

Beyond STEMM-CCS

*A synthesis of what has been accomplished through the project,
and the implications for offshore CCS and marine CO₂ monitoring*

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**plus everyone who contributed to the STEMM-CCS Research Highlights deliverable*



Context

The need for STEMM-CCS



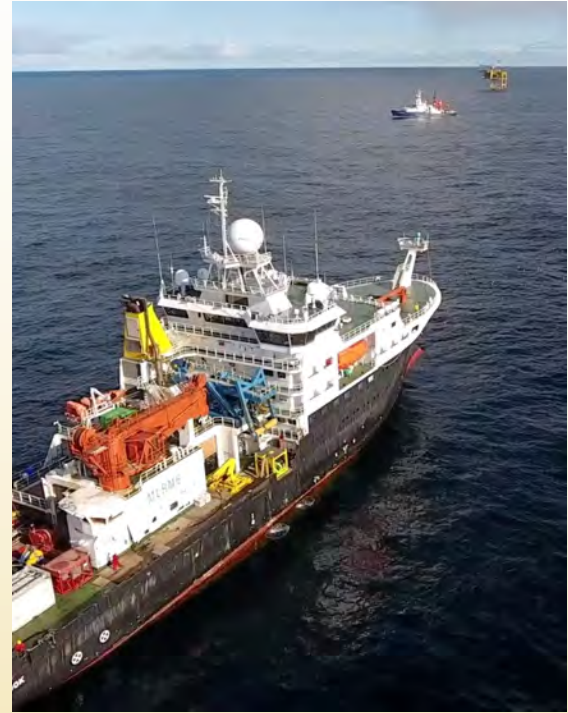
- Estimated that offshore sites represent ~66% of the potential CO₂ storage capacity in Western Europe (IEAGHG, 2009)
- Robust strategies for leakage detection and management are needed to comply with international marine legislation
- Series of precursor projects (e.g. ECO₂, QICS, ETI MMV) advanced our knowledge and ability on how to detect CO₂ at the seafloor
- Many of those techniques were yet to be tested under realistic leakage conditions, and enhanced models were needed to predict the pathways and potential impacts of CO₂ migration through the reservoir overburden



Approach

The activities of STEMM-CCS

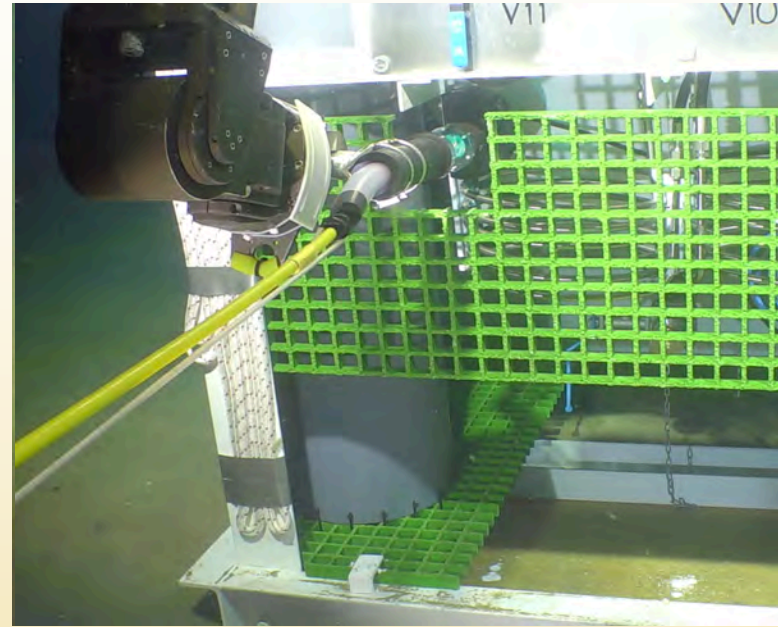
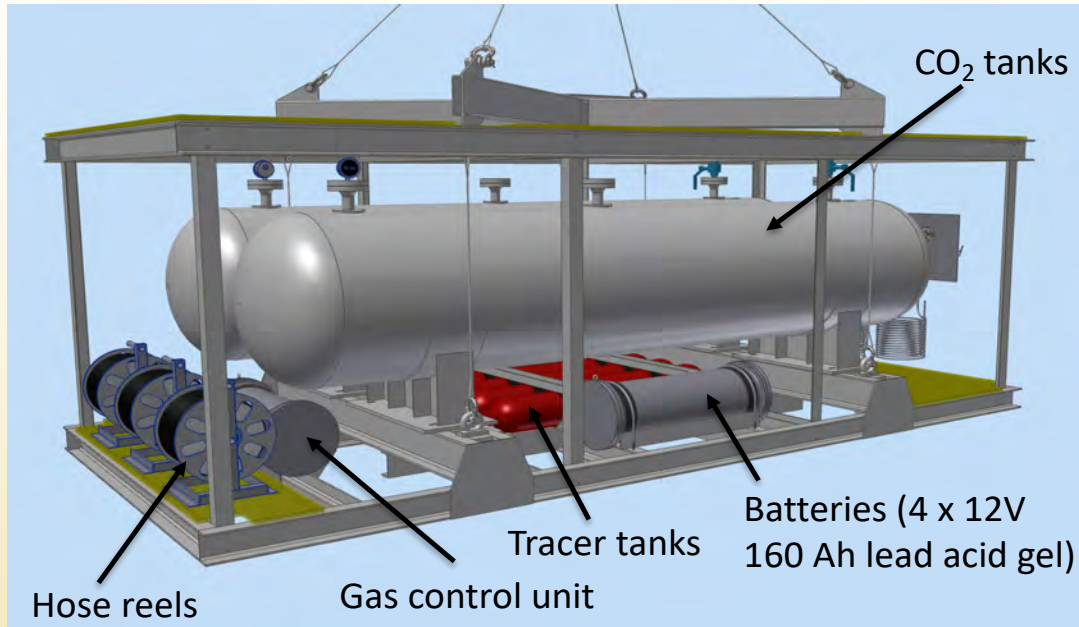
- The first controlled sub-seafloor release of CO₂ to be carried out under real life conditions
- Establish accurate environmental baseline techniques
- Better understanding of fluid flow pathways in the sub-seafloor and their implications for reservoir integrity
- Methodologies for detecting, tracing and quantifying CO₂ leakage in the marine environment
- Test new technologies to enable cost-effective monitoring of marine CCS operations



Outputs

The products of STEMM-CCS

- Engineering solutions for a ground-breaking experiment



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 654462

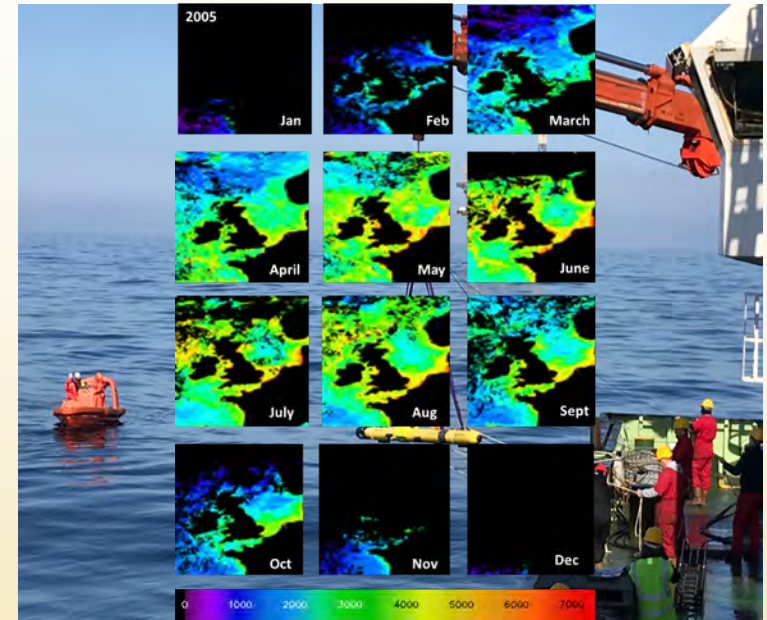
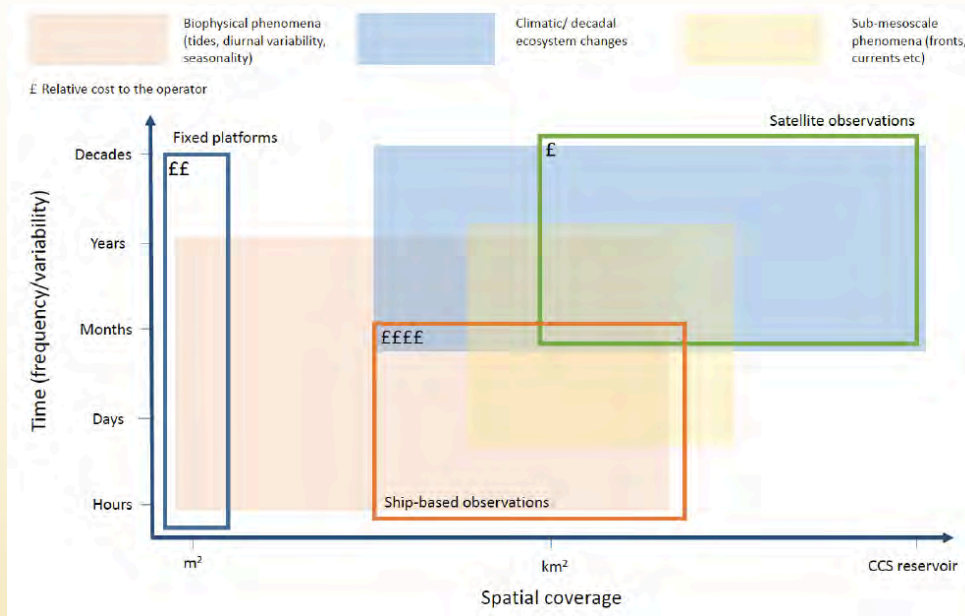


Outputs

The products of STEMM-CCS



- Framework for establishing an effective environmental baseline



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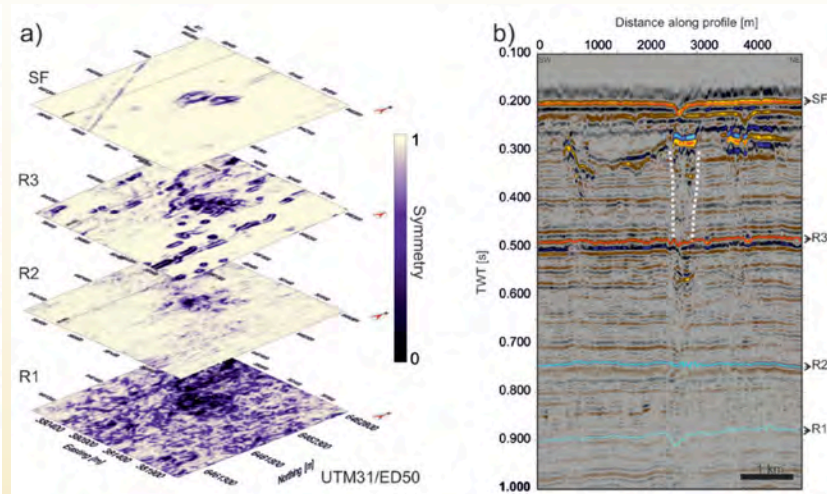
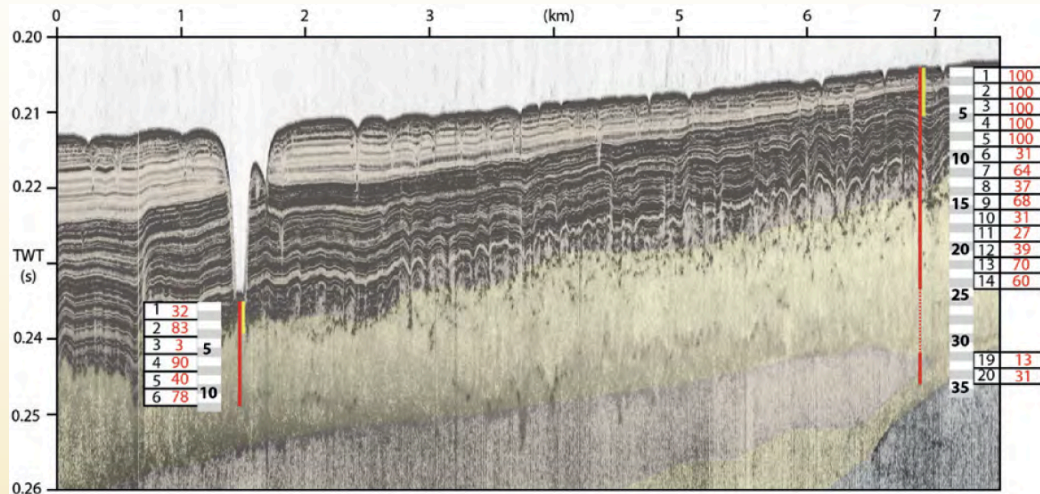


Outputs

The products of STEMM-CCS



- Characterisation of pipe structures and numerical simulation of gas seepage



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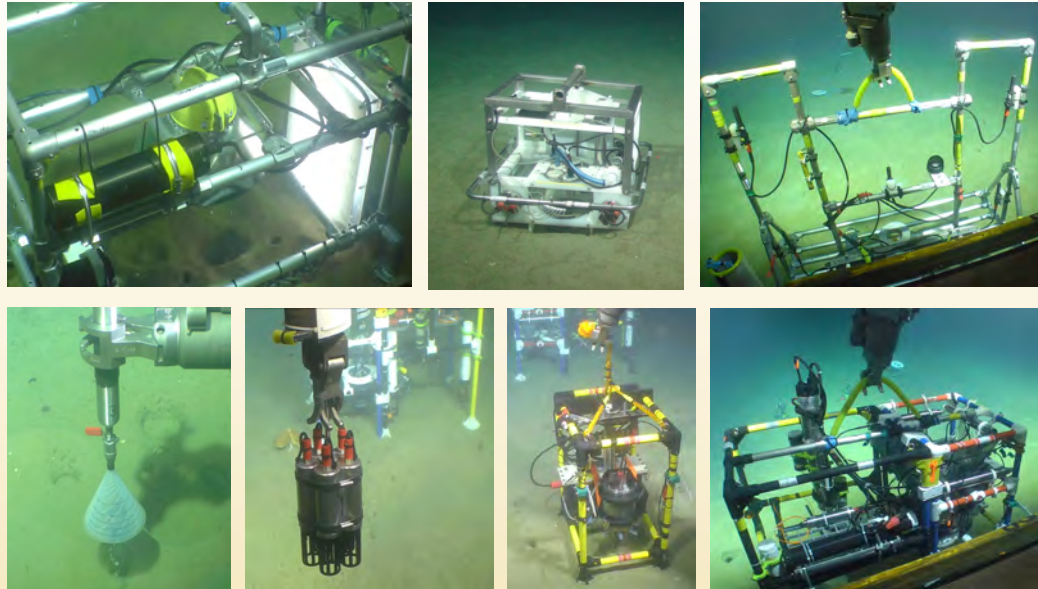


Outputs

The products of STEMM-CCS



- Techniques for detecting and quantifying CO₂ leakage across the seabed



Method	CO ₂ bubbles	CO ₂ dissolved
Acoustical <ul style="list-style-type: none"> Active Passive 	 ✓ ✓	
Optical	 ✓	
Chemical <ul style="list-style-type: none"> Tracers Eddy Covariance Benthic Chambers 	 ✓	 ✓ ✓ ✓



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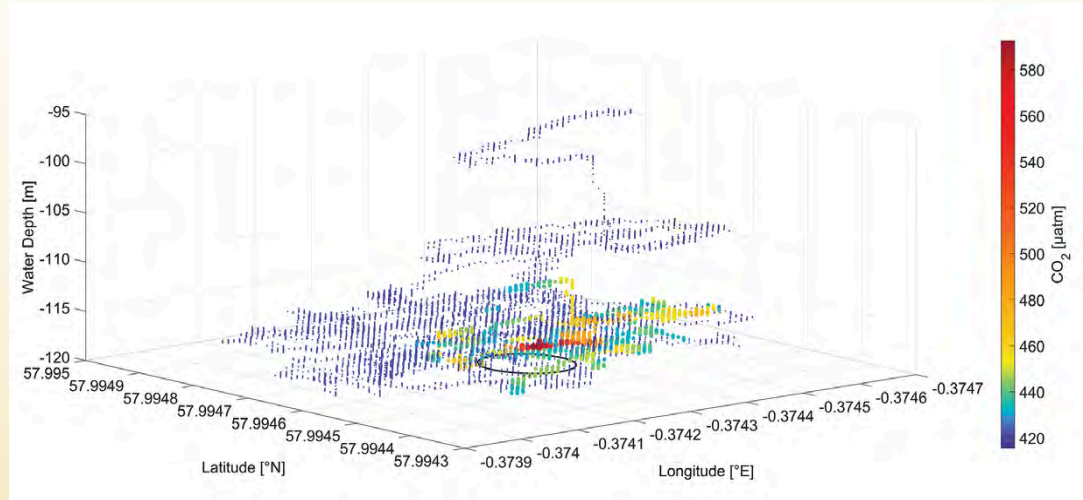
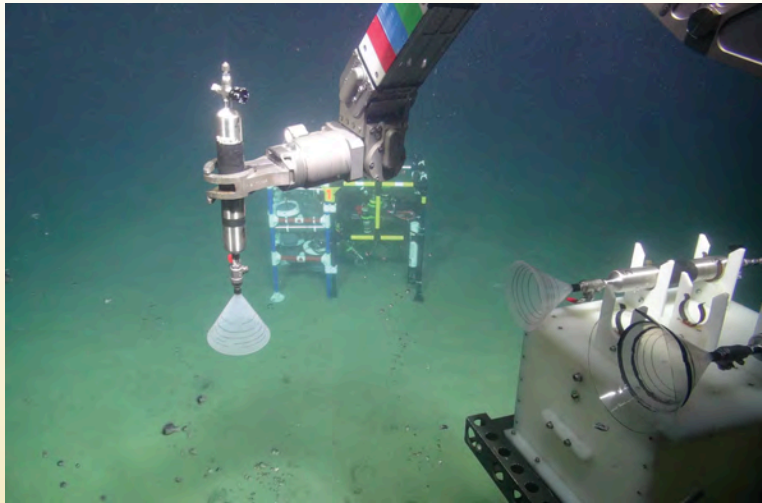


Outputs

The products of STEMM-CCS



- Quantification of the efficacy of a variety of natural and artificial CO₂ tracers for CO₂ detection, quantification and source attribution in the marine environment



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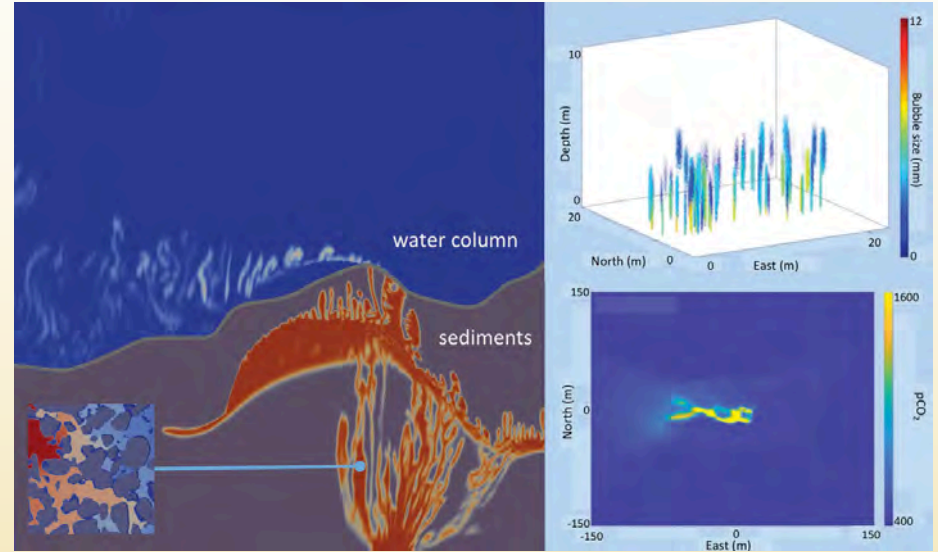
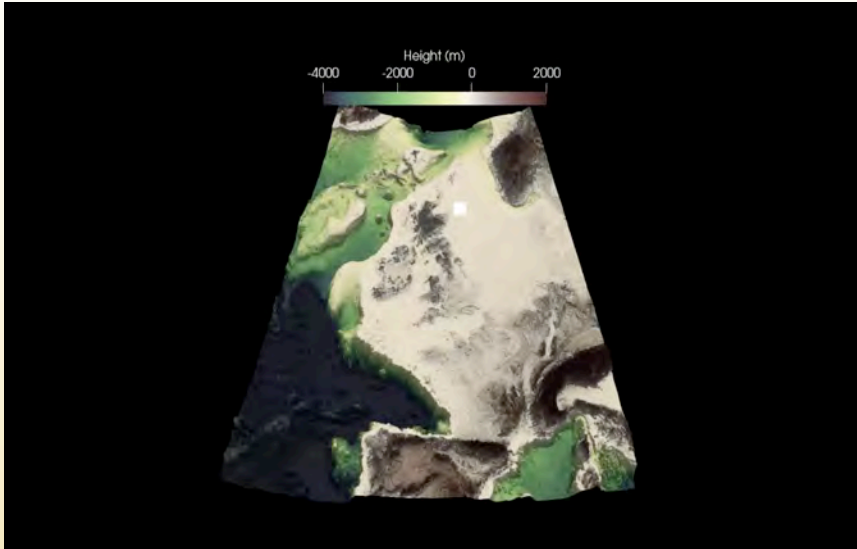


Outputs

The products of STEMM-CCS



- Comprehensive model system for monitoring and predicting the impact of fugitive CO₂ emissions for a range of leakage scenarios



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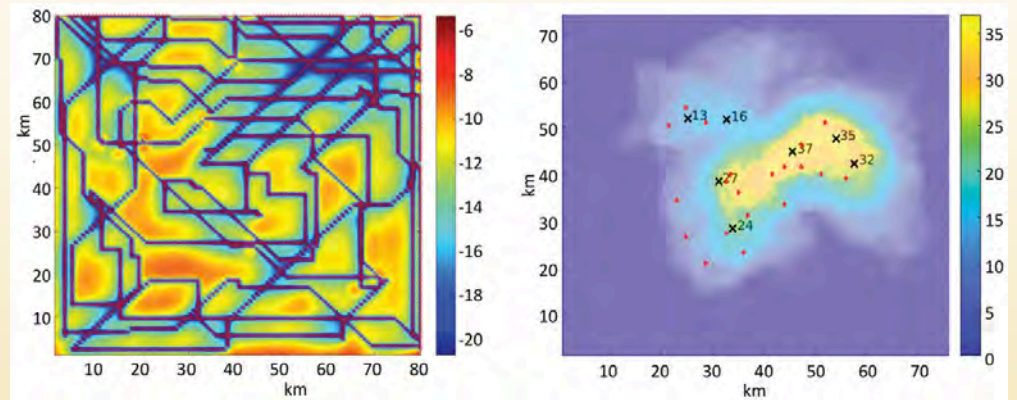


Outcomes



The implications of STEMM-CCS

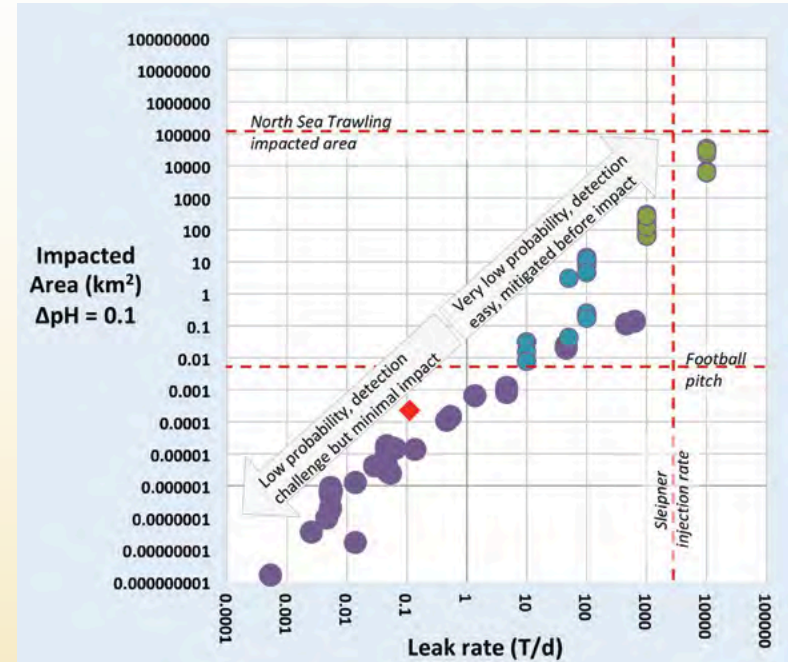
- Methodologies and techniques for establishing environmental and ecological baselines applicable to CCS reservoirs have been tested under ‘real life’ conditions
- A suite of cost-effective tools are available for identifying, detecting and quantifying CO₂ leakage from a sub-seafloor CCS reservoir
- Models can be used to optimise offshore CCS monitoring strategies (both AUV and fixed lander deployments) that maximise detection chances and minimise cost



Outcomes

The implications of STEMM-CCS

- The local and regional impacts of different CO₂ leak scenarios have been modelled, including the potential role that fluid pathways in the shallow subsurface may play in reservoir integrity
- Resulting environmental impact assessment implies that CCS release from offshore complexes is expected to have a small impact footprint, orders of magnitude less than other marine activities such as trawling



Outcomes

The implications of STEMM-CCS

- Best practice guidance for the selection and operation of offshore CCS sites shared with industrial and regulatory stakeholders
- Increased confidence in the physical security of CCS, and support for the European Union's progress towards a carbon neutral society



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Impact

The legacy of STEMM-CCS



- Realising the impact potential of STEMM-CCS requires continuing work...
- Models, technologies and engineering solutions developed through the project are being applied in other projects and future funding applications
- An online monitoring and decision support tool has been developed to assist operators in choosing optimal offshore CCS monitoring mechanisms, and ensure continued access to the knowledge and experience gained through the programme: [A. Lichtschlag \(15:00\)](#)

Leakage Detection

In line with the CCS Directive, any CCS storage complex monitoring strategy needs to assess whether any migration or leakage of CO₂ is occurring within the surrounding area. Such strategies need to accommodate the fact that CO₂ leakage may occur from a single point source or as more diffuse discharge over a larger area, and similarly that the leaking CO₂ may be present in form of CO₂ gas bubbles or dissolved into the interstitial waters of the sediments and overlying water column. Given these complexities, a number of different methods and techniques for detecting CO₂ leakage under varying scenarios were tested through the STEMM-CCS project, with their relative performance and individual merits summarised below.

Monitoring Methods

Method	Score
Acoustic Resonance (PDR)	0.85
Acoustic Resonance (DSS)	0.80
Bubble Counter	0.65
CTD	0.75
CO ₂ Flux Chamber	0.80
Microfluidics	0.65
Multi-Sensor PDR	0.85
Passive Acoustic	0.80
pH Eddy Covariance	0.65
Sealed-Cell	0.75

pH Eddy Covariance

Eddy covariance was developed to quantify natural variations in seawater biological O₂ uptake and dissolved inorganic carbon (DIC) production. As such, it is exceedingly sensitive to a seawater source of DIC. To function, the instruments must be located downstream of the source, within 20 m, at a known distance. As water flows through the source of DIC and to the instruments, it will carry enriched DIC from the seafloor upwards, and dilute DIC from overlying water downwards. The upstart or downward vertical transport of DIC is calculated from this signal. The vertical turbulent transport of only a small fraction of all of the DIC released is recorded. The total release is calculated based on the dispersion of DIC with distance to the instruments. A high level of expertise is required to operate the instruments, analyse, and interpret the data.

Method Scoring: pH Eddy Covariance

CO ₂ leakage rate and nature of leakage	High (Bubbles)	Low to High (Bubbles)	Low (Bubbles and Dissolved)
Cost of measurement	high	medium	low
Spatial extent (coverage) of measurement	low	medium	high
Technical readiness level of the method	In development	near market	commercially available
Time needed to obtain final results (in months)	3+	2	0-1

Final Score: 1.6



Impact

The legacy of STEMM-CCS

- Translate industry awareness of the project to engagement and uptake of its outcomes: *M. Dean (15:15)*
- Inform regulatory bodies and policy makers of project findings, and its broader implications for offshore CCS: *D. Connelly (15:30)*
- Ensure accurate public understanding of the trials conducted through the project and how they can help realise the potential of offshore CCS: *V. Gunn (15:40)*



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Thank you for your attention



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