Sub-seabed CO$_2$ storage: Impact on Marine Ecosystems

Anja Reitz and the ECO$_2$ consortium
Outline

• Background
• ECO\textsubscript{2} consortium
• Project objectives and aims
• Project structure
• Study sites
• Research and policy needs
Background – Why CCS?

- The global community agreed to limit the increase in mean global surface temperature to 2 °C. To this end CO₂ emissions at power plants and other industrial facilities have to be reduced massively.

- This aim can not be achieved by a single technology but only by the deployment of a technology portfolio including improved energy efficiency, renewable energies and CCS.

- CCS is a relatively cost efficient technology that may help to reduce the costs of CO₂ avoidance in a balanced mitigation portfolio.
Background – Why CCS?

• How can we achieve the 2°C target?

Several studies show that abatement of costs can be reduced by ~70% by applying CCS at large scale.

Source: IEA, WOE 2010
Background – CCS in Europe

- The EC has recently selected 6 CCS demonstration projects and allocated €1 bn to support the implementation of these projects. Three of these projects intend to store CO₂ below the seabed (Hatfield, U.K.; Rotterdam, NL; Porto Tolle, I).

Source: P. Lowe 2011
Background – CCS in Europe

- Up to 10 additional demonstration projects will be selected by the EC in 2011 with a total allocation of ~€3 bn to support these projects.
- U.K. committed £1 bn to initiate CCS demos at national level. The first large-scale CCS power plant project will be build in Scotland. CO₂ will be stored offshore in depleted oil reservoirs.

Source: A. Dawson 2011
Background – Storage option sub-seabed

- Gas Hydrates
- Deep-Sea Sediment
- Deep Saline Aquifer
- Cap Rock
- Depleted Oil/Gas Reservoir
- Oceanic Crust

Safety

Cost
The ECO₂ consortium consists of 24 research institutes, one independent foundation (DNV), and 2 commercial entities (Statoil AS and Grupa Lotos) from nine European countries (Germany (8), Norway (5), U.K. (5), Italy (2), The Netherlands (2), Poland (2), Belgium (1), Sweden (1), France (1)).

The project is coordinated by Prof. Klaus Wallmann from IFM-GEOMAR, Germany.

The EC allocated €10.5 million to the ECO₂ consortium.

Project start 1st May 2011, project end 30th April 2015.
ECO$_2$ project

- ECO$_2$ is a merger of three different scientific communities to evaluate the likelihood, ecological impact, economic and legal consequences of leakage from sub-seabed CO$_2$ storage sites.
Objectives of ECO$_2$

- To investigate the likelihood of leakage from sub-seabed storage sites
- To study the potential effects of leakage on benthic organisms and the marine ecosystems
- To assess the risks of sub-seabed carbon storage
- To develop a comprehensive monitoring strategy
- To define guidelines for best environmental practices in implementation and management of sub-seabed storage
**ECO\textsubscript{2} research structure**

<table>
<thead>
<tr>
<th>WP1</th>
<th>Caprock integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP2</td>
<td>Fluid and gas flux across the seabed</td>
</tr>
<tr>
<td>WP3</td>
<td>Fate of emitted CO\textsubscript{2}</td>
</tr>
<tr>
<td>WP4</td>
<td>Impact of leakage on ecosystems</td>
</tr>
<tr>
<td>WP5</td>
<td>Risk assessment, economic &amp; legal studies</td>
</tr>
<tr>
<td>WP6</td>
<td>Public perception</td>
</tr>
<tr>
<td>WP7</td>
<td>Coordination &amp; Data Management</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CCT1</th>
<th>Monitoring techniques &amp; strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCT2</td>
<td>Numerical modelling</td>
</tr>
<tr>
<td>CCT3</td>
<td>International collaboration</td>
</tr>
<tr>
<td>CCT4</td>
<td>Best environmental practices</td>
</tr>
</tbody>
</table>
WP1 Architecture and Integrity of the Sedimentary Cover at Storage Sites

- Characterize the sedimentary cover to better assess CO₂ migration mechanisms and pathways
- Provide a catalogue of possible leakage scenarios and their likelihood of occurrence.
- Constrain potential leakage locations and rates
WP2 Fluid and Gas Fluxes across the Seabed

- Identify effective tracers of leakage from storage sites
- Assess the potential for mobilization of toxic metals and CO$_2$ hydrate formation
- Provide numerical models that can be applied to predict fluxes of CO$_2$ and other chemical species
WP3 Fate of CO$_2$ and other Gases emitted at the Seabed

- Understand CO$_2$ transport mechanisms and biogeochemical transformation in the water column
- Quantify CO$_2$ leakage in the water column; detect precursors
- Develop best practices for monitoring oceanic waters and fingerprinting CO$_2$ leakage
WP4 Impact of Leakage on Benthic Organisms and Marine Ecosystems

- Quantify the consequences of short, medium, and long term CO$_2$ leakage
- Assess the ability of organisms and communities to adapt to elevated CO$_2$ levels
- Identify biological indicators & monitoring techniques to detect CO$_2$ seepage

### Potential environmental effects of leakage

- Benthic ecosystems at CO$_2$ leaks may be affected by local acidification and the release of toxic substances dissolved in formation fluids.
- Pelagic ecosystems could be affected by seawater acidification if large scale leakage would occur.
- Atmospheric pCO$_2$-values might increase under extreme leakage scenarios.

Source: Hall-Spencer et al., 2008
WP5 Risk Assessment, Economic, Legal Studies Policy Stakeholder Dialogue

- Conduct an Environmental risk assessment (entire operational life cycle) & estimate the potential costs (compare benefits and financial risks)
- Review existing legal framework associated with CCS
- Communicate the knowledge produced in ECO₂ to relevant stakeholders

WP6 Public Perception Assessment

- Standardize commonly used terms & concepts in CCS research
- Identify the core factors and processes that influence public perception of CCS
- Provide guidance on how to devise and implement effective public stakeholder communication plans to meet public information needs and concerns
WP7 Coordination and Data Management

- Provide effective management and archiving of ECO$_2$ generated data
- Provide effective project management for ECO$_2$ including communication, integration, dispute management, networking and administrative support
- Disseminate ECO$_2$ results
CCT1 Monitoring Techniques and Strategies

- Coordinate the development of monitoring technologies within ECO$_2$
- Develop guidelines for innovative and cost-effective strategies to detect and quantify leakage

CCT2 Interfacing of the Numerical Models

- Identify model synergies, overlaps and interfaces and development of appropriate computational coupling
- Quantify and evaluate the geological, physical, chemical and ecological risks
CCT3 International Collaboration

- Enhance the international profile of EU environmental CCS research in general, and the ECO$_2$ consortium in particular
- Collaboration with: Australian, Japanese and US CCS research groups

CCT4 Framework of BEP in the Management of Offshore CO$_2$ storage

- Develop a generic environmental risk assessment document
- Conduct a framework of BEP in the preparation and management of offshore storage sites; review and test applicability
ECO$_2$ Study Sites

Legend
- Storage sites
- CO$_2$ seeps
- New storage sites?

+ potential storage sites off Australia and natural CO$_2$ seeps off Japan
CO₂ storage site Sleipner

CO₂ separated from natural gas, 1 Mt CO₂/a, since 1996,
water depth: 80 m,
sediment depths: 900 m

Seepage of natural gas at Sleipner?

Source: Heggland (1997)
CO₂ storage site Snøhvit, Barents Sea

CO₂ separated from natural gas 0.7 Mt CO₂/a, since 2009;
water depth: 330 m;
sediment depth: 2600 m

Source: Statoil

Pockmarks wide-spread at Snøhvit

Source: Judd & Hovland (2007)
Natural CO$_2$ seeps

Salt Dome Juist, North Sea

Seepage of volcanic CO$_2$ in the Okinawa Trough; 2000 m water depth

Source: Linke et al. (2009)

CO$_2$ droplet

CO$_2$ hydrate pipe

bottom water pH: ~5.0

SO 196, CLATHRATE project, Rehder, Haeckel et al. (unpubl.)
Research and policy needs (bioscience perspective)

- Determine the sensitivity and resilience of benthic organisms towards enhanced CO$_2$ values in bottom waters and pore waters.
- Identify indicator organisms featuring a strong response to elevated CO$_2$ levels.
- Characterize and model the effects of CO$_2$ leakage on benthic and pelagic organisms and ecosystems for different CO$_2$ emission rates.
- Identify sensitive areas in the European EEZ that should be excluded from off-shore CO$_2$ storage activities (potential marine protected areas).
- Define a maximum permissible CO$_2$ leakage rate from an ecosystem perspective.