Leveraging lidar for offshore wind energy

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Offshore wind is accelerating

Around the world, offshore wind energy is gaining speed. Growing interest and the project pipeline in Europe, China, and other parts of the world are expected to contribute around 20% of new installations by 2025 — impressive growth compared to 2020 estimates. As the world's largest regional offshore wind market, Europe is expected to maintain steady growth. China is expected to continue dominating the Asian market challenged by such countries as Taiwan, Japan, and South Korea. The United States is entering the offshore wind market with developers planning to implement about nine gigawatts (GW) of offshore wind by 2026.

Offshore wind farms promise excellent wind availability and energy capture, do not disrupt communities, and are immune to many common performance degradations that come with complex terrain and onshore wind farm crowding. They also bring a new set of challenges for wind measurement that require new practices and technology, including:

- Accurately assessing wind characteristics for very large turbines and areas
- Obtaining precise wind data on the water, at long ranges from the shoreline
- Operating in harsh, salted environments far from maintenance resources

These challenges are compounded by the fact that met masts are often either impossible or prohibitively expensive to deploy and maintain offshore. Even if a met mast is feasible, it cannot easily measure up to the full height of today's turbines.
All of these factors have made new, reliable ways of assessing the wind even more critical for offshore projects. Fortunately, remote sensing solutions are already proven, trusted, and ready.

Offshore applications: Solution matrix

Lidar systems are comprehensive, compatible, and simple to deploy and repurpose throughout the life cycle of an offshore project. Because they are so easily integrated, they can grow with you as your needs change.

Lidar Type	Wind Resource assessment / pre-construction				Construction / commissioning		Post-construction / operations		Post-construction / research					
	Green field	Platform available	Nearshore situation or platform close to island or lighthouse	Farm extension Impact of existing farms	Craning Ship operations optimiza-tion	PPT - Contractual Power Curve	Permanent wind monitoring Off-grid compensa-tion	PPT during operations	Blocking Effect Under-stand wind farm layout impacting wind ahead	Wake losses studies Under-stand production intra-farm losses	Wind farm wake effect Impact of existing wind farm on neighbors and extension	Turbine control Cost reduc-tion, AEP in-crease	Wind farm control Global increase of farm production	Short-term forecasting Monitor upcoming wind minutes in advance
Offshore – buoy mounted +vessels/ ships/float-ing drones	●													
Offshore – used fixed		●	●		●		●							
Nacelle-mounted						●		●				●		
Long-range scanning			●	●					●	●	●		●	●

Offshore use cases and examples

Lidar is meeting many previously unmet needs for offshore developers and operators, and can also provide critical data for studying and implementing wind farm extensions. Here are some of examples of the most common and beneficial use cases for which lidar is especially well-suited.

DNV: Analysis of lidar for WRA

Wind Resource Assessment (WRA) is the make-or-break point for any wind farm project. Lidar supports the challenges of WRA to prove wind availability and characteristics, essential to ensure project viability and return on investment. Lidars can facilitate offshore WRA in several ways including floating lidar systems, offshore vertical profiling lidar, and scanning lidar.

As the world's leading classification society, DNV is a recognized advisor for the maritime and other industries. The organization provides highly acclaimed testing, certification, and advisory services to the energy value chain.

DNV presented a detailed analysis in 2020 to compare today's most commonly used wind measurement technologies: met masts, fixed lidar, floating lidar systems (FLS), scanning lidar, and other methods such as met buoys.

The organization focused their analysis on floating lidar technology by reviewing:

- The Carbon Trust Offshore Wind Accelerator Floating Lidar Roadmap
- Sources of uncertainty and variability in determining bankable energy production assessments
- Wind measurement uncertainty using an FLS uncertainty calculation framework (IEA RP18: Floating Lidar Systems, 2017)
- Current industry guidance from OWA, IEA, and IEC

Among their findings:

- Lidar was shown to provide better data and modelling with reduced uncertainty and risk
- Costs on average 80% less than met masts to develop and deploy
- Achieves the best practice performance criteria set out by the Carbon Trust OWA Roadmap

AKROCEAN: FLS validation

DNV completed an independent validation assessment of the WINDSEA floating lidar offshore wind measurement device on behalf of AKROCEAN, an organization providing services for offshore monitoring and site assessment*.

From April to October of 2018, DNV completed the validation process off the coast of France. During this time, the FLS was subject to a wide range of weather conditions and achieved an overall post-processed data availability above 95% at the 51m, 91m, and 111m configured heights. The device also recorded wind speed and direction data with an accuracy in line with CT OWA Roadmap best practice acceptance criteria.

*DNV, "Validation of the WINDSEA_02 Floating LiDAR at the Fécamp offshore platform", Ref. L2C149488-FRPR-R-01, Rev. C, 05 April 2019

The results at these heights showed the verification uncertainty levels of the unit ranged from 1.5% to 3.1% for wind speed bins from 4m/s to 16m/s. These are important indicators for wind farm developers to:

- Obtain an accurate estimation of the wind resource at a potential offshore wind farm site
- Reduce project uncertainty
- Achieve better financial conditions for project realization It also contributes to reduce the levelized cost of energy — important for helping to move the offshore wind industry forward.

First project of AKROCEAN in France after validation by DNV:

250 + 250MW floating project 12NM from the coast 80~100m of depth

Wind and Metocean studies and public consultation launched by French Energy Ministry in 2020 =>Tender 2021 (first 250 MW)

Engie: Validate wind modeling with scanning lidar

Engie is a manufacturer and integrator of renewable energy solutions for wind, solar, and marine applications. Based in France, the organization is dedicated to advancing and digitalizing renewable energy and zero-carbon transition worldwide.

The accuracy of wind models in offshore conditions are generally higher due to lack of appropriate parameterization schemes for resolving the land-sea interaction effects. To assess the accuracy of the offshore models, Engie conducted a six-week campaign at one of their offshore wind farms off the coast of southern France.

The campaign included two comparisons: scanning lidar vs. mesoscale modeling and scanning lidar vs. vertical profiler. The experiment setup included a scanning lidar on the coast to measure accurate wind speed and direction at multiple distances and heights above mean sea level, and a vertical profiler on the coast to correlate the measurements from offshore to onshore conditions, to assess the land-sea interaction effects. Profiles of wind speed measurements at 5km and 9km from the scanning lidar were assimilated to the offshore wind model to reduce the bias and improve the overall assessment of the Annual Energy Production (AEP) of the future wind farm.

Scanning lidar vs. mesoscale modeling findings:

- Discrepancies among sectors were significant:
  relative error observed for southeast winds is three times as much as northwest winds.
- Wind direction measured by the scanning lidar are in line with mesoscale data at 5km 100m height.
- The comparison between the scanning lidar and mesoscale data showed that it was possible to apply a correction factor to the mesoscale data using the scanning lidar as a reference.

Scanning lidar vs. vertical profiler findings:

· Both lidars were deployed on the deck of a cargo boat standing by the sea. The scanning lidar was initially configured in a DBS configuration for three days to verify and compare the wind vertical profile from 40m to 200m high.

· The scanning lidar was first compared to a V1+ vertical profiler lidar system. The correlation between both systems was almost perfect (R^2 = 98,9%; slope = 1,0027).

Siemens Gamesa: Construction and commissioning

Lidars are commonly used for different wind farm development and operation applications such as craning and mounting operations, contractual power curve verification, and IEC-compliant PPT. One lidar unit can be used to conduct PPT for multiple turbines.

As one of the world's biggest wind turbine manufacturers, Siemens Gamesa Renewable Energy provides offshore and onshore wind services and is well-known as a renewable energy industry leader. For several years, the company has been using nacelle-mounted lidar in place of met masts to conduct PPT.

Lidar has many benefits over met masts, giving Siemens Gamesa several advantages as a top-tier manufacturer:

Overall lidar benefits

- Quick deployment with shorter campaigns
- Lower measurement campaign and equipment costs
- Location flexibility

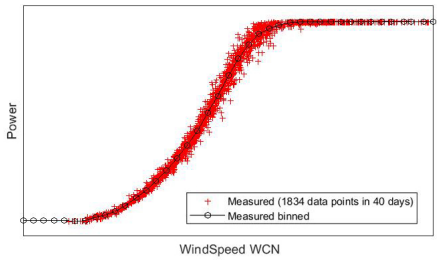
Key benefits of WindCube Nacelle long range lidar compared to met mast

- Wider measurement sector without loss of correlation, allowing for increased number of points on the same period which can lead to faster power curve completion
- Constant alignment with the wind allowing for reduced statistical uncertainty of the power curve
- Yaw error detection

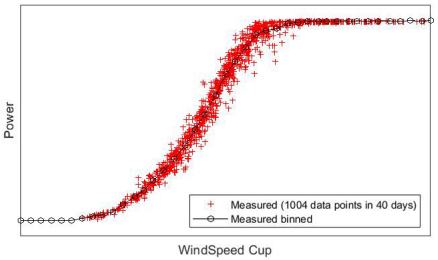
SSE Renewables: Nacellemounted lidar for operational PPT

Lidar can replace a met mast on permanent wind farms to monitor performance and losses when a turbine is stopped or the farm is off the grid. Nacelle-mounted lidar is ideal for crucial operational PPT campaigns where it can quickly, easily, and affordably troubleshoot and identify underperformance.

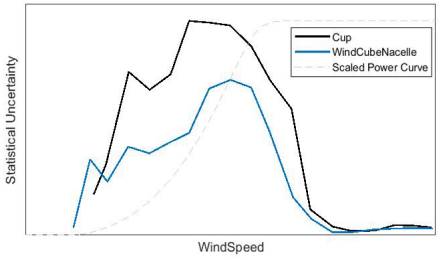
WindCube Nacelle long range power curve



Met mast power curve



Power curve statistical uncertainty



SSE Renewables is a leading developer and operator of renewable energy across the UK and Ireland, with a portfolio that includes the largest offshore wind development pipeline in the region. The organization works hard to keep the turbines running in top condition.

When they wanted to carry out some blade erosion repairs at one of the sites, SSE decided to run a PPT campaign to help determine the impact of the blade repairs on turbine performance. The challenge was deciding which technology to use. SSE selected nacelle-mounted lidar to conduct their PPT campaign because of its ability to collect data over multiple heights and distances in front of the turbine, straightforward installation and configuration, and far lower implementation costs.

Nacelle-mounted lidar allows SSE to measure multiple parameters, measure different ranges at the same time, relocate the device to other locations as needed, and conduct their own research projects. SSE plans to continue using the nacelle-mounted lidars on other wind farms and are already adding one to another site. The combination of lidars will ensure efficient and reliable PPT and research projects long into the future.

Centrale Nantes: Scanning lidar for R&D

With its real-time data, wind lidar is frequently being used to decrease uncertainties compared to statistical models. Promising research and development purposes now include wake loss and blockage effect studies, short-term forecasting, and wind farm control. Centrale Nantes is a French engineering school. Their innovative Research Laboratory in Hydrodynamics, Energetics and Atmospheric Environment (LHEEA) has 1km² of designated maritime zone dedicated to measuring metocean conditions and hosting marine renewable energy prototypes, among which is Floatgen — the first floating offshore wind turbine (FOWT) in France.

LHEEA sought lidar equipment to support two important projects focused on optimizing floating wind turbine operation and FOWT wake unsteadiness. Their greatest challenge: put a scanning lidar on the floating platform of a wind turbine, where it will analyze the wind resource and the wind turbine wake.

> *"SSE recognizes the importance of understanding the performance of a wind farm throughout its lifetime; PPTs are a key component of this and lidars are the enabling technology."*
>
> *Andrew Davidson*
> *Wind Analyst at SSE*

LHEEA deployed a long-range scanning lidar based on its high performance, reliability, and remote access. The 360° spatial capabilities of the lidar make it a leading instrument for wind analysis. Its versatility offers operational possibilities across research themes in the LHEEA laboratory, such as developing Marine Renewable Energies and increasing knowledge of the atmospheric environment.

Scanning lidar is supporting several research initiatives in the LHEEA laboratory, where its availability is quickly advancing the laboratory as a major national player. It is an important lever in establishing collaborative research programs and has already led to the submission and launch of several national and international research collaborations.

The technologies

WindCube®: Made for offshore

Vaisala's WindCube lidar solutions are the most comprehensive set of offshore-ready measurement technologies in the world. There is a WindCube solution to support nearly every part of an offshore project, from WRA, pre-construction, and contractual power curve testing to permanent wind monitoring, research and development, and turbine testing and control.

WindCube Offshore

Rugged and "marinized" offshore version

- The reference lidar for all phases of wind energy development and operations
- Can be placed on a fixed platform or integrated into a FLS
- Consistent, reliable and accurate data — wherever you need it

WindCube Nacelle

Nacelle-mounted lidar for PPT and optimization

- Widely accepted for contractual and operational PPT, proven to dramatically reduce operational costs while increasing efficiency Up to 10x 50m to 700m for a complete wind profile covering the rotor sweep of even the largest offshore turbines

WindCube Scan

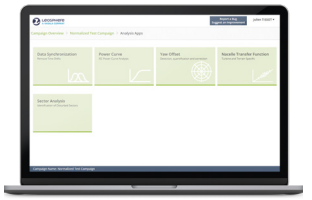
Industry-leading scanning lidar for 3D wind analysis a long range

- Reliably and affordably provides 3D wind mapping and wake studies, indispensable to modern wind farms
- Fully configurable for several uses including 360° monitoring, atmospheric cross-sectioning, and wind profiling
- Ideal for offshore measurement campaigns conducted from the shore

WindCube Insights — Fleet

Modern, cloud-based fleet management software for WindCube lidar

- Provides accurate and transparent system performance data and reporting
- Allows users to monitor, assess, and manage their WindCube vertical profiling lidar fleets
- Appropriate for all campaign types and fleet sizes



WindCube Insights — Analytics

Revolutionary software for WindCube Nacelle

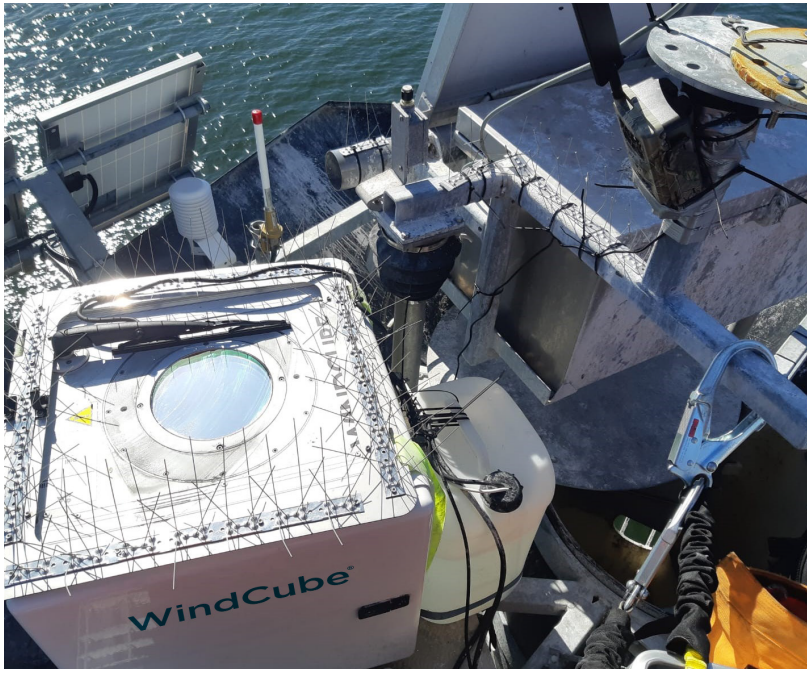
- Provides powerful, ECcompliant PPT and data analysis and reporting
- Enables developers, operators, and manufacturers to easily conduct PPT and get more value from lidar and turbine technologies
- Allows even smaller or emerging wind energy companies to conduct affordable PPT at various points in the offshore life cycle

WindCube®

The gold standard

WindCube® is the iconic and trusted gold standard in wind lidar. The turnkey product suite offers innovative, reliable, and highly accurate solutions for thousands of customers across the globe. Borne from a passion to advance the field, WindCube continues to take wind energy ever higher through a commitment to four guiding principles:

- Trustworthy, superior metrology
- Unrivaled thought leadership
- Innovative lidars from a one-stop shop
- Easy, reliable global solution



Why Vaisala?

We are innovators, scientists, and discoverers who are helping fundamentally change how the world is powered. Vaisala elevates wind and solar customers around the globe so they can meet the greatest energy challenges of our time. Our pioneering approach reflects our priorities of thoughtful evolution in a time of change and extending our legacy of leadership.

Vaisala is the only company to offer 360° of weather intelligence for smarter renewable energy, nearly anywhere on the planet. Every solution benefits from our 85+ years of experience, deployments in 170+ countries, and unrivaled thought leadership.

Our innovation story, like the renewable energy story, continues.

Ref. DID64575EN-A

windcubelidar.com

GWU-Umwelttechnik GmbH

Sales, Support and Servicecenter D-A-CH-PL

Bonner Ring 9
50374 Erftstadt, Germany
+ 49 (0) 2235 95522 0
info@gwu-umwelttechnik.de
www.gwu-umwelttechnik.de