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THEMATIC REPORT

Risk management: lessons learned in 2010

A report from the European CCS Demonstration Project Network

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This report presents an overview of key activities undertaken in the area of Risk Management and lessons drawn in this area from the six member projects of the European CCS Demonstration Project Network.

In accordance with the Network's knowledge sharing protocol[1], the main purpose of this document is to share experiences with the Network's external stakeholders in order to help advance take-up of CCS in Europe and beyond. The intended readership includes CCS project managers, CCS Risk Managers, CCS communication specialists, CCS technical specialists, CCS policy makers and the general public with an interest in CCS.

Contributions on behalf of each of the Network's member projects were provided by the following co-authors[2]:

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The report was edited by Det Norske Veritas as part of its role as facilitator to the European Commission.

General information on the Network and its members can be found at www.ccsnetwork.eu

1 http://ccsnetwork.eu/uploads/publications/european_ccs_project_network_knowledge_sharing_protocol_final_20100531.pdf

2 Full details of the projects represented by the authors can be found at http://www.ccsnetwork.eu/index.php?p=projects

Summary

In 2010 the CCS network organised three workshops on risk management. The activities in this theme have helped the members to create a greater understanding of CCS project-specific risk management more rapidly than they would have otherwise achieved independently. This important topic has helped to inform individual project activities and influence the focus of knowledge sharing activities of the CCS projects in the network during 2011.

This report summarises the achievements of the Network members in accelerating their knowledge of this important topic. Several risk categories were identified with two selected for further exploration. Focus on one of these topics in more detail developed a deeper knowledge of the issues to be addressed. The other risk categories were identified and collated in an emergent risk register that requires further development in parallel to the growing maturity of the projects.

Projects have identified a number of risks of different natures (financial, regulatory, technical, public acceptance, etc.) whose management is crucial for the development of a CCS demonstration project. For example:

- **Risks related to funding**. Understanding timing and predictability of the funding process will help the projects to develop a better preparedness for funding-related risks.
- **The transposition of the EU CCS directive.** This process may create risks to the projects related to uncertainty of timing and detailed interpretation. There is a need for identification of these risks and recommendations on how project managers can deal with those risks.
- **Managing interface risks.** Specific for all integrated CCS projects is the need for managing risks across the CCS value chain. The development and operation of integrated CCS infrastructure, from a power plant to a CO_2 storage facility, involves a variety of partners that maintain organisational interfaces which need to be managed in order to ensure smoothness of operation. Risks associated with these organisational interfaces need to be managed, just as well as the risks associated with the interfaces between the various technology building blocks across the CCS value chain.
- **Risks related to the CO_2 stream.** In practice the approach to CO_2 stream composition will be set by technical and economic possibilities across the value chain, and will be bounded by any regulatory requirements. These limits, and the associated engineering risks, are not fully understood by the projects individually, but might be better managed by coordinating available knowledge on the subject. Residual elements in the CO_2 stream may cause undesired system behaviour for example reduced transport capacity due to hydrate formation. If not well understood, these types of disturbances may result in increased engineering cost or reduced system performance. CO_2 stream specification resulting from emerging regulation or infrastructure standards that compensate knowledge gaps with tight margins pose a risk to the CCS projects as this may result into increased engineering and retro-fitting costs for additional gas treatment facilities.

  For this reason, these risks related to CO_2 stream were singled out for focused attention

during the year.

- Interestingly, the majority of the risks identified were not environmental or safety risks, for example, resulting from the use of amines or from CO_2 storage. Most risks relate to the political and economic environments in which the projects operate.

While some of the risks and challenges faced by the demonstration projects are based on local conditions, most risks are common or shared across Europe. As funding and the foundation for legislation originate from the European Union, this gives rise to the same risks amongst the projects. Common goals like earning the public confidence justify sharing risk management practices and insights related to these goals. Europe has political, economic and social variations; its multiple regulatory, financial, linguistic and cultural dimensions make large infrastructure projects complex and dynamic, even perhaps within their own geographical boundaries. There is, however, much similarity in the underlying risks and effective mitigation approaches.

In this context, an examination of risk management from a European perspective is of value to a variety of stakeholders in that it can offer insights into project developers' challenges and opportunities and also help assess where enabling actions might mitigate those risks. Despite the complex local environment, insights from this pioneering exchange of knowledge in Europe can help to develop lessons that will help accelerate CCS project development elsewhere. The generic nature of the risk categories identified in this report will resonate with project developers globally.

A draft model CCS project risk register has acted as a heuristic for sharing knowledge in this area and helped members to identify their project specific risks. The register has been exploratory in nature and is incomplete as of the end of 2010. Regarded as work in progress by the Network members this can developed further as the projects mature over time. Risks other than CO_2 stream composition were considered under the general banner of the draft register. Analysis of the initial risk register suggests that most risks have consequences on financial objectives. This is to be expected in the early development stages of the projects; the number of listed safety, health and environmental risks is limited. Analysis also revealed that most risks are internal, i.e. the projects are capable of reducing or eliminating the source of the risk, although a significant number of external risks have also been identified. External risks are in general related to obtaining external funding and on dependencies on policy makers and regulators.

A generic risk register will be made available in 2011 on request in line with release procedures described in the Network Knowledge Sharing Protocol.

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Introduction

In December 2009, a preparatory Network workshop[1] was held with the participation of CCS project proponents from across Europe. From this workshop, Risk Management emerged as one of three priority themes for knowledge sharing within the Network during 2010. The other themes identified were permitting and public engagement, for which reports have been prepared separately.

The Network qualification criteria[2] require the member projects to submit information on various aspects of their Risk Management activities. This includes the Project Risk Management Plan, the HSE Risk Management Plan and the Technical and Technology Risk Management Plan.

During the three meetings of the Network Risk Management the focus of the meetings narrowed. Discussions during the first meeting were exploratory and identified common topics worth discussing in more detail, including risks related to funding, risks related to the transposition of the EC CCS directive, risks related to interfaces and risk related to the CO_2 stream. External input from Foundation Polytec and Statoil during the second and third meetings helped to develop a good understanding of CO_2 stream related risks. The discussions of interface risks, in addition to reflections on more generic risks, initiated the development of a Risk Register for large CCS projects.

This report outlines the results of the knowledge sharing activities related to risk management undertaken by the members of the Network in 2010. Section 1 introduces the concept of risk management and its role in CCS projects. Section 2 describes the status of risk management in the member projects as of the end of 2010. Lessons learned and the results from the discussion on risks related to CO_2 stream are described in Section 3. In the final section, the report describes the draft CCS risk register that has been initiated as a vehicle for sharing knowledge and will be subject to further iterations and improvements.

1 http://ccsnetwork.eu/uploads/publications/ccs_network_preparatory_event_report.pdf

2 European CO_2 Capture and Storage (CCS) Demonstration Project Network, Qualification Criteria

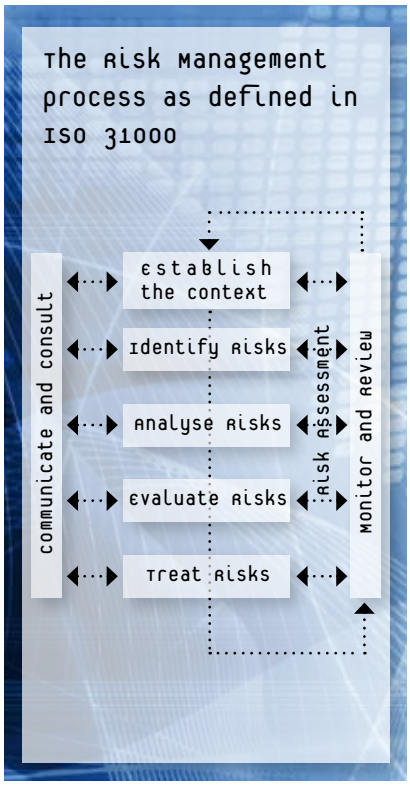
1 Risk Management and CCS Demonstration Projects

Risk can be defined as the effect of uncertainty on objectives. Objectives can have different aspects such as financial, health and safety, and environmental goals and can apply at different levels such as strategic, organisation-wide, project, product and process.

Risk Management is the set of coordinated activities to direct and control an organisation with regard to risk. (ISO 31000[3]).

There are many ways of approaching Risk Management. Different standards and models co-exist. The international standard ISO 31000 *(see Figure 1)* describes principles, a framework and structured processes for identifying, assessing and controlling risks. Increasingly, companies are looking at both downside risks (with a potential negative impact on objectives) and upside risks (with a potential positive impact on objectives).

↓ Figure 1 Example of a Risk Management Model



Organisations and projects should develop a Risk Management framework: a set of components that provide the foundations and organisational arrangements for designing, implementing, monitoring, reviewing and continually improving Risk Management throughout the organisation/project. The organisational arrangements include plans, relationships, accountabilities, resources, processes and activities.

Due to the novel nature of large scale CCS, the demonstration projects may face a wide spectrum of risks; technical, economical, commercial, organisational and political. Hence, a rigorous approach to risk management has been identified as a key success factor for the CCS demonstration projects. Such an approach will help decision-makers within the projects to make informed choices, prioritise actions and distinguish amongst alternative courses of action.

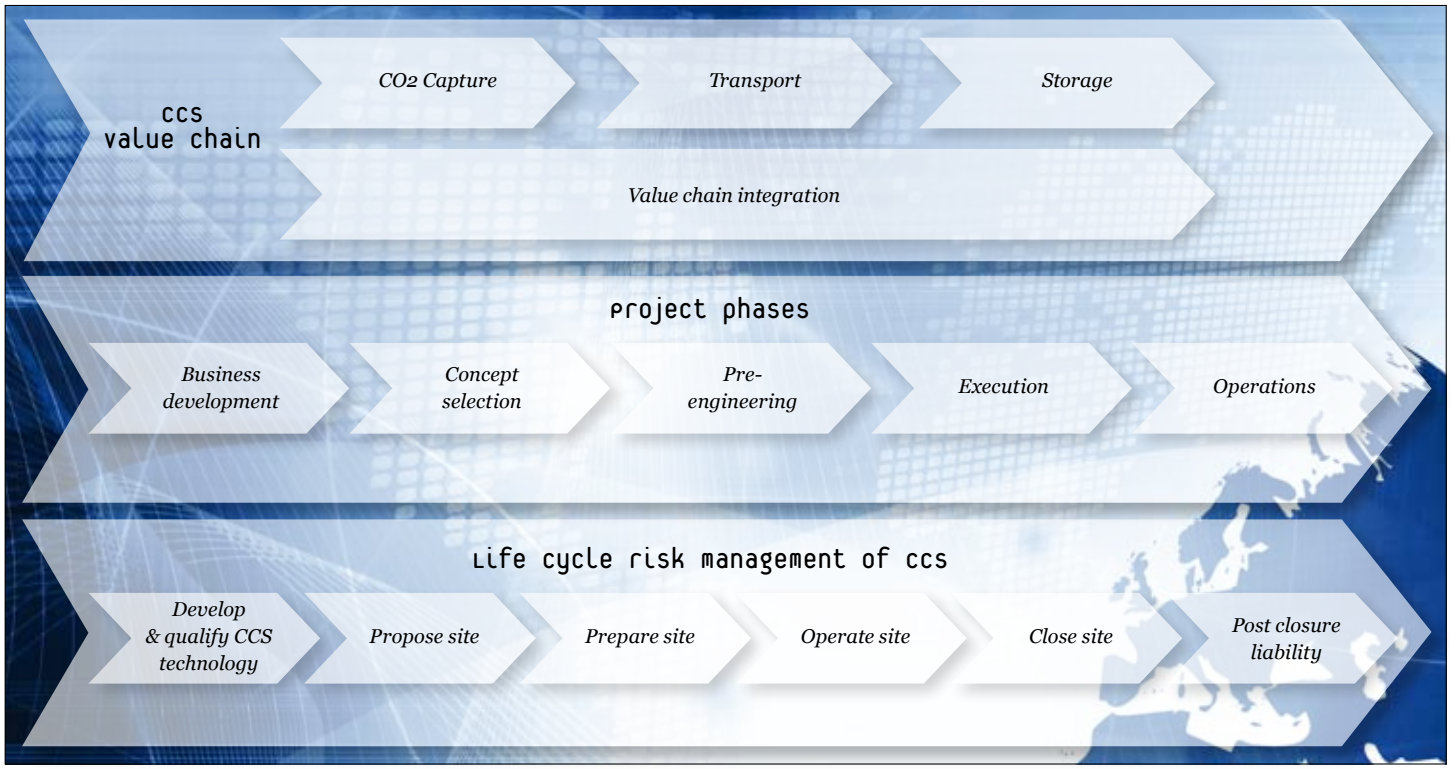
There appear to be three models that can inform risk management in a CCS project *(see figure 2 on the next page)*:

- **The value chain**
- **Project phases**
- **CCS life cycle**

Each approach can be helpful to identify and communicate CCS related risks. The value chain model has been chosen by the CCS Project Network for focusing discussions and presenting project risk management in an aligned manner.

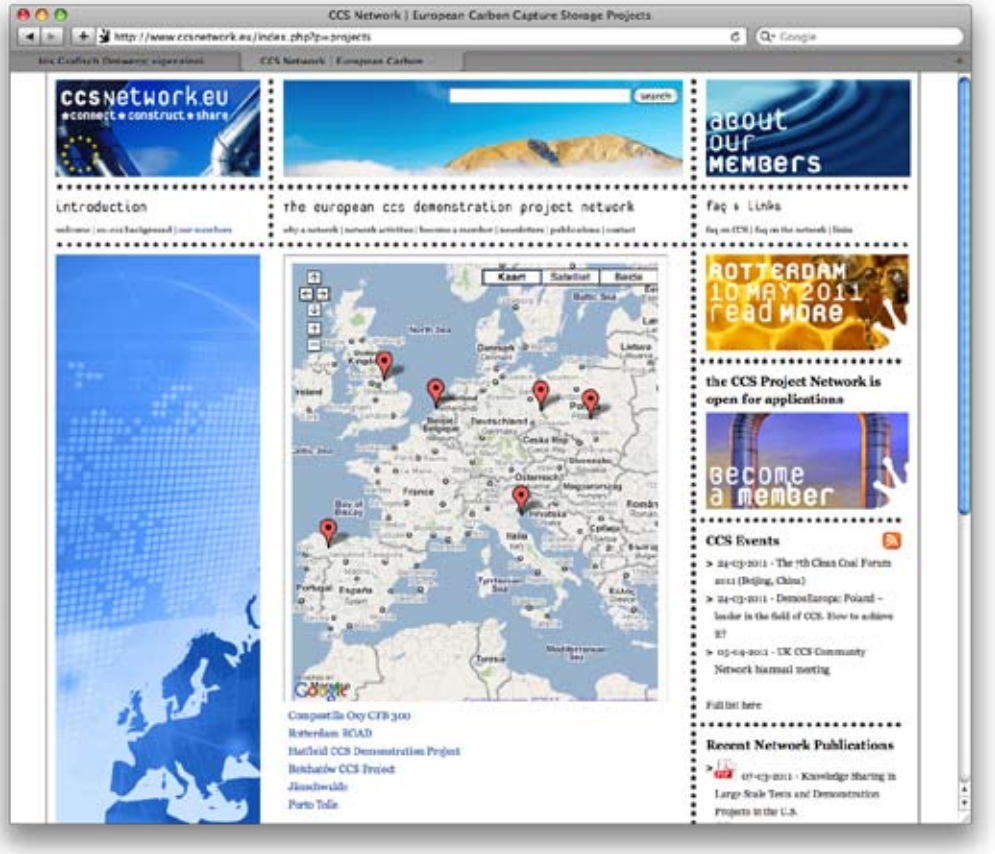
3 ISO 31000:2009 Risk Management - Principles and guidelines

CCS value chain



↑ Figure 2 Approaches for identifying CCS related risks

2 Risk Management in the Projects



Bełchatów, CCS Project

A risk register has been prepared where the risks identified cover the three components of the CCS Project as well as different phases of their lives. Those risks pertain to technical, financial, legislative as well as public awareness aspects of the project. The risk register is updated on a regular basis.

Public acceptance, funding and CCS Directive transposition risks currently receive the most attention from the project team. The project also sees opportunities arising from the EU's support for the initiative on the one hand as well as learning coming from other CCS projects within the CCS Network on the other.

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A broad spectrum of risks have been identified, ranging from technical risks to organisational risks and include issues like CO_2 purity performance, storage feasibility, CAPEX and OPEX and maintenance.

Risk mitigation activities are mainly aimed at addressing technical challenges through utilising prototype and reference plants.

There are several opportunities:

- The EU support (Parliament, EC, Council) demonstrates the public relevance of CCS and this can be a strong enabler in obtaining public acceptance.
- Progress of the Spanish transposition of CO_2 storage directive seems timely.
- The project is receiving Spanish state support driven by domestic coal use in the future.
- The potential of economic stability provides good opportunities for acceptance locally.

Hatfield CCS Demonstration Project

The project is working towards a systematic approach to risk management. The approach builds on results of the work of external bodies, such as the Carbon Capture & Storage Association[4] (CCSA) that is compiling a list of CCS Risks.

Hatfield is looking at both downward ('threats') as well as upward ('opportunities') risks: permitting and planning, technical challenges and industrial relations are the biggest threats to the project, where possibilities for low-cost CCS, multi-access transport and storage infrastructure in the region and enhanced use of UK and European funds pose the biggest opportunities.

Hatfield's organisation is built on a co-operation agreement between Powerfuel Power Limited (responsible for capture) and National Grid Carbon Limited (responsible for transport and storage). Risk management activities mainly focus on risks within each step of the value chain.

In the next twelve months the risk focus will be on technical risk - feasibility of storage and a strategy for mitigating capture risks as well as financial risk related to the NER 300 funding and the Carbon Levy[5]. Risk management development will concentrate on implementing major project risk controls and reporting.

Jänschwalde

Safety is one amongst Vattenfall's three core values and so managing and mitigating risks is of utmost importance to the company. Risk management for the Jänschwalde project is embedded in the responsibility of the overall project manager and his deputies for the three elements of the CCS chain, rather than one overall risk manager. Risk registers are developed and updated on regular basis by internal and external experts. Risk management is controlled according to the registers by checking status and mitigating actions undertaken in respective meetings of the project's steering committee.

The main risks currently identified include the possible unsuitability of the storage site (result of exploration), delays due to permitting and technical issues, lack of public acceptance and uncertainties regarding the implementation of the EU CCS directive in Germany. Additionally, the lack of sufficient funding is identified as a main risk.

Porto Tolle

With the aim of ensuring a comprehensive risk management approach inside the whole Group, ENEL has recently established a Group Risk Management Division headed by the Chief Risk Officer who reports directly to the CEO of the ENEL Group. This enables a homogenous approach and the effective detection, measure, mitigation and monitoring of all kind of risks (operational, financial, commodity, credit and counterparty, strategic, environmental).

In the specific case of the Porto Tolle project, a risk manager will be appointed and work in close cooperation with the project manager with the support of a team of experts highly skilled in the three main areas of the project itself: the carbon capture, the

4 http://www.ccsassociation.org.uk/

5 As of the publication date, the UK Government has withdrawn the CCS specific elements from the carbon levy although it has committed to funding CCS projects from other sources.

transportation and the storage. A detailed risk register has already been developed detecting and assessing more than 100 potential risks. Financial risks are very important to the Porto Tolle project. Not obtaining funding from the EU and the national government would be highly detrimental. Transposition of the EU CCS Directive in Italy is well underway and seems to pose little risk to the project. Public acceptance is also considered a limited risk due to the off-shore storage location. Pilot projects and R&D activities are underway to address technical risks.

ROAD

Managing risk is a fundamental part of the ROAD project. The risk management procedure is intended to ensure the project's manages its responsibilities in terms of HSE (Safety, Health & Environment), time, resources, quality, transparency and cost. Proactive risk management ensures effective allocation of resources to keep risk exposure within acceptable limits throughout the life of the project.

Risk management consists of several tasks. Different people are responsible for these tasks (e.g. the project risk manager), whereas others are accountable for action, support, consultation, or for ensuring that they are informed of issues arsing from the activities.

The risk management process, as given by external and internal guidelines, includes essential process elements like systematic risk identification, evaluation (both quantitative and qualitative), mitigation and control (monitor, review and report). The individual risks will run through these elements sequentially and repeatedly. However, not all necessary steps within these elements have been completed at this stage of the project.

In the **risk identification** element, several steps have been accomplished including expert interviews, risk workshops and brainstorming sessions. All risks identified, have been initially qualified / measured / prioritised in terms of their probability (likelihood of occurrence) and severity (impact on the project).

In **risk evaluation** the risks were re-qualified and then quantified with respect to cost, schedule, etc. The viability, benefit, and cost of mitigation action will be evaluated here. Based on this, risks and mitigation actions can be prioritised further. In quantitative risk evaluation, tools and procedures have to be defined and applied (e.g. by Monte Carlo simulation).

In the **risk mitigation** element the planning and execution of response to each individual risk is executed proactively. A clear escalation path (involvement of higher management) has to be developed depending on the impact of risk on cost, schedule, etc. The overarching goal is to prevent a risk, to reduce the probability of occurrence of a risk, or to reduce its impact.

In the **risk controlling** element is the link in between risk identification, risk evaluation, and risk mitigation. It ensures alignment with shareholders' standardised controlling and reporting processes. It reviews and monitors risks and mitigation actions and is continuously performed throughout the project life.

All major risks to the ROAD project have been identified: a lengthy permitting process (leading to severe project delays and possibly partial loss of funding), excessively strict monitoring requirements (originating from the translation of the EC CCS Directive into national law), liability terms in the secondary legislation (also originating from the translation of the EC CCS Directive into national law) and a lack of public acceptance.

3 CO_2 Stream related risks

A good understanding of the behaviour and properties of the CO_2 stream is essential for the design of the CCS system and for establishing and maintaining a stable CO_2 flow during operations. This is also true for CO_2 specifications and requirements. Discussions with external experts (Gelein de Koeijer, Statoil and Antonie Oosterkamp, Foundation Polytec) helped to establish a better understanding of the risks related to both the CO_2 stream specification and CO_2 stream composition that may result in increased cost or poor system performance.

Current Situation

Currently no CO_2 stream standards exist. Offshore storage in parts of Europe is regulated by the OSPAR convention. OSPAR is "the mechanism by which governments of the western coasts and catchments of Europe, together with the European Community cooperate to protect the marine environment of the North-East Atlantic" (from: www.ospar.org). It requires that the gas stream should consist "overwhelmingly of carbon dioxide" and "no waste or other matter may be added to the CO_2 stream for the purpose of disposing this waste or other matter underground."

Risks related to CO_2 stream specification

CO_2 stream specification will contribute to safe operation of CCS. Several risks are associated with CO_2 stream specifications that could be imposed to the projects by regulators.

Specifications should respect capabilities of different technologies being considered in CCS. Technologies should not be excluded at this stage. Residual components in the CO_2 stream affect different parts of the CCS chain in different ways. A full understanding of the impact of their components across the entire CCS value chain is essential to avoid specifications that will result into sub-optimal solutions and unnecessary costs and risks. The specification should allow the projects to optimise the CO_2 stream composition for their specific conditions (source, storage location and local conditions): both the transport system and the storage system set the requirements.

The members concluded that CO_2 specification should not be restrictive (i.e. complying with regulatory requirements) during the demonstration phase;

- Specifications should not result in cost increase if they do not reduce the HSE hazard or improve system availability;
- The projects should be allowed to demonstrate that they can operate CCS safely;
- Specifications should allow projects to demonstrate different materials and stream compositions.

Risks related to CO_2 stream composition

Residual components in the CO_2 stream may introduce different types of risks, including reduced pipeline integrity, reduced safety and reduced operability - especially during transitions and reduced storage capacity. These risks can be caused by several mechanisms, including increased corrosion rates, changes in the saturation line, changes in the density, hydrate formation and unwanted chemical reactions in the reservoir.

Typical residual components that should be considered to evaluate these risks include:

- **Water**. Free water may form carbonic acid causing high corrosion rates, reactions with other residual components like H_2S, NO_x and SO_x will also result in acids. Water can form hydrates given the right conditions;
- **Hydrogen**. Hydrogen induced cracking and hydrogen embrittlement can affect the pipeline. Hydrogen can affect the saturation line and the stream density;
- **Oxygen**. Corrosion rate and saturation line can be influenced by the presence of oxygen. Oxygen can influence bacteria growth and may react with reservoir rock;
- **N_2, Ar, CH_4 and H_2**. These components affect the saturation line, decrease the density of the stream and increase the probability of dual phase flow;
- **Toxic components**. Components like H_2S, SO_x, NO_x or CO may be present in the stream. Some elements may react in the reservoir and some may affect the saturation line. E.g. H_2S may contribute to corrosion, either by forming free water by reacting with CO_2 or SO_x or by an increased risk on SSC[6].
- **Combination.** Some of the risks related to residual components are possibly interrelated. For instance, there is an engineering trade-off to allow either Hydrogen or Oxygen in the CO_2 stream. If both components coexist in the CO_2 stream the combination will create a high probability on corrosion.

Polytec and Statoil shared the view that ongoing research is needed for further improving HSE and reducing cost as knowledge gaps still exist, such as:[7]

- The reliability of water solubility data under 10°C;
- Insufficiently reliable phase data for hydrates in combination with under-saturated water and carbon steel;
- A lack of data on cross-effects of residual elements on water solubility and hydrate formation;
- An incomplete understanding of the effects of residual elements on CO_2 corrosion rates as input for better corrosion models;
- The degree of MEG/TEG solubility and water carry-over following dehydration.

Improved understanding of existing knowledge gaps will support ongoing scientific R&D with a more operational / industry focus on topics such as interface control, transient behaviour and safety.

Adjusting the CO_2 stream composition either to mitigate risks or to meet CO_2 stream specification

Commercial scale operations and many pilot projects have demonstrated that CCS-projects can mitigate the risks related to residual components. Additional research will help to find more cost effective solutions. If specific residual components are undesirable in the CO_2 stream - due to risks or specification requirements, technologies exist to reduce or remove them at the penalty of additional Capex and or Opex and operations risks due to a more complex setup. For example, water can be reduced with additional drying units using zeolites or glycols. Alternatively the consequences of residual components can be accounted for in the design, perhaps by using a larger pipeline diameter to compensate for decreased density, for instance.

6 SSC: Sulfide stress cracking

7 The listed items are examples shared. It is not intended to be read as a prioritised list.

component	unit
CO2	%
CH4	ppm
N2	%
H2S	ppm
C2+	ppm
CO	ppm
O2	%
NOx	%
SOx	%
H2	%
Ar	%
H2O	ppm
MEA	ppm
Acetic acid	ppm
Acetaldehyde	ppm
TOC	ppm
NH3	ppm
all other	ppm

[1] *All units as Volume fractions, unless stated otherwise*

↑ Table 1 Shared CO_2 stream composition components

CO_2 stream composition in the member projects

The planned CO_2 stream compositions for the projects are still under development. Ongoing research and design decisions are likely to change current specifications. The projects have identified the components that are relevant for the CO_2 stream specification *(see table 1 for details)*. The projects expect that sharing their views on planned CO_2 stream composition will facilitate learning and exchange of ideas.

All projects will share composition data on a regular basis in the future. New or changed values of the planned CO_2 stream composition will be shared, as well as the rationale behind these changes.

Sharing CO_2 specifications outside the network

Sharing CO_2 specifications with interested parties outside the Network is relevant for several reasons:

- **Health, safety and environment**. Sharing data will help to establish a better understanding of health, safety and environmental issues related to CCS.
- **Engineering**. While knowledge gaps exist on the impact of residual elements on corrosion and reservoir behaviour, sharing of specifications will help to develop engineering standards for specific aspects of CCS transport and storage.
- **Regulation**. Regulators will need to understand the set of specifications for the safe operation of CCS. Additionally, they will need to understand how regulations should support the objectives related to the reduction of greenhouse gases and, more specifically, the deployment of CCS.

4 Developing a CCS Risk Register

The member projects are identifying risks as they progress. The Network members have agreed to share the risks specific to the CCS demonstration projects with the other Network members in order to facilitate and accelerate mutual learning. The risks are collected in a shared risk register. This register will help the member projects to identify relevant CCS risks and focus on the most relevant risks.

At the end of 2010 the register is still 'work in progress' and cannot be viewed as a definitive resource by the members. The development of a collective list of risks has been of benefit through acting as a vehicle for sharing knowledge. It is acknowledged that this work is as yet unfinished and that local conditions impact on probabilities and consequences. Analysis of the initial content provides insight into the nature and the type of risks the projects are facing.

Introduction to the risk register

A risk register lists identified risks and is used to manage those risks and helps to communicate risks across project interfaces and between different disciplines. Since projects develop over time and their environments change, the risk register should be continuously updated through all project phases. Failing to identify risks and mitigating actions in time may have a significantly negative impact on the projects objectives.

Developing and updating a risk register is a multi-disciplinary activity: the combined expertise of people from different backgrounds will make it easier to identify and understand the risk at hand. The CCS risk register produced by the Network is intended to be used by the projects as a checklist and may help projects to develop or improve their own project specific risk register.

Risk can be defined as the effect of uncertainty on objectives. Risks can be external (the project is not able to influence the causes), or internal (the project can influence both causes and consequences). A risk assessment will identify the likelihood of specific events occurring and the impact of the consequences on the objectives. Risks can have an impact on a variety of objectives, such as finance, reputation and HSE.

The CCS risk register is generic for all projects. It describes the potential events and threats, their causes and the type of impact they can have on project objectives. The CCS risk register does not contain quantitative information on probability or consequences, as this will differ for each project.

Development process of the risk register

During the past year each of the projects has shared their views on risks.
Input from the guest speakers was considered as well. For example Gelein de Koeijer of Statoil shared his views on the main issues of a CCS transport system:

- **Interface control**: Maintaining a controlled flow across interfaces (e.g. from the pipeline through the wellhead into the well)
- **Transient behaviour**: Controlling the system in a transient state, e.g. during start-up or shut down and during maintenance.

Based on the Statoil presentation the members concluded that the oil and gas sector seems experienced in working with high economic risk and high margin projects and has the competences, methods and (risk) management systems in place; this sector may well prove valuable to CCS projects in terms of benchmarking opportunities that will help accelerate learning and prevent repetition of errors or duplication of effort.

All risks have been collected and organised; similar risks have been combined. To facilitate this process DNV has developed a structure for the risk register.

ID	PHASE	RISK CATEGORY	RISK TITLE	CAUSE	CONSEQUENCE	OBJECTIVE			
						FINANCIAL	HSE	SYSEM PERFORMANCE	REPUTATION
3	Value chain	External	Lack of sufficient private funding	The project fails to obtain suffient loans and other forms of private funding due to unclear risk picture.	The project may be delayed or cancelled	x			
11	Value chain	External	Political influence on planning	Political agendas and timescales may affect the schedule and affect different parts of the CCS chain.	Project delays	x			

↑ Figure 3 Partial view of the Risk Register

For each risk the following information is collected:

phase	The phase of the CCS Value Chain that is affected most by this risk Potential Values: **Source:** The Source or CO_2 emitter **Capture:** The installation for capturing CO_2, which includes the compressor and the dehydration plan (if present) **Transport:** The system to transport the CO_2 (pipeline, vessel, car, ...) **Storage:** The reservoir for permanent storage of CO_2 which could be on land or offshore **Value chain:** Risk may affect the entire CCS value chain
risk category	**Internal:** The source/cause of the risk is internal in the organization/project. **External:** The source/cause of the risk is outside the organization/project.
risk title	A short descriptor of the risk
cause	A specific description of the origin of the risk: element(s) which has the potential to give rise to risk
consequence	A specific description of the outcome of an event affecting the projects objectives
objective	This column specifies which project specific objectives that could be affected by the risk. Objectives of CCS projects can have different aspects such as: **Financial;** including funding, financing, revenue and cost **Health, safety and environment** **System performance;** this may include objectives related to capacity & operability in all phases, capture rate in the capture phase and storage integrity & injectivity in the storage phase. **Reputation;** Credibility of the project and it partners for it's stakeholder, public, governments and institutions (e.g. like financial institutions)

Results

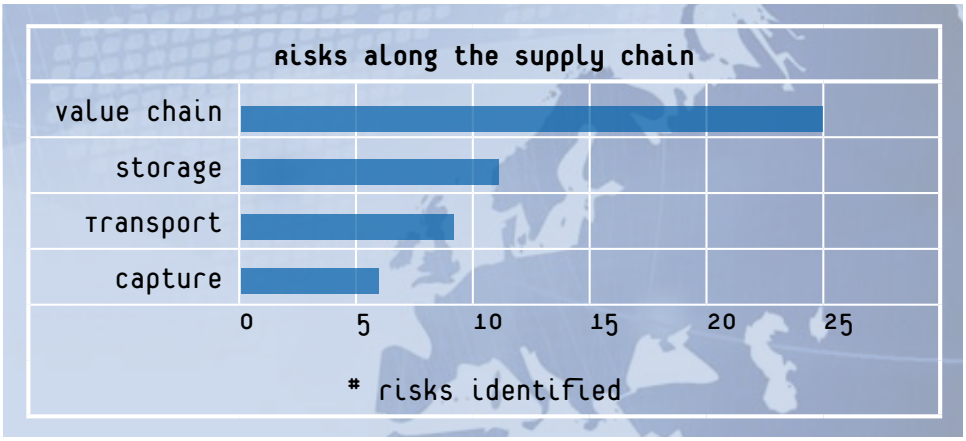
Based on the initial input a high-level analysis of the risk register was established *(see figures 4, 5, 6):*

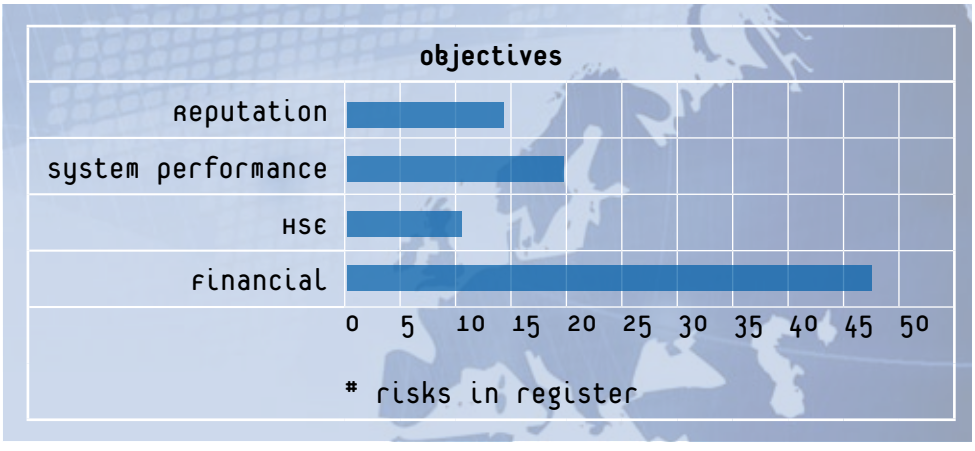
49 risks have been identified after combining similar risks;

Most risks relate to storage or the entire value chain; typically the risks relate to the acquisition, the development and operation of a storage location with sufficient capacity as well as timely acquisition of the required property.

Most risks have consequences on financial objectives. This is to be expected in the early development stages of the projects; the number of listed HSE related risks is limited.

Most risks are internal, although a significant number of external risks have also been identified. External risks are mostly related to obtaining external funding and on dependencies on policy makers and regulators.





↑ Figures 4, 5, 6 Characteristics of the Risk Register

Common risks

Projects have prioritised the risks for their project. The results were used to identify common prioritised risks of the network members as a basis for selecting the most relevant topics for the sharing agenda for 2011 *(see table 2)*.

risk title	cause	consequence	objective			
			financial	HSE	system performance	reputation
Slow permitting process	Permits and licenses are not obtained in time due to lengthy regulatory processes or disagreement on contents. The permiting process may also take more time since this is a new area for the authorities.	Project delays, possible partial loss of funding	x			
Lack of public acceptance	Increased legal objections and lawsuits against operating plans for exploration, storage permit and pipeline permit due to protests from local community ("not in my back yard"), wider public engagement from NGOs etc	Damage to CCS and project reputation, project delays, lack of political support, lack of funding, in worst case project cancellation.	x			x
CCS economic framework	Lack of an attractive economic regime to encourage investments.	Un-affordable financial costs, risking the project	x			
Political influence on planning	Political agendas and timescales may affect the schedule and affect different parts of the CCS chain.	Project delays	x			
Suitable storage site not available	Geological exploration may show that there is no suitable (technical, economical, environmental, political) site for CO_2 storage in the intended area.	Increased cost, time delay, bad reputation for CCS and in worst case no project.	x			x

↑ Table 2 Common Prioritised Risks of the Network members as of 1/11/2010

The projects agreed to define criteria on the most effective channels for sharing the risk register with others. Several sharing mechanisms will be considered during 2011, including direct face to face meeting with new CCS projects.

5 Conclusions

Shared and common challenges and risks facing the European CCS demonstration projects justified the effort of sharing and combining insights and experiences on risk management in 2010. In its own context an examination of risk management within a European perspective is of value to a variety of stakeholders in that it can offer insights into project developers' challenges and opportunities and also help assess where enabling actions might mitigate those risks. Despite the complex local environment, insights from this pioneering exchange of knowledge in Europe can help to develop lessons that will help accelerate CCS project development elsewhere. The generic nature of the risk categories identified in this report will resonate with project developers globally.

The sharing activities of the member projects during 2010 started with an identification of project risks and prioritised risk related to CO_2 stream and interface risks for deeper exploration in this year. This is not to promote these risks above others, but a pragmatic approach to time constraints and the desire to create a tangible outcome from the knowledge sharing efforts.

The part-development of a risk register has helped projects to collate nearly fifty risks and this can be a useful resource when complete. Dissemination will be based on the Network Knowledge Sharing Protocol.

6 Forward plans by the Network

The collaborative work on risk management has helped projects to focus on the challenges they face in a methodological and comparative way. While projects are developing and moving into next project phases, focus of the risk management process is likely to shift to other risks areas, resulting in new experiences and insights.

- The projects will continue to capture and share new and developing insights on the specific risks related to large CCS projects.
- Growing understanding of the risks common to large scale CCS projects will help to focus future network activities on topics that are most relevant for advancing CCS by collecting and sharing lesson lessons learned and best practices in the mitigation of these risks.
- On going effort will be put in developing effective ways to dissimilate relevant experience to address the specific needs of individual stakeholder groups.