
Floating Wind Joint Industry Project: Policy & Regulatory Appraisal

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Comissioned by:





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The Carbon Trust has been at the forefront of the offshore wind industry globally for the past decade, working closely with governments, developers, suppliers, and innovators to reduce the cost of offshore wind energy through informing policy, supporting business decision-making, and commercialising innovative technology.



The Offshore Renewable Energy (ORE) Catapult is the UK's flagship technology innovation and research centre for offshore wind, wave and tidal energy. We combine world-class research, development, demonstration and testing facilities with leadership, industrial reach and engineering expertise to accelerate the design, deployment and commercialisation of renewable energy technology innovation. We are not-for-distributed-profit and will collaborate widely to de-risk and commercialise technological solutions and standards that can be embraced by the market.

Please note that the findings within this report do not necessarily represent those of the supporting industry partners or the Scottish Government, but are drawn out by the authors from the undertaking of the methodology described further within this document.

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Executive Summary

This report was commissioned through a Joint Industry Project (JIP) led by the Carbon Trust, consisting of five offshore wind project developers (DONG Energy, EDF, E.ON, innogy, and Statoil) and supported by the Scottish Government. Its delivery has been undertaken by the Carbon Trust in collaboration with the Offshore Renewable Energy Catapult. The findings and recommendations highlighted within this report are solely those of the authoring organisations based upon their respective inputs and do not necessarily reflect those of the supporting joint industry partners.

Floating offshore wind is an emerging energy technology which offers multiple potential benefits for governments looking to cost-effectively decarbonise their energy system. The ability to exploit areas of strong wind resource in deep water locations can enable floating wind turbines to deliver high volumes of low carbon electricity to the grid, particularly if near shore locations can reduce transmission losses. Indeed, several studies have highlighted the potential to reach cost parity with fixed-bottom offshore wind if commercialised and deployed at scale over the next decade. It is also expected that the synergies between floating wind and other offshore energy technologies, such as fixed-bottom offshore wind, marine power and offshore oil and gas, can bring opportunities for businesses to diversify and expand their product and service offerings, both domestically and overseas.

With potential for up to 90 MW to be installed by 2018, the UK has an opportunity to build on this world leading position and develop supply chain capability to exploit opportunities in international markets. However, a supportive policy framework will be critical to catalyse sector growth and attract inward investment into the UK floating wind industry. This report aims to outline the key policy and regulatory conditions required to support the commercialisation of floating wind technology. The report is divided into sections covering four key aspects of consideration for market development of floating wind: Licensing & Consenting; Subsidy & Grant Support; Supply Chain Development; and Grid Connection.

It is noted that a number of the potential challenges facing a future floating wind industry are not unique to the technology but share commonalities with other forms of offshore renewable technology, including wave and tidal energy, but particularly fixed-bottom offshore wind. This includes many considerations around turbine siting, environmental interactions and stakeholder space conflicts within the licensing and consenting processes, as well as grid availability and integration.

1. Licensing & Consenting

Although consenting bodies and leasing requirements vary between nations, the primary licencing procedure within the EU is the Environmental Impact Assessment (and Habitats Appraisal for sensitive sites). The current European regime of legislation and regulations for marine spatial planning are believed to provide an adequate framework for project consenting, but a lack of proportionality to project scale can act as a barrier to small scale demonstration projects.

In response, Scotland has developed a Survey-Deploy-Monitor approach to scoping that aims to provide a more streamlined process for emerging technologies, such as floating wind. However, it has been noted that there have been delays in the practical application of policy (e.g. EIA processing times) and greater clarity on consenting timelines would aid project developers and de-risk investment decisions.

With regard to factors influencing consenting decisions, initial demonstrations and pilot arrays are expected to be deployed close to shore and so will be likely to have more interactions with human activity, flora and fauna, as would be the case with fixed offshore wind. Commercial arrays in deep-water locations near to shore would be expected to face the same sensitivities, however, should commercial sites be located further offshore (i.e. beyond the 12nm territorial water boundary), there would likely be lower environmental sensitivities and a transition of stakeholder engagement from small fishing and leisure users towards deep-sea trawlers and oil and gas activities.

In terms of human activity, the fishing industry presents a higher potential for conflict due to subsea cable and mooring spread that could preclude fishing activity (e.g. catenary mooring configurations). For navigation and safety, planned and un-planned movement of the structure present some unknowns in terms of technical risk. However, these can likely be managed using existing legislation and best practices.

From a flora and fauna perspective, although there are some levels of uncertainty over the impact of subsea floating systems (e.g. electromagnetic fields from cables in the water column; marine mammal interactions), there will likely be a reduction in the overall perceived impact due to reduced disturbance offshore during the construction phase.

Recommendations on Licensing and Consenting

- Develop a de-risked demonstration site
- Ensure a flexible technology envelope for consents
- Include potential for further build-out beyond initial demonstration and pilot sites
- Adopt and implement a risk-based approach to consent
- Provide clarity and transparency on consenting processes and timescales
- *Immature market*: Maintain an open responsive approach to site leasing
- *Maturing market*: Undertake a Strategic Environmental Assessment followed by appropriate leasing rounds

2. Subsidy & Grant Support

There is a mosaic, albeit limited, number of disaggregated funding options available currently, moving from grant support for technologies at early TRLs and prototype demonstrations to revenue support and loans for pilot and fully commercial arrays. Historically, funding has been provided through different national funding bodies for different stages of TRL, with UK Research Councils (e.g. EPSRC, NERC) supporting fundamental research and innovation, and technology bodies (e.g. InnovateUK, ETI) providing mid-range TRL and ‘translational’ funding (i.e. technology commercialisation). Central and devolved governments have historically provided full-scale demonstration support. More recently, EU support has played a significant role within the funding landscape both at early research and demonstration stages – namely, through FP7, Horizon 2020, and DEMOWIND funding calls – and latterly through European Investment Bank (EIB) support.

From a UK perspective, the primary concern is a foreseeable funding gap once the Electricity Market Reform (EMR) is fully implemented and projects move from 3.5 ROCs (~£187/MWh¹) to £105/MWh or below expected in the upcoming competitive tenders under the CfD FiT, falling to at least £85/MWh by 2025. Several de-risking steps can be taken to support developers wishing to deploy within Scotland, such as helping with initial site identification or supply chain creation; however, this funding gap will undoubtedly halt project development unless alternative finance instruments, such as a ring-fenced CfD pot, are accessible to projects. Other non-revenue support options, such as technology de-risking and innovative R&D, are also recommended where efficacy of spend may be increased if combined with other offshore cost reduction programmes.

Recommendations on Subsidy & Grant Support

- Introduce ring-fenced support for floating wind within the Contracts for Difference (CfD) mechanism
- In the absence of CfD support, seek alternative revenue or grant support mechanisms
- Undertake cost reducing component innovation
- Identify and exploit niche market opportunities
- Maintain support for low TRL concepts

¹ Assumed ROC buy out price of £44/MWh and a wholesale market price of £33/MWh

3. Supply Chain

The development of floating wind introduces unique opportunities and risks for supply chain development. The ability to fabricate and assemble at quay-side means that there is likely to be a higher proportion of installation costs associated to port and harbour activity; however, the ability to tow fully-assembled systems to site means that the supply chain is, in principle, far more de-coupled from the geographic deployment area.

Many developers are seeking to localise project spend and certain sub-systems (e.g. cable, balance of plant, mooring system) will still need to be installed on site and with support from local ports and harbours. Statoil's Hywind Pilot Park, set to be the UK's first pre-commercial floating wind project, has contracted suppliers with strong international track record to build its devices, which will be fabricated in Spain before being assembled in Norway and towed to site in Scotland. The range of suppliers selected from across Europe highlights the geographical decoupling possible with floating wind technology and the export opportunities that exist for key players in the emerging sector.

Much good work has already been done to develop and support the UK and Scottish offshore wind supply chain, although there has been a limited focus on floating wind technology to date. Feedback from stakeholder interviews suggest that, if anything, potential suppliers believe the offshore wind market opportunity has historically been 'over-sold' by economic development bodies and that a more realistic and technically focussed assessment of the likely deployment would increase credibility of the sector.

Building trust and experience from early projects has proved influential in subsequent contract awards, highlighting the benefits of first-mover advantage in the nascent sector. Supporting UK companies to service upcoming projects both domestically and overseas can therefore help to maximise economic benefits. This may include investments in infrastructure and manufacturing facilities, innovation funding, and facilitating consortia building to increase the competitiveness of UK companies. Gaining a clearer understanding of technical requirements for floating wind farms was also highlighted as a requirement from suppliers.

Ultimately, the most impactful way of boosting the UK supply chain is to create a strong domestic market. However, in the absence of a suitable remuneration system for project build out, policy makers can continue to support UK companies to innovate and develop products and services which can be exported to active markets overseas. The UK is arguably in a position of competitive advantage given the capability and expertise that exists from its leading fixed offshore wind and offshore oil and gas industries, but support will be required to ensure competitiveness in a global marketplace, both in funding R&D activities and promoting UK capability to foreign customers.

Recommendations on Supply Chain Development

- Create a strong domestic market
- Invest in key enabling infrastructure
- Support innovation in the supply chain
- Support UK companies to export products and services abroad
- Increase coordination of supply chain activity across the UK
- Align decarbonisation and energy security goals with industrial strategy

4. Grid Connection

Grid connection is another critical factor influencing the business case for floating offshore wind. The most attractive site conditions for floating wind, in terms of water depth and wind resource, are largely in locations far removed from demand centres; namely, in Scotland and south-west of England and Wales. Adequate grid connection is therefore critical to maximise benefit to the UK electricity system.

Findings from this report indicate that three out of the seven zones identified by Marine Scotland as potential development zones for floating wind projects in Scotland (RLGO sites) have suitable and available grid connection points to accommodate up to 100 MW of demonstration sites (South-East and North-East of

Aberdeen and West of Colonsay). North-West of Orkney may also be possible with moderate grid upgrades, but three remaining sites (East of Shetland, North Minch, and West of Barra) are deemed unsuitable given the extensive infrastructural investment required to add sufficient transmission capacity to the onshore grid network. In England and Wales, it was found that in order to accommodate additional capacity, the transmission network in those regions would require further development to either increase the existing network's thermal capability or create new transmission capacity.

A comparison of grid connection strategies in other established and emerging offshore wind markets in Europe found that a more holistic approach to offshore grid planning would be more efficient and cost-effective for the transmission network. However, the attractiveness of such a centralised approach is directly related to the scale and appetite for future developments, with small numbers of projects developed individually less likely to require or justify the additional grid complexity. Furthermore, the grid ownership structure adopted in the UK through the OFTO regime is less amenable to this approach than in other countries, where state TSO control and ownership is in place.

Recommendations on Grid Connection

- Ensure a supportive regulatory framework to enable confident and continued investment in grid infrastructure
- Invest in the expansion of transmission system capacities between the north and south of the UK
- Support innovation in transmission system technology for floating offshore wind (e.g. high voltage dynamic cables, deepwater substations)

Introduction

This report was commissioned through a Joint Industry Project (JIP) consisting of five offshore wind project developers (DONG Energy, EDF, E.ON, innogy, and Statoil) and supported by the Scottish Government. Its delivery has been undertaken by the Carbon Trust in collaboration with the Offshore Renewable Energy Catapult. The findings and recommendations highlighted within this report are solely those of the authoring organisations based upon their respective inputs and do not necessarily reflect those of the supporting joint industry partners.

The report aims to outline the key policy and regulatory conditions required to support the commercialisation of floating wind technology.

This includes a high-level overview of the following focus areas:

- Licensing & consenting (delivered by Carbon Trust)
- Subsidy & grant support (delivered by Carbon Trust)
- Supply chain development (delivered by Carbon Trust)
- Grid connection (delivered by ORE Catapult)

For each of the above, this report assesses:

- Current policy status
- Policy options available
- Recommendations to policy makers

The primary methodology for this study was an extensive desk-based study, including a comprehensive literature review followed by targeted stakeholder interviews and a workshop organised in collaboration with NERC and ARUP to discuss the key findings in relation to licencing and consenting. In total, 26 interviews or written statements were provided with stakeholder organisations (identified within Appendix A).

Throughout the primary data gathering process of this report, it was noted that many of the potential challenges and opportunities for floating wind overlap with those already identified for fixed-bottom offshore wind. For the purpose of conciseness and to ensure clarity on the novel aspects that floating wind may encounter, the report has attempted to solely focus upon unique aspects pertaining to floating wind while appreciating that many aspects will overlap and indeed be identical to that found within fixed-bottom offshore wind.

Where possible, the approach has taken a country agnostic approach, but certain aspects have required a more detailed focus on individual countries. This study has assessed the UK and, where relevant, Scotland as the case study geographies.

Abbreviations

AfL – Agreement for Lease
BEIS - Department for Business, Energy & Industrial Strategy
CDM – Construction Design and Management (regulations)
CFD FiT – Contract for Difference Feed in Tariff
DECC – Department for Energy and Climate Change (defunct)
EEZ – Exclusive Economic Zone
EIA – Environmental Impact Assessment
EIB – European Investment Bank
EFSI – European Fund for Strategic Investments
EMR – Electricity Market Reform
EOR – Enhanced Oil Recovery
EPSRC – Engineering and Physical Sciences Research Council
ERA-NET – European Research Area Network
ETI – Energy Technology Institute
HIE – Highlands and Islands Enterprise
IALA – International Association of Marine Aids to Navigation and Lighthouse Authorities
KTN – Knowledge Transfer Network
MaRS – Marine Resource System
MCA – Maritime and Coastguard Agency
MMO – Marine Management Organisation
MS – Marine Scotland
NER – New Entrants Reserve
NLB – Northern Lighthouse Board
OREC – Offshore Renewable Energy Catapult
POWERS – Prototyping for Offshore Wind Energy Renewables Scotland
RLGO – Regional Locational Guidance Option
RO – Renewables Obligation
ROS – Renewables Obligation Scotland
SEA – Strategic Environmental Assessment
SNCB – Statutory Nature Conservation Body
TCE – The Crown Estate
TRL – Technology Readiness Level
WERS - Wind Energy Reservoir Storage

1 Licensing & Consenting

1.1 Current policy status

This section outlines the current state of licensing and consenting for floating wind marine spatial planning within the UK. The section is split between the England & Wales and Scotland, due to the different consenting regimes implemented. A brief review of current and planned floating wind activity globally is also included within section 1.1.3 to provide international context.

1.1.1. England & Wales

The UK has a large offshore fixed wind capacity both in operation (5GW), already consented (14.9GW) and in planning (3.2GW) (DECC, 2016). The UK Government have committed to roughly 10GW of deployment by 2020 and 20GW by 2030. The vast majority of this is in English and Welsh waters (10.6GW consented and 4.8GW operational); however, in spite of this, there are currently no consented or operational floating wind projects in either England or Wales.

In 2013 the Crown Estate ran a leasing round for floating wind (including Scotland); however, despite receiving interest from potential site developers, no projects were evaluated to be commercially or technically mature enough to be awarded a leasing option at that time.

Following on from this, the recent PelaStar demonstration project led by the ETI, which aimed to deploy a 6MW TLP floating wind turbine at the Wave Hub site in Cornwall, was cancelled due to several factors. This including failure to secure the £65m project investment needed and Ministry of Defence (MOD) objections on the grounds of radar interference. Most recently, Floating Power Plant are at the early stages of seeking to deploy their combined wind and wave device at either the Pembrokeshire Demonstration Zone, Wales, or a site near Dounreay, Scotland.

At a national strategic level, previous Offshore Energy Strategic Environmental Assessments (OESEAs) had assessed water depths of up to 60m and considered depths from 60-200m only as potential areas for future commercial exploitation. The most recent published OESEA (3), does consider floating turbines in water depths ranging from 50-200m. It states a theoretical capacity for floating wind of 257 GW after basic hard constraints are applied over the 77,896 km identified area (i.e. out to the 200nm Exclusive Economic Zone (formerly Renewable Energy Zone) and excluding Scottish waters and Northern Ireland to 12 nm) (Figure 1).

Although most of this theoretical capacity will be practically constrained (due to economic or technical considerations), areas overlap with several identified existing Round 3 sites, which (although in some cases abandoned) could be feasible for floating wind developments, including:

- South west of North Sea (counted as Regional Sea (RS) 1),
- Hornsea region,
- Western parts of RS 6 (Irish Sea),
- RS 3 (Eastern English Channel),
- Majority of RS 4 (Western English Channel and Celtic Sea).

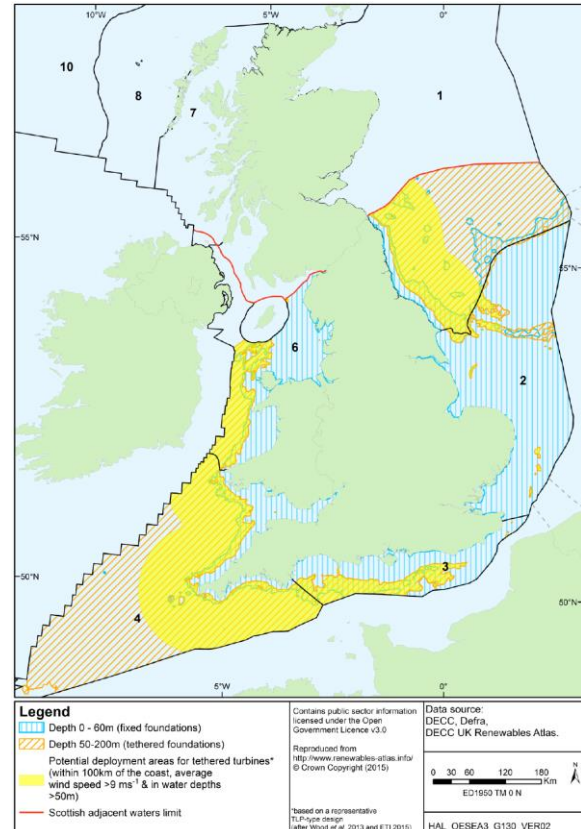


Figure 1: Offshore wind resource map considered within OESEA(3). Yellow indicates potential floating wind sites

The majority of these sites are between the 50-100m depth ranges and thus would be less suitable for spar buoy and most TLP concepts. Even technically viable semi-submersible and TLP concepts may also be less competitive at this depth range, as optimal depth is expected at 100-150m.

Abandoned fixed wind sites have also been noted by stakeholders (although not within the OESEA) as holding potential for 'recycle' for floating wind application. This would have to be where project cancellation was down to technical factors that may not apply to floating wind. An example of this could be the Round 3 Atlantic Array site within the Bristol Channel that was primarily dropped due to unsuitable sea-bed conditions. There may be other close to shore English sites that fit the technical requirements for floating wind over fixed-bottom and could thus be developed more cheaply, however, site identification would need to be undertaken. It should be noted that these sites would still have to compete economically against conventional fixed wind sites elsewhere within the UK, unless they were specifically being developed as test and/or demonstration locations or there was a discrete funding support mechanism for floating wind deployment. The Crown Estate have no process for re-assigning such sites; they have stated, however, that this could be considered if market interest was shown.

1.1.2. Scotland

Despite lagging behind the rest of Great Britain in fixed-bottom offshore wind with 191 MW of installed capacity and 4.3 GW consented, Scotland have a more favourable natural resource for supporting floating wind with large amounts of deep-water locations accessible close to shore with very high wind regimes (see Figure 2). Unfortunately many potential 'sweet-spot' sites are constrained due to a lack of grid access or infrastructure, which has affected the perceived cost competitiveness of floating wind projects (see section 4. Grid Connection for more).

In respect to marine spatial planning, Scotland has not recently undertaken a Strategic Environmental Assessment. Previous sectoral marine plans from 2010 (Deep Seas, Green Energy) identify sweet-spot areas that could have supported floating wind; however, their review was technology agnostic and did not identify floating systems directly as a potential technology solution. The marine licensing authority, Marine Scotland, are currently in the process of developing sectoral marine plans which will include an SEA when complete; however, it is uncertain how much this will focus upon floating wind technologies and appropriate deep sea locations at this time.

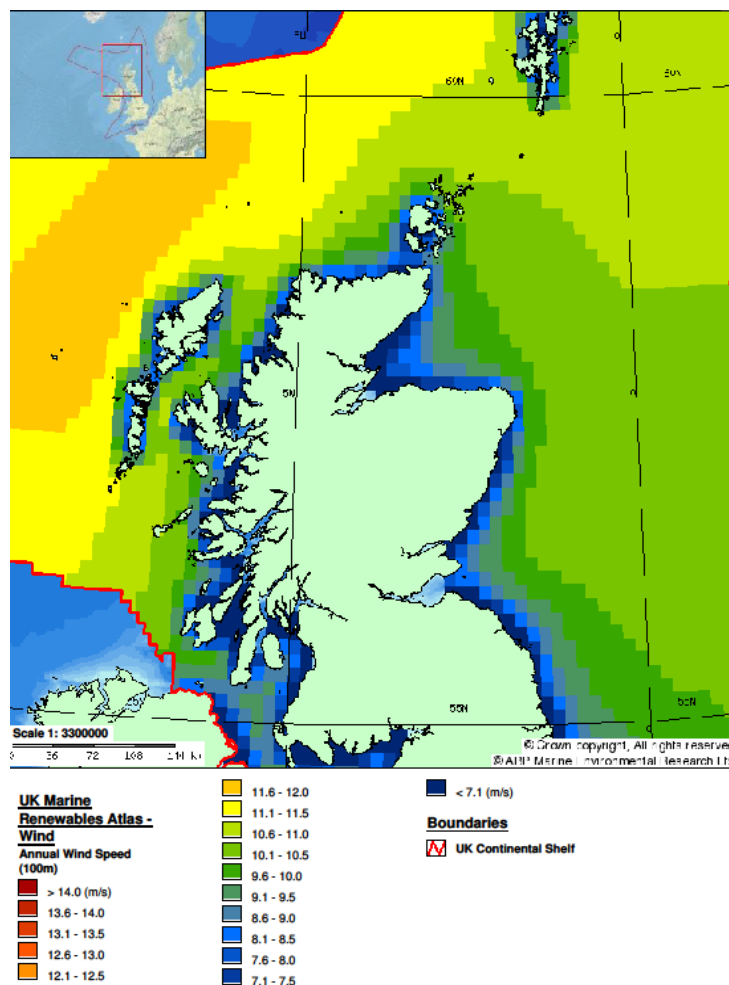


Figure 2: Scottish offshore wind speeds (@ 100m) (ABPMer, 2016)

In 2014, Marine Scotland identified 7 Regional Locational Guidance Options (RLGOs) for deep water floating wind technologies (see Figure 3). These sites were identified as potentially low risk locations for site evaluation and potential project development ranging in depths from 36m (West of Colonsay) to 120m (East of Shetland and South-East of Aberdeen).

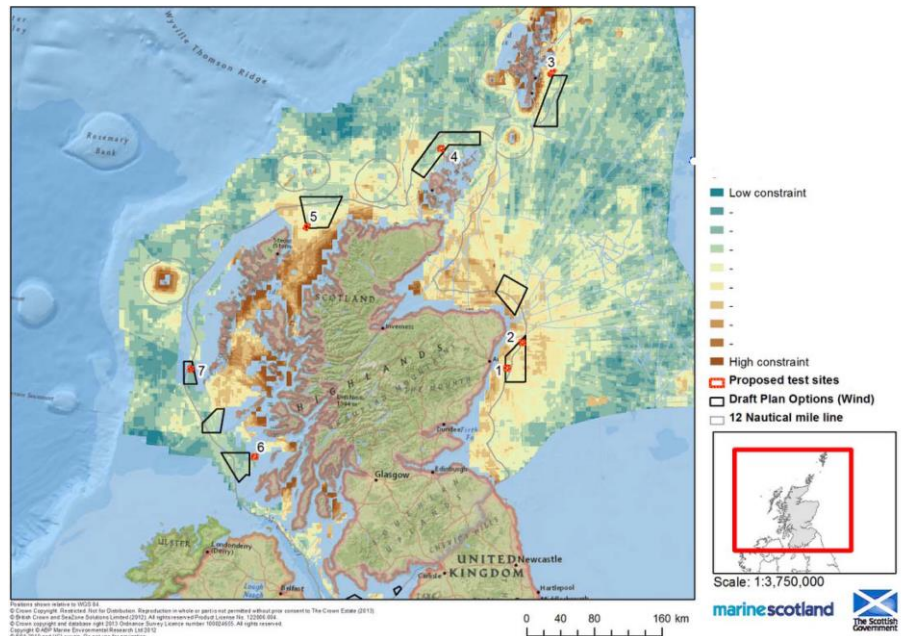


Figure 3: Recommended Regional Location Guidance Options for Scotland

Currently, Marine Scotland are also updating their planning guidance document which informs prospective applicants of the consenting process. It is unlikely there will be any substantive change, however, it may clarify uncertainties, such as expected timeframes for process review.

There have been several key project developments within floating wind over the last few years in Scotland. Statoil are in the processing of developing a site 25km off the coast of Peterhead in the Buchan Deep. The project, which reached FID in November 2015 and is currently under construction, will be the world's first pre-commercial floating wind farm when installed in 2017. It will consist of 5 x 6 MW Hywind spar-buoy devices for a total farm capacity of 30 MW. This is the second stage of a test programme that began with the successful demonstration of a 2.3 MW device in Norway in 2009. A further unique element of this project is that it will integrate the development with onshore battery storage (under the 'Batwind' project) to mitigate against intermittency and optimise market revenue streams.

Another major project within Scottish waters is the Kincardine Offshore Windfarm, approximately 13km from Aberdeen. The project is being progressed by Pilot Offshore and Atkins, while ACS Cobra will provide 8 of their concrete semi-submersible/spar hybrid platforms, supporting 6 MW turbines. The consent application has been submitted, but the project faces a race to secure all the necessary permits and investment to secure commissioning before October 2018.

Floating wind developments are also being pursued on the far north coast, off Dounreay. Here, a planned test centre was previously being developed by Highlands & Islands Enterprise (HIE) (the Dounreay Floating Offshore Wind Development Centre), however, this was recently scrapped due to uncertain market conditions beyond 2018 (see section 2). This site was considered favourable due to a secured grid access (with a 9.9MW grid connection), low concerns over protected bird species (compared to east coast sites) and favourable environmental considerations (wind/wave/tidal regimes etc.). As a result, technology development company Hexicon are now working through a Special Purpose Vehicle (SPV), Dounreay Tri Limited, to proceed the site realisation and capitalise upon already defrayed development expense (e.g. prior consent studies). This project, if realised, will consist of two turbines of 5 MW capacity on a multiple turbine semi-submersible structure.

1.1.3. International

Although there has been no deployment of floating wind to date on a commercial basis, several countries have tested early stage technologies up to full scale prototype demonstration (TRL7²). The licensing conditions for these deployments have varied by country; however, where commonalities of policy exist (e.g. within Europe) an element of uniformity is imposed (e.g. the Environmental Impact Assessment (EIA) process or Habitats Regulation Appraisal (HRA) is followed). Within Europe, Norway and Portugal have hosted prototype demonstrations, and further prototype demonstrations are expected in Germany and France before 2018, with pre-commercial arrays in France by 2020, supported by the 2016 tender for floating wind projects. Japan are another leading market for floating wind, with three floating turbines installed at Fukushima, alongside a floating substation, with another unit installed in the Goto Islands. Further demonstrations have also been confirmed following the announcement of two NEDO-supported prototype demonstrations using the IDEOL floater design. The US too, in the longer term, could play a key role in floating wind commercialisation, but stringent licensing and consenting processes, as well as price competition, may limit large scale build-out in the near term.

The below section assesses, at a high-level, the licensing and consenting requirements in these key markets.

France

The French environment and energy agency ADEME has recently run a French tender for pre-commercial wind farms each with between 3 and 6 floating wind turbines, with a minimum 5 MW power rating. Three of the four zones identified by the French government for the pilot floating wind tenders are in the Mediterranean Sea, where deep waters close to shore and strong wind resource from the Mistral present favourable conditions for floating wind deployment. A fourth area for the tender is off the coast of Bretagne in the Atlantic Ocean, to the south of Groix Island.

Bidders were required to provide plans for the turbine, floating foundation, anchoring system, grid link, installation methods and logistics, and must have carried out a previous feasibility study, life-cycle study and environmental impact assessment (ADEME, 2016). The tender process closed on the 4th April 2016 and four successful bidders were announced later in 2016 (Table 1).

Zone	Capacity	Developer(s)	Turbine supplier	Floater	Other partner(s)
Groix (Atlantic)	24 MW (4x 6 MW)	Eolfi / China Guangdong Nuclear (CGN)	GE	DCNS 'SeaReed'	TBC
Gruissan (Med)	24 MW (4x 6 MW)	Quadran	Senvion	IDEOL 'Damping Pool'	Bouygues Travaux Publics
Faraman (Med)	24 MW (3x 8 MW)	EDF EN	Siemens	SBM Offshore 'TLP'	IFPEN
Leucate (Med)	24 MW (4x 6 MW)	Engie / EDPR	GE	Principle Power 'WindFloat'	Caisse des depots / Eiffage

Table 1: French floating wind tender contract awards

The management of French waters is primarily the responsibility of the central government, through the General Secretariat of the Sea and Maritime Prefect, while the national Transmission System Operator (TSO), RTE, is responsible for developing the network infrastructure and grid management.

Case study project: Floatgen (IDEOL)

Ideol's 2MW Floatgen floating unit has received consent for installation in autumn 2016 at the Sem-Rev test centre site and is expected to be commissioned by April 2017. The project has suffered from some challenges

² Technology Readiness Levels taken from: (Department of Energy, 2011)

due to the original turbine supplier, Gamesa, pulling out of the offshore wind market. However, Ideol have since secured a 2 MW Vestas turbine for the demonstration.

Portugal

The main consent required for floating offshore wind development is the “título de utilização dos recursos hídricos” (licence for water resources use) which can be authorised through a concession process. To initiate the process, the applicant must submit a pre-application form with the project and site characteristics. In cases where a concession is required for the project, a competitive public examination must be carried out. An Environmental Impact Assessment (EIA) may be required during this stage of the process.

In addition to the licence for the water resources use of the project, a licence for the power production installation is required, which is initiated via a pre-application submitted by the applicant to the “Direcção Geral de Engenharia e Geologia” (DGEG, Energy and Geology Directorate-General). If the project is to supply power to the grid the developer should apply to the Portuguese Electricity Utility (EDP, Electricidade De Portugal) for a licence. This application must include a map of the project location identifying the proposed grid access point connection point. If construction of infrastructure on land is required the licence is administered by the municipal council of the area of the project location.

Case study project: WindFloat Atlantic Phase 2

Following on from the successful 2 MW prototype at Agucadora (Phase 1), the 25 MW WindFloat Atlantic Phase 2, consisting of three 8.3 MW MHI-Vestas turbines, will be located 20km of the Portuguese coast at Viana do Castelo. The project is planned to be operational in 2018 with a total capacity of 25 MW.

The project falls under Annex II of the Environmental Impact Assessment (EIA) Directive, and the competent authority has screened the project out of full EIA requirement due to its relative small size (3 turbines) and siting outside of any protected areas. Although no full EIA is required, it will be necessary to go through a less onerous environmental incidences study, for which comprehensive environmental studies are being produced. No major environmental and social risks have been identified at this stage.

Germany

The Federal Maritime and Hydrographic Agency (BSH) is the federal agency overseeing licensing for renewable energy projects in the EEZ based on the Maritime Spatial Plan for the North and the Baltic Seas. Their approval procedure requires the following steps:

1. Authorities including the regional Waterways and Shipping Directorates and the Federal Agency for Nature Conservation are informed about project application and asked to comment.
2. Stakeholder and public involvement is encouraged with regard to inspecting the planning documents. A project presentation is offered to the project planner during an application conference.
3. The applicant prepares an Environmental Impact Assessment and a risk analysis to be reviewed by the BSH and granted approval if requirements have been met.

Permits for offshore wind farms are allocated through an open-door procedure. The first candidate to submit a proposal for a project that meets all of the BSH's stated criteria is given priority to develop the site. This developer is then given exclusive rights to the site. However, it should be noted that this is anticipated to change as Germany adopts a competitive tendering process for future offshore wind developments.

Once the project is fully consented, the developer can submit an application for grid connection. Under the Infrastructure Planning Acceleration Act of 2006, the transmission system operator is obliged to install the grid connection in its controlled area and cover the costs for the grid connection. The Federal Energy Regulator (BundesNetzagentur) is in charge of approving applications for an offshore grid on economic grounds.

Case study project: GICON Baltic demonstration

The GICON-SOF tension leg platform could become this world's first full-scale demonstration of a floating wind TLP concept if a 2 MW unit is installed in the German Baltic Sea in 2017. The site is located 21km off the coast of Zingst, in the German state of Mecklenburg-Vorpommern, and was awarded consent for the erection and operation of an offshore wind turbine by the State Department of Agriculture and Environment in March 2015. In November, 2015, GICON won a permit that allows them to apply for a 2.3 MW network connection to feed power in via the Baltic 1 wind project. However, grid connection delays have resulted in GICON losing access to grant funding, which has put the project at risk and seen the proposed installation date pushed back from 2016 to 2017 at the earliest. A nearby site has already been identified for a scaled-up 6 MW version of the concept.

Norway

In Norway, floating offshore wind shares policies and programs with other renewable energy technologies. The 2010 Ocean Energy Bill regulates renewable offshore energy production by requiring licenses to build offshore wind, wave, and tidal farms in certain geographical areas. Licenses are granted through a governmental process where suitable areas are identified and made subject to consequence assessments and then made available for leasing. Previous projects (notably the Hywind prototype) were funded by the Norwegian Energy Agency (ENOVA) and the Research Council of Norway.

United States

The US has a notably complex system for obtaining marine licences. The Federal Energy Regulatory Commission (FERC) asserts regulatory jurisdiction over marine and hydrokinetic projects in the United States as an extension of its authority under the Federal Power Act to regulate and license hydroelectric projects on navigable waters (approximately within 3 nautical miles of shore), and on any projects with an onshore grid connection. The Bureau of Ocean Energy Management (BOEM) asserts regulatory jurisdiction over marine projects on the outer continental shelf. Permits are also required from US Army Corps of Engineers (USACE) and US Coast Guard (USCG), with further agency consulting for environmental protection.

Case study project: Morro Bay, California

BOEM has kicked off a leasing process in California following the submission of an expression of interest from a consortium led by developer Trident Winds. Trident are seeking permission to build a floating wind farm of up to 765 MW, located in Morro Bay. As part of a recent review, BOEM confirmed that Trident Winds is legally, technically, and financially qualified to hold an offshore wind energy lease in federal waters. BOEM is now requesting expressions of interest from other parties to develop the site. If the agency finds there is competitive interest in the area sought by Trident, it will initiate a competitive leasing process. However, even if no other interest is forthcoming, there remains a process for awarding a lease directly to a developer. BOEM will issue a Federal Register Notice, which will also include a request for the public and interested stakeholders to comment and provide information on site conditions, commercial, military or other uses of the area and potential impacts of the proposed project.

1.2 Overview of current consenting process for floating wind in the UK

1.2.1. Planning and consent requirements

The key environmental legislation (and licences to show compliance) that will be applicable for future deployment of floating wind in the UK are identical to those applied to fixed-bottom wind; however, their scope will vary as a result of the different anticipated impacts (e.g. deeper water sites, different installation methods, different stakeholders affected, etc.).

The designated competent bodies' responsibility for both legislative compliance and marine spatial planning within the UK are divided between the following bodies:

- **England:** The Marine Management Organisation (MMO) (Marine and Coastal Access Act 2009)
- **Scotland:** Marine Scotland (MS) (Marine (Scotland) Act 2010)
- **Wales:** Natural Resources Wales (although the MMO are still the de-facto-managers in terms of application processing)
- **Northern Ireland:** Northern Ireland Executive (Marine Act (Northern Ireland) 2013)

A marine licence can only be granted once all legislative requirements have been met and approved. The below provides a brief outline into the legislations used for attaining marine consent, as well as the assessment process undertaken.

Environmental Impact Assessment Directive

The Environmental Impact Assessment (EIA) Directive (85/337/EC as amended by 97/11/EC, 2003/35/EC and 2009/31/EC) is the primary EU regulation that sets out a procedural process required for assessing and granting permission to projects that may have a significant impact upon the environment. Evidence of compliance requires the undertaking of an environmental assessment (that may result in an impact assessment), which is a process split into several key stages.

Stage 1 – Screening:

The first is the screening stage which allows the competent authority to decide whether or not a formal environmental impact assessment is itself required. Either a project developer or the competent authority can request a project screening. At this stage identification of the broad project plan, including technology, location and project timeframe, should be identified and rationalised (in terms of options appraisal).

Stage 2 – Scoping:

The second stage is the scoping stage. During scoping, environmental receptors that the project may affect (especially species and habitats) are identified, as well as the wider impacts to be included within the impact assessment listed. The scoping is opened to public scrutiny and objection, as well as presented to statutory stakeholders who hold responsibility for different issues that may be affected by the project (e.g. the MOD may wish to know about deployments that affect radar function). Marine Scotland apply a risk based approach to licensing in which the burden of evidence required from developers is weighted according to three key factors:

1. The site location proposed and its environmental sensitivities
2. The size of the deployment expected
3. The risks associated to the technology itself

In reference to the deployment scenarios within this study, these translate as shown below:

	Prototype/ Demonstration	Pre-Commercial Array Proving	First Commercial	Mature Commercial
TRL	TRL 7	TRL 8	TRL 9	-
Expected Rating	2MW+	6MW+	8MW+	10MW+
Number of Units	1	~5	~30	50+
Project Life	1-5 years	20-25 years	20-25 years	20-25 years
Max Project Size	≤8MW	≤50MW	≤240MW	500MW+
Scale of Development	Low	Medium	High	High
Device (or Technology) Classification	Technology specific but likely to be higher at prototype/demonstration due to unknown technology characteristics and behaviour			

Table 2: Project scale, environmental sensitivity, and technology risk for different stages of market maturity

Stage 3 – Environmental Impact Assessment:

The third stage is the EIA itself, which is undertaken and submitted in the form of an Environmental Statement (ES). The scale, scope and complexity of the assessment will be outlined in the scoping stage and relate to the size, location, potential affects and uncertainties of the project. Early demonstration projects for novel technologies may suffer from a higher onus of evidenced studies to mitigate against uncertainties inherent in the project being employed.

Stage 4 – Consultation:

Finally, the ES is assessed and consulted upon by relevant stakeholders. This includes all statutory consultee stakeholders (e.g. Scottish National Heritage, RSPB, Scottish Fisheries Federation, etc.), locally affected stakeholders (communities, local fishermen, etc.) and the wider public.

Stage 5 – Decision:

The decision is then made as to whether to award the licence or not. Awarding of a licence can be provisionally based upon a requirement for mitigating actions to the ES to reduce impacts (e.g. only allowing site traffic during certain less disruptive hours, requiring further measures to reduce onshore disruptions etc.).

Habitats Regulation Appraisal

Directive 2009/147/EC and Directive 92/43/EEC commonly known as the Birds and Habitats Directives respectively are European requirements for the conservation and protection of rare or vulnerable birds and habitats. The regulations place an onus upon states to protect vulnerable natural areas and locations through the creation of Special Protected Areas and Special Areas of Conservation (or Natura sites as they are collectively identified). Site designation does not prohibit farm development (Natura sites are considered a ‘soft constraint’, as opposed to, for example, military training grounds); however, due to the identified sensitivity of the location, the requirement for understanding, characterising and showing minimal impact on plans for such sites is proportionally greater.

Habitat appraisals are conducted in a similar format to EIAs and the process of assessment (referred to as Habitats Regulation Appraisal (HRA)) is separate, but where an in-depth assessment is undertaken, it is usually conducted concurrently with an EIA and results in an Appropriate Assessment (AA).



Figure 4: Marine Scotland Licencing Process (ABP Mer, 2012)³

Further marine licence requirements and other legislation

In addition to the above, site developers are required to show compliance for several other regulations.

For electrical works compliance, section 36 (for offshore) and 37 (for onshore) of the Electricity act (1989) are relevant. This legislation does not focus upon project specification or requirement but, rather, ensuring that anything connected to the national grid performs to a certain code of standard (grid code), such as frequency, trip out time, etc. This is covered in greater detail within the Grid Connection section.

For onshore works, the Town and Country Planning Act (1990) designates the competent body for decision making of onshore structures and works (e.g. sub-stations etc.). This is usually the local council planning authority.

Other licences may also be required such as a Basking Shark Licence (Scotland) or Work Licenses (for ports or harbours works).

³ Blue – Main activity, Green - EIA process, Purple - HRA process, Orange – Other/supporting

Seabed lease

Along with a marine licence, a seabed lease is required for any floating wind developments within UK waters. This can be obtained through The Crown Estate. The Crown Estate is an independent commercial business, created by an Act of Parliament, to manage the assets of The Crown Estate (with profits being paid to the UK Treasury).

The Crown Estate manages about half the foreshore, beds of estuaries and tidal rivers in the United Kingdom and almost the entire seabed (out to 12 nautical miles) along with the management rights to renewable energy and gas and carbon transportation and storage development on the Continental Shelf.

When making a request to The Crown Estate for seabed rights, an application is initially made. Historically, depending on the appetite of various sectors the mechanism for making that application has either been by request or within leasing rounds. For example, wave and tidal is currently by request only, in order to align with the existing demand in the sector. The same approach is currently true for floating wind developments.

The detail of any application itself varies, as would be expected, for the scale of project being requested. The detail required is proportional and appropriate for the project scale being applied for. The application nevertheless generally covers four key areas; technology, H&S, finance, and overall business planning.

If an application is successful an agreement for lease is awarded⁴. An Agreement for Lease generally grants a developer an option over an area of seabed. Exercise of the option by the developer will be conditional on it satisfying certain conditions. If the conditions are satisfied and the developer exercises the option, The Crown Estate will be obliged to grant a lease of the seabed to the developer.

For floating wind The Crown Estate are actively talking to parties interested in deployment about possible routes to market at this time.

Experience from early projects

Consultation with stakeholders involved in early floating wind projects in the UK suggest that, while the processes to obtain consent exist and aim to take a risk-based approach, in reality the consenting process has taken longer than initially expected. In some cases this has caused project delays and introducing unforeseen costs to developers. All stakeholders are in agreement about undertaking a risk-based approach to licencing (i.e. Survey-Deploy-Monitor) that reflects the environmental sensitivity of the site, scale of the project, and the technology characteristics; however, site developers have commented on the need for greater clarity on the timeframe for both the consenting process to be undertaken and the response time requirements for statutory stakeholders (i.e. to screening/scoping/ES submission).

⁴ Further details of The Crown Estate's role in renewable energy development, please see this briefing note: <http://www.thecrownestate.co.uk/media/5411/ei-the-crown-estate-role-in-offshore-renewable-energy.pdf>

1.2.2. Considerations of unique environmental and human impacts of floating wind farms

As stated in the previous section, although the consenting process will be the same for both floating and fixed-bottom wind (e.g. assessment of environmental impacts), specific considerations for evaluation will vary (e.g. floating technology, deep water habitats etc.), as well as the spatial planning considerations (distance from shore, differing stakeholders etc.).

Many of the perceived primary environmental and human impacts that would be identified within a standard fixed-bottom wind development scoping exercise are transferable. Marine Scotland have stated within their Deep Water Floating Wind Technologies Study that fishing, shipping, military practice, protected and designated sites, seabirds, marine mammal species and basking sharks were all considered influential in determining their initial RLGO site locations.

One potential variation for consideration within project scoping for commercial farms is the expected distance from shore. Sites further from shore will likely encounter different habitat and species interactions to near-shore sites, as well as human sea users. Far-shore sites will therefore require different managed responses (such as consideration of the Espoo (EIA) Convention which covers international obligations) than might be the case for sites closer to shore. However, far-shore interactions are only expected to become a consideration at more mature market stages, as demonstration and pilot arrays are expected to be sited closer to shore.

Fishing

Under current UK legislation, access around fixed-bottom foundation offshore wind farms requires vessels to keep a 50m safety zone from any turbine structure (and typically 500m during construction, major maintenance and decommissioning). This allows constrained but available fishing opportunities within current offshore wind farms. It should be noted that the practicality of enforcing this 50m safety zone, and thus the efficacy of designation, has been questioned by some stakeholders.

Spar buoy and semi-submersible foundation turbines present a unique challenge in relation to the fishing industry. Typical catenary mooring spreads will cover a distance of 4 to 6 times the water depth so could reach over 1km from turbine for deep water installations (up to 250m). In addition, semi-buoyant dynamic cabling may be required for part or all intra-array cabling within the farm. This could necessitate a non-fishing zone status for both the site and its extended footprint. For large commercial sites, fishing intensity studies may need to be undertaken to identify the potential commercial impacts of large scale floating wind farms.

Deep sea fishing trawlers also operate further out to sea and natural fish habitats where fishing occurs require different seabed types which therefore defined fishing/non-fishing locations. These locations are clearly not related to the distance from shore. As such, fishing is an industry that, although will change in nature further from shore, tends to persist out to the continental shelf based more upon seabed type than distance from shore.

Despite potential exclusion zones, mitigation options, such as 'reef-effects' within floating wind farms, could in fact promote higher fish stocks in surrounding areas. However, these benefits have yet to be validated.

Tension leg platforms, due to the way in which they are moored (using a vertical and taut resistive anchor solution) have a lower installed footprint than semi-submersible and spar-buoy solutions. This could potentially be more amenable to fishing activities where there would not be a risk of entanglement with mooring lines. However, dynamic inter-array cables are still likely to be present. Further studies would need to be undertaken to understand and validate these options.

Species and habitats

As with other novel marine energy technologies there are opportunities to improve understanding of potential species interactions (receptors) for future floating wind deployment.

As part of this study, initial discussions with a wide range of stakeholders suggest that floating wind presents an option for reduced species and habitat conflicts compared to fixed-bottom wind turbines. This is partly due to expectations for reduced piling and seabed disruption during installation, but also expectations by some stakeholders for commercial floating wind farms being located further offshore. The recently published RSPB 2050 Energy Vision has (in one of its three scenarios) around 50% of UK demand being met by floating offshore wind, much of which is located in far-shore locations (Figure 5). However, it is expected that the business case for using floating wind to open up new areas for development in deepwater sites closer to onshore transmission networks will mean that near shore sites are likely to be considered for deployment before moving further offshore. It will be necessary to maintain a dialogue between interested stakeholder groups and manage perception of risks when planning commercial-scale floating wind farms.

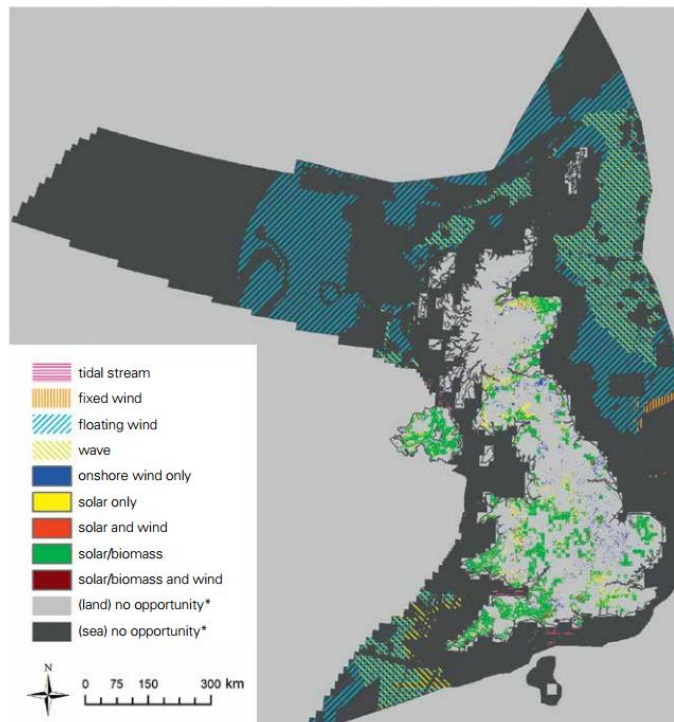


Figure 5: RSPB Geospatial map for future renewable deployment (RSPB, 2016)

Early demonstration sites in locations closer to shore are likely to be in areas where interaction with wildlife is higher. As with fixed-bottom sites it is therefore important that a similar robust approach to environmental impact assessments is undertaken to mitigate risks. The case for situating commercial sites at deep water, close-to-shore locations will be strengthened by appropriate research being undertaken to fully explore the impacts, increase certainty and address concerns of stakeholder groups involved in consent planning. A potential benefit was recently highlighted in the DECC SEA which states that “the use of floating wind turbines would remove much of the construction impact associated with the generation of suspended sediment concentration through dredging and seabed preparation activities, together with the operational impact of scour”. It goes on to state that in terms of all offshore renewable installations, “foundation type with the least environmental impact in terms of decommissioning are floating foundations”.

One further consideration relates to ballast water management (BWM). Current changes within international maritime law are occurring as a result of the adoption of the 2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). This convention is awaiting ratification having been ratified by 51 states representing 34.87% of merchant shipping tonnage as off 01/08/16 (0.13% short on requirement). It is established to control the introduction of invasive species to sea areas as a result of ballast transport (both water and sediment). In practice, this will mean that many vessels will require water treatment systems based upon tonnage and area of operation (i.e. international/national etc.). It is likely that this will have relevance for future floating wind installations that take on ballast and may therefore need some form of water treatment system integrated into their structure.

Stakeholder interviews and workshop identified a number of other potential habitat risks exist in relation to the technical novelty of floating wind, including electromagnetic fields from electrical cables, noise from cable ‘snapping’, and interaction of marine mammals with subsea systems. It is acknowledged that many of these issues may not in practice pose a great threat and are unlikely to require mitigating action. However, there is scope for scientific research studies to further investigate perceived risks.

Navigation and safety

The subsea platforms to be incorporated in floating wind turbines have been in production and used in oil and gas since the 1960s so do not inherently imply more or less risk in terms of navigation or health and safety concern. Combined with existing regulations employed on fixed wind farms (for example, International Association of Lighthouse Authorities (IALA) navigational marking and Search and Rescue (SAR) access lane requirements) there should be very little adaptation required to integrate floating wind projects into existing stakeholder considerations.

Unique areas for consideration relate to the following categories:

- **Mobility or potential for mobility:** Critical failure (although unlikely) could result in turbines losing station. Project developers would be required to develop an emergency response plan for such instances, show third party verification of the mooring system or have GPS tracking/alarm systems.
- **Subsea considerations:** Navigational maps would need marking as prohibitive for both anchoring and fishing. However, these would not be designated as exclusion zones.
- **Service considerations:** Depending upon the service strategy, safety and navigation considerations may be required. For any non-permanent mooring, this would fall under consideration of the Maritime and Coastguard Agency (MCA) effectively as a 'mobile vessel' and would need to conform to collision regulations.

Consideration for the above would be taken into account alongside the site location. Should commercial sites be further from shore, there would be a lower risk of encounters with vessels. Conversely, search and rescue response times will increase the further out to shore a site is, making considerations for potential helicopter rescue even more pertinent.

It is not considered that any of the above considerations will require further research, however, discussions between project developers and statutory bodies (i.e. Northern Lighthouse Board, Maritime and Coastguard Agency) will be required to clarify this for any given project.

1.2.3. Research projects to de-risk the consenting process

As stated above, demonstration projects are important for learning and de-risking non-technical aspects as well as technical ones. There is therefore an opportunity at this stage of market maturity to undertake environmental and planning research that could both de-risk future commercial projects and validate claims about potential impacts (both positive and negative) that have been identified but not substantiated. These include the following:

- **Fishery impact:** As with any new offshore development there is a possibility that the development site will be located within an existing trawling ground, therefore efforts should be made to mitigate conflicts through close engagement and dialogue with fishery representatives. There are two focal research areas that would benefit from being undertaken in order to validate the claims made about the potential benefits to fishing from floating wind technology:
 - Identifying opportunities for mutual site use (e.g. static fishing integration, marine fertilisation/feeding).
 - Validating that sites will act as fish aggregating devices (FADs) allowing ‘reef effects’ to occur, increasing the overall biodiversity and ultimately increasing fishing stocks for surrounding sites.
- **Construction & decommissioning:** Validating claims of reduced construction and decommissioning impact, as well as lower foundation impact, would help to alleviate habitat impact concerns.
- **Ornithological impact:** As with fixed-bottom wind farms, there is a requirement for engagement with representation bodies (such as SNCBs and RSPB) to manage deployment expectations for commercial sites. It is expected that ornithological behaviour at floating wind farms will be similar to fixed-bottom wind farms. This will enable considerable transferability of research studies between the two. However, potential research activities unique to floating wind farms could include:
 - Validation of modified collision risk models (CRM) to account for minor movement of floating wind turbines.
 - Investigation and validation of potential attraction of birds to platform structures within the wind farm.
- **Subsea impact:** The subsea infrastructure of floating wind turbines will differ to those of fixed foundations. Building on existing research from the wider offshore renewables sector to understand the impact of subsea structures on marine mammal, studies could be undertaken alongside operational floating wind farms to investigate the behaviour of marine mammals in these environments.
 - Investigate the impact of electromagnetic fields (EMF) within the water column around electrical cables of floating wind devices.
 - Monitoring studies to assess the behaviour of marine mammals within floating wind farms, including interactions with mooring lines and cables.

1.3 Recommendations for policy makers

There are several stepping stones on the roadmap towards deployment for future floating wind in which the risk, cost and evidence of maturation can be stage-gated such that a controlled industry progression does not expose funders or stakeholders to unnecessary cost⁵. However, this should not preclude undertaking early and relatively low cost stages of stakeholder engagement and site selection to de-risk future planning considerations; nor should it preclude progressing technology de-risking R&D activity that could be conducted concurrently and within early projects.

Demonstration and pilot array

For early demonstration and initial arrays (up to ~8 turbines), a measured approach to leasing and consenting requirements is needed that is proportional to project scale and provides sufficient clarity and certainty to enable prospective project developers to budget accordingly for the time and costs involved. In practice, this translates into a requirement for a clear, transparent and supportive consenting relationship between project developers, authorities and statutory consultees in which uncertainties from both sides can be identified and mitigated as quickly and effectively as possible.

There are several key actions that could be undertaken to de-risk and promote the attractiveness of early stage demonstrations and pilot arrays, as outlined below. It should be noted that these are contingent on the availability of suitable funding support.

- **De-risked demonstration site:** The most attractive proposition to prospective wind farm and technology developers would be a de-risked demonstration site with pre-approved consent and grid connection offer in place. Ideally, this would also include provision of site data. This could include undertaking of detailed bathymetric, geotechnical, met-ocean, and environmental monitoring studies. The provision of electrical infrastructure could also add to the attractiveness of a demonstration site by reducing the overall cost and scope of activities for project developer. However, this would need to be designed to accommodate suitable installed capacity and future proofed against technology innovations. Given the high cost of these activities, they are only recommended if a secure and viable financing mechanism is available.

For open-door project developments, the following conditions are recommended:

- **Flexible technology envelope:** A relatively wide technology envelope can allow greater flexibility for project developers to make low impact changes to technology options and adopt cost-cutting innovations. This may also include variations to enable the inclusion of floating wind technology alongside existing commercial fixed-bottom wind farms.
- **Potential for further build-out:** The ability to expand a site to host more turbine units would significantly increase the attractiveness to prospective developers and investors. This could include, for example, the option for prototype demonstrations to be extended to an array of up to 5-8 turbines, or for an initial pilot array to be expanded to a larger commercial wind farm. This should be a consideration for the initial site location and technology envelope.
- **Risk-based approach to consent:** As with most early technology developments, a risk based process should be applied to consenting that reflects the scale of the project, risk of the technology and sensitivity of the site (i.e. survey-deploy-monitor approach).
- **Clarity on consenting timescales:** Clarity and transparency on both the process and timeframe for consenting decisions is a high priority concern for project developers. Increased certainty for developers would greatly improve opportunities to secure investment and minimise development costs.

⁵ It is important to note that recommendations are not necessarily reflective of supporting bodies for this study, but are provided based upon study findings from the report authors.

Commercial projects

For larger scale commercial deployments, different planning activities and research will be required at different stages of commercial maturity. From a consenting perspective, the same principles and recommendations for demonstration and pilot projects still apply. From a leasing perspective, the recommended approach will depend on the level of maturity.

- **Immature market: Open responsive approach to site leasing.** While market and technology maturity remains relatively low, an open responsive approach to site leasing is advised.
- **Maturing market: Strategic Environmental Assessment followed by appropriate site leasing.** Once there are signs that the sector is maturing to commercial arrays, a more strategic deployment approach is required. Indicators of this transition include: visibility of demand for multiple 100 MW+ farms; clear revenue stream in place; and no obvious bottleneck constraints (e.g. grid availability; environmental concerns). Once the SEA has been completed, The Crown Estate will be able to run a leasing round for floating wind, in line with expected deployment volumes.

It should be noted that the recommendations identified for pilot arrays also apply to commercial deployments, namely:

- Flexible technology envelope
- Potential for further build-out (site extensions)
- Risk-based approach to consent
- Clarity on consenting timescales

Table 3, below, outlines the different planning/leasing requirements for different stages of market maturity.

	Prototype/ Demonstration	Pre-Commercial Array Proving	First Commercial	Mature Commercial
TRL	TRL 7	TRL 8	TRL 9	-
Expected Rating	2MW+	6MW+	8MW+	10MW+
# of turbines	1	5	30	50+
Project Life	1-5 years	20-25 years	20-25 years	20-25 years
Project Size	≤8MW	≤50MW	≤240MW	500MW+
Scottish Planning Requirement	Focused RLGO ⁶	Focused RLGO	SEA for multiple farm locations ⁷	-
Scottish Leasing Requirement	Supporting test site plus ad-hoc open calls that are responsive to market need	Supporting test site plus ad-hoc open calls that are responsive to market need	Leasing rounds responsive to strategic management of resource	Leasing rounds responsive to strategic management of resource

Table 3: Planning and leasing requirements for different stages of market maturity for Scotland

⁶ This would be a redeveloped RLGO study undertaken with tighter technical specifications as presented by industry to Marine Scotland

⁷ Needs to be undertaken several years prior to roll out to allow both full development of SEA as well as leasing to be designed upon SEA constraints

2 Subsidy & Grant Support

2.1 Current policy status

Over the past 10 years, there has been growing but sporadic support funding available for floating wind R&D and demonstration activity. As with all emerging technology support, R&D funding transitions from primarily grant supported high intervention aid (technology push) towards revenue based (market pull) mechanisms as the technology matures.

The majority of the previous funding for floating wind research to date has come from EU funds (predominately FP7/H2020 and NER300); however, national governments are starting to provide substantive support for demonstration and pilot array projects.

2.1.1. Overview of existing support policies for floating wind projects within the UK

The UK has historically had a heterogeneous innovation support community in which different funding bodies have supported different stages of technical maturity (i.e. TRL 1-9), different regional geographies (e.g. Regional Development Agencies, devolved administrations etc.) and different objectives (e.g. economic growth, decarbonisation). When reviewed within inclusion of potential EU support, this has resulted in a mosaic funding landscape.

The below funding map (Figure 6) shows what funding is available to floating wind projects and technology developers within the UK for different stages of maturity and over different time periods⁸. These funding sources are discussed individually in the sections below, split by development stage, with further detail included in Table 4 on Page 35.

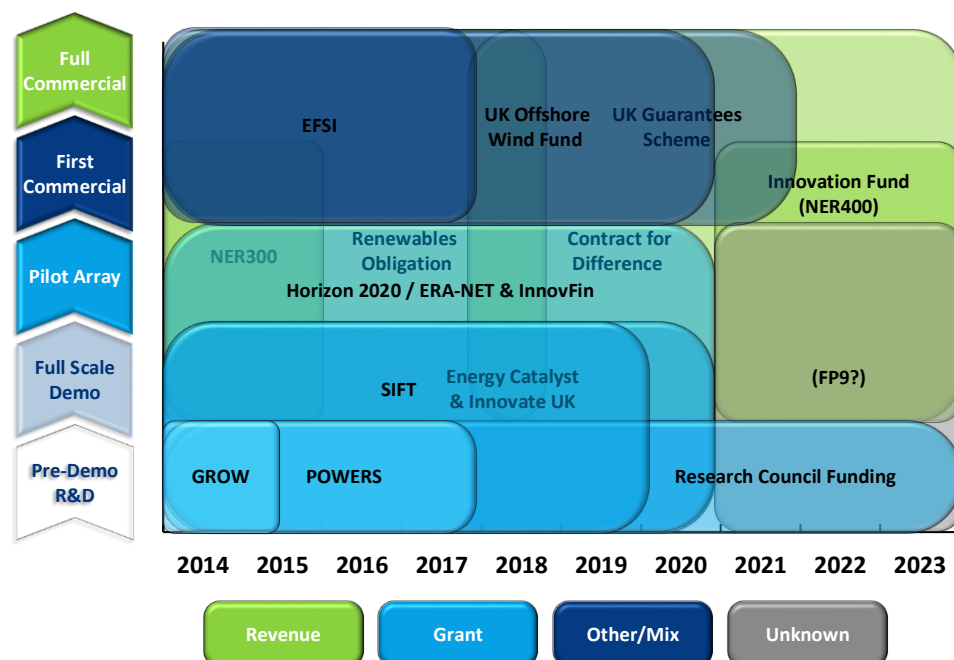


Figure 6: Overview of UK floating wind funding landscape

⁸ Note that programme closure dates may not be accurate where this has not been announced. Impacts from the United Kingdom leaving the European Union have also not been taken into consideration since (at the time of writing) Article 50 had not been enacted and thus the timeframe for EU exit not defined.

Pre-demonstration R&D

UK Research Councils

Within the UK, the primary support funding for low TRL technologies comes from the seven research councils, of which the Engineering and Physical Sciences Research Council (EPSRC) and the Natural Environment Research Council (NERC) are most directly related to floating wind research funding. Both EPSRC and NERC are currently scoping potential research programmes for future calls and work closely to identify where knowledge gaps exist within the sector.

The primary EPSRC platform for research relevant to floating wind are the Marine and Wind SUPERGEN hubs, based at the University of Edinburgh and University of Strathclyde, respectively. These hubs consist of consortia of academic institutes and collaborations/coordination with industry and public sector bodies alike (e.g. InnovateUK/DECC). SUPERGEN platforms focus research from TRL 1 to roughly TRL 4, receive £3m each and have 5 year rolling programmes (2011-2016 for Marine and 2014-2019 for Wind).

In addition to the SUPERGEN platforms, EPSRC run several doctoral training centres relevant to PhD training: Centre for Doctoral Training in Wind and Marine Energy Systems, Renewable Energy Marine Structures CDT (REMS CDT), and Industrial Doctoral Centre for Offshore Renewable Energy (IDCORE).

InnovateUK and the Energy Catalyst

InnovateUK opened the first Energy Catalyst funding round in 2014 in collaboration with EPSRC and DECC. Since then it has held rounds twice per year. The fund will provide early stage research grants (to the level of EU aid limits) for TRL 3-7 research projects that can demonstrate they help solve the criteria of the 'energy trilemma'. This is defined as: reducing emissions, supporting security of supply, and reducing energy cost. Maximum individual awards are £10m for later stage technology validation projects. As of April 2016, the Energy Catalyst is being funded solely by EPSRC and DFID (who have taken over coordination), with a new criteria for round 4 entry that projects must support developing countries.

InnovateUK run a separate core technology innovation programme that includes an Infrastructure strand. This covers floating offshore wind and will be tendered roughly twice per year with different focusses prioritised. They have a grant budget of ~£5m per call (within appropriate levels of State Aid Intensity) for companies seeking to innovate within the UK and meet the individual call objectives.

GROW Offshore Wind

The (now-defunct) GROW Offshore Wind initiative was a Knowledge Transfer Network/Offshore Renewable Energy Catapult support programme with a £2m (£500k per applicant) budget targeted at English companies that were seeking to innovate within the offshore wind sector.

Horizon 2020

Horizon 2020 is the primary support fund for EU research and development. It is by far the single largest research fund within Europe (with €5.9bn committed to non-nuclear energy research between 2014 and 2020), although only a few dedicated programmes within this are directly applicable to floating wind. Research projects are typically focussed on low and mid-TRL levels, but full-scale demonstration is also supported through the DemoWind initiative (further information below under 'Full-scale demonstration').

Another potential fund that has supported offshore wind to date is the InnovFin. This is officially a European Investment Bank Group fund (EIB and EIF), but is delivered in collaboration with Horizon 2020. The substantial €24bn fund provides a range of products from loans and guarantees to support facilities for any highly innovative activity within the EU.

Horizon 2020 is the 8th EU Framework Programme to be funded, however, it is likely that a 9th programme will follow beyond 2020.

Full-scale prototype demonstration

Prototyping for Offshore Wind Energy Renewables Scotland (POWERS)

POWERS was set up by Scottish Enterprise in 2011 and provides grants up to £6.53m (€7.5m) from a total £35m fund, up to State Aid limits. The fund was designed specifically for offshore wind turbines (component part suppliers can be sub-contracted) and supports later stage development around TRL 7+ (demonstration) who will then establish manufacturing within Scotland. This is a clawback exception such that if the company fails to establish a manufacturing base, Scottish Enterprise have the right to be refunded the sum. Scottish Enterprise clarify that the fund may be accessible to developers wishing to demonstrate floating wind systems (including the foundation), however, discussions would be required with potential applicants prior to application to assess project suitability.

Scottish Innovative Foundation Technologies Fund (SWIFT)

SWIFT is another Scottish Enterprise fund that is targeted towards supporting the development of innovative offshore wind foundation technologies for depths in excess of 30m. The overall fund has a budget of £15m and is available to developers who can deploy by 2019. As with all grant funding, EU state aid laws define the maximum aid intensity per project, based on the maturity of the technology, company size and level of collaboration.

DemoWind

DemoWind is a €24m programme part funded by 5 countries (Belgium, Denmark, The Netherlands, Spain and the UK) along with the EU (through Horizon 2020 and ERA-NET). Its aim is to support the development and demonstration of innovative technologies which can reduce the cost of offshore wind energy. There are seven technology areas highlighted for funding within DemoWind, including floating wind. All projects must involve at least 2 organisations from different countries and maximum funding for projects is up to £15m within the UK, although this is subject to EU state intervention limits and also considered within the application tranche at the time of call. DemoWind is currently in its second call (total fund of €24m).

New Entrants Reserve 300 (NER300) and the Innovation Fund

NER300 and the future Innovation Fund (also known as NER400) are both European support programmes that are funded through the sale of 300m tCO₂ (worth to €2.1bn) and 400m tCO₂ (TBC but likely to be around €9bn) respectively within the EU Emissions Trading System. Although the Innovation Fund has not yet been fully designed, it is thought it will operate in a similar style to NER300 and will also be operated by the European Investment Bank (EIB). The existing NER300 did support floating wind demonstration (see WindFloat case study in section 2.1.2). The fund was awarded based on several criteria, including: lowest cost per tonne of CO₂ savings, diversity of project types (i.e. technology), and national engagement. There is not a maximum project budget for support of larger project applications, however, successful applicants receive 50% of their relevant costs over a 3 year period post construction.

Pilot/pre-commercial array

Renewables Obligation (RO) / Renewables Obligation Scotland (ROS)

The Renewables Obligation (RO) (and Renewables Obligation Scotland (ROS)) has been the primary revenue based renewable energy generation support mechanism within the UK since 2002, when it replaced the Non Fossil Fuel Obligation. The legal Act under which the RO was established⁹ places a legal requirement on electricity suppliers to source an incrementally increasing percentage of their electricity from renewable energy sources, evidenced through Renewable Obligation Certificates (ROCs), or be forced to pay a buy-out fee. To provide varied levels of support for differing technologies, the ROC was banded to provide higher and lower support for emerging or mature technologies respectively. In Scotland, floating wind technology currently receives 3.5 ROCs

⁹ *Utilities Act 2000*, London. HMSO

per MWh of generation (with a resale value of roughly £44/ROC at time of writing). The ROC will be replaced in 2017 by the Contract for Difference, with a grace period for floating wind projects up to 30 September 2018.

New Entrants Reserve 300 (NER300) and the Innovation Fund

NER300 and Innovation Fund may also be applicable to pilot arrays (see above).

Commercial projects

Contract for Difference (CfD)

Contract for Difference (CfD) is a replacement mechanism for the RO which will come into force in 2017 (although there is a grace period for projects that have RO agreement up to 2018). The CfD establishes a contract between generators and the Low Carbon Contracts Company (LCCC), set up by the government for this explicit role. The contract will pay a balancing amount for electricity produced between the annual average price (the reference price) and a government determined value (the strike price). If the average price is lower than the subsidy, the LCCC pay the generator, if the average price is higher, the generator must pay the LCCC. A competitive tendering process is implemented to determine which projects are awarded contracts.

In 2014, five fixed-bottom offshore wind projects were awarded contracts under the FIDeR (Final Investment Decision Enabling for Renewables) round, with strike prices between £140-155/MWh. In the first competitive CfD auction round, two offshore wind projects were awarded contracts, with East Anglia One securing a contract at £119/MWh and Neart Na Gaoithe securing a contract at £114/MWh¹⁰. In forthcoming auction rounds BEIS have indicated that offshore wind (incl. floating wind) will need to achieve a strike price of £105/MWh or lower, falling steadily for future allocation rounds to at least £85/MWh by 2026. This is significantly lower than the current revenue support, posing a challenge for commercial deployment of floating wind in the UK.

Offshore Wind Fund

The UK Green Investment Bank (GIB) set up the Offshore Wind Fund in 2014 to create liquidity within the asset market for offshore wind. The fund, managed by its subsidiary (Green Investment Bank Financial Services Limited) is intended to allow pension managers and other low risk investors to buy long term equity stakes in operational farms. This allows developers/utilities to re-invest in new delivery. In March 2016, the UK Government announced plans to privatise the GIB and it is currently uncertain as to how future investments will be affected as a result of this.

UK Guarantees Scheme

The UK Government Guarantee Scheme is an infrastructure support fund that will provide up to £40bn of guarantees for large infrastructural projects (including offshore wind) within the UK. The guarantees include full interest and principle payments and the guarantee will be issued in return for a 'guarantee fee' from the borrower at market rates. Although principally established to support bond financed debt, the guarantee can be applied to alternative forms of debt product also. As of November 2015 (3 years after announcement) the Guarantee Scheme had only approved £3.7bn of projects and, as such, has been extended to 2021.

European Fund for Strategic Investments (EFSI)

This is the primary European Investment Bank fund, consisting of €21bn expecting to leverage private sector investment at 1:15 ratio, or roughly €300-400bn. The fund is split into the provision of multiple services including equity products, loans, guarantees and credit enhancement services/products (similar to those provided through GIB support). To date, EFSI has supported and committed to supporting a number of offshore wind farms including the Beatrice and Galloper Offshore Windfarms in the UK, providing sizable investment (>€300m each). Smaller projects have also been supported, including onshore and offshore farms in the 30-40 MW range.

¹⁰ Neart Na Gaoithe has since had its contract cancelled by the LCCC having missed a milestone deadline.

Name of funding scheme	Responsible organisation	Country/Region	Support Type	Open	Close	Max Per Project	Total Support Value	Min TRL	Max TRL
Research Councils UK / (SUPERGEN)	Research council funding	UK	Academic	2014	2020+	0.12m	na	1	4
Prototyping for Offshore Wind Energy Renewables Scotland (POWERS)	Scottish Enterprise	Scotland	Grant	2011	2017	€7.5m	£35 million	2	6
Scottish Innovation Foundation Technologies Fund (SIFT)	Scottish Enterprise	Scotland	Grant	2014	2019	na	£15 million	2	6
GROW	Manufacturing Advisory Service (MAS), together with Grant Thornton UK, RenewableUK and the Advanced Manufacturing Research Centre	UK	Grant	2014	2015	£0.5m	£4.5 million	2	7
Energy Catalyst	InnovateUK	UK	Grant	2015	2020	£25m	£10m	3	7
InnovateUK	InnovateUK	UK	Grant	2016	2020	£3m	£5m	3	7
Horizon 2020	EC	EU	Grant	2014	2020	na	~€80bn	5	7
DemoWind (ERA-NET) (part of Horizon 2020)	EC	EU	Grant	2015	2020	33% project cost	€26.5m	5	7
ROC	BEIS	Scotland	Revenue	2001	(FID by) 2018	3.5 ROC/MWh	NA	7	9
CfD FIT	BEIS	UK	Revenue	2018	?	£105/MWh	NA	7	9
European Fund for Strategic Investments (EFSI)	EIB	EU	Investment	2015	2017	na	€21bn	8	9
NER300	Funding provided by EC. Applications submitted to EIB	EU	Revenue	2010	(FID by) 2020	na	€2.1bn	8	9
NER400	Funding provided by EC. Applications submitted to EIB	EU	Grant/Revenue	2021	2030	na	€9bn	8	9
UK Offshore Wind Fund	GIB	UK	Other	2014	2020	na	na	8	9
UK Guarantees Scheme	HMT	UK	Other	2014	2021	na	£40bn	8	9

Table 4: Potential funding sources for floating offshore wind activity within the UK

2.1.2. Overview of existing support policies for floating wind projects internationally

France

The French government has set an aspirational target of having 600 MW of floating wind installed by 2030, starting with up to 100 MW of demonstration units. In December 2014 the French Government announced plans for a call for an expression of interest for floating offshore wind systems, which was launched in June 2015. The funding from the Investment Program for the Future (PIA), administered by ADEME, will provide a feed-in tariff between €150 and €275 per megawatt-hour for four floating wind demonstration projects, each consisting of 3-6 turbines with a minimum 5 MW rating.

Four successful consortia have been announced, with a combined cumulative capacity of 96 MW (Table 5). The level of feed-in tariff awarded to the respective projects has yet to be announced. Projects are expected to be commissioned by 2020, after which calls for commercial-scale projects are expected.

Zone	Capacity	Developer(s)	Turbine supplier	Floater	Other partner(s)
Groix (Atlantic)	24 MW (4x 6 MW)	Eolfi / China Guangdong Nuclear (CGN)	GE	DCNS 'SeaReed'	TBC
Gruissan (Med)	24 MW (4x 6 MW)	Quadran	Senvion	IDEOL 'Damping Pool'	Bouygues Travaux Publics
Faraman (Med)	24 MW (3x 8 MW)	EDF EN	Siemens	SBM Offshore 'TLP'	IFPEN
Leucate (Med)	24 MW (4x 6 MW)	Engie / EDPR	GE	Principle Power 'WindFloat'	Caisse des depots / Eiffage

Table 5: French floating wind tender contract awards

France is also expected to see its first full-scale prototype installed in 2017, a 2 MW IDEOL concrete semi-sub at the SEM-REV test site in Groix. The €36m Floatgen demonstrator has largely been funded through the European Commission's FP7 call, but has also sourced a diverse range of investors, which highlights the multitude of funding avenues that can be sourced. Ademe has provided €7.3m and a further €3.8m has been secured from three new investment funds – HPC Capital, PACA and CPG – as well as existing shareholders the Demetre 3 Amorcage Fund, the Emergence Innovation 1 Fund and the IO Group. BNP Paribas and Caisse d'Epargne banks have provided a further €1.2m loan.

Portugal

Principle Power's WindFloat semi-submersible 2 MW unit was installed 5km off the coast of Aguçadoura, Portugal, in 2011. The project, costing €19 million, was developed by EDP Renováveis and was part-funded by the European Commission through the Demowfloat initiative.

Building on the successful 2 MW Phase 1 demonstration in 2011, there are now plans to develop a 25 MW extension off the coast of Aguçadoura. The project will comprise three floating substructures with 8.3 MW MHI-Vestas turbines. The project will also include export cable connections to a fixed subsea cable that is to be installed and operated by the transmission system operator.

The Portuguese Government have awarded a €19m grant to support the project. The WindFloat Phase 2 project will also benefit from support of the European Commission, through the NER 300 program, and the Portuguese government through the Portuguese Carbon Fund. It was also selected for the InnovFin program by the European Investment Bank.

Germany

German engineering company GICON are planning to install their TLP concept, the GICON-SOF, in 2017, supporting a 2.3 MW Siemens turbine. This will be the first deployed TLP foundation. The GICON project is expected to require €18 million of funding, however, a €5.25 million investment from the Mecklenburg-Vorpommern's Ministry of Economy, Construction and Tourism has been withdrawn following grid connection delays. Fabrication has already commenced, but alternative funding sources are being sought in order to complete the construction and installation of the unit.

Norway

Public body Enova provided a grant of NOK 59 million (~£5 million) for Statoil's 2.3 MW Hywind I demonstration in 2009. The Research Council of Norway has also provided funding support for the Sway concept, which was demonstrated at part-scale in 2011.

USA

The Department of Energy (DOE) has provided grants of \$4 million to two potential floating wind demonstrations in the US – Principle Power's 30 MW WindFloat Pacific pre-commercial array off the coast of Oregon, consisting of five 6 MW turbines on the WindFloat semi-submersible concept, and DeepCWind's 2x 6 MW demonstration of the VoltornUS concept in Maine. Principle Power were originally selected to receive up to \$47 million for the build-out of the Oregon project, but failure to secure a power purchase agreement (PPA) resulted in funding being withdrawn and re-allocated to DeepCWind, a consortium based at the University of Maine.

Previous to this, the DOE had granted \$12 million over a 5 year period to DeepCWind, which in 2013 installed a 1:8 scale prototype demonstration of the VoltornUS floating system, the USA's first offshore wind turbine and the world's first concrete-composite floating wind platform.

There is also interest for commercial scale floating wind projects in both California and Hawaii, but no revenue support is currently in place.

Japan

Floating demonstrations have received significant government support in Japan, with consortia being established to share R&D in floating technology and gain experience from developing floating projects. The Japanese government has been funding research in floating technology for more than two decades, however, it is only since the Fukushima nuclear disaster in 2011 that concerted efforts have been focussed on developing floating wind power.

Since 2011 the Japanese Government have invested heavily in research, development, and demonstration activities, including the iconic Fukushima Floating Offshore Wind Farm Demonstration (FORWARD) Project, which has aspirations to eventually reach up to 1 GW in capacity. The Japanese Ministry of Economy, Trade, and Industry (METI) has invested 53 billion yen (~£292 million) in the Fukushima project to commission two semi-submersible units with 2 MW and 7 MW turbines, respectively, as well as a 5 MW turbine and the world's first (25MVA) floating substation, both supported by an advanced spar buoy structure.

In addition, a floating spar-buoy at Kabashima in the Goto Islands has received 6 billion yen (~£33 million) from the Ministry of the Environment (MOE); a project co-developed with Toda Corporation, Kyoto University, Fuji Heavy Industries, and Fuyo Ocean Development & Engineering.

NEDO, the Japanese innovation support agency have also recently announced two further demonstrations, consisting of two variations of the IDEOL Damping Pool concept; a concrete unit supporting a 4.4MW 3-blade turbine and a steel unit supporting a 3MW 2-blade turbine. Both are expected to be installed in 2017/18 at a site off southwest Kyushu. IDEOL are being supported by industry partner Hitachi Zosen.

2.2 Support policies required to accelerate the commercialisation of floating wind

As identified within the opening section of this chapter, the appropriateness of different funding mechanisms at different stages of commercial maturity for a technology vary. This is to reflect the risk/reward profile of the development. Early market, high risk and high cost (per MWh) projects will require higher revenue support as well as higher amounts of up-front grant or capital support to de-risk private sector investment. Meanwhile, more mature technologies may only require access to debt or loans to ensure that larger projects can be built. Figure 7 below conceptually shows the applicability of support mechanisms to different stages of market maturity which, although not prescriptive, provides an understanding of historically proven optimum relationships.

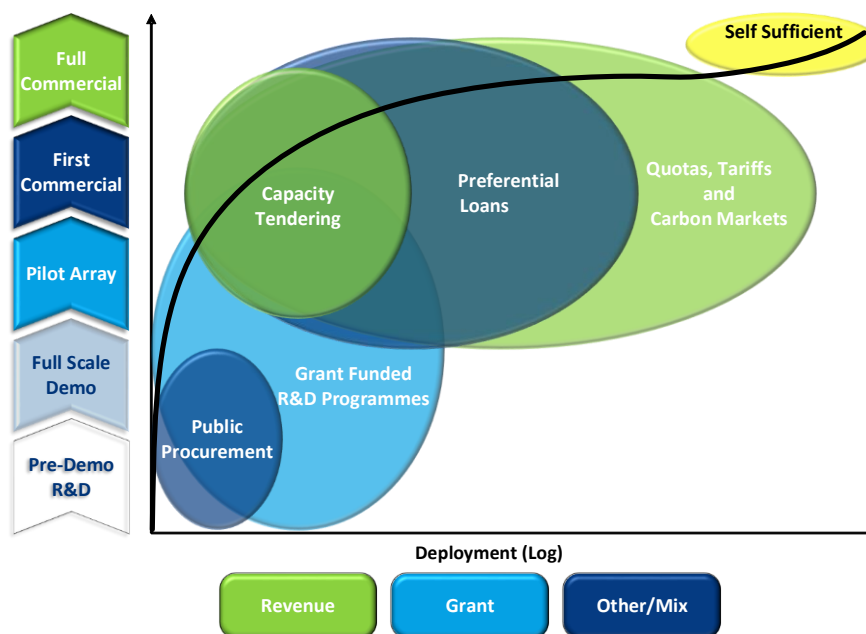


Figure 7: Indicative funding support instruments applied for different technology maturities

The following sections briefly outline the suggested funding requirements for different stages of floating wind market maturity.

2.2.1. Prototype demonstrations

At early market maturity, prior to any arrays having being developed and deployed, expected technology LCOE is high. High levels of uncertainty as a result of a lack of technical convergence, as well as low levels of practical project experience, mean that most costing has not been validated through projects by companies undertaking prototyping and demonstration. As such, grant based subsidies are typically applied at this stage of technology demonstration. As with all nascent energy technologies, CAPEX is high per MW installed for prototype demonstrations, and public sector financing must typically overcome this barrier.

Demonstration phases are often shorter in deployment time (typically 2-5 years) than later commercial stages, which makes revenue-based support mechanisms inappropriate. Revenue support mechanisms may supplement a capital grant payment, but are unlikely to be conducive to the short demonstration timescales for prototype devices. Revenue support is only likely to be effective if the prototype is expected to be operational

for at least 20 years, an approach that will likely only be attractive if the site is built out to a pre-commercial or commercial array once 2-5 years of testing has been completed.

2.2.2. Pilot arrays (pre-commercial)

For pilot arrays, projects will be larger in scale and expected to operate for 20-25 years. As a result, revenue support is likely to be effective in providing suitable returns and rewarding high performance and availability, whilst also spreading government subsidy spend across multiple years. However, given that technology risk is still expected to be high (relative to more mature technologies), debt financing will be challenging, particularly for smaller companies that do not hold suitable balance sheets to finance the project. Thus, revenue support may need to be supplemented with capital grants and low interest loans to minimise the level of project financing required.

In addition to funding project CAPEX, grant funding could also be provided in application to subsystem/component technology innovation, proving and qualification. This has been identified as a requirement within recent market surveys and could help to bring down costs and uncertainties. There are certain technology areas where innovation support could have potential to benefit cross-technology R&D with other marine technologies, such as fixed offshore wind, wave energy, and tidal energy.

2.2.3. Commercial projects

The primary requirement for first and fully commercial arrays is for a secure and viable revenue support mechanism to be in place. For early commercial wind farms, higher levels of ring-fenced support or top-up grant funding may be required to guarantee support for floating wind projects. In this scenario, public sector exposure to costs can be controlled by capacity-constrained mechanisms, such as a cap on deployment or available budget.

For fully commercial projects, lower technical and investor risk will make project financing more feasible, and it is anticipated that all support will be on either commercial loan terms or as revenue support. At mature commercial stages of development, it is expected that the technology could reach cost comparability with fixed-bottom offshore wind and other forms of energy generation.

The appropriate financing mechanisms for different stages of development are summarised in **Error! Reference source not found.**, below.

	Prototype/ Demonstration	Pre-Commercial Array Proving	First Commercial	Mature Commercial
TRL	TRL 7	TRL 8	TRL 9	-
Expected Rating	2MW+	6MW+	8MW+	10MW+
Number of Units	1	5	30	50+
Project Life	1-5 years	20-25 years	20-25 years	20-25 years
Max Project Size	≤8MW	≤50MW	≤240MW	≤500MW+
Primary Financing Format	Grant/Revenue/ Guarantees	Grant/Low interest loan/Revenue/ Guarantees	Loan/Revenue	Loan/Revenue

Table 6: Financing mechanisms for different stages of market maturity.

2.3 UK case study: Subsidy support beyond the Renewables Obligation

A key financial issue recognised by stakeholders as one of the most pressing to the future of UK floating wind deployment is the planned subsidy mechanism change as a result of UK Electricity Market Reform (EMR). This change of policy instrument replaces the Renewables Obligation (RO) green certificate mechanism with the Contract for Difference (CfD) feed in tariff.

Under the RO, floating wind projects in Scotland secure 3.5 certificates (ROCs) per MWh generation. Assuming a ROC value of approx. £44/MWh¹¹, this equates to £154/MWh on top of the market wholesale price of approx. £33/MWh¹². This gives a total value of £187/MWh for floating wind projects installed in Scotland before 1 October 2018. It should be noted that there is some market risk associated with this figure due to variations in both the ROC and electricity market values.

Under the CfD mechanism, contracts for less established renewable technologies (including offshore wind) will be capped at £105/MWh, reducing to £85/MWh by 2026 (HM Treasury, 2016). This is the strike price at which all tier 2 technologies (of which floating wind is included) will be capped. It should be noted that revenue risk for the CfD mechanism is lower than under the ROC mechanism, as the agreed contract value is guaranteed for each unit of electricity produced.

To date, there has not been further clarification or breakdown on the status or support for emerging technologies, including floating wind. As such it can be assumed that floating wind will be expected to compete within the offshore wind contract auction for £105/MWh. As can be seen from Figure 8 below, the expected reduction in revenue as a result of this change is approx. £82/MWh, or 44%.

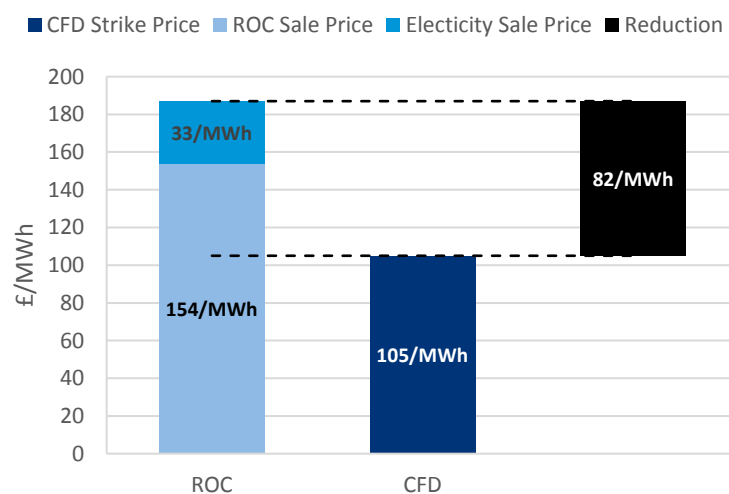


Figure 8: Forecast revenue support change for floating wind as a result of EMR

Previous studies have suggested that, at commercial scale, floating wind could be cost competitive with fixed offshore wind, with an LCOE of ~£85/MWh (Carbon Trust, 2015). However, this assumes sufficient market volume (50-100 units) to reach the levels of deployment necessary to ensure that learning processes and scale effects are realised. It should also be noted that these cost have been forecasted based upon technology

¹¹ <https://www.ofgem.gov.uk/publications-and-updates/renewables-obligation-ro-buy-out-price-and-mutualisation-ceilings-2016-17> Accessed 18/04/16

¹² Figure taken from APX UK Half Hour Day Ahead Auction (monthly average) on 18/04/16. Source: <http://www.apxgroup.com/market-results/apx-power-uk/dashboard/>

developers' assumptions and have not been verified. As such, it is expected that floating wind projects will not be able to compete with other tier 2 technologies, such as fixed-bottom offshore wind, until at least 2025 (Figure 9), and alternative subsidy support will be required to support further deployment in the interim period. A range of options to continue supporting floating wind technology in the UK are outlined in section 2.4.

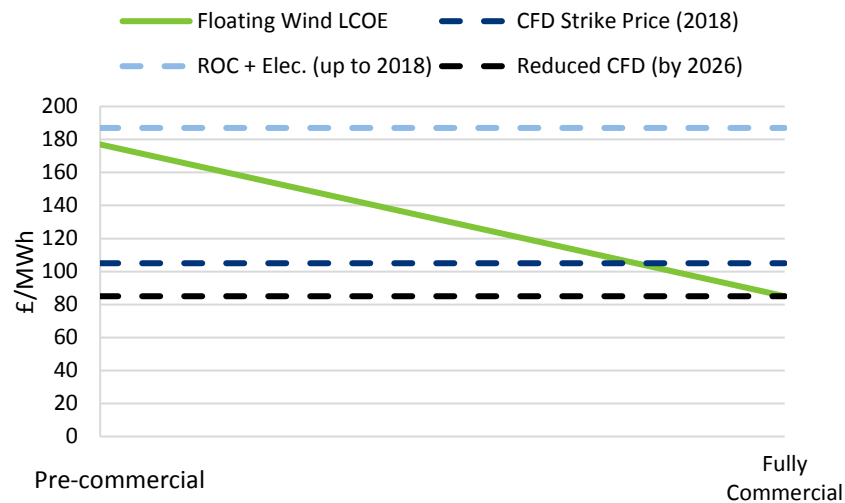


Figure 9: Floating wind LCOE forecast against subsidy support levels

2.4 Recommendations to policy makers

Several policy options are available to support floating wind technology development and bridge the funding gap identified within section 2.3. The options listed below are not considered mutually exclusive in implementation¹³.

Introduce ring-fenced support within the CfD mechanism

Introducing a ring-fenced budget for floating wind within CfD allocation rounds (similar to that which has historically been available for wave and tidal under the first CfD allocations) would provide revenue support which is commensurate with the maturity of the technology. Floating wind would need to be assigned its own strike price and capacity could be capped at a deployment level per spending round or per project.

Depending on the strike price attained, a ring-fenced CfD could independently support pilot arrays and early commercial projects. Even if revenue support is considered insufficient on its own, as a policy instrument alongside others (such as the below), it could be a key enabler should other revenue or grant funding become available.

Seek alternative revenue or grant support mechanisms

As identified within section 2.1.1, there are a range of additional grant and revenue support mechanisms available both within the UK and overseas. There are two support programmes likely to be accessible to TRL8+ within the UK (in addition to the CfD) – the Horizon 2020 DemoWind fund and the future EU Innovation Fund (NER400).

Horizon 2020 DemoWind:

The Horizon 2020 DemoWind fund (discussed in section 2.1.1) is open for its second call and offers up to £15m per project. Due to the innovation support focus of this fund, it will only support full-scale prototype systems, and only for novel technologies that have not been previously demonstrated. The provision of designated and pre-consented sites could attract such demonstration projects to the UK, particularly if these sites included an option for further build out beyond the first prototype. However, pre-commercial or commercial projects would require alternative funding mechanisms.

EU Innovation Fund:

The Innovation Fund is a planned successor to the NER300 fund. This may support first commercial deployments, such as pilot arrays. NER300 has supported both smaller (e.g. WindFloat Atlantic) and significantly sized offshore wind projects (e.g. Veja Mate). However, details of its operation have not yet been decided and it may not be accessible until around 2021, leaving a 3+ year gap in funding of this type.

In the intermediary period, UK-specific schemes could be developed in partnership with innovation funding agencies, such as InnovateUK, and/or through modifications of outlined funding initiatives in development, such as the Scottish Renewable Energy Bond.

Undertake cost reducing component innovation

The UK is considered a world leader in fixed-bottom offshore wind and has considerable expertise and experience from the offshore oil and gas industry. The UK is therefore well-positioned to also take a leading role in the emerging floating wind sector. Despite a very limited number of UK concept-designers, there are several UK-based companies that offer ancillary products and services, such as moorings, anchors, subsea connectors,

¹³ It is important to note that recommendations are not necessarily reflective of supporting bodies for this study but are provided based upon study findings by the report authors.

cables, etc. Providing support for these companies to develop innovative products will help the UK to remain at the forefront of the industry and boost export opportunities, even in the absence of a strong domestic market.

In order to maximise R&D spend, there may also be opportunities to dovetail support to provide cross-technology innovation. Such integrated innovation may be less risky and has the potential to be applicable to other strategically important energy technologies, such as wave and tidal energy, fixed-bottom offshore wind, and energy storage (examples include: dynamic cables, deepwater substations, mooring and anchoring systems, advanced materials and welding techniques, anti-corrosion coatings, etc.). An early example can be seen in the Statoil Hywind Scotland Pilot Park, which has a parallel 'Batwind' project being developed in tandem that will see a 1 MW lithium battery storage system installed as part of the project.

Further discussion on this topic is provided in Section 3 – 'Supply Chain Development'.

Identify and exploit niche market opportunities

As a stepping stone to commercialisation, niche markets, such as island communities or enhanced oil extraction, may present an opportunity for deployment and associated cost reduction. Niche markets are expected to require lower levels of subsidy support to become cost competitive since they are typically off-grid and replacing high cost diesel generators or other systems. However, these tend to be small in generation capacity compared to utility scale deployment and uncertain in terms of the bespoke nature of such markets.

An example of this could be in application to enhanced oil extraction techniques for North Sea rigs. Initial studies into this market opportunity have been undertaken by a DNV-GL led consortium under the Wind-powered Water Injection project (WIN-WIN). Once a well has been fully exploited, either the floating wind system can be relocated to another location or the site could be utilised for reservoir storage (the latter option requiring an export grid connection). Atkins are now undertaking early stage studies on wind energy reservoir storage (WERS).

Maintain support for low TRL concepts

One issue raised by some funders was that if adequate financial bridging mechanisms could be developed or identified to allow floating wind to develop to commercial scale, caution should be taken not to assume a 'first past the post' policy of technology support. With this in mind, the commercial support gateway should, if possible, be left open for second generation floating wind technologies and beyond.

3 Supply Chain Development

3.1 Introduction

This chapter focusses upon UK supply chain creation, where there have been a wide range of high quality studies published both within Scotland and the UK more widely (see for example: The Crown Estate (2010), BVG Associates (2016), Scottish Development International (2016), and Scottish Enterprise (2016)). These reports have for the most part focussed on supply chain development for fixed-bottom offshore wind, with which there is a high degree of overlap with the supply chain required for floating wind. This section therefore discusses some of the more unique supply chain characteristics for floating wind and how government policy can help to retain greater economic and employment benefits for local projects within the UK, as well as support UK companies to capture market share in emerging overseas markets.

Floating wind technology can decouple the supply chain from a given region since the majority of the system can, in theory, be built at any port and transported to site. On the one hand, this presents the opportunity for *higher* local content, for example by reducing the reliance on jack-up barges or heavy lift vessels which are predominately supplied from mainland Europe. However, it also presents the threat of *lower* local supply chain engagement, given the ability to import components and tow structures long distances to site. For example, Statoil's Buchan Deep pilot project employs companies from across Europe (Figure 10).

However, this decoupling also presents an opportunity for UK companies to export products and services to foreign markets, and highlights the potential for floating wind to operate as a truly global industry and deliver cost reduction through economies of scale.



Figure 10: Statoil's Buchan Deep floating wind farm demonstration site supply chain (Statoil, 2016)

It is likely that the supply chain for floating wind will follow that of fixed-bottom wind, given that many sub-system areas are similar, with much of the CAPEX cost being delivered by established fixed-bottom turbine supply chain companies. For example, turbines, which make up ~41% of forecast floating wind CAPEX (Figure 12), will almost certainly be delivered by established fixed-bottom turbine suppliers (e.g. Siemens, MHI Vestas, GE, Senvion).

However, there are several key novel elements of floating wind that present an opportunity for both existing and new supply chain entrants, including:

- Platform design and fabrication
- Mooring design and fabrication
- Anchor design and fabrication
- Mooring connectors
- Dynamic cables
- Cable connectors

- Deepwater substations
- Ballast control systems
- Ballast material
- EPCI and installation contractors
- Vessel suppliers and operators

In many instances, these products and services will be provided by established suppliers already active in the fixed wind market; however, there is also considerable opportunity for new entrants to capture market share, particularly from the offshore oil and gas sector, which has notable synergies with the technical requirements for floating offshore wind. Indeed, a recent Scottish Enterprise report suggests that for fixed-bottom wind, foundations, substation structures and secondary steelwork all present an opportunity for oil and gas sector companies due to the natural alignment of capabilities (Scottish Enterprise, 2010). This can also be said for the specifications of most floating wind substructures, given that all three main substructure categories (semi-submersible, spar-buoy and tension leg platform) are established designs within oil and gas sectors.

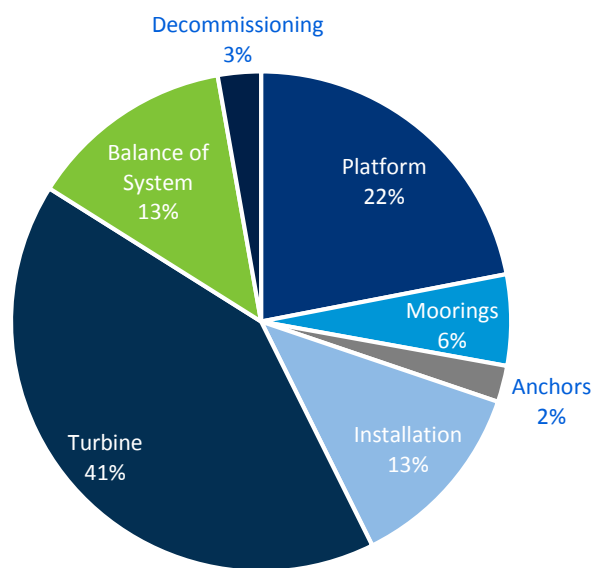


Figure 11: CAPEX breakdown for a typical commercial scale floating wind farm (Carbon Trust, 2015)

In addition to this, Scottish Development International recently produced a UK floating wind supply chain directory based upon Scottish companies and capabilities (Scottish Development International, 2016). Table 7, below, has been modified and expanded to include UK companies (outside Scotland) and exclude those that are no longer active.¹⁴

¹⁴ Several companies have since gone into administration since the original supply chain publication and are thus not listed here.

Organisation	Support Functions	Survey	FEED	Sub-Structure	WTG	Balance of Plant	Moorings & Anchors	Cables	Installation/Commissioning
Aggreko UK Limited						X			X
Apollo Offshore Engineering	X	X				X			X
Aquatera	X	X							X
Atkins		X							
Augmentias	X	X							
Babcock International Group	X	X				X			
Balfour Beatty									X
Bibby Offshore	X					X			X
Briggs Marins		X							X
Bruce Anchors							X		
Burntisland Fabrications Ltd				X		X			
Clyde Fasteners Limited									X
CodaOctopus									X
Cyberhawk Innovations		X							X
DNV GL		X							
Ecosse Subsea Systems Ltd									X
ESS Ecology		X							X
First Subsea							X		
Flowline Specialists Ltd	X								X
FoundOcean									X
Gael Force Engineering Ltd						X			X
Global Energy Group		X				X			X
Hydro Group						X			X
Intermoor									X
Isleburn							X		
JDR Cable Systems								X	
Limpet Technology Ltd	X								
LR Senergy	X	X				X			X
MacArthur Green		X							
Maritime Craft Services (Clyde) Ltd		X							X
Mooring Systems	X								
Mott MacDonald	X	X				X			X
ODE			X						
Offshore Renewable Energy Catapult		X							
Oldbaum Services Ltd		X				X			
Parker Scanrope							X		
Partrac Ltd	X	X							
Prontoport Ltd	X								X

Organisation	Support Functions	Survey	FEED	Sub-Structure	WTG	Balance of Plant	Moorings & Anchors	Cables	Installation/Commissioning
Proserv	X								X
Reach Engineering & Driving Services Ltd	X								X
RES			X						
ROVOP									X
SeaRoc Group	X								
Seaway Heavy lifting/Subsea 7	X	X				X			X
SgurrControl		X				X			
SgurrEnergy Limited	X	X	X						
Systems Engineering and Assessment						X			
TTI Marine Renewables Ltd	X	X							X
Wind Towers (Scotland) Ltd		X				X			
Wood Group Caledonia Ltd	X	X							X
Xodus Group	X	X							

Table 7: UK supply chain companies

3.2 Ports

Ports are a crucial enabler for Scottish supply chain engagement. Sub-systems may be fabricated and shipped to ports from all over Europe, however, the relatively high amount of port-side build and testing required for commercial floating wind farms means that their siting is likely to dictate a significant amount of the project spend within most subsystem areas (e.g. platform final build, installation costs etc.).

Figure 12 identifies Scottish energy port capabilities in terms of their ability to allow accommodation of the primary platform types (semi-submersible, spar buoy and tension leg platform). Constraints are based on average floating wind device developer requirement expectations for an 8 MW first commercial floating wind farm against port specifications (see Table 8)¹⁵. It should be noted that the analysis does not take into account laydown area requirements which are expected to be higher than most ports currently have capability for at commercial array scale (e.g. >100,000m²). Given current levels of laydown area for fabrication available at Scottish ports, first full scale projects are likely to face barriers at present without significant investment. Should a clear market pipeline of delivery present itself, many ports would have a clear business case for improvements in infrastructure and capabilities to accommodate requirements to allow future build out.

Constraint	Unit	Spar Buoy	Semi-Submersible	Tension Leg Platform ¹⁶
Length Overall (LOW)	m	100	53	76
Beam	m	14	53	82
Depth	m	14	28	25
Draft at quay-side	m	100 / 10 ¹⁷	10	10
Onshore Crane Capacity	tonnes	550	550	550

Table 8: Anticipated port requirements for 8MW first commercial floating wind farm

As can be seen from Figure 12, ports at Nigg and Peterhead are already suitable for the construction of all three dominant floating wind typologies. There are relatively high levels of uncertainty (orange) with several ports, specific build requirements (i.e. relatively deep drafts or quayside length) may be overcome through project-specific work-arounds or minor/moderate infrastructure upgrades. In several instances, the long slender structure of spar-buoy designs is more attuned to port facilities which have been developed to fabricate and maintain naval vessels, compared to the wider semi-submersible and TLP substructures. However, it should be noted that this assumes that spar structures are towed to sheltered deepwater sites for turbine assembly and there are no ports in Scotland which could accommodate upending and assembly at port-side.

¹⁵ Values based on steel substructure floating platforms. Crane lifting capacity was not considered a key indicator as this may be hired in specifically for project build. Port data taken from: Scottish Development International (2015), as well as floating wind developer responses.

¹⁶ Many solid form tension leg platform systems may have smaller dimensions than those provided above; however, the dimensions provided account for larger lattice space-frame concepts with larger dimensions.

¹⁷ 100m draft required if assembling turbine at quay-side; 10m draft required if floating out to sheltered deepwater area for turbine assembly. Figure 12 assumes 10m draft is required.

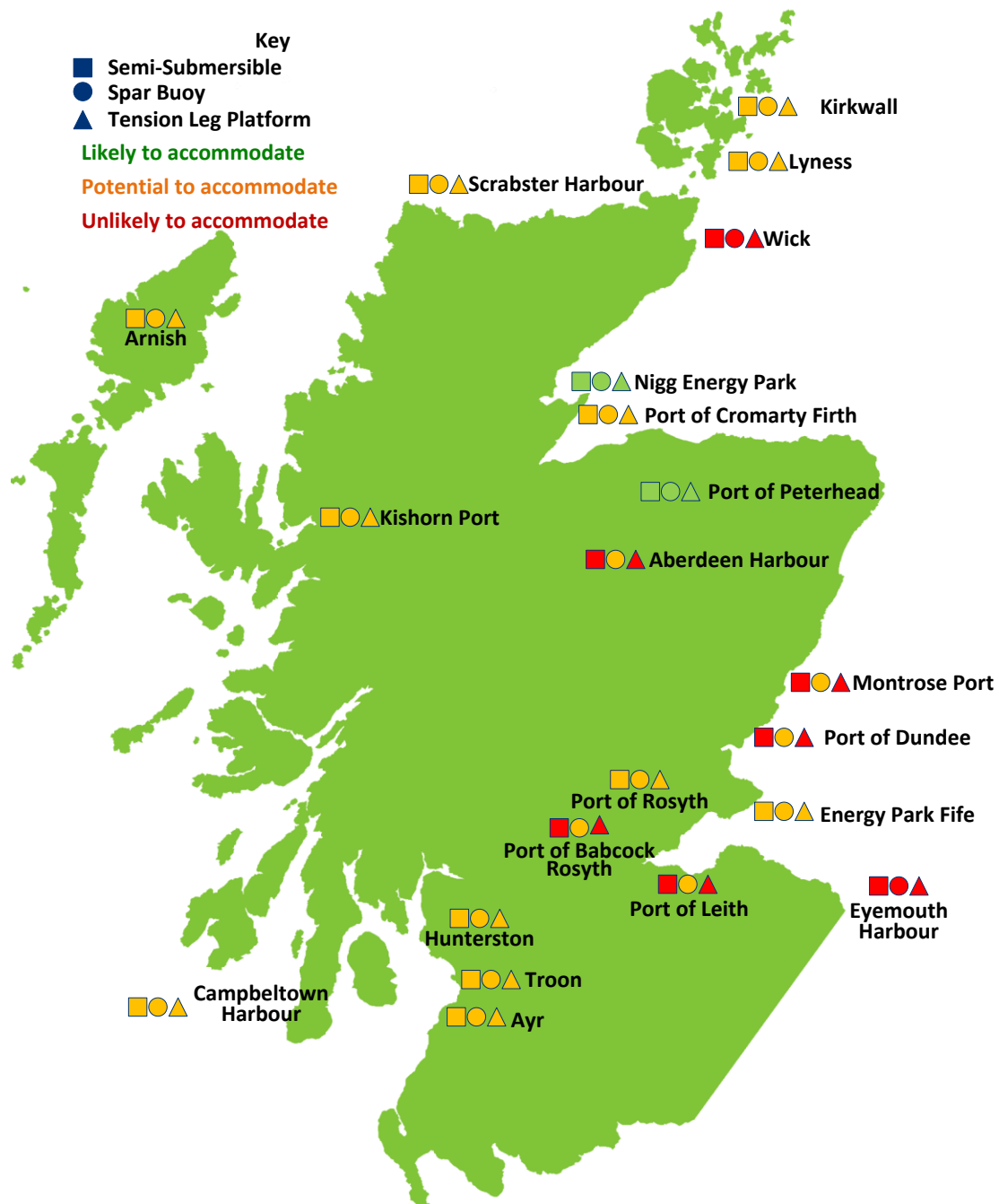


Figure 12: Scottish energy port floating wind capabilities

3.3 Supply chain case studies

The case studies below provide a narrative insight into some of the supply chain challenges faced by companies who have been attempting to engage with the sector. These case studies attempt to show that there are often supply chain challenges that companies have to overcome above simply providing a cheaper service or adequate facilities.

Kishorn Port

Background

The port of Kishorn is a deep water port located on the edge of the Loch Kishorn, a sea water loch which connects to the Inner Sound of Raasay beside Skye, on the Western coast of Scotland. The port boasts 3 hard edged quays with up to 10m of draft at high tide as well as nearby loch depths of up to 80m making it one of the few ports potentially suitable for spar buoy structures. It also has a 160m diameter dry dock (with up to 13m water depth), 45 hectares of laydown area and an onsite quarry with concrete manufacturing facilities.



Figure 13: Aerial view of Kishorn Port

Renewable energy experience

Kishorn's owners have been actively engaged with Scottish development agencies in trying to attract offshore renewable energy business, having visited overseas ports to identify customer requirements, developed a renewable energy masterplan (including floating wind technology), and entered early engagement with potential customers.

Initial discussions with Statoil regarding the Hywind Scotland project looked promising, as Kishorn was identified as a suitable port for fabrication and launching of their 5 x 6MW turbines, to be towed around to their final berth site once they were upended in Kishorn Loch or Raasay Sound. Unfortunately, the contract was awarded to a Norwegian facility (Stordbase AS) due to what the port believes are several factors outside of their control.

Challenges faced

Requirement for facility upgrades: The initial scope of work appeared to be compatible with Kishorn's capabilities. However, as the build process was refined, the requirement was forced to change to allow for optimisation of the installation vessel time, as this was a significant cost driver. As the vessel would only be available for a short period of time, all five of the turbines needed to be ready to load out from a quayside at the same time. This meant that a 500m hard edged and reinforced quay would be required for construction. Kishorn, currently providing 100m, would need to build out to create an extra 400m of reinforced quay at a cost of around £15-£20m. Although this was technically achievable and could have been completed within the timeframe, the payback from the single project (and lack of visibility for future projects) meant that securing a loan would be unfeasible and a grant would need to be at least £10m+ to make a compelling business case.

Contracting requirements: Although this last minute quayside requirement was the primary cause for the site not being used, other factors were cited as being problematic for the port in being able to meet customer needs. Most prominent of these was contracting requirements, which included weighting for previous work in this field, which benefitted prior project partners, and details of subcontractors to be used. The stipulation of contracting party accreditation/certification was something that could have been met. However, despite early engagement, this came as a surprise to the port who believe that earlier visibility of these contract requirements would have greatly reduced pressure during the time-critical contracting process.

As a result of the above, Kishorn lost out on the contract to Stordbase AS in Norway, which built the Hywind I demonstrator in 2009.

Aberdeen Harbour

Background

Aberdeen Harbour is a Trust Port and dates back to the 12th century making it Britain's oldest continuous business and is one of the busiest ports in Scotland. As well as supporting a wide range of general and bulk cargoes, it acts as a strategic central hub for supporting the North Sea oil and gas industry and has extensive fully serviced quaysides, associated ship repair and service facilities to support this operation. The harbour itself consists of numerous quaysides with depths of up to 9.5m, as well as extensive layout areas and supporting warehouses, storage tanks and bulk facilities to suit a wide and diverse range of services.

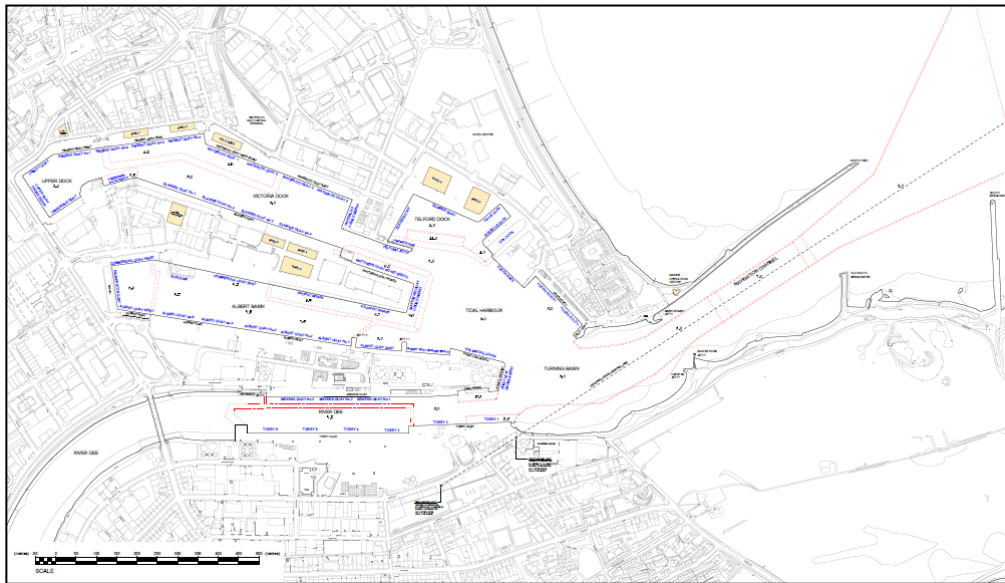


Figure 14: Layout of Aberdeen Harbour

Renewable energy experience

The Trust's mandate is to support the harbour's users as well as their wider stakeholder community and, in following this, they are in the advanced stages of committing to a proposed £400m harbour expansion - the Aberdeen Harbour Expansion Project at the adjacent Nigg Bay- with an aim to support a wide range of activities, including the provision of comprehensive heavy lift and lay down facilities to support Scotland's offshore wind and marine energy deployment ambitions. The new Harbour facility would be fully operational by last quarter 2019.

Aberdeen Harbour's management team have been actively engaged and working with regional support/development bodies, leading fixed-bottom offshore wind site developers, and the industry more generally for many years. Infrastructural improvement planning has been undertaken with (somewhat undefined) offshore renewable energy requirements as a strong consideration.

Challenges faced

Lack of project materialisation: Offshore wind deployment within Scotland has been slower than anticipated to date and this has meant that they are receiving a limited interest to provide offshore wind deployment work. Presently, two future demonstration sites have expressed an interest in utilising the present constrained facilities within the existing harbour and, looking forward, the new harbour expansion would be able to accommodate all of the key components of marshalling, construction, and at the same time provide additional capacity to support the ongoing O&M lifecycle.

Managing expectation: Although eager to engage fully, the long term lack of visibility and actual project materialisation combined with knowledge of the reduced funding threat for floating wind (beyond closure of the enhanced ROCs) has left Aberdeen Harbour without a clear understanding of the scale of opportunity the sector could offer. They believe that expectations have been bullish to date which, in turn, has created

unnecessary momentum and, ultimately, under-delivered upon expectation. As a result, the Ports sector in general are naturally more cautious in business planning for floating wind, which is likely to be 5-10 years or more before any significant demand is present. Aberdeen Harbour believe, however, that the design of the proposed harbour expansion can be delivered within this lead-time and, as such, the harbour will be able to undertake future work on floating wind from the new facilities on a project by project basis.



Figure 15: Proposed new Harbour expansion at Nigg Bay

Lack of pipeline visibility: Lack of clarity in the deployment pipeline (for both fixed-bottom and floating offshore wind) has supported this position and it could be that a more coordinated process of deployment in the future, such as the running of leasing rounds (aligned with funding rounds), would help to define the potential market demand.

Insufficient knowledge of technical requirements: In addition, having a tighter understanding of the technical envelope for the systems to be fabricated and deployed would also provide clarity on specifications for harbour capabilities and developer requirements. Proving capability to fabricate the turbines, along with cost, physical geography and evidence of prior experience, are seen as a key consideration for tendering for ports.

JDR Cables

Background

JDR are a British cable manufacturer with offices in the UK and overseas. They supply cables for a range of offshore services both within the oil and gas and offshore wind sectors. As a company, they are capable of building to any cable specification but also have their own uniquely designed cables, as well as an extensive dynamic modelling team to back up project designs. This back up recognises that cable supplies to the market, especially for dynamic applications, are not simply off-the-shelf commodity purchases but benefit from optimised and designed engineering solutions (e.g. FEED studies).

Renewable energy experience

JDR are the only offshore wind intra-array cable manufacturing company based within the UK. Since the Beatrice Demonstrator project in 2006, they have supplied intra-array cables for over half a dozen of the UK's largest offshore wind farms, as well as the Wave Hub site in Cornwall. They also have an existing and complimentary pedigree in supply to the offshore oil and gas sector, which has included dynamic cables to floating TLP and semi-submersible structures at a range of water depths.

Challenges

Early supply chain engagement: JDR recognise that the immaturity of the floating wind market means that there is not currently (and may never be) a 'standardised' solution for floating wind farm intra-array cables. Variables such as the amount of armouring and even the voltage rating (33/66kV) have yet to be harmonised and are both technology and project specific, but there will likely be some convergence upon preferred designs. Environmental conditions are project specific, and this will likely lead to site specific optimised requirements (in terms of cost and performance) for design, particularly of ballast and buoyancy configurations. Engagement within initial projects is therefore crucially beneficial for suppliers to develop a detailed understanding of both the customer's needs and the nuanced technical challenges to overcome. This, in turn, creates a relationship and trust that, as was the case for JDR with the Beatrice Demonstrator back in 2006, would allow strong growth within the floating offshore wind market as it matures.

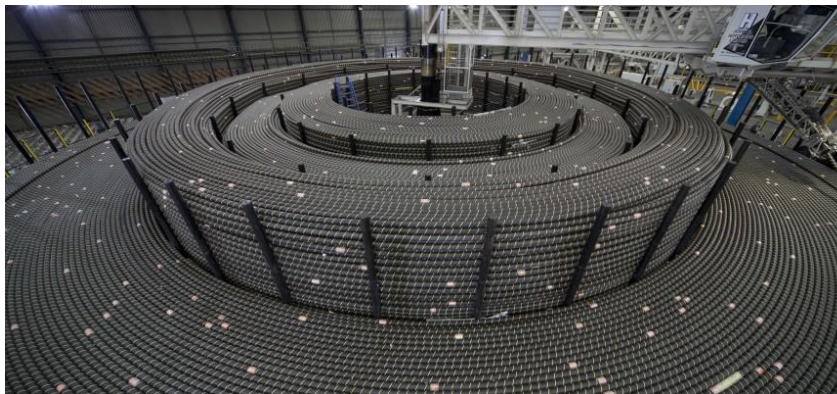


Figure 16: 105km of JDR intra-array cable for the Sandbank offshore wind farm

Pilot projects build trust with customers: Floating wind in the UK has gone straight into a production run with the Hywind project, further to the demonstrator project previously undertaken in Norwegian waters. For many of the suppliers involved, it can be seen that involvement in the demonstrator project led to contracts on the Hywind project, which may have contributed to the unintended consequence of very low UK content in the first floating wind project in UK waters. This is a good example of the importance of demonstrator projects and early involvement of suppliers to build the track record and relationships required.

Understanding technical requirements: Ultimately, JDR perceive that there will need to be further refinement of the technical specifications for dynamic cables used in the sector and that their capabilities, products, and efforts will support them into the emerging market. They are aware that real supply chain advantages will come to those who can win early demonstration/pilot-array contracts and thus build up a trusted relationship with developers for when larger commercial farms are built out.

3.4 Policy interventions to support supply chain development

Supply chain development can be undertaken proactively by policy makers through a range of instruments, some of which are already being undertaken within the UK. These policy interventions are outlined below, as well as their relevance to potential floating wind supply chain development.

Project pipeline visibility

For any supplier to make the necessary investments (both time and capital) to enter the floating wind market, there needs to be a degree of certainty that projects will be built within a near to medium-term time horizon, as well as continued build out over the long-term. Deployment targets and leasing rounds can all provide greater certainty for suppliers, but this will inevitably need to be accompanied by a suitable remuneration system. For UK suppliers, domestic build out will be most critical, particularly for fabricators and installers, but suppliers of more modular component systems will also seek clarity on regional and global deployment scenarios in order to exploit export opportunities.

Local content requirements

A direct means of increasing business opportunities for domestic suppliers is to enforce local content requirements for projects. This could form a part of the evaluation criteria for contract awards and/or consist of targets for local content post-contract award. While effective in boosting local economic benefits, this approach is unlikely to be compatible with cost reduction goals, with reduced access to overseas suppliers, as well as reduced competition, having a negative impact on price. This has been evident in the French fixed-bottom offshore wind industry, where strict local content requirements have seen considerable investment in new manufacturing facilities but high electricity prices. In the UK, applications for contracts for difference auctions mandate the inclusion of a Supply Chain Plan, which should include targets for levels of local content. However, the extent to which these will be enforced is currently unclear.

Infrastructure and other capital equipment support

Providing support funding (through grants, soft loans or other methods) to allow companies to meet potential market requirements is a primary enabler to facilitate market engagement within emerging supply chains. This could include a wide range of options from improving quayside facilities to installing new manufacturing equipment. Such investment can often act as an enabler for the creation of supply chain clusters, catalysing private investment in the surrounding area. This approach has been particularly effective in Bremerhaven, Germany, which has transformed into a leading hub for offshore wind activity.

Current funding programmes that fall under this form of supply chain creation include the Scottish National Renewable Infrastructure Fund (N-RIF), a £70m grant allocation targeted at supporting offshore wind supply chain stimulation for port and near-port manufacturing facilities. This could include consortia applications from throughout the supply chain, such as project developers and ports collectively developing project facilities. Other funds include the Prototyping for Offshore Wind Energy Renewables Scotland (POWERS), which was designed to help companies seeking to establish manufacturing facilities within Scotland, and the Scottish Innovation Foundation Technologies Fund (SIFT), targeted at supporting companies to develop innovative foundation solutions. Both of these are discussed further within section 2.1.1.

Innovative R&D

Floating wind is a nascent energy technology with considerable scope for innovation. Public sector support for research and development activity can enable companies to develop innovative products that can achieve the dual aim of reducing cost of energy and stimulating economic and employment benefits for UK companies. The modular design of floating wind devices lends itself to a decoupling of the supply chain from site location, presenting export opportunities for UK companies. This reduces the risk for public sector and private spend

given that suppliers will be able to export products and services overseas, even in the absence of a strong domestic market.

The UK has considerable existing capability from both the fixed offshore wind and offshore oil and gas industries which can be applied to floating wind. With many of these companies eager to diversify into new sectors, floating wind presents a potentially attractive route to new market opportunities. However, given the nascent state of the industry and uncertainty over future market growth, many suppliers will require a stimulus to dedicate resources and investment to develop new offerings. Public sector support for R&D can therefore encourage UK companies to leverage existing capabilities and gain first mover advantage in a new industry.

R&D delivery models:

R&D projects can be structured in several ways:

1. Research projects in which a supplier solely develops a product or service for a potential future market (e.g. DECC Offshore Wind Component Technologies Scheme)
2. ‘Vertical’ supply chain arrangement in which a customer and supplier(s) work together to resolve a customer challenge. Often undertaken as consortia (e.g. Fukushima FORWARD consortium)
3. ‘Horizontal’ supply chain problem solving arrangements in which multiple customers pool resources to resolve a common problem (e.g. The Carbon Trust’s Offshore Wind Accelerator programme)

The first of these options is arguably the most common approach but generally holds higher commercial risk since there is not a clearly defined final customer. This option is less focussed upon supply chain development as a co-benefit from the R&D and tends to be better suited to either radical innovation (where there is higher risk and therefore less market engagement) or where there is no need for public sector intervention (i.e. both the customer requirement and business case for undertaking the work are perceived as robust enough that funds and risk can be borne by the company itself).

The second of these options (vertically integrated R&D) is often practical when the either the output specification is not clearly defined or the supporting supplier has access to greater specific resources (e.g. knowledge, manufacturing equipment etc.). This form of R&D clearly creates a strong customer/supplier relationship and there are a great many variations to operationalising projects of this kind, based upon: funding structure, intellectual property ownership, commercial exploitation rights, exclusivity, and many other factors.

Generally, the third of these R&D approaches (horizontal supply chain problem solving) requires a strong market expectation to ensure customer buy-in and requires stronger R&D coordination. Once the consortium is established, however, it presents a clear indication of market need to potential contractors undertaking R&D initiatives. Collaborative R&D of this kind is likely to provide more attractive financial leverage and risk sharing, as well as providing a strong market signal, but is only likely to be successful if customer buy-in can be achieved.

Supply chain assessments and stakeholder databases

Arguably the broadest form of supply chain engagement is to undertake a high level review of the industrial base within the region and seek to identify companies that may wish to engage in sector activity. This includes ports, heavy metal fabricators, vessel owners, etc. The amount of effort and detail included within the dataset (i.e. the amount of attached metadata) determines the value of the database. Variations of this could include specialist supplier databases with higher levels of relevant detail (such as port facility or vessel studies). Several national and regional offshore wind databases exist (see below), however, there is currently no national level floating wind technology database.

UK examples of these instruments in practice are included in Table 9, below:

Producer	Name	Technology Detail	Access
SDI	Offshore Floating Wind - Scottish Supply Chain Capability (report)	Floating Wind	Contact SDI
RenewableUK	Supply chain map (online)	Wind	http://www.renewableuk.com/en/renewable-energy/supply-chain-map.cfm
RegenSW	Supply chain map (online)	Offshore Wind	https://www.regen.co.uk/directory/
The Crown Estate	A Guide to an Offshore Wind Farm (report)	Offshore Wind	http://www.thecrownestate.co.uk/media/5408/ei-a-guide-to-an-offshore-wind-farm.pdf
ORE Catapult	Marine Supply Chain Gateway (online)	Marine	http://www.mescg.co.uk/

Table 9: Supply chain databases within the UK

Skills support

The requirements of offshore wind projects are wide ranging, encompassing an abundance of skills and equipment needs. Often, companies wishing to engage in a sector will have some proprietary skill sets (such as high voltage electrical wiring capabilities), but may lack certain specialist knowledge or skills (such as rope access, offshore sea survival or first aid training). Identifying where these gaps to local company engagement are can allow companies from complimentary sectors to move into the industry. Conversely, many specialist or start-up companies (such as university spin-out companies or technical consultants) may have specialist knowledge but lack more general business development skills (such as business planning or financial management). Supporting the development of these skills not only enables the company to engage within the sector but, due to the large overlap in offshore renewable skill requirements, also assists these sectors as well. Examples of successful business skills support include DECC's Energy Entrepreneurs Fund and SSE's High Growth Programme. A 2008 study commissioned by RenewableUK examined the skills requirements for offshore wind, wave and tidal technologies and found the below requirements:

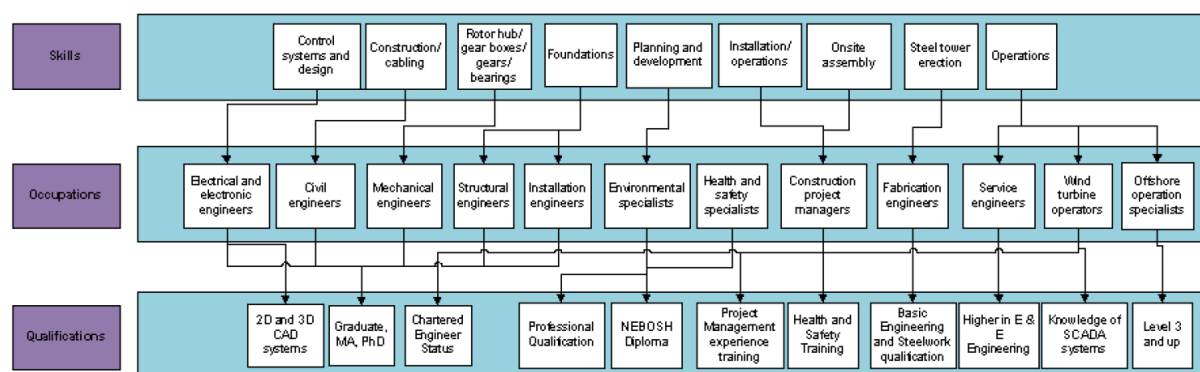


Figure 17: Skills, occupations and qualification requirements within the wind, wave and tidal sector.

Within the UK, the offshore wind energy sector now has established training centres, including RenewableUK's Renewable Training Network and two National Wind Training Centres located in Lowestoft and Barrow-in-Furness.

Supply chain engagement, workshops, conferences and brokerage events

A key challenge to helping companies enter into a sector is showing them where and when business opportunities occur. Often this involves broad education on the projects or sites being developed, the timeframes for activities and the companies with whom to engage. Earlier stage R&D sectors (such as wave and tidal) usually favour higher academic focus, however, the floating wind sector is more developed and focussed upon project delivery and would be better suited to more commercially focussed events that allow brokerage

opportunities. Engagement through regular news updates, workshops and trade shows is a powerful approach to showing that the sector is there to engage with and helps to support sector knowledge transfer. Examples of supply chain engagement instruments include events and conferences hosted by Scottish Renewables and RenewableUK, as well as focussed supply chain support initiatives.

Incubation support

Incubation support is often provided alongside wider innovation initiatives, such as alongside university spin-out support services, or as part of a business park's establishment to work with start-up and spin-out companies. This is usually time limited (in that it will only be available to the company for a limited number of years) and flexibly applied to support the tailored needs of the company and its business development strategy. Examples of this form of support include the Carbon Trust's Energy Entrepreneurs Fast Track and Energy Entrepreneurs Fund.

More generally, incubation support can provide a range of free or reduced cost benefits to recipients, including: targeted business needs support (e.g. business planning or skills training); business contact or collaboration matching services (against capabilities); mentoring from senior/experienced experts; financial subsidies for wages (e.g. % of wage covered for X months); reduced cost or free start-up premises; and communalised resources (e.g. meeting rooms, IT/reception support, specialist business alerts/news, transport facilities).

3.5 Recommendations to policy makers

A great deal of supply chain support has already been undertaken and is ongoing for fixed-bottom offshore wind, largely through dedicated economic support agencies, industry associations, and dedicated innovation programmes. There is also an extensive range of databases and other supporting services for supply chain development (some of which are discussed with Section 3.2). Arguably, supply chain development work has been seen to oversell the opportunity for offshore wind in Scotland, as deployment has been slower than anticipated, leaving some stakeholders unclear on the scale of opportunity the sector could offer. As such, a realistic and technically focussed appraisal of market opportunity from support agencies would help to increase credibility of the sector in the long-term.

The wider supporting activities already being undertaken and discussed in section 3.4 will be useful as demonstration projects roll out and the technology begins to both converge and commercialise. Five broad recommendations, however, can be considered that will help support UK companies access crucially important early project supply chains. The recommendations have been prioritised in order of scale and expected impact.

1. **Create a strong domestic market:** The most effective means of supporting supply chain development is through increased large scale deployment catalysed through an adequate subsidy mechanism. Provision of funding for demonstration, pilot, and commercial projects will be the most effective method of supporting local companies, but is also the most expensive in absolute terms.

Although creating a long term project pipeline is a key requirement for the sector to survive, as a bridging gap, increased public sector support for niche market deployments¹⁸ could provide some supply chain continuity. Until either technology cost reduction occurs or revenue subsidies for electricity are adjusted to better reflect the immature stage of the technology, it is unlikely that there will be many deployments within the UK after 2018. Exploiting niche markets, such as enhanced oil recovery (e.g. DNV-GL WIN-WIN project), could provide a bridging mechanism for deployment, entrench local suppliers, and provide a useful commercial project for the market being serviced.

2. **Invest in key enabling infrastructure:** Provided a strong domestic market exists, investment in key enabling infrastructure, such as ports and manufacturing facilities, can improve the competitiveness of local suppliers and serve as hubs for the development of supply chain clusters.
3. **Support innovation in the supply chain:** Floating wind is a nascent energy technology with considerable scope for innovation. Particularly given pressures to reduce costs and de-risk the technology, companies that can develop innovative products and services are likely to prosper. Supporting innovation activities can therefore help UK companies to be competitive in the global marketplace. In order to maximise the impact of R&D spend, opportunities to dovetail activities with cross-technology benefit to other sectors (i.e. fixed offshore wind, wave & tidal energy) should be pursued.
4. **Support UK companies to export products and services to overseas markets:** The UK is considered a world leader in both the offshore wind and offshore oil and gas sectors. There is thus considerable expertise and capability within the existing supply chain that can be leveraged to provide products and services for the floating wind industry, both within and outside the UK. Even in the absence of a strong domestic market, with support, UK companies could be extremely effective in gaining a foothold in a potentially global market. In addition to supporting innovation, trade missions, networking/brokerage events, publications, and business advisory support can all help UK companies to increase exports.
5. **Increase coordination of supply chain activity across the UK:** Increase the coherency of extensive supply chain creation activity that is already being undertaken within Scotland, England and Wales. This includes the following:

¹⁸ Niche markets exist where the economic business case for employing floating wind technology is greater than for grid connected generation (i.e. substituting oil based generation where electricity costs would be higher).

- **Increase coordination between funding bodies** to ensure that effort is not duplicated, lessons are learned from policy interventions to date, and to ensure that both supply chain gaps and, consequently, regional or national opportunities to reduce barriers to entry are identified.
 - **Refine the technical requirements for tier 1 suppliers** for both products (e.g. technical specifications for mooring systems) and services (e.g. port and manufacturing facility requirements).
 - **Identify and engage with companies** throughout the UK that have capabilities to support the floating wind sector.
 - **Host a range cross-funder supported supply chain events** throughout the UK to raise awareness of floating wind projects, technologies, and opportunities, as well as help contractors to develop bidding consortia to support and supply larger sub-contracts within floating offshore wind projects.
6. **Align decarbonisation and energy security goals with industrial strategy:** Underlying the above requirements is the need for a defined, aligned and agreed industrial development policy within the economic development, innovation and low carbon support community. This must be realistically reflective of both the timeline and size of market opportunity, as well as flexible enough to support engagement requirements on a project-by-project basis.

4 Grid Connection

4.1 Introduction

The importance of grid connections for the deployment of onshore and offshore renewables has long been recognised, and has seen requirements for the development of new technology solutions and market developments to enable the continued development of the grid, such as the development of the HVDC Western Link project¹⁹.

For floating wind the availability of suitable grid connections has been identified more recently as a key determining factor in the location of floating wind parks; Statoil in the development of their Hywind Scotland project identified two locations in Scottish waters which met all or most of their requirements for a demonstrator site for their floating wind park. The sites identified were in The Minch off Stornoway, and the Buchan Deep off Peterhead. According to Statoil's marine application the Buchan Deep site "offered better availability of grid connections and was therefore selected by the Company as the preferred development location"²⁰.

In developing a future market for floating offshore wind this report looks at the current capability of the GB Grid network and also potential scenarios to enable the deployment of floating wind.

¹⁹ <http://www.westernhvdclink.co.uk/>

²⁰ Application For A Marine Licence Under Part 4 Of The Marine (Scotland) Act 2010
<http://www.gov.scot/Resource/0048/00488332.pdf>

4.2 Grid codes

All forms of energy generation, including any potential floating wind projects, connected to a public electricity network must comply with a number of regulations and technical requirements in order for the network to operate safely and efficiently. These technical requirements are referred to as “Grid codes”. Compliance with these codes depend on the size of the project and voltage levels. In addition, there may be other technical requirements which may not exist in the grid code but apply to the project through agreement frameworks (e.g. bilateral connection agreement, power purchase agreement, or other form of agreements).

The grid code is divided into seven main codes including; planning code, connection code, compliance process, operating codes, balancing codes, data registration code and the general conditions (The Grid Code, 2016). Users of these codes include, generators, interconnectors, DC convertor stations, network operators and power park modules. The conditions required for the active operations are outlined over a number of operational codes but not all of these operating codes apply to all users.

The aim of the grid codes are to define technical obligations and requirements for generators so that the system operator can secure a robust operation of the electricity system regardless of the source of generation and technologies used.

In Great Britain, for example, key industry codes applicable to electricity regulation are summarised as follows:

- **National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS)** which defines the criteria and methodologies that transmission licensees (onshore and offshore) use when planning and operating the NETS.
- **Connection and Use of System Code (CUSC)** which constitutes the contractual framework for connection to, and use of, Great Britain's high-voltage transmission system.
- **Balancing and Settlement Code (BSC)** which contains the arrangements for the wholesale market, in particular on electricity balancing and settlement.
- **System Operator–Transmission Owner Code (STC)** which defines the high-level relationship between the system operator and the transmission system owners.
- **Master Registration Agreement (MRA)** which provides a governance mechanism to manage the processes established between electricity suppliers and distribution companies to enable electricity suppliers to transfer customers.
- **Distribution Connection and Use of System Agreement (DCUSA)** which provides a single centralised document that relates to the connection to and use of the distribution networks and is a contract between generation distributors and suppliers in Great Britain.
- **Distribution Code** which specifies the day to day procedures that govern the relationship between the distribution licensee and users of its distribution system for planning and operational purposes, in normal and emergency circumstances. The Distribution Code is also designed to ensure that the distribution licensee can meet its Grid Code compliance obligations.

4.3 GB Grid

GB has currently a total generating capacity of approximately 80 GW from different sources. This is transmitted at a voltage of 132kV or above in Scotland or offshore and at 275kV and above in England and Wales. National Grid owns the transmission network in England and Wales and is the National Electricity Transmission System Operator (NETSO). The transmission network in Scotland is owned by two separate transmission companies: Scottish Hydro Electric Transmission (SHET) in the north of Scotland and Scottish Power Transmission (SPT) in the south of Scotland.

The national network transmission system faces significant challenges in the coming decades as the GB energy landscape continues to diversify. With the expected replacement of ageing generation plant, such as nuclear generators and coal, and the growth in renewables, such as wind, as primary sources of energy, generation is moving farther away from demand centres, raising the issue of transporting power over longer distances. This indicates that the transmission network must respond and adapt to this changing landscape to ensure power is transported from the different energy sources to the demand point.

4.3.1. Electricity Demand

Based on the National Grid Electricity Ten Year Statement 2015 (ETYS 2015), future transmission network investments are considered using the peak Average Cold Spell (ACS), which takes into account weather elements that trigger peak demands. Figure 18 presents the peak total electricity demand forecast trends based on different future energy scenarios. Summary of these scenarios can be found in the Electricity Ten Year Statement²¹.

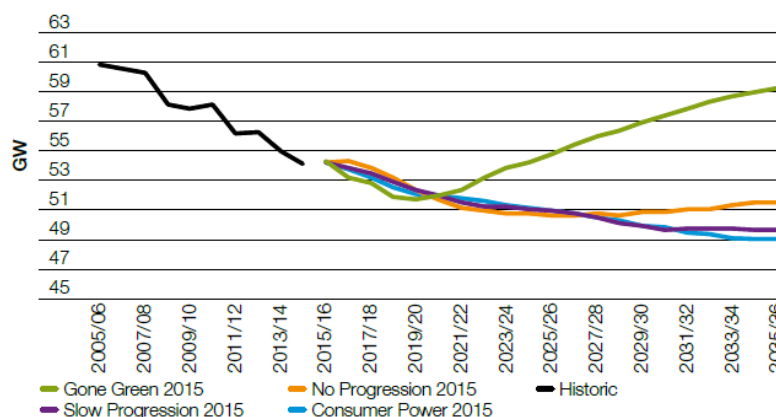


Figure 18: Future development of ACS demand based on the different energy Scenarios

Demand as seen by National Grid on the transmission network (Figure 18) shows that the peak electricity demand has been decreasing in the last ten years. Peak total electricity demand over winter of 2005/2006 was around 61GW, decreasing to around 54 GW in 2014/2015. This reduction is mainly due to reductions in industrial demand and increased contribution from embedded generation (small scale Combined Heat and Power, generation from landfill gas, and biomass).

Although the transmission system has been largely successful in meeting the electricity demand at reasonable cost and reliability for many decades, the capacity of electricity generation from sources which are most likely to operate at times of ACS peak demand is decreasing. This is mostly due to a number of established generation sources (coal and gas) having been decommissioned in order to comply with EU regulations on air pollution and carbon abatement.

²¹ The ETYS is an annual report which forms part of the electricity transmission planning cycle. It addresses the requirements of current and future transmission network in addition to power transfer capability of the National Electricity Transmission System.

In addition, the continuous growth of renewables, in particular wind, which is being developed at locations on the periphery of limited network capacity, is also another challenge. The combination of ageing generation/transmission assets and energy decarbonisation targets therefore requires an upgrade of the transmission system in order to overcome these challenges.

4.4 Transmission network capacity

The transmission network is designed to ensure that there is sufficient transmission capacity to send power from areas of generation to areas of demand. To achieve this, the transmission system is split in the form of boundaries established based on current system capability, future transmission capability requirements and their geographic locations. These boundaries are specified by the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS) and cross important power flow paths where there are major sources of generation, limitations to power transfer capability and also major demand centres. Figure 19 presents the electricity transmission system boundaries used to analyse the ETYS 2015 data.

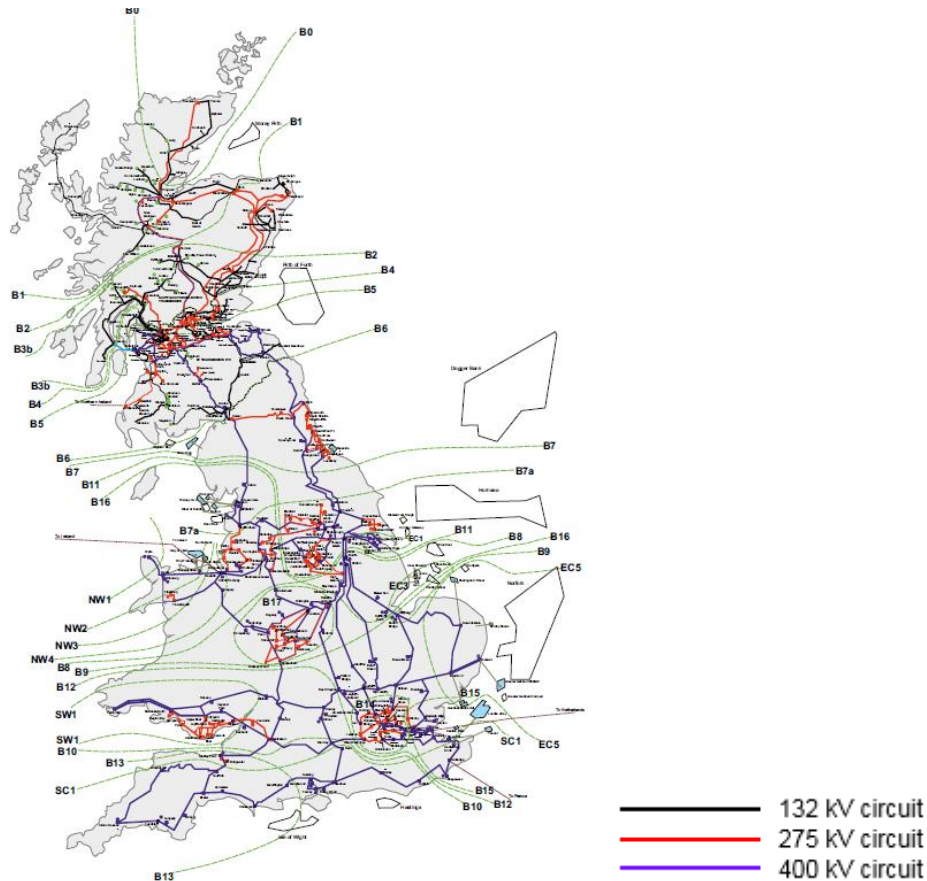


Figure 19: GB boundaries set by the ETYS 2015

Based on the electricity networks strategy group (ENSG) report (ENSG, 2012), the power flow on the transmission system will continue to be predominantly from North towards the South. . In Scotland, power generation is anticipated to significantly increase due to the growing capacity of renewable energy generation, while the level of demand is not anticipated to increase significantly over the next decade. In addition, the capability of the Scotland/England boundary transmission networks are currently limited by stability restrictions including thermal rating and system stability. Stability issues may arise when a fault occurs on one of the two available circuit routes connecting both countries.

In order to resolve the electricity transmission network restrictions in terms of integrating additional power generation, a range of potential reinforcements are required. These requirements are summarised in the following sections.

4.4.1. Scotland transmission network

As illustrated in Figure 20, the electricity transmission system in Scotland, is characterised by a radial interconnected network of 132kV (black line) and 275kV circuits (red line) in the north (Scottish Hydro Electric Transmission Limited area) and a large network of 275kV and 400kV circuits (purple line) in the south (Scottish Power Transmission area).

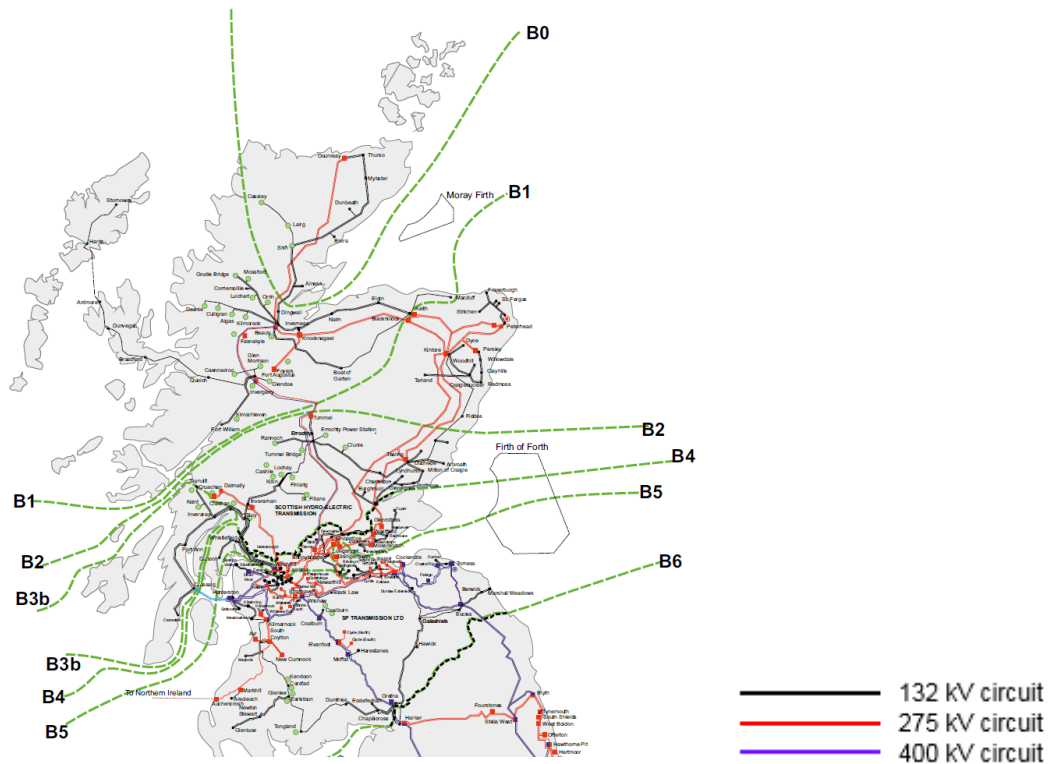


Figure 20: Scotland transmission network boundaries

National Grid's Ten Year Statement 2015 highlights that the primary challenges encountered by the Scottish transmission network is the significant growth of renewable generation capacity from remote locations and the limited power transfer capabilities of the network. Regional drivers for transmission reinforcement were also cited, specifically with regard to limitations in:

- Power transfer from remote areas to the main transmission system;
- Exporting power from Argyll and the Kintyre peninsula;
- Power transfer from north to south of Scotland; and
- Power transfer through the Scottish networks to southerly demand centres in England.

Currently, some of the Scottish network boundaries, as presented in Figure 20, have insufficient capacities to satisfy the boundary transfer requirements as envisaged under some of the scenarios of the National Grid ETYS 2015. Limitations and reinforcements of the different network boundaries are summarised below:

Scotland Upper North (Boundary 0)

This boundary comprises the north Highland (north of Beaulay), Caithness, Sutherland and Orkney. The existing transmission infrastructure in this boundary is relatively sparse and include circuits of 275kV and 132kV transmission lines. The Orkney demand is fed via a 33kV subsea link from Thurso.

Power transfer capability of the upper north boundary is currently at 250MW and network reinforcement is required to accommodate current growth of renewable generation, primarily onshore wind and future marine generation resource in the Pentland Firth and Orkney waters.

To introduce reinforcement to the capability of this network boundary, the Caithness–Moray HVDC link project and Beaulay–Dounreay second 275kV circuit are presently being implemented. These projects, combined together, would increase the capacity of the network up to 900MW.

Scotland North West (Boundary 1)

This boundary covers the area from the Moray coast near Macduff to the west coast near Oban. The transmission infrastructure in this area comprises both 275kV and 132kV assets with a transfer capability estimated at about 1.9GW. Due to the large volume of renewable generation connection expected north of the boundary, this will result in a large increase in export requirements across the boundary. The contracted generation in boundary B1 includes renewable generation on the Western Isles, Orkney and the Shetland Isles as well as a number of large and small onshore wind developments. A large new pump storage generator is also planned in the Fort Augustus area, while MeyGen tidal generation is also expected to connect in this boundary. This is supplemented by existing generation, which comprises around 800MW of hydro and 300MW of pumped storage at Foyers.

There are two key reinforcement projects which would contribute to the increase of power export capabilities across boundary B1. The Caithness–Moray HVDC reinforcement which is expected to accommodate the increase in power generation from renewables and also further enhance the B1 boundary transfer capability from North to South of Scotland. The Caithness–Moray HVDC reinforcement also covers boundary B0 and is expected to accommodate an increase in Generation of 800MW and 850MW in boundaries B0 and B1, respectively. The upgrade is due to be delivered in 2018.

The Beaulay to Denny upgrade is also another reinforcement which will provide additional capability for boundary B1, as well as boundaries B2 and B4. The Beaulay to Denny extends from Beaulay in the north to Denny west of Falkirk. The project is now complete and fully energised. The increase in total transfer capacity of the Beaulay to Denny is estimated at 1200MW.

Scotland North to South (Boundary 2)

Boundary B2 cuts across the Scottish mainland from the east coast between Aberdeen and Dundee to near Oban on the west coast. This boundary crosses all the main north-south transmission routes (275kV and 132kV circuits) from the north of Scotland.

Power transfer capability of the North to South boundary is currently at 2.2GW. Main power generation sources within this boundary includes both onshore and offshore wind, with the prospect of adding significant marine generation resources, offshore windfarms and the proposed future North Connect interconnector with Norway. As a result, transfer capacity forecast for boundary B2 is expected to increase at a significant rate.

As described in boundary B1, the Beaulay–Denny project is a key reinforcement that increases the capability across boundaries B1, B2 and B4. Hence, providing the opportunity of integrating additional power generation to the grid.

Argyll and Kintyre (Boundary 3)

The Argyll and Kintyre area network is a 132kV network characterised by its weakness and low transfer capacity estimated at 150MW. The forecast power transfers across the boundary are increasing at a significant rate because of the high volume of connected and contracted renewable generation seeking connection in Argyll and Kintyre.

Key reinforcement of this boundary include two 220kV AC subsea cables between a new substation at Crossaig (to the north of Carradale) on Kintyre and Hunterston in Ayrshire, which will lead to an increase of the boundary capability to around 400MW. There is still significant interest and proposed connection activity in the area, and it is likely that further reinforcement of this network will be required in the future.

SHE Transmission to SP Transmission (Boundary 4)

Boundary B4 separates the SP and SHE transmission networks with a transfer capability of circa 2.9GW. It is anticipated that the transfer capacity within boundary B4 will increase due to the significant volumes of power

generation connected to boundaries B0, B1 and B2, and also the contracted generation which includes around 2.7GW of offshore wind and over 5GW of large onshore wind generation. Although it is estimated that the current boundary capability is sufficient to satisfy the boundary transfer requirement, future reinforcement may be required in addition to the Beaulieu to Denny upgrade.

SP Transmission North to South (Boundary 5)

Boundary B5 is located within the SP transmission system and expands from the Firth of Clyde in the west to the Firth of Forth in the east. The transmission network across the boundary includes three 275kV double circuit routes with a transfer capability of 3.5GW limited by thermal considerations. It is expected that there will be a significant reduction in required transfer capability across boundary B5 due to the cessation of generation at Longannet power station (2.4GW²²).

Scotland-England (Boundary 6)

Boundary B6 is the interfacing boundary which separates the Scottish Power Transmission (SPT) and the National Grid Electricity Transmission (NGET) networks. The boundary includes 400 kV circuits and a number of 132kV circuits with limited capacity.

The existing capability of these circuits is currently limited to 3.5GW by stability restrictions, expected to increase to around 4.4GW when the series compensation scheme is completed in 2016. The aim of series compensation is to reduce voltage drops and increase the system stability and transfer capacity. On completion of the Western HVDC Link in 2017, the transfer capacity is anticipated to increase further to around 6.6GW. The transmission capability of boundary B6 for power flows north of the border is considered to be sufficient to satisfy requirements in the near future.

²² <http://www.scottishpower.com/userfiles/file/Longannet-Site-Information-2014.pdf>

4.4.2. England & Wales transmission network

The transmission network in England and Wales is operated by National Grid Electricity Transmission (NGET) and characterised predominately by 400kV and a number of 275kV transmission networks for a total generation exceeding 60GW. Figure 21 presents the different electricity transmission system boundaries in both England and Wales.

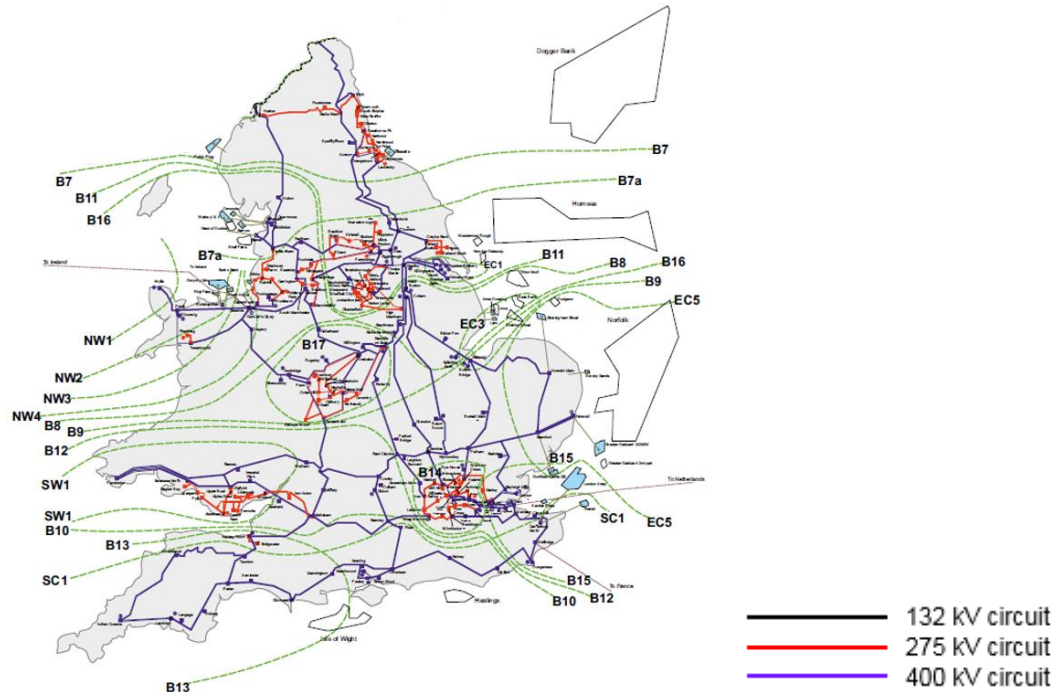


Figure 21: England and Wales transmission network boundaries [2]

Generally, restrictions of the boundary transmission networks are often caused by the continuously increasing electricity demand and new generation from either renewables or other energy sources. Therefore, network development and reinforcement is required to ensure generated power is transported to demand centres. Due to the large number of boundaries within English and Welsh transmission networks, reinforcement to existing transmission network is summarised in Table 10. Details of boundary capacities and infrastructure upgrades can be found in the National Grid ETYS.

Table 10: Transmission system major upgrades

Boundary	Project	Transfer Capacity increase (MW)	Stage: 1. Scoping 2. Optioneering 3. Design 4. Planning 5. Construction	Delivery date (TO view)
B6, B7 & B7a	Western HVDC link	2200	Construction	2017
B4, B6, B7 & B7a	Eastern HVDC Link	2200, 2200, 1000 & 700 respectively	Optioneering	2023
NW1	New 400kV, Pentir-Wylfa Transmission circuit	3800	Optioneering	2024
NW2	Second Pentir-Trawsfynydd 400kV Transmission circuit	3400	Design	2021-2027
North Wales, NW1, NW2, NW3 & NW4	Wylfa-Pembroke HVDC Link	2000-2500	Scoping	2024
Central Wales	Mid Wales 400kV substation and Transmission circuit	1800	Planning	2019
EC1	Humber - Killingholme South New Substation	3900	Scoping	2030+
EC5	East Anglia (New Bramford-Twinstead 400kV Transmission circuit)	2600	Scoping	2023-2025
B14 London	London (Uprate Hackney-Tottenham-Waltham Cross circuit to 400kV+ Pelham Rye House Reconductoring)	800	Delayed ²³	2022-2031
B13	South West (Hinkley Point- Seabank)	2400	Planning	2022

²³ Due to early closure of generation, delay in connection of new interconnectors between the Great Britain and Mainland Europe, slower increase in generation in East Coast and slower growth in London demand as anticipated before

4.5 Grid connection of floating wind

Water depth, distance from areas of high electricity demand, and the availability of connection points to the onshore transmission grid are significant factors in the preferred location of offshore wind developments. Despite a handful of projects currently under development, the UK currently has no floating wind turbines installed. In 2013, the Crown Estate opened a leasing round for floating wind demonstration sites of up to 100 MW, which led to the identification of a number of potential development zones for floating wind sites without any lease being awarded. A study by Marine Scotland (2014) used the Marine Resource System tool developed by the Crown Estate to identify a number of potential development zones for floating wind projects in Scotland. These development zones are highlighted in Figure 22 and include seven different sites:

1. South-East of Aberdeen
2. North-East of Aberdeen
3. East of Shetland
4. North-West of Orkney (Westray)
5. North Minch
6. West of Colonsay
7. West of Barra

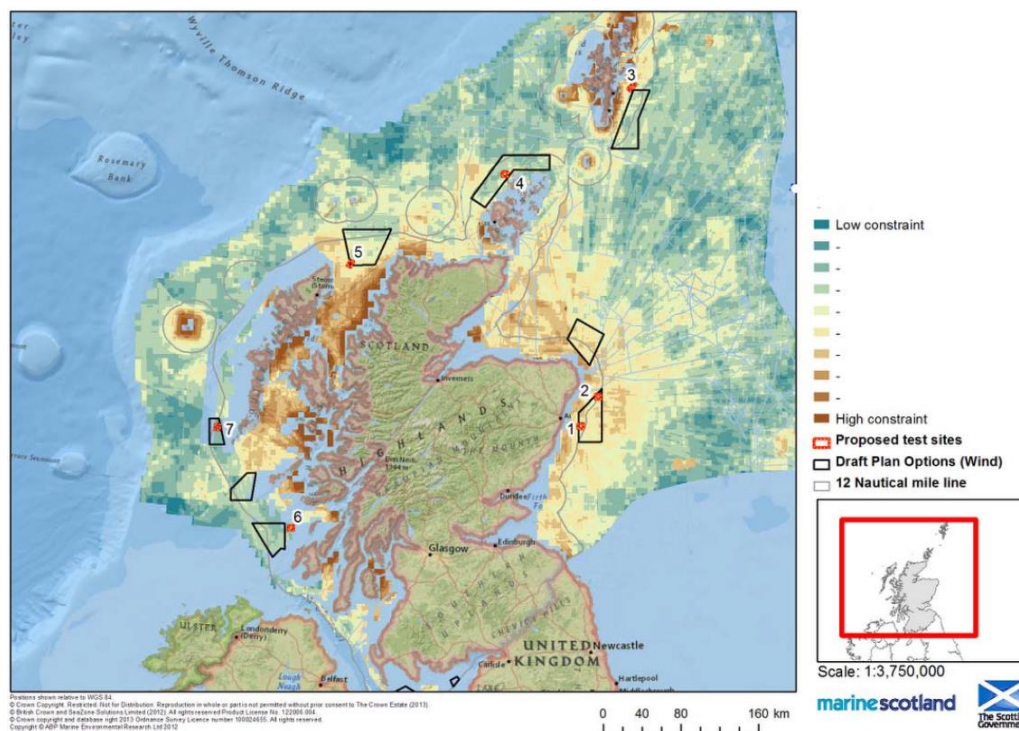


Figure 22: Locations identified for floating wind development in Scotland (Marine Scotland, 2014)

In addition to the seven sites identified in Scotland, grid connection to potential development zones of floating wind farms in England and Wales (as described in the Offshore Energy Strategic Environmental Assessments; see Figure 1, Section 1.1.1) is also discussed.

In an attempt to assess the capabilities of existing grid connection capacity to accommodate the proposed floating wind sites, the following sections summarise the potential of implementing the different floating wind zones.

South-East of Aberdeen

This potential development zone lies within the North to South transmission Boundary 2 and SPT/ SHE Boundary 4. With current network transmission reinforcement (Beaully to Denny, East Coast 400kV upgrade, Eastern HVDC link) the proposed floating development zone may be accommodated. The Grid connection of this zone may be connected via the Eastern HVDC link which connects Peterhead in the SHETL transmission network to Hawthorne in the NGET transmission network. The grid connection may also use the Kintore-Tealing 275 kV circuit line as upgrades were carried out to increase the power transmission capacity of this circuit. Alternatively, the floating wind development may connect into the grid via a substation onshore adjacent to proposed development.

North-East of Aberdeen

This development zone lies within the North to South transmission Boundary 2 which has a transfer capacity of 2.2GW. The North-East development zone is relatively close to possible electrical connection and substations. Peterhead has a suitable onshore grid connection point, which, in addition to current network reinforcement and upgrades, provide a good platform to integrate additional renewable generation, including fixed and floating wind (e.g. European Offshore Wind Deployment centre (EOWDC), located at Aberdeen Bay, and Hywind Scotland, located at the Buchan Deep).

East of Shetland

Shetland is not connected to Great Britain's mainland electricity network. The main sources of electricity generation in the Shetland are Lerwick Power Station and Sullom Voe Terminal Power Station. At 66MW, the Lerwick power station is responsible for the majority of Shetland's supply, while Sullom Voe terminal power station, which has an installed capacity of 100MW currently exports, at most, 22MW to the Shetland system. To accommodate offshore wind generation, Shetland would require a connection to GB's main transmission network to enable the transfer of generated power. A HVDC submarine power cable to connect Shetland Islands to Scottish mainland is currently in early planning and is expected to have a capacity of 550 MW.

North-West of Orkney (Westray)

The amount of renewable generation that can be exported from Orkney is limited by the capacity of the two existing 33kV subsea cables that connect Orkney to the mainland transmission grid at Thurso. Taking into account the renewable generation that has already been connected or is contracted to be connected on Orkney, the existing subsea connection has now reached full capacity. As a result, the connection of additional renewable generation, such as floating wind, would require new transmission infrastructure. The proposed 132kV Orkney-Caithness connection, which is being developed to accommodate current marine energy generation developments (wave and tidal) to the transmission network at Dounreay in Caithness, will provide enough capacity to enable the marine developers to test and develop the technology but will not provide enough long term capacity for the full potential of the leased areas. Therefore, it is expected that there will be a requirement for a HVDC link of greater capacity.

North- Minch

This area does not host any major power stations. Numerous subsea power cables connect parts of the mainland to the Isle of Skye and Outer Hebrides. This area presents constraints in terms of grid connection due to the distances involved and potential landfall locations (132 kV substation exists south of Stornoway and another further south in the vicinity of the Isle of Scalpay). Scottish Hydro Electric Transmission Ltd (SHETL) have proposed the Western Isles Link project (450MW HVDC), which would provide a link between Stornoway, in the Isle of Lewis, and Beaully, near Inverness. However, the project is being delayed due to administrative and regulatory obstacles. In addition to grid connection constraints, other challenges in this area include heavy military activities (submarine and air combat training), which would require detailed communication with the MOD to proceed with renewable generation developments.

West of Colonsay

The development of floating wind in this area can benefit from the fact that this area is relatively close to Hunterston station, where the electrical connection and transformation capabilities could be used to connect to the grid. This area is also close to the Island of Colonsay, where possible electrical grid connection can be made. Energy infrastructure improvements around the Kintyre peninsula and Hunterston would provide this area a 400MW transfer capacity and there is still significant interest and proposed connection activity in the area. Additionally, given nearby developments at Islay wind and tidal developments to the south there may be opportunities for sharing electrical connection with these developments once operational.

West of Barra

This area may be considered unsuitable for floating wind development as the closest connection point is an 11 kV connection. The use of the single connection from Lewis via Skye to Fort Augustus on the Scottish mainland is not possible as this connection is already operating at full capacity. The proposed HDVC cable to link Lewis to the mainland at Beaulieu would deliver 450MW of capacity, however, more grid reinforcements would still be required if the West of Barra site is to generate power to the grid.

North East Boundaries

The North east of England boundaries include B7, B7a and B11 which enclose the Humber region (boundary EC1). The primary challenge facing this area is the rapid growing of renewable generation in Scotland and power flows to the south, which exceeds existing system capability in terms of thermal compliance and system stability.

North East England boundaries are limited in terms of power transfer and voltage compliance in some areas (B11) once the power flows to English boundaries from the Scottish network. The circuits exporting power in this area are reaching their thermal limit. Therefore there are requirements to develop the network to increase the thermal capability to vehicle the power to the south of the country.

Western boundaries (Midlands/Wales/South west England)

The grid in the western region includes the Midlands, Wales and the south west of England. Grid connection boundaries in this region are closely interconnected and some cover wide areas. Due to the increased generation in the north, the large demand in the Midlands and in the south-west of England creates increasing north to south power flows through the networks around the Midlands. These heavy power flows raise concerns around pushing the transmission routes close to their thermal capability.

In the western boundaries, there are limitations on power transfer through the Midlands (boundaries B8, B9, B17) and limitations on power export from North Wales (boundaries NW1, NW2, NW3, and NW4). In North Wales the transmission network is connected by only a few 400kV circuits with limited capacity and there are large amounts of onshore and offshore wind and nuclear generation expected to connect to North Wales.

In South Wales (boundary SW1), there are limitations in terms of power export and significant amounts of new generation capacity are expected to connect to South Wales, including generators powered by wind, gas and tidal. The transmission network in the area is connected by 275kV circuits and few 400kV circuits with limited capacity. This area will require new transmission capacity to export any excess of generation to the rest of the grid when considering the development of floating wind farms.

In South West England to South East England boundary (boundary B13) there are also limitations in terms of power transfer. Future network development in the area will create the needed thermal capacity required for west to east power flow.

Summary

The availability of grid connection points to implement up to 100MW of floating wind demonstration parks is outlined in Table 11, below.

Table 11: Availability of grid connection point for a floating wind park up to 100MW based on potential development zones

Zone	Availability	Comment
1: South-East of Aberdeen		Kintore-Tealing 275 kV circuit line may be used as grid connection point. Current network reinforcement provide additional connection options.
2: North-East of Aberdeen		Peterhead has a suitable onshore grid connection point. Current network reinforcement and upgrades provide an additional connection points.
3: East of Shetland		Grid connection is not available as Shetland is not connect to GB' mainland electricity network.
4: North-West of Orkney		Require new transmission infrastructure as existing one have already reached their full transfer capacity. Thurso grid connection can be used.
5: North Minch		This area presents constraints in terms of grid connection due to the distances involved and potential landfall locations.
6: West of Colonsay		Multiple grid connection point may be available due to infrastructure improvements around the Kintyre peninsula and Hunterston.
7: West of Barra		Unsuitable for floating wind development
8: North East- England		Require network development to increase the transmission network thermal capability.
9: Western boundaries (Midlands/Wales/South west England)		Require the creation of new transmission capacity for exporting excess generation.

4.6 International grid strategies

Currently, commercial scale offshore wind project sites in the UK are determined using the Strategic Environmental Assessments (SEA) guidance as a systematic decision support process. This tool also includes assessment of suitable National Grid connections developed by DECC, Marine Scotland and the Crown Estate. For larger wind farms in the UK, offshore transmission is managed under long-term Offshore Transmission Owners (OFTOs) arrangements, whereby the OFTO will have ownership of the offshore electricity transmission infrastructure to the point of connection to the onshore transmission system. This includes the offshore substation platforms, subsea export cables, and onshore cabling. The framework for OFTOs is managed and regulated by OFGEM and operation payments administered by the National Electricity Transmission System Operator (NETSO).

Looking at international comparisons for grid development, the following sections summarise approaches taken by Germany, Belgium, the Netherlands, France, and Portugal to support the development of offshore wind.

Germany

Germany expects that 15 GW of offshore wind power is to be installed by 2030 in the North and the Baltic Seas. TSOs are obliged to fund, build and operate the required offshore grid connection according to the offshore grid development plan. This approach is expected to deliver cost savings through design optimisation, coordinated connection of windfarms, and investment in technologies such as HVDC transmission.

Although this approach is being considered as centralised, it enables the development of infrastructure and future project connections. The application of such an approach in Great Britain for either floating or offshore wind would require increased confidence of offshore HVDC transmission systems to encourage greater investment, which in turn relates to the structure of the OFTO regime and the generator build model.

Belgium

Grid connection costs are mainly borne by the generation owner and Elia, the Belgian transmission operator (TSO). The TSO is required to contribute financially up to one-third of the total costs of procurement, construction and connection of the export cable (capped at €25 m). Any costs of expanding the grid are borne by the grid operator and use of system costs are incurred by the consumers through their electricity bills. Due to limited financial incentives, but also by a lack of onshore high-voltage grid capacity, Elia is developing a 'modular grid' solution intended to connect several offshore wind farms to the grid via a HVDC connection offshore²⁴. Figure 23 shows a schematic of the proposed grid solution.

The approach being taken in Belgium to enable coordinated development of generation is different to the UK and may prove challenging to be pursued in Great Britain. From a regulatory point of view, this would require a review of the current regulatory framework, OFTO regime and support mechanisms, such as Contracts for Difference (CfD), where distances to shore influence the commercial proposal/offering during the bidding process. On the other hand, as a technical solution, the Belgian modular grid may be very attractive for both floating and offshore wind provided that the grid connection point has the required transmission capacity and the offshore parks are within a development zone close to the offshore modular grid.

²⁴ http://www.elia.be/en/projects/grid-projects/North_Sea

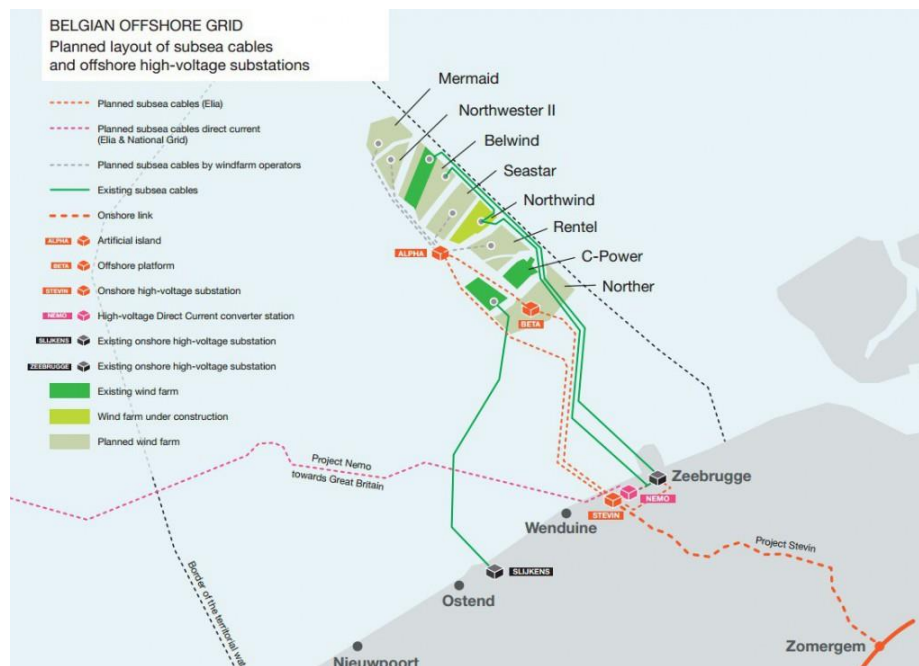


Figure 23: illustration of Belgian Offshore Grid; Image: Elia

Netherlands

In the Netherlands, the Dutch Government has adopted a policy whereby tendered sites will be consented with an environmental impact assessment and a grid connection already in place. The legislation supporting this approach originally expected in July 2015 was announced in July 2016. Aimed at reducing costs, the Government provided relevant site data in the public domain via The Netherlands Enterprise Agency prior to the competitive bidding process. Relevant data includes:

- Geological, morphodynamical and geomorphological data
- Archaeological and Unexploded Ordnance analysis
- Met-ocean data
- Wind resource assessment
- Geophysical and geotechnical data (based on surveys)

In order to create economies of scale, the national electricity Transmission System Operator Tennet is planning to construct five standardised platforms with a capacity of 700 MW each within wind farm zones. Each platform is intended to be connected to the national grid with two 220kV export cables. As soon as a 380kV subsea cables are commercially available, Tennet intention is to use these to reduce the amount of required cables²⁵.

The first two tender rounds for Borssele 1 and 2 in the Netherlands were won by Danish wind farm developer DONG with an average bid strike price, excluding transmission costs, of 72.70 EUR per MWh during the first 15 years of the contract.

In Great Britain the standardisation approach of offshore wind farm capacity may be considered as not supportive of cost effective solutions to offshore wind grid assets. This is mainly because during the bidding process for individual assets OFTOs are focused on achieving value-for-money on a case-by-case basis and therefore the approach may be seen as an obstacle to drive costs down.

²⁵ www.rvo.nl

France

In France, Réseau de Transport d'Électricité (RTE), which is a subsidiary of EDF, is the main transmission system operator. The majority of its revenue is determined by transmission system access pricing (TURPE), the details of which are defined by the Energy Regulator (CRE).

For the offshore wind rounds announced in 2008 feed in tariffs for electricity was set at 130€ / MWh for the first ten years of operation and pegged the funding rates to the operating results for a maximum of ten more years. With limited deployment between 2008 -2014, part of the reason for lack of uptake was the requirement for developers to cover the cost of refinancing the grid connection. Since 2014 the French Government has introduced a competitive auction round with tariffs secured for a 20 year period. For sites deployed far from shore, studies have shown that French wind farms will benefit from the development of a hub approach, similar to the proposed solution in Section 8.2.

Portugal

In Portugal, Redes Energéticas Nacionais (REN) operates the Portuguese National Transmission Grid (RNT) and is the only electricity transmission entity under a concession agreement with the Portuguese state. Based on the Portuguese National Renewable Energy Action Plan (NREAP) 2013–2020, the government have set an action plan to reach an installed minimum capacity of 5,300 MW by 2020 of wind energy generation. This comprises 5,273 MW installed onshore wind generation and 27 MW offshore wind generation.

Network operators in Portugal are obliged to connect all generators to its network on a non-discriminatory basis, provided that the connection is technically and economically feasible and the applicant satisfies the requirements for the connection, with priority given to projects with an installed power of more than 30MW. The transmission operator charges a Global Use of System Tariff (Tarifa de Uso Global do Sistema) and a Use of Transmission Network Tariff (Tarifa de Uso da Rede de Transporte). Rates for offshore wind have not been published at this point.

With a high level of renewable penetration on the grid (see Figure 24), Portugal set a record in June 2016 when it achieved 100% electricity generation from renewables over a period of 107 hours²⁶.

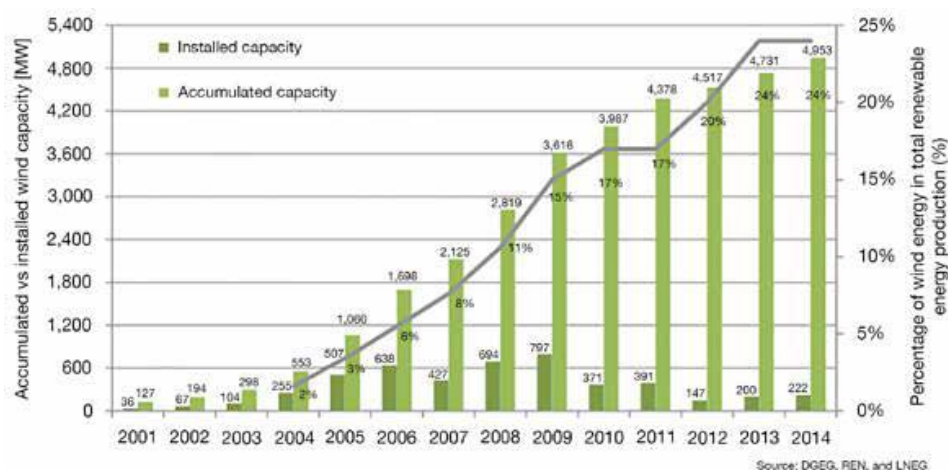


Figure 24: Installed versus accumulated wind capacity (bar graph) and percentage of wind energy production (line graph)

²⁶ The Guardian: Portugal runs for four days straight on renewable energy alone: <https://www.theguardian.com/environment/2016/may/18/portugal-runs-for-four-days-straight-on-renewable-energy-alone>

In order to deliver on its offshore wind target, Portugal will build on the success of the now decommissioned 2MW Principle Power WindFloat floating unit with the further deployment of up to 25MW of floating wind in the WindFloat Atlantic project funded under the NER 300 programme. Planning for offshore wind in Portugal Laboratório Nacional de Energia e Geologia (see Figure 25) has not identified any constraint issues for floating wind in Portugal.

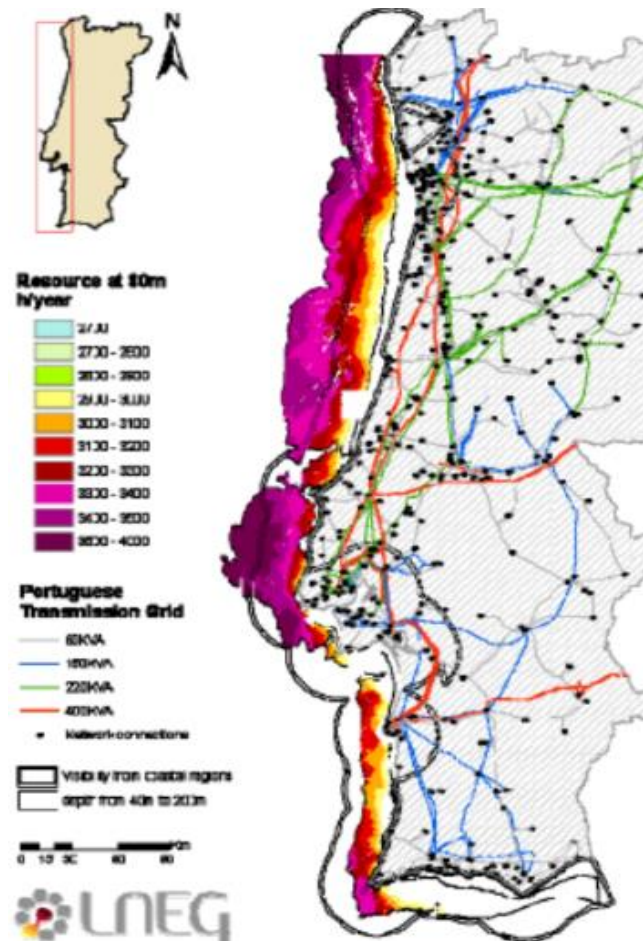


Figure 25: Offshore wind power resource assessment availability in Portugal for open sea areas from 40m < depth < 200m

4.7 Grid solutions in the UK

In 2011, The Crown Estate and National Grid²⁷ studied a number of design approaches towards the feasibility, benefits and challenges of adopting a more coordinated approach to the development of offshore transmission infrastructure. The report found that, to date, the approach to offshore infrastructure has focused on point-to-point or radial systems, and that, in order to meet the objectives of increased deployment of offshore wind, affordability and energy security, this approach needs to be revisited.

Coordinated offshore grid approach

Assuming that there is a long term commitment to offshore renewable energy developments in relatively remote areas and/or at a distance from existing grid access points it is likely that a more coordinated offshore grid approach designed for a number of projects and long term saleability would be advantageous. The attractiveness of a more holistic approach to planning offshore grid is likely to be directly related to the scale and appetite of future developments, with small numbers of projects developed individually less likely to require or justify the additional grid complexity. However, assuming that sufficient volume exists, the 2011 study referenced above identified a number of benefits that were likely to result from the development of a coordinated offshore transmission network:

- Environmental and consenting benefits;
- Improved management of valuable resources including land take, corridor routes, and manufacturing capability;
- Reduced cost for UK consumer (capital cost reductions and also a reduction in operational costs such as maintenance costs and congestion management costs in relation to system operation); and
- A flexible offshore transmission network that is better able to respond to future challenges.

The costs savings (£5.6 billion) relate to reduction in the volume of assets required to connect offshore generation under a coordinated design as opposed to a radial design.

The concept of a coordinated design to offshore renewables has been further explored by the ISLES project, identifying opportunities for cost reduction from a transnational network developed off of the west coast of Scotland. Figure 26 shows a suggested grid solution for offshore renewables using coordinated transmission infrastructure.

²⁷ Offshore Transmission Network Feasibility Study 2011

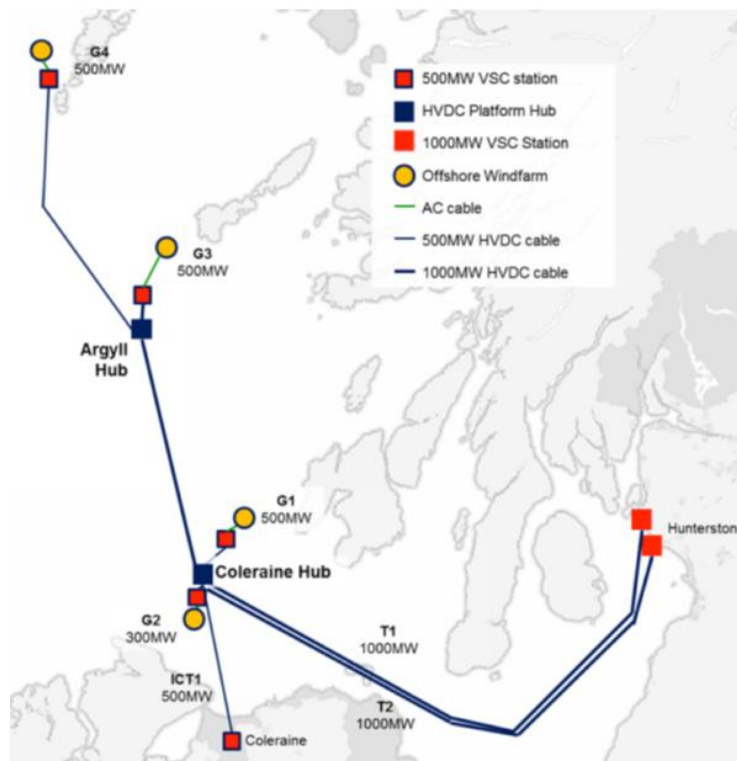


Figure 26: Proposed ISLES grid solution

Developing grid for floating wind

With both the Scottish and UK Governments identifying significant potential for floating offshore wind, the manner in which grid is delivered to support floating offshore wind farms needs to be established in line with the development of the foundation technologies. Based on the UK offshore energy strategic environmental assessment (SEA), DECC drafted a plan which enables further offshore wind farm leasing. This plan includes up to 15MW turbine generating capacity of floating turbines in waters up to 200m. This is a realistic assumption for the next commercial generation of large scale projects using floating wind turbines.

The suitability of various floating wind concepts to these varying water depths means a number of potential solutions being suited to the UK market. As these technologies progress from demonstration projects, to pilot parks of small arrays, to commercial wind farms, the current funding mechanism of competitive auction process makes it difficult for these technologies to compete in the absence of suitable grid. This, in turn, creates the following challenges for industry and government to develop necessary infrastructure:

- **Technology develops at a different rate to the required grid infrastructure:** Grid infrastructure requires a critical mass of wind farms to enable investment. The uncertainty over the commercial readiness of floating wind turbines therefore results in difficulty in planning for grid upgrades.
- **Developers and transmission operator's ability to fund development of necessary offshore or onshore grid with uncertainty of a competitive auction:** The long lead time associated with developing grid may prohibit investment in onshore grid as uncertainty over offshore windfarm build-out may result in a stranded asset.
- **Relevance of grid to energy storage:** The distance from areas of high electricity demand, environmental impacts, and the availability of connection points to the onshore transmission grid are significant factors in the preferred location of current offshore wind developments. When planning for future floating rounds, the policy surrounding grid charges, including advancements in energy storage solutions²⁸, will need to establish costs and benefits to the system.

²⁸ <http://www.statoil.com/en/NewsAndMedia/News/2016/Pages/21mar-batwind.aspx>

4.8 Recommendations

The transmission network faces significant challenges in the coming decades as the GB energy landscape continues to diversify. With the expected replacement of ageing generation plant, such as nuclear generators and coal, and the growth in renewables, particularly wind, as primary sources of energy, the transmission network must respond and adapt to this changing landscape to ensure power is transported from the different energy sources to the demand point.

There are three broad challenges to the grid connection of electricity from floating offshore windfarm in the UK:

- The lack of suitable onshore grid access for many of the sites suitable for floating wind.
- The slow pace of innovation in providing cheaper onshore and offshore grid connection technologies for electricity from floating offshore wind that will prove to be cost competitive.
- The bottleneck in onshore transmission of electricity from point of production to point of demand.

In order to address these challenges, the following recommendations should be considered:

- There is a need to create the right regulatory framework that allows confident and continued investment in grid infrastructure to connect electricity from floating offshore windfarms at competitive price to developers. Grid expansion involves huge capital outlay, and there is need to create a framework that allows an incentivised close cooperation between the Crown Estate, TSOs, developers, and OFTOs. This will ensure that the right investment is made on expanding onshore grid close to where floating wind farms will most likely be built.
- There is a need to deliver a policy that drives innovation in transmission systems for floating offshore wind (e.g. high voltage dynamic cables, deepwater substations). This will force down cost and increase investment in transmission systems in order to make electricity from floating wind more cost competitive. This policy could be in the form of financial incentives to equipment manufacturers to increase investment in R&D and demonstration of their technology(ies).
- Given the bottlenecks that exist in the transmission systems capacities between the north and south of the UK, and between remote areas and the main transmission systems, or even regionally between the north and south of Scotland, there is a need to accelerate investments to address these bottlenecks and create the necessary power transfer capacities between points of production and points of demand. This will ensure that the most suitable sites for floating offshore wind are exploited at a cost competitive rate.

The Beaulieu to Denny circuits upgrade has improved transmission capability across Scotland and provides much needed capacity to transport renewable energy. It is recommended that the Transmission Owners (TSOs) should continue constructing reactive power compensation equipment and HVDC Links where required across the Scottish boundaries to provide new capacity to support the increasing development of renewables.

Appendix

Appendix A: Interview List

Aberdeen Harbour

Atkins

British Ports Association

Bruce Anchors

The Crown Estate

Department of Energy and Climate Change

European Union Directorate-General for Research & Innovation

Energy Technology Institute

Forth Ports Ltd

The Engineering and Physical Sciences Research Council

InnovateUK

JDR Cables

Kishorn Port

Marine Management Organisation

Marine Scotland

Maritime and Coastguard Agency

National Oceanography Centre

Northern Lighthouse Board

Renewable Energy Systems Offshore

Royal Society for the Protection of Birds Scotland

Royal Yachting Association

Scottish Development International

Scottish Enterprise

Scottish Fishermen's Federation

Scottish Natural Heritage

Xodus Group

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