SPARTA
System Performance, Availability and Reliability Trend Analysis

System Performance, Availability and Reliability Trend Analysis – SPARTA

2017/18 Portfolio Review

Sponsors Comments

Formed in the UK in 2013, the System Performance, Availability and Reliability Trend Analysis (SPARTA) initiative brings together the leading companies operating offshore wind power plants. With over 6.6GW of capacity already installed in the UK and a growth plan to reach 30GW by 2030, the industry makes a material contribution to the UK's electricity supply and wider economy. Producing clean, low carbon energy as efficiently as possible has become a key target for owner/operators and collaboration on benchmarking and the setting of Key Performance Indicators (KPIs) for plant performance is one way of achieving rapid continuous improvement.

The SPARTA project aims to support improvements in the availability, reliability and performance of offshore wind assets. Operational data is collected at system level (from blade to onshore substation), analysed and reported upon in the form of benchmarks, allowing relative performance to be understood and acted upon by members. Benefits will be in the form of operational change, sector innovation, investment and development, and result in efficiency improvements, cost reduction and reduced risk to both employees and deployed assets.

Enabled by the sponsorship of The Crown Estate and Offshore Renewable Energy (ORE) Catapult, SPARTA has proven itself as the industry leader in offshore wind benchmarking. Under the leadership of the industry-led steering group, Co-Chaired by Mona Riis, Production Manager at Equinor, SPARTA continues to evolve, with new metrics being introduced and certified year on year. With Production Based Availability (PBA) being approved by DNV-GL in 2017, this review presents aggregated and anonymised results from the 22 participating wind farms over the 2017/18 period and shows some longer-term trends that are emerging.

Long term success of the offshore wind industry will be built firmly on operational excellence and reliability and SPARTA aims to raise the bar to achieve industry-wide superior performance.

Adrian Fox
Head of Offshore Assets,
The Crown Estate

Chris Hill
Offshore Renewable Energy
Catapult

Sponsoring Organisations

CATAPULT Offshore Renewable Energy

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Executive Summary

SPARTA is a data sharing platform designed to allow organisations who own and operate offshore wind farms to anonymously share and validate Key Performance Indicators (KPIs), so that true benchmarking can be undertaken.

This report presents aggregated and anonymised results from the 22 participating wind farms over the period April 2017 to March 2018 and shows some longer-term trends that are emerging.

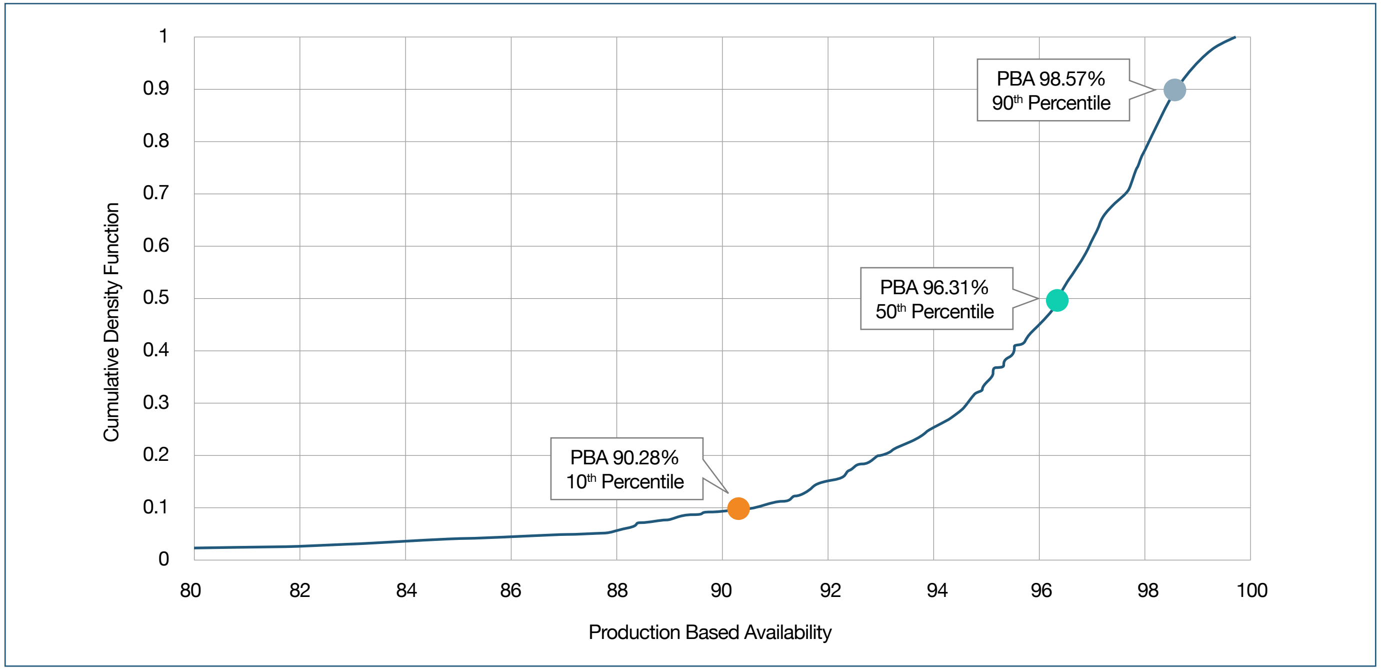
2017/18 Results

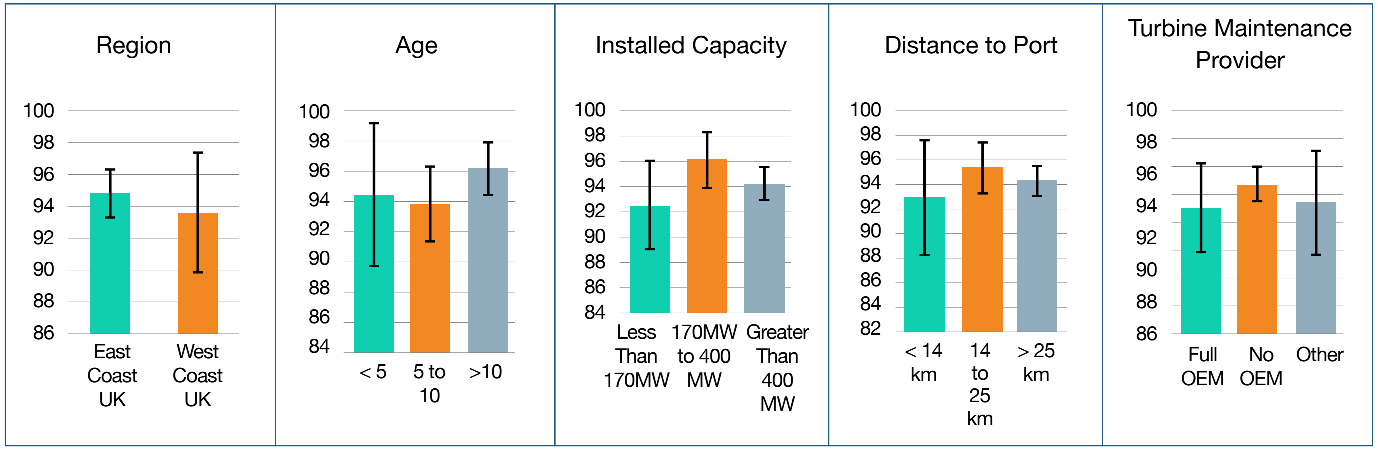
The total energy produced by the portfolio of wind farms reporting to SPARTA was 15,057,978 MWh over the 2017/18 period. This is the equivalent of 4 million UK homes powered for the year.

Throughout this report, production or yield based availability (PBA) is used as the primary measure of performance. The cumulative distribution function reveals the spread of PBA values across the population. This can be directly used to set PBA targets. If a wind farm operator wants to be above 50% of the PBA values across the sector, they should target an annual average PBA of 96.3%.

To examine the drivers of performance across this period, the wind farms are grouped based on the following dimensions:

- Region; Age; Installed Capacity; Distance to Port; Turbine Maintenance Provider
- PBA values for these groupings are shown below





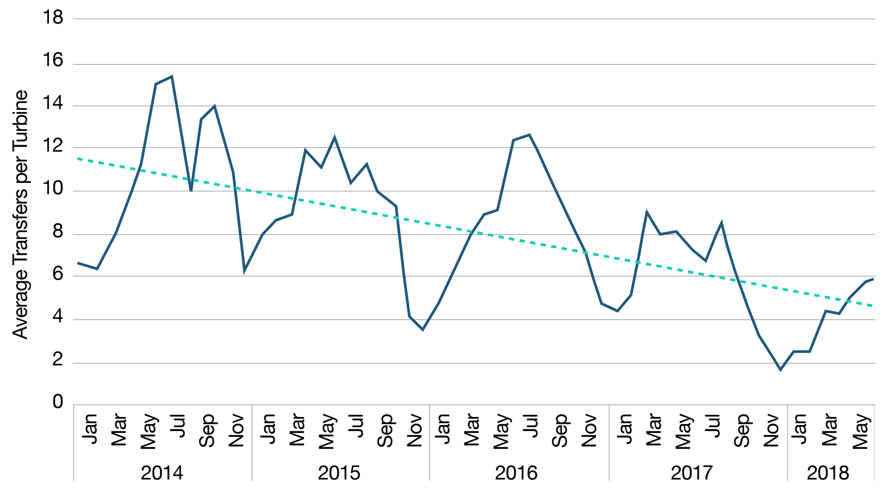
This report also includes extensive analysis of logistics metrics including met ocean conditions, non-access days, vessel charters and turbine transfers. One key finding is that large wind farms further from port appear to be making better utilisation of their vessels.

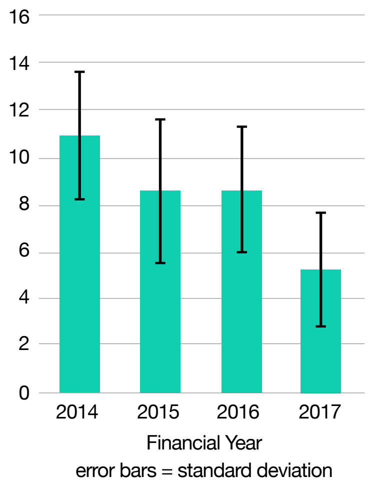
Long Term Trends

Including data back to January 2014, this report also provides long term offshore wind performance trends.

Looking at the Capacity Factor over the lifespan of SPARTA, the seasonal trends are immediately clear with higher values over the winter periods, where winds are stronger, and lower values over the calmer summer periods. However, over this extended period, the average annual Capacity Factor of 37.5% doesn't change.

Another indicator of the evolution of wind farm operations is gleamed from the number of transfers per turbine. Again, seasonality emerges with more transfers being done over the calm summer months and less over the harsh winter periods. However, the average is dropping over time, seeing a 50% reduction from 2014. Volume of transfers is an indicator of the amount of work ongoing at sites and therefore this suggests the industry is maturing, getting to know farms better; forecasting more accurately and knowing how and when to perform operations more efficiently. If this is to continue we can expect to see significant savings in the industry.





Participation in SPARTA

Benchmarking is widely recognised as a critical tool in developing an effective improvement strategy within mature industries. Benchmarking wind farms using SPARTA allows comparative rankings to be generated, showing asset position against industry statistics and leading performers.

All owner/operators with offshore wind farms in UK waters are participating in SPARTA. This enables extremely valuable and representative information sharing across the industry. The SPARTA consortium constitutes an international community who meet regularly to share knowledge and best practice. A goal of SPARTA is to secure participation from offshore wind farms around the world, strengthening the benchmarking process.

Section 1 – Introduction

What is the purpose of this report?

This report provides operational offshore wind farm insight that is informed by data and key performance indicators (KPIs), collected by the SPARTA data sharing platform.

What is SPARTA?

SPARTA, an acronym made from 'System Performance, Availability and Trend Analysis', is a joint industry project that was initiated in 2013 with the objective of enabling data sharing throughout the offshore wind farm operating community. The SPARTA Joint Industry Project (JIP) is facilitated by The Crown Estate and ORE Catapult.

A data sharing platform was designed and delivered in a way that allows organisations who own and operate offshore wind farms to anonymously share and validate KPIs, so that true benchmarking can be undertaken.

Offshore wind performance benchmarks are available dating back to January 2014 on the topics of:

- Availability
- Production and Lost Production
- Reliability
- Operations

Who is involved?

All owner/operators with offshore wind farms in UK waters are participating in SPARTA. An overview of the governance structure is provided in the 2016 SPARTA Portfolio Review (SPARTA, 2016).

A goal of SPARTA is to secure participation from offshore wind farms around the world, strengthening the benchmarking process.

Principles of SPARTA (Value proposition)

The SPARTA platform has been designed based on the following principles, which have helped establish SPARTA as the industry-leading performance benchmark provider for offshore wind:

- **Anonymity:** Generation of benchmarks requires sensitive operational data. SPARTA has solved this by aggregating the metrics that are securely uploaded into an anonymised data pool. Maintaining anonymity has created a pathway for data sharing and industry benchmarking between the owner/operators of wind farms.
- **Transparency:** There is complete transparency in definitions and methodologies used and these are published in a Metric Handbook. Consequently, results are clear, comprehensive and consistent.
- **Quality:** Extremely high quality and reliable output is achieved through continuous metric assurance and verification activity.

In the 2017/18 financial year, an assessment was carried out on the production-based availability metrics. A quantitative analysis of the integrity of these SPARTA inputs by DNV-GL revealed that all participating data providers were within 97% accuracy, with over half above 99%.

- **Representative data volume:** SPARTA benchmarks are based on a representative population, with over 77% of all installed capacity of offshore wind farms in UK waters providing performance data on a monthly basis for over four years.
- **Industry-Led:** The SPARTA system was designed by owner/operators for owner/operators and is continuously improved to ensure it reflects industry needs. The associated joint industry project has representation from all UK offshore wind farm owner/operators at both steering group and technical advisory group level. The steering group is co-chaired by Mona Riis, Production Manager at Equinor and Adrian Fox, Head of Energy Assets at The Crown Estate.
- **Monthly Benchmarks:** New benchmarks are made available to members every month. This reveals seasonal variations and can inform detailed optimisation of operations.

Access to the data points

SPARTA anonymised data is available via the ORE Catapult Platform for Operational Data (POD) https://pod.ore.catapult.org.uk/. Here you will be able to find charts and information as an overview of the benchmarking developed by SPARTA members as well as analytics developed by the ORE Catapult data and digital team.

Section 2 – Annual Analysis of the 2017/18 Period

To demonstrate how the overall portfolio of assets is performing, a year-long review of certain Key Performance Indicators (KPIs) is presented. This is conducted for the year April 2017 to March 2018 and includes 22 wind farms and 1,445 wind turbines, located in a spread of sites across the UK.

Section 2.1 – SPARTA by Numbers

SPARTA is leading the way in benchmarking for offshore wind involving:

- 100% of offshore owner/operators working in the UK
- 79% of wind farms in UK waters
- 85% of wind turbines in UK waters
- 77% of installed capacity in UK waters

With more and more wind turbines being installed offshore and added to the SPARTA population, the number of KPIs uploaded continues to increase year on year, as shown by Figure 2, with a significant ramping up of data volume in the second quarter of 2017.

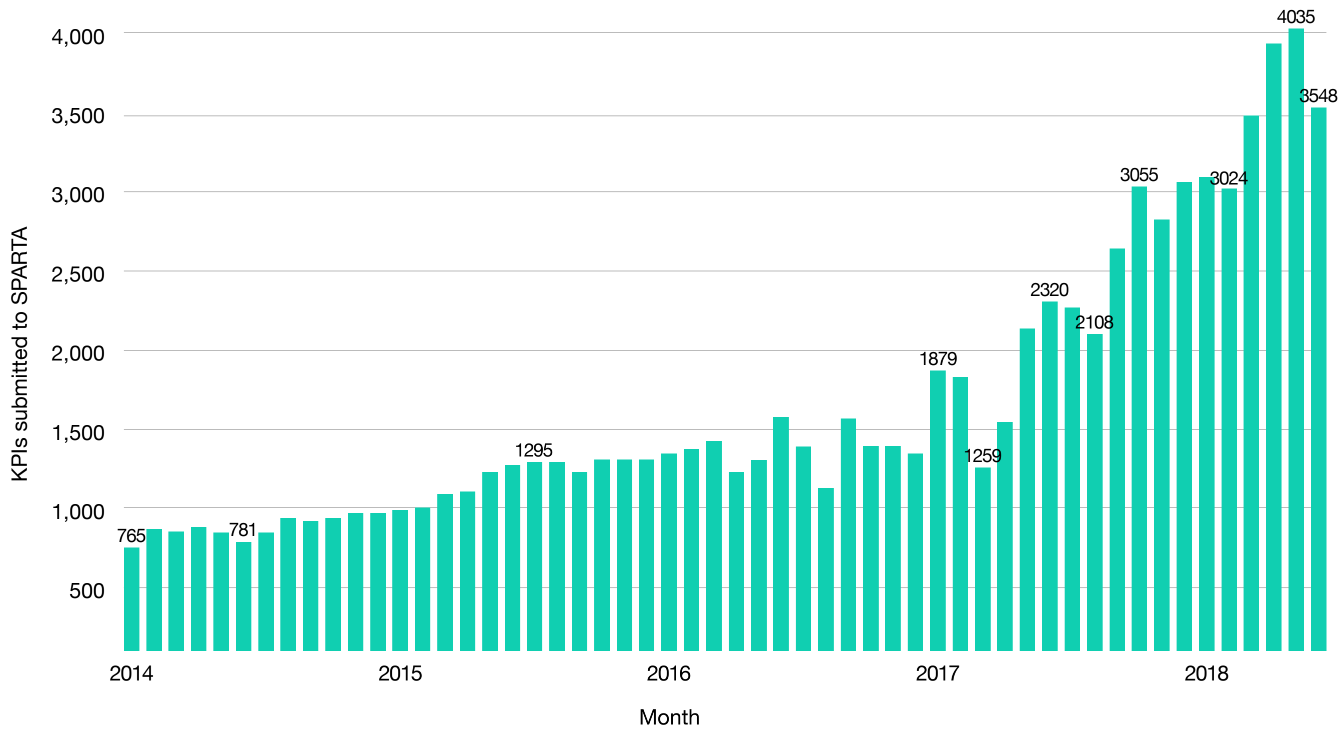


Figure 2 – Total Volume of KPIs submitted to SPARTA

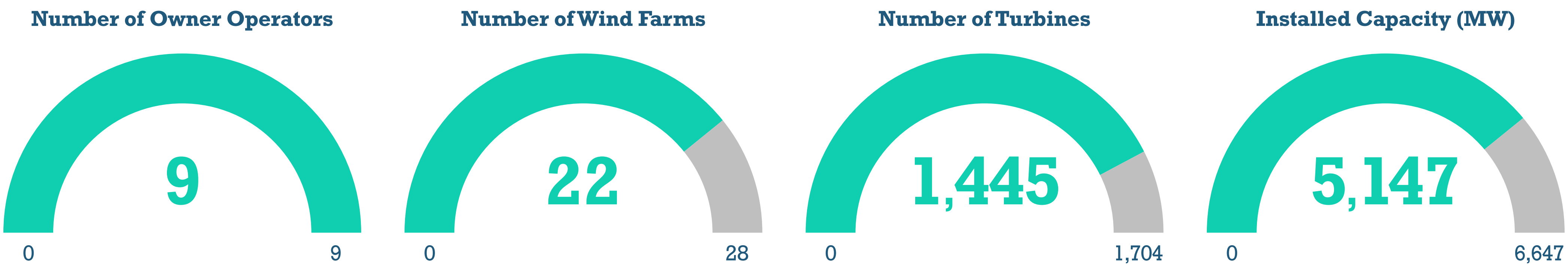


Figure 1 – SPARTA KPIs Compared to UK Totals

The total energy produced by the portfolio of wind farms reporting to SPARTA was 15,057,978 MWh over 2017/18. Figure 3 illustrates the significance of energy produced by SPARTA participants.

15,057,978 MWh	Total Wind Farm Generation
5.8%	Reduction in UK CO_2 Emissions **4.4 Million Tonnes** CO_2 Abated
15%	UK Homes Powered **4 Million Homes** Powered per Year
18.82	Times all **166,000 electric cars** in the UK could travel around the Earth.
94.5%	Production Based Availability

Figure 3 – SPARTA Energy Generation

Section 2.2 – 2017/18 Key Performance Indicators

This section presents how KPIs vary over 2017/18.

Section 2.2.1 – Production Based Availability (PBA) – An Overview

Production Based Availability (PBA) is the percentage of potential energy a turbine is extracting from the wind. For a given wind resource, over a reporting period, the PBA is the actual production divided by the possible production. The SPARTA definition of PBA follows the IEC Technical Specification 61400 26-2 (IEC, 2014). This is the “system user’s view” from Appendix B in the Technical Specification that incorporates all causes of lost production.

The PBA trend for the year (Figure 4 Right) shows the monthly mean with the 25% and 75% quartiles given for every month as well as the maximum and minimum values highlighted by the green area. The PBA average for the year (Figure 4 Right) is shown as a box and whisker plot.

An ideal PBA would be 100%, although this is idealistic and practically unobtainable. A better comparison is to look to onshore wind, which is obtaining an average PBA value of 96.2% (**WEBS, 2018**). Offshore wind obtained an average PBA of 94.5%, a slightly lower value. This difference makes sense as onshore turbines are easier to access, and the industry is more mature, with significantly more years of operating experience.

Figure 5 Right shows how the average PBA varies over 2017/18, with the wind farms being split into groups of High, Medium and Low PBA values. The average PBA for the different groupings is shown on the right, with the standard deviation given as error bars for each value, as can be seen the lower performing wind farms have a much larger degree of variation. August 2017 was a particularly low period. It is normally expected that the summer months will have a lower PBA, although the value for the Low PBA group is particularly low. This is due to one wind farm reporting a monthly PBA value of 30% during this period, an exceptionally low value which brings the whole groups average down.

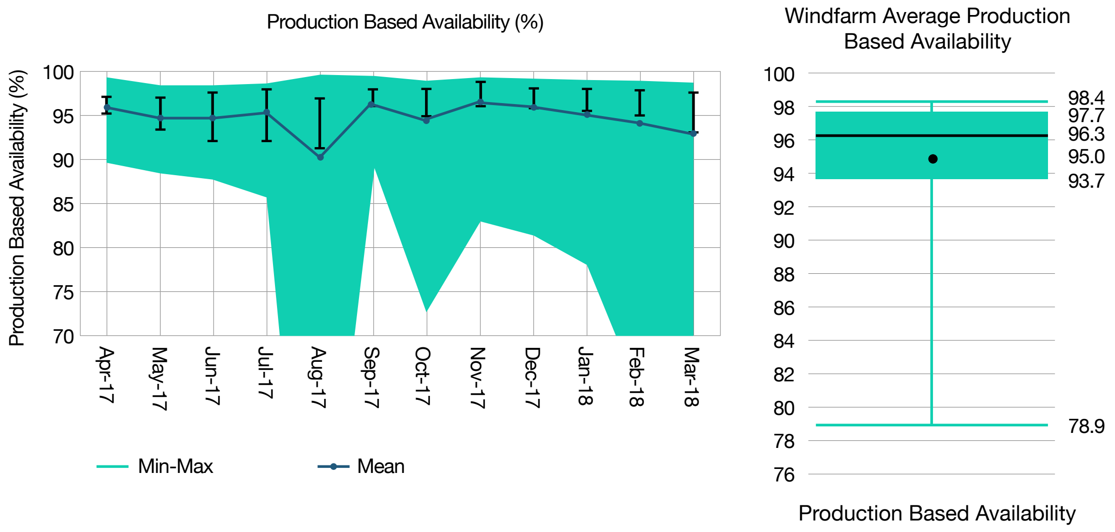


Figure 4 – Averaged Production Based Availability Values per Wind farm

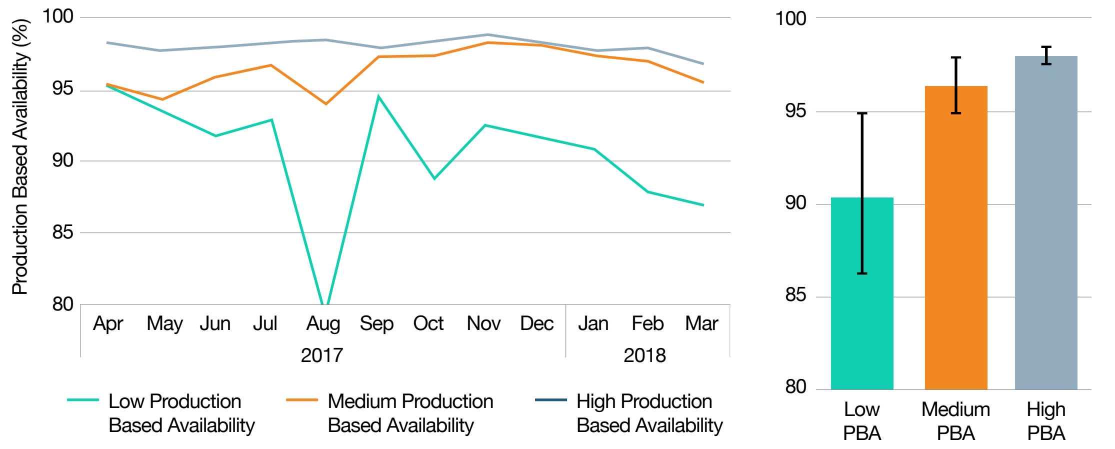


Figure 5 – Production Based Availability Over 2017/18 (Left) & Average Production Based Availability by Grouping (Right), Standard Deviation Shown with Error Bars

To analyse the whole spread of PBA values (for each wind farm for every month) a cumulative density function (CDF) is provided in Figure 6. This quickly reveals the distribution of PBA values across the population and shows where the greatest concentration of PBA values lie. As can be seen, most values lie between 94% and 99%, where the gradient of the curve is greatest.

The information gained from Figure 6 can be directly used to set PBA targets. If a wind farm operator wants to be above 50% of the PBA values across the sector, they should target an annual average PBA value of 96.3%.

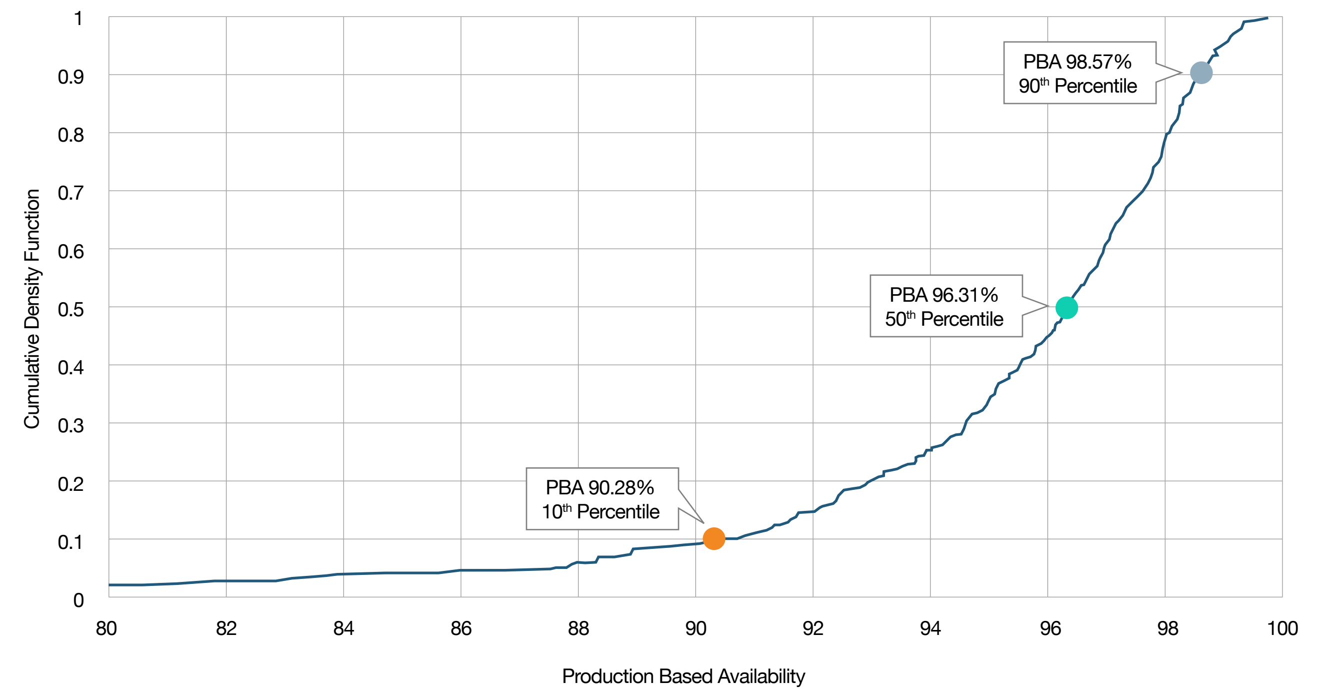


Figure 6 – Cumulative Density Function of Production Based Availability

Section 2.2.2 – Dimensional Breakdown

There are many factors that affect how a wind farm is performing. To further assess the differences in performance across the financial year, the wind farms are grouped based on the following characteristics:

- Region
- Age
- Installed Capacity
- Distance to Port
- Maintenance Provider

The following analysis investigates these characteristics one by one. It is important to note that there is a complex interplay between all of these characteristics and more.

Section 2.2.2.1 – Region

In terms of PBA, the East Coast performs better, with a more consistent PBA over the year and remains higher during the winter months. Contrary to this, the capacity factor for the West Coast is better, as seen in Figure 8.

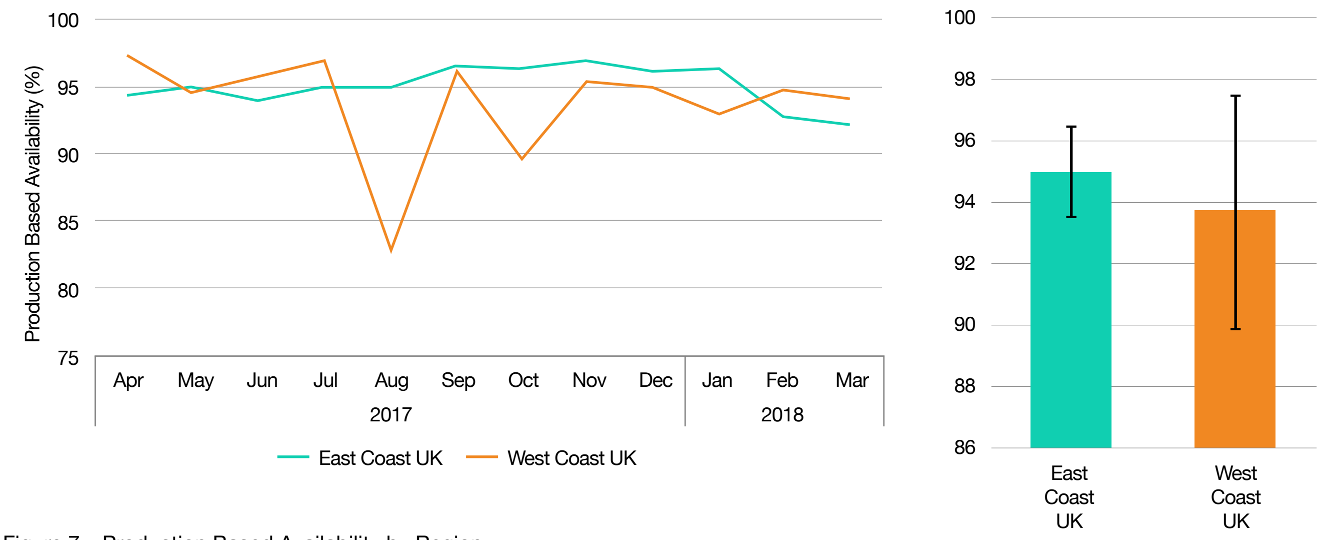


Figure 7 – Production Based Availability by Region

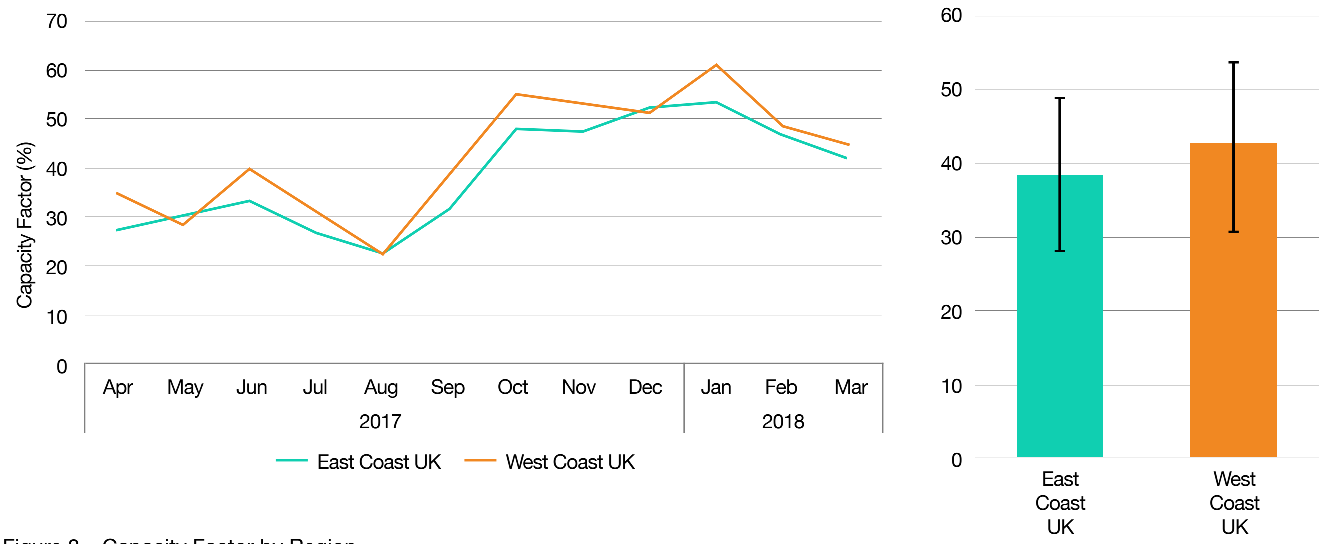


Figure 8 – Capacity Factor by Region

Section 2.2.2.2 – Age

Older wind farms outperform younger wind farms, as can be seen in Figure 9. However, when it comes to the age of wind farms it is hard to draw any reliable conclusion as the industry is still relatively immature, with the oldest wind farms only being around 15 years old (with a predicted lifetime of 20 years or more). This leaves the oldest wind farms being in the middle of the 'bath tub' curve. This can be seen in the PBA results gained, as shown in Figure 9, with the older wind farms having the greatest PBA value. It might be expected that this value will drop as wind farms get closer to end of life.

Section 2.2.2.3 – Installed Capacity

Over the past year mid-sized wind farms seem to be performing the best, in terms of PBA. Interestingly the small wind farms have the lowest PBA, typically it's the old round one sites that have a small installed capacity. It would then be expected that the small windfarms would have a correspondingly high PBA value but the average, for these small wind farms, is brought down by a few underperforming wind farms.

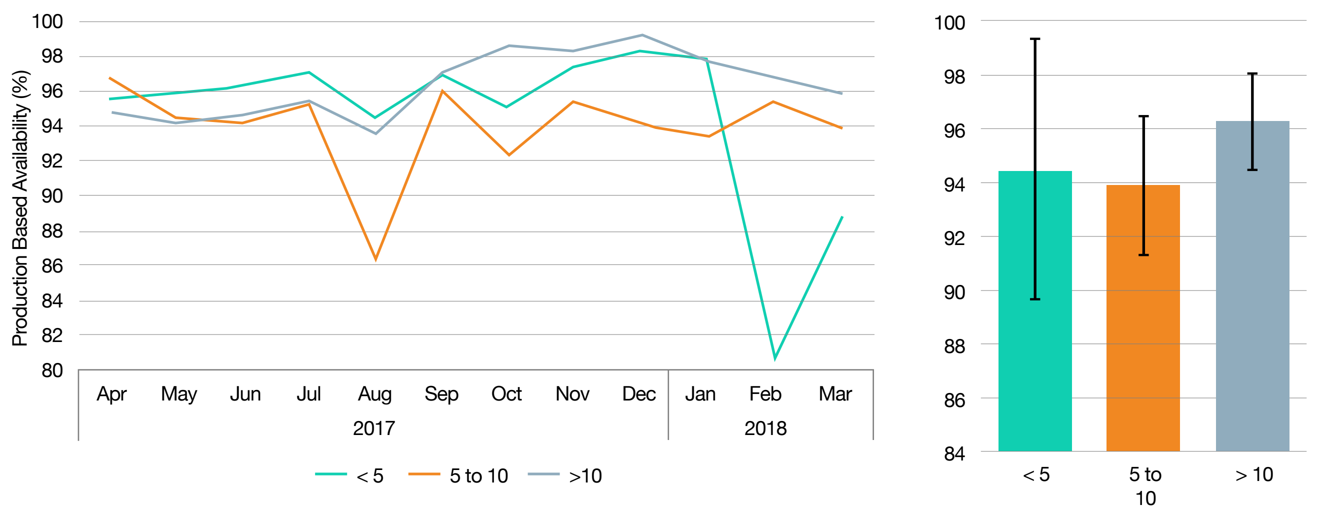


Figure 9 – Production Based Availability by Age of Wind farm

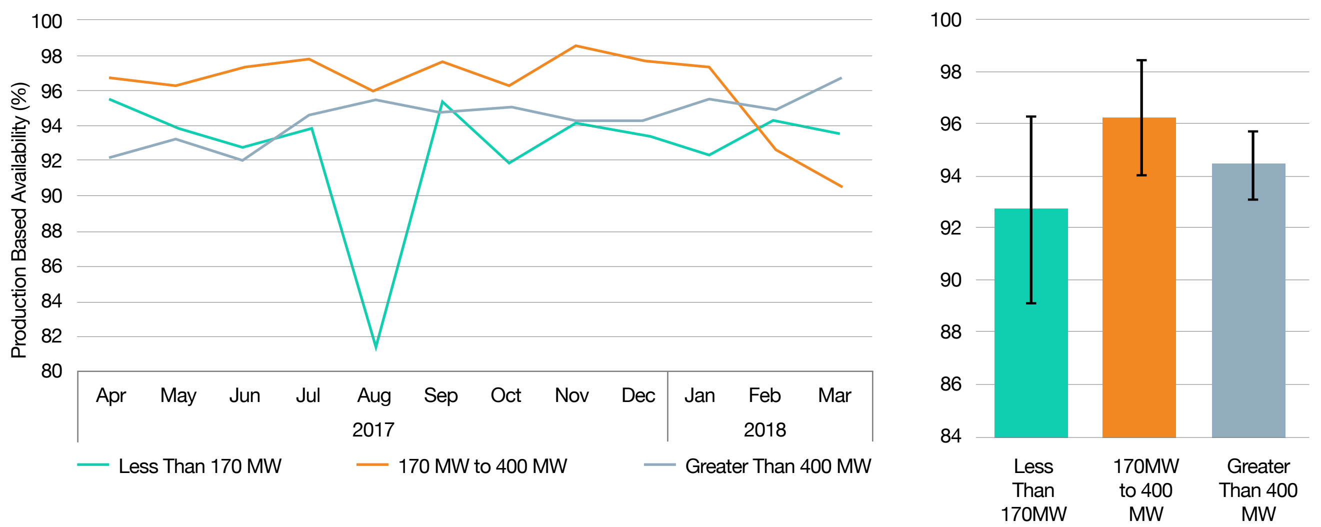


Figure 10 – Production Based Availability by Farm Size

Section 2.2.2.4 – Distance to Port

The distance to port has little effect on the PBA value of wind farms, as shown by Figure 11. The further from shore wind farms have less variation in their PBA, although the average PBA does not increase with distance from port.

Section 2.2.2.5 – Maintenance Provider

To analyse how the turbine maintenance provider affects KPIs, the farms were broken down into the following groups:

- **Full OEM:** All turbine maintenance is the responsibility of the turbine OEM
- **No OEM:** The OEM has no role in the operation and maintenance of the wind farm. This is also known as the self-perform strategy where all O&M is either in-house or sub-contracted to other suppliers.
- **Other:** Any hybrid model where the turbine OEM is involved for certain tasks. An example would be if the turbine OEM is involved for annual servicing but all troubleshooting and reactive maintenance is the responsibility of the wind farm operator.

Wind farms with No OEM have a higher average PBA over 2017/18. Conversely wind farms with Full OEM have a higher capacity factor over the year. This corresponds to expected contract incentives, as when OEMs provide maintenance they are likely to be contracted by production so will therefore seek to maximise this, whilst when O&M is performed on a self-perform strategy, availability would be maximised.

This can be seen in Figure 12 to Figure 14 where Full OEM has a higher capacity factor but a higher lost energy production and No OEM has a higher PBA but lower capacity factor.

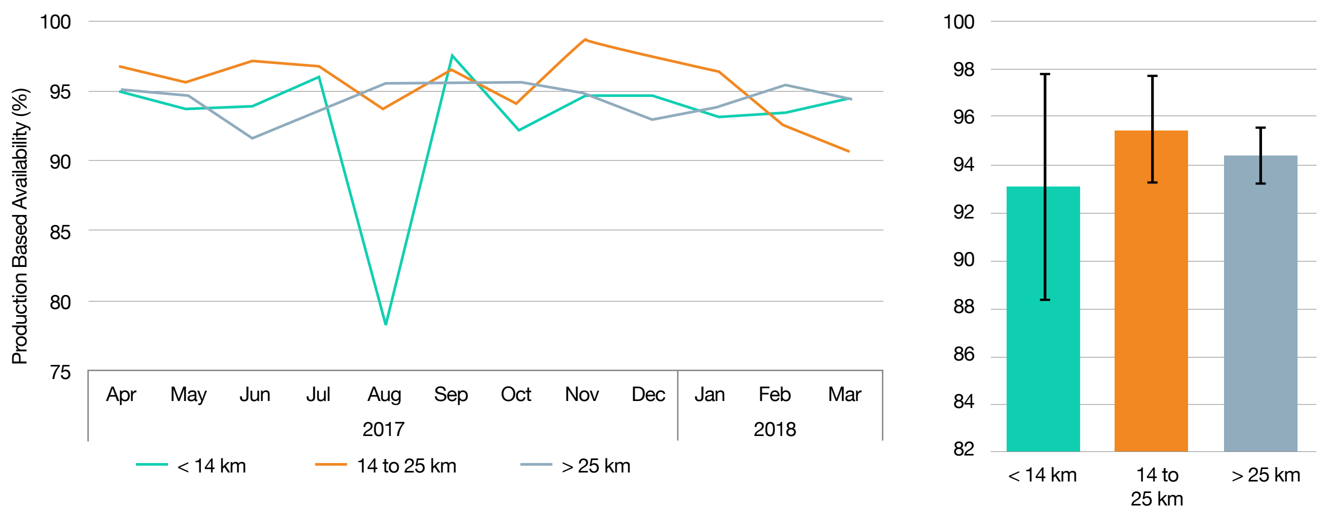


Figure 11 – Production Based Availability by Distance to Port

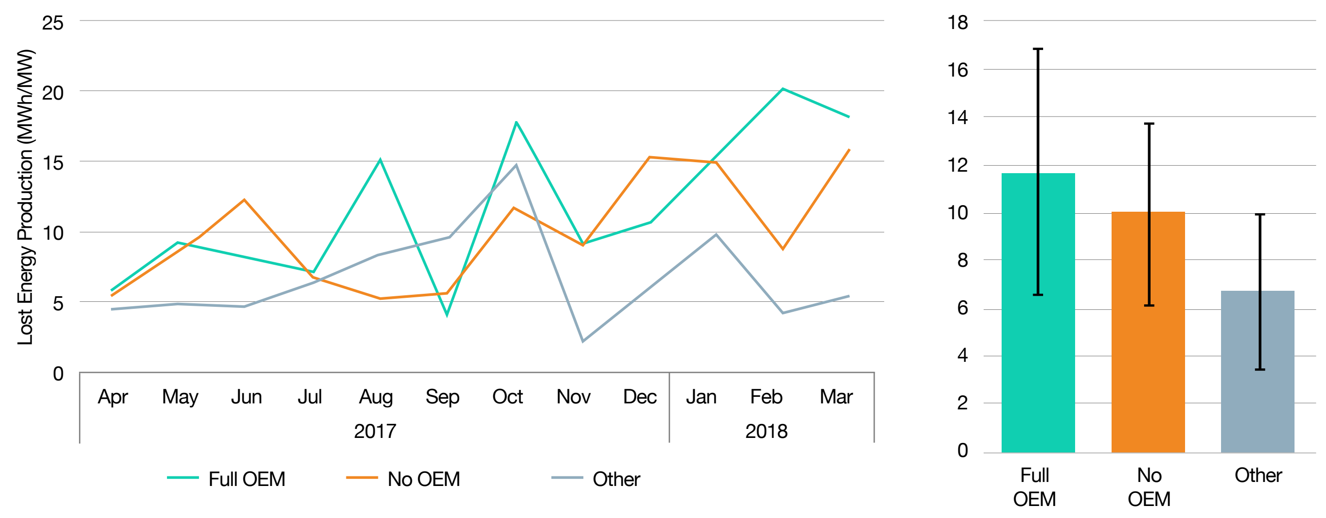


Figure 12 – Normalised Lost Energy Production by Maintenance Provider

It must be noted that the KPIs, used to measure performance, are a function of both the turbine and the balance of plant (BOP). There are other significant factors impacting performance that are out of the turbine maintenance providers control.

N.B. The Normalised Lost Energy Production is given in Lost Energy (MWh) per installed capacity (MW). This gives a value that can be compared across wind farms of different sizes.

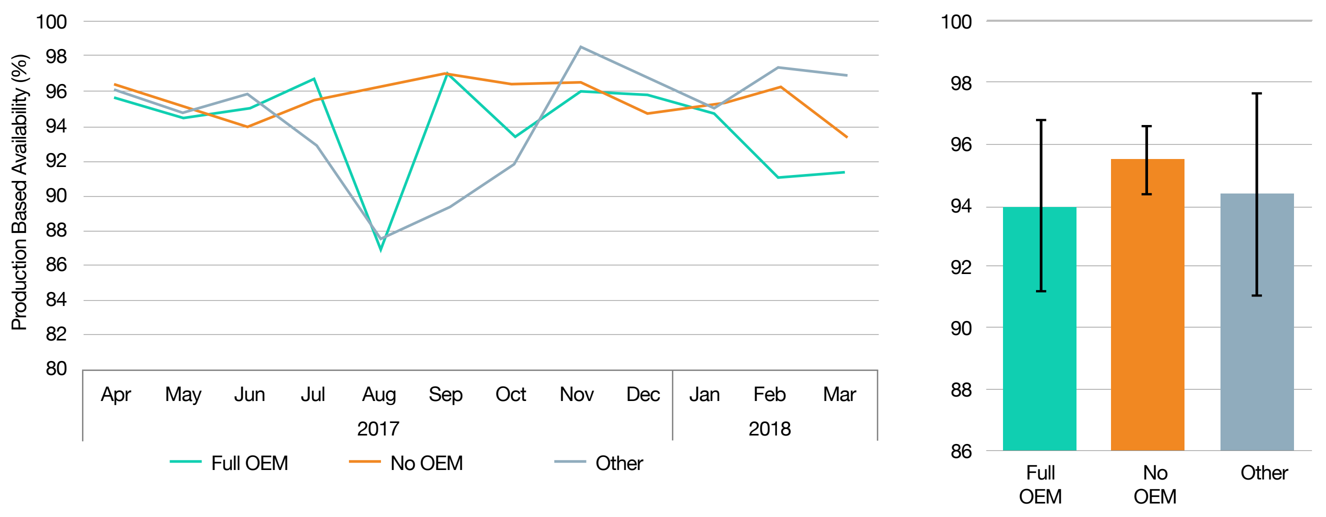


Figure 13 – Production Based Availability by Maintenance Provider

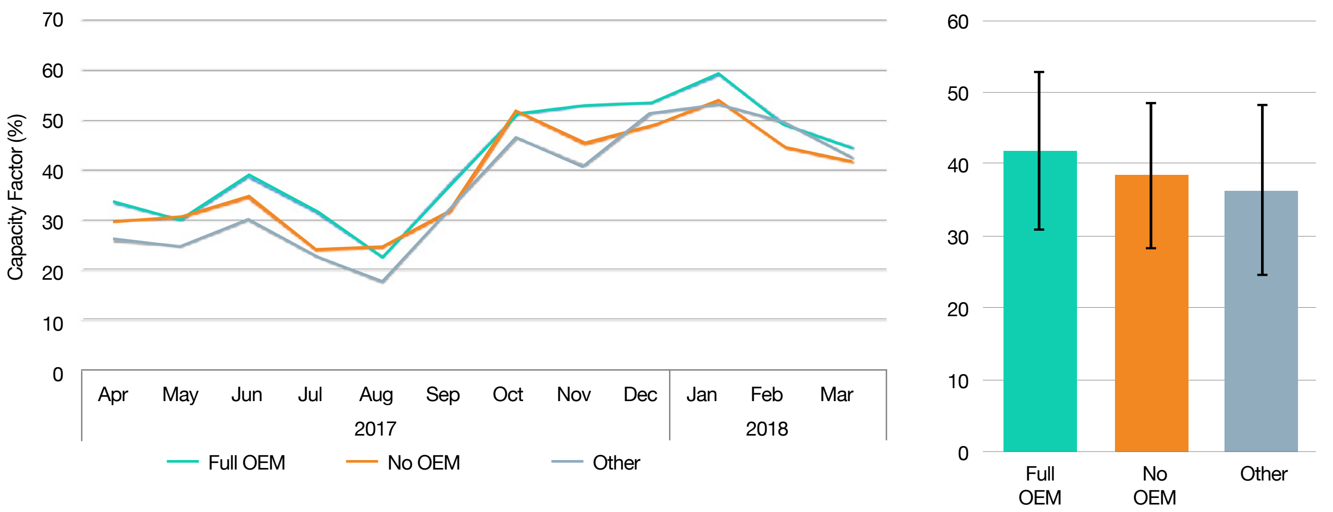


Figure 14 – Capacity Factor by Maintenance Provider

Section 2.2.3 – Vessels and Transfers

This section investigates vessels and transfer KPIs across the portfolio for the 2017/18 financial year.

Figure 15 shows how the mean hub height wind speed, mean significant wave height and number of non-access days due to weather are correlated. As expected, all three values are less over summer months and greater over the winter months. Following this, Figure 16 shows how the number of non-access days and number of transfers per turbine correspond. The data shows more transfers are conducted over the less harsh summer months: access is easier and impact on PBA is reduced.

Section 2.2.3.1 – Transfers by Region

When further breaking down the non-access days and transfers per turbine, it can be seen from Figure 19 and Figure 20 that the West Coast have significantly more non-access days as well as having more transfers per turbine. Interestingly met ocean conditions do not differ significantly as seen from Figure 17 and Figure 18.

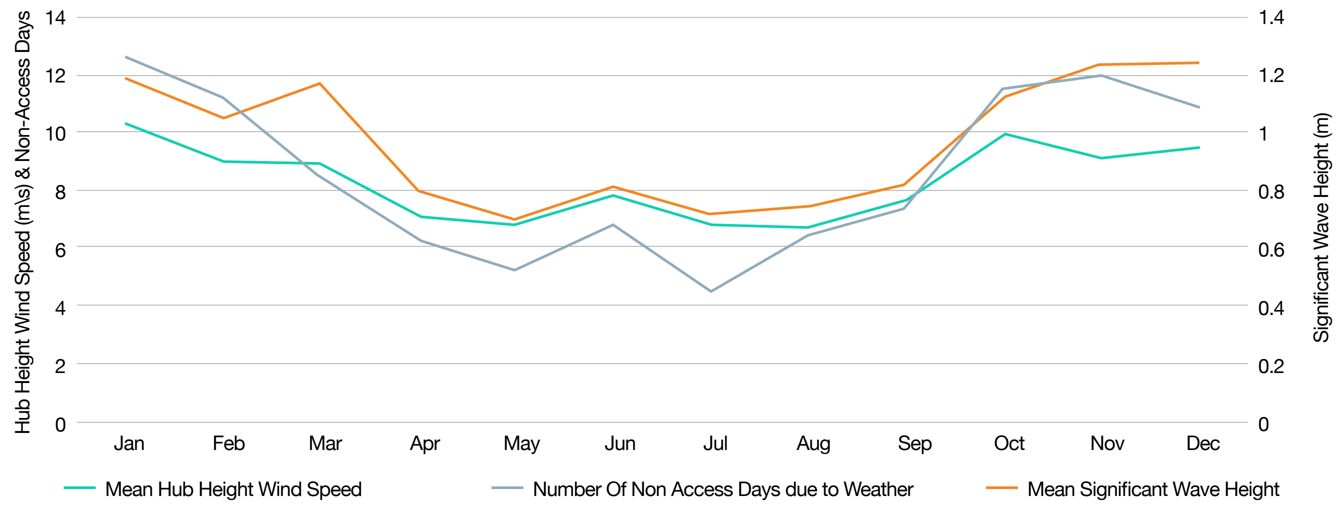


Figure 15 – Average Significant Wave Height, Wind Speed and Non-Access Days

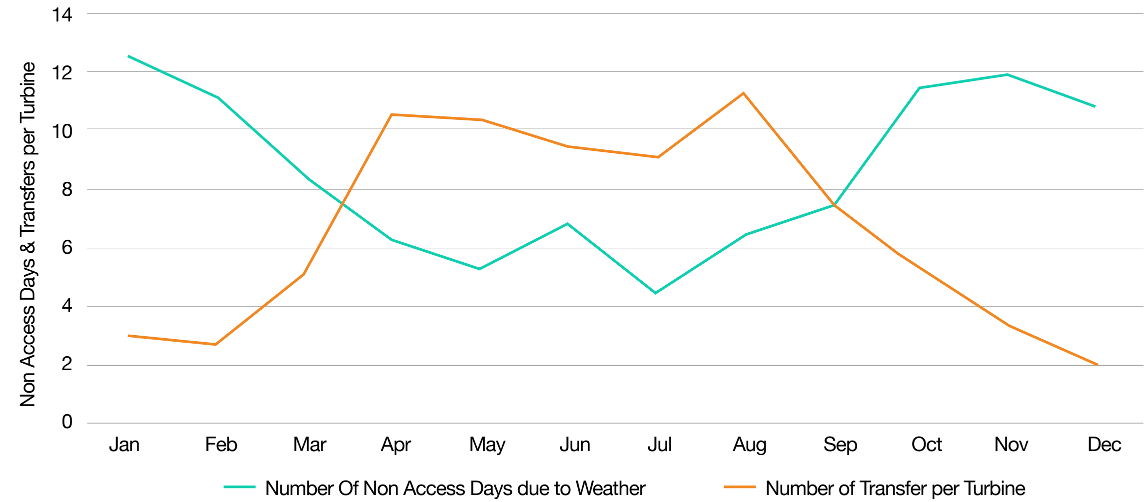


Figure 16 – Number of Non-Access Days to Number of Transfers per Turbine

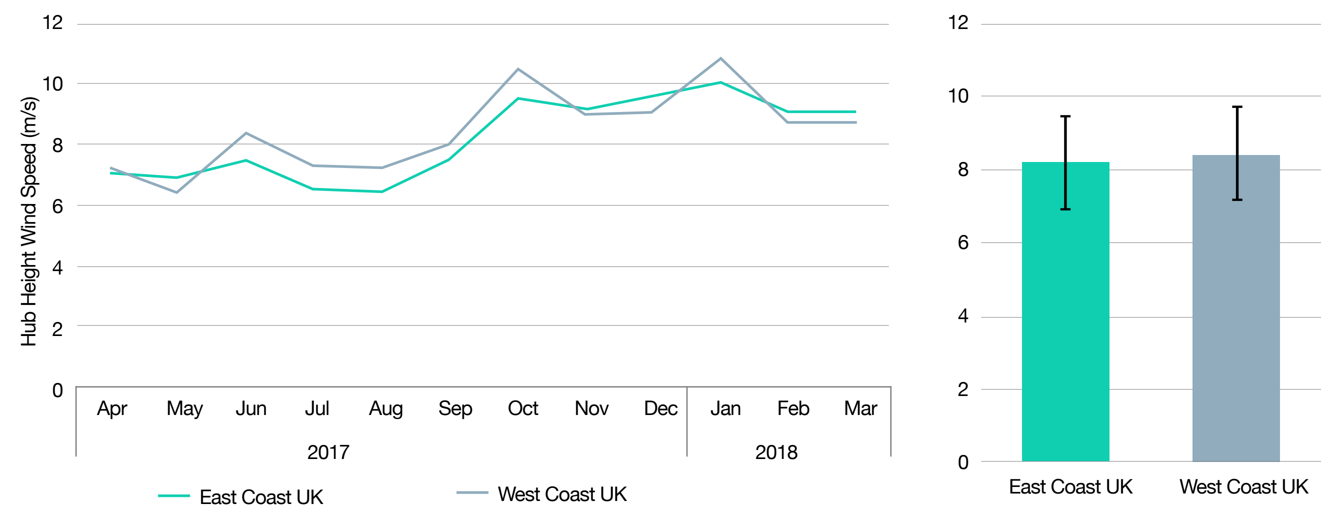


Figure 17 – Mean Hub Height Wind Speed by Region

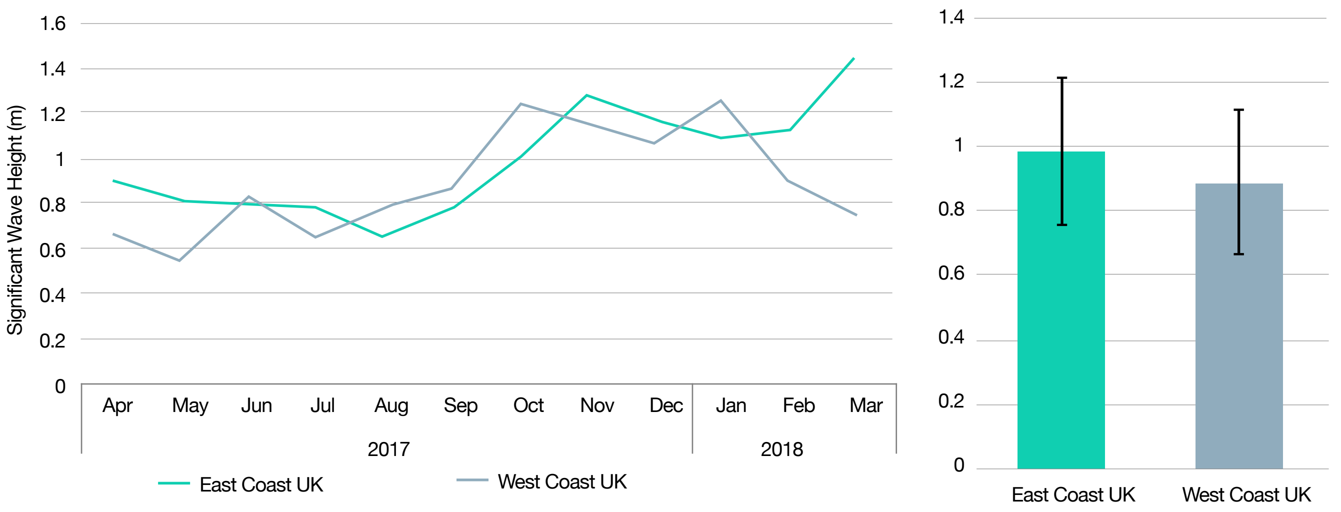


Figure 18 – Mean Significant Wave Height by Region

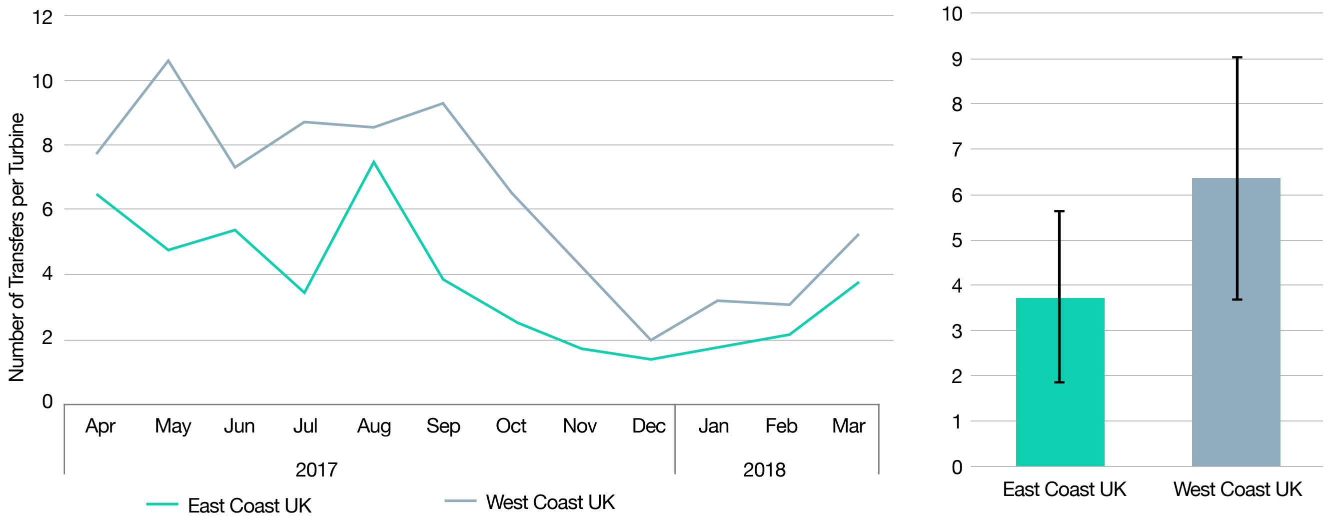


Figure 19 – Mean Number of Transfers per Turbines by Region

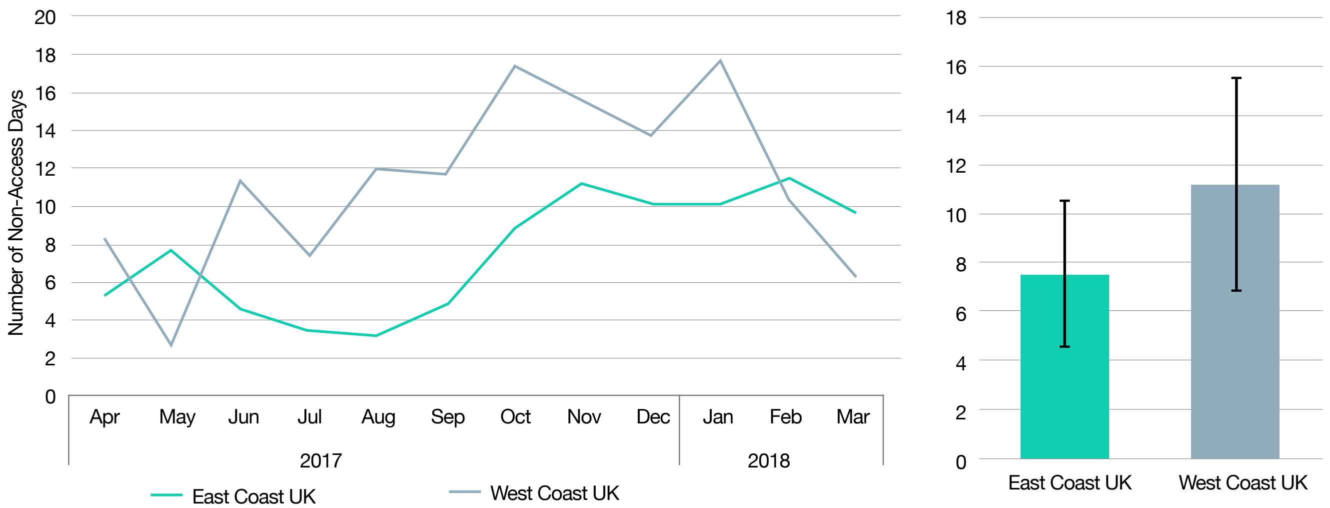
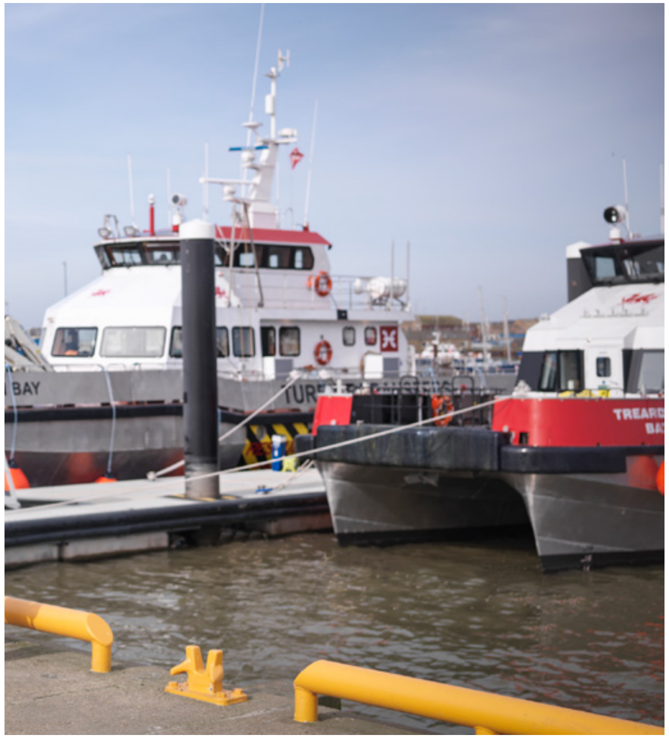


Figure 20 – Mean Number of Non-Access days by Region

Section 2.2.3.2 – Transfers by Distance to Port

Looking at Figure 24 it can be seen how the closest to port farms have the least non-access days. The mid-range located wind farms have the highest number of transfers, as shown in Figure 23, and a correspondingly high number of non-access days. The far from port wind farms are hit hard by winter and have a significantly increased number of non-access days between October and March. Far from port turbines have a high number of non-access days when compared to their number of transfers. It is likely this is due to the higher significant wave heights encountered further from land, as shown in Figure 22.



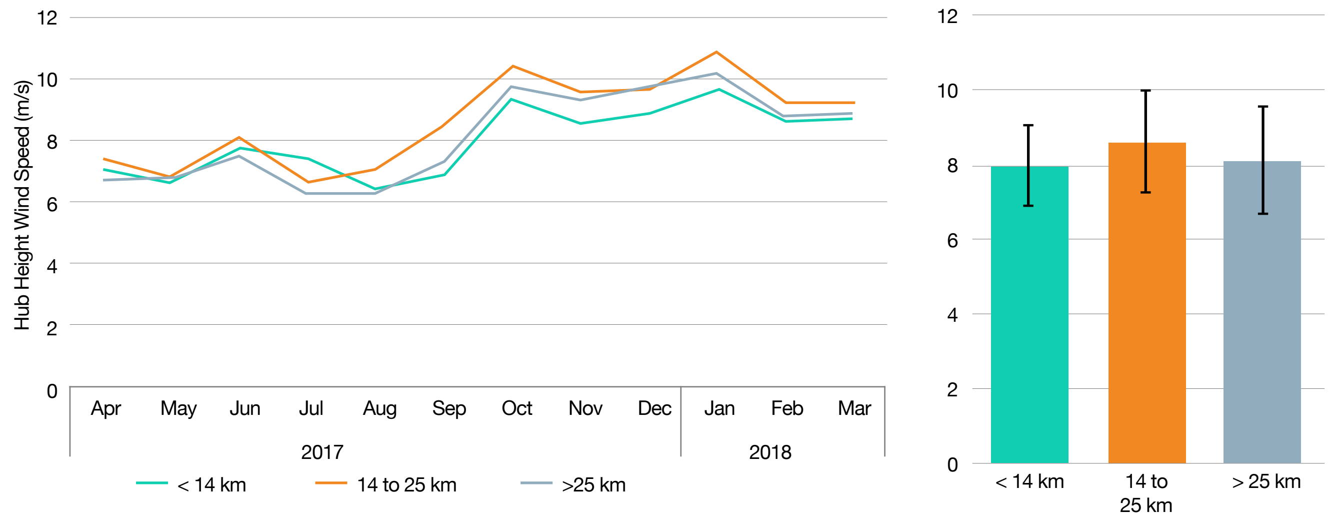


Figure 21 – Mean Hub Height Wind Speed by Distance to Port

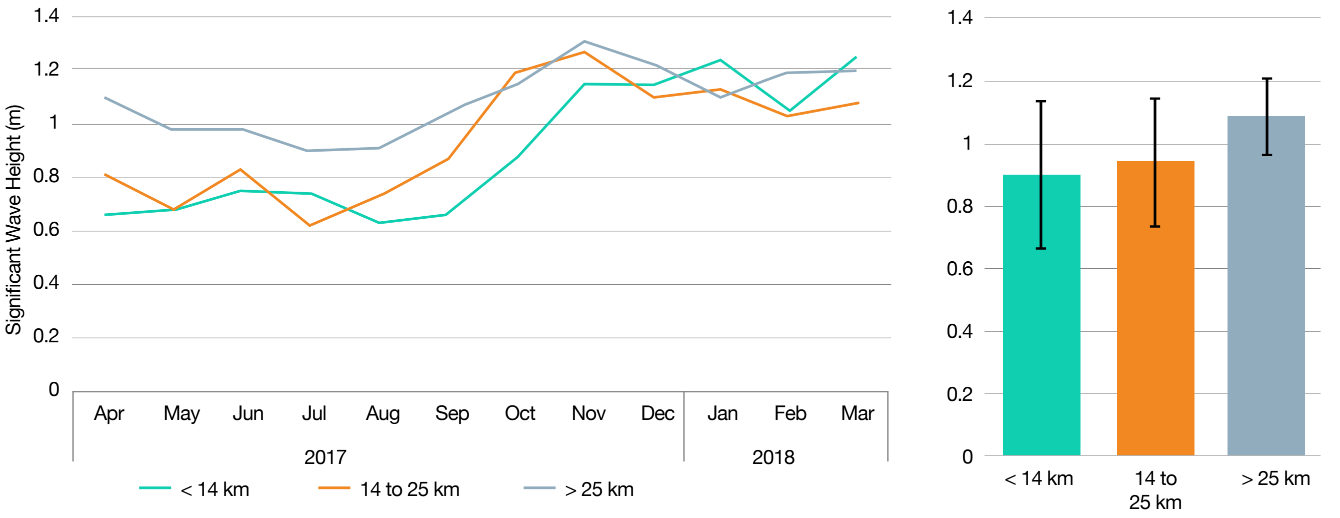


Figure 22 – Mean Significant Wave Height by Distance to Port

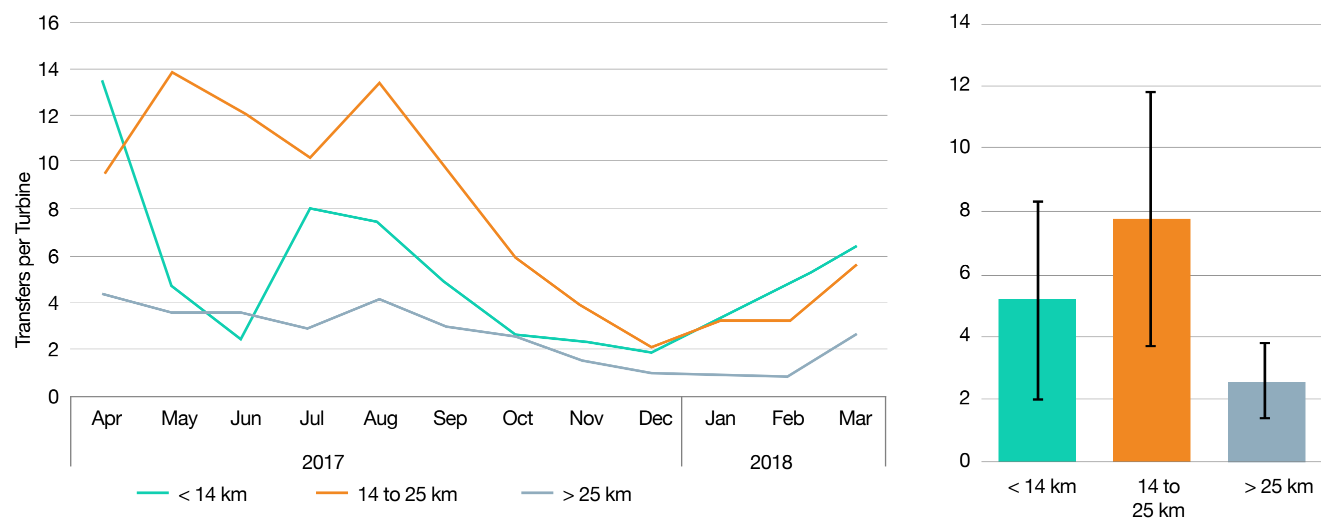


Figure 23 – Mean Number of Transfers per Turbines by Distance to Port

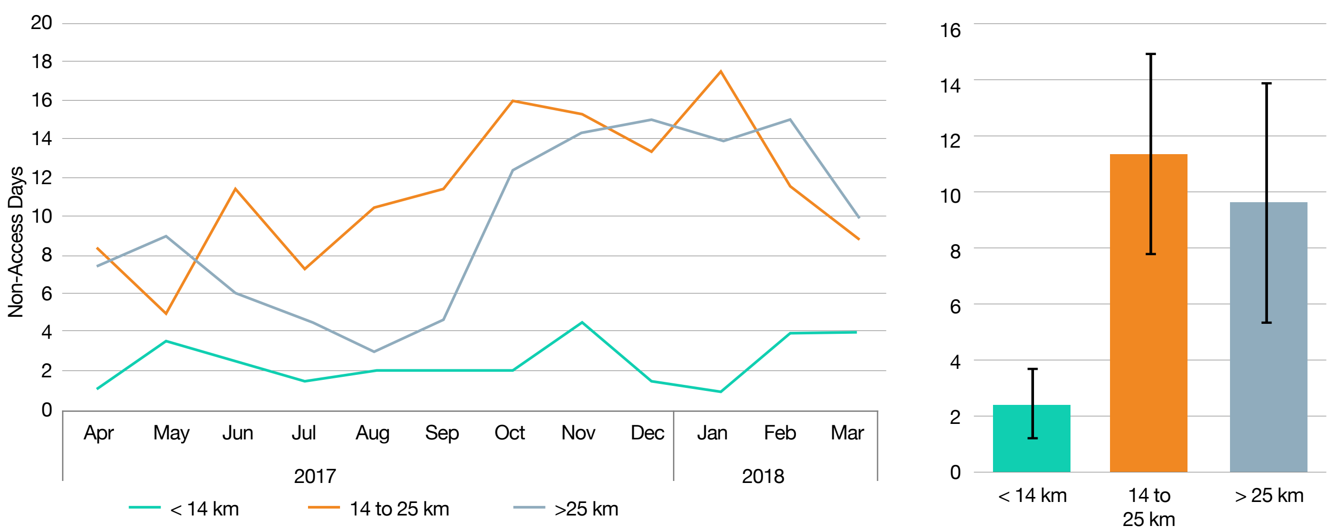


Figure 24 – Mean Number of Non-Access Days by Distance from Port

Section 2.2.3.3 – Vessel Utilisation

To further analyse the trend of Number of Transfers a new metric is explored, 'Number of Crew Transfers per Vessel Day'. This metric introduces the idea of utilisation of vessels; how well is each vessel under chartership being used?

For a standard CTV holding 12 personnel (plus crew), a target value could be around 12. A monthly value of 12 could be interpreted as a full 12 seat vessel sailing every day in the month with each person going to one turbine each day, a lower value may indicate the vessel is not fully utilised. It is possible to exceed this target by multiple turbines being visited per day by the same CTV.

Figure 25 and Figure 26 indicate that the wind farms further from port are making better utilisation of their vessels, whereas the vessels close to port are not utilising their vessels as well. If vessels are used more efficiently this could help reduce costs, fewer vessels will potentially be needed and the overall chartered fleet may be reduced.

Whilst there is a clear trend, the vessel utilisation for far from shore wind farms could also be influenced by the use of Service Offshore Vessels (SOVs). This would increase the Number of Crew Transfers, leading to an exaggerated value for Number of Transfers per Vessel Day.

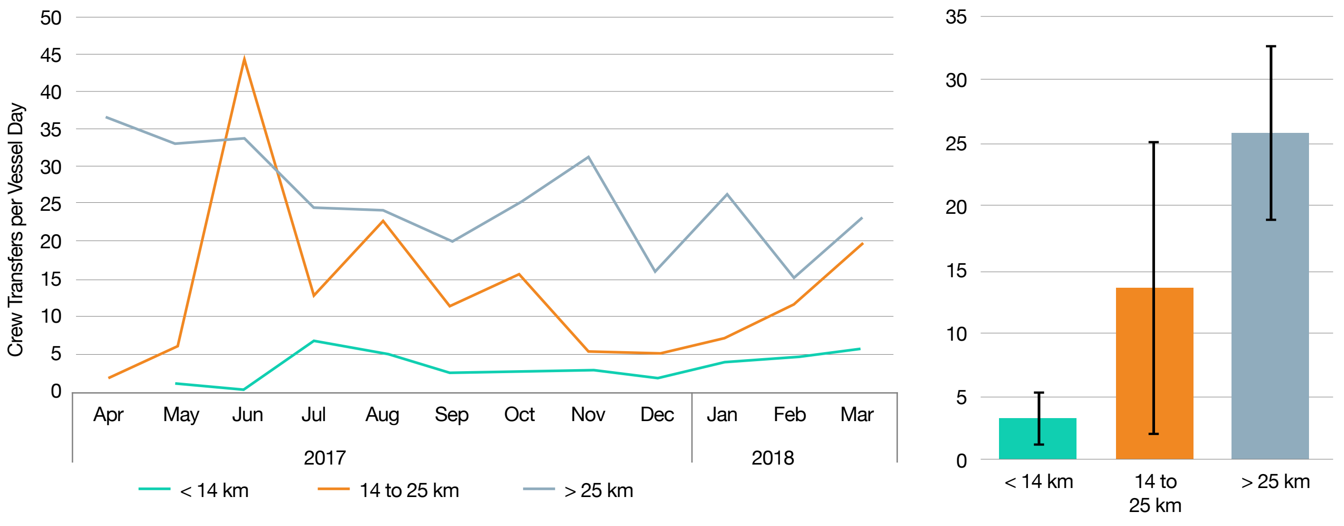


Figure 25 – Number of Transfers per Vessel Day

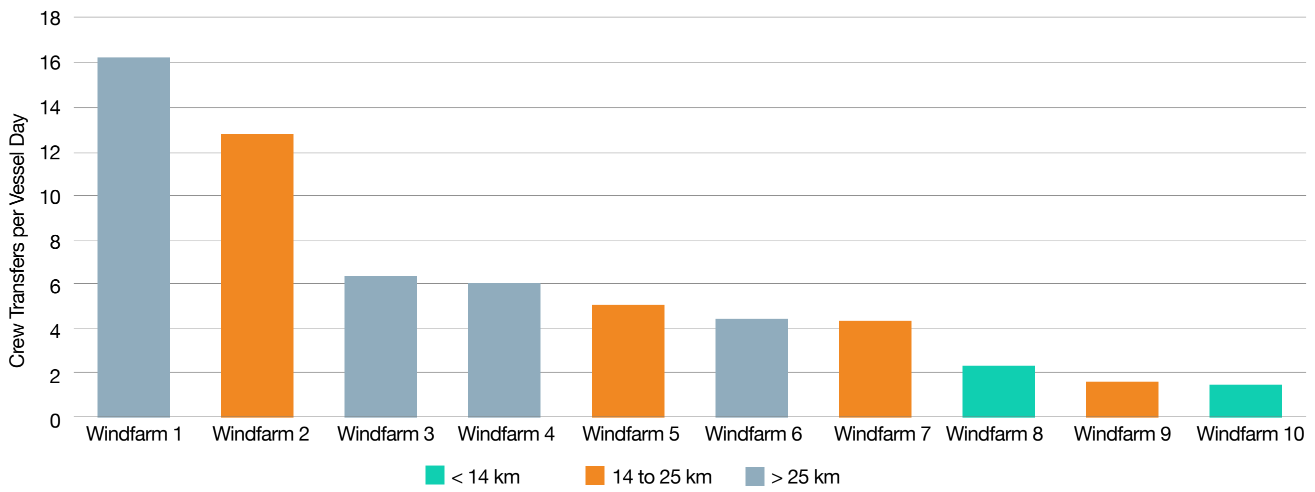


Figure 26 – Number of Transfers per Vessel Day by Wind farm

Small wind farms, which tend to be located close to shore, are obtaining a poor vessel utilisation, as seen from Figure 27 and Figure 28. For smaller farms it is likely less turbines will need to be maintained on a daily basis, however there is consistency, across the groups, in the size of the CTVs used. This leads to the opportunity to increase utilisation at larger farms.

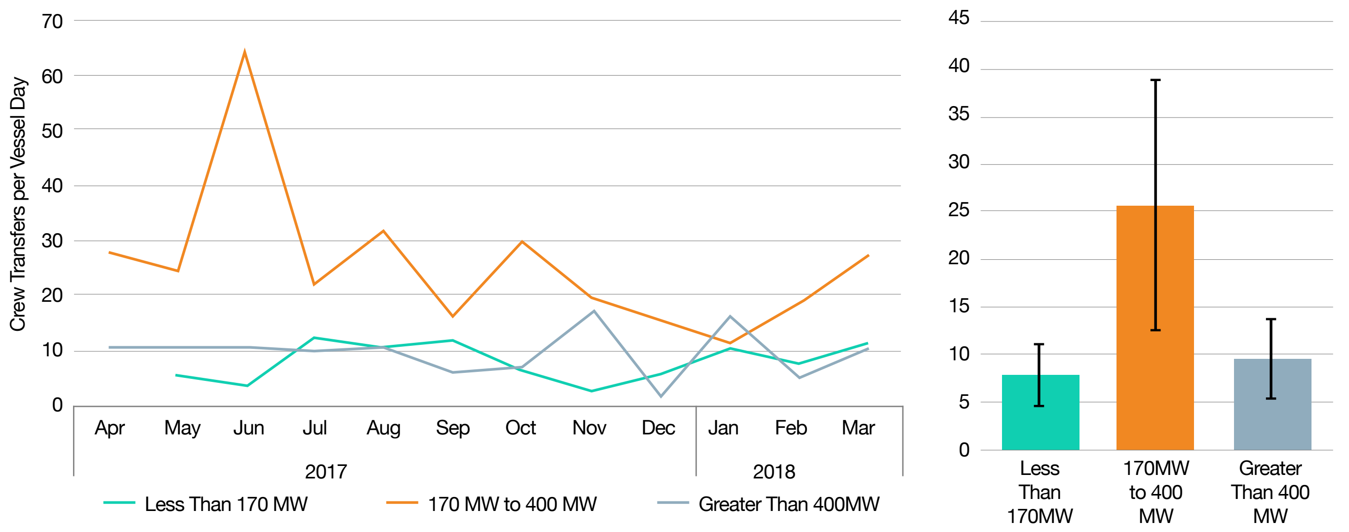


Figure 27 – Crew Transfers per Vessel Day by Installed Capacity

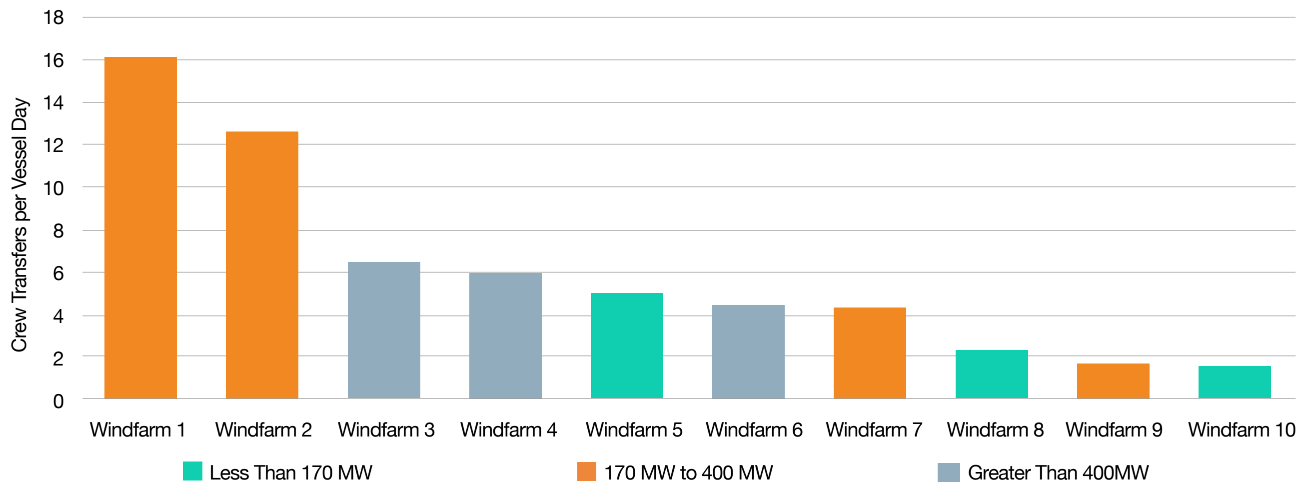


Figure 28 – Crew Transfers per Vessel Day by Wind farms

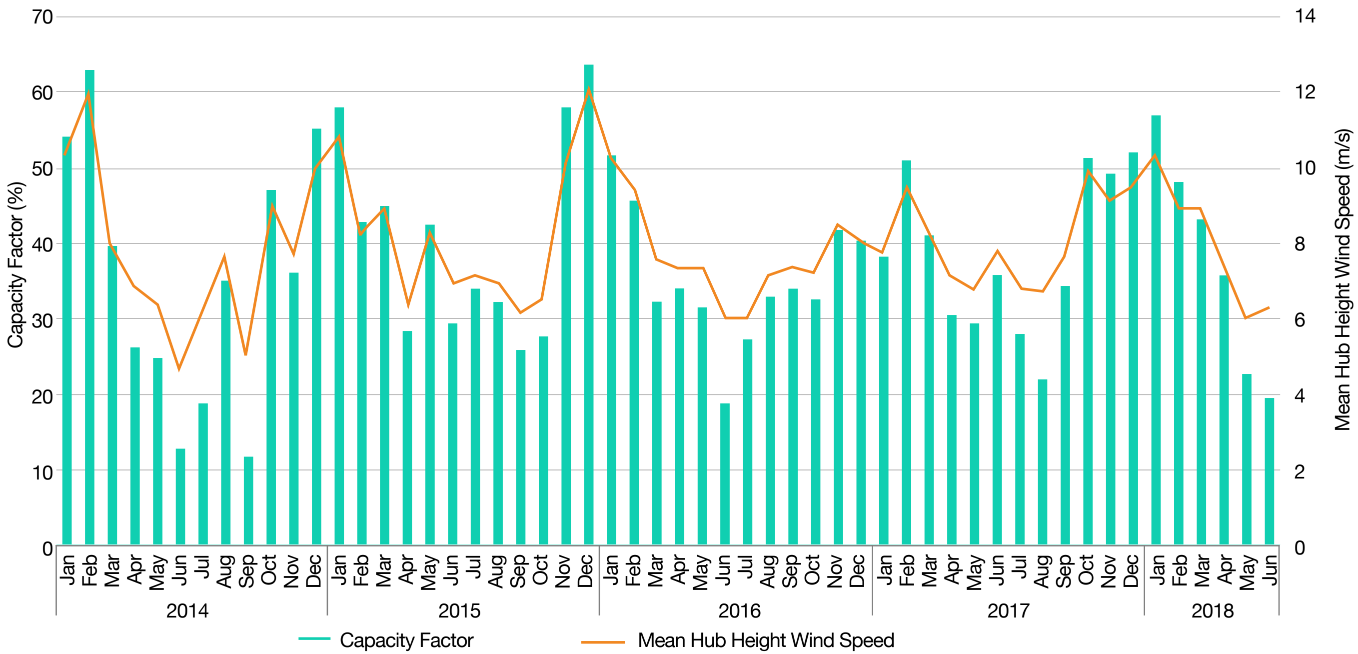


Figure 29 – Capacity Factor and Mean Hub Height Wind Speed Average Over Life of SPARTA

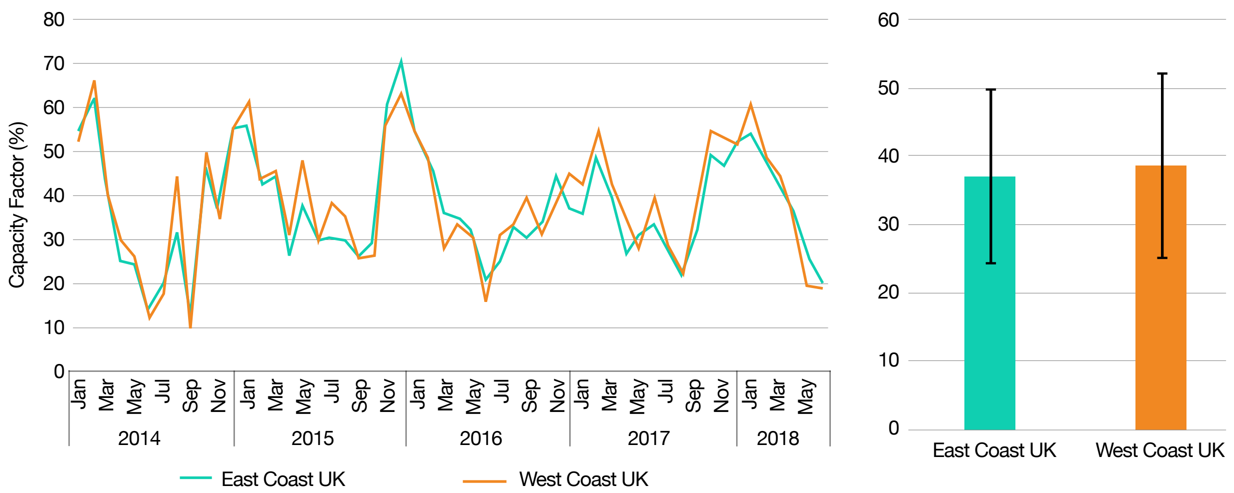


Figure 30 – Capacity Factor by Region

For this section the data is backdated to January 2014 to allow for identification of longer-term trends. Again, the period is broken down by looking at different groupings: Region and Distance to Shore.

Section 3.1 – Capacity Factor

Looking at the Capacity Factor over the lifespan of SPARTA, the seasonal trends are immediately clear with higher values over the winter periods, where winds are stronger, and lower values over the calmer summer periods.

Over this time the average annual Capacity Factor doesn't change from around 37.5% and there seems to be little difference between the East and West Coast, with West Coast doing marginally better.

Section 3.2 – Number of Transfers per Turbine

When looking at this longer period a clear seasonality emerges from the average number of Transfer per Turbine, with more transfers being done over the calm summer months and less over the harsh winter periods. In addition to this seasonality the average is dropping over time. Volume of transfers can be used as a proxy for amount of work ongoing at sites. Therefore, this suggests the industry is maturing and getting to know their farms better, forecasting well and knowing how and when to perform operations more efficiently.

Looking at the number of transfers by distance to shore reveals that the closer to shore wind farms have more transfers per turbine. There are a number of factors that could be driving this result. Wind farms close to shore may be fixing faults on an ad-hoc and reactive basis when they arise, instead of waiting until there are a batch of issues to be resolved. Furthermore, technicians accessing further from shore wind farms will necessarily spend more time in transit for a working day, so more transfers and more work can occur at near to shore wind farms.

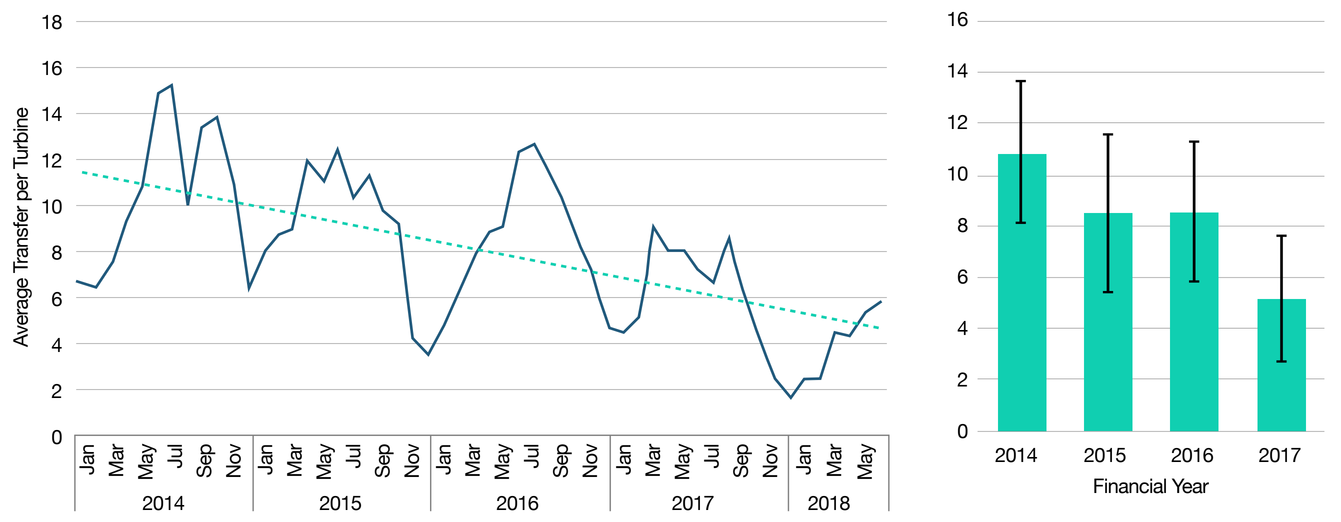


Figure 31 – Average Transfers per Turbine

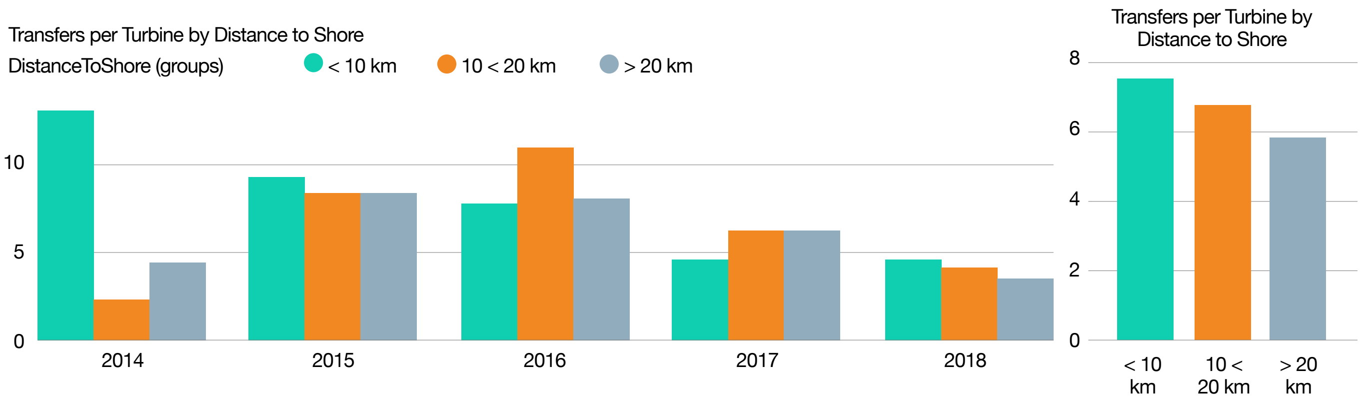


Figure 32 – Transfers per Turbine by Distance to Shore

Section 3.3 – Non-Access Days:

As is shown below, the closer to shore turbines have less non-access days compared to the further from shore turbines. This strongly shows how much an influence being close to shore has on the predictability of the weather conditions. Looking at Figure 34 it is clear how wave height and wind speed increase as distance from shore increases. Operators need to adapt procedures to remain safe in these more severe conditions at far from shore wind farms.

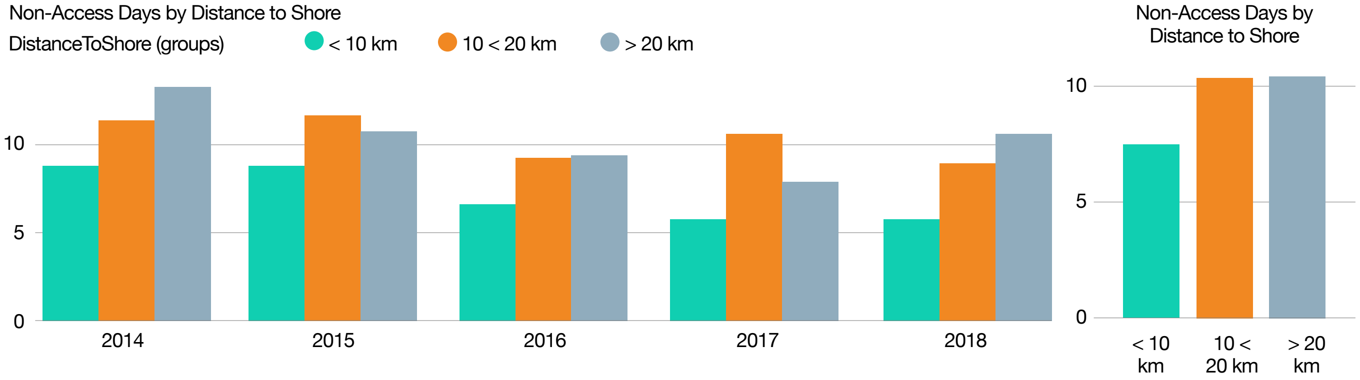


Figure 33 – Non-Access Days by Distance to Shore

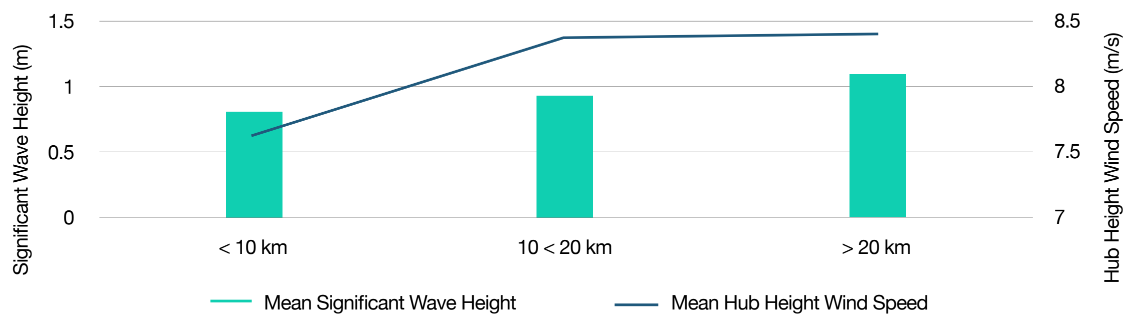


Figure 34 – Significant Wave Height and Wind Speed by Distance to Shore

SPARTA has been established as the trusted provider of performance benchmarks for the offshore wind industry. However, as the global offshore wind industry grows apace, so do opportunities for SPARTA. The vision is for SPARTA to be the hub of essential industry operations and maintenance performance data across the global offshore wind sector. Thus, enabling owner/operators to continuously improve and deliver the best possible performance, whilst continually driving down life-time costs and maintaining the highest health and safety standards offshore.

The following developments over the next year will drive the fulfilment of this vision:

- Grow the reporting population to continue to provide representative benchmarks. The target is to secure participation from offshore wind farms around the world, strengthening the benchmarking process.
- Introduce cost benchmarking to transform SPARTA from a technical performance measurement system into a critical tool for the optimisation of wind farm costs. The impact of availability, maintenance and logistics on relative operational costs has been recognised by participating members as extremely valuable and the logical next step for what SPARTA will anonymise and benchmark. Cost KPI definitions are currently under development.
- Work collaboratively with the G+ Global Offshore Wind Health and Safety Organisation to explore synergies between the anonymised performance benchmarks generated by SPARTA and G+ H&S incident statistics. This will identify useful interplay between frequency of operations, asset performance and H&S incidents, facilitating H&S targets based on operational activity, availability and production.
- With the fundamental anonymisation and benchmark provision system truly established, and quality checked, the focus of SPARTA will shift towards value-adding activity with a focus on converting the anonymised data into insight and actionable advice.

Bibliography

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WEBS, W. E. (2018, September 03). *WEBS Publications. Retrieved from WEBS: https://www.webs-ltd.com/publications/*

Membership

Owner/operators not currently involved in the SPARTA project are invited to join the group through the members collaborative agreement, to add to the benchmarking data set and benefit quickly from an analysis of their performance against their peers.

Participation in SPARTA also provides owner/operators with the opportunity to work with seasoned professionals in the field of offshore wind farm operations and maintenance performance measurement.

Applications or enquiries for new members may be made at any time in writing or by contacting either of the project Sponsors:

Adrian Fox
The Crown Estate,
1 St James's Market, London, SW1Y 4AH

Adrian.Fox@thecrownestate.co.uk

Chris Hill
ORE Catapult,
Inovo, 121 George Street, Glasgow, G1 1RD

chris.hill@ore.catapult.org.uk