World Utilities Congress

Host TAQA طاقة

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INSIGHTS REPORT

INNOVATIONS IN WIND TURBINE TECHNOLOGY

And their impact on the wind Industry

Prepared for World Utilities Congress by:

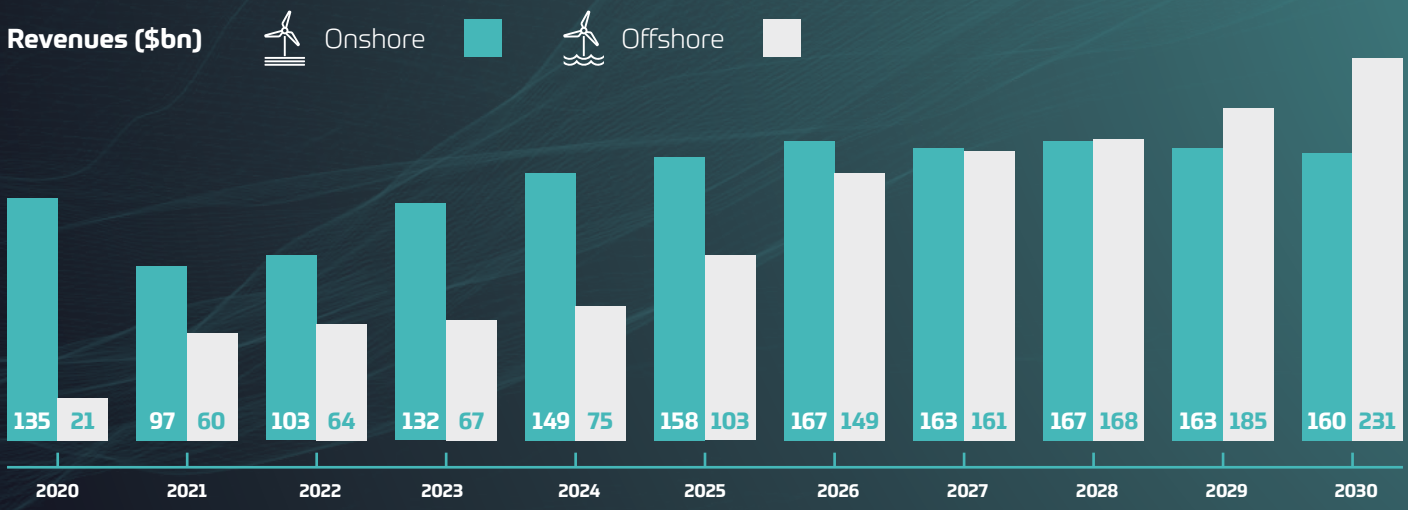
FROST & SULLIVAN

RECENT INNOVATIONS AND THEIR IMPACT ON THE WIND INDUSTRY

2023 was a challenging year for the wind industry. Although investment increased from $167 billion in 2022 to $200 billion in 2023, much of that was due to cost inflation, as opposed to a significant increase in capacity. Onshore wind continued to face challenges in many markets because of regulatory constraints, and the increase in financing and project costs compounded this. Some major offshore projects were either put on hold or abandoned.

Frost & Sullivan believes this is likely to be the low point for the industry, and the medium-to-long-term growth prospects remain strong. Regulators are already acting; the European Union's Renewable Energy Directive III requires member states to simplify planning laws and create zones for renewable energy development. Incentives for offshore wind have been increased, and new developers are starting to take stakes in the market with a view to the longer term. For many countries, offshore wind is fundamental to them being able to achieve decarbonization goals. Frost & Sullivan forecasts that wind investment will increase to $377 billion by 2030, with offshore becoming the largest revenue segment in 2028.

Cost inflation and financing costs have peaked, ut they remain significantly higher than two years earlier. Subsidies and incentives will help entice project developers, but returning to a trend of cost reductions is critical for the industry's future development. This is where technology innovation can play a role.



BELOW ARE 9 INNOVATIONS THAT FROST & SULLIVAN SEES BRINGING MATERIAL BENEFITS TO THE WIND INDUSTRY:

Timeframe for Significant Industry Impact ■ 2024-25 ■ 2026-2028 ■ 2029

Advanced blade design and materials

Increase efficiency and power capture of wind turbines; advanced materials prolong turbine life spansand materials

Advanced Gearbox Designs and Direct Drive Turbines

OPEX and increase efficiency

Artificial Intelligence (AI) and Machine Learning (ML)

Reduced downtime and increased operational efficiency

Mesh networks

Provide real-time robust, scalable, and efficient communication solutions, improving operational efficiency and response to anomalies

Robotic and Drone

Automated drones for blade inspection, robots for servicing, manufacturing

Advanced ESS

Store excess wind energy for use during non-generation periods

Additive Manufacturing (AM)

Can lead to more localised production, reducing transportation needs

Blockchain

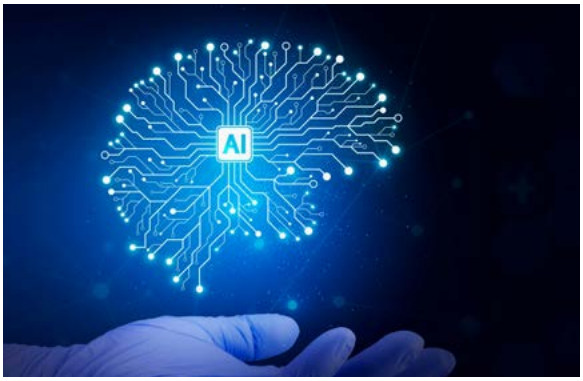
Facilitates transparent management of supply chain and distribution of energy to consumers

Quantum computing

Potential to revolutionise weather modelling simulations and energy forecast optimisation

Advanced blade design and materials are something the industry is already actively innovating on and adopting. Swept blades tailored to specific conditions can increase annual energy production by 5-10%, lowering the LCOE. Blades equipped with sensors and predictive analytics can reduce operation and maintenance costs by 15%. Modular blade designs simplify logistics and cut installation costs by 20-25% at remote offshore sites. The use of durable advanced composites like carbon-fiber-reinforced polymers can extend turbine lifespans up to 30 years. If key technical challenges around manufacturing, logistics, installation and recycling can be effectively addressed, advanced blade technologies can make a material difference to future industry growth, particularly for the offshore sector.

Another component innovation relates to **Advanced Gearbox Designs and Direct Drive Turbines**. These technologies bring a number of benefits. They can ensure higher efficiency and reliability as single-stage designs with hydrodynamic bearings enhance efficiency and turbine availability. A significant portion of the servicing cost of a wind turbine relates to the gearbox, so simplified drivetrains reduce O&M costs. Adopting medium-speed generators enhances efficiency and reduces material costs. SiemensGamesa, Vestas, GE and Goldwind are all incorporating direct drive technology into their newer models.



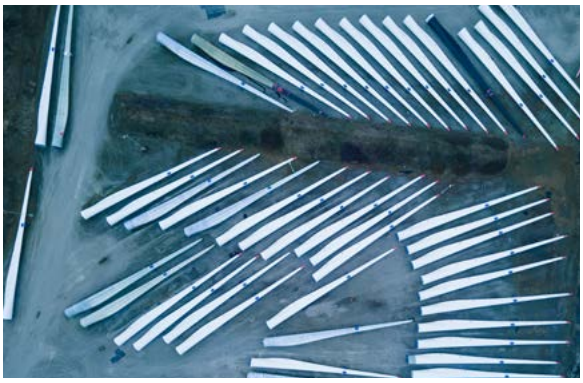
Artificial Intelligence (AI) and Machine Learning (ML) are some of the hottest topics in the global economy at this time and the wind sector is no exception. They are already being deployed for areas such as weather and wind forecasting, turbine performance optimisation, predictive maintenance and condition-based monitoring. Further enhancements will make these solutions run even better. Key providers of solutions in this space include IBM, which provides Maximo for renewables, offering visual analytics and cognitive insights for turbine optimisation and AI-based weather forecasting, and US-headquartered Uptake Technologies, which delivers industrial AI for predictive maintenance, failure analysis, and data analytics dashboards, enhancing offshore asset monitoring.

AI and ML are nothing, however, without sensors and the data from these needs a robust network for transmitting data. **Mesh networks**, with their decentralized design, enhance the reliability, scalability, and flexibility of wind assets. They support monitoring, predictive maintenance, and improved operational efficiency by reducing transmission losses and enabling better forecasting. Despite challenges like interoperability, harsh marine conditions, and cybersecurity, advancements in resilient routers, hybrid topologies, and integrated IoT are leading to more robust and efficient networks.

Robotic and Drone technology is now widely used within the wind industry. The main focus to date has been on inspections to try and detect faults and determine when maintenance will be needed or to see what has happened when there has been a failure. The future will see robots and drones playing a more active role in repairing wind assets, independent of human involvement. Rope Robotics offers a patented robot that autonomously repairs wind turbine blade erosion, doubling the efficiency of manual methods. SkySpecs offers autonomous drone systems for automated inspections, surveys, and AI-enabled damage analysis of wind infrastructure. Drones can also play a role in the logistics of wind farm construction, which has been a major bottleneck for projects in recent years. Danish wind developer Orsted is the world's first wind company to use autonomous giant drones to transport cargo to its offshore wind farms.

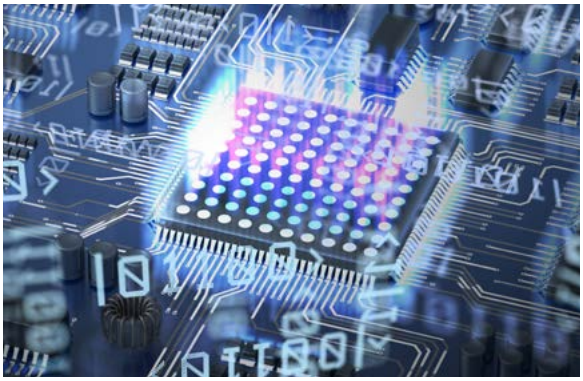
Innovations not only relate to the turbine itself, but to the complimentary technologies that can make asset ownership more attractive. One continuing challenge for the sector is wind curtailment. China suffered from this when it rapidly increased its wind capacity in the mid-2010s, although it has managed to reduce curtailment rates in the past 5 years despite continued strong growth. But the issue still persists, and other country markets are finding similar issues. A number of countries in Europe, such as Denmark, Germany, and the UK, can get in excess of 40% of their electricity from wind power if the conditions are right. Combined with solar PV output and this can lead to more electricity than the European region can use, leading to low prices and electricity wastage. To solve this problem, **Energy Storage Systems** need to be deployed. These can be co-located with wind farms or in different locations on the grid. Lithium-ion batteries dominate this market, but alternative technologies are gaining prominence, particularly as the duration becomes longer. Vanadium, iron and zinc flow and non-flow batteries all have specific use cases. There is also the potential for non-battery storage, particularly for durations exceeding one day. Wind OEMs and developers need to expand their partnerships in this space to take advantage of the solutions available.

WHAT ABOUT THE MEDIUM-TO-LONGER-TERM FUTURE?



Additive Manufacturing (AM) presents a promising avenue for revolutionising the wind industry by enhancing the efficiency, sustainability, and customisation of wind turbines and components. The supply chain is a major issue for the industry, so anything that could enhance this process would be significant. While AM faces challenges in scale, material integrity, and regulatory aspects, ongoing advancements in technology and material science are steadily overcoming these obstacles.

Blockchain created a massive buzz when the concept first gained prominence in the mid-2010s. Since then, progress has been patchy. Blockchain faces challenges in technological maturity, regulatory clarity, ecosystem coordination, and insurance implications. As it matures, it is expected to revolutionise various aspects of the industry, from energy trading to supply chain management, making renewable energy markets more efficient and transparent. However, successful integration depends on addressing these technical, regulatory, and social challenges.



Quantum computing is essentially the next generation in computer technology that will enable problem-solving to occur much faster than it does today, meaning overcoming complex challenges that we cannot solve today. Quantum computing shows immense promise to tackle some of the most pressing optimisation problems in the wind industry, including turbine micro-siting, O&M scheduling, and electricity trading. It offers a sustainable pathway to lower costs and increase revenues. However, adoption barriers should not be underestimated, and close collaboration with specialised quantum firms is key to developing a competitive edge.

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Hosted by TAQA, the World Utilities Congress, scheduled to take place in Abu Dhabi from 16 - 18 September 2024, serves as an international platform that brings together global energy leaders, policymakers, innovators, and industry professionals from across the power & water utilities value chain to discuss the major trends and challenges shaping the industry as utilities worldwide work to deliver secure, sustainable, and affordable energy.

This congress will provide a vital platform for the sector to engage in discussions about the role and pace of decarbonisation in the utility industry's future. It will also showcase the latest innovations and solutions aimed at establishing a renewable utilities sector.

With over 180 global exhibitors and 12,000 utilities professionals expected to attend, seize the opportunity to explore the latest trends and innovations in power generation, transmission and distribution, nuclear energy, water management, and desalination.

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