Offshore Colocation Forum

Offshore Wind and CCUS Colocation Forum

Plenary #9 – December 2023

THE CROWN ESTATE

Agenda

1. **Matters Arising** – review actions and minutes from last meeting – Secretariat – 5mins
2. **Project Colocate** – update from Professor John Underhill and Dr Sam Head at University of Aberdeen – 20 mins
3. **Project Anemone** – presentation from Philippa Parmiter and Mark Hughes at NECCUS – 10 mins
4. **Interplay between the Forum and other bodies** – Adrian Topham, Chair – 15 mins
5. **Whole of Seabed update –** update from Tristan Bromley, Programme Lead at The Crown Estate – 10 mins
6. **MMV Subgroup update** – Adrian Topham, Chair – 10 mins
7. **Next developer event** – Secretariat – 15 mins
8. **Next Plenary Dates** – future Forum programme – 5mins

Matters Arising

Matters Arising

Action	Owner	Status	Action	Owner	Status
Share name of developers impacted by Spatial Characterisation report	The Crown Estate	Complete – to be discussed	Provide further information on OW innovations	RUK	Update required – to be discussed
Share further information on OW timeline	The Crown Estate	Complete – see appendix	Develop event plan on MMV monitoring	The Crown Estate	Update required – to be discussed
Upload NSTA MMV Seismic Report to Forum website	The Crown Estate	Complete	Issue press release on Project Colocate and Project Anemone	Grayling	Complete
Liaise with T&S Taskforce on MMV Subgroup work	The Crown Estate / Storegga	Update required – to be discussed			

Project launch media announcement

- Press release announcing launch of Project Colocate and Project Anemone issued 27th Nov.
- Positioned as supporting UK's first testing and demonstration of viability of colocation.
- Strong trade media interest - 11 pieces of coverage secured so far in energy trade and Aberdeen regional news.
- Raising profile of Forum's work and exposure within OW & CCS industry.

New Civil Engineer

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ABERDEEN BUSINESS NEWS

Project Colocate

Update from Professor John Underhill

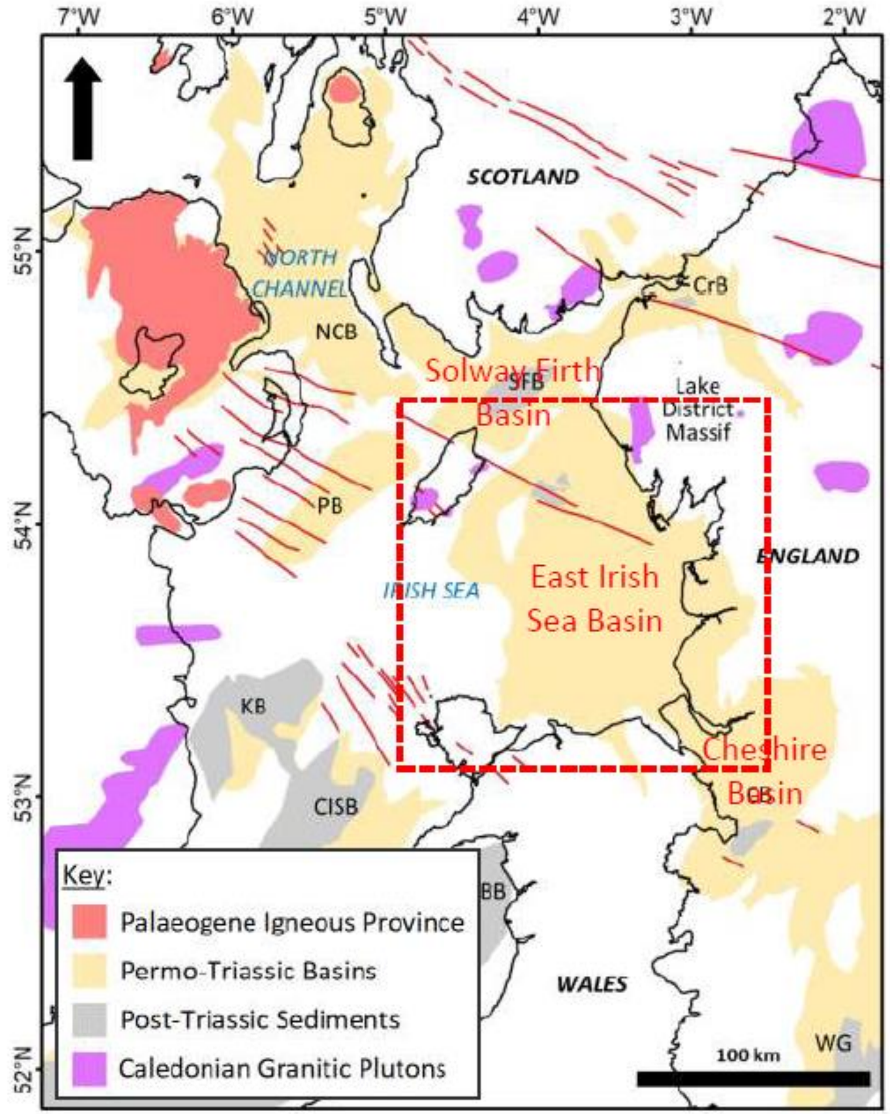
University Director for Energy Transition and Professor of Geoscience at University of Aberdeen

and **Sam Head** at University of Aberdeen

East Irish Sea Project:

Project Colocate

Sam Head appointed.
Started November 1st



Modified after Holford et al. (2005), BGS (1994)

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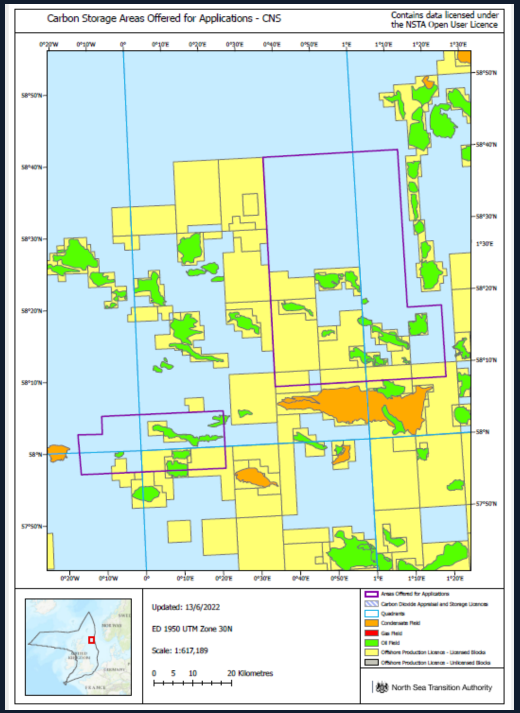
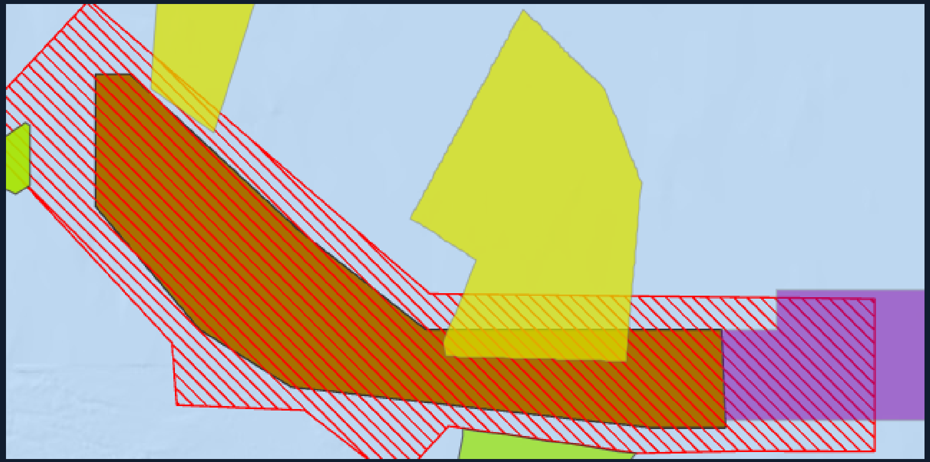
Central North Sea (CES):

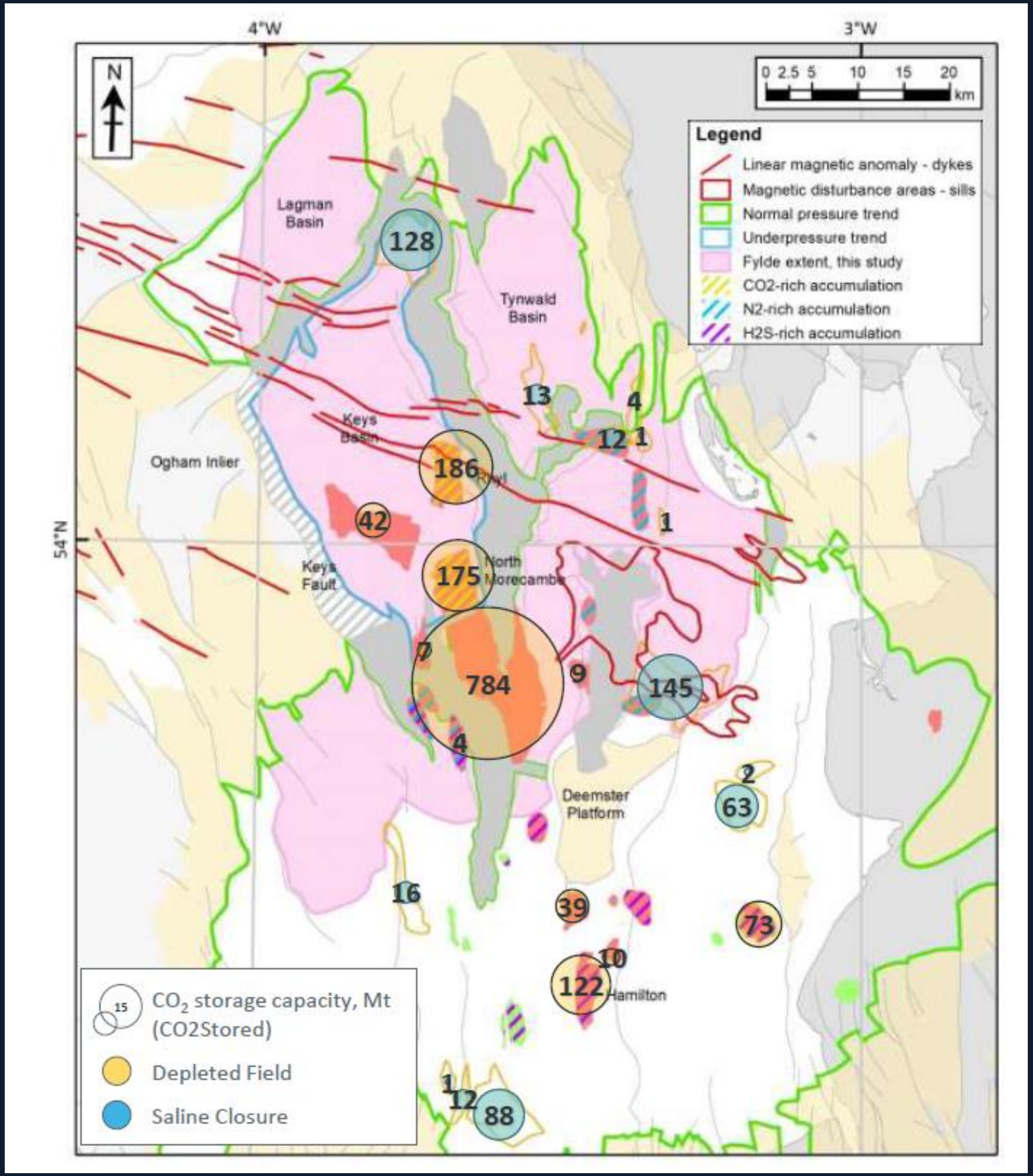
AoI determined;
Currently sourcing a PDRA





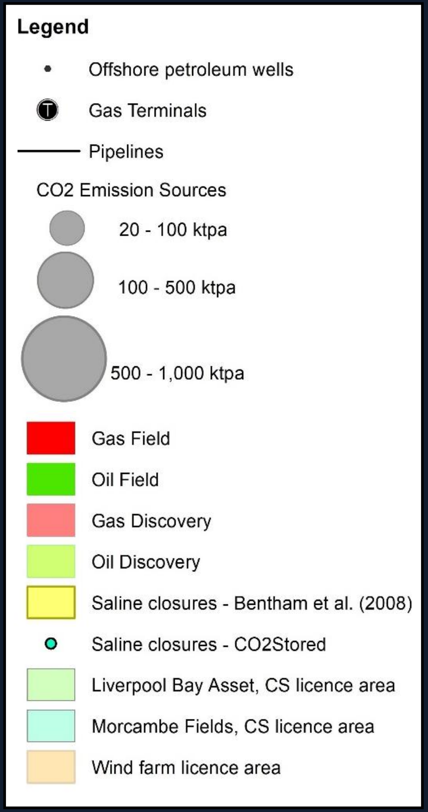
East Irish Sea Project:

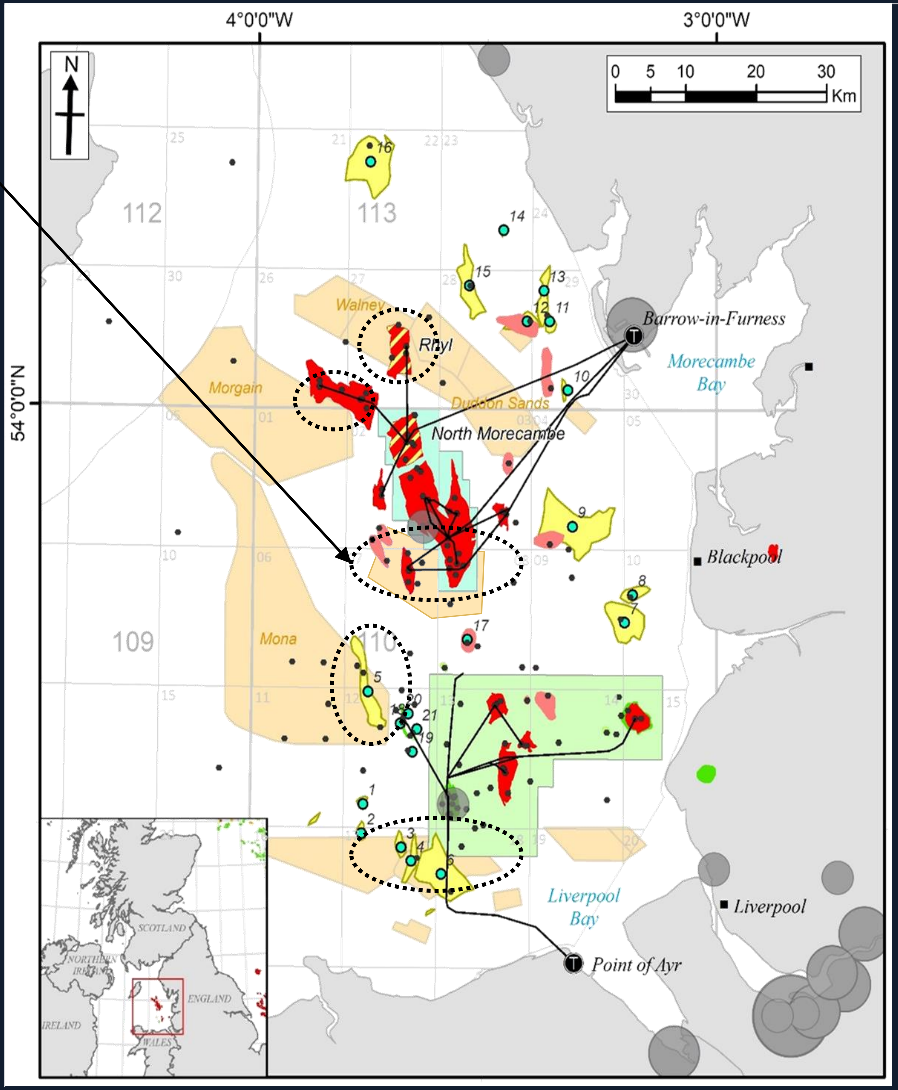
Progress Report –
Sam Head

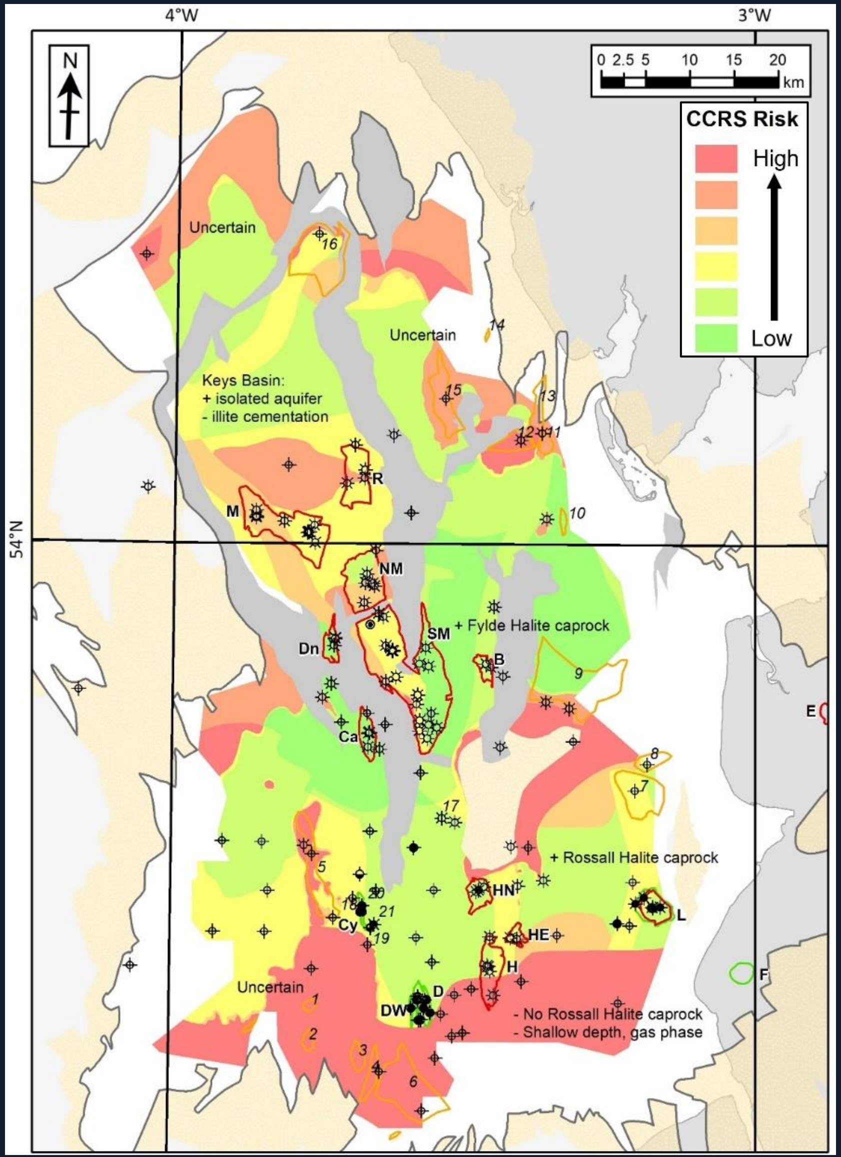


Colocation in the East Irish Sea

Prospective basin
But potential **colocation conflicts** between wind farms, CS sites and others







Not all the basin is prospective for CO_2 storage – nor wind farms

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Work Programme

1. **Literature Review – Define problems and possible solutions**
   - Wind Farm technology requirements
   - CCS MMV technological options (e.g. CCS Licences) (e.g. BGS, TNO, Quintessa, 2010; IEAGHG, 2015)
   - Existing colocation studies – problems & proposed solutions (e.g. Robertson & McAreavey, 2021; IEAGHG, 2014)

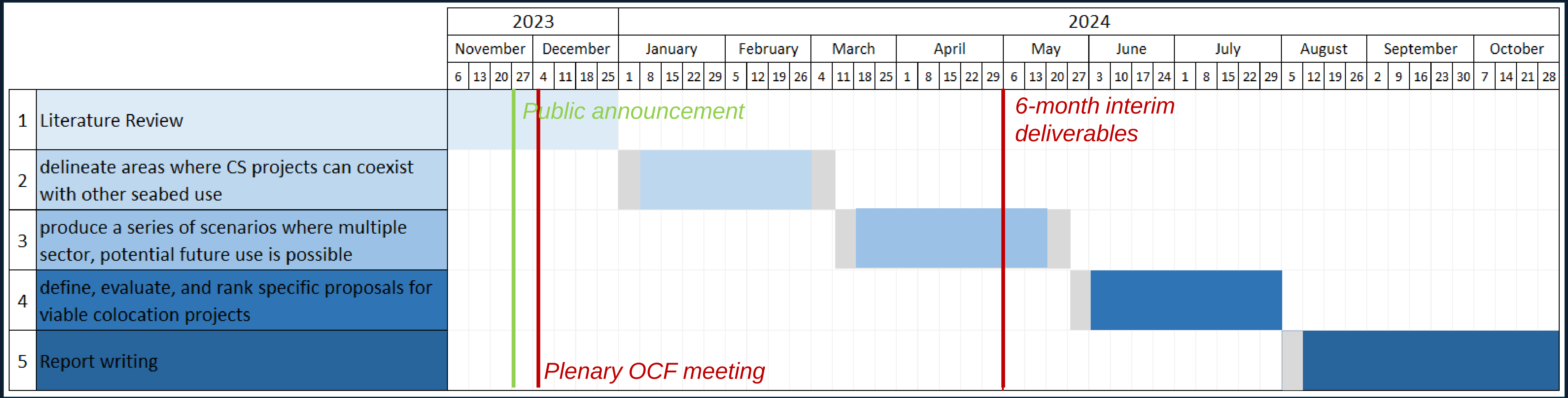
2. **EISB case study: Delineate the areas where CS projects can coexist with other seabed use.**
   - Identify existing or future colocation in the EISB
   - location, status and integrity of legacy wellbores and their likely impact

3. **Produce a series of scenarios where multiple sector, potential future use is possible**
   - Investigate possible solutions and opportunities

4. **Define, evaluate, and rank specific proposals for viable colocation projects**
5. **Report writing**

GO BEYOND BOUNDARIES

Work Programme



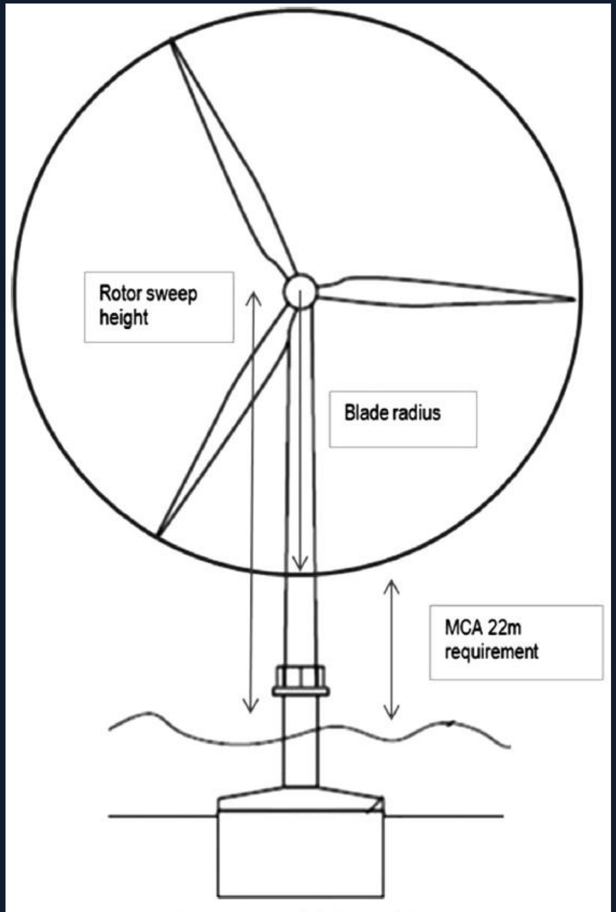
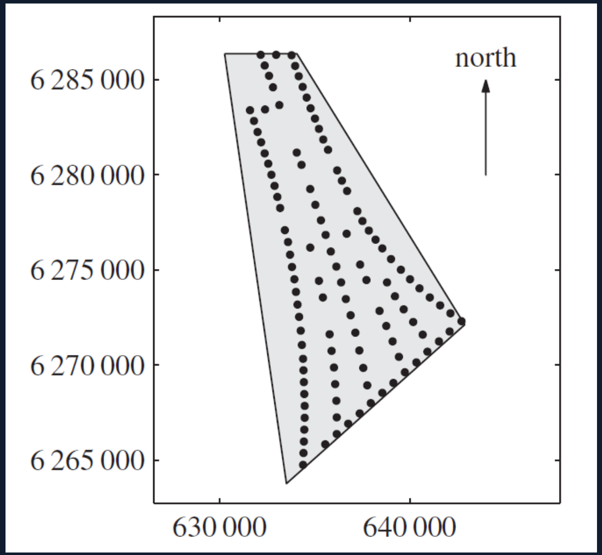


Fig. 6. UK tower height restrictions.

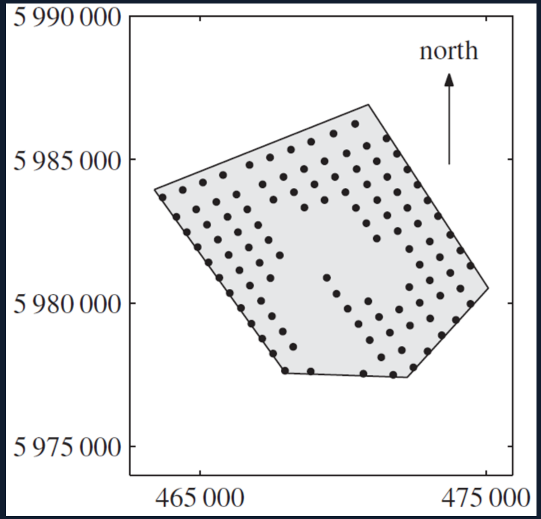
Higgins & Foley (2014)

Sheringham Shoal (Le et al. 2014)
88 wind turbines
~660 m spacing, ~20m water depth
Monopile Penetration depths 23 - 37 m

111 turbines
WSW dominating wind direction,
>30m thick soft clay in north



108 turbines
shallow depth of bedrock in the south, making the installation of large diameter monopiles infeasible



Kallehave et al. (2015)

Wind Farms - Requirements

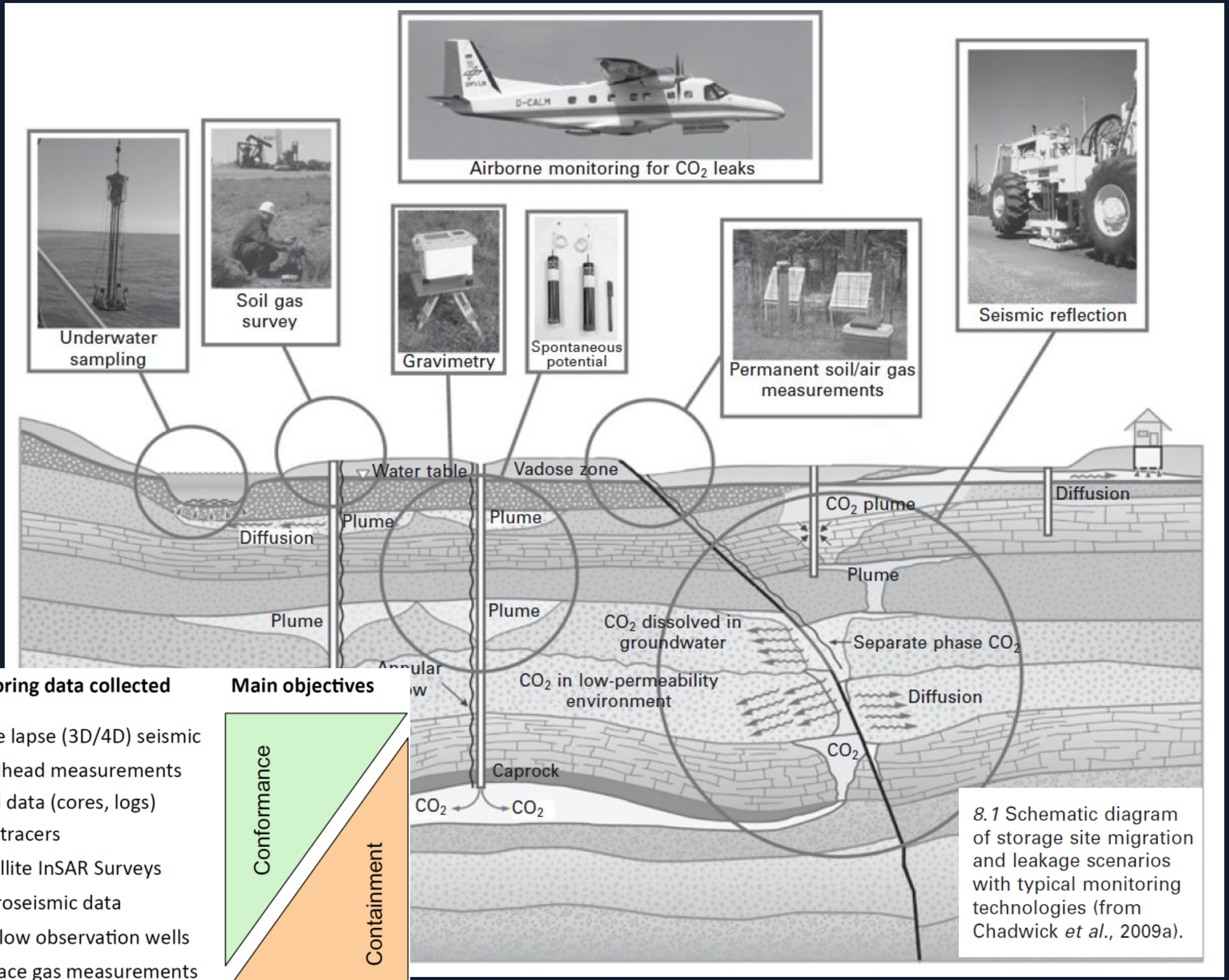
Grid layout optimisation

- Advanced layout algorithms are used to optimise grid layout and **overall power production against total estimated costs**,
- **Wind yield** dominates an optimization of a turbine layout, considering prevailing wind direction, speed and shadowing
- Also driven by **ground conditions**, effects final layout and cost (soil properties & foundations)
- As well as consented area constraints and/or environmental constraints.
- Higher costs offshore drives the importance of **a high-capacity factor** (MW) (more power from as low winds as possible) - larger rotors to capture energy at lower wind speeds (12 MW vs 4 MW)

CCS Projects - MMV

Range of technologies

- Policy requirements: containment & conformance assurance, plus contingency monitoring
- Deep- or shallow-focussed
- Direct (down-hole & surface) or indirect (seismic, remote)
- Geophysical, geochemical, geomechanical
- Reservoir, overburden, surface/environmental



8.1 Schematic diagram of storage site migration and leakage scenarios with typical monitoring technologies (from Chadwick *et al.*, 2009a).

Monitoring data collected

- Time lapse (3D/4D) seismic
- Wellhead measurements
- Well data (cores, logs)
- CO_2 tracers
- Satellite InSAR Surveys
- Microseismic data
- Shallow observation wells
- Surface gas measurements

Main objectives

Conformance

Containment

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CCS Projects - MMV

Review of existing sites and offshore MMV techniques

Which MMV technologies would be impacted by wind farm colocation?

		monitoring tools	Containment	Conformance	comments
Core Monitoring Plan		Downhole P and T (including optic-fibre)			On injection wells and monitoring wells if utilised
		3D time-lapse (4D) seismic			Not applicable to all reservoirs but applicable to all overburdens
		2D time-lapse seismic			Low cost alternative to 3D for some repeats
		VSP			Option if surface seismic not effective
		Passive seismics			If geomechaical issues identified in risk assessment
		Downhole fluid sampling			Post-injection stabilisation (dissolution)
		Geophysical logging			Fluid saturation
		Multibeam echosounding			Spatial coverage to identify potential issues; bubblestream detection
		High resolution sonar			Spatial coverage - Seabed imaging
		Vehicle-mounted sonar			Hydro-acoustic bubble-stream characterisation
		Seabed fluid and gas analysis			
		Seabed CO2 flux			Semi-permanent seabed stations for temporal variation
		Water column measurements			
Contingency Monitoring Plan		3D time-lapse (4D) seismic			Test and re-calibrate models; identify migration pathways.
		Hi-resolution seismic (p-cable)			Leakage out of Storage Complex.
	ETS measurement	Multibeam echosounding			Hydro-acoustic bubble-stream characterisation
		High resolution sonar			Emissions source imaging.
		Vehicle-mounted sonar			Hydro-acoustic bubble-stream characterisation
		Seabed fluid and gas analysis			Emission characterisation including non-CO2 precursors
		Seabed CO2 flux			Semi-permanent seabed stations
		Seawater chemistry			Emission characterisation including non-CO2 precursors

Figure 6.3 Suggested monitoring tool portfolio for an offshore CO_2 storage site

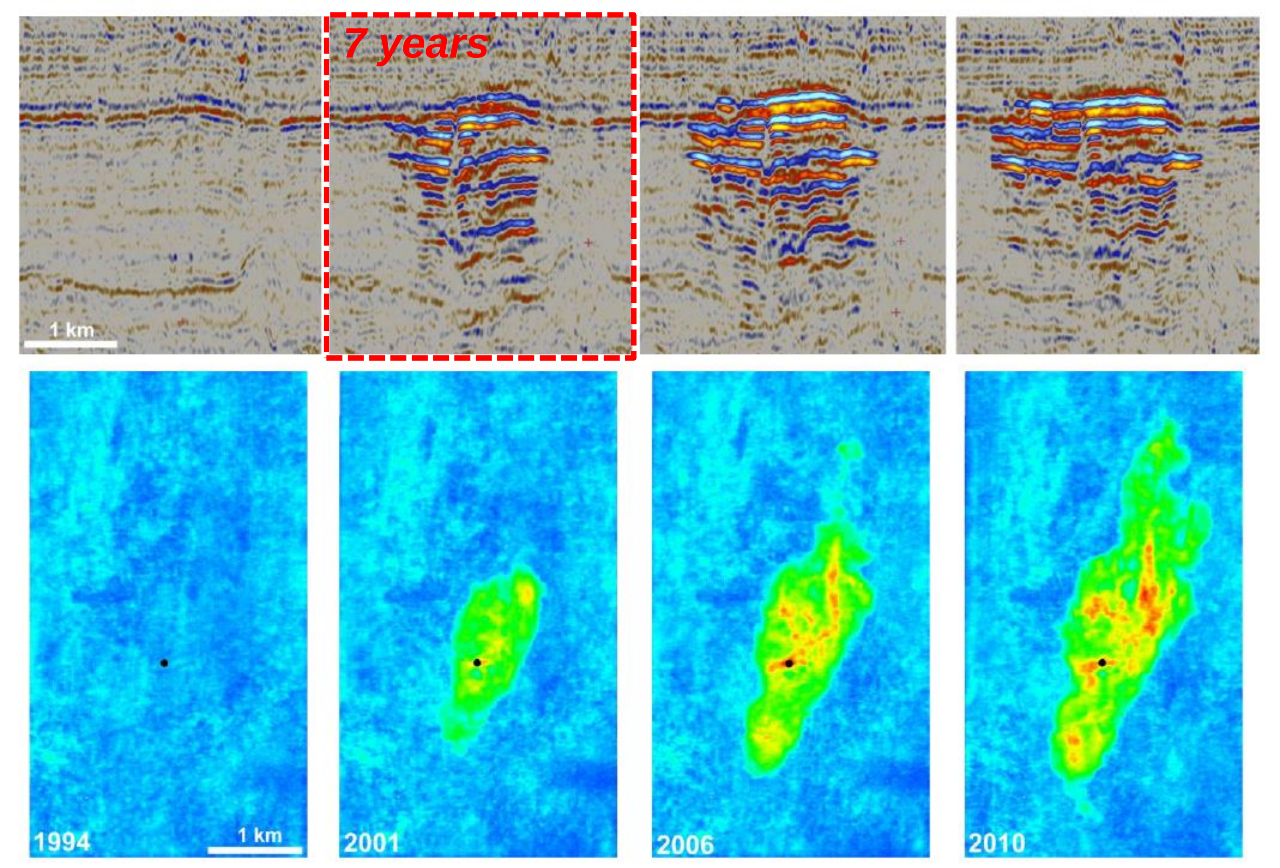
Deep	Shallow	Tool Name	Sleipner	Snøhvit	K12-B	*Goldeneye*	*ROAD*	In Salah	Weyburn	Ketzin	Nagaoka	Otway	Frio	Cranfield	Decatur	Citronelle	Lacq Rousse	Others*
			Offshore					Onshore										
		Site scale: large(L)>1 Mt,small (S)<1 Mt	L	L	S	L	L	L	L	S	S	S	S	S	S	S	S	S
x		2D surface seismic	x				x			x					x			x
x		3D surface seismic	x	x		x	x	x	x	x	x	x		x	x			x
x		Downhole pressure/temperature		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x		Surface gravimetry	x	x														
x		Geophysical logs			x	x	x		x	x	x	x	x	x	x	x		
x		Downhole fluid sampling			x	x		x	x	x	x	x	x	x	x	x		x
x		Surface gravimetry	x	x														
x		Seabottom EM	x															x
x		Microseismic monitoring				x	x	x	x	x		x		x	x		x	x
x		Vertical seismic profiling (VSP)							x	x		x	x	x	x	x		x
x		Well gravimetry												x				
x		Single well EM											x					x
x		Tiltmeters						x										x
x		Cross-hole seismic							x	x	x		x	x		x		
x		Cross-hole EM								x			x					x
x		Cross-hole ERT								x				x				
x		Satellite interferometry						x							x			
x		Multicomponent surface seismic							x									x
x		Land ERT								x					x			x
x		Land EM								x								x
x		Airborne EM												x				
x	x	Tracers			x			x	x	x		x	x	x		x		x
	x	Shallow acoustic imaging	x	x		x												x
	x	Bubble stream detection	x	x														x
	x	Ecosystems studies	x					x		x							x	x
	x	Seabed acoustic imaging	x	x		x	x											
	x	Seabed sampling	x	x		x	x											x
	x	Seawater chemistry	x	x		x	x											
	x	Bubble stream chemistry																x
	x	Fluid geochemistry						x	x	x		x	x	x	x	x	x	
	x	Soil gas concentrations						x	x	x		x		x	x		x	
	x	Surface gas flux						x	x	x		x		x	x	x	x	
	x	IR diode lasers						x	x			x			x			x
	x	Eddy covariance							x			x			x			x
	x	Airborne spectral imaging													x			x
	x	Electric Spontaneous Potential																x
	x	Ground penetrating radar																x

Colocation: Conflicts, Problems & risks

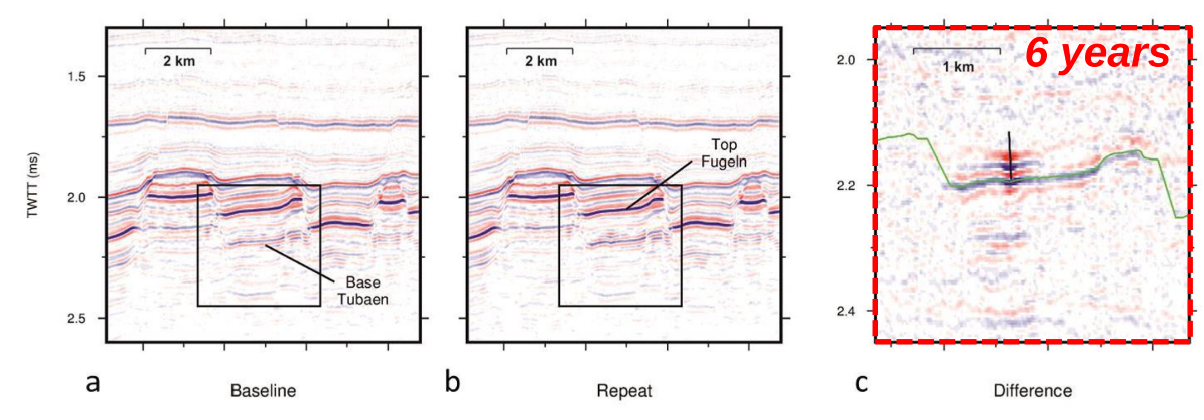
Of the available offshore monitoring techniques, which would be affected by the areal colocation of wind farms?

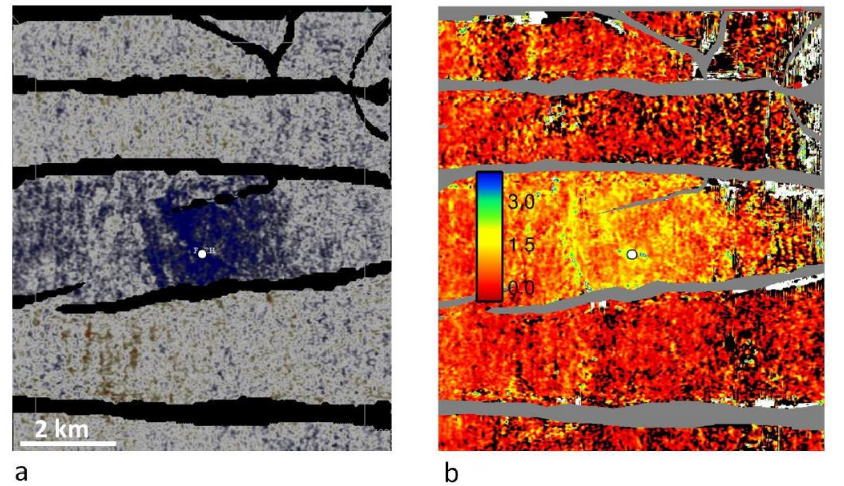
	Colocation conflict	Possible solution
MMV	MMV 4D seismic acquisition prevented due to line density & turbine spacing	Applicability of 4D seismic to deep reservoirs? OBN/OBC? Or too expensive? Multi-well VSP (uncertain reliability) or cross-well seismic (not proven
MMV	Height of turbines may prevent aeroborne MMV survey acquisition (IR diode lasers CO2 flux monitoring, EM)	Appropriate height of aeroborne surveys? >100 m?
MMV	Remediation MMV surveys, drilling or pipelines prevented/impeded	
MMV	Repeatability of shallow-focussed environmental and geomechanical MMV surveys (acoustic seabed imaging, ROV imaging, ecosystems, seabed sampling, tiltmeter/deformation) post-baseline impacted (morphology, sedimentation, currents)	
MMV	Acquisition by vessel (not ROV, AUV) of shallow acoustic imaging,	Use of AUV or ROVs – but limited penetration and coverage?
MMV	Shallow Turbine foundations influence on electromagnetic methods? (Smith et al. 2011) Shallow water bad for sensors?	
MMV	Access to active injection or monitoring well (surface and downhole gauges, sampling)	
MMV	Would turbines create noise and impact passive microseismicity monitoring?	Not been deployed offshore?
MMV	Would turbines create “excessive vibrations” that impact useful data acquisition by gravimeters?	Gravimetry detectability strongly site dependent
Wind	CO_2 injection may cause slight seabed uplift (cm-scale)	
Wind	Induced seismicity by CCS sites	negligible risk? (see Nikitas et al. 2020, Fukishima) see Sleipner
Other	Exclusion of viable storage sites (many sites, but the best may be limited, only determined after appraisal, and large in size)	
Other	Drilling of additional injection or monitoring wells prevented	
Other	Site appraisal, prevent legacy well downhole wellbore integrity	

Colocation Conflicts: – 4D acquisition



IEAGHG (2015)





Sleipner

- Saline aquifer
- 1012 m TVDSS
- High porosity (35-40%)

Snohvit

- Gas and oil reservoirs
- 2420 m TVDSS,
- 10-15% porosity

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Colocation: Conflicts & Problems

Solutions to consider:

Geographical

- Wider turbine spacing?
- Avoid colocation?

Technological

- MMV – seismic identified as the most important

Commercial

- Wind farms cover the change in MMV costs?
- Impact of liability?

Project Anemone

Update from

Philippa Parmiter, Chief Executive at NECCUS

Mark Hughes, Chief Operating Officer at NECCUS

Project Anemone
– Recap on core deliverables

The report will make recommendations to both CCUS and OW developers about how to:

- Coordinate their marine operations
- Manage the spatial requirements over the projects' entire lifecycle
- Mitigate potential operational challenges with other seabed users
- Maximise the potential commercial benefits and arrangements

Project Anemone
– Real-world impact

Providing developers with a best-practice guidance for simultaneous operations that will help guide future projects and provide a baseline for developers to build on.

Help wider marine stakeholders understand the risks and mitigations associated with simultaneous operations.

Project Anemone – Update since Plenary #8

- Meeting held 7/11/23 with NECCUS, Storegga, NSTA, TCE & CES.
- Key objective: Project to kick off by EOY.

Action	Owner	Status
Finalise scope of work	TCE	In progress
Pull together flyer summary of project for stakeholder engagement	NECCUS	Complete
Organise in-person meeting with target partners	NECCUS	In progress
Contact wind & CCS developers, and any appropriate INTOG projects about project	All	In progress

Project Anemone – flyer to developers (draft)

NECCUS

Project Anemone

For the UK to meet its net zero targets, both offshore wind energy (OW) and carbon capture and storage (CCS) need to be deployed at scale, which makes colocation of the two technologies increasingly important.

In partnership with the OW & CCS Colocation Forum, NECCUS has launched a new research project called *Project Anemone*.

Project Anemone will examine practical operational requirements to enable colocation and produce best-practice guidance to support future projects.

We are looking for OW and CCS developers to take part in our surveys to inform our studies, particularly in Scottish North Sea.

Project Anemone will make recommendations in three key areas:

- WP1: Operational requirements, challenges and mitigations
- WP2: Identifying colocation opportunities
- WP3: Developing colocation opportunities

The findings from *Project Anemone's* will inform OW & CCS Colocation Forum's work to deliver a practice test & demonstration (T&D) projects.

Please contact mark.hughes@neccus.co.uk or gordon.walker@neccus.co.uk if you would like to participate in *Project Anemone*.

neccus.co.uk

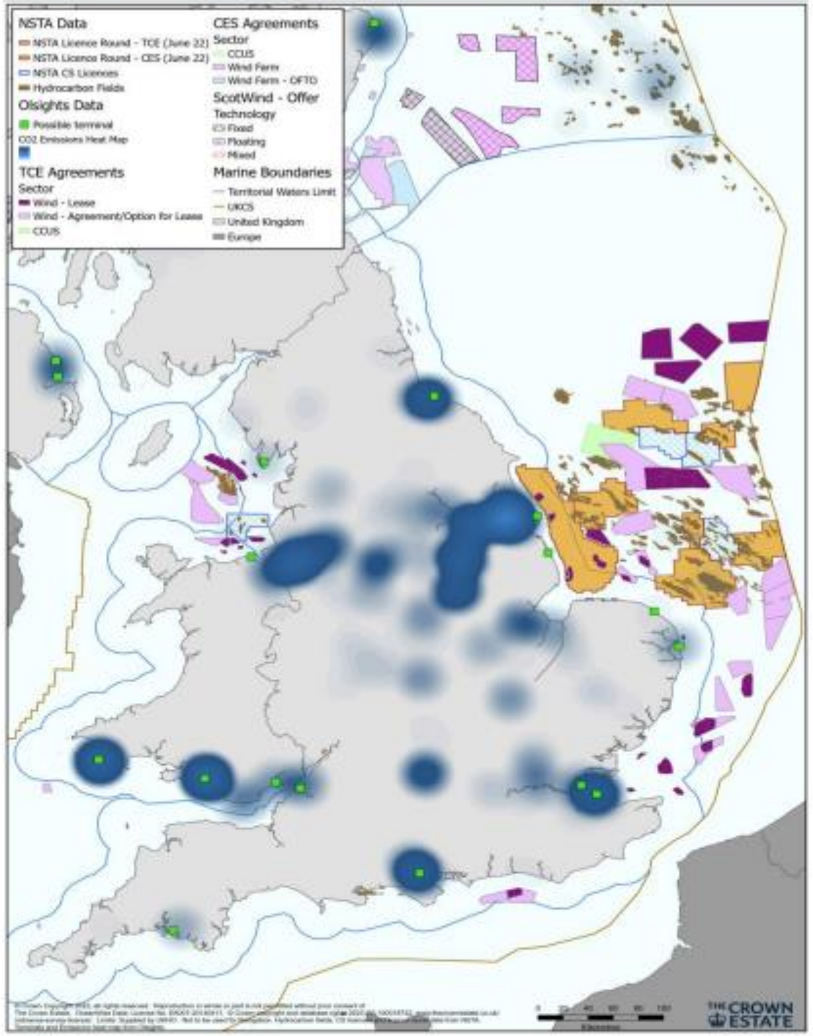
Interplay between the Forum and other bodies

Spatial Characterisation – Developers impacted by report

UK OW/CCS Area Overlaps at December 2023				
CSL*	CS application	CCS Company	OW AfL/Lease	OW Company
1	Endurance	BP	Hornsea4	Ørsted
3	Acorn	Storegga	Marram	Shell
(20)	SNS Area 1b	Neptune Energy	Dogger Bank South East	RWE Renewables
(26)	SNS Area 2b	Shell UK	Norfolk Boreas	Vattenfall
28	SNS Area 3	Shell UK	R1 Lynn	XceCo
			R1 Inner Dowsing	
			R2 Lincs	Ørsted
			R2 Westermost Rough	
			R2 Humber Gateway	RWE
(17)	SNS Area 6a	Perenco UK	R2 Triton Knoll	RWE
10	EIS Area 1	Spirit Energy	R4 Morecambe	Floatation Energy

*significant overlap areas / (insignificant overlap areas)

Figure 1 - Map of public domain information for Existing & Potential Offshore Energy Agreements – Northern Ireland, Wales, England



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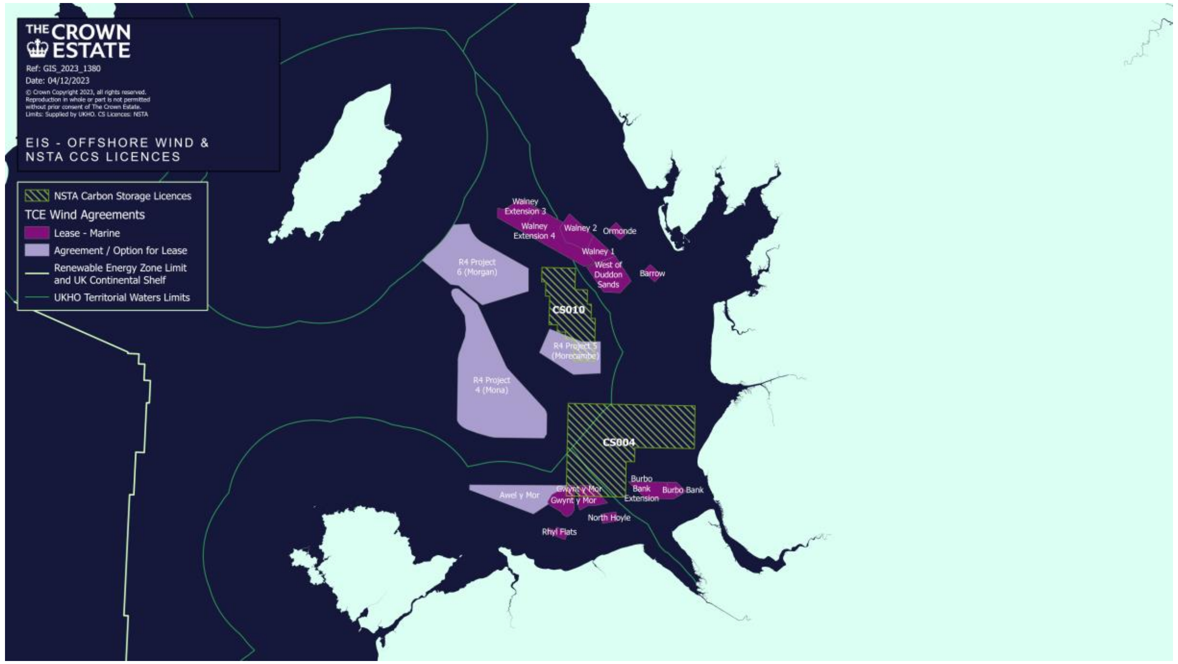
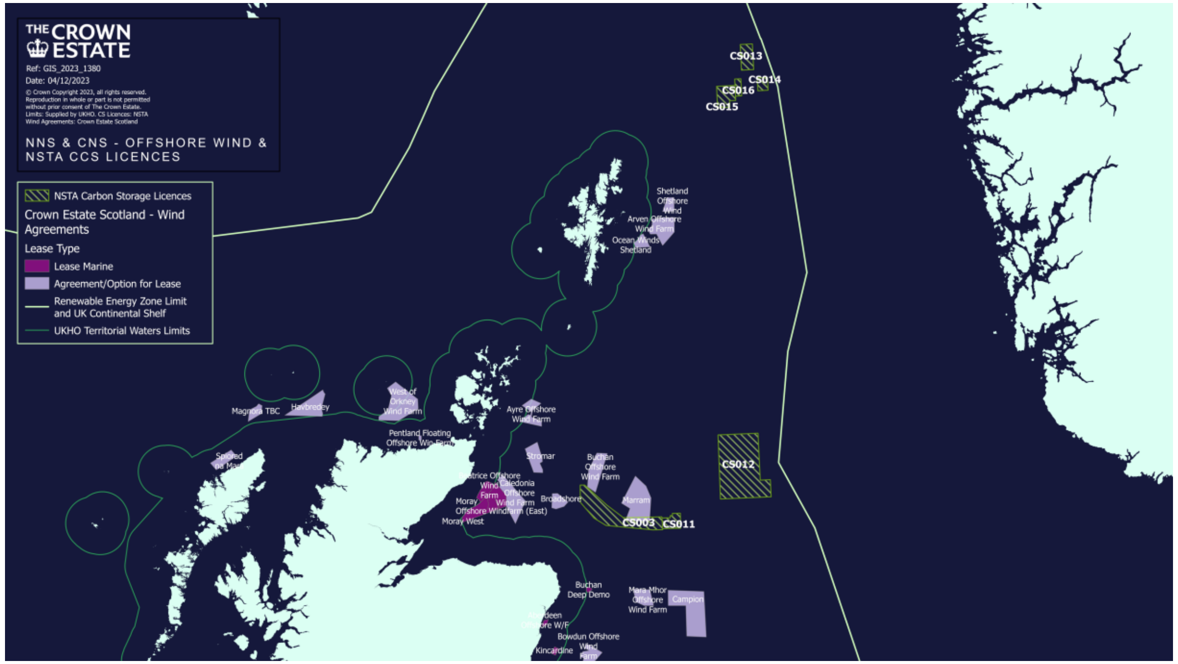
Offshore Wind Agreements & CCS Licenses





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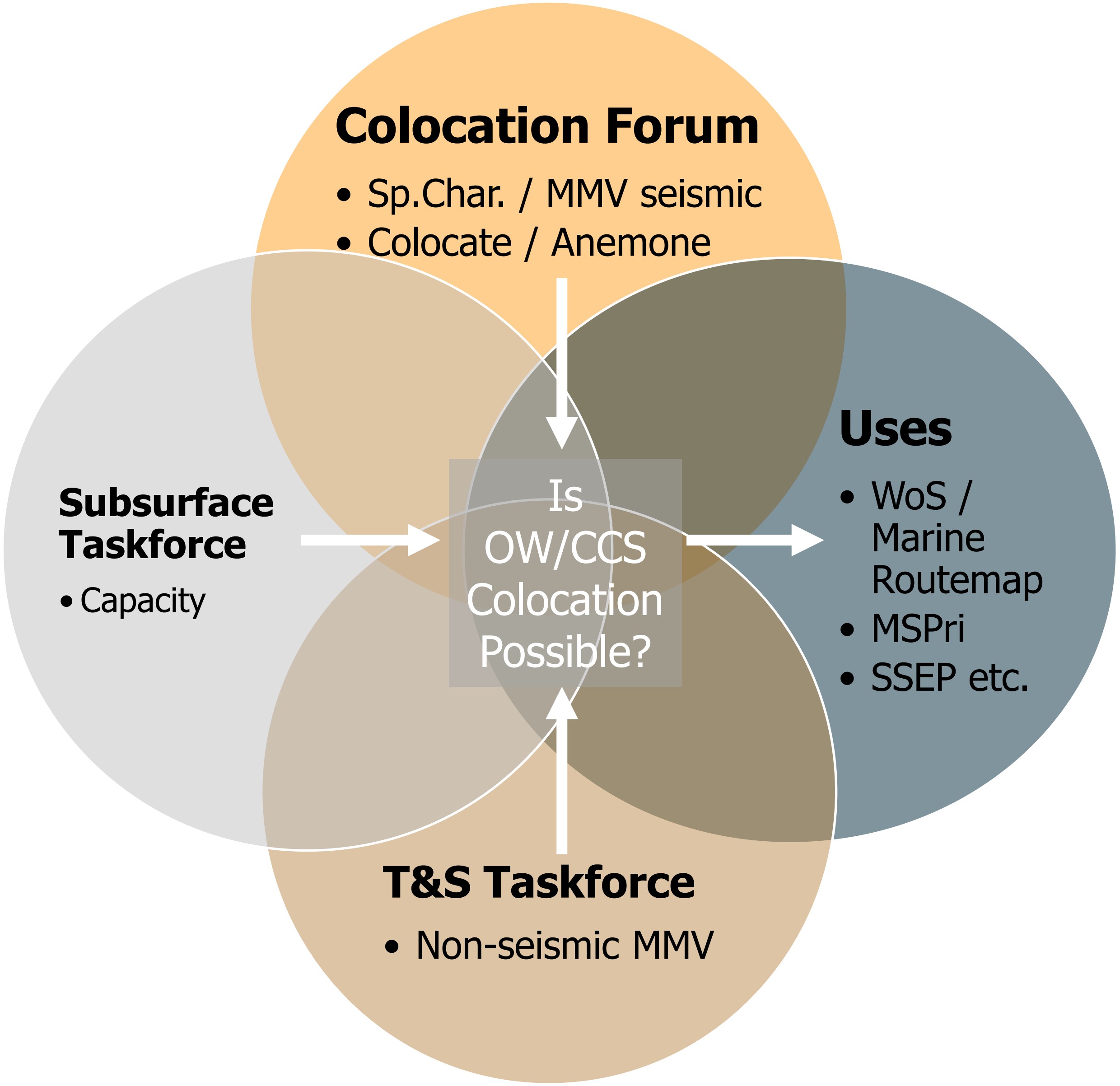
NSTA Carbon Storage Licences
TCE Wind Agreements
Lease - Marine
Agreement / Option for Lease
Renewable Energy Zone Limit and UK Continental Shelf
UKHO Territorial Waters Limits
Dogger Bank A
R4 Project 1 (Dogger Bank South West)
R4 Project 2 (Dogger Bank South East)
CS021
CS020
CS025
CS022
CS001
CS006
CS007
Hornsea Project Four (HOW04)
Hornsea Project 2 - Phase 1 (Breesea)
Hornsea Project 2 - Phase 2 (Soundmark)
Hornsea Project 2 - Phase 3 (Sonningmay)
Hornsea 1 (West)
Hornsea 1 (Centre)
Hornsea 1 (East)
Hornsea Project Three (HOW03)
CS018
Westermost Rough
Humber Gateway
CS017
R4 Project 3 (Outer Dowsing)
CS024
CS028
Triton Knoll
CS005
CS027
CS023
CS026
Dudgeon Extension
Dudgeon
Race Bank
Sheringham Shoal Extension
Dudgeon Extension
Lincs
Lincs
Inner Dowsing
Lynn
Sheringham Shoal
CS008
CS009
CS019
Norfolk Boreas
Norfolk Vanguard West
Norfolk Vanguard East
East Anglia THREE

Bodies working on colocation-related content



Offshore Colocation Forum

Is OW/CCS Colocation possible?

SOLVE

monitoring compatible with wind farm

MITIGATE

degree of compromise needed e.g. commercial, operational

AVOID

monitoring incompatible with wind farm, do not overlap

Whole of Seabed Update

Tristan Bromley
Programme Lead – Whole of Seabed at The Crown Estate

Whole of Seabed Approach

A long term, pro-active and de-risking approach is critical to unlocking the UK's renewable energy potential. The Crown Estate has commenced pioneering work to **digitally map the seabed resource needed to meet future demand**, enabling the delivery of multiple priorities including net zero and nature recovery.

By utilising The Crown Estate's expertise in spatial analysis and data, **the Whole of Seabed Programme is developing** cross-sector analysis of demand and supply for marine space in EWNI waters to 2050, creating an evidence base to support delivery decisions on the 'what', 'where' and 'when' of how space is used.

Energy	Storage
Offshore wind Energy conversion Marine energy	CCUS Hydrogen Natural gas

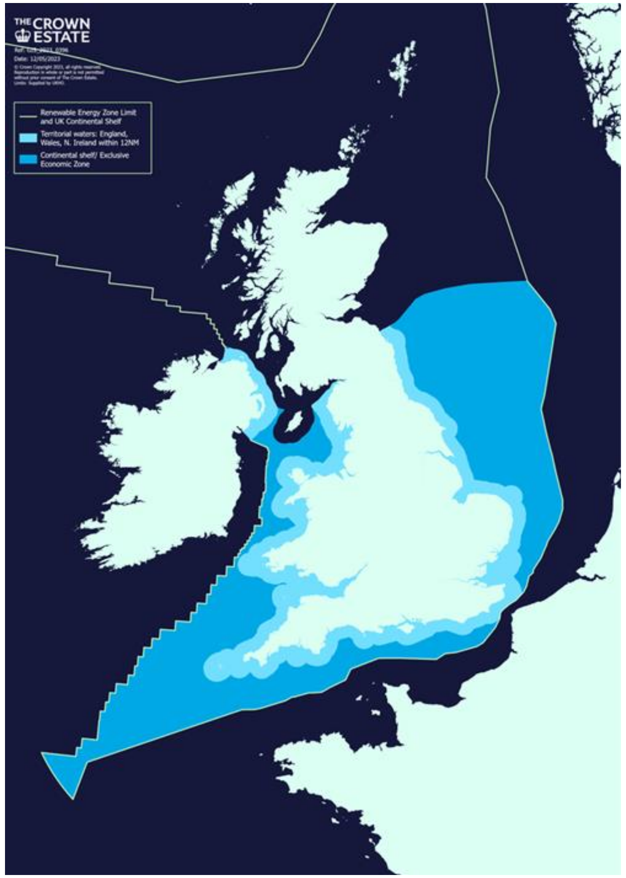
Infrastructure	Minerals
Export/Interconnectors Pipelines Telecoms	Reclamation Aggregate dredging Marine mining

Coastal	Habitats
Ports and harbours Aquaculture Leisure	Habitat creation Biodiversity Nature recovery

The analysis will develop a range of 2050 scenarios on how seabed supply/resource can meet demands across sectors, in 5 year 'epochs'.

This will bring benefits to our full range of stakeholders:

- ✓ Better outcomes for society. Understand the optimal uses of the seabed
- ✓ Better support to government & regulators. Evidence base to support policy and sector delivery (e.g. CSNP, MSPri)
- ✓ Better services for customers/developers. Enables full understanding of the spatial/investment opportunity over time
- ✓ Better leasing design and delivery – driving future leasing plans and pre-development activities (e.g. surveys, siting, grid design)



The Crown Estate's marine spatial analysis capabilities underpin our leasing activities

We are evolving our spatial analysis constantly, allowing us to spatially represent:

Constraints

Key Resource Areas – ensuring technical viability.

Hard Constraints – removing locations where there are complete barriers to development.

Soft Constraints – weighted analysis of other users and uses of the marine space to prioritise remaining space.

Delivery Cost

Delivery costs are important when planning marine assets and resource utilisation.

A range of parameters affect costs e.g. physical conditions, distances, and policy priorities.

The diversity of our marine space drives a significant geographic variance in delivery costs.

Levelised Cost of Energy is one tool that helps identify the most cost-efficient locations.

Onshore Infrastructure

All offshore development interacts with the terrestrial space in some form.

Cable and pipelines land commodities

Ports act as both landing points and hubs to service all stages of the development lifecycle.

Consideration of onshore infrastructure including the terrestrial energy systemm is critical for marine planning.

Social & Env. Value

Emerging area.

Can we identify and prioritise locations that increase environmental or social value?

For example preserving blue carbon or reducing social deprivation.

'Whole of Seabed' analysis: where we are now and what do we want to look at in future

Phase 1

(1st phase complete)

- Offshore Wind
- Electricity Cables
- Marine Aggregates (sand & gravel)
- Telecoms Communication Cables
- Carbon Capture & Storage
- Nature Recovery

Phase 2

(2nd phase to Q4 2023-4)

- CCS Pipelines
- Tidal Range
- Tidal Stream
- Interconnectors (electricity cables that extend to other nations)
- Gas Storage

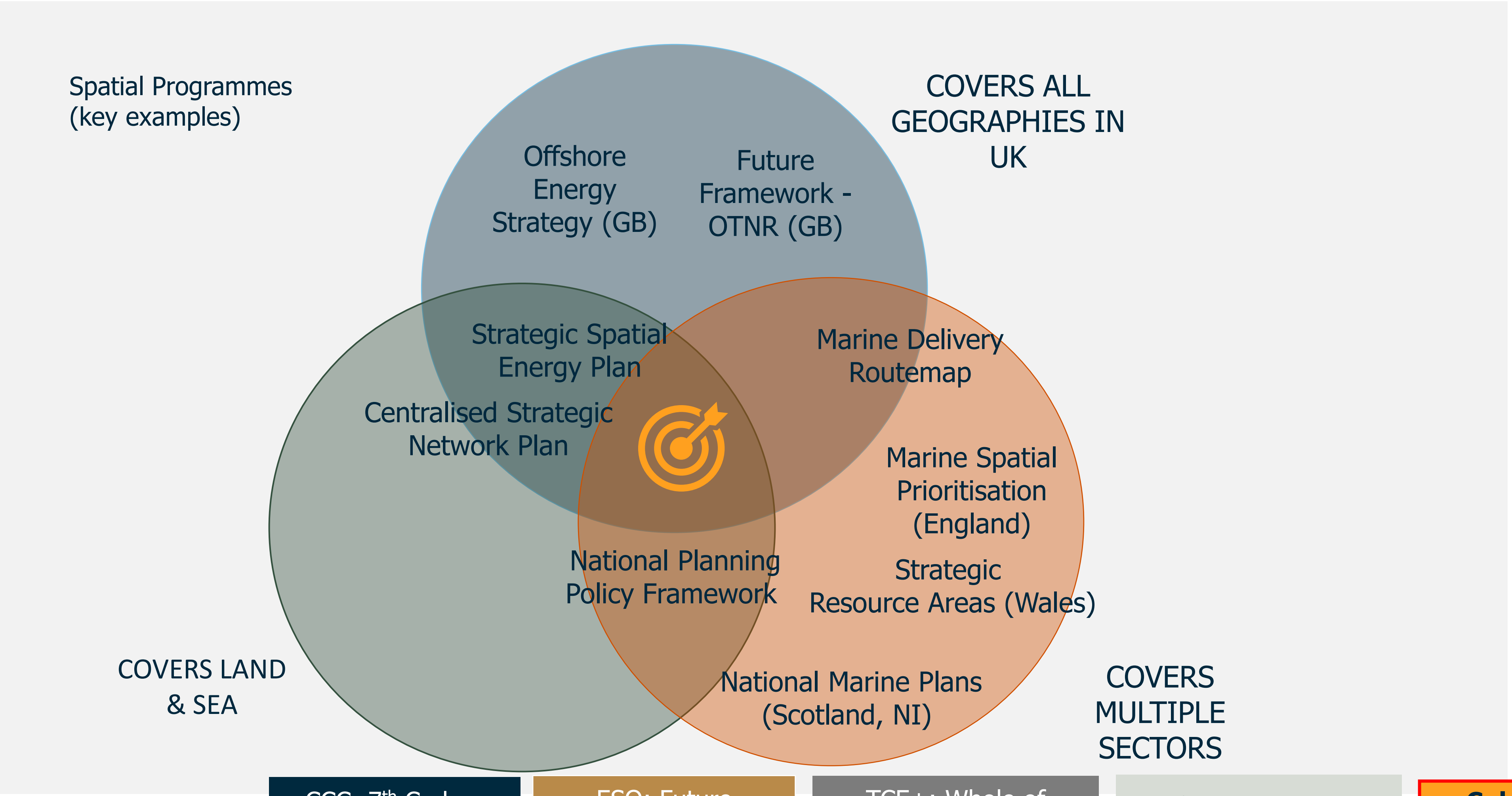
Partner-led

- Oil & Gas (& pipelines)
- Shipping
- Fishing
- Defence
- Coastal Leisure

Future

- Aquaculture
- Hydrogen Generation
- Energy Conversion
- Sub Surface Mining
- Capital Dredging
- Port & Harbours
- Geological Disposal
- Regulating Activities
- Wave Energy
- Other minerals

Coordinating action: no single programme covers all sectors & whole of UK, but we can provide a common evidence base



Common Evidence base

CCC: 7th Carbon Budget Scenarios	ESO: Future Energy Scenarios	TCE+: Whole of Seabed scenarios	TCE & CES: Marine Data Exchange	**Colocation Forum**

MMV Subgroup update

MMV Subgroup – Project overview

Membership	Core Deliverable
NSTA CCS Transport & Storage Taskforce – MMV Subgroup Members of the subgroup: •Storegga (Acorn) •BP (Endurance) •ENI (HyNet) •Shell (Acorn) •Halliburton •CCSA •OEUK •NSTA	The MMV Subgroup is focused on the operational phase of CCS and will produce a report (21 December) that will: **Identify alternative monitoring technologies that could – in theory - reduce the frequency of 3D seismic monitoring needed during the multi-decade operational phase of a CCS store.**

MMV Subgroup – Real-world impact

Short – Medium term impact

Unlock funding opportunities for viability testing of alternative monitoring technologies that have been identified.

Long term impact

Reduce the frequency of 3D seismic monitoring needed to be undertaken during the multi-decade operational phase of a CCS store. This will:

- Reduce costs and maximise viability of CCS projects, including reducing need for taxpayer subsidy and increase viability of sustainable market potential.
- Enable viability testing of alternative technologies.

MMV Subgroup – Next steps

Establish what further viability testing needed to establish the deliverability of these alternative monitoring technologies.

Agree a mechanism for undertaking viability testing with HM Government, regulators and the market.

Undertake viability testing of alternative technologies.

Engage with the Forum's projects to share any learnings that will help address challenges presented by current limitations of seismic monitoring.

Next developer Event -

Monitoring 101

Developer Event Plan

During Plenary #8, presentations from UoA and NSTA on their approaches to seismic monitoring received a high volume of questions from Forum members. The Forum therefore agreed it would be beneficial to clearly explain the existing monitoring techniques, the challenges they present and explore how they might be resolved as the Forum's next "developer event".

Format

A panel event, consisting of 4 individuals:

- Offshore Wind industry representative
- CCS industry representative
- MMV expert / academic
- Offshore Wind construction expert / academic

Objectives

- An overview of the existing methods of CCS monitoring
- The challenges of existing forms of monitoring and the obstacles they present to colocation
- The innovations, technologies and alternative forms of monitoring that can address these challenges

Event currently planned for **March 2024**

Next Plenary Dates – future Forum programme

Appendix

Offshore Wind Timeline

- Diagram created for The Crown Estate's Offshore Wind Leasing Round 4 Information Memorandum (IM).
- There is a maximum of 10 years between Agreement for Lease (AfL) and operation.
- The Crown Estate is unable to share any further information from developers about the development of OSW projects.

Offshore Colocation Forum

CCS Timeline

		Appraise and Assess					Define			Execute		Operational
	Year:	1	2	3	4	5	6	7	8	9	10	
NSTA	Technical Licence							Permit Application				
	Licence Award											
	Cessation of Production				Decommissioning				FID & Permit Award		Injection Starts	
TCE/CES	Seabed agreement	Award Appraisal Rights										
		Technical appraisal: seismic acquisition & interpretation; well planning & execution; injection testing & interpretation					Permit Application Preparation		Application Assessment (6 months)	Construction Investment Phase		
Developer												
	Seismic:	Final seismic prep	Aquire seismic; Process seismic			Contingency						
	Wells:			Plan Appraisal well; Drill well	Injection testing							
	Studies:	Legacy well study	Seismic interpretation		Interpretation & model build							

Offshore Colocation Forum