

Offshore wind operational report

January – December 2016



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The offshore wind fleet generated over **16.4 TWh** last year, that's enough to supply the electricity needs of **4.1m homes**, around **15%** of the UK total

5.4%

Offshore wind supplied **5.4%** of the UK's total estimated electricity consumption in 2016



This performance reduced the UK's CO₂ emissions by **7.0 million tonnes**

The Crown Estate

The Crown Estate is a £13bn specialist real estate business, focused on commercial property in central London, prime regional retail and offshore wind.

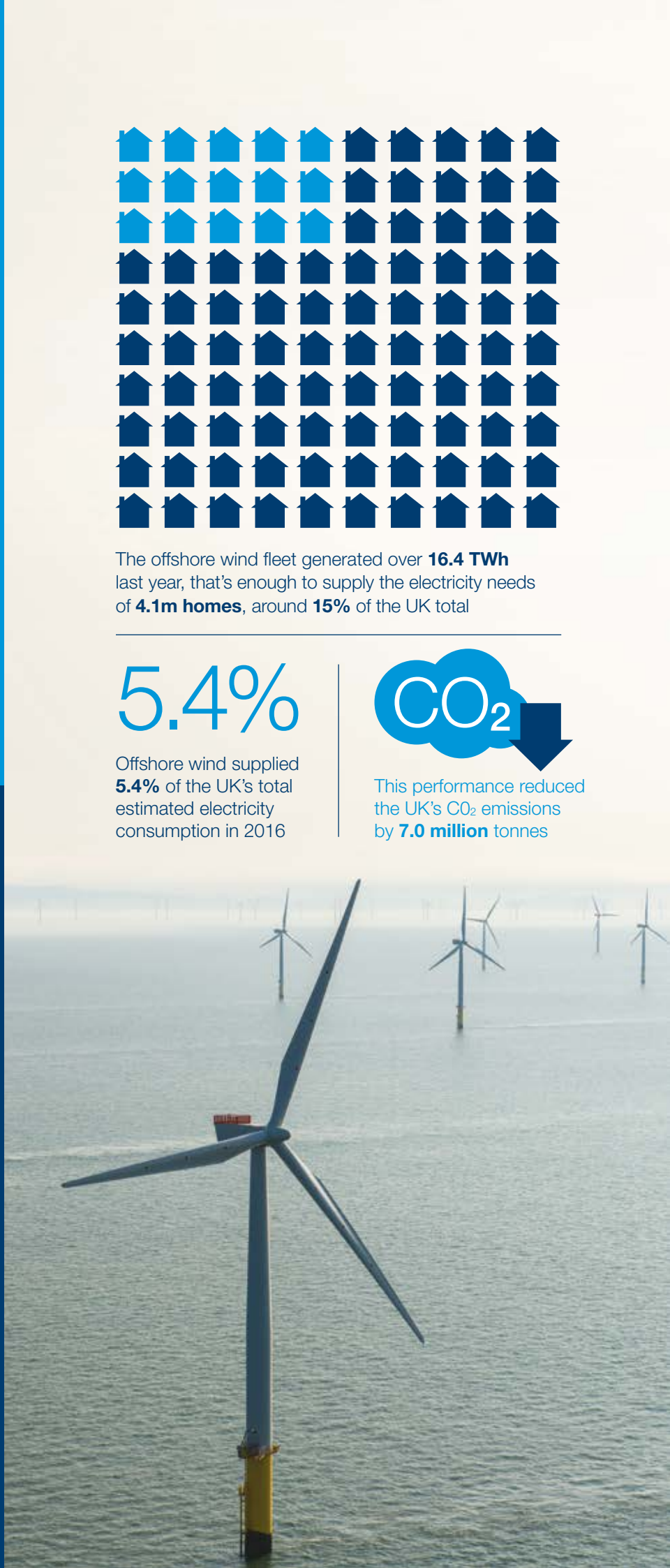
As managers of the seabed around England, Wales and Northern Ireland, our business includes wind, wave and tidal power, as well as marine aggregates and minerals, cables and pipelines and carbon capture and storage.

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.

Scottish interests

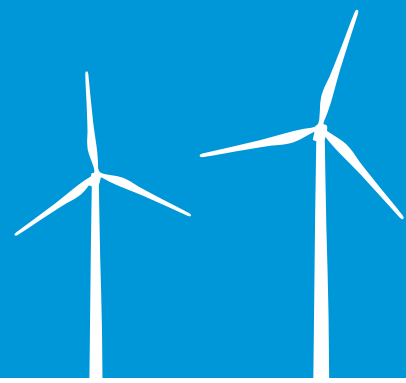
From 1 April 2017, The Crown Estate's management duties in Scotland, including management of the Scottish seabed, were transferred to a new body, Crown Estate Scotland, which reports to Scottish Ministers.

Accordingly, information on offshore wind in Scotland has been included in this report covering the period up to 31 December 2016.



1

Introduction



2016 has been another strong year of growth for the UK's world-leading offshore wind sector.

An average of over 5% of the country's electricity is now being supplied by a technology that barely existed ten years ago. In that period, the number of operational turbines has multiplied ten-fold, with over thirty wind farms now dotted around our shores.

This growth has been driven by three main factors: world class offshore wind resources, strong policy support, and an industry that has risen to the challenge of becoming a mature power player.

With the sector now on track to grow its contribution to the UK's electricity supply to 10% by 2020, the time has come to review the basis for this success and strengthen the foundations for further growth. Our industry abounds with heroic stories about dealing with the unexpected, but in a world of increasing competition, we know that "what got us here, won't get us there".

As I hope these pages show, there is plenty for the UK offshore wind sector to celebrate; from clear improvements in turbine capacity and build out rates, to a broadening pool of investors, and a significant construction pipeline for the year ahead. Last year alone, the UK offshore wind sector exported products and services to over 15 countries across the world, helping to deliver for the UK economy as well as its industry and electricity mix.

As the sector has developed, new challenges have arrived in the shape of power system integration and cumulative environmental impact. As a variable source of electricity generation, the offshore wind sector needs to work together at a system-wide level to tackle power balancing and grid stability by design, not as an afterthought. Similarly, as an industry, we need to work harder to understand the effect that the thousands of turbines in our waters are having on our marine ecosystems, so that these impacts can be properly managed and the offshore wind sector can continue to grow.

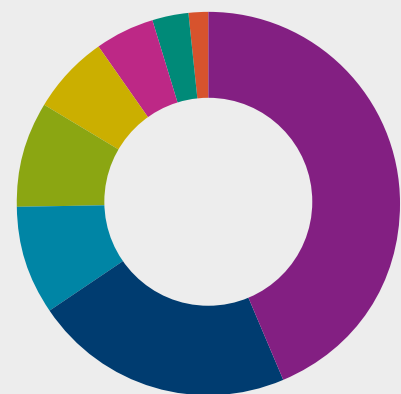
As we tackle the challenges of further growth, the lessons we can take from operational performance, our existing fleet of turbines, will be indispensable. It is for this reason that we are once again issuing this annual report, which aims to provide a reading guide to the major data sources on operating wind farms. Our thanks to all those who have provided content, in particular the SPARTA operators' consortium, the G+ health and safety consortium, the Green Investment Bank, North East Lincolnshire Council, Innogy, Llandrillo College and the Port of Ramsgate.

Huib den Rooijen

Huib den Rooijen
Director of Energy, Minerals and Infrastructure
The Crown Estate

Figure 1: UK electricity generation mix 2016

A breakdown showing offshore wind as a component of UK electricity generation in 2016, excluding oil, pumped storage and other fuels.



- Gas **43.7%**
- Nuclear **21.8%**
- Coal **9.3%**
- Bio energy **9.0%**
- Onshore wind **6.4%**
- Offshore wind **5.0%***
- Solar PV **3.1%**
- Hydro **1.6%**

Source: BEIS Energy Trends 2017

* Offshore wind generation was 5.0% of the generation mix above, which contributed to 5.4% of the estimated consumption in 2016.

2 Offshore wind farm status

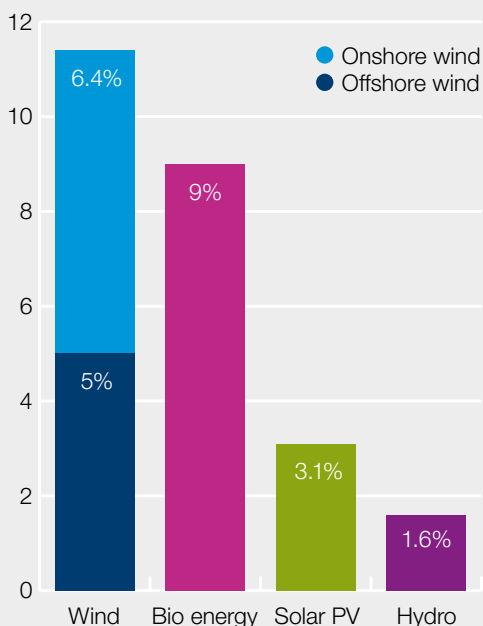
By the end of 2016, there were 29 fully operational offshore wind farms, with construction activity commencing on a further 5.3 GW of new capacity.

These new projects will deliver more than the entire installed capacity of the current operational fleet, demonstrating the growing scale of offshore wind as part of the UK's electricity generation mix. Of this 5.3 GW capacity, some 700 MW should attain full commercial operation during 2017.

Meanwhile the delivery of the remaining 4.6 GW marks 2017 as one of the busiest construction years for offshore wind, delivering benefits around several of the UK's regional ports and harbours (see also page 10).

Figure 3: UK renewable electricity generation by fuel type 2016

Excluding oil, pumped storage and other fuels, renewable energy represented 25% of the UK's electricity generation mix in 2016, of which 5% was provided by offshore wind.



Source: BEIS Energy Trends 2017

Figure 2: UK offshore wind project pipeline – April 2017

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

	Capacity MW ▼
01 Barrow	90
02 Blyth	4
03 Burbo Bank	90
04 Greater Gabbard	504
05 Gunfleet Sands Demonstration	12
06 Gunfleet Sands 1	108
07 Gunfleet Sands 2	65
08 Gwynt y Môr	576
09 Humber Gateway	219
10 Inner Dowsing	97
11 Kentish Flats	90
12 Kentish Flats Extension	49.5
13 Levenmouth Demonstration	7
14 Lincs	270
15 London Array	630
16 Lynn	97
17 North Hoyle	60
18 Ormonde	150
19 Rhyl Flats	90
20 Robin Rigg East ¹	90
21 Robin Rigg West ¹	90
22 Scroby Sands	60
23 Sheringham Shoal	317
24 Teesside	62
25 Thanet	300
26 Walney (Phase 1)	184
27 Walney (Phase 2)	184
28 West of Duddon Sands	389
29 Westermost Rough	210
Total	5,095

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 ▼
30 Aberdeen Demonstration ¹	92.4
31 Beatrice ¹	588
32 Blyth Demonstration Phase 1	41.5
33 Burbo Bank Extension	258
34 Dudgeon	402
35 East Anglia ONE	714
36 Galloper	336
37 Hornsea Project 1	1,218
38 Hywind 2 Demo (Buchan Deep) ¹	30
39 Race Bank	573
40 Rampion	400
41 Walney Extension	659
Total	5,312

Government support on offer:

Total capacity of wind farms that have secured a Contract for Difference or whose publicly stated timescales are consistent with accessing the Renewables Obligation (RO).

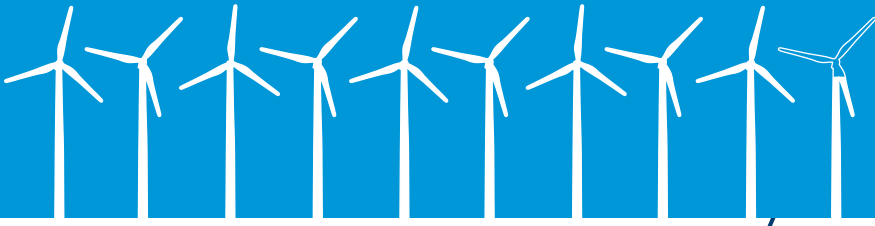
	Up to capacity MW ▼
42 Neart na Gaoithe (NNG) ²	448
Total	448

Awaiting the outcome of Contract for Difference Round 2, for which applications were submitted in April 2017.

1. Asset transferred to the Crown Estate Scotland (Interim Management) from April 2017 following the devolution of the Scotland Portfolio to the Scottish Government.
2. An arbitral procedure relating to the CFD, decided in favour of NNG, preserving its CFD (March 2017)

NOTE: CFDs are private law contracts between CFD generators and the Low Carbon Contracts Company (LCCC), a government-owned company that manages CFDs at arms' length from government.

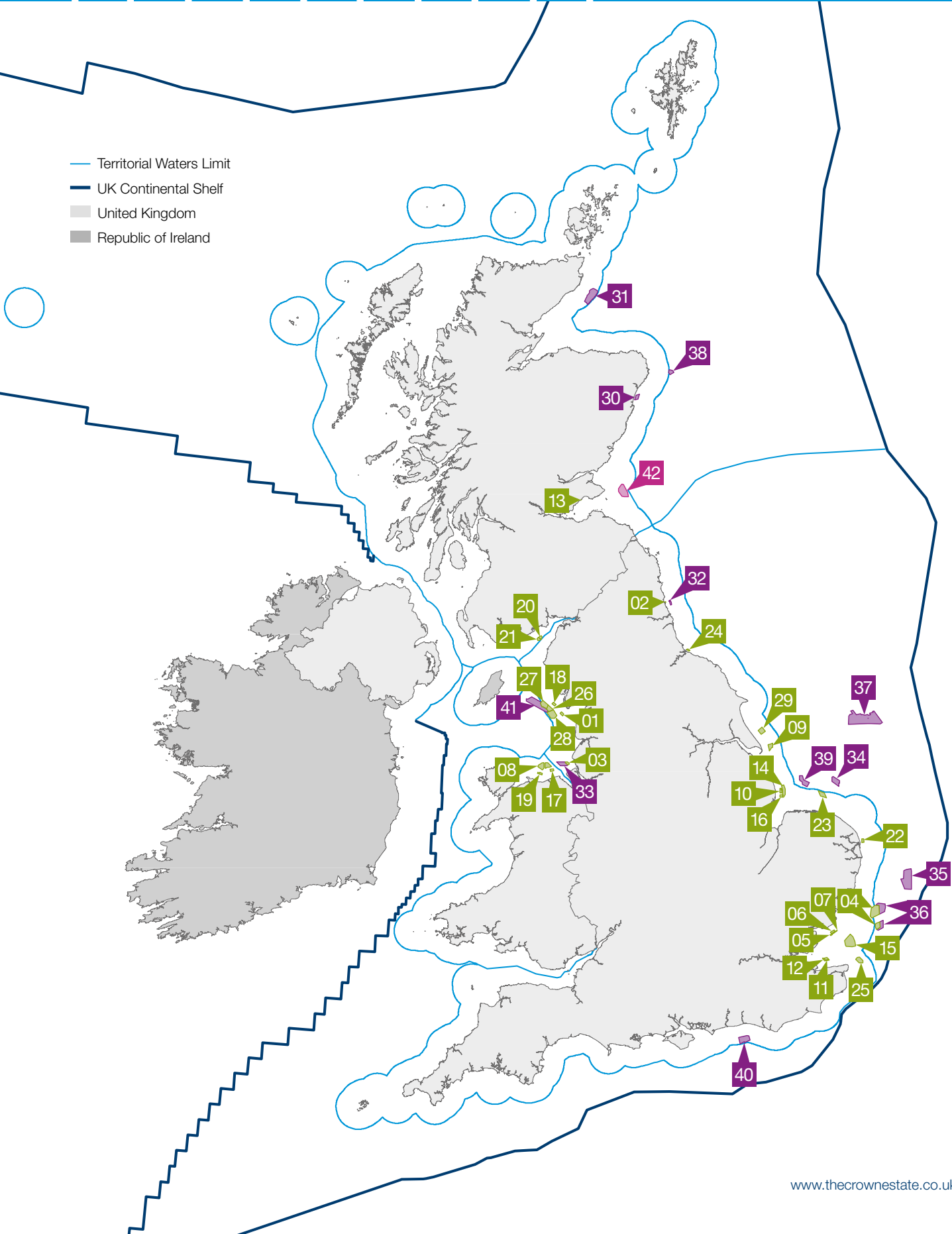
Quoted capacity refers to the property rights held with The Crown Estate and does not necessarily reflect the build out capacity permissible under current or future statutory planning permissions.



97%

In 2016 offshore wind supplied the equivalent of 97% of London, Birmingham and Manchester's domestic electricity requirements (UK's 3 biggest cities)

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



3 Assets

Figure 4: UK offshore wind assets – 31 December 2016

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

	 Offshore turbines	 Offshore substations	 Export cables	 Offshore Masts	 Wind farms
Operating	1,463	20	56	23	29
Under construction*	830	14	25	1	14
Total	2,293	34	81	24	43

At the end of December 2016 there were 1,463 fully operational offshore wind turbines on the UK seabed, with a further 830 under construction. This figure includes some 25 wind turbines which were installed and operating at the Burbo Bank Extension site, but which had not yet attained works completion by 31 December 2016.

Compared with previous years, the volume of construction activity reduced in 2016, but we look forward to a strong development pipeline in 2017, with seven new sites looking to reach first power – a level of development activity not seen since 2010.

The planned sites reaching first power in 2017 include the world's first floating offshore wind farm test and demonstration array, Hywind, off the east coast of Scotland.

In 2016 we saw significant construction activity in northern Europe, with offshore wind spreading to North America, east Asia, India and elsewhere. According to the Global Wind Energy Council, the UK remains the world's largest offshore wind market, with 5.1 GW (36%) of installed global capacity.



4 Health and safety

Constructing, operating and maintaining offshore wind farms requires a constant focus on the health and safety of workers in the challenging conditions they often encounter. Recognising this, the Global Offshore Wind Health and Safety Organisation (G+, formerly G9) was established in order to promote and maintain the highest standards of health and safety throughout the life cycle of offshore wind farms in the UK and internationally.

As asset owners and operators, G+ see themselves as being in the best place to perform the role of creating and delivering world class health and safety performance across all of the activities in the offshore wind industry. Senior executives of the G+ companies have committed resources from their own teams, and have also met under the auspices of the G+ Board to actively lead the industry in finding solutions to the safety challenges facing offshore wind projects.

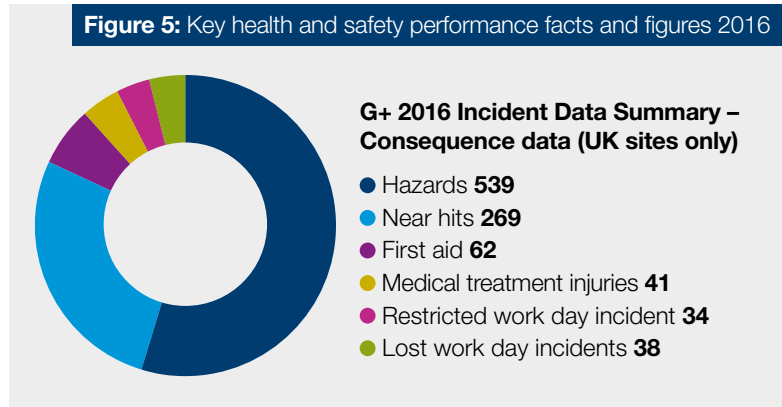
Since the formation of the G+, members have committed to providing health and safety information and statistics for analysis and to share lessons learned. The Energy Institute (EI), secretariat of the G+, collates the health and safety data and produces annual reports which can be found at: <https://www.gplusoffshorewind.com/work-programme/hse-statistics>.

The 2016 health and safety statistics are due to be published in June 2017, and figure 5 provides an early insight into the summary of the incident data reports collected. Initial analysis shows that hazard reporting has increased in 2016, but other incident reporting metrics have remained relatively constant, despite an ever increasing number of wind turbine generators.

Continual improvement lies at the heart of G+ initiatives as evidenced by the progress in rolling out the G+ Good Practice Guidelines (GPGs) such as:

- Working at height in the offshore wind industry
- The safe management of small service vessels used in the offshore wind industry

These two first GPGs were published in December 2014. Since then a number of G+ members have undertaken site audits against the guideline recommendations in order to ascertain their level of compliance. This work has been complemented through the use of the GPGs by various supply



Sharing experience and knowledge: Dropped Objects

The G+ Focal Group believes that dropped objects present significant safety challenges in the construction and operational activities at offshore wind farms. Investigations into the incidents by individual G+ member companies have shown that these occurred due to a number of contributing factors, including: work processes, behaviour, design, environment and the inappropriate securing of tools and equipment.

A number of existing tools to reduce this risk are already available, such as the Dropped Objects Prevention Scheme (DROPS) from the oil and gas industry. A G+ Focal Group workstream will review the transferability of DROPS to the offshore wind industry, as well as incorporating existing guidance from some G+ members into the study.

The resultant guidance document will assist offshore wind developers and operators to establish the underlying causes behind dropped object incidents, identify and assess the hazards, and apply appropriate preventive and mitigating controls and barriers.

chain companies, cross-referencing in a number of IMCA and ISO standards, and by the regulatory authorities in benchmarking safety performance at offshore wind farms.

All these bodies and other key industry stakeholders were invited to provide feedback on the GPGs in 2016 and given the opportunity to identify where updates were required. Based upon a review of this feedback within the Focal Group, both GPGs will be updated in order to ensure they remain fit for purpose and continue to be used by industry to improve H&S performance.

Kate Harvey
General Manager of G+ Global Offshore Wind Health and Safety Organisation



5 Performance through the year

Production

Over the last five years, offshore wind electricity production in the UK has been dominated by its top ten producers. They have contributed an average of just under 75% of the total electricity produced by the sector (Figures: 6 & 9). Over the coming years, these producers look set to be overtaken by Beatrice, Walney Extension and Hornsea Project 1, which are all currently under construction. The last of these, Hornsea 1, will be the world's largest ever offshore wind farm.

Offshore wind produced 5% of the UK's total generation, excluding: oil, pumped storage and other fuels during 2016, with all renewable sources accounting for 25% of that.

Figure 6: Top 10 generators between 2012–2016

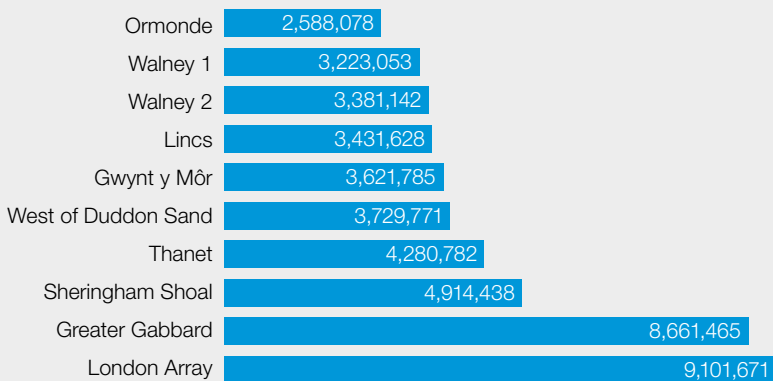
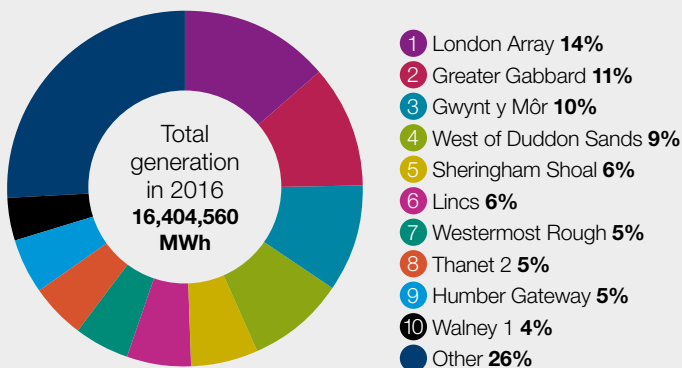


Figure 7: Offshore generation by asset*

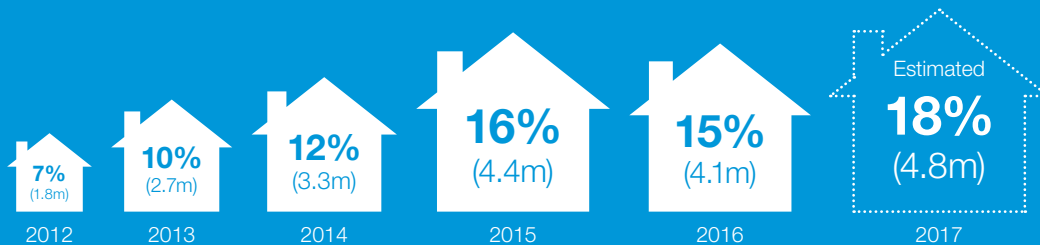


* Supplied from 30 wind farms



Number of UK homes supplied by offshore wind farm electricity generation

Note: wind speeds and energy yield in 2015 were above the long term average.



Positive growth on capacity factors

Analysis of the UK's fleet of offshore wind farms suggests a positive outlook for growth in capacity factors. Figure 8 groups capacity factors by technology, in this case rotor diameter. The graph does not represent projects in date order, but does consider averages over the last 5 years, with each solid shape representing the capacity factor achieved by a wind farm. This shows that capacity factors for wind turbines with a rotor diameter of 120m + are averaging almost 44%, whereas the technology planned for deployment on sites that are under construction suggests an estimate of just under 48%. It demonstrates increasing efficiencies in the technology, management and performance of assets across the UK seabed.

Figure 8: Generation over the last 5 years (2012–2016)

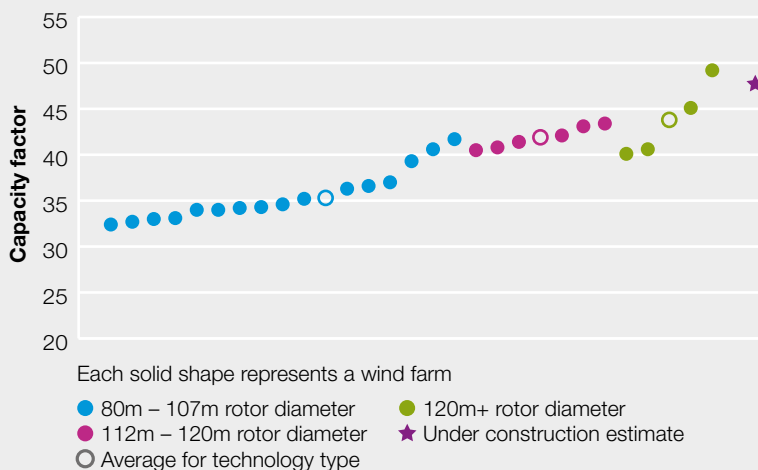
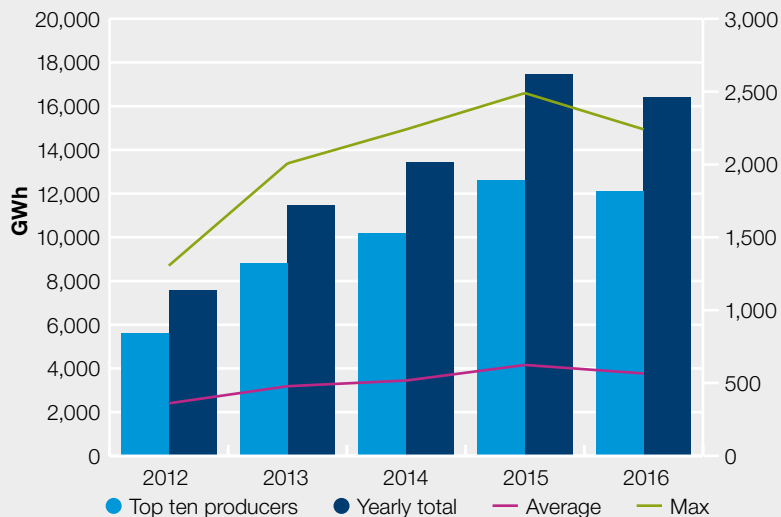


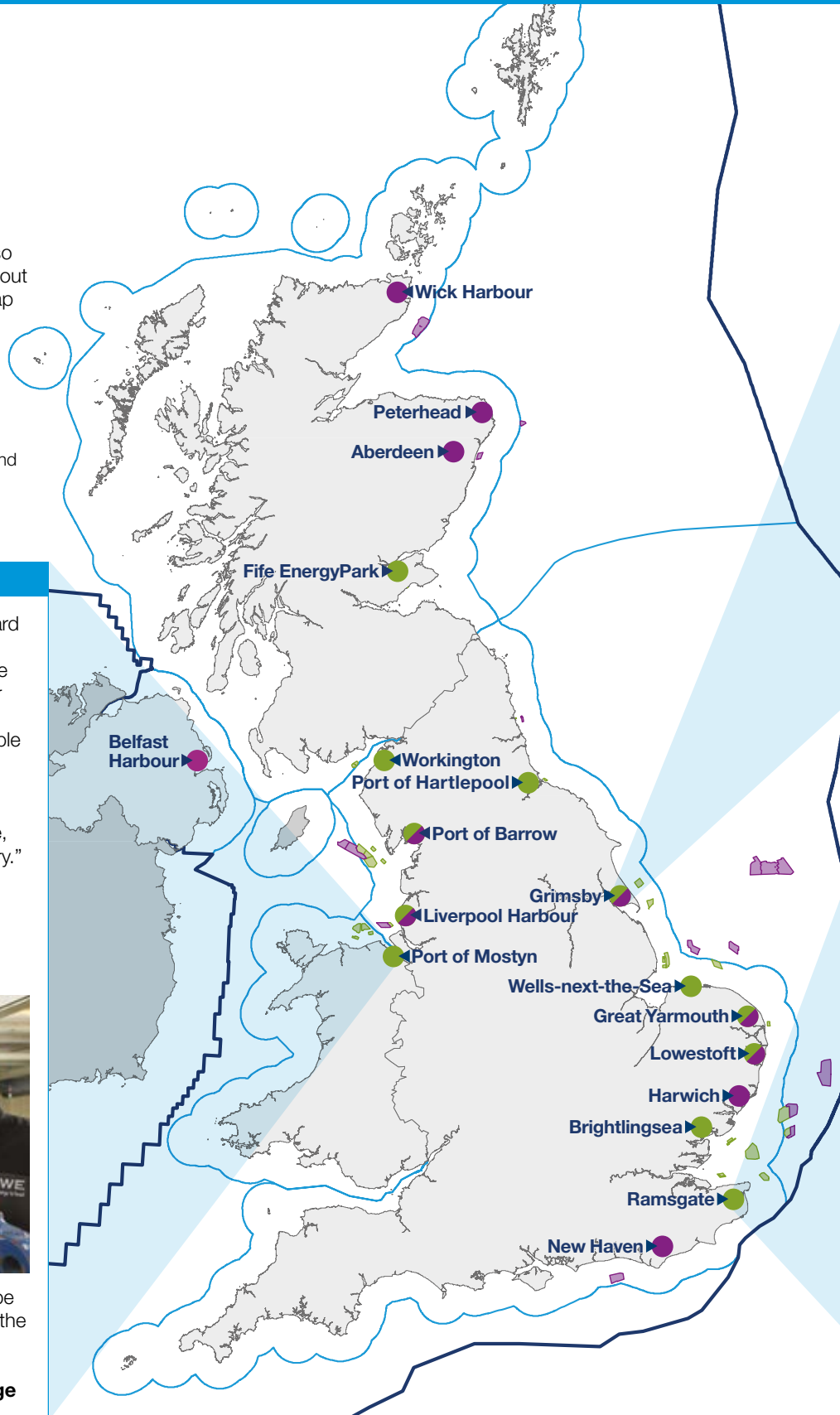
Figure 9: Generation over the last 5 years (2012–2016)



6 Regional influence of offshore wind in the UK

The UK's regional ports and harbours have seen significant investment in operations and maintenance bases (O&M), bringing local economic benefits, including job creation. In many cases, these new jobs complement existing industries, some of which have been in decline over the last 30 years. There are also lasting benefits to local supply chains throughout the year, not just on a seasonal basis. The map below takes stock of existing maintenance bases (as of 31 December 2016), as well as planned bases of those under construction.

- Territorial Waters Limit
- UK Continental Shelf
- OM Base (Operational/Under construction)
- United Kingdom
- Republic of Ireland

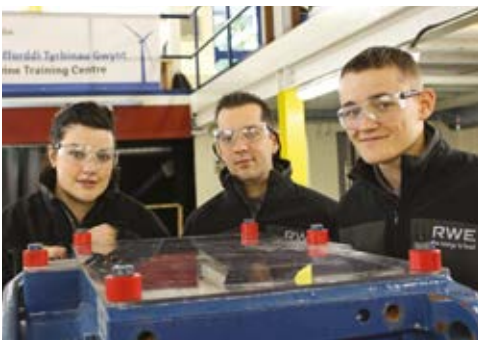


Llandrillo College

“We are really proud of our bespoke and award winning Turbine Technician Apprenticeship Programme. It was designed to address the future needs of the wind industry and wider renewable energy sector, whilst supporting the development of new skills for local people in areas neighbouring our operations. The programme has been expanded by Innogy every year since its launch in 2012, with 26 apprentices now placed on the programme, some 24 of whom remain within the industry.”

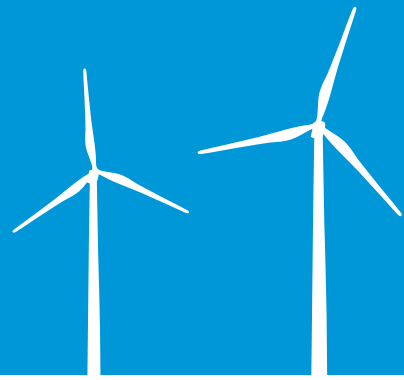
John P Davies – North Hoyle Operations Manager

Innogy Renewables UK Limited



“As apprentices we are incredibly proud to be part of the new generation helping to drive the renewables industry forward”

2015/16 and 2016/17 intake of Wind Turbine Apprentices at Llandrillo College



North East Lincolnshire Council



“The offshore wind industry has breathed a breath of fresh air into our town of Grimsby. We are pleased to see the creation of around 400 new direct high level jobs created in and around our port, with many more supporting these indirectly. We have major companies such as DONG Energy, E.ON, Siemens, MHI Vestas Offshore and their

associated supply chains investing in the order of £50m in new buildings, marine infrastructure and training facilities. This has not only improved the environment but acted as a catalyst for even further development. The future is exciting, with many more turbines due to be deployed in the Southern North Sea, we know that Grimsby will continue to grow and become a world renowned centre over the coming years”.

**Angela Blake – Director of Economy and Growth
North East Lincolnshire Council**

Port of Ramsgate



“The Port of Ramsgate is very experienced in dealing with all aspects of wind farm projects, having facilitated projects from construction to generation, and is currently home to operations and maintenance for a total of 320 offshore turbines along the Thanet coastline.

An excellent working relationship has been nurtured between the offshore sector and existing stakeholders by the Port, in conjunction with both the teams associated with the two operations and maintenance facilities. These relationships are strengthened and maintained through the meetings of the Harbour User Group, the Port User Group and the Offshore Interface group.

The arrival of the offshore sector has directly provided a range of both skilled and semi-skilled, secure jobs for local people and this, coupled with uplift in associated local supply chain, continues to boost our district’s economic prosperity. We look forward to embracing any future offshore renewable opportunities including the expansion of existing offshore installations and the arrival of exciting new green and blue technological advances.”

**Robert Brown – Harbour Master and Maritime Operations
Manager, Port of Ramsgate**

Operational

	Capacity MW ▼	▼ O&M Base
Barrow	90	Port of Barrow
Burbo Bank	90	Liverpool Harbour
Greater Gabbard	504	Lowestoft
Gunfleet Sands Demo	12	Brightlingsea
Gunfleet Sands 1	108	Brightlingsea
Gunfleet Sands 2	65	Brightlingsea
Gwynt y Môr	576	Port of Mostyn
Humber Gateway	219	Grimsby
Inner Dowsing	97	Grimsby
Kentish Flats 1	90	Ramsgate
Kentish Flats 2	49.5	Ramsgate
Levenmouth Demo	7	Fife Energy Park
Lincs	270	Grimsby
London Array	630	Ramsgate
Lynn	97	Grimsby
North Hoyle	60	Port of Mostyn
Ormonde	150	Port of Barrow
Rhyl Flats	90	Port of Mostyn
Robin Rigg East	90	Workington
Robin Rigg West	90	Workington
Scroby Sands	60	Great Yarmouth
Sheringham Shoal	317	Wells-next-the-Sea
Teeside	62	Port of Hartlepool
Thanet	300	Ramsgate
Walney 1	184	Port of Barrow
Walney 2	184	Port of Barrow
West of Duddon Sands	389	Port of Barrow
Westermost Rough	210	Grimsby

Under construction

	Capacity MW ▼	▼ O&M Base
Aberdeen Demo	92.4	Aberdeen
Beatrice	588	Wick Harbour
Blyth Demo – Phase 1	41.5	Blyth
Burbo Bank Extension	259	Liverpool Harbour
Dudgeon	402	Great Yarmouth
East Anglia ONE	714	Lowestoft
Galloper	336	Harwich
Hornsea Project 1	1,218	Grimsby*
Hywind 2 Demo (Buchan Deep)	30	Peterhead
Race Bank	573	Grimsby
Rampion	400	Newhaven
Walney Extension	659	Port of Barrow*

Construction hub

Belfast Harbour

Belfast Harbour serves as a regional construction hub for offshore wind farm projects.

* To be confirmed

7 Performance trends

Construction rates offshore increase

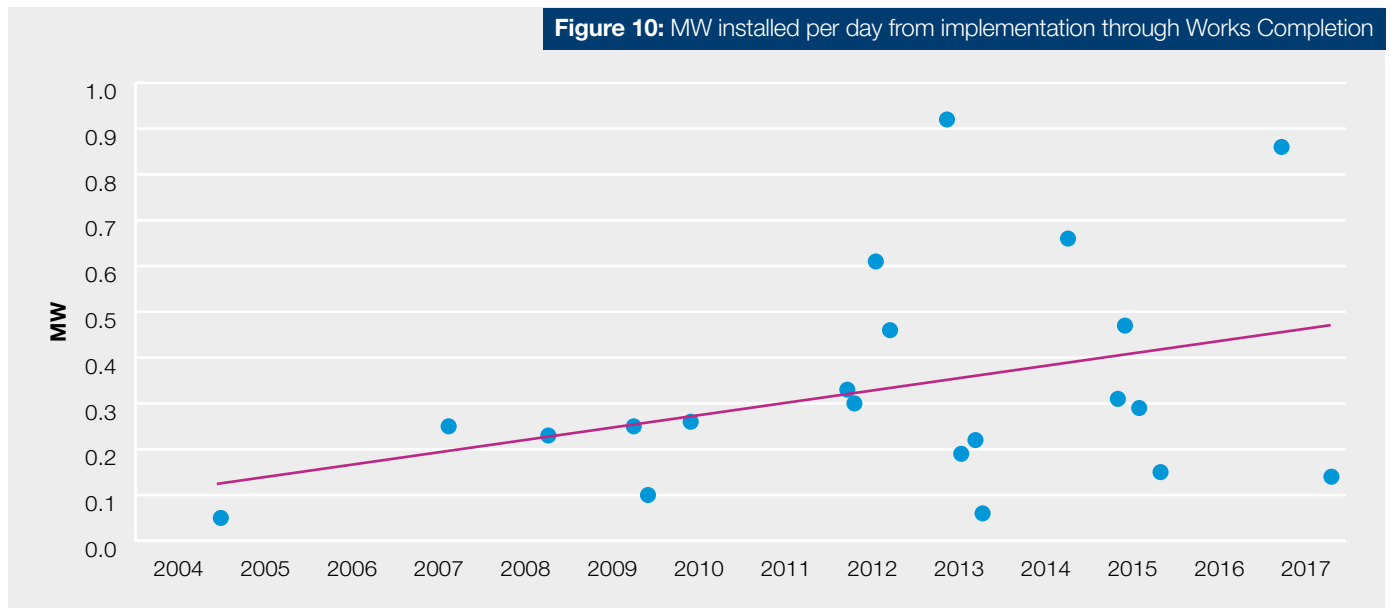


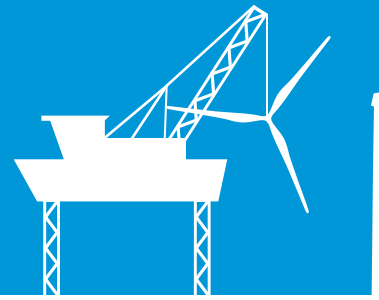
Figure 10 depicts installation rates, from the date offshore works start, to when the final wind turbine reaches commercial operation. The overall story is very positive, demonstrating that the build rate of the industry is increasing and becoming more efficient. There is a clear correlation between the size of the wind farm and installation speed, with larger sites appearing to benefit from economies of scale when placing contracts and hiring vessels.

In Figure 11, average build rates are grouped according to project capacity. It should be noted that London Array, located in the Thames Estuary, was built with remarkable speed (0.92 MW/Day).

Figure 11: Average installation rate by project capacity

▼ Wind farm total power	▼ MW installed per day
0-100 MW	0.17
100-300 MW	0.36
300 MW+	0.62





SPARTA

Currently in its fourth year of operation, 2016 saw increased participation in SPARTA, bringing virtually all UK offshore wind farms into the programme (Figure 12).

In 2016, the new production based availability metric was established and assurance processes – linked to this and the various repair metrics in the Key Performance Indicators (KPI) (Figure 13) – were successfully carried out across all wind farm owner operators. This demonstrates that the programme is now reaching a stage of maturity, where new valuable metrics are being rolled out and best practice in measuring and member reporting against these is being embedded through collaboration. Consequently, confidence in the monthly benchmarking reports has substantially increased and this has enabled trustworthy comparisons of wind farm performance against peers.

The continued growth of data provision and assurance against industry KPIs has enabled the SPARTA project to publish its first portfolio review looking at the impact of various site and environmental characteristics on relevant KPIs.

The full report is available here: <https://ore.catapult.org.uk/press-release/sparta-review-launched-giving-insights-first-full-year-successful-operations/>

Co-sponsored by The Crown Estate and the Offshore Renewable Energy Catapult and directed by an industry steering group, further development of the programme was approved in 2016, including plans to:

- Release of version 3.0 of the benchmarking system, with greatly improved user functionality and analysis capability.
- Introduce a pilot project with G+ to investigate the value of integrating performance metrics with HSE statistics.
- Expand the programme to encompass projects in European waters to enhance the value of the database for all participants



Figure 12: Yearly participation

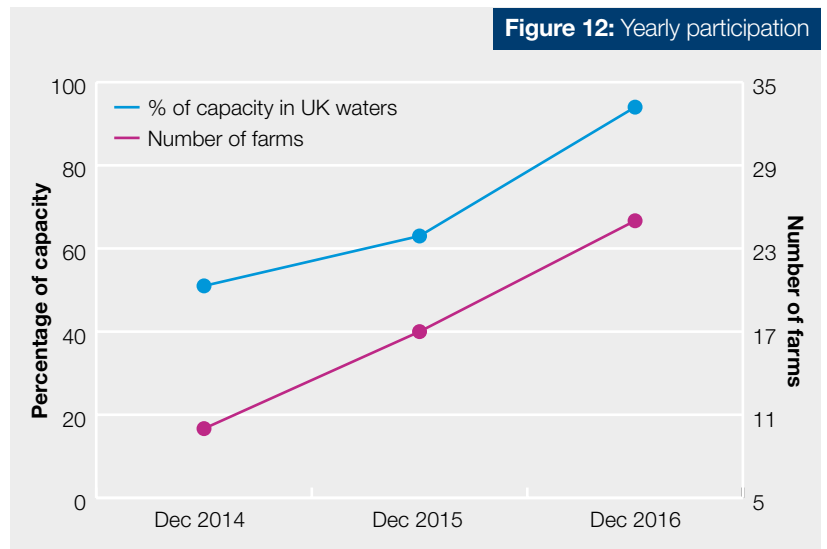
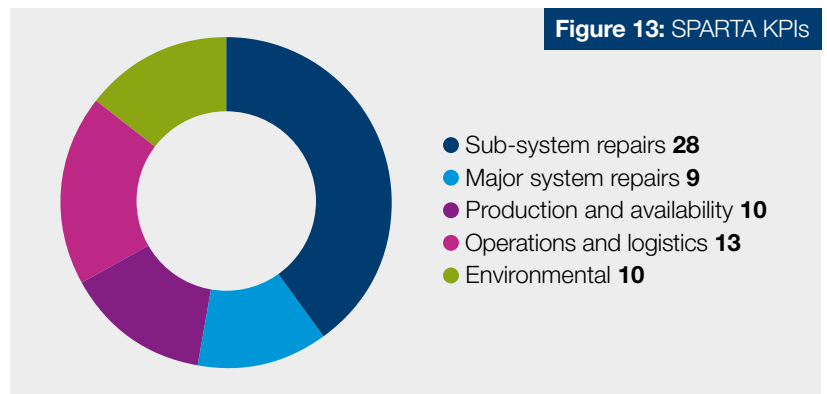


Figure 13: SPARTA KPIs



8 Investment

2016 saw the changes in various project shares of offshore wind farms, as original developers divested themselves of shares to free up capital for reinvestment into the offshore wind development pipeline.

More pension funds and corporates entered the market, including at the construction phase. For example the Danish pension provider PKA and the parent company of the Lego Group (KIRKBI) purchased a 50% stake in the 258MW Burbo Bank Extension Project from DONG.

Funds also took an increasing share of the offshore wind market as the global appetite for infrastructure investment soared. According to the Financial Times, investment in global infrastructure hit a record \$413bn in 2016, up 14% on the previous year.



Figure 14: Principal offshore wind transactions in 2016

▼ Site name	▼ Capacity (MW)	▼ Owner(s)	▼ New investor(s)	▼ Stake	▼ Value
Development and under-construction					
Beatrice	588	SSE, Repsol Nuevas Energias UK, Copenhagen Infrastructure Partners	Copenhagen Infrastructure Partners	+10% (to 35% in total)	–
Burbo Bank Extension	258	DONG	PKA and KIRKBI A/S	50%	Approximately £660m
Inchcape	784	Repsol Nuevas Energias UK	State Development and Investment Corporation (SDIC) Power	100%	Note 1
Beatrice	588	SSE, Repsol Nuevas Energias UK, Copenhagen Infrastructure Partners	State Development and Investment Corporation (SDIC) Power	25%	Note 1
Aberdeen	92.4	Aberdeen Renewable Energy Group	Vattenfall	25%	–
Galloper	336	Innogy, GIB, Siemens Financial Services, and Macquarie Capital	Sumitomo Corporation	12.5%	Note 2
Race Bank	573	DONG	Macquarie European Infrastructure Fund 5 and Macquarie Capital	50%	–
Operational wind farms					
Lynn and Inner Dowsing	194.4	Centrica and EIG Global Energy Partners	UK Green Investment Bank Offshore Wind Fund Funds managed by BlackRock Investment Management	100%	N/A
North Hoyle	60	Zephyr Investments	Zephyr Investments	Note 4	–
Funds managed by BlackRock Investment Management					
Humber Gateway	219	E.ON	Humber Gateway OFTO Limited	100%	£160.3m
Westermost Rough	210	DONG, Maurubeni Corporation, UK GIB	TC Westermost Rough OFTO Limited	100%	£156.7m

1. The acquisition of the Inchcape project and 25% of Beatrice was reported at a total cost of €238 million.
2. Sumitomo Corporation is investing alongside Macquarie Capital in Galloper and so will indirectly take a 12.5% stake in the project.

3. The £423m is a reported Enterprise Value for the acquisition.
4. In July 2016 RWE sold its investment in Zephyr Investments Limited, the indirect parent company of the North Hoyle project company. As at 31 December 2016, Zephyr Investments Limited's stake of the North Hoyle project was indirectly owned 66.67% by JP Morgan and 33.33% by M&G.



4 YEARS

Offshore wind generation in 2016 would keep the UK national rail network on the move for 4 years!

The offshore wind industry – a financial perspective

The past twelve months have been significant for the offshore wind industry. Transaction volumes were at a record high – according to projects tracked by datLive [source: inspiratia]. Total transaction volumes for global offshore wind were almost US\$17bn, which included US\$12bn invested in greenfield projects, and the UK led the way with some US\$4bn in greenfield transactions. Furthermore, we saw highly competitive tenders in the Netherlands, Denmark and Germany and an upsurge in interest in markets outside of Europe, notably in south-east Asia and the eastern seaboard of the US.

A combination of factors has brought about this growth story.

Cost reduction has been a major determinant. Over the past four years, the levelised cost of energy (LCoE) for offshore wind has been steadily falling. It is estimated that projects reaching completion in 2020 will have a 25% lower LCoE than those completed in 2010/11 [source: Catapult: Offshore Wind Cost Reduction – November 2016].

On the technical front, the industry is developing a consistent track record of delivery of projects through construction, both in terms of cost and timescale, and into operations. Advances are being made in such

areas as turbine design, transmission and turbine installation vessels.

This is all good news for the offshore wind sector and this positivity has brought in new investors to the sector, attracted by significant investment volumes against an acceptable risk profile. We can broadly categorise these investors into five types – utilities, project developers, corporates (particularly oil and gas players), institutional investors and supply chain companies. It is, perhaps, the emergence of institutional investors that is the most striking. These investors, which are typically risk-averse funds seeking long-term predictable cash flows, are becoming increasingly comfortable with construction and operational risk and some are now prepared to invest during late stage development.

Looking at debt, commercial banks have long supported the offshore wind sector and, importantly, from the earliest days, these institutions were prepared to take construction risk. Whilst balance sheet finance remains an important feature of the market, we are seeing increasing opportunities for project (non-recourse) finance and new lenders, including institutional investors, are emerging.

Given this competitive market, together with the advances in technology, both equity and debt providers are re-thinking

their commercial approach, including risk-sharing models in construction – for example, time versus yield based production wind turbine warranties. While time based warranties have been an industry standard for many years, the yield warranty concept has gained increasing currency in trying to attain the desired outcome to optimise asset performance. Choosing the right approach for a project requires a clear understanding on, inter alia, the way that data is gathered and analysed, how routine maintenance is scheduled and how the underlying commercial relationships function. Whilst long-term, risk averse, fund investors can work effectively with these contracts, it is necessary that they have the requisite degree of market knowledge to work towards asset optimisation. If that market knowledge is not there, the concern is that any optimisation could potentially be diluted because the contracts are caveated by the investor to protect its position.

Nick Gardiner

Managing Director, Head of Offshore Wind Green Investment Bank

**Green
Investment
Bank**

New study into UK Offshore Wind Variability

A new study into the UK's offshore wind resource undertaken by DNV GL on behalf of The Crown Estate in 2016 revealed that variability in wind speeds is significantly lower than previously understood and paves the way for improved project projections which can help bring down the cost of energy.

Historical studies of the inter-annual variability (IAV) of wind speed have

focused on measurements from onshore meteorological stations. These studies have created an industry standard estimate of wind speed IAV at 6%, which has been widely adopted across many global markets since the early 90's.

The 'Study on UK Offshore Wind Variability' available at <https://www.thecrownestate.co.uk/energy-minerals-and-infrastructure/offshore-wind-energy/>

has now revealed an IAV range of 4-5.5% to be more appropriate across the UK offshore environment. This report reveals a significant improvement in our understanding of the UK's offshore wind resource. We hope that industry will begin to reflect this reduced variability into their assessments to help create a more attractive financing proposition for investors and support continued cost reduction over the long term.

9

Ownership



Wind farms

Ownership of offshore wind is evolving. More energy and infrastructure, and pension funds have entered the market as project shares have been split further. There are very few projects where ownership is retained by one company alone, albeit E.ON is the exception here and to a lesser extent, Vattenfall. Ownership is still dominated by large scale developers but not solely by the big six. The Scandinavian influence on the UK is not limited to furniture design and the Nordic

Noir television genre but extends, significantly, to renewable energy. Danish energy giant, DONG has the largest share of the UK's offshore wind sites in operation and under construction, with a significant presence also from Swedish company Vattenfall. Norwegian company Statoil is growing its presence too through its interest in several offshore wind sites, including Dudgeon off the Norfolk coast and Hywind off the east coast of Scotland, both projects are currently under construction.

Figure 15: Operational offshore wind farm ownership as at 31 December 2016

▼ Project	▼ Company (Share ownership)
Barrow	100% DONG Energy
Blyth Offshore	100% E.ON
Burbo Bank	100% DONG Energy
Greater Gabbard	50% Innogy 50% SSE
Gunfleet Sands Demonstration	100% DONG Energy
Gunfleet Sands I	24.95% Marubeni Corporation 24.95% Development Bank of Japan 50.10% DONG Energy
Gunfleet Sands II	24.95% Marubeni Corporation 24.95% Development Bank of Japan 50.10% DONG Energy
Gwynt y Môr	10% Siemens 30% Stadtwerke München 50% Innogy 10% UK GIB
Humber Gateway	100% E.ON
Inner Dowsing	61% GIB Offshore Wind Fund 39% BlackRock
Kentish Flats	100% Vattenfall
Kentish Flats extension	100% Vattenfall
Levenmouth Demonstration	100% ORE Catapult
Lincs	50% Centrica 25% DONG Energy 25% Siemens
London Array (Phase 1)	25% DONG Energy 25% Caisse dépôt & placement Québec 30% E.ON 20% Masdar

▼ Project	▼ Company (Share ownership)
Lynn	61% GIB Offshore Wind Fund 39% BlackRock
North Hoyle	100% Zephyr Investments*
Ormonde	49% AMF 51% Vattenfall
Rhyl Flats	50.10% Innogy 24.95% Greencoat UK Wind 24.95% GIB Offshore Wind Fund
Robin Rigg East	100% E.ON
Robin Rigg West	100% E.ON
Scroby Sands	100% E.ON
Sheringham Shoal	40% Statkraft 20% GIB Offshore Wind Fund 40% Statoil
Teesside	100% EDF Energy Renewables
Thanet	100% Vattenfall
Walney 1	50.10% DONG Energy 25.10% SSE 24.80% PGGM & Ampère Equity Fund
Walney 2	50.10% DONG Energy 25.10% SSE 24.80% PGGM & Ampère Equity Fund
West of Duddon Sands	50% DONG Energy 50% Scottish Power
Westermost Rough	50% DONG Energy 25% Marubeni Corporation 25% UK GIB

* Zephyr Investments' stake in North Hoyle owned 66.7% JP Morgan and 33.3% M&G at 31 December 2016



102%

In 2016 offshore wind supplied the equivalent of 102% of the domestic electric requirement of London, Manchester and Liverpool

Offshore Transmission Owners (OFTOs)

Transmission Capital Partners and Blue Transmission dominate OFTO ownership. But other players, such as the infrastructure company Equitix, are taking an increasing share in the sector, most recently working as consortium partner with Balfour Beatty on the Humber Gateway offshore transmission purchase.

Figure 16: Offshore Transmission Owner (OFTO) Transactions

Offshore transmission – transfer timelines for transmission assets.
For more information www.ofgem.gov.uk/electricity/transmission-networks/offshore-transmission/offshore-transmission-tenders

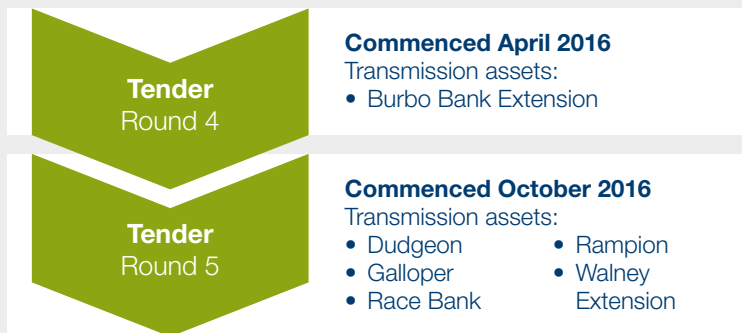
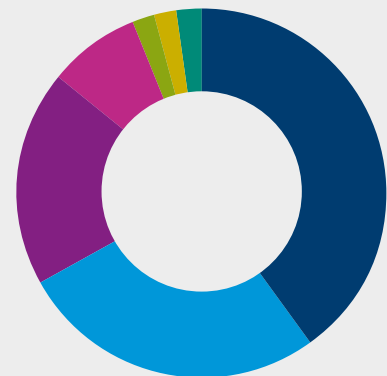


Figure 17: OFTO ownership



- Transmission Capital Partners **40%**
- Blue Transmission **27%**
- Equitix **19%**
- Balfour Beatty Investments **8%**
- Macquarie Corp Holdings **2%**
- 3i infrastructure Plc **2%**
- Frontier Power Ltd **2%**

Figure 18: OFTO ownership as at 31 December 2016

▼ Project	▼ Company (Share ownership)	▼ Connection voltage	▼ Interfacing party*
Barrow OFTO	100% Transmission Capital Partners	132 kV	DNO
Greater Gabbard OFTO	100% Equitix	132 kV	Transmission
Gunfleet Sands OFTO	100% Transmission Capital Partners	132 kV	DNO
Gwynt y Môr OFTO	50% Balfour Beatty 50% Equitix	132 kV	Transmission
Humber Gateway OFTO	50% Balfour Beatty 50% Equitix	132 kV	Transmission
Lincs OFTO	100% Transmission Capital Partners	400 kV	Transmission
London Array Phase 1 OFTO	100% Blue Transmission	400 kV	Transmission
Ormonde OFTO	100% Transmission Capital Partners	132 kV	DNO
Robin Rigg OFTO	100% Transmission Capital Partners	132 kV	DNO
Sheringham Shoal OFTO	100% Blue Transmission	132 kV	DNO
Thanet OFTO	20% Balfour Beatty Investments 80% Equitix	132 kV	DNO
Walney 1 OFTO	100% Blue Transmission	132 kV	Transmission
Walney 2 OFTO	100% Blue Transmission	132 kV	DNO
West of Duddon Sands OFTO	33% Frontier Power Ltd 33% 3i infrastructure Plc 33% Macquarie Corp Holdings	400 kV	Transmission
Westermost Rough OFTO	100% Transmission Capital Partners	275 kV	Transmission

* DNO (Distribution Network Operator)

10 OFTO Performance

Transmission system availability for Offshore Transmission Owners (OFTOs) is published annually by National Grid on a financial year basis (not on a calendar year basis). 2016-17 data is expected to be published in July 2017, so the information in this section utilises data published by National Grid for the period April 2015 to March 2016.

In the preceding table on page 17 are 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).

Annual Availability

The 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 on an annual basis – 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.

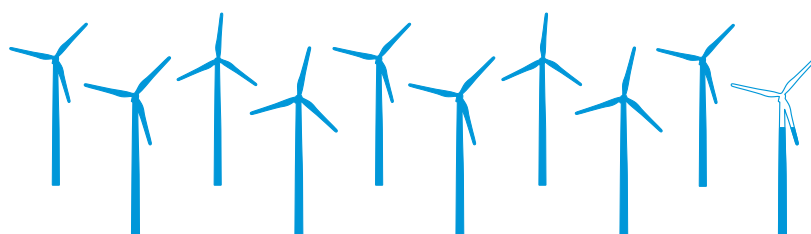
In 2015/16, the average OFTO availability was 95.99%. However, this masks significant differences across OFTOs, where performance ranged between 82.58% and 100%. Whilst the majority of OFTOs performed at, or very close to, 100%, a few systems had issues that impacted their performance. The most significant issues occurred on the transmission systems that connect Walney 2, Gwynt y Môr and Thanet, where performance was significantly below target. Outages were for various reasons but those with the greater impact include: a fault with the Walney 2 export cable in December 2015, with investigation and repair running until March 2016; at Gwynt y Môr there was a primary system fault on export cable 1 and on cable 2 respectively; and at Thanet there were primary system faults on cable 1 in April 2015 and cable 2 in March 2016.

The three year view is considered in Figures 19 and 20. More details can be found in the National Grid's National Electricity Transmission System Performance Report.

Figure 19: Offshore transmission networks % annual availability

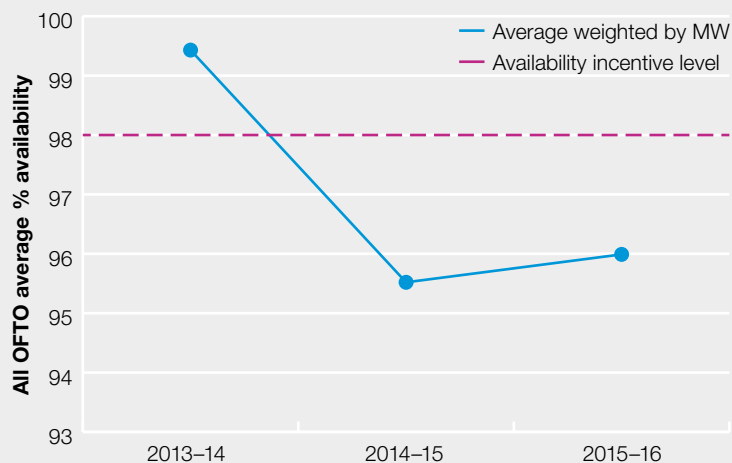
▼ Project	2013-14 ▼	2014-15 ▼	2015-16 ▼
Robin Rigg	99.85	98.19	99.99
Gunfleet Sands	100	99.53	100
Barrow	99.64	100	99.88
Ormonde	100	99.93	100
Lincs	N/A	100	99.96
Westermost Rough	N/A	N/A	100
Walney 1	99.99	100	100
Walney 2	94.89	100	92.47
Sheringham Shoal	99.20	99.84	100
London Array	99.97	99.90	99.98
Greater Gabbard	99.81	100	100
Gwynt y Môr	N/A	82.59	82.58
Thanet	N/A	82.47	83.05
West of Duddon Sands	N/A	N/A	100

Note: Availability data for the Humber Gateway OFTO was not published at the time of writing this report.



95.99% Annual System Availability of Offshore Networks for 2015-16

Figure 20: OFTO availability trend



11 Knowledge



The Crown Estate unlocks value in the UK seabed through enabling activity, carrying out research to help reduce the levelised cost of offshore wind energy and reduce barriers to consenting for sustainable development. A selection of activity related to offshore wind is referenced below.



Offshore Renewables Joint Industry Programme

www.orjip.org.uk

Offshore Renewables Joint Industry Programme (ORJIP) is a UK-wide collaborative programme of environmental research with the aim of reducing consenting risks for offshore wind and marine energy projects.

Currently there are two ORJIP streams: Offshore Wind and Ocean Energy. They bring together industry, regulators, statutory nature conservation bodies and academia to work together on key environmental and consenting issues that the respective sectors are facing.



Marine Data Exchange

www.marinedataexchange.co.uk

The Marine Data Exchange provides access to survey data and reports collated during the planning, building and operating of offshore renewable energy projects.

In 2016, over 500 new surveys were added to the Marine Data Exchange, delivering a 22% increase in total available data. The platform, now one of the biggest sources of marine data in the world, includes a host of new wind, wave and tidal data, as well as landscape assessments, bird and mammal population studies, habitat characterisations and archaeological studies.



Offshore wind electricity map

thecrownestate.co.uk/owmap

An interactive map which refreshes every hour to estimate the total electricity being generated by offshore wind farms in the UK. It is unique in separating offshore wind from a total wind generation figure and it includes estimates for embedded generators not directly supplying the National Grid.



Offshore wind Atlas

thecrownestate.co.uk/owatlas

This is a significant modelled dataset for the UK's offshore wind resource, informed by a 30 year time horizon.

The modelling was undertaken by the Met Office using their world-leading Numerical Weather Prediction capabilities, and verified against on-site wind measurements to provide confidence in the dataset. The wind data provides a higher resolution picture of the UK's offshore wind resource to help inform offshore wind farm planning and development



Understanding the impacts of offshore wind on well-being

thecrownestate.co.uk/owfwb

This study by Plymouth Marine Laboratory explores the impacts of the UK offshore wind industry in terms of well-being. It uses an ecosystems services approach as well as the five capitals model developed by Forum for the Future.



Working with fisheries

The Crown Estate provides the chair and secretariat for the Fishing Liaison with Offshore Wind and Wet Renewables (FLOWW) group. Established in 2002 to foster a good relationship between the fishing and offshore renewables industries and to develop and promote best practice. More information can be found at: thecrownestate.co.uk/floww

Kingfisher Bulletins are an important way for the fishing community to be notified about new developments and activities in the offshore renewables, cables and aggregates sectors to help with managing potential navigation risks. The fortnightly bulletins are available through the KIS-ORCA website: www.kis-orca.eu

A pilot study has been conducted looking at the interaction between fishing activity and the development of offshore wind farms in the Irish Sea, and any potential changes in fishing patterns. The report, *Changes to fishing practices around the UK as a result of the development of offshore wind farms – Phase 1* is available online: thecrownestate.co.uk/owfish

