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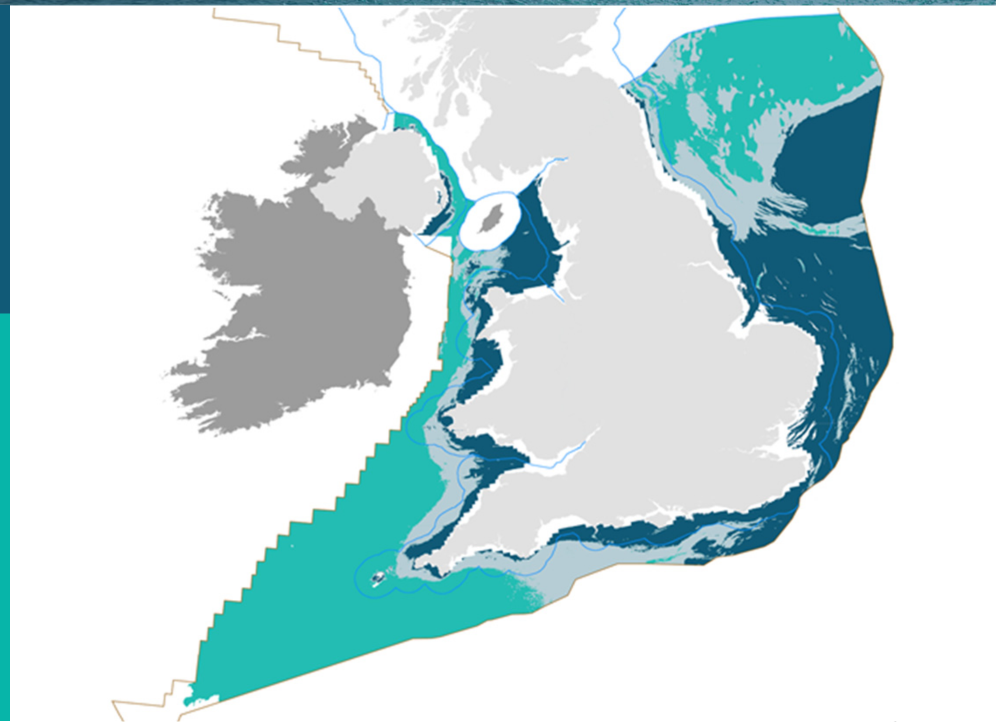
# BROAD HORIZONS:

## Key resource areas for offshore wind

Summary Report



An Everoze Report, commissioned by The Crown Estate

Autumn 2020

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# Executive summary

## Mapping the future technical offshore wind potential of the seabed

### Foreword by The Crown Estate

Since the first wind turbines were installed in the North Sea, just 20 years ago, the UK offshore wind industry has seen unprecedented levels of growth. Today, 10% of all electricity consumed across the country is generated by offshore windfarms, and by the end of the decade the sector is set to deliver enough renewable energy to power every home in the UK.

Despite this extraordinary success, the best is yet to come. Projecting innovation and technological advancements forward to 2040 demonstrates that, by then, there will be few technical limits to where offshore wind developments can be sited.

With the clock ticking on the climate crisis, this much wider choice of potential development sites is an exciting prospect. It presents opportunities for the sector to continue to grow, and to make an even greater contribution to decarbonisation and the nation's 2050 net zero ambitions.

It also means that future windfarms can be sited away from environmentally sensitive areas, as the preservation of rich biodiversity offshore will play a crucial role in the design of our future energy system. The growth of offshore wind must be balanced with many competing demands from an increasingly busy marine environment, and a greater choice of sites will help to strike the right balance.

We hope that this report will provide new data and insights to inform conversations about the sustainable growth of the offshore wind industry. Better data will lead to better dialogues that, in the end, will lead to better decisions, whether from a technical, environmental, societal or policy perspective.

We will continue to work with existing and new customers, stakeholders, and government departments as we share the findings of this report and explore how, together, we can convert this vast technical potential into a safe, clean, and benign source of energy for our country.

Huub den Rooijen

**Huub den Rooijen**

Director of Energy, Minerals and Infrastructure at The Crown Estate

### Overview

The purpose of this report is 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.

The seas around the UK have some of the richest wind energy resources in the world and cost effective UK offshore wind is expected to play a central role in achieving the target of net zero greenhouse gas emissions.

The Crown Estate engaged Everoze to survey the evolving technology landscape to assess how practical limits to offshore wind installation will develop between now and 2040. Working in partnership, Everoze and The Crown Estate have mapped engineering solutions against the physical characteristics of the sea and seabed to define the future technology profiles for nineteen different key resource areas.

The study found that in addition to driving down the cost of clean electricity, technological innovation will expand the range of geographical possibilities for offshore wind deployment. Refinement of fixed foundation installation techniques and the entry to the market of full scale floating offshore wind will bring new areas of UK waters within reach, helping to unlock this increasingly important source of renewable energy and support the UK's clean energy future.

**Defining key resource areas**

A key resource area represents an area of seabed in which offshore wind is projected to be technically viable over a given timeframe, classified according to the most appropriate engineering solution.

### Key findings

1 Advances in engineering will expand the technical reach of offshore wind.

We expect offshore wind to be technically feasible across a large majority of the seabed around England, Wales and Northern Ireland within 20 years.

2 Fixed foundation and floating wind are complementary technologies.

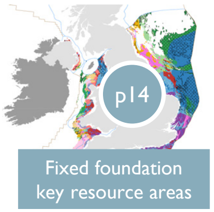
The two main variants of offshore wind technology predominantly occupy different geographical niches, and both will play a role in the UK's offshore wind portfolio and in meeting net-zero targets.

3 There is no one-size-fits-all technology solution.

Although all regions have excellent wind energy resources, wide variation in site conditions results in regional differences in technology focus and differing opportunities for the supply chain.

## Mapping the technical potential

To summarise the findings of the report, the map to the right shows the aggregation of all floating and fixed foundation key resource areas identified by this study. The map shows only the outer extent of the nineteen key resource areas - for a more detailed view, see pages 14 and 15.



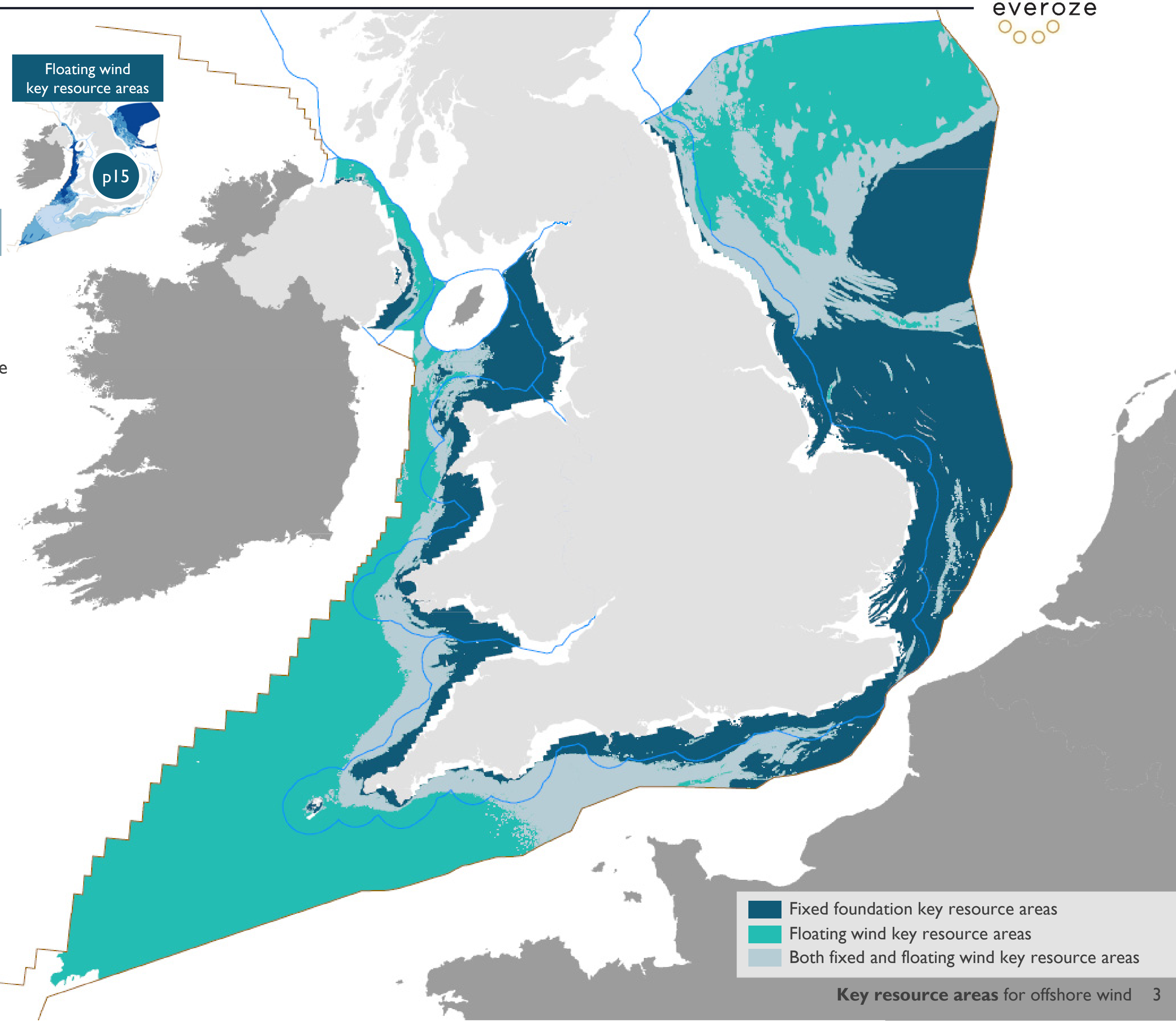

## Broad horizons: next steps

Our findings are encouraging, but we acknowledge that not all of the seabed can or should be developed for offshore wind. A process of refinement, through stakeholder engagement and more localised analysis, is necessary in order to achieve balance with other sea users, interests and sensitivities.

## Our recommendations….

1. **Moving beyond the engineering.**
The engineering potential we have identified is just the first step towards an understanding of which areas could be made available for this vast technical potential into a realisable development, in a practical sense. Effective stakeholder engagement is needed to map out the steps required to translate programme for development - balancing net zero imperatives, cost to consumers, enhancing the marine environment, driving innovation, and providing new economic opportunities in a strong supply chain.

2. **Localising the results.**
This report draws on national-scale datasets, but physical conditions for offshore wind vary widely across the UK. Alongside enhancement of available national data, the regional variation we have identified here will require further, more localised, analyses to fully explore and understand local level implications.



# 1 Introduction

## A need to understand how and where offshore wind could be deployed as we move towards net zero

A strong supply chain and rapid technological innovation has resulted in UK offshore wind energy production costs falling by 65% since 2015.

As well as driving down costs, new technologies and techniques have the potential to expand the range of possibilities for locating offshore wind farms.

A clear understanding of the geo-spatial implications of technology trends is a necessary first step towards defining the future potential for offshore wind.

In the coming decades, the proportion of UK's seabed where it is possible to build wind farms will increase substantially.

Turbines will continue to get larger, fixed foundation designs and installation methods will improve, and floating substructures (currently in the demonstration phase) will become a commercial reality.

Numerous factors influence the technical and economic viability of offshore wind deployment. The reliably windy waters around the coasts of the UK vary enormously in water depth, sea-state, and seabed geology.

Together, these factors determine where construction of offshore wind farms may be feasible, from an engineering perspective, and shape choices about how wind farms are designed and installed.

To illustrate the implications of ongoing innovation for offshore wind siting, this report summarises a technical study* by combining expert technology foresighting and national-scale geospatial data to identify key resource areas in which we anticipate offshore wind development to be technically and economically feasible by 2040.

Our time horizon of interest is twenty years, as this stretches beyond the current offshore wind project development pipeline, but is not so far away as to make technology foresighting unrealistic.

*The full technical report of the study is available for download on The Crown Estate's Marine Data Exchange: www.marinedataexchange.co.uk

### Defining key resource areas: the process

Various social and non-technical factors influence offshore wind investment decisions, including: impact on communities, cost of capital, electricity pricing, and the cost of using the onshore electricity transmission system.

The purpose of this study, however, is to identify key resource areas. To do this, we combined data on spatial variation in the physical environment with a survey of offshore wind technologies and techniques that are expected to be available in 2040.

For both fixed and floating offshore wind, we outlined the **drivers** of techno-economic viability, analysing technology trends to understand the **solutions** that may be available and the **criteria** for their application. Packaging solutions into **technology groups** enabled geo-spatial **mapping** of the groups, to reveal the location and extent of the key resource areas.

## Solutions

To characterise key resource areas for projects reaching investment decisions in 2040, it is necessary to take a view on what technologies we can expect to be available.

Our view is based on an expert review of the current technology landscape, supply chain expectations for mature technologies, and likely commercialisation trajectories for emerging concepts, against a technology and commercial readiness level framework. This review allowed us to match future technological solutions to locational drivers of offshore wind viability.

## Drivers

Physical site conditions determine techno-economic feasibility to a large degree. The most fundamental driver of technology choice is water depth. In many areas, the water is shallow enough to install structures directly to the seabed, but deeper water will require floating foundations.

Wind speed, sea-state and geological conditions on the sea bed are also important determinants of whether and how offshore wind farms can be built in a particular location.

## Criteria

To specify the conditions in which a technological solution is most appropriately applied, we have developed a set of driver-level criteria that indicate the suitability of each solution.

## Technology groups

Bringing technological solutions together with the criteria indicating the conditions to which they are suited produces a finite number of 'technology groups'.

Each technology group is a package of technologies that are best suited to addressing a particular set of criteria.

## Mapping

Finally, we applied national-level data about the seas around the UK, to identify where each technology group is likely to be most suitable – these areas are the key resource areas.

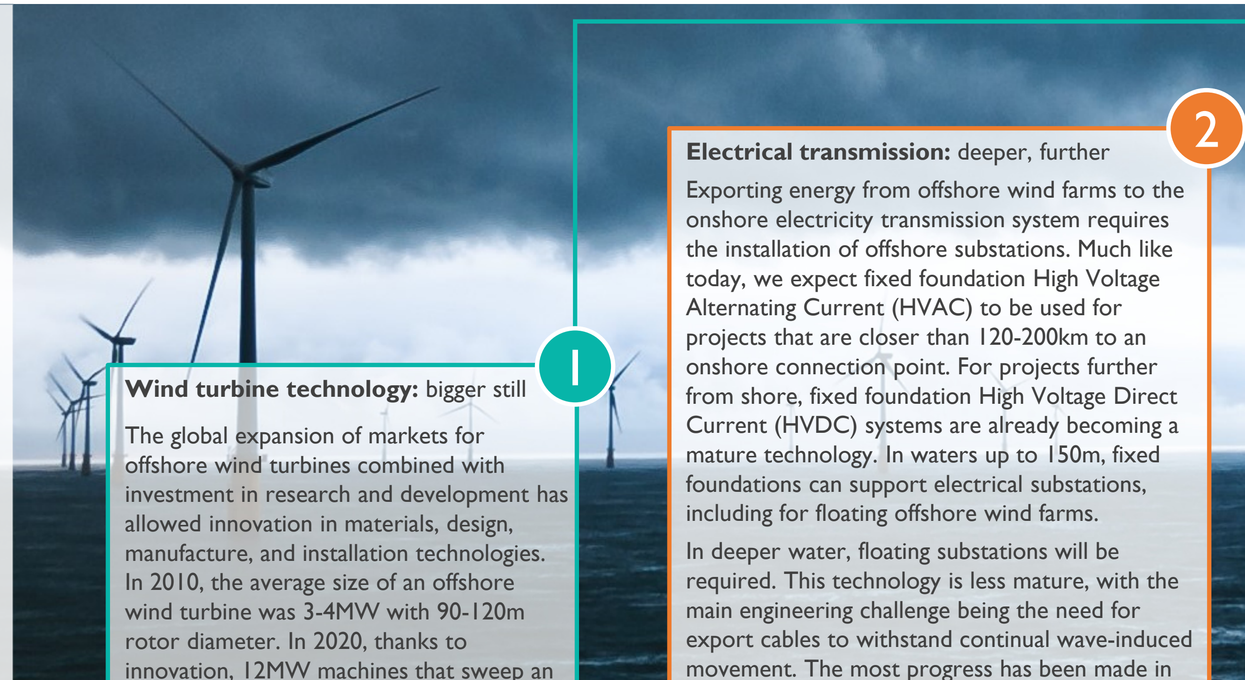
**Section 2 (p6-7):** new solutions
**Section 3 (p8-9):** scaling-up
**Section 4 (p10-11):** fixed wind
**Section 5 (p12-13):** floating wind
**Section 6 (p14):** fixed wind
**Section 6 (p15):** floating wind

# 2

# Technology outlook to 2040: proving new solutions

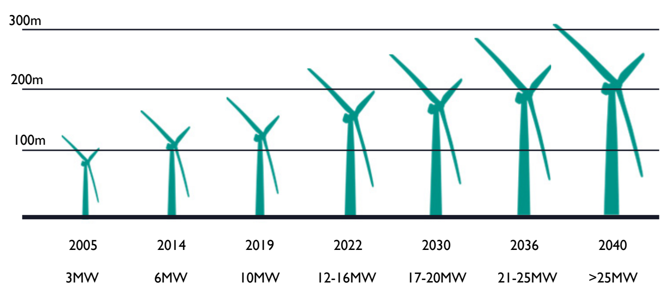
## Ongoing innovation in key technologies will continue to redefine the limits of what is possible

In the last five years alone, offshore wind deployment in the UK has doubled to 10GW of operating projects. This rapid acceleration would not have been possible without significant technological and industrial progress. As we look ahead, we can reflect on the progress made by the sector and consider how key technologies may develop in the coming decades. In consultation with industry partners, Everoze has taken a detailed look at the status and prospects of **six technology areas** and their supply chains. These pages provide an overview of our assessment of the technology landscape in which projects will take financial investment decisions (FID) in 2040.



### 1 **Wind turbine technology:** bigger still

The global expansion of markets for offshore wind turbines combined with investment in research and development has allowed innovation in materials, design, manufacture, and installation technologies. In 2010, the average size of an offshore wind turbine was 3-4MW with 90-120m rotor diameter. In 2020, thanks to innovation, 12MW machines that sweep an area 220m across are commercially available. By 2040, we anticipate that at least one new generation of technology platform will be commercialised with rated capacity in the region of 20MW. If the global offshore wind market continues to expand strongly, it is possible that a further generation of the technology will deliver turbines up to 24MW. Fixed foundation and floating wind are likely to adopt the same turbine technology platforms.




### 2 **Electrical transmission:** deeper, further

Exporting energy from offshore wind farms to the onshore electricity transmission system requires the installation of offshore substations. Much like today, we expect fixed foundation High Voltage Alternating Current (HVAC) to be used for projects that are closer than 120-200km to an onshore connection point. For projects further from shore, fixed foundation High Voltage Direct Current (HVDC) systems are already becoming a mature technology. In waters up to 150m, fixed foundations can support electrical substations, including for floating offshore wind farms.

In deeper water, floating substations will be required. This technology is less mature, with the main engineering challenge being the need for export cables to withstand continual wave-induced movement. The most progress has been made in commercialising floating HVAC systems, but we do not anticipate any insurmountable technological barriers to the future availability of floating HVDC substations.

In addition to technological developments, it is likely that the inefficiencies of point-to-point connection will demand that a coordinated approach to offshore transmission is implemented in the coming decades. The precise model for coordination is unclear, but some form of offshore electrical hub is likely in the North Sea, and possibly even 'energy islands' that would serve multiple countries.

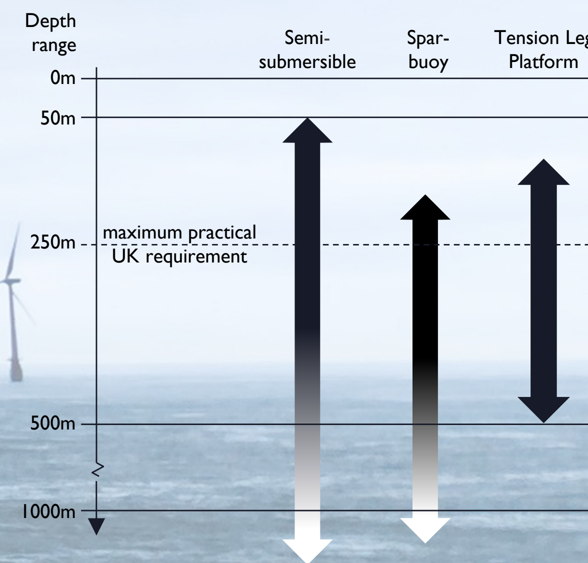
Image: R Redfern

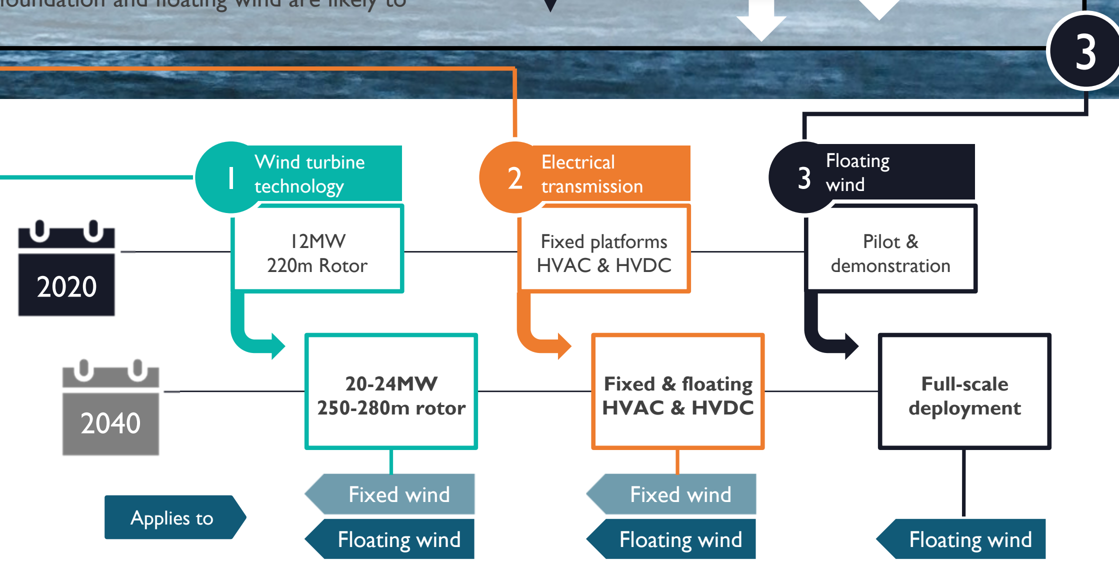
**Floating wind:** from demo to deployment

The availability of floating structures that can support turbines in water too deep for fixed foundations will be a step-change in the scope of offshore wind, with the potential to open up large areas that would be otherwise out of reach. Although floating offshore wind is yet to achieve deployment at a commercial scale, several conceptual approaches are in development, with the most advanced currently in either pilot or demonstration phases. Structures can be classified into three types: Spar-buoy, Semi-submersible, and Tension Leg Platform. Semi-submersibles are the most advanced technology class at present, but all the technologies show promise, and the floating wind market is likely to feature a mix of concepts. Over the coming decade a number of small-scale projects will come online, and by 2040 we anticipate that several concepts will be available at full commercial scale.

Semi-submersibles can be deployed in water depths as shallow as ~50m, while the upper limit for Tension Leg Platforms is around 500m depth; spar-buoy systems or semi-submersibles can cope with water more than 1,000m deep. However, engineering complexity increases with water depth (although less strongly than for fixed foundations), and in the UK's relatively shallow waters we think it is unlikely that wind turbines will be installed beyond a practical depth limit of 250m.

Although specialist floating offshore wind products may become available, the scale and timeline of investment mean that in 2040 fixed foundation and floating wind are likely to adopt the same turbine technology platforms.



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# Technology outlook to 2040: scaling-up existing tech

## Incremental advances will unlock a wider range of sites

Many of the technologies that will underpin UK offshore wind in 2040 already exist, either at a smaller scale or in adjacent industries. In these technology areas, rather than a technological step change, the focus in the coming decades will be on building supply chain capacity, increasing cost-effectiveness, and creating offshore wind-specific standards and practices.


Image: Siemens AG

**Operations & Maintenance:** to the high seas

Offshore wind turbines are complex machines, and keeping their energy flowing to shore requires both regular scheduled maintenance work and unscheduled troubleshooting. Minimising downtime therefore means getting technicians, parts, and equipment safely onboard turbines, when needed. Currently, most operations strategies use crew transfer vessels and helicopters to shuttle the short distances from shore. However, as larger wind farms are installed further from shore and port facilities, the industry is moving towards using offshore logistics, with more operations based entirely offshore. Once available, large capacity site-operated vessels (SOVs), combined with new technologies to allow technicians to safely access turbines and substations (floating and fixed) in all conditions, may also tilt the economics of O&M towards coordinated offshore logistics - even for clusters of closer-to-shore projects where shore-based logistics are currently the norm.

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**Subsea installation:** tools for every job

For both fixed foundation and floating offshore wind, securing wind farms to the seabed presents a technical challenge. Performing complex civil engineering in varied ground conditions under tens of metres of seawater is certainly not easy, but by building on experience from other offshore sectors, the range of techniques available to offshore wind will continue to expand.

The most common technique, to date, has been hammer-driving of monopile foundations (or jacket pin-piles) into the seabed. However, difficult sediment conditions, shallow sediments, and hard bedrock often call for a combination of driving and rock drilling. This 'drive-drill-drive' (DDD) process is widely used to install monopiles, and we expect it to also become common practice for jacket installations.

In hard rock conditions, piles can be cemented into a specially drilled 'rock-socket'. The next generation of XXL monopiles will require larger drilling diameters than are currently available, but the industry is well placed to provide increased drilling diameters, as needed.

Areas with deep, sandy sediment offer the potential to use 'suction caissons', in which pumps are used to draw hollow piles into the seabed. This technique has the potential to reduce both installation cost and environmental impact (especially noise), compared to other methods.

Similar to fixed foundations, the way in which floating turbines are secured to the seabed is dependent on geological conditions. Where there is suitable depth and types of sediment, anchors that embed themselves in the sea floor are the lowest cost option, but we anticipate that suction or socketed piles will also be available, where needed.

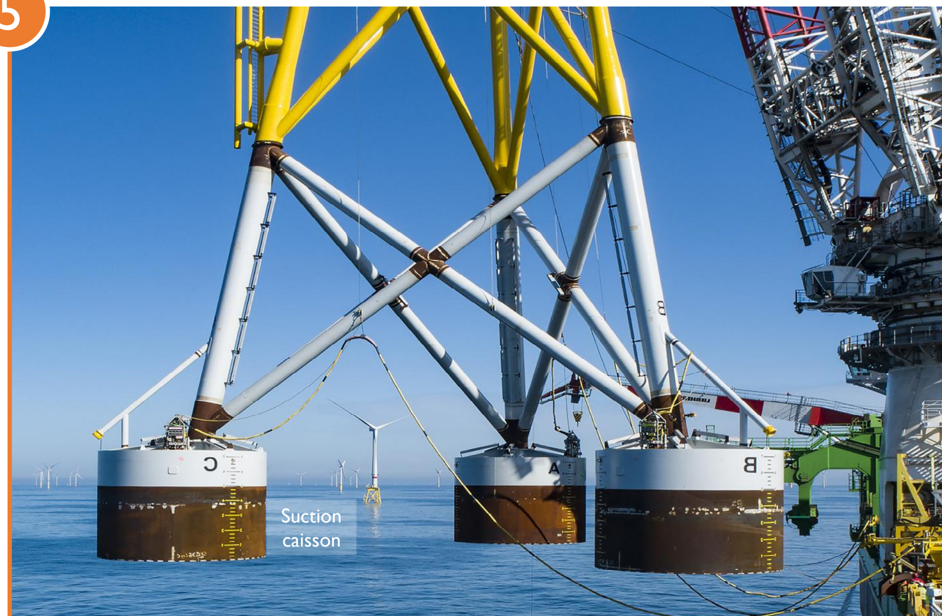
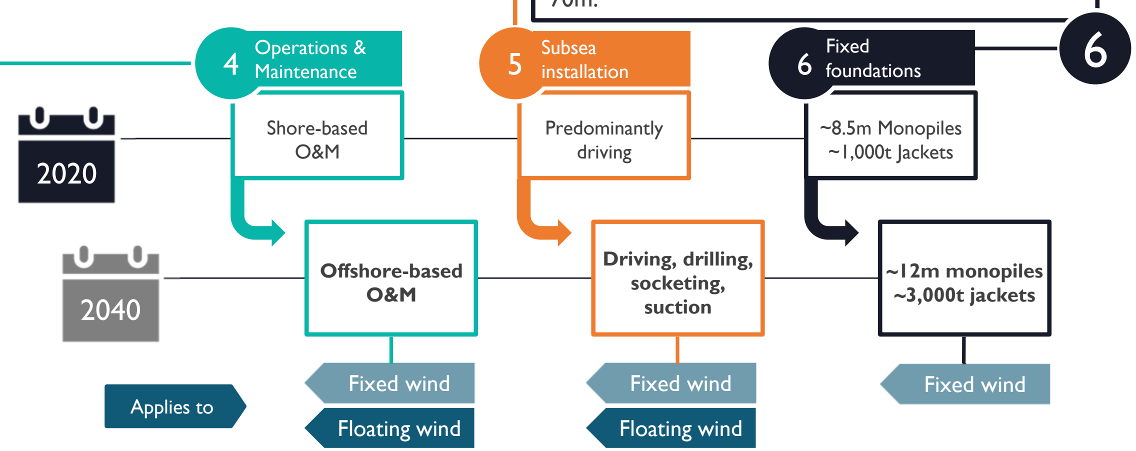



Image: DEME Group

**Fixed foundations:** from XL to XXL

As turbines have become larger and water depths have increased, fixed foundations have grown to keep up. The most common foundation type, the steel monopile, has grown in diameter, wall thickness and weight. To date, the largest monopiles deployed are ~8.5m in diameter and weigh ~1,400 tonnes. Where technically feasible, monopiles will retain an economic advantage over more complex structures, with increasing water depth and turbine size requiring greater monopile diameters. Manufacturing capacity for these enormous steel tubes is expensive, and is currently limited to around 10m. We expect further investment to enable 12m diameter monopiles that weigh 3,200 tonnes, supporting next generation wind turbines in 45m of water.

In deeper water, steel lattice jacket foundations are already proven, with turbines installed in 54m of water on 85m structures that weigh ~1,000 tonnes. Advances in design, fabrication and installation will expand the economic envelope of jacket structures to 3,000 tonnes, installed in water depths of up to 70m.



# 4 Technology Groups: fixed foundation offshore wind

## A maturing asset class, ready to push the envelope

To understand how the technical demands of offshore wind will vary around the coasts of England, Wales and Northern Ireland in 2040, we first drew on analysis of the techno-economics of offshore wind to identify the principal drivers of project viability. Next, we matched each driver to the technology solutions we anticipate will be available, and specified the engineering criteria for technology selection. Finally, we assembled bundles of solutions, or 'technology groups', that can each address a particular combination of site conditions.

**Drivers:** site conditions that directly influence project economics

A wide range of factors affect offshore wind project economics, but not all of them are directly relevant to the identification of key resource areas. For instance, wind speed and distance from shore have very substantial but opposite influences on project economics. Overall, the two opposing tendencies approximately cancel each other out, and the high quality of the UK wind resource means that we have applied a minimum wind speed threshold of 9.5m/s at hub height, in order to filter out a small number of low wind resource areas. Sea-state can affect the accessibility of wind turbines, and therefore exert an influence on O&M costs and turbine availability. However, this effect is relatively small compared to other drivers, and it is already largely mitigated by new access technologies which will continue to develop in future. The effect of sea-state has therefore not been considered in the identification of fixed foundation key resource areas. Two factors have an overriding influence on viability and technology selection for fixed foundation offshore wind: water depth, and seabed conditions.

### Water depth

The sea depth has a strong and direct influence on the class of fixed foundation used for an offshore wind farm. Wherever the water is shallow enough to permit their use, steel monopiles represent the best balance of cost and risk. In deep water, fabricated steel lattice 'jacket' structures are necessary to transfer the loads of the wind turbine to the seabed.

**Solutions for…** *…site criteria*

**Monopiles** for… *…10-45m water depth*

**Jacket structures** for… *…45-70m water depth (20-70m, with suction caissons)*

### Geology

Just as on land, ground conditions beneath the seas around our coast vary enormously. The optimal techniques for securing fixed offshore wind foundations therefore also vary, with implications for viability, cost, environmental impact, and innovation. Expensive drilling techniques are avoided, wherever possible, but often cannot be ruled out. We have therefore also categorised the risk of encountering either simple or more complex and challenging conditions beneath the seabed.

| Ground risk | Solutions for… …site criteria |
|---|---|
| Simple Geology | **Suction caissons** for… *…thick, generally sandy sediments* |
| | **Driven piles** for… *…thick sediment layers and/or weak bedrock* |
| Complex Geology | **Drive-drill-drive piles** for… *…thinner sediments or medium hardness bedrock* |
| | **Rock socket piles** for… *…harder bedrock* |

**TG:** Technology Group

Monopiles: 10m – 45m water depth
Jackets (suction caissons): 20m – 70m water depth
Jackets (piled): 45m – 70m water depth

10m → Water depth | 20m | 45m | 70m

## Suction

Suction caissons not suitable for monopiles.

**TG-1:** Jackets with suction caissons
For sandy sediments at least 20m thick without difficult rock conditions present, known as diamictite.

## Drive

**TG-2A:** Monopiles, driven, simple seabed
For drivable sediments at least 50m thick, in 45-70m water depths.

**TG-4A:** Jackets, driven, simple seabed
For drivable sediments at least 50m thick.

**TG-2B:** Monopiles, driven, complex seabed
For drivable sediments 5-50m thick, presenting some installation challenge.

**TG-4B:** Jackets, driven, simple seabed
For drivable sediments at least 50m thick.

## Drive-drill-drive

**TG-3A:** Monopiles, drive-drill-drive, simple
For sediments 5-50m thick, overlaying moderately hard bedrock.

**TG-5A**: Jackets, drive-drill-drive, simple
For sediments 5-50m thick, overlaying moderately hard bedrock.

**TG-3B:** Monopiles, drive-drill-drive, complex
For harder sediments 5-50m thick, overlaying harder bedrock.

**TG-5B:** Jackets, drive-drill-drive, complex
For harder sediments 5-50m thick, overlaying harder bedrock.

## Rock socket

**TG-6A**: Monopiles, rock-socket, simple
For sediments up to 5m thick only, overlaying moderately hard bedrock.

**TG-7A**: Jackets, rock-socket, simple
For sediments up to 5m thick only, overlaying moderately hard bedrock.

**TG-6B**: Monopiles, rock-socket, complex
For sediments up to 5m thick only, overlaying hard bedrock.

**TG-7B**: Jackets, rock-socket, complex
For sediments up to 5m thick only, overlaying hard bedrock.

5

# Technology Groups: floating offshore wind

## Changing the game with versatile solutions

Floating offshore wind turbines offer the potential to venture into deeper water than is permitted by fixed foundations.

While the emerging design concepts have some differences in applicability, beyond a minimum depth threshold, spatial drivers affect them all similarly, allowing us to consider them as a single technology.

We expect fixed foundation and floating offshore wind to use the same turbine technology.

**Drivers:** site conditions that directly influence project economics

Floating wind turbines must also achieve a secure attachment to the seabed. Although the effect on overall cost is less pronounced than for fixed foundations, seabed conditions inform anchoring decisions as well as the balance of cost and risk.

As with fixed foundation offshore wind, the effects of wind speed and distance to shore approximately negate each other, and we have applied the same minimum wind speed threshold of 9.5m/s at hub height. However, unlike fixed foundations, the sea-state is a significant driver of choices in the design of both structures and mooring systems.

### Sea-state

Floating structures and mooring systems must withstand whatever the sea throws at them. Designers therefore consider the most extreme conditions that might occur in a location, rather than the average wave height. Over a certain threshold, the cost and complexity of coping with storm conditions becomes more challenging. We have differentiated technology groups based on the largest wave that can be expected within 50 years, or Hs50.

**Solutions** for…
*…site criteria*

**Substructures** to withstand…
*…$Hs_{50}$ up to 14m*

**Substructures** to withstand…
*…$Hs_{50}$ more than 14m*

### Geology

Floating wind turbines must be securely moored to the seabed, to keep them in place. The appropriate means of attachment depends primarily on the type and depth of sediment on the sea floor. Where there is adequate sediment depth a single seabed anchor point per mooring line may suffice, but where sedimentary conditions are more complex, multiple anchors may be needed. Sites with very shallow sediment may require more expensive drilling and piling solutions.

**Solutions** for…
*…site criteria*

**Conventional anchoring** for…
*…sediment layers up to 20m thick*

**Complex anchoring** for…
*…sediment layers 5-20m thick*

**Rock-socket piles** for…
*…harder bedrock and sediment less than 5m thick*

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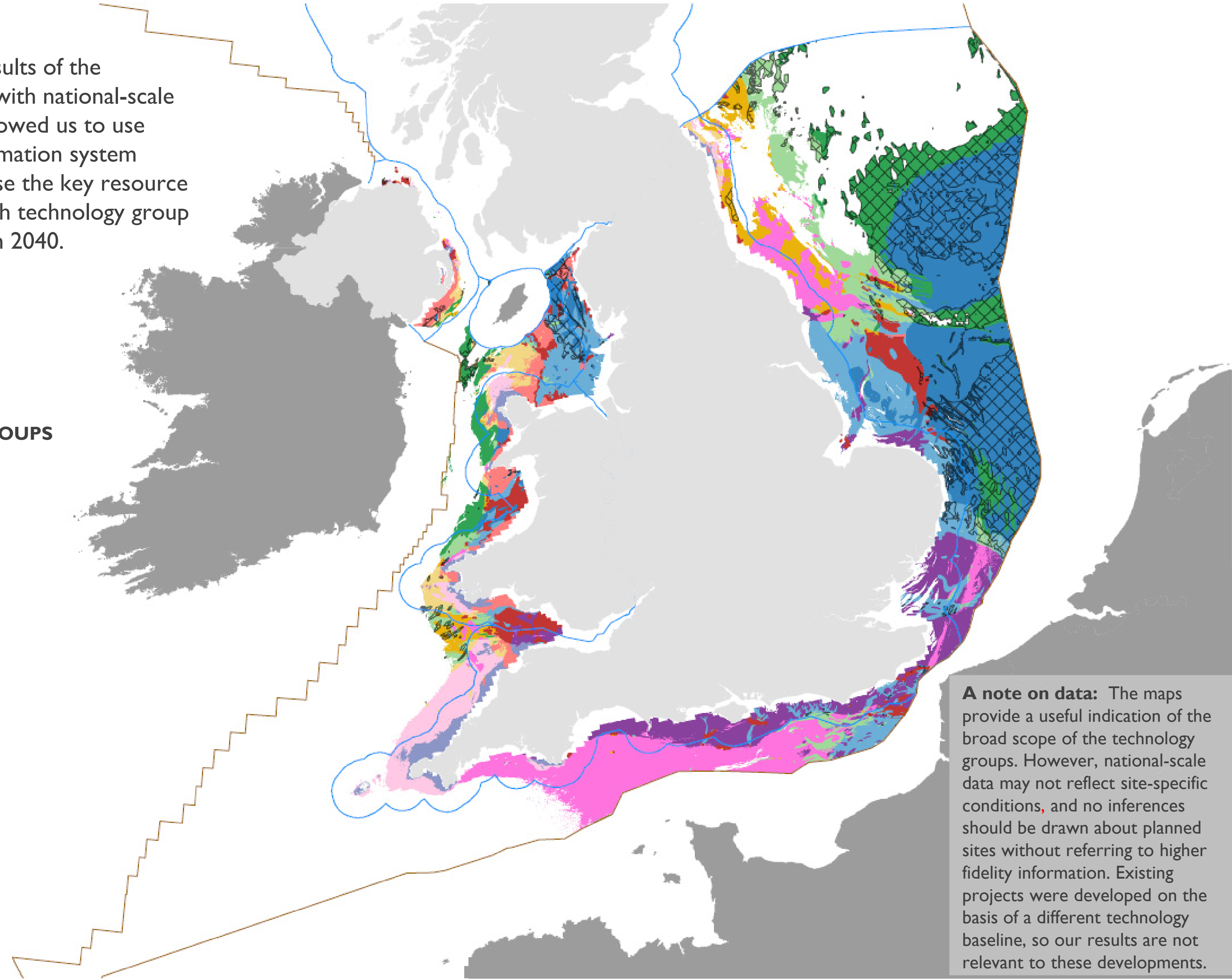
| | minimum depth for semi-submersibles — 50m — Depth range — 250m — maximum practical requirement in UK waters | minimum depth for semi-submersibles — 50m — Depth range — 250m — maximum practical requirement in UK waters |
|---|---|---|
| **TG:** Technology Group | **Substructures** to withstand… <14m Hs50 | **Substructures** to withstand… >14m Hs50 |
| Conventional anchoring | **TG-1:** Conventional anchoring, moderate sea-state<br>For sediments greater than 20m thick | **TG-2:** Conventional anchoring, onerous sea-state<br>For sediments greater than 20m thick |
| Complex anchoring | **TG-3:** Complex anchoring, moderate sea-state<br>For sediments 5-20m thick | **TG-4:** Complex anchoring, onerous sea-state<br>For sediments 5-20m thick |
| Rock-socket piles | **TG-5:** Rock-socket piles, moderate sea-state<br>For sediments less than 5m thick | **TG-6:** Rock-socket piles, onerous sea-state<br>For sediments less than 5m thick |

# 6 Key resource areas for offshore wind

## Embracing the UK's diverse seabed characteristics and recognising regional differences

Combining the results of the technology study with national-scale spatial datasets allowed us to use geographical information system mapping to visualise the key resource areas in which each technology group could be applied in 2040.



**FIXED OFFSHORE WIND TECHNOLOGY GROUPS**

- TG-1 Jackets with suction caissons
- TG-2A Monopiles, driven, simple seabed
- TG-2B Monopiles, driven, complex seabed
- TG-3A Monopiles, drive-drill-drive, simple
- TG-3B Monopiles, drive-drill-drive, complex
- TG-4A Jackets, driven, simple seabed
- TG-4B Jackets, driven, simple seabed
- TG-5A Jackets, drive-drill-drive, simple
- TG-5B Jackets, drive-drill-drive, complex
- TG-6A Monopiles, rock-socket, simple
- TG-6B Monopiles, rock-socket, complex
- TG-7A Jackets, rock-socket, simple
- TG-7B Jackets, rock-socket, complex

**A note on data:** The maps provide a useful indication of the broad scope of the technology groups. However, national-scale data may not reflect site-specific conditions, and no inferences should be drawn about planned sites without referring to higher fidelity information. Existing projects were developed on the basis of a different technology baseline, so our results are not relevant to these developments.

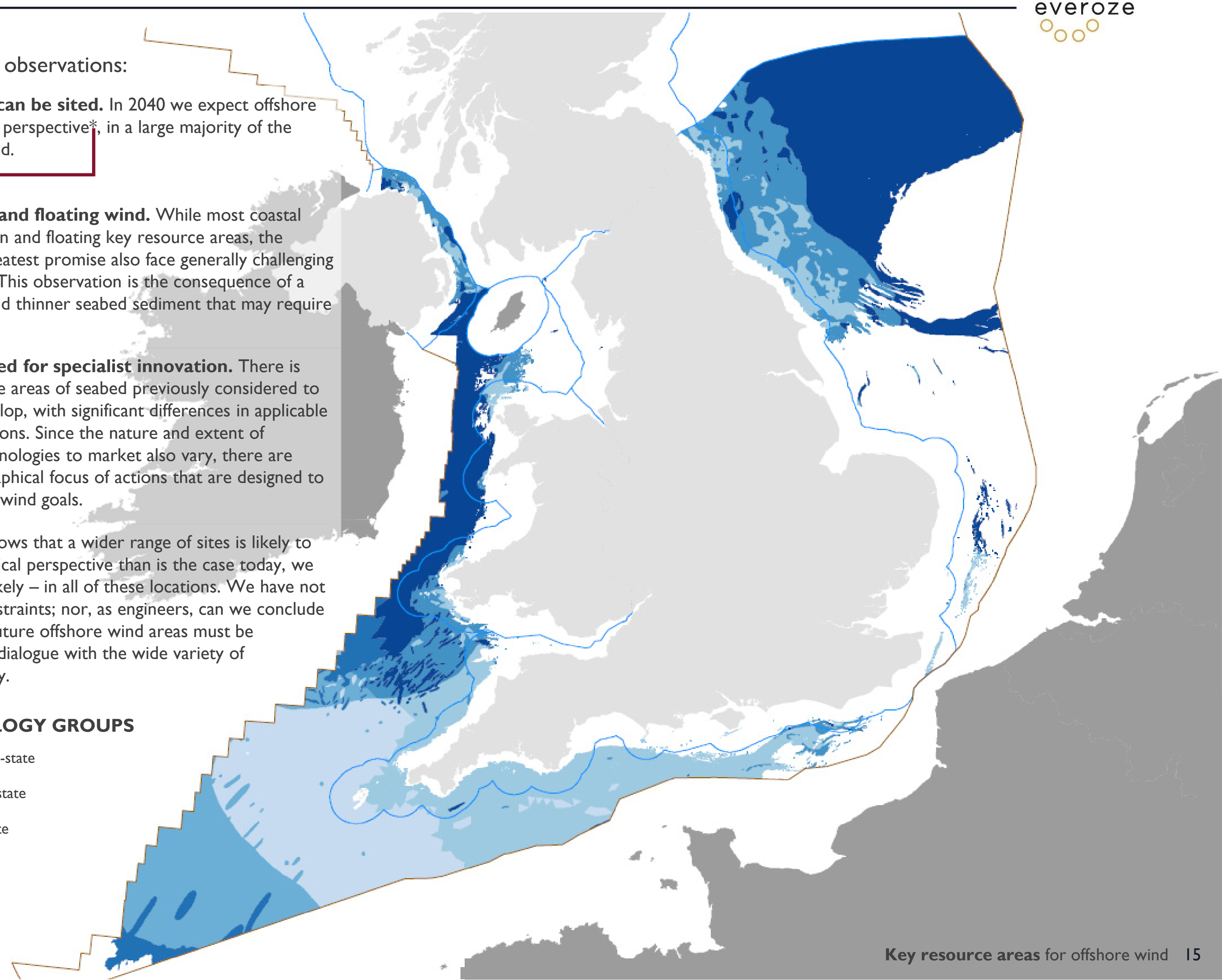
….Within this overall picture, we offer three observations:

1. **Few technical limits to where offshore wind can be sited.** In 2040 we expect offshore wind to be technically feasible, from an engineering perspective*, in a large majority of the seabed around England, Wales and Northern Ireland.

2. **Limited spatial conflict between fixed and floating wind.** While most coastal regions are adjacent to both fixed foundation and floating key resource areas, the regions in which floating wind shows the greatest promise also face generally challenging conditions for fixed foundation installation. This observation is the consequence of a regional correlation between deep-water and thinner seabed sediment that may require drilling.

3. **Regional variation points to a need for specialist innovation.** There is wide variation in site conditions in the areas of seabed previously considered to be too technically challenging to develop, with significant differences in applicable technologies within and between regions. Since the nature and extent of innovation required to bring the technologies to market also vary, there are implications for the timing and geographical focus of actions that are designed to support the UK's long-term offshore wind goals.

* **Super-important footnote:** While this study shows that a wider range of sites is likely to be available for potential deployment from a technical perspective than is the case today, we are not suggesting offshore wind is possible – or likely – in all of these locations. We have not considered the wide range of non-engineering constraints; nor, as engineers, can we conclude that that would be desirable. The location of any future offshore wind areas must be determined through a process of engagement and dialogue with the wide variety of stakeholders that have an interest in marine activity.



**FLOATING OFFSHORE WIND TECHNOLOGY GROUPS**

- TG-1 Conventional anchoring, moderate sea-state
- TG-2 Conventional anchoring, onerous sea-state
- TG-3 Complex anchoring, moderate sea-state
- TG-4 Complex anchoring, onerous sea-state
- TG-5 Rock-socket piles, moderate sea-state
- TG-6 Rock-socket piles, onerous sea-state

7

# The first step towards a broad horizon

## Defining offshore wind key resource areas is just the start of the journey

This study projects an assessment of the technology landscape in 2040 onto physical characteristics of the marine environment, in order to illustrate the key resource areas in which various technology groups may be applicable.

The main finding is that foreseeable advances in engineering mean that almost all of the seabed around England, Wales and Northern Ireland is likely to be within reach of offshore wind technology. That this encouraging outlook is possible, based on the commercialisation of technologies that we can see today, rather than on revolutionary technological leaps, is testament to how far offshore wind technology has already come.

**Looking to the future**

While increased technical viability is an undeniably exciting prospect, especially given the UK's commitment to achieving net-zero greenhouse gas emissions by 2050, it is important to acknowledge that engineering potential and socio-economic feasibility are not the same thing. This report is just the first step towards a shared understanding of which areas could be made available for future development.

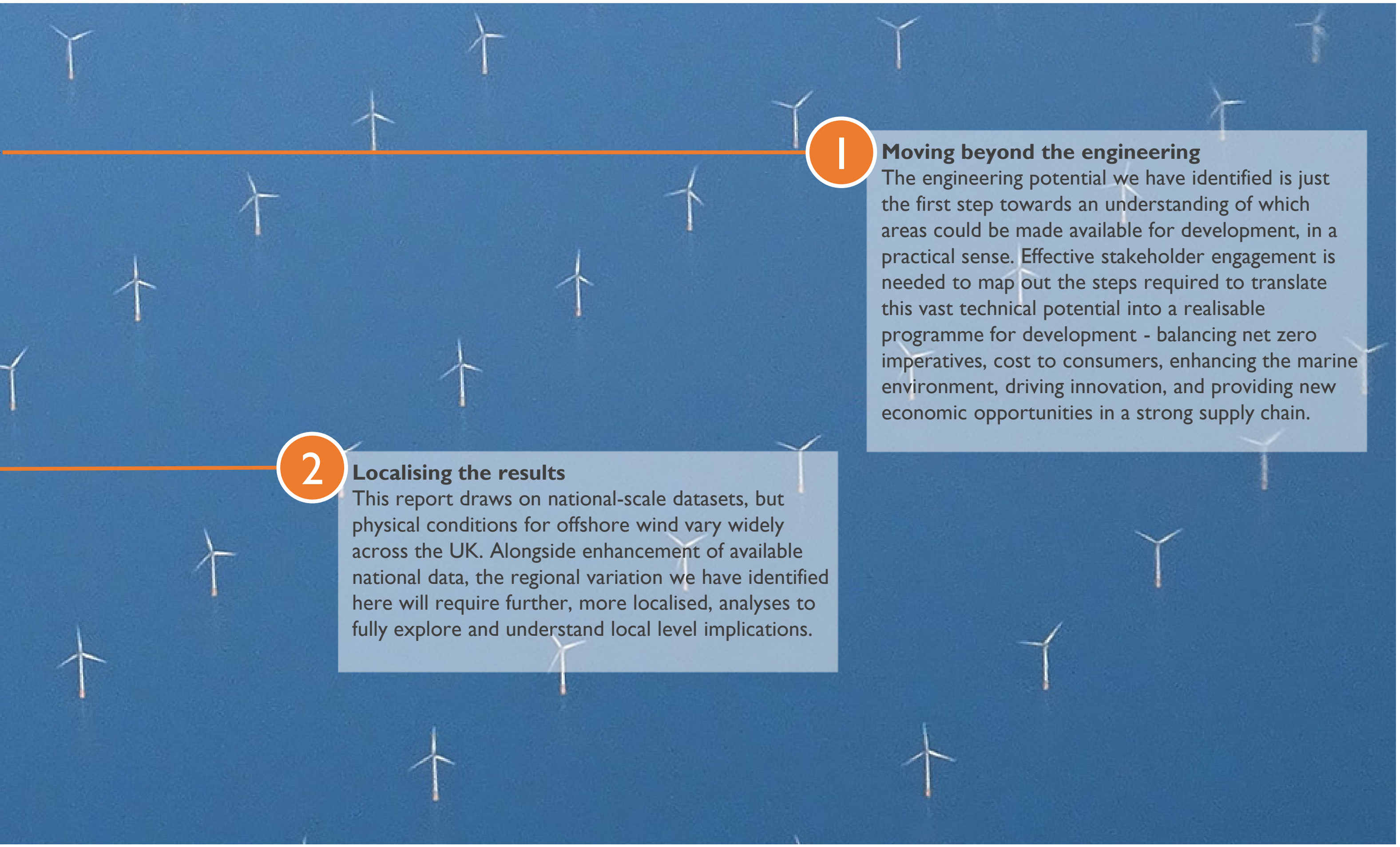
Any future development of offshore wind in UK waters must carefully balance the decarbonisation potential and industrial opportunity with protection of our marine environment, the cost to consumers, and the rights and interests of all those affected by decisions about how our seas are managed. The finding that almost all areas are likely to be technically accessible to offshore wind within two decades should provide the flexibility needed to make the most of our marine resources in a way that balances these priorities.

Achieving such a balance will require engagement with citizens, sea users, nature conservation groups, industry, national and regional governments, regulators, and many others. An open and meaningful conversation is needed about the priorities and trade-offs involved in an equitable and sustainable future for UK offshore wind.

**Starting and sustaining that conversation is the chief recommendation from our report.**

**Directions for future analysis**

Following on from this study of key resource areas, we see **two** broad directions for future work.



**1**

**Moving beyond the engineering**

The engineering potential we have identified is just the first step towards an understanding of which areas could be made available for development, in a practical sense. Effective stakeholder engagement is needed to map out the steps required to translate this vast technical potential into a realisable programme for development - balancing net zero imperatives, cost to consumers, enhancing the marine environment, driving innovation, and providing new economic opportunities in a strong supply chain.

**2**

**Localising the results**

This report draws on national-scale datasets, but physical conditions for offshore wind vary widely across the UK. Alongside enhancement of available national data, the regional variation we have identified here will require further, more localised, analyses to fully explore and understand local level implications.

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**Further reading**

The full technical report of the study and spatial data outputs are available for download on The Crown Estate's Marine Data Exchange.

www.marinedataexchange.co.uk


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THE CROWN ESTATE

**About The Crown Estate**

The Crown Estate manages a unique portfolio, which includes the seabed, natural marine resources and much of the foreshore around England, Wales and Northern Ireland. In this capacity we are responsible for awarding seabed rights for offshore renewable energy projects as well as marine minerals, cables and pipelines. We play a unique role in developing and helping sustain the UK energy supply and infrastructure, working in collaboration with a wide range of organisations. Established by an Act of Parliament, we return all our profit to the Treasury, for the benefit of the nation.

Further information can be found on our website:

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**About Everoze**

Everoze is an employee-owned consultancy, specialising in renewables, storage and wider energy flexibility. Our unique strength is bridging the gap between the technical and the commercial. We exist to help our clients accelerate the transition to a decarbonised energy system. Further information can be found on our website:

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