Offshore Colocation Forum

Offshore Wind and CCUS Colocation Forum

Plenary #11 – June 2024

THE CROWN ESTATE

Agenda

1. **Reflections on Northern Lights visit** – Chair – 15 mins
2. **Matters Arising** – Secretariat – 5 mins
3. **Project Colocate** – Virtual update from Prof John Underhill, Dr Sam Head, and Dr Nigel Platt, University of Aberdeen – 20 mins
4. **Project Anemone** – Philippa Parmiter, NECCUS – 20 mins
5. **Non-technical workstreams** – Chair – 15 mins
6. **Next Plenary Dates** – Secretariat – 5 mins
7. **AOB & Actions Review** - Secretariat - 10 mins

Norway visit – Equinor "Northern Lights" CCS site

"Northern Lights" visit summary

Financing

Monitoring

Business model

Maintenance schedule

Other reflections

Matters Arising

Matters Arising

Action	Owner	Status	Action	Owner	Status
Project Colocate Advisory Group Meeting	Project Colocate advisory group members	Meeting took place on 03.05	Northern Lights visit in Bergen, Norway	Grayling	Visit taking place
Project Colocate update on Outer Moray Firth project	UofA	Update in Plenary #11	Explore how the Forum can quantify / categorise decarbonisation contribution of colocation	TCE	Update in Plenary #11
Geneva Association CCS insurance framework report	Grayling	Report circulated as pre-reading	T&S Taskforce Monitoring sub-group report	T&S Taskforce	Report circulated as pre-reading
RUK / TCE webinar	RUK / TCE	To be progressed post-Northern Lights visit	Consider establishing a cross-industry liabilities / risk assurance workstream	TCE	Update in Plenary #11

Project Colocate

Update from Professor John Underhill

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

Dr Sam Head

Research Fellow, University of Aberdeen

Dr Nigel Platt

Research Fellow, University of Aberdeen

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GO BEYOND BOUNDARIES

Offshore Colocation Forum

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 (OCF)**

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

Dr Nigel Platt, Research Fellow

Crown Estate Scotland
Oighreachd a' Chrùin Alba

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3rd May 2024

Project CoLocate Aims & Objectives

***(1)** Define potential areas for OW and CS*	• Identify areas of colocation with offshore seabed and subsurface users, highlighting areas of multiple potential future uses in prospective areas
***(2)** Design colocation monitoring plans*	• Storage risk assessment, including integrity of legacy boreholes and other infrastructure - "What monitoring data is required?"
***(3)** Explore the viability of colocation projects*	• produce a series of scenarios where multiple sector, potential future use is possible • Evaluate and rank specific proposals

Seek input from wider stakeholders
with offshore interests

Project CoLocate Engagements

- **Spirit Energy, Morecambe Net Zero, Aberdeen – 4/March**
- **Technical Advisory Board, CES, Edinburgh – 3/May**
- **Floatation Energy Kincardine Offshore Floating Wind Fieldtrip – 18/June**
- **Shell Acorn CCS Masterclass – 19/June**
- **The Crown Estate/ORE Catapult Session – Glasgow, 20/June**


Project CoLocate
1. East Irish Sea
THE CROWN ESTATE
2. Outer Moray Firth
Crown Estate Scotland
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East Irish Sea: Carbon Storage site Risk Assessment

To understand monitoring requirements, this study used the CO_2Stored risk parameters and criteria and evaluated the available data to reassess the risk to storage for the site

CO_2 Stored

Depleted Fields (n=9)

Highest Risks:

Fault density, Pressure isolation, Seal degradation

Lowest confidence:

Fracture pres. capacity, Dip, Rugosity

Saline closure (n=4)

Highest Risks:

Seal reactivity, Pressure isolation, Hydrodynamics

Lowest confidence:

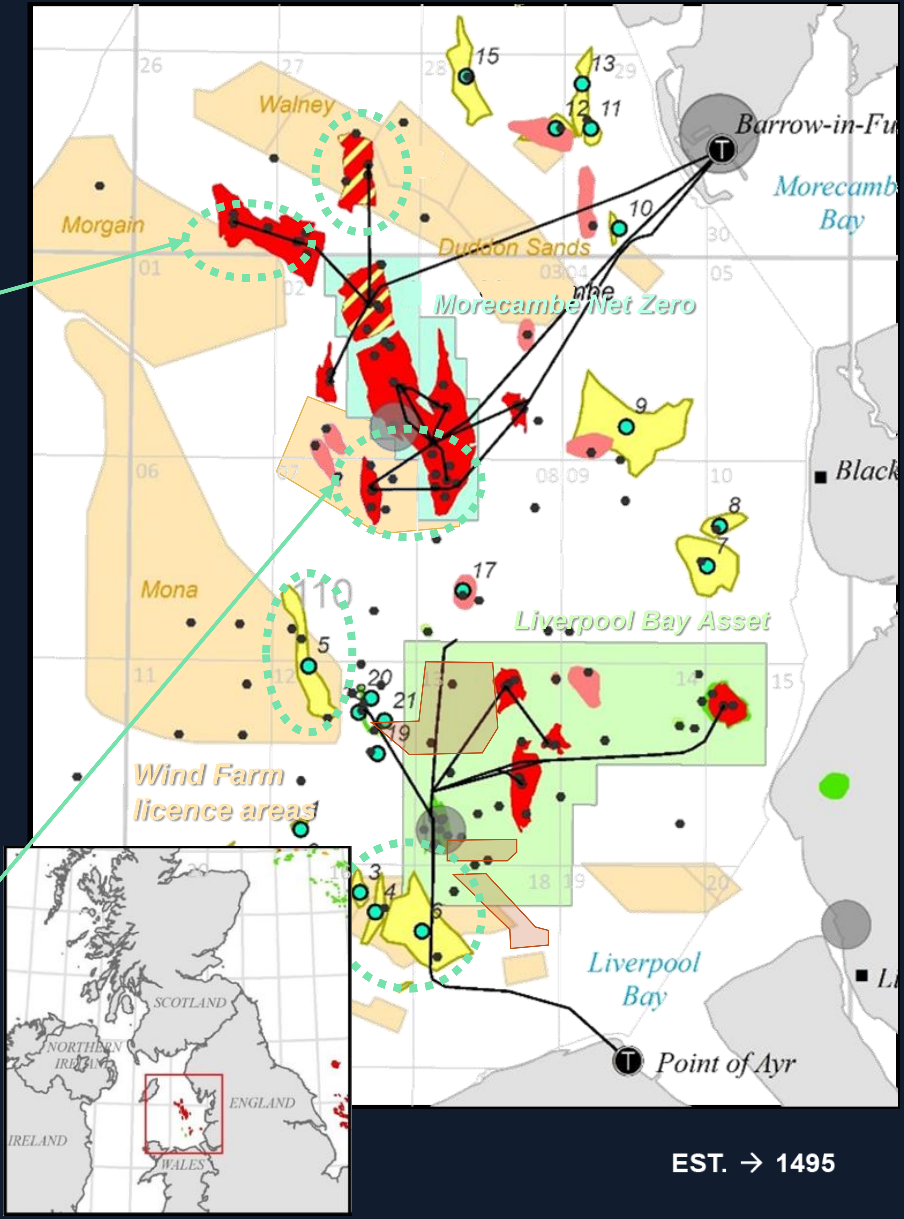
Fracture pres. Capacity, Fault density, Compartmentalisation

Millom

Severity of Impact	Likelihood: Low (1)	Likelihood: Medium (2)	Likelihood: High (3)
Low (1)	Seal chemical reactivity	*Mineralogy of grains and cements*	*Salinity*
Medium (2)	Transnational migration Dip direction likelihood Fracture pressure capacity *Stratigraphic compartmentalisation, vertical* Rugosity	*Stratigraphic compartmentalisation, horizontal* *Diagenesis* Depositional/diagenetic fabric *Structural/Fault compartmentalisation*	Structural trend likelihood Dip
High (3)	Fault vertical extent	Seal degradation Throw and fault seal	Pressure isolation Fault density

South Morecambe

Severity of Impact	Likelihood: Low (1)	Likelihood: Medium (2)	Likelihood: High (3)
Low (1)	Seal chemical reactivity		*Mineralogy of grains and cements* *Salinity* Pressure isolation
Medium (2)	Transnational migration Dip direction likelihood Fracture pressure capacity Rugosity Hydrodynamics *Stratigraphic compartmentalisation, horizontal* Pressure sinks in storage unit Mechanical integrity	Dip	*Diagenesis* Structural trend likelihood Depositional/diagenetic fabric *Stratigraphic compartmentalisation, vertical*
High (3)	Seal degradation	Throw and fault seal	Fault vertical extent Fault density Well density Well vintage



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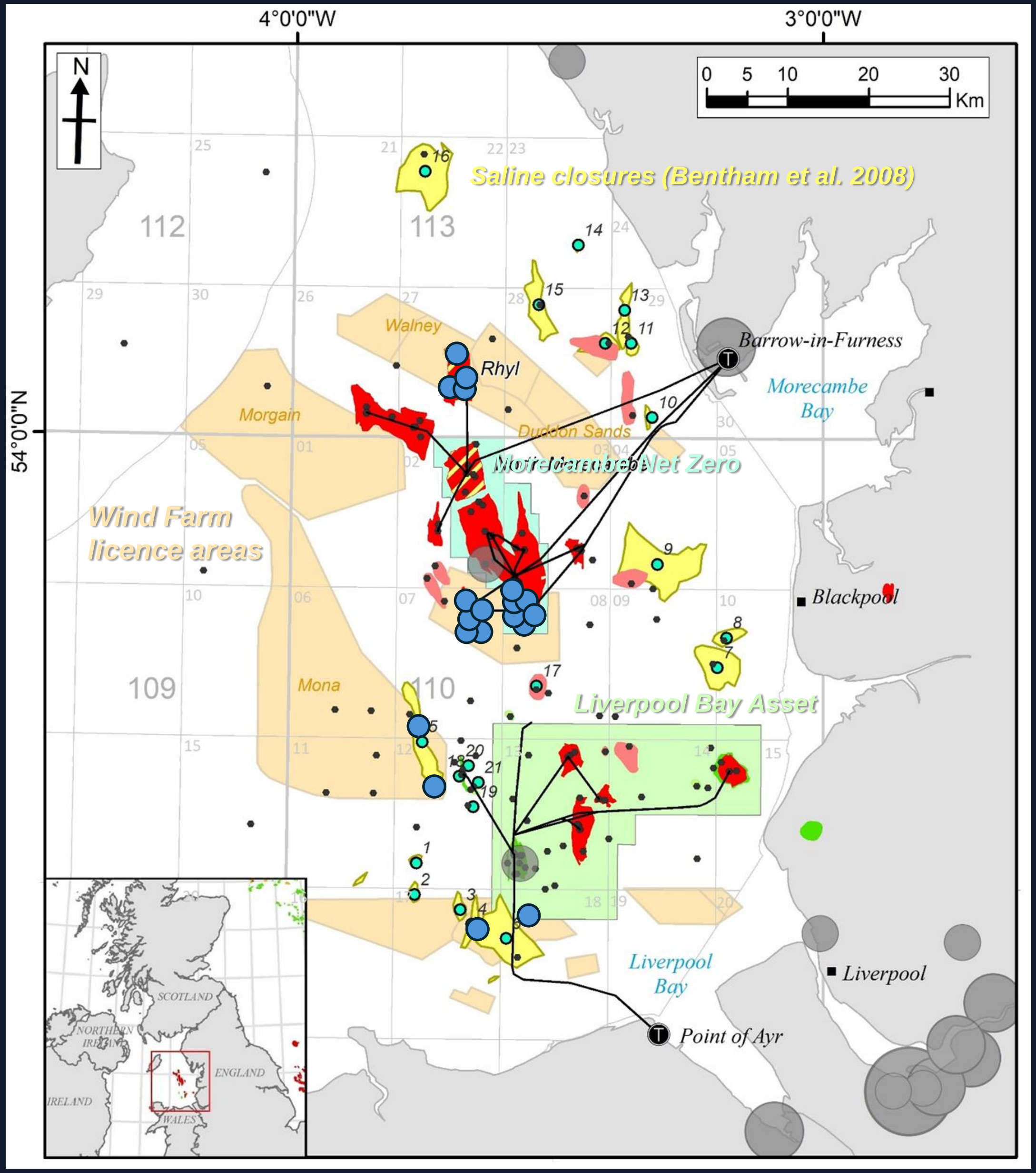
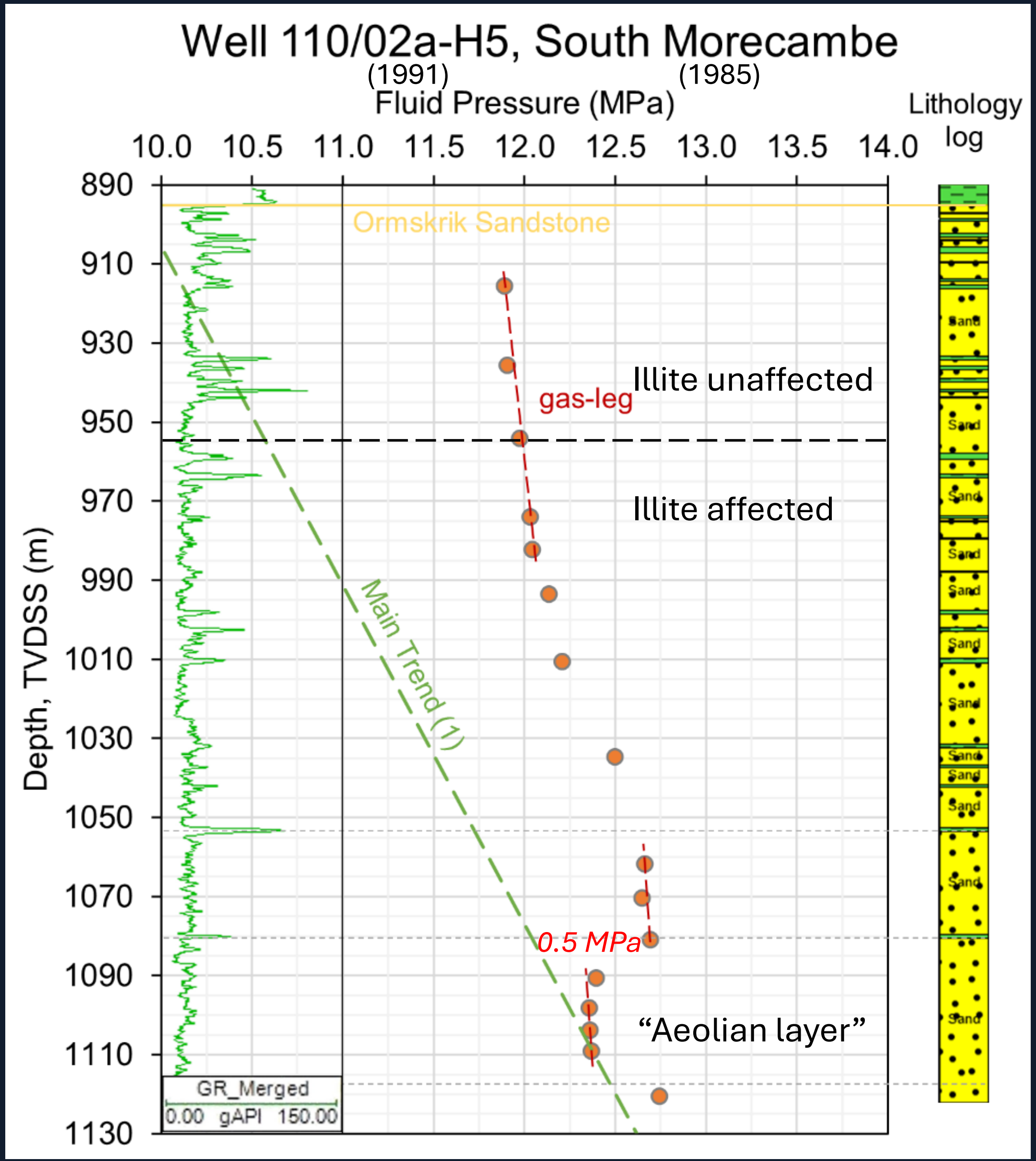
East Irish Sea: Legacy Well Risk Assessment

● = assessed well

Offshore Well	CS prospect	Wind Farm licence area	Compl. year	Aban. year	Plugs abov. res.	Data Confid. (1-5)
110/08-2	S. Morecambe	Morecambe	1969	1969	4	3
110/08a-C1	S. Morecambe	Morecambe	1984	2020	1?	3
110/08a-C2	S. Morecambe	Morecambe	1984	2020	2?	3
110/08a-C3	S. Morecambe	Morecambe	1985	2020	1?	3
110/08a-C4	S. Morecambe	Morecambe	1985	2020	1?	3
110/08a-C5	S. Morecambe	Morecambe	1985	2020	1?	3
110/08a-C6	S. Morecambe	Morecambe	1985	2020	1?	3
110/07-3	S. Morecambe	Morecambe	1982	1982	2	
110/07a-4	Calder	Morecambe	1983	1983	2	
110/07a-T1*	Calder	Morecambe	2003	Unknown	-	
110/07a-T1Z	Calder	Morecambe	2003	Unknown	-	
110/07a-T2	Calder	Morecambe	2003	Unknown	-	
110/07a-T3	Calder	Morecambe	2003	Unknown	-	
110/07-1	Calder	Morecambe	1974	1974	4	3
110/07-8	Calder	Morecambe	1994	1994	3	
113/27-1	Rhyl	Walney extension 4	1986	1986	4	2
113/27b-6	Rhyl	Walney extension 4	2009	2009	2	4
113/27b-7	Rhyl	Walney extension 4	2012	Not	-	
113/27b-8	Rhyl	Walney extension 4	2012	Not	-	
113/27b-9	Rhyl	Walney extension 4	2013	2019	1?	5
110/17-1	OC4	Gwynt y Mor	1994	1994	1	2
110/07b-6	OC5	Mona	1988	1988	2	2
110/12b- 2	OC5	Mona	1991	1991	1	2
110/18-1	OC6	Gwynt y Mor	1996	1996	2	2



East Irish Sea: Regional Risks to Storage



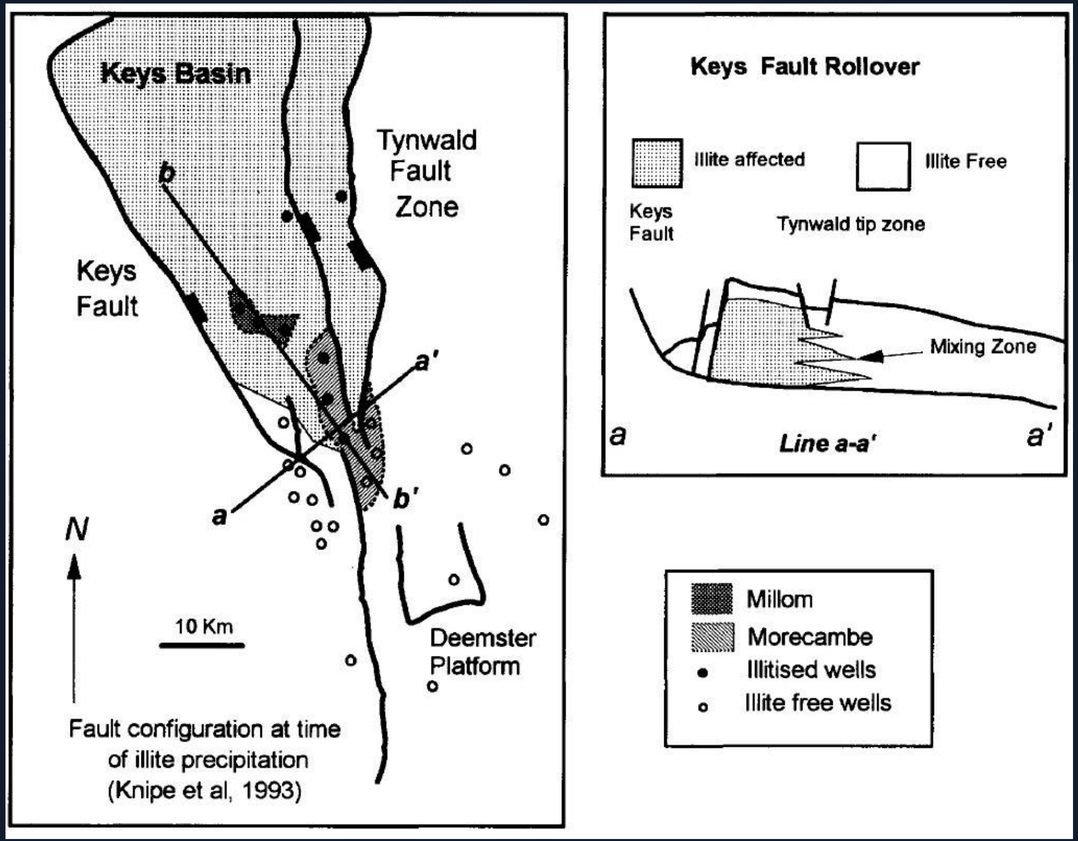
Modified after Cowan (1993)

e.g. Pressure Baffles

Differential pressure depletion due to reservoir heterogeneity (**illite cement, mudstone interbeds**, & high permeability **aeolian facies**)

Heterogeneity impacted depletion and, possibly, will CO_2 migration too

Which, as a result, will impact conformance monitoring



Cowan & Bradney (1997)

East Irish Sea: MMV Requirements

Conformance assurance: CO_2 migration mapping, update dynamic models, verify capacity

Risk to CO_2 storage	- **Pressure baffles** (*igneous dykes, mudstone interbeds, and illite cement*) reduce reservoir connectivity and, possibly, limit injectivity and capacity
MMV techniques for conformance assurance	- Surface seismic (detectability?) - Borehole seismic (lateral resolution?) - Microseismicity (resolution?) - Micro gravity (sufficient vertical res.?) - Downhole press. & temp. gauges
Contingency requirements	- Rig (vessel and heliop) access for a new well (in the event of capacity or injectivity not being achieved in the first place)
Colocation conflicts	- Rig (vessel and heliop) access for drilling secondary wells - Limited area for secondary well location - Surface seismic acquisition (if conventional)
Possible solutions to Colocation conflicts	- Different surface seismic acquisition methods (OBN, DAS) - CO_2 detectability and seismic resolution is too poor - Rig access corridors to contingency well locations

East Irish Sea: Next Steps

Deliverable 2: Design specific colocation project proposals

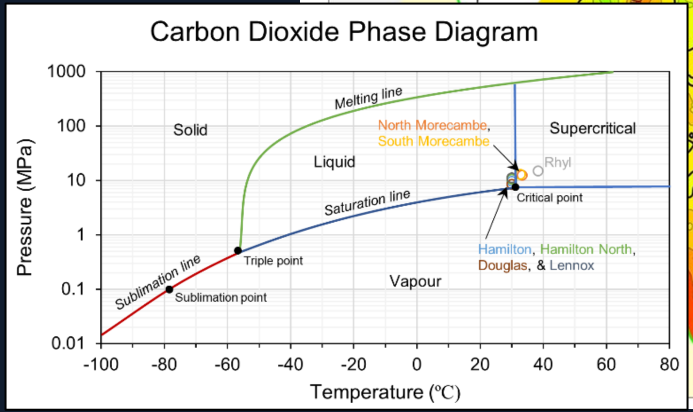
- Identify any CRS that could be de-risked across a larger area
- Design monitoring plans/define ideal techniques
- Identify co-location risks, opportunities, and solutions (MMV options)

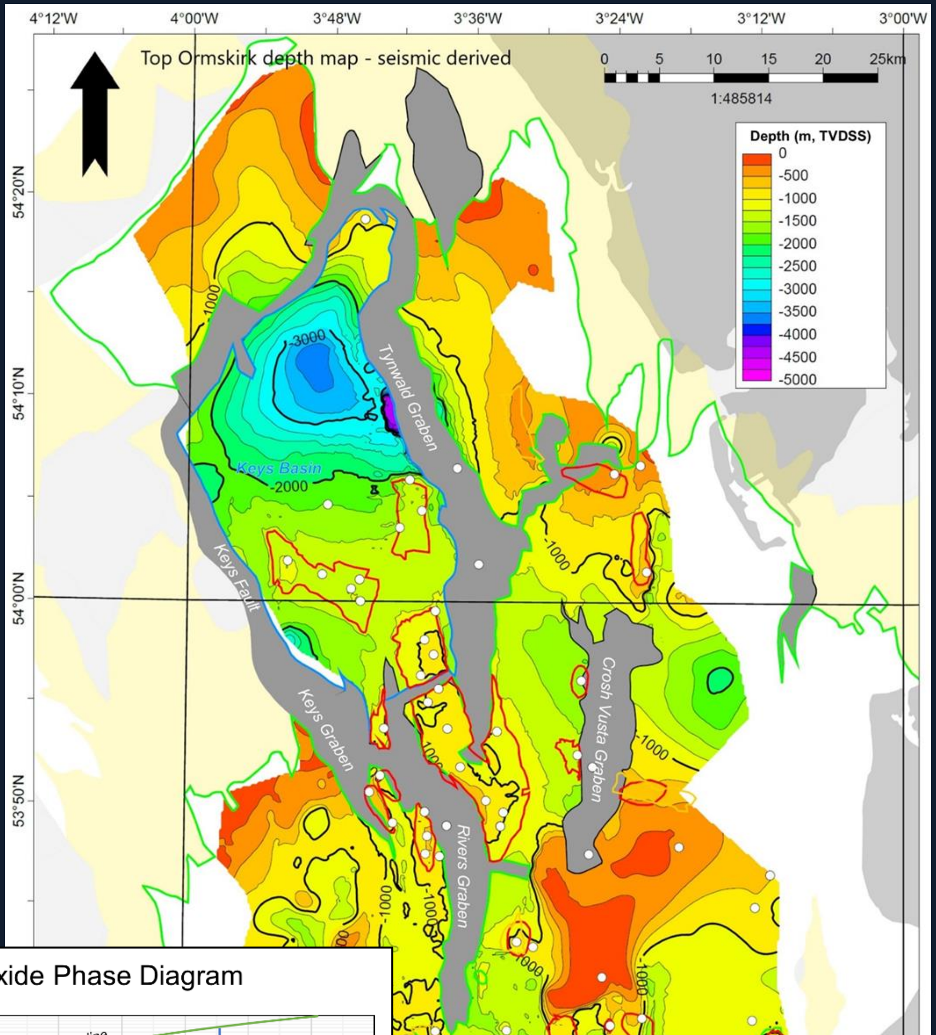
Deliverable 3: Define, evaluate, and rank scenarios for viable colocation projects

- Don't colocate (what is prioritised?)
- Can colocate (MMV solutions, Demonstrated?)
- Degree of compromise (Regulatory decision?)

Where will subsurface CO_2 be seismically detectable in the reservoir and overburden for conformance and containment assurance?

Partially fluid phase dependent, surface and subsurface conditions (velocity, frequency, porosity)





Project Colocate: June 2024
Outer Moray Firth

- Outer Moray Firth Colocation Update
- Acorn: ‘MMV gold standard’: 4D, or not 4D ?
- MarramWind consultation
- Quantifying the decarbonisation effect of Colocation

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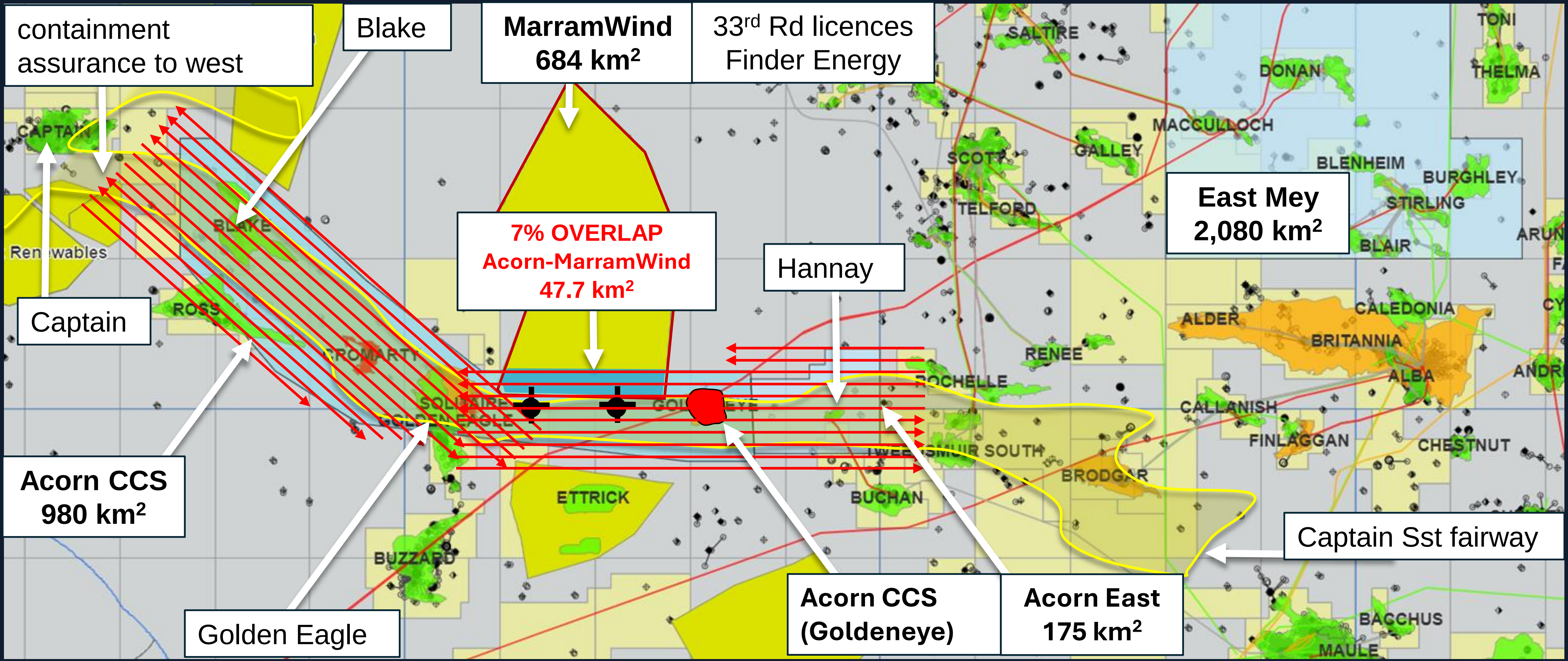
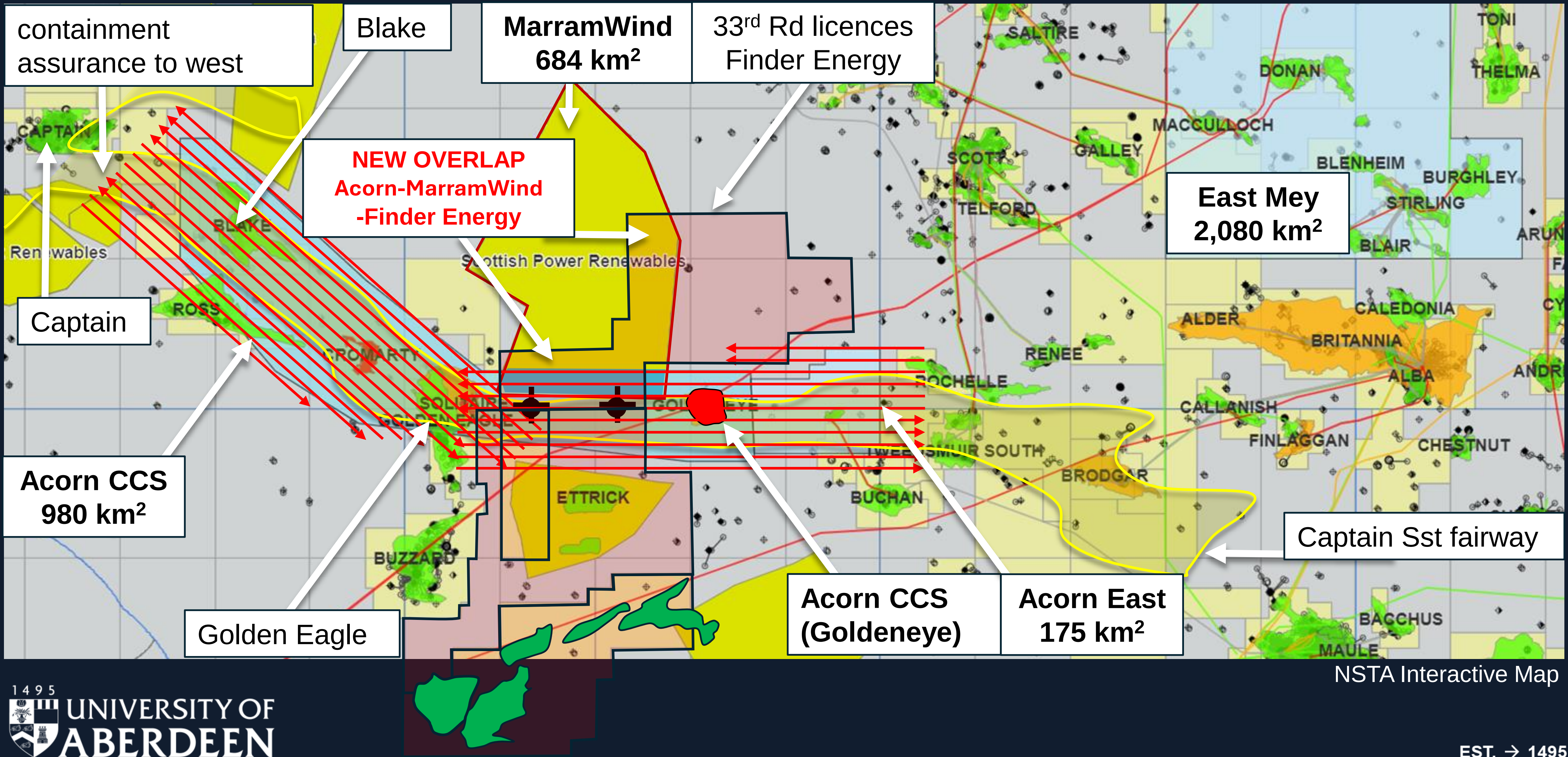
Acorn CCS baseline 3D (schematic concept)



NSTA Interactive Map

New 33rd Round oil and gas licences offered



NSTA Interactive Map

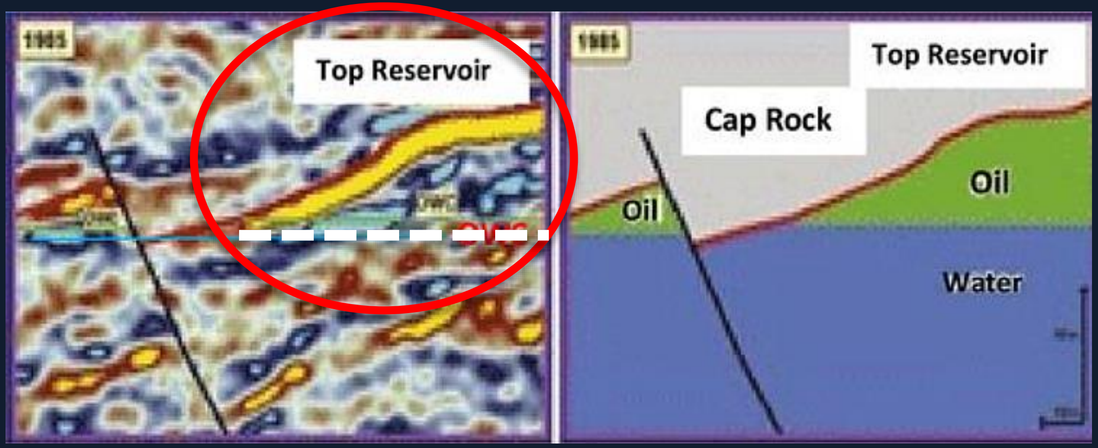
MMV 4D seismic – introduction

1) 4D AVO (amplitude variation with offset) and seismic inversion is routinely used for fluid detection in oil and gas E&P

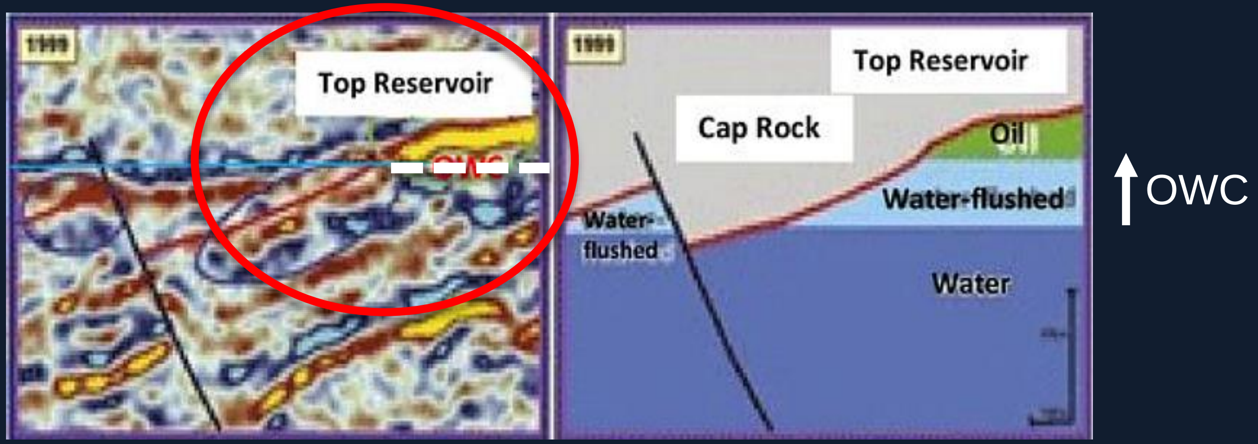
2) The different fluid densities of water, oil, gas and CO_2 affect host rock velocity and Vp/Vs

3) Fluid effects are typically seen on far offsets → long offset seismic data are required: > 4500 m

1985



1999



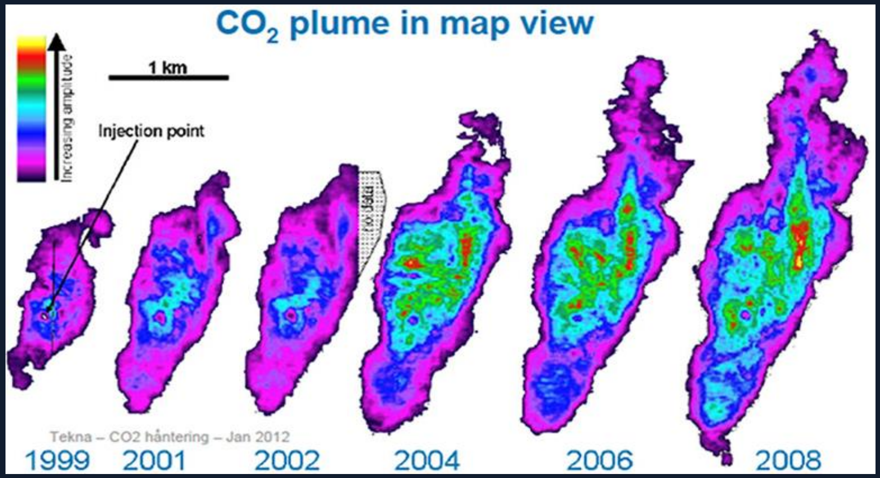
Alvarez et al. 2016

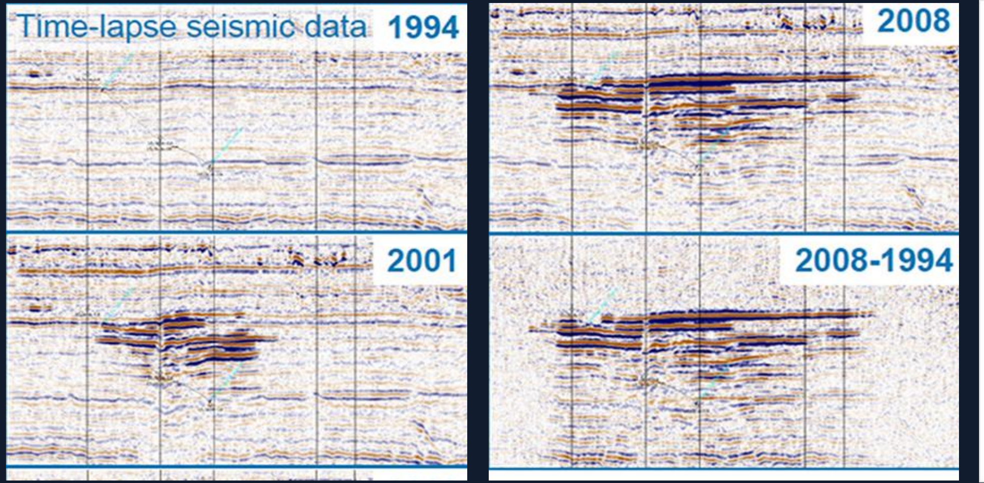
4D seismic – Sleipner CCS case study

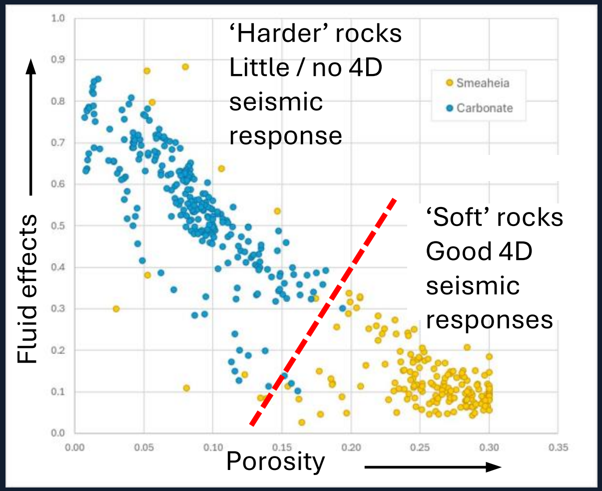
For CCS, a key question is: “do seismic amplitudes change by a discernible amount due to CO_2 injection?”

‘Soft’ rocks [**as at Sleipner**], hold greater proportions of fluids, with a greater effect on bulk rock properties

The well-documented Sleipner CCS example shows clearly demonstrated CO_2 plume effects on 4D seismic.







RPS / Equinor

Merlin Energy Resources / Equinor / Gassnova

Will the same effects be visible at Acorn CCS?

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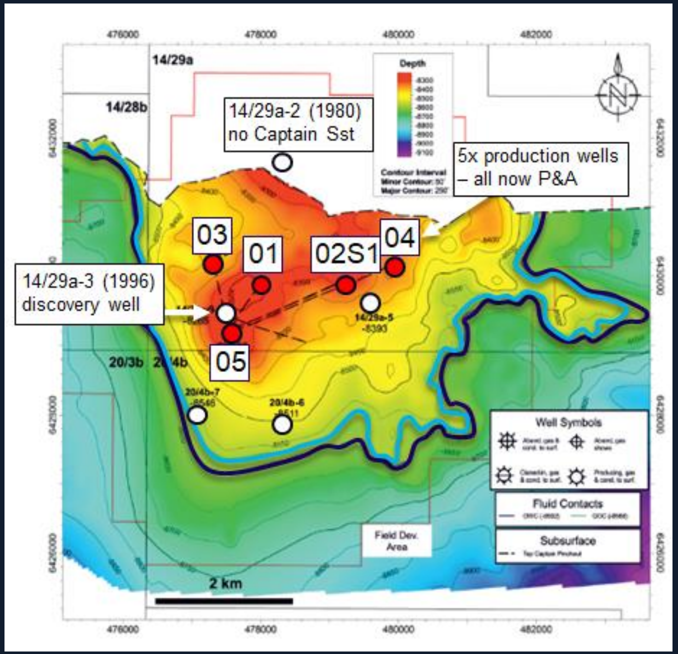
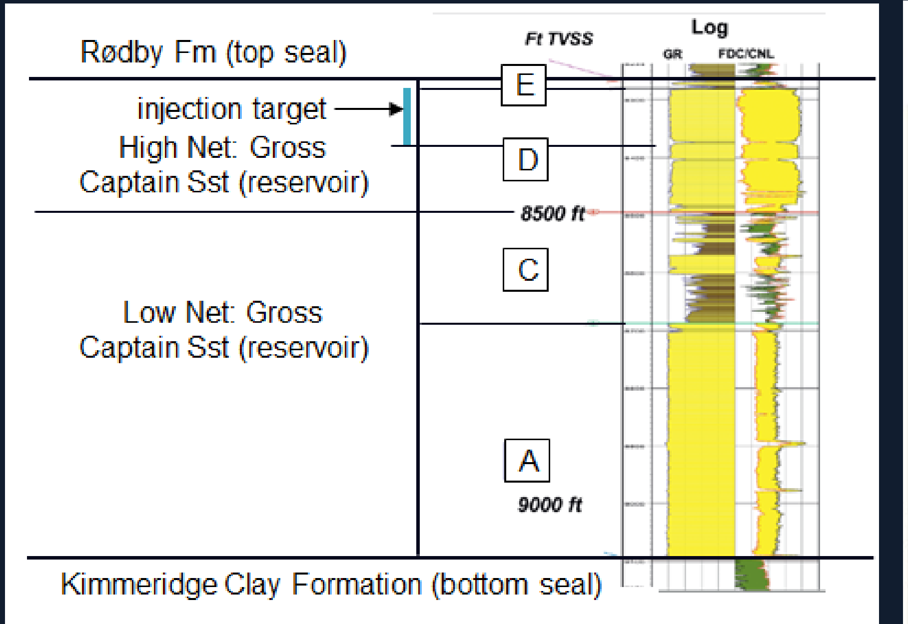
Marshall et al. 2018

4D seismic – Acorn CCS / Goldeneye rock physics



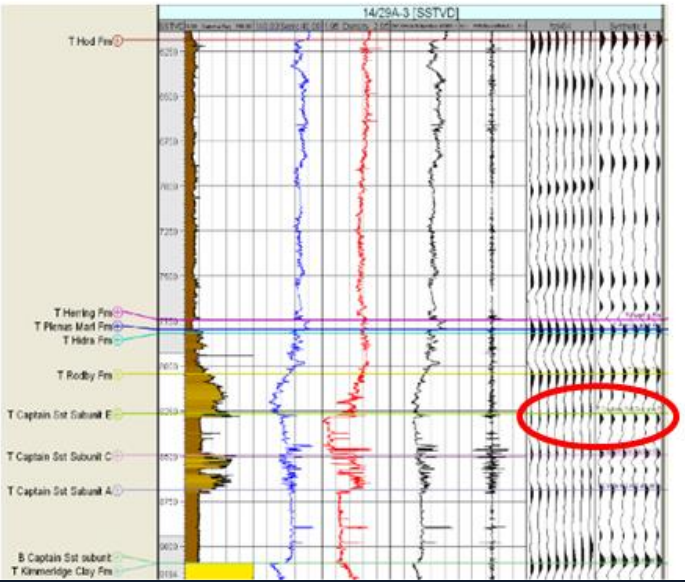
Fluid detection results are typically seen in shallower reservoirs on high frequency data

Property	Threshold	Sleipner		Acorn / Goldeneye	
Porosity	>15%	32-42%	✓	21-25%	✓
Velocity	<3000-3500 m/s	2050 m/s	✓	3350 m/s	✗ ?
Depths	<3500 m TVDss	800-1012 m	✓	2600 m TVDss	✓
		Chadwick et al. 2015		Marshall et al. 2016	

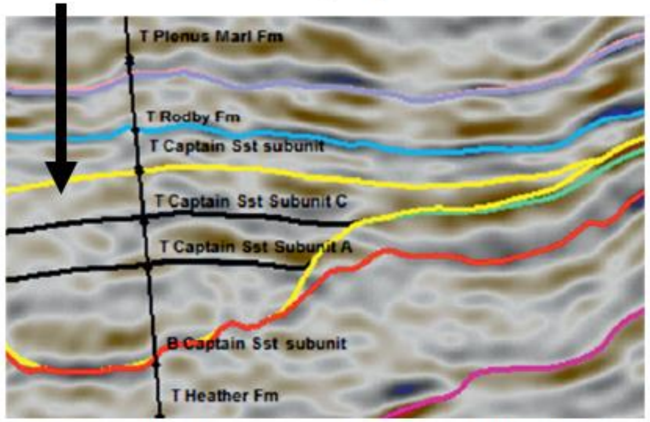


Marshall et al. 2018

Top Captain Sst not a clearly mappable reflector, so is isochored down from Top Rødby Fm above



Top Captain Sst shows a low acoustic impedance contrast with Valhall & Rødby formations above



Some residual gas remains, so fluid substitution will be < 100%. The Captain Sandstone reservoir is not certain to show a clear 4D fluid response

Shell seismic interpretation report 22.05.2015

Acorn CCS: subsurface risks

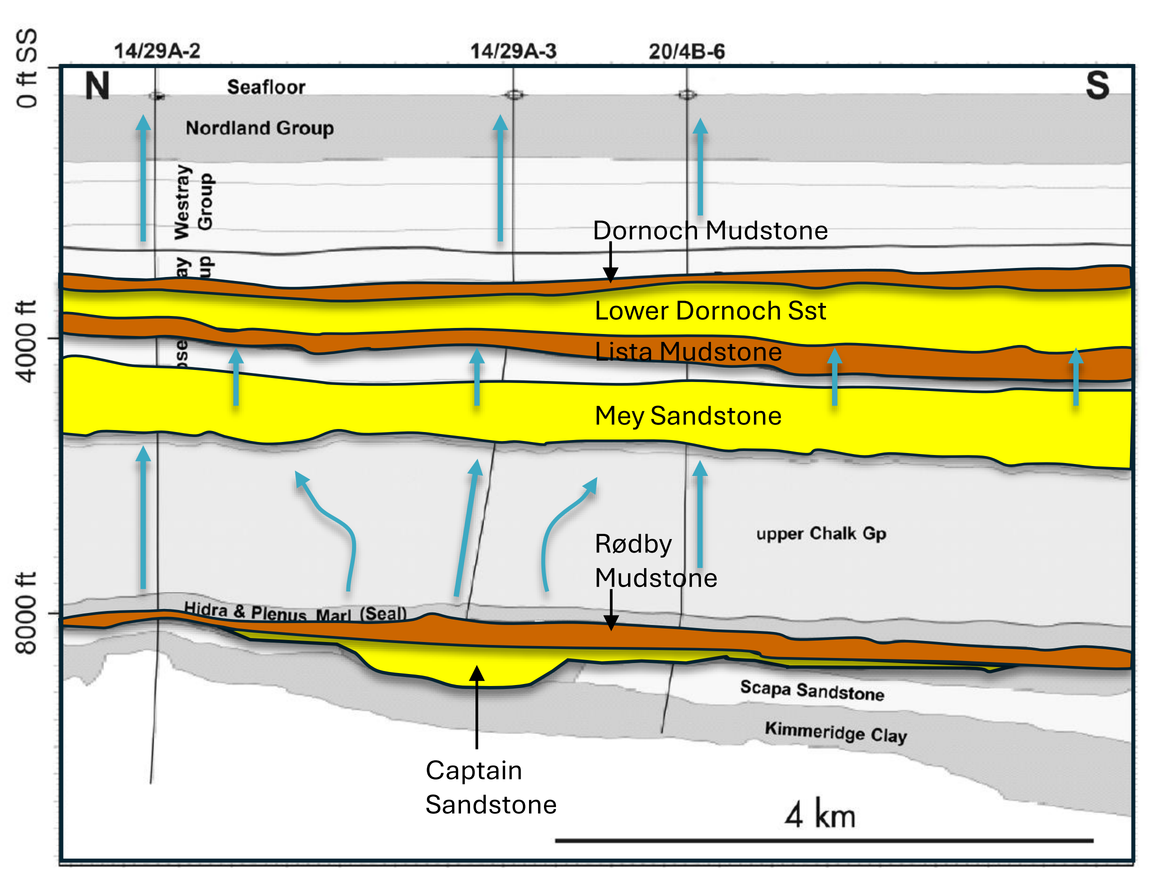
1) Migration through plugged and abandoned wells
2) Migration through injection wells
3) Migration through (conductive and reactive) faults and fractures
4) Lateral migration in permeable Captain Sandstone
5) Combination of wells/fault and lateral migration

MMV Objectives

a) Monitor CO_2 plume development inside the storage complex
b) Monitor pressure development inside the storage complex
c) Monitor legacy well and injection well integrity
d) Monitor geological seal integrity
e) Monitor for marine biosphere impacts

Site-Specific Considerations

- The geological & geophysical setting of the Acorn CCS store is different from Sleipner
- 4D seismic monitoring of the primary CO_2 injection plume in the Captain Sst store may be challenging
- Is the high cost of repeat 4D seismic justified, if CO_2 plume migration in the primary reservoir is not mappable?
- Would other MMV technologies be more appropriate & cost-effective?



Marshall et al. 2018

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Acorn CCS: legacy well plumbing diagram

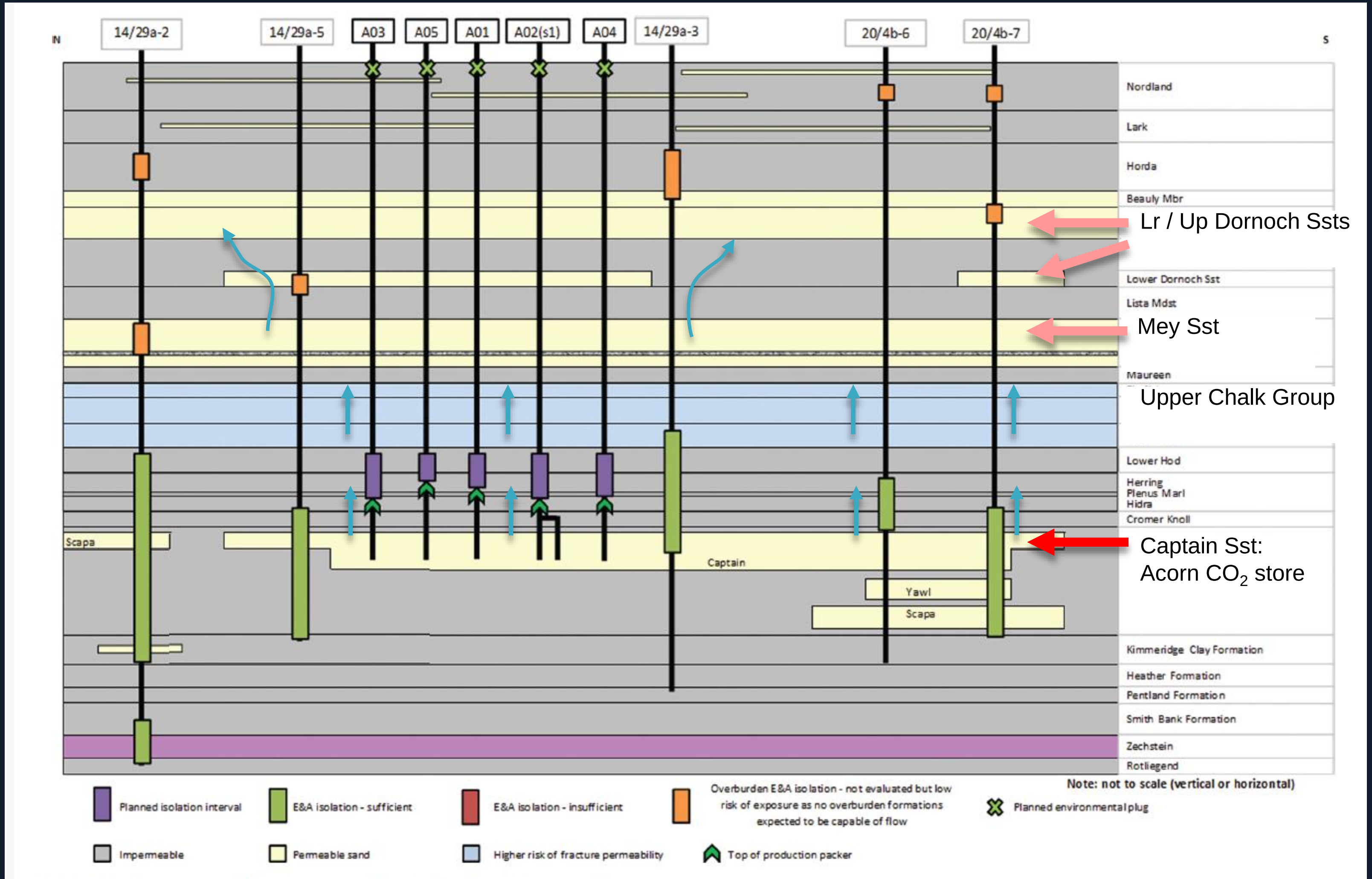
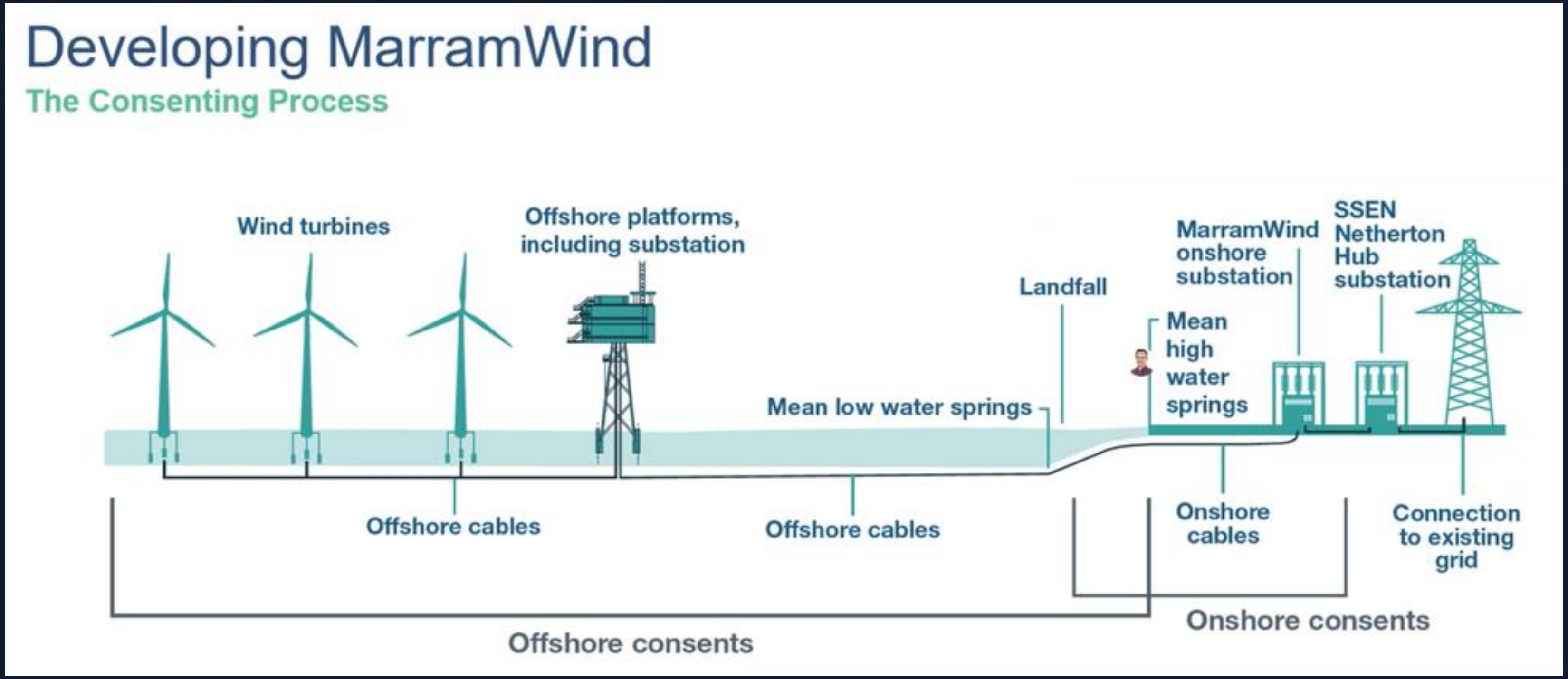


Fig. 12. Plumbing diagram for the Goldeneye isolation strategy. E&A, exploration and appraisal.

Stewart & Marshall 2020

MarramWind update



MarramWind consultation 2024

Public consultation meetings were held in late May / early June, presenting project outline and timelines.

Turbine design TBD: 2025+ gen. (240 m @ 15 MW * 225) vs 2030+ gen., (320 m @ 25 MW * 126)

Targeting permitting submission 2025ting approvals during 2026. Construction from late 2020s for first power early 2030s

Implied similar construction and first operations schedule as Acorn CCS. Dialogue ongoing between the projects

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Decarbonisation effect of Colocation (Acorn CCS + MarramWind 2030-2040)

1) IPCC 2014
2) Thomson & Harrison 2015
3) Scottish Government 2023
4) IEA 2020
Note: CCS operational emissions are not included

Assumptions			
Baseline projects start		year	2030
Delayed projects start		year	2032
Acorn CCS Ph 2 start		year	2032
Acorn CCS Ph1 stored (initial rate)		MT / year	0.30
Acorn CCS Ph2 stored (ramp-up rate)		MT / year	1.00
Natural gas whole lifecycle emissions	1)	kg / kWh	0.490
Offshore wind whole lifecycle emissions	2)	kg / kWh	0.012
Offshore wind decarbonisation		kg / kWh	0.478
Offshore wind decarbonisation		kg / kWh	478000
Offshore wind decarbonisation		T / GWh	478
Offshore wind decarbonisation		MT / GWh	0.000478
Scotland annual CO2 emissions (2022)	3)	MT	40.60

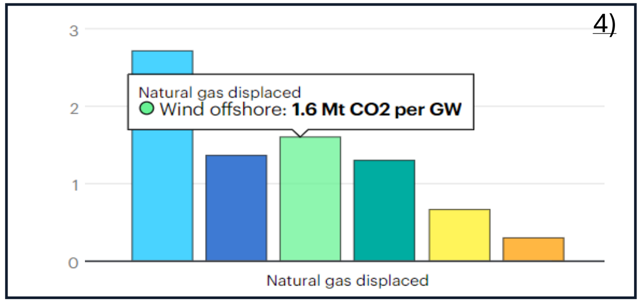
Applying assumptions as shown, Colocation has significant decarbonisation value

- Acorn + MarramWind = c. 1.6 years of Scotland emissions saved 2030-2040
- 2 year delay = 0.3 yr decarbonisation lost (20% of benefit in first decade online)

Alternative assessment approach (IEA):

- 1.0 GWh OW installed =

  1.6 MT annual decarbonisation



	Acorn					MarramWind					Decarbonisation		
Scenario	Ph. 1 Start-up year	Ph.1 decarb/yr MT	Ph. 2 Start-up year	Ph.2 decarb/yr MT	10 year decarb MT	Start-up year	Power output GW	Load factor	Annual gen. GWh	10 year decarb MT	Total MT	Equiv. Scot. emissions yrs	Scenario
Success: CCS + OW	2030	0.3	2032	1.0	8.6	2030	3.0	45%	11,834	56.6	65.2	1.61	Success: CCS + OW
CCS only	2030	0.3	2032	1.0	8.6	0	0.0	45%	-	0.0	8.6	0.21	CCS only
OW only	0	0	0	0	0.0	2030	3.0	45%	11,834	56.6	56.6	1.39	OW only
OW at -10% output	2030	0.3	2032	1.0	8.6	2030	2.7	45%	10,651	50.9	59.5	1.47	OW at -10% output
Projects delayed by 2 years	2032	0.3	2034	1.0	6.6	2032	3.0	45%	11,834	45.3	51.9	1.28	Projects delayed by 2 years

Project CoLocate

Good progress being made with both studies

Next steps are to quantify the seismic response for different scenarios to determine whether it can work at all sites or not

Results will inform decision about the need for alternate strategies that enable colocation between wind and carbon storage sites.

Project Anemone

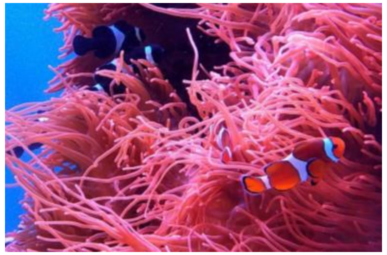
Update from Philippa Parmiter

CEO at NECCUS

Project Anemone – Objectives

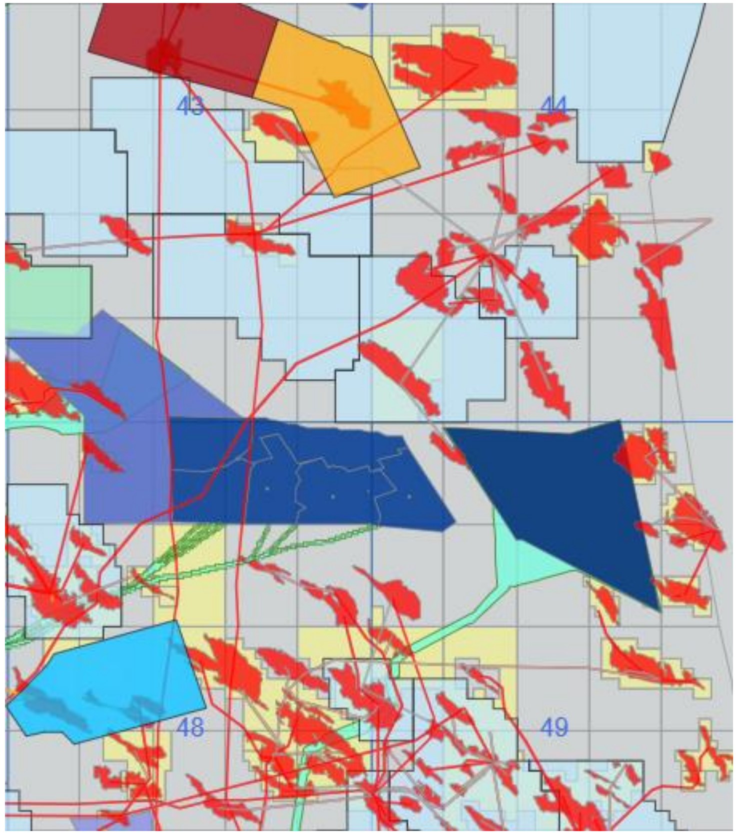
Providing developers with a best-practice guidance for simultaneous operations that will help guide future projects and provide a baseline for developers to build on.

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

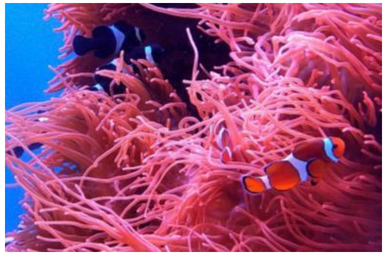


Anemone - Objectives

- Increase understanding of key marine stakeholders (regulators, policymakers, OW developers, CS developers) of the associated challenges and mitigations of colocation
- Develop good practice guidance for simultaneous operations for offshore wind and CO2 storage developers
- Influence policy and regulation to enable colocation of OW and CO_2 storage



NSTA Lease Agreements, Southern North Sea



Update: activity since last plenary

Refinement stage

- **Scrutiny:**
  - Assessed workstream packages via engagement with developers
- **Challenges:**
  - How will outputs be used? What influence will Anemone have on TCE policy?
  - Clarity on scope and tasks
- **Responses:**
  - Updating terms of reference to clarify influence over TCE policy and impact within Colocation Forum (next slide)
  - Tasks to be defined in Work Package #3 are influenced by the analysis undertaken, and feedback received in Work Packages #1 and #2

Use of outputs

The Crown Estate's plans for Anemone regarding policy:

- Specifically, The Crown Estate will use the recommendations from Project Anemone and Project Colocate to inform development of a Marine Delivery Routemap to coordinate multi-agency cross-sector action needed to deliver net zero and nature recovery.
- We will be discussing the updating of Project Anemone's terms of reference at the Forum's next plenary meeting at the end of June, where we will also be discussing an update to the Forum's terms of reference to make clear Forum work will be influencing The Crown Estate's emerging policies.

Facilitation and collaboration

- The Crown Estate has proposed involving Norton Bertram-Smith of On Purpose Ltd
- Building relationships between OW and CCS developers to share approaches, technology and data to inform Work Packages #1 and #2, and scope tasks for #3

	INTERPERSONAL Focused on emotions and relationships	**TECHNICAL** Focused on knowledge and skills
MOTIVATE Funnel energy	Build an engaging vision	Empower agile execution
FACILITATE Remove barriers	Cultivate psychological safety	Develop shared mental models

Altering structure and delivery

- New plan – proceed with Phase 1 with those partners interested in proceeding, including The Crown Estate and Crown Estate Scotland
- **Phase 1**
  - Work Package #1 – mapping stakeholders and processes at each stage of project development for OW and CS:
    - D1.2 summary report (public) = delivery by 30 September 2024
    - D1.1 detailed internal report = delivery by 30 September 2024
    - Kick-off = 18 July 2024
  - Work Package #2 – identifying synergies and challenges, and preparing scope for Phase 2
- **Phase 2**
  - Opportunity for additional partners to join, early engagement enables involvement in scoping tasks in Work Package #3

Non-technical workstreams *for discussion*

Plenary #10 minutes section 4.0
The Forum explored the commercial and financial challenges of making colocation a reality, including securing insurance. The Chair discussed the potential of early projects giving feedback on the financial challenges and opportunities of colocation and the Forum explored adding a commercial, financial and insurance workstream into its work programme.

Additional non-technical workstreams

'Lack of clarity of business overlap issues' (ref. CCUS Offshore Wind Overlap Study)

Issues from study for consideration

1. Development planning / precedence
2. Promotion of collaboration
3. Alignment of standards
4. Cross industry liabilities / Risk assurance
5. Dispute mediation

Known activity on each issue

1. SSEP + Routemap / Common evidence base
2. Forum, trilateral generation & transmission meetings
3. Standards bodies for both industries, compare
4. Insurance industry / Explanation of containment, migration, detection & remediation
5. To be determined

Additional non-technical workstreams

‘Lack of clarity of business overlap issues’ (ref. CCUS Offshore Wind Overlap Study)

Issues from study for consideration	Suggested areas for Forum to pursue
~~1. Development planning / precedence~~	1. Already being progressed via SSEP + Routemap
~~2. Promotion of collaboration~~	2. Forum developer events supporting this
3. Alignment of standards	3. Project Anemone can / should(?) feed into this
4. Cross industry liabilities / Risk assurance	4. New reports to consider; what could / should a Forum workstream explore? 1. Managing Liabilities of CCS A Climatewise Report on Developing Commercially Viable Insurance Solutions 2. Climate Tech For Industrial Decarbonisation What role for insurers?
~~5. Dispute mediation~~	5. For future discussion

Next Plenary Dates

AOB & Actions Review