ECO_2

Sub-seabed CO_2 Storage:
Impact on Marine Ecosystems

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Impact on Marine Ecosystems

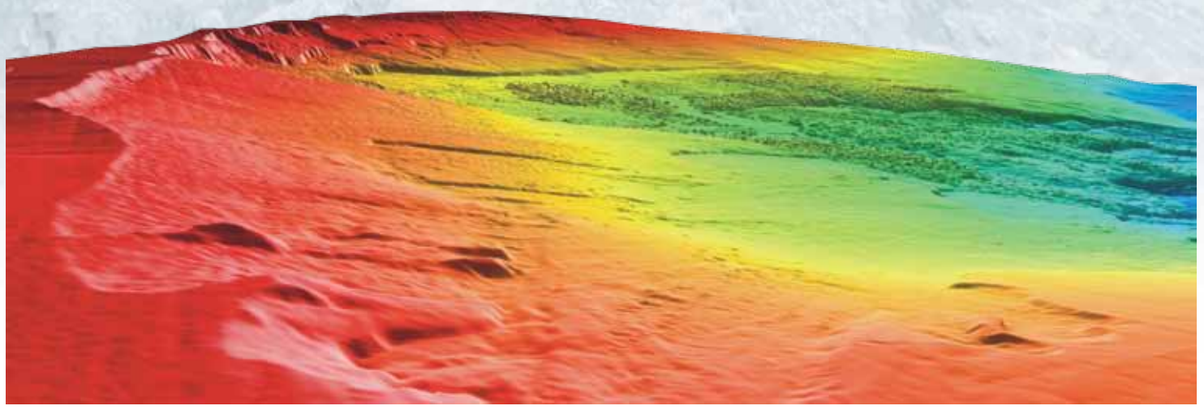
SEVENTH FRAMEWORK PROGRAMME

Introduction and Background

ECO$_2$ - Sub-seabed CO$_2$ storage: Impact on Marine Ecosystems is a large scale integrating collaborative project funded by the European Commission (EC) FP7 work program topic OCEAN.2010.3 Sub-seabed carbon storage and the marine environment. The ECO$_2$ consortium consists of 27 partners - 24 research institutes, one independent foundation (DNV), and two commercial entities (Statoil AS and Grupa Lotos) - from nine European countries (Germany, Norway, U.K., Italy, the Netherlands, Poland, Belgium, Sweden, France). The project is coordinated by GEOMAR in Kiel, Germany. The entire lifetime of ECO$_2$ is from 1st May 2011 to 30th April 2015.

Carbon dioxide capture and storage (CCS) is regarded as a key technology for the reduction of CO$_2$ emissions from power plants and other industrial facilities at the European and international level. Hence, the EC will support selected demonstration projects to promote, at industrial scale, the implementation of CCS in Europe. Consequently, several European states (U.K., Norway, the Netherlands, Italy) aim to store CO$_2$ below the seabed. However, little is known about the short-term and long-term impacts of CO$_2$ storage on marine ecosystems even though CO$_2$ has been stored sub-seabed at industrial scale in the Norwegian North Sea since 1996 (*Sleipner*) and in the Barents Sea since 2008 (*Snøhvit*).

In consequence of this lack of knowledge, the EC supports the ECO$_2$ project to assess the risks associated with storage of CO$_2$ below the seabed. The project will evaluate the likelihood of leakage, the possible impacts on marine ecosystems, and its potential economic and legal consequences by studying existing sub-seabed storage sites in saline aquifers in the Norwegian North Sea and the Barents Sea, and a potential storage site in a depleted oil reservoir as well as natural seeps at the seafloor (North Sea, Barents Sea, Mediterranean Sea, Okinawa Trough).



Objectives

To give consideration to this complex assignment the ECO$_2$ consortium defined the following 5 key objectives:

1. **To investigate** the likelihood of leakage from sub-seabed storage sites
2. **To study** the potential effects of leakage on benthic organisms and marine ecosystems
3. **To assess** the risks of sub-seabed carbon storage
4. **To develop** a comprehensive monitoring strategy using cutting-edge monitoring techniques
5. **To define** guidelines for the best environmental practices in implementation and management of sub-seabed storage sites

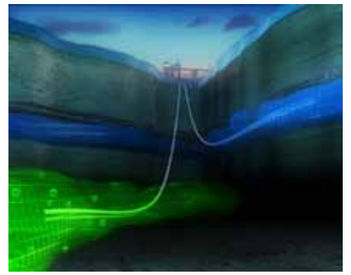
Study Sites

ECO$_2$ will investigate storage sites and potential storage sites that cover the major geological settings to be used for sub-seabed CO$_2$ storage including depleted oil and gas reservoirs and saline aquifers on the continental shelf and upper continental slope. Fieldwork at storage sites will be supported by modelling and laboratory experiments at natural CO$_2$ seep sites.

Study Sites

CO$_2$ storage sites and potential storage sites

- *Sleipner* (North Sea) - in operation since 1996 by Statoil, stores ~1 Mt of CO$_2$ separated from natural gas per year within the Utsira sand formation (saline aquifer) in ~900 m sediment depth in ~80 m water depth. More than 48 million m^3 of CO$_2$ have already been injected.



Carbon storage at Sleipner; photo: Alligator film / BUG / Statoil

- S*nøhvit* (Barents Sea, Norwegian continental slope) - in operation since 2008 by Statoil, stores ~0.7 Mt of CO$_2$ separated from natural gas per year within a saline sandstone formation in ~2.6 km sediment depth in ~330 m water depth. The high pressures and low temperatures at the seabed allow for solid CO$_2$ hydrate formation.
- *B3 field site* (Polish Baltic Sea) - potential storage site in ~80 m water depth that is currently exploited for oil by the Polish companies Grupa Lotos and Petrobaltics; exploitations will be closed by 2016. The Polish operators plan to store CO$_2$ from a nearby oil refinery in the depleted B3 field site oil reservoir.

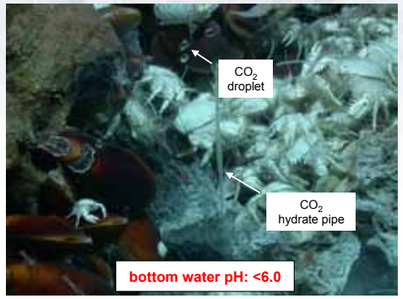
Study Sites

Natural CO_2 seep sites

- *Panarea area* (Southern Tyrrhenian Sea) - is part of the Aeolian Arc north of Sicily; it is a submarine exhalative field located east of Panarea Island. The gas vents are aligned along tectonic features and emit CO_2 originating from degassing magma.

Eddy correlation experiments at Panarea, D. F. McGinnis et al., Eurofleets Project PaCO2 with R/V Urania

- *Southern Okinawa Trough* (NE off Taiwan) - is a back arc basin hosting several hydrothermal fields. Three of these seeps emanate liquid CO_2 droplets at a water depth of 1300 m and CO_2-hydrates form in the surface sediments.



CO_2 droplet release and CO_2-hydrate formation at hydrothermal CO_2 seep sites in the Okinawa Trough; photo: ROV Quest, MARUM Bremen

- *Jan Mayen Vent Field* (North Atlantic) - is situated on the Western Jan Mayen Fracture Zone in ~700 m water depth; its hydrothermal fluids are characterised by high carbon dioxide but low methane and hydrogen concentrations.

- *Salt Dome Juist* (Southern North Sea) - is located in the southern German North Sea in 30 m water depth above the Salt Dome Juist; it is a sedimentary seep where CO_2 levels are ~10-20 times above background.

CO_2 storage sites and potential storage sites
natural CO_2 seep sites

Plus potential CO_2 storage sites off Australia and natural seeps off Japan

Scientific Work Structure

The ECO_2 investigations cover a wide range of approaches from basic marine research to ocean governance. The work is divided into seven work packages (WPs) and four cross-cutting themes (CCTs) forming a matrix structure. The WPs are cross-cut by four themes to support information flow and strengthen cooperation across the WPs. Additionally, the CCTs provide vital ECO_2 products by integrating and evaluating the results of the individual WPs.

WP1: Caprock integrity

WP2: Fluid and gas flux across the seabed

WP3: Fate of emitted CO_2

WP4: Impact of leakage on ecosystems

WP5: Risk assessment, economic & legal studies

WP6: Public perception

WP7: Coordination & Data Management

CCT1: Monitoring techniques & strategies

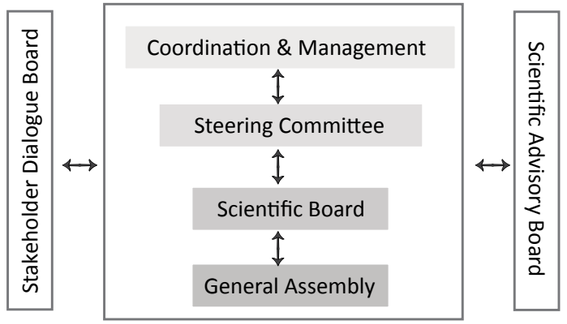
CCT2: Numerical Modelling

CCT3: International collaboration

CCT4: Best environmental practicies

Management and Communication

The **Project Coordinator** (PC) will be supported by the **Project and Data Management Office**, the **Steering Committee** and the **Scientific Board** to ensure the project remains focused.



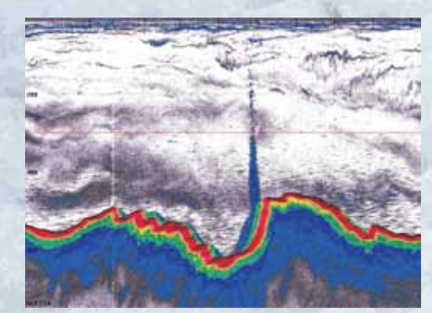
Management and governance structure of the ECO_2 consortium

The internal management structure will be supplemented scientifically by the **Scientific Advisory Board** (renowned scientists covering the ECO_2 research fields) and politically by the **Stakeholder Dialogue Board** (high-level policy consultative group).

WP1 - Caprock Integrity

Architecture and Integrity of the Sedimentary Cover at Storage Sites

will undertake geophysical acquisition, modelling, and hydro-acoustic monitoring to characterise the range of performance and efficiency of sub-seabed geological CO_2 storage, including existing and potential storage sites as well as natural CO_2 seepage sites. State-of-the-art technology will be employed for an enhanced imaging of the seafloor and its sub-surface at unprecedented resolution.



Echogram showing CO_2 gas flares above Troll Wall Vent Field (Jan Mayen); Image: University of Bergen

Objectives:

- to characterise the sedimentary cover to better assess CO_2 migration mechanisms and pathways
- to optimise existing techniques and tools for monitoring CO_2 migration
- to provide a catalogue for possible leakage scenarios, to document the key elements of effective risk management
- to constrain potential leakage pathways

WP2 - Fluid and Gas Flux Across the Seabed

Fluid and Gas Fluxes across the Seabed at Storage Sites and Natural CO_2 Seeps

will carry out a program of fieldwork at existing storage sites as well as natural CO_2 seeps, including analysis of the chemical composition of reservoir fluids. Fieldwork will be supplemented by laboratory studies focussing on CO_2-induced mobilization of toxic metals and the ability of CO_2-hydrate formation to seal leaks. A key part of the work will be to assess the utility of various high-end sensor systems.

Objectives:

- to identify effective tracers of leakage
- to develop a monitoring strategy to quantify leakage rates
- to assess the potential for mobilisation of toxic metals
- to quantify fluxes of CO_2 and other chemicals across the seabed and reactions in the surface sediments

Biogeochemical Observatory (left figure) Microsensors (right figure); photos: GEOMAR

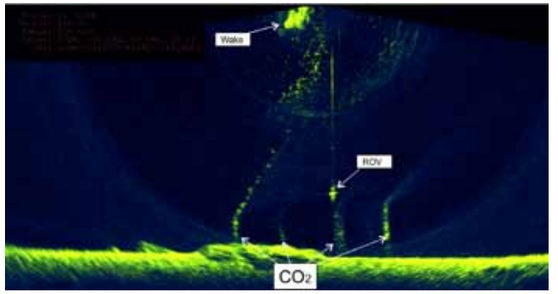
WP3 - Fate of Emitted CO_2

Fate of CO_2 and other Gases emitted at the Seabed

will conduct process studies and model simulations to underpin risk and impact assessments of potential leakage from CO_2 storage sites in the overlying waters. An Ocean General Circulation Model (OGCM) considering the various processes will be built to simulate local and regional oceanic dispersion of CO_2. Natural CO_2 seeps, as analogues of storage leakage, will provide a detailed database on the processes involved.

Objectives:

- to understand CO_2 transport mechanisms
- to develop appropriate monitoring methods to quantify CO_2 leakage and detect precursors
- to develop a simulation framework for risk assessment
- to develop best practices for detecting CO_2 leakage to the overlying water column

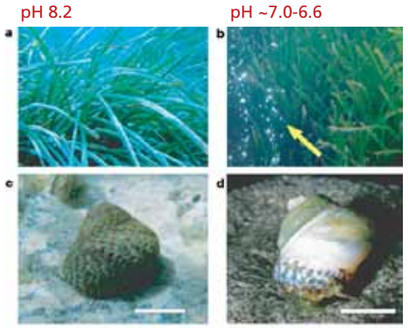


Multibeam echosounder water column image showing natural release of CO_2 bubbles at Panarea (Italy); image: Eurofleets Project PaCO2

WP4 - Impact of Leakage on Ecosystems

Impact of Leakage on Benthic Organisms and the Marine Ecosystems

will determine the biological impacts and risks associated with CO_2 leakage by controlled exposure experiments or in-situ observations at natural seeps, and identify appropriate methods to monitor the marine environment above a storage site.



Benthic ecosystems may be affected by local acidification; figure: Hall-Spencer et al., 2008, Nature 454, 96-99

Objectives:

- to quantify the consequences of CO_2 leakage for the health and function of organisms
- to assess the ability of organisms to adapt to locally elevated CO_2 levels
- to increase our capability to predict ecosystem response to leakage
- to identify biological indicators for CO_2 leakage
- to formulate environmental best practices for monitoring, protection and management of marine biota at offshore CO_2 storage sites

WP5 - Risk Assessment

Risk Assessment, Economics, Legal Studies and Policy Stakeholder Dialogue

will consider the environmental risks associated with CCS and how these risks may impact on the financial, legal, and political considerations surrounding the future geological storage of CO_2.

Objectives:

- to conduct an environmental risk assessment (ERA) including the entire operational life cycle, closure and post-closure of the reservoir.
- to estimate the potential costs associated with monitoring, intervention in the case of CO_2 leakage, compare against the economic and environmental benefits deriving from CCS activities, and assess the financial risks.
- to review the existing legal framework with respect to the precautionary principle and the polluter pays principle.
- to determine the potential applicability of liability with respect to CCS activities.
- to communicate the knowledge produced in ECO_2 to relevant implementation bodies to improve transparency of decision-making for CCS

WP6 - Public Perception

Public Perception Assessment

will investigate two important factors influencing the configuration of public perception patterns: trust and context. Intensive interaction with the public and major stakeholders will be sought to promote dialogue, while at the same time increasing knowledge and awareness of the different public and stakeholders' perspectives. As a result of this process a common framework for CO_2 storage communication and understanding will be proposed.

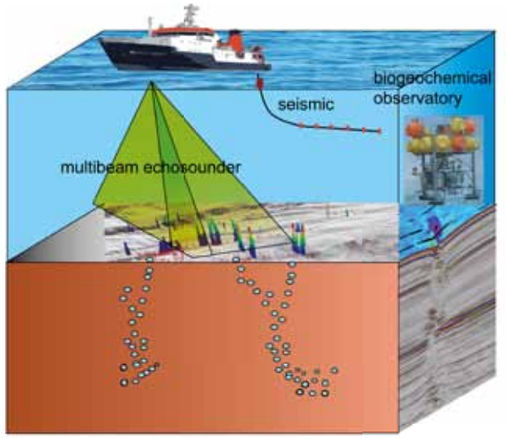
Objectives:

- to agree and clarify the use of CO_2 storage research terms and concepts to facilitate effective communication
- to explore the use of novel methods for capturing and understanding CO_2 storage public perception
- to identify the social processes involved in the formation of public perception of CO_2 storage
- to understand how the scope and the characteristics of the CO_2 storage technology and its costs-benefits are perceived by different social agents
- to provide guidance on public and stakeholder communication activities to meet information needs and concerns

CCT1 - Monitoring Techniques & Strategies

Monitoring Techniques and Strategies

will provide a focus for the synthesis and integration of knowledge towards the optimisation of monitoring methods for different scenarios of CO_2 leakage.



Sketch illustrating different monitoring techniques; figure: GEOMAR

Objectives:

- to coordinate the development of monitoring technologies within ECO_2
- to develop guidelines for innovative and cost-effective monitoring strategies to detect and quantify potential leakage of CO_2 from storage sites and its effects on the marine ecosystems

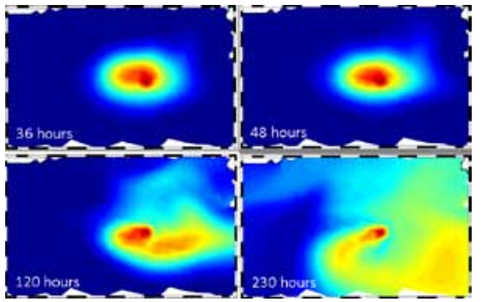
CCT2 - Numerical Modelling

Interfacing of the Numerical Models

intends to model the whole system from reservoir leakage through to CO_2 transfer into the ocean and to the atmosphere, including biological impacts. Subsequently, the physical, chemical and biological knowledge will be transferred into an economic valuation of the costs of leakage, monitoring, and mitigation measures as well as underpin a concept for risk management.

Objectives:

- to define common leakage scenarios that will enable the delivery of integrated risk assessments, economic valuation and the development of conceptual monitoring practices
- to identify model synergies, overlaps and interfaces, and the development of the appropriate computational coupling tools to support data transfer
- to quantify and evaluate the geological, physical, chemical and ecological risks, impacts and associated uncertainties of key CO_2 leakage scenarios



Dispersing CO_2 plume (domain: ~ 4x7 km²); graphic: PML

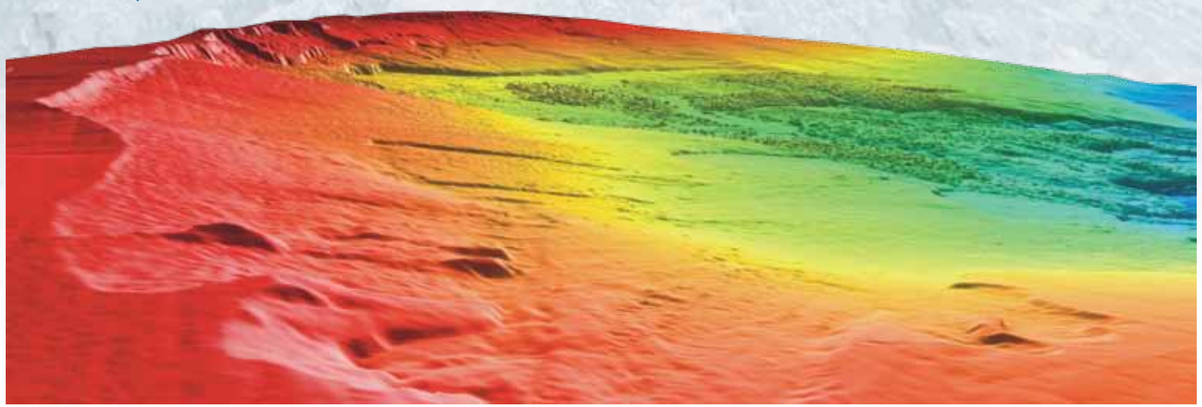
CCT3 - International Collaboration

International Collaboration

will enhance the international profile of European environmental CCS research.

Objectives:

- to enhance collaboration with Australian CCS research groups, with specific topics of sub-seafloor storage monitoring technology and legal concepts and principles, including environmental liability
- to expand collaboration with Japanese CCS research groups, with specific topics of theoretical modelling of CO_2 plume and deep-sea biogeochemistry of natural CO_2 vent sites in Japanese waters
- to strengthen collaboration with US CCS research groups, particularly those working on experimental submarine CO_2 release and theoretical CO_2 buoyancy constraints and benefits of sub-seafloor storage at water depth of >3000 m.



CCT4 - Best Environmental Practicies

Framework of Best Environmental Practices of Offshore CO_2 Injection and Storage

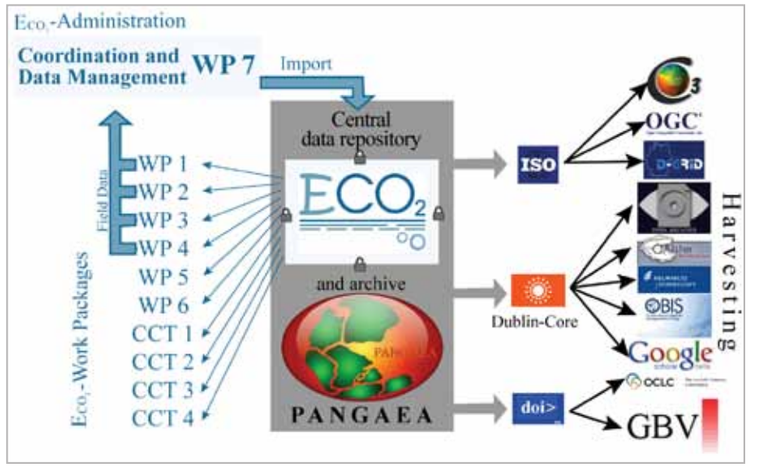
will utilise the knowledge of the ECO_2 consortium to identify considerations associated with operating storage facilities and managing the potential environmental impact of CO_2 storage.

Objectives:

- to construct a Framework of Best Environmental Practices in the preparation, operation and management of offshore storage sites.
- to review and test the applicability of the draft Framework of Best Environmental Practices guidance.

Data Management - PANGAEA

The data management facilitates the flow of data from field work, lab experiments and numerical simulations to all WPs and CCTs. The central data repository is part of the PANGAEA data library with all benefits through a distribution via web services, search engines, portals and library catalogues.



ECO_2 data management concept; illustration: GEOMAR

Data management is combined with project management to guarantee the required data delivery for this multi-disciplinary project with alternating dependencies.

ECO_2 Consortium

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DNV
University of Southampton
Managing Risk
Universität Stuttgart
University of Tromsø
Universitas Bergensis
Marine Biology Ghent University
ECN
The University of Edinburgh
Kiel Institute
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University of Gothenburg
LOTOS
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