ONYX Insight

Ever-Changing Winds

The State of the Wind Industry in 2024 and Beyond

Featuring insights from senior leaders across the global wind industry

Emerging from the COVID-19 years, the wind industry now faces a range of new challenges. For example, inflation, supply chain, skills shortages and major turbine reliability issues that have caught up with OEMs. We have the benefit of an improvement in the political landscape, yielding greater drive to decarbonize, yet can the wind industry meet these expected growth targets? Parts, people, permits, vessels and power prices are all headwinds.

Yet challenges drive change and the industry can embrace technology to become more efficient. The best players are investing in digitalization, as their leaders know they will otherwise be left behind.

We are all chasing skills, and for some it was the 'great rotation', not 'great resignation', as expertise moved around opportunistically within this expanding industry.

We need to embed more knowledge into digital technology and harness the output. We need to leverage our data for decision making and know ahead of time: 'where, when and what' for parts, people and tools.

To develop this report the leadership team at ONYX Insight interviewed over 40 key players across the global industry that own and operate wind turbines, in order to gauge the mood of senior leaders in wind. 58% of the participants had 12+ years in the industry and 73% were VP or higher in their career level. To all who took part, we thank you for your time.

Ultimately, we trust that the information contained within will help shape future approaches in the industry.

Ashley Crowther

Ashley Crowther

Chief Commercial Officer,
ONYX Insight

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The Biggest Challenges in Wind Operations
A global overview

Key Insights

- The **supply chain** remains the greatest challenge to operations, with **reliability** and **OEM** concerns not far behind.
- When it comes to digitalization, only **14%** of participants consider their operations to be mature or market-leading.
- To meet the challenges, **64%** see intelligent planning and decision support as a key area for digital tools.
- The market is changing: participants anticipate a strong **(32%)** or very strong **(35%)** decrease in OEM market share for turbine servicing. The challenge is to be ready to self-operate.

The Biggest Challenges in Wind Operations

Top 3 challenges to operations

Supply Chain
57%

OEM Challenges
49%

Turbine Reliabilty Issues
46%

Greatest areas of value from digitalization

Intelligent planning
57%

Centralized Data (server or cloud)
52%

Aditional Turbine Sensors and Predictive Analytics
45%

Advanced SCADA-based Performance & Diagnostic Tools
45%

Only 14% participants thought they had a mature or market leading situation for digitalization of operations

The State of Play in the Wind Industry
The Supply Chain

Well-documented problems in the supply chain are creating big challenges for the wind industry.

COVID-19 had a pronounced impact on manufacturing, as well as imports & exports, but we were beginning to see signs of recovery until the war in Ukraine and the surge in inflation.

Survey participants are now citing delays on new projects due to longer lead times for supply of new turbines and significant price increases. This is in line with what OEMs have told their investors, for example Vestas noting in their 2022 annual report they `increased our average selling prices of our wind energy solutions by 29%'. Similarly for major components, particularly main bearings on newer turbines with large rotor diameters, long delays are leaving turbines offline for extended periods.

And whilst these are creating challenges to operations teams, the most obvious impact has been on OEMs, as is evident in their recent financial results.

"When we took over a site under a LTSA(long-term service agreement), the site was at 62% availability.

Now, self-performing it's up 30 points to 92%. It's proof that managing your own destiny is the right approach."

US UTILITY COMPANY

How the supply chain is changing the behaviour of OEMs and asset owners

Major western OEMs have recently reported losses or profit warnings and announced major restructuring projects in order to address the challenges they are facing. Some are even re-thinking their approach to the aftermarket which was always seen as the most profitable part of the business.

In some markets, OEMs are scaling back their presence to focus on more lucrative regions. They are also looking to reduce full-scope contracts to shorter terms, adding more 'carve-outs', and shifting more risk to the asset owner for major component replacements.

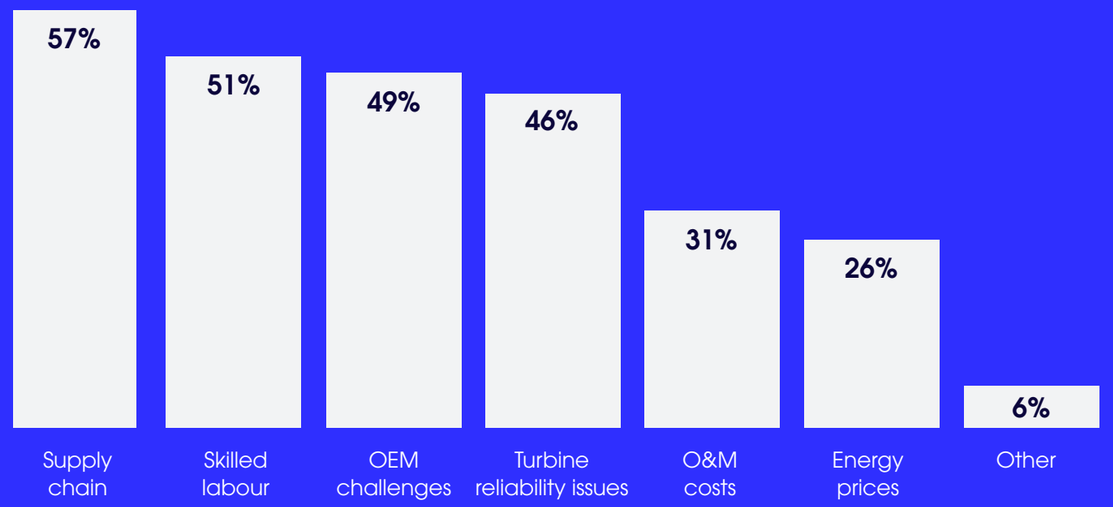
This introduces a new dynamic in the service space where, as the sector matures, asset owners are increasingly looking to in-house their operations & maintenance (O&M).

Coupled with likely increases in OEM service contract pricing and concerns about OEM financial performance, we expect an impact on the market share of OEM contracts. This view is confirmed by most of our respondents **very strongly agreeing (35%)** and **strongly agreeing (32%)** that they expect the share of full wrap OEM service agreements to reduce over time.

There is of course a wider context here – several Brazilian owners have little choice but to prepare as some OEM's scale back in the market, whilst in India there has already been a wider trend of self-performance.

Meanwhile, in the US, an IPP told us that they plan to self-perform the majority of their assets, but not all, adding `first, we want to see that it (new turbine) doesn't have too many problems'.

What do you see as the biggest challenges for your operations in the next 2-3 years?



Getting access to the turbine controller

This brings up another important point – access to the turbine controller.

OEMs have often restricted asset owners' access to the controller, citing cyber security and IP concerns, sometimes using this as another means to secure long-term service contracts.

And whilst this is true for some control algorithms, it's more tenuous when it comes to basic information such as set limits on some parameters or derating options.

Due to the current situation, owners will now be more persuasive when it comes to securing such access (even with limitations) not only because it gives them more opportunity for optimization of their assets, but also because it offers more security in case OEMs are forced to take more drastic actions and exit the business.

Many still remember the challenges around Senvion from a few years ago where owner/operators were locked out of their turbines' controls and will wish to take steps to mitigate any similar risks in the future.

In recent years, owners have been redlining clauses into turbine supply agreements to ensure access to CMS data. We expect this practice to broaden, because data access is required to expand digitalization.

Digitalization

Key Insights

- In recent years, there has been a notable shift in wind organizations' digital-readiness.
- In 2020, **81%** of participants felt they had lots to do or had hardly started.
- Fast-forward to 2023 where **64%** feel they've made great progress or better.
- There has therefore been an acceleration since the COVID-19 outbreak, but the general consensus is that there is much more to do.
- Notably, there is expanded interest in Intelligent Planning, whereby owner/operators can distil vast amounts of data into actionable intelligence.

The key components of digitalization

In order to assess the state of digitalization in wind, we must outline the must-have components of digitalization.

- **Data Historian**
- **Unified SCADA Analytics System**
- **Condition Monitoring Platform or System**
- **Advanced Analytics Platform** (Performance, Predictive, and Event Analytics)
- **Meteorological Data**
- **Vessel, Vehicle, and Aircraft Tracking**
- **Structural Health Monitoring**
- **BoP Monitoring**
- **Digital Maintenance Checklists**
- **Major Component Management**
- **Digital Inspection Methods** (Autonomous blade image capture, drivetrain, towers)
- **CMMS with Digital Work Instructions**
- **Cyber Security**
- **Data Adapters**

When the COVID-19 pandemic began, a number of wind owner/operators were caught out by a lack of investment in digitalization across their fleets. Those relying exclusively on manual climbs were affected critically when lockdowns were enforced.

Those who invested in online monitoring don't need to manually inspect every component annually – they can simply report on what isn't working remotely. Likewise, SCADA data can be mined with analytics to find emerging reliability issues across the turbine, reducing the number of costly turbine climbs. Fewer inspections also lowers safety risks.

Without the ability to continuously judge the remaining useful life of components, operators who failed to digitalize their operations were left in the dark as to when a failure may occur. This put greater pressure on an already-fraught supply chain, with inoperative turbines costing owner/operators millions of dollars.

Most operators have therefore shifted from reactive O&M to a proactive, predictive approach. Likewise, the owner/operators with aging fleets have retrofitted their legacy CMS with more modern technology – this has had a two-fold benefit of reducing the risk of downtime and enabling them to source parts well in advance of needing them, reducing supply chain pressures.

And so looking forward, what does the digitalization landscape look like in 2024?

So, what does the digitalization landscape look like in 2024?

“It is not uncommon for our team to detect 80 failures a year for each 1,000 turbines we monitor on behalf of a client, just on the drivetrain alone. This brings a lot of requirements for planning, decision making and execution to fix all these problems.”

ZHIWEI ZHANG
CHIEF DELIVERY OFFICER, ONYX INSIGHT

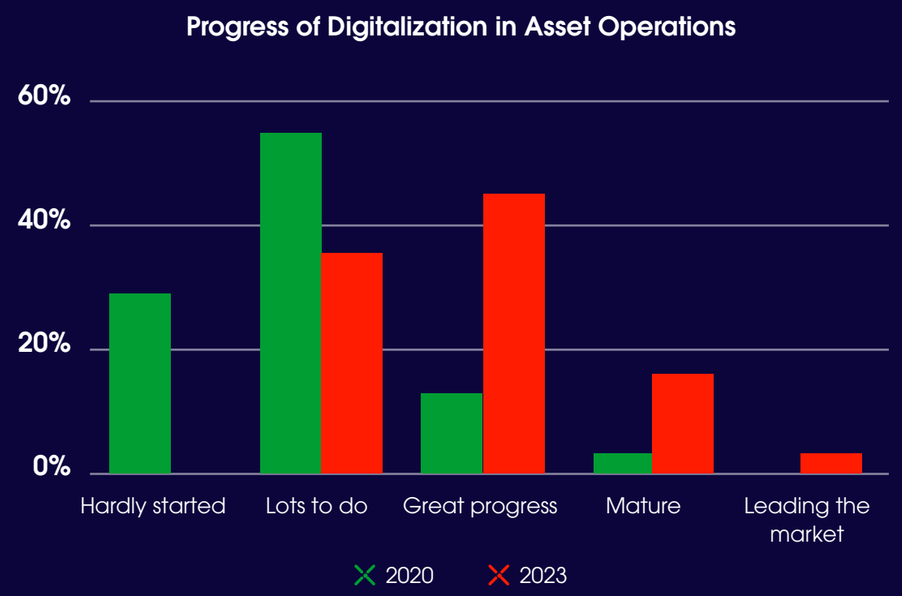
Surge in Digitalization

Since our previous study, the wind industry has seen broader adoption with expanding tools and capabilities including data historians, predictive analytics, and cloud-based solutions such as case management tools for major components. And whilst some projects likely preceded the events of COVID-19, the pandemic was a driving factor behind the shift.

Contributing to the ONYX Insight April 2020 COVID-19 Industry Report, an offshore wind farm owner opined on this, stating:

“Accessibility of wind turbines is poor during normal times. C-19 is further reducing the accessibility and providing a clear business case to move to predictive approaches”.

Putting this in perspective, in 2020, only **19%** of organisations polled had fully integrated digitalization into their O&M strategy.



COVID-19 was, of course, a significant factor in the wider adoption of digitalization, but changes within the industry have also necessitated a greater need for integrated digital platforms. For example, owner/operators are running increasingly diversified technologies across their fleets. This poses a number of challenges for asset owners looking for greater visibility in reporting.

Meanwhile, a greater volume of reliability issues, as well as aging fleets, are contributing towards O&M costs.

This is accelerating the adoption of digitalization in the O&M sphere, with owners clamouring for greater information on their fleet. For example, a number of operators we spoke to opted to retrofit more modern CMS tools across their fleet, whilst others leveraged shadow monitoring tools for turbines under FSA using existing CMS data.

Ultimately, this has been driven by turbines being offline for far too long, whilst waiting for major components to be sourced and installed.

More Work to Do

The industry has made significant progress in the digitalization of asset operations, but work remains to be done.

For example, only **14%** of the industry considers its digitalization efforts to be mature or market leading.

In order to reap the benefits, there are a number of challenges facing owner/operators.

The View from Brazil

"We changed many things and now we don't have to be as present physically.

We learned we can manage the wind farm in a way that is more remote.

We learned we could travel less, visit sites less and still run our business well."

IPP, BRAZIL

What are the challenges around adoption?

Given the current challenges in the market, it's not easy to raise the upfront CAPEX necessary to mobilize a digital data platform. Those who do will reap the benefits as the industry scales to meet the energy transition.

Connecting Data Points

Monitoring a turbine involves collating numerous data points across timeseries, event-driven, sampled, and image data. These all require very different data structures, making storage choice a real challenge.

Internal Adoption

The process of digitalization lives or dies by internal adoption. Change management is crucial here, as well as engaging users early and delivering a good user experience. Doing this improperly can lead to a costly failure.

Vision and Leadership

To get a project off the ground, there needs to be a strong vision, a tight strategy, and a clear scope of objectives. Many failed digitalization projects lacked the leadership and discipline required.

Technology Choices

Deciding whether to opt for single or integrated technologies is key. You also need to ensure that the organization you're working with is experienced with projects delivered at scale and adhere to stringent cyber security protocols.

Enterprise Integration

Ensure your digitalization project accounts for integration with your critical enterprise solutions such as CMMS and ERP systems. Also consider whether Single Sign-On (SSO) is required.

Value Assessment

A trusted relationship with your digitalization partner is essential. Consider their experience around assessing value creation using multiple measures including minimizing lost energy, ensuring the correct weather window for fewer delays, and supply chain optimization.

Where are the key areas of value that senior leaders in wind have identified?

We asked senior leaders to select 2-3 items of greatest value they see from digitalization. This chart shows the most popular responses.

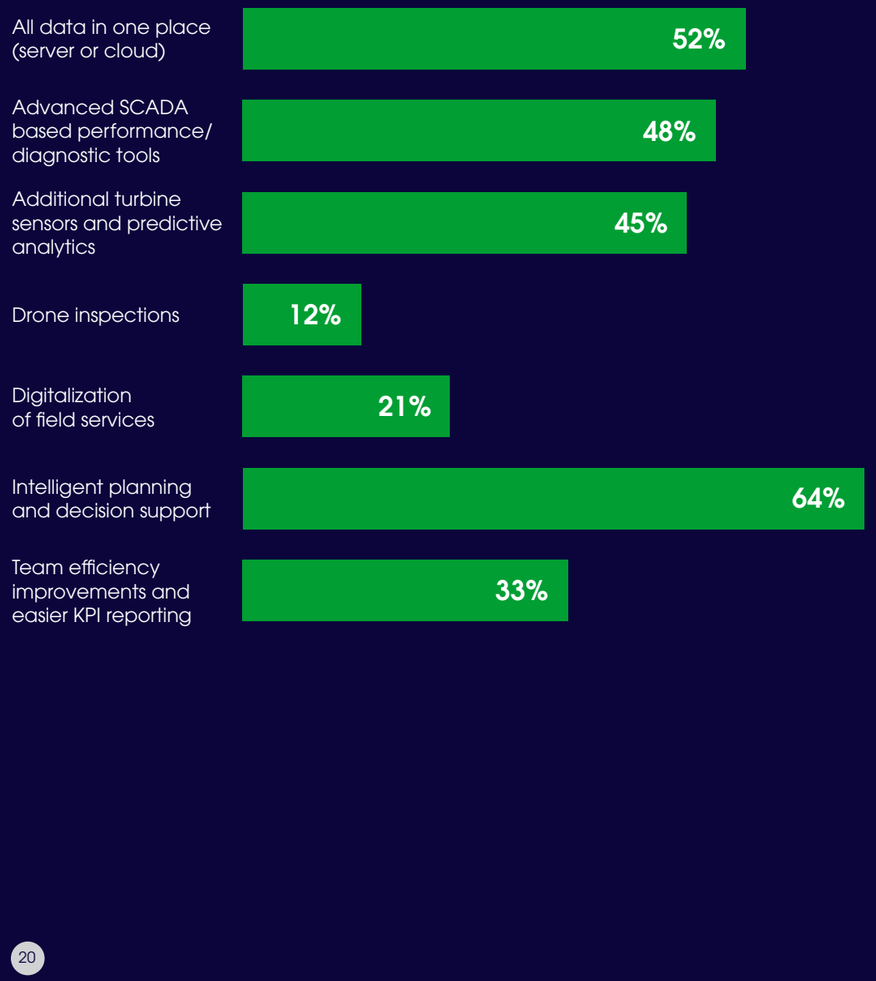
Intelligent planning and decision support is an area needing further industry investment.

Likewise, centralizing data in one place is important because it is the prerequisite to more advanced implementations. For example, intelligent planning is improved with the integration of vibration, temperature, oil and maintenance data.

Advanced SCADA-based performance and diagnostic tools are widely adopted across the industry and contribute great value to owner/operators.

Meanwhile, participants we spoke to are implementing additional turbine sensors and predictive analytics, typically aimed at targeting specific failure modes.

What is the greatest value you see from digitalization?



“The cloud is now ubiquitous in operations – it’s almost a cost of entry to the sector and a requirement.

Data must be accessible and not on some inaccessible on-premise location, because with cloud technology, we can provide access to people to solve problems quickly.”

JEREMY LAW
VP COMMERCIAL ASSET MANAGEMENT, LONGROAD ENERGY

Reliability

Key Insights

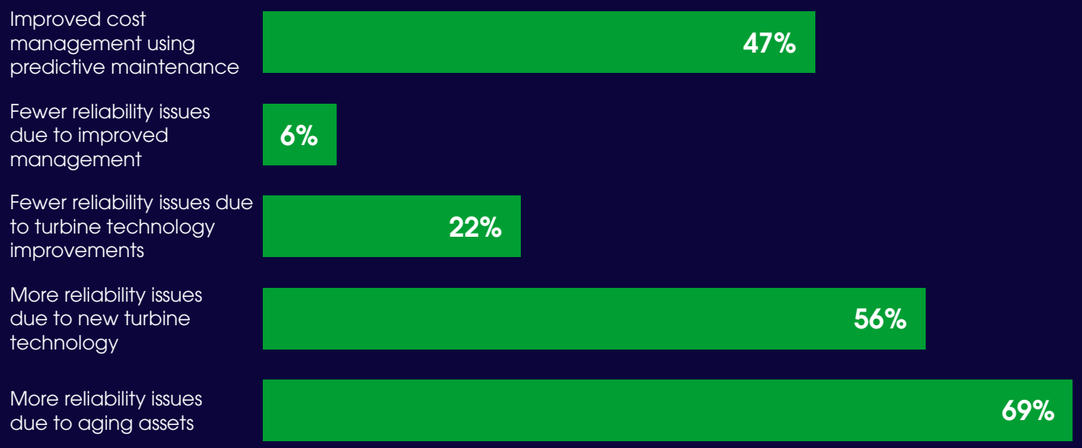
- Participants have expressed reliability concerns with both aging assets **and** new turbines.
- Looking forward, **69%** expect more reliability issues due to aging assets and **56%** due to new turbine technology. Only **22%** expect fewer reliability issues due to turbine technology improvements.
- This uncertainty is making predictive maintenance more important than ever, and the key to improving cost management.
- We are also seeing a growing demand for additional sensors to cover more turbine components (blades, towers, electrical components) as turbines get larger and more complex.

Reliability is the hot topic in the wind energy sector right now, with anxieties about both aging assets and even new turbine technologies.

As the sector matures, turbines are getting older and the failure rate of electro-mechanical systems are increasing with age.

Likewise, the initial operating period of newer turbines are seeing a rash of failures due to shorter development cycles, new turbine designs, and a squeeze on turbine prices. This is resulting in machines that are not durable enough.

Which key factors will impact reliability over time?



The View from India

Whilst manufacturers are suffering similar issues, the main problem owner/operators face is a lack of choice of OEMs.

As a result, some IPPs are only signing new contracts for shorter periods **(7-8 years)** with an option to exit under mutual consent **(3-5 years).**

“Right now, tariffs are too tight to support profitable operation”

IPP, INDIA

Bigger turbines, bigger problems

The wind industry had a boom a number of years ago, and it was during this period that OEMs faced an enormous amount of market demand.

This led to a wide variety of turbine designs, delivered on short cycles to meet the demand of a customer base looking to generate more energy for lower costs and with greater efficiency.

Fast-forward to the present and between the perfect storm of supply chain issues and too many turbine designs to support, OEMs have been losing significant amounts of money, including those paid out in liquidated damages (LDs).

Manufacturers have been locked into a price competition spiral, attempting to produce larger turbines for more competitive pricing. But with bigger turbines produced in shorter production cycles, it’s no surprise that manufacturing quality has diminished. Today, OEMs are looking to streamline their processes and drastically reduce the number of turbine designs.

On the other hand, the more mature wind markets are presiding over increasingly aging fleets. Spain, for example, invested early in wind energy and currently faces a situation where more than 1/3 of their turbines nationally are over 15 years old. This poses a number of questions around repowering and life extension.

It’s important in this situation to act before a failure happens. After all, with aging turbines there is a risk that replacement parts are no longer available from the manufacturer. This, in some cases, leaves owner operators with two options – either pay an eye-watering premium for a one-off order (which isn’t always available) or accept that you cannot replace that part.

“Developers need to push OEMs for a more robust product, rather than the cheapest one.”

VP FLEET OPERATOR, USA

Top 5 Reasons for Turbine Reliability Issues

1) Growing, geographically diverse, aging fleets
2) Rapid growth of turbine size and compressed design cycles for new turbine technologies
3) Cost reduction pressures on the supply chain
4) Declining profitability of Tier 1 turbine OEMs
5) Challenging economic environment and after effects from COVID-19

Automation and Innovation

Automation has long been the key to increasing productivity but in the wind industry's manufacturing circles, it's yet to realise its potential.

Producing such large sizes and at relatively low volumes, when compared to the automotive industry, is one reason.

This requires investment, and higher volumes of a smaller range of turbine models will better support the CAPEX and tooling setup costs. Increasing consistency will feed into product quality if done correctly.

We spoke to a number of manufacturers and the topic of automation came up repeatedly, especially when it comes to blade manufacturing, which is currently a highly labor-intensive process.

To create a blade mold, let alone the blades themselves, the average cost can reach $10m, with some molds taking up to 20 months to manufacture.

But as blades get larger, manufacturing becomes more complex from a logistics point of view.

"Now that blades are much larger, we need automation in the manufacturing process with more modular manufacturing.

How do we scale up with reliability and quality when manufacturing hasn't changed much?

This is where automation can help."

GLOBAL BLADE MANUFACTURER

Advanced blade sensing – the next innovation?

The wind industry has, for the most part, delivered on drivetrain sensing. We can confidently estimate the remaining life of a drivetrain component with the current tools on the market.

To further drive down O&M costs a 'whole turbine predictive maintenance' approach is needed, where all major components have coverage. This involves willingness and leadership to invest in R&D.

Sensor technology has been recently deployed by ONYX to monitor for serial failures of the blade/hub joint for turbine owners.

This is one step on the new frontier of blade sensing, which has a number of failure modes to address.

And as blades are the second most costly component on a turbine, there are great opportunities to be grasped.

Currently, there is no cost-efficient blade crack sensing solution on the market that is accepted as a mature, reliable product whilst remaining affordable. But this is expected to change in the coming years.

"Drivetrain monitoring is now a solved problem. We can detect the majority of failures 6-24 months in advance and only miss 1 in 50.

The next challenge is whole turbine predictive maintenance and ensuring that the rich analytics provided turn into actual actions".

ASHLEY CROWTHER
CCO ONYX INSIGHT

Offshore wind

Key Insights

- Whilst the race for larger turbines has reduced the levelized cost of energy (LCOE) with a higher plant output to CAPEX ratio, it has also been a direct contributor to rising reliability concerns.
- The increasing failure rate of aging assets and early design failures on new turbines have sent ripples through the sector. Many are now questioning announced offshore wind targets.
- Implementation of digital technologies cannot solve all issues. However, it can mitigate the impact of many; from giving investors confidence in their forecasts to enabling cost-efficient operations with predictive maintenance technologies.

Offshore wind is experiencing similar challenges to onshore, albeit on a larger scale because turbines and O&M costs are much greater.

The race to increase turbine size has left the sector in a particularly difficult situation where new turbine technologies are brought to the market frequently, meaning there is scant reliability data available. Compounding this is that older offshore technologies are becoming obsolete too quickly, with limited upgrades and spares available.

OEMs have a more dominant position in offshore wind, where many regional markets are owned by two or three Tier 1 manufacturers. They also tend to dominate in the aftermarket, providing O&M services to a majority of offshore assets. This lack of competition means that any bottlenecks in the supply chain are felt more strongly by asset owners who are reporting longer lead times on spare parts and limited technical resources available.

Access to specialized vessels for major maintenance activities is an even bigger concern. Even in mature regions like UK and Germany, a large number of construction projects means that there are fewer vessels available for O&M activities. In less developed offshore markets such as parts of Asia or North America, this shortage is going to affect construction as well as operations.

Faced with the lack of options and increasing pressure to reduce O&M costs, more offshore asset owners in established markets are beginning to self-perform some or all aspects of O&M after the initial warranty period. Those that do report a reduction in O&M costs and, at some sites, an increase in power-based availability. Taking unscheduled maintenance management of major components in-house has had a significant effect and provides asset owners with greater certainty around reliability and the forecasting of O&M costs.

While larger turbines are the main factor behind the rapid reduction of LCOE in offshore wind, they also mask inefficiencies in offshore operations. Not dissimilar to onshore wind, much progress has been made in digitalizing operations, but a lot of work remains to be done.

The offshore sector has an additional complication brought on by joint venture structures that are typical for offshore projects. These introduce additional complexities around data access, not to mention that any decision needs to be agreed upon by all joint venture partners. Change of ownership is also common for offshore wind farms, and this has implications on the ownership and implementation of centralized data management systems.

“The supply chain is really challenging – if you don’t have spare parts, or vessels you can’t do the work quickly. Planning campaigns is very important. For offshore the vessels make it so much more complicated.”

EUROPEAN OFFSHORE OPERATOR

However, with extra challenges come extra rewards – the value that predictive analytics can unlock in offshore wind is significant across the whole project lifecycle. From defining exposure to new turbine technology risk and specifying plug-and-play CMS systems to mitigate it, through to data-driven life extension planning - there is huge potential to streamline offshore O&M activities, maintain high safety standards and optimise assets’ reliability. The adoption of floating technology will also make systematic adoption of digital tech for offshore operations even more pressing.

The View from Japan

“The Japan market looks less attractive to big turbine suppliers. For example, the APAC HQ of Vestas is moving from Tokyo to Seoul.

My guess is the offshore auction rules and offshore potential in Korea is the driver. Japan requires communication in Japanese language.

Also, auctions are in Japanese Yen and not linked to USD or Euro, which attracts more risk and more costs. This is then less attractive for developers and OEMs“

IPP, JAPAN

Scaling Up: Key Challenges & Opportunities for the Wind Industry

Key Insights

- Permitting is holding back renewable energy targets.
- The Inflation Reduction Act (IRA) is driving investment, but also brings a number of challenges such as market volatility.
- In developing countries, Chinese OEMs may bring more competition to Western OEMs. However, some owners express concerns around the supply chain behind these machines.

Wind farm permits

Wind farms are not being built quickly enough to meet the green targets of governments across the globe. For example, wind farms in the European Union are currently taking longer to permit than to actually build.

Meanwhile, in the UK market, there has been a ban on all new onshore wind farm development since 2015, though this may change in the coming years as the UK Government reconsiders its policy.

In the US wind market, the IRA is incentivizing new farms and repowering tax credits. But permitting is slowing down development – this is especially challenging for offshore as it establishes itself as an industry.

Developments also face long delays to obtain interconnect agreements.

"Two major issues are constraining US offshore wind deployment: challenges in securing permits and cost inflation.

Regulatory uncertainty and a slow approval process are slowing the United States' deployment of offshore wind. Project developers stress that there are not enough regulatory personnel to quickly approve projects.

Meanwhile, projects are also constrained by rising installation costs which are largely macroeconomic in nature. The sector is not immune to broader inflationary forces and rising interest rates, while trade policy and steel tariffs are also raising costs. Still, there are also industry-specific cost pressures, including limited port and vessel infrastructure and skilled labor shortages."

ATLANTIC COUNCIL, JUNE 2023

The impacts of the Inflation Reduction Act

The Inflation Reduction Act, passed into law in 2022 by President Biden's administration, led to a green bank being established. This meant that tax credits would be ring-fenced for American manufacturers and energy producers.

And for the most part, there has been broad support for the IRA from the companies we spoke to. It's driving investment, especially in repowering.

Owners with aging turbines face a number of challenges, including lack of available parts, OEM financial performance, and reliability issues harming their fleets' performance.

The IRA enables these owners to gain a fresh start, perhaps with a new PPA (power purchase agreement), a clearer investment plan, and also a far shorter development cycle. After all, land lease and permits only need to be revised, not started from scratch.

However, in some cases, the IRA is leading owners to rebuild perfectly well-operating energy plants, which is not conducive to helping the environment.

There are also practical concerns around the IRA's implementation. It can mean that older assets are adversely affected competitively, compared to newer assets.

Some IPPs we spoke to repeatedly cited that solar has been the main beneficiary of the Act, rather than wind. The reality is that solar has a far shorter development cycle, taking roughly 3 years on average to complete a project vs 6 years in wind (after securing land leases). This makes meeting growth targets a challenge.

The benefits have been said by some to be skewed more in favour of the tax equity investor, rather than the IPP. Tax equity investors are guaranteed a stable and clear return, whilst equity investors (usually IPPs) can see some highly volatile returns in some markets, particularly ERCOT. This risk/return environment can be a deterrent for IPPs to invest.

Organizations will use the opportunities afforded by the IRA to invest in transmission projects. We may see more efforts like Pattern's SunZia Wind and Transmission project (although this was planned pre-IRA), where investment is made to get power from where it can be generated, to where it can be sold. Pattern expects a total £20.5bn benefit from the project, supplying 3 million Americans with clean power annually.

"Whilst the IRA has provided the wind sector with more support, the reality is that we can build solar projects faster and cheaper than in wind."

JEREMY LAW
VP COMMERCIAL ASSET MANAGEMENT, LONGROAD ENERGY

The emergence of Chinese turbines

Competition and market demand has historically forced OEMs to build bigger turbines, much faster and at greater scale. This has led to the current situation where OEMs have too many models and too few staff, with reliability suffering as a result. For context, it's worth noting that the major Western OEMs all made losses last year. Some more significant than others.

Turbines manufactured in China have been the exception to this rule. In fact, Chinese-made turbines are making headlines right now, with larger machines being produced much more cheaply than their Western counterparts.

So, what does this mean for the wider industry? We spoke to a number of global IPPs and owner/operators, plus a Chinese OEM for their perspective on the growth of the Chinese market.

"We don't currently have any Chinese turbines, but we have analyzed the market.

Because we have no experience of these turbines – not just from a quality perspective, but also aftermarket service, OEM support etc. - we are very careful about it.

Based on our experience with components made in China (bought by Western OEMS) we have seen quality problems. There are problems in manufacturing of the main bearing/shaft fit/seals."

MAJOR EUROPEAN IPP

Reliability and the aftermarket

Whilst Envision and Goldwind have become established names in the wind market, concerns remain amongst site owners around reliability and aftermarket support.

A lack of cost conformity with competitors is also a reason for scepticism around reliability. Are the low prices financially sustainable and how much real-world testing data is available for these machines?

Meanwhile, with supply chain volatility amongst the biggest concerns for survey respondents, parts availability was also cited as a concern.

So, where are Chinese turbines picking up in popularity?

Australia's fleet include a number of Chinese turbines, whilst emerging markets such as Brazil and South Africa have both invested heavily.

Meanwhile, an IPP based in Turkey also expressed an interest in adopting Chinese technology.

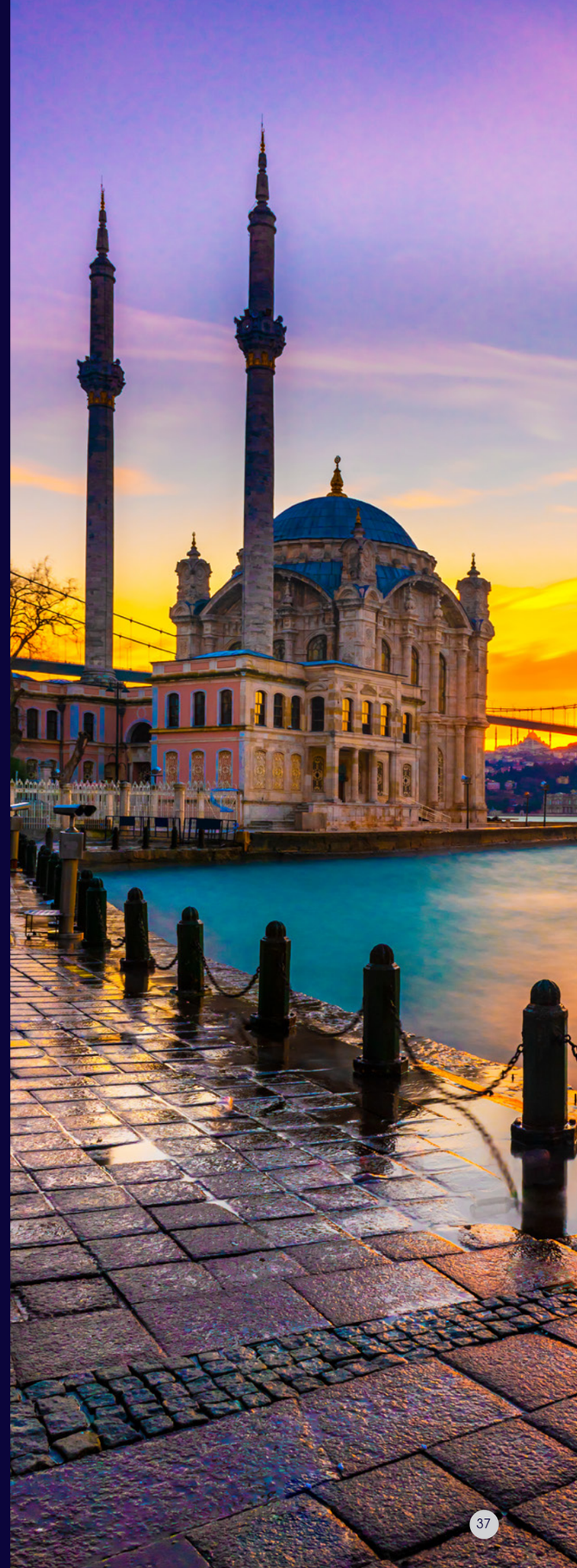
The View from Turkey

"This year we are considering it (Chinese turbines).

We have a site with 10 turbines at the permission stages. After finishing that we will order turbines and Chinese options will be considered.

Currently, there are two Chinese companies in Turkey (Goldwind and Envision) and their turbines have had positive results during their two-years on the market."

TIER 1 IPP, TURKEY



Ever-Changing Winds: Looking to the Future

The wind industry faces a series of ever-changing winds, and having covered the most pressing challenges, it's time to look to the future of the wind industry.

Intelligent planning through digitalization

Intelligent Planning is the next stage of digitalization for wind farm owners. What if you could accurately predict which individual component would fail next and when? What if you could map maintenance actions against cost, risk, and part availability across your whole fleet?

Predictive maintenance in its current form does a relatively good job of this, with drivetrain monitoring all but solved. But as lead times increase and downtime becomes more costly for non-drivetrain issues, we need a smarter approach to interpreting turbine data across the whole turbine.

Based on conversations with wind farm owner/operators and our own internal digitalization champions, we propose the following three-step process.

Detect. Act. Optimize.

So, what does the vision for Intelligent Planning look like?

1 Detect
From pen & paper to dashboards

Detecting is the primary stage of the process. This is about getting all of the essential data into a single place. This may be SCADA data, oil sample data, vibration data and other relevant information.

The drivetrain has been mastered by predictive maintenance, as evident by ONYX customers reporting a 30% cost reduction. The focus now needs to shift to other turbine components. Blades are the second most costly component outside of the drivetrain, which explains why technology companies are investing heavily in blade monitoring.

But structural elements of the turbine such as the tower & foundation also need tools that can gather a larger amount of data, faster.

Capturing data on both of these areas is currently a manual process and reliant on visual inspections. For example, tower strain gauges, whilst accurate, are very manual and involve at least one engineer on-site.

And whilst blade inspections have been improved by autonomous drones, it's still manual data that can only be captured periodically.

In short, rolling out practical and effective technology for additional components such as blades, power electronic systems, and structural components is key. This will make the post-detection stage (digitalization) much easier and far more streamlined, such as actioning repairs.

"The future of O&M is through more intelligent ways of planning maintenance.

A CMS has detailed information about a turbine's condition, whilst the CMMS has all the information about maintenance planning.

However, these two systems are totally separate. The key to Intelligent Planning is getting the CMS data to inform the CMMS so that maintenance can be automatically optimized based on turbine conditions.

This means consolidating all the raw data (from PdM data to spare part, work order, and resource data) and being able to assign the relevant metadata that gives end users actionable results"

WON SHIN, VP PRODUCT OPERATIONS
ONYX INSIGHT

2 Act
From data to actionable intelligence

Data is powerful, but only with context. It's simple enough to ingest raw data into a platform, but without the associated metadata that delivers a site team with actionable insights, it's just added noise.

And so whilst detection is performed by an Independent Service Provider (ISP), or an owner/operator's HQ if they're self-performing the condition monitoring, the site team often use very different tools. For example, the monitoring team may use a data analytics suite whilst site teams tend to use CMMS systems such as IBM Maximo.

Data from a monitoring tool isn't aways analogous to the data presented to the field team, and so this technology gap between the two teams is where major inefficiencies and suboptimal decision-making occurs.

The next step in digitalization and intelligent planning therefore needs to be a tool or platform that consolidates data from both these disparate platforms and unifies the decision-making process.

3 Optimize
From manual action to automation

The final stage of intelligent planning concerns automating the implementation of recommended actions. With so many things happening across your fleet, the process of control over effectiveness of O&M actions is very important.

How effective is your CMS system? What are the largest categories of OPEX spend and how consistent are they across different sites with the same technology? How does your power performance and OPEX compare with your peers?

The industry is getting more comfortable with implementing individual digital solutions, but needs to make them part of the day-to-day operations and reporting. Being able to aggregate information in a global failure database and use an engineering knowledge-embedded algorithm or AI tool, will remove a lot of the intermediary work.

"Once analytics find an issue, we need to plan, schedule and deliver the work and get the feedback. This is closing the loop.

An end-to-end and holistic solution is really difficult to implement, but needed. It needs to be integrated with large company systems and processes and there is nothing available out of the box.

That is what makes it really difficult."

EUROPEAN OFFSHORE OPERATOR

Solving the Skills Shortage
Digitalization & Skill Transferring

Hiring engineers and technicians has never been straightforward, both in the renewables industry and beyond. And although talent acquisition issues have improved post-COVID, challenges remain.

The interviews highlighted some regional differences. For example, on average, it's easier to hire wind professionals in Germany than in the UK for example, with Brexit an undeniable factor.

Part of the reason that the wind industry struggles with talent acquisition is location – a factor that does not affect other forms of energy to the same degree. Thermal plants for example, are usually concentrated in a critical mass. Whereas wind is more fragmented and requires workers to relocate. However, this is predominantly limited to technicians and construction teams.

The great rotation

Running contrary to this (but equally challenging) is **The Great Rotation.**

Essentially, the increase in working from home means that unless you're climbing a turbine or working in construction, almost anybody can go for any job.

At first glance, this means a wider talent pool. It also means greater competition for individuals with specific skills. In short, this has seen recruitment costs rise significantly over the past couple of years, whilst retention issues mean professionals in wind tend to move around.

What's the solution to the skills shortage?

There are two strands to this – digitalization and skills transfer initiatives. The former will help make existing teams' roles easier and the latter can be an essential means to boosting workforce numbers in the wind sector.

Fault finding, for example, takes a lot of time. Digitalizing this process by building databases and training AI models & algorithms, can speed up the process, enabling teams to spend more time addressing the solutions.

Ultimately, this gives decision-makers a clearer view of O&M campaign costs and progression.

APAC respondents cited **team efficiency improvements and easier KPI reporting** as their must-have enabler from digitalization.

Embedded digitalization:
Augmenting talent with tech

Automated Reporting

Optimized planning and digitalized safety forms allow for simple data capture.

Automation frees up time to be spent on ensuring quality data.

Effective Communications

Information spanning different inboxes and spreadsheets has long been a major comms challenge - modern software tools can now address this challenge, delivering a single source of truth.

Decision Support

Fleet statistics, fault libraries, and access to all data in one place codify engineering expertise and enable swift, accurate decision-making.

Whole turbine predictive maintenance
Challenge area: blade monitoring

Over the last 15 or so years, blades have almost tripled in size due to the demand for greater energy generation at a lower cost. The demand for larger rotors hasn't stopped and it's unlikely to anytime soon.

Because of this, blade engineers have gradually been pressured to squeeze as much performance out of the component as possible. This has led to higher stresses as more of the composite material's strength is utilized.

And so, the impact of this is that previously smaller external influences in the field now have greater impact on the blade. For example, twisting of the blade whilst in operation puts far greater pressure on the load structure.

The complexity of blade design now means that using more composite strength leaves less room for errors and defects, both in manufacturing and in the environment the turbines are operating in.

As a result, the consequences of a catastrophic failure are significant.

In the past, a blade failing would mean an expensive replacement. However, these days a failure could destroy the entire turbine. And with this costing almost $10m dollars, including clean-up, downtime, and the replacement turbine – asset owners cannot afford major blade failures.

Compounding this is the 6-10 month timeframe for the replacement blade to be procured, meaning a wind turbine will be idle for an extensive period of time. And if you're facing a serial defect, costs add up fast.

This is why R&D into blade sensing is desirable. The cost of failure is no longer tolerable for asset owners. Suppliers in the industry have responded with a series of products, largely around blade bearings and electrical components, but we're yet to see a commercially viable blade sensing product succeed on the market.

Part of the reason for this is prohibitive cost, another is prohibitive technology. Experiments with SCADA data for blade sensing are limited to 10-minute and 1-minute interval data, which means that typical blade faults cannot be picked up within this signal. Obtaining 1s machine data helps a great deal but is not something that is widely available, so engineers are experimenting with additional sensors on top, such as accelerometers, strain gauges, current sensors and displacement problems.

These overlay systems sit outside the OEM control system and can deliver greater flexibility for data acquisition. The data scientist can then have the data they need for an effective fault detection analytic.

R&D continues in the realm of blade sensing, with the expectation that a solution will be found in the coming years.

A more financially sustainable industry
Healthy OEMs will accelerate decarbonization

The route forward as we head into these ever-changing winds must include long-term thinking.

In recent years, the industry has built ever-larger turbines without considering the ramifications for financial sustainability. And whilst larger turbines have been a big driver behind the reduction of the LCOE, they've also masked problems around turbine reliability.

The industry needs to solve the OEM crisis collectively because it is no longer sustainable. A healthy manufacturing base is critical for the industry to thrive and continue down the path to decarbonization.

The inflation and supply chain issues have not helped. Right now, there are too many players in renewables seeking to maximise short-term returns rather than invest into strategies and tools to enable operation of their assets in a sustainable way.

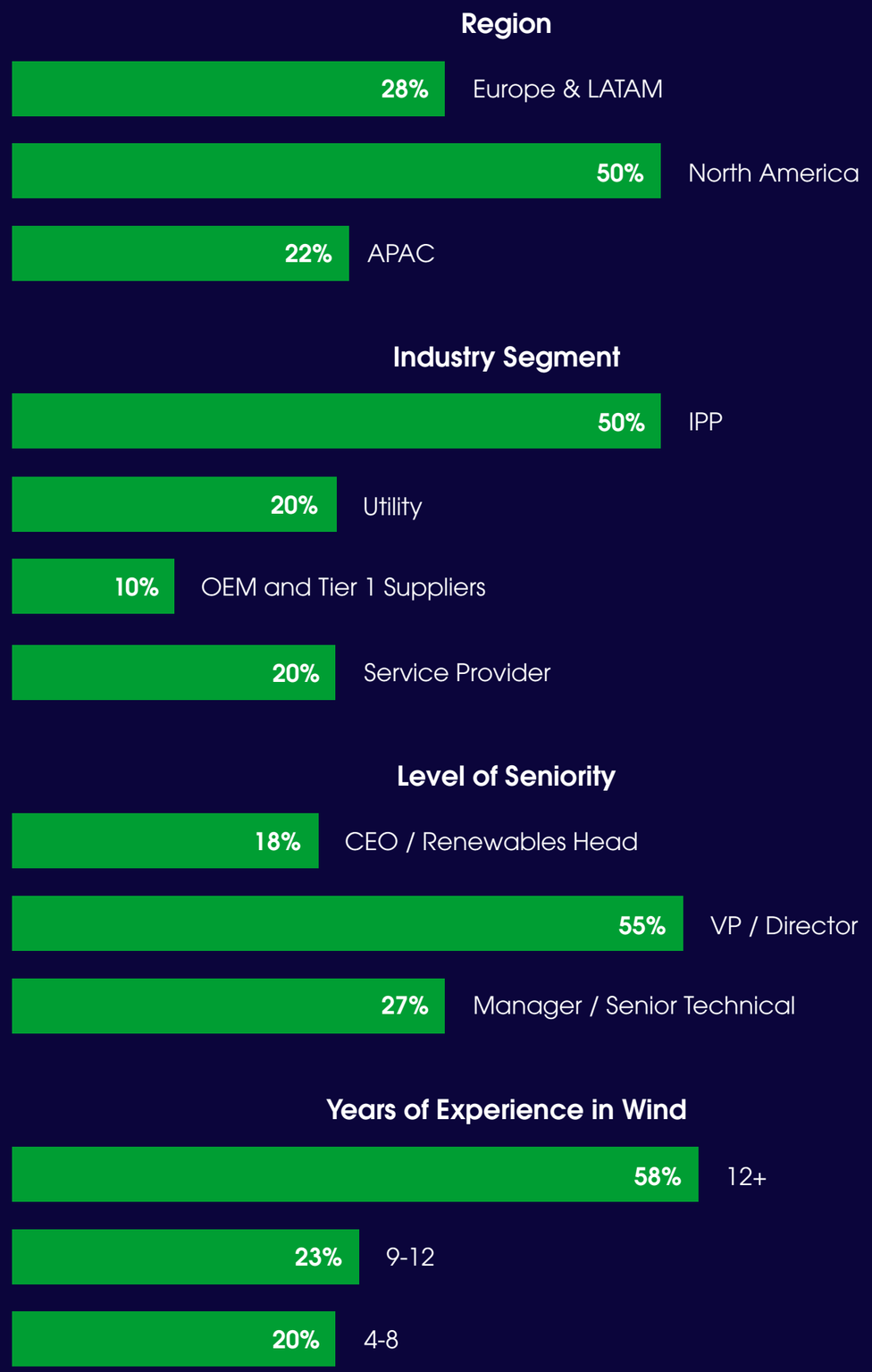
We need to see wider adoption of predictive maintenance, and indeed whole turbine predictive maintenance is where the industry is heading. This will see all major components possess the required sensing and analytics for all the expected failure modes, enabling us to provide asset owners with a healthy lead time to take action so that we can all enjoy a sustainable future.

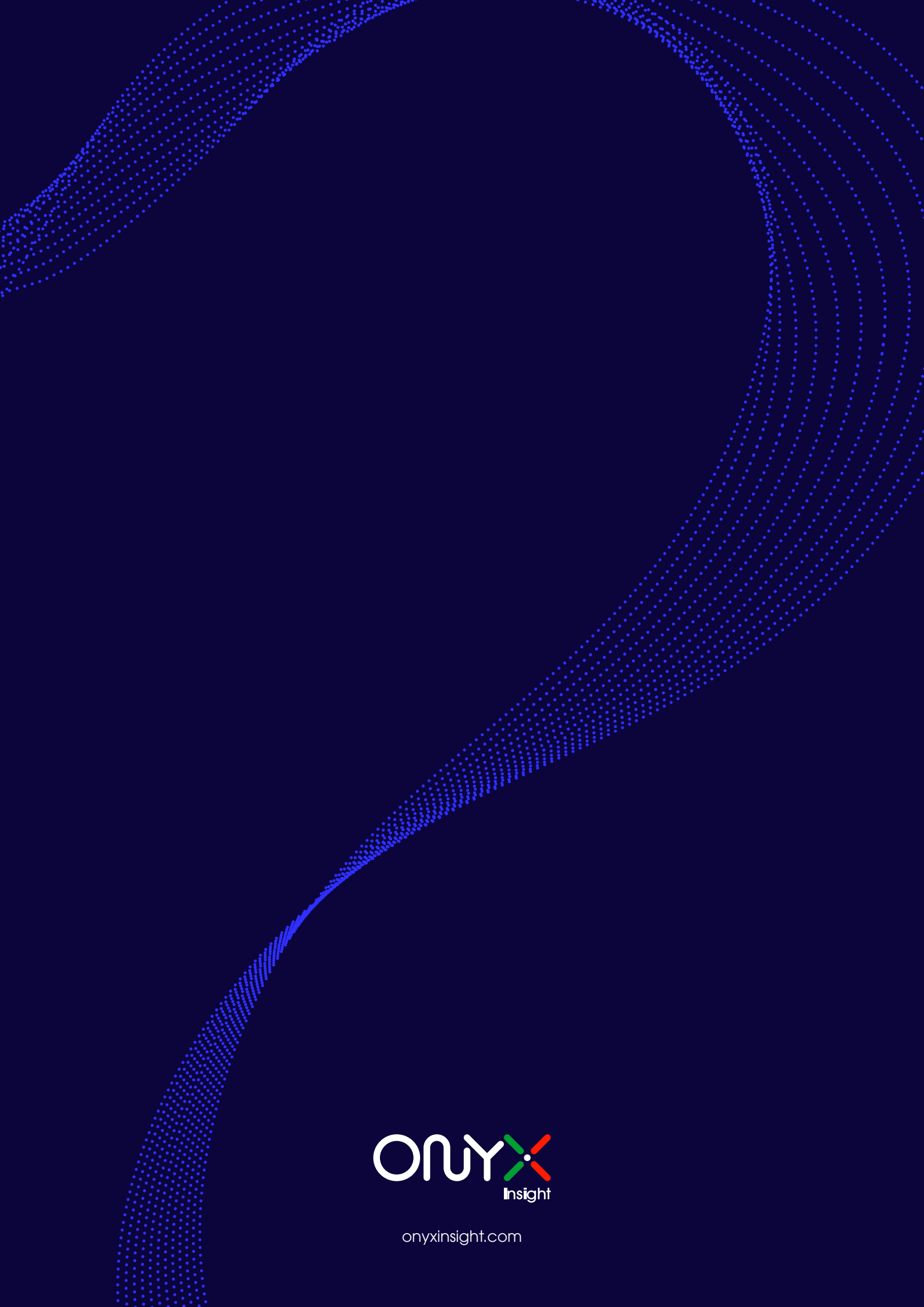
"The industry needs several strong OEMs, with good competition. In Western offshore wind, the market is dominated by 3 OEMs, which is not enough.

We are under pressure to deliver sites for less $/MW and those pressures are being pushed down the supply chain, including OEMS, and as we know, some of them are struggling."

MAJOR GLOBAL OFFSHORE IPP

Breakdown of survey participants





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