IEA GHG Risk Assessment Network

IEA GHG Joint Network Meeting, NY, June 11th – 13th, 2008

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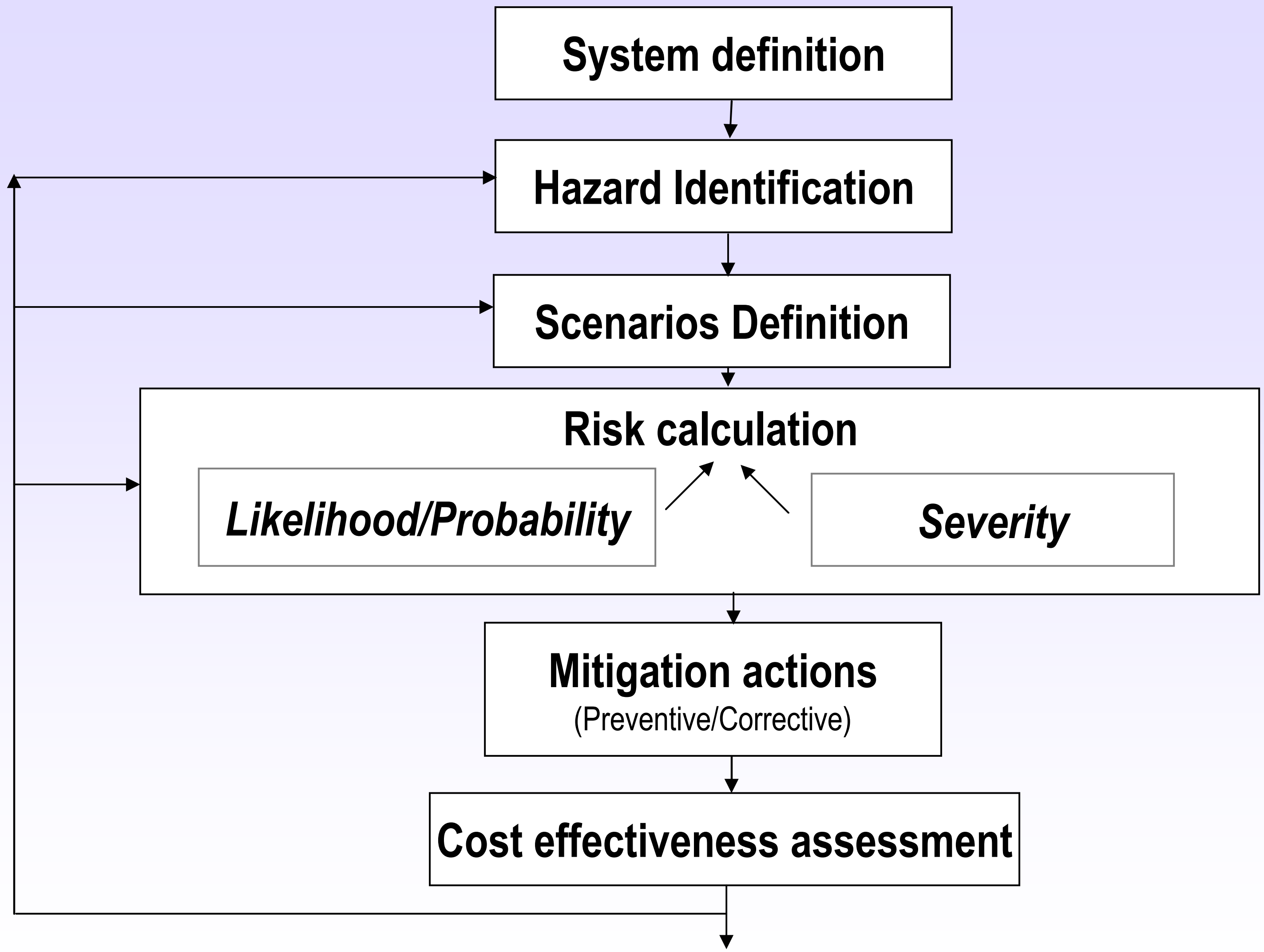
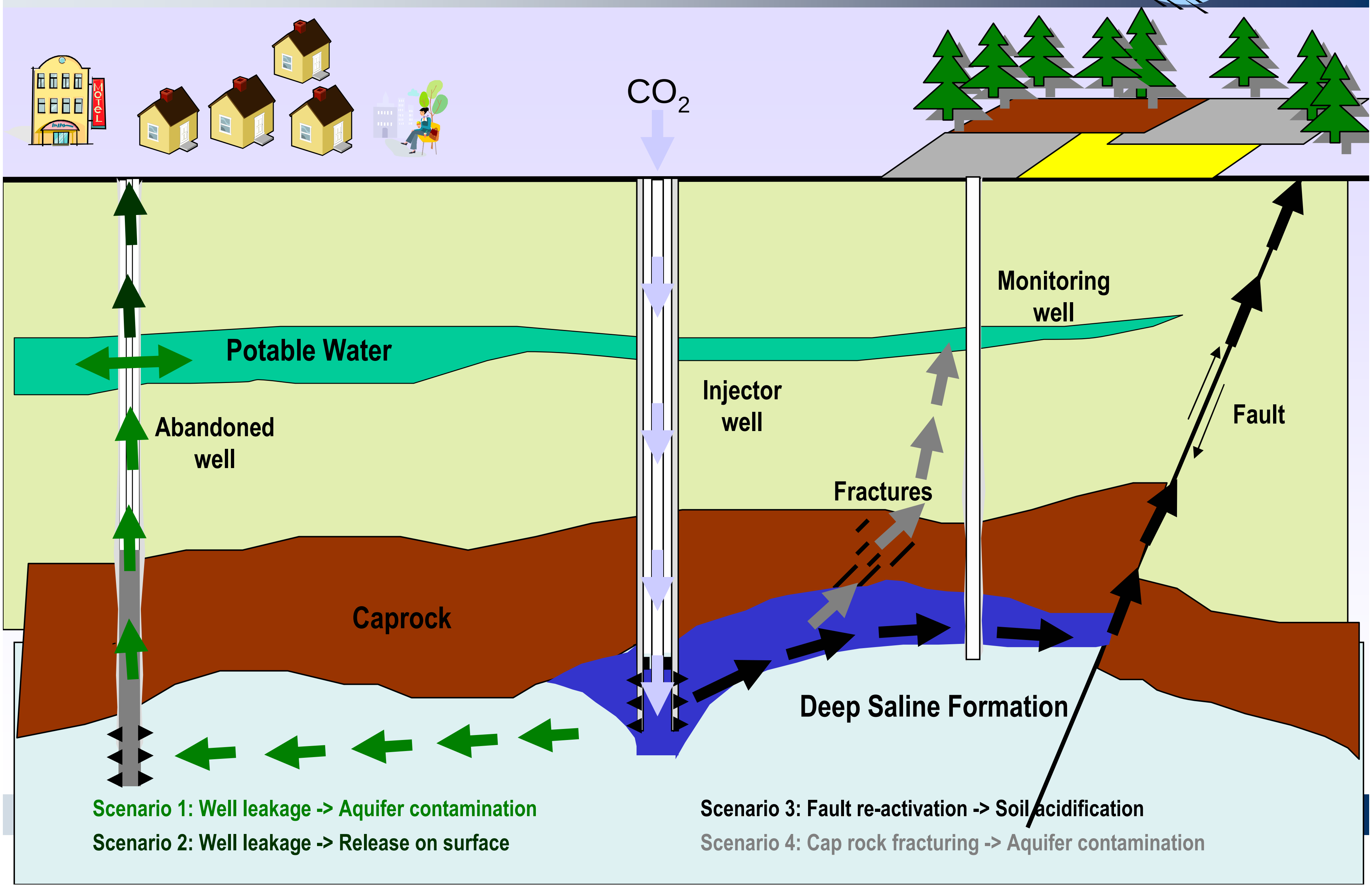
Outline

- Conclusions from the 3rd RA Network Meeting, August 15th -16th 2007
- State of the art review
- Questionnaire results – Risk Assessment Network Perspective

Risk Assessment Process



Containment – Potential Leakage Pathways



IEA GHG 3rd RA Workshop outcome

What we have achieved

- Made progress on issue on terminology
  - Work on this needs to go further
  - Work on Wikipedia idea
- Site characterization – How much is enough
  - Explored but can't answer the question
- Approached a consensus on QRA for CCS
- FEPs – One tool of many

IEA GHG 3rd RA Workshop outcome

Issues/Questions identified

- Guideline for RA / Documentation
- Explore requirements for experts/expert judgments
- How confident are we in modelling results
- How long to monitor for?
- Explore accident/worst case first
- How best to communicate

State of the art review

(From CSLF Risk Assessment Task Force Draft Report – not published yet)

- Risk Assessment Framework
- Risk Assessment Process and Tools
- Modelling for Risk Assessment

State of the art review - RA Framework

(From CSLF Risk Assessment Task Force Draft Report – not published yet)

IPCC Special report on CCS (2006): reference report;

- Identifies main **potential release pathways** for CO2 out of geological reservoirs and the kinds of hazards that could result from storage sites.
- Addresses the question of the **probability of release** according to various types of evidences, stating that "no existing studies systematically estimate the probability and magnitude of release across a sample of credible geological storage systems."
- Identifies the **main challenges** posed by risk assessment for CO2 geological storage,
    - **No well-established methodology** for assessing such risks exists;
    - Use of **FEP methodology** for assessing risks, intended to provide a comprehensive catalogue of the *risks* and their *mechanisms*, of *scenarios* describing possible future evolutions of the storage sites and of *models* to represent these scenarios;
    - Need to acquire **more knowledge about long-term well behaviour**;
    - Need to address **uncertainties** in the risk assessment models;
    - Potential to **learn from natural and engineered analogues** is emphasized.

State of the art review - RA Framework

(From CSLF Risk Assessment Task Force Draft Report)

London (2006) and OSPAR (2007) Convention risk assessment framework – 6 steps:

1. ***Problem formulation***: critical scoping step, describing the boundaries of the assessment;
2. ***Site selection and characterisation***: collection of site-specific data;
3. ***Exposure assessment***: description of the movement of the CO2 stream;
4. ***Effects assessment***: description of the response of receptors to CO2 exposure;
5. ***Risk characterisation***: integration of the exposure and effects information to estimate the likelihood of an adverse impact;
6. ***Risk management***: monitoring, planning, mitigation and remediation measures.

State of the art review - RA Framework

(From CSLF Risk Assessment Task Force Draft Report)

IEA GHG Environmental Impact Assessment Framework (2007) current gaps:

- The **quantification of the impacts** of a CO2 release and the estimation of its probability, which are site-specific;
- The **process** of conducting a **site performance assessment**;
- The **understanding of the health and environmental impacts** of a release of CO2 and impurities;
- The **management of liability**;
- The **balance of positive climate change mitigation impacts against negative local impacts**.

State of the art review - RA Process and Tools

(From CSLF Risk Assessment Task Force Draft Report)

Stenhouse et al (2006) classification of ***main methodologies*** for RA:

- scenario analysis;
- fault/event tree analysis;
- expert judgement;
- screening-level analysis.

Main uncertainties:

- parameter uncertainty;
- conceptual model uncertainty;
- modelling uncertainty;
- scenario/event uncertainty.

State of the art review - RA Process and Tools

(From CSLF Risk Assessment Task Force Draft Report)

RA Process and Tools based on Expert Judgment

Bowden and Rigg (2004) and recent updates:

- RISQUE Method:
  - systematic **quantitative process** based on the **judgement** of a panel of experts
  - **Key risk events identified** in a list and evaluated in terms of likelihood, consequences and time scale of occurrence.
  - Six **key performance indicators** computed and compared against acceptability criteria.

Wildenborg et al (2004); Maul et al (2004):

- FEP Database

State of the art review - RA Process and Tools

(From CSLF Risk Assessment Task Force Draft Report)

RA Process and Tools based on Modelling

Pawar et al. (2006)

- CO2-PENS tool aiming at **integrating in a system-level model** a number of **process-level models** representing:
  - the *storage reservoir*; the *cap rock*; the potential *release mechanisms*; the *transport of CO2* from the reservoir; the *release of CO2 in surface*.

Gerard et al. (2006)

- **quantitative RA** method applied to **wells**
- well decomposed in components
- **scenario** defined as a combination of properties of the different components, to which is associated a probability
- severity of a scenario evaluated based on the results of the modeling of fluids migration in the well to different targets
- for each scenario, the associated probability and the severity enable to **quantify risk** levels associated to well either during injection or abandonment phases

State of the art review - RA Process and Tools

(From CSLF Risk Assessment Task Force Draft Report)

Oldenburg et al. (2007)

- **system decomposition** into **process-level models**
- storage complex divided into **compartments**
- **likelihood of a leak** evaluated by estimating the probability that a leakage pathway encounters the CO2 plume on the one side, and a target on the other side
- CO2 flux across the pathway simulated through **deterministic simplified models**
- **impacts** of the release compared to **acceptable thresholds**. A level of risk is obtained by the product of the values of the probability and the consequences.

State of the art review – Modeling for RA

(From CSLF Risk Assessment Task Force Draft Report)

- **Gaus *et al.* (2008)** review the use of geochemical and transport models for CO_2 storage, and how they can be useful for assessing risks.
- **Birkholzer *et al.* (2006)** discuss modelling needs in the light of CO_2 release mechanisms shown by natural observations, stressing the importance of CO_2 migration along a fault and hydraulic fracturing in the cap rock.
- CO_2 leakage through wells:
  - **Nordbotten, Celia *et al.* (2006)** develop *analytical solutions* for the extension of the CO_2 plume in the reservoir and the potential for leakage through wells.
  - **Frenette *et al.* (2006)** present an *assessment and decision support strategy*, based on the evaluation of gas migrations through wells and components degradation, to evaluate *well leakage*
  - **Bachu *et al.* (2006)** study possible *indicators for CO_2 leakage along wells*.

State of the art review – Modeling for RA

(From CSLF Risk Assessment Task Force Draft Report)

- **Risks to Health and Safety**
  - **Duguid & Celia (2006)** suggest *analytical models* for representing *human exposure and estimating the level of risk* to humans.
- **CO2 behaviour and impacts** following a release:
  - **Bogen *et al.* (2006)** describe the coupled use of a *dispersion model* and a *GIS system* to detect potential areas where *CO2 accumulation* could reach critical levels and provide an estimate of the risk.
- **Risks to the environment** due to CO2 releases are seldom treated, partly because of the limited understanding of the impacts on the ecosystems of CO2 exposure (**IEA GHG, 2007**[b]).

State of the art review – Field cases

(From CSLF Risk Assessment Task Force Draft Report)

- **Sleipner:** *No risk assessment conducted prior to injection*. Lindeberg & Bergmo (2002) only simulate the long-term fate of CO2. Findings: CO2 to be totally dissolved after 5000 years and the maximum diffusion flux through the cap rock to be extremely low and to begin later than 100,000 years after injection.
- **Weyburn**: *Long-term behaviour of the CO2 and leakage* assessed within a methodological framework based on the *FEPs* [Stenhouse *et al.* (2005)].
  - Quintessa FEP database initially developed for this application.
  - A number of simulations performed.
  - Fully probabilistic calculations find a 95% probability that the cumulative amount of CO2 released after 5000 years will be less than 1% of the total amount stored (Walton *et al.*, 2004).
  - A deterministic model for transport in the reservoir with a probabilistic model for leakage through wells shows a maximum release of 0.14% of the total amount of CO2 stored (Zhou *et al.*, 2004).

State of the art review – Field cases

(From CSLF Risk Assessment Task Force Draft Report)

- **Latrobe Valley** (Hooper *et al.*, 2005) and **Otway Basin** (Sharma & Cook, 2007) and **Gorgon project** (Chevron, 2005 and 2006) applied GEODISC approach (Bowden & Rigg, 2004) RISQUE.
- **CO2STORE** project: risk assessments have been realised for various sites.
  - **Valleys** (Chadwick *et al.*, 2006) and **Kalundborg** (Larsen *et al.*, 2007) case studies. Assessment mainly qualitative relying on Quintessa FEP database.
    - analysis of all relevant FEPs,
    - identification of the most important ones, and
    - the development of a few scenarios involving these major FEPs. These scenarios were simulated by numerical reservoir models.
  - For the **Schwarze Pumpe** case study, Schweinrich structure assessed according to the method recommended by Wildenborg *et al.* (2004) (Svensson *et al.*, 2005). Assessment more thorough than for the other two case studies; based on a *systematic screening of the TNO FEP* database and an evaluation of the interactions between the various events and processes, creation of safety scenarios that are then modelled.

State of the art review – Field cases

(From CSLF Risk Assessment Task Force Draft Report)

- **FutureGen** project. Four sites in competition submitted to a human health and environmental risk assessment as part of the **Environmental Impact Statement** (US DOE, 2007). Based on a *comparison with natural and industrial analogues and on expert judgement*,
  - a *semi-quantitative process* conducted to estimate potential CO2 release risks, at a site screening level.
  - *likelihood qualitatively discussed*, whereas the consequences of a release are quantitatively modelled.
- Two **sub-seabed formations** below the **Norwegian** continental shelf subjected to a *coarse risk assessment* with the objective of ranking the sites in terms of risk and functionality (Eldevik *et al.*, 2007). The process organised as an expert workshop and remains mainly qualitative:
  - identification of the *hazards* using a brainstorming session (*Structured What-If Technique*),
  - *selection of the three most relevant ones* for each formation, and the discussion of their *likelihood*, possible *consequences* and *mitigation measures*.

The exercise highlights the **lack of site specific data** at this screening level as a **barrier for risk assessment.**

State of the art review – Field cases

(From CSLF Risk Assessment Task Force Draft Report)

- **Mountaineer – Ohio River Valley** (Sminchak *et al.*, 2006). Investigation of the **performance of the pilot site**: *qualitative screening* of the Quintessa **FEPs** database, designed to identify the potential critical events. Only a *few items* in the database *selected* and analysed in detail to emit *recommendations for risk management*.
- **MGSC Phase III, Decatur, Illinois** (Hnottavange-Telleen and Krapac, 2008). A **full performance assessment** of the storage site in progress. Injection and long-term storage are considered. Qualitative approaches using FEP and Risk registers and quantitative RA based on modelling are employed.

Questionnaire results

- **IEA GHG Network Programme** received **18 completed forms:**
  - 8 attended at least one wellbore integrity network, 5 attended at least one risk assessment network, and 10 attended at least one monitoring network.
  - 14 attended just one network stream, 3 attended 2 different network streams and 1 person attended all 3 network streams.
- **Questions**:
  1. *What do you feel is the **biggest issue** that your network(s) is facing currently?*

     Do you feel your network is addressing this issue? If so, explain how? If not, what are the gaps in your network(s) subject area that have not yet been addressed by the network(s)?
  2. *Do you have an understanding of the **aims of the network(s)** that you do not attend?*
  3. *What **issues** that are dealt with in each particular network(s) do you think could be **relevant to another network**?*
  4. *How can **issues** that are **common** to more than one network be **addressed**?*
  5. *It has been proposed that a **new Network** is set up to look specifically at issues surrounding **modelling**? Do you think there is benefit in such a network? If no, please comment.*
  6. *What **other key issues** - which are currently outside the scope of the networks - could benefit from further discussion and collaboration?*

Questionnaire results (1)

1) What do you feel is the biggest issue that your network(s) is facing currently? **2) Do you feel your network is addressing this issue? If so, explain how? If not, what are the gaps in your network(s) subject area that have not yet been addressed by the network(s)?**
1) Reach consensus among different practitioners - 2) Focus on practical aspects in addition to academic issues 1) Common understanding of input data - 2) Common interest matrix 1) Development of injection well materials and practices - 2) Models for quantification well leakages 1) Development of a common methodology for risk assessment - 2) Work in progress 1) Work together with regulators - 2) Work in progress 1) How to distinguish technical monitoring (e.g. risk avoidance oriented) from public awareness monitoring - 2) Some work done

Questionnaire results (2)

Do you have an understanding of the aims of the network(s) that you do not attend?
Majority YES, 3 NOs

Questionnaire results (3)

What issues that are dealt with in each particular network(s) do you think could be relevant to another network?

- Different aspects concurring to the overall process to qualify CO2 storage sites and secure safety – Coherence to be sought
- Risk indicators that can directly or indirectly measured/monitored
- Necessary input data for risk assessment and their availability
- Link research in WI, RA, M
- Monitoring plan as part of risk management. Role of risk analysis process to drive monitoring strategy
- Short term monitoring to provide input to risk analysis and enable increase confidence or identify weaknesses
- Set up of monitoring protocols that are technically developed and field proven
- CO2 leakage detection methods
- Modelling physical/chemical/mechanical phenomena in a way that can be useful for risk assessment
- Ways to evaluate risks for well integrity
- RA vs cement's resistance to CO2

Questionnaire results (4)

How can issues that are common to more than one network be addressed?

- Setup a joint meeting periodically to cover topics of common interest / Common network meetings
- Incorporation of some inter-network panel discussions
- Creation of transversal working groups (few individuals dedicated to specific topics)
- Mailing groups
- In each network, identification of important crossover topics and use of a session for their discussion. Gap analysis
- Summary notes drafting
- Review outcomes from other networks meetings

Questionnaire results (5)

It has been proposed that a new Network is set up to look specifically at issues surrounding modelling? Do you think there is benefit in such a network? If no, please comment.

Majority YES. To:

- Share information
- Better description of the overall storage site
- Open to others than modellers

2 NOs:

- Crosscutting activity that pertains to all the existing networks
- Economic monitoring more important

Questionnaire results (6)

What other key issues - which are currently outside the scope of the networks - could benefit from further discussion and collaboration?

- Safety aspects of CO2 transport infrastructure
- Regulatory workshops with people who can actually influence legislation
- Influence of input from scientist and engineers in the elaboration of regulatory aspects
- Regulatory tracking
- Legal aspects, cost and benefits, financial matters
- Ways to develop standard practices that are field proven as best practices
- Site integrity in addition to wellbore integrity
- Site selection and Site characterization