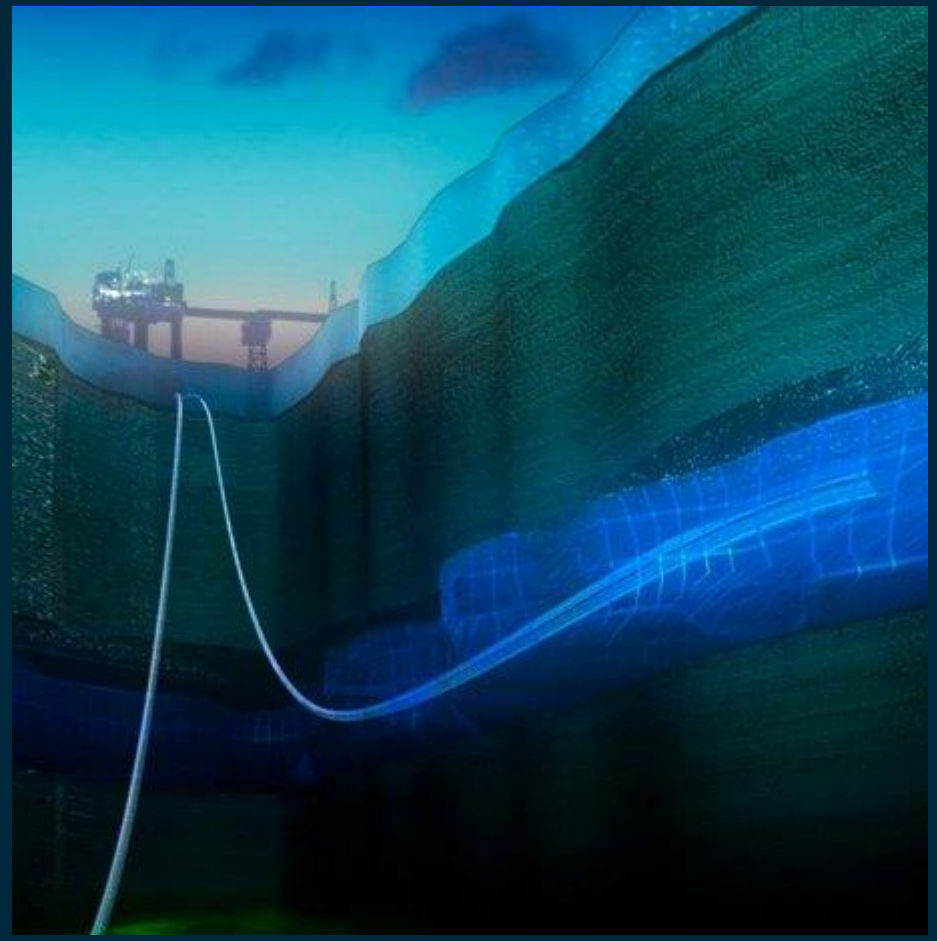
Offshore Colocation Forum

Offshore Wind and CCUS Colocation Forum



Plenary #10 – March 2024

THE CROWN ESTATE

Agenda

1. **Matters Arising** – Secretariat – 5mins
2. **Project Colocate** – Professor John Underhill and Sam Head, University of Aberdeen – 20 mins
3. **Project Anemone** – Gordon Walker, NECCUS – 20 mins
4. **Interplay between the Forum and other bodies** – Adrian Topham, Chair – 20 mins
5. **T&S Taskforce** – Elle Lashko, Storegga – 20 mins
6. **Developer event** – Secretariat – 5 mins
7. **Norway visit** – Adrian Topham, Chair – 15 mins
8. **Next Plenary Dates** – Secretariat – 5 mins

Matters Arising

Matters Arising

Action	Owner	Status	Action	Owner	Status
Further information on new technical innovations in the OW industry	The Crown Estate	Developer 101 event to explore	Recirculate deck on key deliverables, real-world impact and next steps of Forum workstreams	Grayling	Complete
Workshop / roundtable to present technical data used to inform Project Colocate	UoA	Complete – took place on 22.01	Update developer table with CES agreements and OW agreements/CCS license overlap maps with recent commercial agreements	CES	Clarify action – update to be discussed
Refresh and recirculate Forum communications protocol with members	Grayling	Complete – see prereading	Explore how the Forum can quantify / categorise decarbonisation contribution of colocation	TCE / Grayling	Update required – to be discussed
Project Colocate advisory group meeting	UoA / The Crown Estate	Due to take place in March 2024	2024 Forward Calendar of external conferences and events	Grayling	Complete – see prereading

Project Colocate

Update from Professor John Underhill

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

and **Dr Sam Head**

Research Fellow, University of Aberdeen

Offshore Colocation Forum

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Project Colocate – Objectives & Real World Impacts

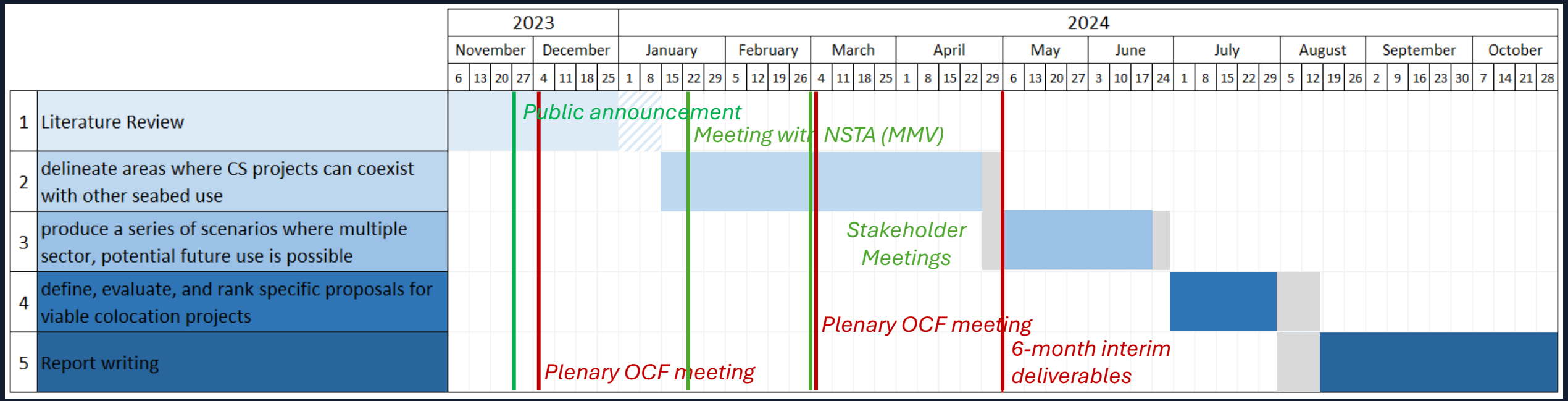
Supporting industry framing of co-location considerations, this project will:

- Identify geological areas where co-location is viable and which stores could have compatible monitoring with OW turbines.
- Establish what monitoring is needed for these geological stores.
- Examine potential benefits through common appraisal.
- Provide an example to developers considering future projects in similar geologies how a viable scheme could operate.

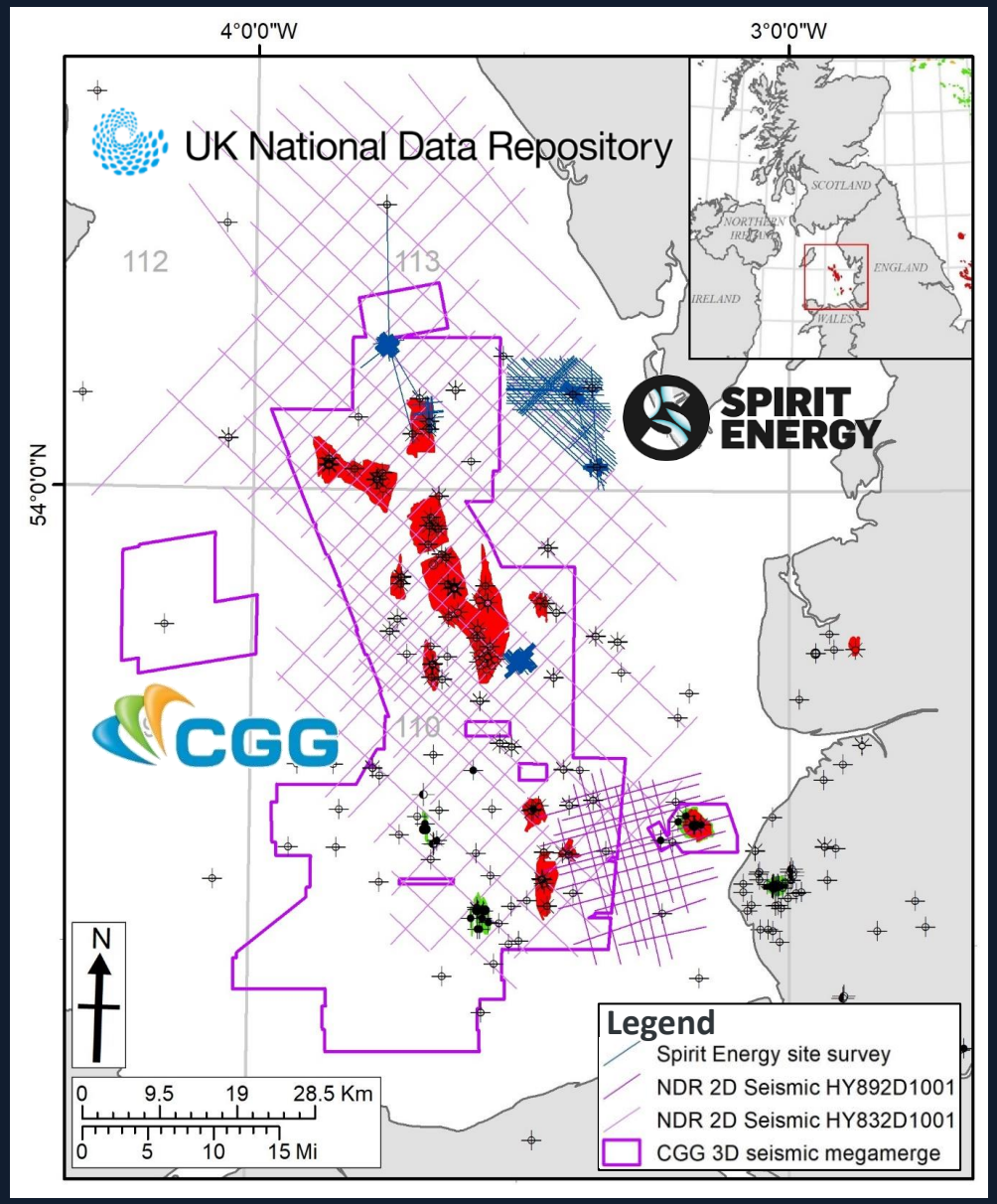
Work Programme

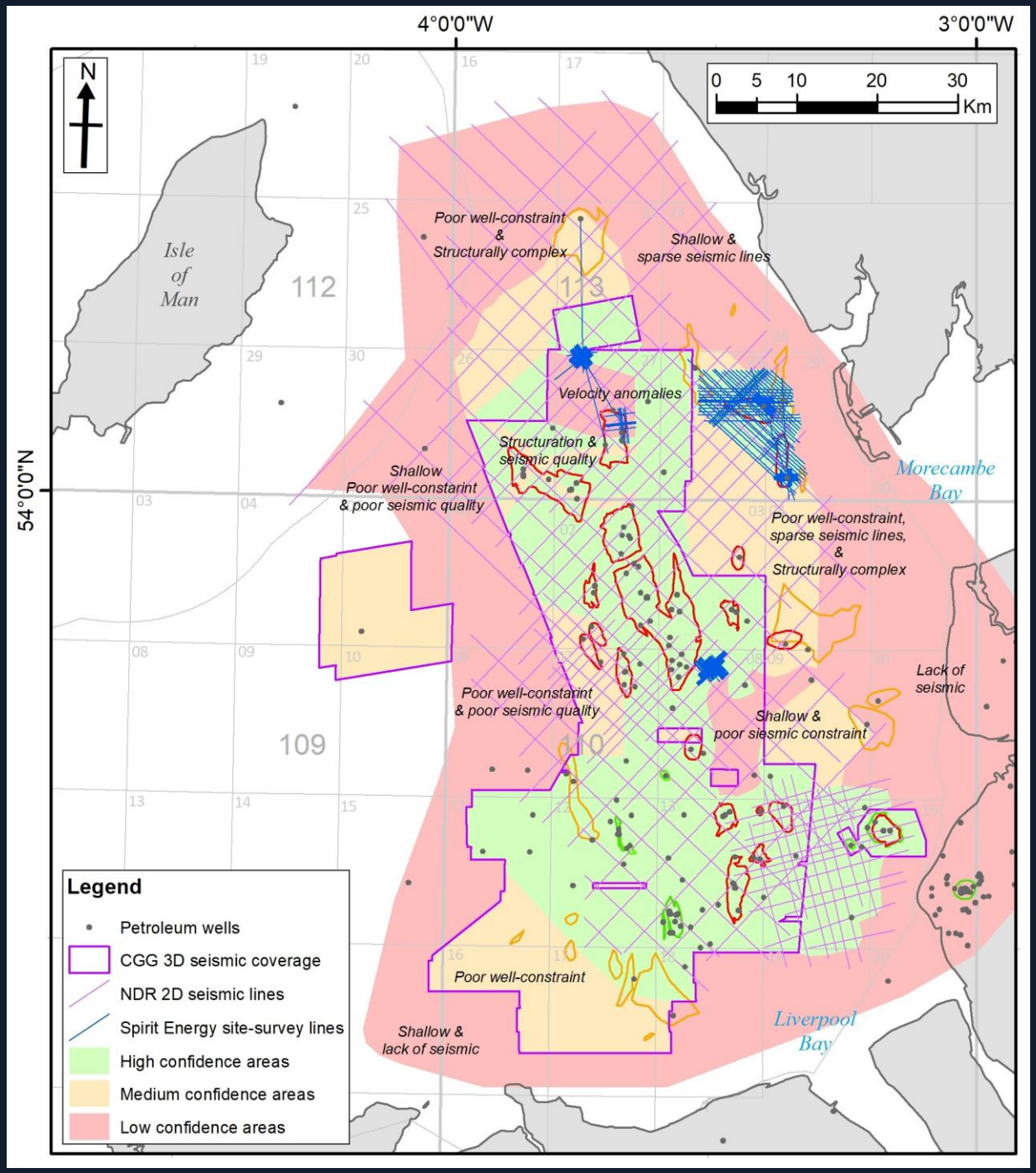
Phase 1 will aim to complete deliverable 1 in the first year with interim deliverables in the first six months

Deliverable 1: *Define future potential areas for OW and CS within the East Irish Sea Basin. Include location, status, and integrity of legacy boreholes and other infrastructure highlighting areas of multiple potential future uses in prospective areas.*



Well & Seismic Data



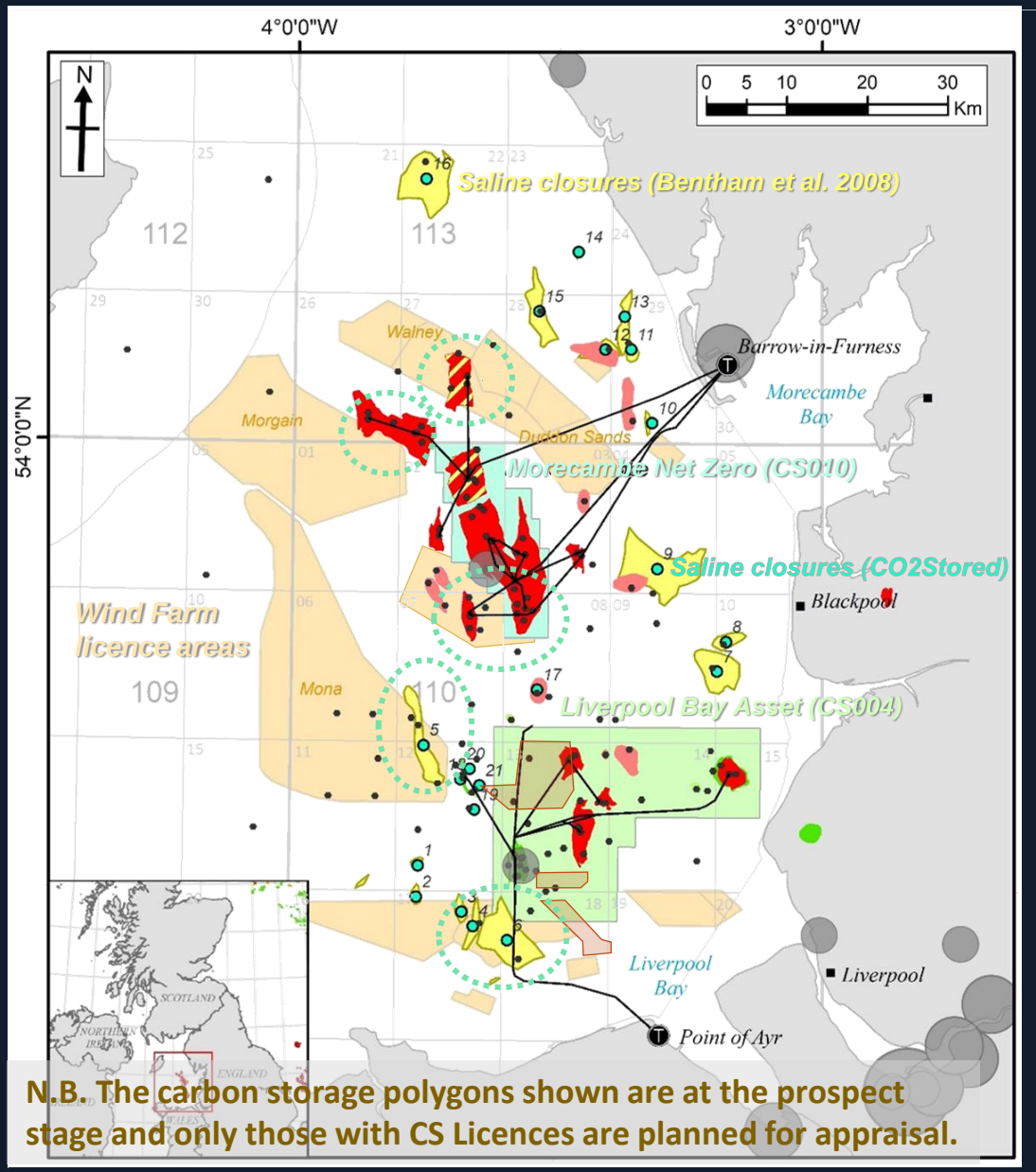


Colocation in the East Irish Sea

Identified **colocation** between **Offshore Wind**, **Carbon Storage prospects**, and **Aggregate dredging**

CCS prospect	Wind Farm	Comment	Storage capacity (Mt)	Priority (urg. & magn.)	Wells in overlap area
Rhyl	Walney extension 4	Large areal overlap, but production ongoing ~2026	186	B6	5
North Morecambe **pipeline**	Duddon Sands	Potential monitoring, or remediation issue	175	A3	N/A
Millom	Morgan	Small areal coverage, larger monitoring coverage?	42	B2	0
South Morecambe (MNZ)	Morecambe	Large areal coverage.	784	A1	8
Calder	Morecambe	Large areal coverage.	4	B1	4
LPBA licence area	Gwynt y Mor	Only small area (future monitoring area?)	134	A2	1
OC4	Gwynt y Mor	Large areal coverage.	12	B5	1
OC6	Gwynt y Mor	Large areal coverage.	88	B4	2
OC3	Awel y Mor	Large areal coverage.	1	B7	0
OC5	Mona	Large areal coverage.	16	B3	2

Potential – all yet to be fully discussed



N.B. The carbon storage polygons shown are at the prospect stage and only those with CS Licences are planned for appraisal.

Colocation in the East Irish Sea

Identified **colocation** between **Offshore Wind**, **Carbon Storage prospects**, and **Aggregate dredging**

CCS prospect	Wind Farm	Comment	Storage capacity (Mt)	Priority (urg. & magn.)	Wells in overlap area
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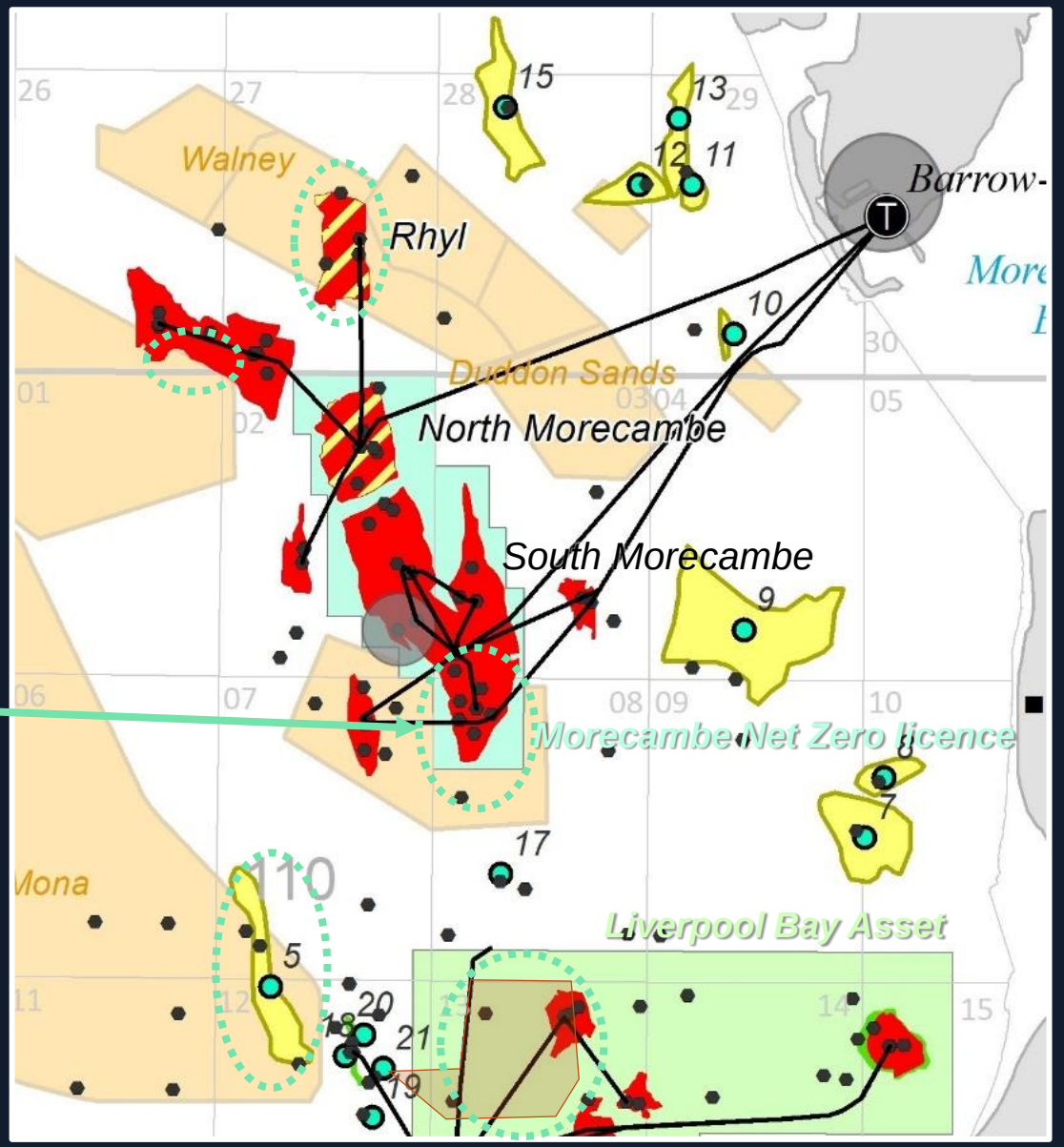
OC5	Mona	Large areal coverage.	16	B3	2

Potential – all yet to be fully discussed



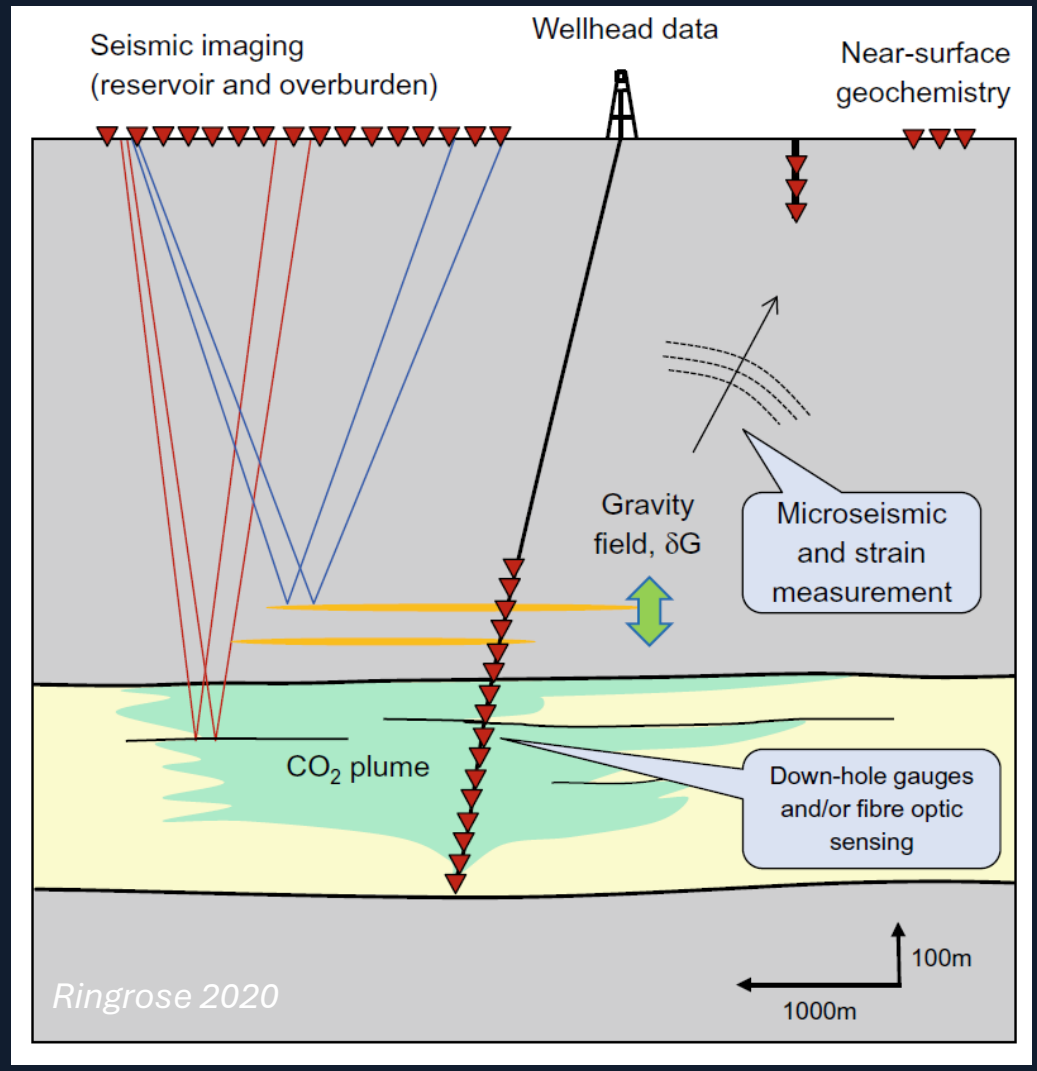
MMV: Programme Design

Site-specific CO_2 Storage risks (cont. / cap. / inj.) → Bow-tie analysis (risk mitigation) → MMV technology review & suitability → Design programme for effective MMV

		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

IEAGHG, 2015



Create own but also review existing MMV programmes in the EISB (e.g. Pale Blue Dot report)

MMV: Site Risk Assessment

Risk assessment to understand monitoring requirements

Not all the basin is prospective for storage (capacity, containment, injectivity) – multiple scenarios possible

Confidence

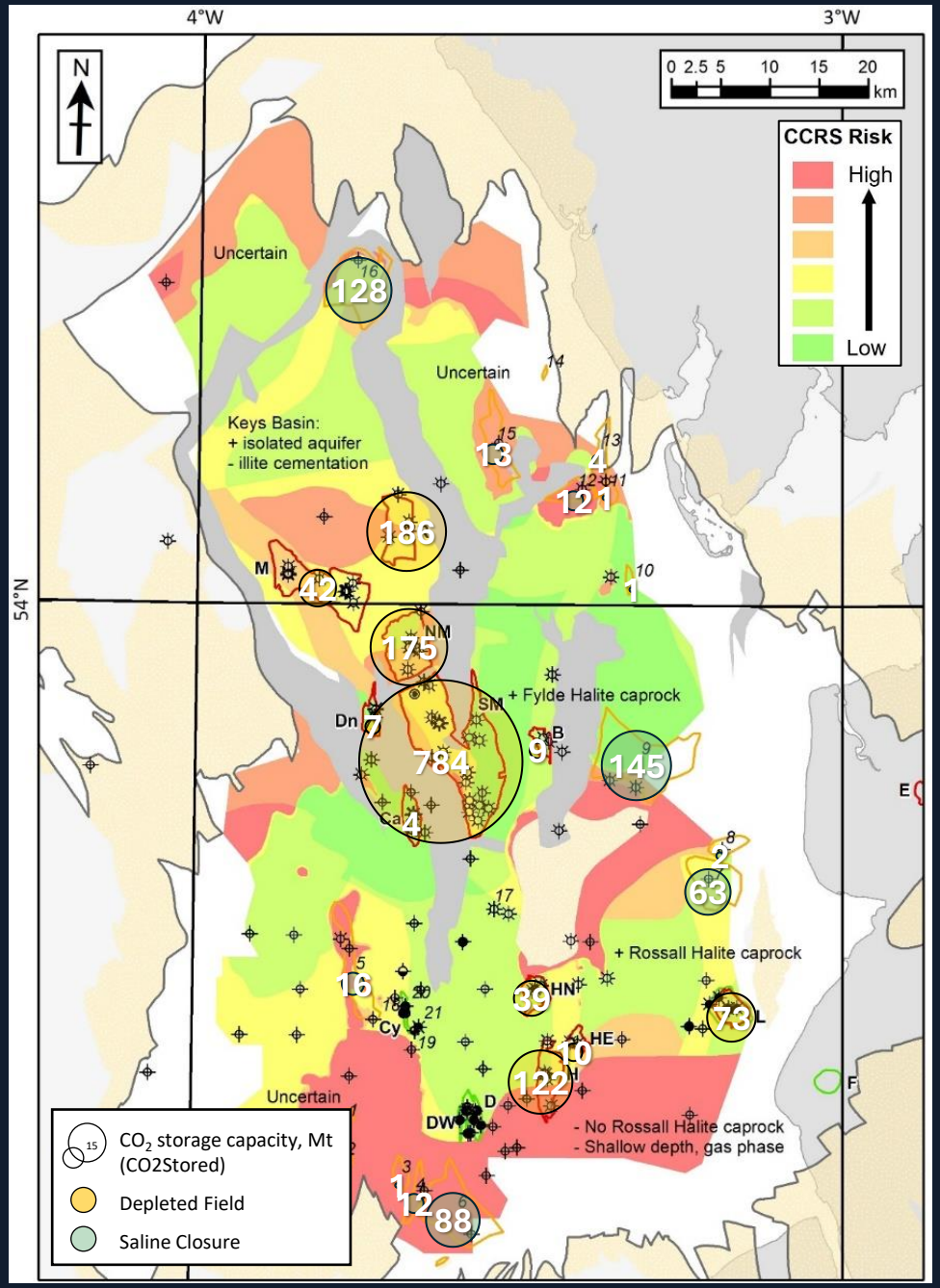
High confidence	Medium confidence	Low confidence	Unknown
Seal degradation Transnational migration Seal chemical reactivity Well vintage Well density	Depositional/diagenetic fabric likelihood Density *Diagenesis* Dip likelihood Dip direction likelihood Fracture pressure capacity *Salinity* Rugosity Throw and fault seal Fault vertical extent	*Mineralogy of grains and cements* *Stratigraphic compartmentalization horizontal* *Stratigraphic compartmentalization vertical* *Structural/fault compartmentalization* Structural trend likelihood	Hydrodynamics *Mechanical integrity* Pressure sinks in storage unit

Capacity

Severity of Impact	low	medium	high
Low	Seal chemical reactivity Well vintage	*Mineralogy of grains and cements* *Salinity*	Well density
Medium	Depositional/diagenetic fabric likelihood Dip direction likelihood Rugosity *Stratigraphic compartmentalization horizontal* *Structural/fault compartmentalization*	*Diagenesis* Structural trend likelihood	Dip likelihood Fracture pressure capacity
High		Seal degradation Density Throw and fault seal	Fault vertical extent
	Likelihood		

CO_2 Stored

Integrate CRS maps with own risk matrices and compare with CO_2Stored work



Next Steps: Colocation Risks & Scenarios

Following the MMV programme design, what would be impacted by wind farm colocation?

Robertson & McAreavey (2021) identified risks (severity & likelihood) to OW and CS based on practices throughout their lifecycles, as well as possible mitigations and opportunities

Building upon those risks & mitigations, we'll develop colocation scenarios within the EISB.
OW and CS coexistence, compromise, or avoidance?

Robertson & McAreavey, 2021

OFFSHORE WIND \ CCUS	Exploration & Appraisal	Development	Operations & Maintenance	Decommissioning	Post-decommissioning
Development	High = 4 Medium = 12 Low = 1	High = 4 Medium = 12 Low = 1	High = 4 Medium = 14 Low = 1	High = 3 Medium = 7 Low = 1	High = 2 Medium = 7 Low = 1
Installation & Commissioning	High = 5 Medium = 12 Low = 1	High = 7 Medium = 14 Low = 2	**High = 9 Medium = 16 Low = 1**	High = 7 Medium = 9 Low = 1	High = 3 Medium = 9 Low = 1
Operations & Maintenance	High = 5 Medium = 11 Low = 2	High = 7 Medium = 13 Low = 2	**High = 11 Medium = 23 Low = 3**	High = 8 Medium = 14 Low = 3	High = 4 Medium = 14 Low = 3
Decommissioning	High = 1 Medium = 4 Low = 1	High = 2 Medium = 6 Low = 1	High = 5 Medium = 14 Low = 2	High = 4 Medium = 11 Low = 2	High = 1 Medium = 11 Low = 2

Table 5.1: Summary of Identified Risks for Offshore Wind and CCUS Over Project Lifecycle
Note: Table shows risk impact levels and number of risks per project overlap stage.

OFFSHORE WIND \ CCUS	Exploration & Appraisal	Development	Operations & Maintenance	Decommissioning	Post-decommissioning
Development	High = 3 Medium = 9 Low = 5	High = 3 Medium = 9 Low = 5	High = 2 Medium = 10 Low = 7	High = 1 Medium = 5 Low = 5	High = 1 Medium = 4 Low = 5
Installation & Commissioning	High = 4 Medium = 9 Low = 5	High = 5 Medium = 12 Low = 6	High = 5 Medium = 15 Low = 6	High = 4 Medium = 8 Low = 5	High = 2 Medium = 6 Low = 5
Operations & Maintenance	High = 4 Medium = 8 Low = 6	High = 5 Medium = 23 Low = 9	**High = 5 Medium = 23 Low = 9**	High = 4 Medium = 14 Low = 7	High = 2 Medium = 12 Low = 7
Decommissioning	High = 0 Medium = 1 Low = 5	High = 0 Medium = 4 Low = 5	High = 1 Medium = 12 Low = 8	High = 1 Medium = 10 Low = 6	High = 0 Medium = 8 Low = 6

Table 6.1: Summary of Overall Lifecycle Risk Reduction with Good Practice Mitigations

OFFSHORE WIND \ CCUS	Exploration & Appraisal	Development	Operations & Maintenance	Decommissioning	Post-decommissioning
Development	High = 1 Medium = 7 Low = 9	High = 1 Medium = 7 Low = 9	High = 1 Medium = 7 Low = 11	High = 0 Medium = 5 Low = 6	High = 0 Medium = 4 Low = 6
Installation & Commissioning	High = 2 Medium = 7 Low = 9	High = 2 Medium = 11 Low = 10	High = 2 Medium = 14 Low = 10	High = 1 Medium = 10 Low = 6	High = 1 Medium = 6 Low = 6
Operations & Maintenance	High = 2 Medium = 5 Low = 11	High = 2 Medium = 9 Low = 11	High = 2 Medium = 16 Low = 18 Very low = 1	High = 1 Medium = 11 Low = 12 Very low = 1	High = 1 Medium = 7 Low = 12 Very low = 1
Decommissioning	High = 0 Medium = 1 Low = 5	High = 0 Medium = 4 Low = 5	High = 0 Medium = 9 Low = 11 Very low = 1	High = 0 Medium = 7 Low = 9 Very low = 1	High = 0 Medium = 4 Low = 9 Very low = 1

Table 6.4: Summary of Overall Lifecycle Risk Reduction with Potential Future Practice Mitigations

Reference List:

CO2Stored. 2024. CO2 Stored database, © The Energy Technologies Institute LLP, NERC and The Crown Estate. All rights reserved. https://www.co2stored.co.uk/home/index

IEAGHG. 2015. Review of Offshore Monitoring for CCS Projects. 2015/02.

NSTA. 2023. Seismic Imaging within the UKCS Energy Transition Environment, Part B: Geophysical Technologies. Technical Report.

Ringrose, P. 2020. How to Store CO2 Underground: Insights from Early-Mover CCS Projects. SpringerBriefs in Earth Sciences, https://doi.org/10.1007/978-3-030-33113-9.

Robertson, S. and McAreavey, J. 2021. CCUS & Offshore Wind Overlap Study Report.

GO BEYOND BOUNDARIES

Project CoLocate

Undertaken at the Interdisciplinary Centre for Energy Transition, **University of Aberdeen**
Prof. John Underhill, Principal Investigator

To inform the Offshore Wind and CCUS **Colocation Forum**

Two 1-year projects, funded by **The Crown Estate** & **The Crown Estate Scotland**

1. East Irish Sea

Dr Sam Head, Research Fellow

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2. Outer Moray Firth

PDRA TBA

Crown Estate Scotland
Oighreachd a' Chrùin Alba

1495 UNIVERSITY OF ABERDEEN

6th March 2024

Project Anemone

Update from Gordon Walker

Project Coordinator at NECCUS

Offshore Colocation Forum

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Project Anemone – Objectives

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 – Overview

Stakeholder Mapping

Identify and map stakeholders and their interactions across development, operation and decommissioning of offshore windfarms and carbon storage sites

Operational & Remediation Studies

Work with the CCUS and wind developers to gain an understanding of their operations and requirements

Opportunities & Synergies

Identify where, when and under which conditions opportunities from co-location are likely to occur as well as any areas of conflict or collaboration

Opportunity & Synergy Development

Building on the opportunities how can conflicts be resolved and opportunities enhanced

Project Anemone – Status

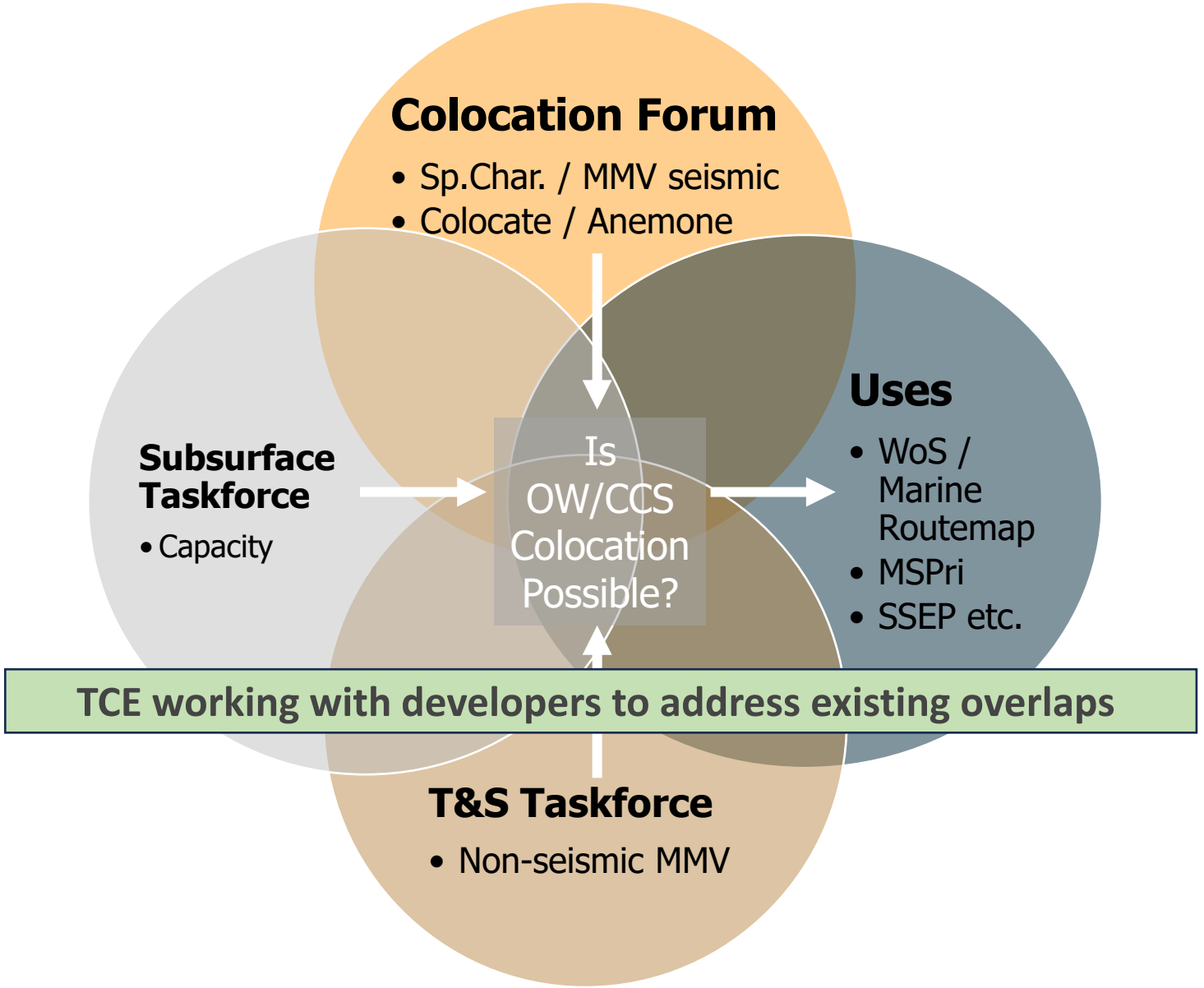
- Several potential partners for the project have been contacted and are interested in further involvement.
- The organisations involved are:
    - Bluefloat
    - Enquest
    - Marram Wind
    - Buchan Offshore Wind
    - Shell
    - Equinor
- This is in addition to the existing partners.
- This led to the organisation of an in-person meeting with the interested parties.
- This meeting is scheduled for March with a confirmed date to be communicated to the partners this week.

Project Anemone – Next steps

- Once the in-person meeting has been held there will be a further round of discussions with those who sign up to support the project to finalise the work packages and responsibilities.
- From this the full project plan and deliverables will be generated and distributed to relevant parties.

Interplay between the Forum and other bodies

Bodies working on colocation-related content



Offshore Colocation Forum

Is OW/CCS Colocation possible?

TCE's three-way discussions with developers and NSTA will identify solutions to existing overlaps; Forum is considering future solutions

Offshore Colocation Forum

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)				

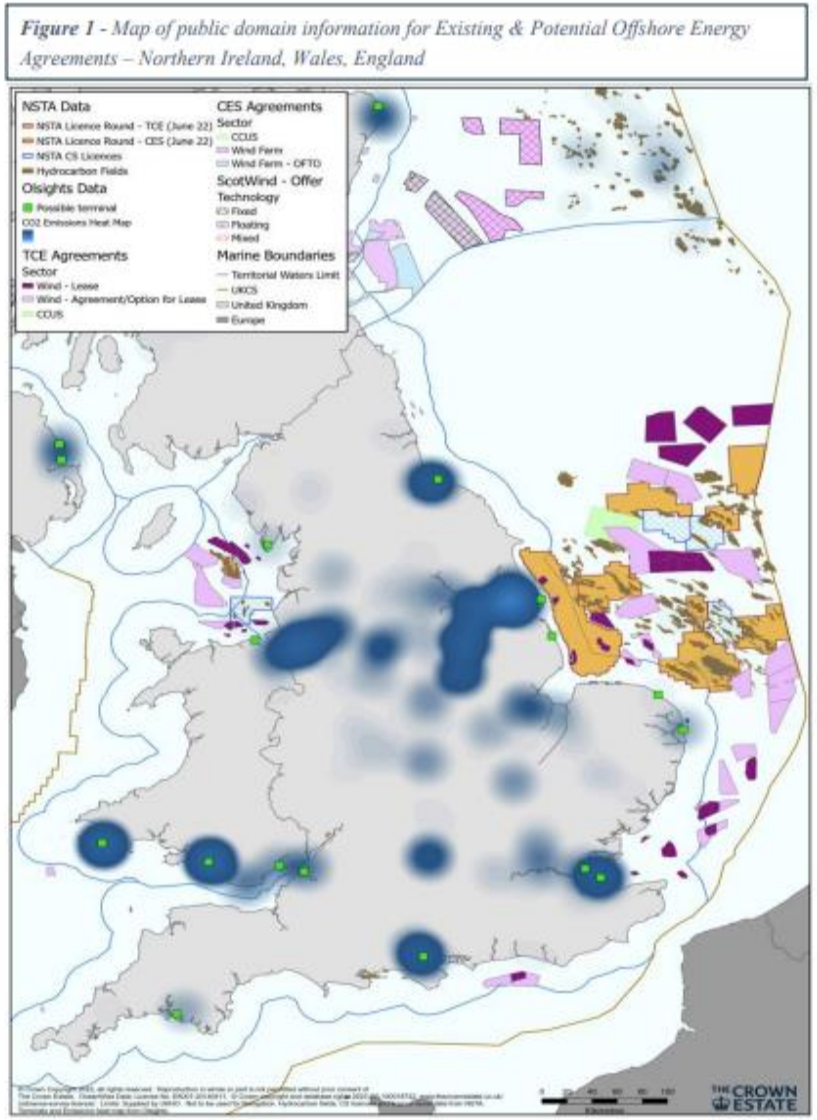


Figure 1 - Map of public domain information for Existing & Potential Offshore Energy Agreements – Northern Ireland, Wales, England

Offshore Colocation Forum

NSTA CCS T&S Taskforce: MMV Subgroup

Update from Elle Lashko

CO2 Storage Geoscientist at Storegga

Offshore Colocation Forum

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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 – Update

- Project duration ~8 months, with members from industry
- Final report submitted to the CCUS T&S Taskforce this week
- Report to be published via NSTA website in due course

Approach

MMV Subgroup – Update

5 technologies identified. Each have pros and cons that make them suited to different store types:

Time-lapse surface gravity	Detects the change in gravitational field caused by low density CO_2 displacing higher density pore fluid in the reservoir. Repeated measurements from same locations on the seabed. Could be beneficial in depleted fields, where the anticipated seismic signal is low.
Time-lapse surface seismic (2D)	Repeat 2D seismic lines in targeted locations to monitor critical locations. Acquisition using a conventional or short streamer vessel depending on store depth.
Time-lapse S-DAS	Emerging technology currently being developed. Permanent DAS (Distributed Acoustic Sensing) fibre-optic cable is deployed on the seabed which could, in theory, monitor both active and passive sources. Only suitable for stores <1500m depth. Relatively low technology readiness
Time-lapse VSP-DAS	Permanent fibre installed in wells to monitor active sources (in the injection well) and passive sources (in a monitor well). Repeat seismic can be quickly acquired close to the wellbore and is proven in the hydrocarbon industry.
Surface microseismic	Established technology in the hydrocarbon industry to monitor hydraulic fracturing and assess geomechanical stability. Effective in multiple store types, especially when deployed as a network.

MMV Subgroup – Update

Technology	Store Depth		Development Type		Seismic Signal			Store Type		Cluster store options for trials
	Shallow (~1000m)	Deep (~2000m)	Subsea	Platform	Good - store	Poor - store	Good - overburden	Saline aquifer	Depleted field	
Time-lapse surface gravity										Hynet, Endurance
Time-lapse surface seismic (2D)										Endurance, Acorn
Time-lapse S-DAS										Hynet, Endurance, Viking
Time-lapse VSP-DAS										Viking, Hynet
Surface microseismic										Hynet, Endurance

Legend: Ranking of the likely technology performance in various scenarios		
Likely good	Performance possible but not best suited	Likely poor

Next developer Event -

Monitoring 101

Developer Event – OW & CCS *Monitoring 101*

Presentations from UoA and NSTA in Plenary #8 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".

A panel of OW and CCS experts

Elle Lashko
CO2 Storage Geoscientist, Storegga

Dr Amy Bloomfield Clarke
Development Manager, CCUS, The Crown Estate

Professor Simon Hogg
Ørsted Chair in Renewable Energy, Durham University

Michael Blair
Senior Technical Manager, The Crown Estate

Objectives

- Existing monitoring techniques within OW and CCS industries
- Challenges existing monitoring techniques present to colocation of OW and CCUS
- How challenges from existing techniques can be resolved through innovations in respective industries

- **Location:** 1 St James's Market, London, SW1Y 4AH
- **Time:** 18:00-20:30
- **Format:** Panel event with Q&A, followed by drinks reception and canapes

Offshore Colocation Forum

Norway visit – Equinor "Northern Lights" CCS site

Equinor "Northern Lights" CCS site visit

Where: Northern Lights Project, Bergen, Norway

When: 5 June 2024, to coincide with Colocation Forum Plenary #11

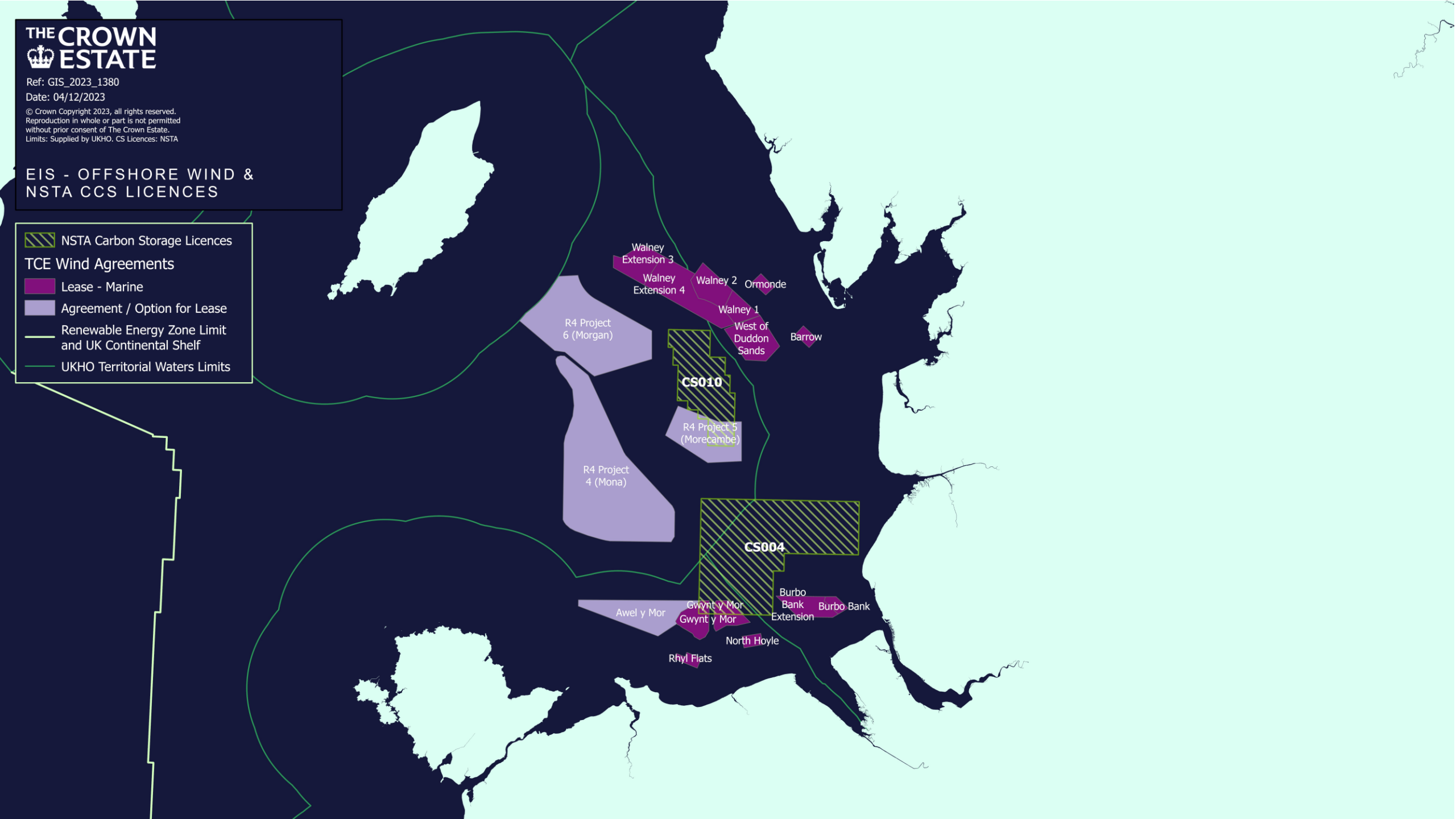
Who: Forum members, selected OW / CCS developers, Secretariat

Formal invitations will be circulated by the Secretariat following plenary meeting #10.

Key objectives:

- Strengthen cross-sectoral understanding of CCS and the challenges and opportunities of colocation
- Further establish the Colocation Forum as a convener and thought leader in OW / CCS colocation
- Give Forum members and guests the opportunity to see part of a CCS project first-hand

Appendix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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
Walney Extension 3
Walney Extension 4
Walney 2
Ormonde
Walney 1
West of Duddon Sands
Barrow
R4 Project 6 (Morgan)
CS010
R4 Project 5 (Morecambe)
R4 Project 4 (Mona)
CS004
Burbo Bank Extension
Burbo Bank
Awel y Mor
Gwynt y Mor
Gwynt y Mor
North Hoyle
Rhyl Flats


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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
CS001
CS006
CS007
CS022
Hornsea Project Four (HOW04)
Hornsea Project 2 - Phase 2 (Soundmark)
Hornsea Project 2 - Phase 1 (Breesea)
Hornsea Project 2 - Phase 3 (Sonningmay)
Hornsea 1 (Centre)
Hornsea 1 (West)
Hornsea 1 (East)
Hornsea Project Three (HOW03)
Westermost Rough
CS018
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
Norfolk Boreas
CS009
CS008
CS019
Norfolk Vanguard West
Norfolk Vanguard East
East Anglia THREE


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Lease Type
Lease Marine
Agreement/Option for Lease
Renewable Energy Zone Limit and UK Continental Shelf
UKHO Territorial Waters Limits
CS013
CS014
CS016
CS015
Sealtainn Offshore Wind Farm
Arven South
Arven Offshore Wind Farm
West of Orkney Wind Farm
Havbredey
Pentland Floating Offshore WF
Talisk Offshore Wind Project
Spiorad na Mara
Ayre Offshore Wind Farm
Beatrice Offshore Wind Farm
Stromar
Moray West
Moray Offshore Windfarm (East)
Buchan Offshore Wind Farm
Caledonia Offshore Wind Farm
Broadshore
CS012
CS003
CS011
Marram
Buchan Deep Demo
Muir Mhor
Aberdeen Offshore Wind Farm
Campion
Bowdun Offshore Wind Farm
Kincardine
Bellrock
Morven
Ossian Offshore Wind Farm
Seagreen Phase 1 Windfarm
Seagreen 1A Offshore Wind Farm
Inch Cape Offshore Wind Farm
Berwick Bank Wind Farm
Marr Bank Wind Farm
Neart na Gaoithe Offshore WF
Methil Demo
2B Energy Methil Demonstration
MachairWind