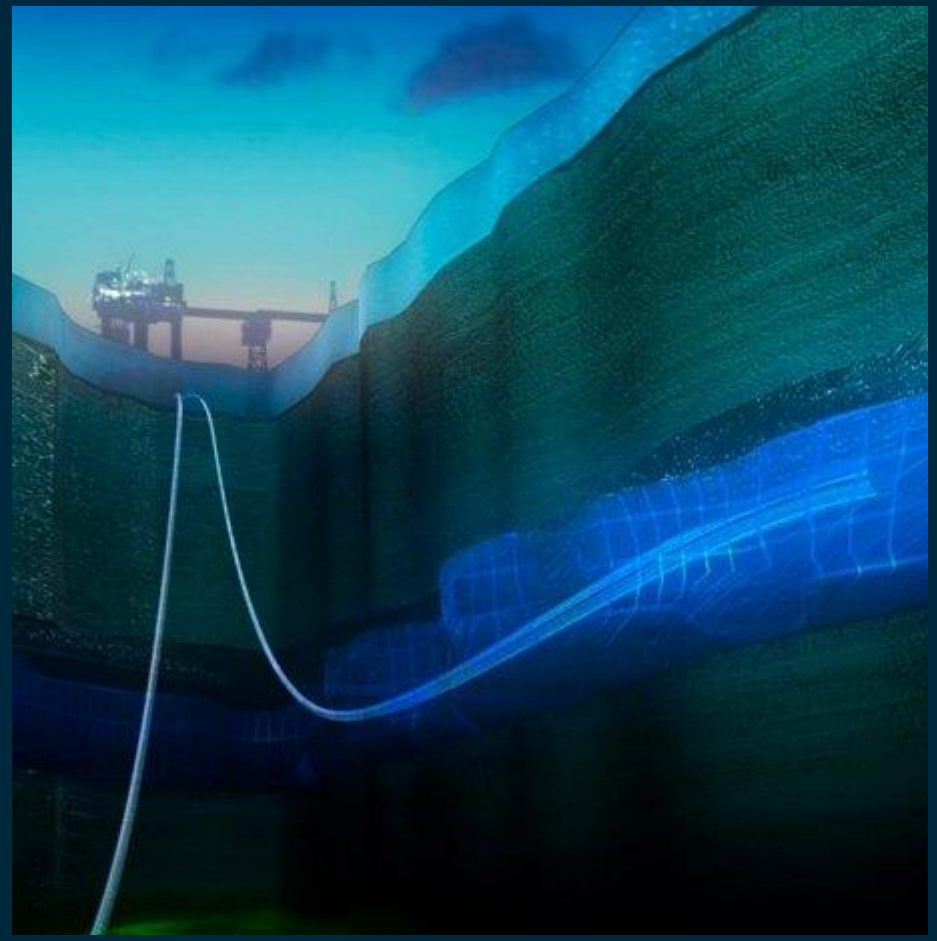
Offshore Colocation Forum

Offshore Wind and CCUS Colocation Forum



Offshore Wind & CCS Panel Event

March 2024

THE CROWN ESTATE

THE CROWN ESTATE

Dating back more than 260 years, The Crown Estate is a unique business with a diverse portfolio that stretches across England, Wales and Northern Ireland

Established by The Crown Estate Act of 1961

As an independent commercial business with accountability to Parliament.

Return our net revenue profit to the Treasury

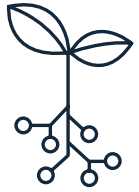
For the benefit of the nation's finances, with £3bn generated in the last 10 years.

Active owners and managers of land and seabed

We are one of the UK's largest landowners, with some of the nation's most remarkable places and spaces. We seek to leverage our scale and convening power to make a meaningful difference.

Guided by a compelling purpose

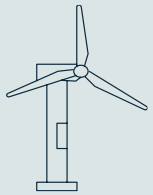
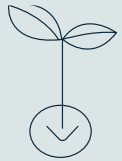
To create lasting and shared prosperity for the nation



Delivering an ambitious strategy

Guided by our purpose and informed by major trends impacting our business, we seek to create broad financial, environmental and social value for our stakeholders, customers and the nation.

THE CROWN ESTATE

Our Purpose	**To create lasting and shared prosperity for the nation**				
Our distinct attributes	Trusted brand and reputation	Independence and simplicity of role	Power to convene and catalyse	Our ownership	Long term view
National Needs	**Energy Security and Net Zero agendas**	**Economic growth & productivity**	**Growing pressure on urban centres**		**Biodiversity loss**
Our Strategic Objectives	 **Being a leader in supporting the UK towards a net zero carbon and energy-secure future**	 **Helping create inclusive communities and supporting equality, economic growth and productivity**	 **Taking a leading role in stewarding the UK's natural environment and biodiversity**	 Responsibly generating value and financial returns for the country	
Enabled Value					
Business Drivers	**Safety First**	**Digital & Data**	**Sustainability**		**Customer**

Our businesses

Marine

Unlocking the potential of our seabed, sea and coastline to support the nation's transition to a resilient, sustainable and decarbonised future.

- £**378m** annual revenue
- £5.7bn portfolio value
- 26 sectors enabled – diverse activities include energy, cables, habitats, minerals, storage and coastal

Regional

Identifying and creating opportunities for thriving and resilient communities across the country to support regeneration, housing and innovation.

- £106m annual revenue
- £1.5bn portfolio value
- 17 retail and leisure destinations incl. retail parks, shopping centres, industrial and business parks.

London

Ensuring London retains its global city status by fostering a greener, more vibrant and inclusive destination for millions of visitors and businesses.

- £223m annual revenue
- £7.2bn portfolio value
- 10m sq ft – the largest contiguous owner in the West End

Windsor & Rural

Supporting the sustainable transformation of land use through diversified, regenerative agricultural and environmental best practice alongside a thriving natural world.

- 6,400 h.a parkland including Windsor Great Park
- 185k acres of agricultural land and property – 70% tenanted farmland

4

As custodian of the marine environment, TCE leads sustainable development to protect the seabed while creating lasting value

As an island nation with high population density and valuable wind/natural resources, the seabed and coastline are critical for the economy, restoring nature and delivering net zero. Therefore, we have a vital role to play managing this space to deliver long-term value for the nation…

OUR PAN-SECTORAL VIEW

Energy
Offshore wind
Energy conversion
Marine energy

Storage
CCUS
Hydrogen
Natural gas

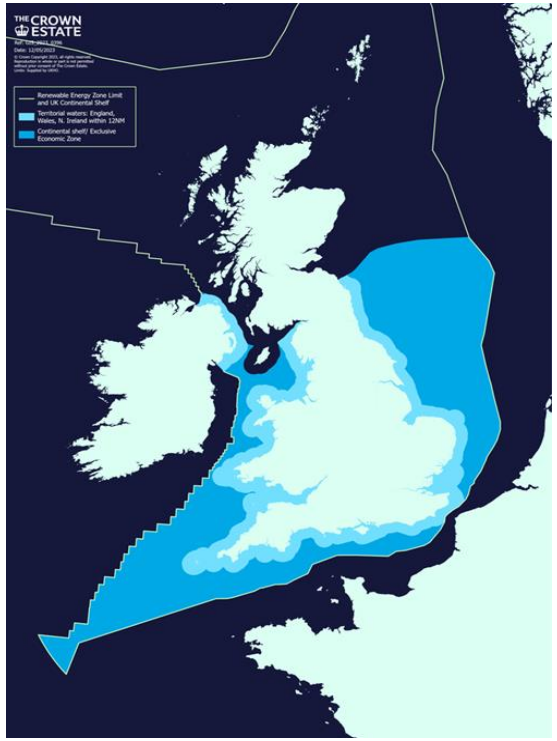
Infrastructure
Power & Telco Cables
Pipelines

Minerals
Reclamation
Aggregate dredging
Marine mining

Coastal
Ports and harbours
Aquaculture
Leisure

Habitats
Habitat creation
Biodiversity
Nature recovery

OUR OFFSHORE & ONSHORE FOOTPRINT



OUR CAPABILITIES

- ✓ Our deep expertise and experience (incl. multi-sector knowledge, data and spatial insight)
- ✓ Our ability to look across sectors (e.g. energy, minerals, nature) balancing competing and complementary demands
- ✓ Requirement and purpose to protect while delivering greatest value for the nation
- ✓ Statutory independence and our ability to take an objective long-term view
- ✓ Our power to convene and partner with others to bring the marine vision to life

VISION: The most sustainable and attractive marine ecosystem in the world

Optimise broad value creation from the seabed

Catalyse UK towards a net zero & energy secure future

Deliver a thriving marine environment

NB. The Crown Estate has complete control over activities in territorial waters. TCE has purpose-limited rights covering the continental shelf, these permit the management of certain activities but TCE's control is not exhaustive.

Co-location Forum
Offshore Wind Siting

Dr Mike Blair, Senior Technical Manager, The Crown Estate

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Why there?

- Dogger Bank is a geological feature in the North Sea, home to six offshore wind projects awarded in TCE Leasing Round 3 and 4:
    - Dogger Bank A, B, C (under construction) – 3 x 1.2 GW
    - Dogger Bank D – up to 2.0GW
    - Sofia (under construction) – 1.4GW
    - Dogger Bank South (East and West) – 2 x 1.5GW
- It has several characteristics which make it attractive for OSW development.
    - **Shallow bathymetry -> smaller sub-structures -> lower cost.**

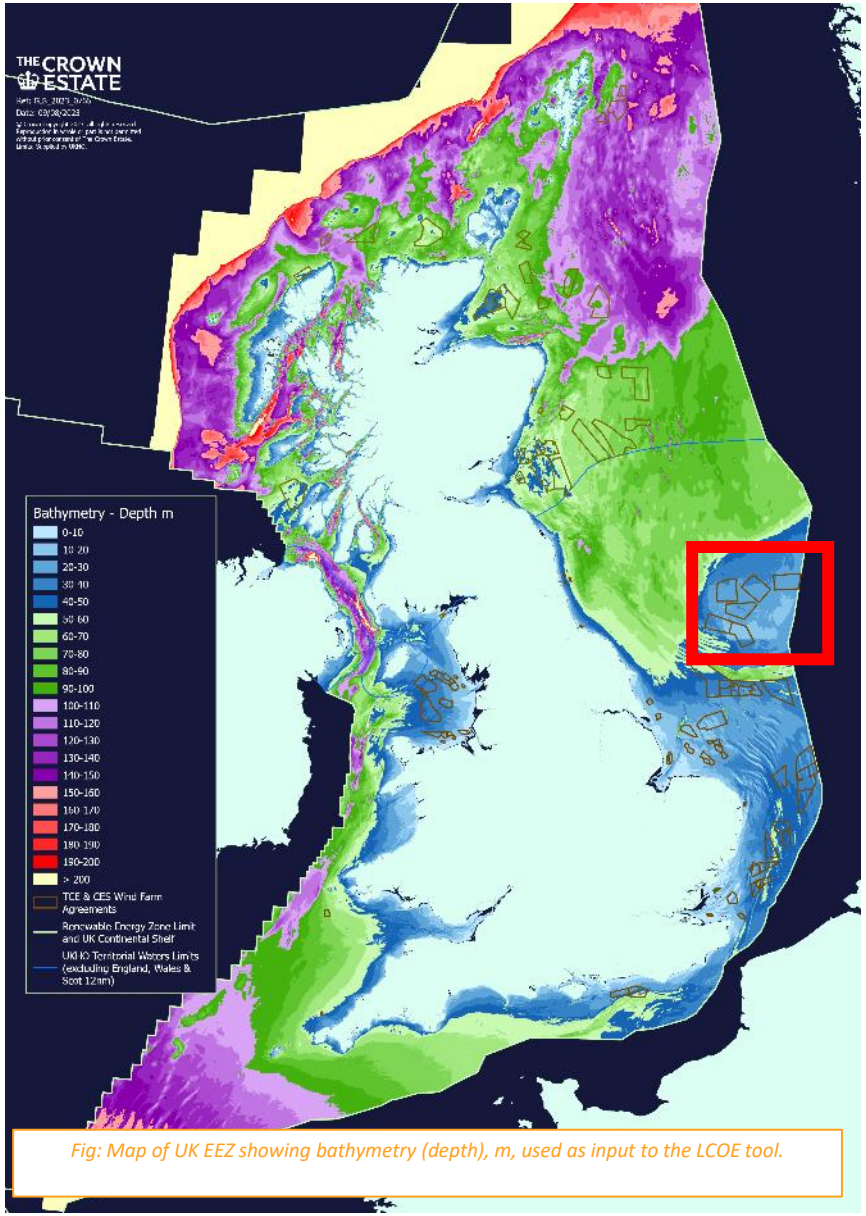

Fig: Map of UK EEZ showing bathymetry (depth), m, used as input to the LCOE tool.

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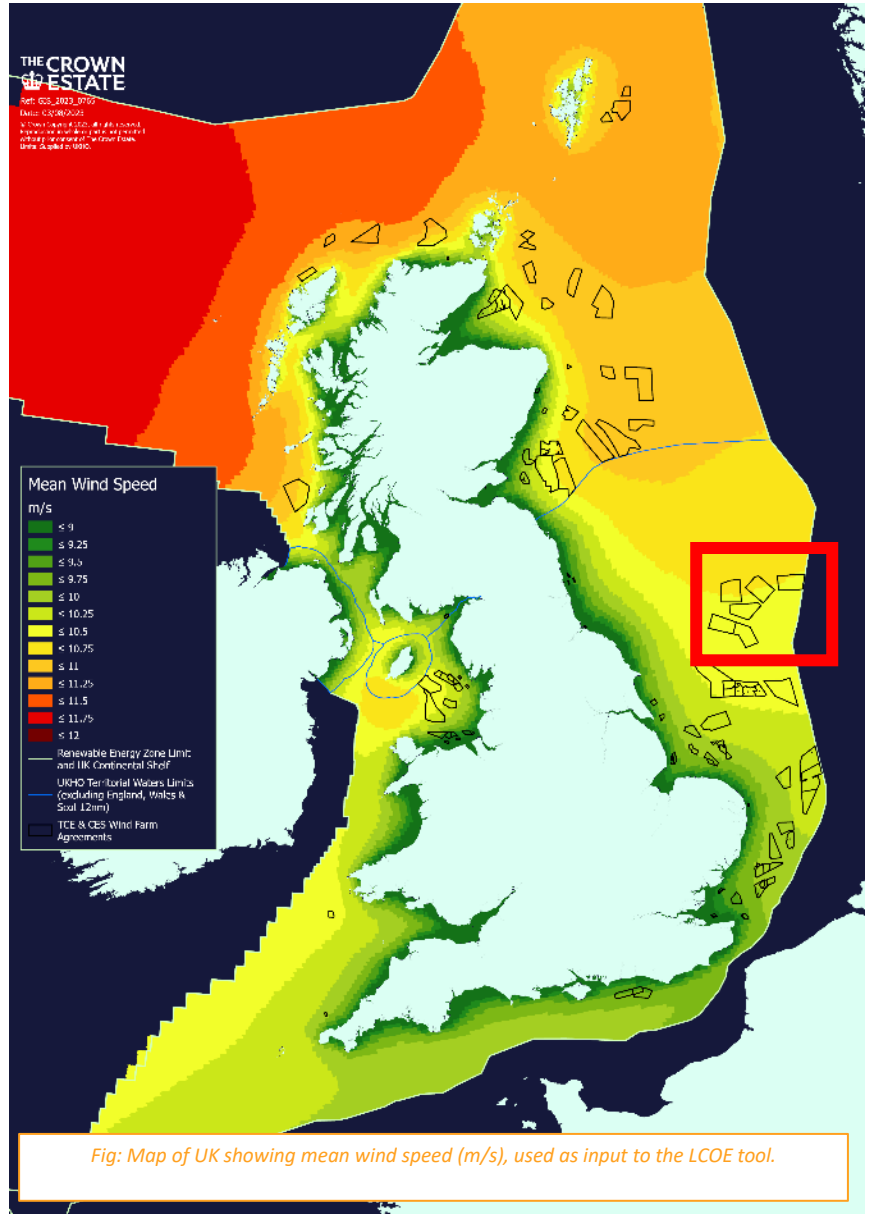

Fig: Map of UK showing mean wind speed (m/s), used as input to the LCOE tool.

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    - **Favourable stiff sediment -> lower embedment depth -> lower materials cost.**

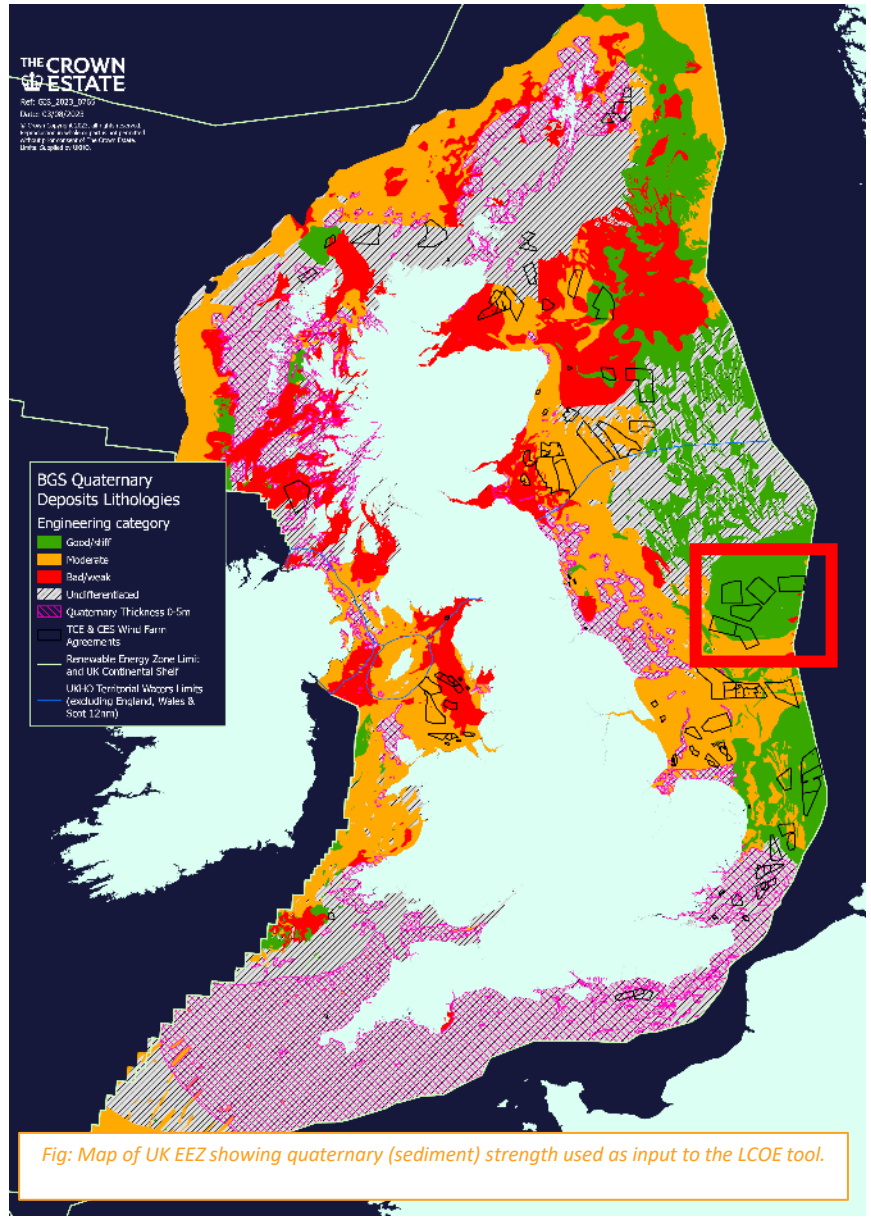

Fig: Map of UK EEZ showing quaternary (sediment) strength used as input to the LCOE tool.

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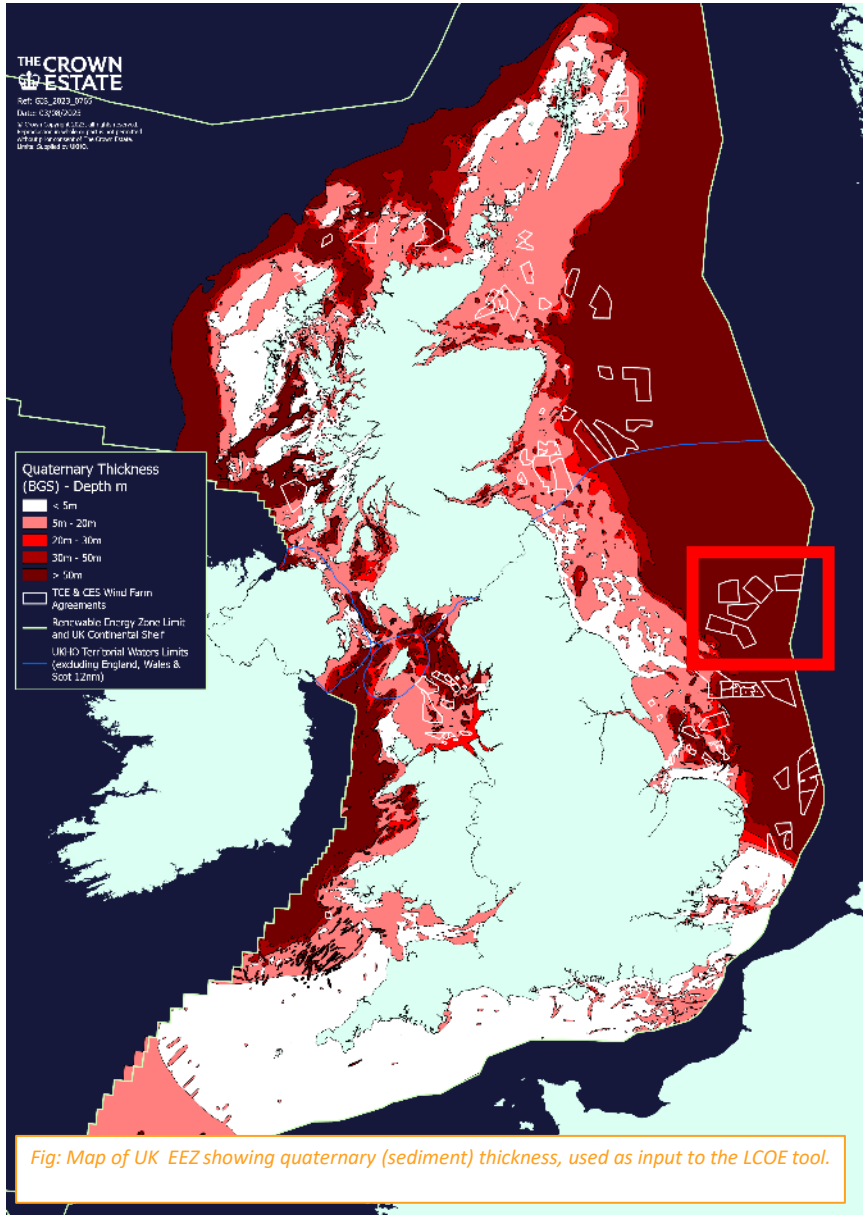

Fig: Map of UK EEZ showing quaternary (sediment) thickness, used as input to the LCOE tool.

Why there?

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    - **Deep sediment -> no need for rock drilling -> lower installation costs.**
    - **Low extreme (50-yr) wave height -> leaner structural design -> lower cost.**

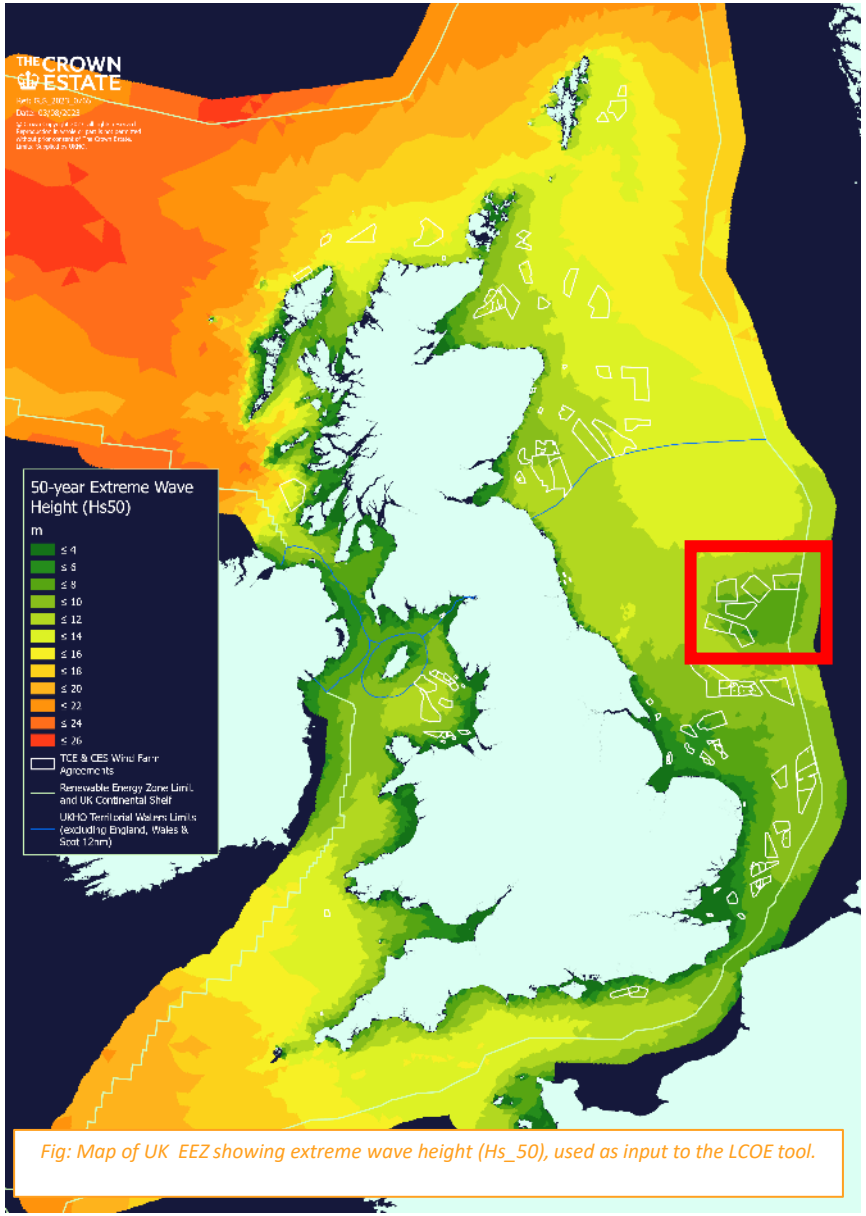
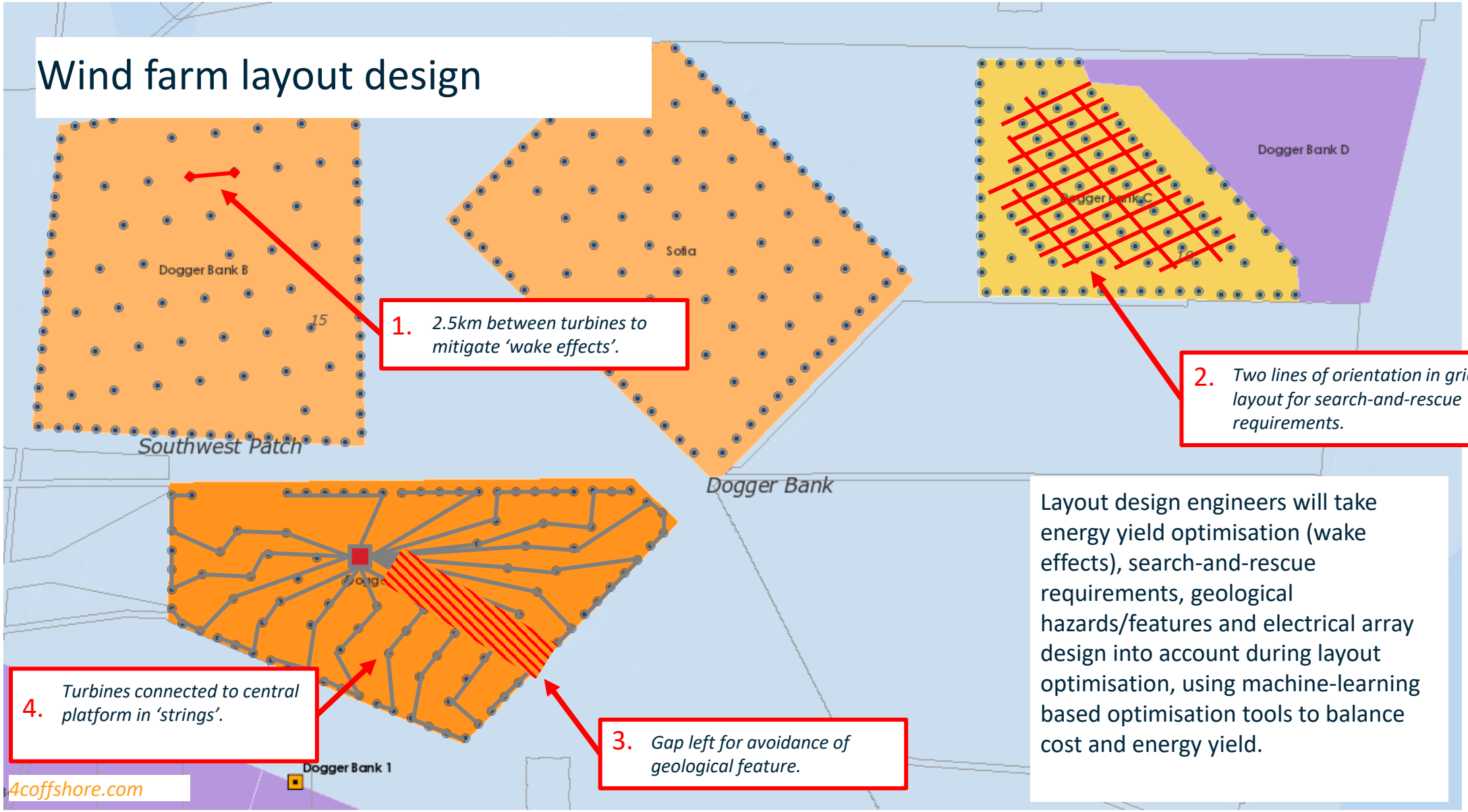


Fig: Map of UK EEZ showing extreme wave height (Hs_50), used as input to the LCOE tool.

Wind farm layout design



Layout design engineers will take energy yield optimisation (wake effects), search-and-rescue requirements, geological hazards/features and electrical array design into account during layout optimisation, using machine-learning based optimisation tools to balance cost and energy yield.

Co-location Forum
Offshore Wind Technology

Prof Simon Hogg, Ørsted Professor of Renewable Energy,
Durham University

Offshore
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Forum

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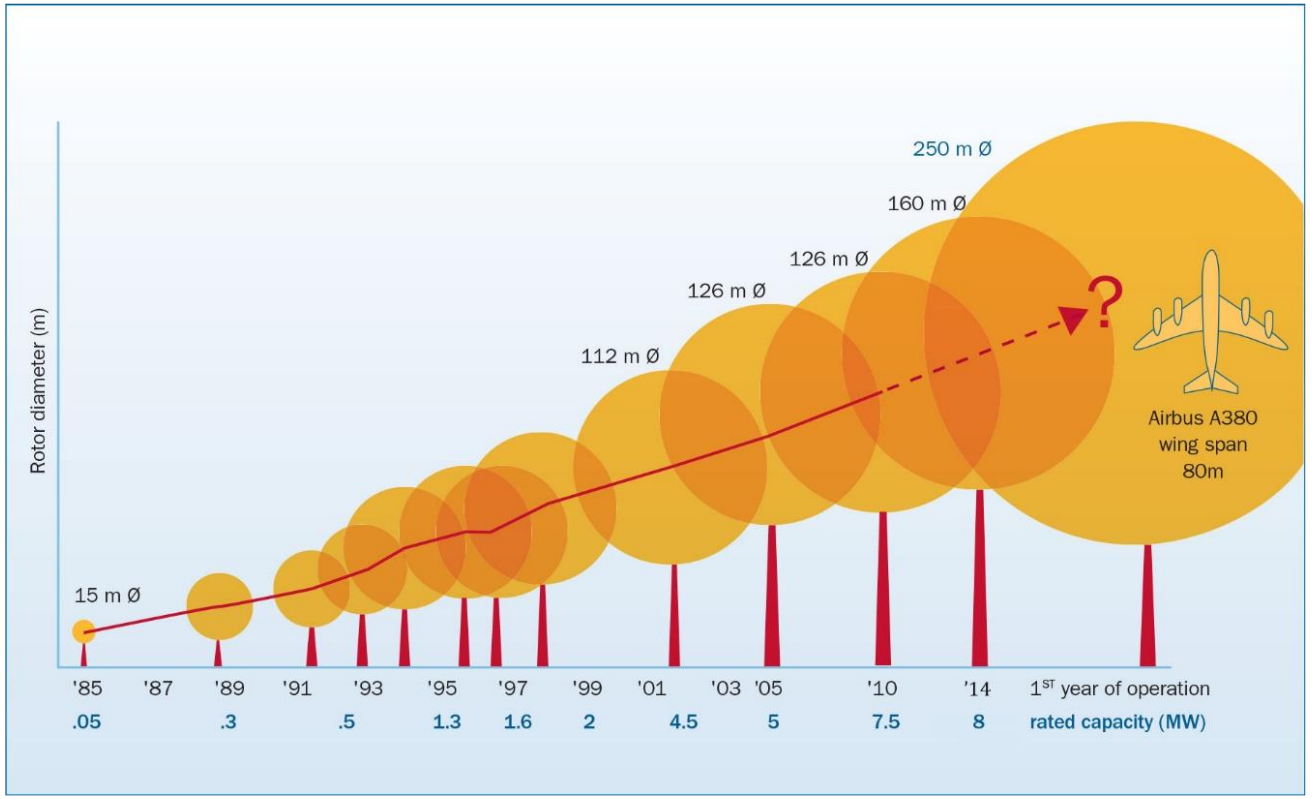
UK Installed Capacities & Turbine Size.

- Current installed onshore wind turbine (WT) capacity c **15.0 GW**, **8,986** turbines with average **26.34%** Load Factor;
- Current installed offshore wind turbine (WT) capacity c **14.7 GW**, **2,766** turbines with **40.58%** Load Factor;



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London Array, Offshore Wind Farm
175 x Siemens 3.6 MW WTs, 630 MW

UK Round 2 Development
Fully operational since 2013.

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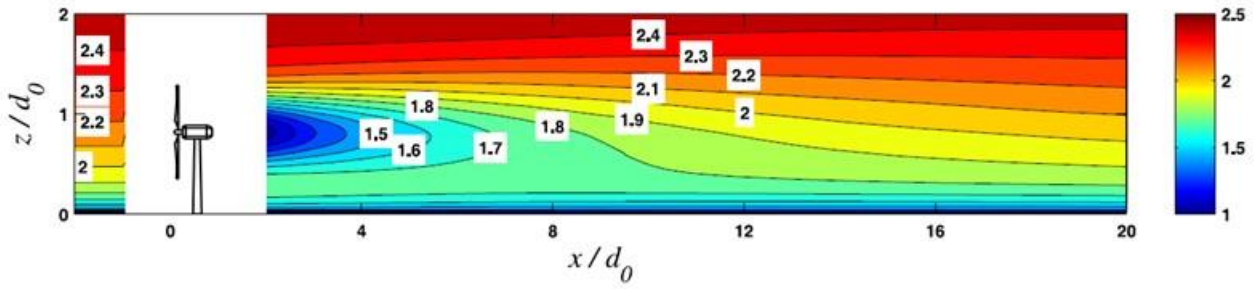
Wake Interactions.



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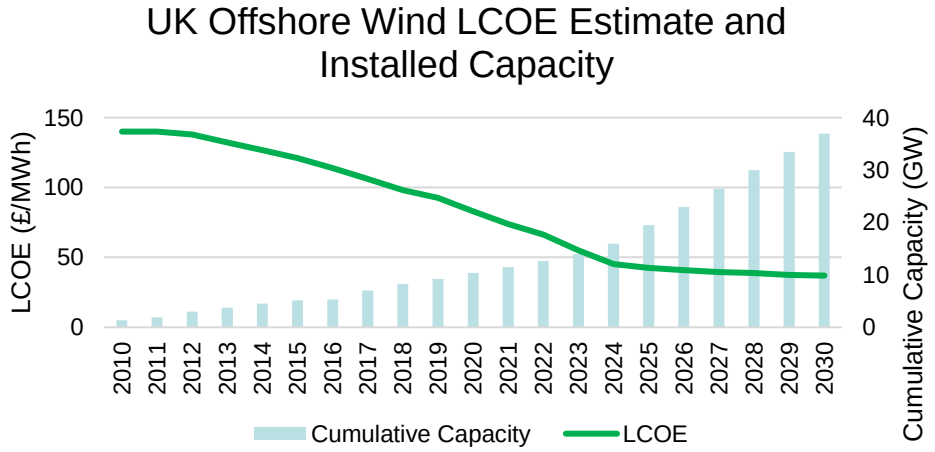
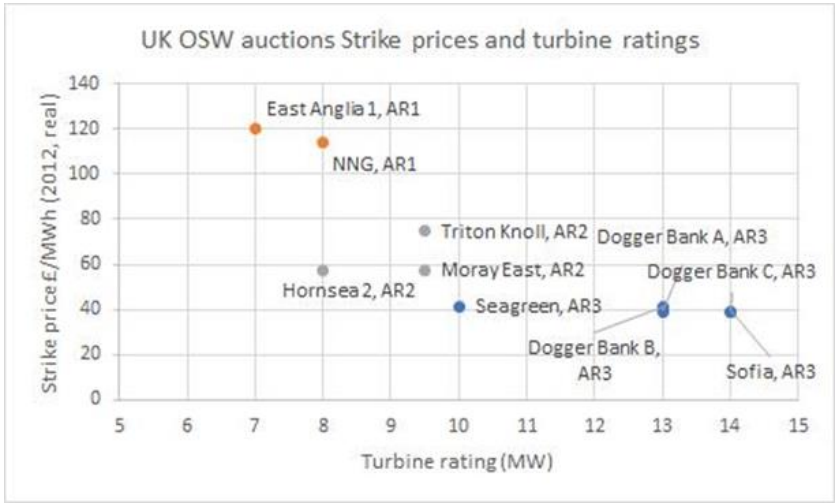
UK Round 3 Wind Farm Sites.





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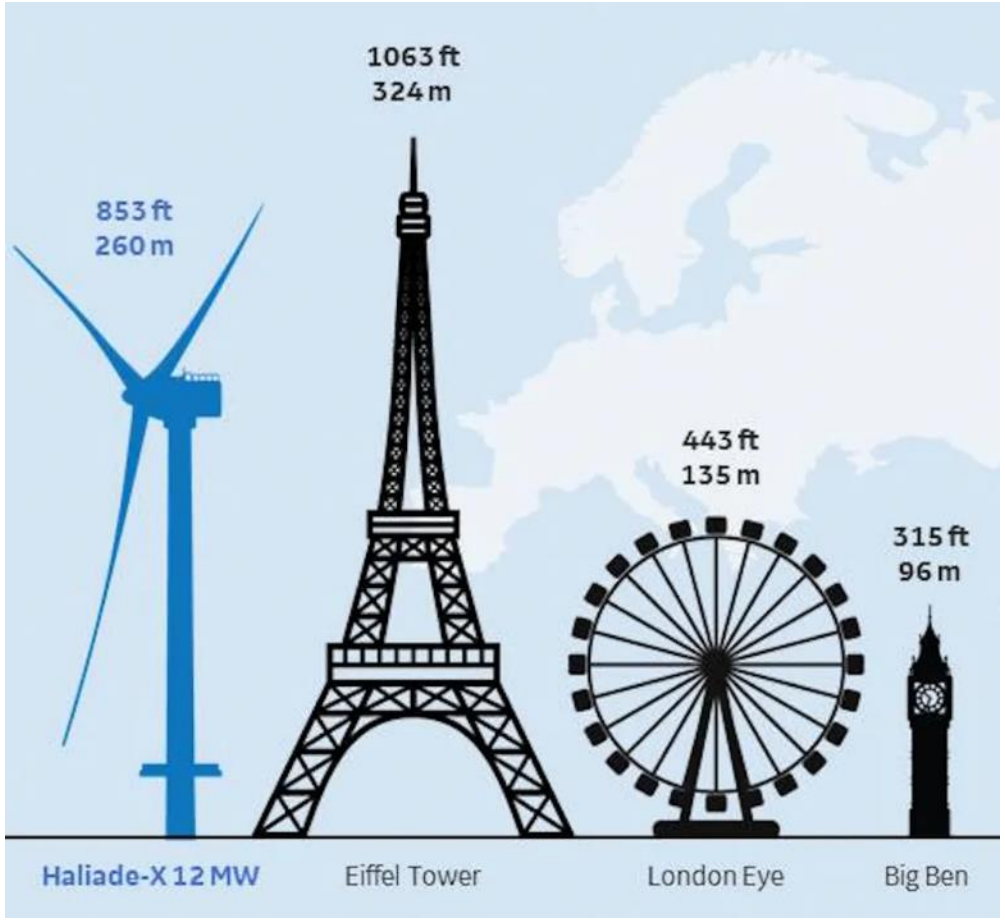
Equinor’s Dogger Bank First Power Oct. 2023. GE Haliade X 13MW turbine.

Durham University

(1st true commercial deployment in the world.)

How big is the GE Haliade X 13MW Turbine?

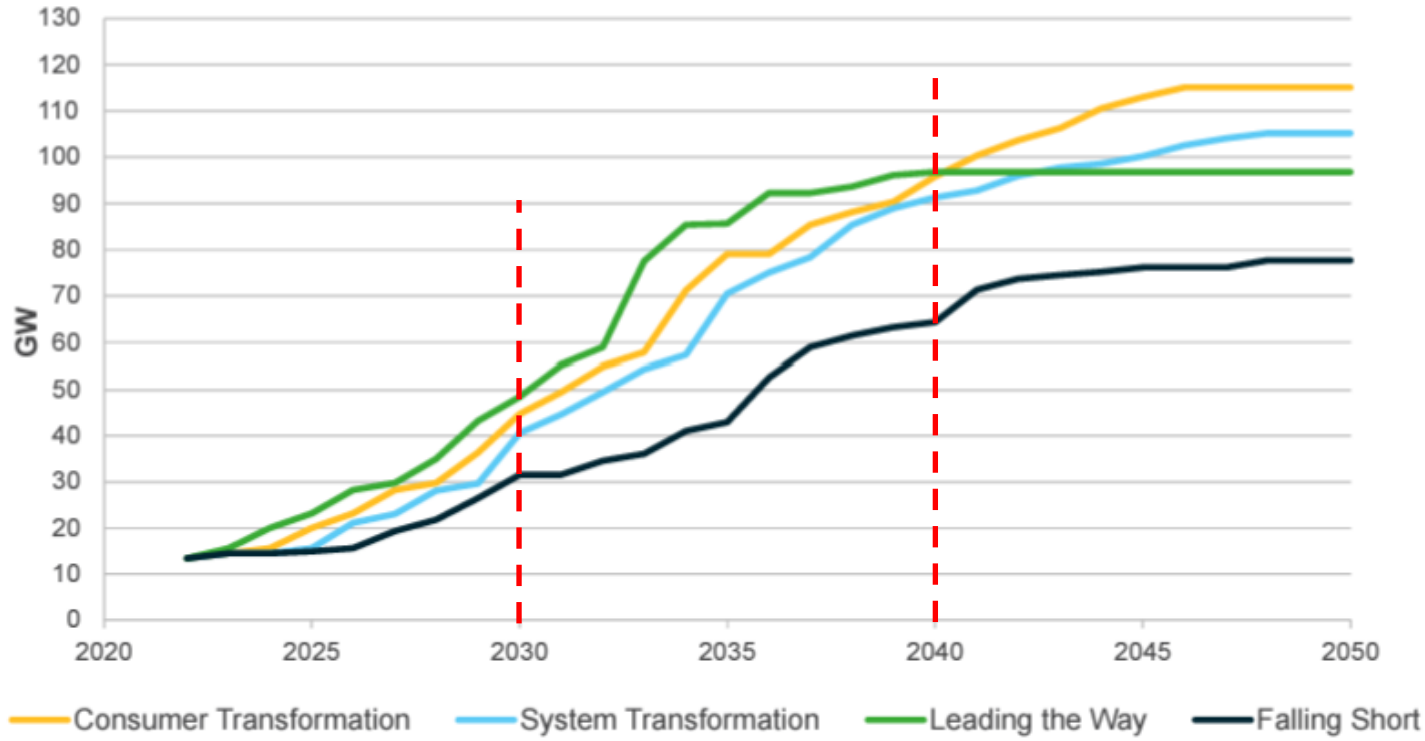


GE Renewable Energy / Facebook.

Durham University

From National Grid Electricity System Operator – Future Energy Scenarios July 2023

Figure ES.11: Offshore wind capacity in GW, excluding non-networked wind



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Scotwind (Crown Estate Scotland)

- Results announced January 2022.
- Lease option awards for 25GW awarded.
- 15GW is floating offshore wind.
- Developers shocked as 10GW had been expected.

Fixed-bottom			
Map no.	**Project, zone**	**MW**	**Developer**
1	Morven, E1	2907	BP, EnBW
6	Cluaran Deas Ear, E3	1008	DEME, Aspiravi, Qair
9	Caledonia, NE4	1000	Ocean Winds
13	West of Orkney, N1	2000	GIG, TotalEnergies, RIDG
16	tbc, N4	840	Northland Power
17	MachairWind, W1	2000	SPR
TOTAL			**9755MW**

Floating			
2	tbc, E1	2610	SSE, Marubeni, CIP
3	tbc, E1	1200	Falck, BlueFloat
4	CampionWind, E2	2000	Shell, SPR
5	tbc, E2	798	Vattenfall
7	Cluaran Ear-Thuath, NE2	1008	DEME, Aspiravi, Qair
8	tbc, NE3	1000	Falck, BlueFloat and Orsted
10	tbc, NE6	500	Falck, BlueFloat
11	MarramWind, NE7	3000	Shell, SPR
12	tbc, NE8	960	BayWa r.e., Elicio, BW Ideol
14	tbc, N2	1500	Northland Power
15	tbc, N3	495	Magnora, TechnipFMC
TOTAL			**15,071MW**

FULL SCOTWIND TALLY	**24,826MW**

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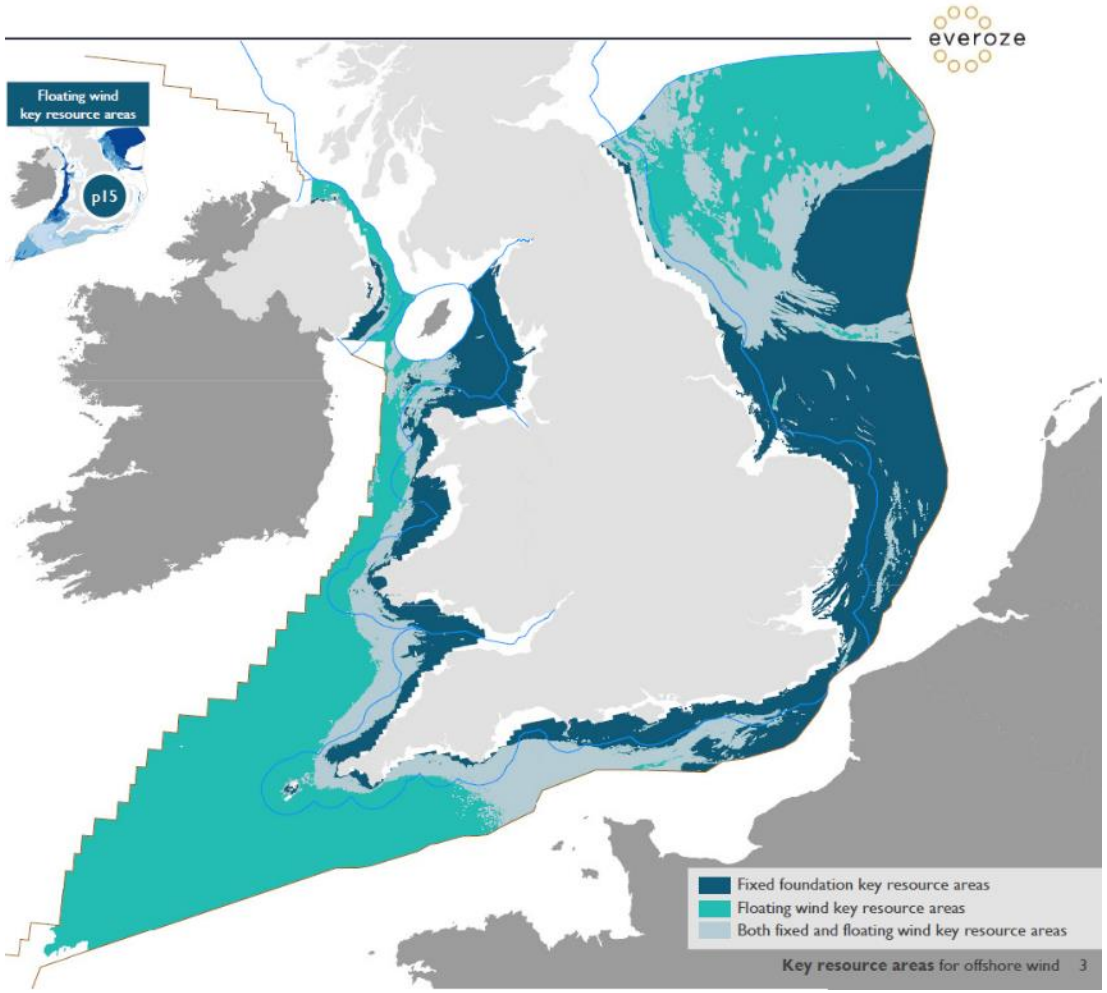
“BROAD HORIZONS: Key resource areas for offshore wind” – Crown Estate 2020



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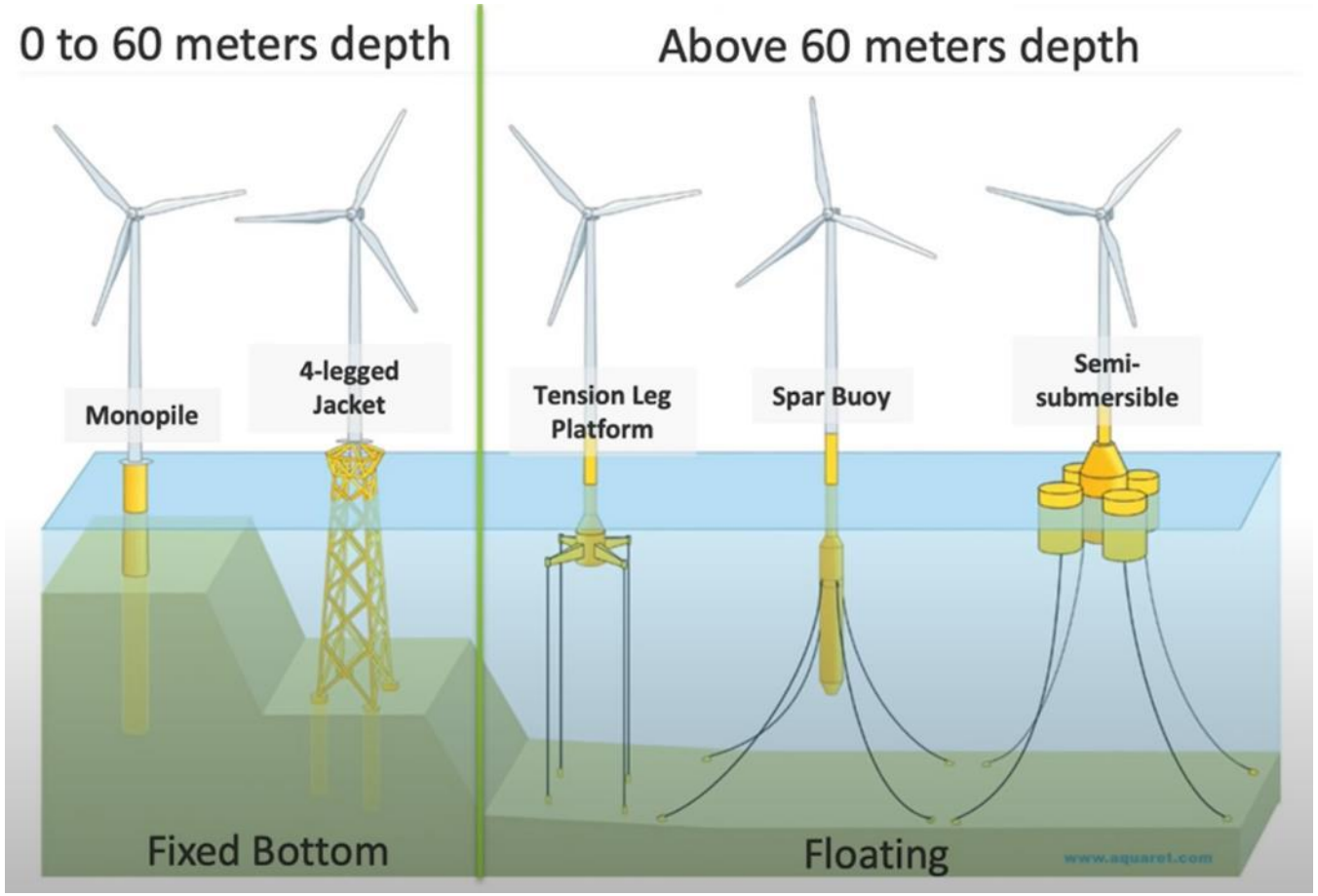
Floating Offshore Wind.



Main challenges:

- Floating platform is a big cost addition.
- Turbine Stability.
- Transmission cable reliability.

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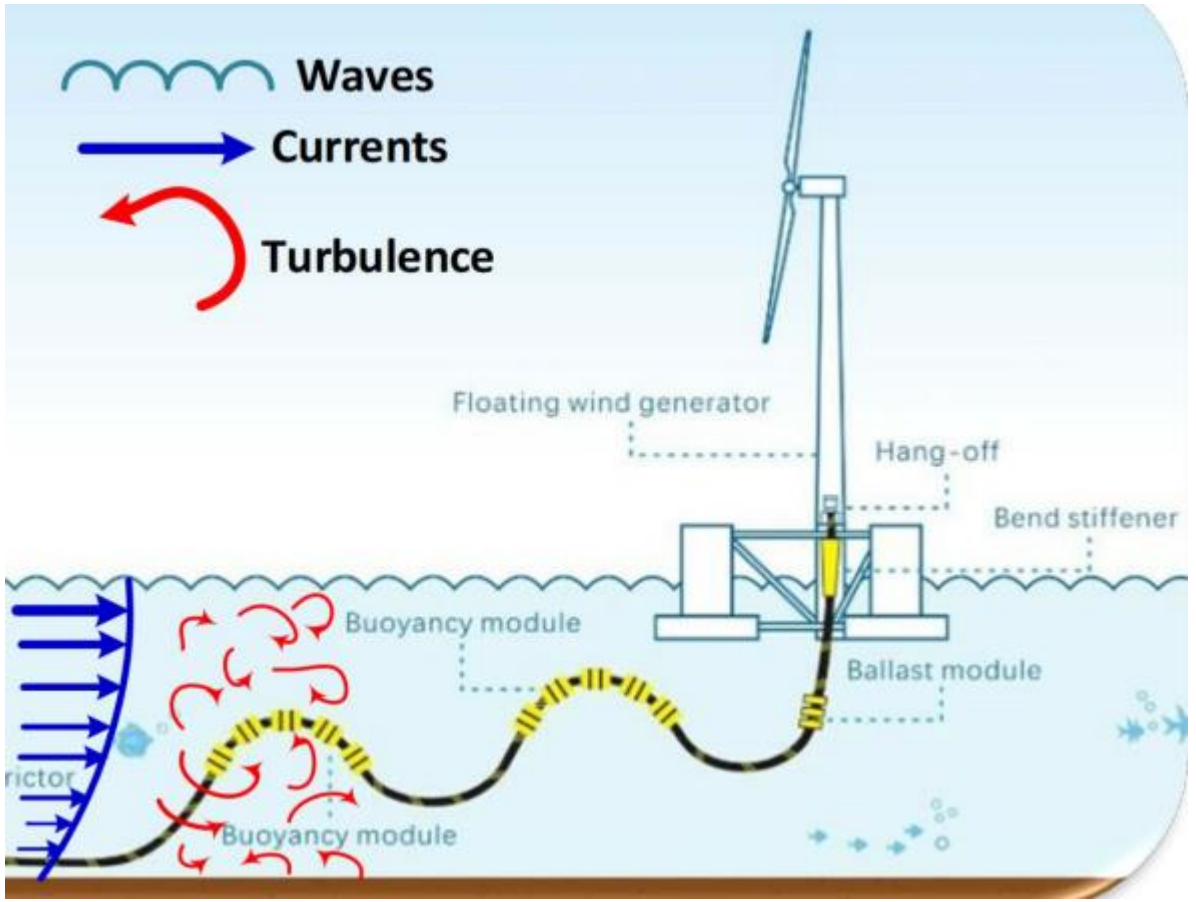
Floating Wind – Not just the Mooring Lines.



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Co-location Forum
Purpose of Monitoring

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

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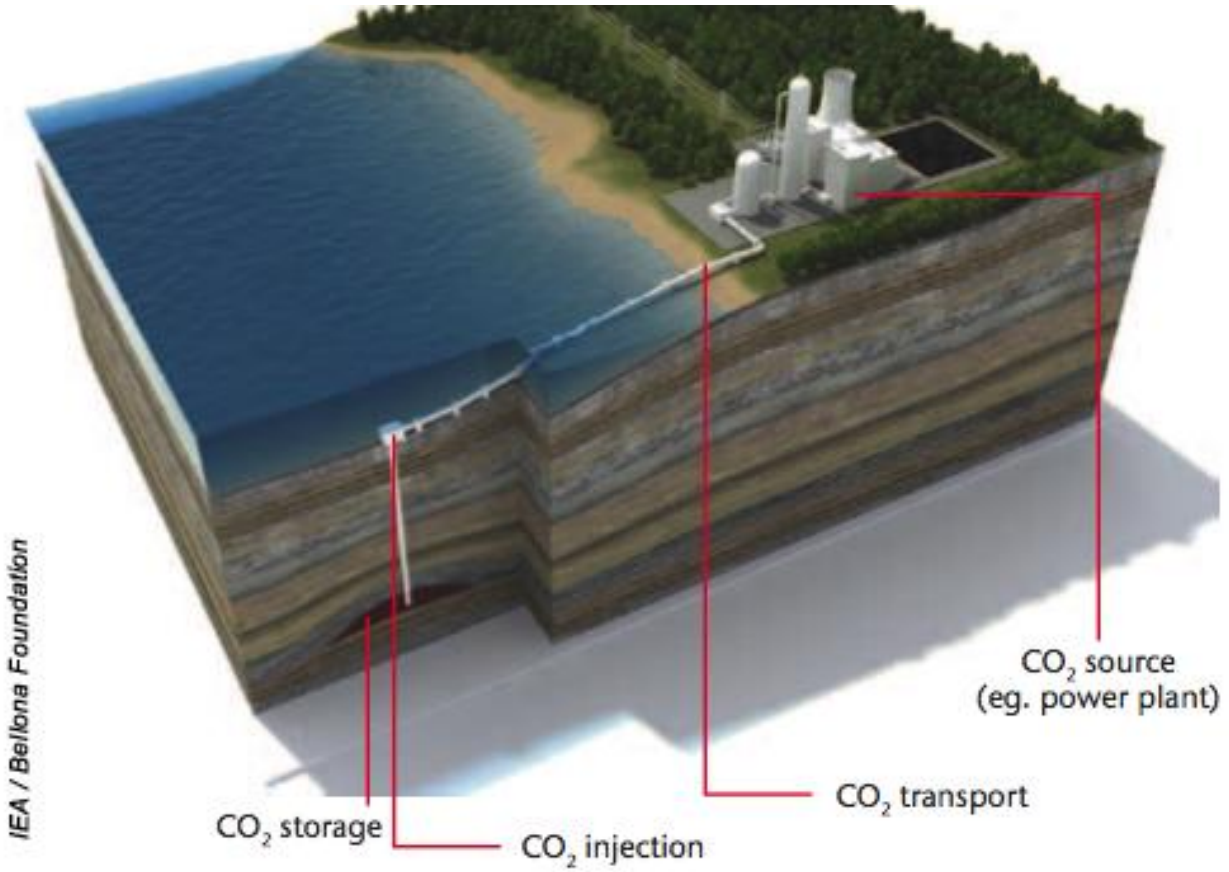
Why do we Monitor CO_2 Storage Sites?

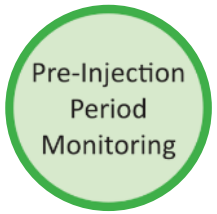
- To manage risk and ensure safe and efficient storage of CO_2
- A Measurement Monitoring and Verification (MMV) plan enables operators and CCS developers to demonstrate containment, conformance and confidence with respect to the injected CO_2 plume and the geological integrity of the target formation
- It ensures the injected CO_2 is conforming to (doesn't deviate from) expected behaviour
- It ensures that CO_2 is contained within the "storage complex"
- It provides confidence or verifies that the entire volume of injected CO_2 is stored within the target area, or can be accounted for in the unlikely event that a loss of containment occurs



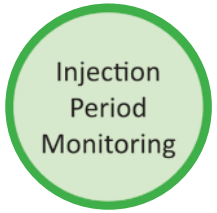
What Techniques can be used for Monitoring, and Where?

Geophysical	In-Well	Geochemical	Marine	Atmospheric	Fluid metering and fluid quality
• Monitor physical changes within the subsurface using remote-sensing techniques • Can provide detailed, 3D images of injected CO2	• Measurement of downhole changes using permanent sensors, or by running logging tools as required • Provides information about changes within the well and near-well environment	• Monitor geochemical changes within the terrestrial hydrosphere and biosphere • Include direct measurement of CO2 (inherent and injected), by-products of subsurface reactions (with injected CO2) and tracers (natural and artificial)	• Monitor marine environmental changes near, on the seabed, and in the water column above an offshore CO2 storage site. • Acoustic and chemical sensors can detect, locate, attribute, and quantify emissions to the marine environment	• Relevant to onshore projects only • Monitor the atmosphere above an onshore CO2 storage site. Similar to other near-surface monitoring technologies	• Measure the mass of injected CO2 and the impurities (if any)
Geosphere	Geosphere	Hydrosphere and Biosphere	Hydrosphere	Atmosphere	

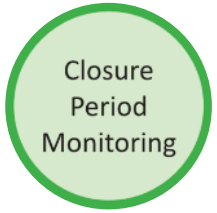
Project Lifecycle: When do we Monitor?



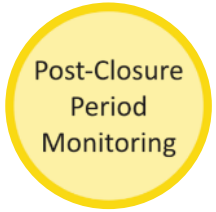
Occurring prior to the onset of sustained injection and corresponding to the site screening, characterisation, design and development periods



The operational period which can also include pilot injection tests

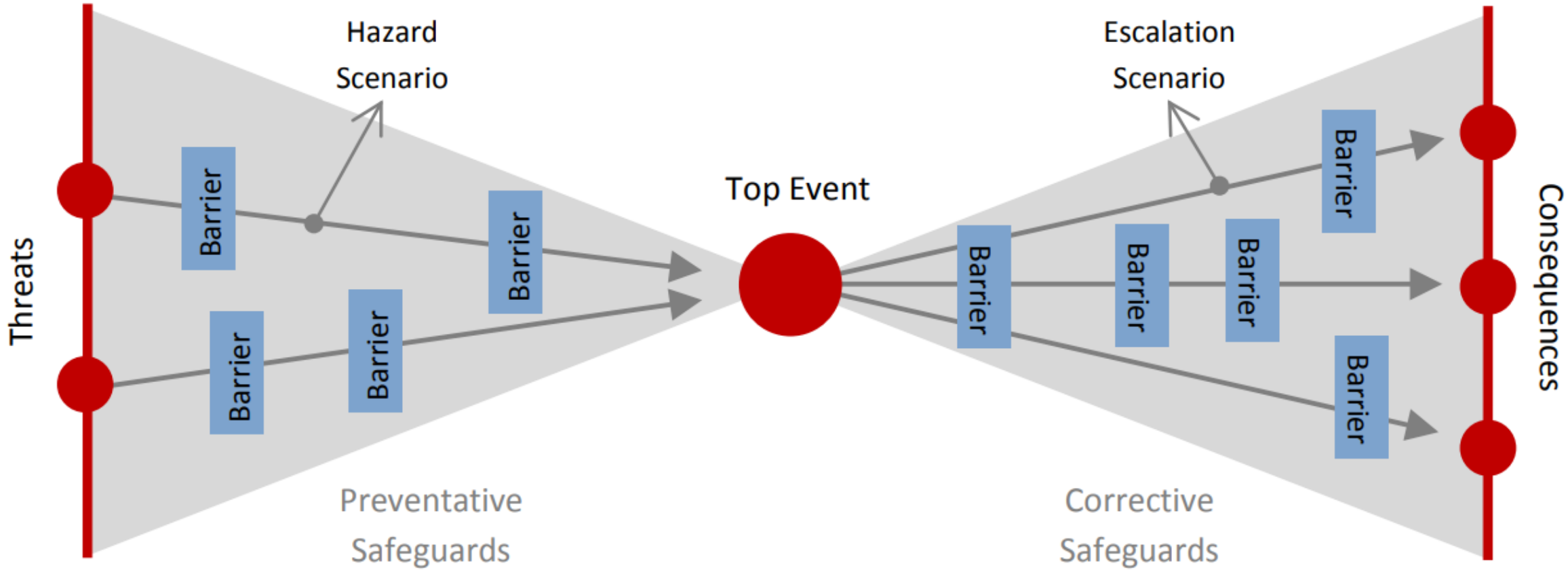


The period towards the end of the injection operations during which injection operations cease



The period following the cessation of injection operations and closure of the site

How are Measurement, Monitoring and Verification Plans Created?



Co-location Forum
T&S Taskforce – MMV Subgroup

Elle Lashko MSc, Carbon Storage Geoscientist, Storegga,
T&S Taskforce

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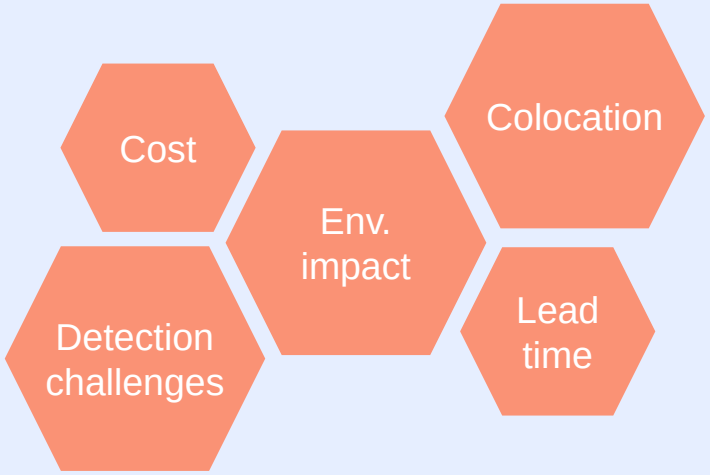
Project drivers and objectives

Today → **Ambition**

Repeat 3D (4D) seismic is routinely in core monitoring plans for CO_2 storage sites, but poses challenges:



Improved understanding of monitoring technologies that have the potential to reduce reliance on 4D seismic as a core monitoring tool, over the Track 1 and Track 2 stores.

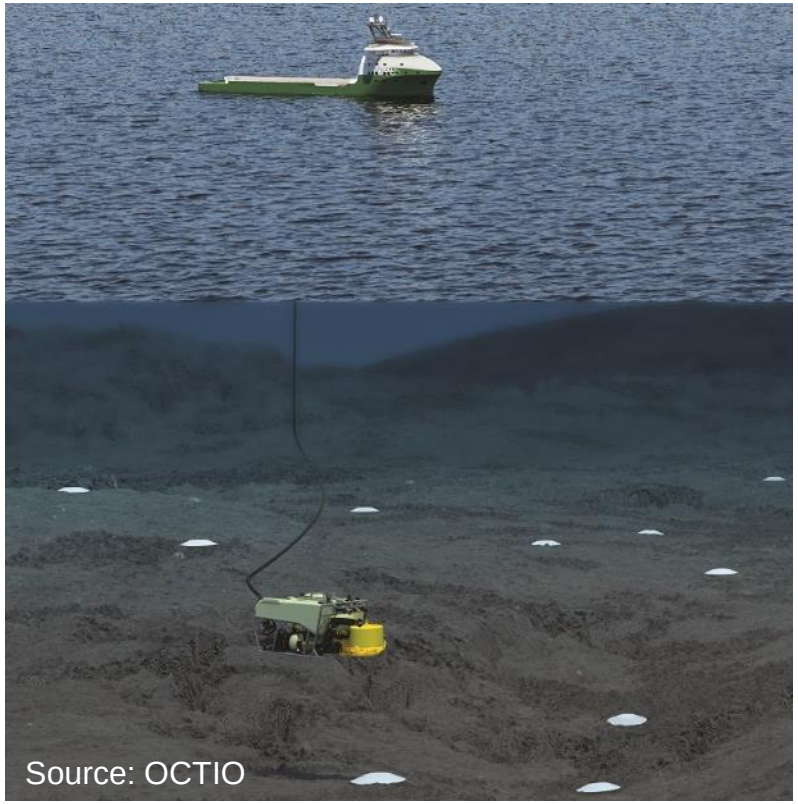
Consider opportunities to improve resolution, reduce cost or environmental impact.

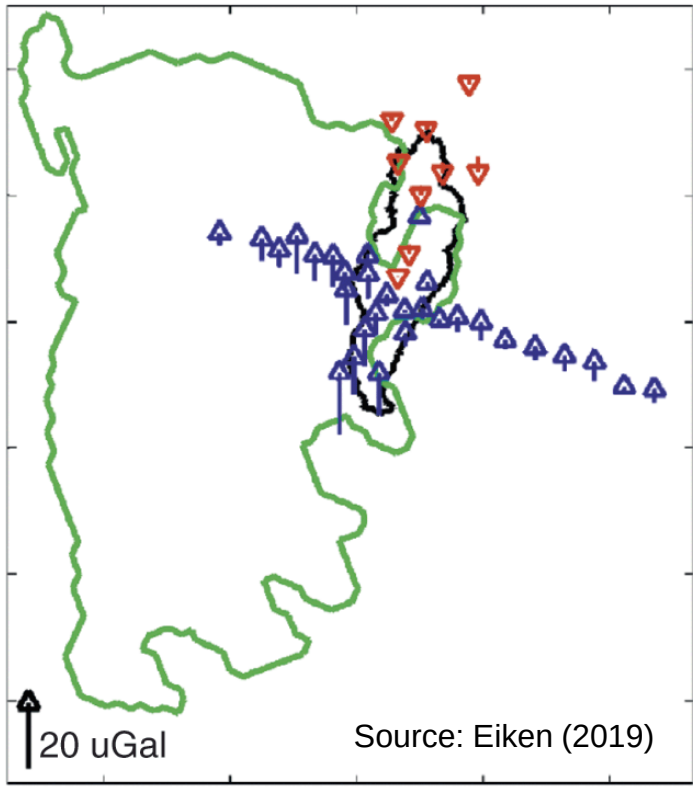
Enable viability testing of alternative technologies to reduce 4D challenges and maximise success of CCS projects.

Recommended Technologies: Gravity

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.

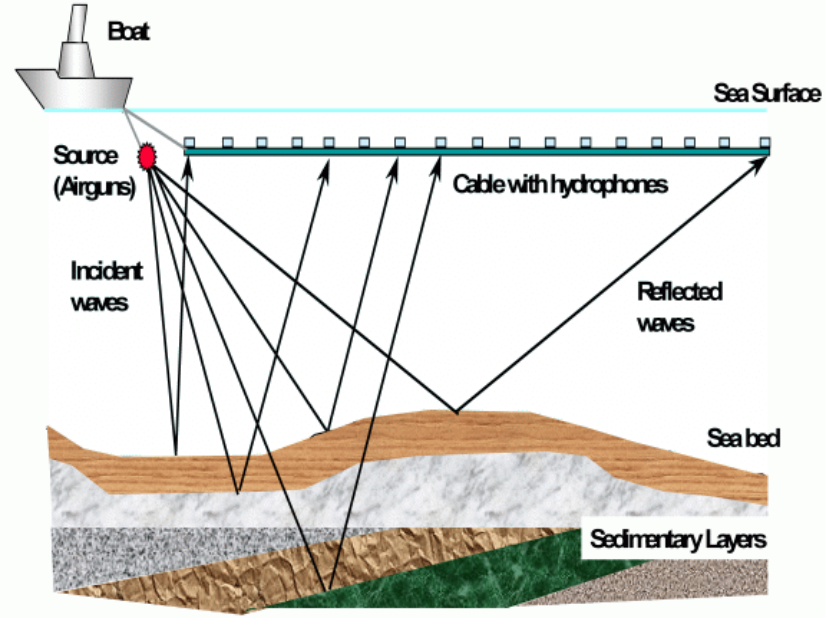




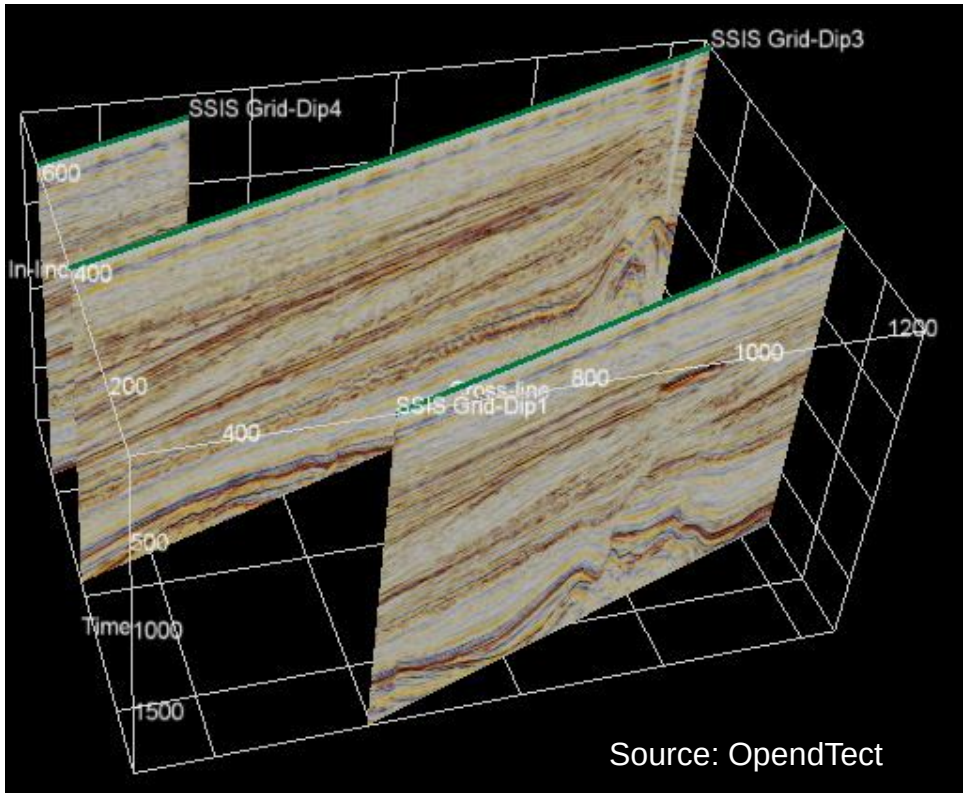
Recommended Technologies: 2D seismic

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.



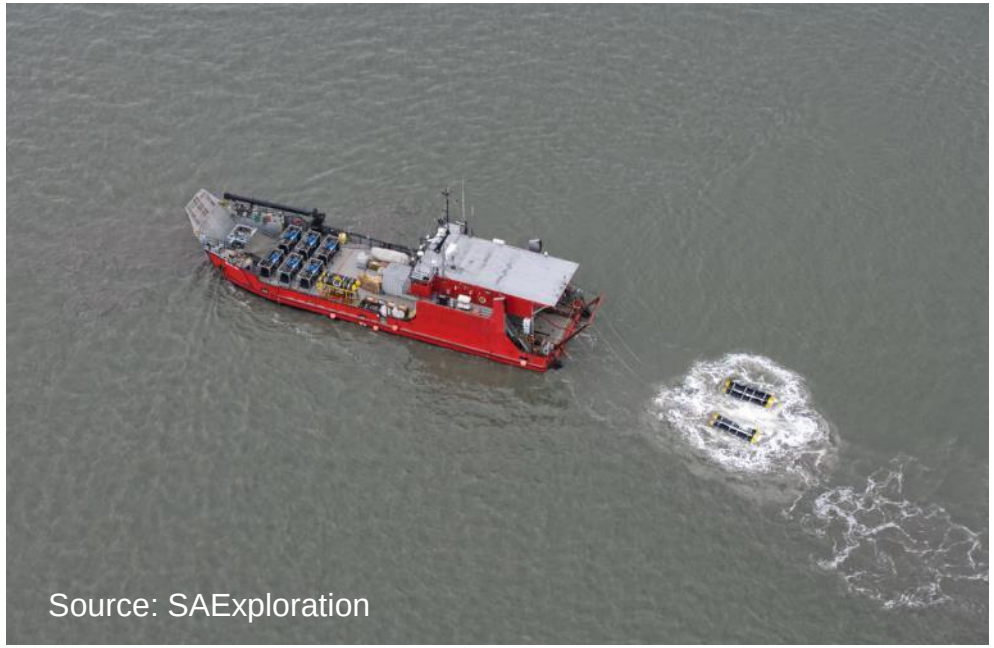
Source: slb



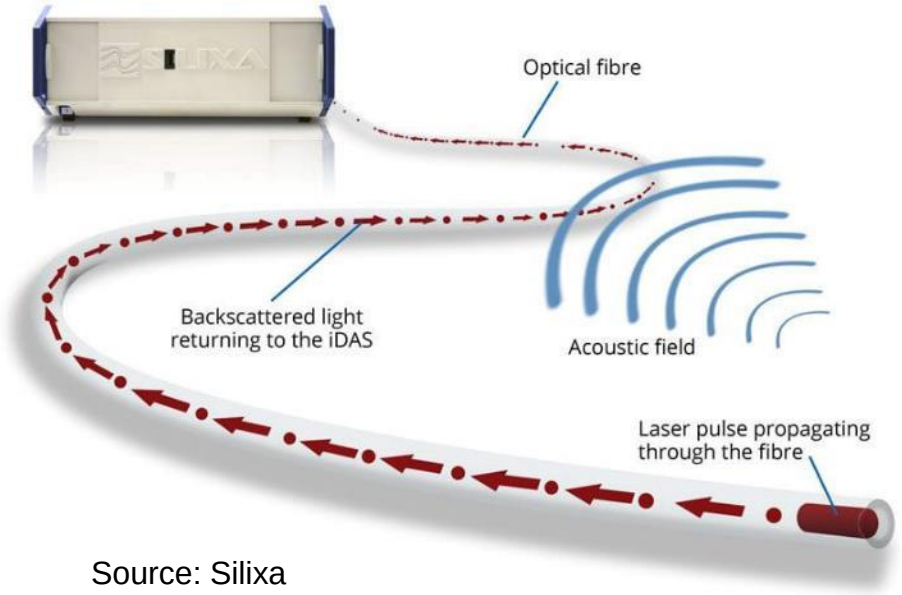
Source: OpendTect

Recommended Technologies: Surface & VSP-DAS

Time-lapse S-DAS	Emerging technology being developed. Permanent DAS (Distributed Acoustic Sensing) fibre 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.



Source: SAExploration

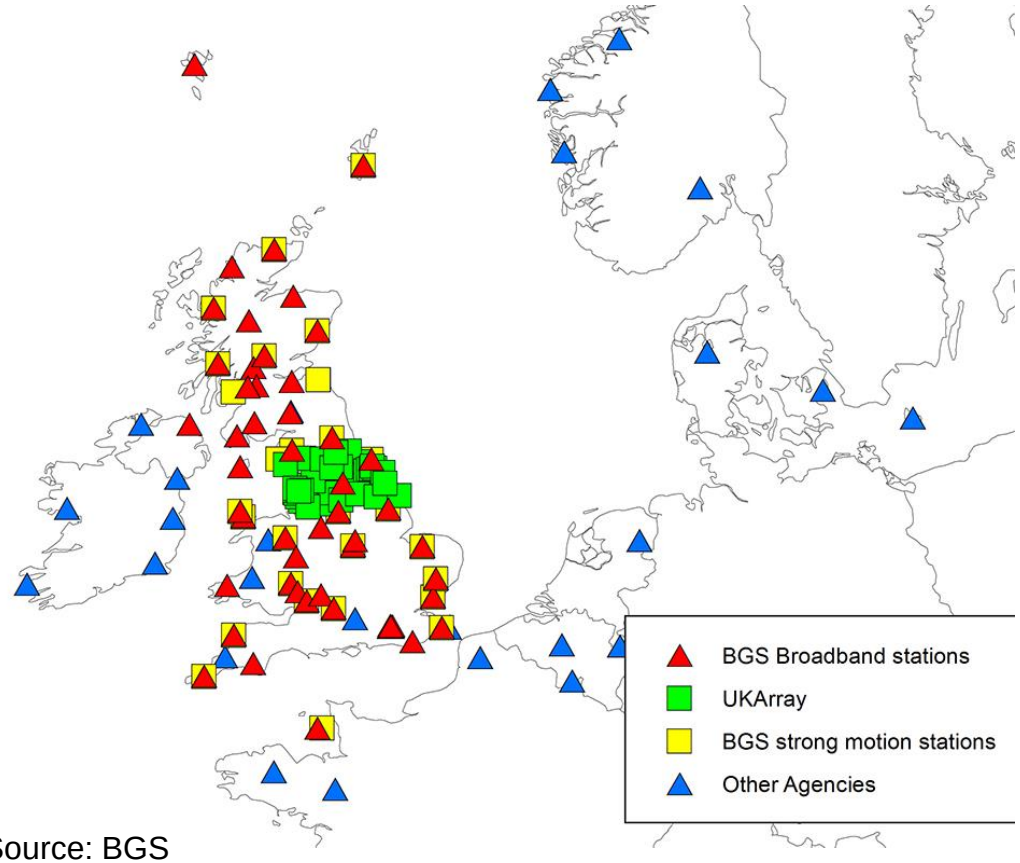


Source: Silixa

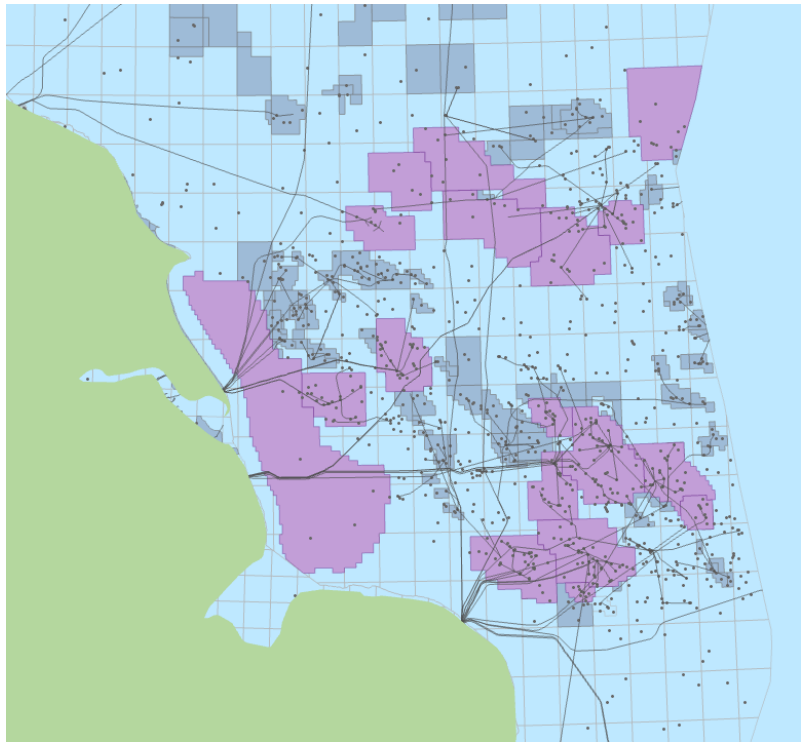
Recommended Technologies: Microseismic

Surface microseismic

Established technology in the hydrocarbon industry to monitor induced seismicity and assess geomechanical stability. Effective in multiple store types, especially when deployed as a network.



Source: BGS



Recommended Technologies vs Store Options

Technology	Store Depth		Development Type		Seismic Signal			Store Type		Recommended 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

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