

Offshore wind operational report

January – December 2018



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The Crown Estate

The Crown Estate is a £14bn specialist real estate business, focused on commercial property in central London, prime regional retail and offshore wind.

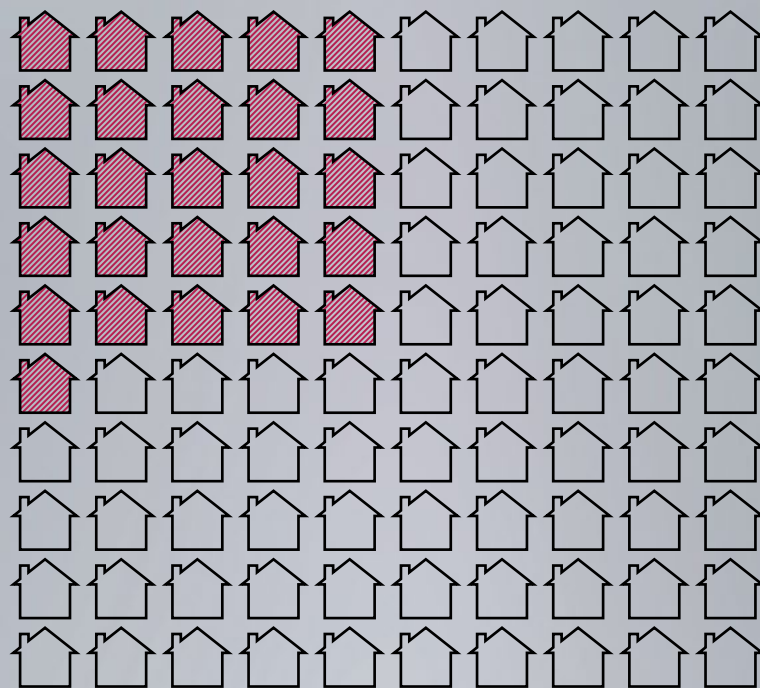
As managers of the seabed and much of the foreshore around England, Wales and Northern Ireland, our business includes wind, wave and tidal power, as well as marine aggregates and minerals, cables, pipelines and carbon capture and storage.

In this capacity, we play a unique role in developing and helping sustain UK energy supply and infrastructure, working in collaboration with a wide range of organisations.

Scotland

The management duties in Scotland, including management of the Scottish seabed, are managed by a separate organisation, the Crown Estate Scotland* which reports to Scottish Ministers. This report has been produced by The Crown Estate but for completeness, publicly available data on the offshore wind in Scotland has been included in key sections, such as offshore wind farm status and national metrics.

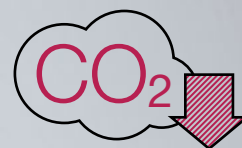
* following implementation of the Scotland Act 2016.



UK offshore wind generated **26.6 TWh** last year, that's enough to supply the electricity needs of **6.9m homes**, around **26%** of the UK total

8%

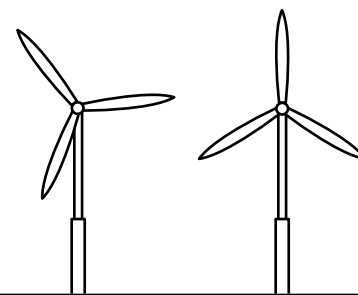
Offshore wind supplied **8%** of the UK's total estimated electricity generation in 2018



This performance reduced the UK's CO₂ emissions by **12 million tonnes**



1 Introduction



After years of strong growth, 2018 was the year when offshore wind entered the Premier League. Historic records fell one after another: Walney Extension, the world's biggest offshore wind farm was commissioned, generation hit an all-time high, an almost-world record of new capacity was completed in the UK, only beaten by China. In addition a "sector deal" was struck between government and industry for 30 GW by 2030 – a fourfold increase in capacity in just over a decade. That's annual growth of 15% over the next ten years, firmly underpinned by government, industry and stakeholders working together, a team effort seen in very few industries. Like the football Premier League, this has become a global success story impacting the lives of millions and generating excitement and opportunity across the country.

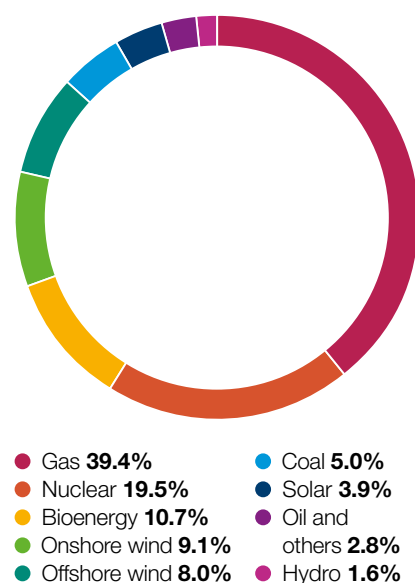
This, our seventh annual Operational Report aims to shed a light on the foundations for this success. With 38 wind farms and 17 OFTOs now operating in UK waters there's a wealth of data that informs business decisions on development, operations, maintenance and future potential. And these data tell an impressive story. Offshore service visits to turbines have halved across the sector in the last four years, as shown by the SPARTA industry collaboration, witness to the increasing reliability of the technology. A relentless drive for performance has seen the industry collaborate on areas of common concern, such as environmental impact and health and safety, where G+ has established itself as the leading industry organisation on safe and healthy working in the sector. These sector-led initiatives demonstrate commitment to lead on reliability, transparency and responsible business – thus earning a licence to grow both domestically and across the world. As managers of the seabed around England, Wales and Northern Ireland we work together with the sector, government and many stakeholders, to help deliver growth in a manner that balances the wide range of interests on the seabed. The extensions to operating projects and our new seabed Leasing Round 4 will ensure a continued growth path for the sector in the years ahead.

As this report highlights, the offshore wind sector has become a large scale, responsible and reliable provider of low-carbon electricity, thus helping address one of the defining issues of our times. We trust you find this report helpful, and as ever welcome your feedback.

Huub den Rooijen

Director of Energy, Minerals and Infrastructure
The Crown Estate

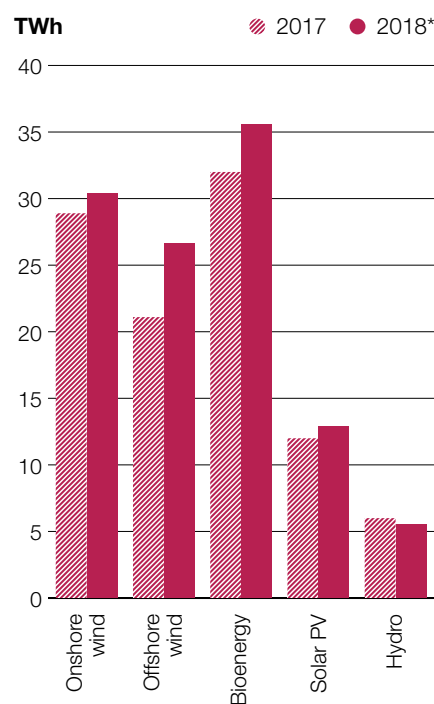
FIGURE 1: UK electricity generation mix 2018*



*Provisional figures

Source: BEIS UK energy statistics

FIGURE 2: Renewable electricity generation by fuel type



* Provisional figures

Source: BEIS UK energy statistics

2 Offshore wind farm status

During 2018, the focus was on commissioning the extensive build-out that occurred in 2017, with five more wind farms (2.1 GW) becoming fully operational. This brought the total count of UK operational wind farms to 38, a staggering 7.9 GW of fully operational sites by December 2018. This makes the UK the nation with the single largest operating capacity in the world. Overall, 1 GW of new generating capacity was commissioned in the UK during 2018, which equates to about 1 MW being commissioned every 10 hours throughout the year.

Whilst construction did not match the highs of 2017 (a turbine a day), at the end of 2018 the UK's share of Europe's 18.5 GW of offshore wind operating capacity stood at 43%, as shown in Figure 3 with a further 5.8 GW having finance secured or under construction.

The UK has a strong track record in the sector with a strong development pipeline and the collective effort of the government, developers, the community and major stakeholders continues to achieve significant milestones.

First R3 site

Rampion, the UK's first Round 3 offshore wind project off the Sussex coast, was completed and fully commissioned.

World's largest offshore wind farm

Walney Extension in the Irish Sea was completed and fully commissioned, which makes it the world's largest operational offshore wind farm, a record until now held by London Array, which is only 29MW smaller.

FIGURE 3: Current European offshore wind generating capacity

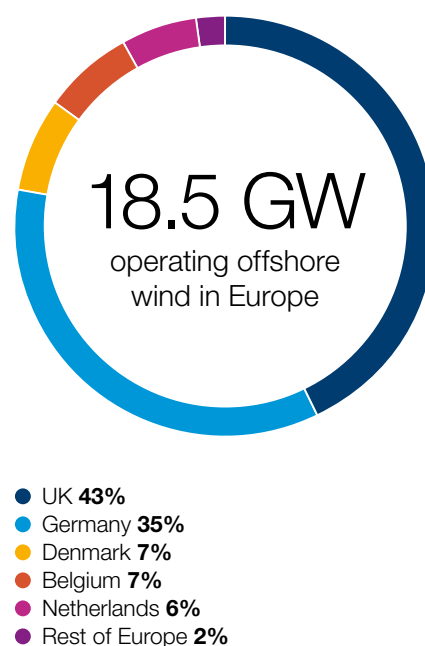


FIGURE 4: UK offshore wind project pipeline – 31 December 2018

Operational: Total capacity of wind farms that have been fully commissioned.

Capacity MW ▼			Capacity MW ▼		
1	Barrow	90	20	Lincs	270
2	Blyth	4	21	London Array	630
3	Blyth Demonstration	41.5	22	Lynn	97
4	Burbo Bank	90	23	North Hoyle	60
5	Burbo Bank Extension	259	24	Ormonde	150
6	Dudgeon	402	25	Race Bank	573
7	European Offshore Wind Deployment Centre*	93.2	26	Rampion	400
8	Galloper	353	27	Rhyl Flats	90
9	Greater Gabbard	504	28	Robin Rigg East*	90
10	Gunfleet Sands Demonstration	12	29	Robin Rigg West*	90
11	Gunfleet Sands I	108	30	Scroby Sands	60
12	Gunfleet Sands II	65	31	Sheringham Shoal	317
13	Gwynt y Môr	576	32	Teesside	62
14	Humber Gateway	219	33	Thanet	300
15	Hywind Scotland*	30	34	Walney 1	184
16	Inner Dowsing	97	35	Walney 2	184
17	Kentish Flats	90	36	Walney Extension	659
18	Kentish Flats Extension	49.5	37	West of Duddon Sands	389
19	Levenmouth Demonstration*	7	38	Westernmost Rough	210
Total			7,905		

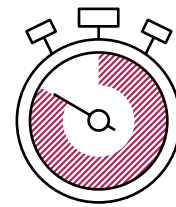
Under construction: Total capacity of wind farms that are under construction or where the developer has confirmed a final investment decision, but are not yet fully operational.

Up to capacity MW ▼		
39	Beatrice*	588
40	East Anglia ONE	714
41	Hornsea 1	1,218
42	Hornsea 2	1,384
43	Kincardine*	48
44	Moray East*	950
45	Triton Knoll	860
Total		5,762

Government support on offer: Total capacity of wind farms that have secured a Contract for Difference.

Up to capacity MW ▼		
46	Neart na Gaoithe*	448
Total		448

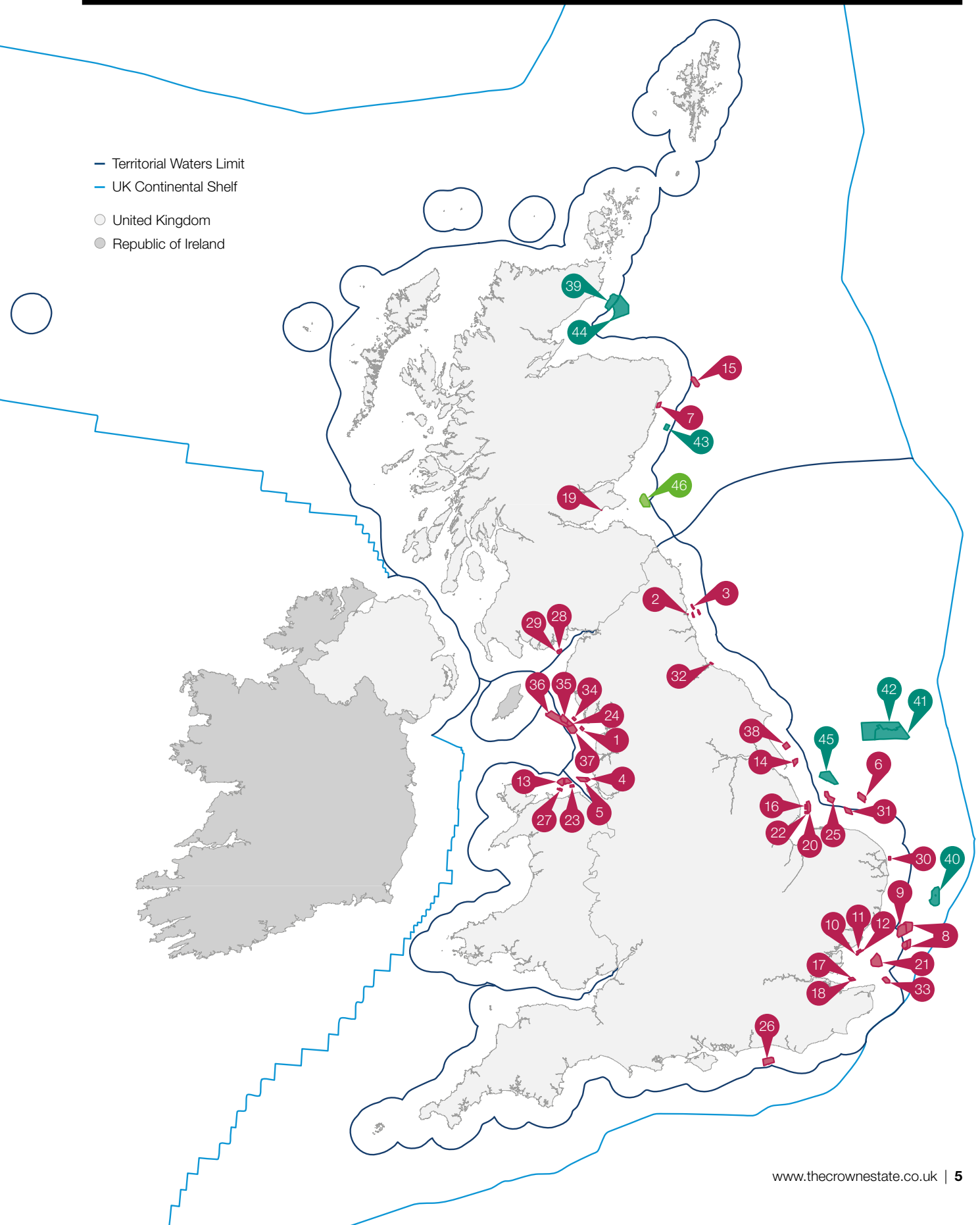
* Asset managed by Crown Estate Scotland



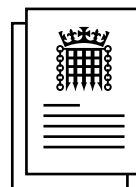
1 MW

of offshore wind was
commissioned every
10 hours in 2018

- Territorial Waters Limit
- UK Continental Shelf
- United Kingdom
- Republic of Ireland








3 Assets



UK Climate Change Act 2008 becomes ten years old!

Early adoption in 2008 of governance on climate change helps increase the UK's annual production from offshore wind ten-fold

FIGURE 5: UK offshore wind assets – 31 December 2018

					
	Offshore turbines	Offshore substations	Export cables	Offshore masts	Wind farms
Operating	1,931	27	70	16	39
Under construction*	992	14	15	1	9
Total	2,923	41	85	17	48

*Sites having reached Final Investment Decision (FID) and those under construction

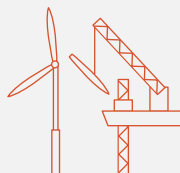
FIGURE 6: Asset activity in 2018

Wind farms having achieved FID (Final Investment Decision)

- Triton Knoll

Wind farms under construction

- Beatrice
- East Anglia ONE
- European Offshore Wind Deployment Centre
- Galloper
- Hornsea 1
- Kincardine
- Moray East
- Race Bank
- Rampion
- Triton Knoll
- Walney Extension



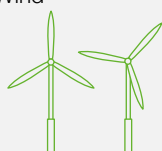
Wind farms achieving first power

- Beatrice
- European Offshore Wind Deployment Centre
- Kincardine



Wind farms completed

- European Offshore Wind Deployment Centre
- Galloper
- Race Bank
- Rampion
- Walney Extension



At the end of December 2018, there were 1,931 fully operational offshore wind turbines on the UK seabed, with a further 992 under construction. This equates to 7.9 GW of grid connected operational capacity in the UK.

During the year, five offshore wind farms became fully operational, adding an additional 1 GW of new operational capacity, accounting for nearly half of the new offshore capacity built in Europe in 2018.

There were 11 offshore wind farms under

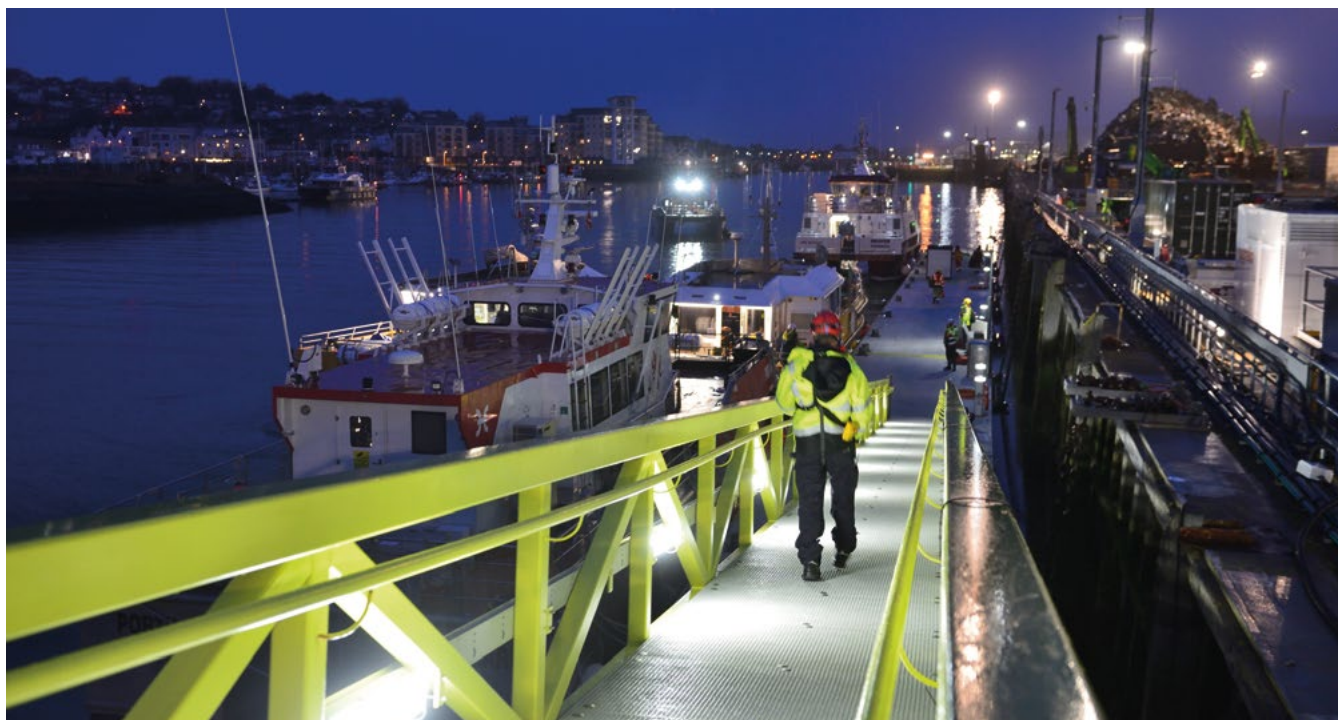
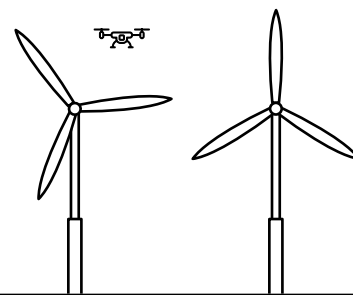
construction during the year, several of which began generating and half of which became fully operational in 2018.

The UK leads the way for deploying new technology with the largest turbine in the world (the MHI Vestas V164 – 8.8MW turbine) deployed at the European Offshore Wind Deployment Centre. Construction also began on what is soon to be the largest offshore wind farm in the world, Hornsea 1, which is to begin operating in 2019. The first Round 3 offshore wind farm, Rampion, became fully operational.



Galloper turbines fully commissioned

4 Health and safety



Heading to work at Newhaven

There continues to be successful progress in prioritising great health and safety management by the UK offshore wind industry. Over the last few years, the quality of the incident data captured continues to be enhanced and 2017 data, which was published in September 2018, shows a decrease in the lost time injury rate compared to previous years.

There is a real focus on achieving better health and safety performance and industry bodies continue to demonstrate their commitment and leadership. The G+ maintains its core objectives which include promoting a strong, sustainable and continually improving health and safety culture. Renewable UK's 2019 Business Plan includes the ambition to build "a safe and skilled future workforce." The government's Industrial Strategy Offshore Wind Sector Deal also seeks to support transferable competency records and drive an even better culture of collaboration:

"The sector will continue to collaborate to deliver a strong, sustainable and continually improving culture, promoting and maintaining the highest possible standards of health and safety through

the life cycle of projects both in the UK and around the world."

The G+ has developed and reviewed more best practice guides over the last year and there is a sustained focus on eliminating and reducing risk in design, through continuing to hold Safety in Design workshops. These workshops provide designers with the opportunity to understand the construction and operational challenges faced by wind farm owners and operators.

Alongside securing progress in core health and safety items, there is also a greater focus on welfare, wellbeing and cultural change. This is especially important as wind farms become bigger and further from shore.

Greater industry collaboration is already progressing with organisations coming together to share best practice, advocate for each other and to avoid duplication. A charter is now being established between the GWO, VGB Powertech, G+, IMCA and Renewable UK. There are also many opportunities for cross industry collaboration, shown at the recent stakeholder event held by G+

where the dialogue with the offshore oil and gas sector continues.

Key benchmarking statistics for 2017 are shown below:



Lost time injury frequency rate (LTIFR) 2017*

*The number of recordable injuries (fatalities + lost work day incidents) per 1 million hours worked.



Total recordable injury rate (TRIR) 2017**

**The number of recordable injuries (fatalities + lost work day incidents + restricted work day incidents + medical treatment injuries) per 1 million hours worked.

5 Wind farm performance

Fleet performance index

The performance index compares metered electricity output against the expected output adjusted for actual wind speed during that year. It gives a direct measure of the performance of the offshore wind farm fleet in England and Wales, without any adjustment for outages.

The analysis only includes fully operational wind farms and excludes the construction period. The analysis includes the whole system of the wind farm and its associated transmission/export of electricity back to shore.

The expected power output is derived from satellite measurements and theoretical power curves. This indirect calculation carries a notable uncertainty, a result above 100% indicates the fleet exceeded its expected output.

Figure 7 shows the variation in fleet performance for the last eight years. 2013 and 2015 were impacted by export cable failures.

Capacity factor

The capacity factor is the average power generated over a period, divided by the rated peak power. It indicates how fully a wind farm's capacity is used.

The capacity factor of offshore wind farms is usually higher than onshore wind farms due to stronger, more stable wind conditions at sea. This is particularly noticeable for the latest wind farms located far offshore.

Figure 8 shows the evolution of the capacity factor and the power output of offshore wind farms in England and Wales, between 2005 and 2018.

In 2005, the capacity factor was about 30%. In 2018 it is close to 40%. This means the power output per unit capacity has increased by a third, which is a considerable improvement.

The overall power output over the same period has increased from 0.5 to 26.6 TWh, a fifty-fold increase. This is a fleet wide average but some newer sites can achieve capacity factors of 50%.

FIGURE 7: Fleet performance index

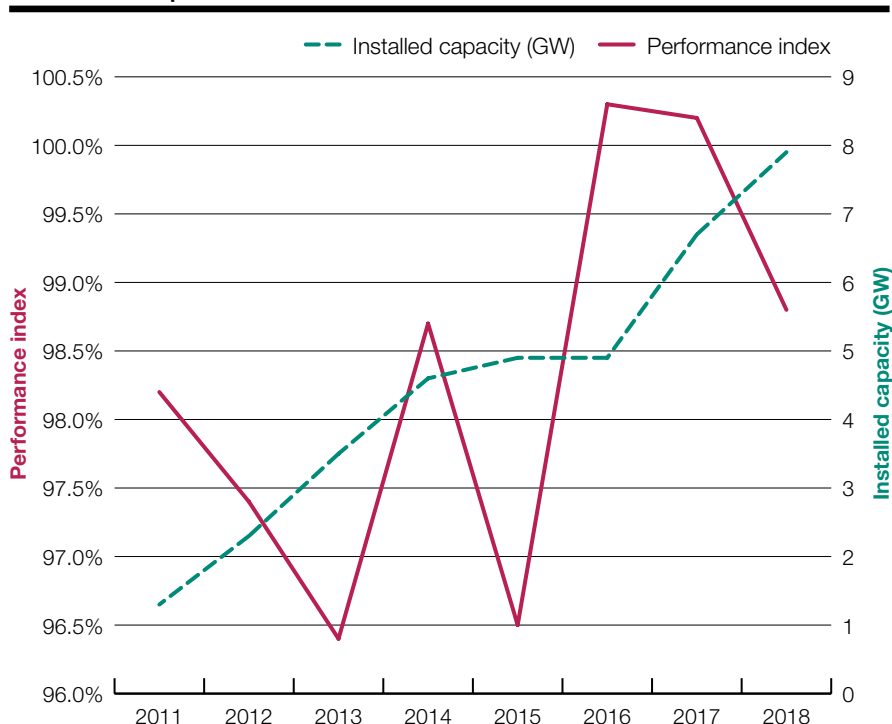
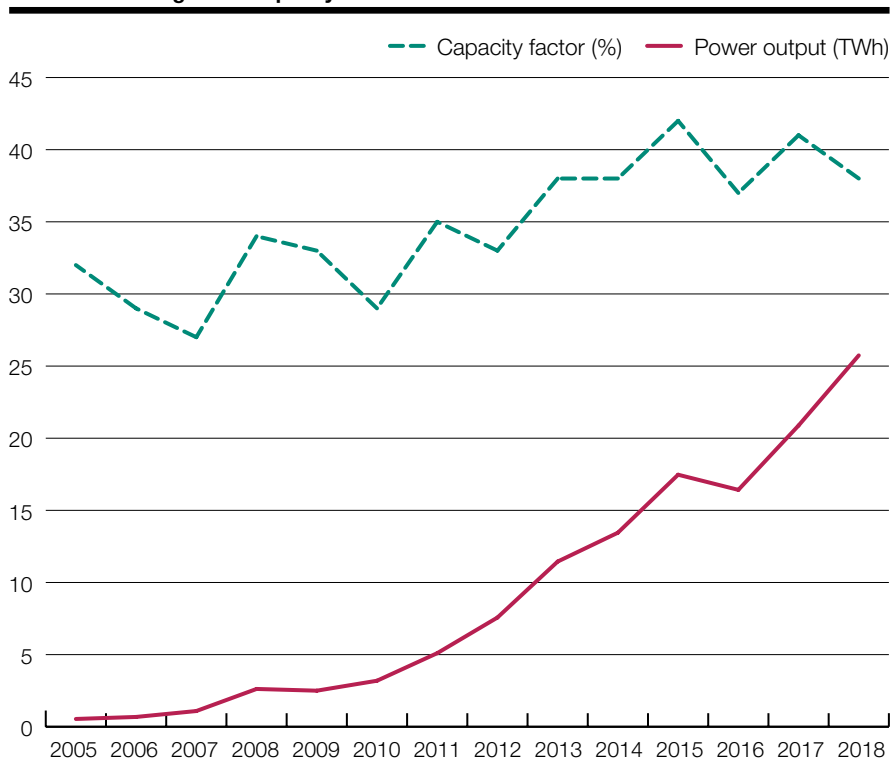
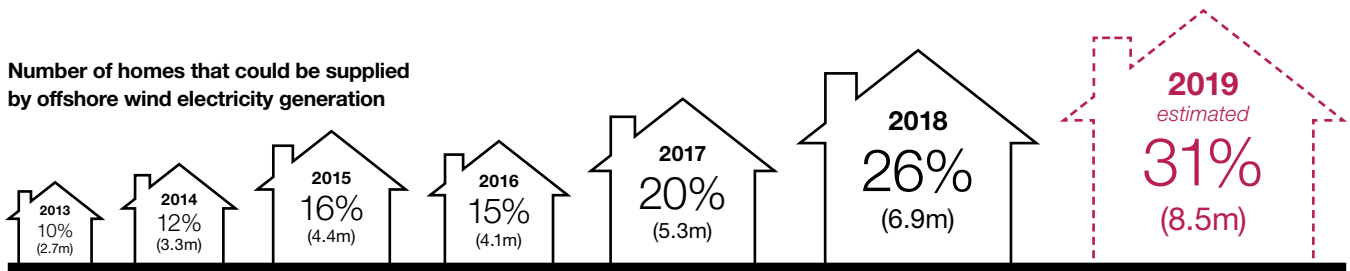


FIGURE 8: Average fleet capacity factor



Number of homes that could be supplied by offshore wind electricity generation



Technicians transferring to a turbine at London Array

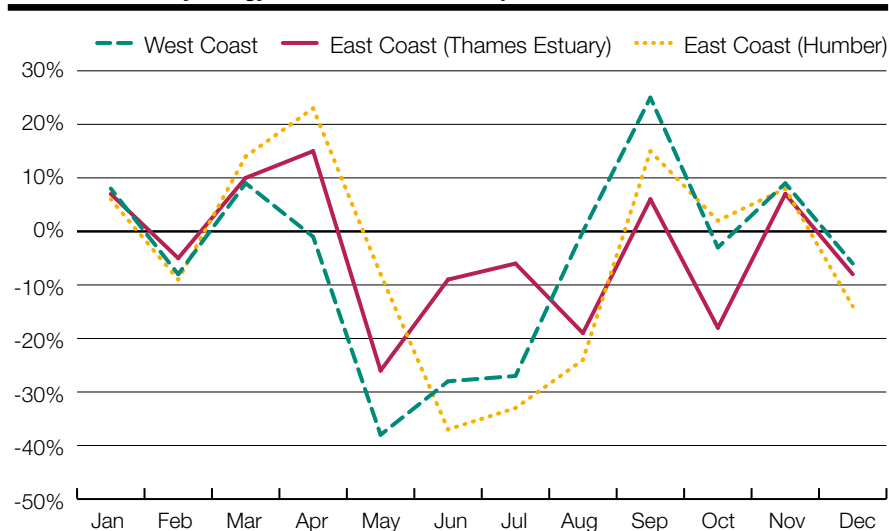
Wind variability

Wind farm output is dependent on wind speed. The average output of a wind farm over its lifetime can be accurately calculated using long-term data, but its performance over a short period of time is entirely dependent on local wind conditions.

Figure 9 shows the impact on energy production due to monthly wind speed variation in England and Wales.

Spring and autumn were windier than expected, but that was not enough to compensate for the unusually calm summer of 2018. The performance across the portfolio follows a similar trend, however it is clear there are some regional variations, due to local wind conditions. The overall energy deviation at the end of 2018 was 3.5% below the long-term average.

FIGURE 9: Monthly energy deviation due to wind speed in 2018



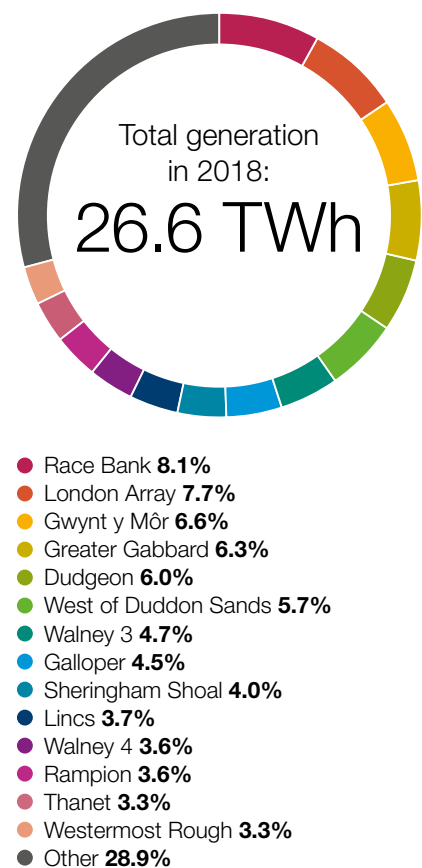
Offshore generation

Figure 10 shows that the top 4 wind farms generated more than 25% of the total offshore wind power in 2018.

The wind speed increases with altitude, therefore a taller turbine will harness more power, all things being equal.

The air flow at a higher altitude is also less turbulent. This greatly reduces transient loads and improves power output.

FIGURE 10: Offshore generation by asset



6 O&M trends



Sister service operation vessels providing a base off the East Coast

More than half of all offshore turbines in the UK are now operating outside the manufacturer's defect warranty. The end of the warranty period represents an opportunity for site owners to change the operations and maintenance (O&M) strategy and Figure 11 shows that almost half of the turbines that are out of warranty are now being maintained using an in-house team of turbine technicians employed directly by the wind farm owner/operator. Around a third of out-of-warranty turbines remain under a service contract with the original turbine supplier.

Independent service providers are used at all offshore wind farms as highlighted in Figure 13. It is common for third parties to support the maintenance of electrical balance of plant, foundations and subsea surveys and to provide vessels directly to owners. A third-party supply chain for wind turbine spare parts has developed and is being used by almost two thirds

of respondents.[†] Opportunities for third parties to deliver turbine maintenance are currently small, however, as the in-house delivery model becomes more established it is anticipated that owners may turn more to independent service providers for the supply of wind turbine technicians for seasonal servicing programmes or to support special projects, campaign-based work and to implement performance improvements.

Figure 12 obtained from the SPARTA* 2017/18 Portfolio Review compares production based availability (PBA) percentages (which are the primary measure of performance), with various turbine maintenance strategies. Greater focus is being placed on PBA across the fleet which plans for routine and predictive maintenance in periods when there is no or low wind.

* SPARTA System Performance Availability and Reliability Trend Analysis

FIGURE 11: Wind turbine maintenance strategy – OEM vs Owner-led**

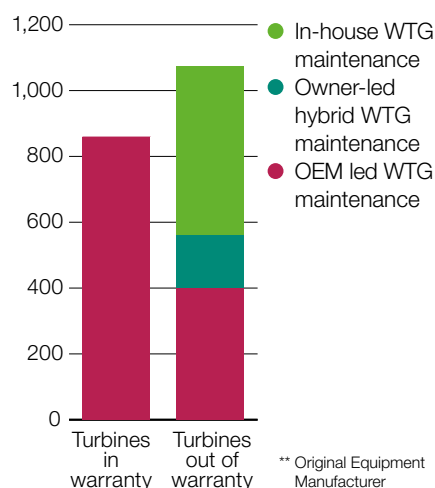


FIGURE 12: Production based availability and OEM status**

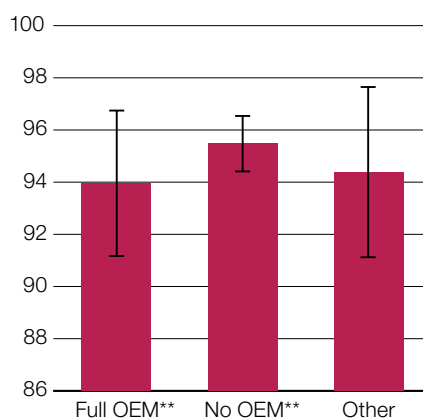
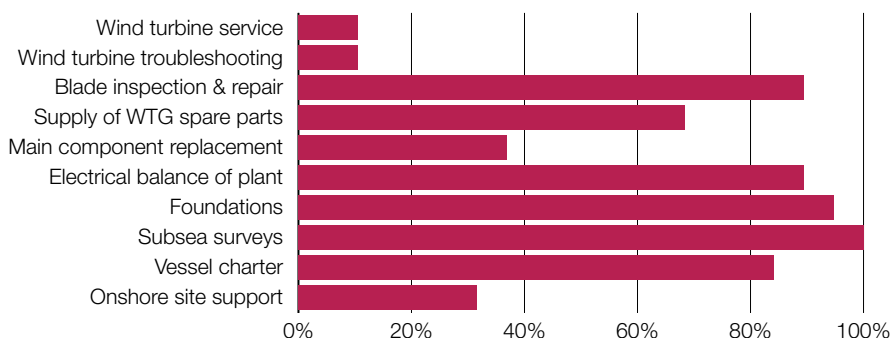


FIGURE 13: Use of third parties at UK operational offshore wind farms



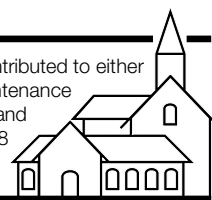
[†] Based on a survey of members of the ORE Catapult O&M Forum in March 2019. The chart indicates the percentage of sites surveyed who use third party providers for O&M activities shown.

The bulk of sites use crew transfer vessels for routine access to and from shore. However sites further offshore such as Dudgeon and Race Bank are now using service operation vessels. With their walk to work systems using motion-compensated gangways and changes to shift patterns of two weeks on/off they pioneer a different approach to servicing and staffing.

Across operating sites new servicing methods have reduced the number of vessel transfers by half over the last four years.

7 Community benefits

86 awarded projects contributed to either the construction or maintenance of community buildings and facilities in the UK in 2018



Moving with the Wind, community art event supported by London Array

Community benefits schemes are now well-established as an integral part of offshore wind energy development – signifying the positive relationships being built between operators and the local communities within which they operate.

While most of the development associated with new projects necessarily takes place offshore, developers increasingly recognise their impact onshore, including for those neighbouring the onshore substations and export cable landing sites, as well as at the ports and harbours that host operation and maintenance bases.

Early engagement with these onshore communities is therefore an essential part of any offshore wind development, and whilst this is voluntary, 'being a good neighbour' has become standard practice for operators.

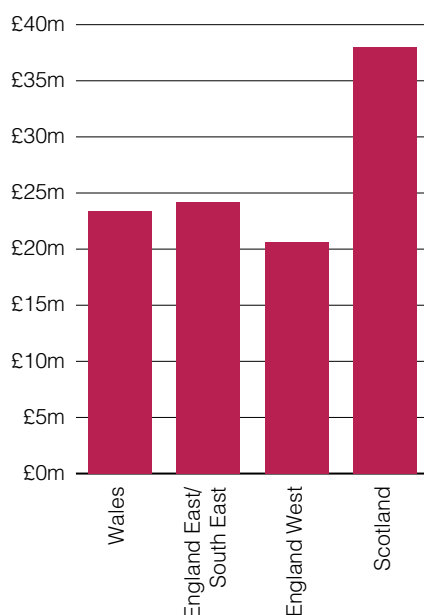
Operator investment in communities often remains a long term commitment over the lifetime of the wind farm with an annual amount being made available and distributed through various application rounds. Grants for specific projects can range from £500 to £100,000. As detailed in Figure 14, over £106 million of funding has been made available by offshore wind farm operators for communities across the UK.

Community benefit schemes are often administered by fund management companies, or local community foundations, such as GrantScape, Community and Voluntary Support Conwy (CVSC) and Norfolk Community Fund, that allocate

funds to the local communities on behalf of the wind farm operator. The majority of wind farm operators publish details of the projects on their website, along with further information on how to apply for the funds and how the funds are allocated.

Community benefits are usually based on the needs of the community and characteristics of the site and project. A breakdown of the types of community funds allocated during 2018 is detailed

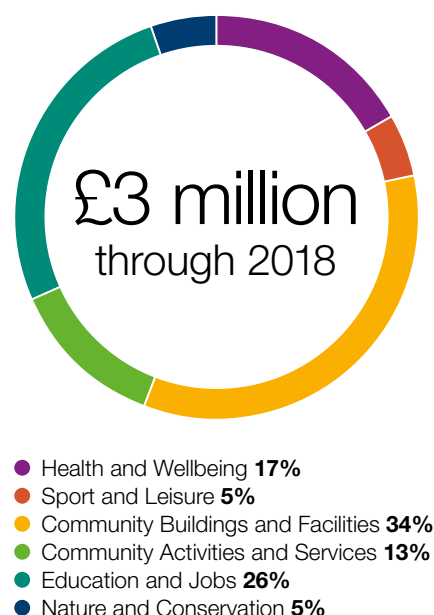
FIGURE 14: Total planned spend by geographical area over the life of assets



dementia stroke victims young people
 army veterans employment
 mental health domestic abuse
 homeless shelters community kitchens
 buildings and facilities
 village halls food and drink festivals
 lifeboat stations renewables
 creative workshops art exhibitions
 regeneration music festivals
 village fetes community events
 helping communities
 community fun days recycling
 nature sponsoring protection
 marine conservation wildlife
 nature reserves natural environment

in Figure 15. There are a vast range of areas that are supported by community funds, as shown above, from helping regenerate community buildings to supporting the delivery of schools recycling and renewables projects. Other initiatives include but are not limited to sponsorship of local sports clubs and community events, contributions to the cost of employing staff, providing equipment for sports clubs, as well as supporting health and wellbeing projects, nature conservation and preservation.

FIGURE 15: 2018 contribution by category



Community case studies

Community benefits range from providing individual sponsorship for projects and community events, to establishing visitor centres to increase awareness and understanding of the wind farm itself, as well as increasing knowledge on the offshore wind industry.

The following case studies provide a flavour of some of the projects that have benefited from the operational offshore wind portfolio. There are many other projects which these and other sites have supported that are not detailed here. Further detail of projects supported can be found on the wind farm websites.



Improving the health and wellbeing of Fleetwood residents




Walney Extension Community Fund awarded a grant to help improve the health and wellbeing of Fleetwood's residents through the redevelopment




of six open areas in the community including a dementia garden and a community growing hub to support and promote healthy lifestyles. The project has been overseen by a Health Creation Officer and involved numerous local volunteers. The project has also established a new GP referral system, referring people from the NHS to the community projects using a social prescribing model.



Colwyn Bay Watersports



Colwyn Bay Watersports (CBW) aims to make sailing, windsurfing and other water-based activities available to all sectors of the community regardless of income, status, ability or disability. In an area with high levels of deprivation and disadvantage, its role is to provide an accessible amenity which unites the community, promotes social cohesion and highlights the health and well-being benefits of taking part. Volunteering plays an important part in ensuring the centre is able to fulfil its remit and work in the community and can provide a positive and collegiate environment for individuals to develop personal and work-based skills leading to employment or entry into further education.



Over 2 years (2017 and 2018) Gwynt y Môr and Rhyl Flats Offshore Wind Community Funds have contributed to

fund a Community Engagement Officer at CBW. This new member of staff has developed the organisation's work with schools and volunteers. Many of the volunteers now have the qualifications and transferable skills required to instruct professionally and gain paid employment either at CBW or elsewhere in the industry.



Friends of Westfield Farm



Friends of Westfield Farm is a group that provides recreation and leisure facilities in the interests of social welfare with the objective of improving quality of life for local residents. The group was awarded a grant from Tees Valley Community Foundation on behalf of Teesside Offshore Wind Farm to help with the cost of hosting a photographic exhibition.

The main benefit of the project was to bring people together and encourage them to interact with people of different

generations, thus breaking down barriers and hopefully combatting some of the area's most serious issues.



Regular sessions around the exhibition were also arranged for local residents to meet up and collate the images that were used in the event.

Friends of Westfield Farm was set up in 2015 to bring together the community around Dormanstown, an area where there is a particularly high rate of social isolation. They do this by organising a range of activities that bring people together whilst at the same time offering the opportunity to learn new skills.

Renewable energy grant to Trimmingham Village Hall



The new village hall in the coastal village of Trimmingham in North Norfolk was formally opened in June 2018, replacing the small Pilgrim Shelter which had served as the village hall since 1935.



Being sited close to the cliff edge meant the Pilgrim Shelter was at risk of being lost to coastal erosion, so local residents spent seven years raising funds to build a replacement hall.

The eco-friendly design of the building enabled the Sheringham Shoal Community Fund to provide a grant to fund the installation of the building's ground source heating system as part of the project to build the new village hall.

"We are delighted with the generous support that the Sheringham Shoal Community Fund has shown to the Village Hall project", said Terry Brown, Chairman of Trimmingham Parish Council.

"The fascinating sight of the Sheringham Shoal wind turbines on the horizon on clear days will be a constant reminder of that generosity to the many people who will use the building over the coming years."

RNLI receives funds for four lifeboat stations



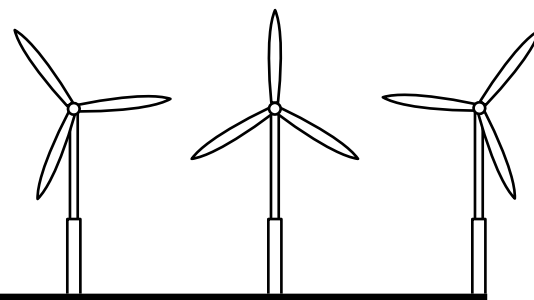
The Royal National Lifeboat Institution (RNLI) received a charitable donation from the Rampion Community Fund, which was set up in November 2017 to benefit communities across Sussex. The funding will be spread across the lifeboat stations in Newhaven, Brighton, Shoreham and Littlehampton, which operate in the area near to the wind farm.

To keep the wind farm in full working order, Rampion's wind turbine technicians will transit between the operations base in Newhaven and the Rampion site, for the lifetime of the project. With a significant level of commercial and recreational sea user activity operating from ports and marinas across the coast, safety at sea will always be a priority for the team.

Rampion is delighted to be able to make the donation to the RNLI, which does an incredible job to keep everyone safe at sea, no matter the time, the season or the weather. This money will help the RNLI's incredible lifeboat volunteers, at these four busy south coast stations, to continue to save lives at sea.



8 Wind farm ownership



Utility companies increasingly dominate ownership of the operating and under construction portfolio with 26% held by financial investors (Figure 16) and the remainder by corporates, oil and gas companies and the supply chain.

These statistics need to be considered against the growth in the portfolio over the year, when some 3.3 GW of projects moved from having a Contract for Difference, to passing Final Investment Decision (FID) and commencing construction. Earlier stage projects are typically developed by utility style owners, with divestment traditionally occurring after FID or full commissioning, hence utility

ownership has grown since 2017. It is anticipated that this will change again in 2019 as further divestment occurs and frees up capital for investment into new projects.

The financial investor mix continues to diversify with renewables and infrastructure funds and pension funds now clearly in the market, with an appetite for the offshore wind asset class. Corporate ownership in the sector increased to 5% reflected by the stakes of companies such as Sumitomo Corporation and Enbridge Inc. Oil and gas ownership fell to 2% precipitated by previous movements away from hydrocarbons by companies such as Ørsted. Early in 2018, Norwegian company Statoil rebranded

as Equinor, reflecting its commitment to become a broad energy company rather than one focused only on oil. Equinor developed and operates Sheringham Shoal and Dudgeon wind farms in the Wash. This lower carbon push is evident across other companies, such as Vattenfall, a utility company with a significant offshore wind portfolio, which has stated its goal to be free from fossil fuels within one generation.

Although oil and gas presence has reduced, this is a trend that could reverse as these organisations seek alternative future income streams that utilise their wealth of offshore experience, particularly in floating technology and its applicability to offshore wind.

FIGURE 16: Operational offshore wind farm ownership as at 31 December 2018 – listed by dominant ownership share

▼ Project	▼ Company (Share ownership)			▼ Operator	
Barrow	100.0% Ørsted			Ørsted	
Burbo Bank	100.0% Ørsted			Ørsted	
Gunfleet Sands Demonstration	100.0% Ørsted			Ørsted	
Gunfleet Sands I	50.1% Ørsted	24.95% DBJ ²	24.95% Marubeni... ³	Ørsted	
Gunfleet Sands II	50.1% Ørsted	24.95% DBJ ²	24.95% Marubeni... ³	Ørsted	
Walney 1	50.1% Ørsted	25.1% SSE	24.8% PGGM & AEF ¹	Ørsted	
Walney 2	50.1% Ørsted	25.1% SSE	24.8% PGGM & AEF ¹	Ørsted	
Burbo Bank Extension	50.0% Ørsted	25.0% KIRKBI Invest	25.0% PKA Holding	Ørsted	
Race Bank	50.0% Ørsted	37.5% Macquarie Capital	12.5% S. ⁵	Ørsted	
Walney Extension	50.0% Ørsted	25.0% PFA Holding	25.0% PKA Holding	Ørsted	
West of Duddon Sands	50.0% Ørsted	50.0% Iberdrola (ScottishPower)		Ørsted	
Westermost Rough	50.0% Ørsted	50.0% UK GIG ⁴		Ørsted	
Blyth	100.0% E.ON			E.ON	
Humber Gateway	100.0% E.ON			E.ON	
Robin Rigg East	100.0% E.ON			E.ON	
Robin Rigg West	100.0% E.ON			E.ON	
Scroby Sands	100.0% E.ON			E.ON	
Rampion	50.1% E.ON	25.0% UK GIG ⁴	24.9% Enbridge Inc.	E.ON	
London Array	30.0% E.ON	25.0% Ørsted	25.0% CDPQ ⁶	20.0% Masdar	London Array Ltd
European Offshore Wind Deployment Centre	100.0% Vattenfall			Vattenfall	
Kentish Flats	100.0% Vattenfall			Vattenfall	

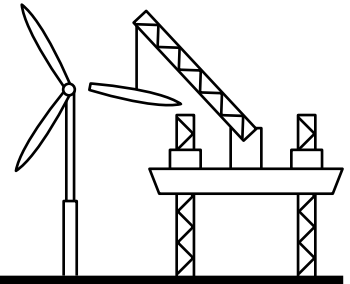
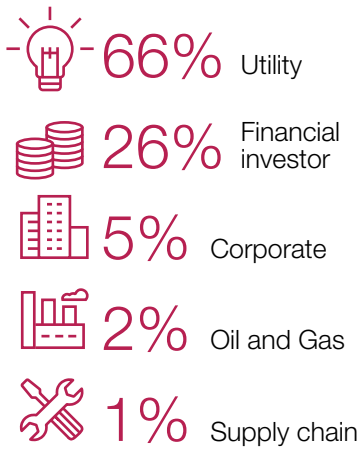


FIGURE 17: Capacity ownership – offshore wind ownership by category



Wind farm array at Thanet wind farm

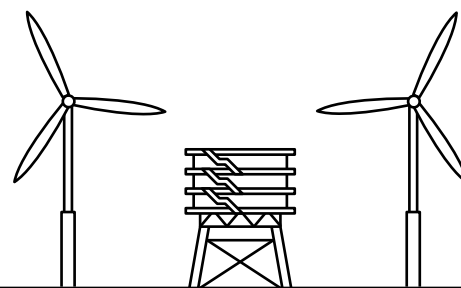
▼ Project	▼ Company (Share ownership)	▼ Operator
Kentish Flats Extension	100.0% Vattenfall	Vattenfall
Thanet	100.0% Vattenfall	Vattenfall
Ormonde	51.0% Vattenfall 49.0% AMF	Vattenfall
Hywind Scotland	75.0% Equinor 25.0% Masdar	Equinor
Sheringham Shoal	40.0% Equinor 25.3% Equitix 20.0% UK GI... ⁷ 14.7% TRIG ⁸	Equinor
Dudgeon	35.0% Equinor 35.0% Masdar 30.0% China Resources	Equinor
Rhyl Flats	50.1% Innogy 24.95% Greencoat... ⁹ 24.95% UK GIG O... ⁷	Innogy
Greater Gabbard	50.0% Innogy 50% SSE	SSE
Gwynt y Môr	50.0% Innogy 30% Stadtwerke München 10.0% ¹⁰ 10.0% ⁴	Innogy
Galloper	25.0% Innogy 25% Siemens F... ¹¹ 25.0% UK GIG ⁴ 12.5% ¹² 12.5% ⁵	Innogy
Inner Dowsing	61.0% UK GIG OWF ⁷ 39.0% BlackRock	Xceco
Lynn	61.0% UK GIG OWF ⁷ 39.0% BlackRock	Xceco
Lincs	44.0% UK GIG OWF ⁷ 31.0% UK GIG ⁴ 25.0% Ørsted	Ørsted
Blyth Demonstration	100.0% EDF Energy Renewables	EDF
Teesside	51.0% EDF Energy Renewables 49.0% Dalmore Cap. Ltd	EDF
Kincardine	100.0% Atkins	KOWL
Levenmouth Demonstration	100.0% Offshore Renewable Energy Catapult (ORE-C)	ORE-C
North Hoyle	100.0% Greencoat UK Wind	Innogy

1 PGGM & Ampère Equity Fund
 2 Development Bank of Japan (DBJ)
 3 Marubeni Corporation
 4 UK Green Investment Group (UK GIG)
 5 Sumitomo Corporation

6 Caisse dépôt & placement Québec (CDPQ)
 7 UK Green Investment Group Offshore Wind Fund (UK GIG OWF)
 8 The Renewables Infrastructure Group
 9 Greencoat UK Wind Plc

10 Siemens
 11 Siemens Financial Services
 12 ESB

9 OFTO ownership



Offshore Transmission Owner (OFTO) Transactions

During 2018, two OFTO licences were granted, Tender Round 6 was launched and several tenders were progressed, with the latest position shown in Figure 18.

OFTO ownership, as detailed in Figure 19, continues to be dominated by three main players: Transmission Capital Partners (28.6%), Blue Transmission (19%) and Equitix (19%). Most transmission assets continue to be managed by the OFTO, with the operation and maintenance contracted to either the wind farm operator or another service provider such as RES.



FIGURE 18: Offshore transmission tenders

Ofgem is responsible for managing the competitive tender process through which offshore transmission licences are granted. The following tenders are currently underway:

TENDER ROUND

4	Licences granted 2018 <ul style="list-style-type: none"> Burbo Bank Extension – April 2018 	
5	Licences granted 2018 <ul style="list-style-type: none"> Dudgeon – November 2018 Licences to be granted 2019 <ul style="list-style-type: none"> Race Bank – Preferred bidder appointed June 2018 Galloper – Preferred bidder appointed November 2018 	Preferred bidder to be appointed 2019 <ul style="list-style-type: none"> Walney Extension – ITT stage commenced May 2018 Rampion – ITT stage commenced November 2018
6	Enhanced Pre-Qualification (EPQ) stage commenced 2018 <ul style="list-style-type: none"> Beatrice East Anglia One Hornsea One projects 	Invitation to Tender (ITT) stage to commence 2019 <ul style="list-style-type: none"> Beatrice – April 2019 Hornsea One – June 2019

For more information on the tenders, please refer to Ofgem's website <https://www.ofgem.gov.uk/electricity/transmission-networks/offshore-transmission/offshore-transmission-tenders>

FIGURE 19: OFTO ownership as at 31 December 2018

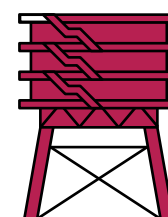
▼ Project	▼ Company (Share ownership)	▼ Connection voltage	▼ Interfacing party	▼ Operator
Barrow OFTO	100% Transmission Capital Partners	132 kV	DNO	Transmission Capital Services
Dudgeon OFTO	100% Transmission Capital Partners	400 kV	Transmission	Transmission Capital Services
Gunfleet Sands OFTO	100% Transmission Capital Partners	132 kV	DNO	Transmission Capital Services
Lincs OFTO	100% Transmission Capital Partners	400 kV	Transmission	Transmission Capital Services
Ormonde OFTO	100% Transmission Capital Partners	132 kV	DNO	Transmission Capital Services
Robin Rigg OFTO	100% Transmission Capital Partners	132 kV	DNO	Transmission Capital Services
Westernmost Rough OFTO	100% Transmission Capital Partners	275 kV	Transmission	Transmission Capital Services
London Array OFTO	100% Blue Transmission	400 kV	Transmission	Frontier Power
Sheringham Shoal OFTO	100% Blue Transmission	132 kV	DNO	Frontier Power
Walney 1 OFTO	100% Blue Transmission	132 kV	Transmission	Frontier Power
Walney 2 OFTO	100% Blue Transmission	132 kV	DNO	Frontier Power
Greater Gabbard OFTO	100% Equitix	132 kV	Transmission	Balfour Beatty Power & Transmission
Humber Gateway OFTO	80% Equitix 20%... ³	275 kV	Transmission	Balfour Beatty Power & Transmission
Thanet OFTO	80% Equitix 20%... ³	132 kV	DNO	Balfour Beatty Power & Transmission
Gwynt y Môr OFTO	60% Balfour Beatty... ³ 40% Equitix	132 kV	Transmission	Balfour Beatty Power & Transmission
Burbo Bank Extension OFTO	50% Diamond... ¹ 50% Infrastruc... ²	400 kV	Transmission	RES
West of Duddon Sands OFTO	50% 3i Infrac... ⁴ 50% Dalmore... ⁵	400 kV	Transmission	Frontier Power

1 Diamond Transmission Corporation Limited
2 Infrastructure Investments OFTO 1 Limited

3 Balfour Beatty Investments
4 3i Infrastructure Plc

5 Dalmore Capital

10 OFTO performance



98.22%

Annual availability of offshore networks for 2017/18 was 98.22%

Figure 19 provides details of the OFTOs, including their connection voltages and interfaces with either the National Electricity Transmission System or the lower voltage distribution networks owned and operated by Distribution Network Operators (DNO).

Transmission system availability for OFTOs is published by National Grid each financial year. 2018/19 data is not expected to be published until July 2019, so the information in this section covers the period April 2017 to March 2018.

Operators of the offshore transmission systems are incentivised through the regulatory framework to provide prescribed minimum levels of availability. The default for this is 98%, with specific targets established for each OFTO.

National Grid collates availability data for each OFTO annually – this includes all outages that originate on an OFTO's system but excludes outages that originate elsewhere, for example on a wind farm generator or DNO. The OFTO availability incentive then adjusts the reported outage data to calculate incentivised performance for each OFTO.

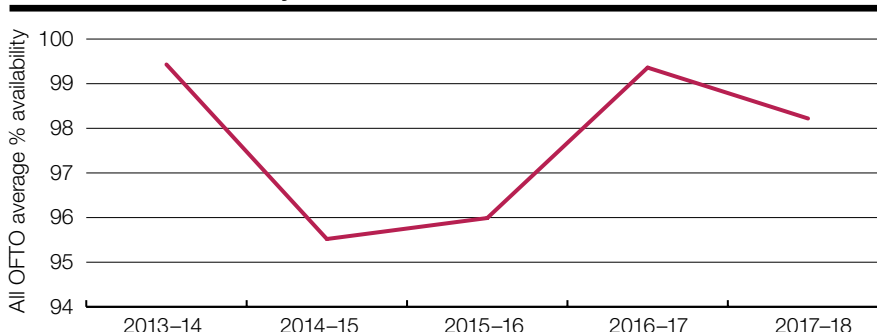
In 2017/18, average OFTO availability was 98.22%, slightly lower than the previous year (99.36%) but still above the minimum level of availability, with Figure 21 showing the general trend of annual availability.

FIGURE 20: Offshore transmission networks % annual system availability

	2013-14 ▼	2014-15 ▼	2015-16 ▼	2016-17 ▼	2017-18 ▼
Barrow OFTO	99.64	100	99.88	100	99.99
Greater Gabbard OFTO	99.81	100	100	99.78	99.61
Gunfleet Sands OFTO	100	99.53	100	99.95	99.81
Gwynt y Môr OFTO	N/A	82.59	82.58	99.73	100
Humber Gateway OFTO	N/A	N/A	N/A	100	93.75
Lincs OFTO	N/A	100	99.96	99.93	99.78
London Array OFTO	99.97	99.90	99.98	98.88	99.80
Ormonde OFTO	100	99.93	100	99.59	100
Robin Rigg OFTO	99.85	100	99.99	99.99*	100
Sheringham Shoal OFTO	99.20	99.84	100	99.95	99.23
Thanet OFTO	N/A	82.47	83.05	96.15	86.92
Walney 1 OFTO	99.99	100	100	99.62	99.70
Walney 2 OFTO	94.89	100	92.47	100	100
West of Duddon Sands OFTO	N/A	N/A	100	99.64	99.45
Westermost Rough OFTO	N/A	N/A	100	100	100

* Figure has been updated from 98.08%. This event has been agreed with OFGEM as an exceptional event.

FIGURE 21: OFTO availability trend



Development of the OFTO regime

The offshore transmission regime was introduced in 2009, and has delivered significant low-cost investment into this essential infrastructure class over the last decade. Over this period, the underlying policy regime has been stable, with minor amendments made to improve its operation rather than fundamental shifts in approach. This stability has provided certainty to the market and at the same time, developers, OFTOs and other interested parties have gained a richer understanding of offshore transmission infrastructure and its policy regime.

In May, Ofgem published a consultation on proposed changes applicable to

projects entering the 6th tender round, taking into consideration industry suggestions for improvements. Much of this focussed on the mechanics of the procurement process Ofgem uses to appoint OFTOs, but it also included consideration of the appropriate length of the revenue term and clarification of arrangements for the end of the revenue term. Ofgem published its decision on these areas in November, extending the default revenue stream from 20 to 25 years, which reflects the longer expected life of the assets. Limited progress was made regarding the arrangements after the initial revenue term has expired however. Ofgem identified two broad

options for the arrangements that would apply if an offshore wind farm sought use of the system beyond 20 years – being either that the revenue stream for the incumbent OFTO was extended or a re-tender for the OFTO for an additional revenue term. These require more detailed work, but provide a basis for a process. Since it is likely a proportion of the fleet could either be repowered or life-extended, it is important that a process is established in the near term to provide clarity on how the process will work in practise to ensure offshore generation can continue seamlessly beyond the initial term of the OFTO's revenue.

11 Investment



West of Duddon Sands

Significant and complex transactions continued to define the UK offshore wind investment landscape in 2018, as detailed in Figure 23. There was an increase in the number of new investments from the previous year and again developers took the opportunity to refinance existing projects at more competitive rates as part of the overall drive to enhance returns to equity. The use of corporate bonds alongside bank debt continued to grow in 2018 with finance secured through both the institutional and private placement bond markets. This is a growing trend over the last 5 years and although bonds have always played a role in the refinancing of projects to a certain extent, there is a general advancement in their issuance earlier in a project's lifecycle. The general increase of bond finance in the sector could be attributable to:

- Attractiveness of the utility asset class to the bond markets (stable, longer term, predictable, strong regulation, government support (most cases) and long term power purchase agreements);
- Scale of offshore wind projects with a larger overall financing requirement and increased asset life assumptions potentially more suitable to bond issuances than bank clubs;
- Growth in precedents for investment grade rated projects within the

sector providing greater guidance on available pricing and terms for potential bond issuances;

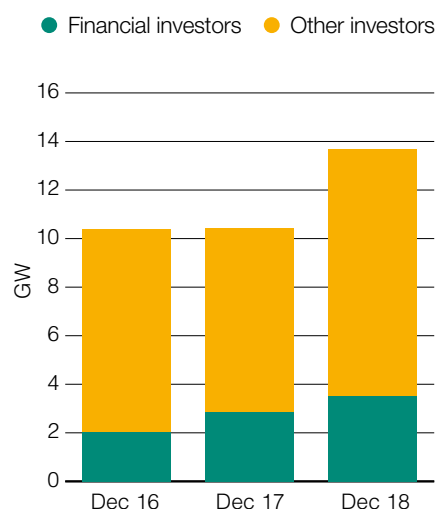
- Sector role models such as early bond financing by the Green Investment Bank*.

Growth in the green bond market

There has been an uptick in the issuance of green bonds, with them now making up around 4% of all global bond issues, from a position of less than 1% 3 years ago. Such bonds are issued to raise finance for climate change solutions and can be issued by governments, banks, municipalities or corporations. Developers of offshore wind projects are well poised to issue green bonds with many of these assets so readily fitting many requirements needed for green bonds. Green bonds can either be verified against the technical standards developed by the Climate Bonds Initiative or can be developed under a set of standards by the bond issuer that are established under the Green Bond Principles, issued by the International Capital Markets Association.

It is likely the development and increased transparency of these accepted standards and principles has driven growth in the green bond market and it is something that is likely to continue in the offshore wind sector in the UK and globally. It's not

FIGURE 22: Operational / under construction portfolio ownership



clear yet if there is a cost benefit in issuing green bonds over conventional bonds but two factors are likely to drive this:

- 1 Evolution in institutional and private investor appetite away from carbon intensive investments towards more investments with certifiable environmental and societal benefits;
- 2 Enhanced prices have been seen for green bonds in the secondary, or resale market, this is partly because demand outstrips supply in £ sterling issuance but if this continues and green bonds trade at better prices then this would benefit the issuer raising finance through future green bond issues.

Some offshore wind operators are already issuing green bonds connected to offshore wind projects.

The other features of 2018 relate to the profile of investors. The sector is highly sought after by financial investors, with further investments in projects under construction and operational. Financial investors hold a quarter-share in the 13.7 GW UK portfolio and grew their assets base from 2.9 GW to 3.5 GW over the year (see Figure 22). The strong and reliable long-term returns have appealed to the financial community and Ørsted's

The Vestas V164 8.8MW, is the world's largest offshore wind turbine. A new global landmark?

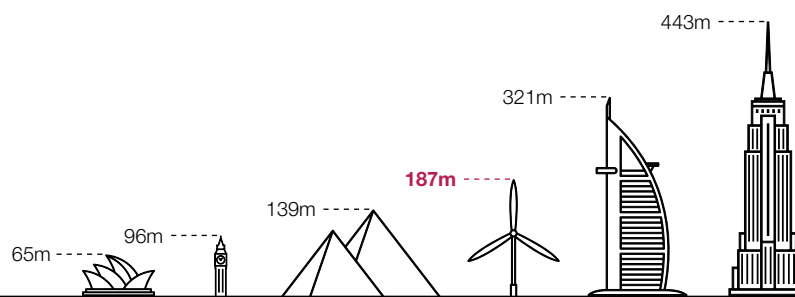


FIGURE 23: Transactional activities

▼ Asset	Seller ▼	▼ Share before sale	Buyer ▼	▼ Buyer share in project after sale	▼ Indicative value	▼ Indicative timing
Westermmost Rough	Marubeni	25%	Green Investment Group	50%	unknown	Mar-18
Galloper	Macquarie	12.5%	ESB	12.5%	£200m	Mar-18
Burbo Bank Extension OFTO	Ørsted	50%	Diamond Transmission Partners	100%	£194m	Apr-18
	KIRKBI Invest A/S	25%				
	PKA Holding ApS	25%				
Teeside	EDF Energy Renewables	100%	Dalmore Capital Ltd	49%	unknown	May-18
Triton Knoll	Innogy	100%	J-Power	25%	unknown	Aug-18
			Kansai Electric Power Company	16%	unknown	Aug-18
Hornsea 1	Ørsted	100%	Global Infrastructure Partners	50%	£4460m	Sep-18
Seagreen	Fluor	50%	SSE	100%	£118m	Sep-18
Dudgeon OFTO	Statoil	35%	Transmission Capital Partners	100%	£377m	Nov-18
	Masdar	35%				
	China Resources	30%				
Moray East	Diamond Generating Europe	33.4%	Kansai Electric Power Company	10%	unknown	Nov-18
			Mitsubishi Corporation	6.7%	unknown	Nov-18
	EDPR	77%	Diamond Generating Europe	20%	£36m	Mar-18
			China 3 Gorges	10%	£35m	Dec-18
			Diamond Generating Europe	13.4%	£54m	Nov-18
Neart Na Goithe	Mainstream Renewable Power	100%	EDF Energy Renewables	100%	unknown	Dec-18

divestment of Hornsea 1 was the largest single-project financing to date in the global renewable energy sector. Infrastructure fund, Global Infrastructure Partners (GIP) invested £4.46bn for a 50% share in the 1.2 GW project, which will be the world's largest offshore wind farm and is due to be fully commissioned in 2020.

It is also noteworthy that 2018 saw the first investment in offshore wind made by Japanese power companies Kansai Electric Power Co and J-Power (see Figure 23) which have their roots in nuclear and fossil fuels respectively. They are hoping to use the investments as opportunities to grow understanding and capability as Japan realises its ambitions for offshore wind. This is something seen elsewhere in 2018 as Mitsubishi Corporation entered the market.



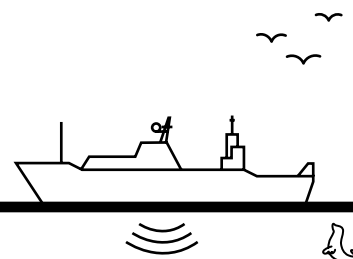
Speaking about Hornsea 1 wind farm, Ole Kjems Sørensen, Executive Vice President for M&A, Partnerships and Asset Management at Ørsted, said:

"This is our third partnership with GIP, and we are delighted to have one of the world's largest infrastructure funds as a partner, in what will be the world's largest offshore wind farm. The Hornsea 1 farm-down is a landmark transaction.

"GIP will partially finance its acquisition using a multi-tranche financing package of more than £3.5bn, containing a mixture of investment grade-rated project bonds issued to a consortium of blue chip institutional debt investors with strong UK presence, commercial bank loans and mezzanine debt provided by the Danish pension fund PFA, with some tranches guaranteed by EKF, Denmark's Export Credit Agency. The financing, will be the largest single-project financing to date in the global renewable energy sector."

* Since branded as the Green Investment Group

12 Marine Data Exchange



The Marine Data Exchange (MDE) is the system created by The Crown Estate to receive, manage and share offshore survey data collected by its customers throughout the lifetime of their projects. This resource, the first of its kind, gives anyone with an interest in the marine environment free access to a pool of data and research.

The Crown Estate works closely with its customers to manage the confidentiality of all survey data and ensure the data enters the public domain within a reasonable time frame. Recognising the wealth of data which has built up on the MDE over the lifetime of the projects, The Crown Estate is aware of the continuing role that the MDE plays in helping to support the ongoing growth of the offshore wind industry.

In 2018, the wealth of data on the MDE was used to promote evidence based decision making through the Industry Evidence Programme, inform feasibility studies for potential developments, enable academic research and to support the divestment process for many active projects.

www.marinedataexchange.co.uk

FIGURE 24: Number of surveys

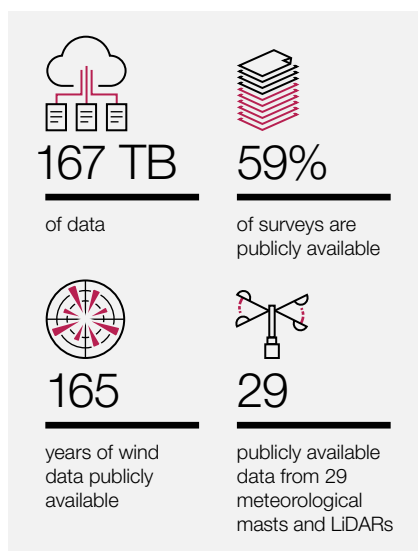
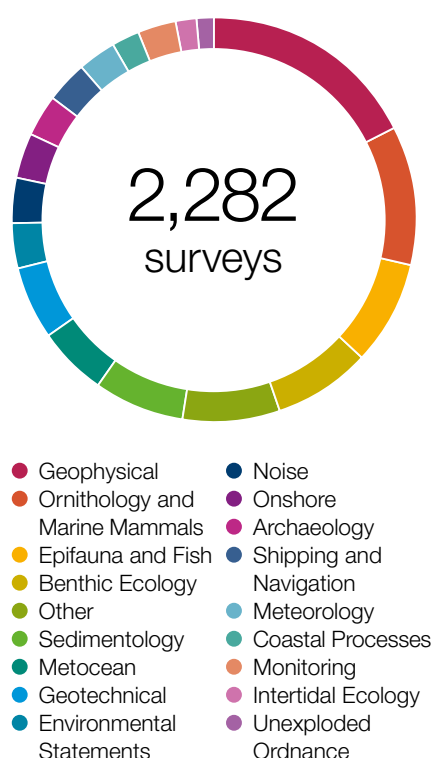
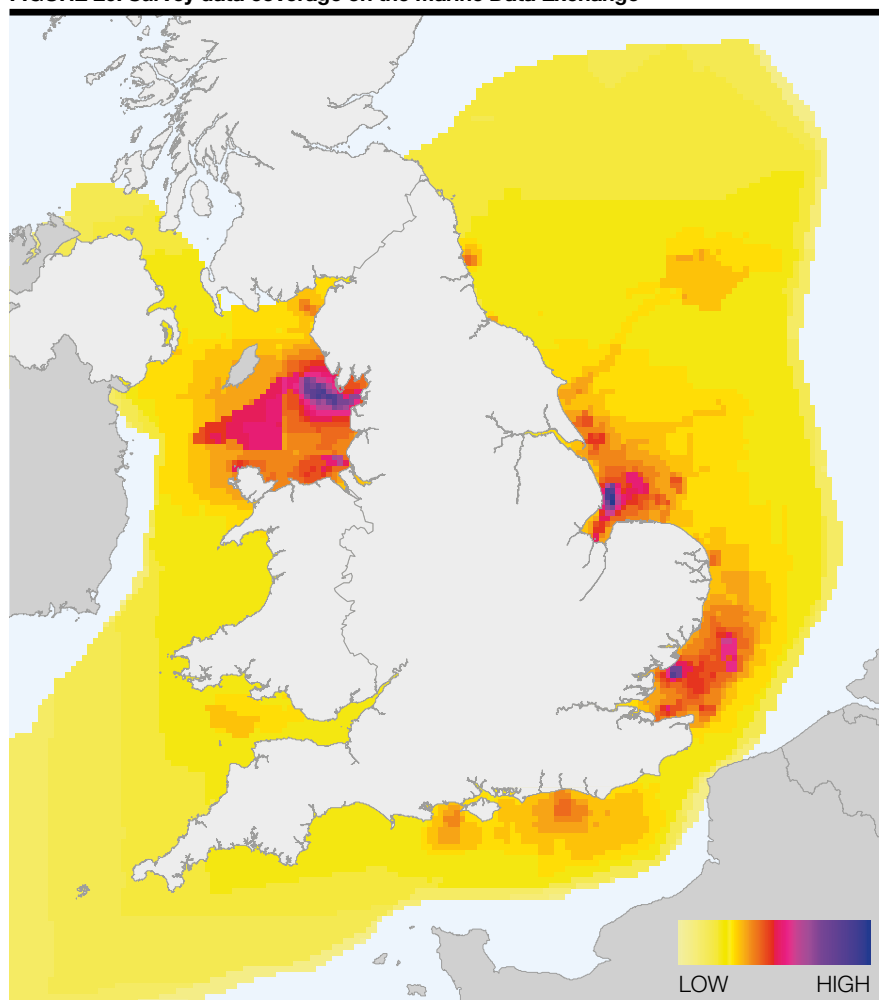


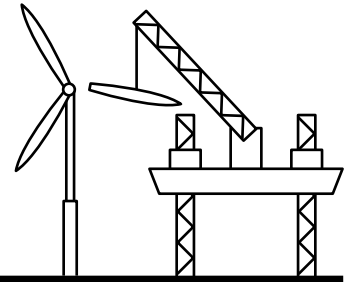
FIGURE 25: Number of downloads in 2018



FIGURE 26: Survey data coverage on the Marine Data Exchange



13 Offshore wind development



The wider portfolio

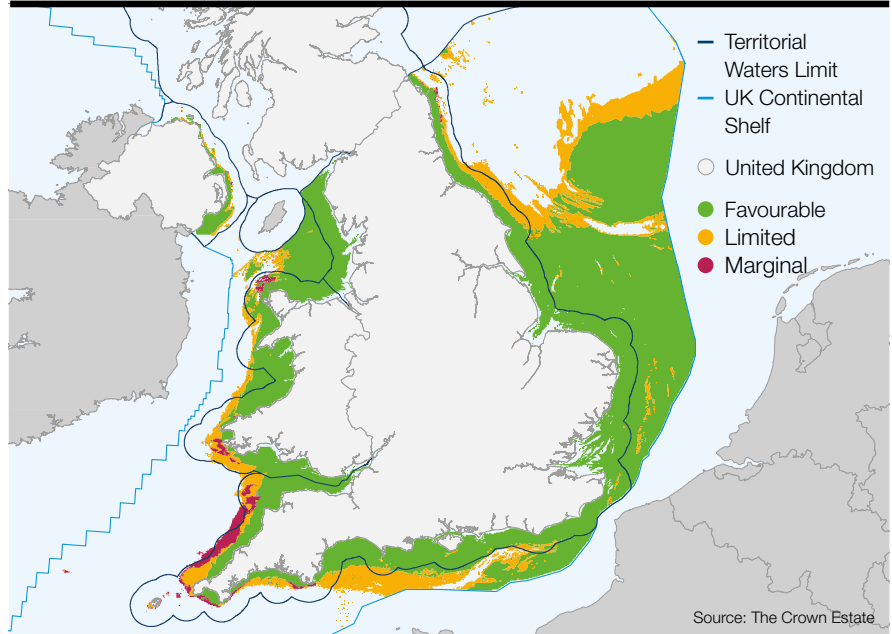
Under the terms of the Energy Act of 2004, The Crown Estate manages the rights to generate electricity from wind, waves and the tides on the continental shelf in English, Welsh and Northern Irish waters, in addition to the territorial seas. This function is typically discharged through the award of lease options, or Agreements for Lease (AfL), providing developers time-limited exclusivity over potential development sites.

Development activity undertaken by The Crown Estate is focussed on understanding the offshore wind potential and ensuring sufficient rights are awarded to satisfy the future need for projects. The UK benefits from a world class natural resource for offshore wind with favourable wind and seabed in England, Wales and Northern Ireland shown in Figure 27.

Largely as a result of cost reduction, the potential role of offshore wind in the UK's energy mix has increased. This has underpinned action taken over the course of 2018, in the form of 2017 extensions and planning for Leasing Round 4, to supplement the already significant portfolio to ensure it is resilient to attrition and able to meet the policy and market demand.

Once projects have obtained their statutory consents and secured access to the electricity grid and other obligations have been met, developers elect to exercise their option and step into the lease prior to commencing construction. Typically, developers will have taken their Final

FIGURE 27: Fixed foundation key resource areas England, Wales and Northern Ireland



Investment Decision, itself likely to be predicated on successfully competing for a Contract for Difference (CfD). Whilst each project might differ, Figure 28 indicates how this process can take seven years or more, discounting the time taken for The Crown Estate's pre-tender and leasing activities.

At the end of 2018, the UK portfolio of projects represented a potential of 33 GW of capacity, almost 27 GW in the waters managed by The Crown Estate (Figure 29). In 2018, scenarios released by the Committee on Climate Change, considering

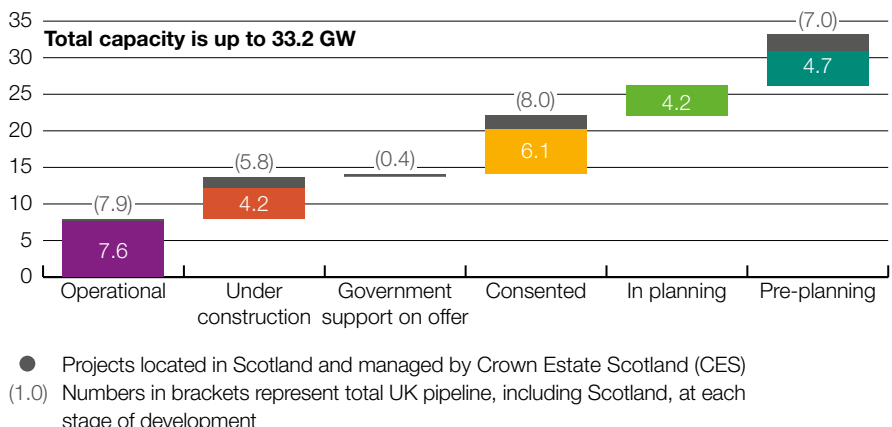
the economic pathways for Government to meet the 5th Carbon Budget, suggested up to 34 GW of further offshore wind could be required. Their previous assessment was up to 25 GW.

With over 11 GW of projects yet to secure a statutory consent and an additional 8 GW without a CfD, it is important to ensure the total portfolio is resilient to capacity attrition and project failure or 'timing out' of consents and lease options, and that there is sufficient project opportunity to meet future need for low carbon power.

FIGURE 28: Time to deliver new projects



FIGURE 29: UK offshore wind development pipeline – Q1 2019 (February)



14 Growing the offshore wind portfolio

2017 Extensions

In May 2018, 14 months after opening, the opportunity for existing operating projects to apply for an extension was closed. In total the process has led to 3.4 GW of new project opportunity being developed in the waters of England and Wales. Over the course of 2019 the plan level Habitats Regulations Assessment (HRA) will be completed, and subject to the outcome of that assessment, the applications will be converted to formal rights in the form of AfLs.

2017 Extensions project applications include:

- Thanet offshore wind farm
- Sheringham Shoal offshore wind farm
- Dudgeon offshore wind farm
- Race Bank offshore wind farm
- Greater Gabbard offshore wind farm
- Galloper offshore wind farm
- Rampion offshore wind farm
- Gwynt y Môr offshore wind farm

More detail can be found here: bit.ly/OWProjectsMap



MPI vessel installing turbines at Rampion

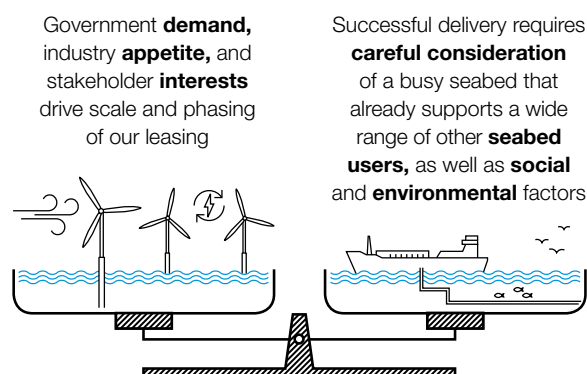
Planning for Leasing Round 4

Following the initial announcement in late 2017, The Crown Estate's consideration and planning for new leasing activity has been progressed over the course of 2018. Thorough analysis of the development potential of the waters of England, Wales and Northern Ireland has been undertaken in conjunction with data and knowledge sharing with statutory stakeholders.

Subject to a final announcement planned in 2019, Leasing Round 4 could see the market identify projects and bid into a competitive tender for 7 GW of new capacity. Again, subject to a plan level HRA, this could lead to the award of new AfLs in 2021.

The scale of the process seeks to balance the need for projects, as outlined above, but with the careful consideration of other factors. Figure 30 highlights the importance of balancing the needs of the portfolio and market with those of stakeholders and the environment. Finding the right balance and using knowledge and evidence, is at the heart of The Crown Estate's approach. bit.ly/OWPotentialNewLeasing

FIGURE 30: Balancing needs in the offshore wind sector



Offshore Wind Sector Deal

In March 2019 the Government released a Sector Deal reached with the offshore wind sector, "maximising the advantages for UK industry from the global shift to clean growth".

Alongside commitments made by both Government and the sector,

The Crown Estate has contributed through making its own commitments to this landmark deal.

In addition to new leasing activity to support the sustained deployment activity, The Crown Estate confirmed its intention to support Government's

action to ensure that the vision of 30 GW by 2030 is delivered in a timely and sustainable way.

A collaborative enabling actions programme facilitated and funded by The Crown Estate will focus on addressing cumulative environmental impacts.

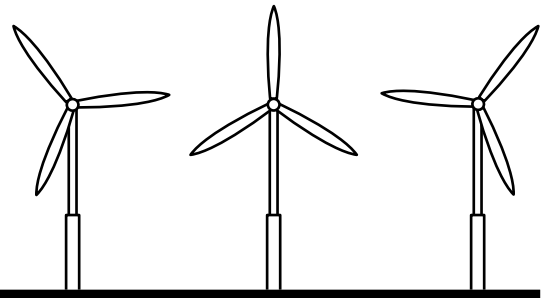
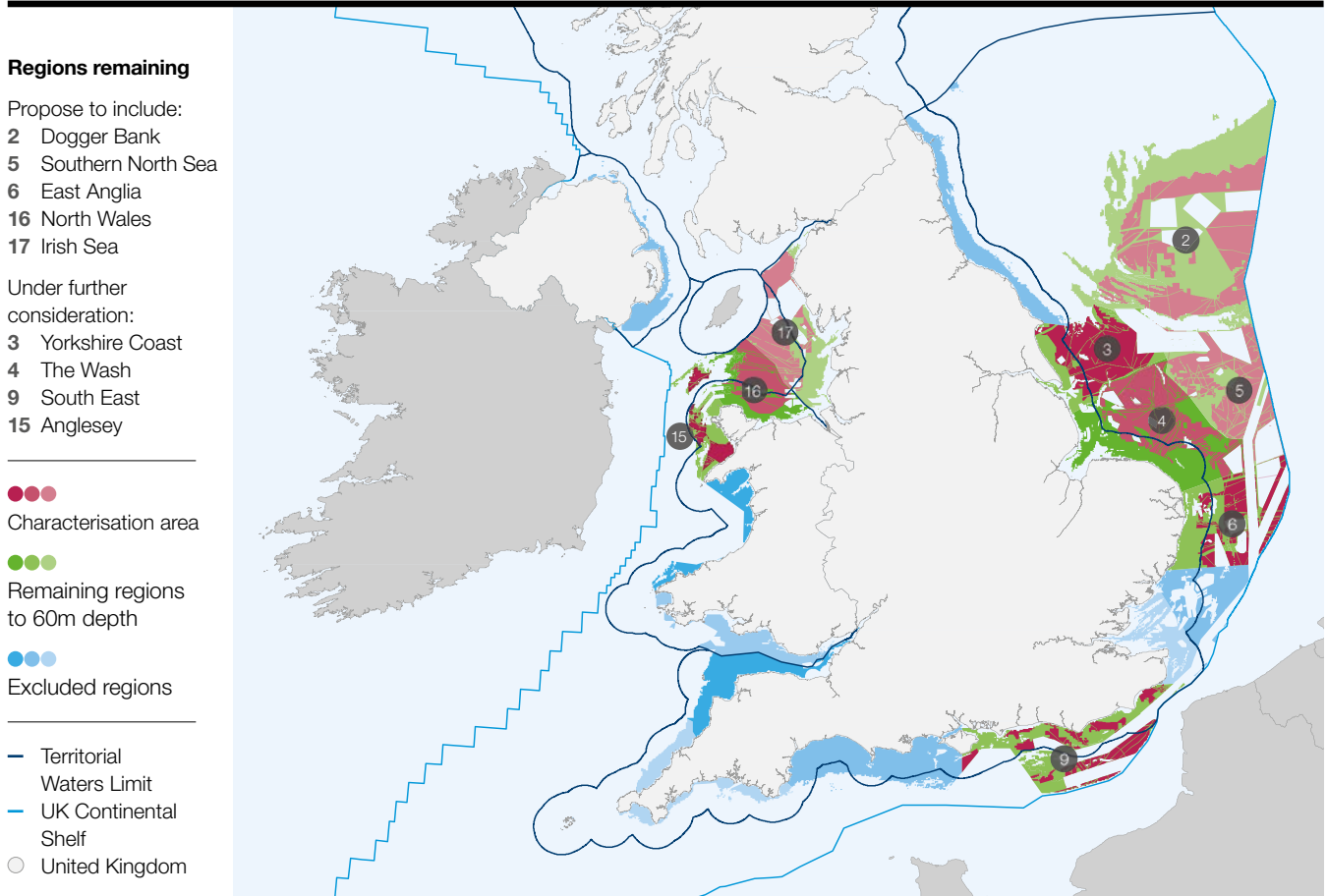


FIGURE 31: Leasing Round 4 proposed regions and characterisation areas



Spatial evidence – driving decision making

The Crown Estate has continuously driven to advance the spatial evidence and understanding of the various uses, sensitivities and resources of the marine space. This activity has continued through into the planned Leasing Round 4 process. The Crown Estate's aim is to develop a leasing round which is fair, balanced and competitive, which ensures that capable, experienced bidders and the strongest possible projects come forward.

To reach this point, The Crown Estate has undertaken extensive spatial analysis of technical resources and constraints, including analysis of policy, other sea users and environmental sensitivities to understand what areas of seabed are potentially suitable for offshore wind development. This involved analysing approximately 40 spatial data layers describing various constraints.

The spatial model has been used to define 18 characterisation areas which have been the focus of significant further qualitative assessment in characterisation documents. This evidence has been used to refine the wider regions that will be open in the Leasing Round 4 for developers to identify projects within. Figure 31 shows the current spatial status of The Crown Estate's proposals with characterisation areas overlaid on top of the refined regions.

The Crown Estate has also carried out significant engagement with the market and stakeholders including workshops, webinars and bilateral meetings. Responses from statutory and non-statutory stakeholders commenting on the methodology and the evidence base has been captured and will be used to support this planned Leasing Round 4.

What next?

Plans for Leasing Round 4 are being finalised. Feedback received following the market and stakeholder engagements is being considered alongside the implications for the tender design. A further update of the proposed plan and process will be provided prior to any formal launch. Subsequently it is expected that a Bidders' Information Day would set out details of the tender including the PQQ (Pre-Qualification) and ITT (Invitation to Tender) stages.

Cover Photo: Technicians ascend a wind turbine at London Array – Courtesy of London Array Limited and photographer Mark Turner

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Correct as of April 2019, unless otherwise stated.