STEMM-CCS: STRategies for Environmental Monitoring of Marine Carbon Capture and Storage

- What is STEMM-CCS and who is involved?
- Objectives of STEMM-CCS
- What are we doing and what are we going to do?
STEMLM-CCS – Horizon 2020

• Funded by CALL FOR COMPETITIVE LOW-CARBON ENERGY (LCE-15-2015) “Enabling decarbonisation of the fossil fuel-based power sector and energy intensive industry through CCS”
• Total Budget: €15.9 M
• Duration: March 2016 – February 2020
• Coordinator: Prof. Doug Connelly – National Oceanography Centre
• Industrial Partner: Shell
Partners

National Oceanography Centre, NERC, UK
University of Southampton, UK
GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
Shell, Netherlands
Plymouth Marine Laboratory, UK
Seascape Consultants Ltd, UK
Heriot Watt University, UK
University of Tromsø, Norway
Max Planck Institute for Marine Microbiology, Germany
Technical University Graz, Austria
University of Bergen, Norway
Norwegian Institute for Water Research (NIVA), Norway
Uni Research, Bergen, Norway

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 654462
Carbon Capture and Storage (CCS) Implementation

Capture + Transport + Storage + Leakage Impact + Assurance Monitoring = CCS Implementation

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What is STEMM-CCS?

• **Multi-disciplinary** (academia + industry) project that will deliver new approaches, methodologies and tools to enhance our understanding of CCS in the marine environment and, therefore, ensure a safe operation of offshore CCS sites

• Ensuring the **selection** of appropriate marine storage sites

• **Monitoring** marine storage sites effectively

• STEMM-CCS combines a unique set of **field experiments**, combining existing technology and **new sensors and techniques** developed by the project, alongside **laboratory work** and mathematical **modelling**

Increasing confidence in CCS as a viable mitigation strategy for addressing the increasing levels of CO₂.
Objectives of STEMM-CCS

1. Develop a robust environmental baseline assessment methodology under “real life conditions”.

2. Develop and implement methods for constraining the natural and anthropogenic induced CO$_2$ permeability of the overburden in offshore CCS sites.

3. Develop a suite of cost effective tools to identify, detect and quantify CO$_2$ leakage from a sub-seafloor CCS reservoir.

4. Assess the applicability of artificial and natural tracers for detection, quantification and attribution of leakage of sequestered CO$_2$ in a marine environment.

5. Model and assess impacts of different reservoir leak morphologies and provide decision support tools for monitoring, mitigation and remediation action.

6. Document best practice for selection and operation of offshore CCS sites and complete knowledge transfer to industrial and regulatory stakeholders.

7. Develop best practice for knowledge sharing.
Approach: Leakage detection, localisation and quantification

Aim: better understand fluid and gas flow in operational conditions, leading to efficient and economic monitoring strategies.

- **Controlled release experiment** (2019): Injection of CO₂ into shallow sediments at Goldeneye – comprehensive monitoring programme based on chemical and acoustic methods for both detection and quantification.

Schematic of the shallow sub-surface release of CO₂ gas in sediments (< 5 m depth) that will be conducted at the Goldeneye field in the North Sea.
Approach: Leakage detection, localisation and quantification

Aim: better understand fluid and gas flow in operational conditions, leading to efficient and economic monitoring strategies.

- **Controlled release experiment:** Injection of CO₂ into shallow sediments at Goldeneye – comprehensive monitoring programme based on chemical and acoustic methods for both detection and quantification.

- **Precursors:** Chemical and isotopic characterisation of precursor fluids/gases in reservoir and overburden.

- **Artificial and natural tracers:** Assessing the utility of a range of tracers as an aid to detection and monitoring.

- **Modelling:** Very fine scale complex hydrodynamic – biogeochemical – bubble / dissolved leakage models coupled to sensor emulators. Multiple scenarios.
Establishing baselines

Geochemical Field Experiments – August 2017

Baseline lander deployment and geochemical sampling, benthic boundary layer experiments (e.g. gradient flux techniques)

Lander equipped with:

1. Commercial instruments
   • Upward looking ADCP
   • Seabird CTD
   • Hydrophones
   • Deep SeapHOx

2. Lab on chip sensors developed at the National Oceanographic Centre to measure nitrate, phosphate and pH

Baseline Lander. Image courtesy Peter Linke

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Establishing baselines

Geochemical Field Experiments – August 2018

3 week cruise at the Goldeneye site:
• Lander retrieving and redeployment until main experiment in 2019
• Additional baseline work:
  • Ecological and biogeochemical characterization
  • Novel eddy covariation techniques for assessment of the stoichiometry of sediment-water fluxes
  • Deployment of an additional lander over the cruise period equipped with novel multifunctional autonomous chemical sensing packages for nutrients and carbonate chemistry variables
Understanding CO$_2$ pathways

Seismic reflection section illustrating a chimney structure in the German sector of the North Sea (Schlesinger, 2006). The chimney (boxed) cross-cuts the top c. 3 seconds two way time (TWT) of the sedimentary overburden (c. 3 km).
Understanding CO₂ pathways

Geophysical Field experiments - 2017/2018

2017
- Tomographic imaging using OBS with a range of acoustic sources (airguns, sparker)
- Electromagnetic experiment – electrical props – permeability
- 2D seismic data
- Multi beam bathymetry data
- Parasound sub bottom profiler date
- Anisotropy experiment (complementary project, CHIMNEY)

2018
- Coring with BGS rock drill to sample top of chimney

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Innovation

• Automated systems for **benthic image processing**
  - BIIGLE and iSIS image annotation (machine recognition) tools
  - Online experts annotate training images
  - Machine learning
  - ‘End to end’ workflow:
    - image collection
    - storage
    - pre-processing
    - training images to feed machine learning
    - improved algorithms skill
    - bulk automatic annotation
    - indicator analytics provided with graphics
  - Photography only indicators
  - Additional inputs: acoustic imagery, water chemistry or seabed sampling

Celtic Sea Cruise DY008 [2014]. Altitude 2.2m

Autosub 6000
Innovation

- Automated systems for benthic image processing
- New acoustic techniques for quantification of leakage

- ETI project models
- Near seabed gas release = bubbles (red = 2 mm)
- Passive and active sonar footprint
- STEMM-CCS will use distributed arrays for low power active and passive bubble tracking and measurement
Innovation

- **Automated** systems for **benthic image processing**
- New **acoustic techniques** for quantification of leakage
- Newly developed high precision pH and O\textsubscript{2} **optodes** on landers and AUV’s

- UT Graz
- Principle: fluorescence
- Objectives
  - Accuracy of pH: ±0.001 pH units
  - Accuracy of O\textsubscript{2}: better than 3µmol/L
Innovation

• **Automated** systems for **benthic image processing**
• New **acoustic techniques** for quantification of leakage
• Newly developed high precision pH and O$_2$ **optodes** on landers and AUV’s
• **Training programs** for industry and science communities
• **Model integration** and interactions
Innovation
Model integration and interactions

- Geophysical chimney models
- Ultra fine scale hydrodynamic models
- Biogeochemical models (Pelagic and benthic)

Flow characterisation

- Bubble plume models

Dissolved plume Models

Acoustic detection models

Detection and sensor emulators

Emulators for AUVs and platforms

Outcomes

- Operational tools
- Detection scales
- Strategies
- Quantification

Baseline characterisation

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Outreach and dissemination

- Website www.stemm-ccs.eu
- Project brochure
  - available for download on website in ‘Resources’
- Glossary of terminology
  - available on website under ‘Links’
- Science Policy Panel Meetings
  - For invited stakeholders. First one held in Feb 2017, next Oct/Nov 2018
- Science briefs
  - first set available for download on website in ‘Resources’. More to be added.
- Training workshops
  - first course ‘CCS: From source to storage’ took place in March 2018
- Research highlights publication
  - will be published in final month of project
Outreach and dissemination

- Website [www.stemm-ccs.eu](http://www.stemm-ccs.eu)

**Sub-seabed carbon dioxide storage**

Carbon dioxide Capture and Storage (CCS) has been identified as an important strategy to mitigate anthropogenic CO2 emissions. The aim of CCS is to take CO2 from large emission sources, such as power stations, transport it to a storage site and permanently lock it away so that it cannot be released into the atmosphere. CCS storage sites are usually geological formations deep underground, either onshore or offshore.

CCS is seen as a key contribution to the target of reducing anthropogenic greenhouse gas emissions into the atmosphere by 80-95% by 2050 in order to keep climate change-derived temperature increases below 2°C. This target was agreed by parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015, and outlined in the European Commission’s Roadmap for moving to a competitive low carbon economy in 2050. In addition, CCS is considered an important strategy to reduce the cost of mitigation measures associated with the continued use of fossil fuels (IPCC, 2014). For most European nations, offshore storage of CO2 in depleted oil and gas reservoirs and saline aquifers is the option of choice.

Drawing together expertise from across academia and industry, STEMM-CCS will provide a set of tools, techniques and methods to enhance our understanding of CCS in the marine environment. Many of our activities will lead to the development or enhancement of sensing technologies, which also have applications beyond the CCS arena and may be suitable for commercialisation. Throughout the project there will be a high level of engagement with policy makers and stakeholders to ensure the widest possible exchange of knowledge, including with countries outside Europe that are currently developing offshore CCS.

**The key project objectives are:**

- Produce new tools and techniques for environmental monitoring as well as CO2 emission monitoring, quantification and assessment;
- Generate new knowledge of the reservoir overburden by direct investigation of natural geological and manmade features;
- Deliver the first CCS demonstration project level implementation of an ecological baseline, incorporating geochemical and biological variability;
- Promote knowledge transfer to industrial and regulatory stakeholders and local and International communities.

**Contact STEMM-CCS | Partners’ area**


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Planning baseline for Smeaheia

Objective
To plan for baseline gathering for the Smeaheia area, supporting risk and impact assessments, and enabling cost-effective monitoring programs.

Sub-objectives:
1. Assure that the geophysical characterisation of the Smeaheia site support the marine tasks required.
2. Initiate baseline gathering by collecting long time series of the chemistry and current conditions in the area.
3. Lay a detail plan on how to gather the baseline based on lessons learned in previous project, such as ECO2 and STEMM-CCS.
4. Overall assessment of the impact of the baseline strategies on the cost of the baseline itself and cost reduction for further implementation of monitoring programs.