Offshore Wind Feasibility Study

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1. Executive Summary

1.1 Background

This report provides an update to the Jersey Offshore Wind Pre-Feasibility Study, carried out in 2018, to some key sections that during the course of the last four years, have evolved, as the offshore wind industry has developed with significant pace in Europe, and in the UK in particular. The focus of the updates has been on the following sections:

- Introduction
- Technology & Infrastructure
- Environmental & Social Impacts
- Economics
- Jersey Waters
- Pre-feasibility for Jersey
- Conclusion

Additionally, further comment has been added on the potential for a direct grid connection to France from any Offshore wind farm in Jersey Waters, and for the potential use of the electricity from the windfarm to support a Hydrogen Production Facility on the Island and further comments on the potential end users.

The section covering St Brieuc Offshore Wind Project, has not been updated, as this is now in construction and was previously in the report to demonstrate the potential of Offshore Wind in a location geographically close to the Jersey as part of the demonstration of suitability and overall feasibility.

During the course of the past four years, the single most significant change has been the growth of the turbines themselves, with significantly larger generating units available and deployed and OEM's in the process of developing larger machines. Over the course of the next decade, we expect units to be regularly deployed in the region of 12-16 MWs in the right locations but operating examples are still in development. 8 MW machines are now more common place.

Additionally, the use of floating structures has evolved, opening up areas for development, such as the Celtic Sea and West of Shetland and the back of successful pilot projects, such as HyWind, are providing greater opportunities for development.

Cabling is also an area of significant development, the HVDC system become more readily available and commercially viable with the deployment of floating offshore wind further off the coast. Additional developments have arisen in the advisory market, as modelling systems for undertaking dynamic cable rating exercises, is helping developers to value engineer export circuits and reduce the overall export circuits, thus further reducing capex.

1.2 Economics

ITPEnergised has calculated a Levelised Cost Of Electricity (LCOE) for offshore wind for 2022 of £66.5/MWh. This aligns well with the published data from Catapult. BEIS has also published its calculations for LCOE for offshore wind using 2018 pricing for all inputs for the forecast year 2025 of £57/MWh. Using annual inflation of 2% this gives a BEIS 2022 LCOE of £61.7/MWh which illustrates the cost reduction learning effects over time. Present macro economics and inflation pressures are currently impacting short to medium term pricing and a more detailed financial modelling exercise is recommended, factoring in sensitivities of future price fluctuations.

The conclusion of this updated report, is that Jersey continues to have significant offshore wind potential within its waters and that the development and exploitation of the resource to generate low cost reliable power for the island is both technically feasible but additionally, the economic landscape has changed dramatically in this short period of time.

ITPEnergised conclusion is based on the assessment of a wide range of factors outlined in this report, from technology developments, environmental and social impact, economic changes which has reduced the LCOE, as expected.

1.3 Offshore windfarm options

The report outlines the process of site selection and the approach being taken in many countries of assigning zones for the potential development of offshore wind based on a range of criteria. These include; wind resource, proximity to grid, areas large enough to accommodate a wind farm with appropriate spacing between turbines. As turbine size is growing, it is balance between capital cost, installed capacity, number of turbines and the suitability of those turbines for the wind resource (turbine classification). Additional factors, that must be considered would be planning criteria including physical conditions, such as water depth, wave and tidal currents, geophysical conditions, as well as biological conditions such as the presence of bird and marine mammals, migration routes, fisheries spawning areas. Additionally, other factors that come in to focus during site selection will be existing infrastructure, such as cables, bridges, tunnels, proximity to ports and shipping lanes, as well as airports. Section 7 of the report provides further detail on these parameters and how they have been evaluated to identify suitable locations and zones for potential development. All of these factors are considered to identify zones that are likely to have the potential for development. A common metric is the energy density of a zone, presented as MW/km^2 , based on the available wind resource in a given developable area. A common acceptable level is circa 5MW/km^2. Given the constraints around Jersey, ITPEnergised has estimated that the practical offshore wind resource of around 3.3GW based on an area of 668km^2.

ITPEnergised has taken this approach and evaluated two offshore wind project models for Jersey

- A large scale, commercial wind farm connected to the French transmission grid, either directly or via Jersey
- A low capacity wind farm, connected directly to Jersey to supply electricity locally

For the large scale commercial offshore windfarm, 2 zones have been identified; Offshore A which would accommodate a total capacity of circa 496MW based on 62x8MW turbines; Offshore B, which lies slightly further north, would accommodate circa 400MW based on 50x8MW turbines. Both developments could conceivably connect directly to France, which would be the most practicable solution, but equally could have export cables to Jersey and export to France via the Jersey-France interconnections.

Additionally, ITPEnergised has assessed 2 options for smaller nearshore OSW sites. Details on the reasons for scale and site selection are outlined in section 7. Nearshore A has evaluated a 170MW (21x8MW) development and Nearshore B is smaller still at only 32MW (4x8MW) and would be considered perhaps suitable for community ownership.

All the sites have been assessed using the same assumptions on development, construction time, project life and energy tariff prices linked to inflation and a discounted cashflow.

1.4 Socio-economic Benefits

The report also provides some background to the positive benefits that are likely to be realised from the development of offshore wind in Jersey. Whilst the report does not set out to provide a detailed assessment of the socio-economic benefits, it highlights the areas that have the potential to provide an upside to the island's economy and its community. This includes development and construction activities, where it is estimated that development pre-construction would likely see a spend of approximately +£20m, and +£60m during construction on projects such as Offshore A. Jersey will receive a share of this through direct award contracts and the State of Jersey may well have further control on this through the procurement rules it may set. The smaller Nearshore projects would have a lower overall value.

Other benefits would likely accrue in areas such as Operation and Maintenance (O&M) where a service base may be developed, Aquaculture opportunities to increase the value of local fisheries and community ownership, similar to Middelgrunden near Copenhagen.

The States of Jersey has the opportunity to generate income from the lease costs of the seabed. As can be seen in the report, the recent UK leasing rounds, Rounds 1, 2, 3 and 4 and ScotWind have led to a wide range of prices from £6/MWh for ScotWind and £33/MWh in Round 4, paid by the BP led consortium. For Jersey, based on the Offshore A concept, this would lead to income of either £4.7m per annum or £25.8m per annum respectively.

1.5 Hydrogen and Offshore Wind

Hydrogen is becoming of increasing interest to offshore wind developers as a potential route to market for power generated offshore. Connection to a proposed offshore wind array would mean that hydrogen could potentially be produced both opportunistically and on a planned basis This is for two fundamental reasons:

1. **Curtailment** - During periods of high offshore wind electrical energy generation and low demand otherwise curtailed generation could be used to supply electrolysers to generate hydrogen and oxygen, with the hydrogen then stored for subsequent use.
2. **Fuel Supply** -if a market for Green Hydrogen emerges, as predicted, the windfarms electrical output could be planned to generate significant volumes of hydrogen to be utilised in modified grid distribution networks via a dedicated connection or to be utilised for other demands, such as transport and logistics fleets.

In order to assess the suitability of Hydrogen use in Jersey, it is necessary to at look both the Upstream scenarios; the case for its production and the resources it needs and its Downstream use; how it would be used and the infrastructure necessary to facilitate this. Section 8 of the report has provided some points for discussion on each of these areas.

Production of hydrogen in Jersey at scale is likely to be constrained by the availability of suitable development land and the lack of immediate off-takers. The viability of hydrogen production will further depend on the location of the connection relative to the offshore wind array cable landfall, co-location with a majority of end users or transporters and a reliable source of (ideally fresh) water.

Land take and water supply may ultimately constrain Jersey's potential as a hydrogen economy and particularly as a major fuelling for aircraft and marine vessels, but if some hectares can be identified in a suitable location for development, the sweet spot for Jersey could be a relatively small production capacity serving a domestic market for plant, machinery, heavy vehicles and portable power supplies, with possibly enough capacity to support an emerging airport or sea port demand in its early years.

2. Introduction

2.1 Background

In 2018, ITPEnergised produced a report for the Government of Jersey's, Department of the Environment, looking at the feasibility of deploying Offshore Wind in the waters around the island of Jersey. Jersey Electricity, in conjunction with the Government of Jersey, has requested an update to this report to evaluate how the landscape has changed over the previous four years and what the future of Offshore Wind looks like in the UK and mainland Europe, following the wider developments in the energy markets over this period.

A number of the changes relate to the technology, which is being deployed, including wind turbines and in particular the capacity of turbines available and in concept, fixed foundations and advancements of floating technology, and further developments in cable technology leading to improved optimisation in connections. Additionally, with a growing demand for energy storage and the potential to grow a hydrogen economy, the generation and storage of hydrogen has become a further consideration in many of the more recent development feasibility studies and early stage project design.

Hydrogen production, storage and potential use has also started to be included as part of the feasibility consideration for a number of offshore wind developments to continue to embed offshore wind energy generation not only as a low cost power supply but also to support the continued drive to decarbonise heat and transport. As a consequence of these changes and further developments, developments in the supply chain and technology has continued to impact the Capex required to deliver offshore wind projects further improving the Levelised Cost of Energy.

As part of the update of this report, we agreed with Jersey Electric, that the following aspects of the 2018 report would be updated:

Table 2-1 – Scope of work

Section	Update Required	How much?
Introduction	Yes	◕
Technology & Infrastructure	Yes	◕
Environmental & Social Impacts	Partial	◐
Economics	Yes	●
St Brieuc Offshore Wind Project	N/A	○
Jersey Waters	Partial	◐
Pre-feasibility for Jersey	Partial	◐
Conclusion	Yes	●
Appendix A	Yes	●

We have indicated the degree to which we believe each section requires updating. The icon is a representation of the degree of update that is required. In some cases, such as Jersey waters, this will only require a refresh where regulatory changes have been made and changes that have occurred in relation to developments that have taken place since the original report was written. Sections on geology and sediments, are largely unchanged.

Additionally, as mentioned above, Hydrogen production has become of increasing interest, and we have therefore included an additional section on the production and potential use of hydrogen in Jersey.

Connecting any offshore wind farm to the country's grid system is vital, but in some circumstances, the connection may be provided to more than one recipient. We have considered the possibility to do this as a scenario in the case of an offshore wind farm in Jersey waters, connecting directly to France.

2.1.1 Setting the scene

Offshore wind is a global and rapidly maturing sector; according to the Global Wind Energy Councils (GWEC) Global Offshore Wind Report, 2021, in excess of 35 GW is operational (mostly in Northern Europe) and this will continue to grow with 270 GW expected to be installed by 2030.

In the UK, there are now there are now 230 Offshore Wind Projects, at various stages of the development lifecycle with 43 operational offshore wind projects[1] The UK Offshore Wind Pipeline now stands at over 86 GW which is a 60% increase in the past 12 months (Offshorewind.biz, March 2022). According to the GWEC Global Wind Report, 2021, the UK was the 4th largest installer of new generation (483MW) globally, in 2020 and continues to be the European leader. With further leasing rounds, AR4, Scotwind, Celtic Sea and INTOG the UK's adoption of offshore wind as a major contributor the UKs NetZero ambitions, is firmly set to continue. Round 4 awarded 8GW of licence options, ScotWind in 2022, issued 25GW of licence options with a mix of fixed and floating wind options. The Crown Estate is currently developing the tender process for the Celtic Sea which will see a further 4GW of licence options issued, with the potential for a further 20GW by 2045. This is likely to be all floating solutions, due to the water depths.

The future of offshore wind in Europe and globally is incredibly positive, as the sector moves from a less conventional form of renewable energy generation to a mainstream technology that is an essential contributor to the electricity mix. Furthermore, the recent cost reductions being seen, as were forecast for projects to be delivered in the 2020s and 30s means that offshore wind is achieving and beating the price of other forms of generation including fossil fuel, thermal power plant.

2.1.2 Purpose and structure of this Report

Jersey currently imports at approximately 95% of its electricity from France via subsea interconnectors. It is therefore dependent on France to supply low cost, low carbon electricity.

Due to land and visual constraints, Jersey has limited potential for onshore renewable energy generation at a utility scale. Jersey's territorial waters, however, have fewer constraints and offer both windy offshore conditions and relatively shallow waters – ideal for offshore wind generation. The island therefore has the potential for offshore wind development. This updated report provides further commentary on that potential.

Both the Jersey Carbon Neutral Roadmap2 and Bridging Island Plan3 make reference to offshore renewables and state that offshore renewable energy resources should be considered for Jersey:

- Carbon neutral Roadmap – Strategic Policy 2 establishes an overall energy policy position, including that the Government of Jersey will: *examine the options for utility scale renewable energy generation, to ensure a diverse, safe and resilient supply of energy to meet the Island's future needs*.
- Bridging Island Plan – Policy ME5 provides broad policy support for the development of utility-scale offshore renewable energy proposals, where proposals provide a viable commercial case for a project

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[1] GWEC, Global Offshore Wind Report, 2021

[2] The Carbon Neutral Roadmap
R Carbon Neutral Roadmap 20220525 JB.pdf (gov.je)

[3] The Bridging Island Plan P Bridging Island Plan.pdf (gov.je)

of an environmentally and socially acceptable scale. It provides a framework for considering such proposals, as set out below.

The aim of this report and associated analysis is to provide the Jersey Electricity and the Government of Jersey, with sufficient information to assess the opportunity of developing offshore wind in the island's waters, potentially within a future French development round, and subsequently to enable more considered discussions with the French offshore wind sector on this opportunity. This work also considers the possibility of developing offshore wind in Jersey's waters to supply electricity directly to the island and to France directly.

This report provides the reader with;

- a general introduction to offshore wind technology, environmental considerations and project economics, including summarising the current characteristics and trends of the offshore wind sector's technology and costs;
- an overview of the general characteristics of sites within Jersey's waters;
- a high-level pre-feasibility analysis that considers different strategic options for developing offshore wind in Jersey, followed by an assessment of the more promising project cases.

3. Technology and Infrastructure

3.1 Introduction

An offshore wind project can be defined as all of the offshore and onshore infrastructure components, up to the grid connection point, required for the generation of electricity, and its subsequent transmission ashore, by wind turbines located in the ocean.

There are a number of key components that comprise an offshore wind farm (OWF) project; a typical project is shown in Figure 3-1. The offshore wind turbines are perhaps the most distinctive and obvious component, but there are many supporting infrastructure systems that are necessary: the turbines are often mounted on transition pieces which connect them to the support structure foundations below. The turbines are connected together and to an offshore substation (OSS) with inter-array cables. The OSS is electrically connected to the shore with one or more export cables that often is connected to an onshore cable in a transition pit close to shore. The onshore cable runs from the transition pit to an onshore substation where the project connects to the local transmission grid and the generated electricity is supplied to the grid.

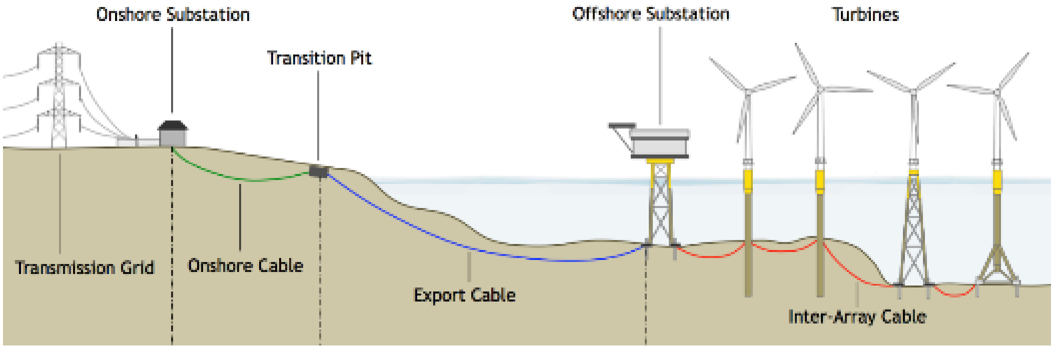


Figure 3-1, The components of a typical offshore wind farm project.

The main components of the offshore infrastructure within an OWF project are the turbines and OSS. Some of the key definitions used when describing turbines and OSS and their associated support structures are provided in Figure 3-2. This shows the key definitions for a typical OWF project.

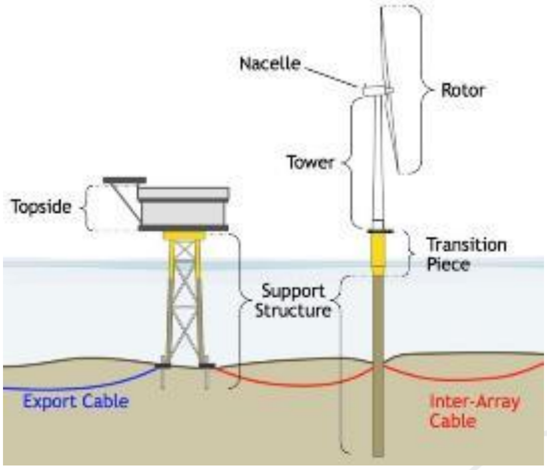


Figure 3-2, Key terminology for offshore wind turbines and substations.

An offshore wind farm is a complex infrastructure project that is delivered through a series of activities including; site selection, feasibility, consenting, design, construction and operations and maintenance (O&M).

Some tasks commence sequentially following major project milestones but the majority of work is undertaken in parallel with other project tasks. Figure 3-3 shows a typical timeline within the development of a European offshore wind project and shows the approximate lengths of each task and when they commence. This timeline will be followed by between 20 to 25 years of wind farm operations and maintenance and subsequently decommissioning or re-powering of the site.

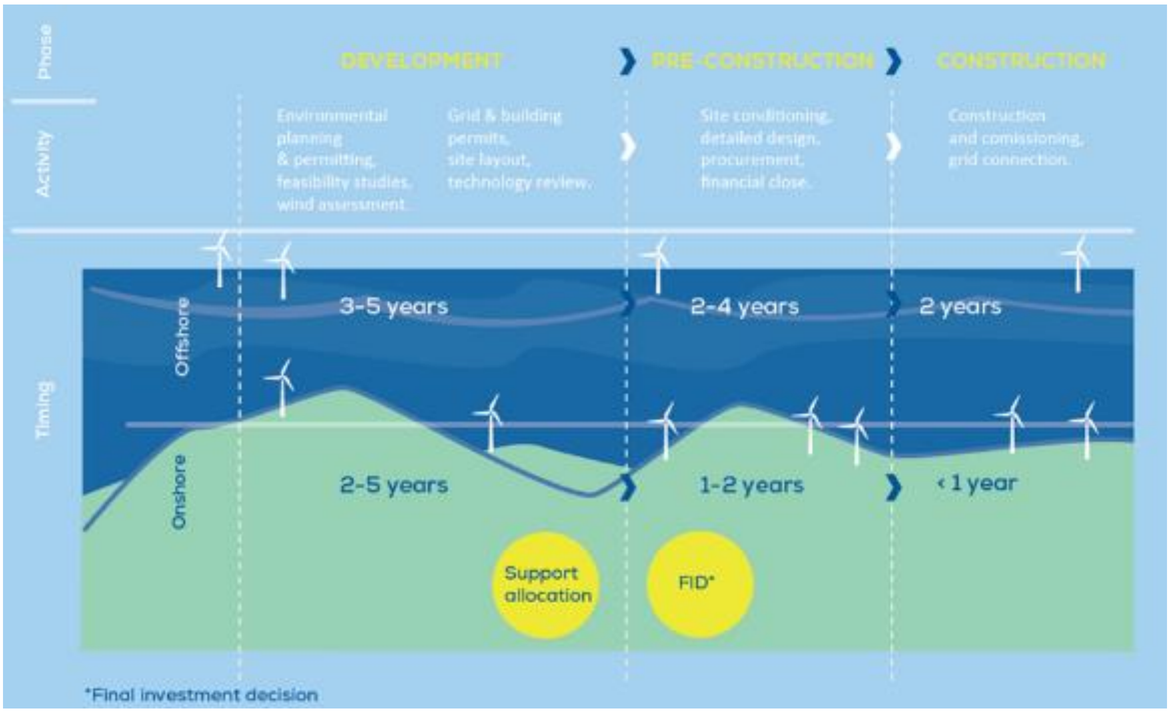


Figure 3-3, An example timeline for the key phases of a typical, European offshore wind farm project

3.2 Project Developers and Owners

Offshore wind farms are highly capital intensive and complex infrastructure projects; their development and operation therefore only suits certain types of firms. The leading project developers tend to be large European utilities and include;

Table 3-1 OSW Developers and Owners

➢ Orsted (formerly DONG Energy)	➢ Vattenfall
➢ EnBW	➢ EdF
➢ E.ON	➢ SSE
➢ Innogy	➢ Iberdrola

Additionally, we have seen a number of new entrants into the offshore wind market, including a number of the oil and gas majors; Shell, Total and BP have significant development and licence options, in Round 4, ScotWind and the Celtic Sea's initial pilot projects. It is also attracting developers, who have traditionally focused on Onshore Renewables in the UK and Internationally. German based developers, BayWa R.E. which has a significant UK footprint onshore, has been successful in the ScotWind auction round, together with DEME Group, who have traditionally been involved in offshore contracting services, are now a major partner in Thistle Wind Partners, together with Qair and Aspiravi. What is clear from the current UK leasing activities is the diversity of developers is increasing due to the growing attractiveness of the offshore wind market and need for bringing in new expertise from other sectors as more challenging locations start to become viable with costs reducing and technology and knowhow advancing.

Whilst many offshore wind projects are bid for, developed and constructed by these large entities, their ownership often alters once operational and the risks associated with construction have passed. As offshore wind projects have become comparatively low risk assets offering long term, stable returns, they are well suited to a far broader range of investors and owners. Project owners are now a diverse range of organisations from electricity cooperatives to pension funds. Chart 3-1 shows the current development of Europe's offshore wind fleet and the variety of developers involved and Chart 3-2 shows the operational ownership of the current fleet.

Chart 3-1 Development of Offshore Wind – Europe – December 2022 [source: Renewable UK, Energy Pulse]

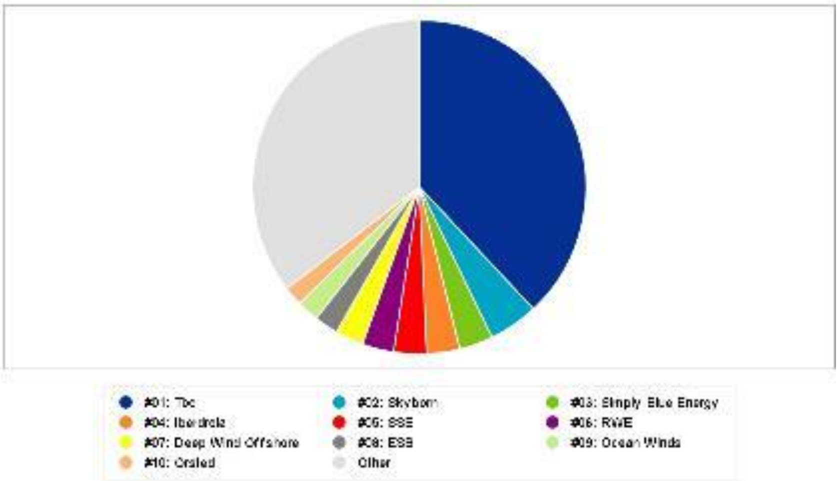
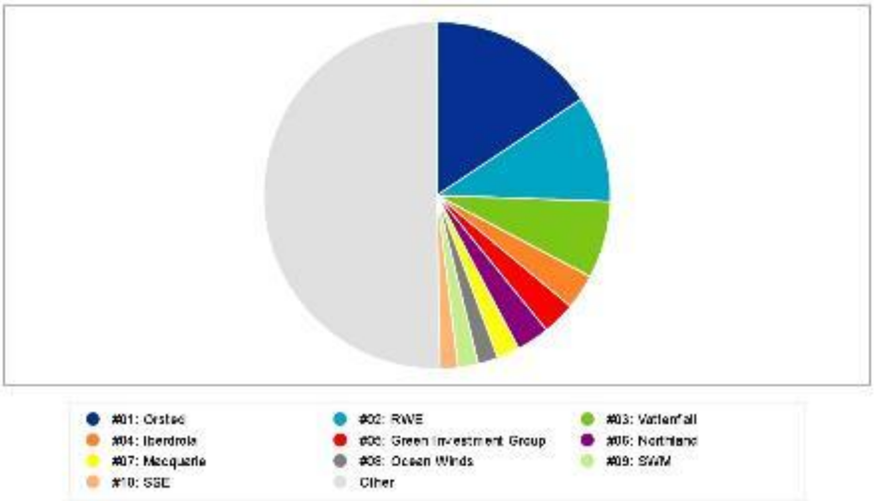


Chart 3-2 Operational of Offshore Wind – Europe – December 2022 [source: Renewable UK, Energy Pulse]



3.3 Turbines

Turbines are the key component of any offshore wind energy project and represent the largest single cost component of a wind farm. Since the first offshore wind turbines were installed in the early 1990s the technology has significantly advanced; the capacity of offshore wind turbines has increased which means that more output can be generated from a single unit; thus, resulting in higher returns and economic viability. Figure 3-4 shows how MHI Vestas' commerical turbine offerings have evolved from small, simple turbines that were modified onshore wind turbines, to their 8 MW turbines that began installation in 2016. Since then, Vestas have developed and released two new turbines; the V164-9.5 MW (2017), the V174-9.5 MW (2021), and the V164-10.0 MW (2021). Additionally, MHI Vestas are developing a new turbine, the V263-15 MW, which much like it's predecessors has minimal design changes but the greater size gives better economies of scale, if it is installed at a sufficiently energetic site. Kincardine floating offshore windfarm in Scotland uses five V164-9.5 MW turbines and has been operating successfully since October 2021. Seagreen offshore windfarm uses 114 V162-10.0 MW turbines and aims to be fully commissioned by May 2023.

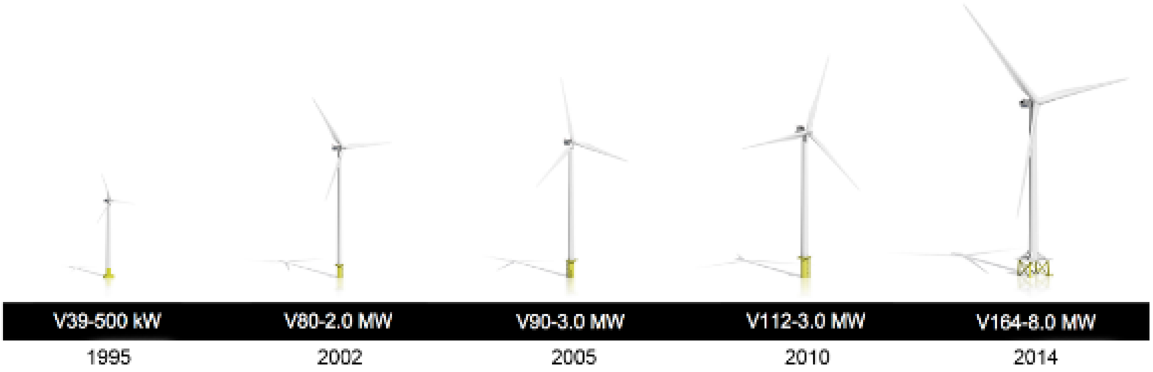
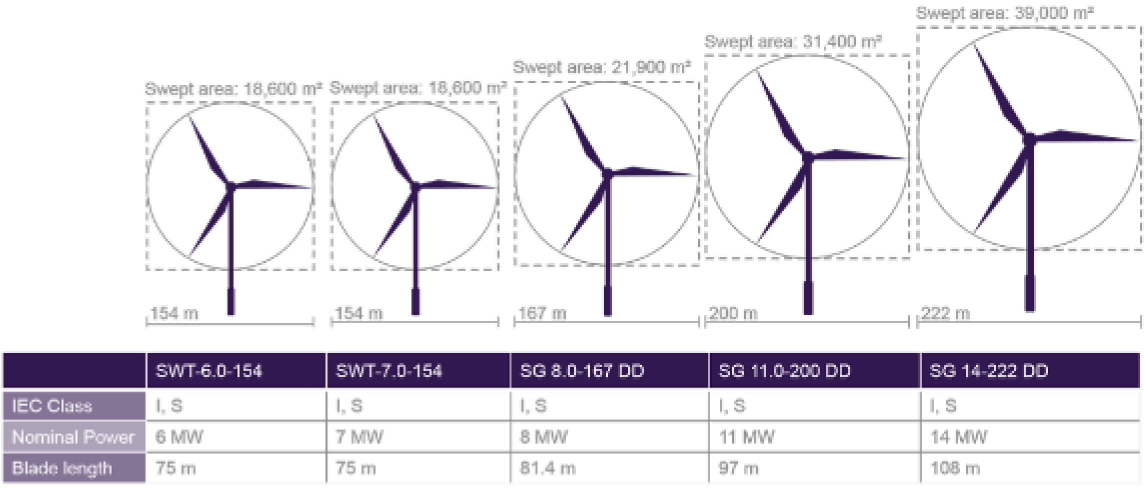


Figure 3-4, The evolution of Vestas' offshore wind turbines over the past few decades. [Source: Vestas]

Siemens-Gamesa newest turbine currently installed and commissioned is the SG8.0-167 DD, an 8 MW direct-drive turbine class. Hornsea Two offshore windfarm is fully commissioned and comprises of 165 SG8.0-167 DD turbines, making it the world's largest at the time of construction. As with previous turbine families, the SG-8.0 DD has been further up-rated to higher capacities. Siemens Gamesa's SG11 DD has recently been released and is currently being installed on the Vattenfall Hollandse Kust Zuid windfarm in Dutch waters. This is due for commissioning in 2023. Additionally, the SG11 DD units are also planned for the other offshore wind projects such as Gode Three in Germany due 2024. Siemens-Gamesa have announced their next generation 14MW unit which is planned for production in 2024 and could be installed as early as 2025. Figure 3-5 shows how Siemens' main offshore wind turbine models have developed in recent years; the 14 MW model is expected to have an annual energy yield that is 25% greater than the 8 MW model operating in the same conditions, with production expected to begin in 2024.



	SWT-6.0-154	SWT-7.0-154	SG 8.0-167 DD	SG 11.0-200 DD	SG 14-222 DD
IEC Class	I, S	I, S	I, S	I, S	I, S
Nominal Power	6 MW	7 MW	8 MW	11 MW	14 MW
Blade length	75 m	75 m	81.4 m	97 m	108 m

Figure 3-5, Recent evolution of Siemens-Gamesa's offshore WTG offerings [Source: Siemens-Gamesa]

In 2019 General Electric (GE) started the installation of a prototype Haliade-X 12MW offshore wind turbine in the port of Rotterdam. Since then, GE have uprated the turbine model to 13 MW and 14 MW both of which are commercially available at the time of writing. Currently, there are no Haliade X models installed and fully commissioned on a windfarm, however, 95 13 MW models are expected to be fully commissioned by October 2023 at Dogger Bank phase A, which is currently under construction.

In November 2022, Chinese turbine manufacturers China Three Gorges and Goldwind completed the first production of the world's largest rated wind turbine, a 16 MW model with a rotor diameter of 252 m. As the global demand for clean renewable energy increases it is expected that turbines will continue to increase in size and capacity over the next 10 years.

As can be seen in Figure 3-6, Siemens-Gamesa and MHI Vestas currently dominate the offshore wind turbine supply market in Europe, having around 68% and 24% share respectively. Senvion had a share of 4% but has since been absorbed by Siemens-Gamesa.

The average size of installed offshore wind turbine in 2021 was 7.4 MW, a slight reduction from 7.6 MW in 2020, however this is still a significant increase from the 5.9 MW average in 2017.

Table 3-2, Selection of currently available offshore wind turbine models and their suppliers

SUPPLIER	MODEL	CAPACITY [MW]	ROTOR DIAMETER [m]
General Electric	Haliade Haliade-X	6.0 12/13/14	150 220
Siemens-Gamesa	SWT-4.0-146 SWT-6.0-154 SWT-7.0-154 SG-8.0-167 DD SG-14-222 DD	4.0 6.0 7.0 8.0 14	130 154 154 167 222
Vestas	V164-7.0 MW V164-8.0 MW V164-9.5 MW V162-10.0 MW V236-15.0 MW	7.0 8.0 9.5 10 15	164 164 164 164 236
China Three Gorges & Goldwind	GW 6S GW 8S - -	6.45 8.0 13.6 16	184 175 252 252

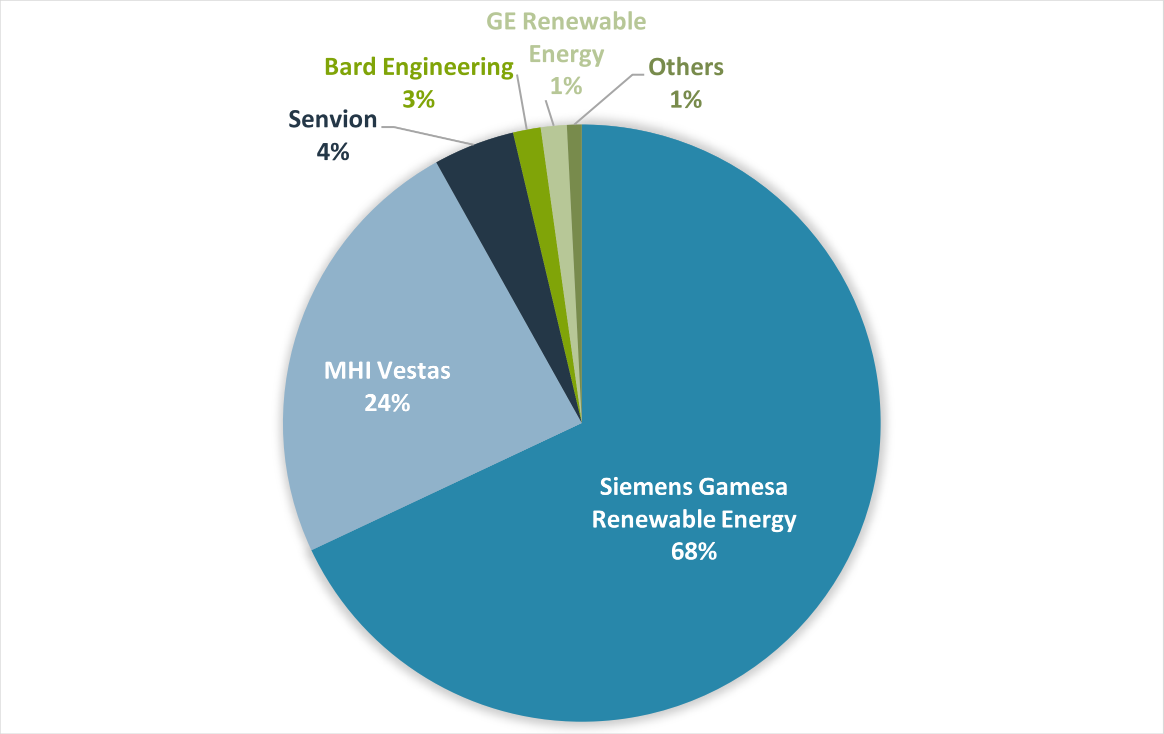


Figure 3-6, Offshore wind turbine manufacturers' European market share at the end of 2020 (MW) [Source: WindEurope][4]

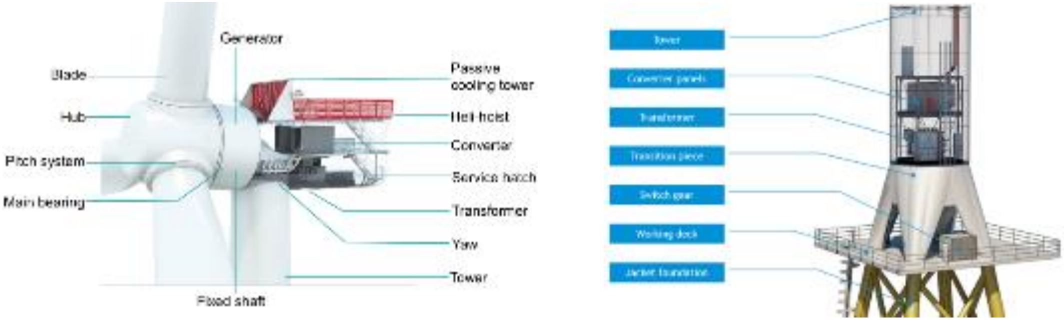


Figure 3-7, The components within the base of a turbine tower (left) [Source: Vestas] and a cutaway showing the main components of an SG-8.0-167 direct drive turbine (right) [Source: Siemens-Gamesa]

The offshore wind turbines that could be used in Jersey's waters would dwarf even the largest structures in Jersey, the latest >10MW units will be larger still – see Figure 3-8. The current state of the art turbines have

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[4] WindEurope Offshore wind turbine manufacturers market share - https://www.statista.com/statistics/666579/wind-turbine-manufacturers-eu/

large hub heights and rotor diameters, however, their distance from shore and orientation will also determine their visibility.

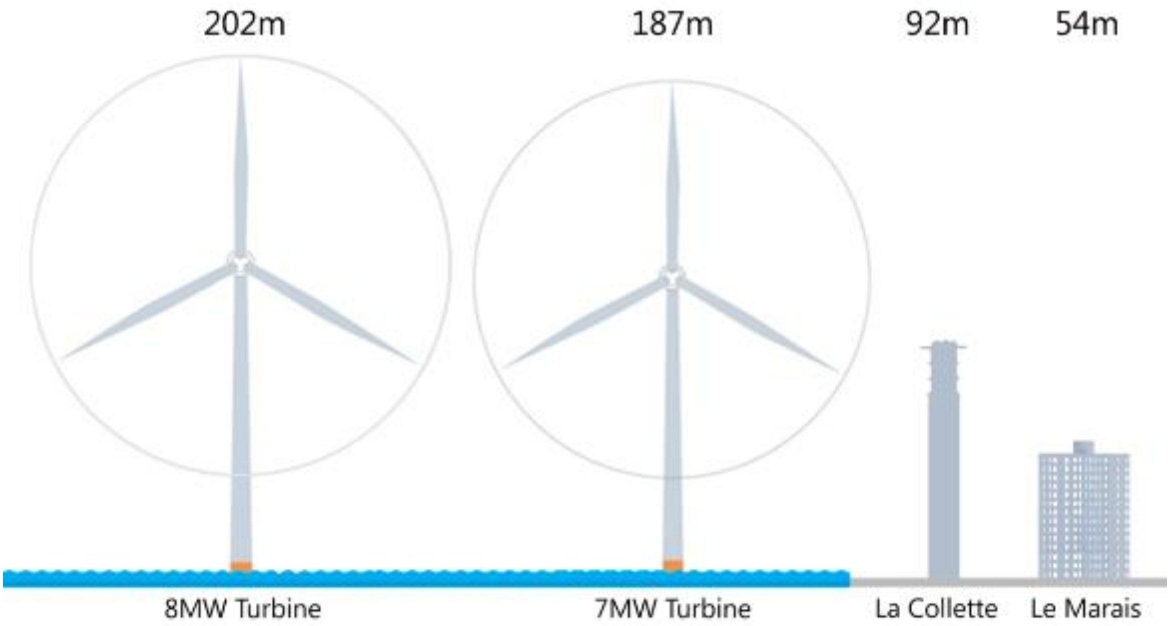


Figure 3-8, Visualisation of the current industry standard offshore wind turbines to scale against Jersey's most prominent landmarks – the maximum height of each structure is indicated.

3.4 Foundations

The foundation and substructures can take different shapes depending on the environmental conditions, the turbine size, and the desired design life. They can be gravity based, driven into the seabed or floating. Driven/drilled structures into the seabed are the most common in Europe. The driven structures can be monopiles or jackets piles of different sizes and shapes.

A transition piece is typically installed on top of the monopile structures, forming the connection with the turbine tower. For jacket structures the transition piece is attached to the foundation prior to transportation offshore.

The design of foundations for offshore wind turbines is dependent on a good understanding of the condition of the ground in which the foundation will be located.

- Geophysical Survey: Bathymetry, seabed features and obstructions, geological info, wave & current measurements.
- Geotechnical Survey: cone-penetration test (CPT) investigation and / or borehole at each turbine location.

Floating support structures for wind turbines are being tested in several sites in Europe but have not been commercially deployed in large scale yet. There are three main types of floating foundation, each has its own pros and cons. Typically, however, all types of floating foundations will only tend to be economically and technically viable in water depths in excess of 50m where the cost of fixed foundations is currently prohibitive.

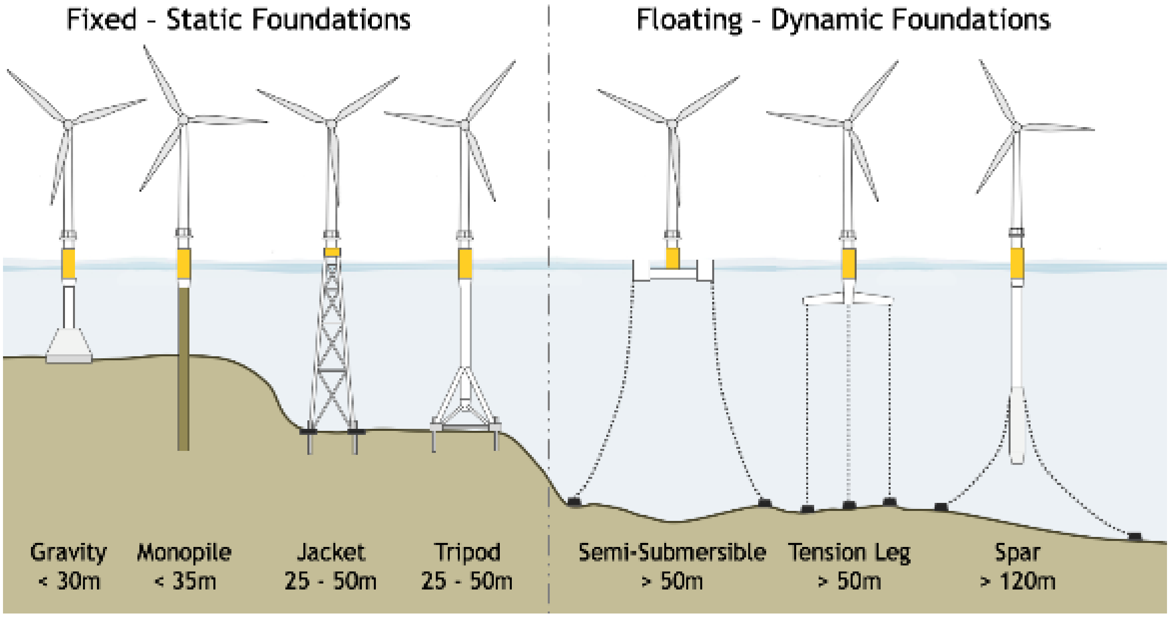


Figure 3-9, Principle foundation types being used in the European markets

3.5 Grid Connection

An offshore wind farm requires three distinct cable solutions to interconnect wind turbines, export energy from an offshore platform to shore and provide a land connection to the contracted point of interconnection (POI). Offshore cable solutions connecting to wind turbines may be required to operate in a dynamic installation for floating offshore wind in deep water or in a static installation for fixed bottom turbines.

- Onshore Cables: typically, single core copper or aluminium conductor, cross linked polyethylene (XLPE) insulated power cables with a welded aluminium radial moisture barrier and a linear polyethylene outer jacket. These cables connect to the subsea cable at a transition joint situated at the cable landfall. The land cables provide the link from landfall to an onshore substation or convertor station in the case of a High Voltage Direct Current system.
- Export Cables: either High Voltage Alternating Current (AC) or Direct Current (DC) cables typically dependent on distance from offshore platform to the point of interconnection. The selection of an AC or DC solution is related to relative costs of reactive power compensation of AC systems versus cost of DC convertors. It is recognised that export systems of greater than 120km would typically require a DC solution to avoid complex and costly reactive compensation. Export cables for AC systems will be three core copper or aluminium conductor, XLPE insulated, individually lead sheathed cores with galvanised steel wire armour and polypropylene string outer servings overall. DC cables solutions (bi pole or mono pole) typically are single core copper conductor, XLPE insulation, lead sheath, galvanised steel wire armour and polypropylene serving. Double armour solutions are often specified in subsea export cables to provide protection from seabed abrasion and other hazards that may damage the cable in its installed environment. Stainless steel armour can be used in areas where additional losses generated in galvanised armour systems prevent the cable from delivering the required power rating of the offshore generation system.
- Inter-Array Cables (IAC): typically AC systems with smaller capacity cables operating at 66 – 132kV, these cables are typically three core aluminium or copper conductor, insulated with water tree-retardant XLPE solutions to facilitate operation in either a wet or partially wet design i.e. the XLPE insulation would be in contact with sea water during operation. IAC cables would typically not contain a lead sheath to reduce cost and, in the case of floating wind turbines, to remove the risk of lead fatigue during uncontrolled movement of the cable. Partially wet solutions have also been developed to reduce overall exposure to the wet environment using foil laminates.

- These cables link the individual wind turbines to each other and then, typically, connect to an offshore substation which collects power from all the turbines in a single location (or potentially multiple locations in GW scale windfarms). The inter-array cables typically connect 7-10 turbines on a single 'string' depending on the size of the inter-array cable used and the rated power capacity of the turbines.
- For floating turbine technology, inter-array cables are designed and tested both electrically and mechanically to allow for controlled movement in operation.

Figure 3-10- Typical Offshore Wind Farm Electrical System

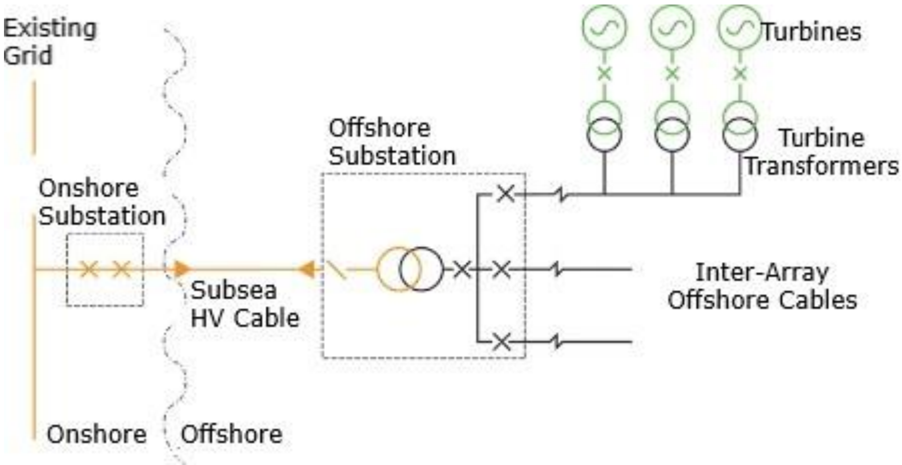


Figure 1 above shows a typical electrical system layout for an offshore wind farm. Fibre optic cables are often embedded within the offshore power cable construction to provide both asset management data as well as SCADA data from offshore assets. The integration of optical fibre sensors allows for the real time analysis of cable temperature and mechanical strain, often providing an early warning of potential cable failure.

Typical AC and DC cable constructions are shown in figure 2 and 3 below:

Figure 3-11 - HVDC Subsea Export Cable

Figure 3-12 HVAC Subsea Export Cable

Offshore substations are typically used when the capacity of the wind farm and distance to shore is such that it is financially advantageous to step up the transmission voltage from the inter-array system voltage to a transmission voltage prior to export to shore. The higher transmission voltage reduces energy lost in long distance transmission. Examples of offshore platforms are provided in figures 4, 5, 6 and 7 below.

Where distance from the point of interconnection is such that capacitive losses in the AC system are prohibitive (typically at distances of >120km), an offshore HVDC convertor would be required and power exported via a low loss HVDC export cable system.

For AC systems there is typically a single offshore substation per 500MW of capacity. The platform is located within the windfarm to minimise cable lengths, electrical losses and to navigate/mitigate any environment constraints.

HVDC systems are increasingly being utilised as floating wind technologies facilitate the development of offshore projects further from shore. There are a number of high profile developments in the North Sea connecting into the Dutch and German grids including the Borwin, Dolwin and Helwin developments. Due to the high costs of HVDC systems, the projects are typically very large capacity, with early examples rated at over 800MW. Rapid technology development in both convertors and export cables is helping to realise 2.5GW offshore platform development with a single bi-pole HVDC export circuit. Given that HVDC systems are only effective at distance to shore in excess of 120km, it is unlikely that this technology will be applicable to developments in Jersey’s waters.

There are different methods of owning, managing and constructing the grid connection (onshore and offshore transmission assets including the offshore substation) applied in different countries:

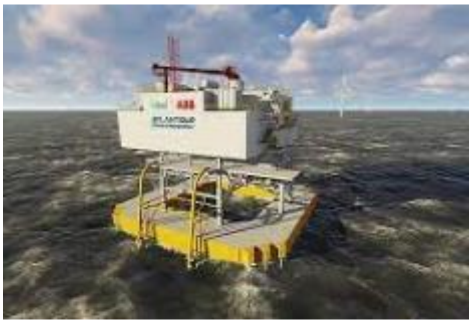
- UK – Grid connection and substations developed and financed by the project developer, then sold to an independent owner and operator. Tariff covers usage fees for transmission.
- Denmark and Germany – Grid connection provided by the state utility/grid operator.
- Netherlands – Grid connection provided by the state and not supported by the subsidy price.
- Belgium – Grid connection provided by the state, but if developed by the project, a higher tariff is given.
- France – Grid connection developed by the project and the costs are included as a percentage of the bid for tariff.

Figure 3-13 - Hornsea HVDC Convertor

Figure 3-14 -Hollandse Kust Zuid HVAC Platform

Figure 3-15 - Triton Knoll HVAC Offshore Platform

Figure 3-16 - Floating Offshore Substation Platform Concept



3.6 International Grid Connections

One of the key considerations for Jersey Electricity is where to connect the Offshore Wind farm. The island currently has an interconnector with mainland France for the provision of power. Jersey Electricity installed its first interconnector (EDF 1) to France in 1985. Since then, a further 3 submarine cables have been installed between France and Jersey by the business. As a result, Jersey Electricity has developed significant experience in the construction, operation and maintenance of these assets over the last 38 years.

One option is to connect directly to a landfall point on the Island itself and explore the potential for any export via the existing interconnectors. However there are technical limitations on this. This is further explored later in the report, in section 7.3.3 where the report explores the various scenarios for the potential location of OSW developments in Jersey Waters.

One option is to connect directly to the French grid. Jersey Electricity experience gained through the work to reach agreement with the French authorities for construction of the current interconnection assets would help inform the connection of an OSW project. Jersey Electricity has also developed a close relationship with RTE over the period of operation of the interconnection cables covering construction, maintenance and operations, and this could be extremely valuable in the development of any OSW project.

3.6.1 Connections to France

The development of Offshore Wind is tightly controlled in French waters[5] and requires Ministerial Authorisation[6].

The transmission network in France is operated by RTE, a public utility charged with providing non-discriminatory access to the French transmission system. If authorised RTE are responsible for the connection. There is no equivalent to the GB competitive provision of offshore connections and OFTOs.

Following the UK's withdrawal from the EU, using interconnectors between energy markets has increased in complexity. It is advised the Government of Jersey seeks advice on this as its status is unique in these situations. For the purpose of this report, we have treated our comments on the basis that Jersey would be seen as connecting into the EU market.

Interconnector regulation has been developed around their role in connecting different markets or bidding zones. EU legislation essentially reinforces this role requiring 70% of the capacity to be used for inter-zonal trading in EU markets. The UK has removed the 70% obligation on interconnector operation into UK markets and replaced with an efficient use requirement.

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[5] (https://cms.law/en/int/expert-guides/cms-expert-guide-to-offshore-wind-in-northern-europe/france section 2)

[6] (https://cms.law/en/int/expert-guides/cms-expert-guide-to-electricity/france see 3.3)

The EU has been considering the issues associated with Offshore wind and its interaction between different markets and the role of Multi-Purpose Interconnectors (MPIs)[7].

The EU has assessed the impacts on generator revenues and pricing and efficient dispatch and market operation of two models:

- **Home Markets**. This considers the interactions of bidding generation through an MPI into an existing market. There are a number of EU legislative issues that would currently give preference to interconnector flows and a specific exemption would be needed to enable reasonable conditions for investment in an associated wind farm. There are also economic issues concerning the correct allocation of congestion costs/value arising from the inability to accurately forecast capacity allocation and some legal impediments to correcting allocations. This is not the EU ‘s preferred approach.
- **Offshore Bidding Zones**. This essentially proposes separate offshore markets are established. There are issues where small amounts of generation exist but the assessment established that these are more robust to future development of offshore demand (P2X) e.g. for hydrogen. These are also easier to fit into existing EU legislation.

French areas will follow the EU approach, implying that an offshore bidding zone could emerge for generators and MPIs connecting to the French markets. It would be logical for GB markets to interface in the same way to any bidding zone. The EU assessment notes that the GB market as an example of regulatory cooperation.

The key issue highlighted by the EU paper is the potential for redistribution of revenues from generation TSO congestion income, estimated at a 1-5% reduction in revenues for the generator.

3.6.2 BEIS and Ofgem

BEIS and Ofgem have also recently consulted on the issue and issued their initial responses[8] From this, two key areas have emerged:

- Licencing and UK law requires the separation of the ownership of Interconnectors and Transmission licencing, needing clarification of which licence applies. Ofgem are minded to proceed with a modified Interconnector licence and BEIS recognise the need to introduce a separate licence class.
- Financial support mechanisms. The UK has different approaches for revenue for generation (CfD), OFTOs (TNUoS revenue) and Interconnectors (cap and floor).

The UK position is that both EU models can co-exist but must be compatible. Whilst much of this may not be relevant to a Jersey based OSW connecting directly to the French it is worth noting.

Ofgem are proposing to use cap and floor mechanism for initial pilot schemes. This raises a number of questions which are still to be resolved:

- Changes to legislation and frameworks appear to be needed to allow interconnector connected generators to participate in the GB capacity markets (potentially along with other overseas generators)
- Interconnectors are not subject to Transmission Use of System Charges (TNUoS) and further clarity is required on the treatment of generators using MPIs to access the GB transmission system.

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[7] (European Commission, Directorate-General for Energy, Market arrangements for offshore hybrid projects in the North Sea, Publications Office, 2020, https://data.europa.eu/doi/10.2833/36426)

[8] (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1071159/otnr-multi-purpose-interconnectors-government-response.pdf ; https://www.ofgem.gov.uk/sites/default/files/2022-01/Offshore%20Coordination%20Summary%20of%20Responses%20and%20Next%20Steps.pdf)

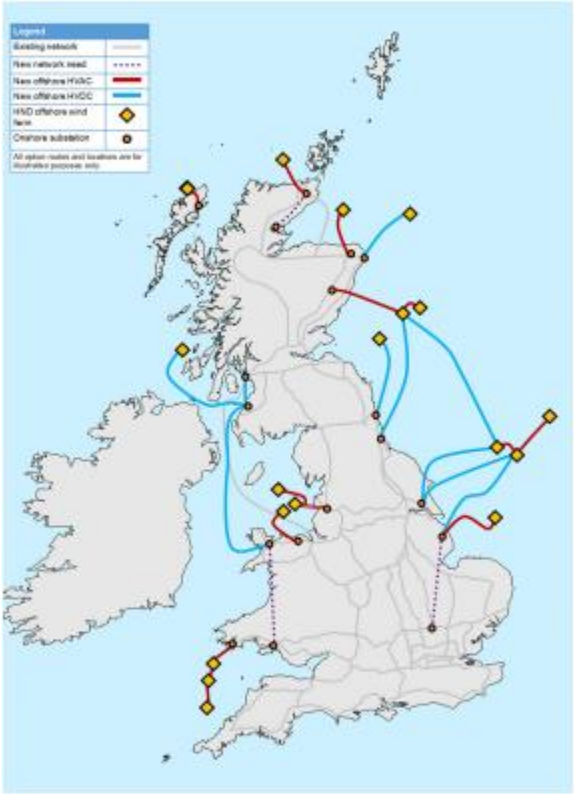
- The UK has removed the 70% obligation on interconnector operation into UK markets and replaced with an efficient use requirement, but some uncertainty remains about how these requirements align with current requirements for priority dispatch and non-discriminatory access.

A 'Home Market' model would require the connecting generator to choose a market into which it would bid. If this was the GB market, then it is expected that this would require a GB generation licence.

3.6.3 National Grid HND

The current National Grid Holistic Network Design (HND) is being developed to enable investment and delivery of infrastructure, including locations in North and South Wales, the Scottish Islands and West Coast, and the East Coast of Scotland and Aberdeenshire, Lancashire, North-East England, and Yorkshire & Humber, opening the door for more jobs and economic growth in these regions. At present, this does not include any developments being planned or discussed along southern Channel coast line.

Figure 3-17 Identified Network Needs Identified through the HND[9]



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[9] Pathway to 2030, Holistic Network Design, July 2022

4. Environmental and Social Impacts of Offshore Wind

All offshore wind projects in Europe require Environmental Impact Assessments (EIA) as per the requirements of European Union Directive 2014/52/EU and in support of the development consenting process. EIA is a tool which can be used to draw together, in a systematic manner, an assessment of the likely significant effects resulting from a proposed development. Although EIA is applied as part of the consenting process the principles can be used to assess the feasibility of offshore wind projects, including site selection and site feasibility.

As per the Policy statement ME5 in the Bridging Island Plan10, an offshore wind project being developed in Jersey's waters will be supported where it can be demonstrated that:

- the energy return is proven to be in the island's strategic interest delivering significant and long-term benefits to the community, and that these benefits are deemed to sufficiently outweigh any environmental impact that will arise as a result of the development; and,
- b. the anticipated environmental impact of the development will be acceptable, with anticipated effects mitigated as far as possible, and appropriately compensated for.

All proposals must be supported with an appropriate monitoring programme and detailed restoration proposals, including funding and management mechanisms to ensure their implementation.

An Environmental Impact Assessment undertaken in accordance with the Planning and Building (Environmental Impact) (Jersey) Order 2006[11] would need to demonstrate inter alia:

- detailed engagement with all stakeholders;
- that there will not be an unacceptable impact on features of ecological, archaeological or historic importance, on hydrology or coastal processes, nor the marine, intertidal or coastal environment;
- there will not be an unacceptable visual impact;
- there will not be an unacceptable impact on the character of the immediate and wider landscape;
- there will not be an unreasonable impact on neighbouring uses and the local environment by reason of noise, odour, pollution (to air, water or soil), visual intrusion or other amenity consideration during construction, operation and decommissioning;
- it will not prejudice the safe operation of shipping and / or Jersey Airport;
- there will not be any unacceptable impacts as a consequence of any associated infrastructure required to service the site, such as connection to shore base and grid connections;
- an appropriate environmental monitoring programme; and,
- acceptable maintenance and decommissioning proposals.

Each of the above points are in-line with the typical approach used for offshore wind projects throughout Europe. The experience from developing projects over the past 20 years has helped to refine the process and provide evidence to better predict the actual effects of offshore wind projects on the natural and human environments.

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[10] https://www.gov.je/SiteCollectionDocuments/Planning%20and%20building/IP%202011%20Natural%20Resources%20and%20Utlilities%20Pages%20349-376.pdf

[11] https://www.jerseylaw.je/laws/current/Pages/22.550.20.aspx

The following chapter presents the typical approach taken to EIAs for offshore wind projects and summarises the potential negative impacts and positive benefits that projects may have.

4.1 Environmental Impact Assessments

EIA on proposals for an offshore windfarm will consider a broad range of impacts and their resulting effects on the existing human, physical and natural environment at the site. Typically this will include the following topics:

- Hydrodynamics and Geomorphology
- Marine and Coastal Water Quality
- Ornithology
- Marine Conservation and Ecology
- Natural Fisheries
- Marine Mammals
- Geology, Water Resources and Land Quality
- Terrestrial Ecology
- Commercial Fisheries
- Landscape, Seascape and Visual Resources and Character
- Shipping and Navigation
- Marine Archaeology
- Military and Aviation Interests
- Socio-Economic Assessment
- Landscape and Visual Character
- Archaeology and Cultural Heritage
- Tourism and Recreation
- Traffic and Access
- Noise, Dust and Air Quality

For each topic, the EIA determines all potential effects and determines those that could be result in significant adverse effects, which may be deemed unacceptable and increase the risk that the project fails to receive consent. To do so, the EIA considers various criteria in order to draw a conclusion on which effects are likely to be significant. The criteria typically applied is listed below:

3. Magnitude – Quantitatively assess the scale of effects.
4. Extent – Determine spatially the area that is affected.
5. Duration – Determine the time over which the effect will last; i.e. both the duration of the activity and the time.
6. Temporal Scale – Whether any changes to the ecology are temporary or permanent.
7. Timing and Frequency – Establish if the effect coincides with any key seasons or events important to that receptor and whether reoccurring effects prevents a recovery of receptor.
8. Cumulative Effects – Assess whether the effects of the development could combine with other, external impacts (possibly from other projects) to magnify or exacerbate original effects.
9. Confidence in Predictions – Judge the accuracy of the predictions and how well the previous points have been estimated.

The EIA will be informed by surveys carried out over the wind farm area. The type and magnitude of survey work required will vary for each environmental receptor; some aspects such as birds may require years of detailed on-site pre-construction ornithology surveys, whereas other aspects such as impacts on sediment dynamics may be largely based upon computation modelling and require little field survey work.

Site surveys required in the UK typically include, at a minimum:

- Mammals and Cetaceans Surveys: Four seasonal surveys and a monitor on the met mast.
- Fisheries Resources Surveys: Four seasonal surveys and catch data from fisheries bodies.
- Ornithological Survey: Monthly surveys over at least two years.
- Seabed habitat Surveys: Including benthic surveys, trawls and grab samples.
- Terrestrial survey: For onshore substation and cable route.
- Marine Traffic Survey: At least two seasonal surveys of 28 days each.

Once the various impact predictions have been made and the significant adverse effects identified, mitigation strategies can be developed in liaison with the appropriate stakeholders in order to help lessen severity of the effects and reduce them to residual levels that allow the project to be consented.

Post construction monitoring is often required for key receptors, to ensure that the actual effects are within the limits of what was predicted and consented.

4.2 Key Environmental and Social Issues

4.2.1 Summary of Typical Impacts and Mitigations

There are now over 4,000 offshore wind turbines operating in European waters across a wide range of environmental conditions and habitats – some of these turbines have been operational since the 1990s. Although there are still some uncertainties of the general impact of offshore wind, there is a strong evidence base for the assessment and reduction of resulting environmental effects. A number of generalisations can be made to summarise the main impacts, effects and mitigation associated with offshore wind projects.

Table 4-1, A summary of the typical effects and mitigations associated with offshore wind projects

RECEPTOR	EFFECT	MITIGATION
Birds	Mortality as a result of collision with turbine towers and blades Displacement and avoidance of area due to presence of turbines Wind farm presents a barrier to migration	Fewer turbines Altered hub heights or rotor diameters Avoiding onshore or offshore works during nesting periods
Marine Mammals	Construction noise causes hearing loss Mortality due to vessels Avoidance due to operational noise	Acoustic deterrents Soft-start or ramp up to piling activities Bubble curtains Marine mammal observers Vibro-hammers rather than piling
Benthic Communities	Construction and operational noise drives species out of the area Sedimentation changes seabed habitats Cable laying and burial will disturb benthos	Avoid undertaking construction activities during sensitive periods such as shellfish spawning seasons Monitor sediment transport

	Drill cuttings and scour protection will alter seabed habitats	Minimise grapnel runs and scour protection used
Fish	Habitat is changed by presence of wind farm Fish mortality due to pile driving Construction and operational noise drives species out of the area	Avoid undertaking construction activities during sensitive periods such as fish spawning seasons Similar mitigations to marine mammals
Vessels	Vessel collision with wind farm Route deviation to avoid wind farm	Undertake navigational risk assessments Alter shipping lanes and navigation channels Education of seafarers Provision of refuge in case of emergencies Emergency response planning
Fishing	Restrictions on fishing grounds Negative impact on fish populations	Work with fishing community to find preferred solutions Assess potentially positive benefits to fish stocks Compensation and jobs for fishermen
Tourism	Visual impact from wind farm reduces tourist numbers	Reduce numbers or sizes of turbines Change orientation of turbines relative to shoreline to reduce visual impact
Radar	Wind farm causes issues for marine and aviation radars (i.e. clutter on radar returns, blocking of radar etc)	Undertake radar impact studies Provide additional radar or more capable, modern radar system
Sediment transport	Presence of subsea structures, cables and cable protection causes changes to sediment dynamics, altering erosion and deposition	Long term monitoring and modelling of sediment transport and hydrodynamics Use scour protection

4.2.2 Marine Navigational Safety

Offshore wind farms are often located close to ports for the ease of installation and O&M purposes, however, for this reason their presence may cause a hazard to shipping transiting through or close to the wind farm's offshore site.

The main methods to establish baseline data in the UK are to carry out vessel traffic surveys and to liaise with maritime stakeholders such as the fishing, dredging and yachting associations, if these are applicable.

Shipping traffic surveys are usually carried out using a combination of Automatic Identification System (AIS) and Radar monitoring techniques to collect track data on vessel movements. The International Maritime Organization's International Convention for the Safety of Life at Sea[12] (SOLAS) requires all international voyaging ships with gross tonnage of 300 or greater, and all passenger ships regardless of their size, to be fitted with an AIS transponder. This allows a vessel's location and type to be monitored and so a dataset of vessel movements by type can be put together from data gathered.

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[12] http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx

For vessels smaller than 300 tonnes, such as fishing, yachts and recreational vessels, a Radar system can be used to spot and track these non-AIS equipped vessels. This technique is supported by visual observation which is required in order to identify and log the vessel types picked up by Radar. Usually, this Radar is accompanied by some form of operator accommodation so that the observer and operator can stay onsite and visually identify passing vessels. It is important that these two survey methods are carried out simultaneously and care should be taken to ensure that vessel observations are not duplicated by the combined data. The surveys should also be designed in order to cover the entire proposed wind farm area and a reasonable buffer zone around it so that all relevant vessels can be monitored.

Typically, surveys are carried out over two separate, continuous 14 day periods; one during winter, the other during summer. This is in order to survey vessel activity during two distinctly different times, for example, the activity of recreational yachts will be much higher in the summer than in the winter.

An example a 28-day radar data compared with AIS data is shown below (Figure 4-1). There are approximately twice as many tracks on the radar data as the AIS data.

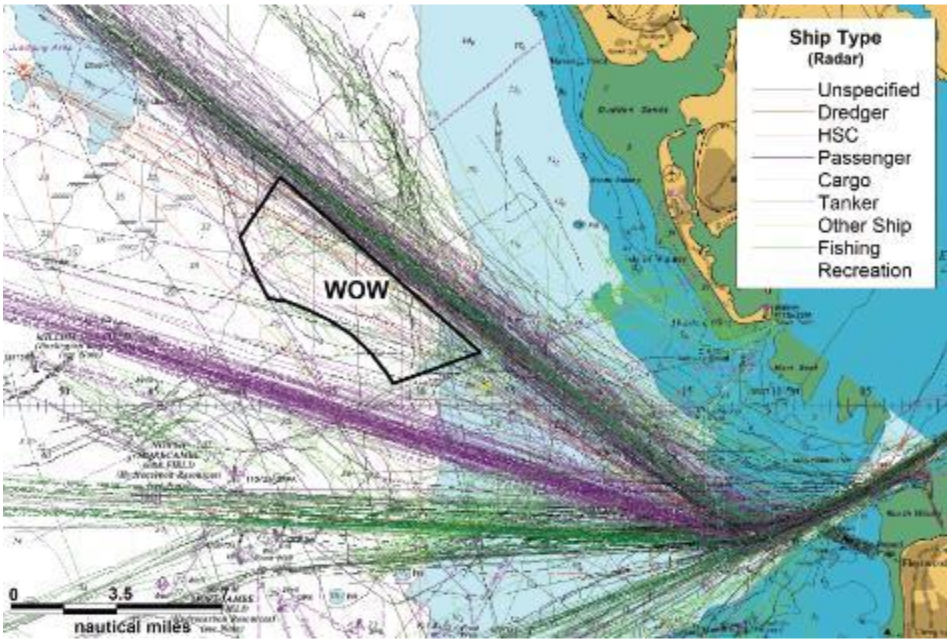

Figure 4-1, Results of a Radar Traffic Survey at a UK Wind Farm [Source: Orsted]

A number of measures are taken to mitigate the risks to shipping and navigation:

- **Site selection** – the simplest approach is taken at an early stage of a project's development and so that the site selection process defines the site to avoid shipping lanes.
- **Marine Aids to Navigation (AtoNs)** – during construction and once constructed, the wind farm will be marked by navigation buoys which will comply with the International Association of Lighthouse Authorities (IALA) standard O-139 on the Marking of Offshore Wind Farms (IALA, 2008). The turbines themselves should also have navigational safety features such as yellow transition pieces, navigation lighting and fog horns.
- **Marking of wind farm on charts** – wind turbines, cables and the wind farm's boundaries should be clearly marked on nautical charts.
- **Vessel restrictions** - Once installed, large vessels are not permitted to travel through the wind farm, however, smaller fishing and recreational vessels are allowed to use the waters. In the UK, all vessels are required to observe a 50m radius, safety buffer zone around each turbine. During construction it is usual to have a 500m safety zone around the entire wind farm site and have guard vessels on site at all times to prevent any small vessels from accidentally entering the area. The UK's Royal

Yachting Association recommends[13] that a minimum of 22mof vertical clearance should be maintained between sea surface (measured at the highest astronomical tide, HAT) and the blade tips of the turbine. This, therefore, also places a limitation on the height of vessels that should avoid the offshore site.

- **Cable protection** – cables should be adequately buried and trenched where the seabed conditions allow or alternatively be protected using other methods such as rock dumping or concrete mattresses. This is in order to ensure that the risk of fishing gear snagging or anchor interaction is mitigated. Periodic subsea inspections of the cable routes should be made to ensure the cables remain buried.

4.2.3 Aviation and Shipping Radar

Similarly to onshore wind farms, the presence of offshore wind farms can cause issues for aircraft and aviation Radar.

Typically, wind turbines may adversely affect a radar's capability. In the case of aviation radar this can mean that air traffic controllers are not able to effectively identify aircraft which could risk mid-air collisions between aircraft or air defences being compromised.

In order to establish baseline data, a developer will need to consult relevant stakeholders. These stakeholders will be able to provide information on the types of radar used and the typical ranges to which they are affected. Guidance provided by the International Civil Aviation Organisation states that an assessment should be conducted if a turbine is within 15 km of an airport's radar[14]. In the UK, it is typical to consult with airports within a 30 km radius of an airport.

Following consultation with the relevant stakeholders, analysis can be carried out to see if the turbines are 'visible' to the various radars within range. This is known as 'line of sight' analysis.

There are a number of ways in which adverse radar effects can be mitigated and the UK has had much experience with this in recent years. Typically, either the project can be modified or the radar can be modified;

- Movement of boundaries – The project's boundaries can be moved so that the turbines are further away from affected radar.
- Reduce turbine numbers – The number of turbines in the project can be reduced to help try and reduce the clutter and unwanted radar returns.
- Reduce heights and rotor diameters – The physical size of the turbines' blades can be reduced to lessen the reflected returns signal.
- Increase spacing between turbines – Reducing the density of turbines in the array may help to reduce the overall impact of the project.
- Low signature rotor blades – New materials and coatings for blades are being developed to try to reduce the radar signature and the amount of radar energy that is reflected.
- Data Processing and filter in Radars – Techniques have been developed to process out some of the radar clutter that appears on the radar screens.
- Additional Gap Filling Radars – Installing a second radar to provide coverage in the 'shadowed' areas allows radar capability to be maintained throughout the region.
- Transponder Mandatory Zones (TMZ) – Aircraft transiting through these zones are required to identify their location via transponder in order to provide an alternative to radar tracking.

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[13] The RYA's Position on Offshore Renewable Energy Developments: Paper 1 (of 3) – Wind Energy. 2011

[14] The European and North Atlantic Office of ICAO. European Guidance Material on Managing Building Restricted Areas; Technical Report, ICAO EUR DOC 015; International Civil Aviation Organization: Paris, France, 2009.

4.2.4 Fish and Shellfish

A key consideration of the EIA is the potential adverse effects on fish and shellfish; these will occur at different stages of development (construction, operation and decommissioning). Fish are typically most affected by the construction of the wind farm due to piling noise and vessel activities. As with marine mammals, artificial noise can cause harm to fish and changes to their biological activities and behaviour.

A key consideration of the EIA is the potential adverse effects on fish and shellfish; these will occur at different stages of development (construction, operation and decommissioning)

Adverse impacts on fish and shellfish population as a result of a wind farm's development are:

- Direct Loss of habitat (nursery, spawning and overwintering grounds) through placement of turbines, piling, scour protection and cable laying operation.
- Disturbance of feeding and breeding activities and use of any migratory pathways.
- Change in the habitat/substrate of the foundation areas may lead to a change in fish and shellfish community composition – re-suspension of sediment may form a "smothering layer".
- The electromagnetic fields associated with the cabling may also affect the behaviour of fish.
- Underwater noise

When designing surveys / sampling methods, it is important to design carefully to capture the presence, distribution and seasonality of the fish and shellfish resource available. There tend to be more fisheries data publicly available for coastal water than offshore areas, where possible use these existing sources in order to avoid duplication of field surveys. There is no single sampling method that would capture data for the entire communities, especially due to the transient nature of fish population, and this will need to be reflected in the survey design.

Typically, the greatest adverse impacts on fish are the disturbance to their seasonal activities and so mitigation methods are often to plan construction/ installation work to avoid fish spawning periods.

The impact from the direct loss of habitat is sometimes compensated by the creation of a new habitat as turbine foundations would create a new habitat for spawning and new refuge for all species passing through between. The species whose spawning activities that will be most disrupted by sedimentary changes will be those who deposit eggs and build nests on the seabed. Displacement of fish not only has implications for fisheries, but also for upper level predators.

Many mitigation approaches for fish and shellfish impacts are provided by the UK's Centre for Environment, Fisheries & Aquaculture Science[15].

4.2.5 Fisheries Stakeholders

During the EIA process, fisheries data is generally collected both within the site and in surrounding areas, methods are likely to include:

- Desk study
- Review of commercial fishing methods such as pots, trawls, fixed nets and lines for collecting fish samples
- Underwater video and stills photography
- Grab samples of seabed benthos
- Acoustic Ground Definition System (AGDS)
- Landings data from fishermen

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[15] http://www.cefas.defra.gov.uk/media/393525/annex-2-fish.pdf

- Effort data on the number of fishermen using the area
- Findings from fisheries liaison

The UK's 'Fishing Liaison with Offshore Wind and Wet Renewables Group' (FLOWW) comprises a number of renewable energy industry and fisheries stakeholder groups. It has recently published guidance[16] on the best practice for fisheries liaison. Guidance on mitigation measures have been published by the UK's COWRIE group[17].

Developers generally begin consultation with the fishing industry early during the development of a project to assess possible fisheries issues and gather information on fishery resources. Ideally, the developer appoints a Fisheries Liaison Officer (FLO) to undertake the consultation with the various fishing groups. The FLO will have a fishing background to understand the concerns and issues raised by the fishermen. It is the FLO's job to keep the key representatives from the industry informed about how the project is progressing and provide them with accurate information about the project. The FLO will also have the responsibility to develop a good relationship with the fishing groups and encourage a level of trust to be established.

Disruption or displacement of commercial fishing activities by wind farms is recognised as a significant issue and one that is likely to affect many offshore wind developments. Where it does arise the contentious issue of commercial compensation, known as disturbance payment, is also often raised. Where possible, evidence is collected about the type and amount of fish and shellfish that is caught each year from the wind farm area. When trying to reach a disturbance payment, however difficult, it is imperative that the developer accurately assesses the value of the fishing site. However, if the developer is able to gain their respect and trust, some might be prepared to share information about their catch on a confidential basis.

Clear and constant communication between all parties involved is important and for discussions with the fisheries industry and it is especially important to have a single point of contact. In addition to local fishing fleets, fishermen from more distant ports and foreign vessels are also identified and informed and this will also aid navigation safety.

This is an option that requires delicate handling and a building of relationships through stakeholder engagement. The earlier fisheries are engaged in the OWF process, the easier it will be to hear their concerns and take action to allay their fears where possible.

As part of their mitigation plans, many UK projects provide financial compensation directly to fishermen and support fisheries groups. An example of this is the 367MW Walney offshore wind farm which, along with a number of other projects in the region donates funds to the West of Morecambe Fisheries group[18] for the purpose of supporting and developing commercial fishing activities.

Certain types of fishing activities are allowed within the wind farm areas, once constructed and operational. Developers will endeavour to design the layout of the turbine arrays and cable burial so that that the snagging of fishing gear is avoided.

4.2.6 Birds

There are four principal ways a wind farm can have impacts on birds:

- Collision Risk with the turbines and associated infrastructure
- Direct Loss of habitat through construction of wind farm infrastructure.

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[16] Best Practice Guidance for Offshore Renewables Developments: Recommendations for Fisheries Liaison - http://www.thecrownestate.co.uk/media/5693/floww-best-practice-guidance-for-offshore-renewables-developments-recommendations-for-fisheries-liaison.pdf

[17] Options and opportunities for marine fisheries mitigation associated with windfarms - http://www.thecrownestate.co.uk/media/5941/2010%20Options%20and%20opportunities%20for%20marine%20fisheries%20mitigation%20associated%20with%20windfarms.pdf

[18] http://www.westofmorecambe.com

- Indirect Loss of habitat through disturbance of foraging and breeding activities during construction, O&M and decommissioning.
- Barrier effect from the large arrays or rows of turbines leading to flight path changes and an increase in energy expenditure for travelling birds.

For each of these risks, detailed knowledge of bird distribution and flight activity is necessary in order to predict the potential effects on birds.

Desk studies are the first step in identifying the relevant bird populations and data can be gathered from local ornithological groups where possible. Site monitoring will usually either be boat-based or aircraft-based depending on the distance to shore/port. Trained bird observers on board the boat or aircraft will use methods to estimate the species, position and height of any observed birds. The observers will traverse pre-defined transects across the site for a period before construction, during construction and then post construction.

Survey techniques will vary according to the species of interest, habitat and time of year.

All bird species have varied seasonal and day activity patterns, in order to capture the most amount of information, the survey should be designed around when birds are most likely to be active and should span all year.

Survey results can often be used to inform turbine layout, mitigation plans and baseline for future monitoring. For full survey methods and design standard, reference should be made to current good practice, including documents such as those produced by COWRIE (Collaborative Offshore Wind Research into the Environment) which was set up by The Crown Estate[19].

A useful report[20] from this series is “A Review of Assessment Methodologies for Offshore Windfarms”. Alternatively, the Scottish Natural Heritage has published[21] “Guidance on survey and monitoring in relation to marine renewables deployments in Scotland” and is a useful document in summarising information on bird survey work.

Impacts on birds may be mitigated by altering the number of turbines in a project, the location of the turbines to avoid migration routes, varying the rotor swept area and varying the timing of construction activities to avoid particular ornithological events. Bird mortality due to collisions with wind turbine rotors may be reduced to ‘acceptable’ levels by increasing the hub height and air gap below the turbine, using a smaller rotor or using fewer turbines.

A 5 year research study[22] on the Egmond aan Zee offshore wind farm in the Netherlands found that birds tended to avoid the wind farm area and that the small number of birds that do enter the area are usually able to avoid the turbines - only 0.01% of birds entering the wind farm are actually hit by the blades of the wind turbines.

Changes to the habitat by the wind farm may be perceived as both positive and negative impacts; the presence of turbines may unsettle some birds, thus displacing them from the area; whereas others may see the turbines as a place of refuge and an offshore feeding ground. Furthermore, the reduction in fishing activities within the wind farm may help to locally increase fish populations, therefore improving the amount of natural food available for birds fishing in the area.

To minimise the impacts on birds, developers should assess typical migration routes, local flight paths, feeding areas, and local coastal and inland wetland sites that may be home to populations of wetland birds

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[19] http://www.thecrownestate.co.uk/energy-and-infrastructure/downloads/cowrie/

[20] http://www.thecrownestate.co.uk/media/5884/2009-05%20A%20review%20of%20assessment%20methodologies%20for%20offshore%20windfarms.pdf

[21] http://www.snh.gov.uk/docs/A585081.pdf

[22] http://www.noordzeewind.nl/en/onderzoek-toont-aan-zeeleven-profiteert-van-eerste-offshore-windpark-van-nederland/

that could be affected by the wind farm when migrating. An established mitigation for birds is to time construction and maintenance programmes to avoid the breeding season.

4.2.7 Marine Mammals

There are many types of marine mammals living in UK waters and are all considered as a fairly high priority in terms of impact avoidance.

Dolphins and other mammals such as seals, whales and porpoises rely on their acute hearing for their sonar detection of prey during feeding. Their hearing may very easily be damaged by piling activities which cause very high sound pressure levels to be radiated through the water. The presence of the project's infrastructure may change the behaviour of mammals using the area and turbines could also change the characteristics of feeding grounds resulting in either an increase or decrease in available prey.

Similar to the bird studies and many other receptors mentioned here, the assessment process will commence with a desk based study to examine any available data which can be used as the baseline and by which the potential effects can be predicted. This will be fundamentally based on the likely proximity of marine mammal species to the site and the activity levels where known as well as the method of construction. In most cases underwater noise modelling will be necessary to predict effects over distance and to gauge the requirements for mitigation, to avoid or limit the effects.

A common survey practice is to use field observers to detect and record marine animals. This requires highly skilled, licensed and experienced observers. In conjunction with observers, Passive Acoustic Monitoring (PAM) which uses hydrophones to record subsea noises, can be used to monitor marine mammals.

Marine mammal observation and PAM approaches are complementary to each other and tend to be used simultaneously to provide better coverage, as some limiting factors such as poor weather conditions, background noise, and non-acoustic animals can be overcome. Other methods such as mammal telemetry tracking may be used to identify if mammals are using the site.

Mitigation measures may include avoiding known breeding (e.g. seal haul out areas) or foraging areas of marine mammals, planning construction times to avoid particular events, such as breeding seasons. Also during construction, particularly where underwater noise is generated mitigation techniques, such as soft starts on piling, exclusion zones, and using observers can be applied to limit the effects on marine mammals.

4.2.8 Pollution

The potential effects of pollution would be a consideration for many of the topics, such as water quality and marine ecology. The greatest risk of significant effect could occur during construction of the offshore turbines and therefore requires the development of detailed Construction Environmental Management Plans. Similarly pollution prevention procedures will be required during all O&M activities and a detailed plan will be required for decommissioning.

Where applicable the potential pollution effects will be evaluated and mitigation measures recommended as well as clear referencing to established industry good practice. Any offshore windfarm will be subject to a detailed post-construction monitoring plan, which will involve key stakeholders.

4.2.9 Visual Impact

Over the years, many proposed onshore wind farms have been refused planning consent because the visual impacts were deemed to be unacceptable to the local landscape, especially in areas of particular scenic or historic value. This is a less significant issue for offshore development, however, near-shore developments, such as that in Figure 4-2Figure 4-2, are very likely to meet public opposition to the visibility of turbines and infrastructure.

Figure 4-2, The presence of an offshore wind farm will have some degree of visual impact on the surrounding environment [Source: W. Szwecji]

For nearer shore developments, visual impacts can be assessed by surface visibility analysis which will identify a zone of visual Influence or the number of wind turbines that are visible from a fixed vantage point or an area; also known as viewshed analysis which can be determined through an assessment of the coastal and inland areas that have line of sight with the wind farm. This takes into account the topology of the land and earth's curvature as well as the dimensions of the proposed turbines.

Once the viewshed analysis has been undertaken, the affected areas can be identified and specific Seascape, Landscape and Visual Impact Assessment (SLVIA) can be undertaken for key onshore viewpoints. In a SLVIA, photographs of the view towards the offshore site are overlaid with graphical representations of the turbine profiles to present a predicted view of the wind farm once complete. An example of this analysis is shown in Figure 4-3Figure 4-3.

Scottish Natural Heritage have published "Guidance on Assessing the Impact on Coastal Landscape and Seascape" for offshore renewables[23].

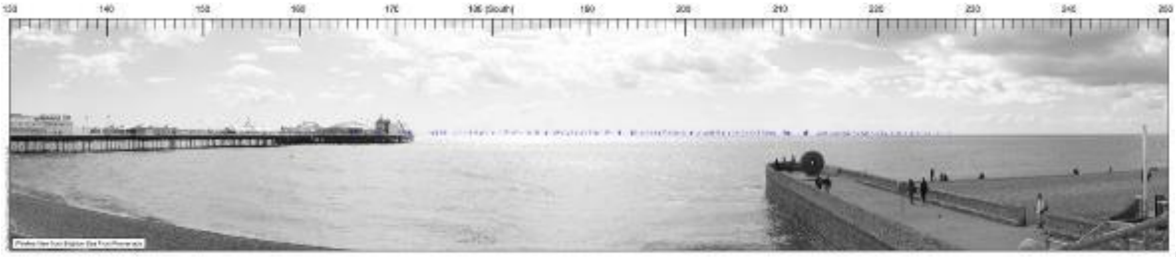

Figure 4-3, An example of a predicted visualisation of the Rampion wind farm from Brighton beach. Note; turbines are highlighted in purple to show them more clearly [Source: EON]

Typically, this process will be accompanied by public consultation and feedback to determine the level of opposition to the development. This may be high in regions with high coastal populations and tourism such as the example in Figure 4-3Figure 4-3.

Visual impacts may be mitigated by reducing the number of turbines; reducing rotor diameters and heights; or moving turbines further offshore.

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[23] http://www.snh.gov.uk/docs/A702206.pdf

4.2.10 Cumulative Effects

For each of the topics covered by the EIA, it is important to consider the potential Cumulative Effects in addition to the direct effects from a single project. This means that similar impacts from other offshore developments in the region should be taken into account and, where applicable, be assessed in-combination with the potential effects of the proposed project. In so doing the overall cumulative effect can be predicted.

Cumulative effects are becoming more important as the offshore wind industry matures and more projects are being constructed. There is an increasing requirement to consider, not just single species populations, but the marine ecosystem as a whole. Regions with good wind resource and suitable seabed characteristics will become popular and be populated by numerous projects.

4.3 Potential for Beneficial Impacts

4.3.1 Fisheries and Marine Ecology

There is a potential for local fish stocks to increase due to reduced fishing and provision of artificial reefs. A pioneering study[24] the Danish Horns Rev 1 offshore wind farm examined the long-term effects of the wind farm's presence on fish communities. Surveys were conducted in September 2001, before the wind farm was set up in 2002, and again in September 2009, 7 years after the commissioning. Overall fish abundance increased slightly in the area where the wind farm was installed but declined in the control area 6 km away. Species diversity was reported to be significantly higher close to the turbines. The study concluded that the artificial reef structures were large enough to attract fish species with a preference for rocky habitats, but not large enough to have adverse negative effects on species inhabiting the original sand bottom between the turbines. These findings were mostly attributed to sandeels which are a source of food for many of the fish studied in the investigation. The study stated that the offshore wind farm was neither a threat nor a direct benefit to sandeels but the sandeels might benefit from the exclusion of commercial fisheries from the wind farm area.

A five-year scientific study[25] has revealed the first offshore wind farm near Egmond aan Zee in the Netherlands has positively impacted life in and around the sea. The study found that there were higher concentrations of cod observed in the wind farm area than before the wind farm was built. The researchers attributed this to the absence of fisheries in this area and the copious amount of food sources near the turbine foundations.

Non-commercial fish and other marine species are likely to benefit from the provision of artificial reefs and reduced fishing. Although further evidence is required, it is possible that the marine biodiversity may increase above baseline given the new structures which offer shelter, foraging and potentially breed opportunities for marine species.

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[24] http://orbit.dtu.dk/files/7615058/246_2011_effect_of_the_horns_rev_1_offshore_wind_farm_on_fish_communities.pdf

[25] http://www.noordzeewind.nl/en/onderzoek-toont-aan-zeeleven-profiteert-van-eerste-offshore-windpark-van-nederland/

Figure 4-4, The colonisation of a monopile by shellfish at Scroby Sands creates a new subsea habitat. [Source: CEFAS]

4.3.2 Tourism

E.ON provided their Scroby Sands near-shore offshore wind farm with visitors' centre[26]. This has interactive educational models and information on the project, offshore wind and renewable energy in general. It is reported to attract 35,000 visitors each year.

Numerous offshore wind farms attract visitors on pleasure cruises to the offshore site[27] and local boat owners often benefit as a result. The authors of this report have frequently charted vessels from Whitstable and Ramsgate to take foreign visitors (on professional, educational trips) to the Kentish Flats and Thanet offshore wind farms. The vessel operators tend to be private individuals that usually offer fishing trip charters and they supplement their income with visits to the wind farms. Often, this can be very lucrative for them; typically earning fees of ~£300 per hour.

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[26] https://www.great-yarmouth.co.uk/Great-Yarmouth-Scroby-Sands-Visitor-Centre/details/?dms=3&feature=2&venue=0115995

[27] http://www.southbaltic-offshore.eu/news/imgs-media/2013_04_SBO_SOW_tourism_study_final_web.pdf

5. Economics

Offshore wind has tended to be a comparatively expensive source of renewable energy. However, the prices of the pot 3 projects for offshore wind awarded in the next UK Contracts for Differences (CfD) Allocation Round 4[28] for delivery windows in 2026/27 has fallen dramatically to strike prices of £46/MWh and a clearing price of £37.35/MWh (representing a maximum saving of 19% due to competition). This makes offshore wind among the most affordable of the pot 2 and 3 technologies in that delivery window. The CfD acts as a price stabilisation mechanism, ensuring certainty of revenue streams to offshore wind developers and lowering the effective weighted average cost of capital. If reference power price in the market is higher than the strike price, the difference flows to the Low Carbon Contracts Company (LCCC) but when the reference power price is lower than the strike price, the difference flows from the LCCC to the generator. Contracts are typically for a 15-year period. The previous high costs have been a direct result of the large technical challenges that need to be overcome in order to install and operate a wind farm in the sea. Understandably, this is significantly more complex and therefore costlier than onshore wind projects, but the advantages of offshore wind over other onshore renewables makes offshore wind an attractive option, provided there is enough financial and political support to ensure its viability.

This chapter presents the overview of the main elements that contribute to a project's capital and operational costs as well as its cost of energy. A comprehensive summary is also given to explain how the cost of offshore wind energy generation is now quickly reducing.

5.1 Capital Expenditure (CAPEX)

A project's CAPEX comprises a number of cost components including those for the: development and design of a project, purchase of onshore and offshore infrastructure, and the installation and commissioning of that infrastructure.

5.1.1 Projected Turbine Size and Load Factor

At a large picture level capex is forecast to decrease over time with economics of scale and scope and as wind turbine sizes increase, average load factors also increase as the UK Government, Department for Business, Energy and Industrial Strategy (BEIS) Electricity Generation Costs 2020 report[29] shows:

Table 5-1 Increasing Load Factor v Turbine MW

	2020	2025	2030	2035	2040
Projected turbine size/ MW	9	12	15	17.5	20
Projected load factor (net of availability)	47%	51%	57%	60%	63%

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[28] BEIS, 7 July 2022, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1103022/contracts-for-difference-allocation-round-4-results.pdf

[29] BEIS, August 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911817/electricity-generation-cost-report-2020.pdf

5.1.2 Current Capex

Present day total turnkey capex for offshore wind farms[30] is around £2,37million /MW for a 1,000MW offshore wind farm. This is based on the following key assumptions:

Parameter	Data
Wind farm rating (MW)	1000
Wind turbine rating (MW)	10
Water depth at site (m)	30
Annual mean wind speed at 100m height (m/s)	10
Distance to shore, grid, port (km)	60
Date of financial investment decision to proceed (FID)	2019
First operation date	2022

5.1.3 Future Capex Reduction Potential

Additionally, BEIS, forecasts a capex learning curve reduction trend as follows:

	2025	2030	2035	2040
Pre-development (£/kW)	130	130	130	130
Construction (£/kW)	1,500	1,300	1,100	1,100
Fixed O&M (£/MW/year)	36,300	28,800	24,500	22,500
Variable O&M (£/MWh)	4	4	4	4
Load factor (net of availability)	51%	57%	60%	63%
Operating period	30 years			
Decommissioning costs	Developers may incur a financing cost of providing decommissioning security but the effect on LCOE is less than £1/MWh			

These capex reductions are being driven by:

- Increased competition between project developers, financiers and suppliers
- Larger projects and turbines (9MW+) which benefit from economies of scale.
- The increasing capability of local supply chains which cuts costs by replacing imports with less expensive local goods and services.
- Technological innovation and learning by doing.
- Reduction of project risks, and greater investor understanding and confidence

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[30] Catapult, https://guidetoanoffshorewindfarm.com/wind-farm-costs

The figure below shows the key areas where there is the greatest potential to reduce the cost of offshore wind projects. The three main contributors are: the cost of wind turbines; the effect of competition in the market; and the cost of equity used by projects.

5.1.4 Typical Devex Breakdown

Table 5-2 A typical Devex breakdown[31] of £120,000/MW

Category	Rounded cost (£/MW)
Development and project management	**120,000**
Development and consenting services	50,000
Environmental impact assessments	8,000
Other (includes developer staff hours and other subcontract work)	42,000
Environmental surveys	4,000
Benthic environmental surveys	450
Fish and shellfish surveys	400
Ornithological environmental surveys	1,000
Marine mammal environmental surveys	1,000
Onshore environmental surveys	550
Human impact studies	350
Resource and metocean assessment	4,000
Structure	3,000
Sensors	650
Maintenance	300
Geological and hydrological surveys	4,000
Geophysical surveys	700
Geotechnical surveys	2,500
Hydrographic surveys	800
Engineering and consultancy	4,000
Other	54,000

5.1.5 Typical Capex Breakdown

Table 5-3 - A typical capex breakdown[32] of £2,250,000/MW

Category	Rounded cost (£/MW)
Turbine	**1,000,000**
Nacelle	400,000

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[31] Catapult, https://guidetoanoffshorewindfarm.com/wind-farm-costs

[32] Catapult, https://guidetoanoffshorewindfarm.com/wind-farm-costs

Bedplate	20,000
Main bearing	20,000
Main shaft	20,000
Gearbox	70,000
Generator	100,000
Power take-off	70,000
Control system	25,000
Yaw system	17,000
Yaw bearing	7,000
Nacelle auxiliary systems	7,000
Nacelle cover	10,000
Small engineering components	25,000
Structural fasteners	7,000
Rotor	190,000
Blades	130,000
Hub casting	15,000
Blade bearings	20,000
Pitch system	10,000
Spinner	2,000
Rotor auxiliary systems	4,000
Fabricated steel components	8,000
Structural fasteners	7,000
Tower	70,000
Steel	60,000
Tower internals	7,000
Other (includes assembly, wind turbine supplier aspects of installation and commissioning, profit and warranty)	340,000
Balance of plant	**600,000**
Cables	170,000
Export cable	130,000
Array cable	35,000
Cable protection	2,000
Turbine foundation	280,000
Transition piece	100,000
Corrosion protection	20,000
Scour protection	10,000

Offshore substation	120,000
Electrical system	45,000
Facilities	20,000
Structure	60,000
Onshore substation	30,000
Buildings, access and security	8,000
Other (includes electrical equipment and systems)	22,000
Operations base	3,000
Installation and commissioning	**650,000**
Foundation installation	100,000
Offshore substation installation	35,000
Onshore substation construction	25,000
Onshore export cable installation	5,000
Offshore cable installation	220,000
Cable burial	20,000
Cable pull-in	7,500
Electrical testing and termination	6,500
Other (includes cable-laying vessel, survey works, route clearance, cable protection systems	186,000
Turbine installation	50,000
Offshore logistics	3,500
Sea-based support	2,500
Marine coordination	850
Weather forecasting and metocean data	300
Other (insurance, contingency (spent) and construction project management)	212,000

5.1.6 Weighted Average Cost of Capital

The hurdle rate or weighted average cost of capital investigated by BEIS in their Electricity Generation Costs 2020 report shows in 2018 shows this to be around 6.3% for offshore wind, compared to 5.2% for onshore wind and 5.0% for solar PV.

5.2 Operational Expenditure (OPEX)

OPEX comprises all of the expenditure associated with the operation and maintenance of a project during its lifetime. In comparison to onshore wind projects, OPEX is significantly more expensive for offshore installations as access to the wind farm is dependent on specialist vessels and the weather. Any large maintenance interventions that become necessary through the failure of components could require systems, such as gearboxes, to be replaced which would necessitate the use of large jack-up vessels at costs similar to the initial installation of the turbines.

Table 5-4 - A typical breakdown of opex[33] of £75,000/MW

Opex	Rounded cost (£/MW)
Operation, maintenance and service (per annum)	75,000
Operations	25,000
Training	500
Onshore logistics	450
Offshore logistics	1,600
Health and safety inspections	400
Other (insurance, environmental studies and compensation payments)	22,000
Maintenance and service	50,000
Turbine maintenance and service	33,000
Balance of plant maintenance and service	18,000

Table 5-5 - A typical breakdown of decommissioning security [34] of £330,000/MW

Decommissioning	Rounded cost (£/MW)
Decommissioning	330,000
Turbine decommissioning	45,000
Foundation decommissioning	75,000
Cable decommissioning	140,000
Substation decommissioning	65,000

5.3 Levelised Cost of Energy (LCOE)

Levelised costs take into account the overall cost of energy across the lifetime of a project by calculating the present value of the total cost of building and operating a power plant over its lifetime. In the calculation of LCOE, capital and operational costs, depreciation, project life and discount rates are all taken into account, to produce long term figures for the cost of energy in £/MWh or equivalent. LCOE figures are useful to provide a comparable estimate of the cost of electricity from different sources.

The LCOE of offshore wind has been higher than the cost of thermal generation and onshore renewables. Consequently, government subsidies have been required to support offshore wind generation. Whilst offshore wind is still more expensive than other forms of electricity generation, the LCOE has fallen over the past few years and is expected to reduce dramatically.

BEIS estimated forecasts of LCOE for offshore wind and benchmark technologies are shown below for projects commissioning in 2025, £/MWh, in real 2018 prices:

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[33] Catapult, https://guidetoanoffshorewindfarm.com/wind-farm-costs

[34] Catapult, https://guidetoanoffshorewindfarm.com/wind-farm-costs

	CCGT H Class	Offshore Wind	Onshore Wind	Large Scale Solar	CCGT + CCS Post Combustion (FOAK)
Pre-Development	<1	3	3	3	<1
Construction Costs	7	31	27	30	23
Fixed O&M	2	19	10	10	4
Variable O&M	4	3	6	0	5
Fuel Costs	40	0	0	0	45
Carbon Costs	32	0	0	0	1
CO2 Transport and Storage	0	0	0	0	4
Decommissioning and waste	0	1	0	0	0
Total	85	57	46	44	85

Our own Nominal LCOE calculations using the detailed devex, capex, opex and decommissioning breakdown in the tables above provides an LCOE as follows which aligns strongly with the Catapult calculation giving a:

LCOE of £66.5/MWh with a Nominal WACC of 6.3%[35] which is taken from a BEIS publication, Table 2.7, Technology-specific hurdle rates provided by Europe Economics for offshore wind**.**

The LCOE formula we use is:

$$LCOE = \frac{\sum_{t=-5}^{n+1} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=-5}^{n+1} \frac{E_t}{(1+r)^t}}$$

Where:

Parameter	Value
I_t	Investment expenditure in year t
M_t	Operation, maintenance and service expenditure in year t
E_t	Net energy generation in year t
R	Discount rate (or Weighted Average Cost of Capital), and
N	Lifetime of the project in year

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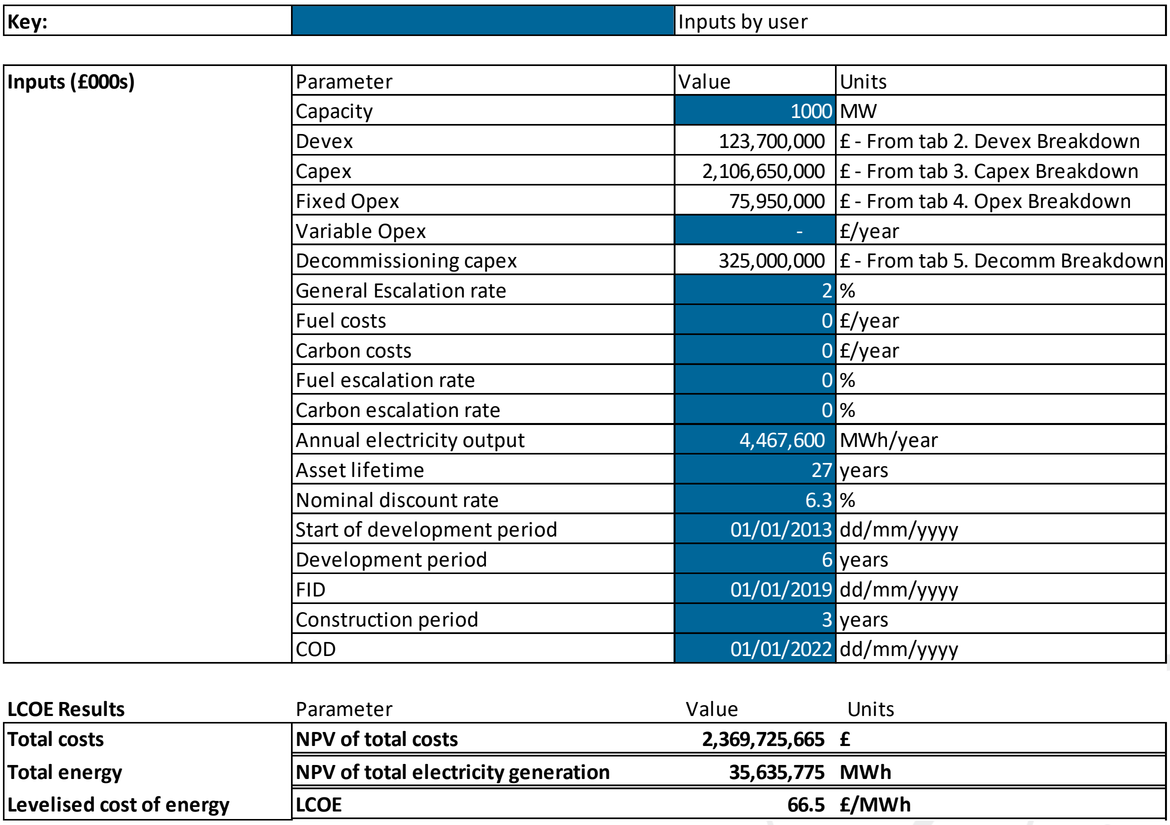
[35] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911817/electricity-generation-cost-report-2020.pdf

Key assumptions are:

Parameter	Value
Wind farm rating (MW)	1000
Wind turbine rating	10
Water depth at site (m)	30
Distance to shore, grid, port (km)	60
First operation date	2022
Annual average OPEX (£/MW)	76000
Nominal WACC (%)	6.3
Escalation (%)	2
Annual mean wind speed at 100m height (m/s)	10
Date of financial investment decision to proceed (FID)	2019
Total CAPEX (£/MW)	2,370,000
Lifetime (years)	27
Net annual average energy production (MWh/year)	4,467,600

An extract from our calculation dashboard is shown below:



Key:	🟦	Inputs by user

Inputs (£000s)	Parameter	Value	Units
	Capacity	1000	MW
	Devex	123,700,000	£ - From tab 2. Devex Breakdown
	Capex	2,106,650,000	£ - From tab 3. Capex Breakdown
	Fixed Opex	75,950,000	£ - From tab 4. Opex Breakdown
	Variable Opex	-	£/year
	Decommissioning capex	325,000,000	£ - From tab 5. Decomm Breakdown
	General Escalation rate	2	%
	Fuel costs	0	£/year
	Carbon costs	0	£/year
	Fuel escalation rate	0	%
	Carbon escalation rate	0	%
	Annual electricity output	4,467,600	MWh/year
	Asset lifetime	27	years
	Nominal discount rate	6.3	%
	Start of development period	01/01/2013	dd/mm/yyyy
	Development period	6	years
	FID	01/01/2019	dd/mm/yyyy
	Construction period	3	years
	COD	01/01/2022	dd/mm/yyyy

LCOE Results	Parameter	Value	Units
Total costs	**NPV of total costs**	**2,369,725,665**	**£**
Total energy	**NPV of total electricity generation**	**35,635,775**	**MWh**
Levelised cost of energy	**LCOE**	**66.5**	**£/MWh**

Chart 5-1 Electricity Generation and Project Expenses

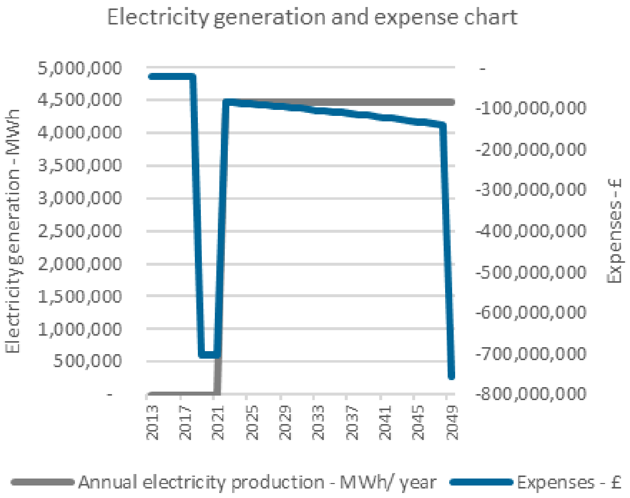
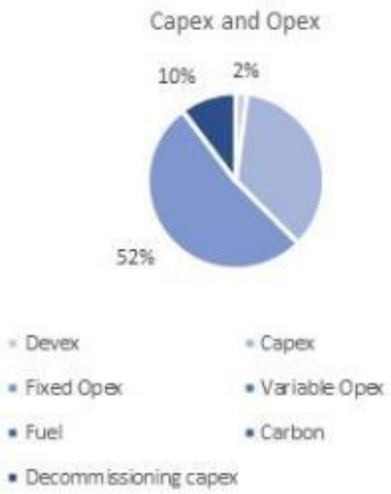


Chart 5-2 – Breakdown of Capex and Opex of the project



6. Jersey’s Waters

6.1 Ramsar

Jersey’s waters contain 4 Ramsar sites[36] and 4 OSPAR marine protected areas, (see Figure 6-1 and Figure 6.5) each focusing on the reef and intertidal habitats around Jersey. The Ramsar sites are designated areas protected under the Ramsar Convention and are important habitats for wildlife (e.g., birds, mammals, etc.). OSPAR sites are designated sites afforded protection under the Oslo-Paris Commission. In 2019 DEFRA approved Jersey’s application to extend Annex V to the island and also registered its MPAs with OSPAR. Jersey has two key habitats designated under OSPAR: maerl beds and Zostera (Seagrass) meadows. Both are high biodiversity habitats which are associated with beneficial ecosystem service functions including sediment stabilisation and removal of carbon from the atmosphere. The most significant of the Ramsar sites to this study is the one surrounding Les Minquiers reef to the south of Jersey[37].

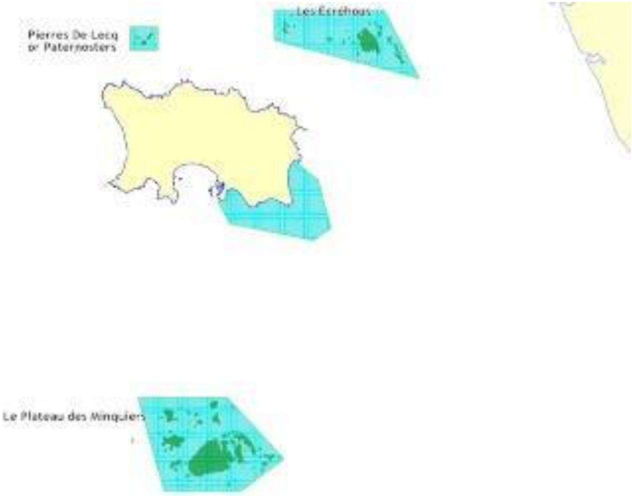


Figure 6-1, Jersey's four RAMSAR designated sites

6.2 Les Minquiers

Le Plateau des Minquiers comprise an extensive area of rock, reef and sand which, at low tide, more than 100km^2 is exposed above the water. At high tide the exposed area decreases to little more than 0.1km^2. The reef extends east/west about 16km and north/south for about 11km. Of this great rock plateau only nine small rock heads remain uncovered at high water. The largest one, La Maîtresse Île, is approximately 100m long by 50m wide and features a number of old, granite huts which are used as temporary accommodation for leisure visits. The huts are owned by Jersey residents and collectively the owners form the Maîtresse Île Residents’ Association (MIRA). MIRA is a potentially influential stakeholder group and likely to oppose any offshore wind developments in Jersey’s southern waters.

6.3 Geology & Sediments

Les Minqiers plateaux is formed by an igneous rock intrusion and is surrounded by sedimentary bed rock. The majority of the exposed rock is made up[38] of the characteristic 'foliated granodiorite' with small outcrops of diorite and pegamite. Within Les Minquiers area there are several sand and shingle banks. See Figure 6-2

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[36] https://www.gov.je/Environment/ProtectingEnvironment/SeaCoast/Pages/Ramsar.aspx

[37] Ramsar site no. 1456 (9,575 ha, 48°58'N 002°07'W)

[38] http://www.jerseygeologytrail.net/Offshore_Geology_Sea_Floor.shtml

for an overview of the geology within Jersey's southern waters – the French online data portal[39] provides further information on the bedrock and its characteristics.

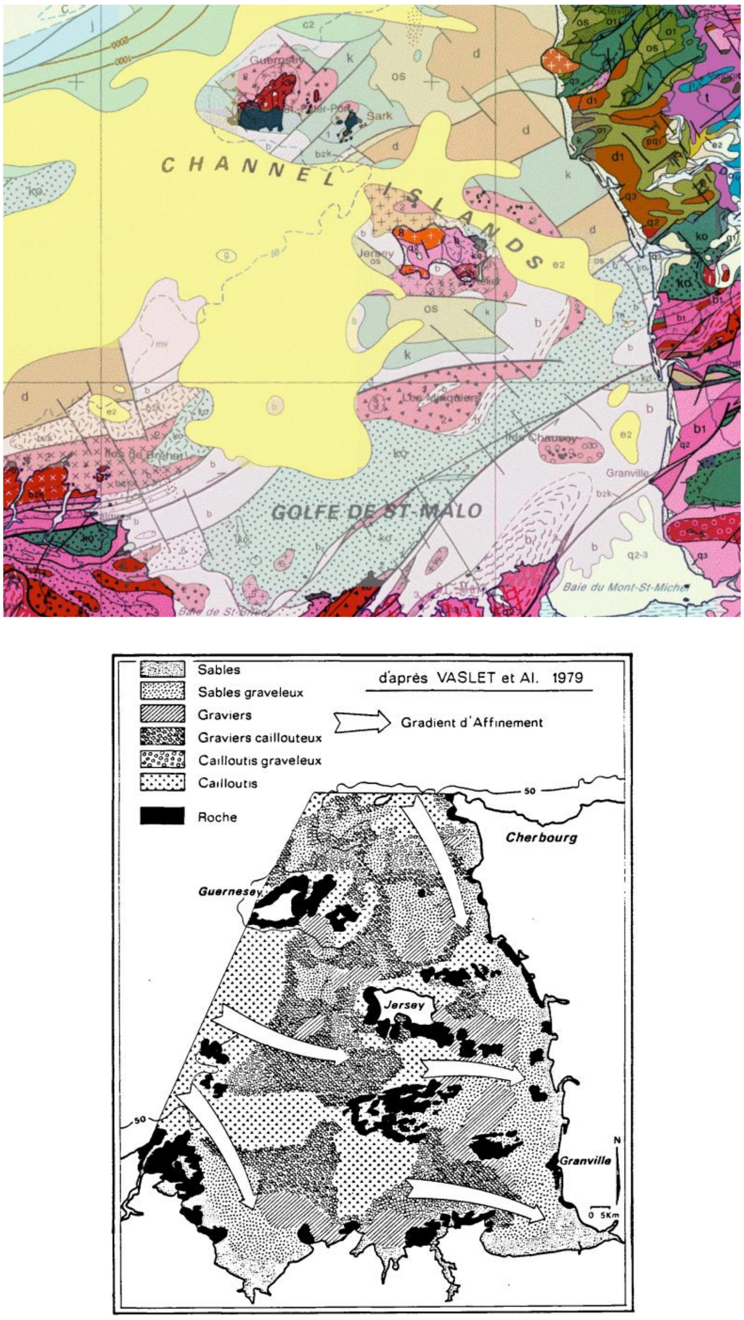

Figure 6-2, Geology of around Jersey and the Gulf of St Malo[39] [left]. Seabed characteristics around the Channel Islands [Right] [Source: Vaslet et Al[40]]

The seabed around Jersey's waters is predominantly Holocene (undifferentiated) gravels and pebbles, with areas of igneous granite rocky outcrops such as those in Les Minquiers reef.

The following table 6-1 describes the seabed conditions shown in Figure 6-3.

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[39] https://www.geoportail.gouv.fr/donnees/cartes-geologiques

[40] http://archimer.ifremer.fr/doc/00047/15837/13240.pdf

Table 6-1 Seabed Conditions

CL1a	CL1a Lithoclastic Pebbles (Pebbles +Carbonate >70%; Carbonate < 30%; lutites < 5%)
GL2a	GL2a Litho-bioclastic pebbly gravel (Pebbles + Carbonate >15%; Carbonate 30 - 50%; Lutite <5%)
CL1b	CL1b Lithoclastic Gravels (Gravels +Carbonate >70%; Carbonate < 30%; lutites < 5%)
GL1a	GL1a Lithoclastic-pebbly gravel (Pebbles + Carbonate > 15%; Carbonate <30%; lutites < 5%)

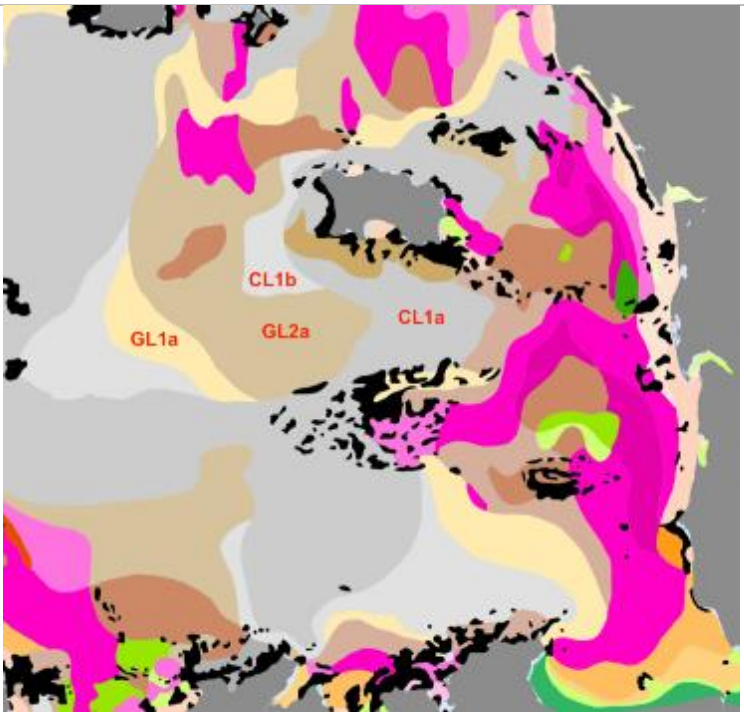

Figure 6-3, Seabed sediments around Jersey's waters [Source: Ifremer[41]]

6.4 Ecology

The reef is of Channel Islands Importance for seabirds and breeding birds including shag and cormorant. The extensive intertidal area provides feeding for large numbers of waders during passage periods and in winter, the tree mallow on La Maîtresse Île is an important refuge for passage migrants.

A small number of grey seals are often seen on and around the Minquiers and Pipettes. Additionally what is thought to be one of the largest populations of bottle nosed dolphins in the British Isles is also regularly seen in the area, particularly to the south of Les Écréhous, but also ranging between Les Écréhous and Les Minquiers.

As with any submerged environment, the subtidal ecology of Jersey's waters is challenging to characterise and little data exists to provide a good understanding of the benthic habitats. Work by Retiere (1979)[42] has recently been digitised and updated by Ifremer[43]. This has been incorporated into their benthic habitat maps for the waters around Normandy and Brittany – an excerpt of which is provided in Figure 6-4.

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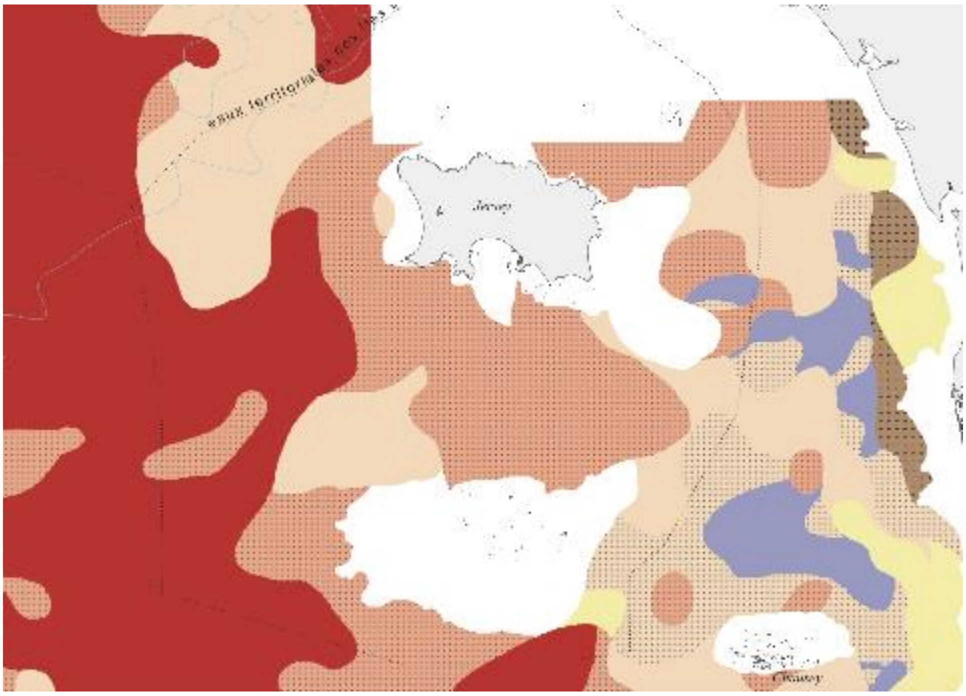
[41] http://sextant.ifremer.fr/fr/geoportail/sextant#/map

[42] Retiere (1979) Contribution a la connaissance des peuplements benthiques du golfe normanno-breton

[43] https://www.data.gouv.fr/fr/datasets/les-peuplements-benthiques-du-golfe-normanno-breton-source-retiere-c-1979-au-1-152000/#_



▨	A4.13_FR01	Sessile fauna on circalittoral coarse gravels and cobbles
🟥	A4.2144	Brittlestars on faunal and algal encrusted exposed to moderately wave-exposed circalittoral rock
🟨	A5.135	Glycera lapidum in impoverished infralittoral mobile gravel and sand
▨	A5.135_FR01	Coarse-gravel sandy sediment with Clausinella fasciata and Branchiostoma lanceolatum with scattered presence of maerl
🟪	A5.513	Lithothamnion corallioides maerl beds on infralittoral muddy gravel

Figure 6-4, Benthic habitats in Jersey's waters [Source: Ifremer[44]]

6.5 Subsea Cables

Jersey’s waters contain a number of subsea electrical interconnector and telecoms cables (Figure 6.5) that link the island to France, Guernsey and the UK. Whilst offshore wind farms can be installed in the vicinity of these cables, adequate safety buffers need to be applied to the cables and, if any cables are crossed by the wind farm’s subsea power cables, the risks associated with the cable crossings need to be carefully managed.

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[44] https://www.ifremer.fr/sextant_doc/granulats_marins/environnement/peupl_benthiques_bretagne_nord.pdf

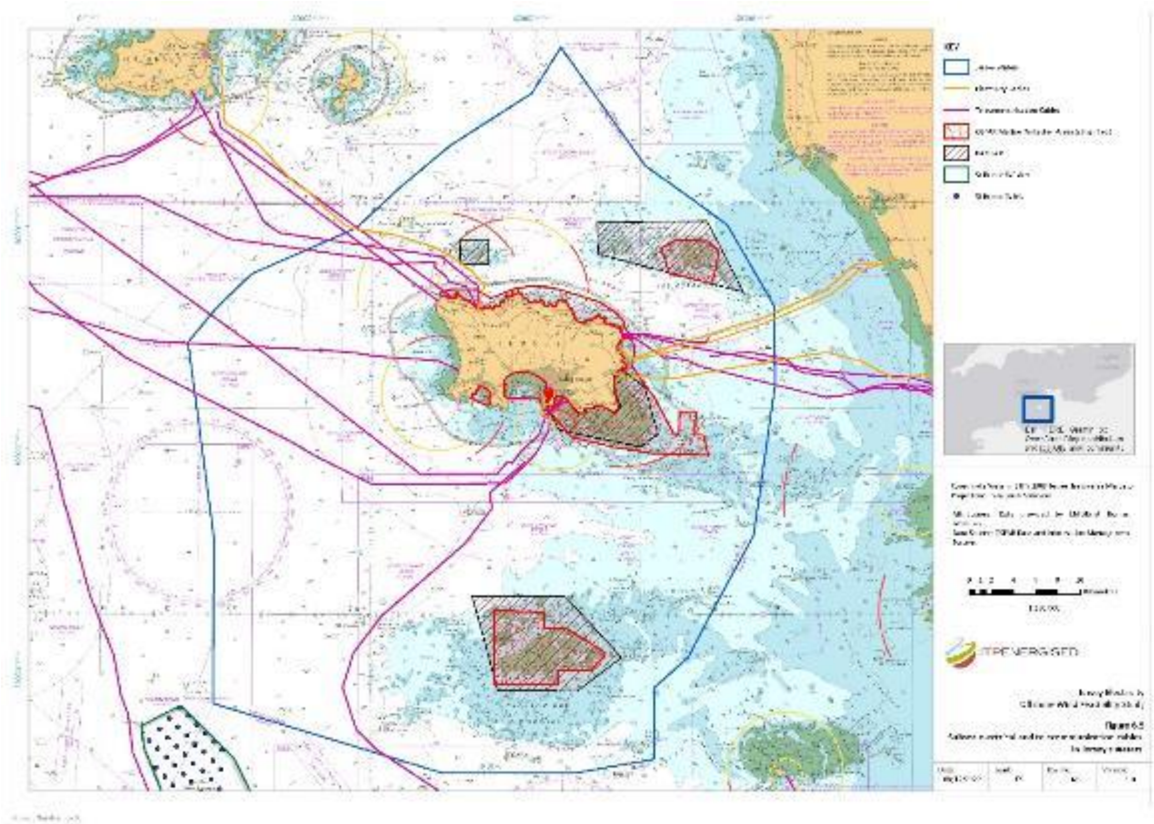

Figure 6-5, Subsea electrical and telecommunication cables in Jersey's waters

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6.6 Commercial Fisheries

Jersey's southern waters provide a rich fishing ground and is particularly fished for shellfish by both Jersey and French fishermen. Les Minquiers' reefs provide an important nursery for the lobsters and crabs that make up 70% of the value of Jersey fishermen's catch[45].

Jersey Territorial Waters were defined in 1997, extending the boundary either to 12 nautical miles or the median line. Access rights to fishing opportunities for French vessels in Jersey Waters and Jersey vessels in French Waters, together with management structures, were set out in the Granville Bay Agreement (GBA) of 2000 (which replaced the previous 1839 Agreement). In 2021, the GBA was itself been superseded by the Trade and Co-operation Agreement, which established the new relationship, including fisheries, between

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[45] ID FOI 6440 Marine Resources Annual Report 2021 20230523.pdf (gov.je)

the UK and the EU following the UK's decision to leave the EU.

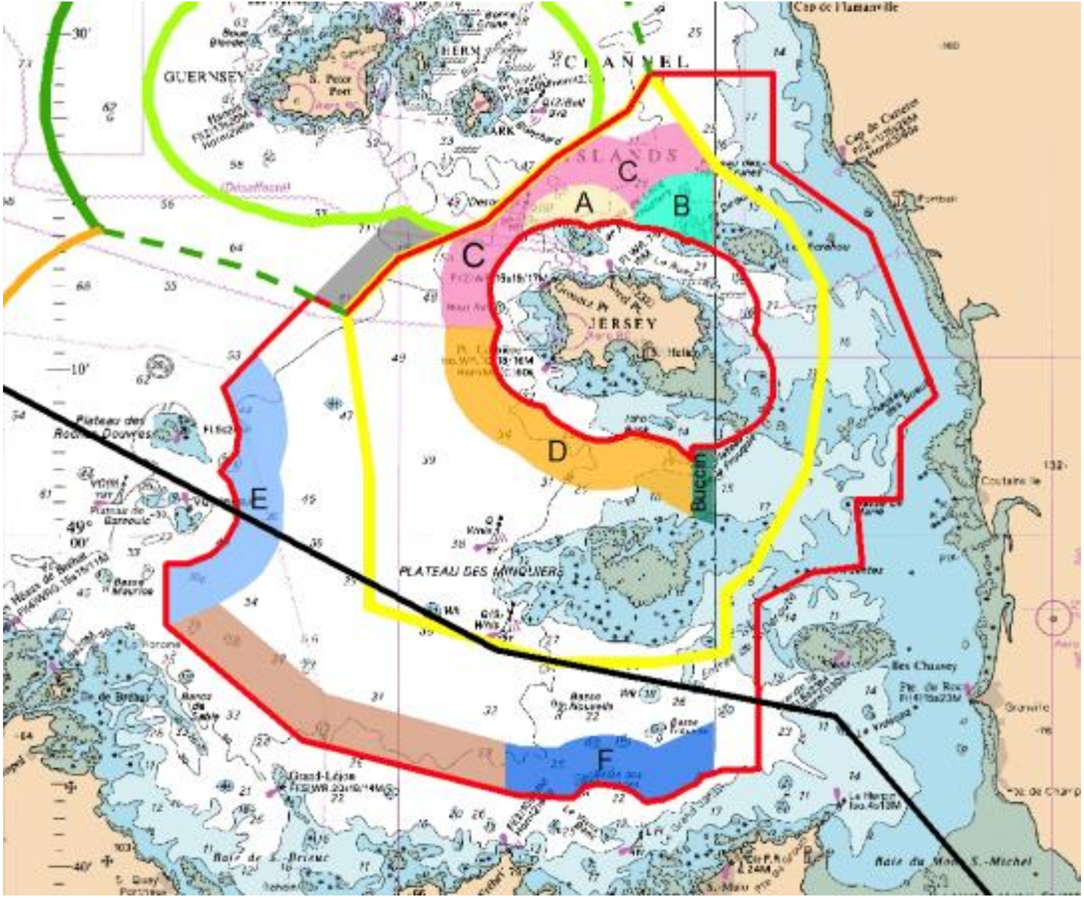

Figure 6-6, the fishing zones and access arrangements that were in force during the GBA.

A = Access for 8 French Boats	D = Access for 6 French Boats
B = Access for 27 French Boats	E = Access for 5 Jersey Boats
C = Access for 62 French Boats	F = Access for 2 Jersey Boats

6.7 Metocean Characteristics

6.7.1 Offshore Winds

In 2012 a 10m wind mast was installed[46] at Les Minquiers on a rock known as Les Maison (48° 58.70 N, 02° 10.38 W) – see Figure 6-7. Along with other instruments, this features two anemometers and an ultrasonic wind measurement sensor, all located at around 19m above mean sea level.

ITPEnergised was provided with all of the wind data that has been gathered by the three sensors since the mast was commissioned. Data was provided as average speeds over 10 minutes along with the maximum 3 second gust within that 10 minute period.

The availability of the data sets provided was generally good, with over 95% of the data present for the years 2014 and 2015 – see Table 6-2.

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[46] https://www.mygov.je/Planning/Pages/PlanningApplicationDocuments.aspx?s=1&r=P/2013/0090

Figure 6-7, Mast on Les Ecrehous – similar to that on Les Minquiers

Table 6-2, Data available from offshore wind measurement records

Raw Data			Missing		
2014	95.06%	complete	18.03	days	15th Sept
2015	97.30%	complete	9.86	days	20th July

Due to the friction of the earth's surface, wind speeds close to the surface are lower than those higher above it. The wind profile power law is a relationship between the wind speeds at one height, and those at another. The relationship uses the following expression to approximate this relationship;

$$u = u_r \left(\frac{Z}{Z_r}\right)^{\alpha}$$

Where u is the wind speed (in metres per second) at height z (in metres), and u_r is the known wind speed at a reference height z_r (in metres). The fixed wind shear coefficient exponent (α) is an empirically derived coefficient that, in this approximation, is constant. In reality, the wind shear coefficient α is not constant and depends on numerous factors including; atmospheric conditions, temperature, pressure, humidity, time of day, seasons of the year, the mean wind speed, direction, and nature of the terrain.

A wind shear coefficient $\alpha = 0.10$ will give a representative model of offshore wind shear and is likely to be slightly pessimistic[47]. This means that the wind speeds predicted for a point higher than those known lower down, could be lower than reality.

Table 6-3 shows the annual average and maximum 10 min average speeds recorded at Les Maison at 19m AMSL and the equivalent wind speeds predicted for a height of 110m AMSL using the previously described expression with a wind shear coefficient $\alpha = 0.10$.

Table 6-3, Average annual recorded (19m) and predicted (110m) wind speeds

Height [m]	Annual Ave Speed [m/s]		Max 10min Ave [m/s]	
	2014	**2015**	**2014**	**2015**
19	7.76	7.82	24.01	21.97

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[47] http://www.orbit.dtu.dk/files/10591005/DTU_Wind_Energy_E_report_0005.pdf

110	9.25	9.32	28.62	26.18

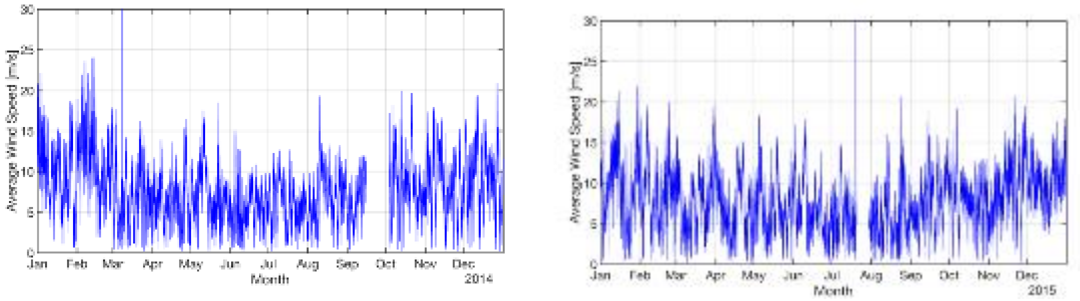

Figure 6-8, Raw data for 19m winds for 2014 (left) and 2015 (right)

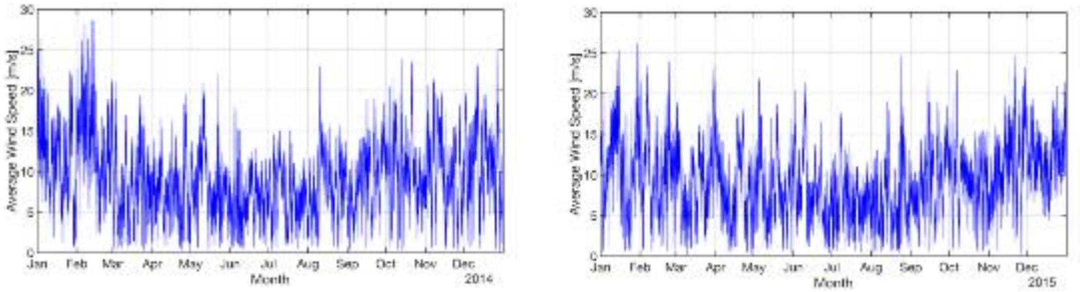

Figure 6-9, Hybrid data for 110m 2014 (left) and 2015 (right)

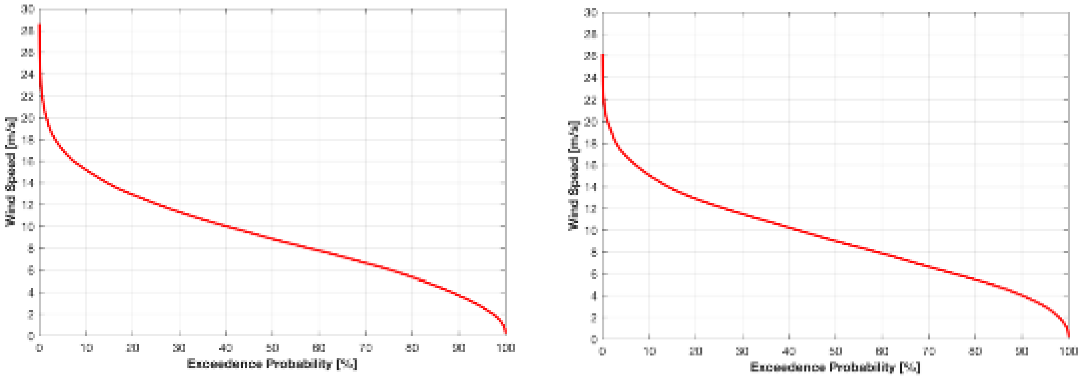

Figure 6-10, Exceedance curves for 110m estimations for 2014 (left) and 2015 (right)

In 2014 the 110m wind was less than 4m/s for 11.5% of the time, whereas for 2015 it was less than 4m/s for 9.9% of the year. Turbines tend to cut-in (start turning and generating) at around 4m/s, therefore for around 10% of the year a wind farm at this site would not generate any power at all.

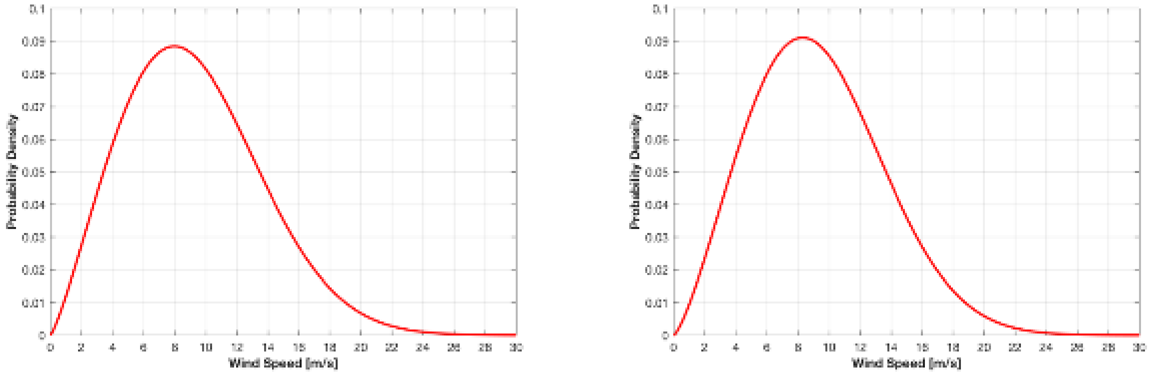

Figure 6-11, Weibull fitted probability curves for 110m estimations for 2014 (left) [shape factor 2.22] and 2015 (right) [shape factor 2.34]

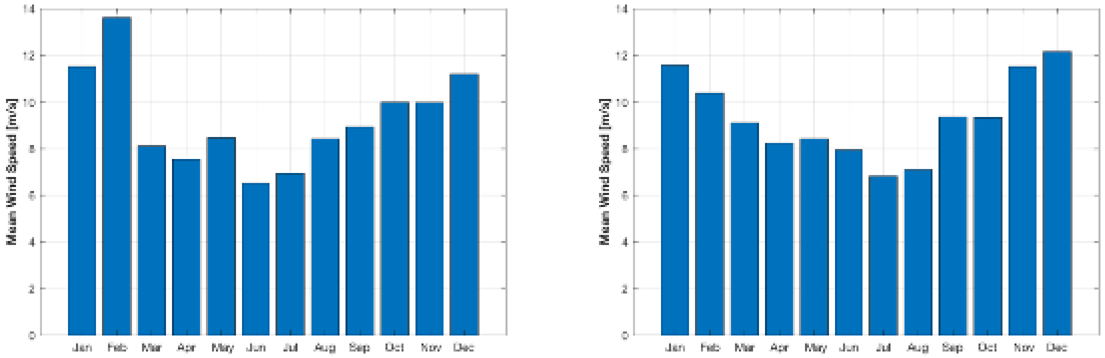

Figure 6-12, Monthly 110m wind speed averages for 2014 (left) and 2015 (right)

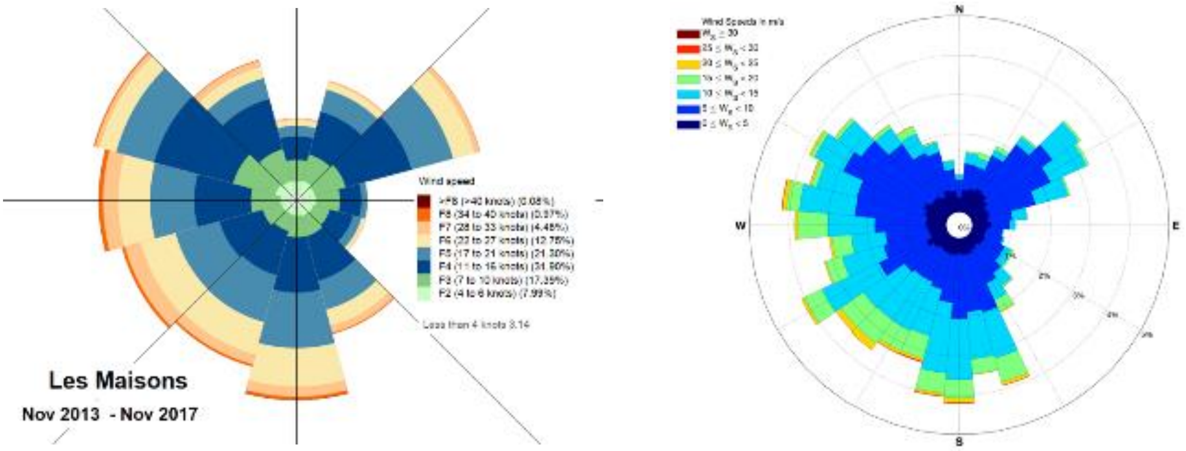

Figure 6-13, Wind rose showing direction and intensity – 19m winds over 4 years (left) and 110m winds for 2014 (right).

6.7.2 Waves

A weather buoy[48] (WMO 62027) has been operational off the south of Jersey since 2015 however, wave data availability is moderate as large periods are missing – see Figure 6-14. Note – WMO 62027 also records other metocean parameters such as near-sea surface winds.

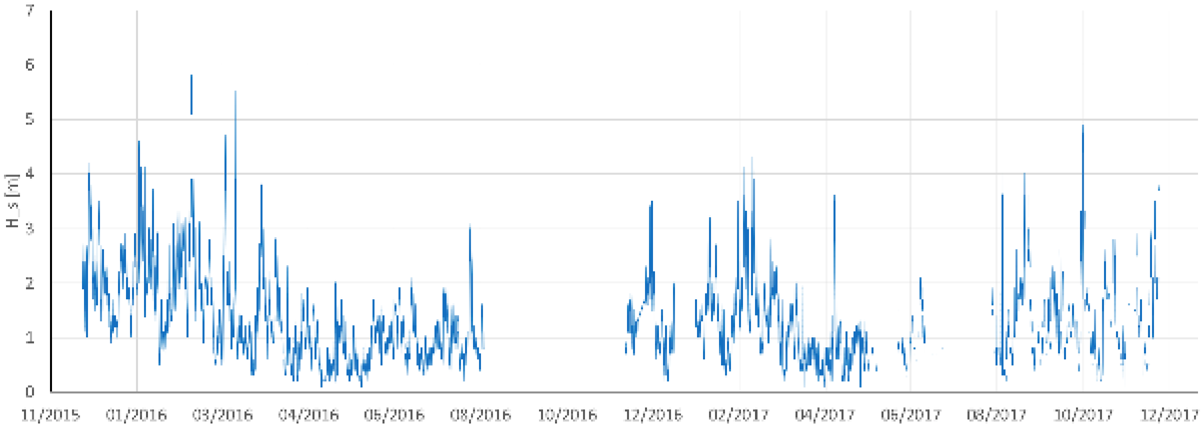

Figure 6-14, 3-hourly average significant wave height data from wave buoy 62027 over the past 2 years of deployment.

MetOcean Solutions Ltd (MSL) have in house and open access metocean models[49] for waves; SWAN (Simulating Waves Nearshore) and wind; Weather Research and Forecasting (WRF) Model. These provide hindcast data across a relatively course series of points in the waters of Northern Europe. Whilst this data is not sufficient for design, it provides an approximate guide to local conditions that could be expected. Figure 6-15 provides statistics derived from the hindcast data from the point 49N, 2.45W (a location in the centre of the main offshore wind zone of interest within Jersey's waters). These show that the vast majority of waves at the location arrive from the west; the North Atlantic, and that the conditions tend to be a mixture of low period wind seas and longer period swells. The data predicts that around 66% of the time the sea-state is H_s<1.5m – the upper limit for most offshore operations.

A French metocean buoy[50] (CANDHIS 02204) has also been operational off Brehat since 2016 and provides a range of measurements that could be used to validate future mesoscale wave models for example. An sample of the time series data, showing 30 minute average H_s for the Brehat location is given in Figure 6-16 and summary statics are provided in Figure 6-17. Since its deployment, the buoy has recorded an H_{max} exceeding 11m.

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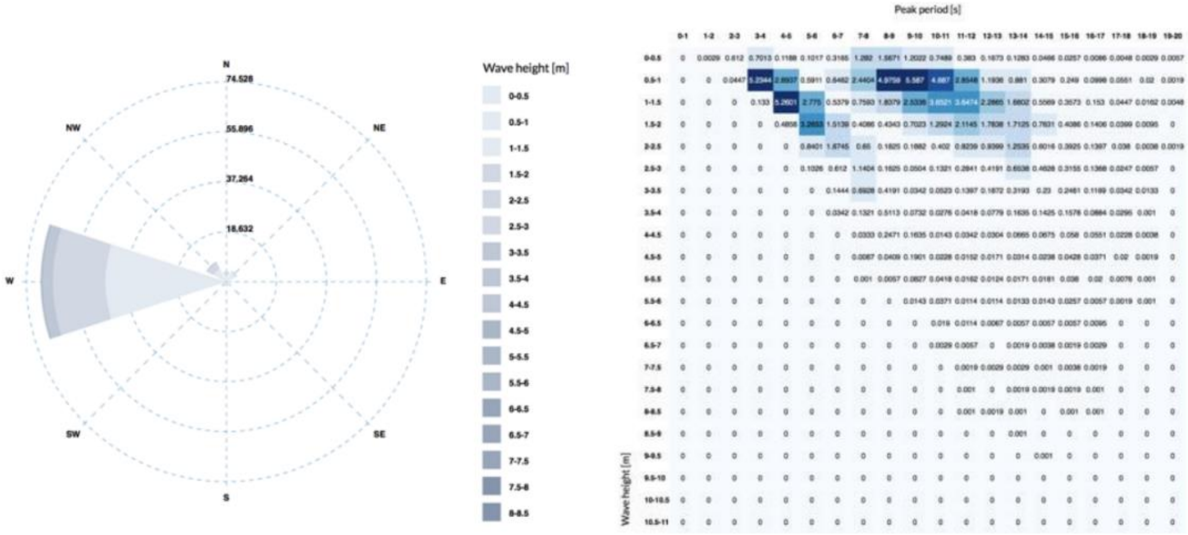
[48] http://www.ndbc.noaa.gov/station_page.php?station=62027

[49] https://app.metoceanview.com/hindcast/sites/nsea/49/-2.45#!

[50] http://candhis.cetmef.developpement-durable.gouv.fr/campagne/?idcampagne=013d407166ec4fa56eb1e1f8cbe183b9



Peak period [s]

Wave height [m]	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
0-0.5	0	0.0029	0.612	0.7013	0.1188	0.1017	0.3165	1.282	1.5671	1.2022	0.7489	0.383	0.1673	0.1283	0.0466	0.0257	0.0086	0.0048	0.0029	0.0057
0.5-1	0	0	0.0447	5.2344	2.8937	0.5911	0.6462	2.4404	4.9758	5.587	4.887	2.8548	1.1936	0.881	0.3079	0.249	0.0996	0.0551	0.02	0.0019
1-1.5	0	0	0	0.133	5.2901	2.775	0.5379	0.7593	1.8079	2.5336	3.8521	3.6474	2.2865	1.6802	0.5569	0.3573	0.153	0.0447	0.0162	0.0048
1.5-2	0	0	0	0	0.4858	3.2653	1.5139	0.4086	0.4343	0.7023	1.2924	2.1145	1.7808	1.7125	0.7631	0.4086	0.1406	0.0399	0.0095	0
2-2.5	0	0	0	0	0	0.8401	1.8745	0.65	0.1825	0.1682	0.402	0.8239	0.9399	1.2535	0.6016	0.3925	0.1397	0.038	0.0038	0.0019
2.5-3	0	0	0	0	0	0.1026	0.612	1.1404	0.1625	0.0504	0.1321	0.2641	0.4191	0.6538	0.4628	0.3155	0.1368	0.0247	0.0057	0
3-3.5	0	0	0	0	0	0	0.1444	0.6928	0.4191	0.0342	0.0523	0.1397	0.1872	0.3193	0.23	0.2461	0.1169	0.0342	0.0133	0
3.5-4	0	0	0	0	0	0	0.0342	0.1321	0.5113	0.0732	0.0276	0.0418	0.0779	0.1635	0.1425	0.1576	0.0884	0.0295	0.001	0
4-4.5	0	0	0	0	0	0	0	0.0333	0.2471	0.1635	0.0143	0.0342	0.0304	0.0665	0.0675	0.058	0.0551	0.0228	0.0038	0
4.5-5	0	0	0	0	0	0	0	0.0067	0.0409	0.1901	0.0228	0.0152	0.0171	0.0314	0.0238	0.0428	0.0371	0.02	0.0019	0
5-5.5	0	0	0	0	0	0	0	0.001	0.0057	0.0627	0.0418	0.0162	0.0124	0.0171	0.0181	0.038	0.02	0.0076	0.001	0
5.5-6	0	0	0	0	0	0	0	0	0	0.0143	0.0371	0.0114	0.0114	0.0133	0.0143	0.0257	0.0057	0.0019	0.001	0
6-6.5	0	0	0	0	0	0	0	0	0	0	0.019	0.0114	0.0067	0.0057	0.0057	0.0057	0.0095	0	0	0
6.5-7	0	0	0	0	0	0	0	0	0	0	0.0029	0.0057	0	0.0019	0.0038	0.0019	0.0029	0	0	0
7-7.5	0	0	0	0	0	0	0	0	0	0	0	0.0019	0.0029	0.0029	0.001	0.0038	0.0019	0	0	0
7.5-8	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0.0019	0.0019	0.0019	0.001	0	0	0
8-8.5	0	0	0	0	0	0	0	0	0	0	0	0.001	0.0019	0.001	0	0.001	0.001	0	0	0
8.5-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0
9-9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0
9.5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.5-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 6-15, Wave hindcast data for 49N 2.45W – [Left] annual percentage occurance by direction; [Right] annual percentage occurance by T_p and H_s. [Source: MetOcean Solutions]

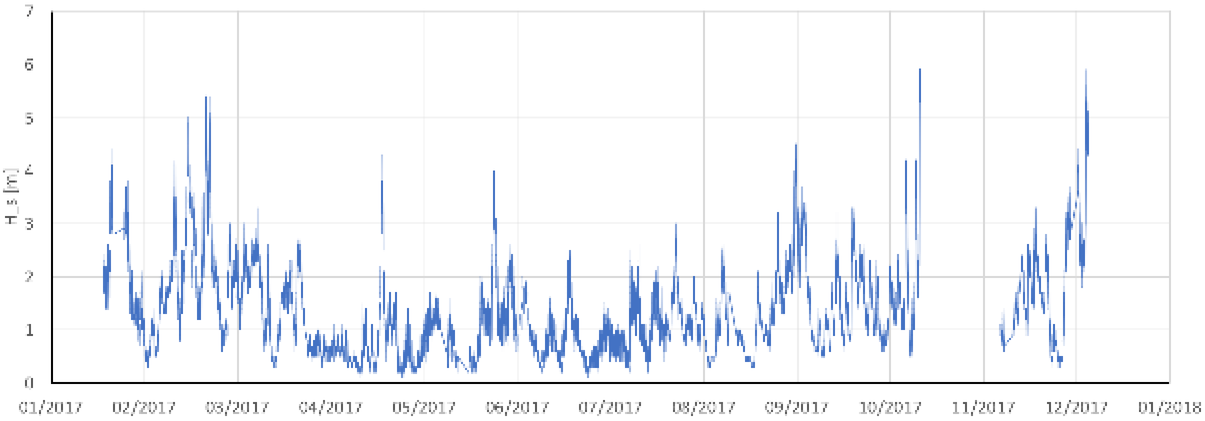


Figure 6-16, Brehat half hourly average significant wave heights for 2017 - CDH02204 [Source: Axsys[51]]

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[51] https://portal.axys-aps.com/downloadadvanced.aspx?id=CDH02204

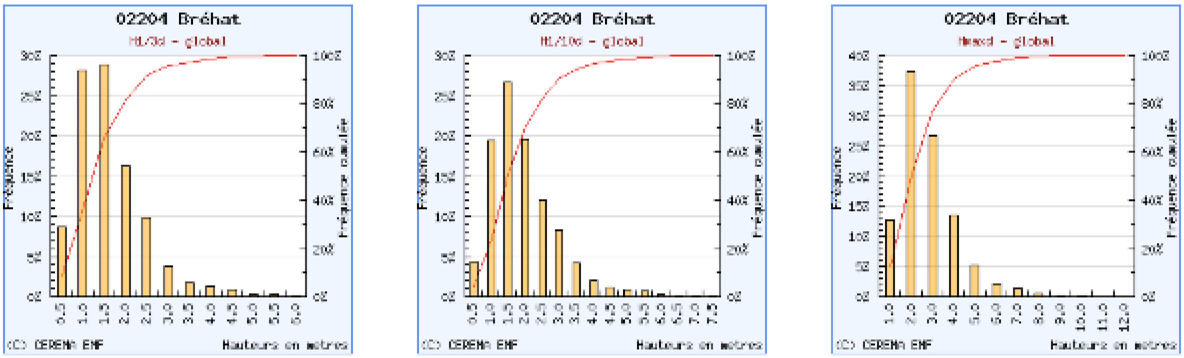

Figure 6-17, Brehat wave statistics for 2016-2018 [Source: CANDHIS[52]]

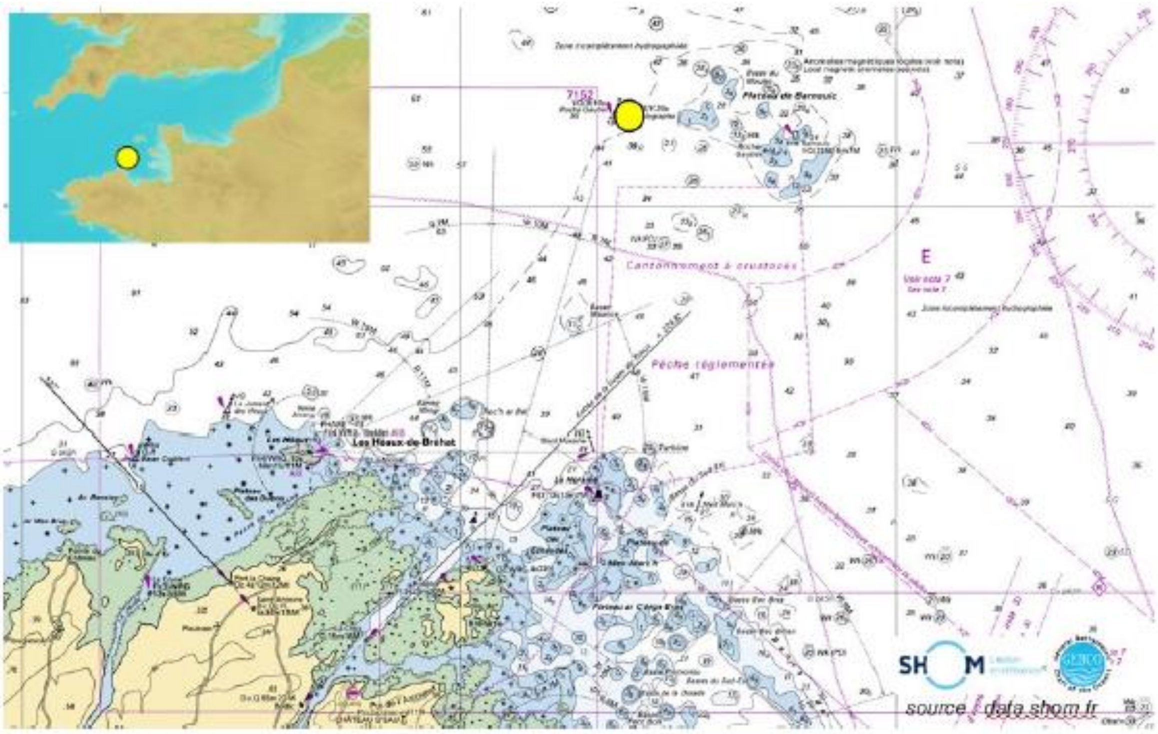

Figure 6-18 Location of Brehat 02204 – Source – Cerema Climat & Territoires de Demain; Candhis:analyses 2022 des etats de mer.

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[52] http://candhis.cetmef.developpement-durable.gouv.fr/publications/02204/histo_02204_global.pdf

7. Pre-feasibility for Jersey

7.1 Conceptual Design of Projects

7.1.1 Site Selection

The first phase in any wind farm development is the initial site selection. A good site selection process can greatly reduce development risk and cost, whilst increasing project returns. The starting point of this process involves looking at a chosen area in order to identify one or more suitable locations for wind farm development. Initial analysis generally uses published environmental and technical data, plotted on a Geographic Information System (GIS) where it is possible to analyse issues and deduce potential areas for wind farm development, then present these on a map. Subsequent phases will require more detailed site investigations.

It has become common practice in many countries to assign zones for development through a marine spatial plan / Strategic Environmental Assessment. Developers are then given the opportunity to bid for their preferred zones(s). Data collated for a Marine Spatial Plan is beneficial for developers in order for them to select sites that they are capable of developing and to submit competitive bids.

If provided with sufficient quality data, developers will be able to identify areas within the zones where they will prioritise development, and areas where they will not be able to install turbines. They will also be able to make preliminary decisions regarding foundation type and installation methods.

Broad site requirements for an offshore wind farm are initially defined. These parameters are chosen to strike a balance between ensuring the site will maximise its economic and technical potential, whilst maximising the chances of finding suitable sites that are likely to secure the relevant licences and permissions. Several of these constraints are absolute and based on technology or methodologies available. There are also a number which are particular to a developer and their circumstances, development strategy and risk appetite.

Key parameters are:

- The site must be in an area of high wind resource.
- The site must be in close proximity to the electrical grid in order to facilitate an economical connection to it.
- The site must be large enough to make it economically viable whilst allowing for adequate spacing between turbines.
- The water depth must be shallow enough to reduce foundation and installation costs.
- A selection of key planning, social, technical, physical and environmental criteria are then identified which could have an impact on the siting of a wind farm. These include:
- Water depth and bathymetry.
- Geology, sedimentology and nature of the seabed.
- Wave and tidal climate.
- Hurricane, typhoon and earthquake risk areas.
- Physical Infrastructure, including:
  - Bridges and tunnels.
  - Proposed reclamation areas.
  - Oil, gas and renewable energy sites.
- Undersea pipelines & cable routes (existing and proposed).

- Constrained water-spaces including:
    - Proposed marine parks and fisheries protection areas.
    - Dumping grounds.
    - Aggregate extraction areas.
    - Restricted areas and military practice areas.
    - Artificial reef deployment areas.
    - Marine fish culture zones.
    - Log ponds.
- Civil / military airports
- Proximity to ports.
- Shipping lanes, Fairways and Anchorage areas, including:
    - Ocean going vessel traffic patterns.
    - Local vessel traffic patterns.
    - Proximity to marine radar installations.
- Areas of medium to high fisheries production.
- Areas of high landscape / seascape value for visual amenity and recreational use.
- Marine parks, designated environmentally sensitive areas and ecologically valuable sites including:
    - Protected species or habitats.
    - Core area for seals and cetaceans.
    - Fisheries spawning areas.
    - Important bird feeding grounds and migration routes.
    - Areas of high coral value.
    - Sensitive tidal mudflats and sandbanks.
    - Areas of archaeological interest.

All of the constraints identified are plotted in GIS. Where appropriate, buffers are added to some selection criteria. Areas found to be relatively free of absolute constraints after the above analysis are compared against the desired site parameters and subjected to further analysis in order to identify potential 'show stoppers' that would render a site un-workable. This includes discussion with various stakeholders to take into account their view of potential sites.

By initiating dialogue with important stakeholders at an early stage of project planning a project developer may be able to obtain valuable feedback on key issues, thus saving abortive work and time and money addressing objections at a later stage.

Table 7-1, UK Project examples with water depths over 40m

PROJECT	DEPTHS	WTGs	CAPACITY	CAPEX COST
Beatrice	35-55m	SG-7.0-154	588 MW	£2.6bn (£4.4m/MW)
Neart na Goithe	44-56m	SG-8.0-167 DD	448 MW	£1.6bn (£3.6m/MW)
Inch Cape	36-57m	8MW 172m	784 MW	£3.0bn (£3.8m/MW)
Seagreen Alpha	31-71m	SG-7.0-167	525 MW	-

Moray East	39-50m	V164-9.5 MW	950 MW	£1.8bn (£1.9m/MW)

7.1.2 Wind Turbine and Infrastructure Layout

To determine layout concepts, wind turbines must be chosen for use in building base cases. It is best to choose wind turbines that are of the right size to meet the potential project envelope of any project site being considered and that can be envisaged as being used in the project due to either their proliferation and track record in the global market or convenience for supply to the local market. Ease of transport, local manufacturing and labour, foresight of supplier bottlenecks or availability should also be taken into consideration.

As such a project envelope (minimum and maximum) should be arrived at with base case turbines, to underpin any iterations of design.

In conjunction with the ground conditions model and wind resource assessment, different iterations of turbine layout can be produced.

During this time, other constraints can also be considered to help shape the spacing of turbines and the project boundary. These constraints include:

- Environmental impacts – particularly influence on birds
- Visual impact – array layouts will alter the visibility of the project from shore
- Navigational – informed by the navigational risk assessment and traffic surveys
- Access safety – including emergency rescue vessels and helicopters
- Grid connection – there may onshore grid capacity constraints that affects the size of the project envelope. There can also be factors in project layout that changes the subsea cabling installation, costs, and risks.
- Different spacing arrangements between the turbines.
- Orientation towards a predominant wind direction – iterations of layout to decide on how to best optimise the performance of the project considering the effect the upwind turbine wakes have on downwind turbines.

Exploration of the options for siting different types of turbines within the deployment area and the way in which the infrastructure such as cabling, offshore substations, onshore substations etc. will be connected to make optimal use of the site wind resource. This will include an estimation of annual energy generation from the project.

The iterations of the project layout with consideration of all the constraints should lead to an optimal arrangement being found – but should also allow some flexibility for changes as the project develops further and revisions or further optimisation may be required.

7.2 Feasibility of Offshore Wind for Jersey

Offshore wind is Jersey's largest renewable energy resource. Extracting energy from 5% of Jersey's offshore waters could generate 3.5 times Jersey's annual electricity demand.

The wind resource data below shows that annual average hub height wind speeds around Jersey are at least 9m/s and so, annual average project capacity factors of 40 – 45% could be expected. It should be noted that hub-heights are significantly higher than the 80m referenced and the winds speeds would therefore be between 3-7% higher.

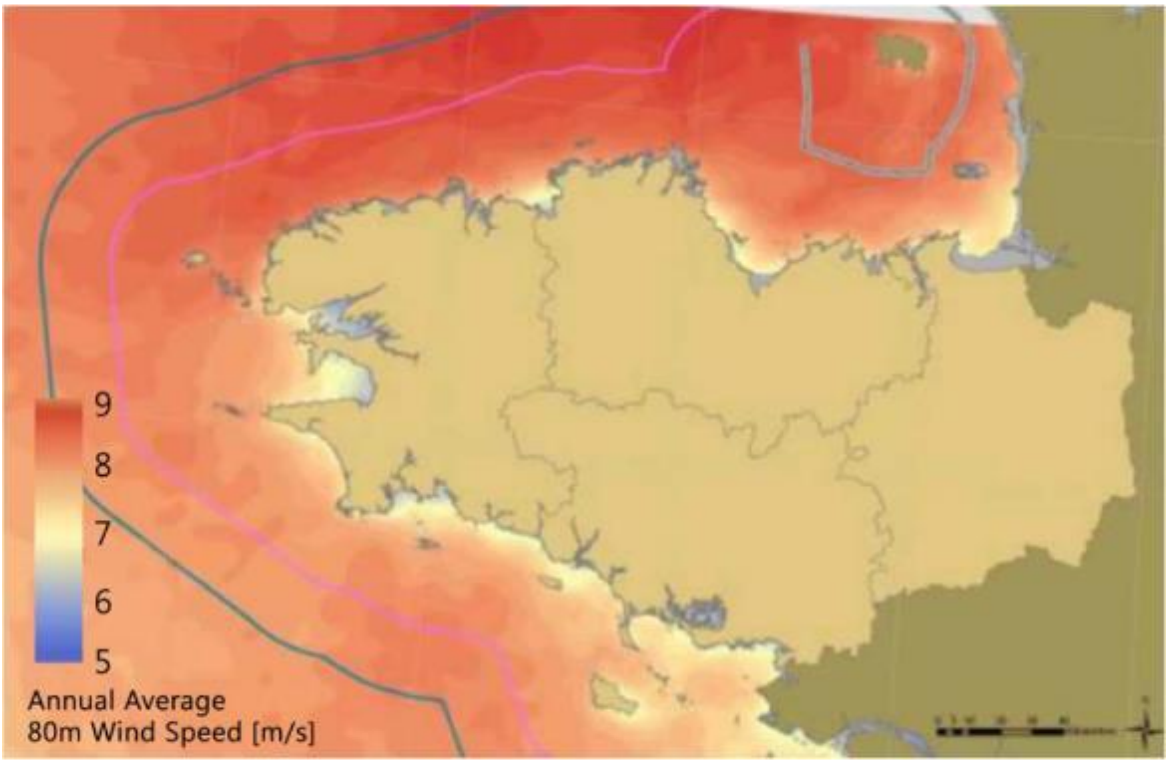

Figure 7-1 Annual Average offshore wind speeds at 80 m height around Brittany. [Source Meteo France]

The boundaries of Jersey's territorial waters encompass a total area of around 2,450km^2 (including land). Figure 7-2 shows the area theoretically available to offshore wind development – this only considers major constraints such as the presence of land/reefs or Ramsar sites. The region to the east of the island has been excluded as a combination of tidal flows, visual impacts and marine mammals are likely to make that region overly challenging to develop offshore wind. Considering basic constraints, the total area available for offshore wind in Jersey's waters is 1,600km^2. With the energetic offshore wind speeds present in Jersey's waters, 5MW/km^2 can be considered a reasonable estimate for the energy density of offshore wind sites (the St Brieuc project for example would generate 500MW from just over 100km^2). Actual densities will depend on the micrositing of turbines, being dependent on depth, ground conditions and other constraints as previously described in section 7.1.2. Planting offshore wind turbines with a density of 5MW/km^2 would therefore suggest a 6.5GW theoretical resource.

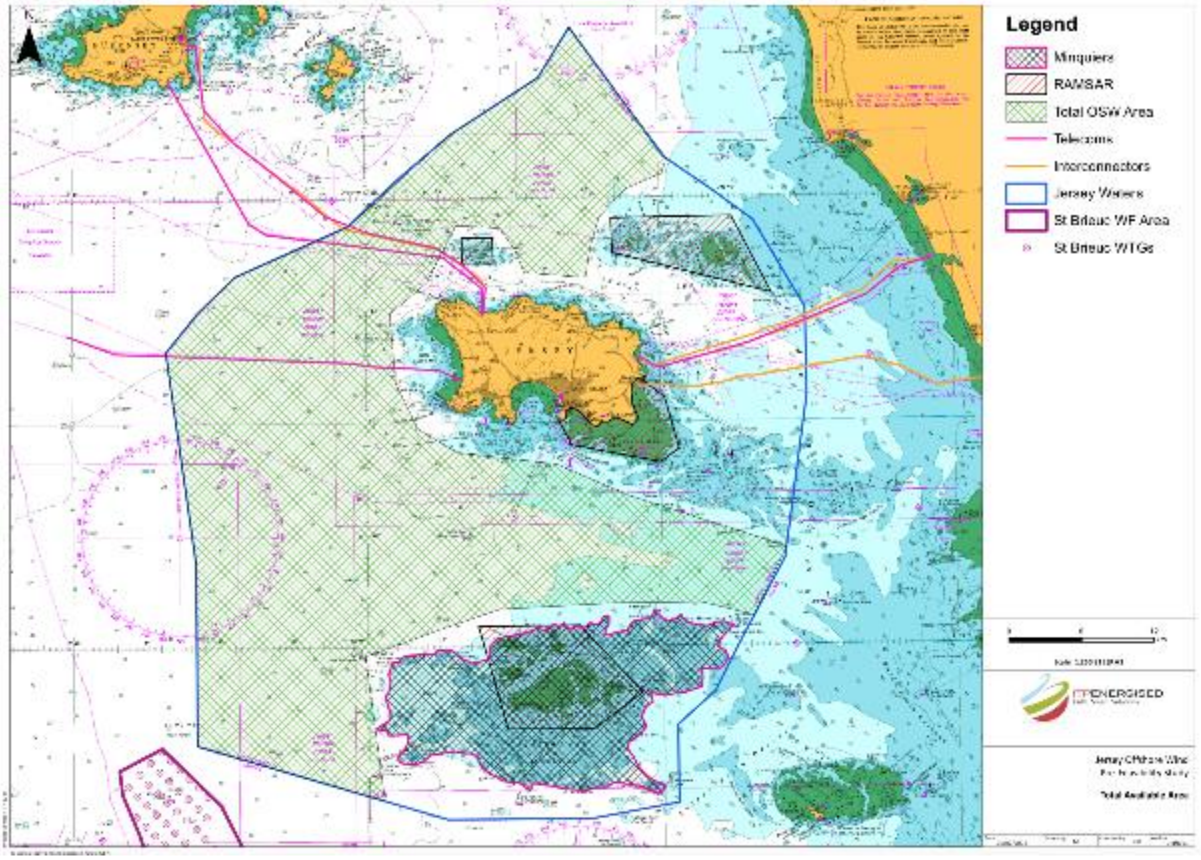

Figure 7-2, The total theoretical area available for offshore wind in Jersey's waters

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6.5GW is a theoretical offshore wind capacity as there are many other constraints to consider that would determine the technical, commercial and environmental viability of projects. For example, taking regions of high intensity shipping traffic and visual impact on Jersey's coast into consideration, would restrict the area available to offshore wind to 668km^2 – see Figure 7-3. Again, assuming a density of 5MW/km^2, Jersey has a 'practical' offshore wind resource potential of around 3.3 GW.

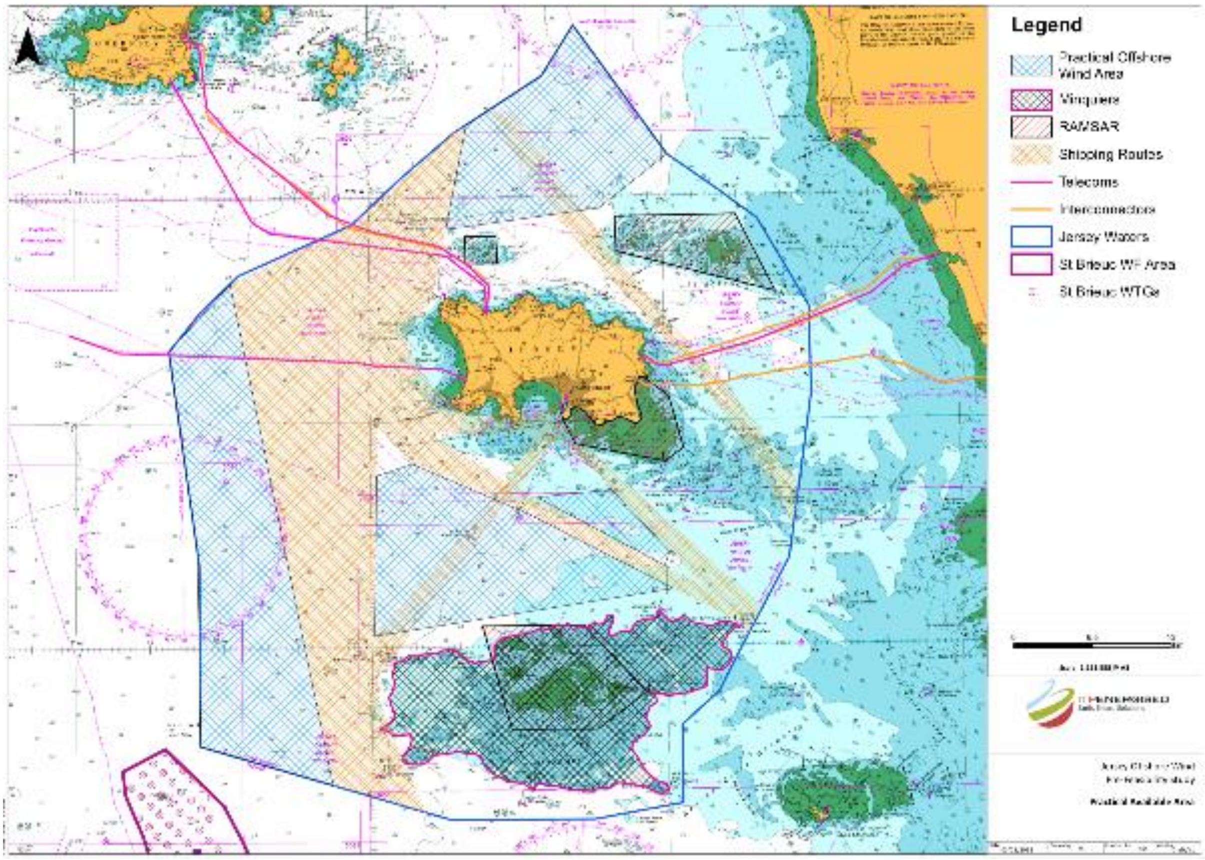

Figure 7-3, The practical area available for offshore wind in Jersey's waters.

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Whilst the practical area suggested in Figure 7-3 considers some constraints, the actual feasibility of offshore wind needs to be assessed on a project level.

There are two offshore wind project models that could be considered for Jersey;

- A large scale, commercial wind farm connected to the French transmission grid, either directly or via Jersey
- A low capacity wind farm, connected directly to Jersey to supply electricity locally

Both options are presented and discussed in the following sections.

7.3 Commercial Scale Project

7.3.1 Rationale

Carbon neutral Roadmap – Strategic Policy 2 establishes an overall energy policy position, including that the Government of Jersey will: *examine the options for utility scale renewable energy generation, to ensure a diverse, safe and resilient supply of energy to meet the Island's future needs*.

The neighbouring St Brieuc project was selected after careful consideration and ruling out of many other areas in the Gulf of St Malo. Developing further projects to either the east or west of the St Brieuc project would likely have a large impact on the navigation channels into St Malo and so, these are not favoured. Building directly to the north or north west of the St Brieuc site would result in deeper waters (>45m). Building to the south would increase visual impact at the French coast – this would be opposed by the coastal populations of Northern Brittany.

An offshore wind project to the north east of the St Brieuc site however, would have low visual impact in France, maintain modest water depths and wind resource, and not impinge on the navigation channels.

This project would need to be located entirely in Jersey's waters as a project that straddled the territorial waters boundary between Jersey and France would, from a regulatory perspective, likely be impossible without some form of high level political agreement.

Further benefits of locating a project close to an existing wind farm development include;

- **Higher certainty of wind resource data** – the existing project would have a long wind data record, meaning a nearby project may not require a wind measurement campaign if enough certainty could be given by the existing data. This also applies to other metocean conditions such as waves and currents.
- **Understanding of environmental receptors** – the existing wind farm would have undertaken years of pre and post construction environmental studies and surveys. Authorities would have a far better understanding of potential impacts from a new project.
- **Knowledge of ground conditions** - geological models could be developed from the ground conditions observed in the development of the existing wind farm. This would depend on the variability of the local geology.
- **Potential to share O&M ports, crews and facilities** – depending on the developers preferences, it may be possible for some O&M services and equipment to be shared between the two projects.
- **Sharing of cable landfall, onshore cable routing and onshore grid connection** – the existing project would have undertaken many studies on landfall, cable route and onshore substation options and subsequently consented and constructed the best choice. This could make installing a second set of onshore electrical infrastructure more straightforward.

It should be noted that, it would not be practical to connect the new wind farm onto the offshore electrical infrastructure of the existing project. In the case of St Brieuc, the offshore substation and cables would have been designed for the project's 496MW capacity, meaning that a new substation and export cabling would be required if further generation capacity were added nearby.

7.3.2 Site Selection and Project Description

As a commercial scale project would feature a large number of turbines, only regions further than 15km from shore were considered in order to reduce the visual impact on Jersey's coastline. This buffer would also help to reduce impact on Jersey Airport's radar services – an issue previously discussed in section 4.2.3.

Figure 7-4 shows the area of Jersey's waters that are suitable for large scale offshore wind projects outside of the 15km buffer zone. The only practical area is the sea space to the West and South West of the island. This area also avoids encroaching on Les Minquiers reef and is also kept some distance from Les Minquier's Ramsar site.

There is a high density of shipping activity within Jersey's waters; this includes both large commercial vessels and smaller recreational and fisheries vessels. AIS ('Automatic Identifications System') tracking data for the UK is collected by the Maritime and Coastguard Agency and is available from ABPmer[53]. This dataset has been sampled from the first seven days of every month of 2015, providing 84 days of AIS information. AIS is able to track vessels with a gross tonnage greater than 300 tonnes, passenger ships, and a number of smaller commercial fisheries and leisure vessels. This dataset was applied to Jersey's waters and is shown in Figure 7-4. The vessel tracks around the island into and out of St Helier are clear, as are the tracks avoiding Les Minquiers. The sea to the west of the island and Les Minquiers has a high density of shipping traffic.

The main busy regions of shipping traffic should be avoided when selecting potential offshore wind sites. The region identified as being suitable for utility scale offshore wind projects appears to be frequently traversed by many vessels, particularly close to Les Minquiers. This region was subsequently reduced in size (see yellow boundary zone in Figure 7-4) to minimise any impact on common navigational routes. The area remaining after taking shipping activities into account is shown in Figure 7-5. A 5km gap has been provided

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[53] http://www.abpmer.co.uk/buzz/view-the-new-uk-2015-national-dataset-of-marine-vessel-traffic/

(see Figure 7-7) between this area and the western extreme of Les Minquires in order to allow shipping to have safe passage between the reef and any future offshore wind farm.

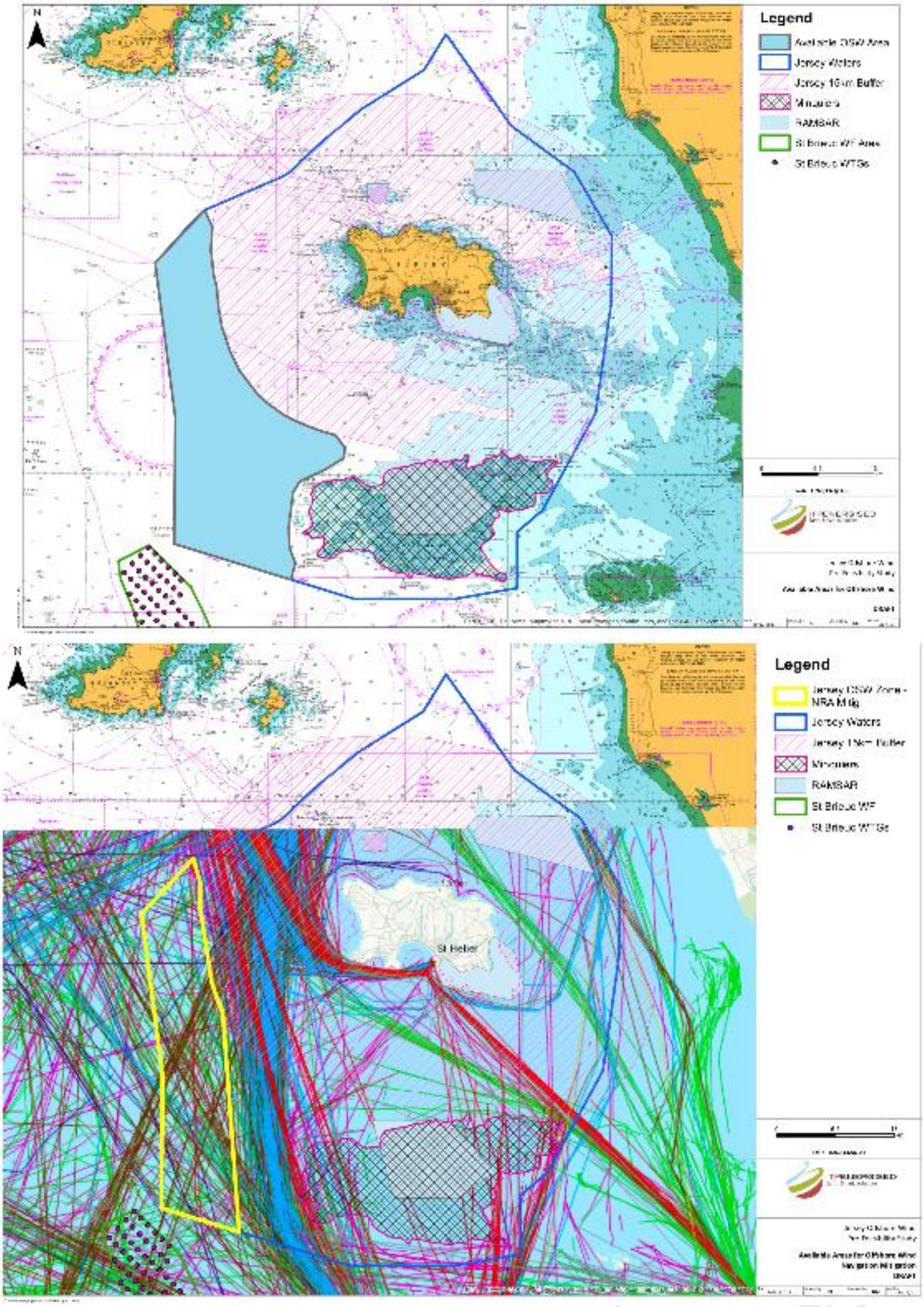

Figure 7-4, The area available for commercial scale offshore wind development outside of the 15km coastal buffer [left] and the remaining area available when considering shipping traffic [right].

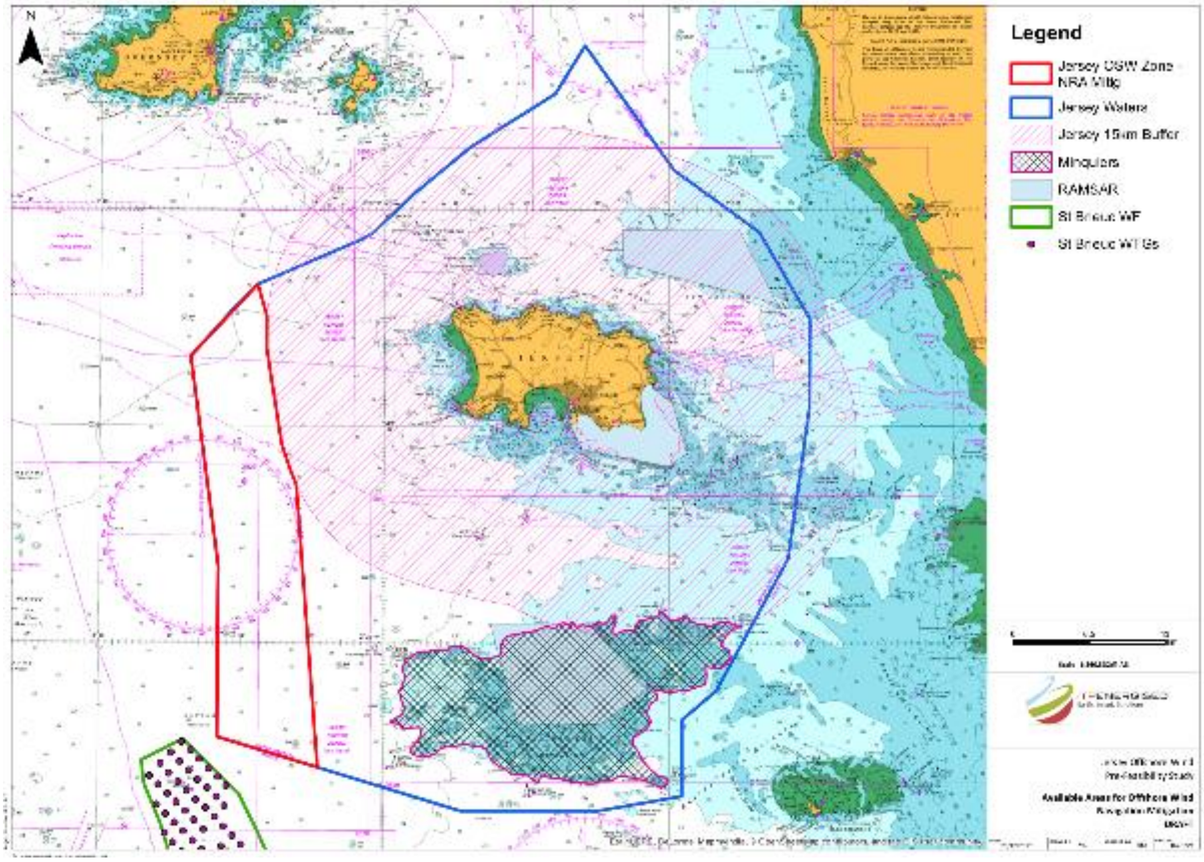

Figure 7-5, Potential area for large utility scale offshore wind deployment.

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The available area shown in Figure 7-5 could have potential for a multi-GW offshore wind project, however a development of this scale in Jersey's waters would likely be deemed to have too large an effect on the local conditions.

The northern region of the area shown in Figure 7-5 is crossed by the flightpath into Jersey Airport. It is possible that a large offshore wind farm in this area could compromise the radar visibility of aircraft landing on an approach in the easterly direction. For this reason, part of this area has been excluded to avoid potential aviation radar conflict.

The remaining area was then roughly divided into two zones; the southern zone being designated Offshore A and the northern zone as Offshore B. These are shown in Figure 7-6.

As the main strategic case for this large utility scale project is the export of power to France and to benefit from similarities or common data with the St Brieuc project, Offshore A is the preferred zone for this project due to its further distance from Jersey (lower visual impact) and proximity to France and the St Brieuc project.

It should be noted that the boundary between Offshore A and B is arbitrary – for a future development, this boundary could be moved north or south depending on the intended scale of the project to be developed.

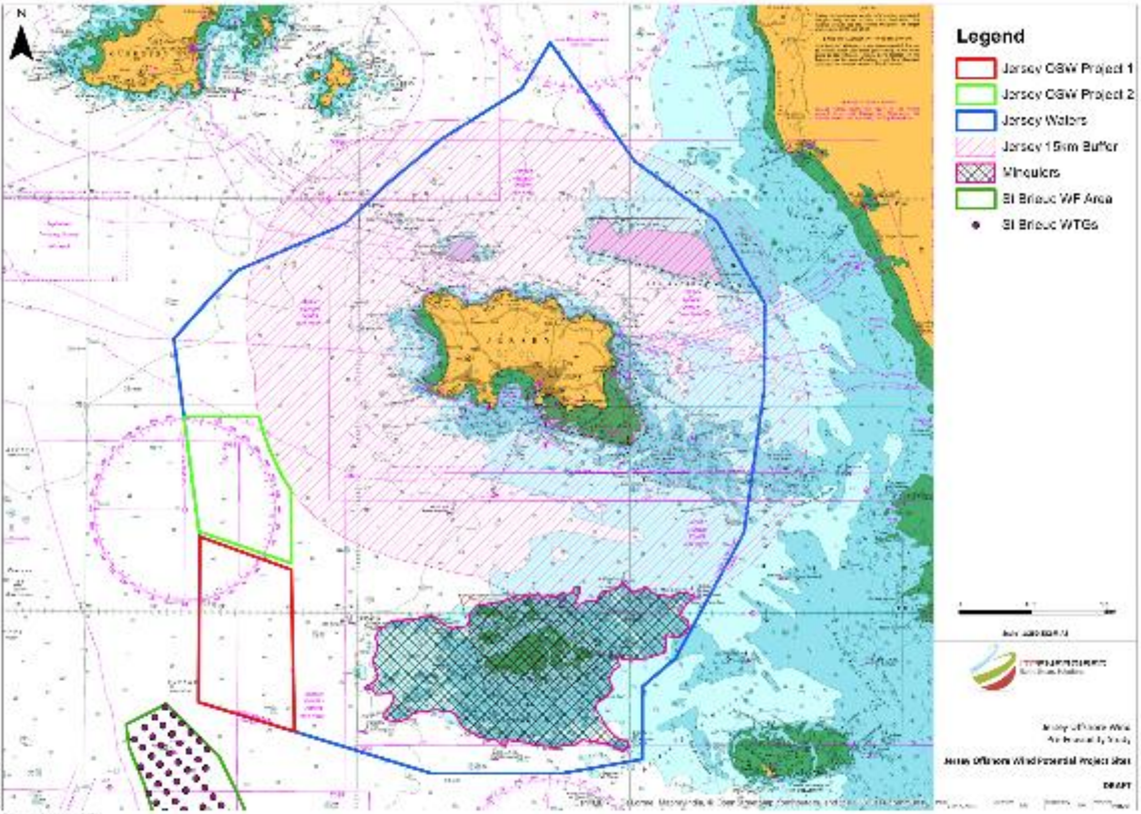

Figure 7-6, Two possible sites for commercial scale development - Offshore A [Red] & Offshore B [Green]

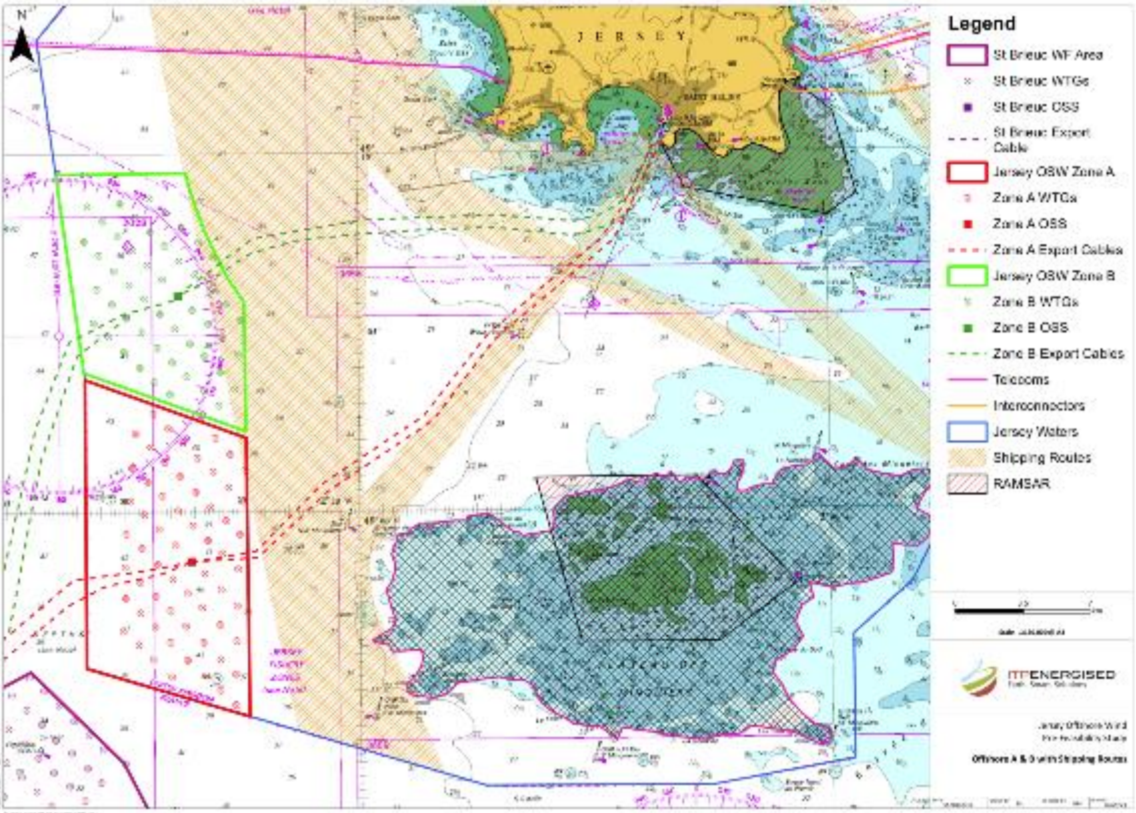

Figure 7-7, A 5km gap has been provided to allow shipping to pass between the Offshore A & B sites and Les Minquiers NW marker buoy

Offshore A

The project concept suggested for Offshore A is in keeping with the characteristics of the St Brieuc project and would provide an opportunity that is of sufficient scale to be attractive to offshore wind developers. It comprises 62 x 8MW turbines, providing a total capacity of 496MW.

Depths across the site vary from 38m to 48m however, initial turbine locations have been chosen to avoid the deeper water (+45m) to the western part of the site.

Key distances include;

- 7.7km to nearest part of Les Minquiers Reef
- 15.2km to nearest point to Les Minquiers Ramsar
- 26.5km to Maîtresse Île
- 20.3 km to Corbière
- 26.5km to Elizabeth Castle

As with the St Brieuc project, the turbines are aligned to the prevailing south-westerly wind direction. In the axis parallel to the prevailing wind directions, turbines are placed one in front of another with a downwind spacing of ~1,300m (7.8 Rotar Diameter). The side by side, crosswind spacing is around 1,000m (6 Rotor Diameter).

Offshore A encompasses seabed which is predominantly a mixture of exposed circalittoral rock, coarse gravels and cobbles. Given the depth, ground conditions, large tidal range and large turbines being used, jacket substructures with piled foundations are almost certainty going to be the most suitable option – this is in-line with the foundations and substructures within the St Brieuc project.

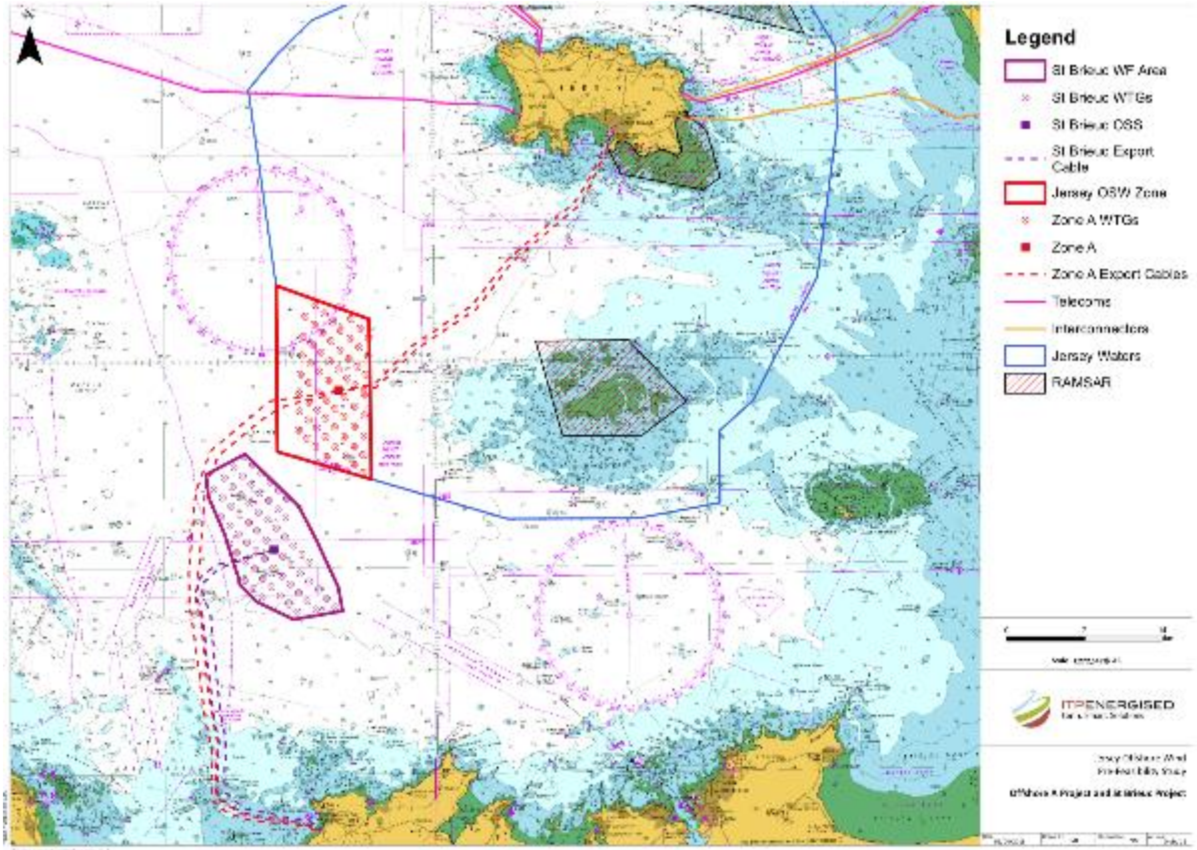

Figure 7-8, Offshore A showing an indicative turbine layout & export cable routes to France/Jersey.

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Offshore B

The Offshore B zone lies to the north of Offshore A and so is 6-7km further from France. Electrical costs will be higher and will have more visual impact on Jersey. It is therefore deemed less attractive than Offshore A. The example project concept shown in Figure 7-9 comprises 50 x 8MW turbines, providing a total capacity of 400MW.

Offshore B could be an extension to Offshore A or included partially or wholly within Offshore A to make a larger scale project or find more suitable waters if future site investigations reveal unfavourable conditions within areas of Offshore A.

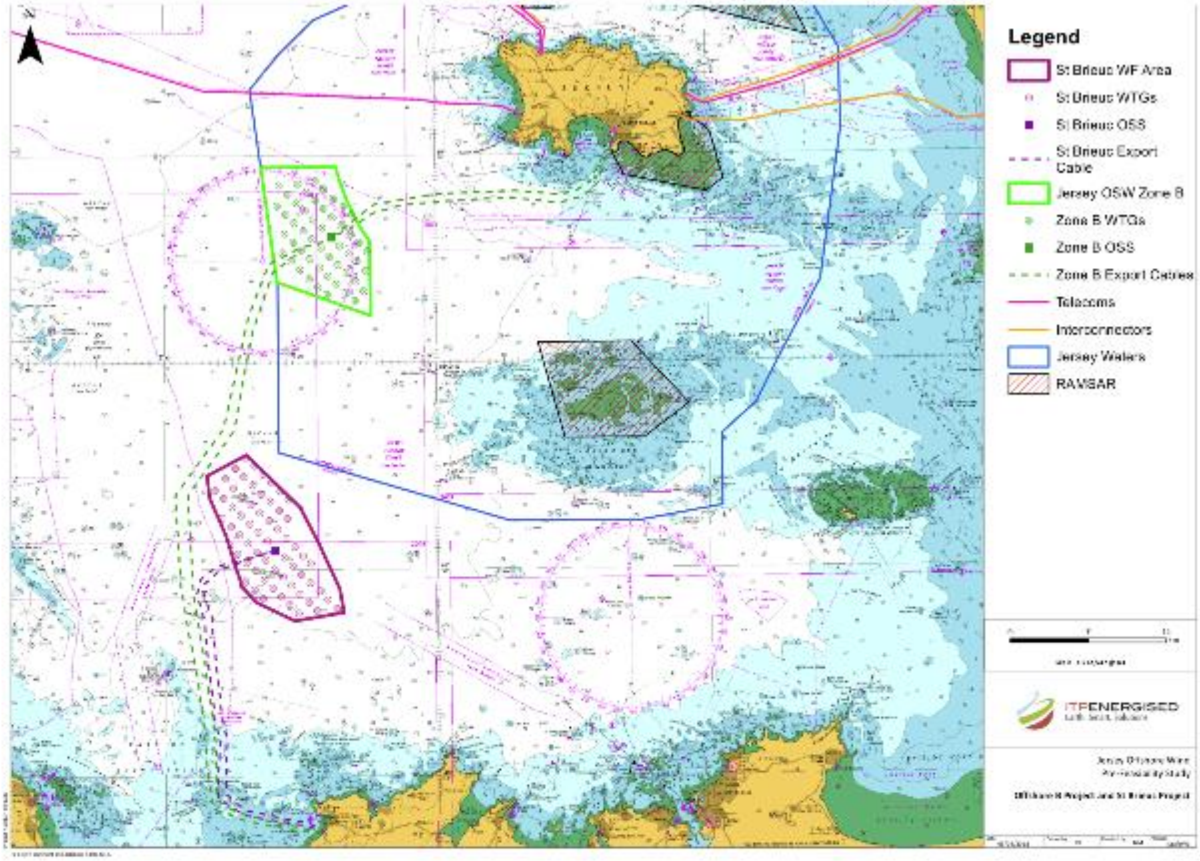

Figure 7-9, Offshore B showing an indicative turbine layout & export cable routes to France/Jersey.

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7.3.3 Grid Connection

The offshore wind farms within Offshore A and B could potentially export power and connect to the grid in either France or Jersey. These projects would be reliant on cooperation with the French state to achieve a direct connection to France, however, export cables could come ashore in Jersey and power then be transmitted onwards through the Jersey-France interconnectors to the French grid.

As both project concepts have a large capacity and will have relatively long export cables, offshore substations will be required to increase the voltage of the power exported from the turbines to a voltage suitable for transmission; typically 225kV for export to France.

The distance between the two projects and the two possible landfall points are as follows;

- 56km from Offshore A OSS to Erqay Beach
- 35km from Offshore A OSS to La Collette
- 68km from Offshore B OSS to Erqay Beach

- 29km from Offshore B OSS to La Collette

Exporting power from these projects to Jersey will provide a far shorter export cable route however, Jersey's grid infrastructure is not able to accept the power and voltage that would be supplied by an offshore wind project of this scale. As a result, extensive reinforcements and upgrades would be required for Jersey's grid – this would likely come at a large cost of expense, land and disruption.

It is likely that the size of an onshore substation to act as a point of coupling between a 400-500MW offshore wind project, the French high voltage transmission grid (through a subsea interconnector) and Jersey's 90kV grid would be comparable to the size of People's Park (~300 x 100m; 3ha). The 450MW Neart na Gaoithe project, for example, has an onshore substation area ~1.3ha (100x144m), however, this is an extension of an existing substation which also has an area of 1.3ha. As a further example, the onshore substation for the St Brieuc offshore wind project has an area of at least 2.5ha in addition to the existing 2.4ha substation.

For these reasons, it is more likely that the Offshore A and B projects would connect directly to the French grid via the southerly cable routes suggested in Figure 7-8 and Figure 7-9.

7.3.4 Project Yield & Costs

Energy Yield

As previously discussed in section 0 a range of offshore wind turbine models are currently available on the market and the current industry standard technology spans rated capacities from 6MW to 9.5MW. Three models of offshore wind turbine are considered in this analysis and have capacities of 7MW, 8MW (both Vestas V164) and 10MW. No wind turbine has yet been offered at a capacity of 10MW but both Siemens and Vestas are currently developing these products. As no information is available a representative 10MW Reference Wind turbine model, devised by DTU[54] has been used.

The turbine power curves for three models of offshore wind turbines are shown in Figure 7-10

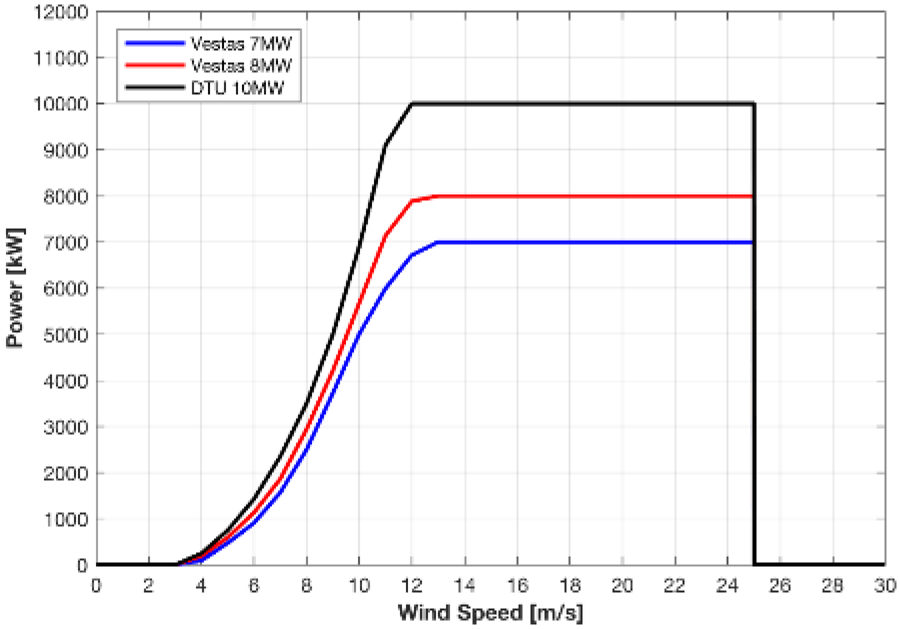

Figure 7-10, Power curves for three models of offshore wind turbines [Source: Vestas and DTU]

Using the power curves for the three turbine models and the wind data derived from Les Minquiers' met station (previously presented in section 6.7), provides the potential gross annual energy production (AEP) for each turbine – see Table 7-2.

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[54] (Bak, 2013) C. Bak, F. Zahle, R. Bitsche, T. Kim, A. Yde, L.C. Henriksen, A. Natarajan, M.H. Hansen. Description of the DTU 10 MW Reference Wind Turbine, DTU Wind Energy Report-I-0092, Roskilde, Denmark.

Table 7-2, Predicted gross annual energy production per turbine [no losses accounted for]

	MWh/Yr/WTG		GROSS CAPACITY FACTOR	
Vestas 7MW	31,968	32,697	52.1%	53.3%
Vestas 8MW	37,032	37,902	52.8%	54.1%
Ref 10MW	45,999	47,153	52.5%	53.8%

Table 6-3 on page 56 shows that the wind recorded in 2015 were, on average, so, conservatively, it can be reasonably assumed that the gross AEP of a Vestas 8MW turbine at the site would be 37 GWh.

The net AEP of a project, i.e. the power delivered to the grid at the project's onshore electricity meter, is dependent on a number of loss factors which result in reduced power output – the main factors are summarised in Table 7-3. These factors have not been calculated for a particular project but are representative of the losses that could be expected.

Table 7-3, Typical loss factors to include in the prediction of net AEP from a project.

LOSS	FACTOR	DESCRIPTION
Array Efficiency	90 %	The wind speed across the array is not uniform as wakes from turbines upstream reduce the energy available to downstream turbines. This reduces the overall efficiency
Electrical Efficiency	98 %	Electrical power losses are incurred as electricity flows through the inter-array and export cables, as well as the project's substations.
Turbine Availability	95 %	Turbines are not always able to operate due to faults. Some potential yield is lost as a result. Typically, 95% availability will be guaranteed in the first 5 years.
Other Losses	98 %	Other energy losses arise due to a range of factors including; Balance of Plant availability, non-optimal performance, hysteresis, performance degradation.

Combining the losses in Table 7-3 leads to a net AEP 82.1% of the gross AEP from a single turbine.

The net AEP from each project would therefore be as follows;

- Offshore A: 62 x 8MW [496MW]
  - Gross AEP = 2,294 GWh
  - Net AEP = 1,883 GWh
- Offshore B: 50 x 8MW [400MW]
  - Gross AEP = 1,850 GWh
  - Net AEP = 1,519 GWh

The average capacity factor for the projects is predicted to be net 43.3%.

7.3.5 Costs

Section 5 of this report provides an updated DEVEX, CAPEX and OPEX figures have been estimated for the Offshore Wind Project. This is based on the authors' current knowledge of typical costs within the industry and considerations for the Offshore A site based on the information available at the moment. Whilst these costs are not accurate, due to the very early stage level of analysis undertaken in this work, they are likely to be +/- 15% of the actual costs.

The cost estimations behind these charts are provided in Appendix A.

These CAPEX, OPEX and yield estimates were entered into a simplified discounted cash flow (DCF) analysis to examine the financial performance of the project over its lifetime. Figure 7-11 shows the results of the DCF analysis and how the discounted cashflow, revenues and costs vary over the lifetime of the project.

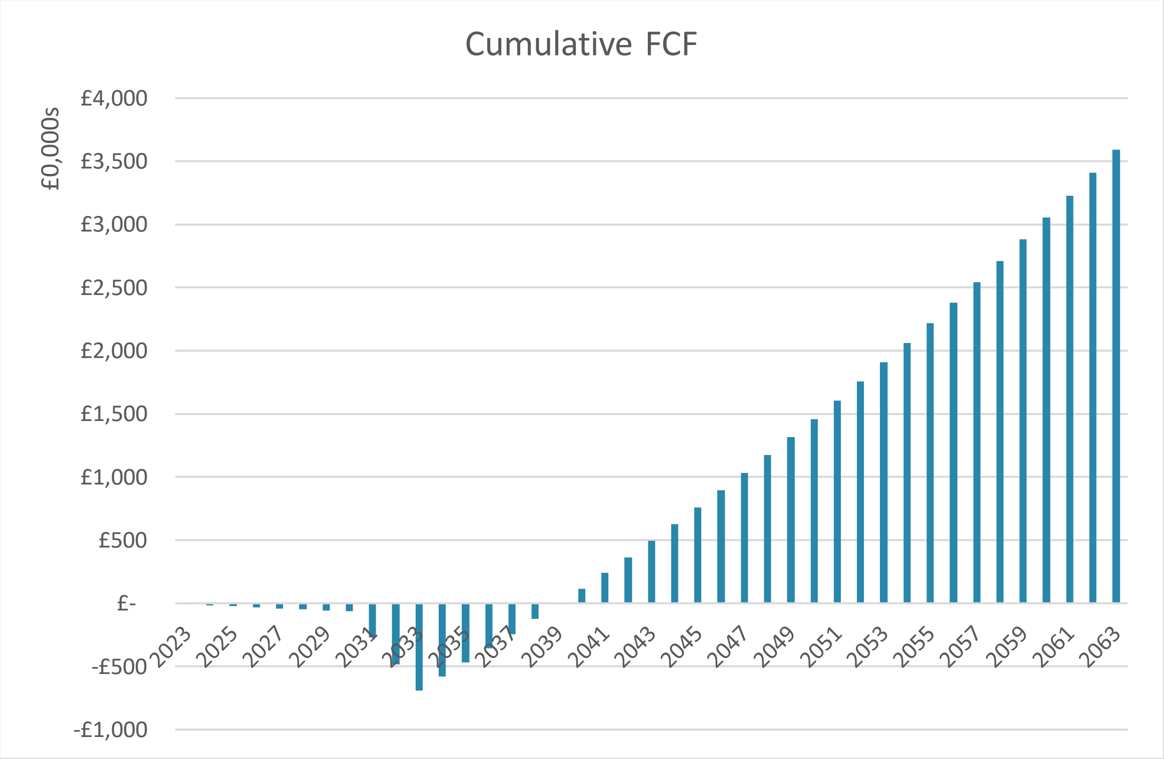

Chart 7-1 Discounted Cashflow Model

Figure 7-11, Costs, revenues and cashflows for Offshore A

A number of assumptions were made to undertake the DCF modelling:

- 496 MW
- 30 year project
- Development over 8 years
- Construction over 3 years
- £55/MWh for 30 years – linked to inflation @ 2%
- Discount rate of 6% (assumed to be analogous to the weighted average cost of capital)

The tariff of £55/MWh is based on current and forecasted prices for this analysis – This is equivalent to the LCOE.

Given the large appetite and competition for offshore wind projects, a discount rate of 8% could be slightly conservative. Larger utility developers are able to lower their cost of capital to ~6% for the right projects and opportunities.

Table 7-4 provides a summary of the key financial figures for the Offshore A project.

Table 7-4, Financial Summary for Offshore A

METRIC	VALUE
CAPEX	£644m (£1.26m/MW)
OPEX	£12.4m (£25.2k/MW/yr)
LCOE	£55/MWh
IRR	13.8%
NPV	£498m

Capex and Opex prices have fallen significantly over the past 5 years. Scale of turbines and a more developed and mature supply chain for O&M has seen prices fall making offshore wind highly competitive.

7.4 Project for Local Supply

7.4.1 Rationale

Excerpts from the States of Jersey Energy Policy[Error! Bookmark not defined.] 2013 claimed;

Jersey's existing annual electricity demand could be met (on average) by some 64 wind turbines of the same 3.6MW capacity; such an array could cover a sea area of approximately 9 square miles, with turbines typically being installed about 750 metres apart to give optimum performance.

If Jersey conditions proved broadly similar to those in the UK examples above, a windfarm to provide for all of Jersey's current electricity consumption (balanced over a year) would need a capacity of about 230 MW. This would require about 64 x 3.6MW turbines (the largest currently in common use.) At a typical spacing of 750m they would occupy a square of sea roughly 5 x 5km (3 x 3 miles.)

The upper JEC estimate of 6 times current electricity consumption would imply about 380 such turbines occupying about 14 x 14km or 9 x 9 miles. (Of course they would not have to be in a square, or even in one block.) It is moot whether this scale of development could be accommodated within Jersey's territorial waters without unacceptable impacts on ecology, shipping, fishing or aesthetics.

The question underpinning this chapter therefore is; "*can a small offshore wind project feasibly supply power directly to Jersey*?".

In 2015 Jersey's electricity demand was 53,475 tonnes of oil equivalent[55], equating to approximately 622GWh. The island's highest ever electricity demand of 178MW was achieved in March 2018, although the island's typical summer demand is around 80MW.

Around 6.5% of electricity in 2015 (~40GWh) was generated locally – the majority was imported from France via the three subsea interconnectors Jersey Electricity shares with Guernsey Electricity, which, combined, can import 263MW of power. In 2016/17, for example, Jersey imported 616GWh of electricity from France.

The supply agreement with EdF, which provides a supply of guaranteed low-carbon power (currently 65% from nuclear, the remainder from hydro) ends in 2027. The figures for island generation, are highly likely to have changed due to the war in Ukraine and various other global demand and supply impacts on overall price of energy. We have not been provided with updated figures, but it is now likely that offshore wind could compete at a comparable price to the existing EdF supply agreement, all be it, the costs of getting sufficient supply onto the island may well negatively impact the final delivery price.

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[55] Jersey Energy Trends 2015, States of Jersey (1 toe = 11,630 kWh)

JE plc. also has plans[56] for a replacement cable installation when Normandie 2 reaches end of life. This is likely to cost in the region of £40m. Normandie 2 was originally constructed in 2000.

7.4.1.1 Jersey's Future Electricity Supply

Jersey will need more electricity in the coming years as it decarbonises its transportation and heating.

Although the current arrangements for Jersey's electricity supply provide low-carbon power at a cheap price, a local source of renewable power would complement this.

Jersey and Guernsey, are heavily reliant on their subsea electrical interconnectors and the supply of electricity from France. Both of these points of reliance come with associated risks;

- Future uncertainty of power supply price from France
- Security of supply - potential interconnector failure or grid failure in France
- Geopolitics – post-Brexit uncertainty for example
- Macroeconomics and future foreign exchange rates

France will need to increase its supply of low carbon generation as well as potentially importing more power from neighbouring countries and France has recently announced plans to build new fleet of 2nd generation nuclear power stations for example. Both of these actions are likely to increase the price of electricity in France over the coming decades.

A further risk is that, any future issues with France's nuclear fleet could have severe implications on EdF's ability to supply power to the islands. Example of this were seen in both 2016 and 2017 when safety concerns regarding 20 of France's reactors caused them to be shut down. France subsequently had to import power from neighbouring markets at a highly inflated price.

Whilst all of the aforementioned risks may not precipitate as predicted, they do add uncertainty to the future of the island's electricity supply. This uncertainty would be significantly reduced if Jersey was responsible for its own power generation from its indigenous energy resources.

7.4.1.2 Self-Sufficiency

Assuming a capacity factor of 42% (comparable to the performance predicted for projects in Jersey's offshore waters) around 170MW of offshore wind capacity would be required to generate 620GWh per year; equivalent to the island's annual electricity demand. It is important to realise however, that the power generated is intermittent and variable, meaning power may not be generated when it is required. Unless large scale battery storage was included with such a project, either on-island backup generation or interconnectors with France would still be required. The following narrative provides examples to demonstrate this point:

It was presented in section 6.7.1 that for around 10% of the year, the hub height wind speeds would not exceed a turbine's cut-in speed of 4m/s. Therefore, an offshore wind project in Jersey's waters would not generate meaningful power for ~10% of the year. This can be seen in the exceedance plots in Figure 7-12.

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[56] https://www.researchpool.com/download/?report_id=34608&show_pdf_data=true

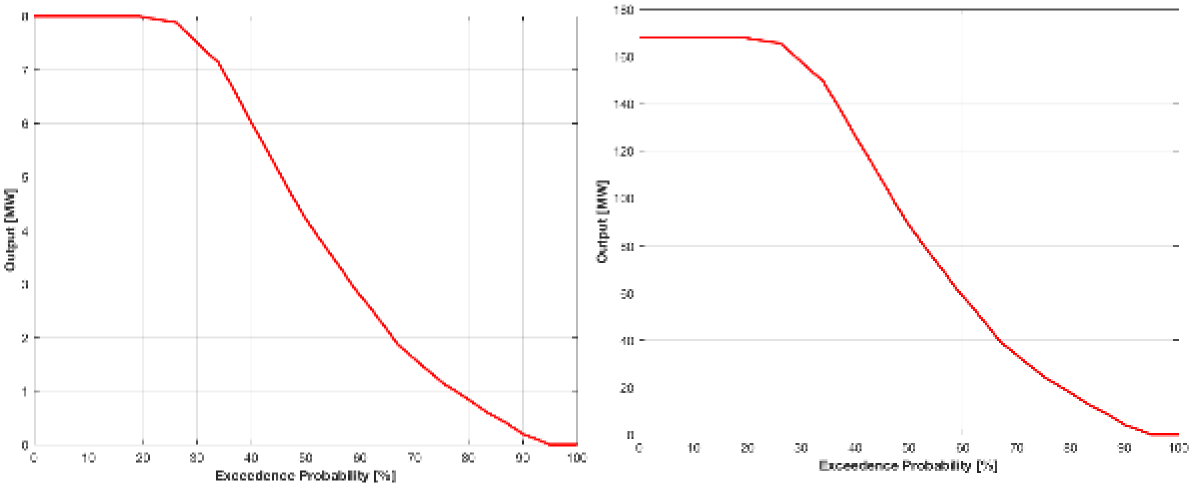

Figure 7-12, Exceedance probabilities for the estimated gross power output a single 8MW turbine [left] and a 168MW project [right] in Jersey's waters.

To provide a supply of 80MW (a typical electricity demand for Jersey), each of the turbines within a 21 turbine 170MW project will need to have an output of ~3.8MW. It is shown in Figure 7-12 that this would be the case for around 53% of the time but this implies that for the remaining 47% of the year, the 170MW project would export less than 80MW. The shortfall in supply would therefore either need to be provided from battery storage, other renewables, Jersey's conventional generation plant or imported through the interconnectors.

A more appropriate solution for the island becoming a self-sufficient power generator would be for an offshore wind project to be supplemented by other forms of renewables such as PV, energy storage and demand management. At present, large scale storage at the scale needed, in terms of Batteries, is probably not economically viable, but this would require further detailed evaluation.

7.4.1.3 Community Ownership

It may be feasible for a project to be partially community owned, meaning that the local population would help finance the project and receive a return for their investment or loan. An example of this model is given in section 7.5.4. Involvement from the States of Jersey in the financing of the project and potentially guaranteeing a community bond could make this an acceptable investment for many islanders. A smaller project would provide a higher percentage of community ownership due to the lower total capital required.

Community ownership would mean a project would likely be more acceptable to some local stakeholders, however, those without a stake in the project could view this as a way to benefit the wealthy with no benefits for those unable to invest or loan.

7.4.1.4 Small Offshore Wind Projects

Typically, the scale of offshore wind projects currently being planned and built are far greater than a small project intended to supply a limited demand. As mentioned in section 5, which describes the economics of offshore wind, the cost of energy from offshore wind projects will reduce with increasing project scale. A small project will have many of the fixed costs of a large project but with less energy yield over which those costs can be recouped. As a result, smaller projects will tend to have higher capital costs per unit of capacity.

There have been two recent examples of small scale projects developed in the UK;

- Blyth Offshore Demonstration site (array 2) features 5 x 8MW Vestas V164 turbines installed on gravity based foundations in 30-40m depth. The project's CAPEX is stated[57] to be £145m (i.e. £3.6m per MW).
- Aberdeen Offshore Wind Farm site features 11 x 8MW Vestas V164 turbines installed on suction bucket jacket foundations in 20-30m depth. The project's CAPEX is stated[58] to be £335m (i.e. £3.8m per MW).

Both of these projects were developed as demonstration sites to test new infrastructure such as turbines and foundations. Both of these projects have high reported CAPEX figures. The economics of these schemes was only possible with government support. However, the landscape has changed significantly since these were developed and may now be viable as standalone projects with a CfD.

7.4.2 Site Selection and Project Description

As a project to supply the island's population would be small, (i.e. not the +500MW utility scale projects currently preferred by the industry) it will be more expensive than a larger scale project in the same conditions. Therefore, in order to reduce costs, the site should be located reasonably close to shore and in shallow waters – this helps to reduce cable, foundation and O&M costs.

Considering the areas available to offshore wind, as shown in Figure 7-3, the most suitable, nearshore area available for a 170MW project is to the South-West of Jersey off Corbière, in the area clear of marine navigation routes. Despite being close to shore, this region has relatively deep water (up to 35m). A site in the shallow waters to the East would be more preferential but the environmental sensitivities, visual impact, interconnectors and navigation routes restrict the area suitable for offshore wind development.

From this consideration, two project concepts have been investigated;

- **Nearshore A**; a 170MW project to the SW of Jersey
- **Nearshore B**; a 32MW community owned project to the SE of Jersey which, through reduced scale and alignment with line of sight from shore, is intended to minimise its impacts.

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[57] http://www.4coffshore.com/windfarms/blyth-offshore-demonstrator-project---array-2-united-kingdom-uk70.html

[58] http://www.4coffshore.com/windfarms/aberdeen-offshore-wind-farm-(eowdc)-united-kingdom-uk47.html

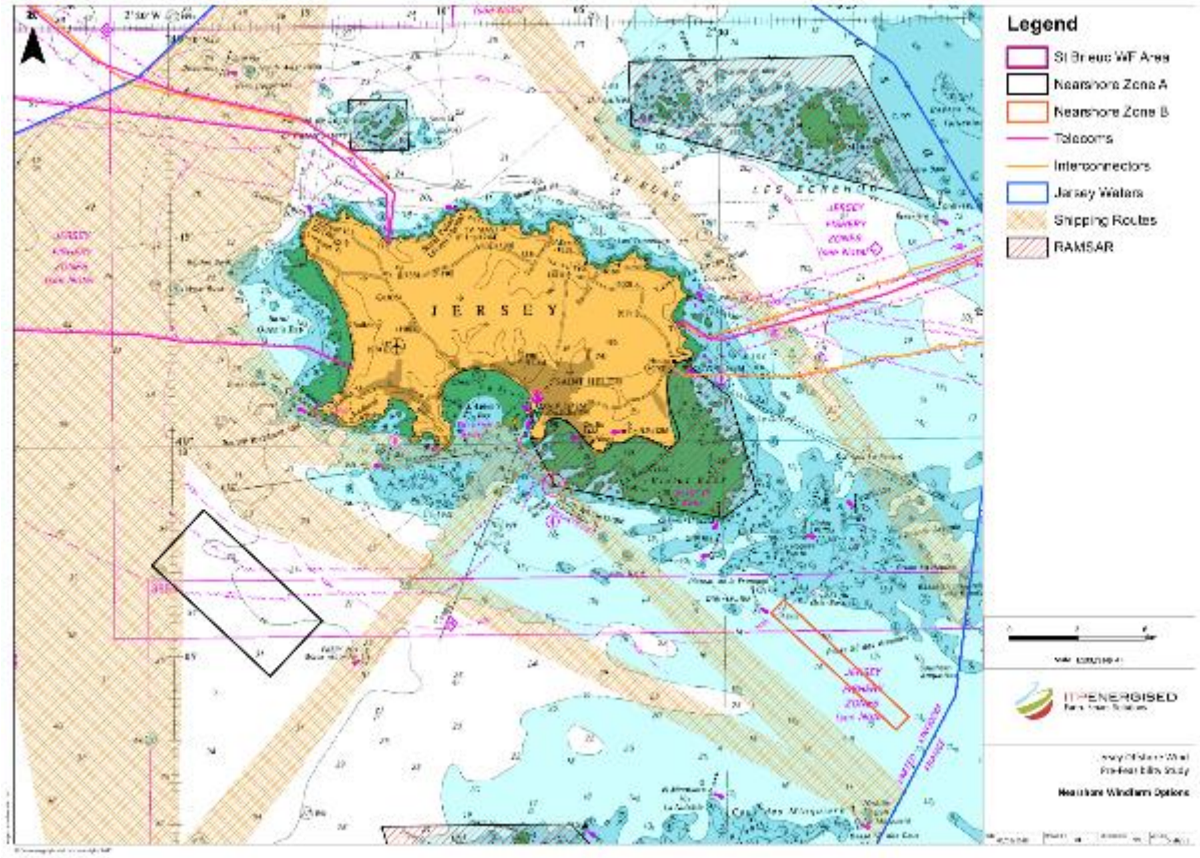

Figure 7-13, The locations of the Nearshore Zones A (Black, to the SW) and B (Red, to the SE)
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The turbines proposed for both of the projects Nearshore A & B are the same as for Offshore A; Vestas V164 8MW – this offers direct comparison with the projects considered in the previous section. Given the large size of these turbines, their visual impact on Jersey's coast could be unacceptable for use in these nearshore projects (see section 7.6.2). If this is the case, it may be more acceptable to use a larger number of smaller capacity turbines – these would have lower heights and smaller rotors but more turbines will be required to produce the same energy yield.

As with the St Brieuc project and Offshore A & B, the turbine spacing for the Nearshore A & B projects is around 1,300m downwind and around 1,000m crosswind, with the turbines orientated to face the prevailing south-westerly wind direction.

7.4.2.1 Nearshore A

This suggested project concept is a 170MW project comprising 21 x 8MW turbines, spaced regularly in an area of 24km^2. The layout is shown in Figure 7-14.

The depths at the site range from 22 - 33m. The ground conditions for Nearshore A is likely to be similar to those for the Offshore A & B sites; mixed gravels and pebbles covering bedrock (although the depth of sediment is currently unknown). The depth of sediment and characteristics of the underlying rock will determine the most suitable foundations for the turbines within the site. Monopiles could be possible as could gravity base foundations – both options could help to reduce project costs.

The cables for Nearshore A could come ashore at West Park to connect with the St Helier West substation or at La Collette to connect with the existing infrastructure at La Collette power station, or around Harve Des Pas to connect with the South Hill substation, although this would mean landing the cable within the Ramsar site.

The export cable route shown in Figure 7-14 is 14km from wind farm to La Collette. Given the relatively short distance to shore, no large offshore substation is anticipated – this will also reduce the project's visual impact. New transformers[59] being developed for offshore wind are allowing turbines to export at 66kV rather than the previous norm of 33kV; this allows transmission losses to be reduced and can, in some cases, remove the need for an offshore substation. Assuming the turbines all export at 66kV and each row of 7 turbines are connected on a single circuit, there will be three cables to shore in addition to the inter-array cables between each turbine. The radial solution suggested represents the lowest cost and complexity for inter-array designs. The tapered string allows for multiple cable cross sections to be deployed in the string minimising capital spend. The downside of the radial topology is that a fault on the string feeder would lead to a disconnection of the entire string or the WTG's behind the fault depending on protection design. The total length of the inter-array and export cables is 63km.

Two disused telecommunications cables pass through the chosen site. These are thought to be the old UK-Jersey cables[60] laid in 1958, 1968, 1973 and 1982 by the General Post Office (which later became BT) and then by BT. These are laid between Tuckton Bridge, Bournemouth, England and Grève D'Azette, Jersey. It is not believed that these cables will pose an issue to the project's location.

Visual impact is likely to be the biggest challenge for this project as the nearest turbine is 7.1km from La Corbière and 12.5km from Elizabeth Castle. Photomontage modelling work presented in section 7.6.2 shows what this project could look like when viewed from La Corbière – although it should be noted that this is only preliminary, indicative analysis.

The proximity of the Nearshore A project to Jersey Airport and the maritime radar on the South West coast could cause radar interference effects. If this is predicted to be an issue, mitigation or management measures such those previously described in section 4.2.3 could be put in place.

ADDITIONAL NOTE: We understand that Jersey utilises a 90kVA network. For a large scale offshore wind farm it would be typical to have an offshore collector substation with a transformer to export energy to the grid at the optimal system voltage. Most UK projects situated within 100m of shore presently utilise 66kV for the inter-array with an export at 220kV to shore. This could be optimised for the jersey grid to develop a power system model that potentially exports at 90kV via a larger number of export cables from offshore platform. This would potentially add additional cost. Latest generation WTG concepts at 18MW are likely to include 132kV inter-array deigns. It is unlikely that WTG manufacturers will make a provision for a bespoke 90kV inter-array system given the industry drive for standardisation.

7.4.2.2 Nearshore B

This project was conceived as a small, community owned project, intended to have a lower visual impact than Nearshore A as it is in-line with the nearest onshore viewpoint.

Nearshore B comprises 4 x 8MW turbines providing a combined capacity of 32MW. These turbines are arranged in the same regular grid layout as for the other projects. The project site encloses an area of 6km^2.

Two export cable routes are proposed;

- Southern cable route to La Collette/Grève D'Azette is 14.9km long
- Northern cable route to Gorey is 15.4km long

Both cable routes have been chosen to avoid the Ramsar site around the south west coast and the rocks off St Clement. There is also precedent for landing cables at both landfall locations.

Assuming that the four turbines are connected together and linked to shore via a single cable, the project will require a total cable length of ~18km.

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[59] ABB 66kV WindSTAR - http://www.abb.com/cawp/seitp202/6c7c2b7457e1c6c4c125814600300707.aspx

[60] https://ipfs.io/ipfs/QmXoypizjW3WknFiJnKLwHCnL72vedxjQkDDP1mXWo6uco/wiki/JT_Group_Limited.html

Depths within the site range from 11 – 14m. The Nearshore B site is in a less exposed region than any of the other projects considered and the seabed is likely to be more sandy than those found in sites in the south western waters, although this sediment cover will depend on the local tidal flows around the Nearshore B site. It is likely that monopile foundations are likely to be far more feasible for the turbines in Nearshore B. Not only are monopiles a cheaper and simpler foundation than a piled jacket, they tend to be easier to install.

The project is 9km to La Roque, 7km to Seymour Tower, 15km to Maîtresse Île. The visibility of the project at each of these sensitive locations will need to be assessed.

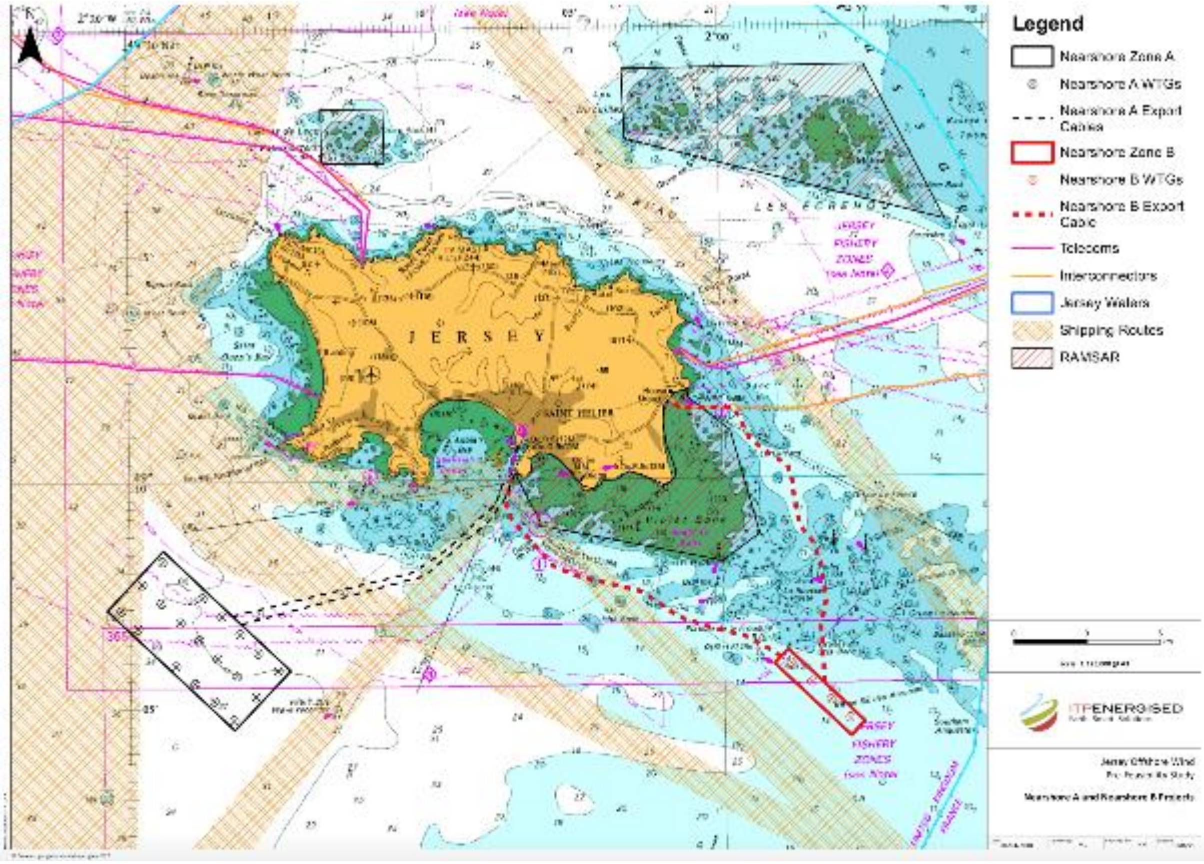

Figure 7-14, The Nearshore A and B projects showing the possible locations of wind turbines and cable routes to shore.

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7.4.3 Project Yield & Costs

Similarly to the assumptions made for the Offshore A & B projects, it is assumed that the Nearshore A & B projects will use Vestas V164 8MW wind turbines, producing a conservative gross AEP of 37 GWh/annum. See section 7.3.4 for further information.

7.4.3.1 Losses

The turbines in Nearshore A will experience some array losses due to wakes but this is not likely to be as great as for Offshore A & B. The array efficiency is therefore assumed to be 93%.

As the turbines in Nearshore B will rarely interact with each other, wake losses will be far lower. The array efficiency is therefore assumed to be 98%.

The other loss factors are assumed to be the same as for Offshore A & B :

- Electrical Efficiency 98 %

- Turbine Availability 95 %
- Other Losses 98 %

As wind speeds closer to shore are likely to be influenced by the presence of Jersey's landmass, the effect on the available energy resource is uncertain. It is likely however, that the resource will be lower in both cases and so, a conservative 2% reduction in yield is assumed.

Combining each of these loss factors leads to the estimation that Nearshore A will have a net AEP that is 83.15% of the gross AEP and Nearshore B will have a net AEP that is 87.63% of the gross AEP.

7.4.3.2 Net Yield

The net AEP from each project would therefore be as follows;

- Nearshore A: 21 x 8MW [168MW]
    - Gross AEP = 777 GWh
    - Net AEP = 646 GWh
    - Net Capacity Factor = 43.9%
- Nearshore B: 4 x 8MW [32MW]
    - Gross AEP = 148 GWh
    - Net AEP = 130 GWh
    - Net Capacity Factor = 46.3%

7.4.3.3 Costs – Nearshore A

The capital costs for this project are comparatively higher, per unit of installed capacity, than those for the 500MW, Offshore A project. This is predominantly due to the fixed costs being shared amongst less capacity and that the economies of scale through supply chain purchasing power are not as pronounced. Both foundations and offshore electrical infrastructure are comparatively cheaper due to the project being in shallower water, closer to shore and not requiring an offshore substation.

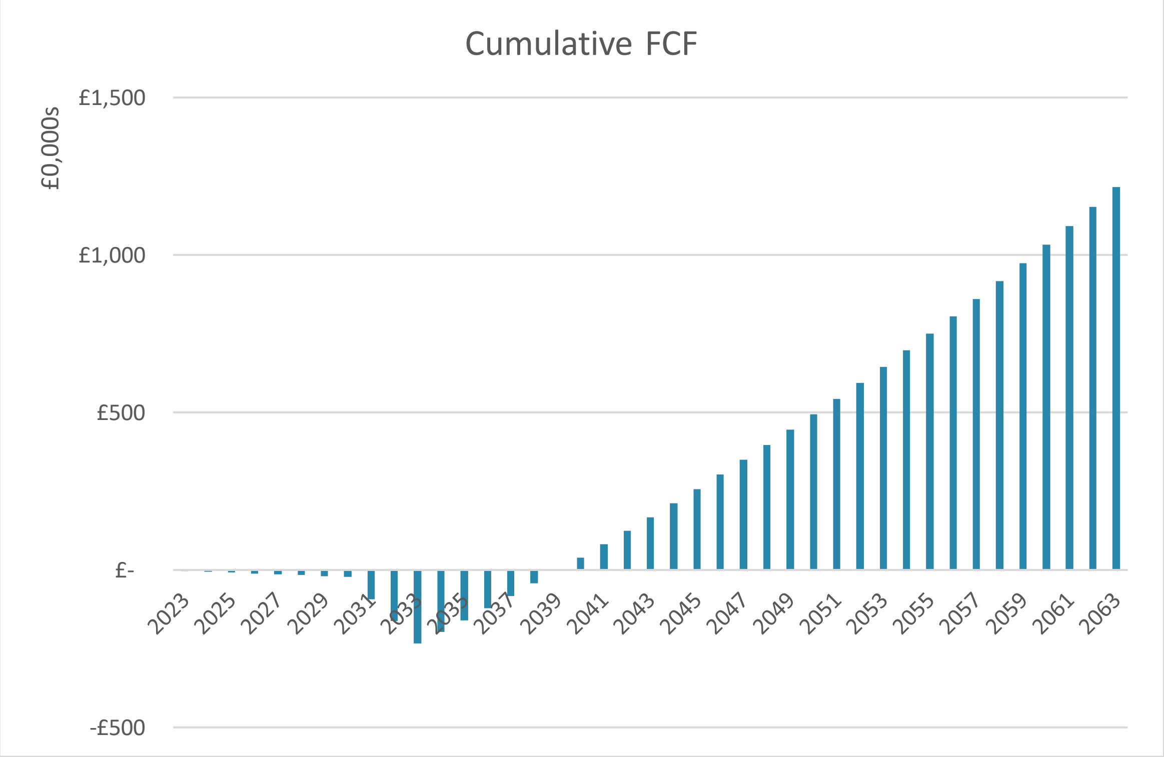

Figure 7-15, Costs, revenues and cashflows for Nearshore A

For comparative purposes, the financial modelling assumptions have been kept the same as for the Offshore A project case;

- 168 MW
- 8 Year Development
- 3 Year Construction
- 30year project
- £55/MWh for 20 years – linked to inflation @ 2%
- Discount rate of 6%

At this point we have not modelled an assumed consumer retail price that would be applicable and have aligned this with the present EdF contract.

Table 7-5, Financial Summary for Nearshore A

METRIC	VALUE
CAPEX	£212m (£1.26M/MW)
OPEX	£4.2m (£25.2k/MW/yr)
LCOE	£55/MWh
IRR	13.9%
NPV	£169m

7.4.3.4 Costs - Nearshore B

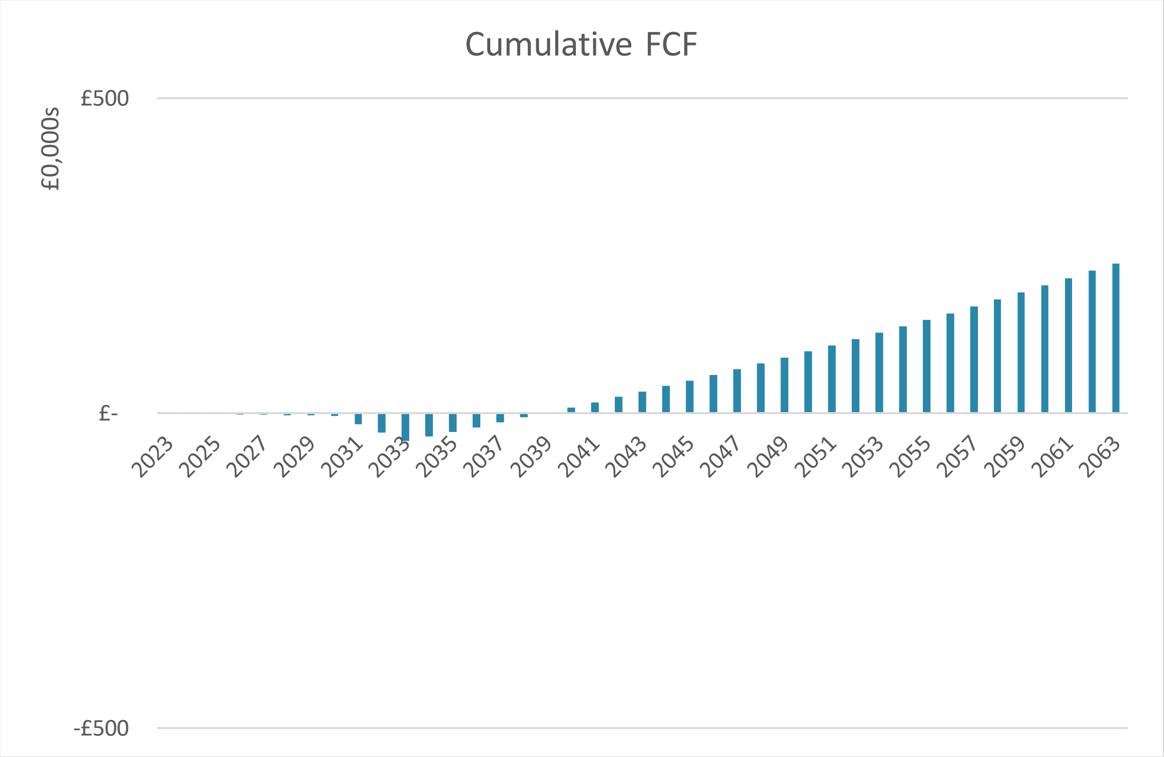

Figure 7-16, Costs, revenues and cashflows for Nearshore B

Table 7-6, Financial Summary for Nearshore B

METRIC	VALUE
CAPEX	£40.3m (£1.26m/MW)
OPEX	£800k (£25.2k/MW/yr)
LCOE	£55/MWh
IRR	14.2%
NPV	£33m

Nearshore B has a slightly IRR due to the slightly reduced losses due to the lower wake effects expected on Nearshore B compared to Nearshore A therefore leading a an array efficiency of 93% for A and 98% for B.

7.5 Positive Benefits

The offshore wind industry has been growing in popularity as its costs have reduced and the benefits of projects have been realised and documented. The UK Government's survey on public attitudes towards Energy Sources and Energy Infrastructure in Autumn 2022 showed that 84% of the general public approved of offshore wind[61] with only 5% opposed.

In 2019, The Government of Jersey published an Island Plan Review 'Strategic Issues and Options' consultation[62], on the future of the Island. 58% of the 363 responses strongly agreed, and 27% agreed, that the Island Plan should continue to encourage the development of offshore renewable (wind and tidal) energy[63].

The following subsections consider the positive impacts that offshore wind projects in Jersey's waters could have on the island.

7.5.1 Development and Construction Support Opportunities

During all phases of an offshore wind farm's development, a wide range of services will be required that could be fulfilled by companies operating out of Jersey. These services could include undertaking hydrographic, geotechnical, and environmental surveys, providing guard vessel duties during construction works, and ferrying tourists and professional visitors out to the offshore site for inspections or a closer look at the wind farm.

Whilst many of the main vessel activities would be conducted from ports used as construction bases which are likely to be on the French mainland, St Helier based companies could capitalise on providing the wide variety of support services required for a nearby project that typically require smaller vessels and less infrastructure than is required for the main construction works.

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[61] https://www.gov.uk/government/collections/public-attitudes-tracking-survey

[62] ID Island Plan Review Stage 1 AM.pdf (gov.je)

[63] gov.je/SiteCollectionDocuments/Planning and building/IP-findings report-digital 111219.pdf

Jersey has already benefitted from the St Brieuc offshore wind project: The Duke of Normandy tug was used to install the two LiDAR wind speed measurement buoys at the northern and southern parts of the site (see Figure 7-17).

For the project concept proposed for Offshore A, +£20m would be spent on pre-construction, site surveys, +£60m would be spent on offshore operations for construction activities. Jersey will likely receive a share of these fees either through direct contracts being awarded to local firms or indirectly through international vessels and crews operating from Jersey. There would be numerous commercial opportunities for Jersey and its workforce throughout the project's development and construction years. Opportunities would likely be similar for the Nearshore projects but with a lower overall value.

Figure 7-17, Jersey's tug the Duke of Normandy being used to install a floating LiDAR buoy for the St Brieuc offshore wind project.

7.5.2 O&M Base

An Operations and Maintenance (O&M) port for an offshore wind farm is the base from which the operation activities of the wind farm are carried out and from where maintenance activities are planned, managed, and delivered. The O&M phase of a project will start following the commissioning of the first turbines, through to the decommissioning phase, typically 25 years later.

The O&M base will require operations and maintenance staff who are essential to the successful operation of the wind farm. These will include technicians, vessel operators, and office-based operations staff. Throughout the O&M phase an offshore wind project can typically provide[64] between 0.1 and 0.4 Full Time Equivalent (FTE) jobs per MW (Note; St Brieuc is predicting[65] 0.28 FTE per MW).

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[64] https://www.eonenergy.com/~/media/PDFs/Generation/wind/offshore/Eon_Robin_Rigg_OM_report.pdf

[65] http://www.eolienoffshoresaintbrieuc.com/en/a-local-project/a-lasting-project-for-brittany/jobs-created

The O&M base will require office space, warehousing for equipment and spare parts, vessels for crew transfer, and moorings and quayside facilities to support the offshore activities. If they are not already suitable then existing port facilities can often be upgraded to meet the requirements of an offshore wind farm. A critical requirement for an offshore wind O&M base is the ability to provide 24-hour access to vessel berths at all states of the tide – a point particularly relevant to Jersey. An example of this is the upgrades to Grimsby Fish Docks in the UK. Crew transfer pontoons were constructed to provide access, moorings, and quayside services (see Figure 7-18).

Jersey does not currently have a quayside suitable for offshore wind O&M, although there is potential to develop on around the La Collette yacht basin or as part of St Helier Port's future development. In addition to new quayside facilities, new office and warehouse space will need to be built next to the quay. These would house the operations staff, maintenance technicians and spare parts for the wind farm.

The project for Offshore A could be maintained from the same O&M facility as the St Brieuc project in order to share common infrastructure. If France were to subsidise the project through a tariff, it is likely that the project would need to be operated and maintained from a French port. That said, it could be viable to have the project's O&M base in Jersey. The Nearshore A & B projects would certainly be operated and maintained from Jersey, so the island would receive the full benefits of the job creation and value addition from these projects.

Assuming reasonable figures for FTE jobs per MW, the following FTE jobs could be generated by the O&M activities of the three projects;

- Offshore A: 150 FTE staff
- Nearshore A: 40 FTE staff
- Nearshore B: 10 FTE staff

Figure 7-18: Crew Transfer Pontoon for Humber Gateway [Source: Marine Designs Ltd]

7.5.3 Aquaculture

Mussels have been found to quickly colonise offshore wind farm foundations in the UK[66]. Trials commenced in November 2017 to test the feasibility of growing mussels on offshore wind farms commercially at the 165 MW Belwind offshore wind farm off the coast of Belgium[67]. The trial will investigate biological, technical, and economic factors to determine the feasibility of combining the activities. Offshore wind farm operators are not expected to have issues with mussel farming as long as they can still safely access the turbines at all times without obstruction[68].

An offshore windfarm is likely to preclude the use of mobile gear by fishing vessels within parts of the wind farm. This creates an opportunity for a fish and shellfish spawning area within the wind farm which will be supported by the new habitats created by marine growth on the turbine foundations and other components

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[66] BERR, Review of Reef Effects of Offshore Wind Farm Structures and Potential for Enhancement and Mitigation, 2008

[67] https://www.offshorewind.biz/2017/11/21/mussel-farming-begins-at-belwind-owf/

[68] https://www.offshorewind.biz/2017/06/02/belgians-start-growing-mussels-on-offshore-wind-farms/

such as scour protection mats. Artificial reefs, as created when offshore wind turbine foundations are colonised by marine life, have been found to increase fish density and species diversity[66]. This has the potential to increase the value of local fisheries.

7.5.4 Community Ownership

In 2000 the 40MW Middelgrunden offshore windfarm located just outside Copenhagen harbour (see Figure 7-19), which was the world's biggest offshore wind farm at the time, became the world's first community owned offshore wind farm. 8,552 local investors collectively own a 50% stake in the project (the southern-most 10 turbines), whilst the other 50% was owned by the local municipal utility at the time. Each share was sold for £500 and represents production of 1 MWh/year of the expected annual generation of 89,000 MWh. Over £20m of investment was raised from the local community.

The projected payback time on the investment was estimated at eight years, with an overall rate of return of 7.5 % after depreciation. In the early years of the cooperative, profits were approximately 13–14 % of investment. Middelgrunden unfortunately has had a lot of O&M issues due to the nascent state of the industry at the time of construction and the turbines are now coming to the end of their lives. Annual returns are now around 3–4 %. The project continues to provide electricity for more than 40,000 households in Copenhagen (around 3% of the city's annual consumption).

The local community's involvement in the project has boosted local acceptance of the near-shore project and people tend to be proud of their local investment. Tourism has also benefitted from the project and local boat tours to the wind farm operate to provide visitors with a closer look of the turbines.

Jersey could establish a similar scheme for any of the offshore wind farms considered in this report. This could take a number of forms including direct investment by the States of Jersey or raising a local bond that is guaranteed by the States of Jersey. It is likely that any initiative for the island to have a financial link to an offshore wind project will need to be led and supported by the States of jersey.

Figure 7-19, The unique shape of the community owned, 40MW Middelgrunden offshore wind farm.

7.5.5 Lease Fees

During the generation period of a UK offshore wind farm, The Crown Estate charges the developer rent which is typically calculated at a rate per MWh of electricity generated. The fee was £0.88/MWh for UK offshore wind leasing Rounds 1 and 2 and has increased for Round 3 to around £1/MWh. There is a calculation within the lease document to determine the exact figure. There is a pre-agreed minimum output per year but it would be expected that actual output would usually be higher than that.

The 496MW Offshore A wind farm concept is predicted to generate 1,883 GWh per year. If, hypothetically, the project was charged a lease fee of £1 per MWh by the States of Jersey, in line with the UK Crown Estate's current arrangements for its Round 3 development, the SoJ would receive an annual income of £1.88m in lease fees.

The outcome of Round 4 has slightly changed the landscape and shows that the Options Fees paid by the developers are significantly higher than in previous rounds. The BP lead consortium has agreed £154k per MW/Annum, which is £231m per annum for the development and lease rights for 1.5GW. On the assumed output of the available energy around Jersey, this would equate to an income or lease cost of £33/MWh or £25.8m per annum for the island.

ScotWind, which also recently closed, used a slightly different mechanism and worked on a capped fee basis. The 25GW bid during that process, has created average lease cost of 28k/MW/Year. If you use the metric of £/MWh and apply the generation output for the Offshore A, this will equate to an income of £4.7m per annum or £6/MWh.

7.5.6 Community Benefit Funds

As part of their ESIA and CSR plans, the operators of offshore wind farms often provide supportive, charitable funds to local communities from the profits of their project. For example, as part of the 254MW Burbo Bank Extension project, Orsted (formerly Dong Energy) is allocating £225k per year for 25 years, to community projects meant to benefit the local area. Each year the owners are offering[69] grants from £500 up to £25,000. Similarly, the 402MW Dudgeon offshore wind farm provides £100k in community grants per annum[70] and the 317MW Sheringham Shoal project has provided[71] over £500k of local grants since its start in 2010.

7.5.7 Grid Resilience

Jersey Electricity will eventually seek to replace Normandie 2. This is expected to utilise the existing connection points, connecting into the 90kV substation at Archirondel. The Normandie 3 interconnector originally cost JE £70m and although this cable is buried it highlights the scale of investment required. These costs are socialised and recouped from the local electricity consumers through their electricity tariffs. It can reasonably be expected that a replacement Normandie 2 interconnector which it shares with Guernsey Electricity, could cost a similar amount to Normandie 3, a proportion of which will eventually be paid for by Jersey's electricity consumers. A component of the retail tariffs that JE charge consumers is therefore attributed to paying for the subsea interconnectors which it shares with Guernsey Electricity.

If a percentage of the island's electricity demand could be met by the generation from an offshore wind project, or if the connection infrastructure for the offshore wind could be used to supply power from France to Jersey (for example at times of low wind output) a new interconnector may not be required. This would help further enhance asset optimisation through the efficient use of offshore wind interconnection assets.

7.5.8 GHG Displacement

The majority of electricity consumed in Jersey comes from low-carbon generation plants in France via the three interconnectors with the mainland. In 2015 the imports accounted for 94% of the total consumption[72]. In addition to other forms of generation, Jersey has fossil fuel powered generation plants located on the island which are high-carbon content[73].

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[69] http://www.grantscape.org.uk/fund/burbo-bank-extension-community-fund/

[70] http://dudgeonoffshorewind.co.uk/community/community-fund

[71] http://sheringhamshoal.co.uk/community/community-fund

[72] States of Jersey, Jersey energy Trends 2015, 2015

[73] States of Jersey, Pathway 2050: An Energy Plan for Jersey, 2014

In 2015 Jersey Electricity (JE) used 2,450 tonnes of oil equivalent (toe) of petroleum products to generate 7.4 GWh of electricity[72]. Assuming this was all diesel and given that 1 tonne of diesel equals 1.01 toe[74], the fuel used would have been 2,426 tonnes of diesel. Given an emissions rate for diesel of 3,190 $kgCO_2e$ /tonne[75], this would equate to a greenhouse gas emission of 7.7 $ktCO_2e$. Due to the low-carbon content of the imported electricity the tiny proportion of electricity generated from petroleum products, about 1% of the total, makes up about 30% of the total emissions associated with electricity supply, which was 25.1 $ktCO_2e$ in 2015[76].

Jersey is following an emissions reduction pathway in line with the Paris Agreement, that will: as a minimum, reduce emissions by 68% compared to our 1990 baseline by 2030; and reduce them to 78% from baseline by 2035; deliver net-zero emissions by 2050; and stay in line with, and respond to further evidenced change in, science-based global emissions reduction targets that are needed to limit global warming to 1.5°C.

The greenhouse gas emissions associated with generation of electricity from offshore wind are estimated to be between 8 and 35 $kgCO_2e$ /MWh, with a median estimate of 12 $kgCO_2e$/MWh[77]. EDF supply JE with an electricity mix of 65% nuclear and 35% hydropower[76]. Estimated greenhouse gas emissions associated with nuclear are similar to that of offshore wind, with the power provided to JE at the lower end of this range. Electricity generated by an offshore wind farm would predominately replace imported electricity from France, with some reduction in greenhouse gas emissions, however the main opportunity for reducing greenhouse gas emissions would be by minimising the operating the on-island power plants.

In 2016/17 the carbon intensity of Guernsey's electricity[78] was 138$kgCO_2e$/MWh; a significant reduction in comparison to 485$kgCO_2e$/MWh in 2012/13. This reduction was brought about by the commissioning of the Jersey-France interconnectors, Normandie1 and Normandie 3, which enables Guernsey to import more low-carbon power from France via Jersey. Guernsey Electricity Limited is planning a 56km long interconnector (GF1) between Guernsey and France. This will allow it to reach the same level of carbon intensity of its electricity that Jersey has, although this solution will also present the same risks to future supply. An additional interconnector to Guernsey from Jersey could also provide another export market for any low carbon wind energy produced in Jersey's waters.

Furthermore, there are a number of large firms on Jersey who may be willing to pay a small premium for locally generated, wind energy to help fulfil their Corporate Social Responsibility (CSR) targets. This may help to reduce the burden of increasing electricity prices on the retail consumers.

7.6 Potential Constraints

7.6.1 Ramsar & Habitats

Les Minquiers, which is roughly 6km east of the proposed wind farm boundary is a Ramsar designated wetland of international importance. It consists of a large intertidal area with many habitats including reefs, mudflats, sandflats, boulder fields, and sand and shingle banks[79].

Overall there is expected to be a low risk of adverse impacts on Jersey's Ramsar sites from all life stages of an offshore wind farm at the proposed locations. A full assessment of environmental risks, including pollution, would be carried out as part of an Environmental Impact Assessment (see Section 4).

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[74] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Tonnes_of_oil_equivalent_(toe)

[75] UK Government, Greenhouse gas reporting: conversion factors 2017, https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2017

[76] https://www.jec.co.uk/energy-hub/jersey-a-low-carbon-island/

[77] IPCC Working Group III – Mitigation of Climate Change, Annex III: Technology - specific cost and performance parameters, 2014, Table A.111.2

[78] https://www.electricity.gg/customer-information/carbon-reporting/

[79] https://rsis.ramsar.org/ris/1456

7.6.2 Visual Impact

Cap Fréhel is the closest onshore point in France to the St Brieuc project and is ~15km from nearest wind turbine. The view of the St Brieuc project from Cap Fréhel is shown in the photomontage in Figure 7-20. This is similar to the Offshore A project – the nearest turbine is ~20.3 km from La Corbière and 26.5km from Elizabeth Castle, so the visual impact of Offshore A on Jersey's coast would be less than the St Brieuc project has on the French coast. The visual impact assessments undertaken by Ailes Marines predict that offshore wind turbines 10-20km away from shore will only visible on 26% to 37% of the days in a year.

Figure 7-20, Visualisation of St Brieuc OWF from Cap Fréhel ~15km away

As an example, projects 'Offshore A' and 'Nearshore A' have been visualised within the same photomontages Ailes Marines provided in the assessment of visual impact of the St Brieuc offshore wind project in Jersey. The images in Figure 7-21 to Figure 7-24 provide representative cases of what these projects could look like based on the 8MW turbines selected and the example layouts given in previous section of this report. It should be noted that these visualisations are only preliminary and further work will be required in the EIA phase to more thoroughly assess a project's visual impact.

Figure 7-21, Panorama from Corbière showing Offshore A with the St Brieuc project in the background

Figure 7-22, A section of the photomontage for Offshore A, shown at 100% to be more representative.

Figure 7-23, Panorama from Corbière showing Nearshore A with the St Brieuc project in the background

Figure 7-24, A section of the photomontage for Nearshore A, shown at 100% to be more representative.

7.6.3 Fisheries

The proposed wind farm location will result in a reduction in the fishing area available to both Jersey and French fishermen for the lifetime of the project. It is normal for offshore wind farm developers to fund mitigation for the loss of fisheries and/or to compensate the fishing industry for the loss. The fishing industry will be engaged at an early stage which should allow the scale of the losses to be minimised, for example by considered layout of the wind farm with regard to the type of fisheries and fishing gear used, improvement of habitats targeted at key species, improving the performance of existing fisheries, or the development of alternative fisheries.

7.6.4 Shipping – Navigation

The proposed wind farm locations have been selected to be outside of the commonly used marine navigation routes in Jersey waters, however the wind farm locations do border one of the routes. The route will be roughly 5 km wide so there is not expected to be any major issues however this would be investigated in further detail at the EIA stage.

7.6.5 Aviation and Marine Radar

Efforts have been made to select offshore wind development areas that are likely to avoid significant impacts on Jersey Airport’s radar. The current elevation (+100m) of Jersey Airport’s primary radar above sea level will help to reduce some effects.

It is likely that mitigation and management measures would be required for both vessels and aircraft however, specific studies would be necessary within the EIA stage to determine the impact of a wind farm in Jersey's waters on the capabilities of Jersey's maritime and aviation radars.

7.6.6 Construction Noise

During construction noise can be generated by vessels and during activities such as pile driving or subsea drilling. This can have a negative impact on marine life. As the offshore wind industry has progressed a number of mitigations and techniques have been developed to reduce the impact on marine life. These include limiting the timing of construction activities to less sensitive periods, acoustic deterrents to keep certain creatures, such as mammals away from the activities, or technological advances such as different piling techniques or acoustic barriers. During the project design and EIA stage these techniques will be explored and included in the project plan to suit the site.

7.6.7 Birds

There are bird populations on Les Minquiers including species of wintering and passage waders and wildfowl. The impact of an offshore wind farm on birds will be assessed at the EIA stage and mitigations proposed to minimise the impact on birds.

7.6.8 Tourism

Wind turbines at the proposed wind farm locations will be visible from land under certain conditions. There is likely to be concern from Jersey's tourism industry that this might reduce the attractiveness of the island or at least parts of it from where the wind farm could be seen. There have been limited studies on the effects of tourism, however the German Offshore Wind Energy Foundation found that there are very few negative effects on tourism and that there are many potential tourist attractions possible with an offshore wind farm[80]. It also states that good communication with stakeholders at the planning and construction stages, and investment, are required to realise the potential tourist attractions of an offshore wind farm.

7.6.9 Cumulative Effects

The proposed locations of the Jersey's potential offshore wind farms are close to the St Brieuc offshore wind farm. This may lead to a cumulative impact issue due to visual, ecological, fishing, transport, or other effects on the environment. This may result in limiting the suitable areas or require additional mitigations that otherwise would not have been required.

The combined, cumulative effects of locating another offshore wind farm in the vicinity of the St Brieuc project should be assessed within the project's EIA.

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[80] German Offshore Wind Energy Foundation, Offshore wind energy creates opportunities for the tourism sector in the South Baltic Region, 2013, http://www.southbaltic-offshore.eu/reports-studies-the-impact-of-offshore-wind-energy-on-tourism.html

8. Hydrogen and Offshore Wind

8.1 Introduction

Hydrogen is becoming of increasing interest to offshore wind developers as a potential route to market for power generated offshore. Connection to a proposed offshore wind array would mean that hydrogen could potentially be produced both opportunistically and on a planned basis This is for two fundamental reasons:

1. **Curtailment** - During periods of high offshore wind electrical energy generation and low demand otherwise curtailed generation could be used to supply electrolysers to generate hydrogen and oxygen, with the hydrogen then stored for subsequent use.
2. **Fuel Supply** -if a market for Green Hydrogen emerges, as predicted, the windfarms electrical output could be planned to generate significant volumes of hydrogen to be utilised in modified grid distribution networks via a dedicated connection or to be utilised for other demands, such as transport and logistics fleets.

This high-level commentary is based on ITPEnergised's experience with Hydrogen Production Facility (HPF) development and the emerging hydrogen market – it is intended to provoke thoughts and discussion and does not represent a technoeconomic analysis of any technology or market sector.

ITPEnergised has reviewed previous work on the decarbonisation of the Jersey economy by Oxera in 2021 (https://www.gov.je/Government/Pages/StatesReports.aspx?ReportID=5472), which included an initial assessment of the potential for hydrogen to be part of the energy mix in Jersey. The review concluded that the potential was currently very limited. The Oxera review discussed hydrogen usage in analogous terms to petrochemical fuel, discussing upstream (concerning production), midstream (distribution) and downstream (user communities). All three stages must be suitably integrated for any sort of hydrogen economy to function, so this structure has been used here.

This commentary considers only green hydrogen i.e. that produced electrolytically using renewable energy. Other colours of hydrogen which are petrochemical in origin are not considered relevant.

8.2 Upstream: hydrogen production in Jersey

Green hydrogen is commonly said to have only two inputs, electricity from renewable sources and water. Whilst this is basically right, further effort must be expended to get the inputs into a useable form, and the process will have an appreciable physical footprint. It is assumed that electrolysis must take place onshore; designs exist for offshore production systems integrated into floating wind turbines which pump hydrogen onshore via an umbilical, but these are not considered credible. It is far easier and more economical for electrons than molecules to travel over long distances.

8.3 Electricity

Modern electrolysers, for instance those employing proton exchange membrane (PEM) technology, are able to operate at a high efficiency under a wide range of electrical loads. Some are reportedly able to operate almost as efficiently at a 10% electrical load as at full load, which gives a very broad operational envelope and means that hydrogen can be efficiently produced under a correspondingly wide range of wind conditions.

To optimise system efficiency, the electrolyser and hence the rest of the HPF will need an offtake near the landfall of the proposed OSW cable to Jersey via a dedicated substation. The supply would need to serve the electrolyser running at full load plus the balance of plant, which represents an additional load of 25% or more on top of electrolyser demand to run compressors, water treatment and product gas purification and dehydration systems.

8.4 Water

The electrolyte used in the electrolyser to generate hydrogen must be water of a high purity, and so further treatment to remove all dissolved solids will be required. Fresh, potable water has a relatively low concentration of dissolved solids and would usually be the input of choice.

According to Jersey Water's 2021 Water Resource and Drought Management Plan (https://www.jerseywater.je/water-resources/), potable water is supplied to the island from four reservoirs during periods of normal rainfall. These are supplemented during drought periods by extraction of groundwater from the Tesson and St Oeun boreholes, and the Le Rosiere desalination plant.

Potable water would appear the optimal choice of water input as it would require less energy and resource intensive treatment than the other option, seawater. An agreement for the required abstraction would be required from Jersey water and given the drought period constraints, it is unlikely that unconstrained hydrogen production could continue during a drought, depending on the ultimate scale of the HPF and the stress that the demand would place on borehole and desalination supplies. The possibility of the electrolyser receiving municipal water which has been desalinated using fossil energy raises an interesting question over the "green" colour of the resulting hydrogen production.

Brine rejected from a potable water treatment system (i.e. a reverse osmosis package) may still have some use as for instance grey water for domestic-type uses or even for irrigation – it will after all contain nothing that was not already present in the fresh water supply (e.g. hardness salts), just at an elevated concentration compared to the supply.

A dedicated desalination system may be considered either in place of a freshwater feed or to supplement during drought periods; this plant would have a higher energy demand than the potable water equivalent pushing the overall site parasitic load above the notional 25% for a fresh water system.

Brine from a seawater treatment system will have to be returned to the sea; the environmental effects of the disposal of such a hypersaline discharge would have to be studied.

8.5 Land take

Land use pressures are relatively high on any small, developed island such as Jersey and any HPF development would attract close attention from the state planning departments. ITPEnergised works with several HPF developers in the UK and an emerging rule of thumb from these associations is that each MW of installed electrolyser capacity requires approximately one hectare of land.

Site selection is beyond the scope of this commentary, but there will be relatively few locations on Jersey where a relatively large, low-rise light industrial-type development will fit the local context – possibly the airport, the port and the La Collette area where the heaviest industries like waste handling are currently concentrated. Proximity to the OSW power supply and water supply will also be major constraints. Storage of hydrogen in bulk quantities presents material risks to health and safety in the event of a failure of containment. Suitable separation distances from human receptors will also need to be considered as part of the land-use planning and consenting processes. Finding the optimum location can therefore be challenging when faced with limited space and end uses.

8.6 Midstream – distribution

Hydrogen is expensive to transport as it requires specialist infrastructure. It is understood that there is not a large-scale natural gas distribution network on Jersey and even if there were, this is unlikely to be suitable for the transport of hydrogen, as it would readily leak and cause damage to steel pipes through embrittlement. Road tankers exist but due the properties of the necessary containment vessels, the actual payload for a tanker can only be a few hundred kilograms. This is sufficient for light and infrequent use (for instance charging a hydrogen dispenser for a relatively small local fuel cell electric vehicle fleet) but heavy consumers will need a dedicated and purpose-made pipe run or ideally to be co-located with the HPF. Large numbers of new heavy duty vehicles on Jersey's road network are likely to be met with community and regulatory resistance.

8.7 Downstream - end users

ITPEnergised has reviewed the major sectors of Jersey's economy (https://www.gov.je/lifeevents/movingtojersey/whychoosejersey/pages/businessandindustries.aspx) and provided initial commentary on their readiness for hydrogen usage and the potential interactions with the island's infrastructure. Where a major potential user is identified, it is assumed that the HPF would have to be located nearby to remove the need for substantial new pipeline infrastructure.

8.7.1 Financial, legal, digital

The energy demand for these professional services will be predominated by electrical energy for built environment operation and space heating. Hydrogen works well as a thermal fuel but its viability would be predicated on retrofitting or replacement of domestic and commercial boiler fleets and an effective distribution system which as discussed will be a significant challenge. The expected availability of relatively cheap energy from the proposed OSW development means that electrification of heating appears to be the more viable approach to decarbonising these sectors than integrating thermal hydrogen.

8.7.2 Tourism and Hospitality, Retail

The above arguments hold true for these sectors in the main. One exception is events (e.g. the annual music festival) which would be an ideal sector to switch away from diesel to fuel cell generators. The UK supply market for fuel cell generators covers a growing fleet of several hundred units with high demand from the events and broadcasting industries driving supply. Currently these fuel cell generators are typically run with grey (natural gas-derived) hydrogen but this is due to the lack of reliable green hydrogen supplies.

8.7.3 Public Sector

Several local authorities in the UK (e.g. Aberdeen) have replaced their end-of life municipal vehicles (refuse trucks etc.) with fuel cell electric vehicles (FCEV) equivalents and incentivised local bus operators to do likewise. This could represent a relatively small but predictable demand for green hydrogen were a similar regime adopted in Jersey.

8.7.4 Agriculture

The pace of development for agricultural vehicles has greatly increased but most models are still at pilot or testing stages, with no recognisable market in the UK. The demand for FCEV equivalent will only grow with security of fuel supply. Electrolysers produce low grade waste heat, unsuitable for recovery in a waste heat boiler but of potential value to tomato and salad crop growers. Any waste heat off-taker would however have to be sited immediately adjacent to the HPF.

8.7.5 Construction

There has been a proliferation of fuel cell electric equipment in the construction sector, much more so relative to agricultural machinery. Well-known suppliers such as JCB are undertaking field tests for technical acceptability of fuel cell machinery. Fuel cell electric generators are widely available to supply temporary site power, with the added benefits of running silently and without emissions to air. Fuelling trucks have also been developed to minimise trips to a hydrogen refuelling depot – the fuel truck takes a relatively large hydrogen load on board and can fill multiple vehicles potentially across several sites. Of all the sectors with a proliferation of small end users, construction is likely to show the most immediate potential for green hydrogen usage given the immediate availability of some equipment.

8.7.6 Port and harbour activity

Marine fuel switching away from fuel oil to both thermal and fuel cell hydrogen application may represent a substantial future use. Uptake would depend on the fleet replacement or retrofit programmes of individual owners and operators. The Port of Jersey is able to berth relatively large vessels so correspondingly large quantities of fuel would be required, representing a large potential market but one which would require considerable buffer storage for surety of supply to potential customers – a relatively small electrolyser as would seem likely on Jersey may not be able to cope with simultaneous demands for several tonnes at a time.

Export by sea to high-demand economies such as Germany is not considered feasible given the likely production capacity constraints on Jersey and the berthing requirements for cryogenic tankers.

Fuel cell electrical generation from stored hydrogen to meet peak power demands may be a further application, for instance to offer temporary hotelling power to a large vessel such as a cruise ship which could then cut her engines with the knock-on benefit of improved local air quality.

The HPF would have to be located at or near the Port of Jersey for this market to be wholeheartedly pursued with the attendant constraints on space, practicality and acceptability.

8.7.7 Aerospace

FCEV light aircraft are currently on trial, and large-volume engine and aircraft manufacturers are developing thermal hydrogen jet engines. Smaller, propellor-driven aircraft which can run on an electric motor powered by a fuel cell will be the first to reach production. Jersey Airport's schedule is predominated by flights to England and Guernsey, which would be ideal routes for FCEV aircraft. The aerospace industry hence represents another potentially large but currently ill-defined market for green hydrogen. Locating a HPF and hydrogen storage at the airport will have functional safety and possibly water supply issues.

8.7.8 Other transport

FCEV taxis and private cars are likely to remain rare in Jersey if battery electric vehicles remain the cheaper alternative to buy and run.

8.7.9 Other major users

Emergency power generation in the event of disruption to the island's electrical supply could potentially be provided by large-scale fuel cell generation. This facility would have to be co-located with the HPF as several hours or even days' worth of storage would be required to make such a development worthwhile. It would not likely be cost-effective for anything beyond emergency use.

8.8 Conclusion

Production of hydrogen in Jersey at scale is likely to be constrained by the availability of suitable development land and the lack of immediate off-takers. The viability of hydrogen production will further depend on the location of the connection relative to the offshore wind array cable landfall, co-location with a majority of end users or transporters and a reliable source of (ideally fresh) water.

Land take and water supply may ultimately constrain Jersey's potential as a hydrogen economy and particularly as a major fuelling for aircraft and marine vessels, but if some hectares can be identified in a suitable location for development, the sweet spot for Jersey could be a relatively small production capacity serving a domestic market for plant, machinery, heavy vehicles and portable power supplies, with possibly enough capacity to support an emerging airport or sea port demand in its early years.

9. Conclusion & Recommendations

The conclusion of this updated report, based on the 2018 study is that Jersey continues to have significant offshore wind potential within its waters and that the development and exploitation of the resource to generate low cost reliable power for the island is both technically feasible but additionally, the economic landscape has changed dramatically in this short period of time.

The key changes that have occurred during the previous 4-5 year period is the reduction in capital costs, together with lifetime Operation & Maintenance costs. This is being driven by the increased deployment of larger more efficient turbines, leading to an overall reduction in the cost/MW installed, together with improvements in the supply chain, great maturity in the O&M Market and at a macro level, great investor confidence due to clearer policy signals.

There have been a number of new entrants into the market, with a particular growth of the Oil & Gas majors, becoming key asset developers and access the new leasing rounds. Additionally, we have seen significant consolidation in the service based markets with greater development and delivery expertise providing further efficiency through more integrated service approach.

Further analysis of the project scenarios as previously presented is recommended with the aim to identify at least one scenario that would be financially and economically viable and also both environmentally and socially responsible.

Appendix 1

Offshore A Costs

Table A-1, Estimated CAPEX costs for Offshore A

DESCRIPTION	COST [GBP]	% CAPEX	£/kW
Development	31,189,239	1.9%	63
Turbine supply	645,792,000	38.3%	1,302
Turbine installation & commissioning	25,008,183	1.5%	50
Foundations supply	288,056,730	17.1%	581
Foundations installation	52,630,183	3.1%	106
Array cable supply	29,998,000	1.8%	60
Array cable installation	33,435,250	2.0%	67
Offshore substation	78,226,365	4.6%	158
Offshore export cable supply & install	48,385,250	2.9%	98
Onshore export cable supply & install	24,896,000	1.5%	50
Onshore substation & grid connection	23,312,000	1.4%	47
Construction insurance	19,840,000	1.2%	40
Project management	37,847,021	2.2%	76
Contingency	189,235,106	11.2%	382
Developer Markup	80,213,191	4.8%	162
Decommissioning	76,412,500	4.5%	154
Grand Total	**£1,684,477,019**	**100.0%**	**3,396**

Table A-2, Estimated OPEX costs for Offshore A

DESCRIPTION	**COST [GBP]**	**% OPEX**	**£/kW/yr**
Offshore technicians	3,562,400	11.6%	7.2
Spare parts	4,216,000	13.7%	8.5
Vessels	9,003,600	29.3%	18.2
Onshore maintenance (electrical)	496,000	1.6%	1.0
Operation, management and general admin	2,818,271	9.2%	5.7

Operating facilities	500,000	1.6%	1.0
Insurance	4,960,000	16.1%	10.0
Annual lease and fees	2,379,410	7.7%	4.8
Developer Markup	1,463,298	4.8%	3.0
Contingency	1,330,271	4.3%	2.7
Total OPEX	**£30,729,249**	**100.0%**	**62.0**

Nearshore A Costs

Table A-3, Estimated CAPEX costs for Nearshore A

DESCRIPTION	COST [GBP]	% CAPEX	£/kW
Development	12,155,513	2.1%	72
Turbine supply	235,536,000	39.9%	1,402
Turbine installation & commissioning	12,406,418	2.1%	74
Foundations supply	95,315,672	16.1%	567
Foundations installation	19,137,418	3.2%	114
Array cable supply	20,084,000	3.4%	120
Array cable installation	16,590,250	2.8%	99
Offshore substation	1,016,836	0.2%	6
Offshore export cable supply & install	20,841,250	3.5%	124
Onshore export cable supply & install	4,968,000	0.8%	30
Onshore substation & grid connection	7,896,000	1.3%	47
Construction insurance	6,720,000	1.1%	40
Project management	13,178,195	2.2%	78
Contingency	65,890,977	11.1%	392
Developer Markup	28,142,764	4.8%	168
Decommissioning	31,118,750	5.3%	185
Grand Total	**£590,998,043**	**100.0%**	**3,518**

Table A-4, Estimated OPEX costs for Nearshore A

DESCRIPTION	COST [GBP]	% OPEX	£/kW/yr

Offshore technicians	1,166,400	10.5%	6.9
Spare parts	1,512,000	13.6%	9.0
Vessels	3,199,600	28.8%	19.0
Onshore maintenance (electrical)	168,000	1.5%	1.0
Operation, management and general admin	1,076,768	9.7%	6.4
Operating facilities	500,000	4.5%	3.0
Insurance	1,680,000	15.1%	10.0
Annual lease and fees	816,138	7.3%	4.9
Developer Markup	529,811	4.8%	3.2
Contingency	477,307	4.3%	2.8
Total OPEX	**£11,126,023**	**100.0%**	**66.2**

Nearshore B Costs

Table A-5, Estimated CAPEX costs for Nearshore B

DESCRIPTION	COST [GBP]	% CAPEX	£/kW
Development	2,964,259	2.4%	93
Turbine supply	44,864,000	35.7%	1,402
Turbine installation & commissioning	3,905,766	3.1%	122
Foundations supply	16,151,065	12.8%	505
Foundations installation	3,999,766	3.2%	125
Array cable supply	8,016,000	6.4%	251
Array cable installation	4,888,000	3.9%	153
Offshore substation	191,532	0.2%	6
Offshore export cable supply & install	2,928,000	2.3%	92
Onshore export cable supply & install	4,832,000	3.8%	151
Onshore substation & grid connection	1,504,000	1.2%	47
Construction insurance	1,280,000	1.0%	40
Project management	2,771,302	2.2%	87
Contingency	13,856,509	11.0%	433
Developer Markup	5,985,735	4.8%	187
Decommissioning	7,562,500	6.0%	236

Grand Total	**£125,700,434**	**100.0%**	**3,928**

Table A-6, Estimated OPEX costs for Nearshore B

DESCRIPTION	COST [GBP]	% OPEX	£/kW/yr
Offshore technicians	256,800	9.1%	8.0
Spare parts	288,000	10.2%	9.0
Vessels	765,200	27.1%	23.9
Onshore maintenance (electrical)	32,000	1.1%	1.0
Operation, management and general admin	241,309	8.5%	7.5
Operating facilities	500,000	17.7%	15.6
Insurance	320,000	11.3%	10.0
Annual lease and fees	163,813	5.8%	5.1
Developer Markup	134,411	4.8%	4.2
Contingency	121,091	4.3%	3.8
Total OPEX	**£2,822,623**	**100.0%**	**88.2**

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