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CARBON TRUST

Future Potential for Offshore Wind in Wales

Prepared for the Welsh Government

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The Carbon Trust is an independent, expert partner that works with public and private section organizations around the world, helping them to accelerate the move to a sustainable, low carbon economy. We advise corporates and governments on carbon emissions reduction, improving resource efficiency, and technology innovation. We have world-leading experience in the development of low carbon energy markets, including offshore wind.

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.

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Executive Summary

Power generation and consumption in Wales

- Wales is a strategically important net exporter of power in the UK electricity system, generating more than double Wales' electricity consumption needs (32.5 TWh generation vs 14.6 TWh consumption).
- Wales has set ambitious renewable energy and decarbonisation targets, including an aspiration to generate 70% of its electricity consumption from renewables by 2030.
- Wales currently generates 22% of its electricity from renewables. This accounts for 48% of consumption in Wales, leaving a sizeable gap to the 70% target by 2030.
- Nearly half of Wales' electricity generation in 2016 could be decommissioned by 2030, mostly consisting of coal and gas power stations that could be replaced by clean, renewable sources.
- Depending on the mix of renewable energy technologies, Wales could need an additional ~1.6-1.8 GW of renewable power to reach its 2030 goal. High load factors of 45-50% in offshore wind farms could limit the capacity requirement to ~1.1-1.2 GW.

The case for offshore wind in Wales

- The improved economics of offshore wind power makes this a highly competitive energy technology and a 'low regrets' option for policy makers.
- The UK has signalled a commitment to offshore wind through confirmed government auctions that could help reach the industry target of 30 GW installed capacity by 2030. A longer term target of 50 GW by 2050 has also been advocated.
- Particularly in the absence of a clear route to market for onshore renewables and the lack of cost competitiveness of marine energy technologies, offshore wind power could be vital to meeting Wales' renewable energy, decarbonisation, and well-being goals.
- An additional 2 GW of offshore wind power could be delivered by just 2-3 projects in Wales, if site extensions and new site leases can be secured in Welsh waters and grid connected in Wales. Taking total offshore wind capacity to 2.8 GW could meet nearly all (68%) of Wales' 70% renewable energy target by 2030.
- Given the competitive landscape for new developments up to 2030, extending the lifetime of existing operational wind farms can support meeting the 2030 target. Importantly, new offshore wind developments can build a pipeline to meet long-term targets up to 2050.
- Typical investment of ~£3-4 bn per project across its lifetime can also bring considerable economic benefits to Welsh businesses and communities.

Deployment opportunities in Wales

- Wales has 726 MW of offshore wind power from three projects in the Irish Sea (North Hoyle, Rhyl Flats, and Gwynt-y-Môr). The cancellation of two large Round 3 development zones in the Irish Sea (Celtic Array) and Bristol Channel (Atlantic Array) has left Wales with no project pipeline to expand on this capacity.

- Site extensions and new leasing rounds administered by The Crown Estate could create an opportunity to build a project pipeline in Wales. Site extensions, in particular, represent a low hanging fruit opportunity to add offshore wind capacity in Wales by the mid-2020s.
- New leasing also represents a considerable opportunity to secure a pipeline of projects in Wales that can attract inward investment from offshore wind developers and major suppliers up to and beyond 2030. The Crown Estate has proposed to include one region in Wales for Round 4 leasing (North Wales) and another for further consideration (Anglesey).
- However, the UK already has a healthy pipeline of projects that exceeds the 30 GW by 2030 target. As such, projects in Wales will have to be highly competitive in order to secure government contracts by 2030. A successful outcome from upcoming leasing activity would be to secure site extension approval for Gwynt-y-Môr and 1-2 new leases for GW-scale projects.

Table 1. Priority deployment opportunities for Wales

Timeframe	Opportunity	Scale	Deployment timeframe
Near-term	Site extensions	0.5-0.6 GW	Mid 2020s
Medium-term	New leasing	1-3 GW	By ~2030
Long-term	Floating wind	Multi-GW	Beyond 2030

Regional assessment of deployment opportunities

- Wales has abundant wind resource in offshore locations, combined with good port, transport, and grid infrastructure in North and South Wales. A lack of suitable infrastructure in Mid-West Wales is likely to be a barrier to development in Cardigan Bay.
- The most attractive locations for offshore wind development are off North Wales in the Irish Sea, where large areas of seabed under 60m water depth could be exploited using fixed foundations. In particular, the area to the north/north-east of Anglesey, partly overlapping with the former Celtic Array development zone, is expected to be attractive to prospective developers in upcoming leasing rounds, provided seabed geology or grid constraints do not impose a barrier. Areas to the west of Anglesey could also be suitable for development.
- The eastern part of the Irish Sea could be attractive, but is likely to be more congested due to existing offshore wind farms, oil and gas leases, and commercial shipping. A potential site extension at Gwynt-y-Môr offshore wind farm is a near-term and high priority opportunity.
- Areas off South Wales in the Bristol Channel could support offshore wind development, including the former Atlantic Array development zone. However, this site is considered to be technically challenging due to complex seabed geology and strong estuarine currents, which may influence the economic viability and competitiveness of projects here.
- Pembrokeshire has excellent wind resources in deep water offshore locations, suitable for floating wind power. Although not expected to feature in the Round 4 leasing process, The Crown Estate retains an open door policy for developments up to 100 MW. Deep water sites for floating wind could also feature in subsequent leasing rounds up to and beyond 2030.
- The Welsh marine environment can be sensitive to offshore wind development, although the level of constraint varies between locations. Any new development in Wales will have to demonstrate an acceptable impact on the natural environment, local communities, and existing commercial activities. Early stakeholder engagement and participation in industry-wide research studies can improve the evidence base for informed decision making.

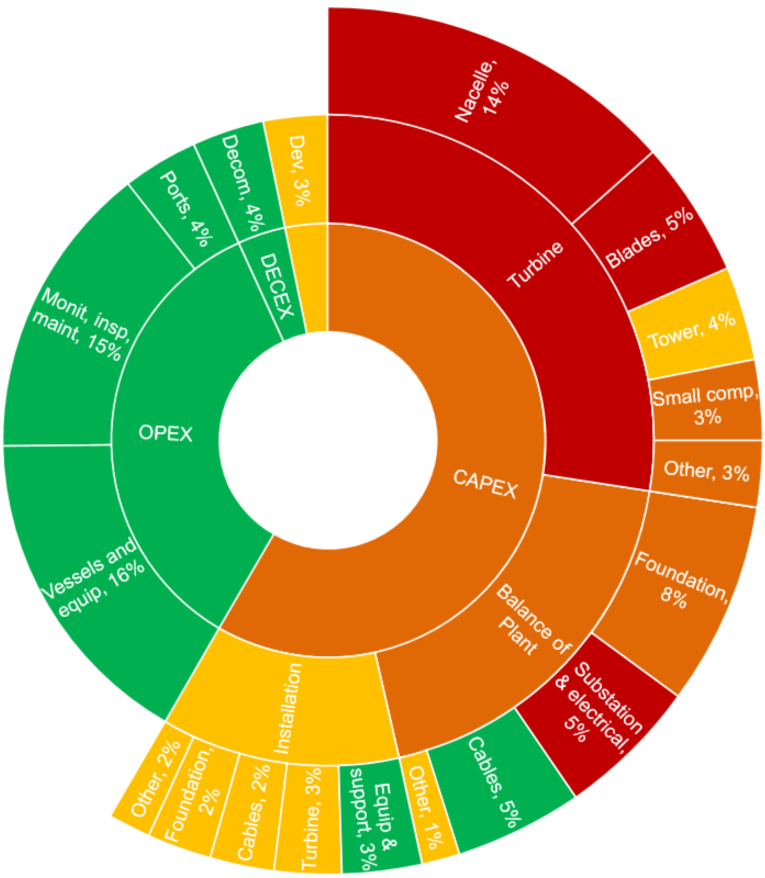
Economic benefits of offshore wind

- Offshore wind farms are capital intensive infrastructure projects that can attract significant investment in Wales' energy infrastructure and supporting supply chain.
- The three existing operational projects in Wales have been criticised for failing to deliver sufficient economic benefits to Welsh businesses, particularly during construction. However, Welsh ports and suppliers have managed to secure valuable contracts worth millions of pounds to the local economy, particularly during operation and maintenance.
- Supply chain plans targeting at least 50% UK content are driving more investment in UK manufacturing facilities, including a recent investment from Prysmian to supply cable cores from its facility in Wrexham.
- Outside supply chain and employment benefits, offshore wind farm community funds have injected millions of pounds into local economies, supporting a range of community schemes.

Supply chain assessment

- Offshore wind supply chain activities often cluster around construction and operations and maintenance ports. Wales has several large ports that could benefit from offshore wind development in Wales and act as a catalyst for supply chain investment.
- If Welsh ports can be secured, local Welsh companies are well placed to provide CTV and workboat vessels, equipment, secondary steel works, and other support services. There may also be opportunities to attract major overseas suppliers to Wales.

Figure 1. Wales supply chain opportunities mapped against project lifetime spend



- The most significant construction opportunities are seen in the supply of array cable cores from Prysmian's Wrexham facility, which will boost employment for the local workforce, particularly if volume orders can trigger additional expansion.
- The lack of established manufacturing facilities in Wales for large components, such as major turbine components and foundations, means that opportunities during construction will be limited and mostly reserved for smaller support contracts and ancillary services. There may be longer-term opportunities in steel fabrications, such as turbine towers and transition pieces, if market volume and increasing UK content requirements are sufficient to justify inward investment.
- The greatest supply chain opportunities for Wales are in operations and maintenance, building on the capabilities that exist from servicing offshore wind farms in the Irish Sea. Although individual contracts may be smaller, over the lifetime of the project these economic benefits could be considerable.
- As the oldest offshore wind farm in the UK fleet, North Hoyle could represent an opportunity for Wales to develop leadership in end-of-life asset management, including lifetime extension, decommissioning and/or repowering.

Policy levers for Welsh Government

- Most policies impacting offshore wind development in Wales are controlled by central UK bodies, including site leasing through The Crown Estate, consenting decisions through the Planning Inspectorate, and allocation of revenue support through the Contracts for Difference mechanism administered by BEIS.
- However, Welsh Government and affiliate bodies are key consultees that can and should exert influence on UK decision making. Welsh Government should be proactive in ensuring that Wales is fully represented in discussions relating to offshore wind development in the UK, both with government and industry bodies. This should include cultivating market interest in development opportunities in Wales.
- Publishing clear guidance on the planning and consenting process for offshore wind projects in Wales would help to attract prospective developers and de-risk the development process.
- Welsh Government can also participate in and support collaborative initiatives to address common challenges, particularly research studies to inform siting and consenting decisions in Wales.
- In the absence of direct control of future development, Welsh Government should use its powers to maximise the competitiveness of projects in Wales, to improve the likelihood of securing sites and government contracts.
- A handful of options to improve the cost of capital or offer separate off-take agreements have been proposed, but require further evaluation to determine their suitability, additionality, and cost-effectiveness.
- A more effective and direct means of supporting both developers and Welsh companies could be to invest in and support supply chain development. For example, co-investment in infrastructure upgrades and provision of greater support to Welsh SMEs would help to boost Welsh interest in the offshore wind sector.

Recommendations

In order to realise the potential benefits offshore wind can bring to Wales, policy makers should:

1. Develop a clear strategy for offshore wind development in Wales and be public in support of future deployment
2. Actively participate in industry-wide discussions on future offshore wind development in the UK
3. Support collaborative industry-wide initiatives to address consenting barriers and de-risk project development in Wales
4. Adopt a strategic approach to prioritising supply chain development activities and infrastructure investment
5. Work with offshore wind developers and Welsh suppliers to maximise Welsh content in future developments
6. Be more active in marketing Welsh capabilities in the offshore wind sector
7. Continue to support technology innovation to develop leadership and competitive advantage in Wales
8. Collaborate with UK counterparts with shared challenges and objectives

1. Introduction & Background

1.1 Report aims and objectives

Accelerated cost reduction in recent years has established offshore wind as a competitive and mainstream source of renewable power in the UK and several European countries, with growth in international markets expected over the next decade. The technology has matured largely as a result of supportive policies in key lead markets, notably the UK, that have attracted inward investment and provided the economic signals to foster industry development.

With almost 8 GW of operational installed capacity, the UK is the world's leading market for offshore wind. However, development has been concentrated in a handful of regions, most notably in the North Sea basin off the east coast of the UK. At present, approximately ~9% of UK offshore wind capacity is grid connected in Wales, from three projects located in the Irish Sea. Expanding on this capacity has been set back by project cancellations, with no large-scale offshore wind farms under active development.

However, upcoming site extensions and leasing rounds in the UK could present an opportunity to build a pipeline of projects in Wales that could help to meet ambitious decarbonisation targets, stimulate economic and industrial development, and make a material contribution to national well-being goals. In addition to conventional fixed-bottom offshore wind, the emergence of floating technology could create opportunities for offshore wind development in deep water locations. However, evaluating the future potential for offshore wind in Wales requires a robust and realistic assessment of the technical and economic viability of future projects to ensure that government policies maximise their efficacy and impact.

This report aims to undertake an initial evaluation of the case for offshore wind in Wales, the potential for increased offshore wind deployment, the associated economic benefits, and the key considerations for policy makers. Given the wide scope and limitations of this far-reaching study, the report identifies a series of recommendations on further work required to better inform future policy and accelerate the development of offshore wind in Wales.

2. The Case for Offshore Wind in Wales

2.1 Energy trends in the UK and Wales

2.1.1 Energy policy

United Kingdom: The UK has introduced several targets for energy generation and decarbonisation. The most significant policies in place are:

- **Climate Change Act (2008):** The Act set that the UK must reduce its greenhouse gas emissions to at least 80% of its 1990 levels by 2050 and established a framework to deliver on these targets. The Act determined that the UK Government must establish carbon budgets that cap the amount of emissions over a 5-year period to achieve the target. The first five carbon budgets have been legislated and run until 2032. BEIS is responsible for ensuring energy security and promoting action on climate change to meet the targets.

- **Energy Act (2013):** The Energy Act established a legislative framework to deliver secure, affordable and low carbon energy. The Act enabled the UK Government to set a decarbonisation target for 2030 for the power sector (100g CO2 per kilowatt hour). It also legislated the Electricity Market Reform, which set up a series of measures to incentivise the investment needed to meet the targets.

- **Clean Growth Strategy (2017):** This paper published by BEIS outlined the policies and proposals to decarbonise all sectors of the UK economy while delivering economic growth. This included actions on green finance, energy efficiency, low carbon heat and transportation or clean, flexible power. Namely, one of the actions was to work with the offshore wind industry to develop a sector deal for increased deployment in the 2020s.

Wales: Wales has also introduced policies influencing its own domestic energy and decarbonisation targets:

- **Well-being of Future Generations Act (2015):** The Act set well-being goals and ways of working, and required public bodies to carry out sustainable development. Namely, section 4 of the Act set a clear direction for Wales to become a low carbon prosperous society that uses its resources efficiently and proportionately.

- **Environment Act (2016):** The Act set the need for Wales to achieve a minimum of 80% reduction in Welsh CO2 emissions by 2050, monitored through phased carbon budgets, in alignment with the UK Climate Change Act 2008. A decarbonisation programme has been established to implement the requirements of the act, namely to set interim targets for 2020, 2030 and 2040 and to set out a delivery plan.

- **Renewables Energy targets (2017):** The Welsh Government announced its key energy targets following a wide engagement with stakeholders from the energy industry. This includes a target to generate 70% of its electricity consumption from renewables by 2030. Another is to ensure all renewable projects are partly or fully owned locally by 2020 and to have 1 GW of renewables owned locally by 2030.

Meeting these ambitious targets will require a major shift in the way in which electricity is generated and consumed. Namely, policymakers in the UK and Wales have set clear ambitions to rapidly decarbonise the power sector, with renewables at the core of its electricity generation mix. The following sections outline the extent of change required, level of progress made to date, and the options to deliver against these medium and long-term targets.

2.1.2 Electricity generation & consumption – current status

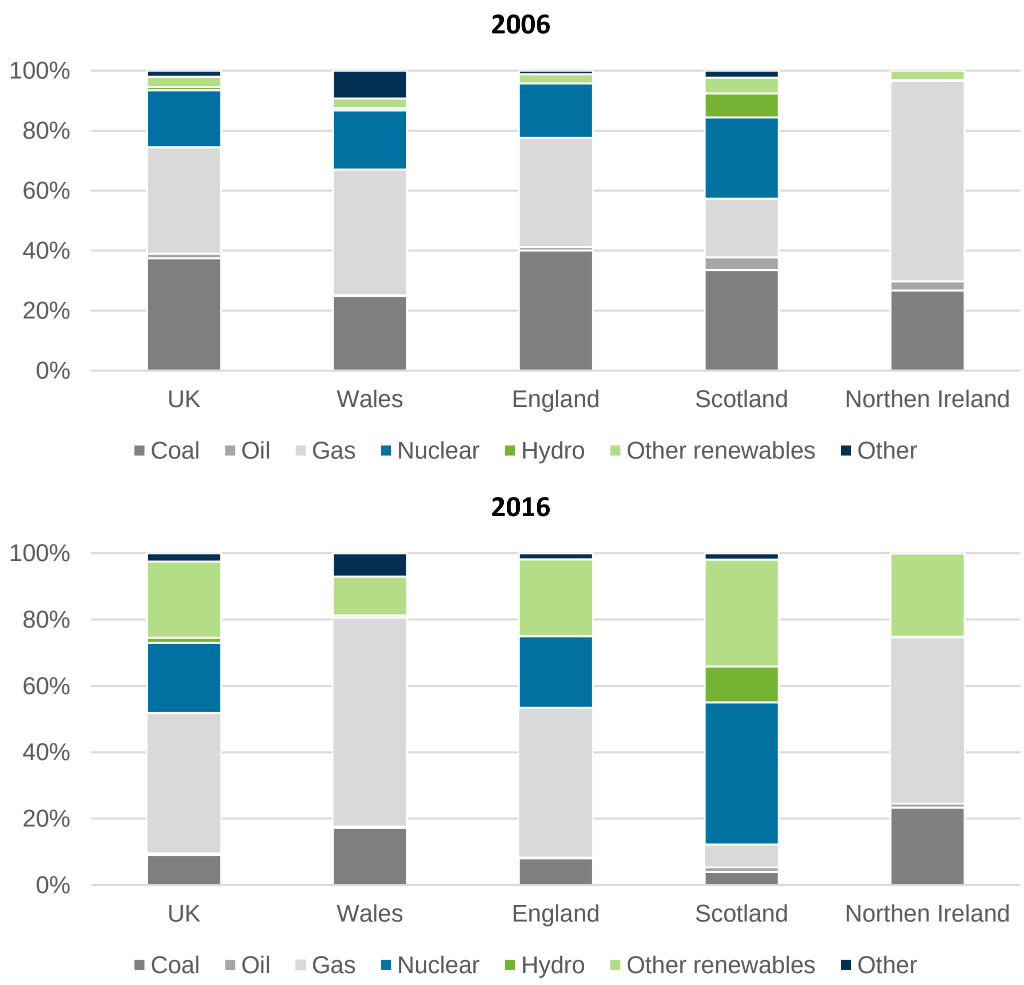
United Kingdom

Electricity generation and supply in the UK has changed significantly over the last decade. From 2006 to 2016, electricity consumption in the UK decreased from 354 TWh to 310 TWh, marking a 12% reduction. In line with the fall in consumption, electricity generation in the UK decreased over the same period from 397 TWh to 339 TWh, representing a 15% reduction [1].

These trends have largely been driven by a combination of: (1) the decline in consumption from the industrial sector, (2) improved energy efficiency across several sectors, including domestic and commercial buildings, and (3) increased interconnection enabling more electricity to be imported than generated domestically (although the UK remains a net exporter of electricity) [2].

As generation has decreased, it has also begun to decarbonise, with fossil fuel generation assets replaced by low carbon sources. From 2006 to 2016, the contribution of renewables to the energy mix increased fivefold, from 5% to 25%.

Figure 2: Change in the UK energy mix from 2006 to 2016 [1]



Wales

Electricity consumption in Wales has mirrored the rest of the UK, with a 12% reduction observed between 2006 and 2016. However, generation trends have differed considerably, increasing 19% over the same period as Wales established itself as a key exporter of electricity to the GB grid. For example, in 2016 Wales transferred 43% of its generation to England whilst importing just 2% from the Republic of Ireland.

Despite this increase in generation, Wales had the lowest growth in renewables contribution to the energy mix, relative to the rest of the UK. While nuclear power has (at least temporarily[1]) been removed from the energy mix following the decommissioning of the 980 MW Wylfa nuclear power station in 2015, generation from combined cycle gas turbines (CCGT) has increased 80%, driven by the addition of 3 GW of installed CCGT capacity from Pembroke Power Station (2.2 GW) and Severn Power (850 MW). CCGT now provides ~61% of electricity generation in Wales, with 16% from coal, 13% from pumped storage, and 17% from a mixture of renewables, including wind, solar, hydro, and biomass.

An overview of power generation in Wales can be found in Box 1 and a full list of generation plants in Wales can be found in Appendix 1:.

At 22% of total electricity generation, renewables account for 48% of Wales' electricity consumption[2]. This is markedly below the 70% target by 2030, as well as being lower than counterparts in England, Scotland, and Northern Ireland.

This also has implications for the decarbonisation targets outlined in the 2008 Climate Change Act (UK) and 2016 Environment Act (Wales). According to data on UK greenhouse gas emissions between 2006 and 2015, although emissions in Wales from electricity and heat production decreased by 5%, steeper reductions in other UK nations means that Wales' relative contribution to UK emissions increased from 8% to 13%. Furthermore, the latest Progress Report to Parliament from the Committee on Climate Change indicates that emissions from the UK power sector currently stand at 263gCO2/kWh, well above the 2030 target of 100gCO2/kWh [3].

It is therefore evident that large strides must be made in order to decarbonise the power sector, which will have implications for decisions regarding the future mix of electricity generation technologies in Wales.

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[1] The UK government has started negotiations over a new nuclear power station at the Wylfa facility site on Anglesey. The plant, which could provide up to 3 GW of installed capacity, is targeting commissioning by the middle of the 2020s and would have a 60 year operational life.

[2] If pumped storage is included in the renewables mix, renewable generation represents 68% of electricity consumption.

BOX 1. POWER GENERATION IN WALES

Overview

As of the end of 2017, Wales had 13.2 GW of installed capacity from 70 grid-connected power generation projects and nearly 60,000 decentralised sources, mostly consisting of domestic solar installations. However, 95% of installed capacity comes from just 16 generation plants with capacity of 50 MW or greater, emphasising the role of large-scale centralised generation in the current mix. Nevertheless, the emergence of a large number of smaller generation sources over the past decade, particularly from onshore renewables, is an indication of the transition towards a more decentralised energy system.

Nearly two-thirds of installed capacity comes from a small number of large fossil fuel plants, predominantly gas and coal, which deliver 73% of the electricity generated in Wales. In contrast, renewable generation is more distributed, with nearly sixty grid-connected wind and solar farms and nearly 60,000 decentralised installations that collectively account for 23% of installed capacity and provide 20% of generation. These generation sources are supplemented by two large-scale pumped storage facilities at Dinorwig and Ffestiniog in Gwynedd, North Wales, which bring total low carbon generation to 39% of installed capacity and 27% of generation.

Table 2. Power generation in Wales in 2017

Fuel	Capacity (MW)	Share of total capacity	Generation (GWh)	Share of total generation	Ave. capacity factor (%)
Coal	1,586	12%	2,588	7%	19%
Gas	6,282	48%	22,425	64%	41%
Other non-renewables	133	1.0%	467	1%	40%
Total Non-renewables	**8,001**	**61%**	**25,480**	**73%**	**36%**
Biomass elec, CHP and waste	113	1%	654	2%	66%
Hydro	181	1%	367	1%	23%
Offshore Wind	726	6%	2,099	6%	33%
Onshore Wind	1,002	8%	2,531	7%	29%
Solar	970	7%	930	3%	11%
Other renewables	94	1%	470	1%	57%
Total Renewables	**3,086**	**23%**	**7,051**	**20%**	**30%**
Pumped storage	2,088	16%	2,474	7%	14%
Nuclear	-	0%	-	0%	
Grand Total	**13,175**	**100%**	**35,005**	**100%**	**30%**

N.B. Data reflects installed capacity and generation in 2017. Other non-renewables includes diesel and oil. Other renewables includes anaerobic digestion, energy from waste, landfill gas, and sewage gas. A full list of power stations in Wales can be found in Appendix 1:.

Future trends

Despite the dominance of fossil fuel generation in the current mix, government policy away from fossil fuels towards more renewable generation, combined with several plants coming towards the end of their operational lifetime, suggests that considerable changes can be expected over the coming decade and beyond.

COAL plants are some of the oldest assets in the generation fleet, first commissioned in the 1960s and 70s. Under current UK policy to phase out coal power, these plants, including the 1.6 GW facility at Aberthaw, are set to be decommissioned by no later than 2025, removing 12% of Wales' installed capacity and 7% of generation. However, existing plants may look to switch their feedstock to biomass to continue operating beyond 2025. For example, Uskmouth B is currently undergoing a conversion to run on biomass.

GAS generation, which accounts for 48% of installed capacity and 64% of generation, is likely to remain an important but diminishing part of the energy mix. Several plants commissioned during the 1990s are approaching the end of their operational lifetime and can be expected to be decommissioned during the 2020s. However, the two most recent additions at Pembroke (2.2 GW) and Severn Power (850 MW) are expected to remain operational through the 2030s.

WIND AND SOLAR POWER are expected to make up a rapidly increasing share of the energy mix in order to replace fossil fuel assets coming offline and to meet UK and Welsh renewable energy and decarbonisation targets. The relative share of solar, onshore wind, offshore wind, and other renewables is less clear. But it is expected that onshore wind and solar will see an increasing share of decentralised generation, while offshore wind has the potential to provide large scale centralised generation capacity. With high load factors of ~50% in modern offshore wind farms, which would exceed existing gas and coal plants (see Table 1), offshore wind could play an important role in replacing the baseload power from decommissioned thermal generation.

WAVE AND TIDAL POWER could also play a role in Wales' future energy mix. Several demonstration wave and tidal stream projects are in development in Anglesey and Pembrokeshire and could be deployed at scale if they can demonstrate cost competitiveness with other generation sources. Tidal lagoons are also being explored, although the proposed 320 MW Swansea Bay tidal lagoon project is currently on hold following a UK government decision to reject a Contract for Difference (CfD) support agreement due to concerns over the cost to UK consumers. This was despite a commitment from the Welsh Government to contribute £200m towards the £1.3bn project [13].

NUCLEAR POWER no longer contributes to Wales' energy mix, following the decommissioning of each of the two 490 MW nuclear reactors at Wylfa power station in 2012 and 2015, respectively. However, the UK government recently entered negotiations with Horizon Nuclear Power, a subsidiary of Hitachi, over a new 3 GW nuclear power station at the Wylfa site. If taken forward, the Wylfa Newydd project could be operational by the mid-2020s and would have an operational lifetime of 60 years. It should be noted that, as a low carbon but non-renewable energy source, nuclear power will make a contribution towards Wales' decarbonisation targets but not towards its renewable energy targets.

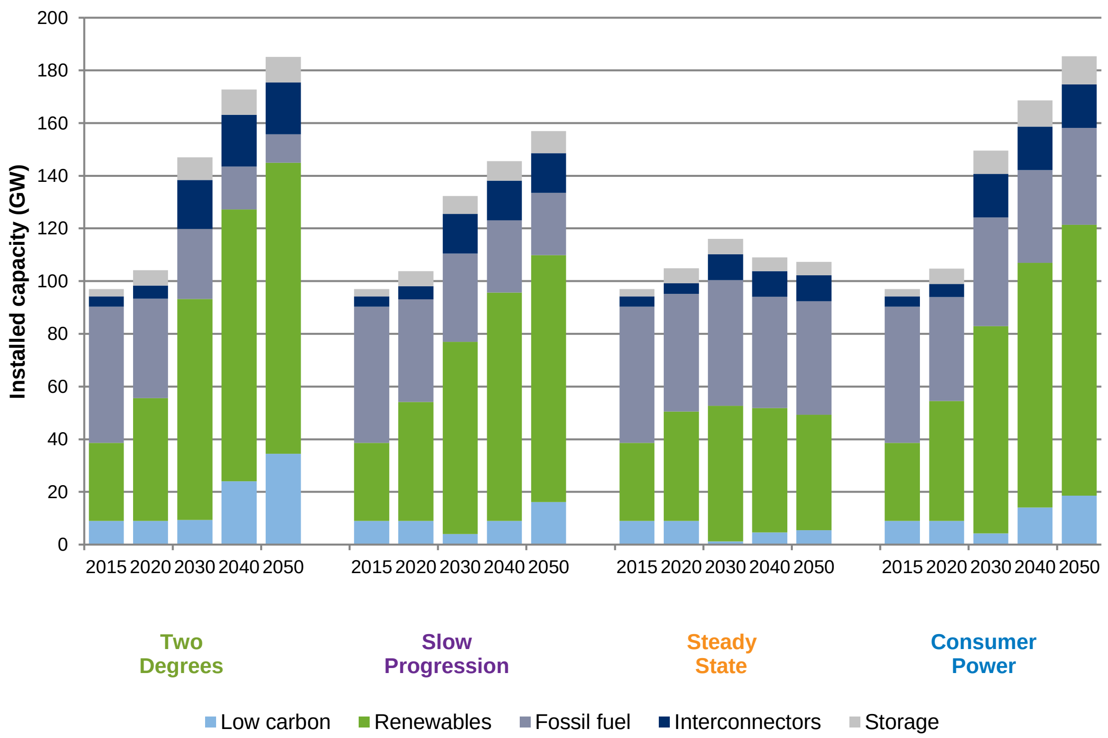
ENERGY STORAGE currently contributes 7% of electricity generation in Wales, through two pumped storage hydroelectric schemes in Gwynedd. Both facilities are expected to continue operating for the foreseeable future, playing an important role in using excess generation in the electricity network. Planning has also been approved for a new 99 MW pumped storage facility at Glyn Rhonwy, Snowdonia. While the potential for additional pumped storage is likely to be limited, alternative energy storage technologies are expected to become more widespread, in order to support grid balancing as the share of intermittent and decentralised renewable generation increases. An example includes the integration of a 22 MW lithium ion battery facility with the Pen-y-Cymoedd onshore wind farm in South Wales.

2.1.3 Electricity generation & consumption – future scenarios

United Kingdom

Despite the decline in electricity generation from 2006 to 2016, UK electricity generation is expected to increase up to 2050, largely driven by the electrification of the heat and transport sectors. The level of installed capacity required to meet demand is subject to different permutations, depending on the nature of the UK energy mix and approach to balancing the grid, as outlined in the National Grid's Future Energy Scenarios. However, two clear trends are consistent in scenarios that deliver against decarbonisation goals: (1) an increase in installed capacity and (2) a shift towards increased renewable generation.

Figure 3: Future Energy Scenarios of installed capacity and energy mix to the GB grid [4]

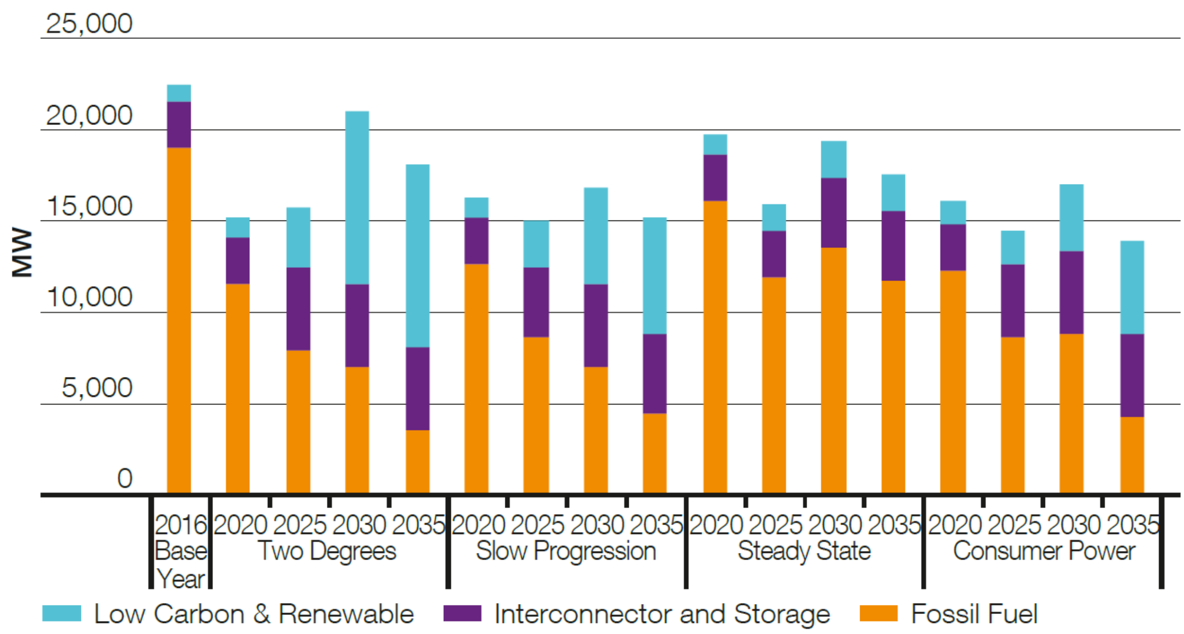


Wales

These UK trends are visible, though less obviously, in projections for the future generation mix in Wales (note that the following analysis is based on data for a combination of Wales and the Midlands). Namely, while a move to more low carbon and renewable power is again consistent in scenarios delivering against decarbonisation targets, the increase in total generation capacity is less clear. Fluctuations in generation capacity are attributed to differing assumptions on several factors, including (1) reduced demand from industrial activity (e.g. steel industry) and consumer behaviour (e.g. demand-side response), (2) increased demand from the electrification of heat and transport (e.g. proliferation of electric vehicles), and (3) government policy related to the incentivisation of different energy generation technologies.

Examples of the uncertainties relating to the latter can be seen in recent government decisions to withdraw support for the Swansea Bay Tidal Lagoon and the decision to enter negotiations to support the Horizon nuclear power station at Wylfa. The level of additional capacity from offshore wind is another uncertainty that this report is aiming to provide greater visibility on.

Figure 4. Generation mix scenarios for Wales and the Midlands [5]



2.2 Strategy to achieve energy targets and wider government objectives

United Kingdom

The UK and Welsh Governments have several options in order to meet the combined goals of decarbonising the energy sector, minimising bills to consumers, ensuring energy security, minimising environmental impact, and maximising local economic and industrial benefits. A full discussion is beyond the scope of this report, but it is increasingly likely that offshore wind power will play a key role in the UK's future energy mix. This is expected to be underlined by a sector deal that could entail government support for up to 30 GW of offshore wind power by 2030, which would represent approximately one-third of UK energy demand. A longer term target of up to 50 GW by 2050 has also been advocated by the industry.

These targets are supported by the latest Committee on Climate Change (CCC) Progress Report to Parliament, which included scenarios for 28-34 GW of offshore wind power in order meet the 2030 carbon budget and power sector carbon intensity target of 100g $CO2$/kWh [3]. This level of installed capacity would deliver between 102-123 TWh of low carbon power to the UK per year and marks a notable increase since the last report, largely driven by the improved economics of offshore wind power over the past 12-24 months. Indeed, the latest analysis from the CCC indicates that pursuing a high renewables strategy would meet energy demand at a comparable cost to extending existing CCGT plant or importing electricity from overseas, making this a 'low regrets' option for policymakers. The 30 GW by 2030 projection is also consistent with the Two Degrees scenario in National Grid's latest Future Energy Scenarios report [6].

Wales

With 2,120km of coastline and a marine area of ~32,000km^2, offshore wind could also play an important role in meeting energy generation and decarbonisation targets in Wales. As outlined in Box 2, Wales is expected to require at least an additional ~1.6-1.8 GW of renewable energy capacity installed by 2030 in order to meet its 2030 renewable energy target. Particularly given the current lack of a route to market for onshore wind and solar power in the UK, as well as the immaturity of wave and tidal power, offshore wind could present a vital and much-needed opportunity to generate high volumes of clean renewable power in Wales.

With modern offshore wind developments ranging from 0.5-1.5 GW per project, Wales' 2030 target could be met by just a handful of projects, if new sites can be attracted to Wales and realised within the period to 2030. Extending the lifetime of existing operational wind farms will also make a sizeable contribution to meeting the target.

However, assessments for the offshore wind potential must be based on a thorough assessment of market conditions and a realistic timeframe for development (see 3.2). Furthermore, a conducive policy and regulatory framework will need to be implemented to ensure that Wales can maximise these benefits and capture economic value to Welsh businesses and communities (see 3.5 and 4.5).

BOX 2. RENEWABLE GENERATION AND CAPACITY NEEDED TO MEET THE RENEWABLE ENERGY GOALS

Meeting 2030 targets

Wales has set an ambitious target to generate 70% of its electricity consumption from renewables by 2030. According to the latest National Grid Energy Future Scenarios report, by 2030 electricity demand in the UK could range from a 1.5% reduction to a 3.5% increase from current levels [14]. Applying this variation in demand to Wales suggests that 2030 electricity consumption can be expected to range from **14.4-15.1 TWh**, resulting in a 70% renewable electricity target of **10.1-10.6 TWh** by 2030.

In 2017, Wales generated **7.1 TWh** of electricity from renewables, representing 48% of electricity consumption and a gap of **3.0-3.5 TWh** to the 2030 target. However, when considering that 200 MW of renewables capacity (~600 GWh of generation) could be decommissioned by 2030 [*], renewable generation falls to 38-40% of demand in 2030, widening the gap to **4.3-4.8 TWh**. Assuming a similar blend of renewables in the energy mix [**], this suggests that an additional **1.6-1.8 GW** of renewables capacity will need to be operational by 2030.

As a highly scalable renewable energy technology with modern wind farms often exceeding 1 GW of installed capacity, offshore wind could play an important role in supplying renewable generation to achieve Wales' 2030 target. Indeed, if a higher load factor is assumed, for example 45-50% possible in modern offshore wind farms, the capacity gap can be reduced to **1.1-1.2 GW**. Pursuing renewables with lower load factors, such as onshore wind (~25-30%) and solar power (~10-12%) would increase the capacity demand.

Table 3. Power generation in Wales up to 2030

	Operational in 2017		Decommissioned by 2030		Existing fleet still operational by 2030	
	Capacity (GW)	Generation (GWh)	Capacity (GW)	Generation (GWh)	Capacity (GW)	Generation (GWh)
Coal	1.59	2,588	1.59	2,588	-	-
Gas	6.28	22,425	2.68	12,550	3.60	9,875
Other non-renewables	0.13	467	-	-	0.13	467
Total non-renewables	**8.00**	**25,480**	**4.27**	**15,138**	**3.73**	**10,342**
Biomass elec, CHP and waste	0.11	654	-	-	0.11	654
Hydro	0.18	367	-	-	0.18	367
Offshore wind	0.73	2,099	0.06	198	0.67	1,901
Onshore wind	1.00	2,531	0.14	399	0.86	2,132
Solar	0.97	930	-	-	0.97	930
Other renewables	0.09	470	-	-	0.09	470
Total renewables	**3.09**	**7,051**	**0.20**	**596**	**2.77**	**5,801**
Pumped storage	2.09	2,474	-	-	2.09	2,474
Nuclear	-	-	-	-	-	-
Grand Total	**13.18**	**35,005**	**4.47**	**15,735**	**8.70**	**19,270**

[*] Assumes 25 year operational lifetime for all wind and solar plants.
[**] Assumes load factor of 30%, in line with 2017 levels.

Important considerations

DECOMMISSIONING: Decommissioning of fossil fuel plants is likely to free up considerable capacity for renewables connecting to the transmission network. UK policy to phase out coal power will remove 1.6 GW of coal capacity by 2025 and 2.7 GW of CCGT plants are set to be decommissioned during the 2020s [***]. Collectively, this represents nearly half of Wales' generation in 2016.

LIFETIME EXTENSION: Several operational assets, including Wales' existing offshore wind fleet, may exceed their anticipated design lives. Extending the lifetime of existing assets can limit the drop in generation. Although most of Wales' renewable energy generation will still be operational in 2030, extending the lifetime of older assets can support meeting the 2030 renewable energy target. For example, North Hoyle and Rhyl Flats offshore wind farms (representing 150 MW installed capacity) will be approaching the end of their design lives in the late 2020s.

NEW NUCLEAR: It should be noted that the addition of planned new capacity may also constrain the available capacity on the transmission network. Most significantly, the up to 3 GW Wylfa Newydd nuclear power plant could deliver 23-24 TWh of electricity per year, more than cancelling out the loss of generation from decommissioning coal and gas plants and potentially constraining grid capacity in North Wales. It should be noted that, while nuclear power will contribute to Wales' decarbonisation targets, it will not contribute to renewable energy goals.

TRANSMISSION LINE UTILISATION: With remaining generation from both existing renewable and non-renewable sources reaching c.21.5 TWh by 2030 (without any additional power plants coming online), there should still be sufficient capacity to meet demand in Wales (~16-17 TWh). However, a reduction in electricity exports could have implications for meeting wider UK demand, as well as a loss of economic benefits to Wales. Reducing generation capacity in Wales could also leave existing transmission lines underutilised, likely necessitating investment in grid reinforcement in other parts of the UK where generation is increasing.

OUTLOOK TO 2050: Longer term, by 2050 the entire existing fleet of generation assets is likely to have been decommissioned, requiring high volumes of new capacity through a combination of lifetime extension, repowering, and new plants. While larger volumes of decentralised generation can be expected by 2050, it is highly likely that significant power generation will be needed from large plants connecting to the transmission network. Offshore wind is one of the few scalable renewable energy sources capable of meeting this demand.

ENERGY CONSUMPTION: Wales' renewable energy target is directly linked to energy consumption. Although National Grid's Future Energy Scenarios predict only a modest variance up to 2030, with up to 4% increase in UK electricity demand, the outlook to 2040 indicates an increase of 15-25%, with a 25-47% increase anticipated by 2050. Maintaining progress against renewable energy targets will therefore require considerable new capacity beyond 2030, which offshore wind could play an important role in meeting.

[***] It should be noted that some coal plants may diversify to biomass and lifetime extension of some CCGT plants could keep them operational up to and beyond 2030.

2.3 Offshore wind power

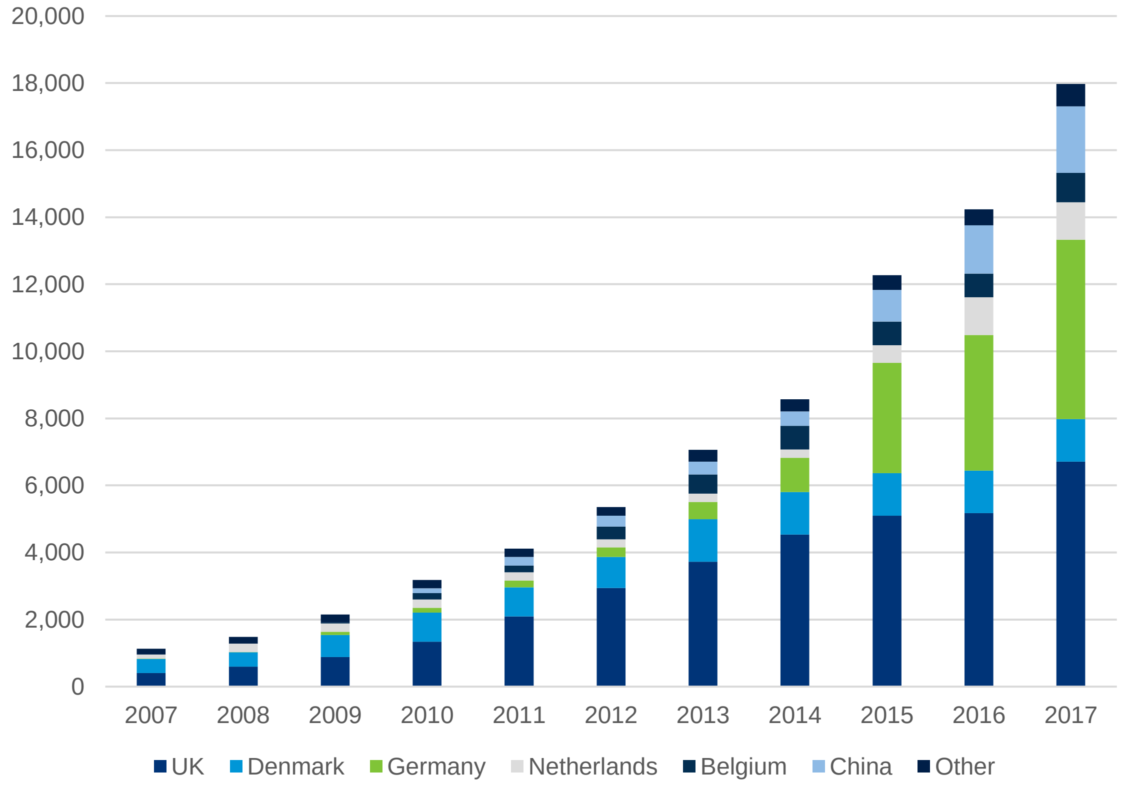
2.3.1 Offshore wind industry development

2.3.1.1 Deployment

Offshore wind has matured as an industry over the last 3-5 years, as evidenced by accelerated deployment and marked cost reduction both within and outside Europe that has taken global installed capacity to over 22 GW in 2018. The rate of deployment has increased steadily over the past ten years, with almost 17 GW installed worldwide from 2007 to 2017, including a doubling of capacity between 2014 and 2017, and accelerated growth expected over the coming decade.

The UK is the world's leading offshore wind market with ~7.8 GW installed, followed by Germany (~5.7 GW) and China (~3.0 GW). Over 85% of offshore wind capacity installed worldwide is concentrated in the neighbouring European countries of the UK, Germany, the Netherlands, Denmark and Belgium. Despite being largely dominated by these leading European markets, offshore wind is rapidly expanding internationally, with sizeable project pipelines and deployment targets in several new markets, particularly in Asia and North America.

Figure 5: Global offshore wind deployment since 2007 [7]

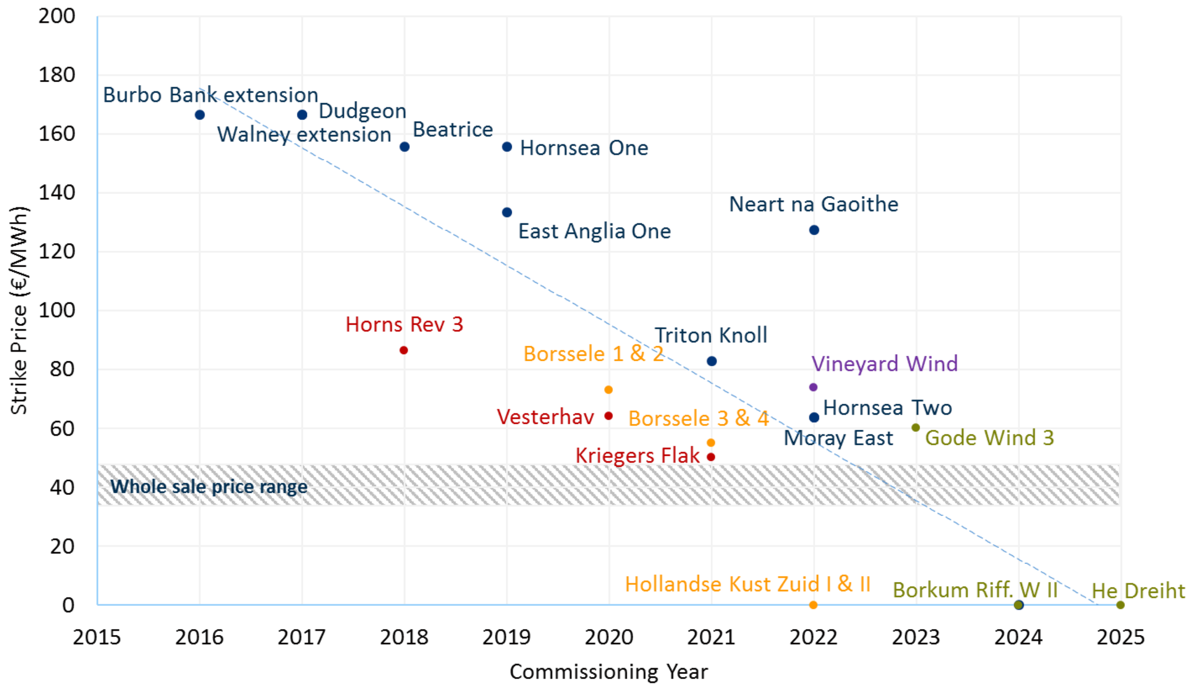


2.3.1.2 Cost reduction

Steadily increasing deployment has seen considerable cost reduction, particularly in the last 2-3 years. In the UK, the levelised cost of energy of offshore wind projects reaching final investment decision decreased ~32% from 2010 to 2016, to £97/MWh, meaning that the industry surpassed its 2020 cost target of £100/MWh four years ahead of schedule [8].

Recent auction results across Europe suggest that costs have fallen even further, with the 2017 Contracts for Difference auction delivering a strike price of £57.5/MWh for two offshore wind projects[3]. A similar trend is visible elsewhere in Europe, where several projects have been awarded zero subsidy contracts[4]. It should be noted that these zero subsidy projects are expected to benefit from favourable regulatory and market dynamics, including the provision of offshore transmission assets, project clustering, and alternative off-take agreements. As such, zero subsidy should not be considered an expectation for all future offshore wind projects. However, these trends strongly indicate that offshore wind can be considered a highly competitive energy technology.

Figure 6: Strike price range of recent offshore wind projects in Europe



2.3.1.3 Drivers of cost reduction

The cost reduction achieved in recent years has been driven by several factors, but underpinned by supportive policy conditions in several leading markets and considerable technological advances from investment in innovation. Key drivers include:

Market visibility: Stable regulatory frameworks in key markets, together with clear ambitions for large scale deployment of offshore wind has enabled investment in project development, infrastructure, local supply chains, and technology innovation. Visibility of future pipelines and national deployment targets will continue to drive investment into the sector.

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[3] Hornsea Project Two and Moray East offshore wind farms.

[4] Zero subsidy contracts include – Germany: OWP West (240 MW, Ørsted), Borkum Riffgrund 2 West (240 MW, Ørsted), He Dreiht (900 MW, EnBW); Netherlands: Hollandse Kust Zuid Holland I and II (700 MW, Vattenfall).

Scale effects: Offshore windfarms are getting bigger. Project capacity is increasing, particularly for commercial projects in mature offshore wind markets. In the UK, projects reaching final investment decision in 2016 had an average capacity of 586 MW – this included the 1.2 GW Hornsea One project. In parallel, the cumulative scale of installed capacity is increasing, with annual installation exceeding 3 GW in Europe in 2017 and expected to increase significantly over the coming decade. These economies of scale are a key enabler of lower procurement costs of wind farm components, including increased buying power for some leading developers.

Technology innovation: Technology innovation is improving performance throughout the project lifecycle. Turbines are becoming larger, more reliable and more efficient; new foundations are enabling deployment at sites that were once unfeasible; and new cable technology is enabling more transmission capacity and reduced energy losses. Furthermore, next generation vessels for installation and operations and maintenance activities are delivering efficiencies that reduce construction timelines and maximise turbine availability. Smaller scale innovations such as floating LiDAR devices for accurate wind measurement are also having a major impact by improving the certainty of yield projections and reducing the cost of finance. In combination, these innovations are also increasing energy capture to deliver high load factors for offshore wind farms of ~50%.

Two of the most significant technological advances include:

- **Larger turbines:** Turbines are increasing in size, improving energy capture and driving cost reduction across the balance of plant as more energy is captured from fewer turbine units. The largest installed turbines have a rated power of 8 MW but manufacturers have announced 9 MW+ solutions that will soon be introduced in upcoming projects. It is expected that turbine capacity could increase to 12-15 MW by 2025.

- **Deeper waters:** Offshore wind technology is progressing to enable deployment in deeper waters, widening the potential site choices and the ability to harness better wind resources. Optimised monopile foundations can now be installed in water depths up to 45m and jacket foundations can be installed in water depths up to 60m. Several novel foundation designs are also ready for commercial application, including suction bucket foundations and gravity base structures.

  While bottom-fixed foundations have been the predominant technological choice to date, the emergence of floating technology is also opening new site conditions and new markets for offshore wind – the most recent example being the 30 MW Hywind Scotland windfarm deployed off the coast of Peterhead, Scotland.

Competition: The introduction of competitive auctions in several leading markets has had a dramatic impact in accelerating cost reduction. In addition to competition between developers to secure limited project sites and government contracts, the pressure on cost reduction is trickling down throughout the supply chain. The maturing supply chain in Europe is also increasing competition among suppliers, resulting in consolidation in several areas.

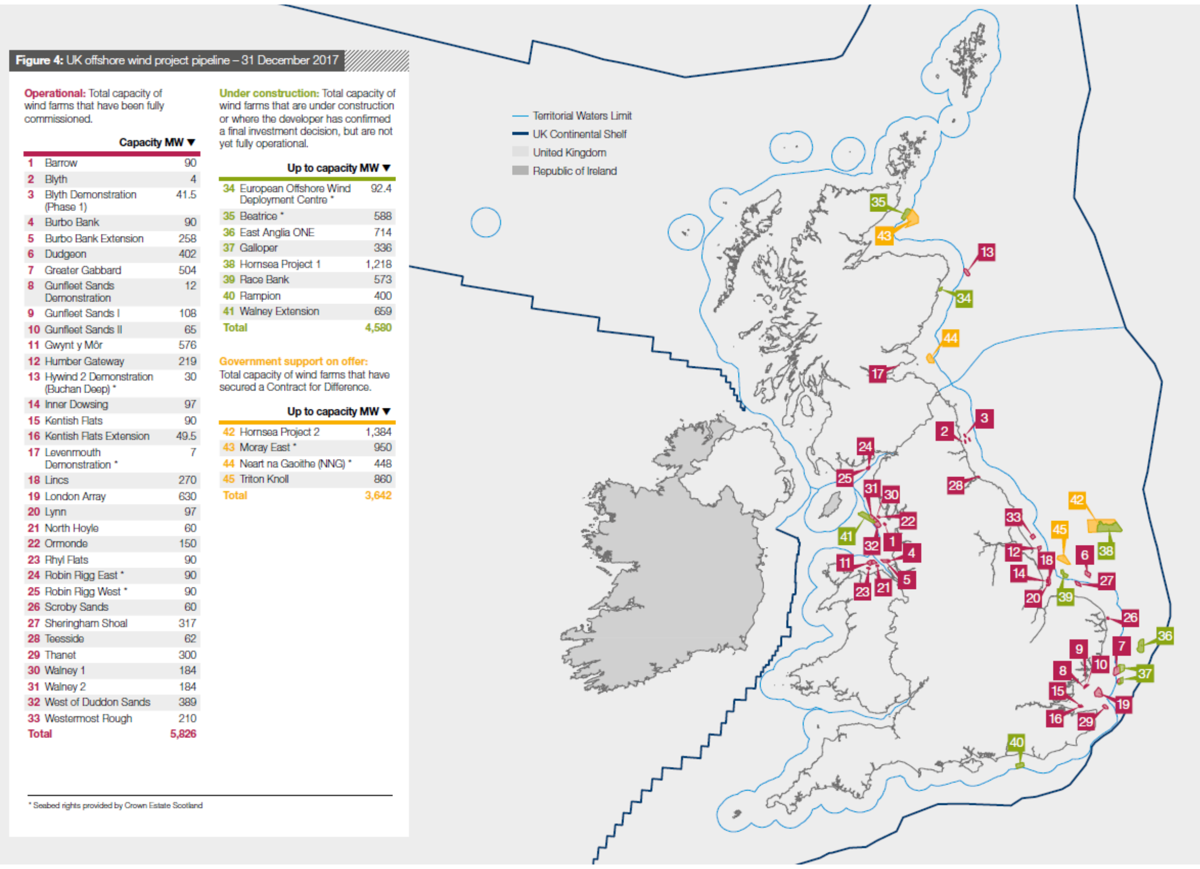
Financing cost: The cost of financing for offshore wind projects has decreased significantly in recent years due to a lower risk perception from the investment and lending community and the introduction of more innovative financing models. This reduced risk perception is a reflection of the increasing maturity of the sector and confidence in the operational performance of offshore wind farms, based on several years of offshore wind technology demonstration and deployment. As well as improved gearing ratios from increased levels of low cost debt, a more diverse range of investors are now active in the sector, including traditionally risk averse institutional lenders such as pension funds.

2.3.2 Offshore wind in the UK

2.3.2.1 Deployment

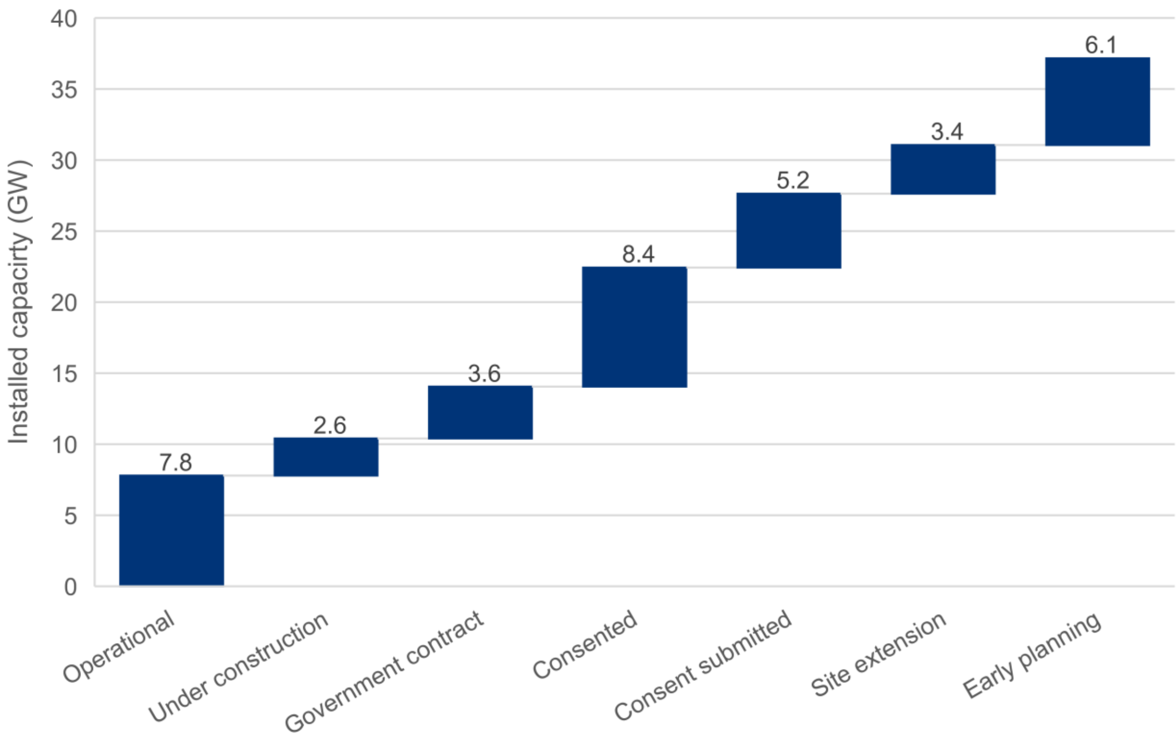
The UK has pursued offshore wind development as a strategic means to meet energy security and decarbonisation goals. Currently, almost 8 GW of offshore wind feed the UK grid (Figure 7), which will increase to over 10 GW once the windfarms currently at construction stage are finalised. Deployment has largely been concentrated off the east coast of England, east of Scotland, the Irish Sea, and smaller developments off the south coast. This siting is largely driven by the shallow water depths in these regions, which are easier for construction using fixed foundations. Conversely, more challenging site conditions off the south-west of the UK and west of Scotland have constrained development here.

Figure 7: Current operational, under construction or consented windfarms around the UK [9]



In addition to projects that are operational and under construction, a further 3.6 GW has been awarded UK government contracts (CfDs), taking total committed deployment to 14 GW. There is also another 8.4 GW of consented sites, 5.2 GW currently going through consent, and ~6 GW of projects at earlier stages of development. In addition, The Crown Estate has accepted applications for 3.4 GW of extensions to existing operational wind farms. In combination, the UK pipeline stands at 37.2 GW, which exceeds the 30 GW industry target for 2030, as outlined in the proposed Sector Deal and supported by the latest CCC progress report to government.

Figure 8. UK offshore wind project pipeline [7]



Note: Pipeline accounts for projects that have indicated an intention to raise the total capacity of their designated sites.

This arguably leaves limited opportunities for new projects targeting commissioning before 2030. However, given the potential for project attrition and the need to maintain a competitive market, The Crown Estate (England, Wales, and Northern Ireland) and The Crown Estate Scotland are preparing for new leasing rounds, expected during 2019. These new leasing rounds could open opportunities for offshore wind deployment in regions previously under-represented/utilised in UK offshore wind, including Wales.

Following recent engagement with industry stakeholders, The Crown Estate (England, Wales, and Northern Ireland) has indicated an intention to award new leases for ~7 GW of new capacity. While the final locations are still to be determined, two of the nine regions for proposed leasing or further investigation are located in Welsh waters. A discussion of the proposed resource areas is included in section 3.3.4.

New leasing will also begin to prepare for deployment post-2030. Assuming typical operational lifetimes of 25 years, industry ambitions for 50 GW by 2050 could require an additional 15 GW to be constructed during the 2030s and 25 GW during the 2040s. Lifetime extension, repowering, and other market and technological developments will influence these projections, but this order of magnitude highlights the potential for considerable deployment and associated investment in the sector over the coming decades.

2.3.2.2 Economic benefits

Offshore wind has brought considerable economic benefits to the UK. A report from the Offshore Renewable Energy Catapult [10] estimates the UK content of offshore windfarms operating or under construction is around 32%, with gross value added per GW installed at ~£1.8bn. A more recent report from Renewable UK (2017) suggests that UK local content is even higher, at around 48%. These latest figures suggest that the UK offshore wind industry is close to meeting the 50% target established in

2012 and the industry continues to push for increasing levels of local content that can align with the UK's industrial strategy. Most notably, a UK supply chain review led by Sir Michael Fallon called for a higher target of 60% local content in UK offshore wind projects, including a 50% target for capital expenditure [11].

A more detailed analysis of UK economic benefits and supply chain development can be found in section 4.

2.3.3 Offshore wind in Wales

Wales has three operational offshore wind projects, all of which are located in the Irish Sea off North Wales. Collectively, these projects account for ~10% of UK offshore wind capacity. However, the relative share of offshore wind in Wales is set to decline over the coming years, with the vast majority of UK projects in development located outside of Wales. Without a pipeline of commercial projects, there is a risk that Wales misses out on the economic, social, and environmental benefits that offshore wind can bring to the UK. However, with the right policy support and strategic direction, offshore wind could play a key role in Wales' future energy strategy, helping to deliver against several government objectives, including the Well-being of Future Generations Act.

In order to capitalise on the benefits offshore wind power could bring to Wales, policy makers must consider two inter-related goals:

1. **Increase offshore wind energy generation in Wales**

   Grid-connected offshore wind power in Wales can play an important role in meeting energy generation and decarbonisation targets. Offshore wind is a scalable energy technology that can deliver high volumes of low carbon electricity to Welsh consumers, making a material contribution to Wales' target of generating 70% of its electricity from renewables by 2030 and achieving an 80% reduction in CO_2 emissions by 2050.

   However, assessing the potential for offshore wind in Wales requires a realistic and evidence based evaluation. Current UK energy policy means that commercial projects will need to compete in auctions in order to secure government contracts. As such, prospective sites and projects in Welsh waters will need to be both technically viable and commercially competitive in the context of the UK development pipeline.

2. **Maximise local economic benefits to Welsh businesses and communities**

   Early developments in Welsh waters have supported several Welsh businesses and brought economic benefits to local communities. However, there has been some criticism that the value captured in Wales has been lower than in other parts of the UK. Policymakers will need to find a suitable means of increasing local content without compromising the competitiveness of Welsh projects.

   Even in the absence of high volumes of new capacity in Wales, support can be targeted to help Welsh businesses to secure contracts in projects outside of Wales, both in the UK and internationally. Several active companies are well-positioned to capture further benefits from future projects within and outside Wales.

These objectives are explored in the subsequent chapters of this report:

3. Offshore Wind Deployment Potential in Wales
4. Economic Benefits of Offshore Wind in Wales

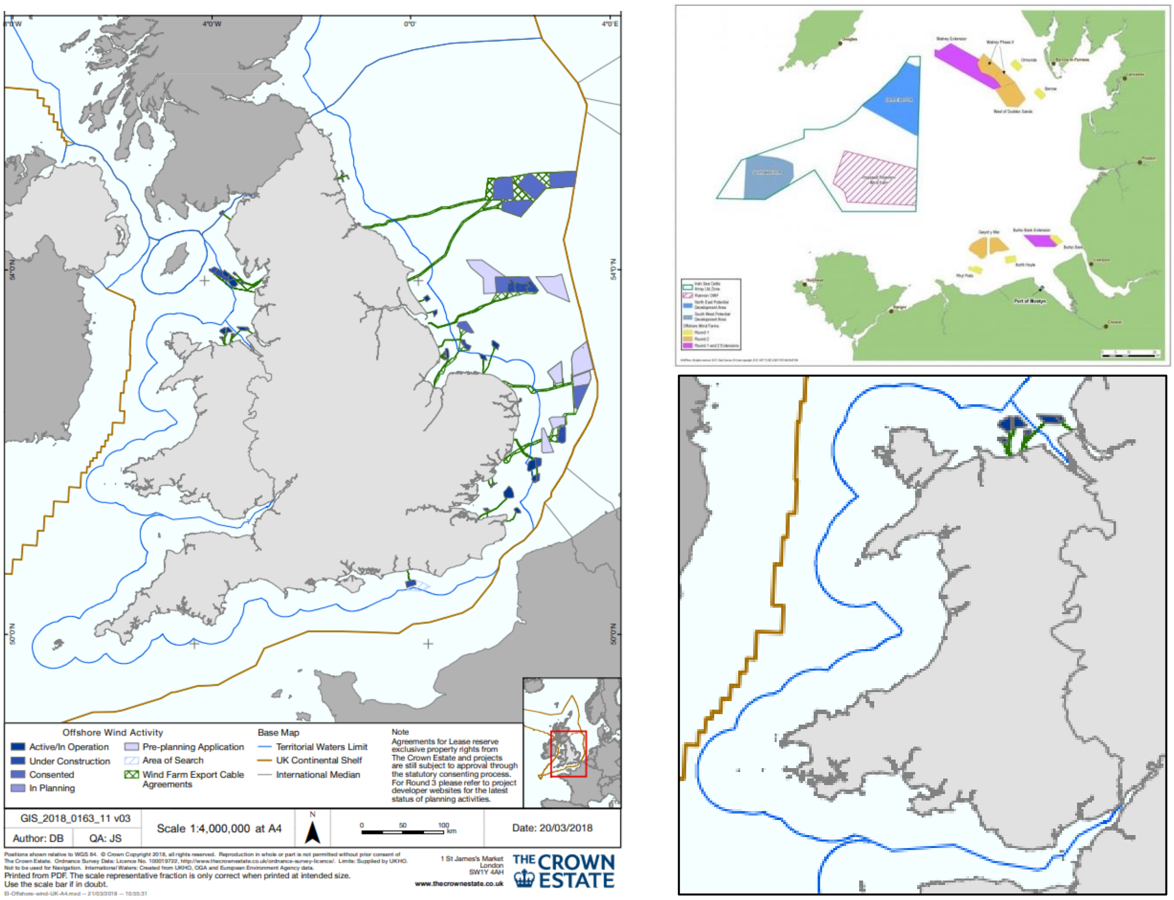
3. Offshore Wind Deployment Potential in Wales

3.1 Current sites and projects

3.1.1 Operational projects

Wales's territorial waters extend over four primary coastal regions – the Irish Sea in North Wales, Cardigan Bay to the West, the Atlantic off Pembrokeshire in the South-West, and the Bristol Channel to the South. To date, offshore wind development in Wales has been concentrated in the Irish Sea, although projects have also been identified in the Bristol Channel and South-West.

Figure 9: Offshore wind developments in the UK and Wales (The Crown Estate, 2018) and the Irish Sea (Port of Mostyn)



There are three offshore wind projects in Wales – North Hoyle, Rhyl Flats, and Gwynt-y-Môr (see Figure 9 and Table 4). As Round 1 wind farms, North Hoyle (60 MW) and Rhyl Flats (90 MW) are relatively small in size, serving as pilot projects to demonstrate the technical viability of offshore wind power. In contrast, at 576 MW, the Round 2 Gwynt-y-Môr windfarm is the second largest in the UK and highlights the trend towards larger projects with more advanced technology and greater efficiencies in order to drive down costs. For example, Gwynt-y-Môr consisted of 3.6 MW turbines, installed in deeper waters and further away from shore.

In addition to technical and commercial viability, the three projects installed to date have been important in demonstrating the applicability of offshore wind power in Wales and in bringing local economic benefits to Welsh businesses and communities in the region. Total investment in the three wind farms reached ~£2.7bn, with several Welsh businesses and employees benefitting. In particular, the Port of Mostyn served as the installation and operations and maintenance base for all three projects, helping to support local companies and establish a hub for offshore wind activity.

Table 4: Operational offshore wind farms in Wales

North Hoyle

Commissioning year	2003
Leasing round	Round 1
Project capacity	60 MW
Turbine rating	2 MW (x 30)
Foundation	Monopile
Water depth	7-11 m
Distance from shore	7.2 km
Owner	Greencoat UK Wind plc
Operator	Innogy
Port base	Mostyn (Installation and O&M)
Investment cost	£81 m
Capacity factor	30.6% (last 12 months)
Generation (annual)	~167 GWh

Rhyl Flats

Commissioning year	2009
Leasing round	Round 1
Project capacity	90 MW
Turbine rating	3.6 MW (x 25)
Foundation	Monopile
Water depth	6-12 m
Distance from shore	8 km
Owner	Innogy, Greencoat UK Wind plc, UK Green Investment Bank
Operator	Innogy
Port base	Mostyn (Installation and O&M)
Investment cost	£190 m
Capacity factor	35.3% (last 12 months)
Generation (annual)	~278 GWh

Gwynt-y-Môr

Commissioning year	2013
Leasing round	Round 2
Project capacity	576 MW
Turbine rating	3.6 MW (x 160)
Foundation	Monopile
Water depth	12-28 m
Distance from shore	16 km
Owner	Innogy, Siemens, Stadtwerke Munchen, UK Green Investment Bank
Operator	Innogy
Port base	Mostyn (Installation and O&M), Birkenhead (Installation)
Investment cost	€2.7 bn
Capacity factor	38.7% (last 12 months)
Generation (annual)	~1,953 GWh

3.1.2 Cancelled projects

Despite the success of the three operational projects in the Irish Sea, offshore wind development in Wales has also suffered setbacks, most notably through the cancellation of three projects.

- **Scarweather Sands (2009), E.ON:** Scarweather Sands was a Round 1, 108 MW windfarm project in the Bristol Channel, off South Wales, cancelled in 2009 due to challenging seabed conditions, relatively poor wind speed and development restrictions on turbine height.

- **Atlantic Array, innogy (2013):** Atlantic Array was a Round 3 1.2 GW development zone in the Bristol Channel, off South Wales, where project development activities were cancelled in 2013 due to challenging seabed conditions, estuarine currents, and water depths.

- **Celtic Array / "Rhiannon", DONG Energy & Centrica (2014):** Celtic Array was a Round 3 4.2 GW development zone in the Irish Sea, later progressed as a 2.2 GW project called "Rhiannon". Project development activities were cancelled in 2014, with challenging seabed conditions cited as the main issue. However, it is believed that large portions of the site are favourable for offshore wind development and could be of interest to prospective developers in future leasing rounds.

These cancelled projects serve as important lessons to policymakers and industry players in identifying and selecting the most suitable sites for offshore wind development. It is acknowledged that Rounds 1-3 were licensed at a time when offshore wind was a nascent industry with limited track record and experience from developing, constructing, and operating windfarms in the UK. Future licensing rounds can benefit from considerable experience from nearly 8 GW of installed capacity and the availability of more advanced technology that can unlock new sites in Welsh waters. Nevertheless, understanding and selecting sites with favourable environmental conditions, access to sufficient grid transmission capacity, support from local stakeholder groups, and adopting a more flexible approach to site selection will be critical to ensuring the success of future development activities. These potential constraints and a discussion on future deployment opportunities in Wales is included in sections 3.3 and 3.4.

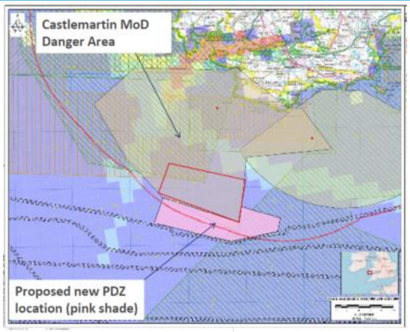
3.1.3 Demonstration and pre-commercial projects

While utility-scale commercial offshore wind farms have been the focus of offshore wind development to date, Wales is also actively involved in technology demonstration and pre-commercial initiatives. Namely, despite originally being developed to host wave energy devices, the Pembrokeshire Demonstration Zone has been expanded to include floating offshore wind technology due to a realisation that wave energy is unlikely to mature within the commercial project development timescales. The site holds a total capacity of 180 MW, with 90 MW expected to be initially set aside for floating offshore wind and potential to expand for the full capacity, depending on the suitability and market readiness of wave energy technology for the second phase of development [12].

The biggest challenge for realising the site is the current lack of a route to market for pre-commercial projects in the UK. At 90-180 MW, deployment of floating wind would require funding support outside of the competitive CfD mechanism. The commercial attractiveness of the site would be improved if it could be used as a springboard for larger commercial deployments of the south-west, but a lack of leasing zones in the near-term in this part of the UK could be a barrier to further build-out.

Table 5: Pembrokeshire Demonstration Zone project characteristics

Pembrokeshire Development Zone (PDZ)

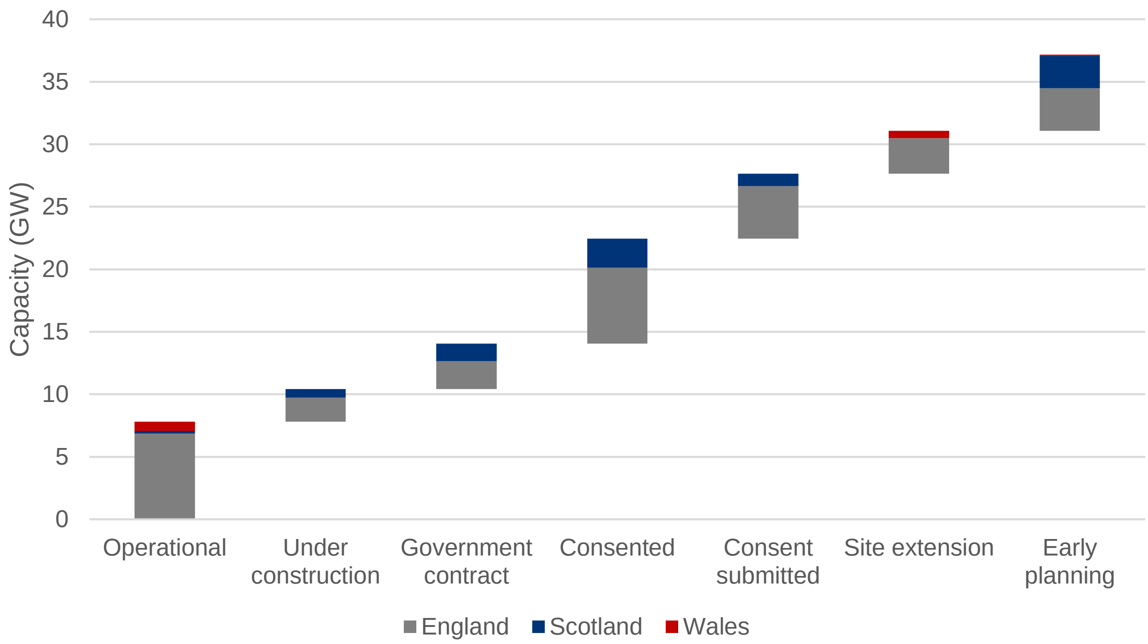


Owner	WaveHub Ltd.
Commissioning year	2024 (target – subject to change)
Site capacity	180 MW (2x 90 MW phases)
Foundation	Floating (TBC)
Water depth	50-65 m
Distance from shore	17-25 km
Area	90 km^2
Wind speed (ave.)	10.0 m/s

3.2 Potential for new capacity

Total offshore wind capacity installed in Wales currently stands at 726 MW, accounting for 6.4% of installed power capacity in Wales, contributing 2.4 TWh per year that delivers 5.6% of total generation and 13% of Wales' electricity consumption. The 726 MW also accounts for ~9% of the total UK offshore wind fleet. However, with no large-scale projects in the existing pipeline, this is set to drop to ~2% by 2030 if no new projects come to market. A failure to build on existing capacity would also risk missing an opportunity to close the gap against its policy targets, including harnessing Wales' offshore natural resources to supply clean, renewable energy to consumers and capitalise on the economic benefits that offshore wind can bring to domestic industries and local communities.

Figure 10. UK pipeline breakdown by country



However, recent developments and announcements in the UK, led by The Crown Estate, could create an opportunity to establish a new pipeline of projects in Welsh waters:

1. **Site extensions:** In February 2017, The Crown Estate announced a call for developers to extend existing operational wind farms in UK waters, with additional capacity limited to the current installed capacity of a given wind farm [12]. Following the closure for applications in May 2018, The Crown Estate received applications for 3.4 GW of capacity from eight UK wind farms, including innogy's 576 MW Gwynt-y-Môr wind farm off North Wales. All eight proposed extension projects have satisfied The Crown Estate's application criteria and will now be subject to a plan level Habitats Regulations Assessment, which will assess any possible impacts on relevant nature conservation sites. Agreement for lease could be granted in 2019, subject to the outcome of the HRA. Successful developers would then commence project-specific environmental assessments and seek consent for their projects through the statutory planning process.

2. **New leasing rounds ('Round 4'):** In order to support the industry towards its goal of delivering 30 GW of offshore wind power in the UK by 2030, The Crown Estate has announced an intention to undertake a new leasing round to strengthen the UK pipeline [14]. Despite over 30 GW already in the existing pipeline, the availability of additional capacity will provide resilience against project attrition and ensure a competitive marketplace to drive cost

reduction. While the total capacity is still to be determined, recent announcements from The Crown Estate indicate an intention to allocate new leases for ~7 GW of new capacity. The Crown Estate have also indicated that additional leasing beyond Round 4 is quite possible, following a suitable gap of at least ~4 years and in response to market need.

From 18 favourable resource areas initially identified, four of which were located in Wales, The Crown Estate has proposed five regions for proposed leasing and four regions for further consideration. Two of the four regions off Wales have been taken forward, with North Wales proposed and Anglesey under further consideration. It should be noted that the final location and size of sites will be defined following a developer-led approach to site selection within these areas.

Recognising that over 30 GW of capacity is already under development in existing UK sites, the window for new projects to be commissioned by 2030 may be limited. Projects in Wales will therefore need to be highly competitive in the context of the wider UK portfolio in order to secure government contracts within a timeframe that can meet Wales' renewable energy targets. Potential for deployment beyond 2030 is considerably greater, but sites in Welsh waters will need to be considered competitive in order to attract developer interest in the upcoming leasing process.

3.3 Constraints analysis

The availability and competitiveness of new sites will be influenced by several factors, many which will be related to technology options and developer strategies, but several which will be influenced by the local environment, particularly in strategic planning for the identification of new leasing areas. These include:

- **Environmental conditions:** Wind speed, water depth, seabed conditions, ocean wave and currents
- **Consenting barriers:** Existing lease agreements and military zones, environmental impact (incl. ornithology, marine mammals), conflict with other sea users (incl. fisheries, shipping, ferry routes), seascape and visual impact
- **Infrastructure:** Grid transmission capacity, port infrastructure, supply chain and workforce capabilities

Each of these influencing factors is assessed in the following sections. The assessment considers the viability of all regions around Wales with relevance for upcoming Round 4 leasing and subsequent leasing during the 2020s and beyond.

It should be noted that no primary analysis has been undertaken to investigate constraints or quantify the resource potential in Wales. The assessment is based on publically available sources of information and interviews with industry stakeholders. In particular, this section has drawn upon data and findings from the latest Offshore Energy Strategic Environmental Assessment (SEA) and draft Wales National Marine Plan, applying relevant learnings and insights to offshore wind development in Wales. Interviews and additional sources of information have also informed the analysis.

Importantly, it should be noted that the analysis below is based on a simplified approach to broadly categorise relatively large regions around Wales. The analysis is therefore indicative only and should not be used to draw conclusions about the acceptability of individual plans or projects, which will be subject to more detailed and granular analyses. It should also be noted that a constraint does not necessarily equate to no development, rather it indicates where an issue needs to be considered early to discuss alternatives and potential solutions.

3.3.1 Environmental conditions

3.3.1.1 Wind resource

Overview: Wind speed is a key driver of offshore wind project economics, closely correlating with annual energy production (AEP). Combined with high turbine availability rates, higher energy production will deliver increased revenues for project developers and higher load factors that can be advantageous for grid balancing. Wind speeds are typically lower closer to shore, which can introduce a trade-off between maximising energy production and minimising offshore transmission costs. Early offshore wind farm developments in the UK, including the three operational project in Wales, were located closer to shore to facilitate easier construction and maintenance. However, Round 3 and additional future developments are expected to be located further from shore, both to mitigate consenting constraints and to maximise energy production.

Wales: Wales is blessed with abundant offshore wind resource, with average wind speeds exceeding 9 m/s in a large proportion of its territorial seas. Wind speeds exceed 10 m/s in areas off North-West Wales and South-West Wales, making these locations particularly attractive for offshore wind development. Conversely, wind speeds are comparatively lower in the Bristol Channel, Cardigan Bay, and eastern areas of the Irish Sea[5].

In the context of the rest of the UK, average wind speeds are competitive with conditions in England. Indeed, North-West and South-West Wales could offer high wind speeds exceeding 10 m/s in locations nearer to shore than prospective sites in England. Wind speeds in Scotland are generally higher than the rest of the UK, but these sites may be more constrained by water depth and grid connection.

Figure 11. Left: Annual mean wind speeds around the UK [15]; Right: Annual mean wind power in Wales [16]

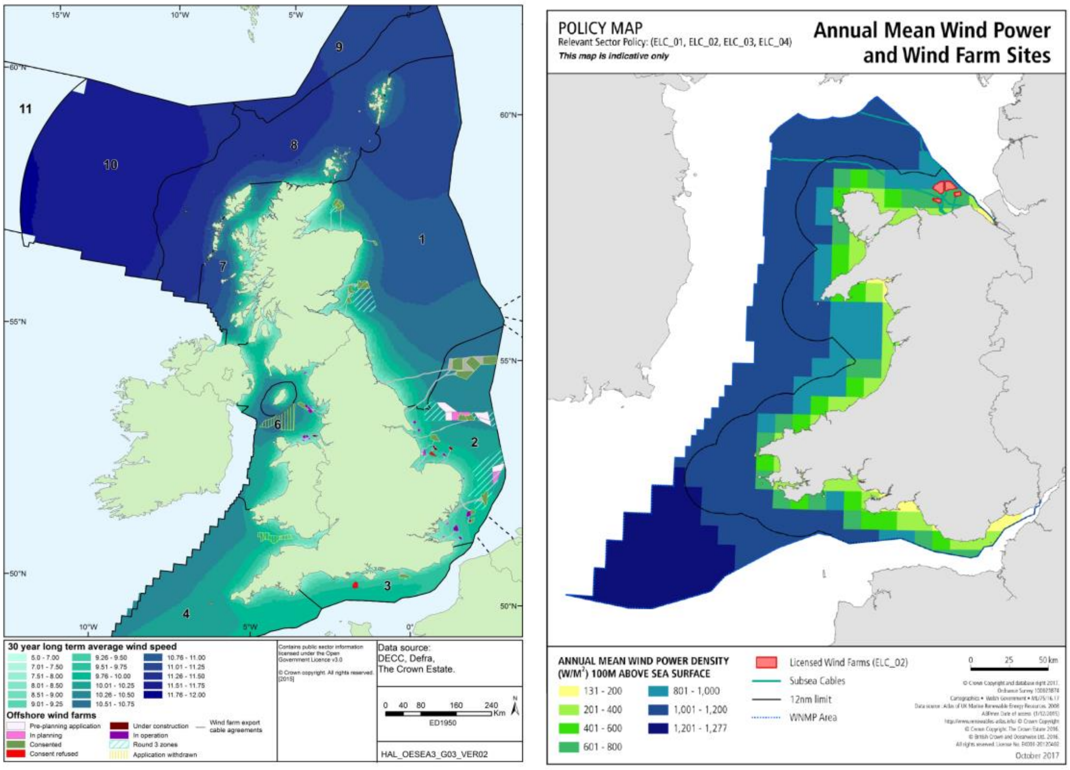


Table 6. Overview of wind speed in Wales

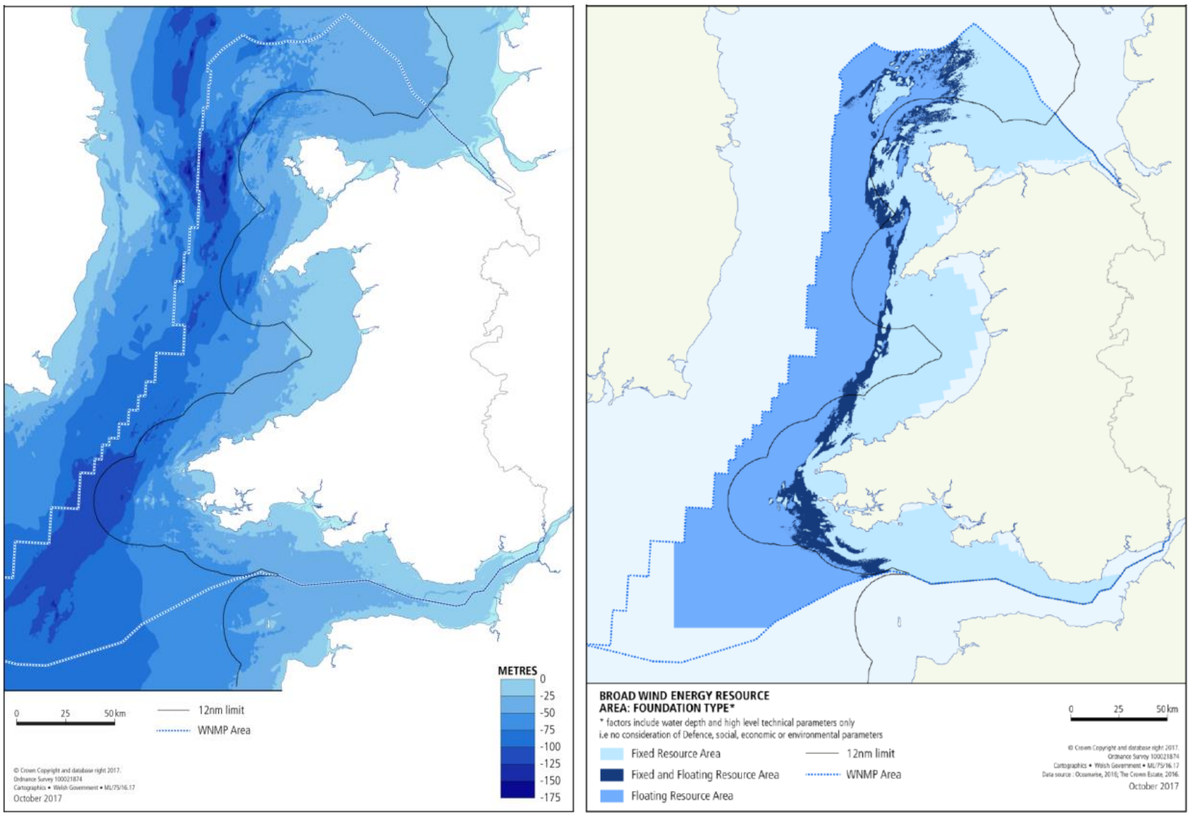
Area	Wind resource	Comment
East Irish Sea	Good	Generally >9 m/s average wind speeds.
West Irish Sea	Excellent	Considerable areas with >10 m/s average wind speeds.
Cardigan Bay	Good	Generally >9 m/s average wind speeds.
Pembrokeshire Atlantic	Excellent	Considerable areas with >10 m/s average wind speeds.
Bristol Channel	Medium	Generally <9 m/s average wind speeds.

[5] It should be noted that wind speeds will be geo-spatially variable and pockets of high average wind speeds may be found within these broad areas. It is also necessary to undertake more accurate site specific wind speed measurements using met masts or floating LiDAR devices to obtain robust estimates of annual energy production for a given project.

3.3.1.2 Bathymetry (water depth)

Overview: Water depth influences the foundation technology required in offshore wind farms. Early offshore wind farms in the UK were deployed in shallow water depths to facilitate lower cost fixed foundations, most commonly monopiles, and easier construction logistics. Round 2 and Round 3 wind farms have been moving into deeper sites, with fixed foundations capable of supporting turbines in water depths up to ~60m (monopiles up to ~45m, jackets up to ~60m). Beyond 60m depth, floating foundations are required. While floating offshore wind is a more nascent technology than conventional fixed foundations, with higher corresponding cost at present, it is possible that floating wind farms could become competitive once matured and deployed at scale, opening new sites and new markets for offshore wind power.

Figure 12. Left: Bathymetry in Wales; Right: Early stage wind resource area assessment by foundation type [16]



Wales: Wales has considerable shallow (<60m) sites in the Irish Sea, Bristol Channel, and Irish Sea that are well-suited to fixed foundations. Water depth remains below 50m throughout most of the Bristol Channel and East Irish Sea. Cardigan Bay is also predominantly suitable for fixed foundations, although floating wind could be viable in far-shore locations. The Pembrokeshire Atlantic and West Irish Sea move into deeper waters closer to shore, but contain areas suitable for both fixed and floating foundations.

Given likelihood of consenting constraints near to shore, Pembrokeshire is likely to require either deep water fixed or floating foundations. The West Irish Sea is more varied, containing pockets of shallower depths (<40m) suitable for monopiles, intermediate depths (40-60m) for jacket or alternative fixed foundations, and deeper sites (>60m) that would require floating foundations.

Table 7. Overview of bathymetric constraints

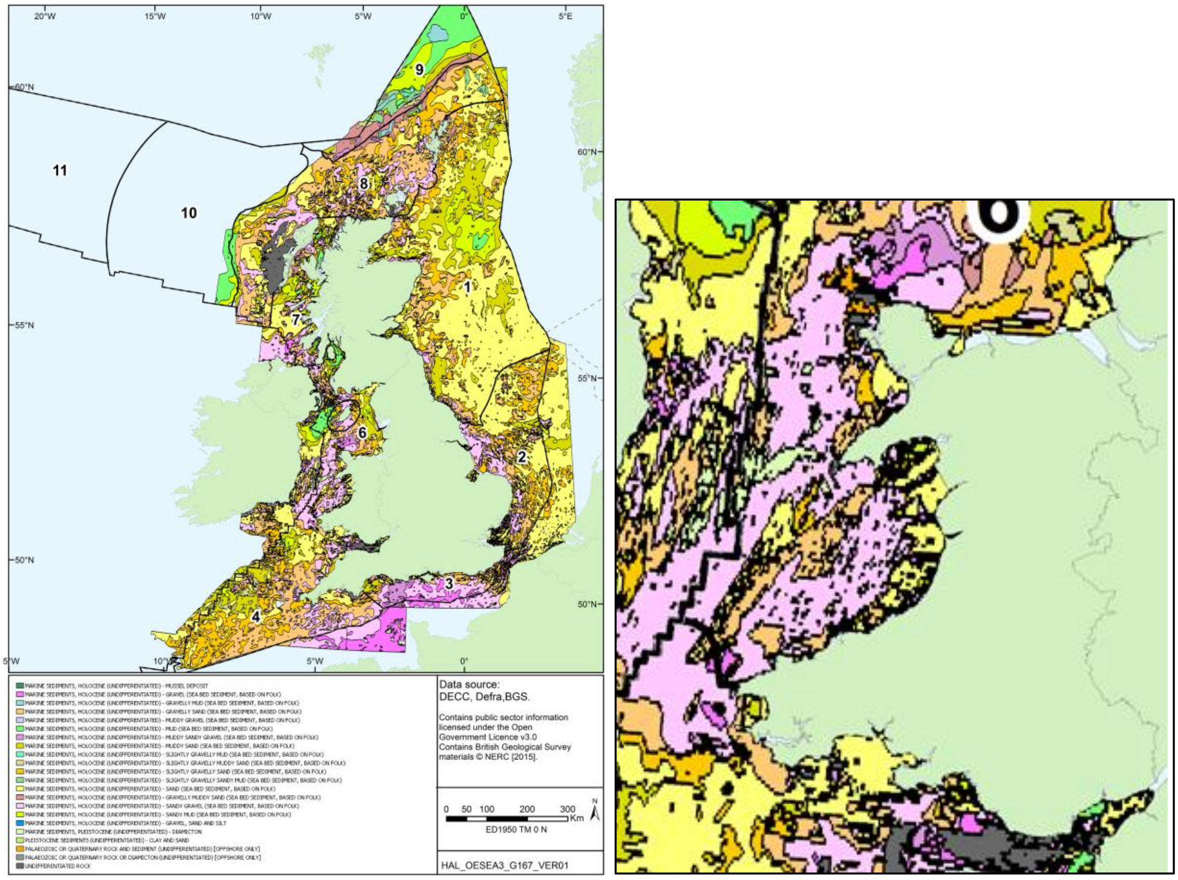
Area	Relative constraint	Comment
East Irish Sea	Low	Mostly shallow water depth <50m.
West Irish Sea	Med	Water depth >50m to the west, but shallow pockets <50m, particularly to the east (central Irish Sea).
Cardigan Bay	Low	Mostly shallow water depth <50m,
Pembrokeshire Atlantic	High	Shallow depths <50m near to shore, but water depths increase to >50m to the south-west.
Bristol Channel	Low	Mostly shallow water depth <50m.

3.3.1.3 Seabed geology

Overview: Seabed geology also has a major influence on foundation technology. Hard rock that is difficult to penetrate with piled foundations is generally avoided, although gravity base foundations may be viable and drilled piling can also be considered. Overly soft seabed is also undesirable if it could compromise the stability of a foundation, although this can often be mitigated by extending the pile length. Floating technology is less design driven by seabed conditions, but the principles above continue to apply for anchoring solutions, albeit with lower penetration depth.

Wales: Seabed geology in the UK is highly variable, even at local spatial scales. The quality of data is also considered fairly poor due to the difficulties in capturing accurate data without performing geophysical and geotechnical surveys (typically undertaken at site-specific level only). A full assessment of seabed geology is beyond the scope of this study, but analysis of the latest SEA indicates some discernible trends.

Figure 13. UK continental shelf seabed substrates, based on the British Geological Survey 1:250,000 scale data [15] [17]



Seabed geology around most of Wales comprises a mixture of sand and gravel sediment (colour coding referring to Figure 13 in brackets):

- **East Irish Sea:** Mostly sand (yellow) and gravelly sand (light and medium amber).
- **West Irish Sea:** Mostly sandy gravel (light pink), with sand (yellow) and gravelly sand (light amber) off the west of Anglesey and gravel (dark pink) to the north of Anglesey. Some complex seabed off the south-west of Anglesey.
- **Cardigan Bay:** Mostly sand (yellow) close to shore, with sandy gravel (light pink) further from shore.
- **Pembrokeshire Atlantic:** Mostly sandy gravel (light pink) and gravel (dark pink) to the west and north of Pembrokeshire. Mostly gravelly sand (light amber) and sand (yellow) to the south of Pembrokeshire. Some complex seabed immediately off the south-west.
- **Bristol Channel:** Large areas of undifferentiated rock (grey), together with areas of gravel (pink), sandy gravel (light pink) and gravelly sand (light amber).

Subject to more detailed surveys, conditions in the East Irish Sea, Cardigan Bay, and Pembrokeshire Atlantic are generally considered suitable for piled foundation technology. However, large areas of rock in the Bristol Channel could pose challenges here, which would likely lead to higher costs and potentially render a project commercially unviable. Indeed, the cancellation of the Atlantic Array project was partially attributed to challenging seabed conditions. Seabed conditions in the West Irish Sea are thought to be better, but again were cited as one of the contributing factors behind cancellation of the Rhiannon project. However, it should also be noted that foundation and piling technology may have advanced sufficiently to mitigate these challenges in future projects.

Table 8. Overview of geological constraints

Area	Relative constraint	Comment
East Irish Sea	Minor	Mostly penetrable sand and gravel.
West Irish Sea	Med	Mostly penetrable sand and gravel. Some complex soils.
Cardigan Bay	Minor	Mostly penetrable sand and gravel.
Pembrokeshire Atlantic	Med	Mostly penetrable sand and gravel. Some complex soils.
Bristol Channel	High/Med	Large areas of undifferentiated rock.

Note: More detailed surveys required to provide robust evaluation of seabed characteristics and suitability for offshore wind construction.

3.3.1.4 Ocean waves and currents

Overview: Ocean waves and currents both influence offshore wind farm design, particularly foundation design. Harsh environments with high wave loading will generally require more robust and expensive foundation designs. High average wave height will also create challenges for accessing turbines of operations and maintenance activities. Ocean currents can shift sediment that could increase the occurrence of scouring at the base of a foundation, as well as making visual inspections more challenging.

Wales: A summary of wave and tidal currents in Wales can be seen in Table 9 and Table 10, based on the spatial analysis visible in Figure 14. Sheltered by Ireland and Welsh peninsulas, the most favourable ocean conditions are found in the Irish Sea and Cardigan Bay. The Pembrokeshire Atlantic experiences higher wave loading from Atlantic swells, which could impact on designs for fixed and floating foundations. The Bristol Channel faces challenges from strong tidal currents running through the Severn Estuary, which could add considerable technical challenges to wind farm construction and maintenance. Indeed, these challenges were cited as one of the primary reasons for cancelling the Atlantic Array project.

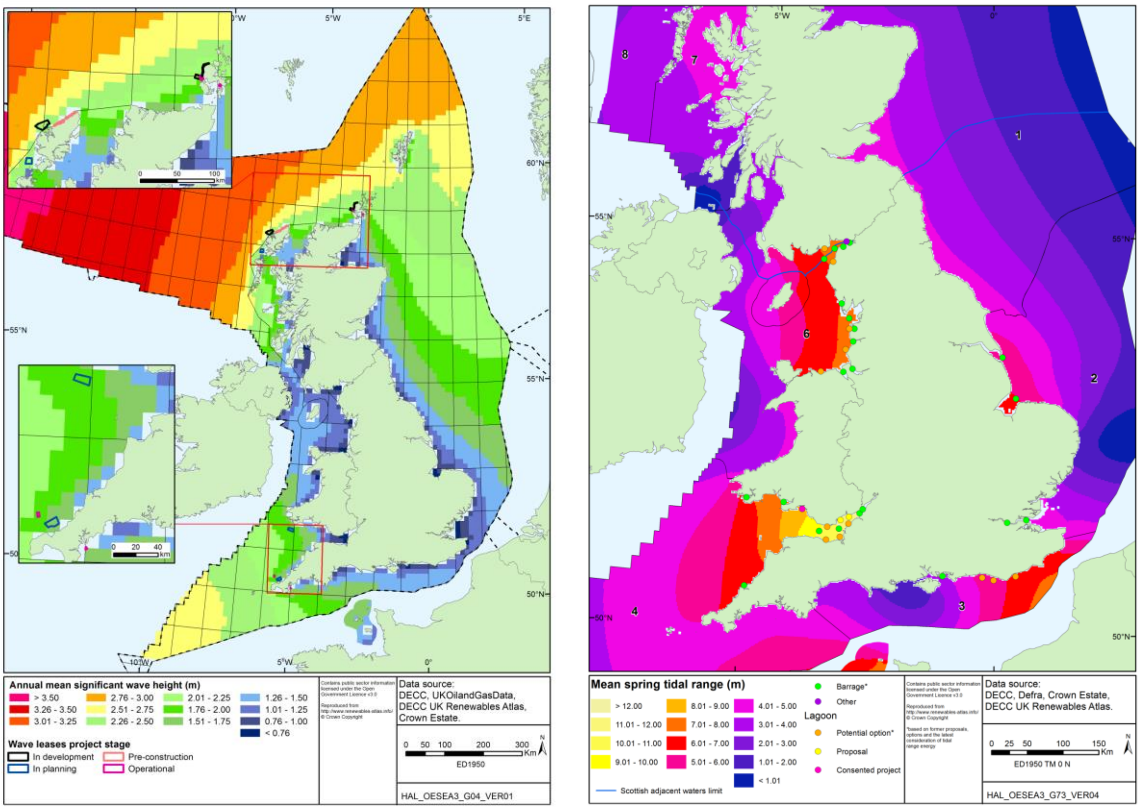
Table 9. Overview of ocean wave conditions

Area	Wave environment	Comment
East Irish Sea	Mild	Largely protected by landmass.
West Irish Sea	Mild	Largely protected by landmass.
Cardigan Bay	Mild / Medium	Partly exposed, largely protected by landmass.
Pembrokeshire Atlantic	Medium / Harsh	Exposed to Atlantic swells.
Bristol Channel	Medium	Partly exposed to Atlantic swells.

Table 10. Overview of tidal current conditions

Area	Tidal current	Comment
East Irish Sea	Medium	Medium current velocities.
West Irish Sea	Low/Medium	Low/med current velocities.
Cardigan Bay	Low	Low current velocities throughout.
Pembrokeshire Atlantic	Medium	Medium current velocities in south Pembs.
Bristol Channel	High	High current velocities through Severn estuary.

Figure 14. Left: Annual mean significant wave height in the UK [15]; Right: Mean spring tidal range in the UK [15]



3.3.2 Consenting barriers

In addition to the environmental site characteristics outlined above, a number of consenting barriers add constraints that will influence project siting and, in turn, the potential for offshore wind deployment in Wales.

3.3.2.1 Existing leases and military zones

Overview: Any new offshore wind developments will need to avoid areas with existing lease agreements. This includes existing lease agreements for offshore wind farms, wave and tidal activity, marine aggregates, cables and pipeline activity (Figure 15), and oil and gas activity (Figure 16). Military Practice and Exercise Areas (PEXA) are another constraint that can restrict development activities (Figure 17).

Wales: Wales is generally less constrained than the east of the UK, where there are considerable areas reserved for existing offshore wind farm leases, oil and gas fields, and other marine activities. However, there are existing activities that will limit the potential for future offshore wind deployment. The most significant existing leases and exclusion zones in Wales include:

- **Oil and gas** licensed areas in the East Irish Sea and off West Wales, spanning both the Pembrokeshire Atlantic and Cardigan Bay. 30th Round Blocks offered in the West Irish Sea.
- **Offshore wind** farms in the East Irish Sea, including the three operational wind farms in Wales and neighbouring offshore wind farms connecting into England.
- **Tidal energy** sites to the west of Anglesey in the West Irish Sea and off the Llŷn Peninsula in the north of Cardigan Bay. However, these sites are unlikely to be desirable for offshore wind development due to the close proximity to shore and strong tidal currents.
- **Wave energy** site to the south of Pembrokeshire (also expected to be at least partially available for floating offshore wind).
- **Aggregates production** activity off the Gower peninsula and eastern parts of the Bristol Channel.
- **Military Practice and Exercise Zones (PEXA)** off south Pembrokeshire and Cardigan Bay. The presence of a PEXA does not preclude other activities, but will likely add challenges for obtaining consent, particularly given the nature of the firing ranges at Castlemartin and Cardigan Bay.

Figure 15. The Crown Estate offshore activity [18]

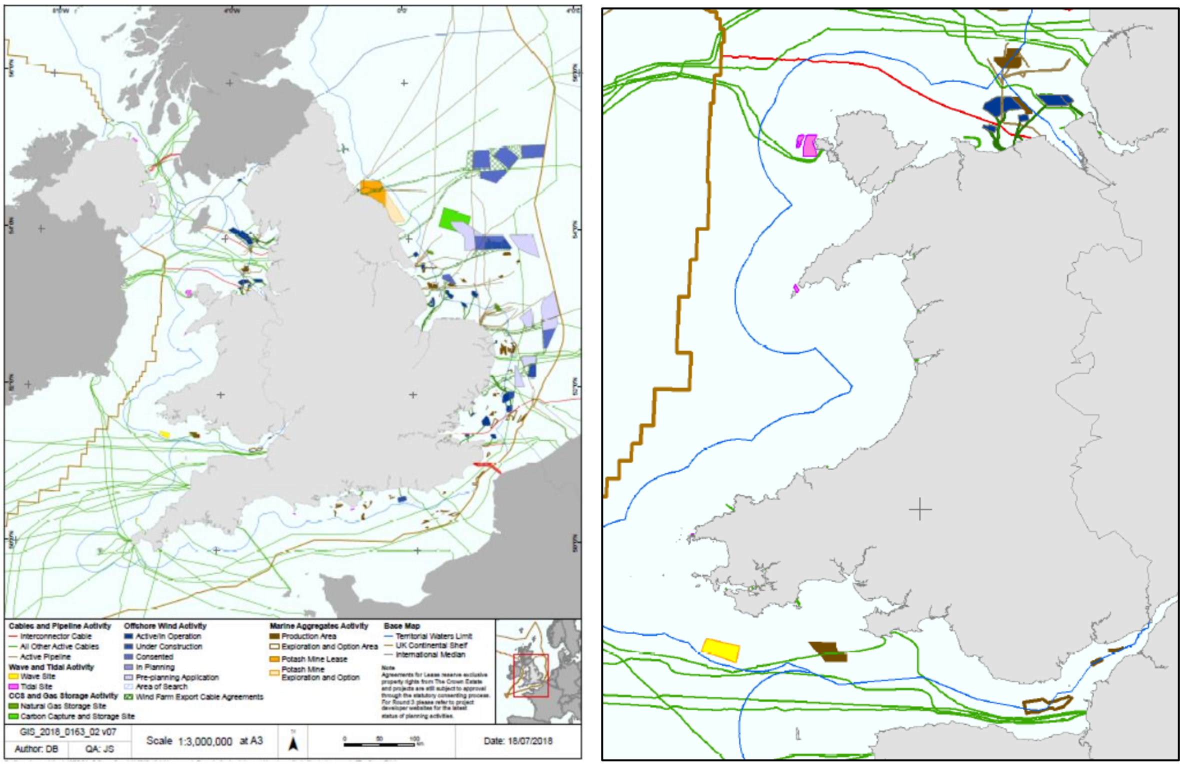


Figure 16. Location of existing oil and gas fields, infrastructure and licence areas in the UK [15] and Wales [16]

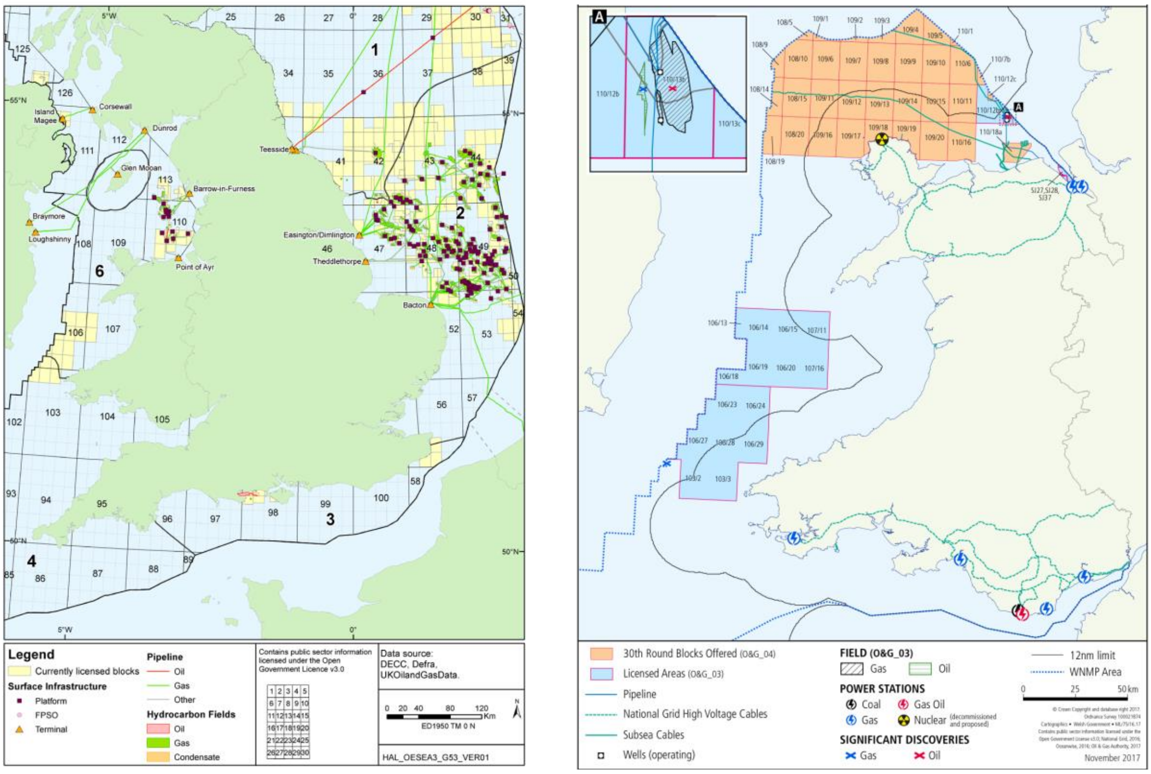
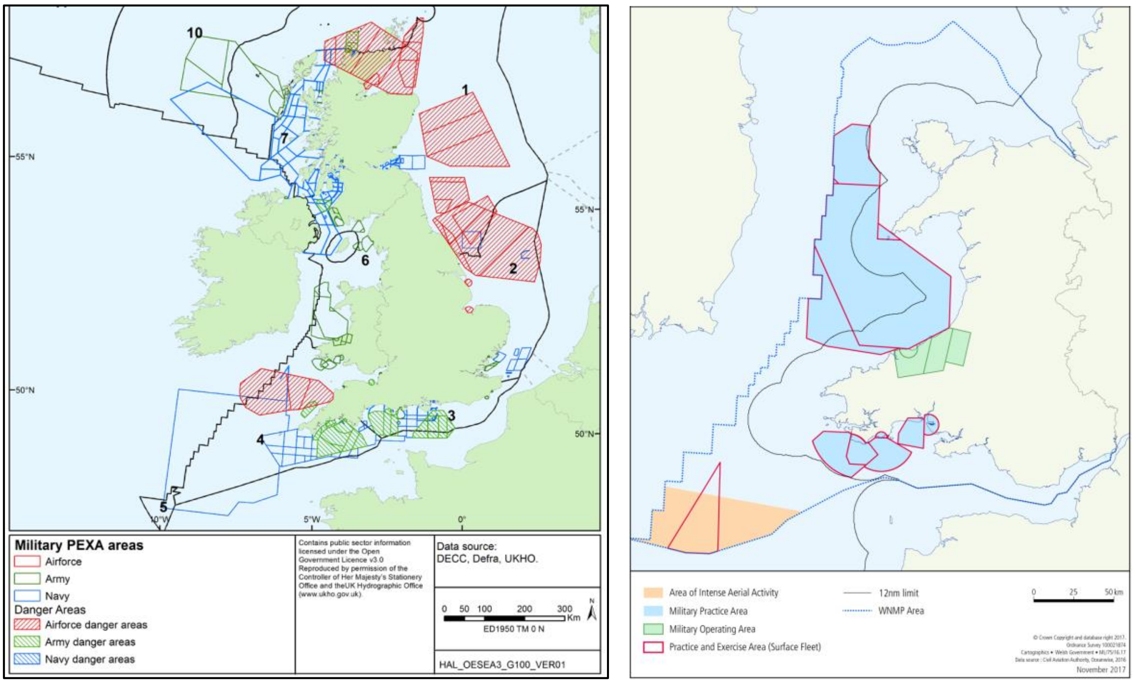


Figure 17. Location of military PEXA areas in the UK [15] and Wales [16]



The East Irish Sea is considered the most constrained, due to the existence of licenses for both offshore wind and oil and gas activities. Cardigan Bay and Pembrokeshire are also likely to be constrained by both oil and gas activity and the presence of military zones. The West Irish Sea is largely unconstrained, but proposed oil and gas leases could add a constraint to development, with prospective offshore wind farms needing to demonstrate an ability to coexist with oil and gas activities.

Table 11. Overview of leasing and military constraints in Wales

Area	Relative constraint	Existing leases and military zones
East Irish Sea	High/Med	Several offshore wind farms and oil and gas activities.
West Irish Sea	Med	No approved leases, but large areas offered.
Cardigan Bay	High/Med	Oil and gas activities off southern and central areas. Cardigan Bay Range (PEXA).
Pembrokeshire Atlantic	Med	Oil and gas activities off north Pembrokeshire. Castlemartin Range (PEXA) off south Pembrokeshire.
Bristol Channel	Low	No major existing leases.

3.3.2.2 Environmental impact

Overview: The development of offshore infrastructure must minimise its impact on the natural environment, and in some circumstances significant effects must be completely avoided or discounted. Offshore wind farm construction involves the installation of large physical structures and extensive electrical cabling in offshore environments, which can disrupt the seabed, flora, and fauna, such as marine mammals. Once operational, wind farms can pose a perceived threat to avian species, such as birds and bats, but may also support wildlife by forming artificial reefs. In addition to the impact from a single project, the growing fleet of offshore wind farms in the UK has resulted in an increasing focus on cumulative impacts at a regional level.

The siting of offshore wind farms during strategic planning and subsequent decisions to award consent to specific projects must consider whether the benefits of wind farm construction (i.e. energy security, decarbonisation, economic benefits) outweigh any potentially detrimental environmental impacts. Doing so requires a sound scientific evidence base to make informed decisions.

There are two primary procedures in place to undertake such assessments:

- **Habitats Regulation Appraisal (HRA):** Plan-level assessment led by The Crown Estate and project-level assessment led by the wind farm developer.
- **Environmental Impact Assessment (EIA):** Project-specific assessment submitted by the wind farm developer to demonstrate the expected impact and how this will be mitigated.

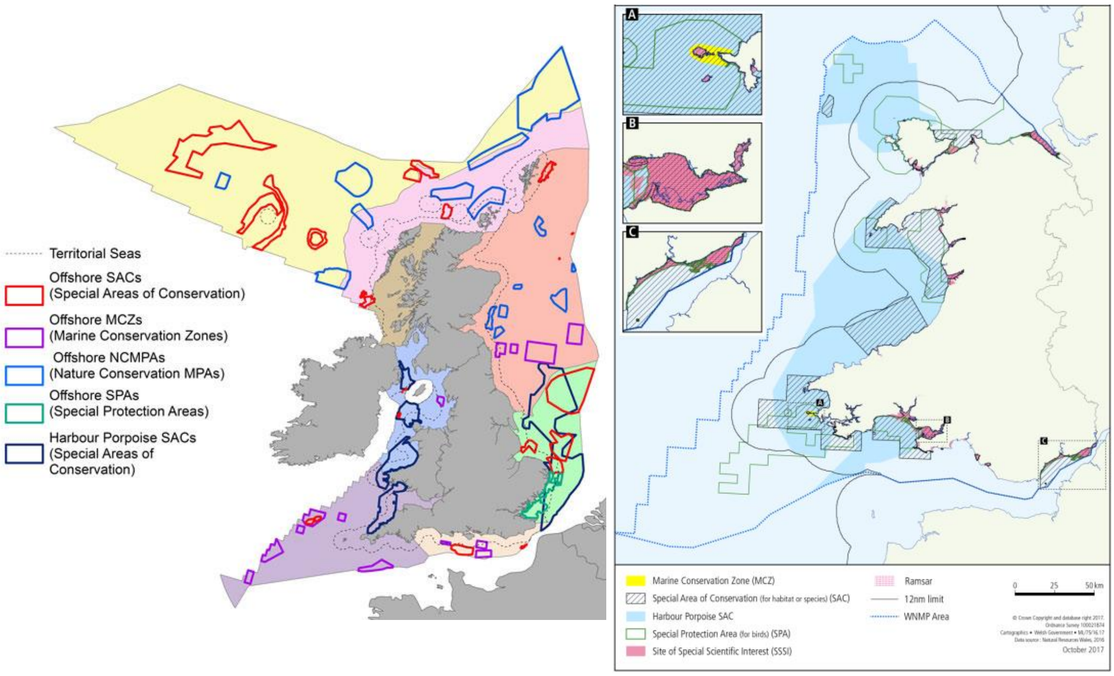
Following 15 years of offshore wind deployment in the UK, which has included a number of scientific research studies, there is a far improved understanding of the real impact of offshore wind farms. In particular, collaborative research programmes such as the Collaborative Offshore Wind Research into the Environment (COWRIE) and Offshore Renewables Joint Industry Programme (ORJIP) have proved successful in improving understanding and knowledge of the potential environmental impacts of offshore windfarm development in UK waters. Nevertheless, knowledge gaps remain and further work is necessary in order to improve the robustness of evidence to support consenting decisions.

Strategic planning regarding the siting of new offshore wind developments aims to identify areas that will minimise environmental impact and thereby reduce consenting risk for future projects. This is partly informed by the location of Marine Protected Areas (MPAs) in the UK, which constitute a combination of: Special Areas of Conservations (SAC), Special Protection Areas (SPAs), Marine Conservation Zones (MCZ), Nature Conservation MPAs (NCMPA), Marine Nature Reserves (MNR), and Sites of Special Scientific Interest (SSSI).

It should be noted that using the location of MPAs as a proxy for spatially defining environmental sensitivity is an oversimplification, given the need to account for mobile species in offshore environments. For example, migratory bird and marine mammal populations will extend beyond MPA boundaries. Furthermore, as a ‘soft’ constraint, the presence of an MPA does not prohibit wind farm development. However, a spatial analysis based on MPA locations is presented here as an indicative guide, since the increased sensitivity of the location means that the requirement for understanding, characterising, and demonstrating minimal impact is proportionally greater, and thus the risk of not obtaining consent is higher. More detailed and higher resolution assessments will be necessary to fully determine the anticipated impact on the natural environment, and all prospective offshore wind farm locations will be subject to HRA and EIA assessments during the planning and consenting process. In many cases it will be necessary to go beyond minimising impact to completely avoid/discount significant effects. It should be stressed that early engagement with consultees on the siting and design of offshore wind farms can reduce the likelihood of conflict and consenting risk later in the development process.

Wales: The Welsh coastline and coastal waters host an array of wildlife and diverse underwater habitats and species. As such, a large proportion of coastal waters are protected, with 133 Marine Protected Areas covering 69% of Welsh seas [19]. This compares with 24% at a UK level [20]. Wales may therefore be considered more environmentally sensitive to new offshore wind development than other parts of the UK. However, this will vary by region and may not necessarily be a major barrier to new projects, provided that significant adverse effects can be discounted and that this can be demonstrated through Habitats Regulation Appraisals and Environmental Impact Assessments.

Figure 18. Left: Marine Protected Areas in the UK [21]; Right: Marine Protected Areas in Wales [16]



Wales' coastal waters are important for marine mammals, for which there are several SACs stretching from the West Irish Sea down to the Pembrokeshire Atlantic, making these some of the most constrained areas for development. Several SPAs are also located in the Irish Sea, Cardigan Bay, Pembrokeshire, and Gower Peninsula in the Bristol Channel, but are generally near to shore and may not overlap with offshore wind developments. The anomaly here is Pembrokeshire, where the Skomer & Skokholm SPA extends to the south-west. The least constrained area is considered between Anglesey and the Llyn Peninsula, where there are no significant MPAs present. The East Irish Sea is less sensitive to marine mammals, but the presence of multiple offshore wind farms could create greater risks of cumulative impacts, particularly bird life protected under the Liverpool Bay SPA.

Table 12. Overview of environmental constraints in Wales

Area	Relative constraint	Marine Protected Areas (MPAs)
East Irish Sea	High-Low	Liverpool Bay SPA. Cumulative impacts.
West Irish Sea	High-Med	Harbour porpoise SAC. Anglesey and Conway Bay SPAs.
Cardigan Bay	High-Med	Harbour porpoise SAC. Cardigan Bay and Aberdaron SPAs.
Pembrokeshire	High-Low	Harbour porpoise SAC. Skomer & Skokholm SPA.
Bristol Channel	High-Low	Gower and Carmarthen Bay SACs.

3.3.2.3 Conflict with other sea users

In addition to interactions with the natural environment, offshore wind developments will need to manage potential conflict with human sea activities. The most significant interactions include: commercial fishing, commercial shipping, ferry transport, and recreational activities.

Commercial fishing

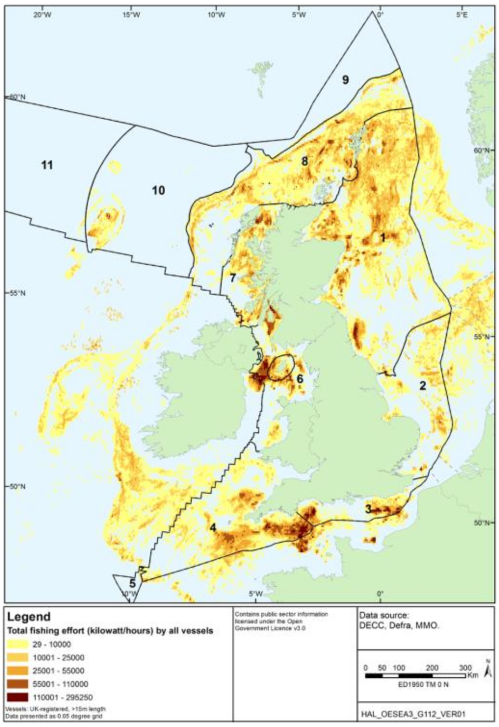
Overview: Commercial fisheries are understandably reluctant to lose potential fishing territories to offshore wind farms. Compensation can be paid to fisheries to account for potential loss of earnings and close engagement early in the planning phase can also support industry acceptance. Collaborative working groups such as the Fishing Liaison with Offshore Wind and Wet Renewables Group (FLOWW) have been successful in this regard.

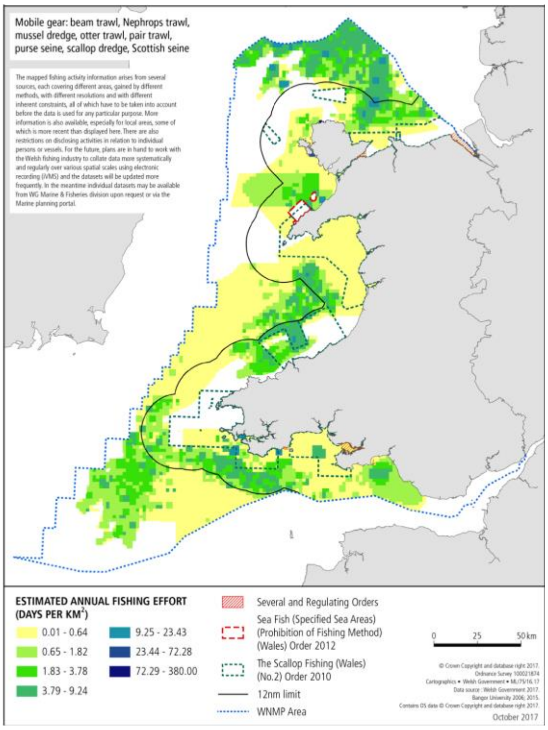
In the UK, conventional fixed-bottom offshore wind farms do not impose exclusion zones, which can support coexistence by enabling fishing activities to continue within the wind farm. However, the presence of mooring lines and dynamic cables in the water column in floating wind farms could result in exclusion zones that limit fishing activity, requiring higher compensation and closer engagement to gain acceptance.

Wales: Commercial fishing has a long history in Wales. Like the rest of the UK, it has seen intense pressure over the last few decades with fleet numbers falling as many fishermen leaving the industry, but commercial fishing remains an important part of the Welsh economy. The main concentrations of sea fishing vessels are found in Milford Haven in the south-west and Holyhead in the north-west, although fishing vessels can be found in small ports all around the Welsh coast.

Fishing locations are variable and rarely disclosed due to commercial sensitivities, but analysis of Vessel Monitoring System (VMS) data provides an indicative view on areas of greatest activity. As seen in Figure 19, fishing intensity is greatest in the West Irish Sea, Cardigan Bay and south-west Pembrokeshire, with pockets of activity in the East Irish Sea and very little in the Bristol Channel.

Figure 19. Left: Total fishing effort of UK vessels >15m length in 2013 [15]; Right: Fishing activity with mobile gear in Wales [16]





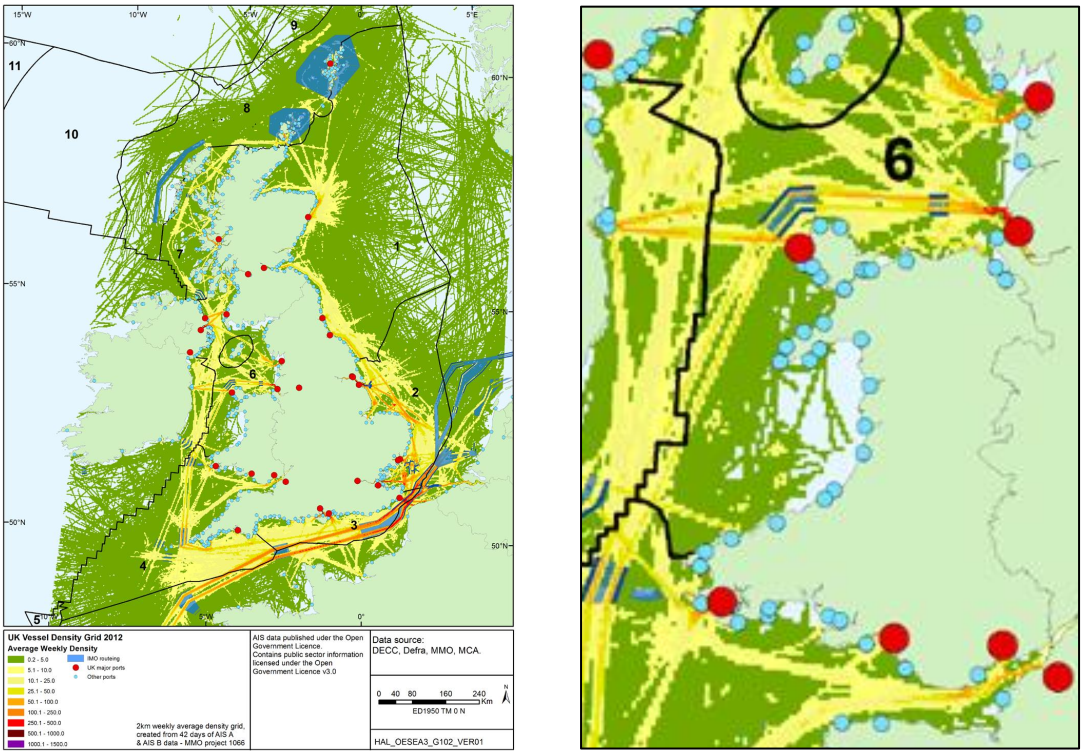
Commercial shipping

Overview: With ~95% of UK imports and exports transported by sea, the UK has a network of large and busy ports. While there is a modest level of activity in shipping routes out at sea, vessel density is concentrated near to major ports. This could pose a barrier to prospective offshore wind developments that dissect these shipping routes.

Wales: The most intensive shipping activity is seen in the south and south-east of the UK. However, Wales has several major ports and busy shipping routes that could interact with prospective offshore wind developments. Greatest activity is seen in the Irish Sea, with shipping routes into Liverpool Port to the east and Holyhead to the west. The presence of several offshore wind farms in close proximity to Liverpool Bay highlights the potential for co-existence, but also indicates that further development in the East Irish Sea could be constrained.

Milford Haven is Wales' largest port for shipping cargo, increasing vessel density off south Pembrokeshire. Port Talbot and Newport are relatively more modest but nevertheless busy ports that increase vessel traffic in the Bristol Channel. With no major cargo ports, Cardigan Bay has limited vessel traffic.

Figure 20. Automatic Identification System (AIS) density grid, 2012 [15]

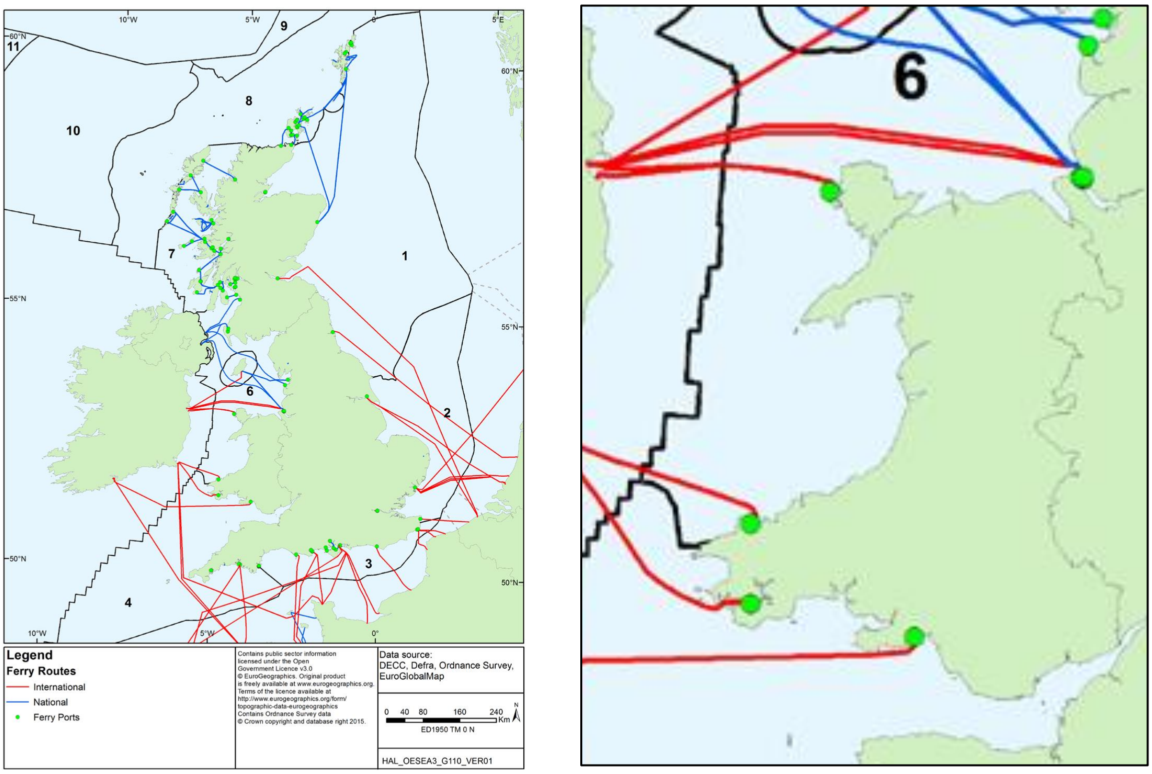


Ferry transport

Overview: In addition to commercial shipping, there are numerous passenger ferry routes that can also interfere with offshore wind farm developments.

Wales: The major ferry routes in and around Wales consist of passenger ferries between the UK and Ireland. These largely mirror commercial shipping routes across the Irish Sea from Holyhead and Liverpool to Dublin and from Fishguard and Pembroke Dock to Rosslare. A ferry route from Swansea to Cork is no longer commercially operated. Although outside the Welsh National Marin Plan area, routes to the Isle of Man could also be a constraint for some sites, including around the former Celtic Array Zone.

Figure 21. Ferry terminals and indicative ferry routes [15]



Recreational activities

In addition commercial and industrial activities, the Welsh coastline supports a range of recreational activities, such as sailing, fishing, kayaking, and surfing. While typically near-shore activities that won't directly interact with offshore wind farms, these activities are an important part of the Welsh tourism industry and must be considered in offshore wind developments. Coastal tourism and recreational activities are particularly concentrated around Pembrokeshire to the south-west, the Gower peninsular to the south, and along the coast of North Wales.

Summary of constraints from other sea users

Table 13. Overview of sea user conflicts and constraints in Wales

Area	Relative constraint	Comment
East Irish Sea	Med	Heavy shipping traffic in and around Liverpool Bay.
West Irish Sea	Minor	Busy shipping routes and fishing activity.
Cardigan Bay	Minimal	Minimal vessel traffic.
Pembrokeshire Atlantic	Med	Busy shipping routes and fishing activity.
Bristol Channel	Minimal	Minimal vessel traffic.

3.3.2.4 Seascape and visual impact

Overview: Local stakeholder objections are another potential barrier to obtaining consent. These objections are typically based on the visual impact of wind farms, particularly if there are concerns that this may impact on local tourism. While offshore wind farms are generally less visible than onshore wind farms, there are have been high profile project casualties as a result of local objections, such as the Navitus Bay Wind Park on the English south coast[6].

The visibility of an offshore wind farm is influenced by the size of the project (i.e. number of turbines), size of turbine, distance from shore, and onshore topography. Early offshore wind farms (2003-2013) were deployed relatively near to shore, typically with 50-100 turbines at 2-4 MW power rating (Table 14). The next fleet of offshore wind farms up to 2020 will see an increase in turbine rating and project size, with a modest increase in average distance to shore. However, beyond 2020, the development of several Round 3 wind farms means that distance from shore will increase significantly, alongside a doubling in project size and further increase in turbine rating, which could reach 12-15 MW from 2025.

Table 14. Offshore wind farm project characteristics from 2003-2025[7]

Year	Turbine capacity (MW, average)	No. turbines (average, #)	Project capacity (average, MW)	Distance From Shore (average, km)
2003-2013	3.4	61	210	11
2014-2020	5.9	75	437	25
2021-2025	7.3	151	1,107	81

Analysis by White Consultants (2016) offers an indication of the extent of offshore wind farm visibility, in relation to turbine size and distance from shore (Table 15). Based on this analysis, wind farm visibility will be negligible for future offshore developments beyond ~35km. However, wind farms within 35km from shore may be susceptible to challenge over seascape visibility, and even beyond these distances there may be important sensitivities when there is intervisibility between headlands.

Table 15. Thresholds of significance for a representative 500 MW wind farm scenario [15]

Turbine size (MW)	Distance from shore			
	13km	18km	24km	35km
3.6	Moderate and moderate/large	Small and small/moderate	Small	n/a
5	Moderate and large	Moderate and moderate/large	Small and small/moderate	n/a
7/8	Moderate and large	Moderate and large	Small	Very small
10	Large	Moderate and large	Small and small/moderate	Very small
15	Large	Moderate and large	Moderate	Very small

Wales: Visual impact could be particularly sensitive in regions of Wales where there are designated National Parks, Areas of Outstanding Natural Beauty (AONB), and/or high levels of tourism. Wales has a combined total of eight National Parks and AONBs, five of which are coastal lying (Figure 22, left). The most sensitive areas include Cardigan Bay, the Pembrokeshire Coast National Park to the south-west, Gower AONB to the south, Snowdonia National Park and the Llyn AONB to the west, and

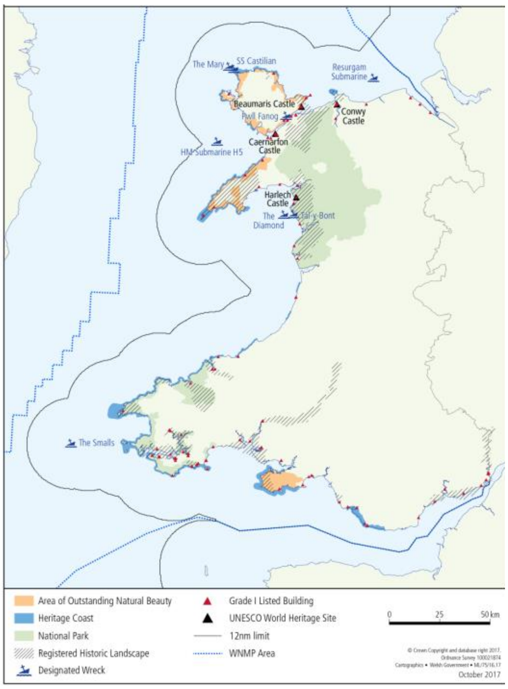
[6] Navitus Bay was located just 10km off the Jurassic Coast of Dorset, a World Heritage Site with considerable tourism activity. The project was planning to deploy up to 121 MHI-Vestas V-164-8MW turbines, which would have been visible from the coastline.
[7] Carbon Trust analysis based on data from 4coffshore. Excludes demonstration projects <50 MW capacity.

Anglesey AONB to the north-west. These areas are also popular tourist destinations. The Bristol Channel could be particularly sensitive given that the entire region is within 12 nm (~22 km) of the coast.

Viewshed analysis, as seen in Figure 22 (right), provides an indication of the visibility of sea from land around Wales. This largely reflects changing topography around the Welsh coastline that may increase visibility in certain regions, such as to the west of Snowdonia in Cardigan Bay, to the west of Anglesey in the West Irish Sea, and to the south of Cardiff and Newport in the Bristol Channel. However, it should be noted that this analysis is limited and a more detailed understanding of the visual influence of individual developments can only be gained through a Seascape and Visual Impact Assessment.

In contrast to the robust and substantial HRA and EIA procedures to assess environmental impact, seascape was identified in interviews as an area that requires further investigation to improve the evidence base for making planning and consenting decisions. Given the increased sensitivities in several coastal regions in Wales, this could be an area for Welsh Government to investigate more closely, through close collaboration with Natural Resources Wales and other relevant statutory bodies.

Figure 22. Left: Designated Coastal Landscape and Heritage Features in Wales [16]; Right: Land with sea views and sea visibility from land [15]



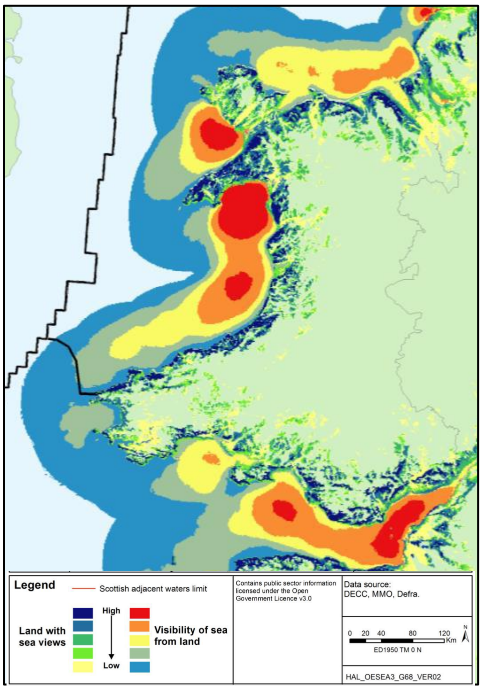


Table 16. Overview of potential seascape constraints in Wales

Area	Relative constraint	Comment
East Irish Sea	Minor	No protected areas and modest viewshed.
West Irish Sea	Med	Anglesey AONB; Llyn AONB.
Cardigan Bay	High	Snowdonia National Park; Llyn AONB.
Pembrokeshire Atlantic	Med	Pembrokeshire National Park.
Bristol Channel	Med	Densely populated with high viewshed.

3.3.3 Infrastructure

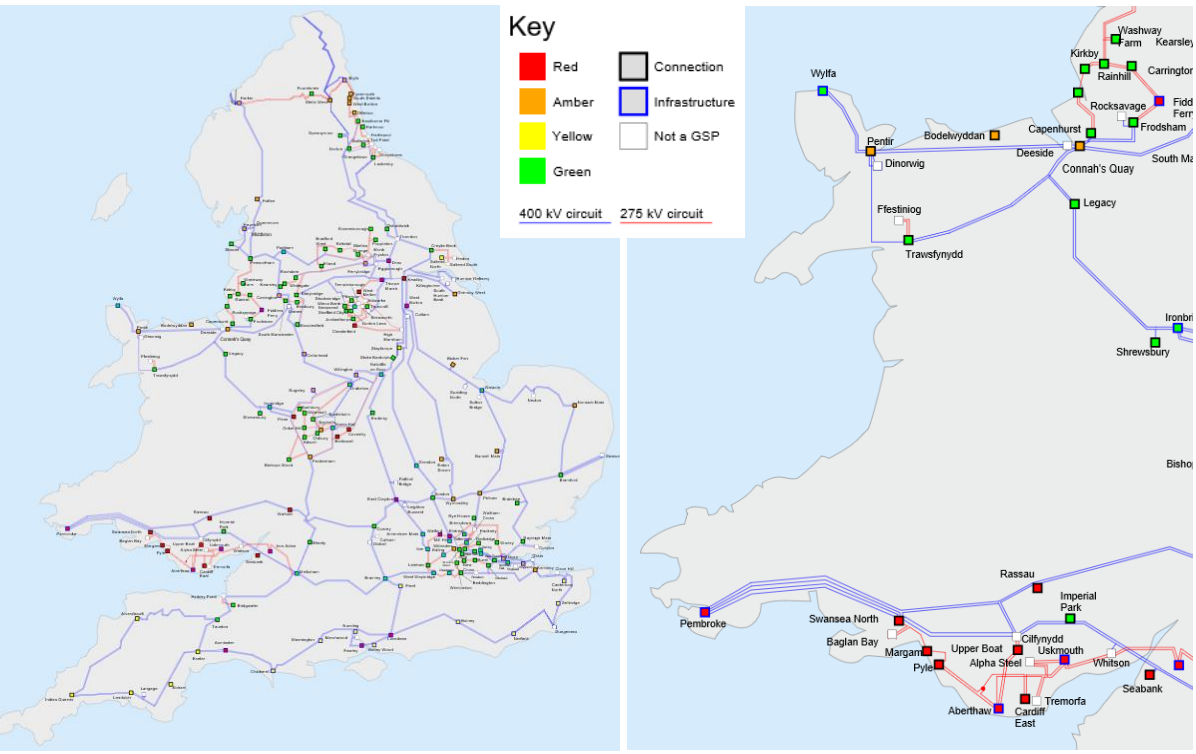
3.3.3.1 Grid transmission capacity

Overview: Utility scale offshore wind farms – ranging from hundreds of MW to GW capacity – require connection to the onshore transmission network. To minimise costs, onshore connection should be as close as possible to the project site and connect into existing high voltage transmission lines. Projects sited away from suitable grid connection points will either face higher offshore transmission costs to increase export cable lengths or onshore infrastructure upgrades to bring high voltage lines to a closer onshore landfall point. The latter is typically favourable and falls under the responsibility of National Grid, who will provide a connection offer to an offshore wind developer. While constructing the physical assets is not considered a major barrier, greater challenges may lie in obtaining consent to build new onshore infrastructure, which can increase the risk of delayed connection. New infrastructure may also result in higher transmission charges, which is undesirable for wind farm operators and may impact the competitiveness of a project. As such, in strategic planning there is a desire to maximise the utilisation of existing lines, which could favour sites in close proximity to established grid infrastructure.

Grid infrastructure in Wales: High voltage transmission assets in Wales are principally located along the north and south coasts, where population density and demand is greatest. This includes all 275kV and 400kV transmission lines connecting large-scale generation, interconnectors, and demand on the distribution network.

There is currently one interconnector operating – the 505 MW East-West Interconnector (EWIC) – linking North Wales to the Republic of Ireland, operational since 2012. Another, the Greenlink interconnector (500 MW), is planned to be commissioned in 2023, linking South Wales (Pembrokeshire) to the Republic of Ireland. While interconnectors can increase peak loads during certain periods, they are expected to deliver a net benefit for integrating a higher volume of renewable generation on the system.

Figure 23: Existing electricity transmission network in the UK and Wales [22]



The availability of 400kV lines in close proximity to prospective offshore wind farms off the north and south coasts of Wales makes these locations favourable for project siting. Interconnectors with the Republic of Ireland are also beneficial in adding new generation capacity in these areas. In contrast, Cardigan Bay lacks access to suitable grid connection points, which could be a significant barrier to connecting new capacity. While the transmission network could be extended, this would require building new transmission lines through rural parts of West Wales, potentially incurring significant investment costs and risks to obtaining consent.

Grid constraints in Wales: As well as having access to the physical assets, the addition of new power generation to the system also requires consideration of the available capacity and constraints on existing transmission lines. The transmission network can be constrained by several factors, including exceeding voltage limits, thermal limits, and short circuit limits, as a result of having too much generation in particular parts of the network. Importantly, grid constraints in Wales could result in landfall being made in England, which would prevent new offshore wind developments from contributing to Wales' renewable energy and decarbonisation targets, even if sited within the Welsh National Marine Plan area.

South Wales: There are high volumes of power generation in South Wales, which has resulted in severe constraints for new thermal generation capacity due to SQSS Winter Peak conditions. New thermal connections in the region will not be able to connect before 2026, unless grid reinforcement is approved or thermal capacity is released by the closure of old plant. For example, the decommissioning of some fossil fuel generation assets could alleviate constraints in South-East Wales over the coming decade (e.g. coal plants at Aberthaw and Uskmouth). The proposed Greenlink interconnector may also alleviate constraints in the South-West.

Despite these constraints on thermal generation, there is currently no restriction on renewables connecting in this region, with capacity still available for renewables at most grid supply points. This includes grid supply points (GSP) at Pembroke, Swansea North, Maragm, Pyle, Aberthaw, Cardiff East, and Uskmouth. The addition of offshore wind should therefore not be constrained in South Wales. However, depending on the location of sites in the Bristol Channel, landfall could also be made in south-west England, as proposed for the Atlantic Array project.

***North Wales*:** Transmission assets in North-West Wales have good availability at present, but the addition of the 3 GW Wylfa Newydd nuclear power station, if approved, could add constraints for other new generation. Pumped storage facilities at Dinorwig, Ffestiniog, and proposed at Glyn Rhonwy could help to manage excess generation. However, North-West Wales is likely to require grid reinforcement if new nuclear and additional new capacity, including offshore wind, is approved for development. For example, Wylfa Newydd and new offshore wind could add 4-5 GW of new capacity in a single region.

North-East Wales has two GSPs, at Bodelwyddan and Connah's Quay, both of which are currently under onerous operating conditions and approaching the limit at the GSPs. This could require developers to take a flexible operating arrangement, which would limit their ability to sell to the grid and without reimbursement for curtailment. Grid reinforcement is therefore expected to be required to connect new offshore wind generation, which could result in connection delays and higher grid charges to wind farm operators. Decommissioning of some existing generation plants by 2030 (e.g. CCGT plants at Connahs Quay and Deeside) could alleviate constraints. Alternatively, offshore wind farms in the East Irish Sea may connect into GSPs in England (Capenhurst, Birkenhead, and Lister Drive), which currently have good availability. This would have implications for meeting Wales' renewable energy and decarbonisation targets.

Grid reinforcement: The need for grid reinforcement may not necessarily be a barrier to adding new generation to the system. Reinforcement is a continual and ongoing process managed by National

Grid, who are mandated to provide a connection offer to new developers. The National Grid produces annual Electricity Ten Year Statements (ETYS) to identify reinforcement needs on the transmission network, which is translated into an evaluation of investment upgrades in a Network Options Assessment (NOA). The latest NOA (National Grid, 2017) recommended several grid investments for Wales, but these are not deemed to be necessary in the near-term, with no significant grid constraints expected in the 2020s (details of proposed upgrades in Appendix 2:). However, National Grid remain reactive to the development of new generation assets and would evaluate earlier upgrades should the need be apparent, for example, from the addition of new offshore wind capacity around Wales.

Consent and grid charging: As noted above, challenges are more likely to be faced in obtaining consent for new onshore transmission lines and the impact of higher transmission charges on project developers. For example, the Mid Wales Electricity Connection has been in development for over eight years and generators are still struggling to obtain consent. The potential for such delays could be a major risk to wind farm developers in areas needing reinforcement, such as Cardigan Bay.

Grid charges are specific to each project and need to be explored in detail following a connection application. As a general principle, however, the charging methodology considers the categorisation of the works involved to deliver the connection, depending on the number of beneficiaries from the new assets. If assets are installed solely for the use of one customer they may be liable for increased connection charges. Conversely, if the wider reinforcement work is driven by a number of customers and the works are classified as 'infrastructure' assets, the cost is not passed onto the generator and instead funded via network charges.

Given these potential barriers, reinforcement of existing assets is likely to be more effective than the development of new assets.

Table 17. Overview of potential grid constraints in Wales

Area	Relative constraint	Comment
East Irish Sea	High	400kV lines available, but GSPs at Bodelwyddan and Connah's Quay are constrained. Good availability at GSPs in England could mean that grid connection is made outside Wales.
West Irish Sea	Med	400kV lines available, but likely to become constrained if Wylfa Newydd nuclear power station comes online.
Cardigan Bay	Severe	No access to the transmission network, requiring considerable investment to connect prospective offshore wind farms.
Pembrokeshire Atlantic	Minor	400kV lines available. Thermal generation constrained at Pembroke GSP, but there is available capacity for new renewables.
Bristol Channel	Minor	275kV lines available. Thermal generation constrained at several GSPs, but there is capacity for new renewables.

3.3.3.2 Port infrastructure

Wales has a number of large ports that have traditionally been used for commercial shipping, cargo handling, passenger ferries, commercial fishing, and oil and gas activity. Major ports include Holyhead Port in Anglesey (north-west), Milford Haven, Pembroke Dock and Fishguard in Pembrokeshire (south-west), and Port Talbot, Swansea and Newport (south). Although a lack of offshore wind deployment has limited involved in the renewables sector to date, several of these major ports are expected to be suitable for servicing future offshore wind farms and a handful are already preparing necessary infrastructure upgrades to future proof their facilities for commercial offshore wind projects.

Further details on port infrastructure and supply chain capabilities in Wales can be found in section 4.2, but a summary regional analysis is outlined below.

North-East Wales (East Irish Sea)

Offshore wind deployment in the Irish Sea has meant that port activity in Wales has been concentrated in North Wales, most notably at the Port of Mostyn, which served as construction base for all three Welsh offshore wind farms and continues to serve as the operations and maintenance base for these projects. Low carbon and renewable operations are now a core part of activities at the port, with potential for further investment to upgrade facilities for the construction and operation of large-scale future deployments in the Irish Sea. Upgrades would include dredging works to host large construction vessels and the expansion of onshore areas for set-down of wind farm components. The port already has consent for expansion, but would require private investment and commercial contracts to proceed.

North-West Wales (West Irish Sea)

The Port of Holyhead is a busy cargo and ferry terminal in Anglesey. The port has a large roll-on, roll-off (RO-RO) berth for efficient loading and unloading of large freight and, potentially, offshore wind structures. However, offshore wind activity may clash with existing commercial operations, particularly ferry crossing operated by the port owner and operator, Stena Lines. Limited onshore set-down areas could also be a barrier to large construction campaigns, but the port would be well-positioned to serve as an operations and maintenance base for wind farms in the West Irish Sea and northern parts of Cardigan Bay.

West Wales (Cardigan Bay)

There are no major ports in Cardigan Bay, meaning that wind farm construction would need to be based elsewhere in Wales or the UK (e.g. Belfast). Operations and maintenance might be viable at smaller local ports, such as Aberystwyth, but would require investment and may lack proximity to suitable suppliers. Depending on a project's location, the O&M activities could be based out of the Port of Holyhead in North Wales or Fishguard in South-West Wales, but longer transit times would not be desirable for wind farm operators.

South-West Wales (Pembrokeshire Atlantic)

South-West Wales has three large commercial ports – Fishguard, Milford Haven, and Pembroke Dock. The close proximity of Milford Haven and Pembroke Dock either side of the Cleddau Estuary has supported a concentration and high volume of cargo and oil and gas activity over recent decades, making it the busiest port in Wales and one of the busiest in the UK. The concentration of oil and gas activity, including a large CCGT plant, oil refineries, LNG terminals and storage facilities, has created an energy cluster in the region. However, a decline in oil and gas activity has triggered efforts to diversify activity towards other sectors, including renewables. Pembroke Port is already hosting several wave and tidal device developers, including prototype deployment in the waterway, but is also preparing for future offshore wind developments.

Milford Haven Port Authority (MHPA) was previously in discussions to service the subsequently cancelled Atlantic Array project, but is now turning attention towards floating offshore wind, including the proposed Pembrokeshire Demonstration Zone pre-commercial project. The waterway has a deep mid channel that is suitable for transporting large floating structures, but would require investment to increase draft at the port-side and create a large slipway for off-loading structure, together with some redevelopment of onshore set-down areas. MHPA is currently awaiting approval for investment to begin redevelopment as part of the Swansea City Deal.

South Wales (Bristol Channel)

There are several active ports in South Wales, with the largest including Port Talbot, Swansea, and Newport. As the largest port with close proximity to steel works, Port Talbot could be particularly suitable for offshore wind development. The port was previously considered as construction base for the Glosten PelaStar floating wind demonstration off the coast of Cornwall, before issues around interference with military radar caused the project to be cancelled. The lack of a project pipeline has limited activity in offshore wind since, but Port Talbot could be suitable for commercial projects in the Bristol Channel, should they arise.

Table 18. Overview of port infrastructure in Wales

Area	Relative constraint	Comment
East Irish Sea	Minor	Port of Mostyn – established offshore wind track record and operations base, but investment required to upgrade for large-scale deployments.
West Irish Sea	Med	Port of Holyhead – large RO-RO berth for efficient loading and off-loading of large structures, but may conflict with existing commercial operations.
Cardigan Bay	High	No major ports available. Would be reliant on ports in North and/or South Wales, which could create logistical challenges. Potential to use Fishguard for projects further south.
Pembrokeshire Atlantic	Minor	Good facilities at Milford and Pembroke Dock ports. Actively pursuing investment to upgrade facilities for large-scale offshore wind deployment, partly expected through Swansea City Deal investment, if approved.
Bristol Channel	Med	Several ports available, with Port Talbot particularly suitable, but limited activity to diversify into offshore wind to date.

3.3.3.3 Road and rail links

Overview: Road and railway links are critical to facilitate the transit of people, smaller materials and smaller components between different locations. This is particularly relevant for ports, manufacturing, and assembly facilities that need to be accessed and supplied on a regular and timely basis.

Wales: Road links in Wales are more prevalent in North and South Wales. This includes the M4 motorway that stretches from west London to Cross Hands and several good quality A roads connecting Wales' major cities and ports along the north and south coasts. Motorway links between the north and south regions are available but more limited and could be more challenging for transporting large components. Rail links mirror a similar pattern, with good links along the north and south coast but limited rail links across mid-Wales.

Figure 24: Road (left) and rail (right) links in Wales [23]

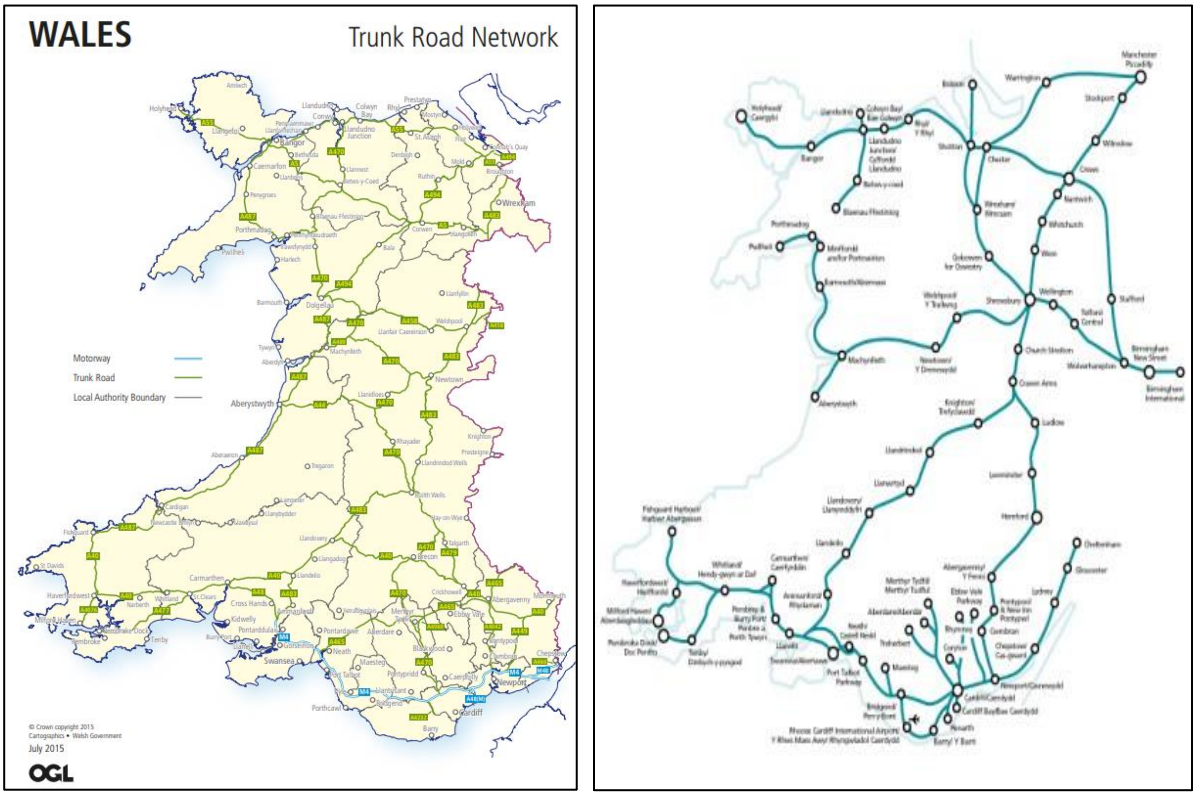


Table 19. Overview of road and rail links in Wales

Area	Relative constraint	Comment
East Irish Sea	Minimal	Excellent road and rail links.
West Irish Sea	Minor	Good road and rail links.
Cardigan Bay	Med	Road and rail links are more limited.
Pembrokeshire Atlantic	Minor	Good road and rail links.
Bristol Channel	Minimal	Excellent road and rail links.

3.3.4 Summary constraints analysis

3.3.4.1 Overall regional assessment

A comprehensive assessment of all environmental conditions, infrastructure, and constraints (hard and soft) requires the application of sophisticated spatial analysis tools and is beyond the scope of this study. However, based on the information available, some general assessments can be made, as outlined below for each of the four primary Welsh territories. It should be noted that a broad assessment such as this may not capture the variability of site conditions and constraints within each region, including pockets of seabed where constraints may be higher or lower than implied here. The Crown Estate has recently released more detailed site characterisation data (available via The Crown Estate website, from 26 Nov 2018) to inform the upcoming leasing process, which will provide greater granularity than is available here.

Outputs of hard constraints mapping from the latest Offshore Energy Strategic Environmental Assessment (OESEA3) are analysed in section 3.3.4.2, followed by a discussion of the alignment with Crown Estate favourable resource areas in section 3.3.4.3 and a summary of the near, medium, and long-term opportunities for offshore wind deployment in Wales in section 3.4.

Table 20. Summary constraints analysis for offshore wind development in Wales

	East Irish Sea	West Irish Sea	Cardigan Bay	Pembs. Atlantic	Bristol Channel
Environmental conditions					
Wind resource	Low/Med	Low	Low/Med	Low	Medium
Bathymetry	Low	High/Med	Low	High/Med	Low
Seabed geology	Low/Med	Medium	Low/Med	Low/Med	High/Med
Ocean waves	Low	Low	Low/Med	Medium	Low/Med
Ocean currents	Medium	Medium	Low	Medium	High
Consenting barriers					
Existing leases and military	High/Med	Medium	High/Med	Medium	Low/Med
Environmental impact	Medium	High/Med	High/Med	Medium	Medium
Other sea users	Medium	Low/Med	Low	Low/Med	Low
Seascape & visual impact	Medium	Medium	High/Med	Medium	Medium
Infrastructure					
Grid transmission	High/Med	Medium	High	Low/Med	Low/Med
Ports infrastructure	Low/Med	Medium	High/Med	Medium	Medium
Road and rail transport	Low	Low/Med	Medium	Low/Med	Low

Relative constraint: Low | Low/Med | Medium | High/Med | High

East Irish Sea

Good wind resource, shallow water depths, and mild wave climate makes this area attractive for offshore wind development. North-East Wales also has some of the best infrastructure to support offshore wind deployment, including transport links and port infrastructure, such Wales' premier offshore wind port at Mostyn. Grid connection could be an issue without reinforcement or the decommissioning of existing thermal generation. There is also a risk that Wales misses out on grid connection of offshore wind farms that connect into north-west England.

The East Irish Sea is likely to be constrained by existing leases for offshore wind farms and oil and gas activity. The clustering of existing leases, combined with the high volume of vessel traffic in Liverpool Bay, could add spatial constraints. While the area is arguably less environmentally sensitive than others around Wales on an individual project basis, the close proximity of several offshore wind farms could create concerns regarding cumulative impacts.

West Irish Sea

The West Irish Sea has some of the best wind resource in Wales, with average wind speeds exceeding 10 m/s in large areas. A mild wave climate is also favourable for offshore wind development. However, a more complex seafloor and bathymetry with variable water depths often exceeding 50m means that accessing these higher wind speeds could come at a higher cost for the wind farm foundations. Several pockets of seabed will be suitable for fixed foundations, but floating foundations will be needed to fully exploit this region. Seabed issues cited following the cancellation of the Rhiannon project could also add challenges.

Infrastructure is generally considered to be good, although grid constraints may become an issue if the 3 GW Wylfa Newydd nuclear plant is progressed. The Port of Holyhead would be well placed to support some construction activities and serve as an operations and maintenance base. Proximity to Belfast could also support construction, although this would limit the economic benefits to competing Welsh ports, such as Mostyn.

Consenting barriers are split by potential oil and gas leases to the north-west of Anglesey and MoD PEXA to the west of Anglesey and Llyn peninsula. However, these are not considered to be hard constraints so should not prove to be major barriers to project development.

Cardigan Bay

Cardigan Bay has good wind speeds, shallow seabed, and a mild wave climate that would be attractive for offshore wind deployment. However, a combination of environmental sensitivities from a large harbour porpoise SAC and a lack of infrastructure make this area challenging for development. The lack of grid and port infrastructure, in particular, could be major barriers to developing projects here, due to the high levels of investment that would be needed to connect to the transmission network and upgrade local port facilities. Poor road and rail links are also a barrier to building a robust supply chain in the area.

Pembrokeshire Atlantic

Exposure to the prevailing south-westerly Atlantic wind and swells means that the waters off Pembrokeshire have excellent wind speeds, often exceeding 10 m/s, but also a harsher wave environment than elsewhere in Wales. Significantly, water depths quickly increase to over 50m, suggesting that floating foundations are likely to be required, particularly if projects are located further from shore, which is likely given constraints from environmental impact and seascape near to the Pembrokeshire Coast National Park.

Grid infrastructure is constrained for thermal generation but should not be a barrier to new renewables. The Greenlink interconnector could also support the addition of new capacity. The region has good port infrastructure at Milford Haven and Pembroke Dock, which is already actively pursuing upgrades to future proof the port for potential offshore wind deployment.

Bristol Channel

Despite high energy demand and good infrastructure, environmental conditions in the Bristol Channel makes this area challenging for offshore wind development. In addition to lower average wind speeds, the Bristol Channel has complex seabed, including areas of hard rock, and is exposed to strong tidal currents from the Severn Estuary. Seabed conditions and tidal currents were the main drivers behind cancellation of the Atlantic Array project and it is considered unlikely that a developer would look to revive this site in the near-term, particularly given competition with other more favourable UK sites.

3.3.4.2 Application of hard constraints

The latest Offshore Energy Strategic Environmental Assessment (OESEA3) presents spatial analysis for offshore wind development following the application of hard constraints only. Hard constraints include existing Crown Estate seabed leases, aggregates licenses, oil and gas infrastructure, offshore marine cables and pipelines (500m buffer), MoD PEXA danger areas, and some primary navigation routes. It should be noted that the outputs from this constraints analysis is indicative only and that additional sites for offshore wind development could still be viable outside of the designated areas, pending further strategic analysis and site specific assessments. For example, MoD PEXA areas included as hard constraints here may be relaxed to unlock additional sites.

The constraints mapping is undertaken for both fixed foundation in 0-60m depth (Figure 26) and floating foundations in 50-200m depth (Figure 27). These constraints maps include the application of a 12 nm (~22 km) buffer. Although this 12 nm buffer zone is not a hard constraint, it is included here for illustrative purposes, given that constraints can be more acute closer to shore. However, it should be recognised that impacts, such as seascape, will be variable in their sensitivity relative to distance from shore and should assessed on a site-specific basis. An additional chart excluding the application of the 12 nm buffer is also included for fixed foundations (Figure 25). The removal of the 12 nm buffer has very limited impact on the potential for floating foundations, which are mostly located in deep water sites beyond 12 nm.

It should be noted that several Round 1 and 2 offshore wind farms, including all three operational projects in Wales, are located within the 12 nm zone. Future development within this boundary would be possible, particularly for site extensions, but is likely to face increased consenting risk for new lease sites due to increased interfaces with existing activities and seascape/visual impact issues, particularly given trends towards larger turbines and larger project sizes. Increasing distance from shore is also generally consistent with exploiting stronger wind resource.

Fixed foundations

Analysis of the available seabed following application of hard constraints largely aligns with the qualitative regional analysis presented above, with opportunities for the development of fixed-bottom offshore wind mostly concentrated in the West Irish Sea and western part of the East Irish Sea. This area partly correlates with the original Celtic Array Round 3 development zone, suggesting that the site remains viable for development. Indeed, the site could offer access to high wind speeds nearer to shore than alternatives off the east of England, an area which could also be more vulnerable to cumulative impacts given the extent of existing and planned deployment in the North Sea.

Floating foundations

The available seabed for floating wind is more extensive and is particularly concentrated off the south-west in the Pembrokeshire Atlantic. These sites are in areas with strong wind resource exceeding 10 m/s and relatively near to shore, which could facilitate reduced offshore transmission costs and improved logistics through close proximity to port facilities at Milford Haven and Pembroke Dock.

Prospective floating wind sites are also evident in the West Irish Sea. Much of this area overlaps with areas also suitable for fixed foundations in intermediate 50-60m depths. Given that such depths may be more challenging for cost-effective mooring systems, it may be considered that fixed foundation development is more likely in the near-term, with floating wind considered a longer term opportunity in the Irish Sea. However, if more detailed analysis identifies challenging seabed conditions for fixed foundations, floating wind could come into play sooner, with access to high wind speeds negating additional substructure and mooring system costs.

Figure 25: Offshore wind seabed area remaining following application of hard constraints buffer: Fixed foundations (0-60m depth) [15]

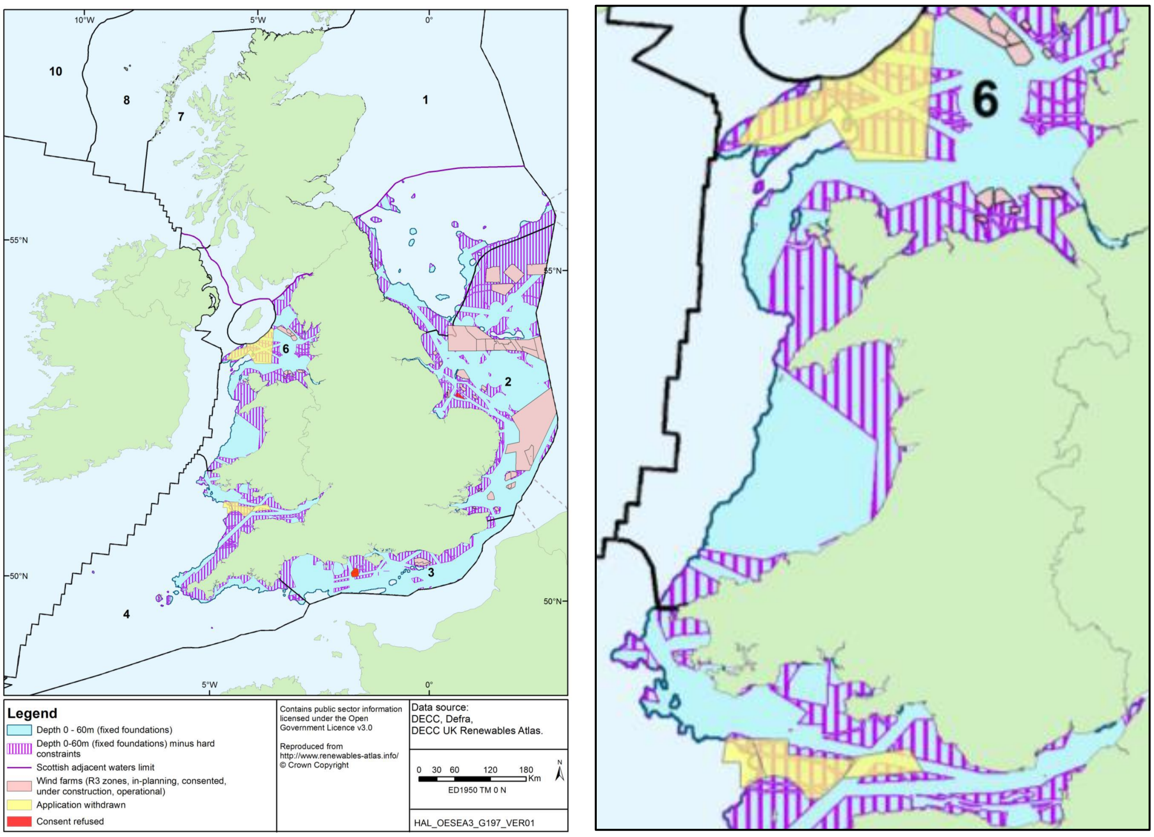


Figure 26: Offshore wind seabed area remaining following application of hard constraints and 12 nm buffer: Fixed foundations (0-60m depth) [15]

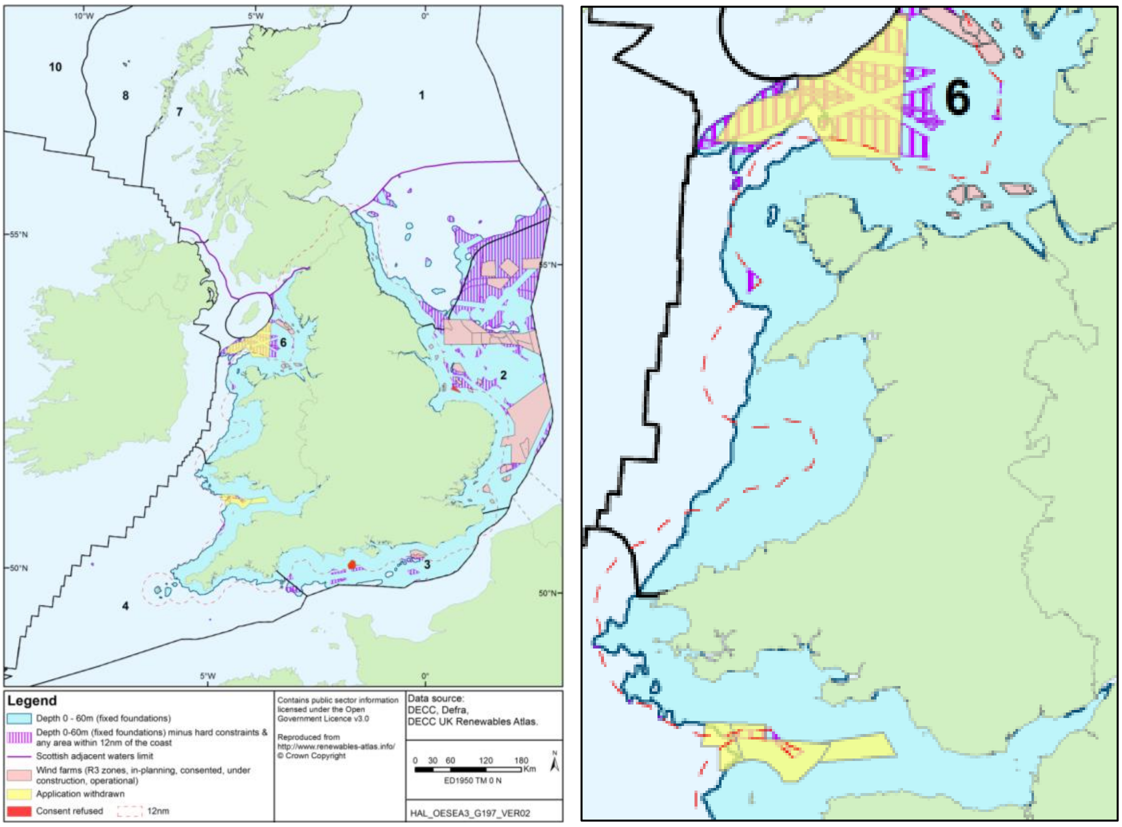
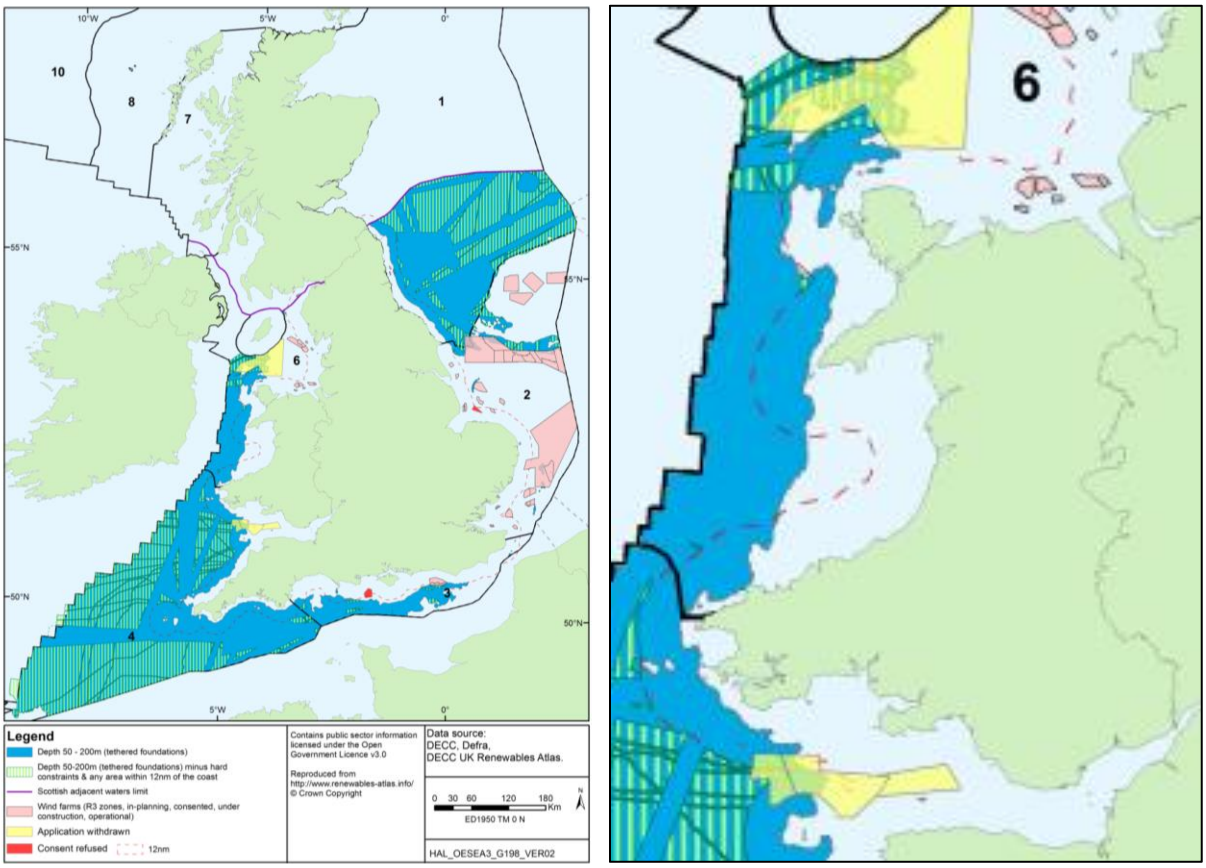


Figure 27: Offshore wind seabed area remaining following application of hard constraints: Floating foundations (50-200m depth) [15]



3.3.4.3 Alignment with Crown Estate favourable resource areas

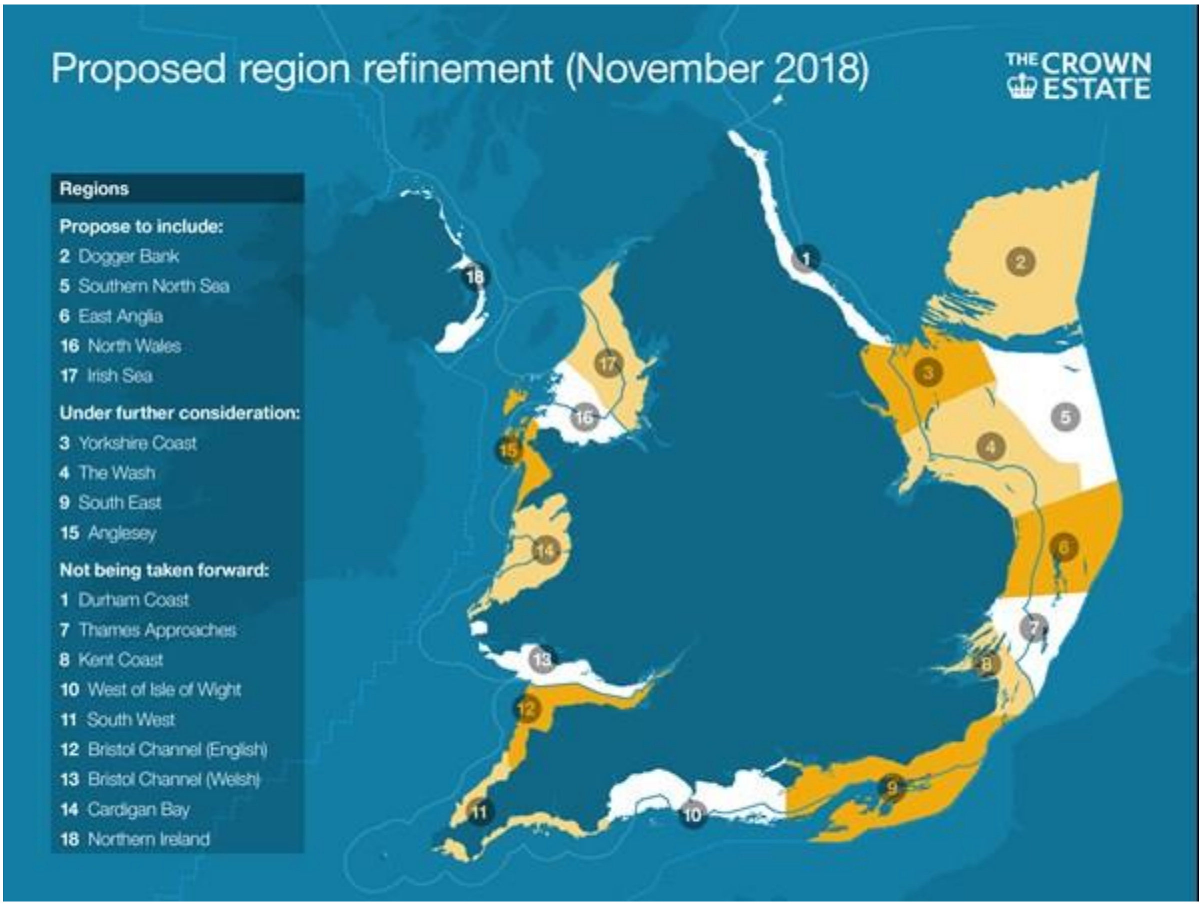
Overview

In preparing for a potential new leasing round in England, Wales, and Northern Ireland ('Round 4'), The Crown Estate has undertaken a period of stakeholder engagement and site characterisation mapping in order to inform site selection. Outputs from initial an initial site characterisation exercise led to the identification of 18 'favourable resource areas' that have been subject to further investigation and refined to five priority areas for proposed leasing and an additional four regions for further consideration. The proposed regions will be reviewed following a period of engagement with industry before a final set of locations are progressed for competitive leasing. A comprehensive geospatial site characterisation is expected to be made available to prospective developers to better inform project site selection.

The spatial analysis undertaken in this early assessment has focussed on water depth as the primary constraint, limiting favourable sites to those below 60m depth and therefore suitable for fixed foundations. Deep water sites suitable for floating technology are not expected to be included, unless there is sufficient market interest, but may feature in future leasing processes beyond Round 4.

It should be noted that the resource areas identified are subject to change and that The Crown Estate will respond to feedback and market interest when determining the final areas that will be made available for competitive leasing.

Figure 28. The Crown Estate proposed regions for upcoming leasing [14]



NOTES: *'Favourable' technical resource area for fixed foundation offshore wind defined by water depths 5-60m and good accessibility (>80%@2.5m Hs).*

Implications for Wales

Of the 18 areas originally identified, four are located in Wales. These broadly align with the five regions assessed in this study, but with the Crown Estate's analysis combining the Pembrokeshire Atlantic and Bristol Channel into a single resource area. Following a recent announcement by The Crown Estate in November 2018, North Wales (TCE area #16) has been identified as one of five UK regions deemed most suitable for Round 4 leasing, while Anglesey (TCE area #15) has been included as one of four regions for further consideration. This is in close agreement with the results of this study, which highlighted the areas off North Wales and Anglesey as the most promising for offshore wind development, due to high wind speeds, good grid and port infrastructure, and water depths suitable for fixed foundations.

This represents an excellent opportunity to secure large lease areas and a long-term project pipeline for future offshore wind development in Wales. Welsh Government should support The Crown Estate with the further investigation activities in the Anglesey region to maximise opportunities for potential leasing, as well as proactively engage with the market to attract interest from prospective developers.

While the latest announcement is positive for the North Wales region, it does suggest that there will be limited opportunities for large-scale deployment off West and South Wales, at least in the near-term. Cardigan Bay (TCE area #14) is the largest favourable resource area identified, but the application of additional constraints, including environmental sensitivities and the availability of suitable grid and port infrastructure, are barriers to development in this region.

Water depth constraints are the main drivers behind the Pembrokeshire Atlantic (western side of TCE area #13) not being taken forward in Round 4 leasing. It is considered highly unlikely that fixed foundation projects would be progressed near to shore given the environmental and seascape impact sensitivities near to the Pembrokeshire Coast National Park. It would require relaxing the water depth constraint to include floating foundations in order for commercial-scale developments to become available. While this is unlikely in Round 4 leasing, it could be viable in subsequent rounds during the 2020s. Excellent wind speeds and access to good port and grid infrastructure could make this region attractive once floating technology has been matured to commercial-scale readiness. It should be noted that demonstration and pre-commercial projects will still be possible through The Crown Estate's open-door policy for projects up to 100 MW capacity. However, given the minimum project capacity of 300 MW for competitive leasing, this leaves a gap for projects of 100-300 MW, which are expected to be a likely scale for first commercial floating wind projects.

The Bristol Channel (eastern side of TCE area #13) is unaffected by the water depth constraint, however, the area is considered to be technically challenging for offshore wind development, largely attributed to strong tidal currents and complex seabed geology. Proximity to shore could also increase seascape concerns. Much of the former Atlantic Array site is captured by this area and considerable site data would be readily available, but the site may be less desirable in the context of more favourable sites elsewhere in the UK. It should be noted that prospective projects in this area may also be captured by TCE area #12 off North Devon. As such, it is possible that wind farms may connect into the grid at Devon (as proposed with Atlantic Array), thereby not contributing to Wales' renewable energy generation. However, South Wales would be well positioned to capture local economic benefits through supporting the construction and maintenance of the wind farm.

3.4 Priority opportunities

Wales has abundant wind resource in offshore locations that could be exploited by both fixed and floating offshore wind technology. Offshore wind could deliver high volumes of low carbon renewable power to consumers in Wales, making a material contribution to 2030 and 2050 renewable energy and decarbonisation targets.

While opportunities for adding offshore wind capacity up to 2050 are considerable, the existing UK offshore wind portfolio indicates that opportunities for deployment prior to 2030 could be more limited. Given development timescales of 6-10 years for large-scale offshore wind projects, building a pipeline of projects for deployment up to and beyond 2030 should be a priority for Welsh Government. The primary deployment opportunities are summarised into near-, medium-, and long-term time horizons below.

Timeframe	Opportunity	Deployment expectation
Near-term	Site extensions	Mid 2020s
Medium-term	New leasing	By 2030
Long-term	Floating wind	Beyond 2030

Near-term (mid 2020s) – Site extensions

In the absence of a pipeline of new projects, site extensions of existing projects represents a key opportunity for Wales to add to its generation fleet within the next decade. Gwynt-y-Môr wind farm has been submitted as one of eight projects in the UK. Assuming that the request is for the maximum allowable capacity (up to the original project capacity) this could add 576 MW of offshore wind power in Wales.

An extension of Gwynt-y-Môr could represent a 'low hanging fruit' opportunity for Wales. The availability of considerable site data and established relationships with key stakeholders should reduce development costs and streamline the consenting process. The project can also draw on a better understanding of the true environmental and social impact of the original development to mitigate perceived risks from an extension. Once operational, there are substantial O&M synergies with the existing wind farm that can support cost reduction. As such, extension projects are expected to be highly competitive in UK CfD auctions, increasing the probability of commissioning within the 2030 time horizon.

Nevertheless, there remain barriers to progressing an extension project. The application has been accepted by The Crown Estate but will now be subject of a plan-level Habitats Regulation Assessment (HRA) to evaluate the impact of further development on relevant nature conservation sites. Assuming this still allows the extension to progress, an Agreement for Lease will need to be negotiated/agreed with the Crown Estate. Following this, the project will need to obtain planning consent, a process which will be in excess of 4 years from start to finish assuming it is successful. The project could also be susceptible to seascape challenges, given the close proximity to shore and industry trend towards larger turbines, as well as conflicts with busy shipping routes into Liverpool Bay.

Extending the lifetime of existing operational assets could also support Wales in meeting its 2030 renewable energy target, with North Hoyle and Rhyl Flats (combined 150 MW capacity) both approaching the end of their design lives in the late 2020s.

Pilot and demonstration projects (up to 100 MW) could also be a near-term opportunity for technologies such as floating wind deployment at the Pembrokeshire Demonstration Zone.

Medium-term (by ~2030) – New leasing

New leasing rounds from The Crown Estate are a crucial opportunity for Wales to secure a pipeline of projects up to and beyond 2030. Wales will need to maximise allocation of the up to 7 GW of capacity that could be made available in Round 4. North Wales has been prioritised as one of five regions for proposed leasing, with Anglesey under further consideration. High wind speeds in relative close proximity to shore, as well as access to good port and grid infrastructure, should make sites in these regions attractive to prospective developers.

Although classified as a medium-term opportunity in terms of expected timeframe to deployment, with proposed resource areas expected to be finalised by early 2019 new leasing is an immediate priority for Wales to ensure that it capitalises on the opportunity to build a pipeline of projects that can attract investment in Wales' energy infrastructure.

Beyond Round 4, there may be additional opportunities for new leasing in the early 2020s, which could open opportunities for development in regions outside North Wales. While opportunities for shallow water depths are likely to be concentrated off the North and South coasts, deep water sites also hold considerable potential off the South-West and North-West of Wales, once floating wind technology matures to commercial-scale readiness.

Long-term (beyond 2030) – Floating wind

Fully exploiting Wales' offshore wind resource will require moving into deep water sites using floating foundations. Wales possesses considerable wind resource in deep waters off Pembrokeshire, as well as pockets of deep water off the north-west. The technology is currently not considered sufficiently mature or cost competitive for inclusion in the upcoming Crown Estate leasing round, but subsequent rounds may require floating technology in order to build a post-2030 pipeline that can meet the UK industry's 50 GW target by 2050. Taking a leading role in commercialising floating wind technology, starting with the 90-180 MW Pembrokeshire Development Zone, could deliver economic benefits to Welsh companies active in the sector, particularly given the synergies with existing wave and tidal activity in Wales.

Although currently omitted from upcoming leasing process, it should be noted that The Crown Estate will be responsive to market interest. Commercial-scale floating wind could become a nearer term opportunity in Wales if there is sufficient appetite from a developer to invest the necessary development expenditure to bring a project to market.

3.5 Policy levers to support increased deployment in Wales

Policies affecting offshore wind development in the UK are largely controlled by central UK Government in Westminster. As such, the scope for policy intervention from Welsh Government is rather limited. Nevertheless, there are opportunities for Welsh Government and local authorities to either influence national UK policy or introduce measures that can help to accelerate offshore wind development in Wales and maximise the associated economic benefits. These are outlined in the subsequent report sections:

- Site identification, development, and consent
- Support mechanisms
- Local ownership

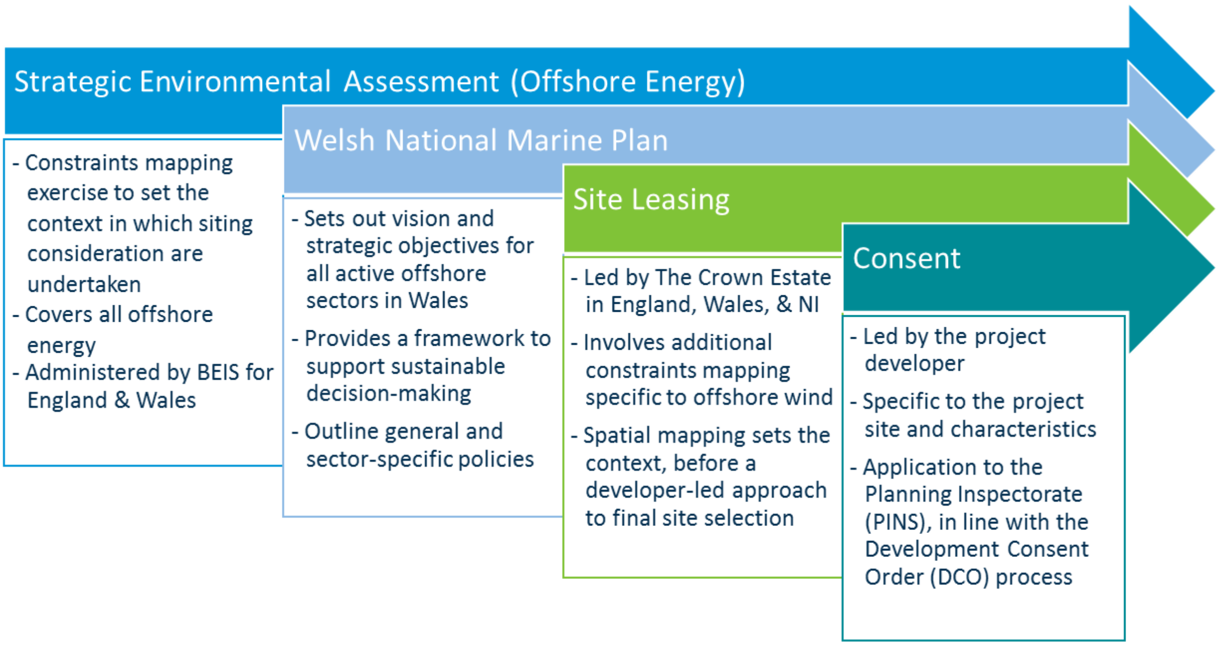
3.5.1 Site identification, leasing, and consent

3.5.1.1 Current status

Offshore wind development follows a process of strategic planning, site leasing, and project consent (Figure 29). The identification and leasing of sites is a vital first step to build a pipeline of projects that can attract investment from developers and the surrounding supply chain. Effective spatial planning and constraints mapping at the outset is also a crucial means of managing competing seabed interests and minimising the environmental and social impact of offshore wind development, both for individual projects and the cumulative portfolio of assets. A greater emphasis on strategic studies up-front can help to avoid conflict and potential issues later on in the development process.

Once lease agreements have been assigned, the project developer will lead the process to obtain planning consent, but can be supported by government initiatives to streamline the process and mitigate potential consenting risks.

Figure 29. Offshore wind site identification, development, and consenting process in Wales



3.5.1.2 Role of Welsh Government

Strategic planning

Welsh Government are a consultee to the BEIS Offshore Energy Strategic Environmental Assessment (OESEA) and lead the delivery of the Welsh National Marine Plan (WNMP). These initiatives are considered complementary. The OESEA, with a dedicated focus on offshore energy, provides a valuable resource on existing environmental characteristics and human activities around England and Wales, including policies set by the UK and Welsh Governments. The WNMP provides an expanded scope that considers outputs from the OESEA, as well as other marine activities of strategic importance to Wales. The Crown Estate support the Welsh Government in the marine planning process evidence gathering activity. Collectively, the OESEA and WNMP set the context for siting considerations and outline a framework to support sustainable decision making in Wales.

Site leasing

Seabed leasing in England, Wales, and Northern Ireland is led by The Crown Estate. Welsh Government are a key consultee in the leasing process and can provide input to inform the location of potential new leases. However, decision making rests with The Crown Estate and there is no dedicated allocation for sites in Wales. Welsh Government can support the initial spatial mapping process, but, ultimately, site selection will be determined by the market through a developer-led approach. It should be noted that two regions of Wales are currently among nine UK regions under consideration for Round 4 leasing.

In Scotland, leasing of sites has been devolved through the establishment of Crown Estate Scotland in 2017. This could be a consideration for Wales in order to obtain greater powers in the site identification process. A legal separation such as this would require a comprehensive evaluation that is outside the scope of this study. In the context of offshore wind, it should be acknowledged that, according to current policy, projects would still have to compete for central UK government contracts, so there would be no guarantee of increased deployment.

Consent

Currently, approval of offshore wind projects in Wales typically requires the following permissions: (1) a Development Consent Order to construct and operate a wind farm (above 100MW) from the UK Secretary of State, (2) a marine licence from NRW for projects within 12 nautical miles (or deemed by the DCO for aspects of the development that are beyond 12 nm) and potentially[8] (3) planning permission for the connection to land from the Local Planning Authority. In the unlikely event of an offshore wind farm project under 100MW capacity coming forward, these would need to be consented under s36 of the Electricity Act (currently determined by the MMO) and they would also require a Marine Licence and planning permission. NRW acts as consultee to each of these approvals.

From April 2019, Welsh Ministers will have greater responsibility for energy consenting decisions, as part of changes arising from the Wales Act 2017. This will include consenting decisions for offshore energy generation assets up to 350 MW, via the Section 36 Electricity Act. However, this is unlikely to capture most offshore wind developments, which typically exceed 350 MW[9]. Planning permission and consent for projects exceeding 350 MW will remain under the control of the UK Secretary of State via the Development Consent Order (DCO) process administered by the Planning Inspectorate (PINS).

[8] N.B. The changes in the Wales Act now allows for associated development to be in a Development Consent Order (DCO), so planning permission may not always be required.
[9] NRW will have responsibility for awarding planning permission to demonstration and pre-commercial projects <350 MW, such as the Pembrokeshire Demonstration Zone.

NRW will continue to determine Marine Licenses for development within 12 nautical miles (nm) and act as a consultee for developments within and beyond 12 nm.

Welsh Government has recently consulted on proposals for a new consenting regime for major infrastructure projects in Wales up to 350 MW, although there is no timetable for the introduction of a new consenting regime.

Given the changing landscape for consenting in Wales, the Welsh Government could support industry by publishing clear guidelines on the approach and necessary steps for obtaining consent in Welsh offshore wind projects (and renewable energy projects more broadly). This could replicate similar efforts by public bodies in other countries to offer guidance to prospective developers, such as RVO in the Netherlands.

In the long-term, increasing the threshold for Welsh Minister approval to 1.5 GW, in line with The Crown Estate capacity limit for new leasing, would ensure that Welsh Ministers can take full control of consenting decisions for the foreseeable future. However, with the Wales Act 2017 still yet to fully come into force, it is considered unlikely that the threshold will be increased further, at least in the near-term. The priority for Welsh Government in the near- and medium-term should be to work closely with BEIS, PINS, MMO, NRW, The Crown Estate, and other relevant bodies to ensure that Welsh interests are fully considered in consenting decisions.

3.5.1.3 Key considerations

The site identification, leasing and consenting processes are all underpinned by need to make informed decisions from a robust evidence base on the expected environmental and social impact of offshore wind development. For early offshore wind developments, a conservative approach was adopted due to the lack of deployment and higher perceived risks. With nearly 8 GW of offshore wind installed in the UK and over 20 GW installed globally, there is now an improved understanding of the true impact of offshore wind farms, which can support better informed decisions. Nevertheless, there remain several uncertainties that must be considered and require further investigation.

Some of the most significant items identified in stakeholders interviews include:

- Bird collision risk
- Acoustic disturbance during wind farm construction (marine mammals)
- Displacement and habitat loss (various)
- Barrier effects (marine mammals and seabirds)
- Fishery impact
- Seascape and visual impact
- Cable routing and landfall
- Cumulative impacts

Several of these items have been the focus of important research studies that have improved the evidence base on the real impact of offshore wind farms. An example includes bird collision, which was the focus of a 3 year monitoring programme under the Offshore Renewables Joint Industry Programme (ORJIP). The results suggest that bird collision risk is lower than originally anticipated and the body of data has been made available for further research and analysis.

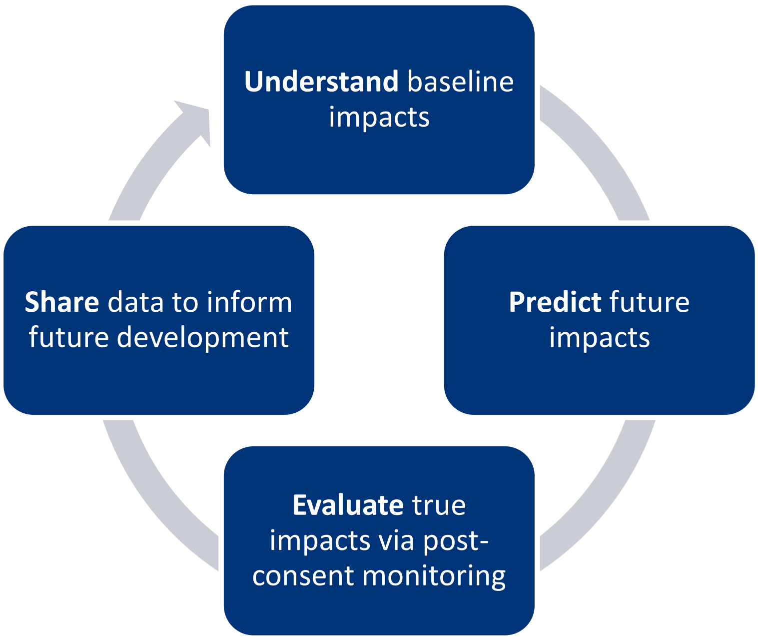
Cumulative impacts was highlighted as a priority for future research as the fleet of UK offshore wind assets grows, both from an environmental and human interaction perspective. This, like most items identified, is not unique to Wales and would be best addressed through industry-wide initiatives. Although Wales may be less sensitive to cumulative impacts than other parts of the UK, such as the east coast of England, Wales has a large number of protected marine areas which include several mobile species, such as harbour porpoise. It should be noted that, across the UK, there are now more protected areas since the Round 3 leasing process in 2008-2010.

Seascape was highlighted as an issue that could be particularly sensitive in Wales, given the importance of tourism to many coastal communities. In contrast to the Habitats Regulation Appraisal and Environmental Impact Assessment, which provides comprehensive coverage of environmental issues, seascape assessment is less well defined and would benefit from further research. The impact of offshore wind development on commercial fishing activities is another area where the evidence base could be improved.

3.5.1.4 Approach to risk mitigation

Improving the evidence base to manage and mitigate these potential risks requires scientific research studies before and after consent. Before consent, strategic planning should aim to identify impacts early and express them visually via spatial mapping tools to inform site location. More detailed site specific studies, via Habitats Regulation Appraisals (HRA) and Environmental Impact Assessments (EIA), can improve the robustness of assessments on the baseline and predicted future impacts. Ongoing post-consent monitoring should then be implemented to evaluate the true impact and data should be shared to inform future offshore wind development.

Figure 30. Approach to improving the evidence base for offshore wind impact assessments



Industry-wide research initiatives have proved to be an effective means of undertaking strategic research studies to support offshore wind development. Programmes such as COWRIE (Collaborative Offshore Windfarm Research Into the Environment) and ORJIP (Offshore Renewables Joint Industry Programme) have been successful in providing a platform for public bodies, industry players, and key stakeholders to collectively address key issues. Industry interviews highlighted that participating in these initiatives would give Welsh Government more of a voice in informing strategic research priorities, as well as providing access to valuable research outputs.

Data sharing is largely enabled by the Marine Data Exchange, a portal hosted by The Crown Estate. Interviews with industry stakeholders suggested that there would be little benefit in creating additional data sharing tools, but Welsh Government should support the Marine Data Exchange and encourage more data sharing from Wales-based project and research studies.

3.5.1.5 Policy levers for Welsh Government

Given the context above, the following priorities for Welsh Government have been identified to support site identification, development, and consent.

Site identification and leasing

- **Work with The Crown Estate** to inform resource area identification and site selection for upcoming and future leasing rounds. This will include supporting the further investigations needed to evaluate proposed regions around Wales.
- **Share information on prospective sites in Wales** (e.g. environmental data) to inform market interest from the developer community.
- **Pro-actively engage with developers** to demonstrate support for offshore wind development in Wales and gauge market interest for Welsh sites in upcoming and future leasing rounds.
- **Ensure alignment between Welsh Government and NRW** on a collective approach to offshore wind development, in line with responsible development. However, this should preserve the integrity and independence of NRW as a statutory consultee and the Welsh Ministers decision-making responsibilities under the Marine & Coastal Access Act (Marine Licence).

Consent

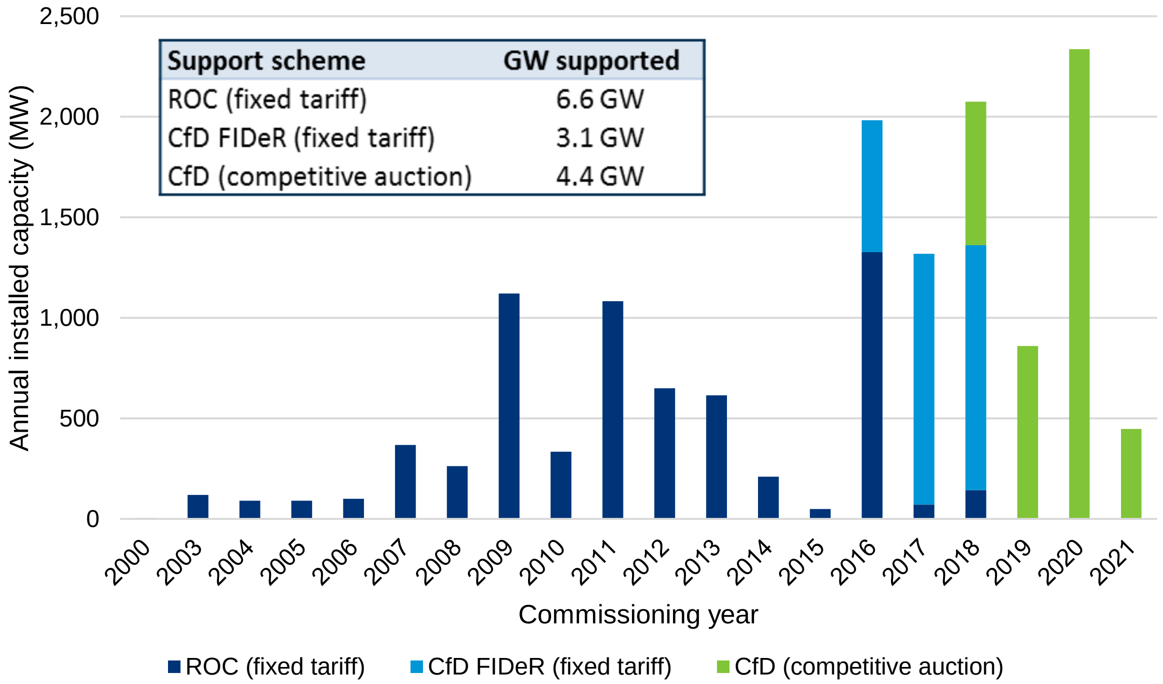
- **Be public in support** of offshore wind development and work with developers to mitigate consenting risks and gain local stakeholder support. This should include highlighting the benefits of offshore wind to local stakeholders.
- **Publish clear guidance on the consenting process for offshore wind projects in Welsh waters** to encourage market interest and improve the level of clarity and certainty for prospective developers.
- **Participate in industry-wide research studies** to address key strategic issues for offshore wind development (e.g. ORJIP-Wind).
- **Support universities and research bodies** to undertake dedicated studies on issues that are critical to Wales, but not addressed through industry-wide initiatives (e.g. seascape issues).
- **Encourage and support post-consent monitoring** at wind farms in Wales. Where possible, seek to make data public and available for inclusion in research studies.
- **Encourage data sharing** via the Marine Data Exchange to develop a repository of high resolution environmental data, including wind speed, bathymetry, geology, and environmental receptors (flora and fauna).
- **Evaluate potential to increase Welsh Ministerial power** to grant consenting to projects up to 1.5 GW capacity.

3.5.2 Support mechanisms

3.5.2.1 Current status

The UK has adopted a range of support mechanisms for offshore wind. Higher risk early projects, including North Hoyle and Rhyl Flats, were supported by a combination of capital grants and revenue subsidy through the Renewables Obligation (RO). Following Electricity Market Reform (via the 2013 Energy Act), the RO was replaced with the Contracts for Difference (CfD) mechanism[10], which provides revenue stabilisation through a fixed feed-in premium over a 15 year period. In contrast to the RO, CfD contracts are awarded through a competitive process, determined by price in a competitive auction. The level of capacity supported in each auction round is determined by the available funding from the allocated Levy Control Framework budget, the administered strike price (cost per unit of electricity generated), and assumptions on the wholesale electricity price[11].

Figure 31. UK offshore wind capacity by support mechanism[12]



The increased competition has had a dramatic impact on cost reduction, with the latest CfD auction delivering a strike price of £57.50/MWh, sufficient to support 3.2 GW of capacity from three offshore wind projects[13]. This was achieved by drawing down on just 60% of the available £295m budget.

BEIS has committed £557m to CfD auctions every two years up to 2030, starting from 2019. The level of capacity capable of being supported will be determined by future wholesale power prices and CfD strike prices, but current market trends indicate that ~2-4 GW could be supported per round, equating to ~1-2 GW per year. This could potentially be sufficient to meet the 30 GW by 2030 target, if auction

[10] CfD available from 2015. RO closed in 2017.
[11] The CfD mechanism pays generators the difference between the strike price and wholesale power price. If wholesale prices exceed the strike price, the generators pays back to government.
[12] FIDeR (Final Investment Decision Enabling for Renewables) was introduced to smooth the transition between RO closure and the competitive CfD mechanism.
[13] Two projects at £57.50 – Hornsea TWO (1,386 MW) and Moray East (950 MW); one project at £74.75 – Triton Knoll (860 MW).

strike prices continue to fall and wholesale prices rise. A recent announcement in from BEIS in November 2018 has indicated a budget of £60m will be made available for the next allocation round (AR3) in Spring 2019, with a cap of 6 GW for the delivery years 2023-24 and 2024-25.

It should be noted that BEIS will be undertaking its five year review of Electricity Market Reform (EMR) during 2018, which may introduce changes to the CfD mechanism (most likely beyond AR3). Notably, rapidly falling strike prices and rising wholesale prices could result in offshore wind becoming subsidy-neutral within the next EMR period. This has led to calls for the introduction of a revenue stabilisation mechanism [24] to limit exposure to volatile wholesale market prices, which may include a floor price to mitigate the risk of price cannibalism as the share of renewables in the system increases and causes price depression during periods of high wind and solar generation [25]. Allowing renewables to participate in the capacity market could also unlock new revenue streams for offshore wind.

There is currently no mechanism outside the competitive CfD process to support full-scale demonstration or pre-commercial projects for innovative technologies, such as floating wind.

3.5.2.2 Role of Welsh Government

The Welsh Government currently has very limited powers to influence the existing CfD mechanism or introduce new support mechanisms. Influencing opportunities are generally limited to lobbying UK Government. However, Welsh Government has previously proposed financial support for renewable projects, most notably in offering a £200m equity investment towards the Swansea Bay Tidal Lagoon.

A range of potential levers are outlined below. These measures are proposed for consideration only and would require a more comprehensive evaluation to determine their suitability.

3.5.2.3 Policy levers for Welsh Government

Although policy levers to directly influence additional offshore wind capacity are limited, Welsh Government could consider policy interventions that:

1. Improve the competitiveness of projects in competitive UK CfD auctions by reducing the cost of capital;
2. Bypass the CfD process through power purchase agreements; or
3. Provide a route to market for demonstration and pre-commercial projects

1: Reducing the cost of capital

The provision of low cost capital could reduce the financing cost of offshore wind projects in Wales, improving their competitiveness in UK CfD auctions. Public investment could also contribute towards Wales' local ownership targets (see 3.5.3).

- **Equity investment:** Welsh Government could take an equity stake in a project, offering investment on favourable terms, as proposed for the proposed Swansea Bay Tidal Lagoon. Alternatively, a new publically-owned entity could be established to operate on a similar basis to the UK Green Investment Bank, prior to its privatisation.
- **Debt finance:** Welsh Government, or an equivalent public body or publically-owned company, could offer debt finance at preferential rates.

Challenges to consider:

- ***Sufficient low cost capital in the sector:*** Despite concerns over the shortage of capital in the sector's formative years, these risks have not materialised. Offshore wind has benefitted from the availability of low cost capital from commercial lenders and investors in recent years, making a material contribution to cost reduction. A diverse range of sophisticated investors are active in the sector, which limits the need for and potential impact of separate public finance.

- ***Competition law***: Public intervention will be subject to competition law, including State Aid regulations (or equivalent competition laws following Brexit).

- ***Cost of setting up a dedicated entity:*** Establishing a dedicated entity to develop or offer low cost finance to renewable projects in Wales could be significant. Offering finance through existing channels, coordinated by the Wales Infrastructure Investment Plan and Development Bank of Wales would be advantageous.

2: Power purchase agreements

Making separate off-take arrangements available to generators through power purchase agreements (PPAs) could allow projects to bypass the CfD process and associated competition with other UK offshore wind projects. Particularly considering the 5-10+ year timeframe for new offshore wind developments in Wales, offshore wind is expected to be highly competitive and potentially subsidy-neutral, making it an attractive choice for public and private bodies looking to secure their electricity supply on a stable long-term contract. Changes through upcoming EMR reviews could also alter the advantages of government CfD contracts relative to alternative PPA arrangements.

- **Welsh Government and public sector as off-taker:** Welsh Government and wider public sector is a large consumer of electricity. Welsh Government and/or separate public sector bodies, including local authorities, may consider securing power purchase agreements with offshore wind farm generators in Wales.

- **Industrial and corporate off-takers:** The corporate PPA market in Europe is growing rapidly. Wales has several large energy consumers, including steel producers in South Wales, that could provide an alternative route to market for Welsh projects. This could also include gas-to-wire and enhance oil recovery in some offshore locations.

Challenges to consider:

- ***Scale of offshore wind projects:*** Given typical offshore wind project capacities of 0.5-1.5 GW, it is unlikely that a single off-taker will be able to procure the full project capacity. A 1 GW offshore wind farm would be expected to generate ~3.5-4.4 TWh per year, which is ~19-24% of total electricity consumption in Wales. PPAs are therefore only likely to be viable for small scale projects or for partial off-take arrangements.

- ***Duration of off-take agreements:*** Although private PPAs can provide valuable revenue stability, the duration of contracts is typically ~5-10 years, considerably lower than 15 year government contracts.

- ***Competition with onshore renewables:*** Given the challenges above, smaller scale onshore renewables may be more attractive to public and private energy consumers, limiting the opportunities for offshore wind to secure PPA contracts.

3: Demonstration and pre-commercial projects

Given that mechanisms are already in place in the UK to support utility-scale projects, Welsh Government could have greater impact by providing financial support for innovative technologies that currently do not have a route to market, including floating offshore wind. Wales has historically benefitted from European Structural Funds, via the Welsh European Funding Office (WEFO), which has committed £2bn to various initiatives in Wales, including renewable energy. However, with this source of funding set to expire in 2020 and the UK leaving the EU, Wales will need to introduce alternative support mechanisms for early stage renewable projects.

Options for direct intervention from Welsh Government include:

- **Capital grants:** Grant funding towards innovative demonstration projects (within competition law constraints).
- **Equity or debt finance:** Low cost capital on favourable terms, as in #1, above, but arguably with an ability to have greater impact given the challenges of securing investment in higher risk technology demonstrations.

Options for indirect intervention from Welsh Government, through lobbying and influencing UK Government policy, include:

- **Ring-fenced CfD:** A portion of the available CfD budget (or underspend) could be reserved for more innovative pre-commercial projects, such as floating wind, wave, and tidal energy. Allocation could be capacity or budget constrained to control government spend.
- **Innovation PPA:** Power purchase agreement, as above, but with wholesale prices supplemented by a top-up payment to a reference strike price. The mechanism is similar to a contract for difference, but funded through government taxation, as opposed to charges on consumer energy bills.
- **Commercial follow-on project:** Securing a commercial-scale lease off the south-west of Wales would improve the attractiveness of the Pembrokeshire Demonstration Zone, which could act as a springboard to large-scale deployment. Welsh Government would need to exert influence on The Crown Estate to include deep water sites in future leasing rounds and/or increase the 100 MW threshold for open door applications, as well as engage with prospective developers to generate market interest.

3.5.3 Local ownership

3.5.3.1 Current status

While not necessarily a direct lever to increasing deployment, local ownership of renewable energy projects is an increasingly important area for several governments, including Wales, that future offshore wind developments will need to comply with. Local ownership is believed to deliver both financial and non-financial benefits, including revenue generation, job creation, and greater control and autonomy for local communities. The majority of locally-owned renewable energy projects consist of small-scale onshore renewables, such as wind, solar, biomass, and hydro power schemes, where the lower generation capacity and investment requirements lend themselves to greater levels of community involvement.

In contrast to small-scale onshore renewables, offshore wind projects are large-scale and capital intensive, with ownership largely exclusive to major utilities, independent power producers, and an increasingly diverse set of institutional investors. Ownership from local authorities, businesses and communities is rare, since the scale of investment and complex ownership models required can impede local entities from owning offshore wind assets, either fully or partially.

Local ownership, depending on the scope of the definition, is most common in offshore wind through UK utilities and investment entities. But the international nature of the offshore wind market means that this represents a minor share of total installed capacity, with just 7.3% of the installed offshore wind capacity owned by UK entities [26]. This excludes the former publically-owned UK Green Investment Bank, now Green Investment Group and owned by the Macquarie Group, an Australian asset management firm, which owns an additional 4.8% of UK offshore wind capacity, including stakes in Rhyl Flats and Gwynt-y-Môr wind farms in Wales. As a result, there is currently no local ownership of offshore wind farms in Wales. However, local community benefits have been delivered through non-ownership methods, such as community funds.

Outside the UK, there are examples of local ownership in offshore wind farms, including:

- **Cooperative ownership:** In Denmark, the Middelgrunden Wind Farm is a 40 MW project off the city of Copenhagen, commissioned in 2000, that is half-owned by a local co-operative of over 10,000 members, who collectively invested in the wind farm alongside the local municipal utility, Copenhagen Energy, now part of state-owned national utility Ørsted Wind Power. However, this model has not been repeated, partly attributed to the increasing scale of offshore wind developments.

- **Municipal public utility:** In Germany, Stadtwerke Munchen is Munich's public utility that has invested in several renewable energy projects in Germany and elsewhere in Europe. The company aims to generate through its own plants as much electricity as the demand from the city of Munich by 2025, prioritising projects in Munich and its surrounding regions [27]. This includes three German offshore windfarms in the North Sea and, notably, the Gwynt-y-Môr offshore windfarm in Wales, where the utility has a 30% ownership stake.

- **National public utility:** Across Europe there are several examples of state-owned energy companies that are active in the offshore wind sector, including Ørsted (Denmark), Equinor (Norway), and EDF (France). Scotland has also announced intentions to create a national publically-owned not-for-profit energy company, whose scope may extend to investing in renewable energy projects.

3.5.3.2 Role of Welsh Government

The Welsh Government has established two targets to encourage local ownership of renewable energy projects in Wales:

- 1 GW of locally owned renewable electricity generation by 2030
- All renewable energy projects must include an element of local ownership by 2020

DEFINITION OF LOCAL OWNERSHIP

In the Call for Evidence on local ownership the Welsh Government has suggested the local ownership definition is "energy installations located in Wales and owned by an individual or an organisation wholly based in Wales or whose principal headquarters are in Wales. This includes the following categories:

- Farms and estates
- Local Authorities
- Registered Social Landlords
- Businesses based solely in Wales
- Businesses whose principal headquarters are in Wales
- Other public sector organisations
- Charities and other third sector organisations
- Households and other domestic scale generation

The Call for Evidence has asked whether respondents agree with this definition.

As of the end of 2017, an estimated 751 MW of locally-owned renewable energy (electricity and heat) was installed in Wales. This includes 529 MW of locally-owned renewable electricity, which accounts for 17% of the 3,087 MW of total renewable electricity currently operating in Wales and leaves a gap of 471 MW of locally-owned renewable generation to reach the 2030 target. The vast majority of locally-owned schemes consist of onshore wind and solar PV, installed by local businesses and residential owners. Communities and local authorities have minimal ownership.

Despite the challenges of establishing local ownership of offshore wind farms, the scale of these projects means that even capturing a small element of local ownership could have a material impact on the 2030 target. Offshore wind farms can also deliver local benefits through job creation and provision of high volumes of low cost, low carbon electricity for Welsh consumers.

The Welsh Government has recently undertaken a call for evidence exercise to evaluate the benefits renewable energy generation are currently providing to Wales and identify how new generation could benefit Wales in an equitable way. The call for evidence also sought input on what would be needed to meet the targets for locally owned energy generation in Wales. As detailed in the call for evidence, this will "explore the implications of the commitment to local ownership, taking into account the current difficult environment for renewable energy developments as well as their long term benefits." The aim is to "gather evidence about how renewable energy generation can secure benefits for Wales and spread this benefit in a more equitable way" and "to help identify the challenges developers, businesses, local authorities, communities and others will need to overcome to deliver more renewable generation in local and shared ownership."

Table 21. Local ownership of renewable energy in Wales [28]

Ownership Category	Total number of projects	Capacity (MWe)	Capacity (MWth)	Estimated generation (MWh)
Community	168	37.0	0.5	50
Domestic	55,459	180.9	72.5	34
Farms and Estates	714	22.6	102.3	411
Housing Association	5,655	7.0	4.6	11
Local Authority	300	13.5	3.2	33
Local Business	364	264.0	15.7	822
Other public sector and charity	411	4.4	22.6	73
Total	63,071	529	221	1,700

The response to the call for evidence is expected later this year and this will outline the actions Welsh Government will take as a result of the evidence. Nevertheless, the subsequent sections outline some of the key considerations relating to offshore wind power and possible policy levers that could be evaluated.

3.5.3.3 Key considerations

Challenges of local ownership in offshore wind

Offshore wind is a difficult industry in which to achieve ownership from local authorities, businesses or communities. The market is dominated by a relatively small number of large multi-national players and there is no shortage of capital for investment, making it difficult for any smaller participant to be effective as an offshore windfarm owner. Furthermore, the industry is fairly adaptive and agile in how it manages its assets, requiring from all participants a much higher level of involvement and understanding in management decisions. This contrasts with small-scale onshore renewables, where investments can be substantially smaller and the market is much more decentralised. Indeed, industry interviews suggest that the presence of local community owners in an offshore wind project is likely to be seen unfavourably by developers and shareholders and could be detrimental to the viability and competitiveness of projects in Wales.

Ownership vs benefit

Although ownership of projects can offer benefits to local communities, there are several alternative methods of delivering benefits that could mitigate some of the challenges identified above. Evaluating projects according to the benefits they offer, as opposed to stipulating an ownership requirement, could be a more effective means of boosting both renewable generation and maximising economic benefits.

For example, community funds have proved to be successful in several large-scale renewables energy projects, including the Gwynt-y-Môr offshore wind farm and Pen-y-Cymoedd onshore wind farm in Wales. Extending the definition of local ownership to capture these activities as achieving “an element of local ownership” would ensure that local benefits are delivered without compromising the competitiveness of Welsh offshore wind farms. Proceeds from community funds may even be used to support small-scale locally-owned renewable energy projects that contribute towards the 1 GW target by 2030.

3.5.3.4 Policy levers for Welsh Government

A range of options for enabling local ownership and/or local community benefits are outlined below, ranging from more conventional ownership to alternative measures that could deliver equivalent local benefits. It is acknowledged that some measures may not actually increase local ownership or indeed the local retention of benefit, hence the need to consider these measures based on the impact they could deliver for local communities in Wales.

Ownership:

- **National publically-owned not-for-profit energy company:** Creation of a national publically-owned energy company with an ability to supply electricity to Welsh consumers and invest in renewable energy projects in Wales, including offshore wind. However, the creation of such an entity could be high cost and high risk. A recent independent review determined that "overall, it was felt the risks of creating a Welsh Government supply company would heavily outweigh the potential benefits" [29].

- **National publically-owned investment entity:** Establishment of a publically-owned entity to invest in renewable energy infrastructure projects in Wales, equivalent to the former UK Green Investment Bank. Creation of such an entity would likely encounter similar challenges to a national energy company and there is currently limited need for low cost capital in offshore wind projects, thereby limiting the potential impact of this approach.

Financial mechanisms:

- **Wales-wide investment mechanism:** Establishing a coordinated and centralised approach to raising finance from Welsh individuals, communities, and businesses for investment in renewable energy schemes, including offshore wind farms, could circumvent some of the challenges of small and distributed community groups investing in projects. Such a mechanism could enable individuals to invest in a central fund to raise finance for debt or equity investment that provides a return to individuals and community groups. The mechanism could also comprise a bond issued to Wales-based individuals and businesses, or even a crowdfunding platform.

Off-take agreements:

- **Power purchase agreements (PPAs) with Welsh entities:** Offshore wind farms typically connect into the transmission network, which removes one of the benefits of local ownership relative to small-scale renewable projects that supply directly to consumers by private wire or via the distribution network. However, establishing power purchase agreements (PPAs) with local authorities or industrial consumers in Wales could boost local ownership of the power being generated, as well as provide price stability and greater resilience to market volatility. There are several challenges with establishing PPAs in offshore wind, as noted in 3.5.2.3, particularly in finding an off-taker for sufficient power. It is considered unlikely that operators will enter into multiple PPA agreements with small consumers, which could be a barrier.

Community investment:

- **Community funds:** Two large scale wind power projects in Wales, Gwynt-y-Môr offshore wind farm and Pen-y-Cymoedd onshore wind farm, have introduced successful community funds that have supported a wide range of schemes in close proximity to the wind farm developments. Both funds are owned and administered by local entities and represent direct local community investment into the areas hosting the projects. This approach ensures that benefits are achieved without needing to navigate complex ownership models or risk compromising the competitiveness of prospective projects in Wales, which could attract considerable investment into Wales' energy and port infrastructure.

4. Economic Benefits of Offshore Wind in Wales

4.1 Economic benefits of offshore wind

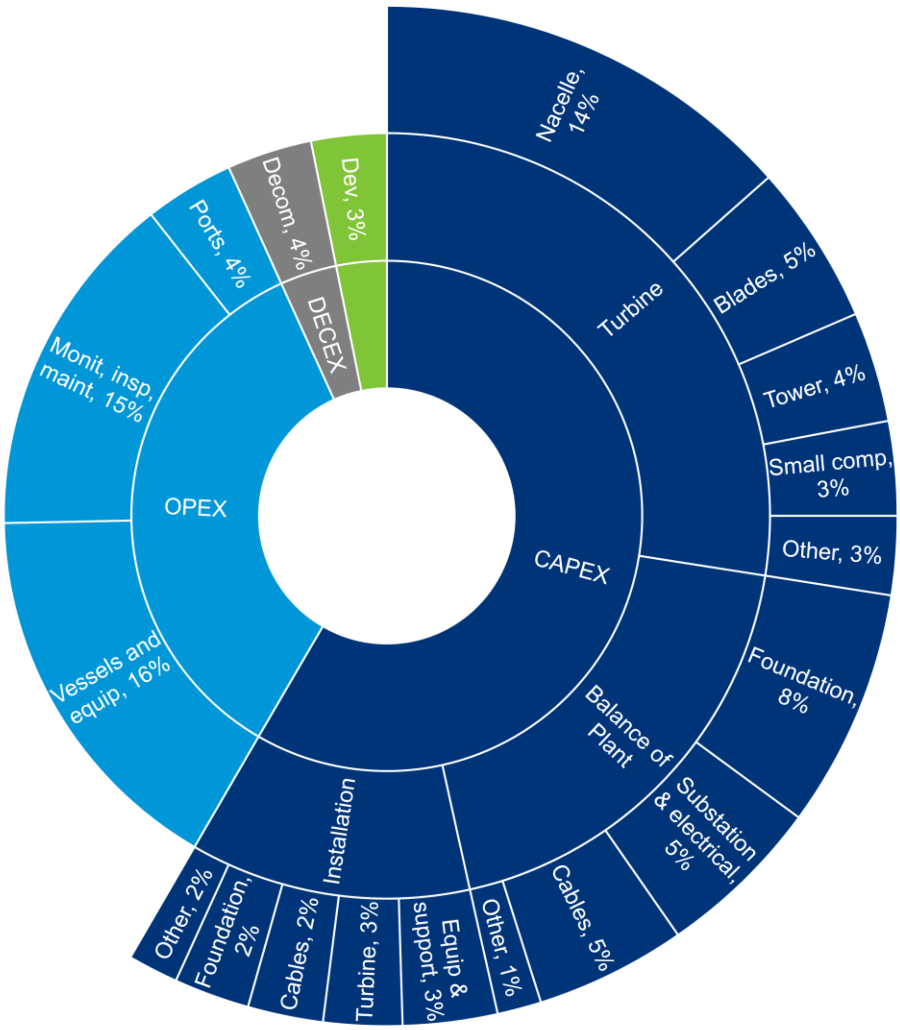
4.1.1 Drivers of economic impact

Offshore wind projects are a major driver of economic activity, catalysing transactions worth billions of pounds throughout their lifespan in areas such as engineering and construction, port and marine operations, insurance, and finance. Project pipelines also support non-project-specific activity such as research and development, product development, and market intelligence services.

Capital expenditure (CAPEX) represents the largest share of project lifetime spend in offshore windfarms. Turbine supply is the biggest CAPEX driver, but the manufacturing and assembly of the balance of plant and the installation and commissioning of the windfarm also represent a significant share of the total project CAPEX.

Operational expenditure (OPEX) also represents a significant share of project expenditure, split across its operational lifespan into windfarm monitoring, inspection and maintenance activities.

Figure 32: Illustrative life cycle cost breakdown of a windfarm [30]



Actual project costs are difficult to obtain due to confidentiality constraints, but publically available investment figures provide an indication of the level of capital expenditure in a given project. Capital expenditure typically ranges from £1-3bn per project for large-scale deployments, but varies depending on the total installed capacity. Capital investment for every MW of installed capacity typically ranges from £2-4m per MW, but is decreasing over time as the industry matures and drives down cost in several areas. For example, growing project size has seen total investment increase significantly (Figure 33), but this has been accompanied in recent years with cost reduction that has seen CAPEX per MW fall to below £2m/MW in the latest CfD auction (Figure 34).

Figure 33: Capital expenditure (CAPEX) in UK offshore wind projects [7]

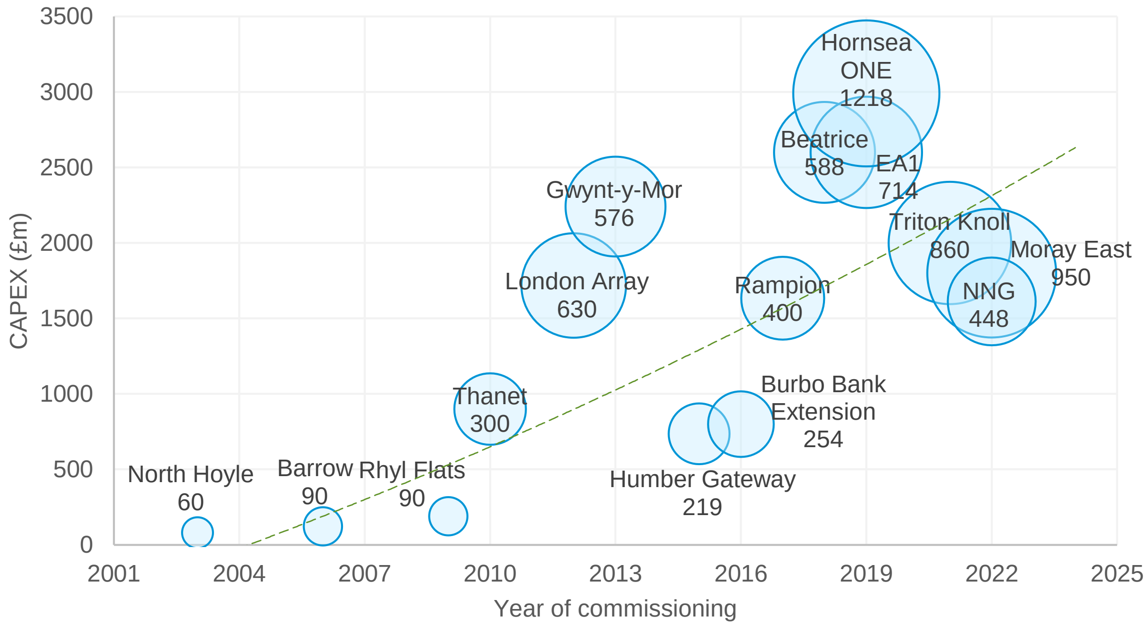
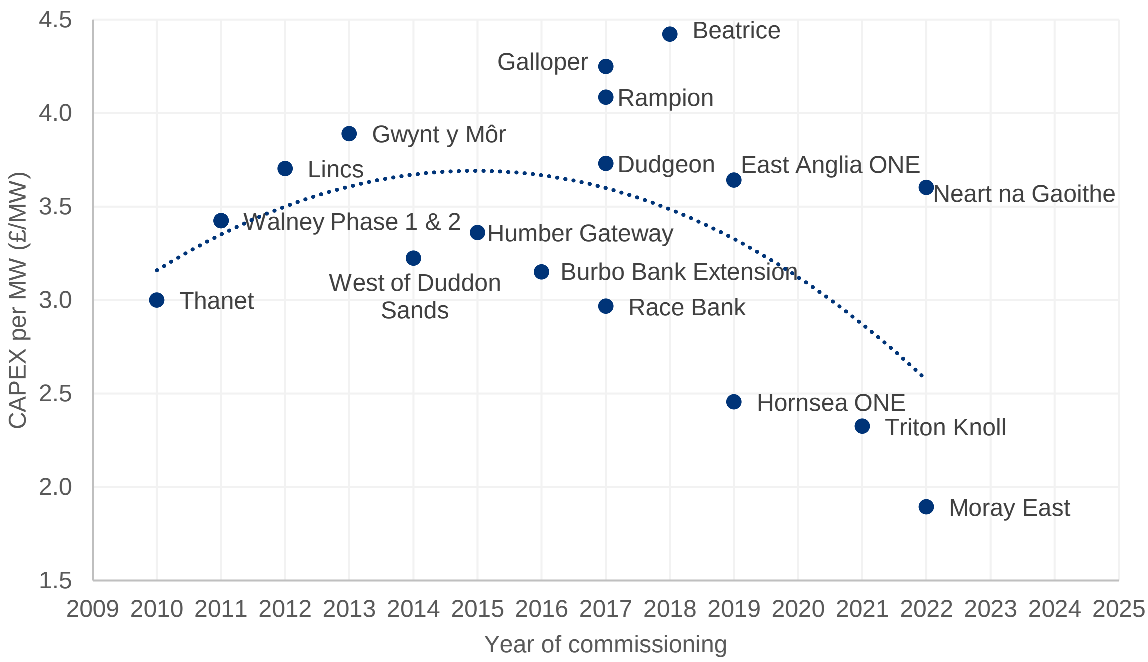


Figure 34: Capital expenditure (CAPEX) per MW in UK offshore wind projects [7]



4.1.2 Economic impact of offshore wind development

Offshore wind projects require considerable capital investment and specialised capabilities, both in terms of facilities and workforce. Economic benefits can be captured through a combination of:

- Investment in local infrastructure and supply chains
- Localised job creation and skills development
- Exporting products and services to overseas markets

A 2017 report from WindEurope estimated that offshore wind added €19.3bn to EU gross domestic product (GDP) between 2011 and 2016, accounting for the impact from offshore wind developers, turbine manufacturers and substructure manufacturers alone [31]. This includes an increase in gross domestic value from €1.7bn in 2011 to over €4.4bn in 2016.

Job creation is another critical aspect of economic benefits for local communities and public decision-makers. According to the same 2017 Wind Europe report on the economic impact of the wind industry, offshore wind was responsible for around 20,500 jobs in the EU in 2016, nearly double the number of jobs in 2011 (around 10,900). The number of jobs supported by offshore wind in the EU is expected to continue to grow as deployment increases over the coming decade.

4.1.2.1 Economic impact in the UK

The economic impact of offshore wind in the UK has increased over the past decade, both in cumulative terms as the level of investment into the sector has increased and also in relative terms as the share of UK content has increased. Some of the key indicators of this growth include:

- Offshore wind deployment unlocked total investment of €35bn in the UK from 2010 to 2017 [32].
- Large pipeline of projects, each typically worth billions of pounds that could deliver 10-20 GW during the 2020s to reach the industry target of 30 GW by 2030. An additional 20 GW could attract over £40bn in the UK's energy infrastructure.
- 48% UK content achieved in recent projects, according to a 2017 study from RenewableUK [33]. The value represents a 5 percentage point (p.p.) increase relative to a similar RenewableUK study in 2015. Future projects are targeting at least 50% UK content, with aspirations to increase this target to 60%.

Most of the local content achieved in UK offshore wind projects comes during development and operation, with 73% of DEVEX and 75% of OPEX captured in the UK (Table 22). Capital expenditure during wind farm construction is considerably lower, at 29% UK content, but the high levels of investment mean that considerable value is still realised in the UK. For example, at current UK content levels, a single 1 GW offshore wind farm could attract ~£0.6bn of up-front investment in the UK during development and construction, followed by ~£1.2bn of investment during the operational lifetime of the project.

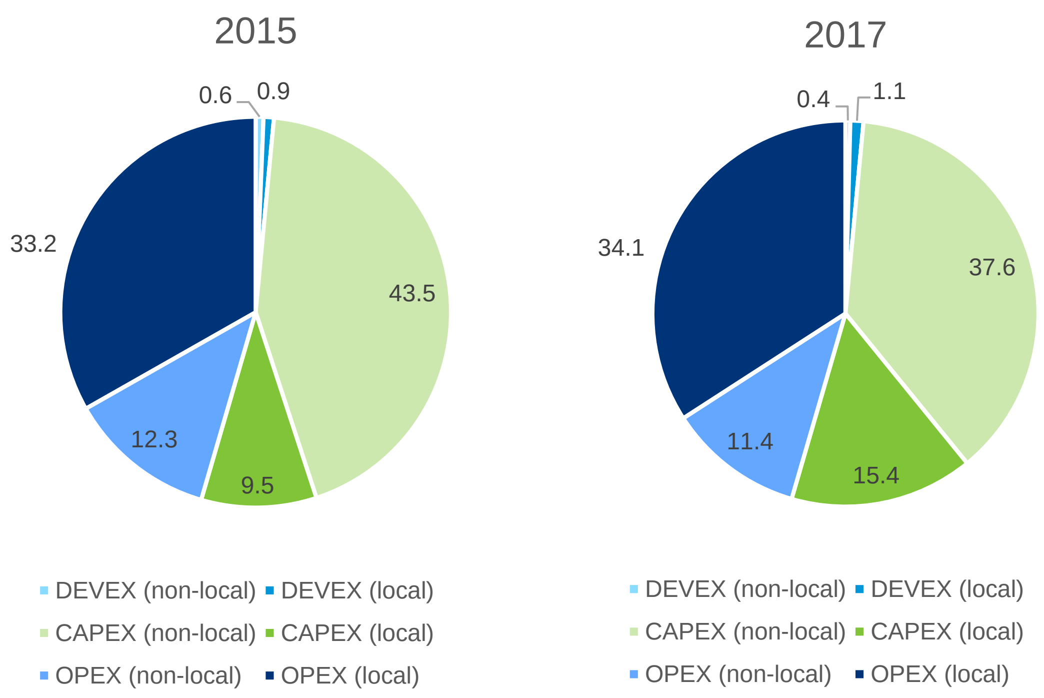
Table 22: Local content achieved by offshore windfarms in the UK

	% total project value	Indicative investment for 1 GW project	% total project value captured in the UK (2017)	Indicative UK investment for 1 GW project	% of component captured in the UK (2017)	% change from 2015 to 2017
DEVEX	1.5 %	£ 55 m	1 %	£ 37 m	73 %	+16 %
CAPEX	53 %	£ 1,945 m	15 %	£ 550 m	29 %	+11 %
OPEX	45.5 %	£ 1,670 m	32 %	£ 1,174 m	75 %	+2 %
TOTEX	**100 %**	**£ 3,670 m**	**48 %**	**£ 1,761 m**	**48 %**	**+5 %**

Note: Indicative investment assumes £2m per MW for CAPEX and DEVEX, extrapolated to OPEX based on local content % from RenewableUK.

Overall, local content achieved in offshore wind projects in the UK stands at 48% [33], which is close to the 50% target set by the UK Government for 2020. A recent report led by former UK Defence Secretary Sir Michael Fallon recommended that the UK Government should set a new local content target of 60%, including a 50% target for UK content during construction to encourage investment in UK manufacturing [11]. While challenging, the relative share of capital expenditure in the UK increased 11% in just two years, from 2015 to 2017, with further increases expected with continued support and commitment from both the public and private sector.

Figure 35: UK local content (%) in UK offshore wind projects - progression from 2015 (left) to 2017 (right)



Supply chain plans

In the UK, offshore wind developers must produce a supply chain plan prior to auctioning for a Contract for Difference, which is geared towards promoting local business opportunities, supplier competition, technology innovation, and skills development. The goal of supply chain plans is to drive investment in the domestic market and improve the competitiveness of the UK supply chain.

UK supply chain plans are currently targeting 50% local content over the project lifetime. The monitoring and enforcement of progress against these commitments is unclear, with some criticism that there are limited penalties for failing to deliver against targets. In a move to improve transparency and accountability, the Offshore Wind Industry Council (OWIC) has created an initiative to monitor and report progress on local content across offshore wind projects in the UK, with the intention to demonstrate an alignment with UK industrial strategy and the ability to deliver against supply chain plans. Further backing from offshore wind project developers may manifest in a commitment to UK supply chain investment as part of the Sector Deal currently under discussion.

Clustering of supply chain and economic benefits

Offshore wind activity and associated economic activities are often concentrated around major ports servicing offshore wind farms. In many cases, this has led to a clustering of supply chain activity and inward investment in key regions. A notable example is the Humber region on the English east coast, which is well-positioned in close proximity to a large pipeline of offshore wind developments in the North Sea. While the volume of activity has been a key enabler for investment decisions, the Humber has also benefitted from supportive policies and activities from local public and private actors, which has attracted several major suppliers to establish manufacturing and service bases in the region (see Box 3).

BOX 3. THE HUMBER REGIONAL CLUSTER

Overview

In the UK, the Humber region has established itself as a strategic centre for offshore wind [27]. Its enterprise zone is the largest in the UK, offering 30 sites that are readily accessible via road and railway and closely located to the ports of Grimsby, Hull, Goole and Immingham and various deep water quays. The region is in close proximity to some of the largest offshore wind project and active markets in the European North Sea.

The region, including the Humber Local Enterprise Partnership, has been supportive of renewables and offshore wind in particular. Grant and loan schemes, tax relief, and simplified infrastructure planning arrangements have been put in place to incentivise the establishment of businesses in the area. These interventions have been successful in developing a supply chain cluster and increasing the competitiveness of companies active in the sector, attracting inward investment from several leading suppliers and match funding from public and private sources.

Siemens-Gamesa blade manufacturing facility, Hull

The Siemens-Gamesa turbine blade factory has been one of the most significant investments in the region, with assembly and servicing facilities located in the Alexandra Dock Greenport, Hull. The facility was a £310m private investment by Siemens Gamesa (£160m) and the Associated British Ports (£150m) that created around 1000 direct jobs, most recruited locally. This investment benefitted several local suppliers that have subsequently been subcontracted to service UK offshore wind farms.

Plant construction works started in early 2015, ending a year later when the factory became operational. Siemens-Gamesa has since used the factory to produce 75-metre turbine blades, but also plans to produce the 81.5-metre version for their next generation 8 MW machines. Initially, the plant has been supplying the UK market, but is aiming to export to other offshore wind markets, particularly in the North Sea region.

Figure 36. Siemens blade manufacturing facility in Hull

Able Marine Energy Park

The Able Marine Energy Park project is a large private investment led by Able UK to develop a port facility near Hull, tailored to the needs of offshore renewables, particularly large scale offshore wind [25]. The aim is to create the right environment and conditions to bring together offshore wind turbine manufacturers, substructure manufacturers, and other related suppliers, creating a base for manufacturing, assembly and deployment activities. The port, a £450 million investment, will cover around 366 hectares, provide 1,389 metres new deep-water quays and create an estimated 4,100 jobs [26] [24]. Planning permission was obtained in 2015 and, despite encountering delays, is aiming to complete a series of upgrades that could unlock contracts to service major wind farms in the area, including the 860 MW Triton Knoll project.

O&M Centre of Excellence

The O&M Centre of Excellence is a collaboration between the Offshore Renewable Energy Catapult and the University of Hull to undertake research and innovation activities for offshore wind operations and maintenance, leveraging the local capabilities and experience of the supply chain in the region [28] [29]. In this regard, the port of Grimsby – a construction and maintenance base – has proved to be particularly suitable for the current offshore wind O&M activities, servicing around 1.5 GW of offshore wind farms, which is likely to increase with further offshore wind deployment in the area. The centre first started focussing its work on defining with the industry a roadmap for O&M R&D in offshore wind and has then undertaken a total of six projects, mostly desk-based studies, focussed on topics such as cable management, condition monitoring systems, techniques to reduce mandatory inspections or autonomous vehicles for tools and parts delivery [30].

4.1.2.2 Economic impact in Wales

The three existing operational offshore wind farms in Wales have been criticised for low levels of Welsh content achieved, particularly during construction. Analysis of capital expenditure in the 576 MW Gwynt-y-Môr offshore wind, a £2 billion investment, achieved 33% UK content during construction but just 5% in Wales (Table 23). This is supported by anecdotal evidence from interviews with key stakeholders and analysis of key supply contracts (Table 24). Nevertheless, a handful of significant contracts, particularly during operation, have delivered important benefits to local businesses and communities in Wales. As such, the level of Welsh content across the full project lifetime is expected to be considerably higher. It is also expected that, with the influence of UK supply chain plans and more dedicated efforts to support Welsh companies, future developments can achieve higher levels of Welsh content than previous projects.

Table 23. Capital expenditure and local content in Gwynt-y-Môr offshore wind farm.

	Investment (£m)	Local content (%)
GyM total investment	£ 2,000	
Spend in the UK	£ 660	33%
Spend in Wales	£ 90	5%

Note: Investment and local content during construction only – does not account for economic activity during operation.

Construction

The limited Welsh content achieved in the existing fleet of offshore wind farms can partly be attributed to the early build of the North Hoyle (2003) and Rhyl Flats (2009) wind farms, which were reliant on more experienced overseas suppliers and contractors. For example, turbine supply from Vestas and Siemens, respectively, resulted in considerable imports from Denmark, emanating from Danish leadership in the onshore wind turbine industry. Similarly, foundation supply contracts were awarded to leading European fabricators in the Netherlands and Belgium.

However, a handful of Welsh facilities and companies did manage to secure contracts that triggered investment into the local economy. Most significantly, the Port of Mostyn was selected as the construction base for all operations at North Hoyle and Rhyl Flats. Mostyn also served as construction base for turbine assembly operations at Gwynt-y-Môr, but a contract for the foundation installation campaign was lost to Birkenhead, Liverpool, as a result of investment delays to upgrade facilities. While most major procurement and installation contracts were awarded to overseas suppliers, there were benefits for local subcontractors providing ancillary services and local personnel involved in the construction campaigns, which in some cases led to opportunities outside Wales (Table 24).

Table 24: Supplier listing for offshore wind projects in and around Wales

Project	Wales-based suppliers
North Hoyle - Wales - 2003	• Port of Mostyn (primary construction base) • Ocean Marine Services Ltd (diving, site audit) • Wind Farm Equipment Safety Ltd (equipment)
Rhyl Flats - Wales - 2009	• Port of Mostyn (primary construction base) • Titan Environmental Surveys Ltd (site surveys) • Ocean Marine Services Ltd (Diving, site audit) • Wind Farm Equipment Safety Ltd (equipment)

Gwynt-y-Môr - Wales - 2013	• Port of Mostyn (construction base – turbine assembly) • Griffiths (Contractors) Ltd (civil engineering contractors) • Jones Bros Ruthin Ltd (civil engineering contractors) • Wind Farm Equipment Safety Ltd (equipment)
Barrow - England - 2006	• Wind Farm Equipment Safety Ltd (equipment) • Ocean Marine Services Ltd (diving, site audit)
Robin Rigg - Scotland - 2009	• Port of Mostyn (secondary construction base) • Natural Power Consultants Ltd (technical consultancy) • Titan Environmental Surveys Ltd (site surveys)

Note: Supplier listing is not exhaustive and will not account for lower tier contracts not captured by 4coffshore.

Operations and maintenance

Wales has had considerably more success in securing benefits from wind farm operations and maintenance, with a number of Welsh companies active suppliers in the sector. Construction contracts at Mostyn were supplemented with agreements to use the port as the operations and maintenance base for the full project lifetime, which has delivered long-term benefits for several local businesses and supported employment of skilled personnel. RWE Npower (now "innogy") has invested ~£8m in its operations and maintenance base, which hosts service teams from Siemens-Gamesa and MHI-Vestas. The majority of technicians working from the base have been employed locally, leveraging the engineering skills and expertise that exists in North Wales. Indeed, wind power recruitment specialists Total Wind, based in Llandudno, played a key role in supplying local engineers for early projects.

The Port of Mostyn has also been able to invest in port upgrades that have helped to develop advanced facilities and attracted several companies to establish manufacturing and service bases around the port. Local businesses benefitting from offshore wind activity at the port include Gibbs Steel Fabricators Ltd. (Offshore welding and metalwork), Ocean Marine Services (Marine engineering), and Wind Farm Equipment Ltd (Safety clothing and equipment). The wider Welsh supply chain has also benefitted, helping companies to develop a track record that has opened opportunities outside of Wales. For example, North Sea Logistics has supplied vessels to several UK windfarms, including Barrow, Blyth, and Kentish Flats. The company is also developing a next generation access vessel that could improve turbine accessibility in harsh offshore conditions.

Table 25. List of Wales-based suppliers active in offshore wind operations and maintenance

Company	Offering	Location	County
North Sea Logistics	Offshore vessels and logistics	Holyhead	Anglesey
Turbine Transfers	Crew transfer vessels (CTV)	Holyhead	Anglesey
Mistras Group Ltd (Bridgend)	Asset protection solutions	Bridgend	Bridgend
DMM International Ltd	Climbing equipment	Llanberis	Caernarfonshire
Offshore Transfer Devices Ltd	Vessel transfer equipment	Llandudno	Caernarfonshire
Total Wind UK Ltd	Service technician recruitment	Llandudno	Caernarfonshire
Severn Offshore Services	Crew transfer vessels (CTV)	Cardiff	Cardiff
Oftech Wind Ltd	O&M technicians and equipment	Rhyl	Denbighshire
Workplace Worksafe Ltd	Safety clothing and equipment	Ruthin	Denbighshire
DBR Group	Mechanical & electrical engineering	Deeside	Flintshire

Gibbs Steel Fabricators Ltd.	Offshore welding and metalwork	Mostyn	Flintshire
MHI Vestas Offshore Wind UK	Turbine service base	Mostyn	Flintshire
Ocean Marine Services Ltd	Marine engineering	Mostyn	Flintshire
Wind Farm Equipment Ltd	Safety clothing and equipment	Mostyn	Flintshire
Safety Technology Ltd	Safety training and equipment	Raglan	Monmouthshire
Mainstay Marine Solutions Ltd	Offshore vessels and logistics	Pembroke Dock	Pembrokeshire
Pinpoint Manufacturing Ltd	Lifting bags for wind farm O&M	Swansea	Swansea

Note: List may not be exhaustive.

4.1.2.3 Community funds

The economic impact of offshore wind in Wales is not exclusive to the companies servicing the wind farms. The establishment of community funds by project developers has brought investment and benefits to local communities in North Wales, as evident in the Gwynt-y-Môr community fund, which will invest over £19m into local community schemes over the 25 year lifetime of the wind farm (Box 4).

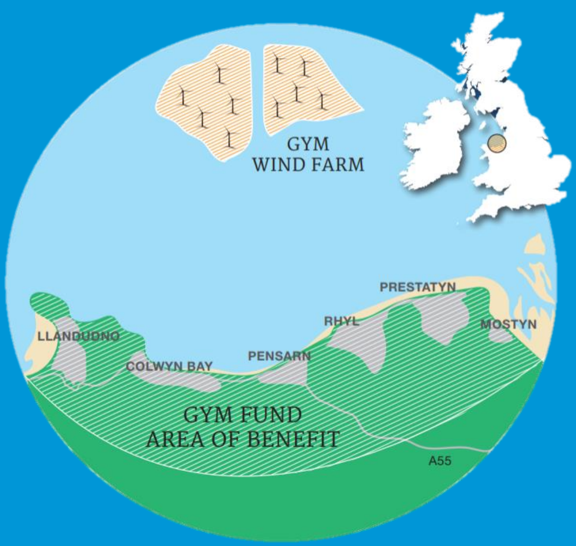
BOX 4. GWYNT-Y-MOR COMMUNITY FUND

The Gwynt-y-Môr Community Fund was established in 2015 to ensure that the wind farm development delivers lasting socio-economic benefits to communities in close proximity to the project. The Fund represents a £19m investment that will be made available to community schemes in Flintshire, Denbighshire and Conwy. Grants of up to £10,000 are available to fund both capital and revenue projects that focus on three core themes, which align well with the Well-being of Future Generations Act:

1. Building strong, cohesive and sustainable communities
2. Developing prosperous, enterprising communities with strong economic growth
3. Reducing poverty and inequality in communities

The fund is administered independently of Gwynt-y-Môr by Community & Voluntary Support Conwy (CVSC), with support from Denbighshire & Flintshire Voluntary Services Councils, to ensure impartiality and community ownership of the funding.

As of end-August 2017, just 2 years into the scheme, nearly £900,000 of funding had been committed to 36 community projects, unlocking £1.7m of match funding. Investments made to date have created and safeguarded 32 and 73 jobs, respectively. Events supported by the fund have also attracted nearly 80,000 tourists in the area.



4.2 Infrastructure assessment

Offshore windfarms rely on considerable infrastructure requirements throughout their lifespan to undertake construction, installation and operations and maintenance activities. Particularly critical to any windfarm development are grid infrastructure, port facilities, and road and rail links. A regional assessment of infrastructure in Wales is included in section 3.3.3. This section includes an assessment of grid infrastructure, which will be critical to connecting new offshore wind power to the transmission network in Wales in order to qualify as a contribution to Wales' renewable energy and decarbonisation targets. Section 3.3.3 also includes more detail on port facilities, which can serve as important enablers of supply chain activity.

4.2.1 Ports

Most activity in offshore windfarms (manufacturing, assembly, installation, O&M) is operated from a port base. The growth of the offshore wind industry over the last decade was both preceded and followed by considerable investment in new or reinforced port infrastructure across leading markets in Europe, led by public and private parties. This investment has often led to a concentration of supply chain activity around major ports, capturing significant economic benefits for local businesses and communities (see Humber case study in Box 3). Port activities can include:

- **Wind farm construction:** Siting, handling, assembly, and off-loading of offshore wind turbines, support structures, and cabling
- **Operations and maintenance:** Centre of operations for wind farm operators, including maintenance and repair procedures
- **Decommissioning:** Siting, handling, dis-assembly, and off-loading of offshore wind turbines, support structures, and cabling
- **Supply chain clustering:** Co-location of manufacturers and suppliers in close proximity to construction and operations activities
- **Research and development:** Testing and demonstration of innovative technologies, including new turbine models and operations and maintenance technologies
- **Training:** Centres of excellence to train skilled personnel

These activities may be operated from different ports and large-scale deployments can require multiple ports and manufacturing and assembly sites in order to meet demanding construction schedules. Likewise, a single port may be capable of servicing multiple wind farms simultaneously, particularly for less intensive campaigns, such as operations and maintenance activities.

Port base	
Requirements	**Construction:** Large windfarm components such as the turbine, foundations or substations are typically fabricated and assembled at port facilities to ease logistical operations. Suitable ports to hold these activities require large indoor facilities and storage areas with high soil bearing capacity and crane lifting capacity to handle these components. Quayside access, water depth, and proximity to suppliers and a skilled workforce are also important.

	The increasing size of both individual turbines and total project capacity is imposing more stringent requirements for construction ports. Several UK and European ports are investing in facility upgrades in order to expand their capabilities and secure major contracts for upcoming wind farms. **Operations & maintenance:** O&M ports can be much smaller than manufacturing and assembly ports. Their main requirements are proximity to project site to minimise transit time, quayside access with minimal restrictions regarding the existence of locks, accommodation of service vessels (minimum 2m draft), weather or tidal constraints, and berth availability. Shore-side services and local specialist workforce (e.g. technicians) are also important. One port can serve multiple windfarms simultaneously, particularly for maintenance and minor service operations. Repair or replacement of large components may require ports with increased draft and/or handling capabilities (similar requirements to construction ports). **Floating wind variances:** Depending on the foundation concept and installation and maintenance strategy, floating wind could add additional constraints for ports. Semi-submersible, barge, and some TLP concepts will offer the opportunity to assemble turbines at the quayside, thereby mitigating the need for expensive heavy lift installation vessels. However, this requires ports with deep draft (8-15 m) at the quayside and a very large crane for turbine assembly. Large onshore area will also be needed for substructure and turbine assembly (although these may take place at different ports). The same constraints apply for concepts looking to undertake large correctives at port. Mooring system installation is an additional installation campaign that is required for floating wind farms. This would again require a port with large onshore area for set-down of the mooring lines and anchors. However, this installation campaign could be led from a smaller port that is separate from turbine and substructure assembly.
Synergies w/ other industries	Several synergies, including cargo shipping, oil and gas, marine engineering, workboat services.
Life cycle cost	**Medium**
Capacity in Wales	**Medium-High** Wales has a number of large ports, traditionally used for commercial shipping, cargo handling, passenger ferries, commercial fishing, and oil and gas terminals. Major ports include Holyhead Port in Anglesey (north-west), Milford Haven, Pembroke Dock, and Fishguard in Pembrokeshire (south-west), and Port Talbot and Newport in South Wales. There has been limited offshore wind activity in these ports to date, with most activity having been concentrated at the Port of Mostyn, largely due to its close proximity to the three operational wind farms in the Irish Sea, but also as a result of targeted investment to capitalise on the opportunities that offshore wind can bring to the facility (see Box 5).

Opportunity for Wales	**Medium-High** Port opportunities will be closely tied to future deployment in and around Wales. Both Mostyn and Holyhead are well-placed to service wind farms in the Irish Sea, but will face competition from several nearby ports in Belfast, Liverpool, and Barrow. Investment is likely to be required to expand facilities and improve competitiveness, particularly for construction contracts. O&M is likely to be more competitive, but will be heavily influenced by proximity to project sites. Ports in South Wales, such as Milford, Pembroke Dock, Port Talbot, and Newport, are well-placed to service developments in the Bristol Channel and off the south-west. Competition with ports outside Wales is expected to be lower, but the project pipeline may be more limited, potentially making investment decisions more challenging. Proposed investment for Pembroke Dock as part of the Swansea Bay City Deal will support upgrades here.

BOX 5. PORT OF MOSTYN

The Port of Mostyn, located in North-East Wales, is Wales' leading offshore wind base, used for installation and operation and maintenance activities. The port has been involved in servicing all three operational wind farms in Wales (North Hoyle, Rhyl Flats, Gwynt-y-Môr), as well as four other projects in the Irish Sea (Burbo Bank, Robin Rigg, Walney 1, and Walney 2). North Hoyle and Rhyl Flats were both constructed from Mostyn and the port has been contracted as the operations and maintenance base for North Hoyle, Rhyl Flats and Gwynt-y-Môr windfarms for the duration of their 25 years operational lifespan. As a result, both Innogy Renewables UK Ltd (developer) and MHI Vestas Offshore Wind Ltd (turbine supplier) have a long-term presence at the port. Several local companies have also established offices at Mostyn.

The port has good facilities and transport links, but is subject to some access constraints due to tidal restrictions. Larger vessel carriers required for loading and transporting larger next generation turbines (9.5+ MW) may face channel restrictions, which could require dredging work. Construction activity will also require expanded onshore area and soil bearing capacity.

The port owners have been proactive in planning for upgrades, with planning consent already secured to add 4 acres of land behind the roll-on roll-off (RO-RO) berth and increase load bearing capacity to 20t per square meter, expected to cater for turbines up to 15 MW capacity. A 200m section of the riverside berth can be dredged down to provide unrestricted vessel access, but would require commercial contracts to justify the necessary investment.

Figure 37: Port of Mostyn – aerial view (4AllPorts)

4.3 Supply chain assessment

The supply chain requirements of offshore windfarms throughout their lifespan are considerable due to the scale and complexity of constructing and operating wind farm assets in harsh offshore environments. The availability of capable suppliers able to deliver the various project activities is therefore as critical as the need for capable infrastructure.

Supply chain requirements span the following core areas:

- Development and consent
- Turbine supply
- Balance of plant supply
- Installation and commissioning
- Operations and maintenance
- Decommissioning

The European offshore wind industry has benefitted from the presence of an established supply chain from synergistic sectors, such as onshore wind, oil and gas, and other maritime industries. These existing capabilities and track record has meant that opportunities for new market entrants has been limited in certain sections of the supply chain, particularly in large components where up-front investment is high. However, there are unique characteristics to offshore wind that require tailored solutions and specific expertise or know-how, which can create opportunities for suppliers. The following sections present an assessment of each area of the supply chain, including:

- Requirements
- Synergies with other sectors
- Lifecycle cost
- Capacity in Wales
- Opportunity for Wales

4.3.1 Development and consent

During the development and consent stage some of the main activities include:

- **Site surveys** to assess environmental impacts, coastal effects, met-ocean and seabed conditions
- **Front end engineering and design** studies to detail the windfarm design and reduce technical uncertainty

Site surveys	
Requirements	To perform site surveys, offshore wind developers will procure suppliers that can collect and analyse site data; namely environmental, wind resource, met-ocean, geophysical, and geotechnical data. Skilled staff such as surveyors, oceanographers, engineers or geophysicists are critical to these activities. ***Environmental surveys*** assess any environmental impacts that a wind farm may have on species that live, use or frequent the offshore environment in the sea and in the air. This can include benthic, pelagic, bird, and marine mammal surveys, typically undertaken using local vessels and supplemented by aerial surveys. ***Wind resource data*** is captured using either bottom-fixed or floating meteorological stations. While fixed met masts were common in early projects, the commercialisation of floating LiDAR technology means that this is now a lower cost and more flexible means gathering accurate wind resource data. ***Met-ocean data*** is collected using wave buoys, floating LiDAR devices, and/or technology mounted on a capable vessel. ***Geophysical and geotechnical investigations*** are used to assess the bathymetry and geology of the seabed at the project site and along the cable route. Geophysical surveys use sonar and acoustic methods to assess large areas at relatively low cost. These are supplemented by more expensive geotechnical surveys, which entail conducting cone penetration tests and analysing soil cores at specific turbine locations. **Figure 38: Typical fit-for-purpose vessel used for geotechnical and geophysical surveys in offshore wind (Fugro)** 

Synergies w/ other industries	There are some synergies with other industries, including the oil and gas sector, which also performs offshore surveying, and general maritime industries using multi-purpose vessels.
Life cycle cost share	**Low (<2%)**
Capacity in Wales	**Medium-High** There are a handful of Welsh-based companies active in this area: - **Titan Environmental Surveys Ltd:** Undertake a range of environmental, hydrographic, and geophysical surveys. - **Solarwheel Ltd:** Supply met masts
Opportunity for Wales	**Medium** Companies such as Titan Environmental Surveys are well-placed to service offshore wind farms both within and outside Wales. Offshore survey campaigns could also bring benefits to local ports, vessel suppliers, and personnel. However, total lifecycle costs and associated economic value is low.

Front end engineering and design (FEED)	
Requirements	Most offshore wind developers will procure suppliers that can support the technical design of a windfarm. These are typically large multi-national engineering consultancies with proven track record in the offshore wind and oil and gas sectors. Leading organisations include DNV-GL, Ramboll, and Atkins.
Synergies w/ other industries	There are good synergies with other maritime industries since the experience and know-how in particular engineering and design considerations (e.g. structural fatigue, ergonomics) are fairly transferable.
Life cycle cost share	**Low (<2%)**
Capacity in Wales	**Low** There are no leading Welsh companies active in this area.
Opportunity for Wales	**Low-Medium** A handful of leading international engineering firms have offices in Wales (e.g. Atkins, Mott Macdonald) that could employ local staff to undertake engineering work, but these are activities that could also be delivered from offices outside of Wales, depending on the location of core specialists.

4.3.2 Turbine

The turbine is typically the largest cost component of an offshore wind farm. The market is currently dominated by a small handful of leading tier 1 suppliers, including Siemens-Gamesa, MHI-Vestas, GE, and Senvion. These manufacturers typically procure components from a range of distributed suppliers, which are assembled prior to offshore load-out. There is limited scope for new tier 1 entrants, but there may be opportunities for the supply of components further down the supply chain. Turbine supply can be broken down to include:

- Blades
- Tower
- Nacelle (drive train and power conversion)
- Other large fabrications
- Turbine assembly

Blades	
Requirements	Blades are one of the main components of the turbine rotor, typically made from fibreglass or carbon fibre. They are a key determinant of turbine performance and reliability and most turbine OEMs design and manufacture them in-house, partly facilitated by several acquisitions of blade manufacturers by leading OEMs in recent years. The large dimensions of turbine blades (typically 50-100m in length), means that manufacturing facilities need to be located at a quayside to avoid complex onshore logistics and ensure efficient delivery to offshore sites. The high cost of such facilities means that manufacturing is concentrated in a small number of facilities, which can export to projects across Europe. The UK already has two large blade manufacturing sites, with MHI-Vestas based in the Isle of Wight and Siemens-Gamesa having recently completed construction of a new facility in Hull.
Synergies w/ other industries	There is a direct synergy with onshore wind, although the size of blades is comparatively smaller. Other possible synergies could include aviation, but there are currently no major aviation suppliers active in the wind power industry.
Life cycle cost share	**High (5-10%)**
Capacity in Wales	**Low** There are no Welsh-based companies active in this area.

	Airbus have a facility in North Wales and use the Port of Mostyn for transporting components to assembly facilities elsewhere in Europe. However, it is considered unlikely that Airbus will move into the offshore wind sector in the near term.
Opportunity for Wales	**Low** Given recent investments in UK blade manufacturing facilities in the Isle of Wight (MHI-Vestas) and Hull (Siemens-Gamesa), it is unlikely that there will be a strong business case for investing in a Wales-based facility.

Tower	
Requirements	Towers are large (80+m) modular components that support the turbine nacelle. Most towers are made of steel tube sections that are flanged or bolted together at the assembly port. Turbine OEMs typically procure towers from external fabricators, though some manufacture them in-house. Towers can generally benefit from standardised designs to enable serial production at dedicated manufacturing facilities. As such, tower fabrication is concentrated in a relatively small number of facilities across Europe. Facilities are located at ports to facilitate efficient delivery to offshore wind projects. There is one major tower supplier in the UK – CS Wind, based in Campbeltown, Scotland.
Synergies w/ other industries	There is a direct synergy with onshore wind. As relatively simple cylindrical components, there could be synergies with other steel rolling plants. The move to larger turbines and increased tower dimensions could bring conventional monopile fabricators into play.
Life cycle cost share	**Medium-High (3-5%)**
Capacity in Wales	**Low** There are currently no tower suppliers based in Wales.
Opportunity for Wales	**Medium** Wales has an established steel industry based in Port Talbot, South Wales, which could be leveraged to set up a tower production facility nearby, or near to market demand in North Wales. Limited market volume could be challenging to justify major investment, particularly given the close proximity of CS Wind (Campbeltown, west Scotland) to the Irish Sea market. However, increasing local content requirements could improve the business case for investment in new tower manufacturing facilities in the UK.

Nacelle (drive train and power conversion)	
Requirements	The drive train unit of a turbine includes the generator and gearbox. Turbine OEMs procure these and other supporting components, such as bearings, from specialist suppliers. These components are critical to turbine performance and reliability and turbine OEMs value credible suppliers with significant expertise and track record. Thus, there is no significant advantage for turbine OEMs in opting for local suppliers if these don't meet their quality and track record criteria.
Synergies w/ other industries	There is a direct synergy with onshore wind, but also other industries where drive trains are used (e.g. conventional power generation, wave and tidal energy, maritime vessel engineering).
Life cycle cost share	**Very high (>10%)**
Capacity in Wales	**Low** There are currently no drive train suppliers in Wales.
Opportunity for Wales	**Low** Opportunities are likely to be very limited, given the high cost of investment and existence of established suppliers elsewhere in Europe. Lower tier opportunities might be available for small components and secondary steel works.

Other large fabrications	
Requirements	Large turbine fabrications include the rotor hub, the nacelle bedplate or the housings for the bearings and gearbox. Turbine OEMs often procure these casting structures from external fabricators. Lower manufacturing complexity means that these services can be sourced more flexibly, but locational drivers to procure near to the turbine assembly facility could constrain opportunities for new entrants.
Synergies w/ other industries	There are several synergies with other offshore and maritime industries and more general steel works, where similar components in size, fabrication process and materials are manufactured.
Life cycle cost share	**Low (<2%)**

Capacity in Wales	**Low** There are no Welsh-based companies active in this area.
Opportunity for Wales	**Low-Medium** Wales has an established steel industry based in Port Talbot, South Wales, which could be leveraged to manufacture secondary components. However, investment may be required and limited proximity to nacelle assembly facilities could be a barrier to competitiveness.

Nacelle assembly	
Requirements	Turbine assembly is undertaken by turbine OEMs at a nacelle assembly facility, typically located at a port to facilitate delivery of components and export of fully-assembled nacelles. Turbine OEMs typically operate in a single or small number of facility sites, from which they supply various markets. Site selection is a strategic decision and considerable investment that takes into account factors such as component logistics, component facilities clustering, local political support and market potential. Full turbine assembly (including the tower and rotor) will take place at the installation port or directly at the offshore site – see Installation.
Synergies w/ other industries	There is a direct synergy with onshore wind, but also other industries where turbine generators are used (e.g. conventional power generation, wave and tidal energy, maritime vessel engineering).
Life cycle cost share	**Low (<2%)**
Capacity in Wales	**Low** There are no Welsh-based companies active in this area.
Opportunity for Wales	**Low** Limited appetite to establish a new nacelle assembly factory in Wales given concentration in a small number of existing facilities in Europe.

4.3.3 Balance of plant

Balance of plant is a major cost driver. During the construction stage, some of the main activities include:

- Foundation structure
- Mooring system supply *(floating wind only)*
- Subsea cables (array and export)
- Offshore substation
- Electrical systems
- Secondary steel works

<table>
<tr><th colspan="2">Foundation structure</th></tr>
<tr><td>Requirements</td><td>
Foundations are procured by offshore wind developers, with designs tailored to individual project site characteristics, based on designs in the FEED analysis. Foundation designs vary, but can be classified by fixed and floating designs:

Fixed: Monopile, jacket, suction bucket monopile/jacket, gravity base
Floating: Semi-submersible, spar, tension leg platform, barge

Fixed foundations have been the dominated foundation type to date, with monopiles the predominant choice in shallow sites (<45m) and jacket structures deployed in deeper sites (up to 60m).
The fabrication of monopiles is more automated and its transportation is relatively low cost. As such, structures are often delivered to the installation port from a small number of leading European fabricators.
Figure 39. XXL monopile fabrication (EEW, 2016)

</td></tr>
</table>

	The fabrication of jackets is typically less automated and their transportation cost can be higher. The case for procuring locally is therefore comparatively stronger, but it is still common to import from a handful of leading suppliers. The past few years have been turbulent for jacket fabricators, with a number of high profile companies entering administration or requiring public and private investment to remain active. Concrete structures are more amenable to local production, due to the challenges of lifting and transporting between different locations. However, concrete fabrication facilities require comprehensive facilities that may require considerable up-front investment. A large pipeline of projects is usually required to justify such investments.
Synergies w/ other industries	Primary synergies are with the shipbuilding and oil and gas sectors.
Life cycle cost share	**High (5-10%)**
Capacity in Wales	**Low** There are no existing foundation suppliers in Wales.
Opportunity for Wales	**Low-Medium** Wales has an established steel industry based in Port Talbot, South Wales, which could be leveraged to produce or provide steel for foundation structures. However, considerable investment may be required and fierce competition can be expected with other European suppliers that are closer to the larger North Sea market. Some foundation designs may lend themselves to local production (e.g. concrete structures), but the dominance of steel monopiles and jackets means that market volumes may not justify the up-front investment in new facilities. There may be smaller opportunities in scour and corrosion protection, which would be more amenable to local procurement.

Mooring system (floating wind only)	
Requirements	Mooring systems are an additional part of the balance of plant in floating wind farms that provide station keeping for the foundation structure. Mooring technology is already largely well-established from other marine sectors, including oil and gas, but requires design alterations for floating wind and will vary by substructure concept. A mooring system consists of the mooring lines, anchors, and additional components, such as shackles, clump weights, and buoyancy modules.

	Steel chains are the most common design for catenary mooring configurations. The large volume of chains needed in commercial floating wind farms (a 50 turbine wind farm will require 150-300 mooring lines, each exceeding 100m in length) requires considerable fabrication facilities and competencies. Synthetic mooring lines could support reduced line lengths and improved logistics, but are at an earlier stage of development. Anchor types vary – drag embedded, piled, suction – but are generally large steel fabrications. A number of established suppliers exist in Europe, largely emanating from the oil and gas supply chain.
Synergies w/ other industries	Considerable synergies with oil and gas, as well as aquaculture and marine energy (wave and tidal stream).
Life cycle cost share	**Medium (2-3%)**
Capacity in Wales	**Low** There are no existing mooring or anchor suppliers in Wales.
Opportunity for Wales	**Low** Competition with established suppliers based around the North Sea region means that opportunities for new market entrants is limited, particularly given the lower volumes of floating wind deployment at present. However, there may be opportunities for component suppliers or novel mooring system designs to capture market share, particularly if synergies can be achieved with marine energy activities in Wales.

Cables (array and export)	
Requirements	Windfarms require both array cables that connect turbines to the offshore substation and export cables that connect the offshore substation to shore. Some cable suppliers are able to provide both array and export cables, while others currently specialise at either medium voltages (array) or high voltages (export). Some cable suppliers also offer installation within their scope of work. Similar to turbine supply, leading cable manufacturers often procure several components from external suppliers, before bundling the cables at a separate site. Facilities for fully bundled submarine cables are located at a port due to logistical constraints of transporting on land. There are several facilities owned and operated by leading European subsea cable suppliers.

Synergies w/ other industries	Primary synergies with land-based power cables, subsea power cables, subsea telecoms, and umbilicals from the oil and gas sector.
Life cycle cost share	**Medium-High (3-5%)**
Capacity in Wales	**Medium-High** Prysmian has a factory in Wrexham that produces cable cores for both onshore and submarine cables. The capability to produce submarine cable cores for medium-voltage array cables follows a recently announced investment upgrade triggered by a contract to supply to Ørsted's 1.2 GW Hornsea ONE project. Cable cores manufactured in Wrexham will be transported to one of Prysmian's lay-up facilities in Europe (e.g. Dramen, Norway) for bundling, before being loaded onto bespoke cable installation vessels and taken to the installation port or directly to site. **Figure 40. Prysmian cable core facility in Wrexham (Prysmian)** 
Opportunity for Wales	**High** Wrexham will be the UK's first and only submarine cable core facility, which could open opportunities to supply further projects, particularly given the increased pressure to meet 50% UK content targets in developer supply chain plans. Upgrading the facility to increase production capacity could increase local employment and economic benefits, but would require large order volumes to justify the investment needed. Due to its in-land location, Wrexham would not be suitable for lay-up capabilities. Such facilities would need to be located at a port. While this would be possible at Welsh ports, the presence of existing facilities across Europe makes this unlikely in the near-term. Additional to cable supply, there may be smaller opportunities in auxiliary components, such as cable protection systems. Dynamic cables in floating wind projects will require additional components, such as bend stiffeners and buoyancy modules, which could offer synergies with wave and tidal activities.

Offshore substation (foundation and topside)	
Requirements	Offshore substation structures provide support and protection for the AC or DC electrical system. This consists of both the foundation structure and the topside to hold the electrical equipment. These are large steel structures that can be complex in their design and the associated fabrication logistics. Developers typically procure the full engineering, procurement and construction to external suppliers. The large size of structure means that fabrication in advanced facilities with very deep ports in Europe, the Middle East or East Asia is common.
Synergies w/ other industries	Primary synergies are with the oil and gas sector.
Life cycle cost share	**Medium (2-3%)**
Capacity in Wales	**Low** There are no existing substation suppliers in Wales.
Opportunity for Wales	**Low** The scale of fabrication facilities needed for large steel structures makes this an unlikely prospect for locating in Wales.

Electrical systems	
Requirements	Electrical systems are hosted in the offshore substations and the interface between array and export cables. They include elements such as reactive power compensation systems, switchgears, transformers or back-up generators. These systems can be AC or DC, with DC systems having larger footprint and weight (and cost) but allowing more efficient power transmission, which is more relevant over long transmission distances. Electrical system components are often standard and provided by a small number of established suppliers (e.g. ABB, GE Grid Solutions, Siemens Energy Transmission).
Synergies w/ other industries	There are good synergies with the wider power sector.
Life cycle cost share	**Medium-High (3-5%)**

Capacity in Wales	**Low** There are no existing electrical system suppliers in Wales.
Opportunity for Wales	**Low** Limited opportunities given the competition with existing and established suppliers across Europe.

Secondary steel work	
Requirements	Secondary steel work is delivered for the turbine and substation foundation structures. This can include elements such as railings, support frames, J-tubes or boat landings, which are normally smaller in size and easier to transport. As smaller components that are more amenable to smaller fabrication facilities and efficient transportation logistics, these elements are can be procured flexibly. There are often benefits to sourcing from local contractors in close proximity to the installation port base and project site.
Synergies w/ other industries	There are good synergies with the maritime and general steelwork industries, where similar small steel fabrications are produced.
Life cycle cost share	**Low (<2%)**
Capacity in Wales	**High** There are several small steel fabricators in Wales, including Gibbs Steel, based at the Port of Mostyn and with a track record of servicing offshore wind farms in the Irish Sea.
Opportunity for Wales	**Medium** Wales has a large number of steel fabricators that would be well-placed to service future offshore wind farm developments. The low share of total lifecycle costs limits the scale of the opportunity, but with sufficient volumes of deployment this could provide valuable new business opportunities to a number of Welsh businesses.

4.3.4 Installation and commissioning

Installation activities are usually based out of a single or small number of ports. Wales has a number of ports that could serve as installation bases for offshore wind projects (see 4.2 Infrastructure assessment). There are also several supply chain competencies that are required during the major installation campaigns, which include:

- Foundation installation
- Turbine installation
- Substation installation
- Cable installation

Foundation installation	
Requirements	Foundation installation requires the use of large heavy lift vessels to transport and install the structures. Vessels to install foundations require considerable deck space and crane capacity. There are a number of capable vessels from the oil and gas industry with large lifting capacity and sufficient hook height. Most of these are owned and operated by European installation contractors. In addition to the vessel, equipment such as piling hammers, cranes, gangways or racks and support services such as support vessels, diving crew, certification or ROV operations are required. **Floating wind variances:** Floating wind farms adopt a different approach to installation, which includes an additional campaign for mooring system installation. Mooring and anchors are typically pre-installed using anchor handling vessels (AHVs). The substructure is then towed to site using tug boats and AHVs for hook-up. For several concepts, the turbine will have been assembled on the substructure at port prior to hook-up. This approach avoids the need to heavy lift vessels.
Synergies w/ other industries	There are good synergies with the oil and gas industry, particularly in offshore installation logistics, vessel capabilities, and the handling of scour protection. There are also good synergies with other maritime industries where there is a need for similar equipment and support services.
Life cycle cost share	**Medium (2-3%)**
Capacity in Wales	**Medium** There are no major installation contractors in Wales. However, there are several marine service companies that could offer support services to installation campaigns. There are several ports capable of serving as the construction base

	for foundation installation, although Welsh ports would face competition with larger ports with foundation fabrication capabilities.
Opportunity for Wales	**Medium** Opportunities are most likely in support services from smaller vessels and logistical operations. Larger contracts for ports serving as the foundation installation base would offer greater economic benefits, if Welsh ports can demonstrate competitiveness with larger rival ports. For floating wind, Pembroke Dock has potential to serve as an installation base, but will require upgrades to develop sufficient quayside draught and onshore area for substructure and turbine assembly. Mooring system installation could be delivered out of several medium and large ports in Wales.

Turbine installation	
Requirements	Turbine installation can vary in approach related to the number of lifting operations conducted at the port versus offshore. For fixed foundations, a stick-build approach is most common, whereby the turbine components are assembled at the offshore site, building directly on the installed foundation. A fully integrated lift is also possible and has been conducted in the past, but the increased lift weight can add challenges. Some floating wind concepts will also adopt an offshore assembly approach, including spar-buoys and some tension leg platforms. Offshore assembly requires a vessel with large deck area to transport components and a large crane with sufficient hook height and lifting capacity to install all the turbine components. Jack-up vessels have been favoured to date due to the improved stability, but dynamic positioning vessels are being developed that could offer comparable stability and mitigate the need for jacking up. There are a number of capable jack-up vessels on the market, owned and operated by leading European installation contractors. Increased hook height for larger generation turbines could impose constraints and create bottlenecks in future wind farms, but pipeline visibility should trigger the necessary investment to upgrade existing or develop new vessels. **Floating wind variances:** Several floating wind concepts can mitigate the need for large vessels by undertaking turbine assembly at the quay-side. This approach can support cost reduction, but could also impose greater requirements on the port and availability of suitable onshore cranes.
Synergies w/ other industries	There are good synergies with the oil and gas industry, but increased lift height is more unique to offshore wind.

Life cycle cost share	**Medium (2-3%)**
Capacity in Wales	**Medium** There are no major installation contractors in Wales. However, there are several marine service companies that could offer support services to installation campaigns. There are several ports capable of serving as the construction base for turbine installation, including the Port of Mostyn, which was the turbine installation base for all three existing offshore wind farms in Wales.
Opportunity for Wales	**Medium** Greatest opportunities are most evident in establishing Welsh ports for the turbine assembly and installation campaign. However, the increasing size of offshore wind turbines and scale of modern wind farm projects will add constraints that weren't present in early projects. Investment is therefore likely to be necessary to ensure that Welsh ports can be competitive. Mostyn has been proactive in planning for such upgrades. Opportunities are also possible in support services from smaller vessels and logistical operations.

Offshore substation installation	
Requirements	The installation of offshore substations is often part of the substation supply contract. The activity involves installing the foundation (as above), followed by the substation topside. Specialist heavy-lift vessels with considerable crane lifting capacity are often required, particularly for larger DC substations. In addition, equipment such as piling hammers, sea fastenings or racks and support services such as support vessels, diving crew, certification or ROV operations are required. **Floating wind variance:** The need for a heavy lift vessel can be mitigated if a floating substation is used. In this instance, the topside would be installed on the foundation substructure at quay-side and floated to site for hook-up to a pre-installed mooring system. Cost savings from lower vessel requirements will need to be assessed against possible additional costs from port activities and procurement of the foundation structure and topside.
Synergies w/ other industries	There are direct synergies with the offshore oil and gas industry, due to the similarity between the installation of these structures and oil and gas platforms. There are also good synergies with other maritime industries where there is a need for similar equipment and support services.

Life cycle cost share	**Low (<2%)**
Capacity in Wales	**Low** There are no existing substation suppliers in Wales.
Opportunity for Wales	**Low** Limited opportunity for Wales, given the large size of substation structures and likelihood of installing directly from fabrication site. Smaller contracts might be available for support service vessels and logistics. Floating substations could operate the mooring installation campaign from a Welsh port.

Cable installation	
Requirements	Cable installation is usually the final installation campaign in an offshore wind farm. The activity involves transporting the cables from the lay-up facility to site (either directly or via a local port base) and proceeding with cable laying and burial operations, using a plough or a jetting tool on a ROV. There are a handful of established cable installation contractors with proven track record and access to suitable cable lay vessels. Export cables are both thicker and longer than array cables and thus require larger vessels equipped with larger carrousels. In addition, equipment such as trenching and burial tools, tensioners, and support services such as support vessels, diving crew, and ROVs are required. Cable installation is a critical operation in wind farm construction due to the risk of damaging power cables during the cable lay, burial, and pull-in processes. Cable failures have been the primary cause of insurance claims in offshore wind, many of which have been attributed to issues during installation. Wind farm developers will therefore contract with established contractors, making this a difficult area for new entrants.
Synergies w/ other industries	There are some synergies with the telecommunications and oil and gas industries, due to similarities with the installation of telecommunication and umbilical cables, which utilise similar vessels and installation approaches. There are also good synergies with other maritime industries where there is a need for similar equipment and support services.
Life cycle cost share	**Medium (2-3%)**
Capacity in Wales	**Low-Medium**

	There are no existing cable installation contractors in Wales, but there are suitable ports and support service providers that could benefit if locally sourced.
Opportunity for Wales	**Medium** Competition with leading cable installation contractors based around the North Sea means that opportunities for major contracts will be limited. However, there may be opportunities for support services and logistics. Welsh ports would also be used as the installation base.

4.3.5 Operations and maintenance

Although individual contracts during operations and maintenance (O&M) can be relatively small, over the lifetime of a project O&M activities can contribute over a third of total spend on an offshore wind farm. Larger long-term contracts can also be available for local ports, vessel providers, and service providers. With servicing activities typically undertaken from a local port base, there can be greater opportunities to capture local supply chain and economic benefits. Primary activities include:

- Monitoring, inspection and maintenance
- Vessel and equipment supply

Monitoring, inspection, and maintenance	
Requirements	Inspection and maintenance involves providing windfarm support during its operational lifespan to reduce downtime. This encompasses monitoring the performance and integrity of the wind farm assets and undertaking both scheduled and unscheduled maintenance and repair activities. Offshore wind operators can either undertake the inspection and maintenance activities themselves or source them to OEMs or third parties. Typically, turbine suppliers undertake the inspection and maintenance of the turbines for the first 5 years of operation, with potential to either extend the contract or take on responsibility in-house. Wind farm operators or third parties undertake the inspection and maintenance of the balance of plant (e.g. foundation, array cables, and mooring system, if applicable). Many of the activities are procured externally, which can deliver benefits to local companies and skilled personnel. Inspection and maintenance work requires skilled technicians, engineers, skippers and other qualified professionals to plan, manage, perform and assess all off-site and on-site activities and data. Technicians are particularly important as they are responsible for accessing the turbines and undertake the inspection and maintenance work. They are usually certified and experienced professionals able to work effectively in difficult conditions and in line with strict health and safety requirements. Another requirement is the ability to effectively access the windfarm and transfer technicians, considering transportation costs and weather constraints. As a result, parties performing inspection and maintenance activities usually locate their operations base in the nearest suitable port that meets their criteria in terms of vessel access and available facilities.
Synergies w/ other industries	There are good synergies with onshore wind (turbine repairs, working at heights) and other offshore and maritime industries, such as oil and gas (structural integrity, remote inspection, weather management, and health & safety).
Life cycle cost share	**Very high (>10%)**

Capacity in Wales	**Medium-High** Wales has a number of companies that are already active or capable of servicing offshore wind farms. This has partly been built on the experience to date from the three operational wind farms in the Irish Sea. Innogy and MHI-Vestas both have service bases at the Port of Mostyn. Several contracts have been by awarded to local companies, but these have typically been for small-scale secondary activities, as opposed to major works. Nevertheless, O&M activities have boosted employment of local technicians, facilitated by locally-based recruitment specialists such as Total Wind and Oftech Wind.
Opportunity for Wales	**High** The high lifetime value of O&M activities and existence of several operational wind farms in the Irish Sea means that monitoring, inspection, and maintenance activities represent a sizeable opportunity for Welsh businesses. However, efforts will be needed to ensure that local companies are competitive and can capture a greater share of the available opportunities, including higher value contracts with larger scopes of work.

Vessel and equipment supply	
Requirements	To undertake monitoring, inspection and maintenance activities, operators and OEMs will usually procure the equipment, vessels, and wind farm technicians from third parties. The benefits of having vessels and equipment readily available can result in greater opportunities for local companies. Vessel and equipment for inspection and maintenance activities typically involve workboats such as crew transfer vessels (CTVs) or service operations vessels (SOVs), safety, inspection and maintenance tools or spare parts. Operators typically select their vessels depending on requirements such as transit speed, carrying capacity, fuel efficiency or personnel transferability. SOVs are larger vessels that can effectively serve as an offshore base for inspection and maintenance activities, whereas CTVs and other smaller vessels usually go offshore and return to port on a more frequent basis. Selection of CTVs or SOVs depends on the distance between the port base and wind farm, met-ocean conditions, and the operator’s O&M strategy. While scheduled repairs are typically relatively minor and are undertaken with the full-time technician team and more basic vessels and equipment, unscheduled repairs relating to major malfunctions can require large campaigns, more comparable to installation operations. Such events can require large heavy lift vessels and larger ports to accommodate the exchange of components and ensure unrestricted vessel access.

Synergies w/ other industries	There are good synergies with other offshore and maritime industries that use similar vessels and equipment.
Life cycle cost share	**Very high (>10%)**
Capacity in Wales	**Medium-High** There are several Welsh-based companies active in this area, both in terms of vessel and equipment supply: • **Vessels and logistics:** North Sea Logistics (Port of Anglesey), Turbine Transfers (Port of Anglesey), Offshore Transfer Devices (Llandudno), Mainstay Marine Solutions (Pembroke Dock), and Severn Offshore Services (Cardiff). • **Safety and handling equipment:** DMM International (Llanberis), Workplace Worksafe (Ruthin), Wind Farm Equipment (Mostyn), Pinpoint Manufacturing (Swansea), Safety Technology (Raglan).
Opportunity for Wales	**High** Wales has an established base of companies already servicing the offshore wind industry and would be well-positioned to expand these activities with additional deployment to unlock more business opportunities. The supply of crew transfer vessels and safety equipment is a strength, but there could be opportunities to also expand outside these areas. CTV suppliers will also need to be prepared for future deployments further from shore that may require SOV solutions.

4.3.6 Decommissioning

Decommissioning of offshore wind farms has been limited to date, given the relative nascence of the industry. The world's first offshore wind farm, at Vindeby in Denmark, was only decommissioned in 2017. The wind farm consisted of eleven 450 kW wind turbines. Decommissioning of larger wind farms and larger turbines will create new challenges and is largely untested, despite some synergies with oil and gas. As such, there is scope for companies to take a leading role in the removal, salvage, and recycling of wind farm assets.

<table>
<tr><th colspan="2">Decommissioning</th></tr>
<tr><td>Requirements</td><td>Decommissioning involves the removal of the offshore assets of a windfarm, including the turbine, foundation, scour protection, and subsea cabling. The process is, in effect, a reversal of the installation process. The removed components are then either reused, recycled, or disposed of. Reuse might be possible for some turbine parts and the high volume of steel in offshore wind farms means that recycling is an attractive option that could return value to operators, in addition to the environmental benefits.

There has been little experience in offshore wind regarding decommissioning activities so far. Offshore wind developers are likely to source contractors to undertake activities including:

• Port base: Port with suitable vessel access and on-shore area for component set-down.
• Marine operations: Vessels, cutting tools, logistics, safety equipment
• Salvage and recycling: Onshore disassembly and sorting of wind farm components, including sale for re-use or recycling.
• Project management: Logistical planning and management of the on and offshore operations.

The removal of large components such as turbines or foundations will require large vessels with the necessary lifting capacity and deck space for component transportation back to shore. The port base will need to accommodate both the vessels and decommissioned components. It is possible that some of these ports may even develop specific infrastructure for decommissioning.</td></tr>
<tr><td>Synergies w/ other industries</td><td>There are synergies with other maritime salvage and offshore industries, such as oil and gas, where decommissioning activities are common.</td></tr>
<tr><td>Life cycle cost share</td><td>Medium-High (3-5%)</td></tr>
<tr><td>Capacity in Wales</td><td>Medium

There is limited decommissioning experience in Wales and few Welsh companies with a dedicated specialism in this area. However, there are suitable ports to serve as the decommissioning base and several marine vessel and logistics companies that could support decommissioning activities.</td></tr>
</table>

Opportunity for Wales	**High** Despite only a modest contribution to lifetime costs (~3-4%) and no obvious specialist suppliers, the expected decommissioning of the UK's first commercial offshore wind farm (North Hoyle) during the 2020s means that this could be a high value area of Wales. Assuming a 20-25 year lifetime, North Hoyle is expected to be decommissioned between 2023-2028 and is likely to be the first UK offshore wind farm to do so. This could present an opportunity for Welsh companies to generate competencies and intellectual property in this novel area that will become a core part of wind farm operations of the coming decades as the existing fleet is decommissioned. In addition to opportunities for offshore salvage and marine contractors, there could be opportunities for civil contractors onshore and companies involved in the metallic recycling. The latter, in particular, could represent an opportunity for Wales to become a leader in the safe removal, reuse and recycling of wind farm assets, tying into other initiatives Wales is leading in the circular economy. Generation of IP in this could open export opportunities for Welsh companies.

4.4 Gap analysis and opportunity mapping

4.4.1 Summary supply chain assessment

A summary of the supply chain assessment is presented in Table 26. Opportunities for Wales are then mapped against a typical project cost breakdown (Figure 41) and against the number of existing Welsh-based companies active in the offshore wind sector (Figure 42).

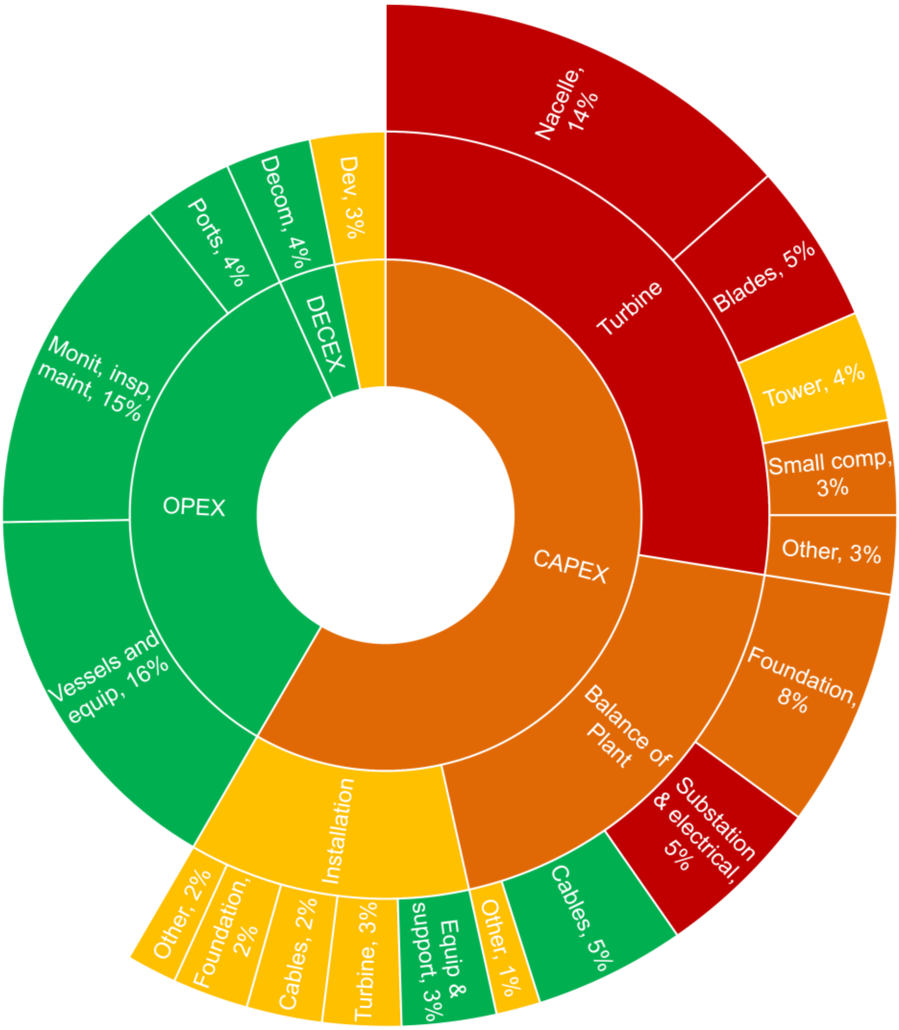
The lack of established manufacturing facilities for large components, such as major turbine components and foundations, means that opportunities during construction will be limited and mostly reserved for smaller support contracts and ancillary services. The most significant construction opportunities are seen in the supply of array cable cores from Prysmian's Wrexham facility, which will boost employment for the local workforce, particularly if volume orders can trigger additional expansion.

Table 26. Supply chain assessment for offshore wind in Wales

	Lifecycle cost	Capacity in Wales (Current)	Opportunity for Wales (Future)
DEVELOPMENT			
Development, consent & design			
Site surveys			
FEED			
CONSTRUCTION			
Turbine			
Blades			
Tower			
Nacelle (drive train & power conversion)			
Other large fabrications			
Nacelle assembly			
Balance of Plant			
Foundation			
Mooring System			
Cables			
Offshore substation			
Electrical systems			
Secondary steel works			
Installation			
Foundation installation			
Turbine installation			
Offshore substation installation			
Cable installation			
OPERATION			
O&M and decommissioning			
Inspection and maintenance			
Vessel and equipment supply			
Decommissioning			

Wales has several ports that could serve as the construction base for wind farms around Wales. However, investment is expected to be needed to upgrade facilities to meet the more stringent requirements for large-scale developments installing larger next generation turbines and the associated supporting infrastructure (foundations, cables, etc.). If Welsh ports can be secured, local Welsh companies are well placed to provide CTV and workboat vessels, equipment, and support services. Major installation contracts are likely to go to established and experienced European contractors, but there could be opportunities for Welsh technicians to work on these projects.

Figure 41. Wales supply chain opportunities mapped against project lifetime spend



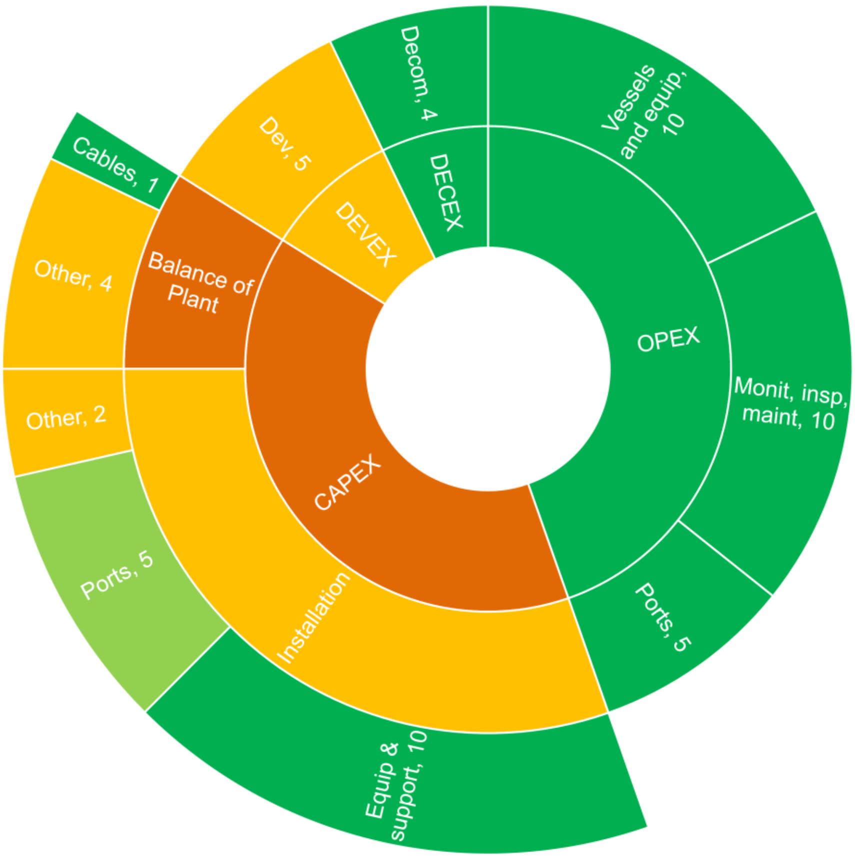
Note: Categorisation is indicative only and should not be interpreted to reflect full capture of certain cost areas (green) or no capture of others (red). For example, cable supply recognises value from cable cores only, which only represents a portion of full cable supply costs.

The greatest supply chain opportunities for Wales are in operations and maintenance, building on the capabilities that exist from servicing offshore wind farms in the Irish Sea. Although individual contracts may be smaller, over the lifetime of the project these economic benefits could be considerable. Wales has particular strengths in the provision of support vessels and safety equipment and should look to build on these capabilities to ensure competitiveness in both existing and future wind farm developments. The Port of Mostyn is well placed to support O&M activities and could become a hub for supply chain companies, technology innovation, and training activities.

A future opportunity for Wales may lie in lifetime extension, repowering and/or decommissioning. As the UK's oldest commercial offshore wind farm, North Hoyle is due to be decommissioned within the next 5-10 years, which could offer an opportunity for Welsh companies to develop capabilities and know-how in an area that will become increasingly active over the coming decades as the current fleet of wind farm assets reach the end of their operational lifetime. In decommissioning, there could also be opportunities to develop leadership in the reuse and recycling of wind farm assets, particularly if this can align with other circular economy initiatives in Wales.

Wales should also explore opportunities to leverage its steel production and manufacturing heritage, particularly in response to increasing UK content requirements. For example, achieving 60% UK content may increase the business case for investment in new turbine tower and secondary steel facilities (e.g. transition pieces, boat landings, etc.) in the UK.

Figure 42. Breakdown of Welsh companies active in the offshore wind sector, categorised by potential economic impact



Note: Assessment includes 33 companies, with several companies capable of servicing multiple supply chain areas. Note that the chart presents the number of companies only and does not account the scale of economic activity or ability to capture significant market share.

4.4.2 Future opportunities

The immaturity of the Welsh and wider UK supply chain for early projects meant that early projects failed to fully capitalise on the economic opportunities available, but steadily increasing deployment has resulted in higher levels of UK content, now approaching 50% of project value for the latest UK wind farms. Wales also stands to benefit more from future offshore wind projects, but will need to be realistic about the level of Welsh content expected, given the lack of activity over the past 5+ years. During this period, other parts of the UK have been proactively developing supply chain capabilities and attracting inward investment in new facilities, such as the Siemens-Gamesa blade factory in Hull. The supply chain assessment in this study also identified several barriers to capturing major construction contracts in Wales.

Nevertheless, site extensions and new leasing rounds could create a pipeline of projects that stimulates supply chain activity in Wales and attracts investment that can deliver economic benefits to Welsh businesses and communities. In general, Wales has a strong industrial base, with good port facilities, road links, and catchment of highly skilled engineers and technicians, including existing skills from early offshore wind projects and transferable skills from other industries, such as marine engineering (e.g. Stena), automotive (e.g. Toyota, Vauxhall) and aviation (e.g. Airbus). Offshore wind also aligns with academic institutions, including universities in Cardiff, Swansea, Bangor, and Aberystwyth, and several local colleges near to potential offshore wind activity. Offshore wind has already supported apprentices at Llandudno College, which could be replicated elsewhere.

To ensure that Wales can maximise its share of the 50-60% UK content in future offshore wind farms, policy makers and industry players will need to focus on areas of strength and competitive advantage. Priority opportunities include:

Near-term (existing assets)

1. **Operations and maintenance:** Building on existing capabilities and fleet of operational assets in the Irish Sea, support Welsh companies to capture market share. This could include developing a cluster of O&M activity, or a Centre of Excellence, around the Port of Mostyn to foster supply chain innovation and training initiatives.

2. **Asset enhancement and decommissioning:** Wales is in the unique position of hosting the UK's oldest offshore wind farm. This presents an opportunity to develop leadership in asset enhancement (incl. lifetime extension and repowering) and decommissioning.

3. **Environmental and socio-economic impact:** Wales has a rich sea life and communities that rely on the coastal environment for tourism and other industrial activities. Coupled with a networks of strong academic institutions, Wales could take a leading role in research studies to better understand the environmental and socio-economic impact of offshore wind farms.

Medium-term (new lease developments)

4. **Construction port base and support services:** Welsh ports are highly capable but will need support to invest in necessary upgrades. Securing construction activities in Wales would act as a catalyst for Welsh business opportunities in providing support services, as well as potentially attract investment from major suppliers. This could be a near-term opportunity for site extensions.

5. **Cable core supply:** Prysmian are the only tier 1 supplier with a manufacturing base in Wales. Recent investment to develop submarine cable cores is a major boost to Wales and volume orders could support further expansion.

Long-term (contingent on market volume)

6. **Large steel fabrication facilities:** Wales has an established steel industry and skilled workforce. Depending on market need, there may be opportunities to attract leading suppliers to locate facilities in Wales. One opportunity could be tower fabrication, for which there is currently only one existing facility in the UK.

7. **Cable lay-up facility:** To complement the cable core facility in Wrexham, attracting investment in a cable lay-up facility would help to concentrate expertise and supply chain capabilities in Wales. High order volumes across Europe would be needed to justify investment in new facilities.

8. **Floating wind technology:** Floating wind has synergies with both fixed offshore wind and marine energy. Wales could be well-placed to leverage the existing activity in each of these areas to develop complementary capabilities in areas such as mooring systems, dynamic cables, cable connectors, logistical operations, and other auxiliary components.

   If a route to market can be identified for the Pembrokeshire Development Zone and deep water sites are included in upcoming and/or future leasing rounds, this would become a priority near/medium-term opportunity. But in the absence of such guarantees, it will be difficult to justify considerable investment. There may, however, still be near-term innovation opportunities, particularly if this can dovetail with wave and tidal activities.

4.5 Policy levers to maximise the economic impact of offshore wind in Wales

4.5.1.1 Current status and the role of Welsh Government

The most impactful policy levers to increase local economic impacts are related to building a pipeline of offshore wind projects that can attract inward investment from the private sector. Such levers are captured in section 3.5, with most controlled by central UK Government.

Local content requirements have been adopted in some geographies to mandate a specified level of investment in local manufacturing and infrastructure. While effective in increasing local content levels, stringent requirements tend to have a negative impact on project competitiveness and development timeframes, as exemplified by high costs and project delays in France. The UK has adopted a more flexible approach through supply chain plans, which should target at least 50% UK content. Welsh Government cannot directly influence the content of UK supply chain plans, but should proactively work with offshore wind developers and Wales-based companies to maximise the level of Welsh content.

Public investment in infrastructure (e.g. port facilities) is another high impact lever and within the powers of Welsh Government, but is a high cost and higher risk option without guarantees of a project pipeline. Lighter touch interventions include providing support for SMEs to develop products and services for the offshore wind sector. This could include innovation grants, business incubation programmes, and creating networks to coordinate Welsh supply chain activities, such as the provision of intelligence services and helping companies to market themselves to potential customers, both within and outside the UK.

4.5.1.2 Policy levers for Welsh Government

Policy levers for Welsh Government include:

- **Project pipeline:** Proactively engage with UK Government, The Crown Estate, and offshore wind developers to attract new projects to Wales through site extensions and new leasing rounds. This is likely to be the single most effective means of attracting investment and supply chain opportunities to Wales.

- **Supply chain plans:** Work with offshore wind developers and Wales-based suppliers to maximise Welsh content in future developments. This could include explicit inclusion of Welsh content in supply chain plans and expressing an interest for a given level of Welsh content, but caution should be taken to avoid introducing arduous requirements that damage project competitiveness and the ability to build a pipeline of projects in Wales.

- **Infrastructure investment:** Work with Welsh port owners to identify upgrade needs and attract capital investment from the private sector. This could include providing match funding towards infrastructure upgrades that improve the capabilities and competitiveness of Welsh ports. Welsh Government and local authorities can also be proactive in engaging with leading Tier 1 suppliers that may invest in facilities in Wales. This could include industrialisation of existing facilities (e.g. cable cores in Wrexham) or investment in new facilities to expand Wales' capabilities in the sector (e.g. turbine tower fabrication).

- **SME support:** There are very few Tier 1 suppliers Wales, but several SMEs that are active in the offshore wind sector but would benefit from increased support to better position themselves to secure contracts both within and outside Wales. For example, Welsh suppliers are located in close proximity to other developments in the Irish Sea, where there is scope for increased deployment in both England and Ireland.

Welsh Government bodies could learn from the excellent work undertaken by enterprise agencies in other countries, such as Scotland (e.g. Scottish Enterprise; Highlands & Islands Enterprise), where there is far greater activity in supporting local companies.

In addition to national coordination of Welsh businesses, local authorities (LA) and local enterprise partnerships (LEP) can coordinate regional activity in close proximity to offshore wind developments. For example, the Humber LEP has been effective in stimulating supply chain activity in the Humber east coast cluster.

- **Research, development, and demonstration (RD&D):** Linked to SME activity, support for innovation in the Welsh supply chain can help companies to develop products and services that can facilitate competitive advantage over competitors. Policy interventions could include grants for research, development, and demonstration, incubation support for start-ups and university spin-outs, and creating links between Welsh academic institutions, Welsh businesses, and prospective customers in the offshore wind market, such as developers and leading suppliers.

  Wales could also leverage its existing assets and facilities to host RD&D activities. For example, Gwynt-y-Môr offshore wind farm and the Port of Mostyn have already hosted RD&D activities from the Carbon Trust's Offshore Wind Accelerator programme. This activity should be encouraged across Wales' operational fleet.

  Proposed floating wind deployment at the Pembrokeshire Development Zone also presents an opportunity for Wales to develop leadership in a new and emerging technology, but Welsh Government will need to work with developers and suppliers to maximise the role of Welsh companies.

- **Training:** Wales can also leverage existing assets to host training for offshore wind technicians and establish apprenticeships with local colleges and suppliers, which aligns with Wales' competence in operations and maintenance. Training centres can up-skill the local workforce to service wind farms both within and outside Wales, building on the engineering expertise that already exists from the automotive, aviation, and energy sectors in Wales.

- **Academic research:** Wales has several universities that can develop expertise and intellectual property in offshore wind by undertaking cutting-edge research in new technologies, materials, and the socio-economic and environmental impact of offshore wind development.

- **Community funds:** The Gwynt-y-Môr Community Fund has proved effective in delivering socio-economic benefits to local residents. The establishment of community funds should be encouraged in future projects, particularly if this can also make a contribution towards demonstrating local ownership of offshore wind investment in Wales.

5. Conclusions & Recommendations

5.1 Opportunities for increasing offshore wind deployment

Despite suffering from the lack of a project pipeline in recent years, site extensions and new leasing rounds administered by The Crown Estate will create opportunities for Wales to exploit its extensive offshore wind resource and attract new investment in Wales' energy infrastructure. A potential extension at Gwynt-y-Môr is a priority near-term opportunity for Wales to add up to 576 MW to its existing fleet of assets, which would represent an 80% increase on the 726 MW already installed. If realised, cumulative capacity of 1.3 GW could meet 27% of total electricity consumption in Wales.

New leasing rounds for offshore wind in England and Wales of up to 7 GW could open opportunities for new regions of Wales to develop offshore wind, with both North Wales and Anglesey shortlisted for proposed Round 4 leasing. Analysis of environmental conditions and constraints in Wales suggests that this aligns with the best opportunities for offshore wind in Wales, in the Irish Sea. In particular, the area to the north-east of Anglesey, overlapping with the former 4.2 GW Celtic Array development zone, is expected to be attractive to offshore wind developers. A single project could add up to 1.5 GW of new capacity, lifting the total generation fleet to 2.8 GW capacity, enough to meet 68% of Wales' electricity consumption. Combined with existing onshore renewable capacity, this would contribute 82% by 2030, putting Wales on course to exceed its renewable energy and decarbonisation goals and building a pipeline of projects to meet more demanding target beyond 2030.[14]

Further deployment opportunities in upcoming leasing rounds could also emerge elsewhere in the Irish Sea and in the Bristol Channel, although challenging seabed geology and estuarine currents could be a barrier in the latter. Pembrokeshire has considerable potential to develop floating offshore wind farms, but is unlikely to feature in Round 4 leasing. Nevertheless, floating wind represents an opportunity to meet Wales' longer-term energy targets in subsequent leasing rounds and through pre-commercial projects (<100 MW) in the near term. Cardigan Bay is heavily constrained by a lack of grid transmission infrastructure, which is a major barrier to offshore wind development.

Table 27. Offshore wind electricity generation scenarios in Wales[15]

Scenario	Capacity (MW)	Capacity factor (%)	Generation (TWh)	% of total elec. consumption
OSW current	726	33%	2.1	14%
OSW current + extension	1,302	36%	4.1	28%
OSW current + extension + 1.5 GW new leasing	2,802	40%	9.9	68%
OSW total (2.8 GW) + existing renewables	3,657	37%	12.0	82%

[14] It should be noted that projects in new leasing rounds may not be commissioned before 2030. Figures do not account for potential decommissioning by 2030 – it is possible that North Hoyle and/or Rhyl Flats could be decommissioned before 2030, collectively representing 150 MW of capacity and 2% of electricity consumption. Figures do not account for decommissioning or new build of other renewables, which are also expected to expand considerably up to 2030.

[15] Generation based on 2016 performance. Capacity factor of site extension assumed at 40%. Capacity factor of new lease assumed at 45% to account for higher wind speeds and advanced turbine technology. This may be considered conservative given projections of capacity factors of ~50% in future offshore wind farms, which would further increase generation potential and impact against energy and decarbonisation targets.

5.2 Opportunities for increasing economic benefits

The three existing offshore wind projects have been criticised for the lack of economic benefit captured in Wales – a criticism directed at several UK early offshore wind farms. Local content in the UK has increased markedly since, with the latest figures indicating 48% UK content in recent projects. Supply chain plans are putting further pressure on developers to achieve at least 50% UK content, with a stretch target of 60% advocated by some.

However, the increase in UK content has largely been driven by activity outside Wales, particularly on the English east coast where clusters of activity, established in response to a large project pipeline in the North Sea, are delivering considerable economic benefits for local businesses and communities. A lack of project development in Wales has constrained activity here, but there have been successes in some areas, most notably at the Port of Mostyn and in operations and maintenance contracts for local suppliers. Prysmian's cable core facility in Wrexham is the only major Tier 1 supply facility in Wales, following a recent investment to expand capabilities to subsea cable cores, largely in response to local content requirements in UK supply chain plans. Community funds have also injected millions of pounds into local community schemes.

Future supply chain opportunities in Wales will be driven by the level of deployment. If site extensions and new lease developments can be realised, this could unlock 2 GW of offshore wind construction in North Wales, which would result in up to 2.8 GW of capacity requiring operations and maintenance services. This scale of activity in a single region could create significant opportunities for supply chain clustering to develop around Welsh ports, with the Ports of Mostyn and Holyhead well-positioned to benefit.

Nevertheless, Wales will need to be realistic about the supply chain opportunities that can be expected, particularly during construction. Welsh ports will face fierce competition with other ports around the Irish Sea, including Belfast, Liverpool, and Barrow, and investment is likely to be required to increase the capabilities and competitiveness of Welsh ports. Given the clustering of activity that exists around ports, this should be a priority focus that could act as a catalyst for creating supply chain hubs in Wales.

Even with construction ports in Wales, it may still be challenging to attract suppliers of major components (e.g. turbine nacelle assembly, blades, foundations), which are typically sourced from a small number of large and established manufacturing facilities around Europe. The high investment costs related to such facilities means that setting up production bases in Wales will require a large volume of deployment in the Irish Sea. If scale can be delivered, possible opportunities for Wales could lie in expanding production capacity of the cable core factory in Wrexham, possibly supplementing this with a cable lay-up facility, and attracting suppliers of steel fabrications, such as turbine towers, potentially leveraging Wales' steel industry in South Wales.

However, more tangible near-term opportunities are expected in areas where Wales has existing capabilities, particularly in operations and maintenance and in support services during construction. Although individual contracts may be smaller, the longevity of O&M activity can help to create sustainable, long-term employment in Wales. There may also be opportunities for Wales to develop leadership in areas such as lifetime extension, repowering, and decommissioning, generating know-how and IP that can be exported to overseas markets.

5.3 Recommendations to policy makers

A variety of policy levers to accelerate offshore wind deployment and increase economic benefits are outlined in sections 3.5 and 4.5, respectively. The following priority recommendations have been extracted to guide the implementation of these levers.

Develop a clear strategy for offshore wind development in Wales and be public in support of future deployment

Following several years of limited activity in Wales, there is a need to establish a clear strategy towards offshore wind in Wales, with a shared vision and common objectives across government departments. The development of a strategic framework for offshore wind development, as undertaken for marine energy in Wales, would provide clarity to developers, suppliers, regulators, and other relevant stakeholders. Such a strategy should align with the Wales National Marine Plan and outline the role offshore wind is expected to play in meeting government targets, including renewable energy, decarbonisation, and well-being goals, as well as how offshore wind can contribute towards local ownership targets. Publishing clear guidance on the planning and consenting procedure for offshore wind projects in Welsh waters would also encourage market interest and support companies looking to develop offshore wind projects in Wales.

Being public in support of offshore wind will be important in sending a signal to prospective developers and suppliers that Welsh Government will be supportive of offshore wind development. Public support can boost market confidence to reduce development risk and create an attractive environment for inward investment. This should include support for site extensions, new leasing, and exploiting deep water locations around Wales.

Actively participate in industry-wide discussions on future offshore wind development in the UK

The next 12 months are expected to be critical in the development of offshore wind in the UK, with a possible Sector Deal earmarked for Autumn 2018 and decisions on site extension applications and potential new leasing rounds expected in 2019. Welsh Government will need to be proactive in ensuring that Wales is fully represented in these discussions and exert influence to maximise opportunities for new deployment and capture of supply chain investment in the UK.

Namely, Wales should engage with the Offshore Wind Industry Council to steer Sector Deal discussions and engage with The Crown Estate to inform upcoming and future leasing processes. Welsh Government should be proactive in understanding and cultivating market interest and supporting developers with their site selection activities.

Support collaborative industry-wide initiatives to address consenting barriers and de-risk project development in Wales

Wales’ coastal waters host a rich diversity of bird and marine life and are integral to tourism, fishing, and leisure activities around Wales. Ensuring that offshore wind development can be undertaken in harmony with the natural environment and existing commercial activities is paramount and should be informed by a robust body of scientific evidence. Several collaborative industry-wide initiatives have been successfully implemented in the UK, with research studies helping to better understand the true risks of offshore wind development and reduce conservativism. Welsh Government should participate in initiatives, such as ORJIP, and support research activities that are relevant to Wales. Industry interviews suggest that seascape issues, cumulative impacts, and analysis of post-consent monitoring data could be priority areas.

Adopt a strategic approach to prioritising supply chain development activities and infrastructure investment

It is unrealistic for Wales to develop supply chain capabilities across the full project breakdown. A more effective strategy would involve focussing efforts on a subset of high priority areas where Welsh businesses can develop competitive advantage to secure contracts in future projects. Initial analysis in this study suggests that operations and maintenance, site surveying, secondary support services, and cable core supply could build on existing strengths, with potential opportunities to attract larger steel manufacturing with sufficient deployment volume. However, more in-depth analysis and engagement with suppliers will be necessary to identify priority opportunities and evaluate options for government support.

Work with offshore wind developers and Welsh suppliers to maximise Welsh content in future developments

If a project pipeline can be secured, Welsh Government will need to be proactive in working with developers and suppliers to maximise capture of economic benefits in Wales. This could include requesting evidence of Welsh content in supply chain plans and working with developers to understand their procurement strategies and drivers for contractor selection. These discussions are likely to better inform Welsh Government activities in supporting local suppliers to improve their competitiveness and in attracting overseas suppliers to establish facilities in Wales.

Be more active in marketing Welsh capabilities in the offshore wind sector

Wales can learn a great deal from other countries that have been proactive in supporting domestic suppliers to enter the offshore wind market, largely facilitated by enterprise bodies and local authorities providing market intelligence and support services to SMEs. Scottish Enterprise and the Humber Local Energy Partnership (LEP) are good examples of how SMEs have been supported to understand industry trends and understand how to meet market need. Welsh Government should be more active in marketing Welsh capabilities, leveraging entities such as Business Wales and Welsh LEPs to coordinate supply chain activity, create a forum for networking and collaboration, host industry events to showcase Welsh capabilities, and lead trade delegations to support exports to UK and overseas markets.

Continue to support technology innovation to develop leadership and competitive advantage in Wales

Innovation is key to unlocking new opportunities for Welsh suppliers, helping businesses to develop products and services that can create competitive advantage and establish Wales as a leader in renewable energy technologies. Potential opportunities include establishing the Port of Mostyn as a Centre of Excellence for operations and maintenance, hosting research and development and training activities, and supporting floating wind in south-west Wales, centred around the Pembrokeshire Development Zone.

Collaborate with UK counterparts with shared challenges and objectives

Several UK regions, such as Scotland, Ireland, and Cornwall, are encountering similar challenges to Wales in accelerating offshore wind development. Collaborating with relevant counterparts to share learnings and pool resources could help to achieve greater collective impact. Where possible, Welsh Government could explore opportunities to co-fund studies, combine trade missions, and create forums for networking and collaboration between Welsh and other UK businesses.

Appendix

Appendix 1: List of operational power stations in Wales

Note: Includes power stations >50 MW only.

Station Name	Operator	Fuel	Installed Capacity (MW)	Commissioning year
Rheidol	Statkraft Energy Ltd	Hydro	56	1961
Ffestiniog	ENGIE	Pumped storage	360	1961
Uskmouth Power	SIMEC	Coal (under conversion to biomass)	230	1966
Aberthaw B	RWE Npower Plc	Coal	1,586	1971
Aberthaw GT	RWE Npower Plc	Gas oil	51	1971
Dinorwig	ENGIE	Pumped storage	1,800	1983
Deeside	ENGIE	CCGT	515	1994
Connahs Quay	Uniper UK Limited	CCGT	1,380	1996
Barry	Centrica	CCGT	235	1998
Baglan Bay CCGT	MPF Operations Limited	CCGT	520	2002
North Hoyle	RWE Innogy UK Ltd	Wind (offshore)	60	2003
Rhyl Flats	RWE Innogy UK Ltd	Wind (offshore)	90	2009
Severn Power	MPF Operations Limited	CCGT	850	2010
Pembroke	RWE Npower Plc	CCGT	2,180	2012
Gwynt y Môr	RWE Innogy UK Ltd	Wind (offshore)	576	2013
Pen y Cymoedd	Vattenfall Wind Power	Wind (onshore)	228	2016

Source: BEIS Power Stations in the United Kingdom, May 2017.

Appendix 2: Proposed grid infrastructure upgrades in Wales

Grid investment	Description	Status	Date
BCRE **(Replacement)**	Higher-rated conductor in the sections between Bodelwyddan and Connah' Quay	Recommendation / Project not started	2029+
PBRE **(Replacement)**	Higher-rated conductor in the sections between Pentir and Bodelwyddan	Recommendation / Project not started	2031+
PTNO **(Reinforcement)**	Second 400kV circuit between Pentir and Trawsfynydd, using existing infrastructure and corridor	Recommendation / Project not started	2028+
PTC1 **(Replacement)**	Large cable sections in the Pentir to Trawsfynydd 1 circuit	Recommendation / Project not started	2028+
PTC2 **(Replacement and Reinforcement)**	Higher-rated conductorS in part of circuits between Pentir and Trawsfynydd Second single core per phase cable section in the circuits between Pentir and Trawsfynydd	Recommendation / Project not started	2028+
PTRE **(Replacement)**	Higher-rated conductor in the remaining parts of the circuits between Pentir and Trawsfynydd	Recommendation / Project not started	2030+

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