Project no.
ERAC-CT-2005- 016210

Project acronym
FENCO-ERA

Project title
Promotion of an Integrated European and National R&D Initiative for Fossil Energy Technologies towards Zero-Emission Power Plants

Instrument: Coordination Action

Thematic Priority: ERA-NET: Energy Technology

Work Package 5

Proceedings of the 6th FENCO-ERA workshop, June 10th 2009

Coherence of Non-Technical Aspects of CCS and Monitoring

Peter Versteegh and Harry Schreurs
SenterNovem

Organisation name of lead contractor for this working document:
SenterNovem, the Netherlands

Start date of the project: 01/06/2005 Duration: 48 months

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

1 Table of contents

2 Introduction

On June 10th, 2009, a FENCO ERA-net Workshop was organised by SenterNovem in Amsterdam, the Netherlands. The title of the workshop was '*On the coherence of Non-Technical Aspects of CCS and Monitoring*'. This document represents the proceedings of this workshop.

Geological CO_2 storage seems to be developing into a realistic option. It has been recognised that monitoring of the transport and storage is a crucial element. For this reason a lot of effort has gone into the identification and development of suitable and cost-effective monitoring techniques, depending on the geological setting and uncertainties for different non-technical purposes.

Many FENCO-ERA members are now getting near the first implementation of CO_2 storage in the form of demonstration projects. Consequently, they are faced with their first real-life problems and their coherence with monitoring systems. At this point they are not only confronting the geological and technical issues inherent in CO_2 transport and storage monitoring, but also many aspects of a non-technical nature that form the context within which the technical system is deployed. Aspects such as policy (storage and transport), legal compliance relating to the OSPAR (offshore) convention and the CCS directive, background measurements, liability, economics, emission trading and permits from the national emission authorities, public communication to local inhabitants, as well as transferring the storage to the state and ethics. The workshop therefore focused on *The coherence of Non-Technical Aspects of CCS and Monitoring*.

In total 34 public officers, representatives of national authorities, technical experts, behaviourists, future CO_2 storage operators from FENCO-ERA members and the European Commission joined the workshop. Appendix 5 shows the list of participants.

The workshop aimed to:

I. identify, analyse and exchange information on the non-technical aspects and their coherence with monitoring of CO_2, more precisely during project development and implementation in the different countries
II. discuss viewpoints concerning the possible consequences of these aspects for project (and/or monitoring system) design and operations
III. identify areas for the EC's CCS scientific panel, where a common European approach could be beneficial

Appendices 6 and 7 provide summaries of the presentations and discussions.

3 Concluding remarks

I. Identification, analyses and information exchange on the non-technical aspects and their coherence with monitoring of CO_2, more precisely during project development and implementation in the different countries.

Several non-technical aspects of CCS and monitoring were discussed, identified and analysed during the workshop. Concerning the following non-technical aspects of CCS and monitoring, information was exchanged between the FENCO-ERA members and other experts:

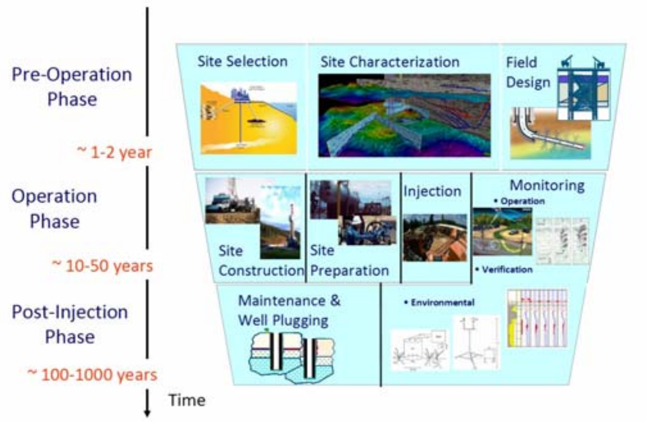
1) EU legal framework for carbon dioxide capture and geological storage
2) Monitoring and reporting guidelines (MRG) for carbon capture and storage under the EU-ETS
3) Monitoring, verification, accounting, and reporting (MVAR) monitoring system, as developed by a working group of the North Sea Basin Task Force
4) CCS project financing and the relationship with monitoring of CO_2 storage
5) The transfer of liability, the shift in responsibility, and the role of monitoring
6) Public communication approach and the usage of monitoring data
7) Ethics and CCS: the philosophy of intergenerational burdens and benefits distribution
8) The technology status of, and experience with, CCS monitoring

During the project development and implementation phase, different legal frameworks come into effect. The **geological storage directive** states that the Member States should determine whether and where CCS will occur on their territory, and sets environmental rules and liability requirements. As of 2013, the avoided emissions are recognised under the **Emissions Trading System/MRG**. Finally, the companies decide whether to use CCS on the basis of the conditions in the carbon market. The revised ETS will ensure a robust carbon price and demonstrations will bring CCS costs down; no mandatory CCS implementation at this stage.

Leakages at the storage site are IDENTIFIED under the CCS Directive and QUANTIFIED under the EU-ETS/MRG

The EU Monitoring and Reporting Guidelines should pursue several objectives. MRG must consist of transparent monitoring plans and reflect environmental integrity – 'A ton stored is a ton not emitted'. It is important that accuracy at a level of a few percent uncertainties (up to 5%) for each installation can be assured. MRG must be applied throughout the EU-27 level playing field and be consistent with national inventories under UNFCCC. The guidelines have to lead to market and stakeholder confidence and result in cost-effectiveness for different sectors, technologies, installation sizes and ages.

Figure 1, pre-, actual, and post-operation phase (EIB)



Which type of monitoring is required depends on several aspects such as:

- Location of site onshore/offshore
- Type of storage site e.g. aquifer, gas field, etc.
- Phase of deployment, see Figure 1:
    - Pre-operation phase
    - Operation phase
    - Post-injection phase

Different types of monitoring are also required depending on the situation:
- **the normal situation** –basic (for all sites), baseline and mandatory monitoring (site specific)
- **the alert situation** –additional monitoring
- **the contingency situation** -contingency monitoring (if leakage occurs)

When communicating with the general public, and in order to create acceptance, the answer to the following questions play a key role:
- Why are we still bothering with coal?
- What is CCS?
- Is it clean enough?
- Is it safe?
- Can/does it work?
- Isn't it too expensive?
- Why isn't this technology here now?
- Won't this delay, or prevent, the switch to renewables?
- What do I, as a consumer, gain from CCS?

At this point in time there is a low to non-existent awareness and understanding of CCS. Communication and public acceptance are therefore very important. The message should be that CCS is a bridge to help us cross to a sustainable society.

The ethical benefit of CCS is sustainability, but it also causes concerns about reliability, safety and the level of cleanness. These aspects need to be evaluated. Another area that concerns ethical evaluation is the relationship between CCS and other energy technologies such as renewables. For example, funds invested in CCS technologies cannot be used for renewable technology.

There is a problem with climate change. People who suffer the consequences are often not those who cause climate change. The burdens and benefits are shifted to new generations. However, it brings about a shift in burdens and benefits, and in both (spatial and temporal) directions. More philosophically: '…*to meet the need of the present without compromising the ability of future'*.

Appendices 6 and 7 provide summaries of the presentations and discussions.

II. Viewpoints concerning the possible consequences of these aspects for project (and/or monitoring system) design and operations.

Ad I. Eight non-technical aspects of CCS and monitoring were mentioned. This section clusters these aspects into four categories:

a. Legal framework and transfer of liability (1, 2, and 4)
b. Monitoring techniques and site characteristics (3 and 8)
c. Financial consequences (5)
d. Ethics, public acceptance and communication (6 and 7)

The viewpoints concerning the possible consequences of the aforementioned aspects are elaborated below.

a. Legal framework and transfer of liability

The regulatory framework will probably give a clear and comprehensive set of provisions that will have consequences for the project design and operations.

Provisions for:	*Guidance on the following issues*:
▪ Site selection ▪ Operation of storage sites ▪ Monitoring and reporting requirements ▪ Liability measures in case sites do leak ▪ Closure and post-closure obligations, and transfer of responsibilities ▪ Access to transport networks and storage sites	▪ Composition of CO_2 stream (Art 12): one participant explained that toxic elements are also relevant and the focus should not only be on CO_2 percentage but also on other chemicals in the stream ▪ Criteria for transferring responsibility (Art 18) ▪ Financial transfer when transferring responsibility ▪ Site characterisation and selection (Art 4 and Annex I) ▪ Monitoring and relations with MRGs (Art. 13 and Ann II): the possibility to monitor will be allowed by the assigned authority ▪ Amount and form of financial security (Art 19)

The Monitoring and Reporting Guidelines will also bring administrative work and require integration into the project's design and operation. Three pillars in the EU-MRG are distinguished:

1. *Monitoring of emissions*: installation-based calculation and measurement of CO_2 emissions, including archiving, QA/QC and documentation
2. *Reporting of emissions*: annual installation-specific emissions report
3. *Verification of emission report*: checked by an independent verifier

After 20-30 years, liability (in the sense of responsibility) is transferred from the operator to the government. The transfer of responsibility after the closure of the storage site is regulated in Article 18 and prescribes the following:

- All data indicates that CO_2 is completely and permanently stored
- The CO_2 is stored for at least 20 years
- The financial obligations are fulfilled. There must be enough funds available to allow monitoring for at least 30 more years.
- The site is sealed and injection facilities are removed

Operators will probably not be very happy with 60 years of liability. Operators therefore need to reserve money for monitoring (directive). The monitoring period depends on risk assessment studies. The 30 years chosen is a political decision, not a technological choice.

b. Monitoring techniques and site characteristics
Several monitoring techniques need to be designed and installed, and must measure:
- seal integrity
- fault integrity
- well integrity
- ground movement
- leakage of saline fluids

EU Storage Directive defined minimum conditions for closure. These conditions are:
- *Actual behaviour of the injected CO_2 conforms with the modelled behaviour*
- *No detectable leakage*
- *Storage site is evolving towards a situation of long-term stability*

c. Financial consequences
In order to obtain funding for CCS projects, some non-technical aspects are important and should be kept in mind when designing the project:
- Show a good credit risk perspective
- Possible loan construction
- Guarantees by national governments of CO_2 delivery and price levels
- Risks: project; performance; CO_2 price (is the highest risk)
- Financing depends on amount of CO_2 stored and the permanence of that storage
- Project – from site selection to all phases of monitoring
  - technology (chance of failure)
  - financial and economic viability
  - environment (public acceptance)
  - procurement
  - legal issues
- Capacity of a promoter, a contractor, a regulator

d. Public acceptance and communication, and ethics
The viewpoint is that open and transparent communication is very important. It enhances public acceptance and scientific learning effects. Communication should start in an early stage, e.g. the design phase. Suggestions are to:
- create awareness and build visibility toward target groups using 'basic' communication channels and tools
- align communication activities with national CCS institutions and interest groups (where they exist)
- reinforce credibility and strengthen communication opportunities and links between all stakeholders, to achieve maximum synergies, consistency and impact
- use advanced communications to position opinion leaders as the leading voice on, and partner for, CCS at an EU level

4 Recommendations

III. Identified areas for the EC's CCS scientific panel, where a common European approach could be beneficial.

FENCO-ERA members believe that a scientific panel for communication and public acceptance could be very useful. This panel facilitates discussion between all stakeholders, such as opinion leaders, industrial representatives, governmental officials, NGOs, etc.

A panel can also decide on the monitoring techniques to be used for a regulation framework. It is important that extensive monitoring should take place initially. 'We need as much information as possible now, to develop experience and to convince the general public.' Secondly, complete openness regarding findings must be given. This is the only way to gain the best learning effects and the maximum public acceptance.

Due to the lack of industrial experience, it is also important to set up a scientific panel to support and harmonise the implementation. Tasks could be to:

- assess quantification approaches for emissions from leakage
- collect and evaluate experiences with quantifying emissions from leakage
- develop guidance from collected experiences
- indicate the need for further related research to the Commission
- support Member States with additional CCS-related tasks, such as accreditation criteria for CCS verifiers

From a financial point of view the CCS scientific panel should also look at other areas, such as:

- constant CO_2 price
- guarantees with regard to CO_2 delivery and permanent storage
- creating public acceptance, as a lack of acceptance is risky

Finally the scientific panel should promote the development of a wider network of researchers and independent experts. New, independent experts who are not taking part in the recent studies are required. The present CCS community is too small.

5 Appendix, list of participants at the FENCO workshop

	Name	Organisation		E-mail address
√	Ashworth, Peta	CSIRO	AU	peta.ashworth@csiro.au
X	Chatzinikolaou, Panagiotis	Ministry of Development	GR	hagin@gsrt.gr
√	Dijkshoorn, Lydia	SenterNovem	NL	l.dijkshoorn@senternovem.nl
√	Andreas, Spahn	TUE	NL	a.spahn@tue.nl
√	Dixon, Tim	IEA GHG	UK	tim.dixon@ieaghg.org
√	Elsen van, Rob	Ministry of Economic Affairs	NL	r.p.h.vanelsen@minez.nl
√	Fernandes, Rei	University of Lisbon	PT	reifernandes@ist.utl.pt
√	Gemmill, Rob	Environment-agency	UK	rob.gemmill@environment-agency.gov.uk
√	Haduong, Minh	CIRED	FR	haduong@centre-cired.fr
√	Höwener, Hubert	Jülich	DE	h.hoewener@fz-juelich.de
√	Jammes, Laurent	SLB		jammes1@slb.com
√	Koukouzas, Nikolaos	CERTH/ISFT	GR	koukouzas@certh.gr
X	Kuckshinrichs, Wilhelm	FZ Jülich	DE	w.kuckshinrichs@fz-juelich.de
√	Lartice, Jonathan	Department for Environment, Food and Rural Affairs	UK	jonathan.lartice@defra.gsi.gov.uk
√	Le Gallo, Yann	Geogreen	FR	ylg@geogreen.fr
√	Pettersson, Magnus	Vattenfall	SE	magnus.pettersson@vattenfall.com
X	Picard, Guillemette	SLB	FR	gpicard@la-defense.oilfield.slb.com
√	Sage, Peter	AEA	UK	peter.sage@aeat.co.uk
√	Schreurs, Harry	SenterNovem	NL	h.schreurs@senternovem.nl
√	Schrevel de, Raymond	GTI	NL	rdschrevel@gti-group.com
√	Schumann, Diana	FZ Jülich	DE	d.schumann@fz-juelich.de
√	Shlihta, Gunta	Letland Institute of Physical Energetics	LV	fei@edi.lv
√	Spörker, Thomas	Federal Ministry of Economy, Family and Youth	AT	thomas.spoerker@bmwa.gv.at
√	Stroobants, Wouter	Flemish Government	BE	wouter.stroobants@lne.vlaanderen.be
√	Thompson, Eva	Ministry of Environment	NL	eva.thompson@minvrom.nl
√	Torp, Tore A.	Statoil Hydro	NO	tat@statoilhydro.com
√	Versteegh, Peter	SenterNovem	NL	p.versteegh@senternovem.nl
√	Chadwick, Andy	IEA GHG Monitoring Network	UK	rach@bgs.ac.uk
√	Dijk, Jan Willem	DConsult	NL	jan.willem.dijk@dconsult.nl
√	Drosin, Eric	Zero Emission Platform	BE	edrosin@zero-emissionplatform.eu
√	Jongerius, Pieter	Ministry of Economic Affairs	NL	p.jongerius@minez.nl
√	Podkanski, Jacek	European Investment Bank	LU	j.podkanski@eib.org
√	Santurio, Daniël	Croon Advocaten	NL	daniel.santurio@croonadvocaten.nl
√	Taebi, Behnam	Technical University Delft	NL	b.taebi@tudelft.nl
√	Tomescu, Mihai	European Commission	BE	mihai.tomescu@ec.europa.eu
√	Wartmann, Sina	Ecofys	DE	s.wartmann@ecofys.de

√ attending workshop; X regrets

6 Appendix, exchange of information

6.1 Overview of presentations

A large part of the workshop consisted of exchanging information on the coherence of Non-Technical Aspects of CCS and Monitoring. The table below summarises all presentations.

Title	Presenter	Key words
Enabling a legal framework for carbon dioxide capture and geological storage	Mr Mihai Tomescu, Unit 'Energy and Environment', Directorate-General Environment European Commission	Capture, transport, and geological storage framework; IPCC directive; OSPAR; ETS; MRG
Monitoring and Reporting Guidelines for Carbon Capture and Storage under the EU-ETS	Ms Sina Wartmann, Ecofys Germany GmbH	MRG; ETS; approach determining leakage occurring during capture, transport, injection, storage
MVAR working group North Sea Basin Task Force	Ms Lydia Dijkshoorn, SenterNovem	Monitoring, verification, accounting, and reporting; type of reservoir versus monitoring technique
Monitoring of CO_2 storage and CCS projects financing	Mr Jacek Podkanski, European Investment Bank	Loans for CCS projects; lending criteria; evaluation criteria
Liability of CCS and monitoring	Mr Daniel Santurio González, Croon Advocaten	Liability versus responsibility of government and operator; transfer after 20-30 years
ZEP and Public Communications	Mr Eric Drosin, Technology Platform, Zero Emission Fossil Fuel Power Plants	Public acceptance; respected authority; key opinion leaders; communication tactics
Sustainability, ethics and CCS	Mr Andreas Spahn TU/e Mr Behnam Taebi, TUD	Public acceptance; moral values; burdens and benefits for future generations
CCS Monitoring	Mr Andy Chadwick, Team Leader CO_2 Storage research of the British Geological Survey	CO_2 Monitoring at Sleipner: no leakage, simulated vs actual behaviour, long-term stability

The following sections contain a short summary of each presentation.

6.2 Enabling a legal framework for carbon dioxide capture and geological storage

Mr Mihai Tomescu of the 'Energy and Environment' unit, Directorate-General for the Environment at the European Commission spoke of the legal framework and proposals for carbon dioxide capture and geological storage, and the changes as defined by the European Commission. The documents will be published on the Internet at the end of June, and adoption will occur at the end of 2009.

The legal framework is enabled through three lines of risk management:

- **Legal capture framework**: this will be regulated and permitted under the IPPC Directive
- **Legal transport framework**: this will be regulated at Member State level and through environment impact assessments (EIA)
- **Legal geological storage framework**: the scope is:
  - Territory of Member state, their exclusive economic zones and continental shelves
  - Storage in water column prohibited
  - Does not apply to research projects (<100 ktCO_2)
  - Covers Enhanced Hydrocarbon Recovery combined with CO_2 storage

Mr Tomescu also presented the main elements of the EC proposal. He explained that the **geological storage directive** states that Member States should determine whether and where CCS will occur on their territory, and sets environmental rules and liability requirements. The avoided emissions are recognised under the **Emissions Trading System**. Finally, the companies decide whether to use CCS on the basis of conditions in the carbon market. The revised ETS will ensure a robust carbon price and demonstrations will bring CCS costs down; no mandatory CCS implementation at this stage.

The new proposal will also set clear and comprehensive provisions for:

- Site selection
- Operation of storage sites
- Monitoring and reporting requirements
- Liability measures, in case sites do leak
- Closure and post-closure obligations, and the transfer of responsibilities
- Access to transport networks and storage sites

Article 5: Duration of exploration permit ▪ Adopts approach of hydrocarbon licensing directive 94/22/EC: duration of permit should not exceed the period necessary to carry out of the exploration for which it is granted.	**Article 18: transfer of responsibility** ▪ Clarified procedure, but only two main changes ▪ A minimum period before transfer to be determined by CA, no shorter than 20 years unless the CA is convinced that the key transfer criterion is met before that (paragraph 1 (b)) ▪ Post-transfer monitoring, reduced to a level which allows identification of leakages or significant irregularities (paragraph 6)
Article 6: Priority for storage permit, for holder of exploration permit ▪ Provided that exploration is completed, the conditions in the permit are complied with, and application made during validity period of exploration permit.	
Article 8: Hydraulic unit provisions ▪ EP is concerned about pressure interactions between sites. Arguably covered already by Article 4 and Annex I, step 1 point (k), but added in Article 8 for clarity	**(new) Article 20** ▪ Consequent on changes to 18.6 ▪ Covers at least cost of monitoring for 30 years ▪ Member States can go further ▪ Commission guidance
Articles 10 and 18: Commission review of storage permits and draft transfer decisions ▪ Timing modified: permit application submitted in parallel to Commission; deadline 4 months after submission of draft permit decision (analogous changes for transfer in Article 18).	**Art 33: New combustion plant** ▪ Assessment of availability of suitable storage sites and feasibility of transport and retrofit (not only technical but also economic) ▪ Reservation of space conditional on positive assessment.
Art 11: Responsibilities taken over on withdrawal of permit clarification that these cover responsibilities under this ▪ Directive, the ETS Directive 2003/87 for surrender of allowances, and the ELD Directive 2004/35 on remediation of environmental damage	**Art 38: Review article covering** ▪ Experience with CO_2 storage ▪ The need for continued review of draft permits ▪ Composition of CO_2 stream ▪ Third-party access ▪ New combustion plant ▪ Storage in third countries ▪ Need for adaptation of site selection and monitoring criteria ▪ Experience with incentives for CCS applied to biomass ▪ The need for further regulation on transport.
Art 12: CO_2 acceptance criteria ▪ Clarified requirement in para. 3 that a risk assessment of the proposed stream is required to ensure that it meets the conditions established under para. 1 ▪ COM guidance	
Article 13: Requirement that the **draft monitoring plan** should integrate the **monitoring and reporting plan** to quantify leakage of CO_2 to be produced under the MRGs	**Art 38.3: Emissions performance standards** ▪ Once environmental security and economic feasibility of CCS has been demonstrated, review of whether performance standards are needed and practicable

Table 1, main changes with regard to EC-proposals

Implementation and other tasks

- Ratification of OSPAR amendment and associated decisions: proposal for a Council Decision
- Finalisation of Monitoring and Reporting Guidelines: proposal for a Commission Decision voted by Climate Change Committee, currently under European Parliament and Council scrutiny
- Establishment of Scientific Panel: Commission decision

Implementation process:

- Exchange of information process established
- Guidance on issues requested by European Parliament and Council, and possibly others:
  - Composition of CO_2 stream (Article 12): one participant explained that toxic elements are also relevant and the focus should not only be on CO_2 percentage but also on other chemicals in the stream

- Criteria for transfer of responsibility (Article 18)
- Financial transfer when transferring responsibility
- Site characterisation and selection (Article 4 and Annex I)
- Monitoring and relations with MRGs (Article 13 and Annex II): possibility to monitor will be allowed by the assigned authority
- Amount and form of financial security (Article 19)

6.3 Monitoring and Reporting Guidelines for Carbon Capture and Storage under the EU-ETS

Ms Sina Wartmann of Ecofys Germany GmbH presented her work on Monitoring and Reporting Guidelines for Carbon Capture and Storage under the EU-ETS, as conducted for the EC. She explained that by 2013 captured and stored CO_2 emissions will be seen as not emitted. The question is, nevertheless, how much CO_2 is actually not emitted, because losses occur during e.g. transport and storage. Ecofys, together with other organisations, has developed a methodology to determine the actual storage.

The EU Monitoring and Reporting Guidelines should pursue several aims. MRG must consist of transparent monitoring plans and reflect environmental integrity – 'A ton stored is a ton not emitted'. It is important that accuracy can be assured at a level of a few percent uncertainties (up to 5%) for each installation. MRG must be applied throughout the EU-27 level playing field and be consistent with national inventories under UNFCCC. The guidelines must lead to market and stakeholder confidence and result in cost-effectiveness for different sectors, technologies, installation sizes and ages.

According to Ms Wartmann, three pillars are distinguished in the EU-MRG:

1. *Monitoring of emissions*: installation-based calculation and measurement of CO_2 emissions, including archiving, QA/QC and documentation
2. *Reporting of emissions*: annual installation-specific emissions report
3. *Verification of emission report*: checked by an independent verifier

Monitoring during capture[1] and transport is the easiest, because a comparison of the flue gas stream coming in and out is not difficult. The most difficult aspect to monitor is leakage at the storage site itself. **Capture** accuracy requirements for determining leakage can reach ±2.5 %, depending on the chosen tier for activities and on the type of installation.

For **transport,** two approaches can be used to determine emissions:

I. *Based on input-output balance*[2]: accuracy requirements of ±2.5 % for continuous emission measurement can be achieved
II. *Based on potential sources of emissions*[3]: accuracy requirements of ±7.5 % for overall approach can be achieved

Pipeline integrity has to be proven using temperature and pressure data, and the validation of approach II is established at least once per year through evaluation of approach I data.

Finally Ms Wartmann presented ways to approach **injection** and **storage** leakage determination. Looking at the Monitoring and Reporting Guidelines/ETS and the CCS Directive, she suggested the following strike attention. As prescribed by the CCS Directive, the storage site requires monitoring. The EU-ETS Directive also requires monitoring of emissions from injection and leakage from storage sites. Both Directives imply different basic assumptions. The CCS Directive addresses behaviour of CO_2 in a storage complex, whereas the EU-ETS Directive/MRGs addresses quantification of CO_2 emitted during injection or from the storage site.

[1] *Capture*: CO_2 emissions = INPUT + potential emissions – OUTPUT
[2] *Transport I.*: CO_2 emissions = INPUT+ E-combustion + OUTPUT
[3] *Transport II.*: CO_2 emissions = E-fugitive + E-venting + E-leakage incident + E-combustion

- *E-fugitive*: fugitive emissions from transport network, calculated based on emission factors for categories of pipeline equipment, e.g. valves, seals, compressors
- *E-venting + E-leakage incident*: emissions from venting and leakage, to be determined by industry best practice
- *E-combustion*: emissions from combustion activities, e.g. booster stations

This actually means that leakages at the storage site are IDENTIFIED under the CCS Directive and QUANTIFIED under the MRG

Ms Wartmann also explained that injection and storage leakage occur due to: (1) emissions from fuel use[4]; (2) vented[5] and fugitive[6] emissions from injection; (3) vented[7] and fugitive[8] emissions from enhanced hydrocarbon recovery; and (4) leakage from the storage complex[9].

Quantification of leakage from the storage complex is only necessary if the CO_2 is emitted into the air or into the water column. The identification of such leakage takes place under the Storage Directive and 'kick-starts' quantification of those CO_2 emissions under the EU-ETS Directive/MRGs as described above.

The basic problem with quantification of emissions from leakage is the lack of experience. The uncertainty levels occurring with quantification approaches are considerably higher (±20%) than average uncertainty of CO_2 monitoring in the existing EU ETS. This causes direct environmental-integrity problems for the system. To safeguard environmental integrity, Ms Wartmann suggested using a maximum uncertainty threshold of ±7.5%. To reach this level of uncertainty a new mechanism will be introduced, namely the '*uncertainty supplement approach*'[10].

In order to cope with the lack of industrial experience, it was decided to set up a scientific panel in order to support and harmonise the implementation. The panel's tasks are to:

- Assess quantification approaches for emissions from leakage
- Collect and evaluate experiences with quantification of emissions from leakage
- Develop guidance from collected experiences
- Indicate any need for further related research to the Commission
- Support Member States with additional CCS-related tasks such as accreditation criteria for CCS verifiers

6.4 MVAR working group North Sea Basin Task Force

Ms Lydia Dijkshoorn of SenterNovem gave a presentation concerning the *Monitoring, Verification, Accounting and Reporting* (MVAR) working group of the North Sea Basin Task Force. The aims of the North Sea Basin Task Force are to develop broad, common principles that could form a basis for regulating the storage of CO_2 in the North Sea and to provide a consistent basis for managing this activity. The Task Force consists of governmental, industrial, and research representatives from Norway, the United Kingdom, the Netherlands, and Germany.

Caveat: as work on this protocol is ongoing, all these presented findings are to be considered provisional.

The North Sea Basin Task Force conducted a gap analysis on legal, regulatory and economical issues related to CCS. This work was undertaken by DNV on behalf of the Norwegian Ministry of Petroleum and Energy as part of the work carried out in phase I of the North Sea Basin Task Force (NSBTF) on CCS (2007-01-19). Since then, this updated gap analysis shows that there are still substantial legal, regulatory and economic gaps that need to be resolved and/or closed in order to make the CCS option a more viable solution.

Most of the work planned for phase II of the NSBTF concerns these identified critical gaps. For phase II, three working groups were established:

- Trans-boundary issues

[4] Determination according to provisions under Annex II of 2007 MRGs
[5] Determination with continuous emission measurement according to revised MRG Annex XII
[6] Determination according to industry best practice
[7] Determination with continuous emission measurement according to revised MRG Annex XII
[8] Determination according to Annex II of the 2007 MRGs
[9] Leakage defined as in Directive on Geological Storage of CO_2
[10] Uncertainty supplement approach:

- CO_2-reported = CO_2-quantified + CO_2-uncertainty supplement
- CO_2-uncertainty supplement = CO_2-measured * (Uncertainty-measurement - 0.075)

- RASQ (Risk Assessment, Site Qualification)
- MVAR (Monitoring, Verification, Accounting and Reporting)

The MVAR working group is developing a monitoring protocol that:

- complies with common principles
- complies with:
  - *EU-ETS* and National GHG inventories (*IPCC guidelines*) Quantification Leakage and Accounting
  - *EU Directive* and *OSPAR*: monitoring is required in order to see whether stored CO_2 behaves as expected, migration or leakage occurs, and whether an identified leakage damages the environment or human health
- systematically applies to typical North Sea reservoirs

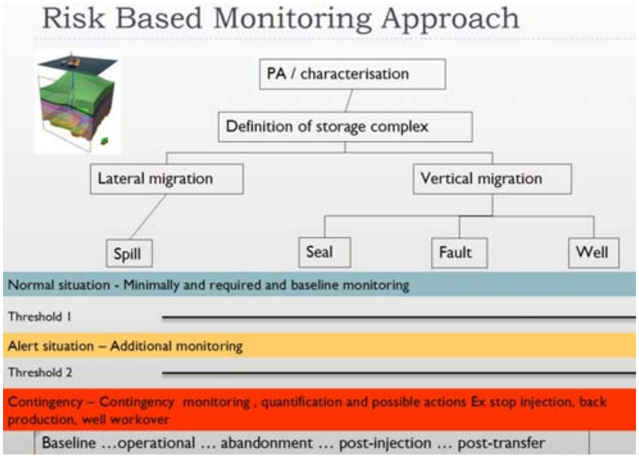


Figure 2 shows a draft of the risk-based monitoring approach. Three situations and corresponding types of monitoring are identified:

- **the normal situation** –basic (for all sites), baseline and mandatory monitoring (site - specific)
- **the alert situation** –additional monitoring
- **the contingency situation** -contingency monitoring (if leakage occurs)

Figure 2, Draft: risk-based monitoring

Table 2 shows typical North Sea reservoirs and their relevant characteristics for the Netherlands.

Type of storage structure	Reservoir	Seal			Well			Faults				
	Reactive minerals	S	Sh	Cl	1	1-5	>5	Bounding Faults	Horst blocks	Anticline structures	Non-con-formity	Extension to shallow depth
Rotliegend		X	X		X	X			X			
Bunter		X	X	X	X	X	X	X		X	X	X
Jurassic/Cretaceous	X		X		X	X			X	X	X	X
Tertiary/Quaternary				X						X		

Table 2, Draft: Typical North Sea reservoirs with relevant characteristics

Table 3 qualifies the risk management effort that needs to be conducted per type of storage structure.

Type of storage structure	Gas/oil field				Aquifer			
	Seal	Fault	Spill	Well	Seal	Fault	Spill	Well
Permian	o	o	o/+	+	o	o	o/+	o/+
Triassic	o/+	+	o/+	+/++	o/++	+/++	+	o/+
Jurassic/Cretaceous	+	o/+	o/+	+/++	++	+/++	+	o/+
Tertiary/Quaternary	++	o	+	+	++	o	+	o

o = minor effort, + = average effort, ++ = high effort. [to be checked for UK, GE and NO sectors]

Table 3, Draft: Typical North Sea reservoirs management efforts for the risk paths of CO_2 containment

Finally, the working group is preparing an appendix showing monitoring techniques and their relationship to potential risks. Deep reservoirs do not need a lot of monitoring, while aquifers require considerable monitoring. Therefore, a monitoring technique matrix will be developed representing the suitability, per storage site, for monitoring:

- seal integrity
- fault integrity
- well integrity
- ground movement
- leakage of saline fluids

6.5 Monitoring of CO_2 storage and CCS project financing

Mr Jacek Podkanski of the European Investment Bank (EIB) explained that energy is one of the EIB's priority objectives. The bank is especially interested in sustainable, competitive and secure energy. EIB plans to lend a total of 9.5 billion euro in 2009 and 10.25 billion euro in 2010. Mr Podanski indicated that this includes financing CCS R&D and Demonstration plants.

EIB has put in place a 3 billion euro Energy Sustainability and Security of Supply facility to finance, inter alia, climate abatement and CCS projects outside the European Union. EIB will work with both developing as well as developed countries around the world to help achieve the EU's objectives for abating climate change.

EIB is ready to create an additional joint initiative with the Commission to finance energy and climate change, which will take account of the needs of CCS where specific and realistic proposals are advanced by industry. Discussions are still being held on the best ways to do this and EIB would welcome input from, and further dialogue with, the utilities, fossil fuel companies, manufacturers and regulators.

The financial incentives for CCS implementation include:

- Adjusting state aid rules – Member States may subsidise CCS projects
- 300 million in CO_2 allowances for CCS and innovative technologies. This translates into 6-7 billion euro
- Approximately 1.05 billion euro for CCS projects

EIB foresees that the following issues still need to be resolved:

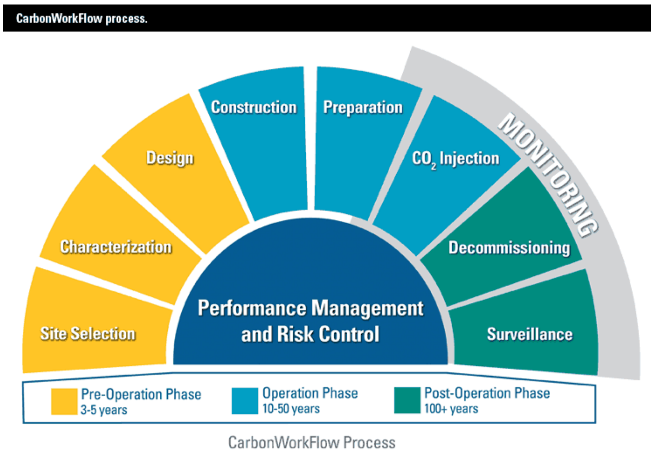
- Liability issues – who should be responsible for potential leaks and for how long?
- Ownership issues – who should be responsible for maintaining the storage site and for how long?
- Public acceptance – CCS is not well known by the general public, some NGOs oppose CCS in principle
- Should companies be requested to comply with zero emission levels by a certain deadline (as proposed in the UK's 'No coal without CCS'?
- Despite the EU´s efforts on the financial side, substantial funding gaps still remain

Mr Podkanski explained the EIB's CCS approach. EIB initiates a dialogue with stakeholders. It is important to actively discuss this with Greenpeace, other NGOs, and ZEP in order to enhance public acceptance. One of EIB's main concerns is the lack of acceptance, which brings high uncertainty levels.

When EIB starts lending to CCS projects, several aspects are important:

- Loans must
  - be technically sound
  - be viable and show an acceptable economic return
  - comply with environmental protection and procurement regulations
- EIB will assess a project from a credit-risk perspective
- Once approved, signed and disbursed, a project will be monitored throughout its lifetime
- Considered issues are:
  - possible loan construction

- guarantees by national governments of CO_2 delivery and price levels
- risks: project; performance; CO_2 price (is the highest risk)



- Financing depends on the amount of CO_2 delivered and permanently stored

EIB will also look at:
- Projects – from site selection to all phases of monitoring
  - technology (chance of failure)
  - financial and economic viability
  - environment (public acceptance)
  - procurement
  - legal issues
- A promoter's capacity
- A contractor's capacity
- A regulator's capacity

Figure 3, Carbon work-flow process

6.6 Liability of CCS and monitoring

Mr Daniel Santurio González of Croon Advocaten gave a presentation on liability of CO_2 storage. The legal framework consists of four parts:
- Directive on the geological storage of carbon dioxide (2008/0015)
- Directive 2003/87/EC (emissions trading system)
- Directive 2004/35/EC (Environmental liability)
- National legislation

The liability is covered in the geological storage directive, which distinguishes two types of liability, namely:
- Liability for environmental damage: directive 2004/35/EC
- Liability for climate damage: directive 2003/87/EC

Long-term liability is not covered by the directive. A level playing field could be endangered because Member States have different liability regulations.

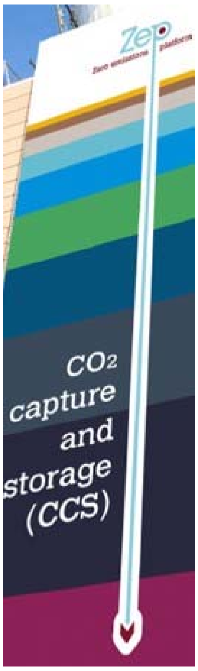
After 20-30 years, liability (in the sense of responsibility) is transferred from the operator to the government. The transfer of responsibility after the closure of the storage site is regulated in Article 18 and prescribes the following:
- All data indicates that CO_2 is completely and permanently stored
- The CO_2 is stored for at least 20 years
- The financial obligations are fulfilled. There must be enough funds available to allow monitoring for at least 30 more years.
- The site is sealed and injection facilities are removed

Operators will probably not be very happy with 60 years of liability, and will therefore need to reserve money for monitoring (directive). The monitoring period depends on risk assessment studies. The 30 years chosen is a political decision, not a technological choice.

Mr González stated that, by then the liability should be covered by national legislation. Consideration (34) indicates that 'Liabilities other than those covered by this Directive, Directive 2003/87/EC and Directive 2004/35/EC, in particular concerning the injection phase, the closure of the storage site and the period after transfer of legal obligations to the competent authority, should be dealt with at national level.'

Mr González also gave some examples of liability issues:
- Physical damage to real estate (caused by soil movement)

- Value decrease of real estate
- Personal injuries (blow out?)



Finally he indicated several issues that still need to be resolved:

- How to deal with the transfer of responsibility (and liability?)
- How to deal with long-term liability
- How to deal with differences in national legislation between Member States regarding (long-term) liability (level playing field?)

6.7 ZEP and Public Communications

Mr Eric Drosin of the Technology Platform, Zero Emission Fossil Fuel Power Plants (ZEP) explained that public acceptance of CCS is one of the biggest challenges at the moment. His organisation (ZEP) was founded in 2005 and has 200 members from 19 countries, such as European utilities, petroleum and coal companies, equipment suppliers, scientists, geologists and environmental NGOs.

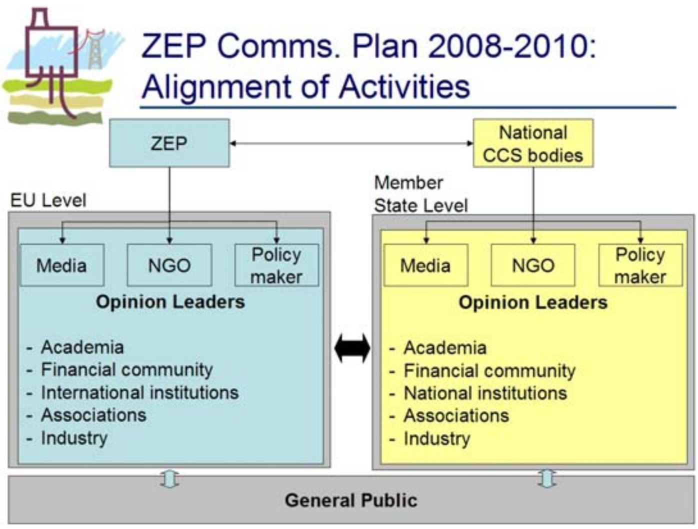
According to Mr Drosin, with respect to the communication with, and the creation of, public acceptance the answers to the following questions play a key role:

- Why are we still bothering with coal?
- What is CCS?
- Is it clean enough?
- Is it safe?
- Can/does it work?
- Isn't it too expensive?
- Why isn't this technology here now?
- Won't this delay, or prevent, the switch to renewables?
- What do I, as a consumer, gain from CCS?

At this point in time there is a low to non-existent awareness and understanding of CCS. Communication and public acceptance are therefore of major importance. The message should be that CCS is a bridge that allows us to cross to a sustainable society.

ZEP sees this as an opportunity to become the authoritative, trusted voice on CCS and its role in the climate change/energy debate. Unfortunately there is a very short, two-year window before the construction of demonstration projects needs to begin. It is a hell of a challenge to fulfil this opportunity. ZEP should weigh the opportunity to mitigate the risk of inactivity, and ignorance of CCS, and select the appropriate communications approach to meet its objectives.

Figure 4, Position of opinion leaders



The plan is to position ZEP as a credible authority on all aspects of CCS by positioning its members to become major, visible players in the climate change/energy debate. The organisation wants to engage key stakeholders in open dialogue using holistic communications and targeted, effective platforms to educate and positively influence their perceptions of CCS, energy and climate change.

You cannot go directly to the public. You have to use a key influencer. Public acceptance is established by reliable persons or institutes that communicate on the subject. ZEP's main target groups are: the **media, NGOs, policy-makers** and the other members that comprise the **opinion leaders** segment. The opinion leaders:

- are key influencers in shaping the long-term opinions of mass audiences:
  - they play a role as a forwarder of information and..
  - …bridge the gap between innovators and the early majority (relevant to CCS as a breakthrough technology)
- are not exclusive - you also reach influencers and stakeholders, as well as the more mass up-scale adult groups
- group consists of several million individuals within the EU

How will this be achieved? The tactics:

- Create awareness and build visibility toward target groups using 'basic' communication channels and tools
- Align ZEP communication activities with national CCS institutions and interest groups (where they exist)
- Mobilise ZEP membership to reinforce credibility and strengthen communications opportunities and links between ZEP members for maximum synergies, consistency and impact.
- Use advanced communications to position ZEP as the leading voice on, and partner for, CCS at an EU level

6.8 Sustainability, ethics and CCS

Mr Andreas Spahn (Eindhoven University of Technology) and Mr Behnam Taebi (Delft University of Technology) gave a presentation on sustainability, ethics and CCS. According to Mr Spahn, CCS is philosophically of interest because it holds the answer to ethical challenges, namely it is a partial solution to climate change.

The ethical benefit of CCS is sustainability, but it also causes concerns about reliability, safety and the level of cleanness. These aspects have to be evaluated. Another area that has to deal with ethical evaluation is the relationship of CCS to other energy technologies such as renewables. For example, funds invested in CCS technologies cannot be used for renewable technology.

Determining the ethical criteria for evaluating mitigation options can be achieved with two types of analyses, namely:

- **Cost Benefit Analysis (CBA)**
  - Important tool for policy decisions (Sunstein 2005)
  - Limits from ethical perspective
    - difficult to translate moral values into economic numbers
    - implicit ethical assumption (e.g. discount rate)
    - justice: distribution of benefits and burdens
- **Vs. Ethical Multi-Criteria analysis**
  - Includes evaluation of moral values
  - Compares how different values are promoted

CCS and public acceptance form a difficult pact. Mr Spahn presented two examples to demonstrate this:

- From the Barendrecht pilot, Mr. Spahn learnt that public hesitation was mainly caused by safety concerns and the NIMBY phenomenon. There is of course a problem in the distribution of burdens and benefits, as also indicated by Shell.
- The Rathenau Institute also encountered limited public support for CCS. This was mainly due to long-term management of storage facilities, storing foreign CO_2 under the Dutch soil, and of course NIMBY

Creating acceptance is a social process and trust plays an important role. Acceptance or trust increases if stakeholders share the same values.

Mr Taebi elaborated on the relationship between *sustainability* and *justice*. He proposed that we should '…*meet the need of the present without compromising the ability of future'*. This indicates the justice, in both space and time, and between generations.

There is a problem with climate change. People who suffer the consequences are often not those who caused climate change. The burdens and benefits are shifted to future generations. However, it brings about a shift in burdens and benefits and in both (spatial and temporal) directions.

How is this new distribution justified? How do you distribute responsibility through time?

It is important to be aware of the risks and know who is exposed to:

- CO_2 spillages
- Damage to the ecosystem/biosphere
- Rock instability (drilling) and earthquakes

According to Mr Taebi, the distribution of burdens and benefits is unfair. The question is whether it is justifiable to leave problems, such as monitoring, to future generations? How do you compensate the risks for future generations? How far does our obligation extend into the future? How do we deal with possible future failure to monitor versus our responsibility?

Figure 5 shows moral values from sustainability.

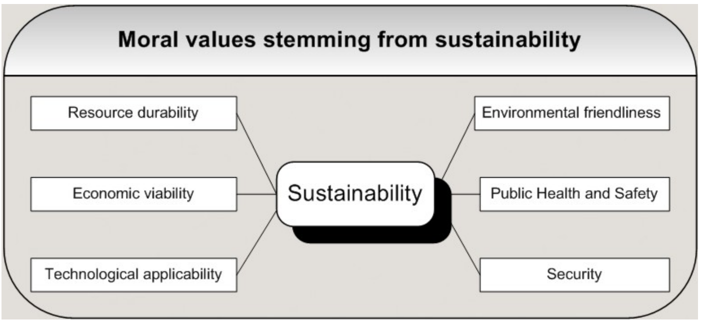


Figure 5, moral values from sustainability

Mr Taebi used the conceptual understanding model of sustainability (as presented on the left) to give an example of temporal distribution regarding nuclear power and intergenerational justice. The figure presents the moral values and the consequences for future generations.

The following figure shows the moral values of interest to different generations, with respect to nuclear power.

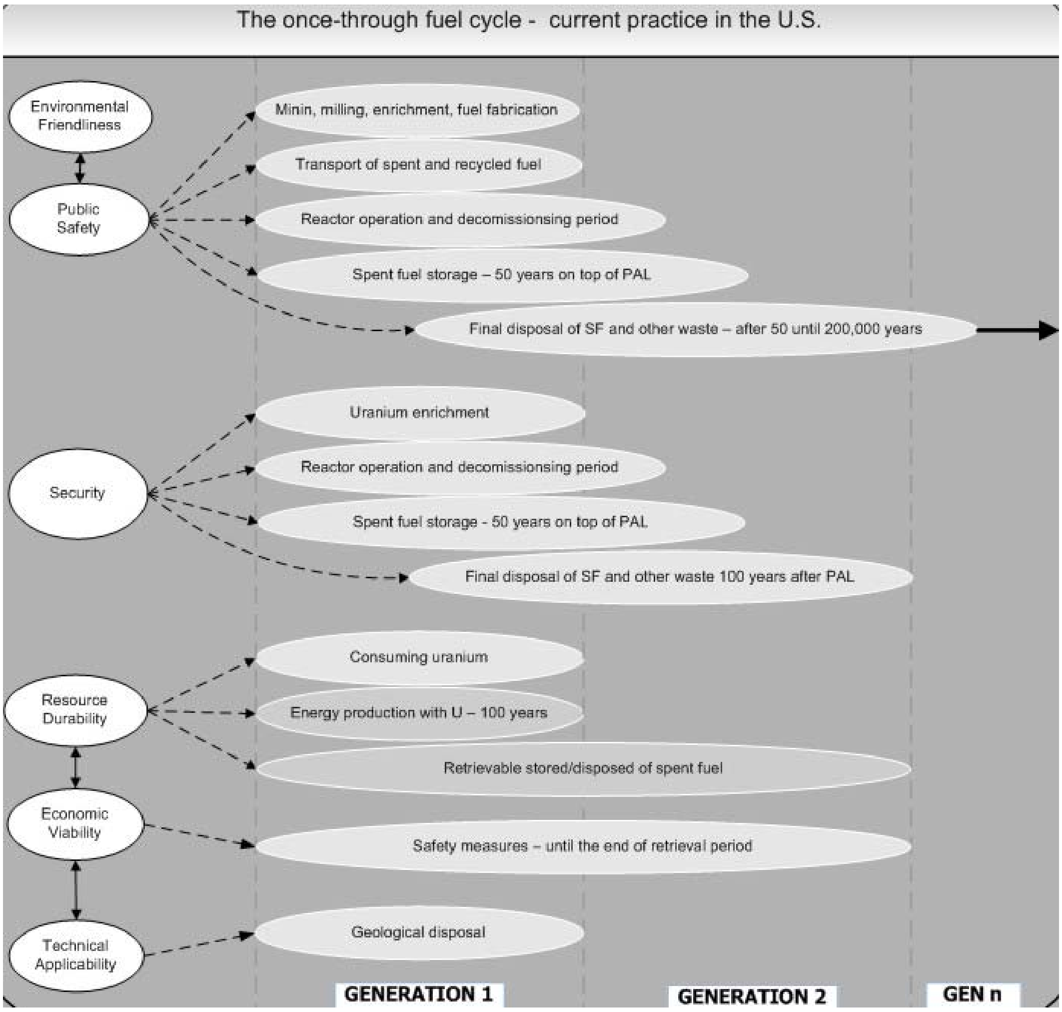


Table 4 addresses the burdens and benefits, and pinpoints the awareness of the distribution of burdens and benefits. It could encourage just decisions for both contemporaries and future generations.

Table 4, Addressing burdens and benefits

IMPACTS	ALTERNATIVES					
	Current Practice		LWR-FR (Burner)		LWR-FR (Breeders)	
	Gen 1	Gen 2-n	Gen 1	Gen 2-n	Gen 1	Gen 2-n
Environmental Friendliness/Public Safety						
Mining, milling, enrichment, fuel fabrication	High		High		Low	
Transport of fresh and spent fuel	Low		Low		Low	
Reactor operation and decommissioning period	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent
Spent fuel storage	High	High	High	High	High	High
Final disposal of spent fuel and other waste	Medium	High	Medium	Low	Medium	Medium
Reprocessing – applying breeders	None		Minor		Major	
Security						
Uranium enrichment	High		Medium		Low	
Reactor operation and decommissioning period	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent
Spent fuel storage	High	High	High	High	High	High
Final disposal of spent fuel and other waste	High	High	Low	Low	Medium	Medium
Reprocessing and Pu in breeders	None		None		Major	

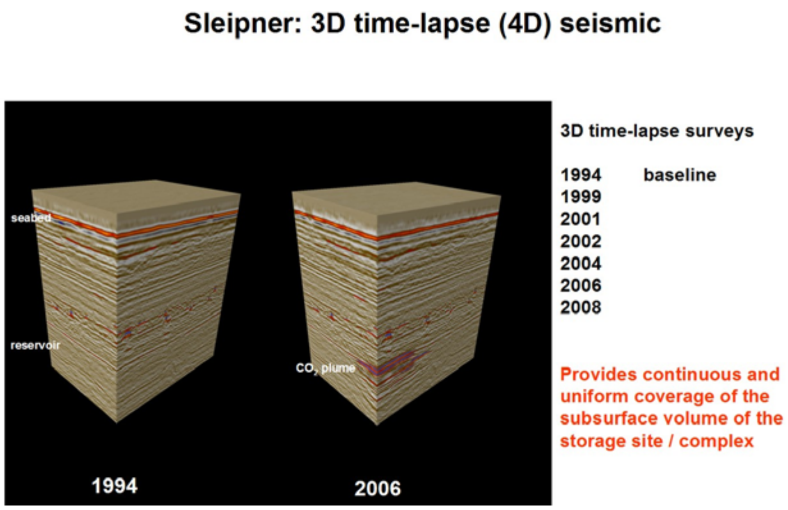
The lessons learned include:

- We must be aware of the burdens and benefits of CCS and its distribution
- We must answer the question: why are extra burdens for some people justified? informed consent and compensation for contemporaries
- We must address future interests of generations. We should not forget our temporary advantageous position and the temptation of 'moral corruption'

6.9 CCS Monitoring

Mr Andy Chadwick, Team Leader CO_2 Storage Research at the British Geological Survey, has experience with monitoring at the Sleipner field. He has defined the following monitoring aims:

- *Site performance monitoring*: current and future (EC Storage Directive):
  - Image / measure CO_2 in the reservoir
  - Monitor containment risks
  - Show that the site is currently performing as expected
  - Constrain predictions of long-term site behaviour
  - Enable site closure
- *Emissions accounting (EU ETS / National Inventories)*: monitor outer envelope of the storage complex
- *Health and safety monitoring (national legislations)*: detect potentially hazardous leakages / accumulations at or near the surface



Since 1996, at Sleipner, 1 Mt CO_2 has been injected per annum and a total of 11 Mt is now stored. The following types of monitoring are conducted:

- 4D surface seismic
- 2D hi-res seismic
- Seabed gravity
- CSEM
- Seabed imaging

A lot of experience has been gained.

Storage monitoring is very important because it is necessary to justify the swiftness of liability after closure. A lot of monitoring experience has been gained at Sleipner. The Seismic 3D method seems to be a good system for showing CO_2 behaviour in the lower segment, as shown in the figure on the left.

EU Storage Directive defined minimum conditions for closure. These conditions are:

- *Actual behaviour of the injected CO_2 conforms with the modelled behaviour*, see Figure 6: OK subject to detectability limits
- *No detectable leakage*, see Figure 7: observations and simulations are essentially coherent
- *Storage site is evolving towards a situation of long-term stability*, see Figure 8: simulation suggests this is the case. No well data, but observations, for example, from Nagaoka support.

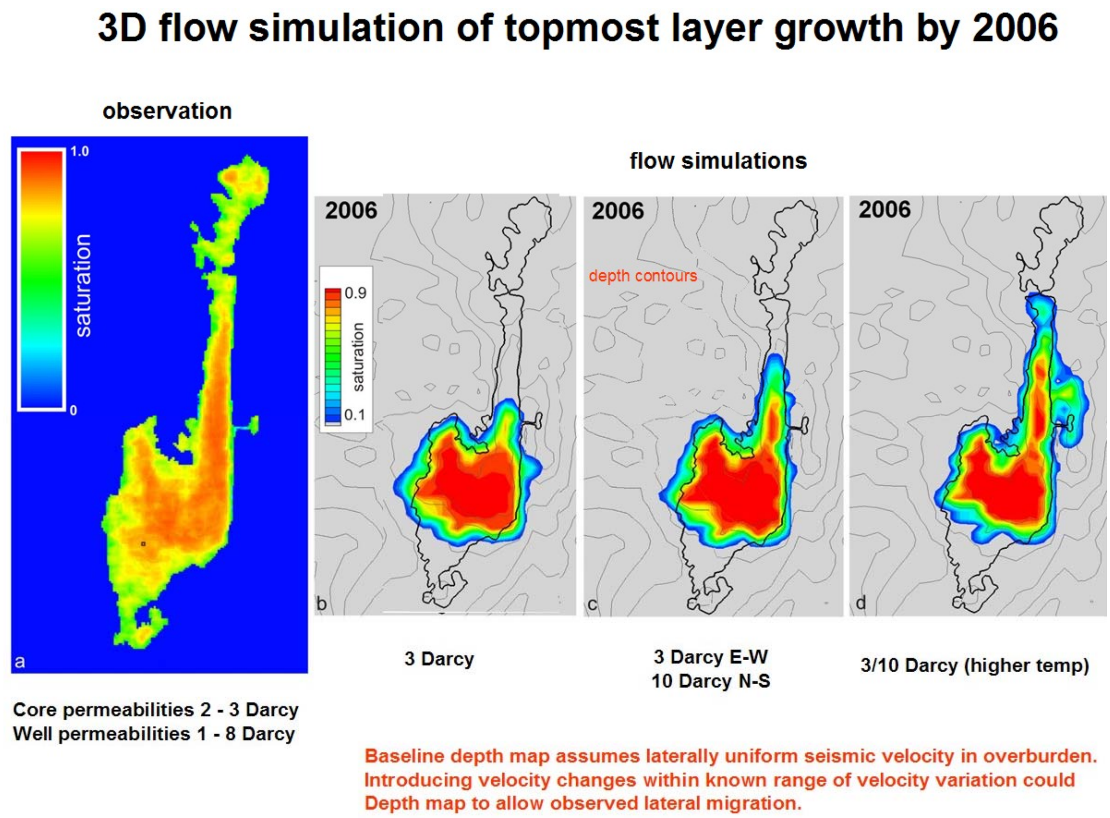


Figure 6, Actual behaviour of the injected CO_2 conforms to the modelled behaviour

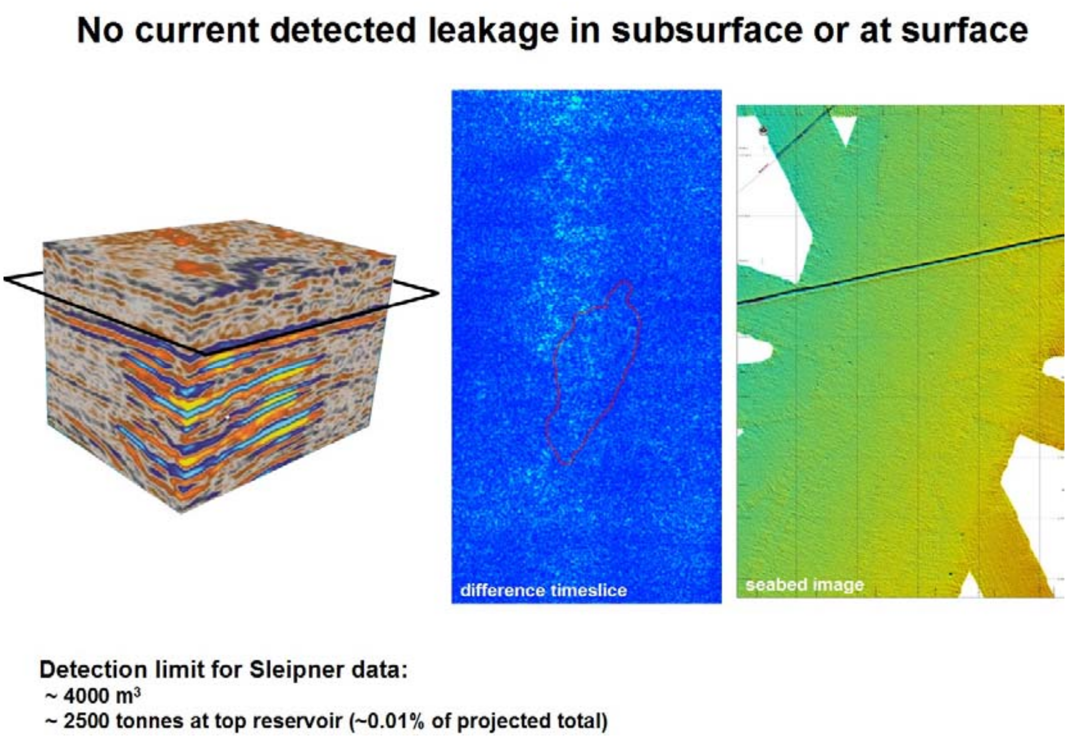
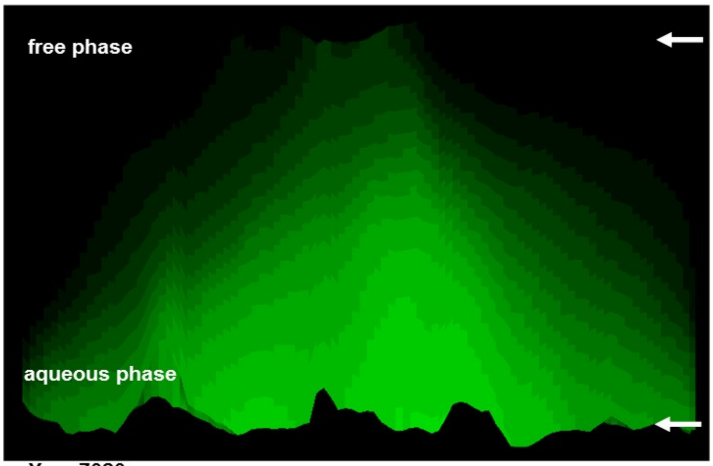


Figure 7, No detectable leakage

7000 year flow simulation



top reservoir

base reservoir

Year 7020

0 to 160 years: free CO_2 spreads laterally at top reservoir

> 160 years: CO_2 in aqueous phase sinks in reservoir

BUT how do we demonstrate this is reasonable?

[simulation courtesy of Erik Lindeberg SINTEF)

Figure 8, Storage site is evolving towards a situation of long-term stability

7 Appendix (panel) discussions

7.1 Discussion on integrating requirements

During the first discussion of the day, the question concerned what should be done if leakage from a storage site occurs? Members of the FENCO-ERA-NET indicated that the leakage must be stopped immediately and the emitted CO_2 should be quantified. If the amount of leakage is estimated then certificates under the ETS should be purchased in order to compensate for the emitted CO_2. It is not really expected that CO_2 will be blown out; at 800-900 metres under the surface CO_2 is liquid. It is also important that repair methods should be developed, similar to those currently available in the oil and gas industry.

Another discussion dealt with the cost of monitoring. If 10Mt a year is stored, the net present value of monitoring will be around $1 dollar per ton. This does not make monitoring the most expensive part of CCS. The capture and transport costs are particularly high, at over $60 per tonnes.

FENCO-ERA members believe that a scientific panel for communication and public acceptance could be very useful, and could also decide on the monitoring techniques to be used.

7.2 Final discussion: panel

During the panel discussion, the issue of **which monitoring programme should be used** came up. Mr Dixon (of IEA-GHG) said that extensive monitoring is necessary and that the selection of valuable technologies is a necessity. The choice of monitoring largely depends on the type of storage site. Some types of sites (such as aquifers) require more monitoring techniques than, for example, deep gas fields. However, at this point in time more types of monitor techniques must be used in order to gain more learning effects. It means that, eventually, less monitoring will be required if the commercial exploration of sites starts.

Mr Podkanski (of EIB) agreed with regard to extensive monitoring. 'We need as much information as possible now, to develop experience and to convince the general public.'

Mr Torp (of Statoil Hydro) said that not all monitoring techniques work well. It depends a lot on what to you need to measure. Stigmatic, electromagnetic survey and testing of methodologies is always necessary. The regulator should then decide on the methodology for monitoring. Additionally, it is also important that marine monitoring techniques be developed, for example for storing CO_2 on the ocean bottom, or for identifying leakage on the sea bed. At this point in time we do not know how to monitor this type of leakage.

According to Mr Drosin (of ZEP), monitoring is a sole link between present and future generations. Monitoring is a promise to the future.

The second part of the discussion dealt with **how the results of monitoring should be communicated to the general public?** Mr Torp felt that openness should be top priority. This type of information is currently kept secret by governments. Openness is important in order to develop new methods. If leakage occurs everybody should be informed, in order to create high learning effects. Global research cooperation is therefore necessary. According to Mr Drosin, transparency on a global perspective should be pursued. However, whether or not this is possible is unknown, because a number of countries, such as China, are holding back information. Mr Dixon also agreed that information should be shared with the general public. Mr Podkanski was curious to know how much this communication will cost.

The panel also discussed upon **how stakeholders, such as politicians, NGOs, opinion leaders, etc. can be informed properly**? Mr Podkanski participated in a good seminar in Sweden. During this event discussions were facilitated between several kinds of stakeholders, such as governmental officials, representatives of industry and NGOs. The EU could also organise this type of event. It worked well. According to Mr Torp, the regulators and scientists should bring the information to the NGOs and other stakeholders. There is only one problem - NGOs could lose credibility if they change their method of communication to that of industry and the government. New techniques can currently only be promoted through conferences and periodicals. Mr Drosin is more sceptical about how we could unite the message as spoken by all stakeholders. Mr Dixon asked the participants the question how, what, and who?

Finally the panel was asked **how do you develop CCS knowledge?** The members of the panel agreed that more independent experts are needed, I.e. experts who did not take part in the recent studies and are thus truly independent. The CCS community is too small, and new academics should be found.