents

Acronyms

The following acronyms are used in this report:

ART	Alternative Risk Transfer mechanism
CA	Competent Authority of Member States in the EU
CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
CoW	Control of Well insurance policy
DECC	UK Department of Energy and Climate Change
EUA	European Union Allowance to emit one tonne of greenhouse gases
EOR	Enhanced Oil Recovery
ETS	European Emissions Trading Scheme
IEA	International Energy Agency
LSIP	Large-scale Integrated Project
MWh	Mega Watt Hours

Executive summary

SUMMARY OF THE SUMMARY

1. **The absence of viable risk management solutions presents a material barrier to the development of Carbon Capture and Storage (CCS) at scale in Europe.**
2. **Insurance does have a role to play as a tool to manage the risks arising from the liabilities that the CCS industry faces in Europe.**
3. **For many of the familiar operational risks, insurance solutions already exist and are known to both the insurance and oil and gas industries.**
4. **For the CCS-specific liabilities identified by the EU CCS Directive, 'off the shelf' insurance solutions do not exist. This report identifies an innovative way that insurance could address a defined subset of these liabilities.**
5. **However, some liabilities will remain uninsurable because of their nature and insurance solutions do present commercial challenges for storage operators. Insurance does not, therefore, offer an easy or comprehensive solution.**
6. **Ultimately, neither insurers nor storage operators will be able to bear unlimited liabilities, so where liabilities are not limited in size, risk sharing with government will be required to develop CCS at scale in Europe.**

Carbon Capture and Storage (CCS) is recognised by the International Energy Agency (IEA), amongst others, as a core component of a cost-effective strategy to limit global temperature rise to 2°C by 2050. The IEA has projected that investment of USD 2.5 to USD 3 trillion from 2010 to 2050 in CCS will be needed to achieve the required reductions in greenhouse gas emissions. The CCS industry globally, however, is still in an early stage of development.

In Europe, the EU CCS Directive identifies a number of liabilities for CCS storage providers. These liabilities, together with the commercial liabilities associated with a CCS value chain, create risks for which the storage provider requires risk management. If commercially viable risk management solutions are not available, this presents a material barrier to the development of CCS at scale in Europe. The purpose of this report is to bring a cross-section of insurance industry expertise together to assess whether insurance could be a risk management instrument for any of these liabilities.

A second requirement of the EU CCS Directive is for storage providers to have 'Financial Security' in place before being awarded a storage permit. This is to protect the Competent Authority (CA) in the event it is required to step in under the terms of the Directive. Financial Security covers, to a large extent, the liabilities identified by the Directive. The secondary purpose of this report is to investigate if insurance could contribute to meeting Financial Security obligations.

A large number of the operational risks in the CCS storage process can be addressed through existing risk mitigation and risk transfer options that are familiar to the insurance and oil and gas industries. This represents a significant market opportunity for the insurance industry.

However, a small number of the liabilities are specific to the CCS business. These include:

a) 'CO_2 Leakage Risk'
b) 'Decommissioning Cost Risk'
c) 'Premature Determination and Possession Risk' and
d) 'CCS Value Chain Integration Risk'

While the risks giving rise to these liabilities are not considered more likely to occur than others, a combination of the potential size of the exposure being unknown, the Directive's requirement to provide Financial Security to meet all but the last of them and the absence of existing, comprehensive risk management solutions to address them means that they represent a material barrier to the development of CCS at scale in Europe. This report examines each of these four risks in more detail.

In particular, focus is given to CO_2 Leakage Risk, which is the risk that, following

CO_2 leakage to the atmosphere, storage operators have to surrender European Union Allowances (EUAs) at an unknown future price under the EU Emissions Trading Scheme (ETS). Linking this liability to the unknown future price of EUAs means that the size of this liability is not limited. This is a liability for which storage operators must also provide Financial Security.

An innovative way that existing insurance products could be modified such that, under tightly defined criteria, they would provide cover for at least a subset of the total liability has been identified. However, insurance can only be provided for a defined (and therefore limited) liability and so this does not present a comprehensive solution for CO_2 Leakage Risk. Equally, short-term insurance solutions present commercial challenges for storage operators.

Nonetheless, if the size of this liability could be capped by government, in combination with an insurance risk transfer solution, this could make for a viable risk management approach that significantly reduces the uncertainties faced by the CCS industry in relation to CO_2 Leakage Risk.

KEY TAKEAWAYS FOR CCS STORAGE OPERATORS

1. A large number of the operational risks in the CCS storage process can be addressed through existing risk transfer options and where the EU CCS Directive creates new liabilities, this report gives a clear view of how these risks do or do not meet fundamental principles of insurability.
2. ClimateWise members have identified an innovative, technically feasible way a new insurance product could be developed to transfer a subset of CO_2 Leakage Risk. Such a risk transfer mechanism would likely be more capital efficient than alternatives but does not remove all investment uncertainty since it would be a short-term policy.
3. To increase the insurance industry's comfort around how site-specific, risk-based approaches to quantifying loss from a CO_2 leakage event work in practice, the implementation of industry-wide standards for monitoring of storage sites, building on those created by DNV under their Qualstore programme, is recommended throughout the DECC CCS Commercialisation Programme.

KEY TAKEAWAYS FOR THE INSURANCE INDUSTRY

1. If the CCS industry can develop to the scale advised by bodies like the IEA, significant new demand for insurance for risks that the oil and gas and insurance industries are already familiar with will flow from these multi billion pound projects.
2. This market development is being held back by the lack of available risk management solutions for a small number of nonetheless significant liabilities that are largely created by the EU CCS Directive.
3. ClimateWise members have identified an innovative, technically feasible way that existing insurance products could be modified to transfer at least a subset of CO_2 Leakage Risk. This would limit the liability being transferred to insurers but to grow this market, demand from the industry and broad market participation are required.

KEY TAKEAWAYS FOR GOVERNMENT

1. A large number of the operational risks in the CCS storage process can be addressed through existing risk transfer options familiar to industry, but the EU CCS Directive creates particularly challenging Financial Security obligations and risks which still stand in the way of commercial development of CCS at scale, the most important of which is the uncapped liability associated with CO_2 Leakage Risk.
2. ClimateWise members have identified an innovative, technically feasible way that a bespoke insurance product could be developed to transfer at least a subset of this risk. However, insurance can only be provided for a defined (and therefore limited) liability and so this does not present a comprehensive solution. Operators will still face residual, uncapped liability, which is considered a roadblock for investors.
3. Nonetheless, if the size of CO_2 Leakage Risk could be capped by government whilst avoiding moral hazard, in combination with an insurance risk transfer solution, this could make for a viable risk management approach that significantly reduces the uncertainties faced by the CCS industry in relation to CO_2 Leakage Risk.

KEY CONCLUSIONS FOR PRIORITY RISKS

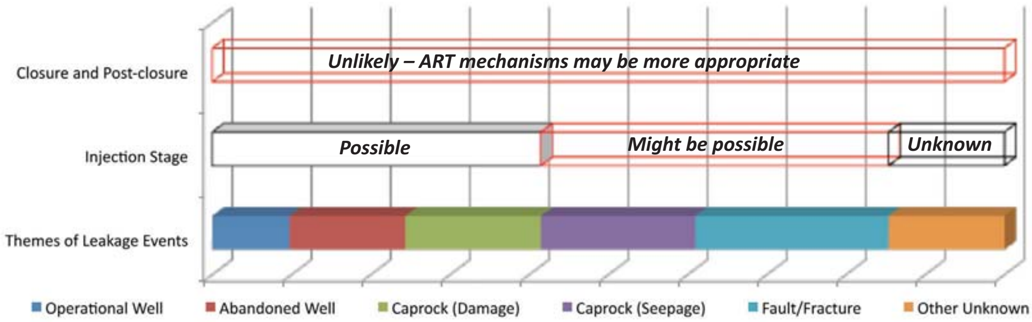
CO_2 Leakage Risk

CO_2 Leakage Risk is defined as the risk storage operators face of having to surrender EUAs under the ETS as a consequence of CO_2 leakage to the atmosphere, for which they must also provide Financial Security.

Ways forward have been identified

- An innovative way that existing insurance products could be modified such that, under tightly defined criteria, they would provide cover for at least a subset of the total liability has been identified.
- This product development is theoretically feasible, although an actual product is not yet fully developed and available.
- Insurance is likely to be provided on an annually renewable basis and could provide cover against leakage events resulting from damage to operational wells, abandoned wells and from the caprock seal over the well bores.
- These are the more likely, of the albeit unlikely overall, proximate causes for a leakage event.
- By modifying other environmental insurance policies, it might be possible to cover gradual seepage through faults and fractures.
- The insured is likely to need to declare the volume of stored CO_2 to be insured up front and the insurer and insured would need to agree the EUA price at which the policy would indemnify the insured following a leakage event, based on a 'ceiling and floor' price or on a moving average based on the previous few years' price.
- An initial aggregate market capacity of £100 – 300 million per annum is likely to be available, based on the assumption that this product would be a natural extension of existing insurance markets. This is the total available insurance capacity that could be available to each store, assuming that there was no regional or other aggregation of risks between stores. The practical availability of capacity is dependent on the risk appetite of the insurers and reinsurers involved.
- With the engagement of a range of insurers and reinsurers, this market capacity could grow alongside the CCS industry.

ILLUSTRATION OF WHERE TRADITIONAL INSURANCE COULD HAVE A ROLE TO PLAY IN THE TRANSFER OF CO_2 LEAKAGE RISK.



But are not without their challenges

- The limited insurance market capacity available will in turn limit the indemnity that can be offered to storage operators. Insurance will not, therefore, be a comprehensive solution in the context of the size of the CO_2 Leakage Risk liability being uncapped.
- The fact that insurance would be an annually renewable risk transfer mechanism means that the storage provider still faces a degree of cost uncertainty and may even have to consider the eventuality that insurance cover is withdrawn at some point in the future if CO_2 Leakage Risk for some reason turns out to be more poorly managed than expected. The report identifies some ways to mitigate this, but these implications of using short-term insurance risk transfer solutions in the context of long-term liabilities will continue to challenge investors.
- CO_2 Leakage Risk for the post-closure phase is more likely to be associated with gradual seepage through faults and factures. Even if an insurance product could be developed for these scenarios, it is not clear whether storage operators would be receiving income during this phase and an annually renewable insurance policy may therefore not be appropriate.
- Alternative risk transfer mechanisms (such as surety bonds, risk mutualisation or CAT Bonds) might be able to transfer losses beyond the scope or ability of traditional insurance, but these approaches have significant technical and commercial barriers to overcome before they could be considered feasible.

- Overall, CO_2 Leakage Risk therefore remains a difficult risk to transfer in its entirety through the mechanism of insurance. The fact that all insurance policies must indemnify the insured for a defined risk exposure, mean that there will be residual risk residing with operators under the current liability regime.
- By linking the liability to the unknown future price of EUAs under the ETS, the EU CCS Directive does not cap the size of this liability for operators. Ultimately, neither insurers nor storage operators will be able to bear unlimited liabilities, so where liabilities are not limited in either size or time, risk sharing with government will be required to develop CCS at scale in Europe.
- If commercial liability could be capped by the government, this, in combination with an insurance risk transfer solution, could make for a viable risk management approach that significantly reduces the uncertainties faced by the CCS industry in relation to CO_2 Leakage Risk.

Decommissioning Cost Risk

Storage operators face significant uncertainty about the timing of decommissioning their stores following meeting the requirements of the post closure monitoring period, but still need to provide Financial Security for this liability up front as part of obtaining a permit. In other contexts, oil and gas companies are permitted to build up a decommissioning fund over time.

- Due to this focus on the timing of costs being the real risk, there is insufficient fortuity in this risk for it to meet the fundamental principles of insurability and for a risk transfer mechanism such as insurance to be appropriate.
- Some structured financial products have already been created to help manage this risk as alternatives to insurance.

Premature Determination and Possession Risk

'Premature Determination and Possession Risk' is defined as the risk that the operator faces in incurring financial liabilities if its storage licence is temporarily or permanently withdrawn by the CA before the planned 'Transfer of Responsibility'.

- Again, this is a liability for which adequate Financial Security is required by the EU CCS Directive.
- The two main proximate causes identified are operator incompetence or operator insolvency, both of which raise fundamental insurability challenges because of the degree of moral hazard involved on the behalf of the insured. This risk has therefore been deemed uninsurable.

Value Chain Integration Risk

Value chain integration risk is the risk faced by all parties of loss of revenue because of failure in part of the CCS value chain.

- This is not a risk for which Financial Security is required, but because of its potential impact on the economic case for CCS, it was put forward as a priority by CCS operators.
- Most unexpected interruptions to a CCS value chain could be deemed to be fortuitous, sudden and accidental. Where they cause temporary interruption, such as mechanical failure in the CO_2 capture plant, they could probably be covered by traditional insurance policies such as Business Interruption.
- It is very difficult to define a quantum of loss for more serious events causing permanent interruption, such as serious storage complex formation failure, which means a traditional insurance approach is much more difficult.

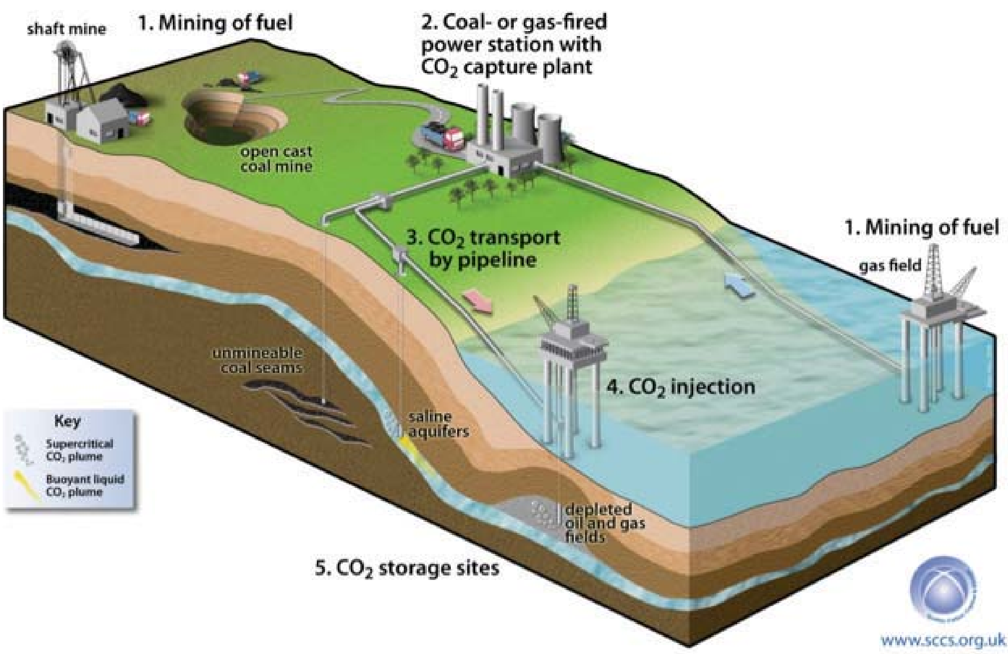
01

Introduction to Carbon Capture and Storage (CCS)

CCS is a greenhouse gas emission control technology with three major processes, as set out in **Figure 1.1**:

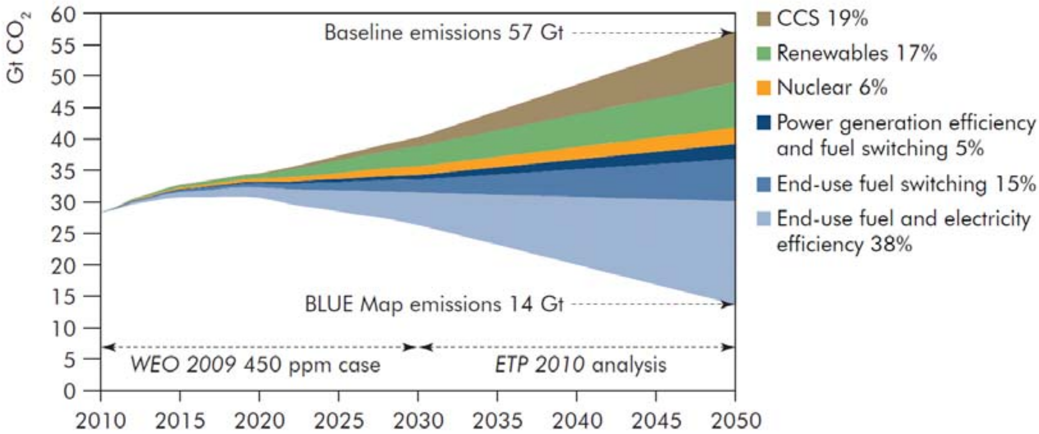
1. Capturing CO2 from stationary emission sources (eg power plants, cement plants, refinery plants),
2. Transporting CO2 to a potential storage site (eg by pipeline, by ship) and
3. Injecting CO2 into geological formations deep underground (eg depleted oil and gas fields, saline aquifer formations1-3km beneath the earth's surface) for secure storage.

FIGURE 1.1
SYSTEMIC DIAGRAM OF CCS TECHNOLOGIES (SCCS, 2012)



CCS is considered by both the United Nations Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) to be one of the key low carbon technologies required to stabilise atmospheric greenhouse gas emissions concentrations at the level consistent with limiting the global projected temperature rise to 2°C by 2050.

FIGURE 1.2
KEY TECHNOLOGIES FOR REDUCING CO2 EMISSIONS UNDER THE IEA BLUE MAP SCENARIO (IEA, 2010a)



As shown in **Figure 1.2**, the IEA (2010a: 47-48) estimates that **CCS technologies could contribute up to 19 per cent of least-cost emissions reductions by 2050**; if CCS is excluded as an option in the power sector, the IEA states that the cost for carbon reduction could increase by 40 per cent from 2010 to 2050.

OVERVIEW OF CCS TECHNOLOGIES

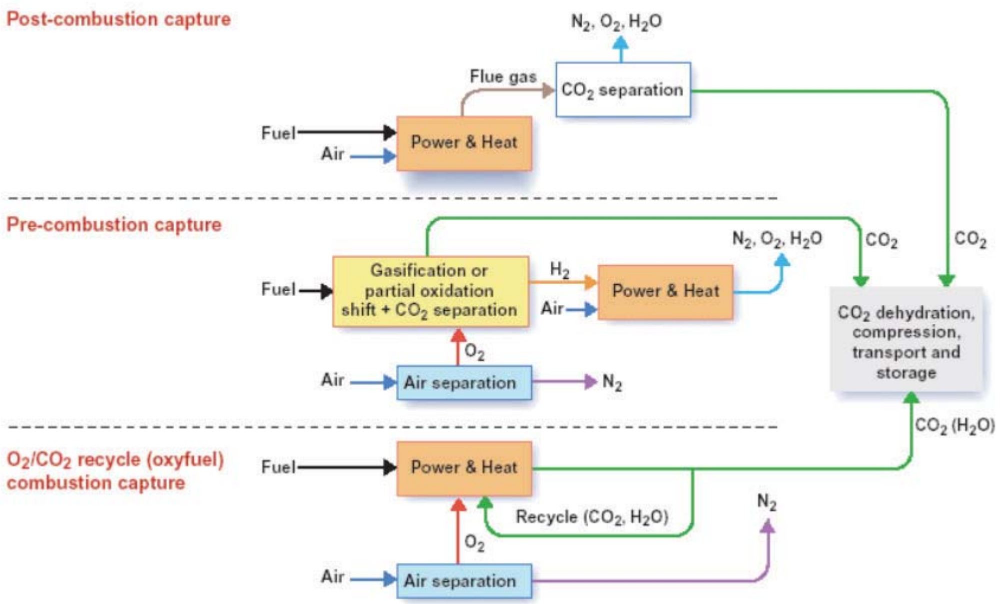
There are three major processes to capture CO2 from fossil fuel power plants, as shown in **Figure 1.3**:

1. Post-combustion: CO2 is separated from the exhaust gas using selective solvents.
2. Pre-combustion: the fuel (ie coal or gas) is converted into a mix of CO2 and hydrogen through gasification and a shift reaction and then hydrogen is burned to generate electricity.
3. Oxyfuel (also called 'O2/CO2 cycle'): the fuel (ie coal or gas) is burnt with a mix of oxygen and CO2 instead of air, which produces a higher CO2 concentration (without nitrogen) in the flue gas stream, thus making CO2 separation easier. Thereafter, CO2 is removed from the flue gas stream while some separated CO2 is recycled and mixed with oxygen.

The primary method for transporting large quantities of CO2 to the storage site is anticipated to be by pipeline, while ship transportation is another possible option.

The two principal CO2 storage options are depleted oil and gas fields and deep saline aquifer formations. In addition, CO2 can be stored underground in combination with CO2-enhanced hydrocarbon recovery (ie enhanced oil recovery, EOR) though this is only classed as CCS when the EOR site is designated as a geological store under the CCS Directive.

FIGURE 1.3:
MAJOR PROCESSES TO CAPTURE CO2 FROM FOSSIL FUEL POWER PLANTS (VGB, 2004: 20)



The estimated emission of CO2 from energy supply in the UK in 2011 was 184 million tonnes (DECC 2012a: 5). The total estimated CO2 storage capacity in oil and gas fields in the UK section of North Sea ranges from 7.4 to 9.9 Gt CO2[1] and in addition the theoretical capacity for the ten largest offshore saline aquifers would be in the range 4.6 to 46 Gt CO2 (DECC, 2010: 18-20).

CCS INCENTIVE SCHEMES IN THE UK AND THE EU

The UK and other major economies are actively pioneering CCS technologies with CCS demonstration programmes ahead of commercial scale deployment anticipated from 2020. The UK Climate Change Committee (CCC) expects that gas power plants without CCS would be incompatible with meeting the legislative carbon target (CCC, 2012). The UK Department of Energy and Climate Change (DECC) has launched a **CCS commercialisation programme** with £1 billion in direct funding support for the design and construction of large-scale CCS demonstration projects. In addition to the direct funding support, the CCS demonstration projects will be supported by a **Feed-in-Tariff with Contract for Differences (FIT with CfDs)** as part of the on-going UK electricity market reform (DECC, 2011: 43-44). Further, the European Commission (EC) has set aside 300 million EUA for co-funding CCS and innovative renewable technologies through the **NER300 programme** (EC, 2012)[2].

CCS RISK MANAGEMENT

Globally, a total of 16 CCS 'large-scale integrated projects' (LSIPs)[3] are in the 'operate' or 'execute' stages, while there are 59 active LSIPs in the 'development' stage. 21 of these developing projects are in Europe and 6 are in the UK (GCCSI, 2012: 3). Even if all of these projects were completed on time, the current progress is still far behind the IEA's target for CCS projects by 2015.

[1] SCCS (2009: 12) estimated that the largest CO2 storag at the Brent Oil Field has 300 to 1000 million tonne CO2 capacity.

[2] NER300 could fund 2 to 3 CCS projects and each project will receive up to 15 per cent of the total available allowance (ie up to the amount of funding raised from selling 45 million EUA). Currently, 10 CCS projects are either on the list of 'Candidates for award decisions' or the 'Reserve List', of which 5 projects are based in the UK (EC, 2012: 3, 7).

[3] LSIPs are defined as those which involve the capture, transport and storage of CO2 at a scale of not less than 800 000 tonnes of CO2 annually for a coal-based power plant; or not less than 400 000 tonnes of CO2 annually for other emission-intensive industrial facilities (including natural gas-based power generation) (GCCSI, 2011: 109).

If the risks associated with CCS (as illustrated in **Table A.1** in the Annex), in particular the risks associated with long-term CO_2 storage, are not adequately mitigated or transferred, there may be at least two commercial consequences. First, the actual cost of a commercial CCS project could increase dramatically. Second, investors in CCS may require a higher return compared to mature generation technologies to reflect the higher risk they perceive they are taking. It is of course also possible that the decision to invest at all may be abandoned. **The absence of comprehensive risk management processes for the implementation of CCS is therefore widely recognised as one of the core barriers for making a successful business case for CCS.**

From a regulatory perspective, CCS project developers around the world need to comply with very different legal and regulatory regimes[4]. In Europe, CCS project developers are required to satisfy the legal requirements of the EU CCS Directive[5], which in turn is linked to the EU Emissions Trading Scheme Directive (ETS), and the EU Environmental Liability Directive before the project can receive a permit for operation (EPC, 2004; EPC, 2009).

Importantly, the EU CCS Directive contains a requirement, in Article 19, that obliges CCS operators to establish adequate Financial Security to cover part of the operator's obligations throughout the lifecycle of a CO_2 storage site (EPC, 2009). These obligations are set out in **Table 1.1** and the Financial Security must be in place *before* the permit for a store can be granted. The CCS industry is particularly concerned about the requirement (3.A and 3.B) to have Financial Security in place to cover the risk of having to surrender European Union Allowances (EUAs) in the event of CO_2 leakage (CCSA, 2012: 3). The unknown future price of EUAs means this is an uncapped liability.

TABLE 1.1
OBLIGATIONS THAT MUST BE COVERED BY FINANCIAL SECURITY UNDER THE EU CCS DIRECTIVE

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 EUAs for any emissions from the site, including leakages, pursuant to ETS Directive	3.B	surrender of EUAs 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 Competent Authority until new storage permit is issued, if storage permit is withdrawn	5.B	making required financial contribution available to the Competent Authority

[4] Most countries require CO_2 storage operators to bear the long-term CO_2 storage liability (eg in many US states and in the EU) but some governments may consider bearing the liability (eg Australia) (Ulardic, 2007).

[5] The CCS Directive was transposed into UK law in the Energy Act 2008.

The European Commission has identified nine possible instruments to meet these Financial Security requirements[6], which range from deposits being made to the Competent Authority (CA) through to insurance policies for payments due to leakages. A few studies have investigated the potential for these different instruments to meet the liabilities for CO_2 storage in Europe (Trabucchi and Patton, 2008; Dooley et al, 2010; CCSA, 2012), but the commercial insurability of key risks in the CCS process is not yet sufficiently understood.

OBJECTIVE AND APPROACH OF THIS REPORT

It is for this reason that ClimateWise has collaborated with the CCSA to produce this report. The objective is to provide the CCS industry, the wider insurance industry and policymakers with an objective overview, informed by a range of leading insurance industry actors, of the likely commercial insurability of risks in the lifecycle of CCS projects. Particular focus is given to the liability and Financial Security requirements of the EU CCS Directive because of this important regulatory context, although some consideration is also given to other material liabilities that operators face.

First, the fundamental principles of insurability are set out since they form the guiding framework for the analysis that follows. An overview of the risks associated with the CCS process follows. This was generated by CCS industry experts and then refined by both CCS and insurance industry professionals in a workshop.

A more detailed analysis of four particularly challenging risks is then presented using the following framework:

i) Risk definition (including vulnerability, causes, and consequences)
ii) Assessment against principles of insurability
iii) Potential for traditional insurance policies to be applied
iv) Potential for Alternative Risk Transfer (ART) mechanisms to be applied
v) Analogous insurance or ART policies
vi) Additional action required to build capacity for risk transfer

[6] 9 financial instruments are identified by EC GD4 for meeting FS requirements. (1) Deposits to a Competent Authority; (2) Irrevocable Trust Fund; (3) Escrow Account; (4) Bank Demand (Payment) Guarantee; Irrevocable Standby Letter of Credit; Surety Bond (Payment Bond); (5) Prepaid Insurance Policy for Assurance of Closure and Post-closure Monitoring; (6) Liability Insurance Policy for Payments due to Leakages; (7) Self-assurance based on Annual Financial Test; (8) Corporate Guarantee from Affiliated Company based on Annual Financial Test; (9) Corporate Guarantee or Indemnity from Non-affiliated Corporation based on Annual Financial Test.

02

Fundamental principles of insurability

The transfer of risk to an insurer is traditionally based on the insurance contract (the ***insurance policy***). The insured party pays the ***premium*** to secure the ***benefits***, which will be paid according to the ***policy conditions***. The benefits of a typical non-life insurance policy usually consist of:

1. The ***reimbursement*** of expenses paid by the insured
2. An ***indemnity*** covering the relevant loss, to re-instate the insured to the position they were in before the loss, and no better or worse

A typical insurance product development process will include five phases[7], as set out in **Figure 2.1**, which start with risk identification and risk analysis.

FIGURE 2.1
TYPICAL INSURANCE PRODUCT DEVELOPMENT PROCESS

Certain risk characteristics are considered critical pre-conditions for insurance to be an appropriate risk transfer mechanism. These are listed below, although it is still sometimes possible for certain risks which do not possess these characteristics to be insured under specific circumstances (Vaughan and Vaughan, 2002).

1. **Proximate Cause**: It must be possible to identify a peril or a proximate cause that will trigger the loss.

2. **Fortuity**: The loss must be the result something that may or may not happen and the loss should be beyond the control of the insured. Where the insured has a control over the fortuity of the loss, there is said to be moral hazard, which undermines the ability of insurance to be an appropriate risk transfer mechanism.

3. **Ability to Price**: The loss needs to be capable of quantification. Insurers must be able to set a value on the key variables such as scope and probabilities of loss events.

[7] This process is also adopted as the framework methodology for this study.

Ideally, there are a large number of homogeneous exposures to make the losses reasonably predictable.

4. **Commercial Feasibility**: The price of the insurance policy must not be too high in relation to the possible loss, otherwise the insured will not see insurance as an attractive risk transfer mechanism compared with alternative risk management mechanisms, such as self-insurance, contractual arrangements, hedging, or risk mitigation through technical measures. Generally, insurance tends to be a capital efficient method of risk transfer.

A typical life cycle of a non-life insurance policy consists of six stages, as illustrated by **Figure 2.2**. When a ***peril*** (ie an event that would give rise to possible damage) is identified and deemed 'insurable', the party who would suffer that damage pays a premium in exchange for insurance benefits (ie ***risk transfer***). If the event occurs, the insured raises a ***claim***. The insurer has to assess the ***damage***, and then define the amount of the benefit in order to ***settle*** the claim. The ***payment*** reaches the insured party based on the ***policy conditions***.

FIGURE 2.2
LIFE CYCLE OVERVIEW AND TERMINOLOGIES IN NON-LIFE INSURANCE (MODIFIED BASED ON OLIVIERI AND PITACCO, 2011: 53-54)

Traditional forms of insurance (eg **first party property damage** or **third party liability**), may not always be the most appropriate techniques for dealing with different kinds of risk and thus a number of alternative risk transfer (ART) mechanisms have been developed to accommodate emerging risk transfer requirements. A number of potential ART mechanisms for managing risks in CO_2 storage will be discussed in this report including surety bonds, risk mutualisation, CAT bonds and other structured financial products , though it should be noted that insurance tends to be a more capital efficient method of risk transfer.

03

Overview of risks in the CCS process

The obligations imposed on CCS project developers by the EU CCS Directive are not the only liabilities that they face. With the intention of focusing on those liabilities that currently pose the most significant barriers to development of CCS at scale, it was therefore felt important to assess the full range of risk exposures associated with the CCS process at the outset. The intention was to understand which risks can already be managed adequately and which risks are particularly challenging and cannot be adequately managed at present.

MAPPING THE CCS RISK REGISTER

Stakeholder perception of risks is a key factor in determining the potential demand for risk transfer instruments as well as which party should or could bear the risk (Elkington, 2007; Ekmann, 2007; Zurich, 2009b: 8). A number of studies have analysed stakeholders' perceptions on developing CCS technologies (eg Shackley et al, 2009; Johnsson et al, 2010), but very little research has investigated the risk perceptions of a future mature CCS industry (Polson et al, 2012). As part of this study, in order to understand the perception of CCS risks in the industry and to prioritise risks in the CCS process, a stakeholder consultation process was implemented in July 2012. The stakeholder consultation process included two stages:

1. **Anonymous online survey**: Instead of prescribing the key risk register in the CCS process, CCS industry experts were asked to **propose** and **define** their own key risk register based on their own understanding and experience.
2. **Stakeholder workshop**: A workshop was convened to produce an agreed risk list, with definitions being understood by both insurance and CCS representatives. Anonymous electronic voting was then applied in order to prioritise the key risk exposures according to insurance and CCS industry experts' assessment of **severity** and **likelihood**[8] during the workshop.

Before any prioritisation was carried out, 43 risks were identified through the online survey. This full list is captured in **Table A.1** in the Annex to this report along with definitions of each risk. This is not purported to be an exhaustive list. The majority of risk exposures (33 out of 43) identified related to the CO_2 storage process as opposed to the capture or transportation phases or the integrated project as a whole.

[8] The methodology has also been applied for other risk perception studies, eg Polson et al (2012) investigated stakeholders' perceived likelihood and severity for reservoir evaluation during a CO_2 storage project.

The output of this consultation process is not presented as a rigorous or exhaustive scientific assessment of risks, but rather was a concerted effort to combine a range of expert views from the CCS and insurance industries to ensure that the key risks prioritised were those that felt most important to all. **Figure 3.1** sets out a summary of the risk categories identified through the entire CCS process[9].

FIGURE 3.1
MAJOR RISKS CATEGORIES IN INTEGRATED CCS PROJECTS

Capture	Transportation	Storage	Project Wide
Health and Safety	Health and Safety	CO_2 Leakege	Value Chain Integration
Environmental Damage	Pipeline Leakage	Premature Determination and Possession by CA	Technology Performance
Technology Performance	Shipping Leakage	Decommissioning Costs	Change in Law
Technology Development	Third Party Access	Measurement and Monitoring	Public Perception
Energy and Carbon Prices		Alternative Storage Site	Cost of Financing
Capital Cost		Health and Safety	
		Environmental Damage	
		Financial Security	
		Third Party Access	

It is worth noting that these risks sit in a wider business context for CCS project developers, which introduces further risks. For example, the chance that there is a mismatch between the future revenues from operating a CCS store and the costs involved is a commercial risk for CCS project developers.

The 43 risk exposures were then presented in a stakeholder workshop attended by CCS and insurance industry experts to score their **likelihood** and **severity**. Four particularly challenging risk exposures were identified through this process because of the lack of known risk management processes available to operators in each of their cases:

1. CO_2 Leakage Risk
2. Decommissioning Costs Risk
3. Premature Determination and Possession Risk
4. Value Chain Integration Risk

Reference back to Table 1.1 shows that the EU CCS Directive also requires Financial Security to be in place for the first three of these risk exposures – obligations 3.A and 3.B for 'CO_2 Leakage Risk', obligation 4.B for 'Decommissioning Costs Risk' and obligation 5.A for 'Premature Determination and Possession Risk'.

[9] A sample of a more detailed risk register can be found through the Front End Engineering Design Study by EON (2011) for the Kingsnorth project.

The prioritisation of these risk exposures should therefore be seen as a reflection of significance of the lack of available risk management options, rather than as a reflection of the perceived likelihood of these risks occurring. They are all, also, risks that are specific to the CCS business rather than being familiar in other energy industry contexts. Each of these prioritised risk exposures is analysed in further detail in Sections 4, 5, 6, and 7.

GENERAL ASSESSMENT OF RISK TRANSFER OPTIONS FOR THE CCS PROCESS

CCS projects are multi billion pound investments and the IEA (2010b) has projected that investment of USD 2.5 to USD 3 trillion from 2010 to 2050 in CCS will be needed to achieve the required reductions in greenhouse gas emissions in that timeframe. A large number of the operational risks identified in the CCS process can be addressed through existing risk mitigation and risk transfer options that are familiar to the insurance and oil and gas industries. This represents a significant market opportunity for the insurance industry.

By way of example, **Box 3.1** sets out six risk transfer requirements identified by the Scottish Power Consortium in its FEED study for the Longannet demonstration project, identifying the relevant existing insurance policies that could be applied.

BOX 3.1
INSURANCE REQUIREMENTS IDENTIFIED IN THE LONGANNET CCS FEED STUDY

The Scottish Power Consortium identified six potential insurance policies:

1. **Construction All Risks (CAR):** addresses any risks for physical damage to construction works, damage to existing property and third party liability as a result of such construction works.
2. **Property Damage / Business Interruption (PDBI):** PD cover can be purchased for all assets, which would be reinstated or replaced in the event of damage or destruction. BI coverage will provide protection for fixed costs and profit and is triggered by a covered event under the PD cover accordingly.
3. **General Third Party Liability (GTPL):** insures against loss of, or damage to, third party property and personal injury, death or disease to persons, including environmental liability
4. **Control of Well (CoW):** coverage would apply for the injection wells related to CO_2 injection as it already does on Enhanced Oil Recovery (EOR) projects.
5. **Director's and Officer's Liability (D&O):** protect project partner's directors and offices for private liability.
6. **Obligatory Local Insurance Covers:** Any obligatory insurance covers by law or contract will be taken out accordingly. ***Source: SPCCSC, 2011***

In addition, many of the potential environmental liability exposures associated with CCS[10] are analogous to those covered by traditional Environmental Liability Policies.

Potential environmental damage can arise out of a number of operations within the CCS process. CCS projects would require a comprehensive environmental impact study, which should identify baseline conditions and make determining remedial obligations more clearly. That said, given how the EU Environmental Liability Directive is implemented, understanding how remediation costs will be calculated in the case of CCS, particularly complementary and compensatory remediation, is still very difficult. Evaluating the environmental exposures and loss potential associated with the various stages of the CCS processes mentioned in this report will therefore range in complexity and in the resources and expertise required.

Many of the exposures are similar to existing industrial customers and as such, the remedial costs and potential for other losses such as bodily injury or property damage can more easily be estimated. Other potential risks, such as the requirement to undertake remedial measures associated with environmental damage from a CO_2 release could be more complex and require specific expertise in geology, hydrogeology, biology and other expertise. A traditional Environmental Liability policy could also cover bodily injury and property damage arising out of the various stages in the CCS process.

Market capacity for traditional environmental liability insurance, including environmental damage coverage to address exposures associated with the local transposition of the EU Environmental Liability Directive is upwards of $150 million and could extend to $200 million depending on the risk. The market has more limited capacity for longer term deals and typically operational coverage is not available beyond five years with an aggregate stretched over that policy period.

Box 3.2 shows how, in reality, a number of these liabilities can be bundled into a single policy for CCS operators, drawing on an existing product that has been developed by Zurich.

[10] The main concern currently is the chemical solvent waste (Amine) from the post-combustion capture process. However, there are other emerging issues, eg environmental impact of trace elements from a CCS site (Payan et al, 2012)

BOX 3.2

ZURICH'S CARBON CAPTURE & SEQUESTRATION INSURANCE POLICY (CCS POLICY) BUNDLES FIVE MAJOR COVERAGES WHICH ARE SUMMARISED HERE

The policy will:

1. Pay costs as a result of a claim for bodily injury, property damage, clean-up costs or natural resource damages resulting from a pollution event that happens as a direct result of carbon injection and storage operations and is within, at, under or migrating from the storage location;
2. Indemnify the insured for loss of business income and reasonable and necessary expenses to the extent resulting from either a pollution event or geomechanical event (geomechanical event can include induced seismicity) within, at, under or migrating from the storage location. This does not include reimbursement for loss of EUAs;
3. Indemnify the insured for reasonable and necessary costs, charges and expenses incurred by the insured to bring an "out of control" well "under control";
4. Indemnify the insured for a loss as a result of a claim for bodily injury, property damage, natural resource damages or clean-up costs sustained by a third-party resulting from a pollution event that happens during transportation of the gas stream;
5. Indemnify the insured for loss an insured is legally obligated to pay as a result of bodily injury, property damage, clean-up costs or natural resource damages resulting from a "geomechanical event" (including induced seismicity). This does not include reimbursement for loss of EUAs;

04

CO_2 Leakage Risk

RISK DEFINITION

The precise definition of 'CO2 Leakage Risk' used throughout this report is the risk the operator faces of having to surrender EUAs as a consequence of CO_2 leakage from the storage complex to atmosphere[11].

As noted, this is a risk exposure for which the EU CCS Directive requires operators to have Financial Security in place before a permit for storage is awarded. The implications of the liability are therefore specific to the regulatory context of the EU and are distinct from other liabilities associated with a leakage event, such as those relating to the EU Environmental Liability Directive.

RISK CHARACTERISTICS

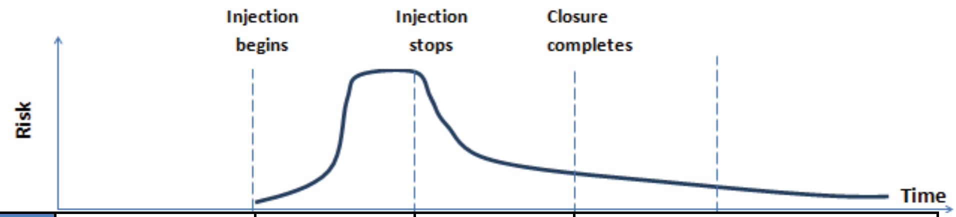
EU CCS Directive Guidance Document 1 (GD1) indicates that the lifecycle of a CO_2 storage project could be divided into six phases, as set out in **Figure 4.1**. The CO_2 storage operator needs to comply with all requirements of the CCS Directive in order to be awarded a storage permit, including meeting the Financial Security requirements. This is required to take place between phase 2 (Characterisations on and assessment of storage complex) and phase 3 (Development). The CO_2 storage operator will be liable for CO_2 leakage events during the operation, closure and post-closure stages until the liability is transferred to the CA, when storage is deemed to be permanent, in each member state.

Through the lifecycle of a CO_2 storage project, the estimated risk of leakage builds up steadily after injection starts and flaws in the system may be exposed and starts to plateau a few years before injection is completed as pressure in the store reaches its maximum level. The risk of leakage reduces once injection has ceased and closure of the store has been completed but there is still residual risk as assets age. Note that the same trend does not apply to the risk exposure; even though the volume of CO_2 stored does not change once injection has been completed, the value of the CO_2 will continue to change as the price of EUAs fluctuates (and presumably rises) so the contingent financial liability will continue to increase as well.

[11] More precisely, the Monitoring and Reporting Guidelines updated by the EU in 2010 (Commission Decision 2010/345/EU) indicate 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 included as emission sources for the respective installation and shall be monitored accordingly as required under the provisions of Annex XVIII." The storage complex is expected to include multiple sealing layers in the sequences above the primary reservoir. Further, as part of the storage permit application process, a site-specific monitoring plan must be drawn up which will include definitions of the thresholds of 'irregular activity' in the store that will define when a leakage event is said to have occurred.

FIGURE 4.1
ILLUSTRATIVE DIAGRAM OF THE LIFECYCLE AND RISK OF LEAKAGE FOR A CO_2 STORAGE PROJECT IN THE EU REGULATORY CONTEXT.

NB this figure was formulated based on EU CCS Directive Guidance Document 1 (EPC, 2009) and CO_2 storage lifecycle risk literatures (Bachu, 2008; Benson, 2008; DECC, 2010: 31-32; Dooley et al, 2010; Koornneef et al, 2012)



Operation	Preparation	Injection	Closure	Post closure	
Phase defined by GD1 of EU CCS Directive	1. Assessment of storage capacity 2. Characterisation on and assessment of storage complex 3. Development	4. Operations		5. Post-closure / Pre-transfer 6. Post-transfer	
Estimated Duration	Phase 1: 0.5 - 2 years Phase 2: 2 - 11 years Phase 3: 1-3 years	Phase 4: 5 – 50 years		Phase 5: uncertain Phase 6: perpetual (long-term stewardship of site by member states)	
Liability	n/a	Operators*	Operators*	Operators*	Competent Authority
Actions by operators during each phase	-site screening; and ranking; -simulation; -risk assessment - apply for CO2 storage permit (need to comply with ALL CCS Directive requirements) - monitoring, reporting and corrective plan	- monitoring - update models - risk assessment - corrective plan	- target monitoring - Update models - risk Assessment - corrective plan - decommission	- decrease monitoring - evaluate long term monitoring and corrective plan - transfer responsibility to Competent Authority (CA) when evidences indicate CO2 will be completely and permanently stored	

* Member state of the project will be liable for CO_2 storage obligations in an event of operator default.

PROXIMATE CAUSES

Guidance Document 1 (GD1) for the EU CCS Directive identified four main potential pathways for leakage of CO_2 from a store. A UK Department of Energy and Climate Change (DECC) study (2012), carried out by AGR and SCCSS, added further detail:

Well leakage pathways

1. **Operational wells**: accidental damage or partial or total failure of the containment in the well bore.
2. **Abandoned wells**: deterioration of the annular cement and/or casing cement plugs due to the action of CO_2; deterioration of pre-existing annular cement bonding around abandoned well casings; known or undocumented sections of wells that have not been cemented during decommissioning.

Geological leakage pathways

3. **Caprocks**: movement of CO_2 from the primary storage reservoir through the overlying caprock and outside of the storage complex into the overlying formations.
4. **Faults and fractures**: leakage of CO_2 through re-activated faults and fractures, along a new pathway created by CO_2 injection or induced by natural seismicity.

In the absence of a loss history, the DECC study estimated the probability of a leak and the likely magnitude or flux of the leak for these different pathways[12]. A summary of these estimations is set out in **Table 4.1**.

TABLE 4.1
SUMMARY OF ESTIMATED LEAKAGE PROBABILITY, RATE AND DURATION FOR DIFFERENT LEAKAGE PATHWAYS (AGR AND SCCSS, 2012)

Pathways	Scenarios	Probability	Potential Leakage Rates (tonne/day)	Duration (Years)	Potential Amount of CO2 (tonne)
Operational Well [a]	Low Level Leakage Scenario	10^{-4} - 10^{-3}	0.1-10	0.5-20	18-73,000
	Worst Case Scenario	10^{-4} - 10^{-5}	5000	0.25-0.5 (with remediation measures)	0.45m - 0.9m
Abandoned Well [b]	Low Level Leakage Scenario	1.2×10^{-3} - 5×10^{-3}	0.6-6	1-100	220-220,000
	Worst Case Scenario	n/a	1000	0.25-0.5*	90-180,000
Migration through Caprock		Negligible	Very low	100-1000	Very low
Leakage via Fault	Vertical Migration - Low Flux	site specific	1-5	1-100	0-1.8m (100 yrs)
	Vertical Migration - Moderate Flux	site specific	50-250	1-5*	0.018-0.46m
	High Flux Migration	site specific	1500	1-5*	0.55-2.7m

a: Assuming a single store with 5 injection wells, a 20 year injection period and 200 million tonnes of CO_2 stored in total
b: Assuming a single store with 6 abandoned wells, 200 million tonnes of CO_2 stored in total and a probability of leakage over 100 years.

Of the four pathways, an abandoned well[13] is considered as the most probable source of leakage, but the flux rate in a leakage event is likely to be very low. The potential flux rate from leakage in an operational well is higher (ie up to 5000 tonnes/day) but the leak could be more easily detected and remediated from as early as day 1 of a leakage event. Remediation work[14] in such a scenario is expected to be completed within 6 months, thereby limiting the total amount of leakage.

Caprock leakage is considered to be unlikely in the UK sector of the North Sea while the estimated leakage rates will be very low. Leakage via faults and fractures is also considered to be unlikely, but is more uncertain and site specific.

CONSEQUENCES

A CO_2 store has to be registered as an "installation" under the ETS Directive. If a leakage event occurs and CO_2 reaches the atmosphere, the CO_2 storage operator is therefore required to surrender EUAs for the volume of CO_2 lost, pursuant to the ETS Directive, and may be required to implement corrective measures under the CCS Directive. There may be other consequences relating to environmental damage which would be covered by the EU

[12] The estimate is based on Norwegian data provided by SINTEF. The leakage rate and flux is highly site specific and the ratios for onshore store could be very different IEC (2012).

[13] Including wells previously applied for pre-existing exploration, appraisal and development.

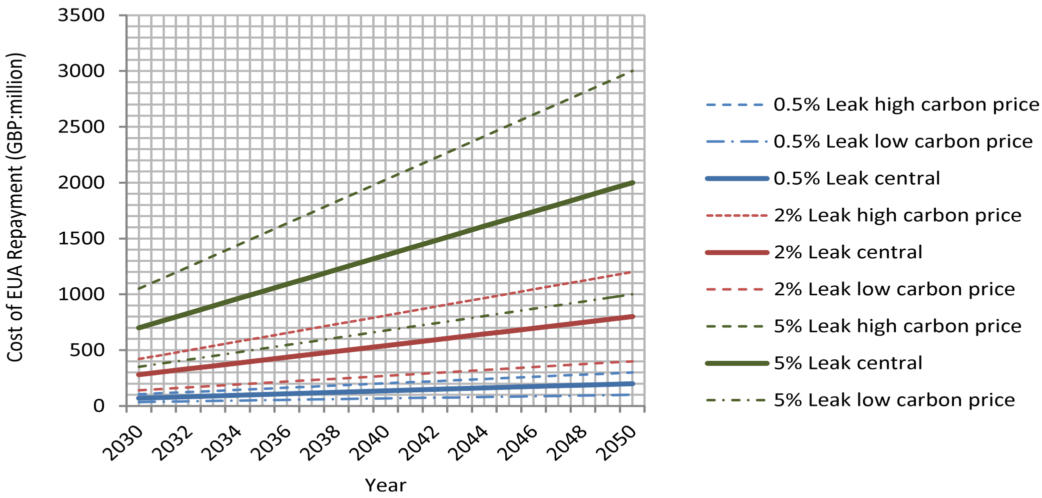
[14] It is sometimes necessary to drill a dedicated relief well.

Environmental Liability Directive, but these are not considered in the scope of the definition of CO_2 Leakage Risk here and have been discussed in Section 3.

The financial consequence of a CO_2 leakage event depends on the specific leakage circumstances (flux rate and duration), the potential for corrective measures and the market price of EUAs at the time of the leak. As illustrated in **Figure 4.2**, a leakage of 2 per cent of a store of 200 million tonnes in 2035 would require approximately £412 million for the surrendered EUAs, based on the central carbon price estimate provided by DECC (2009: 119).

FIGURE 4.2
ESTIMATED COSTS OF SURRENDERING EUAS FOLLOWING 0.5 PER CENT, 2 PER CENT AND 5 PER CENT CO_2 LEAKAGE SCENARIOS FROM A 200 MILLION TONNE CO_2 STORAGE SITE (FOR ILLUSTRATION ONLY).

NB the EUA Price estimates are based on DECC (2009: 119) study on traded carbon value at 2009 constant price. The risk free rate assumption by DECC (2009: 42) is 3.5%.



The potential financial impact of these liabilities is different when you compare the largest storage operators with smaller organisations, even though they might all be working together in a consortium. However, without risk transfer options, the balance between returns and liabilities may undermine the business case for CCS for them all.

There are also financial consequences of implementing corrective measures in a leakage event as set out by the EU CCS Directive Guidance Document 2 (GD2). In some major leakage scenarios, a relief well is required to pump drilling fluids and cement into the leakage zone to seal it off. This process may take 2 months or more and cost approximately £25-30 million (AGR and SCCSS, 2012: 25) depending on key variables such as reservoir depth, rig availability etc. In extreme scenarios, a relief well could cost significantly more (£50-£100 million) if problems are encountered.

Finally, it should be noted that the operator will face further commercial implications following a leakage event, not least through the cessation of CO_2 injection and the consequent liability to other actors in the CCS value chain, as well as potential reputational damage.

RISK MITIGATION MEASURES

Best practice for risk mitigation during the site selection, characterisation, development, injection, closure, and post-closure stages has been outlined by the EU CCS Directives, particularly highlighted in Guidance Document 2 (GD2). In principle, an effective risk transfer mechanism should be designed to incentivise, and must not jeopardise, the operator's willingness to adopt the best practice for risk mitigation, otherwise, it could be considered to create moral hazard.

ASSESSMENT AGAINST FUNDAMENTAL PRINCIPLES OF INSURABILITY

Assessing CO_2 Leakage Risk, as defined above, against the fundamental principles of insurability, we see that the major challenges are to do with the ability to price, and the commercial feasibility of, a risk transfer solution:

1. **Proximate Cause**: using the DECC pathways set out in Table 4.1, it is possible to define proximate causes for CO_2 leakage events, such as operational or abandoned well blow-out giving rise to the 'worst case scenario' pathways. These could be classified as sudden or accidental events and may be seen as distinct from other proximate causes that would lead to gradual leakage, or seepage, events through faults and fractures, which can be approached with other analogous products.

2. **Fortuity**: In these cases, the proximate cause would indeed be fortuitous.

3. **Ability to Price**: The risk exposure as it is defined by the EU CCS Directive represents an unquantifiable and potentially unlimited liability, principally because of the linkage between the financial liability and the unknown future price of EUAs. In order to meet the principle of being able to price the risk, specific parameters will need to be placed around the risk exposure. The lack of a loss history also presents a challenge here, with the DECC scenarios being the main source of data around the likelihood of different pathways leading to leakage.

4. **Commercial Feasibility**: If an insurance solution is possible, it would provide cover for a defined, and therefore limited, liability. Under the current wording of the EU CCS Directive, this would still leave CCS operators with liability for any losses above the limit of the cover. If operators were unable to bear such an unlimited liability, it may undermine the case for an insurance solution playing a role as well. There are also questions about whether the insurance premium, payable upfront in accordance with the EU CCS Directive, would be attractively priced in the context of the CCS business model.

This analysis shows that for a insurance risk transfer solution to be commercially viable, most attention will have to be given to the 'ability to price' and the 'commercial feasibility' once the proximate causes have been clearly defined.

POTENTIAL ROLE FOR TRADITIONAL INSURANCE RISK TRANSFER

There is no existing insurance risk transfer solution for CO_2 Leakage Risk. Through a process of collaboration, however, the group of ClimateWise insurance, reinsurance and broking experts contributing to this report have identified an innovative way that certain existing insurance products could be modified such that, under tightly defined criteria, they would provide cover for a subset of the total EUA liability operators will face. An actual product has not been developed by this group, but the theoretical ability to do so has been explored in detail and confirmed.

In developing this concept, it was agreed that the injection phase and the post-closure phase of the CCS process should be treated separately when considering risk transfer solutions for CO_2 Leakage Risk. This is for three reasons:

1. The risk exposures are quite different for the two phases; during the injection phase, the risk exposure is gradually building up over the many years that CO_2 is being injected into the store whereas in the post-closure phase the volume of CO_2 stored is at its maximum and the risk exposure continues to grow as the price of EUAs increases. This distinction is meaningful in that potential exposures in the post-closure phase may exceed likely (re)insurance capacity.

2. Once the site has completed its operational phase and been abandoned, the likelihood of leakage through the abandoned wells may significantly reduce. Through the post closure phase, the most likely cause of leakage is likely to be though faults and fracturing around the storage complex (where they exist), rather than through the man-made well bores. As is seen through the discussion of proximate causes coverable by a traditional insurance policy below, this is a further material distinction and there are significant practical challenges that need to be resolved before insurance can be applied to such situations.

3. Finally, during the injection phase, the CO_2 storage operator is receiving an income based on the volume of CO_2 it is preventing being released into the atmosphere, whereas when injection stops and the post-closure phase takes over, the operator is less likely to be accruing income. This is likely to undermine the attractiveness of an annually renewable insurance policy in the post-closure phase as compared to other risk transfer mechanisms, although some business models may allow for it.

The concept for an insurance product to transfer a subset of the CO_2 Leakage Risk therefore **applies to the injection phase** in the first instance. The key features of the concept for this policy are outlined in **Box 4.1**.

BOX 4.1
KEY FEATURES OF CONCEPTUAL 'CARBON ALLOWANCE REIMBURSEMENT INSURANCE' (CARI) POLICY TO INDEMNIFY THE INSURED AGAINST THE COST OF SURRENDERING EUAS FOLLOWING A CO_2 LEAKAGE TO THE ATMOSPHERE.

Term: The CARI policy would be an annually renewable insurance policy.

Phase of CCS lifecycle: The CARI policy would apply to the injection phase in the first instance.

Proximate causes covered: Leakage events resulting from damage to operational wells, abandoned wells and the caprock seal over the well bores. In the insurance industry, this would best be termed 'all risks'. By modifying other environmental insurance policies, it might be possible to cover gradual seepage through faults and fractures.

Exclusions:
- Defects in design, plan, specification, materials or workmanship
- Normal wear and tear, gradual deterioration or normal corrosion
- Earthquake (can be included, but could give rise to aggregation risk given the geographic focus of this market)
- Normal settling, normal shrinkage or normal expansion in land and/or caprock

Limit of Liability: Precise limit TBC but the insured would need to declare the volume of stored CO_2 to be insured up front and the insurer and insured would need to agree the EUA price at which the policy would indemnify the insured following a leakage event. This could be based on a 'ceiling and floor' (or 'cap and collar') price or on a moving average based on the previous few years' price. This approach is analogous to how future electricity prices are dealt with in other insurance policies.

Deductibles: A monetary deductible would need to be agreed as there would be an expectation that the insured would retain a primary portion of the risk.

DISCUSSION OF KEY FEATURES

Type of policy

The risk of surrendering EUAs is a financial liability created by the EU CCS and ETS Directives. The EU CCS Directive's Guidance Document 4 (GD4) identifies "Liability Insurance Policy for Payments due to Leakages" as a possible mechanism to deliver the required Financial Security. We argue that a more nuanced view of the type of insurance policy that could be appropriate needs to be taken.

The proximate causes for CO_2 leakage included in the scope of the CARI policy concept are damage to physical assets owned by the insured (ie operational or abandoned wells and the caprock structures around the well bores). These are the more likely, of the albeit unlikely overall, proximate causes for a leakage event. In defining the proximate causes that would be covered, it was helpful to draw from analogous policies such as Control of Well (CoW) insurance, whereby all fluids escaping uncontrolled through the well bore, including the caprock immediately over the well bore, are covered. Similarly, Control of Well (CoW) policies are commonly triggered by uncontrolled flow (whatever the cause) through the well.

The CARI policy concept has therefore been developed as an extension of existing first party (energy) property damage policies, with analogous policy wording to that found in CoW policies offered to oil and gas companies engaged in exploration and production activities. Insurers and reinsurers have confirmed that they are comfortable with this approach and this is the basis for estimating the likely initial market capacity. However, there is an open question over this interpretation; if the policy were to be set up on a 'claims-occurrence' basis[15], a first party property damage policy would likely be appropriate but if the policy were set up on a 'claims-made' basis[16], a third party liability policy structure would likely be more appropriate. The underlying market capacity is likely to be the same.

Gradual seepage events

As noted in Box 4.1, by modifying other environmental insurance policies, it might be possible to cover gradual seepage through faults and fractures. However, this does raise a number of issues around discovery and the time taken for such seepage to become manifest as a measured loss. These difficulties, while not insurmountable in theory, will create practical challenges, which emphasises the fact that the CARI policy concept is a potential insurance risk transfer solution that, even extended to gradual leakage, can only address a subset of CO_2 Leakage Risk liabilities.

Effect of limiting the liability

All insurance policies must indemnify the insured for a defined risk exposure. In the regulatory context in question, the fact that the CARI policy concept has to define parameters for the risk exposure, principally by agreeing an EUA price up front as the basis for the policy, means that the policy would operate on a 'first loss' basis, because if the actual EUA price rose above the price agreed in the policy, the insured would retain that additional liability.

Calculation of technical price

The lack of claims experience means that the actuaries consulted for this report looked to the estimated probabilities for different leakage pathways produced by DECC (see Table 4.1) to inform their view on how a technical price for the CARI policy concept would be calculated. Given that these estimated probabilities are so low, they concluded that the technical price for the CARI policy concept would be mainly driven by the cost of capital[17]. The market price in the early years would probably also be driven by a more conservative underwriting view of the risk as well given the lack of claims experience, which is normal in the development of a new insurance product.

[15] A type of insurance policy which pays only those claims that occur during the period covered by the policy; it does not matter when they are filed.

[16] A type of insurance policy which pays only those claims that occur and are filed during the period covered by the policy.

Remediation costs

As noted above, there are also financial consequences of implementing corrective measures in a leakage event as set out by the EU CCS Directive Guidance Document 2 (GD2). These could be incorporated into this policy under 'Operators Extra Expenses' (OEE) cover if desired.

Growth of market capacity

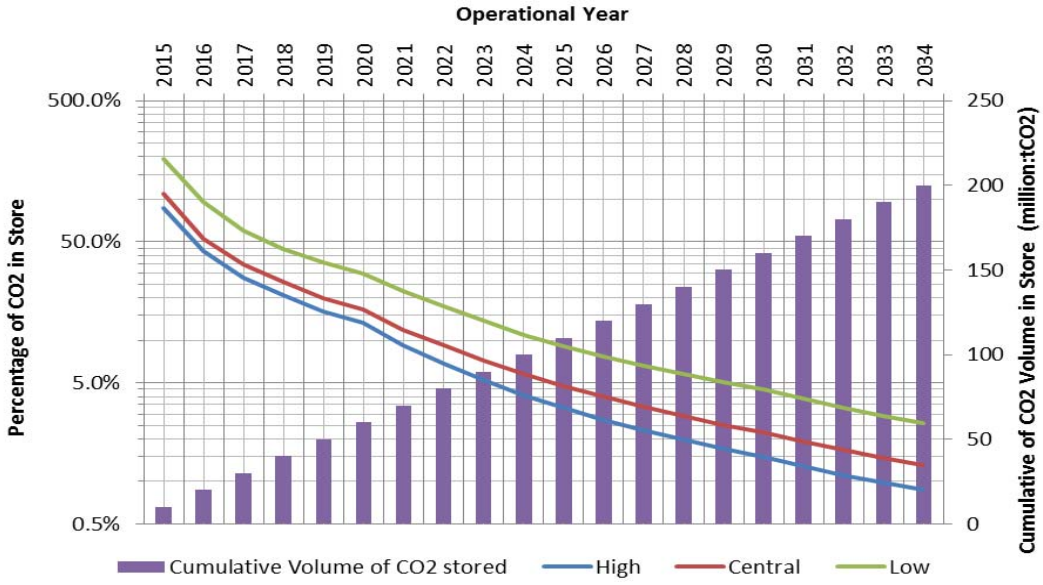
The challenge of growing a new insurance market should not be underestimated. A syndicated approach is a way to manage new risks where there is a lack of loss experience. We estimate that an initial aggregate market capacity of £100 – 300 million per annum is likely to be available, based on the assumption that this product would be a natural extension of existing insurance markets. This is the total available insurance capacity that could be available to each store, assuming that there was no regional or other aggregation of risks between stores. The practical availability of capacity is dependent on the risk appetite of the insurers and reinsurers involved. The willingness of major reinsurers to provide reinsurance in this market would be fundamental to supporting its growth as a further risk sharing mechanism within the insurance industry.

Figure 4.3 gives an illustrative view of the percentage of stored CO_2 that could be insured with a hypothetical £250 million of annual insurance capacity, based on the CARI policy concept over time. The DECC technical scenarios set out in Table 4.1 do not envisage operational or abandoned wells leading to leakage events of more than 2% of stored CO_2. Furthermore, scenario modelling work by the ETI's Energy System Modelling Environment (ESME) suggests that the UK CCS industry will have grown to the extent that it is storing 100 – 130 million tonnes of CO_2 per annum in 2030[18]. Taking into account the fact insurance capacity could grow as the CCS industry develops, this initial capacity might therefore appear to be sufficient for the risks it is intended to cover.

[17] Insurers' cost of capital is a function of a number of different factors including the changing cost of reinsurance, which can be driven by unrelated extreme events, operating expenses and investment returns

[18] Personal communication, Energy Technologies Institute, 1 November 2012

FIGURE 4.3
AN ILLUSTRATIVE GRAPH OF THE PERCENTAGE OF STORED CO2 THAT COULD BE COVERED BY A HYPOTHETICAL £250 MILLION OF INSURANCE CAPACITY FOR A LEAKAGE EVENT.



NB: 1. The injection rate is assumed at 2 million tonnes per well annually starting in 2015 with 5 injection wells (AGR and SCCSS, 2012). 2. The EUA price scenario is based on DECC's (2009: 119) estimates of traded carbon allowance values such that in 2030, EUAs cost £105 (High), £70 (Central) and £35 (Low). 3. Neither corrective measure costs nor revenue loss are considered, as the diagram only reflects the cost of surrendering EUA allowances. 4. The risk free rate assumption by DECC (2009: 42) is 3.5%.

Moral hazard

It has been noted that the provision of insurance based on the CARI policy concept would not be likely to create moral hazard, both because of its operation on a 'first loss' basis and because the CCS operator faces other liabilities associated with a CO_2 leakage event, such as the commercial and reputational liabilities discussed in the 'Consequences' section above.

CHALLENGES

The CARI policy concept is an innovative solution that does not exist yet in the insurance market. It is however not presented here as a perfect or complete solution for CCS operators looking for ways to manage and transfer CO_2 Leakage Risk. Here, some important remaining challenges with the CARI policy concept are discussed, along with possible ways to address those challenges.

Annual renewability creates investment uncertainty

One of the most important challenges with the CARI policy concept is that it is an annually renewable insurance policy. While this does allow the premium to reflect the gradually rising risk exposure throughout the injection phase, from a CCS operator investment point of view looking to make an investment case for the multi-decadal lifecycle of a CCS store, annual renewability retains a degree of cost uncertainty around this Financial Security. Operators may expect premiums to rise significantly if a loss event is incurred, or even for market appetite to participate in the CARI market to dry up in response to an extreme loss experience. These factors would affect the commercial desirability of a traditional insurance risk transfer solution.

It could in theory be possible to address some of these challenges by introducing a multi-year (for example, a 3 year) policy renewable on a rolling annual basis. This would not remove the risk of annual premium variability but would give operators more confidence in the on-going provision of the insurance product. It would, however, be a more difficult policy to place in the market, so is not a straightforward suggestion.

Premium volatility is also likely to reduce as the number of insured CCS projects increases to create a larger, and in theory roughly homogeneous pool. It is not until several dozen CCS projects are being insured though that you have a chance of generating a homogenous risk pool. At the same time, aggregation of risk is something that the insurance industry must guard carefully against, so if there is a risk that the incidence of a leak in one storage complex could trigger a leak in a nearby store, this will significantly dampen the insurance industry's appetite. The exclusion of major natural catastrophe perils such as earthquake in the CARI policy concept is of reassurance in this regard.

Limited insurance capacity

The limited insurance market capacity available will in turn limit the indemnity that can be offered to storage operators. Insurance will not, therefore, be a comprehensive solution in the context of the size of the CO_2 Leakage Risk liability being uncapped.

The importance of the trigger definition

In the event of a leakage, the CA will need to agree the volume of CO_2 thought to have been lost from the store, which will in turn determine the number of EUAs that must be surrendered. There is an open question as to whether the trigger for the CARI policy concept should be the proximate cause itself or the regulatory decision on the quantum of loss. Since there will be a time delay between the two, which may extend beyond the duration of an annual policy, this is an important decision, which also affects whether the policy is best drawn up on a 'claims-occurrence' or 'claims-made' basis. For example, on a 'claims-made' basis, with the regulatory decision being the trigger, if a leakage is known to have occurred towards the end of a policy period but the regulatory decision will not be taken until the following policy period, the insurer will be incentivised to not renew the policy.

Quantifying the loss from a leakage event

As described above, the monitoring plan agreed with the CA as part of the process to secure the storage permit will include a site-specific monitoring plan and plan to deal with thresholds for 'significant irregularities' so the operator and CA have an agreed understanding of how a leakage event will be defined, detected and potentially remediated up front. The monitoring plan will be risk-based and will include an scheduled frequency of site monitoring surveys so that if leakage is detected it can be attributed to a particular well and a particular period of time. GD2 for the EU CCS Directive is the key document relating to the required monitoring practices and techniques that operators should abide by. It includes guidance on how the loss from a leakage event will be calculated as well as an adjustment formula that must be used in the event of significant uncertainty on the quantification methodology. Despite this, the consistency and predictability with which losses of CO_2 from a leakage event are quantified will be of particular concern to the insurance industry. The implementation of industry-wide standards for monitoring of storage sites, building on those created by DNV under their Qualstore programme, is recommended throughout the DECC CCS Commercialisation Programme.

It should be noted that actual development of the modified insurance products detailed in this report will be dependent, amongst other things, on:

- Identifiable demand in the market from a range of storage operators, offering the insurance industry a pool of risks that does not present an aggregation risk
- Agreement with the CA that such an instrument would be deemed acceptable as a contribution to Financial Security
- Strong policy signals that CCS will be supported as part of the clean energy mix

POTENTIAL ROLE FOR ALTERNATIVE RISK TRANSFER MECHANISMS

As set out above, there are a number of reasons to treat the injection and the post-closure phase differently when considering possible risk transfer mechanisms for CO_2 Leakage Risk. Since traditional insurance risk transfer has not always been appropriate in other contexts as well, the insurance industry has developed significant expertise in a range of Alternative Risk Transfer (ART) mechanisms.

For the purposes of this report, we have not attempted to carry out an exhaustive study of the various different instruments suggested by the European Commission that may be appropriate to address the Financial Securities required by the EU CCS Directive such as self-insurance captives, Escrow accounts and so on. Instead, where the insurance industry has valuable analogous experience of applying appropriate ART mechanisms in relevant industries, we have drawn together that experience in the following analysis.

SURETY BOND SCHEME

A surety bond is a contract among at least three parties:

- The Obligee – the party who is the recipient of an obligation
- The Principal – the primary party who will be performing the contractual obligation
- The Surety – who assures the Obligee that the Principal can perform the task

In a surety bond scheme, **the Surety** guarantees to pay **the Obligee** a certain amount of a loss if **the Principal** fails to meet a specified obligation. The Surety normally has only the secondary responsibility in performing the obligations and therefore only the residual liability has been transferred. Therefore, it could be used to meet the Financial Security obligation for the liability associated with surrendering EUAs above a certain limit, with the Principal being the store operator.

Surety bonds already have commercial applications in the energy sector, such as in transferring the credit risk of utility bill non-payment or securing the long-term liability for post-mining site reclamation. The main difference between a surety bond and an insurance policy is that an insurance premium is calculated based on the expected loss caused by accidental damages, while a surety bond is priced based on the credit profile of the Principal. Therefore large CO_2 storage operators with stronger balance sheets will likely have cost advantages in a Surety Bond Scheme[19]. Another key issue in applying surety bonds for managing CO_2 Leakage Risk in the post-closure phase is how to define the task and conditions for bond release (Gerard and Wilson, 2009), which is still somewhat ambiguous under the EU CCS directive.

The insurance industry has seen a renewable surety bond be applied successfully in the Waste Management industry. See **Box 4.2** for further details. A key challenge could be raised, however, if joint ventures become a common feature of the CCS industry because different parties are likely to have different sized balance sheets and risk appetites.

[19] Gerard (2000) studied the application of surety bond in the mining sector, and found the premium for large firm could be less than 1% but small firms may face premiums of 15% to 20% or higher.

BOX 4.2
MANAGING WASTE MANAGEMENT/LANDFILL LIABILITIES WITH RENEWABLE SURETY BONDS

Under UK Waste Management Regulations, landfill operators have to provide evidence of being financially fit and proper both to operate a landfill site and to provide aftercare once the landfill is closed. This test takes into account the ability of the operator to make financial provisions sufficient to comply with licence requirements until the landfill permit can be surrendered. This may be an estimated period of in excess of 60 years and so the parallels with CCS are clear.

In a document entitled 'Guidance for Financial Provision for Landfill' (EPR 5.02.2 2011) the Environment Agency lists the following as being acceptable mechanisms for making this financial provision:

- Renewable Bonds/Surety
- Escrow Accounts
- Cash deposits with the Agency
- Local Authority Deed Agreement: only applicable to local authority as operator
- Trust based investment portfolios

Where renewable bonds are used, the performance agreement will contain a requirement for the operator to renew the bond arrangement prior to expiry of the current bond. Failure to comply constitutes a default and the Agency can then draw down on the bond.
All other mechanisms require that the provisions are pre-funded either in part or full and guaranteed in full.

RISK MUTUALISATION (EG A FUNDING POOL ESTABLISHED BY CO2 STORAGE OPERATORS)

Risk Mutualisation in the energy sector has been applied at large scale since 1970s, prompted in part by insufficient capacity in the commercial insurance market. Indeed, there are a large number of energy risk mutual companies operating in the world, such as Oil Insurance Limited (OIL), the Offshore Pollution Liability Agreement (OPOL) and Nuclear Risk Insurers Limited (NRI). Several risk mutualisation principles are being evaluated by the CCS industry already and what follows only represents examples. **Box 4.3** gives more detail about the existing example of OIL, **Box 4.4** illustrates the example of OPOL and **Box 4.5** details the nuclear insurance pool in the UK.

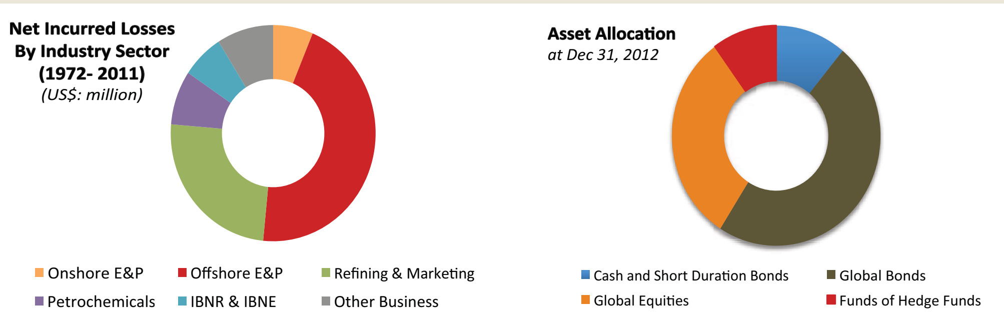
BOX 4.3
OIL INSURANCE LIMITED (OIL)

OIL was formed in 1972 by 16 energy companies in response to inadequate commercial coverage for two large-scale industry accidents: an oil spill in Santa Barbara, California (1969), and a refinery explosion in Lake Charles, Louisiana (1967). The current membership of OIL has increased to 55 (including 16 European companies, such as Dong Energy, BG Group, Eni, Statoil and TOTAL). The global insured assets have reached US$2 trillion and shareholder equity reached US$3 billion by the end of 2011.

Unlike traditional insurance underwriting, the 'premium' is determined by a formula, ie a five-year post loss funding facility. The minimum premium paid by all policyholders is a function of the insured's gross assets. These gross assets are adjusted for operational risk and coverage profile (Weighted Gross Assets - WGA). A member's pool percentage (or percentage share of losses) is based on their WGA. Premiums are determined based on a member's Pool percentage multiplied by Annual Losses, which is paid back over 5 years.

The lifecycle of an insurance policy provided by OIL is similar to that provided by commercial insurance companies except that profits made from OIL insurance policies will be distributed to members (policyholders) who in turn will distribute it to shareholders in the case of public companies. The policy limit for non-windstorm events is higher than most traditional insurance policies, at US$300 million per occurrence by the end of 2011.

The insurance portfolio of OIL has been diversified across offshore and onshore exploration and production (E&P), Refining, and Petrochemicals sectors. The large funding pool with diversified exposures provides OIL a strong risk tolerance in asset allocation with approximately 40% of asset allocated in Equities and Hedge Funds.



Source: OIL, 2012

BOX 4.4
OFFSHORE POLLUTION LIABILITY: OPOL

Source: www.opol.org.uk

Under the Offshore Pollution Liability Agreement dated 4th September 1974, referred to as OPOL, operating companies agree to accept strict liability for pollution damage and the cost of remedial measures with only certain exceptions, up to a maximum of US$250,000,000 per incident and US$500,000,000 in the annual aggregate.

Offshore Pollution Liability Association Limited (referred to as OPOL) members bear a mutual guarantee for each other's obligations up to these liability limits. OPOL covers escapes or discharges of oil from offshore facilities within the jurisdictions of United Kingdom of Great Britain and Northern Ireland, Norway, Denmark, the Netherlands, the Federal Republic of Germany, France, the Isle of Man, the Faroe Islands and Greenland.

Parties to OPOL undertake to establish and maintain their financial responsibility to meet claims arising under OPOL by producing evidence of insurance, self-insurance or other satisfactory means. They also jointly agree that in the event of a default by one of the parties, each will contribute proportionally to meet claims.

OPOL provides a convenient means of enabling compliance by licensees with the provisions of model Clause 23(9) of the UK Petroleum (Production) (Seaward Areas) Regulations 1988. It is further re-enforced by the inclusion of a standard OPOL Clause in all Joint Operating Agreements.

All offshore operators currently active in exploration and production on the UK continental shelf are party to OPOL.

BOX 4.5
THE BRITISH NUCLEAR POOL

Source: Reitsma and Tetley, 2010; INDECS, 2012; NRI, 2012; WNA, 2012

The first national nuclear insurance pool was applied in the UK in 1956 to enhance the insurance capacity for the possibility of serious accidents in the early development of the nuclear industry. The UK pool was formed by a group insurance companies and Lloyd's underwriters for insuring public liability, material damage and business interruption risks of nuclear installations. The pool is now known as Nuclear Risk Insurers Limited (NRI). NRI currently represents a majority of the total cover for nuclear liabilities in the UK followed by nuclear operators' own captives and mutual arrangements with other nuclear operators.

Method of Operation

The Insurance Companies and Lloyd's Underwriters who support NRI have all signed a Pool Members' Agreement (PMA) and have thus delegated their authority to the NRI Board of Directors. In turn the Board delegates much of its authority to the permanent staff of NRI. NRI is a company limited by guarantee, a business structure suited to non-profit organisations. The member company's liability is limited to a prescribed amount and all premiums received are remitted to the members. NRI therefore only has to account for its running costs and surpluses are distributed to members at quarterly intervals.

Currently, member insurers can opt to provide insurance capacity to categories of business underwritten by NRI, such as material damage to the installation and liability to the public. Capacity is subscribed from 1st January each year and is renewable on an annual basis in accordance with procedures laid out in the PMA. NRI only accepts insurance or reinsurance for up to 12 months and it operates on an underwriting year of account basis with each account remaining open for three years, in order to ensure realistic assessment of any claims or notifications of incidents.

Evolution of Capacity

In the UK, the Energy Act 1983 brought the legislation into line with earlier revisions to the Paris/Brussels Conventions and the limit was increased to £140 million for each major installation (ie each nuclear power plant operator is liable for a claim up to this amount and must insure accordingly). The current insurance capacity of NRI is higher than traditional insurance policies at around £400 million. However, the insurance capacity and scope of NRI is expected to increase when the 2004 amended Paris/Brussels convention comes into force. The 2004 convention introduces four new categories of damage for which compensation must be made available and requires the financial liability levels of each nuclear power plant to increase from the current £140 million to €1200 million per incident (the level will be phased in over 5 years, starting from €700 million). Notably, all mechanisms have limited capacity and the role of government is still considered essential in covering environmental damage and limiting the duration of the liability. The government is liable for any loss beyond the legal liability for operators, such as in a catastrophic nuclear accident.

Unlike traditional insurance policies which must exclude some proximate causes, a risk mutualisation approach amongst CO_2 storage operators that established a funding pool could potentially cover all causes of leakage.

In theory, the capital in the funding pool could increase gradually because CO_2 exposure in the storage complex will not build up overnight. However, in reality, a significant initial capital injection would likely be required to comply with the EU CCS Directive because of the requirement to have Financial Securities in place before being awarded a storage permit. A risk mutualisation approach may make this more feasible, but this is dependent on the number of operators and projects participating.

Drawing from experience with such risk mutualisation pools as OIL, a number of lessons can be drawn. Such an approach offers benefits in terms of both diversifying risks and meeting regulatory requirements, but a number of practical issues[20] need to be addressed including:

1. **The opportunity cost of capital** (or capital commitment) in the fund may not be justified given that the probability of loss is very low and only a small number of projects may be included in the scheme – ie it is expensive to set aside a large pool of money for a low probability occurrence in the distant future. This said, a mutualisation approach may be more efficient than operators attempting this on their own.
2. **Larger operators may choose not to participate** if the entry criteria appear to leverage their balance sheet strength to the benefit of smaller operators, which would restrict the viability of the pool.
3. While not an insurmountable barrier, it could be challenging to set up **a rule for pay-out and contribution** since CO_2 Leakage Risk is site specific and there may also be differences between the performance of storage operators.
4. The **responsibility for re-capitalising** in the event of a funding shortfall needs to be defined.
5. How to guarantee **company financial strength** over the post-closure period (ie several decades).
6. The role of government in schemes such as NRI is significant.

CAPITAL MARKET SOLUTIONS: CATASTROPHE BONDS (CAT BONDS)

Catastrophe bonds (CAT bonds) were introduced in the mid-1990s, driven by the rising (re) insurance costs for natural catastrophes following events such as Hurricane Andrew in 1992 and the Northridge earthquake in 1994.

CAT bonds are risk-linked financial securities that transfer 'low probability, high impact' risks to investors. Most CAT bonds have trigger criteria, for example based on wind speed or earthquake strength (De Mey, 2007). If no natural catastrophe occurs, investors in CAT bonds will receive a coupon payment from the bond issuer (eg reinsurance companies).

[20] This analysis is building on the findings by CCSA (2012: 16).

If the natural catastrophe does occur, then the bond issuer uses the principal to pay its policyholders.

It could be that CAT bonds could be developed to transfer CO_2 Leakage Risk during the post-closure phase, in particular for leakage scenarios beyond the capacity of insurance markets. However, there are a number of issues to be addressed:

1. Investors may find it difficult to fully understand the complex technicalities of the different pathways that can give rise to CO_2 Leakage Risk if many proximate causes were included in the CAT bonds trigger criteria. This could lead to mispricing or insufficient liquidity in the market but could be mitigated by market makers with a thorough understanding of CO_2 Leakage Risk.
2. The yield (investors' required return ratio) of CAT bonds could be much higher than traditional corporate bonds with the same credit rating. The credit rating for CAT bonds depends on the catastrophe loss model and the adequacy of capital, and the ratings for CAT bonds generally are lower than 'investment-grade'.
3. The trigger needs to be clearly defined as the capital market requires higher certainty than the traditional insurance market. This raises the question whether a major CO_2 leakage event (which could cause catastrophe loss) that is not driven by a catastrophe trigger could be insured by CAT bonds.
4. The future risk profiles and liability expiry dates are highly uncertain because (a) the timing for closure is uncertain; (b) the timing for transferring liability to the CA is uncertain. A rolling bond scheme may be required to address these uncertainties.
5. Capital market participants tend to have a lower tolerance for uncertainty around the trigger criteria for a CAT bond. Uncertainty around the timing and quantum of CO_2 lost from a store would therefore make for a difficult investment proposition, unless a much clearer trigger could be identified. Using the regulatory decision to confirm a leakage event as the trigger

SUMMARY

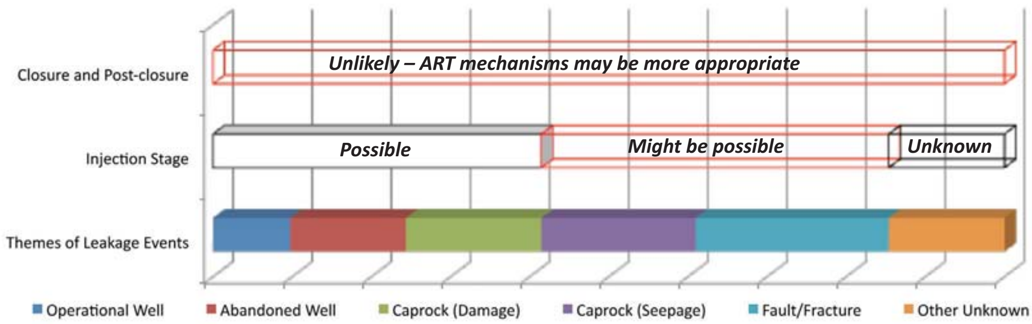
CO_2 Leakage Risk is defined as the risk storage operators face of having to surrender EUAs under the ETS as a consequence of CO_2 leakage to the atmosphere, for which they must also provide Financial Security.

Ways forward have been identified

- An innovative way that existing insurance products could be modified such that, under tightly defined criteria, they would provide cover for at least a subset of the total liability has been identified.
- This product development is theoretically feasible, although an actual product is not yet fully developed and available.

- Insurance is likely to be provided on an annually renewable basis and could provide cover against leakage events resulting from damage to operational wells, abandoned wells and from the caprock seal over the well bores.
- These are the more likely, of the albeit unlikely overall, proximate causes for a leakage event.
- By modifying other environmental insurance policies, it might be possible to cover gradual seepage through faults and fractures.
- The insured is likely to need to declare the volume of stored CO_2 to be insured up front and the insurer and insured would need to agree the EUA price at which the policy would indemnify the insured following a leakage event, based on a 'ceiling and floor' price or on a moving average based on the previous few years' price.
- An initial aggregate market capacity of £100 – 300 million per annum is likely to be available, based on the assumption that this product would be a natural extension of existing insurance markets. This is the total available insurance capacity that could be available to each store, assuming that there was no regional or other aggregation of risks between stores. The practical availability of capacity is dependent on the risk appetite of the insurers and reinsurers involved.
- With the engagement of a range of insurers and reinsurers, this market capacity could grow alongside the CCS industry.

ILLUSTRATION OF WHERE TRADITIONAL INSURANCE COULD HAVE A ROLE TO PLAY IN THE TRANSFER OF CO_2 LEAKAGE RISK.



But are not without their challenges

- The limited insurance market capacity available will in turn limit the indemnity that can be offered to storage operators. Insurance will not, therefore, be a comprehensive solution in the context of the size of the CO_2 Leakage Risk liability being uncapped.

- The fact that insurance would be an annually renewable risk transfer mechanism means that the storage provider still faces a degree of cost uncertainty and may even have to consider the eventuality that insurance cover is withdrawn at some point in the future if CO_2 Leakage Risk for some reason turns out to be more poorly managed than expected. The report identifies some ways to mitigate this, but these implications of using short-term insurance risk transfer solutions in the context of long-term liabilities will continue to challenge investors.
- CO_2 Leakage Risk for the post-closure phase is more likely to be associated with gradual seepage through faults and factures. Even if an insurance product could be developed for these scenarios, it is not clear whether storage operators would be receiving income during this phase and an annually renewable insurance policy may therefore not be appropriate.
- Alternative risk transfer mechanisms (such as surety bonds, risk mutualisation or CAT Bonds) might be able to transfer losses beyond the scope or ability of traditional insurance, but these approaches have significant technical and commercial barriers to overcome before they could be considered feasible.
- Overall, CO_2 Leakage Risk therefore remains a difficult risk to transfer in its entirety through the mechanism of insurance. The fact that all insurance policies must indemnify the insured for a defined risk exposure, mean that there will be residual risk residing with operators under the current liability regime.
- By linking the liability to the unknown future price of EUAs under the ETS, the EU CCS Directive does not cap the size of this liability for operators. Ultimately, neither insurers nor storage operators will be able to bear unlimited liabilities, so where liabilities are not limited in either size or time, risk sharing with government will be required to develop CCS at scale in Europe.
- If commercial liability could be capped by the government, this, in combination with an insurance risk transfer solution, could make for a viable risk management approach that significantly reduces the uncertainties faced by the CCS industry in relation to CO_2 Leakage Risk.

05

Decommissioning Cost Risk

RISK DEFINITION

Store operators face significant uncertainty about timing of decommissioning their stores.

The EU CCS Directive however requires that storage operators must have Financial Security to meet decommissioning liabilities in place up front in order to be awarded their storage permit.

RISK CHARACTERISTICS

The major cost drivers for decommissioning are labour, capital equipment (eg crane barges and drilling rigs for plugging well bores), materials, management and administration and contingencies. Offshore decommissioning activity typically includes (a) pre-decommissioning operation and preparation, (b) facility shutdown, (c) decontamination and dismantling, (d) waste processing and disposal, (e) site clean-up and restoration, as well as (f) project management and site support. For example, the estimated cost for decommissioning the Camelot CA platform (with six platform wells) in the North Sea is approximately £12.4m to £14.5m (and an additional £2.5m to £6.5m for a 14km pipeline) (ERT, 2012), which is regarded as a good analogue for the majority of offshore platforms anticipated for CO_2 injection purposes.

Variability in the cost of decommissioning could be brought about by a range of market, operational and regulatory factors:

a) increased cost of hiring crane and rig equipment
b) increased cost of labour and commodity prices
c) major accidents in the decommissioning process
d) default of a subcontractor (returning the liability and financial consequences to the CO_2 operator)
e) decommissioning time overrun
f) the timing of decommissioning

g) change of decommissioning regulation (eg a more strict requirement for decontamination)

ASSESSMENT AGAINST FUNDAMENTAL PRINCIPLES OF INSURABILITY

The need for decommissioning is certain, but it is the variation in the projected costs and most significantly the timing of decommissioning that is uncertain. Due to this focus on the timing of costs being the real risk, there is insufficient fortuity in this risk for it to meet the fundamental principles of insurability and for a risk transfer mechanism such as insurance to be appropriate. In addition, it could be very difficult to identify a proximate cause that has triggered an increase in decommissioning cost, around which to structure an insurance policy.

POTENTIAL ROLE FOR ALTERNATIVE RISK TRANSFER MECHANISMS

The oil and gas industry is already faced with the need to make provisions for future decommissioning costs and deals with it by setting aside certain deposits or setting up a decommissioning fund. In these scenarios, requests by the government to provide Financial Security are normally triggered when the remaining net present value (RNPV) of a project falls below a threshold value (eg 150% of the expected decommissioning cost), in order to ensure the decommissioning cost for offshore E&P facilities can be fully financed (Kemp and Stephen, 2006).

Accumulating a fund is currently not permitted under the EU CCS Directive. However, some index-linked structured financial products have been developed to manage the uncertainty around the timing of future decommissioning costs. Zurich has developed such a product, the Geological Sequestration Financial Assurance (GSFA)[21] (Zurich, 2009a), which, because it is designed to manage the uncertainty around the timing of future decommissioning costs, has been structured in an 'Evergreen Funding Style' to allow the maturity date to be flexible.

SUMMARY

Storage operators face significant uncertainty about the timing of decommissioning their stores following meeting the requirements of the post closure monitoring period, but still need to provide Financial Security for this liability up front as part of obtaining a permit. In other contexts, oil and gas companies are permitted to build up a decommissioning fund over time.

- Due to this focus on the timing of costs being the real risk, there is insufficient fortuity in this risk for it to meet the fundamental principles of insurability and for a risk transfer mechanism such as insurance to be appropriate.
- Some structured financial products have already been created to help manage this risk as alternatives to insurance.

[21] There is no detailed information about the structure of the product in the public domain.

06

Premature Determination and Possession Risk

RISK DEFINITION

'Premature Determination and Possession' Risk is defined as the risk that the operator faces in incurring financial liabilities if its storage licence is temporarily or permanently withdrawn by the CA during the operational period before the planned 'Transfer of Responsibility'.

This is a risk exposure for which the EU CCS Directive requires operators to have Financial Security in place before a permit for storage is awarded.

RISK CHARACTERISTICS

Proximate causes

Under the EU CCS Directive, if an operator is deemed to be operating incompetently or if an operator becomes insolvent, the CA in the member state may force the operator to transfer responsibility for the store to itself before the planned 'Transfer of Responsibility' date.

The two possible proximate causes are operator incompetence or operator insolvency.

Consequences

As a result, the CA may temporarily withdraw the operator's permit, in which case operators will need to provide Financial Security to the CA for corrective measures, surrender of allowances, monitoring, verification, audit programme and site operation costs.

Further, the CA may withdraw the operator's permit permanently and close the site, in which case operators will need to provide Financial Security to the CA for monitoring, corrective measures, surrender of allowances, update provisional post-closure plan and decommissioning costs.

ASSESSMENT AGAINST FUNDAMENTAL PRINCIPLES OF INSURABILITY

Since the proximate causes for the loss associated with this risk cannot be deemed accidental or fortuitous, there is a fundamental barrier preventing this from being an insurable risk; the moral hazard that would be created by enabling an operator to transfer the risk of their own incompetence or insolvency to an insurer is considered sufficiently significant as to violate this fundamental principle of insurability.

SUMMARY

- 'Premature Determination and Possession Risk' is defined as the risk that the operator faces in incurring financial liabilities if its storage licence is temporarily or permanently withdrawn by the CA before the planned 'Transfer of Responsibility'.
- Again, this is a liability for which adequate Financial Security is required by the EU CCS Directive.
- The two main proximate causes identified are operator incompetence or operator insolvency, both of which raise fundamental insurability challenges because of the degree of moral hazard involved on the behalf of the insured. This risk has therefore been deemed uninsurable.

07

Value Chain Integration Risk

RISK DEFINITION

'Value Chain Integration Risk' is defined as the risk faced by all parties of loss of revenue because of failure in part of the CCS value chain.

This is not a risk for which Financial Security is required by the EU CCS Directive, but it was deemed a priority by the CCS industry representatives because of the potential impact it could have on the commerciality of CCS development.

RISK CHARACTERISTICS

The complexity of a CCS value chain poses challenges to the operational reliability of an integrated CCS project. Each link in the chain will in most cases be operated by a different entity (eg utility, oil company, pipeline operator) that do not have control over the risks associated with the rest of the chain. In addition, each party in the CCS chain may have different risk appetites. However, a major technical or financial failure of one party in the value chain could have material impacts on the operations of other parties[22], so value chain integration is a risk management challenge operators face.

Proximate causes

A number of proximate causes could trigger interruption of an integrated CCS project, for example:

- Pipeline rupture or puncture
- Failures of the emission plant or CO2 capture model equipment because of technical problems
- Suspension of the emission plant's activities due to market conditions
- A major leakage caused by damage to operational or abandoned wells (likely to result in temporarily disruption to flow of stored CO2)
- Serious damage to the store formation (possibly resulting in the storage site being permanently unable to accept CO2)

[22] Temporarily suspension of operation due to expected routine maintenance of CO2 capture plant, pipeline or the injection platform is not considered as a risk.

These proximate causes of interruption can be further differentiated by the ability, and length of time, for the interruption to be resolved. For example, a failed capture plant could be repaired and therefore the interruption would be temporary, but serious damage to the store formation may be permanent.

Consequences

Failure of one party in the CCS value chain could cause serious financial and regulatory consequences for other parties, for example:

- In any event where CO_2 is being emitted and not stored, EUAs will have to be surrendered by the emitter.
- In the event of interruption to storage caused by damage to wells, the storage provider will suffer a loss of revenue.
- In the event of leakage caused by formation damage, the original storage infrastructure could become a stranded asset. The CO_2 emitter may have to suspend operations and wait until a new pipeline is connected to a new storage site or find alternative storage sites itself, or surrender EUAs if it is allowed to emit.
- In the event of pipeline failure, the CO_2 emitter and the storage provider will suffer financial loss as well.

One clear risk mitigation measure for this value chain integration risk would be to establish an integrated CCS network (ie multiple sources connected with multiple sinks through multiple pipeline routes) could possibly mitigate the risk, but this is unlikely to happen in the early stage of CCS development.

ASSESSMENT AGAINST FUNDAMENTAL PRINCIPLES OF INSURABILITY

Most unexpected interruptions to a CCS value chain could be deemed to be fortuitous. The proximate causes could also be clearly defined. Consequently most temporary interruption events could probably be covered by traditional insurance policies such as Business Interruption, explained in more detail in **Box 7.1**.

In addition, credit insurance could probably be applied for mitigating credit risk within the CCS value chain. Commercial property damage cover could be extended to cover the loss of another party in the chain caused by an accidental event. Machinery insurance could complement business interruption policies to cover failures in CCS operation (eg failure of a compressor).

However, when a serious interruption event occurs (eg a permanent shut down of a CO_2 store caused by serious formation failure), the original pipeline becomes a stranded asset, a new pipeline and storage site need to be identified and constructed before the capture

BOX 7.1
BUSINESS INTERRUPTION POLICY

Business Interruption (BI) insurance provides for the Insured suffering a reduction in expected revenue when their operations are interrupted by an insured peril to an extent where normal operations prior to the loss can no longer be maintained. A BI policy generally has the following features:

- **Maximum Indemnity Period:** The period beginning at the commencement of the Incident and ending no later than the number of months shown in the schedule during which the Insured's business shall suffer Consequential Loss.
- **Indemnity Period:** The period beginning with the occurrence of the Incident and ending not later than the Maximum Indemnity Period thereafter during which the results of the Business shall be affected in consequence thereof.
- **Coverage:** The insurer will pay the amount of consequential loss resulting from interruption of business upon damage to property. The turnover paid to the Insured is usually on a gross profit basis (gross profit = net profit + fixed costs) or calculated by the gross profit ratio multiplied by the turnover.
- **Limit of Liability:** To be negotiated between insurer and operator, but usually with a cap of a certain percentage of revenue
- **Deductible:** For major risks in CCS value chain, a combined deductible with property damage insurance could possibly be requested. BI policies usually have a time-related deductible provision (ie a waiting period).

plant restarts, and the stationery emitter may have to surrender EUAs. In this case, unknown future CO_2 prices, the uncertain residual value of pipeline infrastructure, and the cost of new pipeline infrastructure could impair the abilities of insurers to price an insurance product and to pay for the losses. In this extreme scenario, there is unlikely to be a commercially feasible option available through the traditional insurance policy approach.

POTENTIAL ROLE FOR ALTERNATIVE RISK TRANSFER MECHANISMS

A detailed study has not yet been conducted on possible ART mechanisms for CCS value chain risks. However, effective contractual mechanisms should be the first focus of future work.

SUMMARY

Value chain integration risk is the risk faced by all parties of loss of revenue because of failure in part of the CCS value chain.

- This is not a risk for which Financial Security is required, but because of its potential impact on the economic case for CCS, it was put forward as a priority by CCS operators.
- Most unexpected interruptions to a CCS value chain could be deemed to be fortuitous, sudden and accidental. Where they cause temporary interruption, such as mechanical failure in the CO_2 capture plant, they could probably be covered by traditional insurance policies such as Business Interruption.
- It is very difficult to define a quantum of loss for more serious events causing permanent interruption, such as serious storage complex formation failure, which means a traditional insurance approach is much more difficult.

08

Key takeaways

KEY TAKEAWAYS FOR CCS STORAGE OPERATORS

1. A large number of the operational risks in the CCS storage process can be addressed through existing risk transfer options familiar to industry and where the EU CCS Directive creates new liabilities in Europe, this report gives a clear view of how these risks do or do not meet fundamental principles of insurability.
2. ClimateWise members have identified an innovative, technically feasible way a new insurance product could be developed to transfer a subset of CO_2 Leakage Risk. Such a risk transfer mechanism would likely be more capital efficient than alternatives but does not remove all investment uncertainty since it would be a short-term policy.
3. To increase the insurance industry's comfort around how site-specific, risk-based approaches to quantifying loss from a CO_2 leakage event work in practice, the implementation of industry-wide standards for monitoring of storage sites, building on those created by DNV under their Qualstore programme, is recommended throughout the DECC CCS Commercialisation Programme.

KEY TAKEAWAYS FOR THE INSURANCE INDUSTRY

1. If the CCS industry can develop to the scale advised by bodies like the IEA, significant new demand for insurance for risks that the oil and gas and insurance industries are already familiar with will flow from these multi billion pound projects.
2. This market development is being held back by the lack of available risk management solutions for a small number of nonetheless significant liabilities that are largely created by the EU CCS Directive.
3. ClimateWise members have identified an innovative, technically feasible way that existing insurance products could be modified to transfer at least a subset of CO_2 Leakage Risk. This would limit the liability being transferred to insurers but to grow this market, demand from the industry and broad market participation are required.

KEY TAKEAWAYS FOR GOVERNMENT

1. A large number of the operational risks in the CCS storage process can be addressed through existing risk transfer options familiar to industry, but the EU CCS Directive creates particularly challenging Financial Security obligations and risks which still stand in the way of commercial development of CCS at scale, the most important of which is the uncapped liability associated with CO_2 Leakage Risk.
2. ClimateWise members have identified an innovative, technically feasible way that a bespoke insurance products could be developed to transfer at least a subset of this risk. However, insurance can only be provided for a defined (and therefore limited) liability and so this does not present a comprehensive solution. Operators will still face residual, uncapped liability, which is considered a roadblock for investors.
3. Nonetheless, if the size of CO_2 Leakage Risk could be capped by government whilst avoiding moral hazard, in combination with an insurance risk transfer solution, this could make for a viable risk management approach that significantly reduces the uncertainties faced by the CCS industry in relation to CO_2 Leakage Risk.

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Annex

TABLE A.1
RISKS IDENTIFIED BY CCS INDUSTRY STAKEHOLDERS IN THE ONLINE SURVEY (TOTAL NUMBER OF RISKS: 43) THIS IS NOT PURPORTED TO BE AN EXHAUSTIVE LIST

Process	Risk Categories	Specific Risks Identified by CCS Industry Stakeholders	Risk Definition
Transportation	Health and Safety		
	Pipeline leakage	Onshore Impact Infrastructure Leak Risk	A major leak from the onshore infrastructure (eg pipes) results from impact
		Offshore Impact Infrastructure Leak Risk	A major leak from the offshore infrastructure (eg well heads, valves) results from impact
		Gradual Infrastructure Leak Risk	A gradual leak from the infrastructure (eg pipes, well heads, valves)
	Shipping Leakage		
	Third Party Access		
Storage	CO_2 Leakage	Future Onshore Drilling Risk	A major leak from an onshore geological store results from future drilling
		Future Offshore Drilling Risk	A major leak from an offshore geological store results from future drilling
		Onshore Reservoir Mismanagement Risk	A major leak from an onshore geological store results from mismanagement
		Offshore Reservoir Mismanagement Risk	A major leak from an offshore geological store results from mismanagement
		Earthquake Risk	An earthquake causes major leakage from the geological store
		Hurricane/Storm Surge Risk	A hurricane or storm surge event causes major leakage from the sub sea infrastructure
		Other Force Majeure Risk	Storage providers are not relieved from their obligations where force majeure circumstances such as war/terrorism cause a major leak
		Other Sudden and Accidental Risk	An unforeseen event causes a major leak from the geological store (the unknown unknowns)
		Gradual Store Leakage Risk	A gradual leak occurs in the geological store from a naturally occurring feature
		Gradual Infrastructure Leakage Risk	A gradual leak from the infrastructure (eg pipes, well heads, valves.)
		Other Gradual Leakage Risk	An unforeseen event causes a gradual leak from the geological store (the unknown unknowns)
		Gradual Store Leakage Risk (man-made)	A gradual leak occurs in the geological store from a man-made feature (eg: abandoned well)
		Shipping Incident Risk	A major leak from the geological store leads to a shipping incident
		CO_2 Volume Risk	Financial exposure is limited by the volume of the CO_2 in the store that may be released but not by the EU CCS Directive
		CO_2 Liability Duration Risk	Unlimited financial exposure because there is no limit to the duration of a storage provider's obligation
		CO_2 Price Risk	Unlimited financial exposure because the future price of emitted CO_2 (ie EUAs) is unknown
		CO_2 Futures Market/Liability Mismatch	Time period for which the market is able to offer a forward price for CO2 is significantly shorter than the liability period
	Premature Determination and Possession by CA	Forced Possession Financial Risk	Operators face an unknown amount of residual liability if the CA forces possession of the store
		Forced Possession Duration Risk	The duration of time for which operators may face residual liability if the CA forces possession of the store is unknown
	Decommissioning Costs	Transfer of Responsibility Risk	Operators face an unknown post-closure duration because of uncertainty around the criteria for the Transfer of Responsibility for a project to the Competent Authority

		Decommissioning Regulatory Risk Decommissioning Timing Risk	The future cost of decommissioning is unknown due to the potential for new requirements to be imposed after the final investment decision The future timing of decommissioning is unknown due to the potential for the deferral of decommissioning for reasons such as monitoring requirements
	Measurement and Monitoring	Technology Operating Cost Risk	The future cost of running the store is unknown due to the potential for new, more costly technologies being introduced in areas such as monitoring
	Alternative storage Site/Well Development	Injection Rate Risk Storage Capacity Risk	Unknown costs may be incurred in developing more wells or alternative storage sites to mitigate a lower than expected injection rate Unknown costs may be incurred in developing more wells or alternative storage sites to mitigate a lower than expected storage capacity
	Health and Safety		
	Environmental Damage	Environmental Liability Risk	The operator's activities or a leakage event create liabilities under the EU Environmental Liability Directive by damaging habitats
	Financial Security	Financial Security Definition Risk Financial Security Size Risk Financial Security Structure Risk Financial Security Price Risk Financial Mechanism Future Requirement Risk	The wording of the EU CCS Directive leaves the magnitude of some Financial Securities uncertain It is unknown how the size of Financial Security obligations compares to expected revenue The structure of Financial Security obligations is unknown because the EU CCS Directive reflects all potential liabilities The future price of Finance Securities is unknown It is unknown what the future requirements for the Financial Mechanism will be because responsibility for determining which costs are taken into account in calculating the security and transfer rests with individual Member States
	Third Party Access	Third Party Access Risk Third Party Access Liability Duration Risk	The terms of access for third party access are unknown The length of time the risk to the storage provider arising from third party access will apply is unknown
	Value Chain Integration	Contract Risk Value Chain Integration Risk	The contractual relationships between the CO_2 producer, transporter, and store is uncertain The storage provider faces an unknown risk of reduced revenue because of failure in part of the Capture/Transport/Store CCS value chain
	Technology Performance	Application Non-performance Risk	The storage provider faces an unknown risk of reduced revenue because of failure of the power plant/industry application
CCS Value Chain / Project Wide	Change in Law	Transnational Legislation Risk General Change of Law Risk	Transnational projects face an unknown risk of national legislative requirements changing independently of each other General Change of Law Risk
	Public Perception	Public Perception Risk	The risk that CCS projects are delayed or abandoned as a result of negative public perception risk is unknown
	Cost of Financing	Credit Rating Risk	Risk that ratings agencies do not recognise risk transfer solutions when calculating an operator's credit rating

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