THE CROWN ESTATE

Offshore wind operational report

January – December 2017

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.

Scotland

The management duties in Scotland, including management of the Scottish seabed, were transferred to a separate organisation, Crown Estate Scotland following implementation of the Scotland Act 2016. Crown Estate Scotland 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.

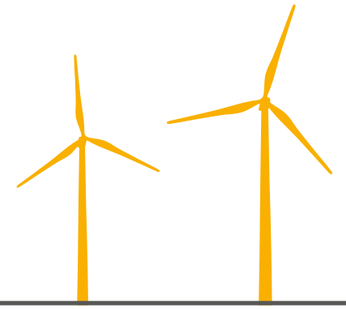
UK offshore wind generated over **20.8 TWh** last year, that's enough to supply the electricity needs of **5.3m homes,** around **20%** of the UK total

6.2%

Offshore wind supplied **6.2%** of the UK's total estimated electricity generation in 2017

This performance reduced the UK's $C0_2$ emissions by **8.6 million** tonnes

1 Introduction



Welcome to our 2017 Offshore Wind Operational Report, an annual publication summarising progress in the development of the UK's offshore wind resources.

With 36[1] large offshore wind farms already contributing on average 6% of the nation's electricity demand, the sector is on track to becoming a vital source of power generation for the country.

As The Crown Estate, we manage the seabed around England, Wales, and Northern Ireland[2] out to international borders. These waters harbour some of the best wind resources worldwide, alongside the infrastructure of ports, transmission grids, a diverse supply chain and a skilled labour force.

This is well illustrated by the Rampion wind farm situated off Brighton. The first Round 3 wind farm to be constructed, it can provide 400 MW of power, enough for 405,000 homes. A new purpose-built operations and maintenance facility located on the East Quay and Newhaven Port will be home to over 60 newly hired apprentices, technicians, engineers and marine workers to service all the offshore assets. The base is helping to kick start a regeneration programme in the area and is part of the Newhaven Enterprise Zone.

Government policy has long recognised offshore wind's strengths in providing large-scale low-carbon power, creating jobs and opportunities across the country, and its ability to do so in harmony with the natural environment. Further, on the back of the Contracts for Difference auction results last year, this can now be done at historic low costs. These strands are being woven together in an ambitious "sector deal", part of the government's industrial strategy, that is designed to drive continued growth in the years ahead.

Sector ambition is to grow operating capacity from 6.9 GW at the end of 2017 to 30 GW in the 2030s. This will make our energy system more reliable and sustainable, lower overall costs, and provides a huge opportunity for all stakeholders involved to have their say in this exciting "energy transition". To facilitate market demand for new offshore sites we have commenced dialogue with industry and statutory stakeholders to scope a potential new leasing round.[3]

At the end of 2017, there were 1,762 wind turbines and 21 transformer stations operational on the seabed. These numbers are set to increase by around 50% over the next five years, making it one of the largest infrastructure projects in the country. Driven by its world-leading approach to safety and performance, as witnessed by the G+ and SPARTA projects, the sector is broadening its appeal to a wide range of investors.

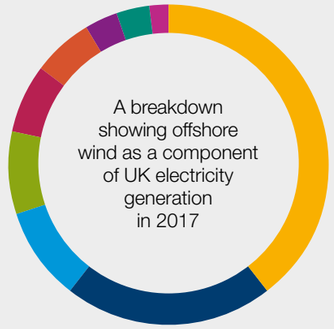
Our thanks to all those who have provided content, in particular Paul Cowling and the G+ team, Forewind, PFA, PKA, Sally Shenton and Chris Hill at ORE Catapult.

Huub den Rooijen

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

1 Sites that were fully operational and those under construction but already generating at December 2017
2 An independent organisation, Crown Estate Scotland, manages Scottish seabed
3 https://www.thecrownestate.co.uk/news-and-media/news/2018/update-on-potential-new-offshore-wind-leasing/

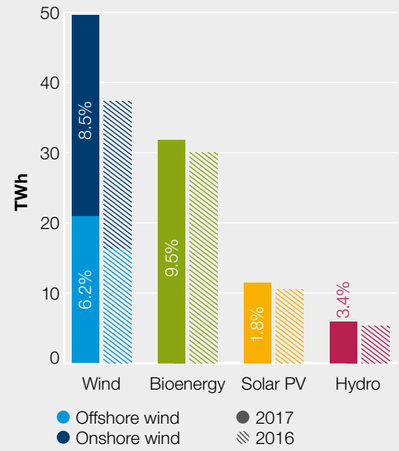
Figure 1: UK electricity generation mix 2017



Source: Statistical press release – UK Energy Statistics, 2017 & Q4 2017: DBEIS

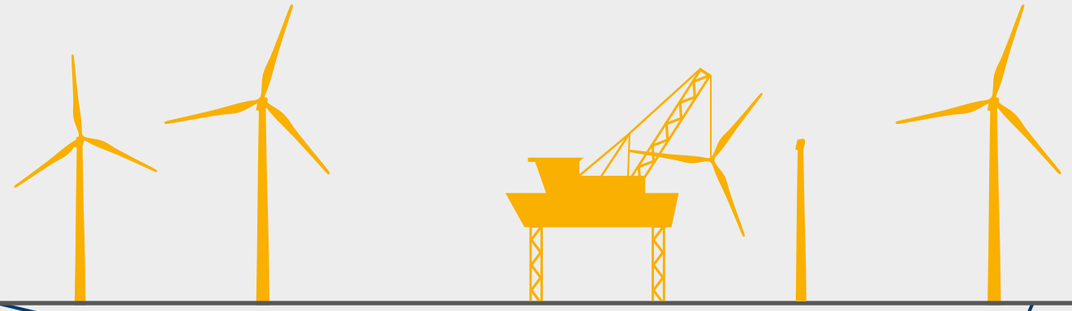
Figure 2: UK renewable electricity generation by fuel type 2017

Renewable energy represented 29.4% of the UK's electricity generation mix in 2017, of which 6.2% was provided by offshore wind.



Source: Statistical press release – UK Energy Statistics, 2017 & Q4 2017: DBEIS

2 Offshore wind farm status



A turbine a day...

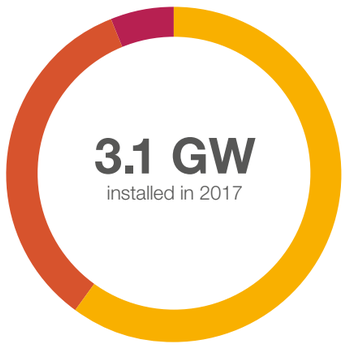
In the UK an offshore wind turbine was installed every day on average in 2017

By the end of 2017, there were 33 fully operational offshore wind farms, with a further eight under construction, set to contribute an additional 4.5 GW of new capacity over the coming years.

The resounding theme for 2017 was construction, construction, construction, with it being the UK's busiest year yet in offshore wind. An amazing 2 GW of new capacity was added to UK offshore wind in 2017, of which 1.8 GW was operational by the end of the year. This contributed significantly to Europe's overall 3.1 GW increase in new offshore wind capacity installed in 2017. The UK currently has the largest operational capacity of offshore wind installed in Europe providing 43% of the total.

To give an idea of the pace of construction this year, an additional 372 wind turbines were installed between January and December 2017, on average that's just over one new wind turbine installed every day. This pace is underpinned by a sophisticated supply chain and teams of designers, planners, construction experts, project managers and cable installers. To be able to deliver complex projects at this scale is a major achievement for the UK and its partners.

Figure 3: new European offshore wind capacity delivered in 2017



1. UK **60%**
2. Germany **34%**
3. Belguim, Finland & France **6%**

Figure 4: UK offshore wind project pipeline – 31 December 2017

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

		Capacity MW ▼
1	Barrow	90
2	Blyth	4
3	Blyth Demonstration (Phase 1)	41.5
4	Burbo Bank	90
5	Burbo Bank Extension	258
6	Dudgeon	402
7	Greater Gabbard	504
8	Gunfleet Sands Demonstration	12
9	Gunfleet Sands I	108
10	Gunfleet Sands II	65
11	Gwynt y Môr	576
12	Humber Gateway	219
13	Hywind 2 Demonstration (Buchan Deep) *	30
14	Inner Dowsing	97
15	Kentish Flats	90
16	Kentish Flats Extension	49.5
17	Levenmouth Demonstration *	7
18	Lincs	270
19	London Array	630
20	Lynn	97
21	North Hoyle	60
22	Ormonde	150
23	Rhyl Flats	90
24	Robin Rigg East *	90
25	Robin Rigg West *	90
26	Scroby Sands	60
27	Sheringham Shoal	317
28	Teesside	62
29	Thanet	300
30	Walney 1	184
31	Walney 2	184
32	West of Duddon Sands	389
33	Westermost Rough	210
Total		**5,826**

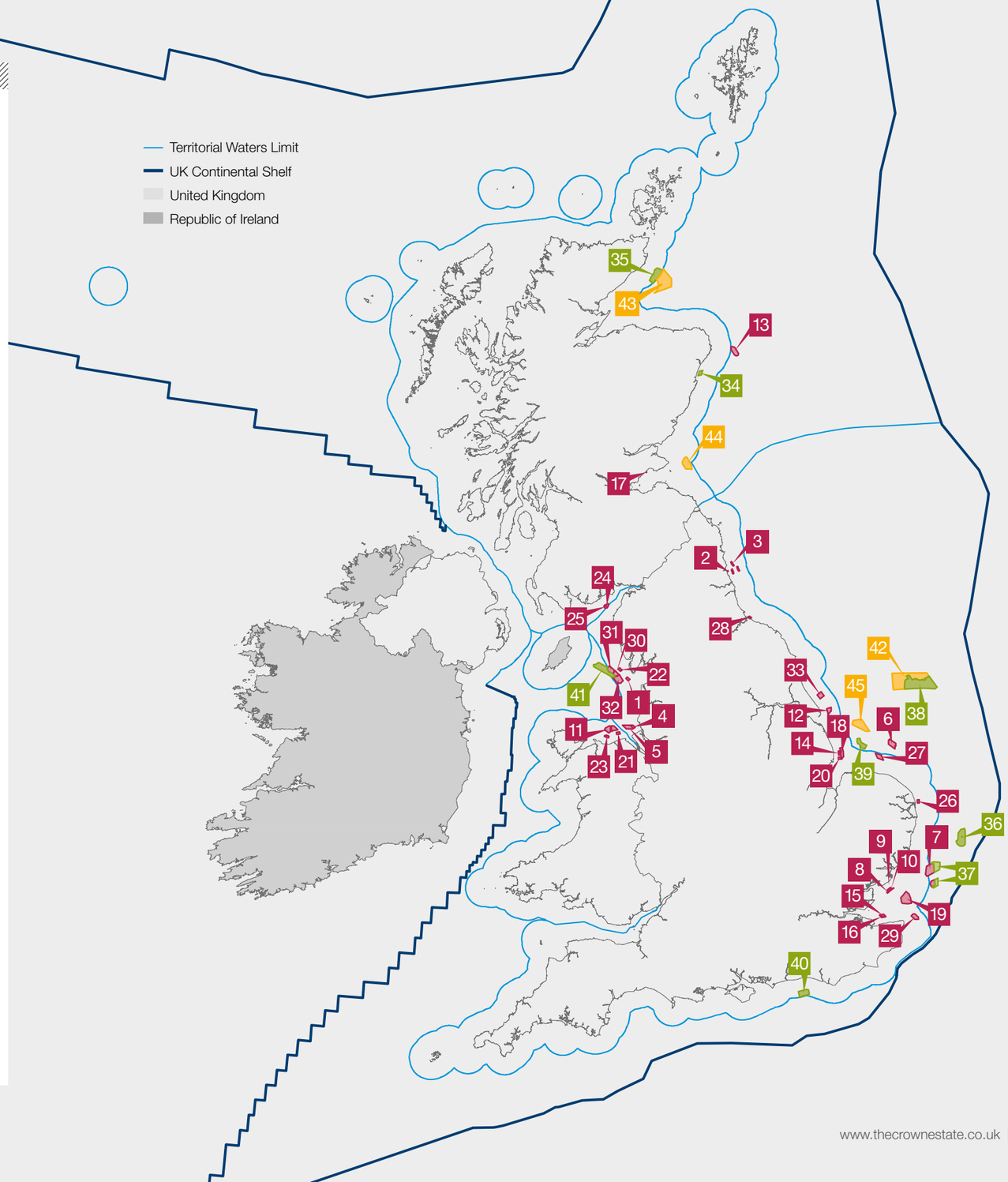
Under construction: Total capacity of wind farms that are under construction or where the developer has confirmed a final investment decision, but are not yet fully operational.

		Up to capacity MW ▼
34	European Offshore Wind Deployment Centre *	92.4
35	Beatrice *	588
36	East Anglia ONE	714
37	Galloper	336
38	Hornsea Project 1	1,218
39	Race Bank	573
40	Rampion	400
41	Walney Extension	659
Total		**4,580**

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

		Up to capacity MW ▼
42	Hornsea Project 2	1,384
43	Moray East *	950
44	Neart na Gaoithe (NNG) *	448
45	Triton Knoll	860
Total		**3,642**

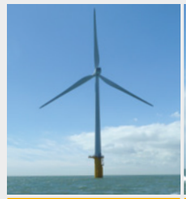
* Seabed rights provided by Crown Estate Scotland

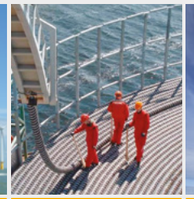


3 Assets

Figure 5: UK offshore wind assets – 31 December 2017

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





	Offshore turbines	Offshore substations	Export cables	Offshore masts	Wind farms
Operating	1,762	21	61	20	33
Under construction*	1,161	18	25	1	15
Total	2,923	39	86	21	48

Construction activity

At the end of December 2017 there were 1,762 fully operational offshore wind turbines on the UK seabed, with a further 1,161 under construction. During the year, seven new wind farms began generating, four of which reached full operation, adding an additional 1.8 GW of new operational capacity.

The UK had a total operational capacity of 6.9 GW, with a further 0.6 GW installed but not yet operational at the end of the year. There were 15 offshore wind farm sites under construction during the year, several of which continue into 2018. The 7 GW milestone has since been reached (February 2018), a significant point which highlights the industry's progression.

2017 also witnessed some major industry highlights:

- The first 8 MW turbines becoming fully operational were at Burbo Bank Extension;
- The world's first floating offshore wind farm installed and generating at the Hywind demonstration project off the Aberdeenshire coast in Scotland; and
- The first five pioneering reinforced concrete gravity-based foundations, an alternative to traditional monopile and jacket solutions, being constructed, transported and installed at the Blyth Offshore Demonstrator project off the coast of Blyth.

These examples demonstrate the UK's place at the forefront of testing new technologies in the offshore wind sector.

2017 also saw the first Round 3 wind farm, Rampion, complete construction and begin generating off the Sussex coast. The growth of offshore wind is set to continue with the some of the larger, further offshore wind farms beginning construction and reaching full commercial operation in the coming years, enabling the sector to grow its contribution to the UK's electricity supply to 10% by 2020.

Asset activity in 2017

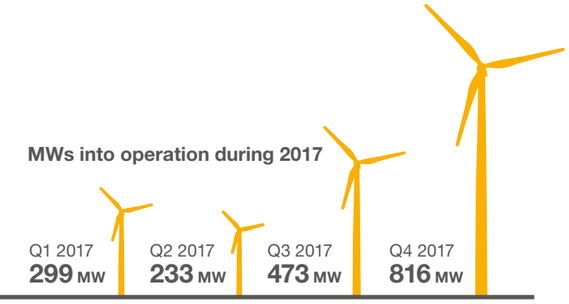
Wind farms having achieved FID (Final Investment Decision)
- Hornsea Project 2

Wind farms under construction
- Aberdeen Bay
- Beatrice
- Blyth Demo – Ph1
- Burbo Bank Extension
- Dudgeon
- East Anglia ONE
- Galloper
- Hornsea Project 1
- Hywind 2 Demo
- Race Bank
- Rampion
- Walney Extension

Wind farms achieving first power
- Blyth Demo – Ph1
- Dudgeon
- Galloper
- Hywind 2 Demo
- Race Bank
- Rampion
- Walney Extn – Ph1

Wind farms completed
- Blyth Demo – Ph1
- Burbo Bank Extension
- Dudgeon
- Hywind 2 Demo

4 Construction trends



Construction rates offshore increase

Figure 6: MW installed per day from implementation through to final commissioning

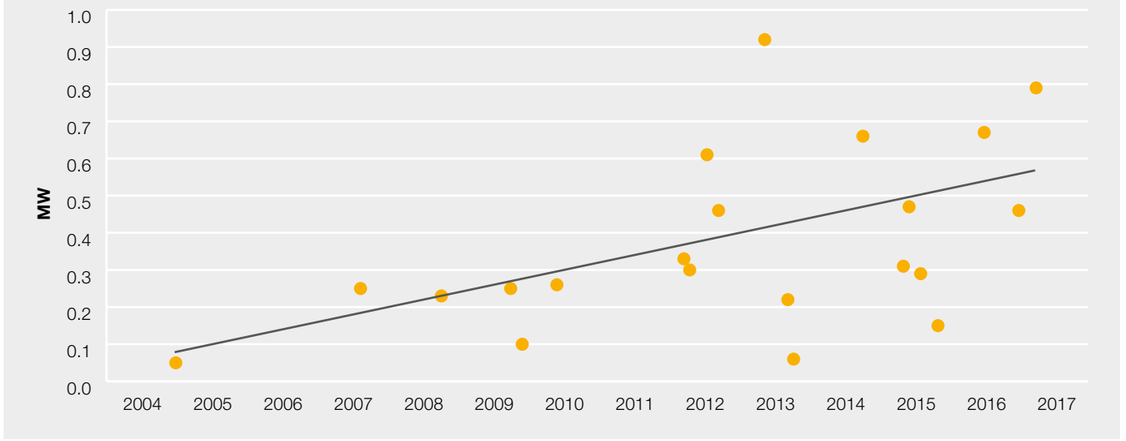


Figure 6 depicts installation rates, from the date offshore works start, to when the final wind turbine reaches commercial operation. The trend line demonstrates that the build rate of the industry is increasing and becoming more efficient, with the average build rate having increased five-fold between 2005 and 2017.

In Figure 7, average build rates are grouped according to project capacity. 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. The most recent wind farms tend to confirm the speed of construction of large assets, which remains unchanged from 2016 at 0.62 MW/day.

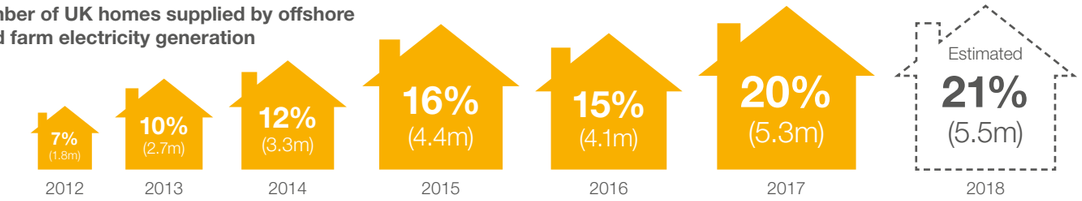
Figure 7: Average installation rate by project capacity

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

Construction at Race Bank Offshore Wind Farm

5 Performance

Number of UK homes supplied by offshore wind farm electricity generation



Ramp up

During the powering-up phase, turbines are built and commissioned sequentially. The rate at which turbines are brought online can be influenced by meteorological conditions, availability of jack-up vessels, components supply chain, technical difficulties and other factors.

- The first months of construction are usually slow. The first half of a wind farm takes approximately 25% longer to build than the second half.
- Construction in the winter is marginally slower than in the summer. The latitude of the project is a factor to keep in consideration, due to reduced sunlight and harsher weather in the winter.

Once a project has been commissioned and is fully operational, it is usual to see a sub-optimal performance in the first months of operation. However, the industry has become very efficient at ironing out infancy issues and new assets now reach expected performance much sooner than in the past.

This trend is illustrated by the following graphs (Figures 8 and 9), showing the power output of two wind farms from full commissioning onwards.

Figure 8: 2009

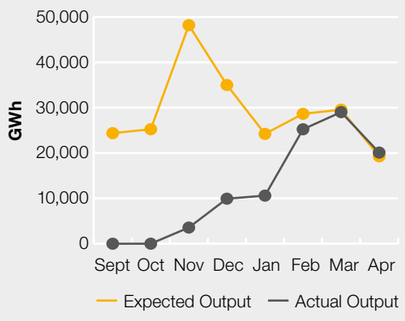
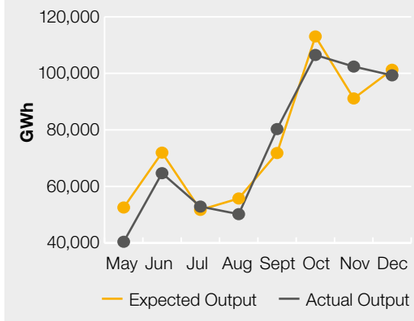


Figure 9: 2017



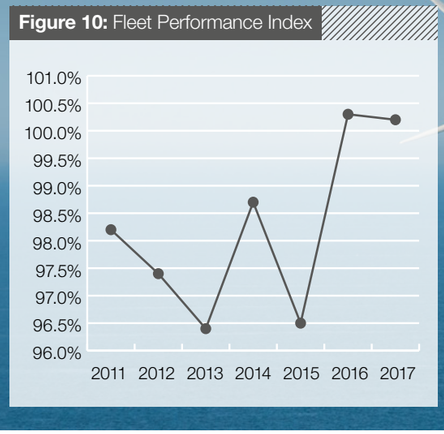
Fleet Performance Index

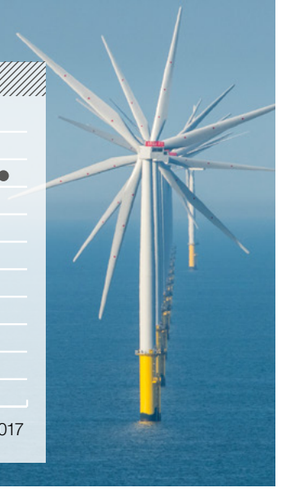
The Performance Index compares metered electricity output against the expected, pre-construction output, adjusted for actual wind speed during that period. It gives a direct measure of the performance of the offshore wind farm fleet in England and Wales, without any adjustment for outages. A result above 100% indicates the fleet exceeded its expected output.

The analysis is for 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 the shore.

Figure 10 shows the variation in fleet performance for the last seven years. 2013 and 2015 were impacted by export cable failures.

Figure 10: Fleet Performance Index





Wind variability

Wind farm output is dependent on wind speed, dictated by the movement of large air masses. 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.

This illustrates the difference between "weather", which forecasts the precise meteorological conditions for the following days and "climate" which predicts the average conditions over a much longer period.

Figure 12 shows England & Wales' offshore portfolio's monthly energy deviation from the long term average in 2017. The power output in January was 28% lower than the long-term average due to calm weather conditions across the UK. This was compensated in June and October, with generation figures 33% and 23% higher than the long-term average, respectively. These figures are averaged for England and Wales. Regional power output is dependent on local conditions and may differ from the countrywide average.

The annual variability of energy produced as a result of wind deviation from 2011 to 2017 is illustrated in Figure 13. The overall energy deviation at the end of 2017 was 1% above the long-term average. 2015 saw the power output exceed the long-term average by almost 10%, whereas 2016 was 5% below expectations. This is illustrated in the homes supplied graphic above, which shows little incremental change between 2015 and 2016 due to these factors.

Figure 11: Offshore generation by asset

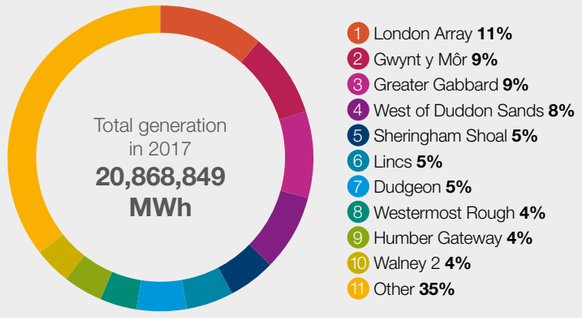


Figure 12: Monthly energy deviation due to wind speed in 2017

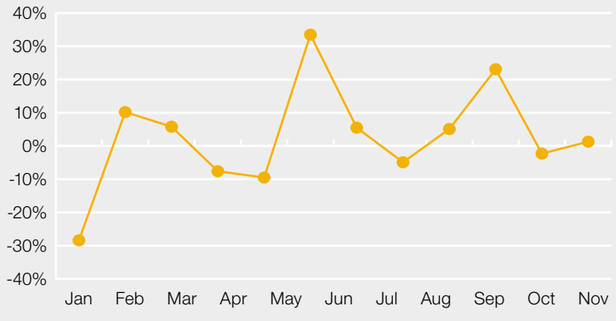
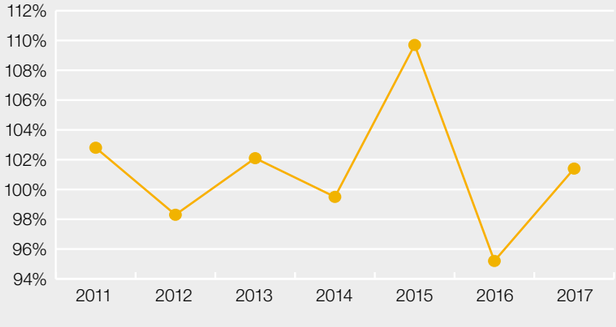


Figure 13: Annual energy deviation due to wind speed – 2011 to 2017



6 O&M initiatives and innovation

5 years

Offshore wind generation in 2017 would keep the UK national rail network on the move for 5 years!

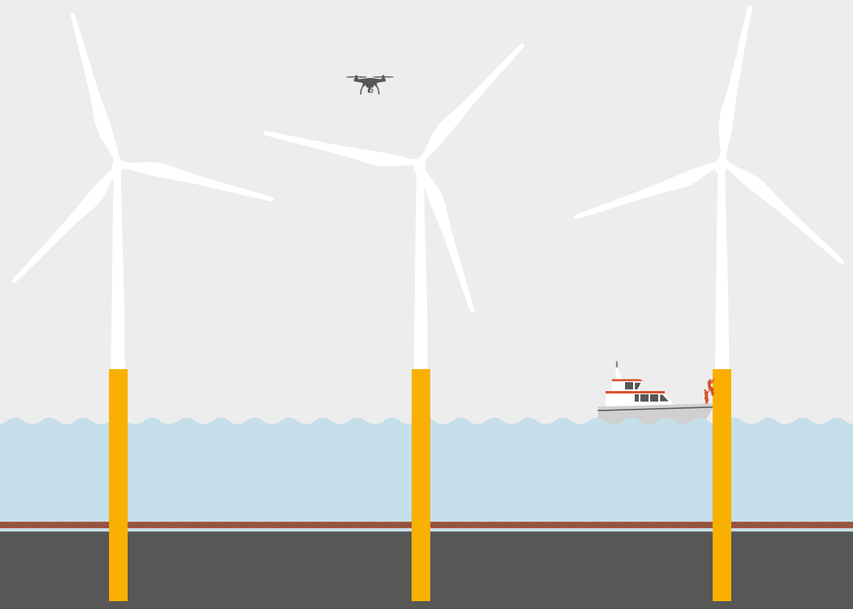
There is an enormous amount of offshore wind research and innovation being undertaken in the UK and beyond, but it's often challenging to grasp all the strands of work and understand how, or if they are joined-up. This table brings together current UK research, initiatives and centres of knowledge. Each entry forms a hyperlink to the relevant website, so that you can find out more. A PDF version of this report, including all the links needed, is available at **www.thecrownestate.co.uk**

The Offshore Wind Innovation Hub Roadmaps

The Offshore Wind Innovation Hub (a partnership between the Offshore Renewable Energy Catapult and KTN) has been working with stakeholders from across the offshore wind sector on a series of Innovation Roadmaps for UK Offshore Wind sector, such as a roadmap for operations and maintenance (O&M) and wind farm lifecycle. These roadmaps aim to identify areas for innovation which can help reduce the levelised cost of energy and where the UK is well placed in terms of capability and skills. The roadmaps are now available here: **https://roadmaps.offshorewindinnovationhub.com**

Offshore Wind Innovation Hub

CATAPULT Offshore Renewable Energy



Holistic projects and disruptive innovation

- HOME Project – Holistic Operation and Maintenance for Energy from Offshore Wind Farms. A programme on the use of advanced sensing, robotics, virtual reality models and artificial intelligence to reduce maintenance cost and effort for offshore wind farms
- AURA – a multidisciplinary programme of offshore wind innovation & skills development which aims to reduce costs by creating an offshore wind innovation hub that brings together research and development, innovation, industry collaboration and talent development
- O&M Innovation Hub – highlighting O&M challenges and driving innovative solutions
- O&M Centre of Excellence – working with UK industry to drive improvements in O&M
- Centre for Doctoral Training (CDT) comprehensive research into Wind & Marine Energy – Strathclyde and Edinburgh Universities

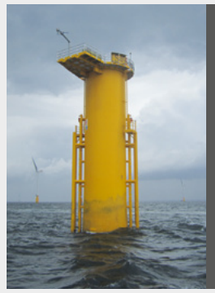
Turbines

- BLEEP Blade Leading Edge Programme

Both the AURA and HOME projects (noted opposite) contain elements relating to turbine & blade innovation

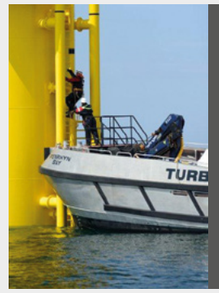
Data Management & Knowledge Sharing

- SPARTA – performance and reliability benchmarking scheme for offshore wind
- O&M Case Studies (ORE Catapult)
- O&M Forum



Foundations

- Carbon Trust Sub-sea Inspection Competition
- SLIC Structural Life Cycle Industry Collaboration
- Scour Research Liverpool University
- Scour Research Southampton University
- Centre for Doctoral Training (CDT) Renewable Energy Marine Structures – Cranfield & Oxford Universities



Access

- Carbon Trust OWA Access Competition
- Strathclyde University access & commercial modelling

Cables

- Carbon Trust Cable Burial Assessment Methodology
- OWPB Export Cable Reliability study
- Southampton University Cable Reliability improvement

Health & Safety improvement & Standardisation

- GWO/RUK offshore access training
- G+ access procedure
- G+ Good Practice Guidelines
- Renewables UK OREEF (Offshore Renewable Energy Emergency Forum)
- URIECA (UK Remote Immediate Emergency Care Advanced) advanced medical training development
- Wind Turbine Safety Rules Review Group

Key

- Industry
- Academia
- Industry/academia

Jargon

Carbon Trust OWA – Offshore Wind Accelerator – an industry-led programme of research and innovation for offshore wind

GWO – Global Wind Organisation

KTN – Knowledge Transfer Network

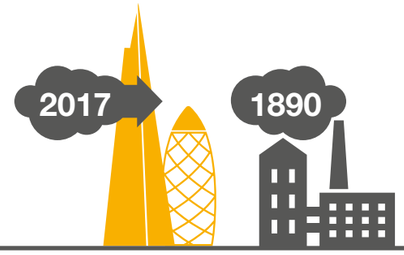
O&M – operations and maintenance

OWPB – Offshore Wind Programme Board

RUK – Renewable UK (Trade Body)

SLIC – an industry collaboration which calculated the structural integrity of the structures used to support wind turbines

7 Investment



2017 UK carbon emissions fall to 1890 levels

Source: Carbon Brief

2017 broke new ground for financing in the sector, with several 'firsts' during a very active 2017 (see facing page).

For operating and under-construction offshore wind, there was an 8% increase in the number of financial investors, including pension funds, in 2017, bringing their overall share of the market to almost 30%. Some familiar names exited the market, including Statkraft and Centrica, both of which completed sales of project shares (see figure 15).

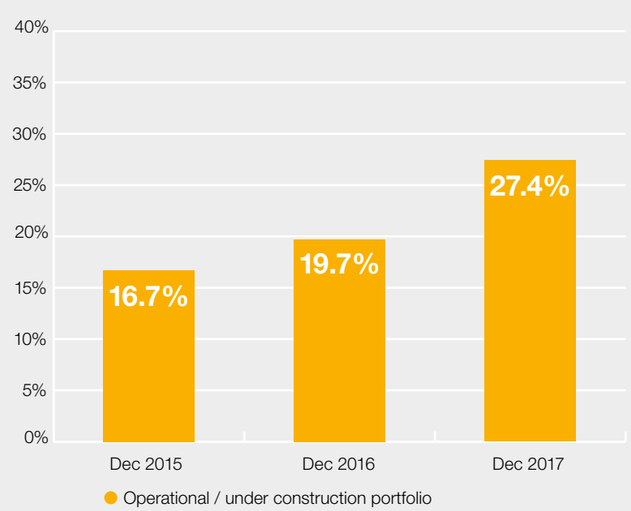
In November 2017 Danish pension providers PKA and PFA purchased 50% of Ørsted's Walney 3 project. This consolidated PKA's presence in the market as the firm, which was 100 years old in 2017, had purchased a 25% share of the Burbo Bank Extension project in 2016 and in other European projects before that.

2017 was also the year of refinancing in Europe, some 50 banks now providing debt financing in the offshore wind sector, of which about 30 are taking construction risk. Over the last 12 months movement was also experienced in the debt to equity ratio for project financing from 70:30 to 75:25.

2017 also saw the introduction of more hold-co financing structures, as projects sought to refinance. The introduction of more bond finance seems to be a trend that will continue as investor appetite for this asset class grows now that the sector is maturing and the risks are more easily understood.

Looking to the future, as auctions for capacity encourage price competition, those providing project finance will need to understand what other contractual certainties are in place, such as power purchase agreements, as pressure on subsidies continues.

Figure 14: Share of financial investors ownership (%)



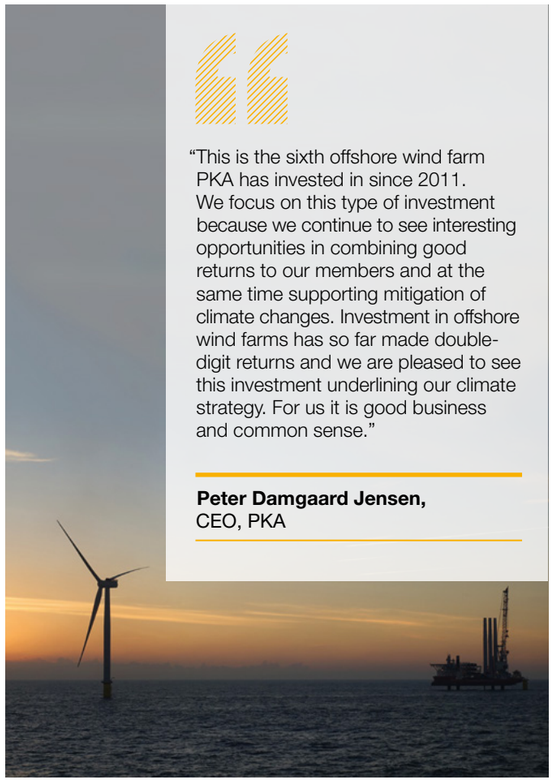
> "With this investment, we take yet another step into the renewable energy market which is actively contributing towards the green transition. We are proud to do so together with our business partner Ørsted, which is a front runner in this field and which has accumulated great expertise when it comes to establishing efficient offshore wind farms. The investment fits perfectly into our strategic work with focus on alternative investments that contribute to providing our customers with reliable and stable long-term returns."
>
> **Allan Polack**
> Group CEO, PFA

Figure 15: Principal offshore wind transactions in 2017

Asset	Seller	Share before sale	Buyer	Share of buyer in the project after sale	Value (£m)
Lincs	Centrica and Siemens Project Ventures	75%	UK Green Investment Bank Financial Services managed entities and the UK Green Investment Bank plc	75%	£731m
Moray Firth	EDP Renovaies	23%	Engie	25%	£21m
North Hoyle	M&G Investments	33%	JP Morgan	100%	
North Hoyle	JP Morgan	100%	Greencoat UK Wind	100%	£105m
Race Bank	Macquarie	50%	Sumitomo	13%	unknown
Sheringham Shoal	Statkraft	40%	Equitix	40%	£558m
Sheringham Shoal	Equitix	40%	TRIG The Renewables Infrastructure Group	14.7%	£80m
Triton Knoll	Statkraft	50%	Innogy	100%	unknown
Walney Extension	Orsted	100%	PFA	25%	c£2bn
			PKA	25%	

Firsts in 2017

- Legal and General made its first provision of debt finance into the sector with £300m of long term debt support for PFA and PKA's purchase of Walney 3. In doing so, the organisation recognised the importance of the offshore wind industry in providing clean energy and stimulating job growth in the UK.
- The privatisation of the Green Investment Bank completed in August 2017 following its purchase by Macquarie via a £2.3bn transaction. The Green Investment Bank became the Green Investment Group and as part of the transaction, a number of the investor's offshore wind assets moved into a new offshore wind investment vehicle, which the Green Investment Group manage and hold a 25% stake in. Investors are long-term institutional investors: Macquarie European Infrastructure Fund 5 (MEIF5) and the Universities Superannuation Scheme (USS).
- For the first time, Danish developer Ørsted issued two €500m green bonds to fund offshore wind and coal-to-bio conversion projects. These were developed in alignment with the Green Bond Principles 2017 and were reviewed by the not-for-profit research institute Center for International Climate and Environmental Research (CICERO) which allocated them a "dark green shading", the highest environmental grading a green bond issuer can receive.
- The Renewables Infrastructure Group (TRIG) made its first investment into the offshore wind sector through its purchase of a 14.7% indirect equity stake in Sheringham Shoal wind farm. The London listed investment company said the investment was consistent with its strategy of investing in long-term income-producing projects.



> "This is the sixth offshore wind farm PKA has invested in since 2011. We focus on this type of investment because we continue to see interesting opportunities in combining good returns to our members and at the same time supporting mitigation of climate changes. Investment in offshore wind farms has so far made double-digit returns and we are pleased to see this investment underlining our climate strategy. For us it is good business and common sense."
>
> **Peter Damgaard Jensen,**
> CEO, PKA

8 Wind farm ownership

91% of homes in UK's 10 biggest cities

In 2017, offshore wind supplied the equivalent of 91% of the domestic electricity requirement of all 10 of the UK's top cities combined (London, Birmingham, Manchester, Glasgow, Newcastle, Sheffield, Liverpool, Leeds, Bristol and Belfast)

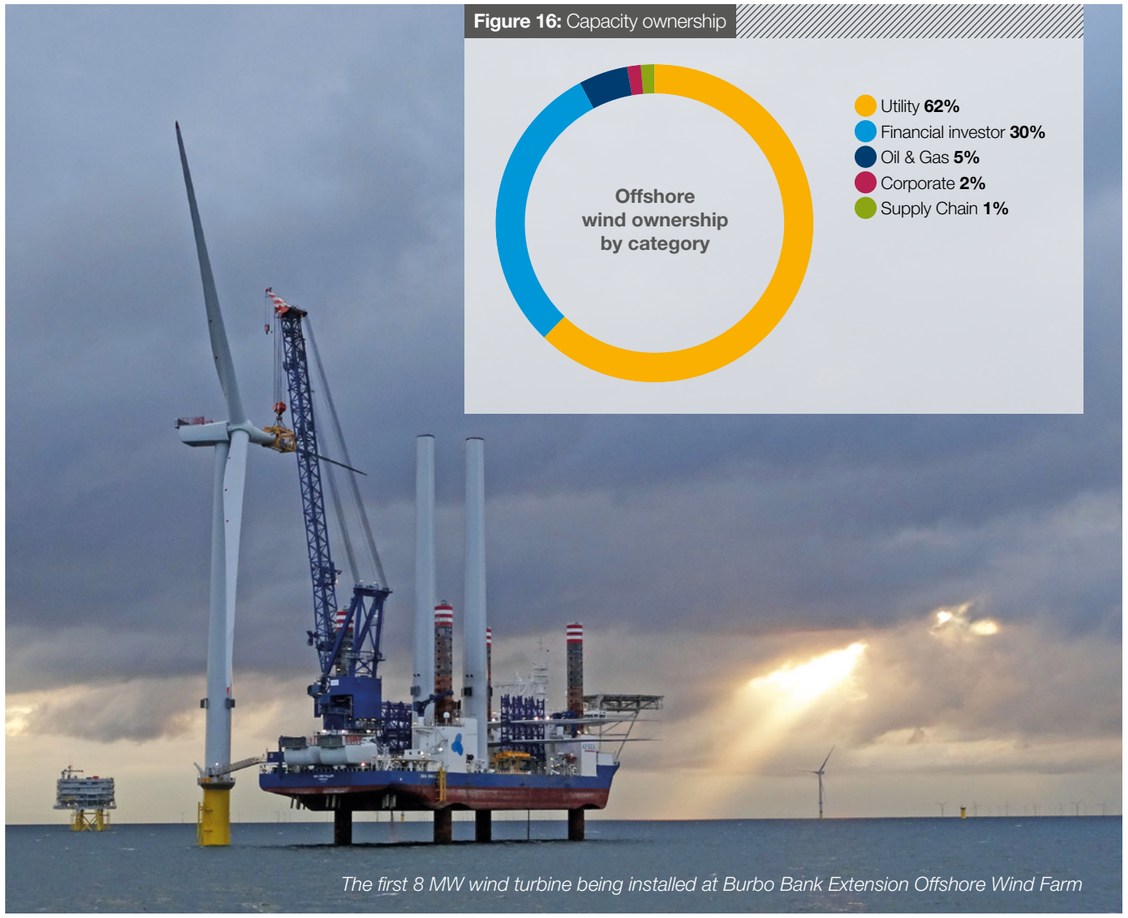
Offshore wind ownership is still dominated by utility style owners, which represent 62% of the market. Traditionally these are firms with their roots in hydrocarbons but which have restructured out of these markets in recent years. This repurposing, combined with Centrica and Statkraft's departure from the sector is indicative of a wider trend as corporates begin transitioning to lower carbon economies and change focus to greener goals.[1]

The growing ownership stake of financial investors, especially pension providers, in the sector signals a maturing of the market. Over the 6 year period between 2011 and 2017, the number of financial investors in offshore wind grew by 350%.

2017 also saw the introduction of a new operations and maintenance (O&M) provider ExceCo at Lynn and Inner Dowsing wind farms. This move represents a departure from the more typical O&M provision by a parent company/project shareholder, enabling projects to be wholly owned by financial investors. An example of this in action is Innogy's provision of O&M services for North Hoyle, on behalf of financial investor/owner Greencoat. As ownership and project shares continue to change, there may be further opportunities for O&M services and contracting packages to develop further.

1 Statoil has since announced its planned name change to Equinor, reflecting its low carbon strategy

Figure 16: Capacity ownership



The first 8 MW wind turbine being installed at Burbo Bank Extension Offshore Wind Farm

Figure 17 Operational offshore wind farm ownership as at 31 December 2017

Project	Company (Share ownership)		Operator
Barrow	100%	Ørsted	Ørsted
Blyth	100%	E.ON	E.ON
Blyth Demonstration (Phase 1)	100%	EDF Energy Renewables	EDF
Burbo Bank	100%	Ørsted	Ørsted
Burbo Bank Extension	50%	Ørsted	Ørsted
	25%	KIRKBI Invest	
	25%	PKA	
Dudgeon	35%	Statoil	Statoil
	35%	Masdar	
	30%	Statkraft	
Greater Gabbard	50%	Innogy	SSE
	50%	SSE	
Gunfleet Sands Demonstration	100%	Ørsted	Ørsted
Gunfleet Sands I	50.10%	Ørsted	Ørsted
	24.95%	Development Bank of Japan	
	24.95%	Marubeni Corporation	
Gunfleet Sands II	50.10%	Ørsted	Ørsted
	24.95%	Development Bank of Japan	
	24.95%	Marubeni Corporation	
Gwynt y Môr	50%	Innogy	Innogy
	30%	Stadtwerke München	
	10%	Siemens	
	10%	UK Green Investment Group	
Humber Gateway	100%	E.ON	E.ON
Hywind 2 Demonstration (Buchan Deep)	75%	Statoil	Statoil
	25%	Masdar	
Inner Dowsing	61%	UK Green Investment Group Offshore Wind Fund	XceCo Ltd
	39%	BlackRock	
Kentish Flats	100%	Vattenfall	Vattenfall
Kentish Flats Extension	100%	Vattenfall	Vattenfall
Levenmouth Demonstration	100%	ORE Catapult	OREC
Lincs	44%	UK Green Investment Group Offshore Wind Fund	Ørsted
	31%	UK Green Investment Group	
	25%	Ørsted	

Project	Company (Share ownership)		Operator
London Array	30%	E.ON	London Array Ltd
	25%	Ørsted	
	25%	Caisse dépôt & placement Québec	
	20%	Masdar	
Lynn	61%	UK Green Investment Group Offshore Wind Fund	XceCo Ltd
	39%	BlackRock	
North Hoyle	100%	Greencoat UK Wind	Innogy
Ormonde	51%	Vattenfall	Vattenfall
	49%	AMF	
Rhyl Flats	50.10%	Innogy	Innogy
	24.95%	Greencoat UK Wind	
	24.95%	UK Green Investment Group Offshore Wind Fund	
Robin Rigg East	100%	E.ON	E.ON
Robin Rigg West	100%	E.ON	E.ON
Scroby Sands	100%	E.ON	E.ON
Sheringham Shoal	40.0%	Statoil	Statoil
	25.3%	Equitix	
	20.0%	UK Green Investment Group Offshore Wind Fund	
	14.7%	TRIG	
Teesside	100%	EDF Energy Renewables	EDF
Thanet	100%	Vattenfall	Vattenfall
Walney 1	50.1%	Ørsted	Ørsted
	25.1%	SSE	
	24.8%	PGGM & Ampère Equity Fund	
Walney 2	50.1%	Ørsted	Ørsted
	25.1%	SSE	
	24.8%	PGGM & Ampère Equity Fund	
West of Duddon Sands	50%	Ørsted	Ørsted
	50%	ScottishPower	
Westermost Rough	50%	Ørsted	Ørsted
	25%	Marubeni Corporation	
	25%	UK Green Investment Group	

9 OFTO ownership

Offshore Transmission Owner (OFTO) transactions

During 2017 no new transfers of OFTO assets occurred but the tender processes for several sites progressed, with the latest position shown in Figure 18. Transmission Capital Partners has the largest slice of the OFTO market with almost a third, followed by Blue Transmission and Equitix, Figure 19 provides an overview with additional detail in Figure 20.

Figure 18: Offshore Transmission Owner (OFTO) Transactions

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

Licence to be granted 2018
- Burbo Bank Extension – Preferred Bidder appointed July 2017

Tender Round 5

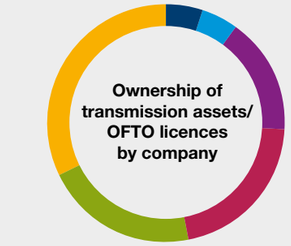
Licence to be granted 2018
- Dudgeon – Preferred Bidder appointed November 2017

Preferred Bidder to be appointed 2018
- Race Bank – ITT stage commenced 2017

Invitation to Tender (ITT) stage to commence 2018
- Galloper • Walney Extension • Rampion

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



- 3i infrastructure Plc **5%**
- Dalmore Capital **5%**
- Balfour Beatty Investments **16%**
- Blue Transmission **21%**
- Equitix **21%**
- Transmission Capital Partners **32%**

Figure 20: OFTO ownership as at 31 December 2017

Project	Company (Share ownership)	Connection voltage	Interfacing party*	Operator/ O&M Provider
Barrow OFTO	100% Transmission Capital Partners	132 kV	DNO	Transmission Capital Services
Greater Gabbard OFTO	100% Equitix	400 kV	Transmission	Balfour Beatty Power & Transmission
Gunfleet Sands OFTO	100% Transmission Capital Partners	132 kV	DNO	Transmission Capital Services
Gwynt y Môr OFTO	60% Balfour Beatty 40% Equitix	400 kV	Transmission	Balfour Beatty Power & Transmission
Humber Gateway OFTO	80% Equitix 20% Balfour Beatty	275 kV	Transmission	Balfour Beatty Power & Transmission
Lincs OFTO	100% Transmission Capital Partners	400 kV	Transmission	Transmission Capital Services
London Array OFTO	100% Blue Transmission	400 kV	Transmission	Frontier Power
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
Sheringham Shoal OFTO	100% Blue Transmission	132 kV	DNO	Frontier Power
Thanet OFTO	80% Equitix 20% Balfour Beatty	132 kV	DNO	Balfour Beatty Power & Transmission
Walney 1 OFTO	100% Blue Transmission	132 kV	Transmission	RES
Walney 2 OFTO	100% Blue Transmission	132 kV	DNO	RES
West of Duddon Sands OFTO	50% 3i infrastructure Plc 50% Dalmore Capital	400 kV	Transmission	Frontier Power/Ørsted
Westermost Rough OFTO	100% Transmission Capital Partners	275 kV	Transmission	Transmission Capital Services

10 OFTO performance

Figure 20 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. 2017–18 data is not expected to be published until July 2018, so the information in this section covers the period April 2016 to March 2017.

Annual Availability

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 2016/17, average OFTO availability was 99.36%, significantly higher than the previous year (95.99%) with Figure 22 showing a general trend of increasing availability. The only OFTO not to attain 98% availability was Thanet which was impacted by repairs to Export Cable 2 and the replacement of a transformer radiator in 2016. Information is available in the National Grid's National Electricity Transmission System Performance Report. Transmission Capital Partners made a pre-emptive export cable repair at Ormonde during 2017. Whilst the impact will not be shown until latest National Grid figures are published, it is encouraging to industry and investors to see a proactive approach to management of transmission assets in order to minimize losses.

The Offshore Wind Programme Board (OWPB) Grid Group commissioned an assessment of export cable reliability in 2017, with the aim to better understand the causes of cable failures connecting offshore wind farms, as such failures had increased in frequency at that time. All OFTOs and many offshore wind developers input to the project[1] and further work is being progressed through the OWPB Grid Group.

1 Report available at https://ore.catapult.org.uk/work-with-us/industry/offshore-wind-programme-board

Figure 21: Offshore transmission networks % annual availability

Project	2013-14	2014-15	2015-16	2016-17
Barrow OFTO	99.64	100	99.88	100
Greater Gabbard OFTO	99.81	100	100	99.78
Gunfleet Sands OFTO	100	99.53	100	99.95
Gwynt y Môr OFTO	N/A	82.59	82.58	99.73
Humber Gateway OFTO	N/A	N/A	N/A	100
Lincs OFTO	N/A	100	99.96	99.93
London Array OFTO	99.97	99.90	99.98	98.88
Ormonde OFTO	100	99.93	100	99.59
Robin Rigg OFTO	99.85	98.19	99.99	98.08
Sheringham Shoal OFTO	99.20	99.84	100	99.95
Thanet OFTO	N/A	82.47	83.05	96.15
Walney 1 OFTO	99.99	100	100	99.62
Walney 2 OFTO	94.89	100	92.47	100
West of Duddon Sands OFTO	N/A	N/A	100	99.64
Westermost Rough OFTO	N/A	N/A	100	100

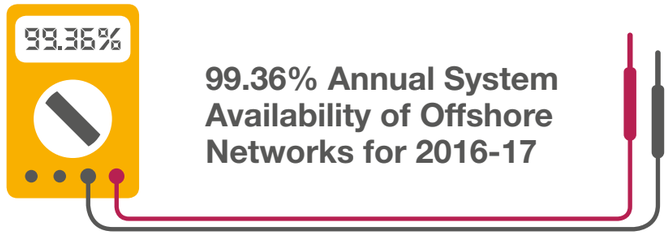
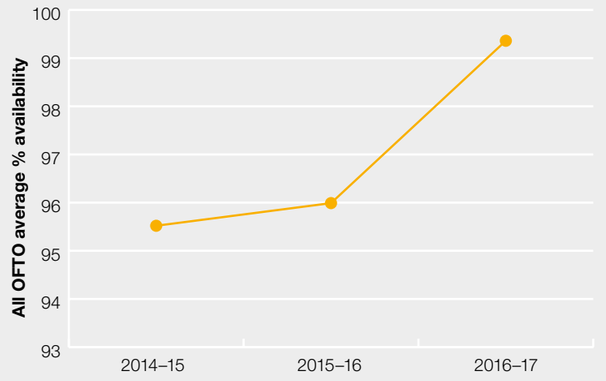


Figure 22: OFTO availability trend



11 Health and safety

Total recordable injury rate 2017[1] 5.85

Lost time injury frequency 2017[2] 1.83

"As the new Chairman of G+ I am committed to continually challenging and improving our industry's health and safety performance. Through our own work programme and collaboration with other related organisations and key stakeholders our focus continues to be on tackling the issues which are resulting in the highest risks to our workforce. Also, as we seek to internationalise the G+ organisation and take the lessons we have learned into new and emerging markets it's vitally important that we don't lose sight of the key challenges in the UK."

Paul Cowling
Chairman, G+

The Global Offshore Wind Health and Safety Organisation (G+) continues to create and support health and safety best practice throughout the offshore wind industry. During 2017, the focus has been to strengthen links to stakeholder organisations in order to bring more international best practice and learnings into the G+ and expand its influence. The G+ has introduced a new level of Associate Membership to involve contractors, OFTOs, non-operating owners and non-lead operators/developers, which has already seen a number of new members join the G+.

Drawing on applicable safety culture guidance from other industries, for example construction and oil and gas, is helping G+ members identify potential risk areas and streamline solutions. The G+ is now a member of the cross-industry organisation set up to prevent incidents caused by dropped objects, DROPS, and a working group has been set up to apply their key material to the offshore wind industry.

The Safe by Design workshop programme remains a key output, with topic areas for 2018 including the design of and access within WTG foundation internals. Past topics have included access and egress, davit crane operations, and service lifts.

There is an emerging focus on occupational health. A key 2018 publication will describe the results of G+ commissioned research on the ergonomics of ladder climbing, which has the potential to transform physical fitness standards for offshore wind.

The G+ continues to base its work streams on the best available evidence; accident and incident data submitted by G+ members. The next annual incident data report is due to be published in April 2018. Key benchmarking statistics included every year are the lost time injury frequency, and the total recordable injury rate.

Looking ahead, the G+ recognises the need to increase international communication of its work outside the most mature offshore wind markets, and internationalisation will be a key theme over the next few years as the offshore wind industry expands outside of Europe.

G+ Global Offshore Wind Health & Safety Organisation

Sharing experience and knowledge: Safe decommissioning of suction buckets without divers

In May 2017 Forewind commenced planning for the decommissioning of its two meteorological masts, situated in the consented Doggerbank Wind Farm. Each meteorological mast stood at a height of 110m above mean sea level and was founded on a suction bucket structure of 50m in length. The larger of the two structures weighed 768t, meaning that there was potential for clay deposits to have built up on the suction bucket structures. If present, these would have impacted the lifting plan.

Robust planning for the decommissioning was key to the success and safety of the operation, as well as to ensuring that the seabed environment was not negatively impacted. Forewind and its contractors undertook months of technical reviews and scenario planning to ensure that the entire process was a success and required no repetition or remedial work.

Both mast structures were removed successfully in September 2017 using the Seafox 5 vessel, a process which involved the depressurisation of the bucket components using pump hoses. These were connected by a remotely operated vehicle (ROV), avoiding the need for divers. The incremental depressurisation process was monitored closely from the vessel using the ROV to confirm the integrity of the bucket components was maintained. The bucket skirts started to dislodge from the seabed at just over 1 bar whereupon the lift continued and was, again, closely monitored by ROV until the unit was visible above the sea.

Once the masts were secured to the vessel, Seafox 5 set sail for Flushing, Holland where the structures were removed for re-use elsewhere.

1 Total recordable injury rate (TRIR): The number of recordable injuries (fatalities + lost work day incidents + restricted work day incidents + medical treatment injuries) per million hours worked
2 Lost time injury frequency (LTIF): The number of recordable injuries (fatalities + lost work day incidents) per million hours worked

12 Knowledge

The Crown Estate unlocks value in the seabed by enabling and promoting its sustainable development. It is committed to the success of its customers and works across a range of topics to help promote the sustainable development of the seabed. Highlighted below are some of the initiatives and collaborations between The Crown Estate and its customers:

Offshore wind electricity map
thecrownestate.co.uk/owmap

The Crown Estate's interactive wind map, which received record views last year, refreshes hourly 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 includes estimates of the production for embedded generators not directly supplying the National Grid.

The map also gives useful facts, including a live comparison with generation from other fuel types and total generation figures for offshore wind for the previous month as well as the year to date.

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. The two ORJIP streams, Offshore Wind and Ocean Energy, 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.

ORJIP Offshore Wind has recently seen the publication of groundbreaking research on the use of acoustic deterrent devices for marine mammal mitigation, with further publications on the Bird Collision Avoidance study conducted at Thanet Offshore Wind Farm, and the sensitivity of fish species to piling, due during Spring 2018.

Offshore Wind orjip working to accelerate offshore consenting

Marine Data Exchange
www.marinedataexchange.co.uk

The Marine Data Exchange (MDE) was created to store, manage and share offshore survey data collected by developers/operators throughout the lifetime of a project. In 2017, 160 new surveys were delivered by The Crown Estate's offshore renewable and marine aggregate customers, taking the total number of surveys held on the MDE to over 2,500. Of that data, 46% is publicly available, including the Cumulative Ornithological Collision Risk Database. The Crown Estate's offshore wind customers and their contractors are the biggest users of the data and throughout 2018 more data will be added to the system.

SPARTA
bit.ly/SPARTAPortfolioReview2016

In its second year of enduring operations, System Performance and Reliability Trend Analysis (SPARTA) continues to demonstrate how crucial industry benchmarking and collaboration is in enabling continuous improvements in production performance and reducing operational costs. The group is now working to widen membership and data coverage to enable more detailed analysis and help support more informed decision making about the management of assets in both the short and long term. It has recently appointed an industry co–chair to drive further industry collaboration and the future development of the system.

SPARTA System Performance, Availability and Reliability Trend Analysis

You may also be interested in...

Seabed Morphology Report
www.thecrownestate.co.uk/energy-minerals-and-infrastructure/research/energy-research/reports

This report, prepared by University College London, presents a workflow for the evaluation of seabed mobility from sedimentary features for a range of scales from the regional to more local areas of interest. These include initial assessment of potential seabed mobility, broad-scale bathymetric visualisation, and analysis of seabed morphological change at decadal to century scales. Outputs of such assessments should further inform initial site selection as well as the risk profile for operating assets in such regions.

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thecrownestate.co.uk/energy-minerals-and-infrastructure/offshore-wind-energy

@TheCrownEstate

Correct as of April 2018, unless otherwise stated.

Cover Photo – Courtesy of Chris Henderson Photography and EDF Energy. Thank you to the following for providing images for this report: Orsted (Race Bank/Burbo Bank/Walney Extension); Forewind (Dogger Bank); Innogy (Galloper); Matthew Woods / Alamy Stock Photo (page 12)