CELTICSEAPOWER

A view from Cornwall on the role of Regional Environmental Characterisation in supporting the streamlining of consent for Floating Offshore Wind in the Celtic Sea.

Figure 1 South-West Deeps - https://www.gov.uk/government/news/mmo-response-to-greenpeace-action-in-south-west-deeps-east

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CELTICSEAPOWER

Document Title		A view from Cornwall on the role of Regional Environmental Characterisation in supporting the streamlining of consent for FLOW in the Celtic sea.	
Document Reference			
Date of Issue			
Author		Neil Farrington, Harrison Smith	
Revision History	**Date**	**Amended by**	**Reviewed By**
A - First Draft	28/09/2024	HS	NF
B- Second Draft	21/10/2024	NF	HS
00 - First Issue	31/10/24		
01 - Rev 1			
02 - Rev 2			
03 - Rev 3			
04 - Rev 4			

1. Introduction

Celtic Sea Power (CSP - www.celticseapower.co.uk) is a strategic enabling organization working towards the sustainable development of Floating Offshore Wind (FLOW) in the Celtic Sea, in order to maximize the once-in-a-generation economic opportunity for Cornwall and the wider Celtic Sea region.

Our aim is to enhance retention of the social, environmental and economic benefits of FLOW and other low carbon energy opportunities. So far, we are in the early stages of supporting the roll out of FLOW through promoting economic and environmental opportunities across Cornwall and the Celtic Sea region. We provide a platform for stakeholder engagement, innovation, knowledge and data sharing. Eventually, we plan to be at the heart of a thriving and sustainable FLOW ecosystem with the benefits realised for people across Cornwall and the Celtic Sea Region.

Celtic Sea Power is an autonomous subsidiary of Cornwall Council, member of the Celtic Sea Alliance and Celtic Sea Cluster. We use our influencing role to work closely with the FLOW industry and relevant decision making bodies to both embed and make available quantifiable solutions to increasing both the short and long term sustainability of the emerging FLOW sector.

FLOW is set to be a major contributor to the UK's low carbon economy and forms a major element of the UK's Energy Security Strategy (which sets a target of 5GW by 2030). With respect to Cornwall, circa 640MW (at a capacity factor of 45%) of installed offshore wind would meet 100% of our 2021 electricity usage (2510.8 GW/H – BEIS sub-national electricity consumption figures) .

This report has been produced with funding through the Cornwall Good growth Programme. The report is intended to provide an insight into Cornwall's current approach to Regional Environmental Characterisation (REC) as a key contributing factor to streamlining of the offshore consenting process in the UK.
Celtic Sea Power has been delivering REC activities since 2021 with all campaigns described in detail in part 3 of this report.
REC in itself holds intrinsic value through new data and evidence acquisition, however to maximise its value it is best placed within wider frameworks and processes that can support the more holistic sustainable development of an emerging new FLOW sector. A number of these wider frameworks and processes are described in Chapter 1 establishing the more expansive development environment that can host and enhance the recognition of REC activity.
A future focus section by the ORE Catapult is also provided as an addendum to this document and considers the utilisation of new technology to potentially more efficiently capture required data and evidence inputs.

1.1 Identifying need and taking action at a regional receptor level

A key purpose of this document and related engagement activities is to support one of Celtic Sea Power's key strategic objectives in helping to streamline the licensing and consenting process for FLOW. Targeting this objective and providing a long-term holistic view of the existing and evolving regional environmental baseline, acquired through REC, can help ensure the full potential benefits of FLOW in the Celtic Sea can be realised , thereby enabling a long-term sustainable FLOW development pipeline within the region.

It has been noted that a significant current challenge to sustainable development and future long term planning for FLOW in the Celtic Sea is the lack of baseline data, partly due to the lack of a legacy development industry. At the project level there has been concern that this could inhibit projects from being able to measure relative change and set their specific project-level datasets within a regional context, which could increase consenting risk and/or effect future leasing decision making. Actionable regional scale evidence is also crucial for the longer term strategic spatial planning of FLOW which requires the consideration of multiple environmental receptors and users of the sea space alongside related issues such as supporting infrastructure development and the assessment of large scale, long term cumulative impacts for industrial scale FLOW deployment in a new environment.

To this end, CSP has been working collaboratively over the last three years to try and understand where the potential data/ evidence pinch points might occur in order that early pro-active action can be taken to resolve them ahead of need. Following early engagement with the FLOW sector, regulators, consenting bodies, local authorities, national research programmes and other relevant key stakeholders we have adopted a receptor-based approach to Regional Environmental Characterisation (REC) of the UK Celtic Sea area.

1.2 Applying actionable evidence

By taking a more collaborative strategic regional approach to the acquisition and application of appropriate, actionable, baseline evidence in the FLOW design and development process, we hope the related leasing, consenting and licensing process in the Celtic Sea can be delivered more effectively, reducing conflict, and approval timeframes. We aim for this approach to be recognised by all actors in the Celtic Sea leasing and consenting processes, with the support of a common consensus on the Celtic Sea environmental evidence baseline and collaborative action on new data collection and evidence building.

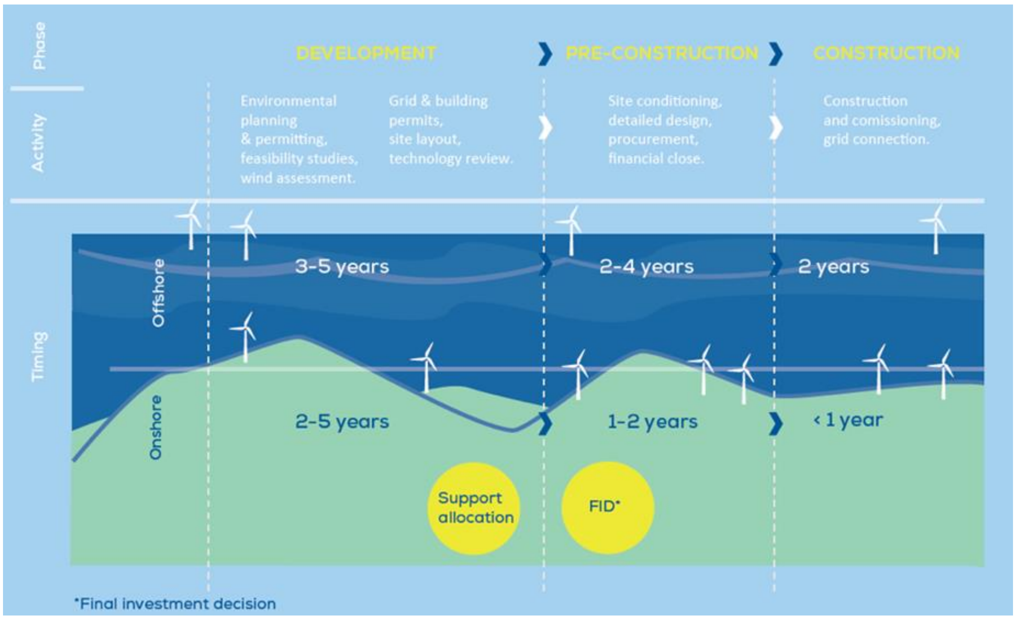

Figure 2 Wind energy (on-shore & off-shore) projects' development timeline (Source: WindEurope)

Standardizing the approach to regional scale evidence acquisition and application in the Celtic Sea through REC provides the potential opportunity not only to reduce the level of debate around evidence base uncertainty but to also promote more efficient and effective new evidence collection. This could include the adoption of new surveying and modelling methods for example, supported by new financing mechanisms and data sharing arrangements, whilst the availability of regional scale receptor evidence can also potentially reduce ongoing project monitoring requirements and adaptive management needs. This enables REC activity to be applied both at the project development stage, effecting the current 3-5 year completion timeframes as well as the operational stage when it can directly contribute to minimising ongoing monitoring requirements and operational risks that may relate to consenting conditions and potential impacts on environmental receptors.

These type of actions are crucial to support the Government's ambition of bringing forward 5GW of new FLOW generation by 2030 (British Energy Security strategy 2022) and a further 12GW of FLOW to the Celtic Sea by 2035-2040[1] .

A clearly defined development and consenting process that includes REC offers many advantages to both developers and decision makers whilst gaining the appropriate permissions and licenses is critical to device deployment and development. Onerous and/or poorly defined consenting processes can directly restrict investment and scheme deployment, increasing determination timeframes and associated costs (Martin & Rice 2015).

1.3 Supporting development frameworks and practices that can be enhanced with REC input

REC is a method for acquiring new environmental data and evidence at a regional scale. This approach generates its own intrinsic value through new data and evidence availability for project scale development and can directly contribute to streamlining of the consenting process for FLOW (discussed in more detail at chapter 3). However, REC can also be applied to other key functions from technology development to long term marine spatial planning that considers the interaction between multiple activities and actors seeking to utilise the same marine space.

Acquiring evidence on the basis of key sensitive environmental receptors also enables the evidence to be applied to multiple sectorial considerations from FLOW, Fisheries and conservation management to the strategic planning of new infrastructure deployment. The following sections introduce some of the broader applications of REC as an intrinsic part of the solution to streamlining consent whilst also considering key spatial planning constructs and delivery frameworks that seek to better manage our marine environment.

We will also provide a review of alternative approaches to offshore wind development from the UK to areas of Europe in Chapter 2, introducing a concept of centralised and decentralised drivers to environmental data acquisition, application and availability.

1.3.1 Technology Readiness – TRL to CRI and LCoE

Though not always recognised, one of the earliest potential applications of REC to FLOW development comes at the technology development and design stage. Whilst this early development stage is often dominated by more engineering focused considerations an understanding of how a technology may impact key environmental receptors in a given area (with information provided by REC for example) can directly affect the technologies future acceptance and ability to be deployed in a live environment.   REC as part of a clearly defined consenting process offers many advantages to the technology developer that may yet be undervalued.

The TRL and CRL indexes are globally recognised benchmarking tools for tracking specific technology development pathways and making commercial investment decisions into new emerging MRE technologies, with a wide body of knowledge and literature on the general commercialisation process having evolved to inform public policy and associated funding tools to enable RE. (Australian Government 2014). The general indexes take little early notice of critical consenting requirements and levels of stakeholder consideration. (Figure.4.), which offers two clear missed opportunities for technology developers.

[1] Offshore wind | The Crown Estate

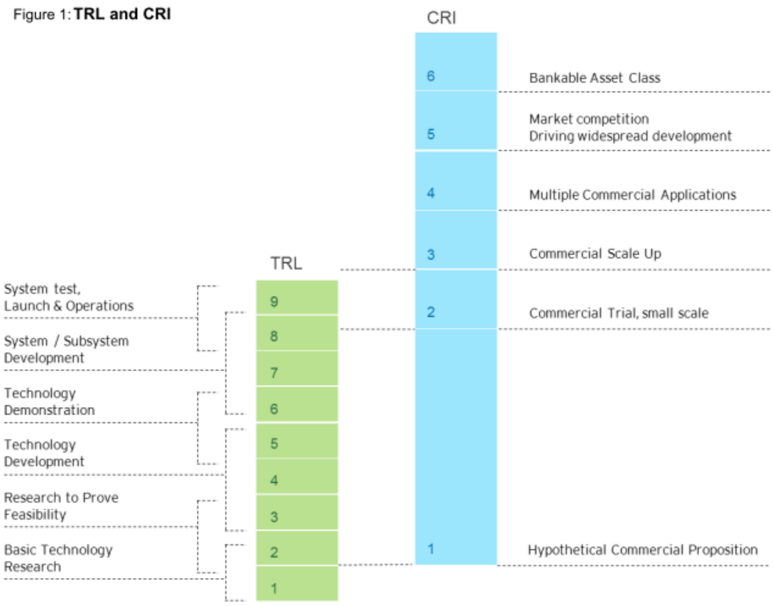

Figure 3 The Technology Readiness level and Commercial Readiness Index. Source ARENA 2014

Early stakeholder engagement and the recognition of likely consenting requirements could have a direct impact on technology design and function and should therefore arguably form a specific element of early TRL index developments. It has also been suggested that a more evolved Commercial Readiness index (CRI) is needed (Australian government 2014), that has the ability to cover all facets of a typical investment due diligence process with a stronger focus on stakeholder acceptance and the regulatory environment to demonstrate an applications overall commercial readiness and ability to enter the market.
REC provides a potential route to acquiring environmental data at an early stage of an offshore energy markets evolution that can feed back into consenting considerations for a region and be available to support early technology development and selection considerations that can be applied to a spatially defined market area. Developing REC programmes in co-ordination with key consenting bodies and environmental stakeholders helps to ensure that data and evidence released is directly applicable to consenting considerations in an area and helps to de-risk the commercial applicability of a technology.

Indicators	**Summary of Indicators**
Regulatory Environment	The maturity of the planning, permitting and standards relating to the technology.
Stakeholder Acceptance	The maturity of the process for evidence based stakeholder consultation linked to renewable energy integration into the energy markets.

Figure 4 Description of an evolved CRI index indicator. Source: ARENA 2014

Alongside the TRI and CRL indexes the Levelized Cost of Energy (LCOE) is a common metric utilised to describe the unitised cost, through life, of delivering energy from a particular project and is commonly used to make public policy and high level preliminary investment appraisal decisions across the full range of energy generating technologies. A critical function of the LCOE is capital expenditure which includes project development costs and securing the necessary consents. This may be particularly hard to establish with a new emerging technology but this risk could be mitigated through early stakeholder engagement and readily available regional environmental data, helping to establish relative costs which may then ideally also be reduced as part of a more streamlined decision making process. Reducing assumptions and risk not only reduces costs, leading to a more competitive LCOE, but also helps to improve investor and decision maker confidence in the rationale for the presented LCOE figure.

Other broader advantages that can be induced through the early development of REC approaches include the establishing of direct relationships with accountable bodies and specific personnel that can very much help the negotiating and consenting process. Trust and good communications backed by sound baseline evidence can directly contribute to the streamlining of the process and reduction of risk and whilst not part of the prescribed consenting process, human nature can be considered as a contributory factor in the determination process, particularly avoiding what can be termed as a "rabbit in the headlights reaction". Early engagement with actionable evidence also provides the opportunity for the potential benefits of schemes to be presented at the early stage which can directly influence future dialogue and perceptions of a new MRE technology and its impact on the environment that may be crucial to its future deployment levels and in itself help to streamline the process by limiting public challenge and subsequent delays.

1.3.2 Applications of REC to Marine Spatial Planning

This section of the report provides a background on the emergence of Marine Spatial Planning (MSP) which can provide an overarching framework for the implementation and utilisation of a Regional Environmental Characterisation approach. A key pre-requisite for quality MSP is high quality data and evidence across multiple receptors that may be affected by a variety of planning policies and objectives.

MSP has become active over the last 20 years with the first International Workshop on MSP in 2006 led by the Intergovernmental Oceanographic Commission (IOC). Although MSP adoption is increasing worldwide, many regions, countries or municipalities still need support to adopt it or to fully implement it where the process has already started. The first guide to "Marine Spatial Planning: A Step-by-Step Approach toward Ecosystem-based Management" was produced in 2009 and became an internationally recognized standard that contributed to formulating the conceptual approach behind MSP. In March 2017, following the second International Conference on MSP, the IOC adopted the "Joint Roadmap to accelerate MSP processes worldwide" (MSProadmap).

1.3.2.1 A definition of Marine Spatial Planning

Marine spatial planning is a public process of analyzing and allocating parts of three-dimensional marine spaces (or ecosystems) to specific uses or objectives, to achieve ecological, economic, and social objectives that are usually specified through a political process. (UNESCO 2013)

MSP is a process that is place- or area-based , Integrated across economic sectors and among governmental agencies, Adaptive, Strategic, Participatory, Balanced and is only one element of the management process

1.3.2.2 Some potential benefits of MSP

MSP offers benefits across the full range of sustainability criteria including; Ecological – e.g. Identification of areas for special value for protection; recognition of ecosystem values; Identification of cumulative effects; Economic – e.g. Greater certainty for developers and managers; co-location of compatible activities; opportunity to plan ahead and Social – e.g. Opportunities for participation; perceived value of seascape and heritage recognised; recognition of social impacts of decision making

1.3.2.3 Key steps in MSP Development

The following information is provided by UNESCO and describes the key steps for effective MSP development. A critical aspect that will be featured in following sections of this report is Step 5 – **Defining and analysing existing conditions**. A REC approach enables the regional scale collection of new environmental data and evidence to better define the existing baseline environment and understand its current condition, facilitating evidence based considerations and decisions making for key environmental receptors and environments.

Table 1 Key Steps for effective MSP development. UNESCO

1. Identifying need and establishing authority
2. Obtaining financial support
3. Organising the process through pre-planning
4. Organising stakeholder participation
5. **DEFINING AND ANALYSING EXISTING CONDITIONS**
6. Defining and analysing future conditions
7. Preparing and approving the spatial management plan
8. Implementing and enforcing
9. Monitoring and evaluating performance
10. Adapting the spatial management plan and process

1.3.3 A brief history of spatial planning for FLOW in the Celtic Sea

To bring the focus of this report directly onto the UK Celtic Sea Area the following information provides a brief history of spatial planning in the Celtic Sea region, helping to identify key areas of activity that could directly benefit from the provision of a REC approach and the new data and evidence it can derive.

1.3.3.1 2020 - Floating Offshore Wind Constraint Mapping in the Celtic Sea

The first published efforts to spatially map the UK Celtic Sea area based on FLOW considerations came with the report '**Floating Offshore Wind Constraint Mapping in the Celtic Sea[2]'** produced by the ORE Catapult and ITPE Energised in 2020.

The report had a number of objectives and was a critical first stage action in guiding CSP's early Regional Environmental Characterisation planning both in terms of understanding data/evidence gaps and spatial and temporal coverage as well as ensuring a spatially targeting environmental survey programme could be developed. Wider objectives of the report included;

- To support the Welsh Government and other authorities in taking a proactive approach to understanding the spatial potential for the development of Floating Offshore Wind in the Celtic Sea. This will form a starting point for informed further discussion with stakeholders and a clearer understanding of the opportunity, its potential scale, possible location(s) and critical wider interests for full consideration.
- To identify potential areas of least constraint that can influence the development of spatial planning policies, including the Welsh National Marine Plan and SW Marine Plan, and a more strategic approach to supporting the development of this important opportunity. This is not a techno-economic analysis though there are known synergies with these approaches and common features that were considered. The intention was not to determine the ultimate technical viability and final location of future Floating Offshore Wind deployments, as these will be directly affected by specific technology selection and individual developer requirements.
- To support the acceleration and streamlining of the leasing and licensing process to decrease conflict and reduce permitting timeframes to match industry aspirations. This includes assisting the Crown Estate, in their early stage planning for the identification of key resource areas to support future Floating Offshore Wind leasing rounds.
- To identify gaps, align and focus ongoing and future research and data collection across the Celtic Sea to inform factors such as site design features and the collection of higher resolution data sets for critical interests such as marine mammal distributions.
- To help rationalise sector development benefits including supply chain and skills development opportunities across Wales and the SW as well as LCOE cost reduction modelling strategies.

[2] cms.ore.catapult.org.uk/wp-content/uploads/2019/11/floating-offshore-wind-constraint-mapping-in-the-celtic-sea.pdf

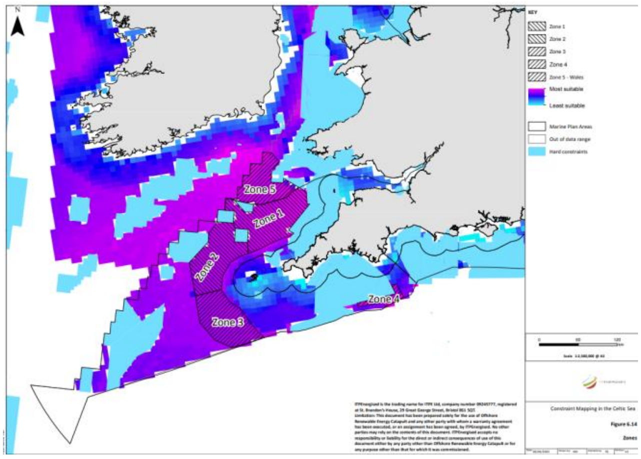

Figure 5 OREC/ITPE 2020

Hard Constraints	Military Danger Zones	Ramsar Sites	SPA's	SAC's
	SSSI's	MPA's	Existing lease areas	
Weighted Constraints	Military exercise zones	Shipping Routes	Fishing	Wind Resource
	Wave Power	Currents	Bathymetry	Wrecks
	Visual 30km	Visual 45km	NATS radar	
Reference Data	Ports	Transmission grid	Seabed	Comm's cables
	Habitat	Marine Mammals	Nursery Grounds	Spawning areas
	Shellfish waters	Seabird foraging	Heritage	

Figure 6 Applied Constraint and Reference layers

This wide range of objectives enabled application of the outputs from this spatial planning process to be applied in multiple areas to advance the nascent understanding of offshore wind potential in the Celtic Sea Region and some of the key requirements to accelerate its deployment. Alongside the application of hard and weighted constraints a number of reference data layers were included that could not be weighted or considered in other data categories largely due to the low quality of available, regionally specific data and evidence.

1.3.3.2 Autumn 2020 - Key resource areas for offshore wind

Later in 2020 The Crown Estate commissioned Everoze to produce the report 'BROAD HORIZONS: Key resource areas for offshore wind Summary Report.[3]' The main purpose of the report was to map key resource areas for offshore wind to enable early conversations over future development potential in the waters off England, Wales and Northern Ireland. By mapping engineering solutions against the physical characteristics of the sea and seabed the report provided further early indications into both the potential market area and potential applicable technologies for FLOW in the Celtic Sea. The report also provided further rationale for the spatial targeting of CSP's evolving REC activities. Limited data layers were applied in the constraining process partly due to lack of available, regionally specific data across multiple environmental receptors.

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[3] https://www.thecrownestate.co.uk/media/3642/broad-horizons-offshore-wind-key-resource-area-summary-report.pdf

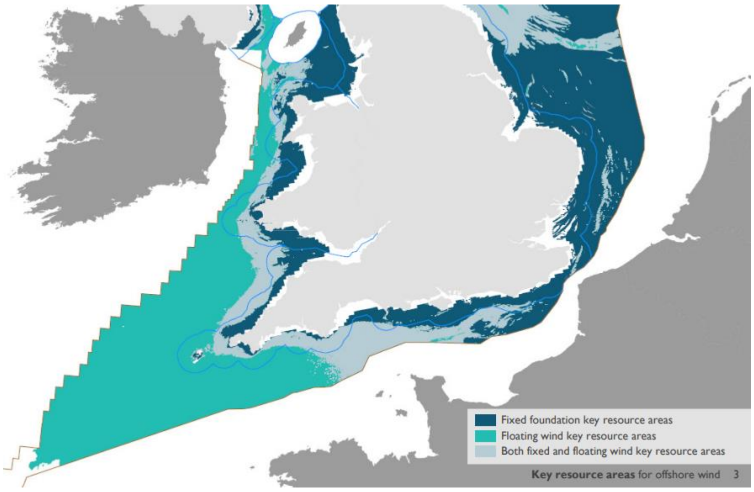

Figure 7 Everoze 2020

1.3.3.3 2021 - The SouthWest Marine Plan

The SouthWest Inshore and Offshore Marine Plan[4] was first published in June 2021 and provides a framework intended to shape and inform decisions over how the areas' waters are developed, protected and improved over the next 20 years. The Plan intends to ensure effective and sustainable use has been made of the space and resources available, whilst taking account of the areas' distinctive characteristics. Through an extensive process of stakeholder engagement and spatial mapping a range of policies were produced including a Renewable Energy Policy and associated constraints map.

However restrictions in the original allocation methodology on applied constraints led to a focus of areas of potential along the SW coastline within applied bathymetry bandings for Fixed Offshore Wind. It appeared a methodology for Fixed Offshore Wind on the East Coast, that is dominated by Fixed Offshore Wind opportunities, may have been directly applied to the SW Marine Plan area without full consideration of whether the technology is appropriate for the SW Marine Plan areas physical conditions and designated areas. This highlights a key issue in the spatial planning process as the constraints to be applied for emerging new technologies such as FLOW are not always known or understood by all parties.

Since the time of the plans production an additional Offshore Wind Energy Areas of Potential layer has been included in the plans more up to date on line data portal[5] that is more frequently refreshed that the plan itself which runs on a 3-4 year cycle.

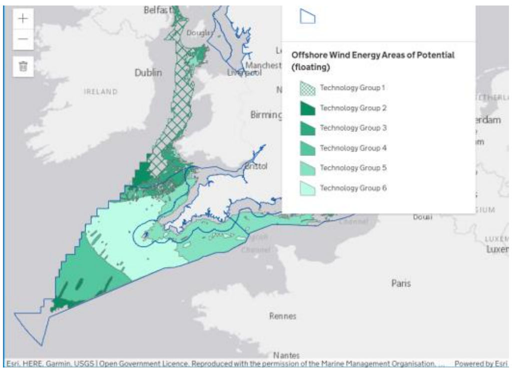

Figure 8 Explore Marine Plans - Floating Wind Layer

Spatial consideration of what are deemed potential development areas within the broader regional policy context created by the SW Marine Plan enables weight to be applied in the planning and consenting process for future FLOW developments. Again, spatial considerations contained within the plan provided further

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[4] South West Inshore and South West Offshore Marine Plan (publishing.service.gov.uk)
[5] Explore marine plans (marineservices.org.uk)

rationale for the spatial targeting of CSP's REC activity. It is also important to recognise that the lack of available data and evidence for FLOW at the time of the plans production directly contributed to its initial exclusion from the plan policies.

1.3.3.4 2022 TCE Round 5 Areas of Search and 2024 future focus

Offshore Wind Leasing Round 5 is currently active to Q2 2025 and seeks to establish a new FLOW market in the Celtic Sea. Round 5 is expected to be the first phase of commercial development in the Celtic Sea, with an opportunity to create up to 4.5GW of new renewable energy capacity, while acting as a springboard for new social, economic and environmental opportunities.

In July 2022 The Crown Estate released their first five broad 'Areas of Search' in relation to the development of floating offshore wind in the Celtic Sea. This followed initial high level spatial planning activity considering the application of an exclusions and restrictions model. The areas were identified following technical analysis and extensive engagement between The Crown Estate, the UK and Welsh governments and key agencies, and specialist stakeholders. The Areas of Search take account of a variety of factors, including navigation routes, fisheries activity and environmental sensitivities. By balancing these and other factors, and incorporating feedback from stakeholders, the Areas of Search were assessed as the most favourable locations for FLOW and those most likely to be deliverable in the near term, accelerating secure domestic energy.

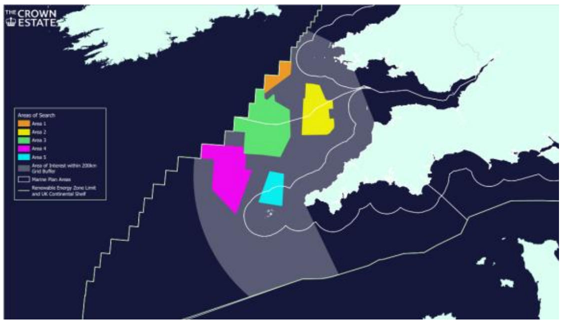

Figure 9 Five identified Areas or Search (AOS)

The Crown Estate's overall approach to spatial analysis follows six steps, each of which identifies progressively smaller, less constrained and technically attractive areas of seabed. The figure below details at a high level how spatial opportunity is refined from a Key Resource Area (KRA) to Project Development Areas (PDAs).

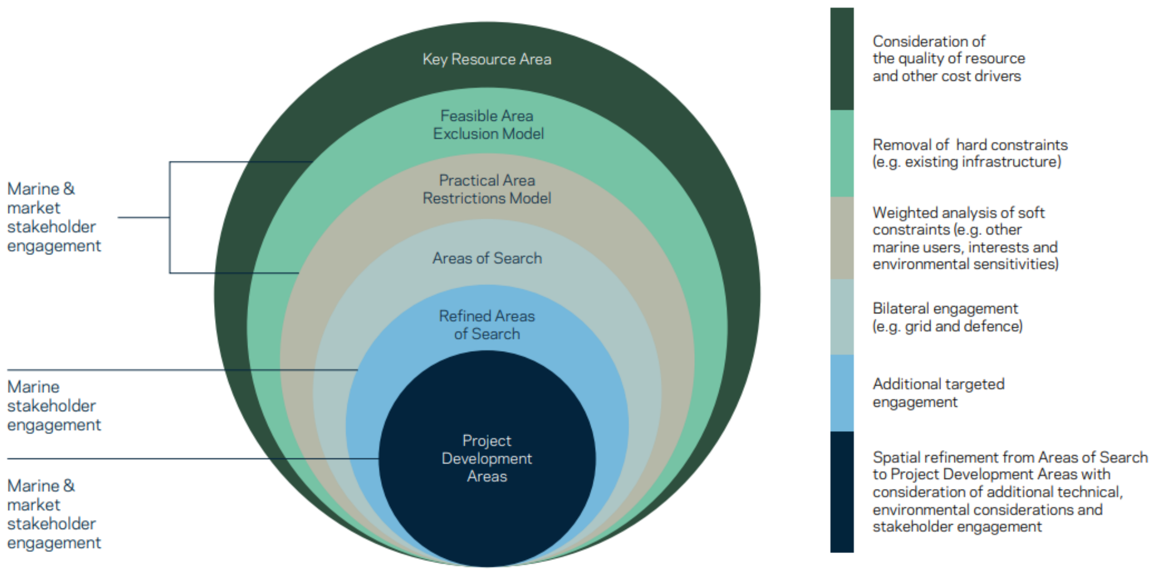

Figure 10 High-level stages of spatial assessment showing decreasing spatial footprint at each stage

Key considerations for the Crown Estate when identifying areas of seabed for FLOW include striking a balance between the economic potential for developers and local communities, and minimising potential harm to the environment and other users of the sea.

The final Round 5 Project Development Areas (PDA's) were announced in December 2023 following conclusion of the Crown Estate spatial planning Process. Full detail of the site selection methodology are available.[6]

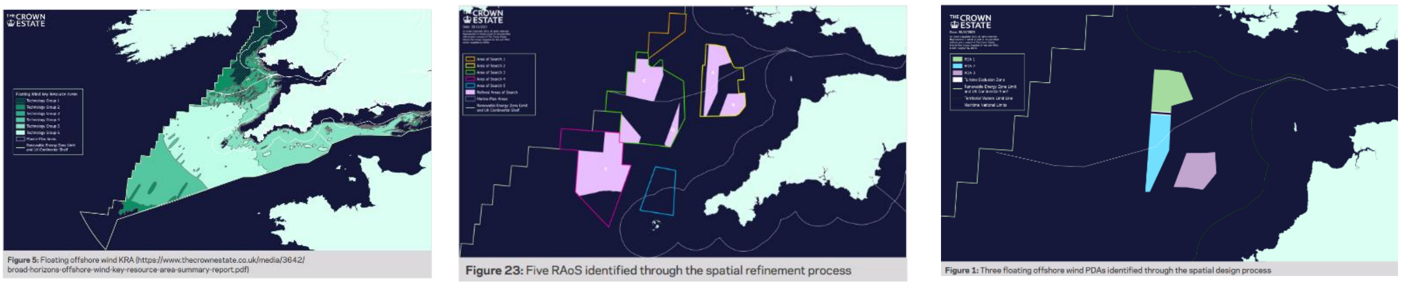

Figure 11 Some of the progressive stages in the TCE R5 spatial mapping process

At each evolutionary stage of the Crown Estate spatial mapping process crucial information can be derived on both the lack of available actionable data and evidence to assess particular environmental receptors and the potential spatial focus for planned development activity with an associated project level need for environmental data. For example when looking closely into the environmental data sets applied to the spatial mapping process, critical species that create high risk factors for FLOW development in particular include seabirds and marine mammals. Due to the virtually non-existent regionally specific data available for these two species groups and a reliance on broad scale distribution models with no regional input, the data input layer relates species to designated spatial features (SACs/SPAs/MCZ). This is unlikely to reflect the true extent of species type and distribution across the Celtic Sea region, particularly for highly mobile species, and consequently forms part of the rationale for CSP's REC campaigns discussed in more detail in chapter 3.

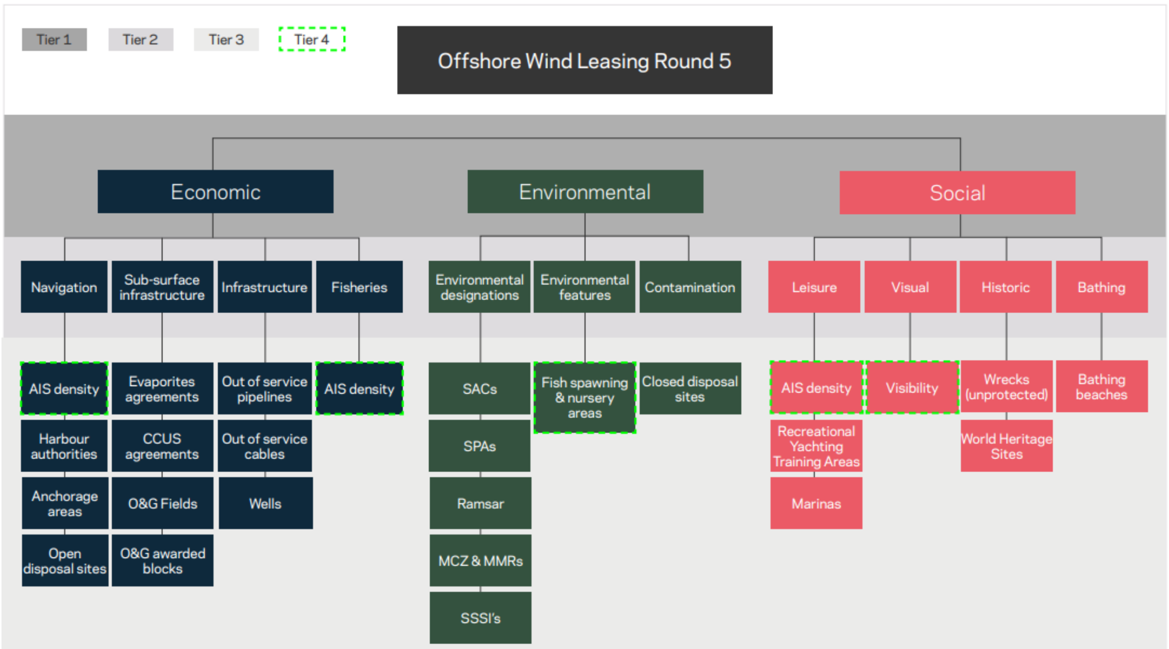

Figure 12 Final AHP model structure for Offshore Wind Leasing R5 where datasets are grouped info themes and subthemes across 4 tiers

[6] . [1720790173-site-selection-methodology-v2.pdf (datocms-assets.com)]

The Crown Estate are themselves well aware of many of the data and evidence deficiencies for environmental receptors in the Celtic Sea as can be seen with their initiation of key activities including the Offshore Wind Evidence and Change Programme[7], Offshore Wind Evidence and Knowledge hub[8] and Active Round 5 pre-consent survey programme[9].

It is useful here to make a further clear distinction between the Crown Estate spatial mapping approach for Round 5 and CSP's REC approach. The Crown Estate activity is directly linked to relatively short term project scale development outcomes which in this case sought to allocate a specific area for 4.5GW of FLOW deployment for lease in 2025. CSP's REC activity seeks to establish a regional scale (and eventually ocean basin scale) environmental baseline across all key environmental receptors with a common regional scale modelling output. This can offer advantages when considering infrastructure needs outside of direct project sites, effects on migratory highly mobile species and a longer term view of larger spatial and temporal scale cumulative ecosystem level impacts of development for example.

In September 2024 the Crown Estate released a report entitled "Future of Offshore Wind - Considerations for development and leasing to 2030 and beyond[10]" which includes consideration for FLOW in the Celtic Sea post leasing round 5. This has initiated a new spatial mapping process at the Crown Estate as the report sets out how seabed rights for 20-30GW of new offshore capacity could be brought to market before the end of the decade to support the UK's net zero and energy security ambitions. The specific potential for the Celtic Sea to provide up to 12GW, of which 4-10GW could be leased by 2030 and in operation from 2035 to 2040, has been recognized.

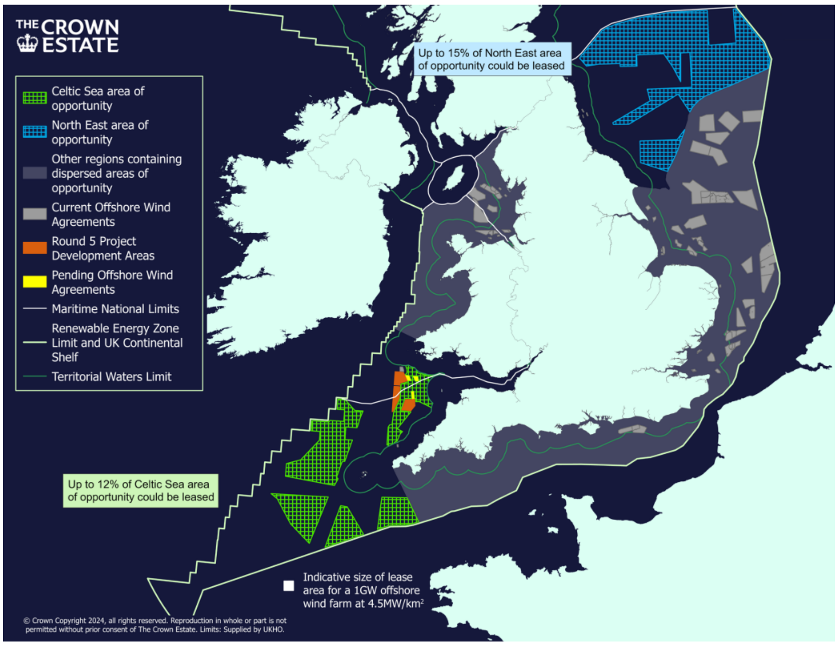

Figure 13 Future of Offshore wind 2024 - Initial Areas of Search

The need for Regional scale environmental data and a REC approach become self-evident as development interests again consider longer term aspirations across a broader spatial area.

[7] Offshore Wind Evidence and Change Programme (thecrownestate.co.uk)
[8] Offshore Wind Evidence & Knowledge Hub enters Discovery Phase on road to streamlining consenting process through data (thecrownestate.co.uk)
[9] Pre-Consent Surveys | Marine Data Exchange
[10] datocms-assets.com/136653/1725984848-tce_future-offshore-wind.pdf

2 Bridging Approaches: A Comparative Analysis and Strategic Insights into Offshore Wind Development in the UK & Europe

To better understand the value of Regional Environmental Characterization (REC) as a key component of effective spatial planning and its relationship to offshore wind consenting timeframes, this overview examines how various European countries have approached offshore wind development. It will cover centralized development models, highlighting examples from the Netherlands and Germany, as well as the generally decentralized (developer-led) approach previously seen in the UK, alongside the current trend towards more strategic regional-scale considerations.

As discussed later in Chapter 2, the Collaborative Spatial Planning and REC approaches offer a hybrid model that leverages both private and public support and financing. This model aims to foster a collaborative approach to regional data and evidence acquisition, facilitating its application in a range of key decision-making processes for both short- and long-term objectives.

2.1 UK: Overview of Offshore Wind Market and development processes

By the end of 2022, the United Kingdom had installed over 10 GW of offshore wind capacity, a leader in this sector. The government has set a goal of achieving 50 GW of offshore wind capacity by 2030, as part of its wider aim to reach net zero emissions by 2050.

Highlights from Contracts for Difference Allocation Rounds:

- **Round One:** Two projects, totalling 1.16 GW capacity, at an average price of £117.14/MWh.
- **Round Two:** 3.1 GW capacity awarded, with prices falling to £57.50/MWh.
- **Round Three:** 5.46 GW offered, including bids below wholesale prices.
- **Round Four:** Nearly 7 GW awarded at £37.35/MWh.
- **Round Five:** No offshore wind projects bid for or received support, reflecting rising costs and economic uncertainties.

2.1.1 Development and Project Management

The development and project management phase encompasses all critical activities leading up to financial closure or the commitment to commence construction on wind farms. Key tasks include securing planning permissions, conducting environmental impact assessments (EIAs), and developing design and engineering specifications.

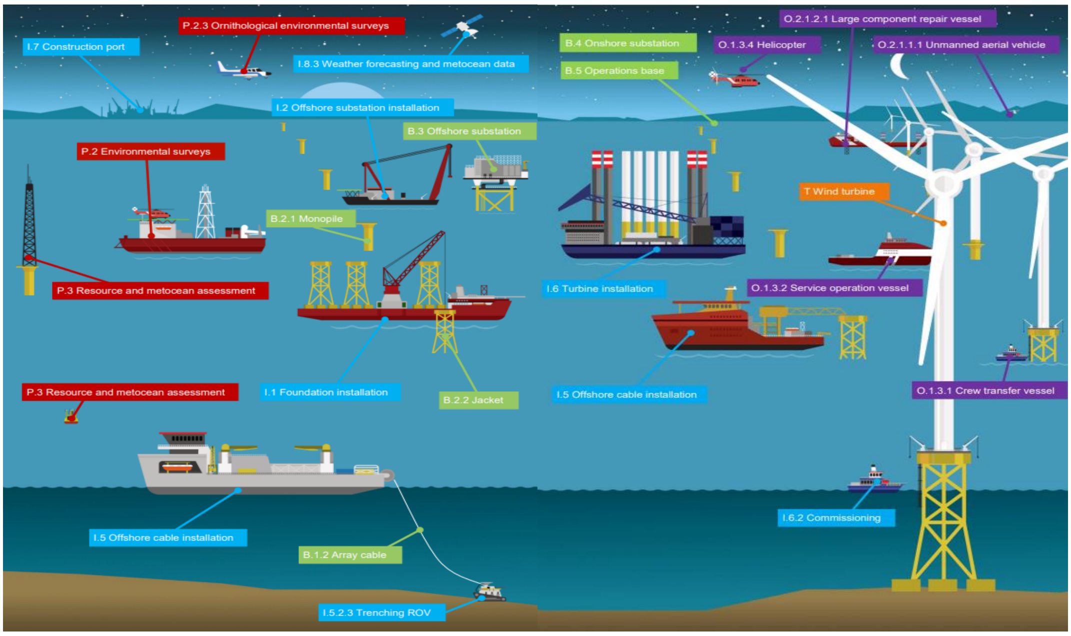

Figure 14 Processes in the development, installation and operation of an offshore wind farm. BVG Associates, 2019.

2.1.2 Seabed Leasing and Regulatory Oversight

The leasing of seabed areas for offshore wind farms is overseen by The Crown Estate, which organizes periodic leasing rounds to allocate large areas for development. Crown Estate Scotland was established in 2017 to manage seabed rights in Scottish waters, facilitating streamlined management and early project development.

2.1.3 Approval Process for Offshore Wind Projects

Offshore wind projects with a capacity over 100 MW are classified as nationally significant infrastructure projects (NSIPs) in England and Scotland with a 350MW threshold in Wales. The Planning Inspectorate reviews these projects, and the Secretary of State for the Department for Business, Energy and Industrial Strategy (BEIS) either grants or denies consent based on the Inspectorate's recommendations. This centralised approach ensures alignment with national energy goals.

In England, a Development Consent Order (DCO) is issued under the Planning Act 2008, covering various consents, including marine licenses and onshore permissions. In Wales, Natural Resources Wales issues the marine license. In Scotland, Marine Scotland evaluates offshore projects and grants consent under the Marine (Scotland) Act 2010. In Northern Ireland, the Marine Strategy and Licensing team within DAERA manages consent applications.

2.1.4 Decentralization development Challenges

In the UK, many of the mechanisms and support structures necessary for a successful offshore wind sector are centrally managed by the UK government and its relevant departments, alongside the Crown Estate (an independent business sitting between the public and private sectors, acting in the national interest and owner/manager of most of the UK seabed). This includes the initial seabed lease allocation process, revenue support structures, and the determination of consent applications.

However, when it comes to individual project-scale development and progression through the consenting process, a contrasting decentralized development model emerges. Once an individual developer has secured seabed lease rights, environmental baselining and the production of data and evidence are conducted and retained at the private project level. This approach limits the availability of evidence and data for broader interested parties. Typically financed by the developer, this process understandably creates immediate commercial value, leading to a reluctance to publicly release data that could harm their competitive position. Consequently, this impacts the efficiency of the project consenting process. Conflicts may arise over data sources and interpretations, resulting in increased project-level survey requirements and significant delays due to additional environmental survey activities needed at the final decision-making stages of the consenting process.

We recognize that in the UK, the Crown Estate-managed Marine Data Exchange does host project-level environmental data. The Crown Estate launched the Marine Data Exchange (https://medin.org.uk/) in 2012, a dedicated platform for storing, managing, and sharing information such as geophysical surveys, ornithology, benthic ecology, wind resource assessments, and noise level data gathered by developers. This was created to promote the sharing and reuse of this essential data among developers and stakeholders, enhancing understanding of seabed resources, disseminating valuable lessons learned, and supporting evidence-based decision-making (Crown Estate, 2019).
However, this information is generally not released publicly until approximately two years after the project's financial close. This results in a time lag of around six to eight years after the initial data collection period (based on two years for DAS surveys, two years for the consenting phase, two years for the development phase until financial close, and two years for release on the Marine Data Exchange). While the data and evidence may still hold some general value at this stage, they are inadequate for other project development considerations due to this time lag and cannot be considered representative of the environment at that time. To effectively streamline future project consenting considerations and long-term cumulative impact studies, it is critical that data and evidence become available much earlier, while still valid, allowing for direct integration into Regional Environmental Characterization models and wider consideration of a projects interaction with environmental receptors.
To further demonstrate this issue, the UK's Offshore Wind Round 4 leasing round opened for applications on July 9, 2020, and closed on July 31, 2020. Following the closure, developers commenced their survey data collection, a process that typically continues through the project development phase. While timelines for completing surveys can vary, many developers strive to finish initial data collection within a year or two after securing their lease. However, despite the Crown Estate's requirement for developers to publicly release their survey data for Round 4 on the Marine Data Exchange, this data has not yet been made available, even after several years.

We also recognize that the new Crown Estate pre-consent survey program, introduced as part of Leasing Round 5, acknowledges the value of making environmental data available to successful seabed lease winners at the start of the development process to help streamline consenting considerations. However, this data and evidence will only be provided to private developers who succeed in the auction process and will have restricted wider use due to the time lags associated with eventual release through the Marine Data Portal. Unfortunately, this means that the data and evidence collected for the Round 5 Project Development Agreements will not be available for wider stakeholder consideration or integration into the evolving Regional Environmental Characterization models or other regional environmental modelling programs, such as the Crown Estate's OWEC-funded projects: POSEIDON, ReSCUE, and ProcBE.[11]

This highlights a significant limitation in the ability of a decentralized developer model, as well as similarly directed programs focused on individual project developer needs, to support Regional Environmental Characterization activities that could yield clear short- and long-term benefits for facilitating a more sustainable Floating Offshore Wind (FLOW) sector, with a more efficient consenting process that engages a much wider range of stakeholders earlier in the development process.

2.1.5 Investment Outlook and Challenges

The future of the UK offshore wind market is supported by government policies and a strong project pipeline. However, challenges such as regulatory complexities, supply chain issues, and the need for improved grid connectivity remain. Developers are increasingly considering shared infrastructure to lower costs. The

[11] Offshore Wind Evidence and Change Programme

government is also assessing current offshore transmission infrastructure to align with net-zero objectives, highlighting the need for collaboration among stakeholders to facilitate development.

2.2 Germany: Offshore Wind Market Overview and Approval Regime for Offshore Wind Projects

By the end of 2022, Germany had connected over 1,500 offshore wind turbines to the grid, totalling approximately 8 GW of capacity, increasing the installed capacity increased by more than 300 MW. The Site Development Plan (Flächenentwicklungsplan) released by the German Federal Maritime and Hydrographic Agency (BSH) in January 2023 outlines a target of 24.7 GW to be commissioned by 2030, raising the total installed capacity to 36.5 GW by 2030. This includes projects tendered in 2021 and 2022 that are set to be operational by 2026 and 2027. Current statutory targets set forth that offshore wind capacity should reach 30 GW by 2030, 40 GW by 2035, and 70 GW by 2045, as outlined in the reformed Wind Energy at Sea Act (WindSeeG) of 2022.

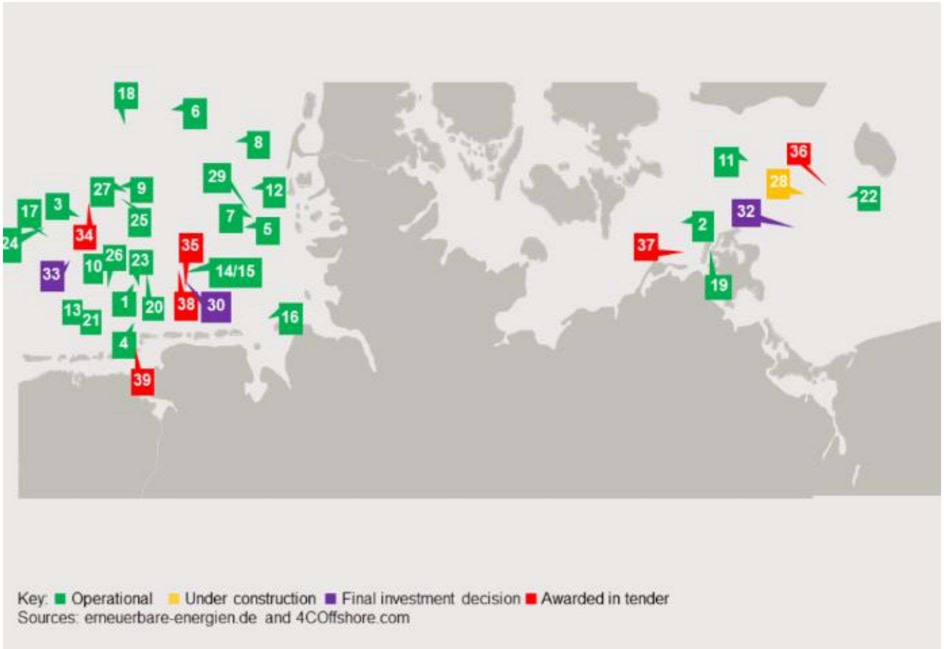

Figure 15 Offshore Wind Projects, Germany - Norton Rose Fulbright

2.2.1 Approval Regime for Offshore Wind Projects

The construction of an offshore wind farm in Germany requires a permit from the BSH. Typically, the application for constructing wind turbines and the transformer platform is submitted and approved as a single project. Given the high complexity of these projects, the BSH has the authority to permit individual construction measures or commissioning processes, allowing for some review to shift into the enforcement phase.

Since January 1, 2017, the legal foundation for these approvals has been the WindSeeG. Prior to this, approvals were granted under the Offshore Installations Ordinance (Seeanlagenverordnung). Both frameworks require a planning approval procedure before official approval is granted, with waivers permitted only in exceptional cases. An EIA is required as part of this process, ensuring public involvement and careful consideration of environmental impacts that can only be determined with the availability of high quality actionable environmental data.

Once a contract is awarded through the tender process by the Federal Network Agency (BNetzA), the BSH generally initiates a Scoping or Application Conference before commencing the planning approval process. The developer must submit various documents and drawings, including a detailed list of minimum application and planning documents tailored for both non-centrally and centrally pre-investigated sites.

Approval of the project plan hinges on meeting specific requirements, including a declaration of commitment to surrender and transfer ownership of the wind farm to subsequent users if the plan approval becomes invalid. The BSH provides a mandatory form for this declaration. After planning approval is granted, the BSH supervises the project, issuing orders as necessary to ensure proper implementation, particularly concerning technical stipulations and certified documents.

2.2.2 Offshore Wind Tender Process

Germany employs an annual tender process for offshore wind projects, evolving to favour bidders offering the lowest market premium. Recent reforms allow developers to bid for concessions on sites that have undergone central pre-investigation. Award criteria now include decarbonization efforts and other qualitative measures alongside traditional concession payments.

Beginning in 2023, Germany introduced a dual auction model to accelerate offshore wind expansion. Bidders for centrally pre-investigated sites must offer a concession payment per kWh produced, with a bond of €200,000 per MW required to ensure compliance with development milestones. Non-centrally pre-investigated sites will continue to utilize the market premium model, with a bond of €100,000 per MW also required.

Successful bidders gain exclusive rights to permit procedures and must conduct site investigations if the site was not previously pre-investigated.

2.2.3 Process for Centrally Pre-Investigated Sites

The Site Development Plan, released in January 2023, outlines the spatial and temporal requirements for prospective offshore wind locations. Following this, relevant authorities will conduct initial assessments of potential sites in accordance with the development plan. Sites will then be awarded through a competitive tender process that incorporates both quantitative and qualitative criteria. Bidders who succeed in the auctions are permitted to proceed with the permitting process and are entitled to grid capacity and connection.

2.2.4 Process for Sites Without Central Pre-Investigation

Similarly, the Site Development Plan from January 2023 defines the spatial and temporal requirements for potential offshore wind sites. These sites will be tendered through a competitive process that relies solely on quantitative criteria. Successful bidders will be responsible for (pre)investigating the sites themselves. Winning bidders in the auctions can undertake the permitting process and have rights to grid capacity, connection, and the market premium, unless all bids are exclusively at 0 cents.

2.2.5 Regulatory Framework

The primary legal framework for offshore wind energy in Germany comprises the Renewable Energies Sources Act (EEG), WindSeeG, and the German Energy Industry Act (EnWG). The EEG grants operators a statutory claim for grid connection and electricity off-take. Historically, developers were responsible for site investigations; however, the WindSeeG aims to centralize planning to streamline processes and minimize redundancy.

To bolster energy security and meet climate goals, Germany aims for nearly complete reliance on renewable energy by 2035. Significant amendments to the EEG and WindSeeG in July 2022 facilitate faster installations and support measures for offshore wind energy.

2.2.6 Regulatory Challenges

The regulatory environment poses significant challenges, particularly regarding the clarity of new qualitative criteria in tenders for pre-investigated areas. Regulatory uncertainties can lead to delays in project development. Additionally, the introduction of a price cap on electricity aimed at curtailing windfall profits may impact investor sentiment, though certain profits will remain unaffected.

2.2.7 Environmental Data Release and Public Finance in Germany's Offshore Wind Sector

In Germany, the release of environmental data related to offshore wind projects primarily occurs during the planning approval process governed by the WindSeeG and associated regulations. The EIA must be completed before any official project approval is granted, ensuring public involvement and a thorough evaluation of potential environmental impacts. The findings are typically made available to the public during the scoping phase or application conference, allowing stakeholders to review the data and provide feedback on environmental considerations. Public consultations are conducted at various stages of the approval process, further enhancing transparency and community engagement. Additionally, once a project is awarded a tender, relevant authorities may publish further environmental data as part of ongoing monitoring and compliance requirements.

Figure 16 BSH GeoSeaPortal

Beyond this, environmental and survey data for Germany's offshore wind projects are primarily held by the German Federal Maritime and Hydrographic Agency (https://www.bsh.de/EN/DATA/data_node.html). They maintain comprehensive datasets and resources related to offshore wind farm planning and environmental assessments. From the initial site selection process to the final approval for a project, the timeline can range from about 3 to 6 years for data to be publicly disseminated. However, this can vary based on factors such as project scale, regulatory changes, and public engagement.

While there is no direct correlation established between public finance and the timing of environmental data availability, increased public funding can facilitate earlier and more comprehensive data releases in several ways. Enhanced resources for regulatory agencies, such as the Federal Maritime and Hydrographic Agency (BSH), can improve the capacity to conduct thorough EIAs and engage in public consultations, potentially expediting the overall process. Moreover, government funding may support central pre-investigations, leading to better-prepared data that can be shared more quickly with stakeholders.

Additionally, public finance may incentivise regulatory frameworks that prioritize transparency and public involvement, which can lead to earlier releases of environmental data. Thus, while public finance does not directly dictate the timing of data availability, it can significantly influence the efficiency and thoroughness of assessment processes.

Developers in the German offshore wind sector include Ørsted, EnBW, E.ON/Innogy, Vattenfall, and RWE, with growing interest from foreign utilities and new entrants. The future for Germany's offshore wind market is supported by policy stability and a strong project pipeline. However, challenges remain, including regulatory complexities, geographical constraints, and intricate land rights issues.

In conclusion, Germany's offshore wind market is positioned for significant growth, driven by regulatory support, technological advancements, and a rising commitment to renewable energy. The strategic focus on collaborative development and transparent auction processes do enhance the sector's competitiveness and sustainability.

2.3 Netherlands: Offshore Wind Market Overview and Approval Regime for Offshore Wind Projects

As of 2023, the Netherlands has made significant strides in offshore wind energy, with a growing capacity aimed at bolstering its renewable energy portfolio. The preparatory work for constructing a wind farm in the North Sea involves a detailed process that includes statutory procedures leading up to the organization of a tender procedure. Once a suitable party is selected through this process, construction can commence. The government established this more supportive and proactive regulatory framework in 2013. This centralised approach addresses the shortcomings of the previous model, which placed the responsibility of site selection, investigation, and permitting solely on individual developers. The updated framework offers beneficial conditions, such as designated zones for long-term offshore wind initiatives, multi-year tender schedules for pre-approved sites (Roadmaps), and prompt connections to state-owned electrical grids.

Figure 17 Preparatory work for offshore wind farms on the North Sea - RWS Zee en Delta

A notable aspect of this framework is the availability of pre-collected site survey data and EIAs. The Netherlands Enterprise Agency (RVO.nl) functions as the main coordinating body, acting as a comprehensive resource under the Ministry of Economic Affairs and Climate Policy. Furthermore, the EIA and permitting processes are managed by Rijkswaterstaat, which is part of the Ministry of Infrastructure and Water Management. As an element of this proactive strategy, the environmental surveys and impact evaluations carried out by the government are made accessible to the public via the RVO.nl portal, promoting transparency and ensuring that all stakeholders can easily access the information.

This extensive framework not only streamlines the development process but also creates a level playing field by offering clear consenting procedures and prompt permitting. This ultimately helps to expedite the transition to renewable energy sources in the Netherlands.

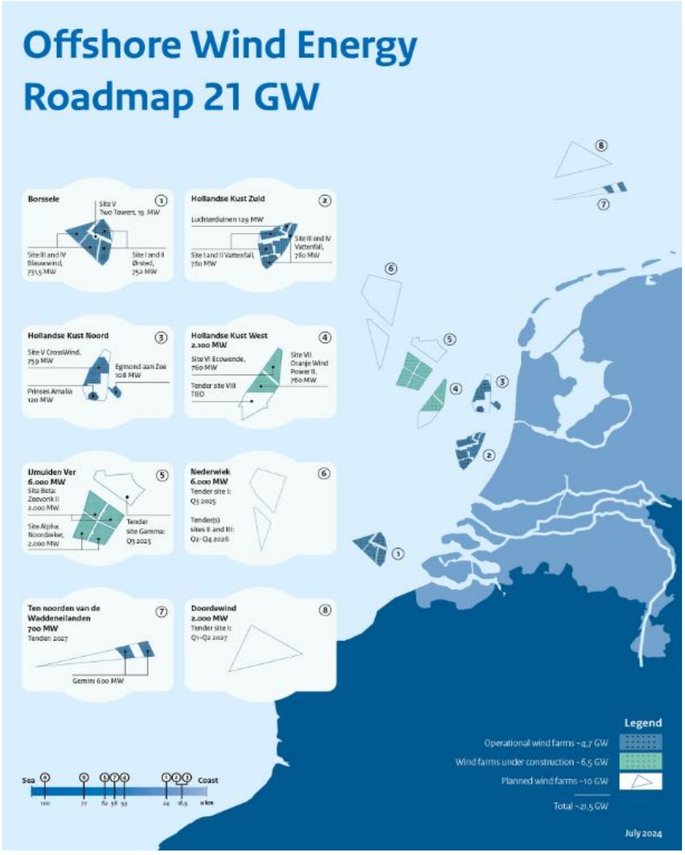

Figure 18 Offshore Wind Energy Roadmap 21 GW. RVO, 2024.

2.3.1 Designation of Wind Farm Zones

The process begins with the designation of offshore zones suitable for wind farm development. This designation is complex, given the multiple uses of the North Sea, including shipping, fishing, and ecological considerations. The National Water Programme defines these designated zones, providing an integrated vision for offshore wind development. Factors such as wind speeds, seabed conditions, and potential impacts on existing activities are carefully evaluated to determine the feasibility of new wind farms within these zones.

The Ministry of Climate Policy and Green Growth (formerly the Ministry of Economic Affairs and Climate Policy) develops an "Offshore Wind Energy Roadmap." This roadmap outlines the timeline for the construction of wind farms based on market conditions and evaluates spatial developments, such as oil and gas extraction, to ensure comprehensive planning.

2.3.2 Preliminary Allocation of Sites

Designated wind farm zones often include multiple uses, necessitating the preliminary division of zones into specific sites. The Ministry of Climate Policy and Green Growth creates initial sketches to identify potential sites, considering factors like current insights on wind patterns and existing infrastructure. The aim is to optimise space usage while ensuring equitable energy yields across multiple sites within a zone.

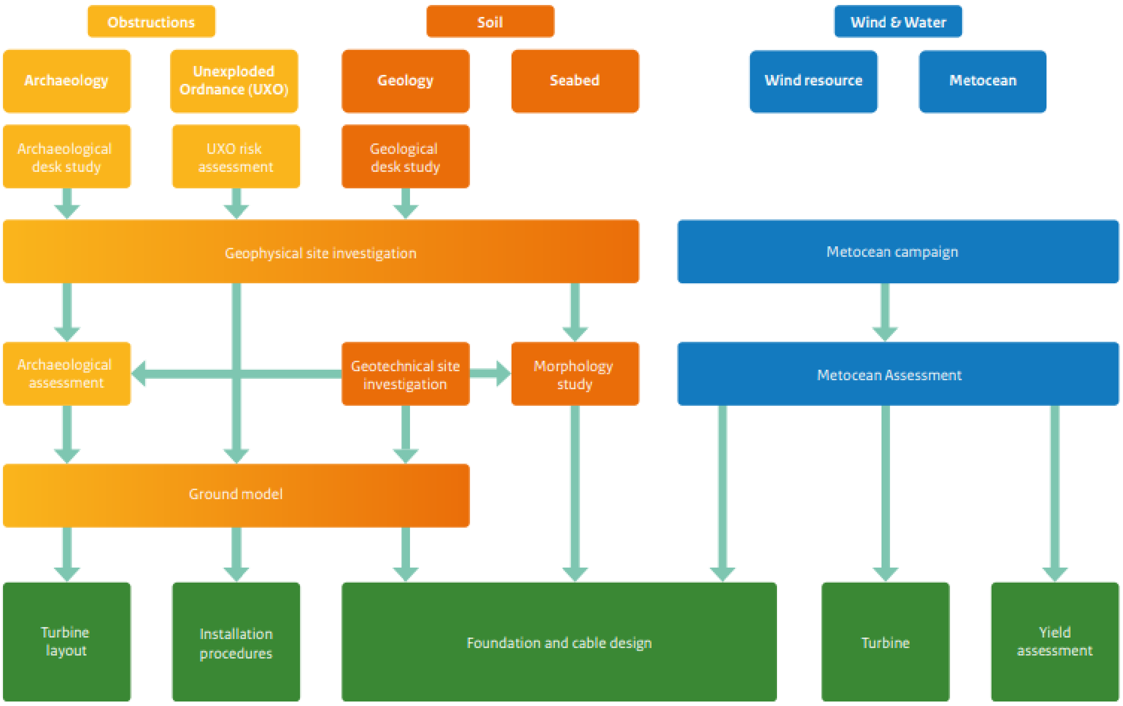

Figure 19 Site studies and investigations for the IJVWFZ. RVO. (2023). IJmuiden Ver Wind Farm Zone: Sites Alpha and Beta - Project and Site Description (Final version). Netherlands Enterprise Agency.

Extensive research is conducted to assess the characteristics and existing uses of each wind farm zone. Results are published and provide essential information for developers, including data on wind speed, water depth, seabed conditions, and historical artifacts. These studies are conducted by market parties on behalf of the Netherlands Enterprise Agency (RVO). Data, such as that from the IJmuiden ver Wind Farm Zone (IJVWFZ) database can be found on the RVO website (https://offshorewind.rvo.nl/page/view/2dd28a50-5344-47a6-b3ff-7d0e36911159/soil-ijmuiden-ver).

2.3.3 Preparatory Work for Connection to the Electricity Network (Offshore Grid)

To transport generated wind energy to the mainland, electricity cables must be laid from the offshore wind farm to a high-voltage station. The initial step involves drafting an Exploration of Cable Landing Points for Offshore Wind Energy (Dutch acronym: VAWOZ). This exploration guides the Ministry of Climate Policy and Green Growth in determining which connections require a planning procedure. The entire process, including cabling, can take 8 to 10 years, influenced by technology and distance.

The legal framework for the offshore grid is established under the Electricity Act 1998. TenneT has been designated as the network operator for this grid. Necessary permits and land-use plans for the offshore grid are generated under the State Coordination Scheme (RCR), which simplifies consultations and appeals. An EIA is required, along with appropriate assessments concerning protected ecological features in Natura 2000 areas.

The site decision outlines the conditions under which a wind farm may be constructed and operated. This decision also considers the implications under the Environment and Planning Act (Omgevingswet). An EIA is conducted to analyze the potential impacts of the proposed wind farm on marine life, seabed conditions, and existing activities. The decision may include measures to mitigate environmental impacts, such as specifying turbine types and operational restrictions.

The legal framework for site decisions is governed by the Offshore Wind Energy Act, and such decisions are subject to appeals.

2.3.4 Consultation/Participation

Throughout the preparation and permitting phases, there are opportunities for public consultation and participation, including:

- Input on the draft NRD (Range and Detail Memorandum).
- Feedback on draft site decisions and accompanying documentation.
- Appeal options at the Dutch Council of State, Administrative Jurisdiction Division, after final site decisions are made.

2.3.5 Tender

Once the site decision is finalized, the Netherlands Enterprise Agency organizes a tender procedure on behalf of the Ministry of Climate Policy and Green Growth. Interested commercial parties submit proposals, and the government selects one party to develop and operate the wind farm, granting the necessary permits for construction.

The Offshore Wind Energy Act outlines the tender process and instruments used.

2.3.6 Construction and Operation

Upon announcing the tender winner, the new owner receives permits and can begin preparatory work for construction immediately. The Ministry of Infrastructure and Water Management establishes a temporary safety zone around the construction area. During construction and operation, monitoring and enforcement are carried out by Rijkswaterstaat and SodM (Dutch State Supervision of Mines). The timeline from permit approval to full operational status for a wind farm is approximately four years, whilst the UK can range from about 3 to 6 years, depending on various factors like project size, location, and regulatory hurdles.

2.4 Comparing the various Offshore Wind Farm Development Approaches

Offshore wind energy has become a pivotal component of Europe's and surrounding countries renewable energy strategy, with countries like Germany, the UK, and the Netherlands employing distinct approaches to project development. This section of the report highlights the centralised model of Germany, the decentralised approach of the UK, and the structured framework of the Netherlands, proposing a hybrid model that incorporates elements of all three to optimize efficiency and data sharing in offshore wind farm construction.

Country	Development Approach	Key Features	Description
Germany	Centralised	Strong government oversight and streamlined processes. ~3-6 years for survey data dissemination	Germany employs a **centralised approach** where the Federal Maritime and Hydrographic Agency (BSH) oversees approvals through comprehensive environmental assessments. The Wind Energy at Sea Act (WindSeeG) facilitates a coordinated development process, minimizing risks for developers by providing a clear regulatory framework. This model encourages public investment, ensuring initial surveys and assessments are handled efficiently, thus expediting project execution.
UK	Decentralised	Independent project developer responsibility.	The UK follows a **decentralised model**, where the Crown Estate designates areas for development but allows developers to conduct their own surveys. While there is government support, the lack of

		~3-6 years for survey data dissemination.	standardized data-sharing can lead to inconsistencies and project delays. Developers often manage their data privately, resulting in variability in timelines and challenges in assessing cumulative environmental impacts. This independence can hinder collaboration and increase investment risks.
Netherlands	Structured Hybrid	Structured balance of government and developer roles. ~4 years for survey data dissemination	The Netherlands adopts a **structured framework** that incorporates both centralization and decentralization. The government designates development zones and conducts preliminary research, which is then shared with developers. This approach enables a balanced allocation of responsibilities, allowing developers to innovate while benefiting from comprehensive initial data. The structured process helps reduce uncertainties and enhances project planning while still providing some developer autonomy.

2.4.1 Germany: Centralised Approach

Germany's offshore wind development model is characterized by strong government intervention and centralised planning. The Federal Maritime and Hydrographic Agency (BSH) plays a crucial role in overseeing project approvals, which are based on comprehensive environmental assessments and planning procedures. The Wind Energy at Sea Act (WindSeeG) facilitates a streamlined process, where the government conducts pre-investigations and outlines development zones.

This model ensures a coordinated approach to offshore wind energy, with public investment driving initial surveys and environmental assessments. Developers benefit from a clear regulatory framework, enabling them to focus on execution rather than navigating complex permitting processes. This centralised model minimizes risks and uncertainties, making it easier for developers to secure financing and move projects forward.

2.4.2 UK: Decentralised Approach

In contrast, the UK has historically adopted a more decentralised approach to offshore wind construction. The Crown Estate designates large areas for development, but project developers are responsible for conducting their own surveys and retaining data privately. While there are elements of government intervention, such as funding and policy support, developers operate independently, leading to variability in project timelines and data accessibility.

This model can create challenges: developers may experience delays in obtaining consent, and without a standardized approach to data sharing, it can be difficult to assess cumulative environmental impacts across multiple projects. The lack of transparency in data management can hinder collaboration and increase risks associated with financing and investment.

2.4.3 Netherlands: Structured Framework

The Netherlands employs a structured approach that combines elements of both centralised and decentralised models. The preparatory process for offshore wind farms begins with the government designating specific zones for development through the National Water Programme. The Ministry of Climate Policy and Green Growth drafts an "Offshore Wind Energy Roadmap," outlining timelines for construction based on market conditions.

Following the designation, the government conducts extensive research and preliminary studies to assess site characteristics, which are then made available to developers. The Netherlands Enterprise Agency organizes a tender procedure after final site decisions, allowing developers to submit proposals based on government-defined parameters.

This structured framework allows for a balance between government oversight and developer responsibility. Developers benefit from comprehensive initial data, reducing uncertainties and enhancing project planning. However, they still retain the autonomy to innovate and optimize their projects within the established guidelines.

2.4.4 Recommending a Hybrid Approach: Balancing Government and Developer Roles

Recognising the strengths and weaknesses of these models, our proposed approach for floating offshore wind in the Celtic Sea combines elements of centralisation and decentralisation. By leveraging public sector investment to fund preliminary environmental surveys, we can create a shared knowledge base that benefits all stakeholders. This investment would allow for comprehensive data collection that is openly accessible to developers, fostering transparency and collaboration.

Furthermore, by implementing data-sharing agreements, we can ensure that developers are committed to contributing their findings, thereby enriching the overall dataset available for future projects. This hybrid model mitigates the risks associated with placing the entire burden on either the government or the developers.

Key Advantages of the Hybrid Approach

1. **Risk Mitigation**: By distributing responsibilities between the public and private sectors, we reduce the likelihood of project delays and unforeseen challenges.
2. **Enhanced Data Sharing**: Open access to environmental data promotes informed decision-making and more effective project planning.
3. **Increased Efficiency**: Government support can expedite initial survey processes, allowing developers to focus on execution and innovation.
4. **Value Creation**: By involving both sectors, we create a more valuable ecosystem for offshore wind development that attracts investment while ensuring environmental sustainability.

In conclusion, the hybrid model represents a balanced approach that maximizes the strengths of the German, UK, and Dutch systems. By aligning government investment with developer autonomy, we can foster a more efficient, transparent, and collaborative offshore wind energy landscape, ultimately driving the transition to renewable energy.

3: Regional Environmental Characterisation – Strategies for Cornwall and Beyond

3.1 Introduction

This chapter focuses on how Cornwall has structured its Regional Environmental Characterisation (REC) programme and spatial planning efforts to support a more strategic zonal planning approach to the Celtic Sea and will include commentary on engaging developers and leveraging public and private funding.

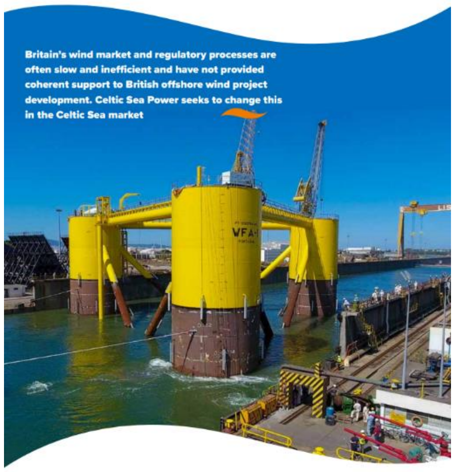

Figure 20 Celtic Sea Vision – Celtic Sea Power 2022.

By examining the strategies and partnerships used to achieve these goals, this chapter will also explore how similar approaches could be applied in new regions or countries, especially where consenting processes and routes to infrastructure development are either non-existent or under developed.

Aspirations for Cornwall's REC include targeting key gaps in existing data and evidence to support decision making processes, alignment with key decision maker requirements is crucial. A key goal is to develop a single agreed evidence base to help enable efficient decision making and outcomes are focused on the creation of REC models with high confidence levels. Collaborative data sharing and partnership working offers the opportunity to maximise efficiency, minimise replication and decrease conflict.

3.1.2 A more holistic approach to supporting the streamlining of Offshore Development in the UK:

The UK's offshore wind market is one of the largest and most successful in the world, with more than 50 wind farms around the UK coastline at various stages of development, producing enough renewable energy to power half of all UK homes. The UK's offshore wind pipeline currently stands at approximately 95GW, with a Government ambition to decarbonise the power system by 2030, including a radical increase in offshore wind capacity in the same timeframe

However, Britain's wind market and regulatory processes have often been considered slow and inefficient, lacking coherent support for short and long term offshore wind project development. Over the last 4 years Celtic Sea Power (CSP) has been seeking to improve these processes in the Celtic Sea region by enhancing data availability, knowledge sharing, and supporting actions to shorten planning and consenting times with the delivery of our Regional Environmental Characterisation programmes and associated works. The company is working across both the public and private sectors to share extensive data, modelling, and knowledge from projects like the Cornwall FLOW Commission strategic sector project, Cornwall Flow Accelerator (CFA) and the works on the Pembrokeshire Demonstration Zone (PDZ)[12]. A goal is to develop a more holistic and integrated approach to offshore wind development with a key objective to reduce consenting times for Celtic Sea FLOW projects, thus accelerating Cornwall's potential GVA and job creation benefits from a successful, sustainable new FLOW sector.

This more holistic approach has gained recent recognition in published Crown Estate reports including "Future of Offshore Wind" (2024) and the Marine Delivery Routemap (2024), which recognise the core need to plan more strategically, with a more coordinated , long-term view of meeting future demand on the UK seabed, whilst addressing each of these challenges faster than ever before means that we need a whole system approach. Actions to maintain a "Whole of Seabed" approach include exploring opportunities to

[12] Our Projects - Celtic Sea Power

support the consenting process through front-loading some of the Crown Estate activities (i.e. environmental surveys and analysis), securing statements of common ground from key stakeholders at a plan-level and/or anticipating other activities that could de-risk and accelerate the consenting process post-lease.

3.1.3 Strategic Integration of Investments in Regional Planning

Cornwall's REC approach led by CSP enables a blend of public investment and private sector value to be strategically deployed to support both initial environmental data baselining activity and continual access to future data and evidence as it becomes available. This enables REC models to become more sustainable and self-evolving, ultimately adding value to Cornwall's strategic planning capabilities. For example, public funds are used to de-risk early-stage work and to run initial regional scale baseline environmental surveys. Data and evidence is made available to private developers through the establishing of reciprocal data sharing agreements which require equivalent private data to be supplied for provision into REC models as it becomes available. . The ability to extract more private data through strategic collaboration has become one of the cornerstones of Cornwall's REC approach.

This approach helps to create long-term added value not only for the region but also for the private companies involved. This is achieved by aligning project goals with regional objectives, making private investment a central part of Cornwall's planning and development ecosystem.

3.1.3.1 Funding Models and Leveraging Public-Private Partnerships

One of the key elements in Cornwall's REC approach is the creative use of funding sources. A mixture of public and private money is often pooled to support regional characterisation and spatial planning. Public funds, including government grants and EU funds (prior and post Brexit), have been deployed to stimulate early-stage research, development, and planning. However, Cornwall has also demonstrated the ability to attract significant private investment, leveraging match funding models and partnerships with commercial entities.

For instance, the use of the Swansea Bay City Deal as capital match funding for the Strategic Regional Soundscape project exemplifies how Cornwall has been able to combine public initiatives with private investment. Unlike traditional public funding streams, the City Deal brought in a mix of government and commercial funds, allowing for more flexible, responsive project development.

This blended funding model has been critical to Cornwall's success in delivering REC, enabling it to undertake large-scale projects at extensive spatial and temporal scales while securing necessary private sector buy-in.

3.1.3.2 Regional & National Funding Sources

National grant opportunities for FLOW and offshore/maritime projects are currently widespread. These include for example the Offshore Wind Evidence and change programme funded by the Crown Estate, UK Research Institute - UKRI 2022-27 Strategy Innovate UK - IUK Strategic Delivery Plan, Floating Offshore Wind Manufacturing Investment Scheme – FLOWMIS (£160M DESNZ Fund), Offshore Wind Growth Partnership - OWGP (£100M fund), and Clean Maritime (£20M DfT fund). CSP can often qualify for high % grant intervention rates due to its SME Research Organisation status and/or local authority ownership , allowing the company to potentially secure significant grants with lower match requirements than a purely commercial entity. Additional funding opportunities include The Crown Estate's Pathfinder Fund, which supports inward investment into the Celtic Sea Region, and forthcoming Celtic Sea leasing rounds requiring demonstration of regional support and investment.

3.1.4 Data Sharing and Collaboration

Another major component of Cornwall's approach is collaboration with key stakeholders, developers, and governing bodies. Organisations like Natural England, Crown Estate, and the Centre for Environment, Fisheries, and Aquaculture Science (CEFAS) are integral to the successful planning and implementation of REC. Through data-sharing agreements and collaborative efforts, CSP has been able to ensure that both public and private stakeholders are operating from a shared base of information whilst minimising replication of survey effort with combined approaches to regional survey planning with specific environmental receptor focuses. This approach fosters transparency, speeds up the decision-making process, and ultimately facilitates smoother development projects that can work from a single sound evidence base.

The involvement of universities and research centres helps to ground Cornwall's projects in cutting-edge science and technology. It also creates a feedback loop where research informs development, and development informs research. This integration has been critical to the success of projects like Soundscape, where the combination of academic input, public and private funding has allowed for the development of a state-of-the-art environmental monitoring systems.

Offshore wind developers also have the potential opportunity to benefit from these regional planning strategies through their participation in data sharing agreements, strategic level projects and alignment with regional objectives. This collaborative approach ensures that private investment becomes a key component of Cornwall's development ecosystem, supporting both regional and private sector interests.

3.2 Celtic Sea Regional Environmental Campaign Selection

Celtic Sea Power's decision-making processes in selecting which REC campaigns to focus on at which time contains a number of key assessment steps;

Key Decision-Making Parameters for REC Campaigns	
Receptor relationship with Offshore Wind	*Impact and risk level*
Receptor level basis of knowledge	*Offshore wind consenting and industry reports, Offshore Wind Environmental Evidence Register (OWEER)*
State of the science	*Internal and external review*
Research and literature review	*Published and other scientific literature*
Alignment with other strategic programmes	*For example, OWIC P2G, OWEC funded programmes*
Stakeholder engagement	*Offshore Wind developers, Academics, researchers, Technical Experts*
Receptor value and influence	*Influence on regional processes and other REC programmes*
Availability of potential funding and/or finance	*Alignment with funding parameters and commercial developer needs.*

Though not necessarily a linear process, the steps above provide an indication of how the subjects of CSP's REC campaigns have been resolved. An initial early crucial step is bringing together an informed specialist group to open up the conversation and identify what relevant information may already be available and where key gaps in environmental evidence for Offshore wind may exist. For example, Offshore wind development in the UK has resulted in a number of industry led partnership and collaborations such as the Offshore Wind Industry Council which manage a specific programme (P2G) which focuses on challenges in consenting for offshore wind. A specific role for CSP and our regional environmental team is to take learning from other national and international offshore wind development activities and barriers and to frame them in the specific context of the Celtic Sea and its unique environment.

To compliment Industry input into evidence gap analysis CSP also works closely with relevant consenting bodies and decision makers to maximise the validity and utilization of new data and evidence we produce through REC activities. This engagement occurs at the early stages to assist survey design and technology selection for example and is maintained throughout and beyond the life of the REC activity to enable continual improvement and enhancement of modelling and other data outputs produced.

Ecological Receptor	Evidence Gap	Key reason why evidence gap cannot be resolved
Ornithology	Compensation	Lack of empirical data relating to many potential compensatory measures.
	Displacement	Consequences of displacement on demographics unquantified, causes driving displacement to be poorly understood.
	Cumulative, in-combination & ecosystem effects	Cumulative effects are a result of collision and displacement impacts, and uncertainty around both means that cumulative impacts remain problematic. Ecosystem effects are likely to be complex, and it is anticipated that arriving at a full understanding may take years.
	Bird Collision	Not enough empirical data gathered.
	Baseline understanding	Although there has been substantial progress, a greater level of understanding is required to identify suitable compensatory measures.
	Mitigation	Little or no empirical data available in relation to virtually all mitigation options.
Marine Mammals	Baseline understanding	Many areas unsurveyed (particularly further offshore). Small Cetaceans in European Atlantic waters and the North Sea (SCANS) surveys limited to a single sampling occasion.
	Floating Offshore Wind (FLOW): entanglement in mooring infrastructure	Not many large FLOW sites yet, therefore difficulties in understanding response of marine mammals (entanglement, displacement etc) which often occur at low density.
Benthic	Baseline understanding	Uncertainty regarding the distribution of protected habitats and species.
	Compensation	Difficulties in compensating for potential impacts on Marine Protected Area (MPA) sandbank features.
Fish	EFH (baseline mapping)	Currently assessment relies on data gathered >10 years ago, although some work is now underway further data gathering is needed to produce comprehensive reliable UK wide datasets.
	EMF (FLOW)	Data lacking in understanding of marine species sensitivity to EMF, especially pelagic fish species.

Figure 21 Status of critical gaps - OWIC 2024 - Use of evidence and data in decision-making[13]

3.3 Introducing CSP's Regional Environmental Characterisation Campaigns

Further full details on CSP's REC campaigns and how they were constructed are contained in the following sections of this report.

Our first Campaign utilising 2 Floating LiDAR platforms was crucial to supporting the emergence of a new FLOW market in the Celtic Sea (Resource and energy generation potential), has increased CSP's capabilities to better plan offshore environmental surveys (weather wind availability and extreme weather conditions) and has provided a critical input into CSP's infrastructure planning abilities (Port use, transit time, extreme loadings). The CSP FLS data is now being used by commercial FLOW developers as they bid for Round 5 leasing allocations (the only point data sources of wind and metocean data for the Celtic Sea) and has provided significant leverage for CSP to establish data sharing agreements with commercial FLOW

[13] OWIC P2G - Use of evidence and data in decision-making in offshore wind farm consenting - 2024

developers that will see future FLS data collected in the Celtic Sea flowing back to the Celtic Sea Regional Wind resource model. Developer relationships have also now extended into the Irish FLOW market.

Our second campaign focused on Ornithology. Ornithology is well recognised as one of the biggest environmental risks affecting offshore wind development, as can be identified in work by the Offshore Wind Industry Council[14] whereby ornithology featured in 6 of the top 10 critical evidence gaps affecting both the rate and success of development. Density and distribution data for the Celtic Sea was reliant on derived distribution models (Waggitt et al., 2020)[15] with no data inputs from the actual Celtic Sea area leaving an extremely weak ornithological baseline evidence case. By CSP working in collaboration with Natural England, the Crown Estate and private developers a new Ornithological density and distribution model for the UK Celtic Sea area, driven by Digital Aerial survey (DAS) data, with close to 100% coverage of the offshore area will be available in Summer 2025.

Campaign three built on a continuing gap in Ornithological data for the region that specifically focused on bird flight height evidence. DAS survey techniques are not currently considered accurate enough to derive sound flight height information so CSP ran an Airborne LiDAR survey.

Campaign four moved to a focus on new receptors. The marine mammal evidence base for the region will be significantly improved by supplementing existing DAS data for marine mammals from campaign two with additional data and evidence from a regional subsea acoustic network. As well as supporting our understanding of marine mammals density and distributions in the region this new data and evidence will expand out our receptor considerations with the incorporation of underwater noise data. A number of new data collection and modelling methods will also be developed with the cross validation of DAS, Acoustic and eDNA sampling and development of neural networks to separate out seal vocalisations and vessel noise.

In all our campaign designs CSP seeks wherever possible to maximise value through the application of multiple survey techniques supporting a number of receptors and the collation of data and evidence at often varying spatial and temporal scales into single Regional Environmental Characterisation models. These models can be continually improved as new data and evidence emerges, setting the foundations to consider both short- and longer-term offshore wind aspirations at a full regional scale.

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[14] OWIC Use of evidence and data in decision-making in offshore wind farm consenting 2024

[15] Waggitt et al. (2019). Distribution maps of cetacean and seabird populations in the North-East Atlantic. *Journal of Applied Ecology, 56*(11), 2630–2647. https://doi.org/10.1111/1365-2664.13525

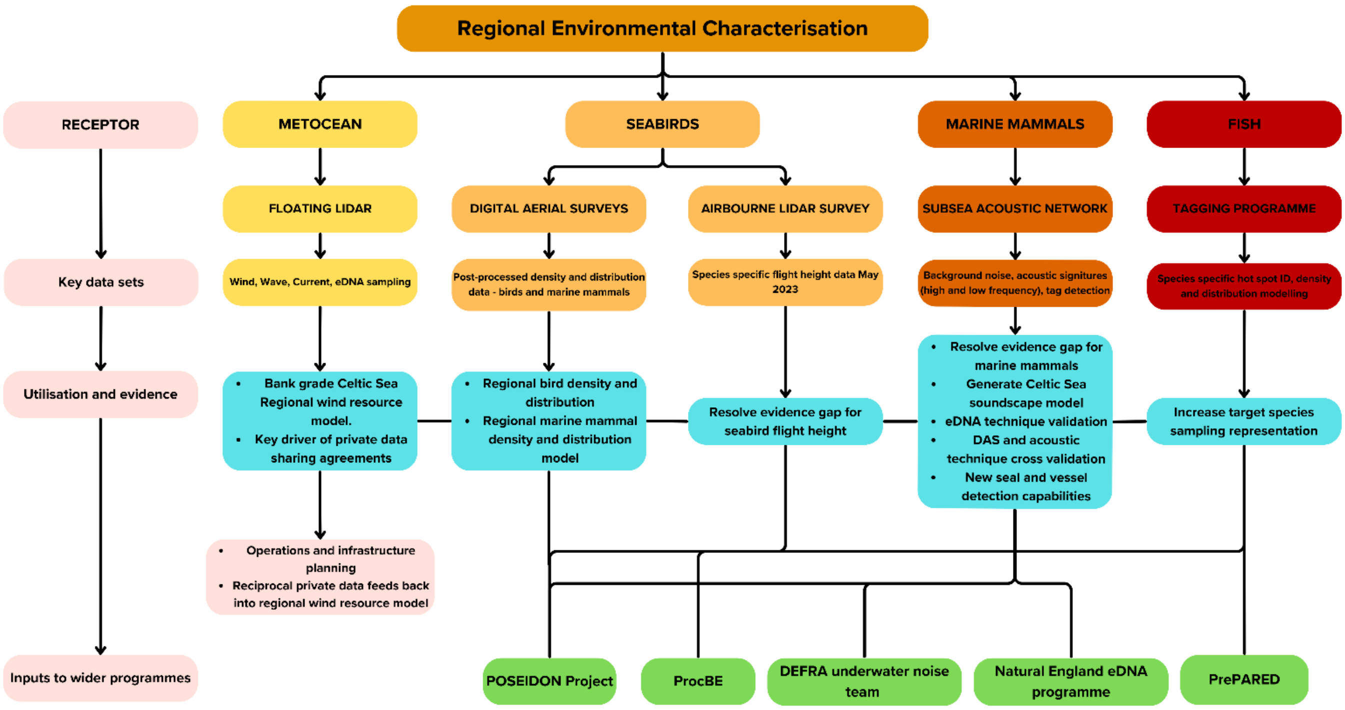


Figure 22 Celtic Sea Power's Regional Environmental Characterisation Approach

3.4 A Strategic Approach to wind and metocean data collection

This section of the report outlines how a strategic and multi-faceted approach was used to collect and integrate baseline data on wind and metocean conditions to support FLOW development in the Celtic Sea, demonstrating the thorough planning and execution involved in the project.

3.4.1 Implementing Floating LiDAR surveys

3.4.1.1 Survey Design and Methodology:

At the time of planning this campaign in September 2021 the only piece of spatial mapping work available to indicate potential target areas for FLOW came through the ITPE/OREC report. This report was crucial in identifying the initial target areas for the deployment of 2 floating LiDAR systems (FLS) and supports the need for early stage spatial mapping of an area despite the relative resolution of data that may be available at the time.

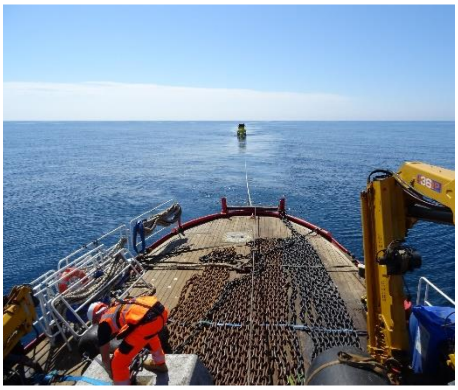


Figure 23 CSP FLS deployment

One of CSP's wider objectives with this campaign was the creation of a "bank grade" regional wind resource model that can support development and investment decisions for floating wind in the UK Celtic Sea, resolving point data into a regional model that could provide insights into these resource areas at a regional scale . This action could help to accelerate project deployment, decrease project risk and avoid any unnecessarily repetitive Floating LiDAR deployments and their associated carbon emissions across a wide area, detracting from the risk of running a targeted project level campaign without knowledge of specific project areas. To integrate this consideration at the project planning stage, the Wood group (Lenders technical authority) were contracted to support the campaign design and final decisions on locations for the FLS deployments with a key aim of maximising spatial coverage whilst not losing data integrity and confidence in its application to project financing as the horizontal distance from point measurement locations increases.

To support development of the regional wind resource model and its veracity a number of ongoing activities have been delivered by CSP. These include;

- Deployment of 2 strategically placed Floating LiDAR systems (FLS) in the Celtic Sea.
- Data correlation activity with ERA5, EMD-WRF Europe+ and Vortex metocean data sources.
- The development of data sharing agreements with FLOW developers that can add additional FLS data validation points to the wind resource model.
- Engagement of the Wood group to increase investor confidence in modelled outputs.

3.4.1.2 Survey Specifications:

2 x CSP Floating LiDAR systems (FLS) were deployed in June 2022 and ran to 25th September 2023. CSP utilized two WINDSEA FLS units provided by Akrocean.

3.4.1.3 Cost Efficiency and Coverage Expansion

CSP Campaign Design support - £23,664
FLS 15 month Campaign Cost - £1,281,228
Wind Resource Model cost – £11,910
Total Cost - £1,316,802

The FLS deployment and wind resource model development work was funded by the European Regional Development Fund and Celtic Sea Power at a cost of just over £1.3m. This enabled bank grade data to be available over a significant area of the Celtic Sea though confidence in its application starts to reduce as it extends more than 60km from point data sets.

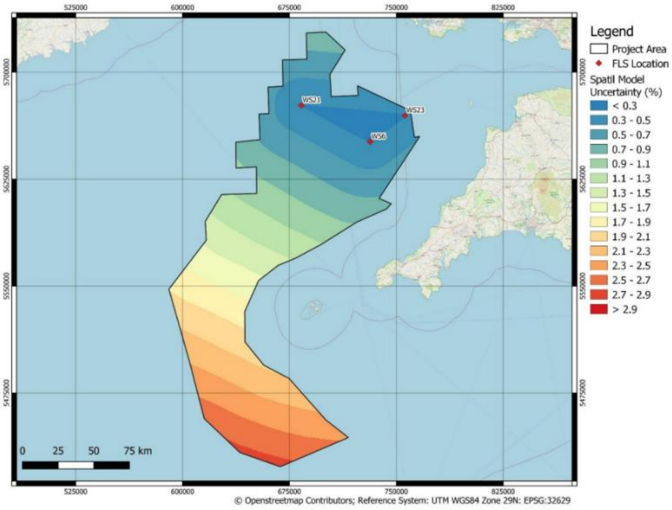


Figure 24 Spatial model wind speed uncertainty

In order to supplement this initial spatial and temporal coverage CSP has progressed 12 data sharing agreements with private commercial developers that have an interest in the Celtic Sea FLOW market (UK and Ireland). The CSP FLS campaign data is a crucial driver for these reciprocal agreements which require developers that deploy their own FLS systems in the future to share the data back with CSP for integration into the regional wind resource model enabling its future sustainable development and creating the capacity to continually improve spatial and/or temporal coverage whilst also increasing confidence in the models utilisation. Currently a single developer data set is integrated into the model bringing an estimated value of approx. £600,000 to the overall data set. If CSP can access FLS data from the 3 eventual Round 5 winners the overall value of the data sets in the model would increase to £3.6m against an initial outlay of £1.2m.

To bring considerations up to date, following the announcement of the Round 5 PDA's, it is now clear that the locations selected for CSP's FLS deployments show strong alignment with what are now the anticipated first wave of commercial FLOW developments in the Celtic Sea. This is largely a result of an effective early spatial mapping process which had many synergies with the later Crown Estate spatial planning process, particularly in regard to the selection of applied data layers and constraints.

Future iterations of the regional wind resource model could be much improved by integration of additional 2 year FLS data sets from each of the 3 PDA's selected for the round 5 process and in which the Crown Estate has already deployed FLS systems as part of its pre-consent survey programme. Unfortunately the Crown Estate has chosen to only make this data available exclusively to winners of the Round 5 leasing process and cannot therefore feed directly into strategic regional activities. This is disappointing given the strategic development position the Crown Estate hold but may be overcome by CSP through the private data sharing agreements it already has in place with prospective Round 5 winners.

3.4.1.4 Data availability summary table

Data Campaign	Sensors	Frequency	Data Type	TimeStamp	Size	Unit
Wind and Metocean	ADCP	every 6 hours	Velocity and direction	15 mins	80	KB
	Conductivity Sensor		Conductivity, Temperature	10 mins	8	KB
	Depth Sensor		Depth	10 mins	4	KB
	LIDAR		Wind Speed, dispersion, Direction - 10 heights, +	10 mins	36	KB
	Wave Sensor		Significant Wave Height, Wave Peak, +	30 mins	8	KB
	Altimeter		Water levels	10 mins		
	Weather Station		Wind direction, speed, pressure, relative humidity, air temp, lat, long, gust direction, gust speed	10 mins	8	KB
	WindCube WLS 866 V2.1	Quarterly	Wind Speed, dispersion, Direction - 10 heights, +	RTD data 1 s	1228	MB
	(MET) Weather station Gill GMX500		Wind direction, speed, pressure, relative humidity, air temp, lat, long, gust direction, gust speed, conductivity, temperature, depth	5s	128	MB
	Wave Sensor 5729 AANDERAA MOTUS		Significant Wave Height, Wave Peak, +	30 min	0.9	MB
	Altimeter AIRMAR Echorange SS510		Water levels	5s		
	Nortek Signature 250 (ADCP)		Velocity and direction	PNORS 15 min	0.6	MB

3.5 Strategic Approach to Seabird Monitoring and Baseline Evidence

Figure 25 Offshore Ornithology

This section outlines how a strategic and multi-faceted approach was used to collect and integrate baseline data on offshore ornithology, demonstrating the thorough planning and execution involved in the project.

3.5.1. Implementing Digital Aerial Surveys

3.5.1.1 Survey Design and Methodology:

Collaborative Planning was used to establish a comprehensive approach to producing a baseline for offshore ornithology, seeking to maximise regional spatial coverage within available budgetary limitations whilst avoiding replication of other known or planned DAS activity in the area. In 2022 CSP initiated a series of digital aerial surveys with APEM Ltd. This effort was guided by a method for REC agreed upon with key stakeholders including the RSPB, Natural England, Natural Resources Wales, and the JNCC. The surveys were designed to cover a minimum of 5% of the area with transects oriented SE/NW to ensure efficient spatial coverage.

3.5.1.2 Survey Specifications:

The surveys were conducted seasonally (four runs per year) to target sensitive species and seasonal combinations critical for consenting processes. High-resolution images were captured from an altitude of approximately 2,000 ft, adhering to EU safety standards, with a ground sampling distance (GSD) of at least 2 cm. This approach allowed us to record not only avian species but also marine mammals, turtles, sharks, large bony fish, and other relevant marine fauna.

3.5.1.3 Cost Efficiency and Coverage Expansion:

CSP Campaign design support - £0
DAS survey - £169,073
Airborne LiDAR survey - £119,907
CSP Regional model cost - £0
Total Cost - £288,980

APEM Ltd implemented a DAS survey design that covered CSP areas A and B, achieving more than 5% coverage initially. This required a sacrifice on resolution (a standard 10% coverage would be a likely EIA requirement) to attain more extensive spatial coverage which was deemed more important at this early stage as we are still establishing which species may be present rather than seeking to qualify exact densities.

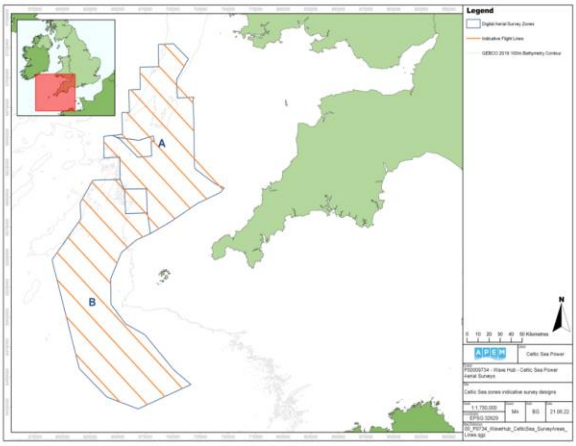


Figure 26 CSP DAS survey area

Future plans include increasing this coverage to 10% through coordination with the Crown Estate, aligning with other ongoing activities and ensuring greater spatial and temporal data representation. Though not individually identifiable on the image below due to data sensitivities, shared DAS survey planning between CSP, Natural England and the Crown Estate (see 3.5.1.4) alongside the securing of data sharing agreements by CSP with private developers has led to extensive regional spatial and temporal coverage when combined.

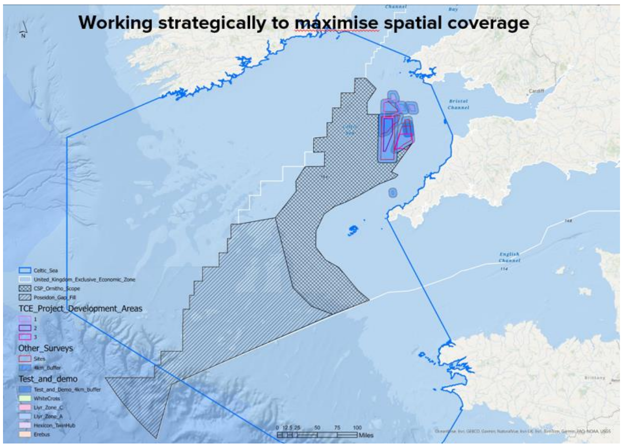


Figure 27 Working strategically to maximise DAS ata coverage

3.5.1.4 Integration with Broader Projects

- **Crown Estate Round 5 Pre-Consent survey programme:** As part of activity to support the Round 5 leasing process, the Crown Estate planned two years of monthly DAS surveys across the 3 x Round 5 PDA's with a 6km buffer. This formed part of joined survey delivery planning avoiding replication with other activities.
- **POSEIDON Project Collaboration:** To further maximize data utility and minimize duplication, the data from these surveys were integrated into the POSEIDON project. This collaboration aims to produce a new Seabird Density and Distribution Model for the UK Celtic Sea Area (UKCSA). This regional model is expected to be a cornerstone of the UKCSA ornithological evidence baseline from 2025.

3.5.2 Advancing with Airborne LiDAR Technology

3.5.2.1 Survey Implementation and Design

- **Commissioned Survey:** In May 2023, CSP commissioned an airborne LiDAR survey through APEM Ltd to develop an initial flight height index for seabirds within the UKCSA. The survey covered 1,050 km of flight length with 12 lines, focusing on maximizing species capture and deriving flight height data over an area most likely to include the largest mix of species type within the specific season.

- **Technological Integration:** The state-of-the-art digital camera systems integrated with custom flight planning software enabled precise mapping of flight paths and accurate measurement of bird flight heights. This approach provided detailed data on the altitude at which birds fly, contributing to a better understanding of seabird behaviour in relation to offshore wind farms.

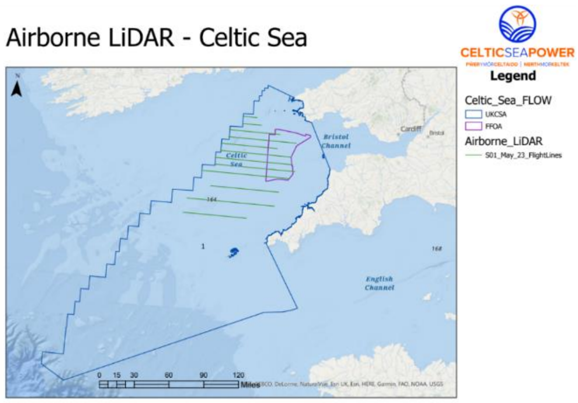


Figure 28 CSP LiDAR flight plan

3.5.2.2 Data Utilization:

- **Flight Height Index and Density Estimates:** The LiDAR survey results, including design-based density estimates and flight height indexes, are now available and will contribute to refining our understanding of seabird interactions with offshore wind farms.

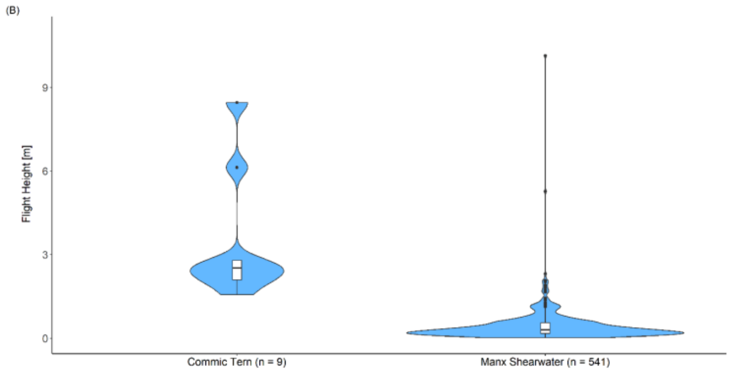


Figure 29 Violin Plots - Bird flight height

3.5.3 Engaging Stakeholders and Aligning Efforts

3.5.3.1 Collaborative Engagement

- **Stakeholder Collaboration:** Close coordination with Natural England, the Crown Estate, and other stakeholders through projects like POSEIDON ensured that survey plans and data collection efforts were aligned with broader environmental and regulatory goals.

- **Feedback and Refinement:** Continuous engagement with stakeholders provided valuable feedback for refining survey methodologies and data interpretation, ensuring that the results met the needs of both conservation and development objectives.

The POSEIDON project now provides a solid platform to integrate DAS data with temporal and spatial variations into a single combined regional bird density and distribution model. High levels of confidence can be installed in the model with its creation by one of the UK's lead specialist bodies with responsibility for the Natural Environment; Natural England. The model now provides a sound basis and method for the future integration of DAS data as it becomes available, enabling continual improvement of this critical environmental baseline.

The OWEC funded ReSCUE project (Reducing Seabird Collisions Using Evidence)[16] has also recently emerged and CSP Airborne LiDAR data has been provided to help influence the programmes early campaign design work, being the first airborne LiDAR data set available for the Celtic Sea. Outputs and learning from the CSP programme have also supported test and validation activities at Predannick airfield in Cornwall in 2024, helping to establish preferred and most effective techniques for deriving future bird flight height data both onshore and offshore.

3.5.3.2 Long-Term Monitoring and Impact Assessment

- **Baseline Establishment:** The comprehensive data collection efforts, including digital aerial surveys, LiDAR technology, and complementary methods, contributes to a solid baseline for assessing seabird populations and their potential interactions with offshore wind farms in the Celtic Sea.

  By integrating available baseline survey data for the region, with new aerial and LiDAR data, the project aimed to maximize coverage and efficiency while minimizing redundancy in data collection efforts.

- **Future Research and Policy Development:** The data collected will inform future research, policy development, and environmental management strategies, ensuring that seabird conservation and offshore wind development are balanced effectively.

3.6 Subsea Soundscape Program

The Subsea Soundscape (S3) program pioneers a regional framework in the Celtic Sea to provide valuable insights into underwater noise conditions and marine mammal presence, two further critical indicators of the offshore environment.

S3 develops a comprehensive acoustic soundscape model using advanced techniques and machine learning algorithms to identify significant features and reduce future data collection complexity.

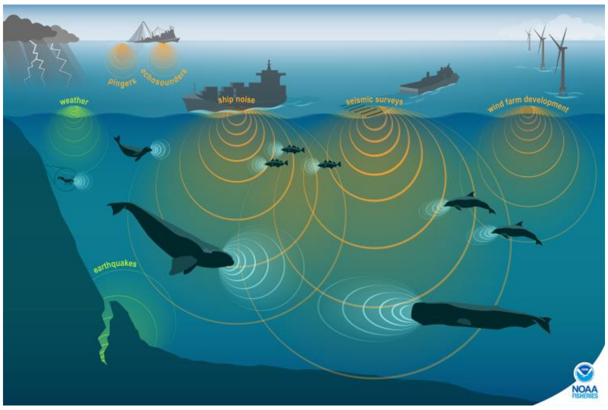


Figure 30 Ocean Noise- NOAA Fisheries - 2024

S3 outputs will; significantly enhance understanding of the environment; enable improved tools for environmental decision-making; improve cetacean population assessments and quantify development risks including underwater noise; enable efficient parallel rather than sequential development processes.

The project works will allow us to; support accelerated FLOW deployment; mitigate environmental impacts; and offer significant regional economic benefits. S3 addresses environmental conservation and economic growth, offers a disruptive approach to marine ecosystem monitoring and supports UKs commitments to a cleaner future

[16] The Crown Estate invests a further £9m in new research to drive nature-positive offshore wind development

3.6.1 Project development: A Comprehensive Approach

3.6.1.1 Structuring Regional Characterisation

By combining new and existing acoustic data, S3 will establish a marine mammal & noise evidence base, informing maritime spatial planning and consenting decisions for floating wind development in the Celtic Sea. This will provide a supporting foundation for a regional environmental characterisation approach.

1. **Defining Objectives and Scope:**
    - **Initial Goals:** In Cornwall, the objectives were to enhance regional environmental understanding adding to our evolving suite of REC campaigns whilst supporting streamlining of the offshore development processes.
    - **Collaborative Framework:** A collaborative framework was established involving public bodies, private developers, and research institutions. This ensured that the project benefited from diverse expertise and stakeholder support.

3.6.1.3 Survey, Project Design and Implementation:

At-sea mooring units, equipped with state-of-the-art broadband acoustic recorders, pop-up acoustic retrieval systems and tag detection capabilities will be deployed with eDNA and CTD environmental sampling at service intervals to maximise data capture. The systems will be deployed for a minimum of 2 years.

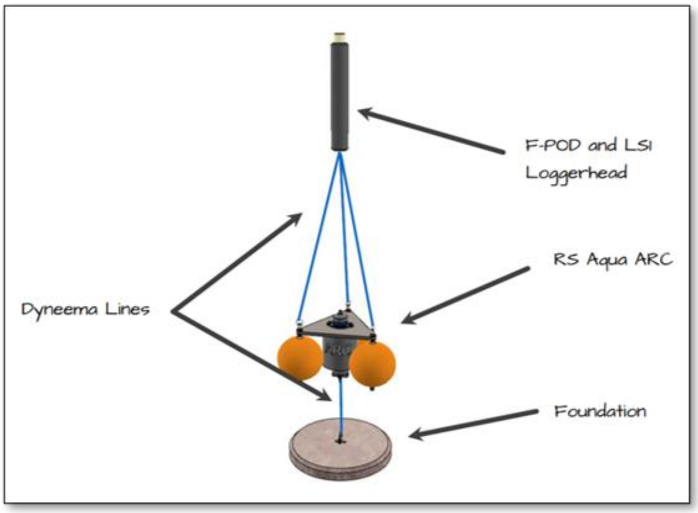


Figure 31 An S3 station

The systems will be deployed in a grid network to support a new marine mammal evidence base and creation of a region wide acoustic soundscape model and open-source baseline acoustic data integrating new S3 data and other secured regional acoustic data sources (F-POD's/C-POD's).

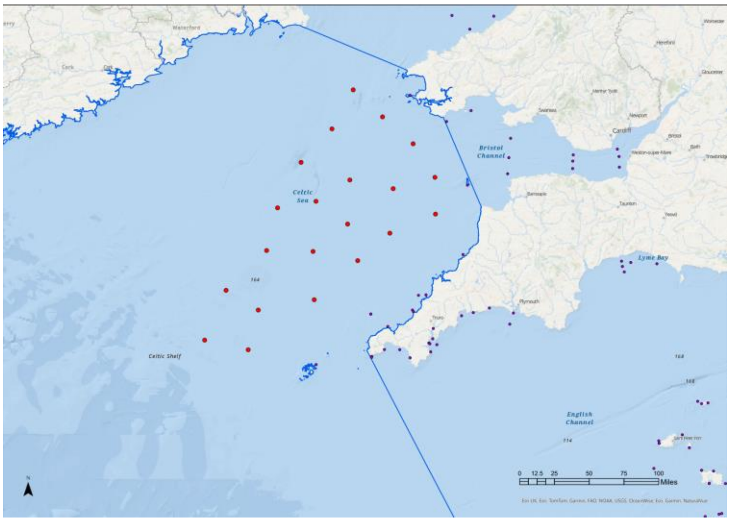


Figure 32 S3 Offshore array and complimentary data points

3.6.1.3 Cost efficiency and coverage expansion:

CSP Campaign Design support - £0
Campaign delivery - £1,316,851
Soundscape model production – £295,628
Match funding value (in kind, data and capital) - £1,166,245
Full programme cost - £2,718,733

Public Funding: CSP utilized public revenue funds secured through the Cornwall FLOW Commission programme to kickstart the project development process, engage critical collaborators and scope out a full project proposal .

The Swansea Bay City Deal was also instrumental in providing crucial capital match funding, showcasing a successful integration of regional economic development funds into the project's financial structure.

Private and Commercial Funding: To leverage additional resources, Cornwall sought match funding and commercial contributions, highlighting a strategic use of regional economic development funds to support research and infrastructure.

All project partners charge to the project at "Research" rather than "commercial" costs. This significantly affects the projects revenue costs with a reduction of 20-56%.

Matching Funding and Financial Contributions:

- **Match Funding for CATT Dataset:** A significant component of the S^3 project's financial strategy involved utilising the costs associated with the CATT (Cetacean Assessment and Telemetry Technology) project datasets as match funding. The total estimated value for the CATT dataset, including both deployment and retrieval costs and device costs, amounted to £344,711 annually.
    - **Deployment and Retrieval Costs:** The annual cost for deployment and data retrieval is estimated at £101,511, based on a standard deployment and service cycle.
    - **Device Costs:** The initial costs for the 76 F-PODs, each priced at £3,200, total £243,200.
    - **Total Estimated Value:** Combining these, the total estimated value of the dataset per year is £344,711. This significant financial commitment demonstrates the project's scale and the value of the data collected.
    - **Data Sharing Agreements:** To facilitate comprehensive data collection and analysis, Cornwall established data-sharing agreements with stakeholders and other research institutions. These agreements ensured access to valuable data sets and fostered collaborative research efforts.

Support from Key Organizations: The project was endorsed by several prominent organizations, whose letters of support validated the project's objectives and facilitated additional resources and expertise. These organizations include:

- **Natural England:** Their support ensured alignment with national conservation objectives and regulatory compliance.
- **The Crown Estate:** Provided essential data sharing agreements and financial contributions, enhancing the project's scope and effectiveness.
- **Chelonia:** Offered support in the form of data provision and expertise, which was crucial for comprehensive environmental analysis.
- **RDUK (Research & Development UK):** Contributed data and insights that enriched the project's data sets and analysis capabilities.
- **Cornwall Wildlife Trust:** Their involvement ensured that local conservation needs were addressed and integrated into the project's framework.

3.6.1.4 . Integrating Research Institutions and Private Sector Expertise

a. Collaboration with Research Institutions:

- **University Partnerships:** Collaboration with institutions like the University of Exeter was pivotal to the projects ability to deliver its objectives. Their expertise in marine science and technology integration was critical for designing and implementing the subsea acoustic monitoring network and developing the anticipated soundscape model. Other Universities both nationally and internationally have also engaged with CSP on mechanisms for tagging and modelling acoustic data sets for example.
- **The Offshore Renewable Energy Catapult** (UK Research Institution) formed an additional critical part of the project delivery team. ORE Catapult enables innovation and accelerates the development of offshore renewable energy, growing businesses and creating jobs throughout the UK whilst also holding internal environmental and acoustics expertise.
- **Leveraging Institutional Resources:** The partnership enabled access to cutting-edge research, technological innovations, and a robust academic framework that supported the project's scientific rigor.

b. Private Sector Engagement:

- **Leveraging Existing Networks and Initiatives:** Cornwall leveraged existing networks and initiatives, such as our project advisory positions on OWEC projects for example, to gain support and funding. These networks provided a platform for collaboration and knowledge sharing, which was essential for the successful execution of the projects.
- **Commercial Partnerships:** Engaging with commercial entities provided additional resources and expertise. For example, data sharing agreements commercial partners enhanced the project's data collection and analysis capabilities.
- **Maximizing Financial Efficiency:** Private sector contributions, including equipment and data provision, complemented public funding and reduced overall project costs. This approach was vital in ensuring the project's financial sustainability.

The S3 Project Advisory Group includes private sector participation from Seiche, RDUK, Chelonia, RS Aqua, Marine Energy Wales.

3.6.1.5 Building Relationships with Governing Bodies

a. Securing Regulatory Endorsements:

- **Engagement with Regulatory Bodies:** Establishing relationships with governing bodies such as Natural England, Cefas and DEFRA was crucial. These collaborations helped align the project with regulatory requirements and facilitated smoother consenting processes.

  The S3 project has an extensive project advisory group including; Natural England, CEFAS, Cornwall Wildlife Trust, Cornwall Council DEFRA, MoD, DESNZ, Crown Estate, Scottish Association of Marine Science and Natural Resources Wales.

- **Data Sharing Agreements:** Agreements with these bodies ensured that data collected was accessible for regulatory review and contributed to the broader environmental management framework.

b. Streamlining Consent Processes:

- **Early Data Availability:** By working closely with statutory bodies and integrating data from the S^3 project and the CATT datasets, the project aims to provide an upfront evidence base that supports streamlining of the offshore wind farm consenting process. This proactive approach could reduce potential delays and conflicts in obtaining necessary approvals whilst enabling earlier stage consideration of more realistic project level risk and impact analysis.

3.6.1.6 Maximizing Project Impact and Sustainability

a. Leveraging Data and Results:

- **Comprehensive Data Utilization:** The data collected through the S^3 project and the CATT datasets provides valuable insights into marine ecosystems, which were used to inform regional marine management and sustainable development practices.
  Whilst marine mammals and underwater noise are a key focus, the S3 project will also seek to build an acoustic evidence base for seal presence and behaviour alongside vessel identification capabilities. eDNA and CTD sampling will also occur and support wider cross validation activities across techniques for marine mammal identification including DAS and acoustics.

- **Public and Private Sector Benefits:** The project's outcomes will benefit both public and private sectors by providing a detailed environmental baseline and enhancing the commercial viability of offshore wind projects. Key outputs from the S3 programme will be made publicly available and will likely also feature in academic publications.

b. Future Planning and Replication:

- **Scalable Model:** The approach and methodologies developed through the S^3 project were designed to be scalable and adaptable for other regions or countries. This involved creating a replicable model for regional environmental characterisation.

- **Long-Term Investment:** Ongoing investment into the project and its methodologies could ensure that the benefits were sustained and expanded over time, integrating new data and evidence as it becomes available.

3.7 Applying Cornwall's REC Approach in New Areas

If replicating the Cornwall approach in a new area, it would be essential to adapt the methods to local conditions. This would involve understanding regional environmental challenges, engaging with local stakeholders, and navigating local regulatory frameworks.

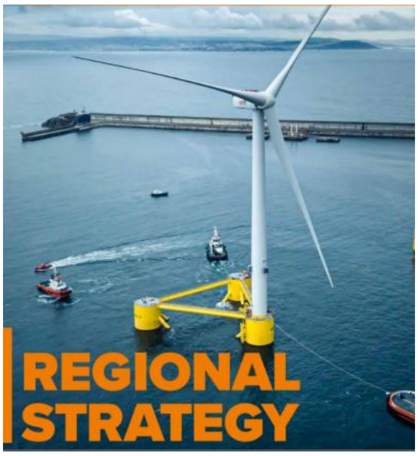


Figure 33 Celtic Sea Regional Strategy

3.7.1 Building Local Partnerships:

Establishing relationships with local governing bodies and research institutions would be critical. This includes identifying key stakeholders and forming collaborative agreements to support regional characterisation efforts.

3.7.2 Financing and Permitting

Financial Models: The financial models used in Cornwall, including the integration of public funds with private and commercial contributions, could be applicable in new regions. Securing match funding and exploring commercial partnerships would be key to ensuring financial sustainability.

Permitting Strategies: Developing a clear permitting strategy that aligns with local regulations and engages with relevant authorities would be crucial. This would involve adapting the Cornwall model to fit the specific regulatory environment of the new location.

3.7.3 Data Integration and Mapping:

Comprehensive Data Collection: The approach to data integration and mapping used in Cornwall, such as combining acoustic data with environmental monitoring, would be applicable in new regions. Ensuring that data is collected comprehensively and integrated effectively would support the creation of accurate regional environmental characterisation models.

Knowledge Transfer: Sharing knowledge and best practices from Cornwall's experience would help in establishing effective regional environmental characterisation and spatial planning processes in new areas.

3.7.4 Commercial and Private Sector Involvement

Engaging the Private Sector:

- **Commercial Partnerships:** Cornwall's use of commercial and private sector contributions and data sharing agreements demonstrates the value of engaging private entities. This approach could be replicated in new regions to secure additional funding and expertise and future data inputs.
- **Leveraging Commercial Data:** Integrating commercial data and leveraging private sector expertise would enhance the quality and scope of regional environmental characterisation efforts.

Long-term Sustainability:

- **Continued Investment:** Ensuring long-term sustainability through ongoing private sector investment and collaboration would be essential. This includes developing strategies for securing future funding and maintaining partnerships. Data sharing agreements also provide the opportunities for new data collected in the future to be integrated into now established REC models.

3.7.5 Key Lessons for New Areas or Countries

If this process were to be replicated in a new region or country where the consenting process or route to offshore infrastructure development might not yet exist—there are several key lessons to take from Cornwall's approach:

1. **Early stage spatial mapping activity;** As demonstrated in chapter 1, early spatial mapping activity is crucial for the development of successful REC campaigns. Even at a high level, spatial mapping can help to identify deficiencies in spatial and temporal environmental data coverage and a spatial focus for the design of new REC delivery plans.
2. **Early Engagement with Developers:** From the outset, it is essential to involve developers who can bring in private investment and expertise. Developing a clear, attractive portfolio of projects is key to securing their buy-in. These projects should align with the region's broader economic and environmental goals to ensure long-term benefits.
3. **Blended Funding Models:** As in Cornwall, public funds can be used to de-risk early-stage projects, making them more attractive to private investors. Match funding models, such as the Swansea Bay City Deal, provide a flexible approach that leverages both public and private money for maximum impact.
4. **Data Sharing and Stakeholder Collaboration:** Establishing agreements with private developers, governing bodies and research institutions is crucial to ensuring that all parties work from a common information base. In regions where the infrastructure for large-scale development might be underdeveloped, collaboration with international agencies, local governments, and universities/research organisations will be vital.
5. **Integration with Research Institutions:** Cornwall's integration of universities and research centres into its planning process and project delivery offers a valuable lesson for new regions. Research institutions bring cutting-edge expertise that can both inform and enhance development projects. Partnerships with international and local universities can help fill knowledge gaps and ensure that development is grounded in sustainable, science-based approaches.
6. **Building Long-Term Relationships with Governing Bodies:** Establishing relationships with entities like Natural England or CEFAS in the UK has helped Cornwall streamline its planning and regulatory processes. For new areas, developing strong ties with local, regional, and international governing bodies will help build the regulatory framework required to support the sustainable development of projects.

REC is a key part of CSP's strategic approach to overcoming regulatory and market inefficiencies through streamlining of processes, effective use of funding, and strategic partnerships. By leveraging data, securing grants, and managing funds carefully, CSPS approach could be adopted in other areas to accelerate more sustainable offshore wind development, ultimately benefiting the environment, economy and social standing of a region or nation.

3.9 Conclusion

Cornwall's experience in the delivery of Regional Environmental characterisation activities offers a valuable model for other regions seeking to balance public and private investment in sustainable infrastructure development. By leveraging a blend of public funding, private investment, and research partnerships, Cornwall has been able to build a robust portfolio of projects that deliver long-term value and have the means to become self-sustaining by securing future data inputs upfront.

When applying these lessons to new regions or countries, particularly those with underdeveloped consenting processes or infrastructure pathways, early engagement with developers, creative funding models, and strong stakeholder collaboration will be crucial. This holistic approach, focused on long-term sustainability and economic growth, is essential for replicating Cornwall's success in new contexts.

Addendum 1 – Future of Environmental Monitoring for the Offshore Wind Industry

To date Cornwall's approach to Regional Environmental Characterisation led by CSP has relied on relatively standard, tried and tested technical equipment to secure new data though it has been developed, acquired, utilised and modelled in many novel ways as described in Chapter 3.

However, given our more general focus on supporting sustainable development of the FLOW sector in the long term, including reducing the time, costs and emissions of data collection campaigns, we felt it was important to provide an overview of the role future new technologies could play in expanding and improving the Regional Environmental Characterisation approach which has been provided below by the ORE Catapult (Dr Caroline Whalley, Environmental Specialist, Offshore Renewable Energy (ORE) Catapult, October 2024)

AD 1.1 Introduction

Current environmental impacts assessments (EIAs) are not optimally designed for a robust and proper assessment of the present ecological and/or environmental status and assessment of pressures associated with the offshore wind sector (ORE Catapult, 2024). This leads to uncertainties regarding the prediction of adverse impacts, meaning UK regulators often take a precautionary approach to consenting new developments (ORE Catapult, 2024). There is a need for research that takes advantage of innovative technologies to better understand the functioning of the UK marine ecosystems within which large-scale offshore wind deployment is situated (ORE Catapult, 2024). The increased use of autonomous technologies for environmental monitoring could help to close critical knowledge gaps of these impacts (Isaksson et al., 2023), as long as these technologies can provide robust data to answer the key questions that are affecting consenting.

Marine monitoring can be both a time and resource-intensive process that often covers a network of sampling stations where data is collected manually by divers or using in situ water samples at different depths at fixed positions followed by laboratory analysis. As such, there is often a time lag in reporting the environmental status of a monitored site. However, recent advances in technologies, such as remote sensing (Medina-Lopez et al., 2021), machine learning (ML) techniques, acoustic monitoring, and intelligent integration of modelling and sensor measurements are revolutionising the future of marine environmental monitoring and monitoring systems (Erichsen and Middelboe, 2022).

Baseline environmental data acquisition is predominantly collected from *in situ* survey campaigns, for example, fish trawl surveys, seabed grabs and aircraft-based bird surveys. These methods are time, carbon and cost-intensive, subject to weather disruption and inherently involve a safety risk with humans working offshore (ORE Catapult, 2024). The data is often collected ad hoc, and only covers small areas both spatially and temporally. Efficient and time-relevant monitoring methods capable of monitoring at greater temporal and spatial scales are needed to better understand the impacts (ORE Catapult, 2024). In addition, there is an increasing demand for data and transparency in decision-making, and marine data must be detailed, precise, and readily available.

Advanced techniques are only applied to a limited extent in the offshore wind industry and often for research purposes, such as the automated detection of bird collisions on wind turbines using cameras and radar (ORE Catapult, 2024). There are still unresolved issues to be addressed before some of the techniques can be used in operational monitoring but different technologies can also strengthen and optimise other technologies or traditional monitoring. Marine autonomous systems (MAS) and uncrewed aerial vehicles (UAV) of increasing sophistication have been developed over the last twenty years and are now in regular use in the oceanographic community. Whilst performance and commercial availability have increased in the last decade, there are no proven systems in regular use for surveys pertinent to offshore renewable energy project consenting (ORE Catapult, 2024). This is due to a lack of commercially available MAS/UAV-based survey services and to the regulators' low confidence in such methods (ORE Catapult, 2024).

There needs to be a collaborative effort to enable a transformation in data gathering driven by trialling and testing new technologies that can be confidently incorporated into impact assessments and future monitoring plans (ORE Catapult, 2024). NOC's Net Zero Oceanographic Capability Summary Report (2022) stated that:

"The incremental nature of technology based transition requires a clear articulation of the intent but also the flexibility to move forward with numerous technologies at different speeds and thereafter adapt as necessary".

The report by NOC (2022) 'seeks to identify options for developing a world-class oceanographic capability with a reduced carbon footprint by presenting a range of options for transitioning to low or zero carbon capabilities'. It highlights key recommendations and future science recommendations to support the transition to automating data collection.

AD 1.2 Next-generation technology

The two basic categories of technology used to monitor seas are: (1) the platform from which a measurement is taken, such as a research vessel, a static observatory, or an unmanned automated vehicle; and (2) the actual sensor or methodology used to take the measurement, such as a multibeam sonar array, a seabed camera or a chemical analysis of a physical sample. Both categories have seen rapid advancement into more technology-based solutions.

AD 1.3 Monitoring platforms

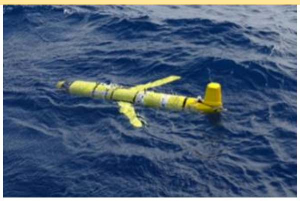
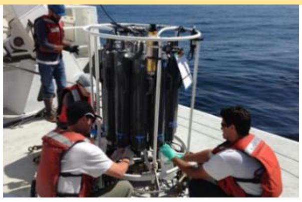
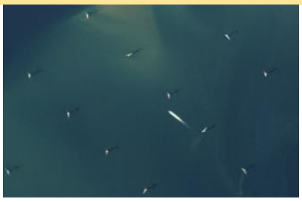
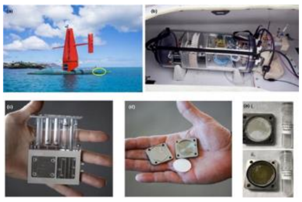
There exists a diverse collection of robotic vehicles for use in the marine environment, including autonomous underwater vehicles (AUVs), deep-sea landing vehicles, uncrewed surface vehicles (USVs), remotely operated vehicles (ROVs), and gliders/drifters which can be untethered, self-propelled and self-navigating and operate freely from a shore or vessel carrying scientific payloads and performing various sampling and monitoring tasks.

AD 1.4 Monitoring sensors

A suite of environmental monitoring instruments is used to monitor the potential environmental effects of offshore wind developments. The most common instrumentation used to document interactions of marine animals and habitats include both passive and active acoustic instruments, and optical cameras, increasingly the collection of environmental DNA, while other instrumentation is used to help define the physical environment in which these interactions may occur.

A report by ORE Catapult (2023) identified the various platforms and sensors that could be used for baseline monitoring, but also throughout the lifecycle of the wind farm (Figure 1).

Figure 34. Types of innovative marine monitoring technology and digital solutions for use in the offshore wind industry

Monitoring platforms	Monitoring sensors	Biomonitoring tools	Data and digital solutions
			
• Autonomous underwater vehicles • Uncrewed surface vessels • Subsea gliders • Wave gliders • Unmanned aerial vehicles • Offshore infrastructure as platforms for environmental monitoring • Multi-sensor suite added to 5G-enabled buoys	• Passive acoustic monitoring • Subsea cameras • Aerial cameras • Radar • Telemetry - solar-powered tracking tags	• Environmental DNA (eDNA) • metabarcoding	• Artificial intelligence • Cloud technologies • Machine learning • Satellite imagery
			

AD 1.5 Regional ecosystem-based monitoring programme

Following on from the report by ORE Catapult in 2023, it launched the project titled 'Accelerating Consenting for Offshore Renewables Deployment' (ACORD) which aims to accelerate the deployment of major offshore renewable energy infrastructure projects, minimise the damage to the environment and maximise the potential to reach net zero by promoting the use of smart technologies, appropriately developed, tested and demonstrated to enhance environmental data collection and monitoring. Other key elements of ACORD are:

- The development of an ecosystem-based approach to regional monitoring
- The development of a flexible online central data portal to hold offshore wind datasets

- The creation of a significant market sector with potential for global exportation for the UK supply chain.

The recommendation to move to a regional ecosystem-based approach and removal of project-level assessments stems from a need to streamline the consenting process. The current consenting process is inefficient and cumbersome resulting in significantly delayed approvals which delay the start and completion of projects. The report by ORE Catapult (2024) provides a framework for how a regional monitoring approach might be developed and operated. A collaborative and multi-disciplinary approach with scientific experts, developers, academics, researchers, regulators and technical specialists, focused on knowledge gaps at regional scales, could deliver independent and rigorous scientific outcomes, allowing consistency in environmental assessments. Robotics, AI and smart/autonomous technologies will help to improve data gathering and speed up processes for consenting and environmental monitoring and such data must be made available at the earliest opportunity.

The development of such an approach for the UK offshore wind industry has numerous benefits including:

- Reduced costs for the developers
- Reduced carbon footprint by using autonomous and unmanned monitoring vessels
- Greater certainty in the data collection and standardisation of methods and datasets
- Streamlined EIA reporting requirements
- Transparency in the data; benefiting wider monitoring initiatives and research opportunities
- Address the resourcing issues that hinder the organisations responsible for regulatory decision-making
- Reduction in overall consenting timelines
- A new national and global supply chain in innovative marine monitoring technologies.

AD 1.6 Use cases

Table 1 describes the current methods used for monitoring the different receptor groups as part of the EIA process where additional surveys are required to support the initial desk-based analysis. Potential alternative methods have also been discussed using innovative technology.

Table 2. Current methods and potential innovative technologies that could be used for baseline monitoring

Current method	**Innovative method**
Metocean	
Deploy floating LiDAR for 2-3 years to calibrate mesoscale wind resource data. This comes with challenges, as floating LiDAR campaigns are costly and weather dependent. They can be expensive to permit, install, and service.	USVs, powered by renewable wind and solar energy with a minimal or zero operational carbon footprint, can collect comprehensive real-time metocean data from wind monitoring to high-resolution ocean mapping, persistent year-round ecosystem monitoring, and maritime security solutions. An environmentally friendly, cost-efficient solution for persistent data collection above and below the sea surface.

Current method	Innovative method
Additionally, maintaining floating LiDAR systems in rough seas is difficult.	Transmitting critical data back to shore in real-time and sailing autonomously back to base for recalibration and service. USVs can carry a complete set of metocean sensors plus a sub-bottom profiler to identify and characterise layers of sediment or rock under the seafloor and capable of multibeam ocean mapping down to 300 m. Some USVs are integrated with passive acoustics, optical cameras, and advanced machine learning algorithms to deliver real-time detection of objects in the vicinity of offshore wind farms, including commercial and recreational boats or other vessels that may choose not to transmit their position, as well as identifying wildlife such as whales, seabirds, and bats to support environmental impact mitigation strategies.
	There is potential to replace project-specific floating LiDAR deployments with physics-based models.
Marine mammals	
Monthly digital aerial surveys and/or marine mammal observers on boats.	Use of hydrophones mounted on autonomous vehicles integrated with AI. Whale and dolphin vocalisations can be automatically identified and reported in real-time. Seals have low vocalisation rates and therefore drone imagery using AI could be an additional method. During the installation phase, utilise advanced uncrewed observing, artificial intelligence, and machine learning (ML) technologies to create a line-of-sight monitoring network to detect, classify, and localise marine mammals in areas with offshore wind developments.
	Autonomous eDNA sampling using an environmental sample processor (ESP) to identify species composition. A current challenge in these applications is building eDNA analysis systems that can work on autonomous vehicles. Recent steps toward a full in situ eDNA measurement system on board an autonomous vehicle involve collecting and preserving samples for laboratory analysis.
	Coordinated multi-platform surveys and monitoring programmes using hydrophones or AUVs to indicate

Current method	Innovative method
	cetacean presence, with UAV then tasked to localise and classify on the surface.
Fish	
Traditional fish trawling and net survey methods.	Innovative underwater acoustic tracking technology to monitor marine species. Through a combination of fish tracking and underwater video surveys, the technology can establish a comprehensive picture of fish movements and their preferred habitats.
	Autonomous eDNA sampling using an ESP to identify species composition.
	Integrate low-power sonar instruments, echosounders, into the autonomous vehicle. Echosounders send sound pulses into the water and measure how much of this energy echoes back from fish. From this, scientists can estimate the population of fish. As this technology is not very effective at differentiating between fish species, the use of eDNA combined with an echosounder integrated into an AUV or USV could provide a measure of both species composition and abundance.
Benthic habitats	
Surveys include geophysical surveys (multi-beam bathymetry, side scan sonar, and sub-bottom profiler) and benthic characterisation surveys involving grab samples and seabed imagery.	AUV with photogrammetry and computer vision to identify benthic epifauna and habitats.
	AUV combined with side-scan and multi-beam bathymetry for seabed mapping.
	Autonomous eDNA sampling to identify epifaunal species composition.
	eDNA sampling for benthic infauna. Sediment collection for identifying infauna species and particle size analysis – this still requires humans on vessels to collect the sediment samples from corers or grab samples. The use of eDNA instead of manual taxonomic identification would help to speed up the post-processing of the samples for species ID.
Birds	

Current method	Innovative method
Monthly digital aerial surveys (increasingly with LiDAR usually flown at a height between 270 and 550 metres (a minimum altitude of 270 m ensures that there is no risk of flushing those species known to be easily disturbed by aircraft noise).	Drones or buoys with LiDAR, radar and hi-resolution camera capabilities. Current limitations on battery size and power availability. Size of the payload is also an issue. Combined LiDAR or radar and digital photography method enables the recording and analysis of flight heights and direction, species, age classes, distribution, and bird numbers. It will be important to investigate the potential for using this technique for estimating seabird flight speeds.
	Satellite telemetry tags.

Surveys for particular species need to be designed around methods that can answer the key monitoring questions and measure priority indicators for species and threats, adapted as necessary to local conditions. Monitoring needs to be adapted depending on the phase of offshore wind development to take account of the different impacts on different taxa. Surveys at the planning stage rely more on data on the presence of threatened or sensitive species and habitats; the construction phase has more impact on habitats, mammals and fish; operating wind farms have more impact on birds; and the decommissioning phase is still relatively new and less well understood.

The development of indicators needs to follow best practices (Stephenson, 2021) to ensure they are:

- scientifically credible (e.g. using methods that have been peer-reviewed in the scientific literature)
- feasible and cost-effective to apply (i.e., data can be collected either directly or through others using identified methods)
- measurable (in quantitative or qualitative terms)
- precise (defined the same way by everyone who uses them)
- consistent (always measuring the same thing)
- understandable (everyone who is concerned by the results can interpret what they mean)
- relevant to a specific impact on a specific species group or habitat type;
- sensitive to changes in the pressure, state, response or benefit being measured

AD 1.7 Benefits of next-generation technology

The sensors capable of continuous multi-day and concurrent bio-physical parameter measurements relevant to offshore wind farms and the autonomous and uncrewed platforms capable of hosting multiple sensors for studies offshore are listed in Appendix 1 (taken from Isaksson et al., 2023). These include active and passive acoustic techniques that can measure the spatio-temporal distribution and abundance of organisms and also track their movements (Williamson et al., 2021, Gillespie et al., 2022), whilst combining acoustic sensors with concurrent environmental measurements allows for multitrophic monitoring (Chapman et al., 2024).

Autonomous platforms can fill some of the important temporal continuity gaps inherent with traditional platforms, improving observation frequency in the open ocean from monthly or seasonal to daily and weekly timescales (Chai et al., 2020). Recent advances have led to the use of swarm autonomous underwater vehicles (AUVs) where multiple vehicles work together to achieve a common objective, offering advantages such as greater spatio-temporal resolution, enhanced robustness to sensor errors and reduced survey time (Lin et al., 2017). With the deployment of wind farms into deeper waters, the need for similar multi-sensor floating platforms and sensor integration with turbine structures will become increasingly valuable (Isaksson et al., 2023). The major perceived limitation of autonomy in monitoring is the general inability to collect physical samples, particularly in the case of the seabed sediments. This necessarily limits the use of particular current standard practices. Jones et al., (2019) reported that these issues may well be surmountable through careful re-evaluation of appropriate indicators and/or by rapid technological advances.

Compared with traditional in situ observations by ships and moorings, the greatest strength of autonomous platform networks is their capacity to conduct multiscale and cross-disciplinary measurements. The appropriate scale of sampling (both spatial and temporal) will depend on the variables and species of interest, the methods being used and the overall objectives of the monitoring program (Booth et al., 2020). The benefits of concurrent data collection methods utilising mobile and static platforms, with multi-parameter instruments, can greatly increase the information needed to explain variations in seabird, fish and marine mammal distributions (Chapman et al., 2024) and provide robust, informative outputs that can help to reduce uncertainties.

Advances in in-situ measurement techniques over the past decade have made it possible to study environmental drivers of marine ecosystem processes at fine-scale resolutions and capture any (predictable) variation (Isaksson et al., 2023). Impact assessment methodologies must evolve to progress the reliability and transferability of predictions of effects on protected marine species at individual and population levels. Utilisation of a range of complementary methodologies can better inform understanding of ecosystem effects and potentially reduce survey and EIA costs and offer an alternative, practical and more efficient approach to resolving uncertainties.

AD 1.8 Conclusions

With a growing need to better understand the functioning of the UK marine ecosystems within which large-scale offshore wind deployment is situated, it is critical to take advantage of innovative technologies, such as the use of robotics and artificial intelligence that will support the need for highly efficient survey and environmental monitoring procedures that limits potential costs and that fit with needs of the regulators (ORE Catapult, 2024).

In 2022, Professor Sir Ian Boyd[17] wrote:

“Almost 150 years after HMS Challenger set out on the expedition that laid the foundations for the field of marine science, the UK has the opportunity to play a leading role in the transition of the research ecosystem that supports this expanding field of research. By leveraging its expertise in marine science, robotics and autonomy, sensor development, global data transfer networks, artificial intelligence and machine learning and supported by its expertise in marine policy and regulation, the UK can maintain its position as a world leader”.

For the Statutory Nature Conservation Bodies (SNCBs) responsible for providing advice to the regulator, there is uncertainty around the use of new technology to monitor the impacts of offshore wind (ORE Catapult, 2024). There is a need to properly assess the pros and cons of novel methods, comparing them with benchmark technologies and integrating these into long-standing time series for data continuity (Borja

[17] NOC (2022). Net Zero Oceanographic Capability Summary Report. https://noc.ac.uk/files/documents/facilities/NZOC%20SUMMARY%20REPORT%20V2.pdf

et al., 2024). This requires transition periods and careful planning, which can be covered through a collaboration of current and future research projects on marine biodiversity and ecosystem health (Borja et al., 2024). It is important to demonstrate the efficacy and scientific rigour of new methods to ensure the adoption into best practice guidelines, thereby giving confidence to both the developer and the SNCBs (ORE Catapult, 2024).

Although the adoption of emerging and novel monitoring techniques can improve data collection, it is important to continue data collection in a coherent manner (McGeady et al., 2023). For this reason, many monitoring programmes have retained traditional methods, such as trawls and towed nets. Where a transition in monitoring technique is proposed, a long period of temporal overlap will normally be required to allow inter-calibration of the methods. However, in some cases it may be possible to supplement the older technology with modern instrumentation whilst retaining the essential original sampling characteristics (Reid et al., 2003). Where new monitoring programmes are proposed then maintaining historical consistency may be less critical, although it may still be desirable to be able to compare new data with results from surrounding locations.

A transition to technology with reduced carbon footprint would also see the offshore renewables sector aligning with UKRI's Environmental Sustainability Strategy[18] and complements the UK government's Greening Government Commitments[19] which set out actions on how to reduce their environmental impacts.

Industry demand and regulatory support could help to increase the pace of technology transfer. There seems little doubt that uncrewed and autonomous vessels will be a transformative technology for environmental monitoring, only the rate of change is uncertain (ORE Catapult, 2024).

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[18] https://www.ukri.org/publications/ukri-environmental-sustainability-strategy/

[19] https://www.gov.uk/government/publications/greening-government-commitments-2021-to-2025/greening-government-commitments-2021-to-2025

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AD 1.10 Appendix 1.

Table 1A. Sensors capable of continuous multi-day and concurrent bio-physical parameter measurements relevant to offshore windfarm impacts, including coverage and/or range *Diving seabirds only (taken from Isaksson et al., 2023).

Sensor type and Instrument	**Parameter(s) of interest**				**Typical coverage/range**
	Fish	**Seabirds**	**Marine mammals**	**Environmental**	
Acoustics - active					
Multi-frequency split-beam echosounder	P	P*	P	Zooplankton	7°, 100’s of metres
Multibeam echosounder (imaging sonar)	P	P*	P		120°, 10s to 100s of metres
ADCP with echosounder as centre beam	P	P*	P	Hydrodynamics Zooplankton	3°, 10s to 100s of metres
Acoustics - passive					
Hydrophone	P	-	P	Noise	50 Hz – 150 kHz, 10’s to 100’s of m, species &

					environment dependent
Visual					
Underwater camera	P	P*	P	-	10's of m
Aerial camera	P	P	P	Sea surface features (i.e. wake)	1000's of m
Photographic systems	-	-	-	Phytoplankton/ Zooplankton	Point measurement
Oceanographic					
eDNA sensor	P	P	P	Nuclear or mitochondrial DNA	Point measurement
CTD (conductivity, temperature and depth)	-	-	-	Salinity Temperature Depth	Point measurement
Fluorometer	-	-	-	Phytoplankton Chlorophyll	Point measurement
Macro- and micro nutrient sensors	-	-	-	Dissolved inorganic nitrate, nitrite, phosphate, iron, silicate	Point measurement
Microstructure profiler	-	-	-	Turbulence and diapycnal mixing, flux; Flux rates (when combined with nutrient profiles)	Point measurement
Optical / galvanic dissolved oxygen probe	-	-	-	Oxygen	Point measurement
Optical or backscatter of suspended sediment	-	-	-	Suspended material; Dissolved organic matter	Point measurement
PAR sensor	-	-	-	Photosynthetically Active Radiation (PAR)	Point measurement
pH sensor	-	-	-	pH	Point measurement

Table 1B. Comparison of autonomous and/or uncrewed platforms capable of hosting multiple sensors for multitrophic marine studies in shelf and coastal waters, including coverage, advantages and limitations (taken from Isaksson et al., 2023).

Mooring type and Platform	Coverage			Advantages	Limitations
	Water column	**Spatial**	**Temporal**		
Static					
Lander	From the seabed to instrument max range	Fixed point	Weeks to months (limited by power)	Robust	Large vessel required for deployment Limited by power unless cabled
Floating buoy	Surface, down to instrument max range	Fixed point	Weeks to months, longer with solar panels	Easy deployment, flexible payload, real time summary data	Wind/wave induced movement affects data quality Requires navigational awareness
Fixed to existing structure	Structure dependent	Fixed point	Months, years possible with power integrated or obtained from structure	Robust	Requires structure integration
Mobile					
Ship	Surface less keel, down to instrument max range	~km transects	Days	No instrument recovery required, real time data (reactive survey possible)	Vessel availability, cost
Uncrewed Surface Vehicles (USV)	Surface down to instrument max range	~km transects	Days/months	Easy deployment, embedded instrumentation options, real time summary data	Survey duration, power against currents, data quality in high wave conditions, requires pilot
Autonomous Surface Vehicles (ASV)	Surface	~km transects	Days/months	No pilot, easy deployment, embedded instrumentation options	Survey duration, power against currents, data quality in high wave conditions
Autonomous Underwater Vehicle (AUV)	Entire water column	~km transects	Days/weeks	No pilot, easy deployment, embedded instrumentation options	Survey duration, power against currents, limited sensor payload
Remotely Operated Vehicle (ROV)	Entire water column (dependent on positioning)	~100-300 m dependent on umbilical	Hours/days	Real time data so points of interest can be investigated further	Requires pilot and deployment ship

Glider	Entire water column (dependent on positioning)	~km transects	Weeks/months (depending on sensor load and sampling strategy)	Autonomous and web-based piloting tools, easy deployment, embedded instrumentation options Near real-time data collection High vertical data resolution	Glider 'sawtooth' profiles can complicate acoustic data collection, presently unsuitable in high current conditions
Drifter	Surface	~km transects	Months	Low cost, survey Survey duration	Limited positional control
Uncrewed Aerial Vehicle (UAV)	Surface	~500 m transects unless beyond visual line of site (BVLOS)	Hours/days	Low cost	Limited by Visual Line Of Sight (VLOS), weather conditions, battery duration, take-off locations and need for piloting, On or at-surface measurements only Post-processing of imagery datasets challenging to fully automate