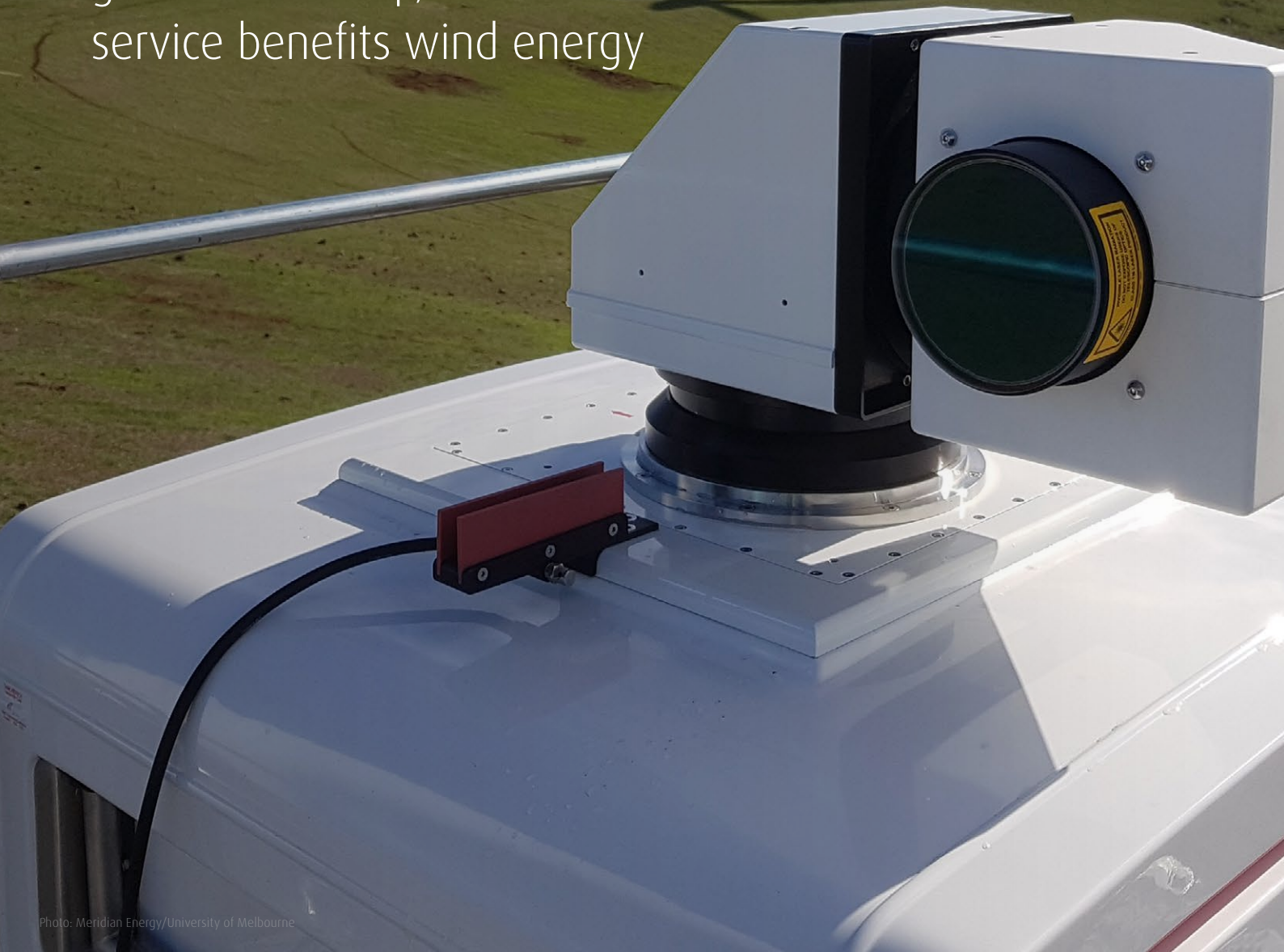




LEOSPHERE
A VAISALA COMPANY

Ever higher

How transformative technology,
global leadership, and unmatched
service benefits wind energy



Smarter wind energy

People have harnessed the wind for centuries, and for countless applications. Today, the wind energy industry has inherited this tradition. It is filled with innovators who use the wind like no one before imagined, and the world is better for it.

At Leosphere, a Vaisala company, we are modern innovators, scientists, and discoverers driven by relentless curiosity, and we create a better world by empowering wind energy leaders, decision-makers, and researchers to create transformative change. Our decisions are driven by data and sound judgment; our dedication to our work is driven by passion and the desire to create a better world. We seek to be the steady

champions of this industry, pushing it ever higher to everyone's benefit.

Our successes are rooted in our long history of scientific and industry contribution, our philosophy of end-to-end partnership, and the comprehensive capabilities of the WindCube® suite, which are the most recognized and trusted lidar solutions in the world.



Lidar without limits: Our guiding principles



Trustworthy, superior metrology

Our solutions are backed by the best science and metrology, and validated by the most demanding testing and certifications in the industry. Our contributions make wind energy smarter.



Unrivaled thought leadership

Our years of experience, impressive global client roster, and plethora of industry breakthroughs demonstrate that we are the iconic gold standard in wind energy.



Innovative lidars from a one-stop shop

Customers know we have the right suite of solutions for their needs in wind energy — taking them ever higher by adding value at each step of the project lifecycle.



Easy, reliable global solution

We make our clients' lives easier. Our easy to use, turnkey WindCube product suite enables customers to harness the power of wind energy efficiently and affordably.



Photo: ©Jacques Vapillon AKROCEAN GEPS Techno



Contents

How we power wind energy	5
Pulsed lidar technology in depth	14
The WindCube suite	15
Key applications summary	23

How we power wind energy

Making wind energy smarter

Leosphere, a Vaisala company, has earned its leadership position in wind energy largely because our scientific and R&D contributions are aggressive, strategic, and unmatched.

In recent years, we have produced more than 500 authored or co-authored

scientific publications at the highest levels of study, and we have longstanding, fruitful partnerships with more than 20 leading research institutes worldwide. One of our latest advancements, a hybrid measurement capability that integrates scalar and vector averaging to reduce

uncertainty, is patent-pending and unlike anything offered elsewhere.

WindCube is also the industry's reference lidar, a status earned over more than 15 years of scientific innovation and approximately 5,000 deployments around the globe.



Proud to be the industry's reference lidar

15+ | Years of scientific lidar innovation

500+ | Co-authored or authored scientific publications in recent years

2,000+ lidar units, 5,000 deployments around the globe



Global company, global capabilities

Leosphere, a Vaisala company, has established truly global reach, which brings several distinct benefits to customers.

First, our size and well-established business practices allow for scalability, worldwide service provision, and stability in changing economic environments.

In times of uncertainty, our track record and multinational infrastructure can provide certainty and peace of mind unlike any other lidar provider.

Our network includes two factories, both of which utilize industry-level manufacturing and related practices, as well as seven

global service centers. This is an enormous asset to Leosphere, a Vaisala company, and our customers because it ensures we can meet demand, provide quick and correct servicing, and leverage the most sophisticated benches, calibration tools, and related technologies.

2 factories, 7 global service centers





Welcome to Paris. And Shanghai.

To satisfy global demand, Leosphere, a Vaisala company, built a lidar factory and service center in Shanghai, in addition to our location at Paris-Saclay. The Shanghai factory has been operational since early 2019 and its level of performance has allowed us to progressively increase its capacities. It now manufactures and services WindCube, WindCube Nacelle, and WindCube Scan lidar systems.

The experience and feedback collected in each factory enriches our overall manufacturing and quality control practices. Having two sites allows us to increase the quality and repeatability of WindCube systems globally, and we are excited to pass these gains along to our customers as our innovation and growth continue.

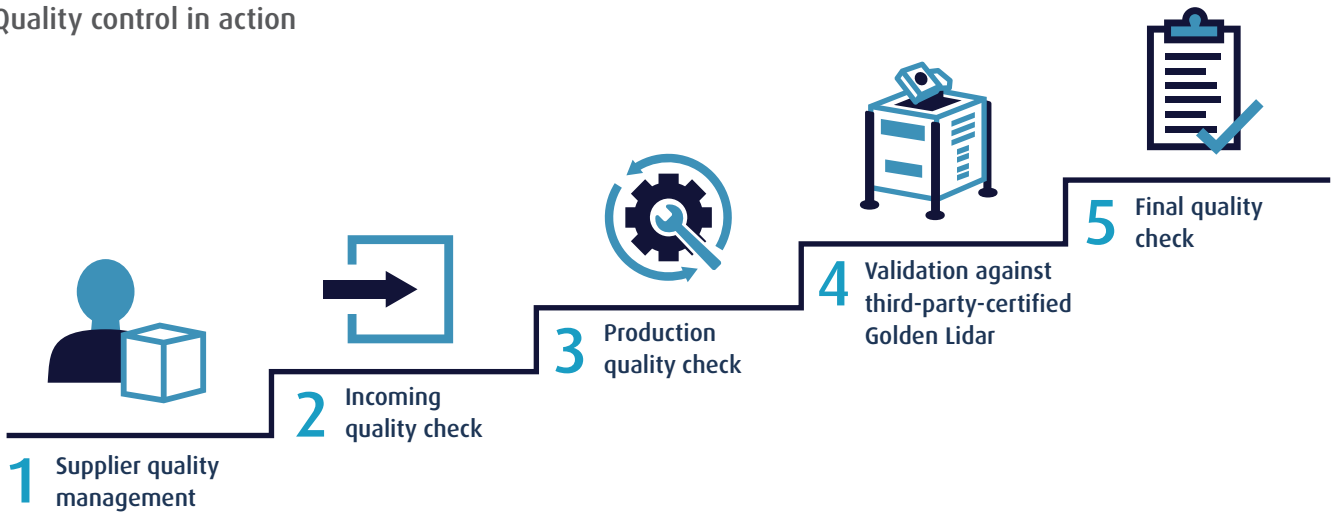
Industry-level value

Leosphere, a Vaisala company, leads the industry with our industry-level manufacturing and servicing practices, meaning that we apply consistent, rigorous quality-control and testing protocols to each lidar unit and component.

This includes using a unique set of benches and soft tools for manufacturing, testing, and calibration. Many of these are patented by Leosphere, a Vaisala company, and have accelerated production while ensuring higher and more uniform quality.

For example, as each lidar unit makes its way through the process, it passes through more than 150 electro-optical control points, with more than 60 controlled wind parameters.

Quality control in action



Certification and bankability

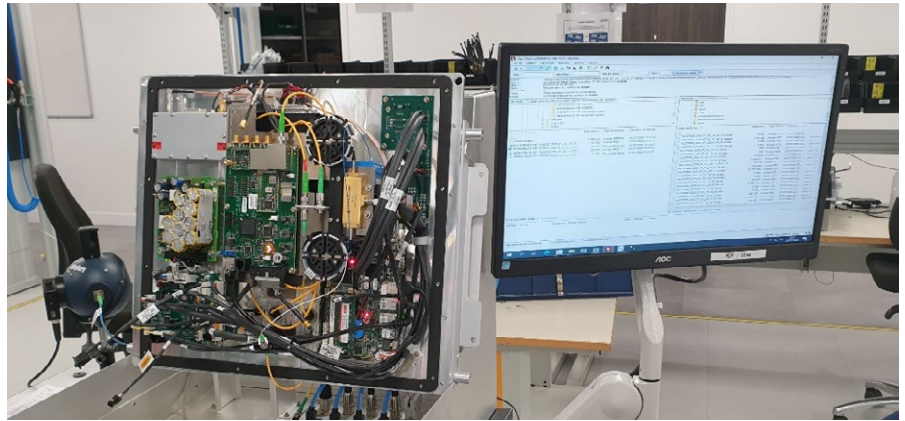
Leosphere, a Vaisala company, products meet the latest and most rigorous international verification standards, including ISO9001. All WindCube products are compliant to the latest IEC standards, and they are recognized and verified by the world's leading independent certifying bodies and research institutes, including DNV GL, DTU Wind Energy, UL, Deutsche WindGuard, NREL, and AIST.

Each WindCube vertical profiling lidar unit we make is validated against a Golden Lidar and shipped with a document of validation issued by DNV GL. Leosphere, a Vaisala company, owns several Golden Lidars, which helps us ensure speed and continuity of operations. Our Golden Lidars are certified every two years across more than 20 key performance indicators, and this process is applied for more than 10 years.

This level of rigor gives us:

- Improved speed while achieving full traceability and quality
- Ability to verify at the greatest heights and distances to cover even the largest turbines
- A high degree of certainty in verification results
- Backup capacity using fully certified Golden Lidars
- Weather- and terrain-insensitive processes
- Complete verification across heights, turbulences, and CNR levels

In the past, the wind energy industry was skeptical of lidar because it hadn't been tested as thoroughly as legacy technologies. But those days are gone, and the mountains of data supporting lidar's accuracy and effectiveness are undeniable. Much of that data, in fact, has come from our many years of deployments and validations.



Selected certifications



DTU Wind Energy
Department of Wind Energy



WINDGUARD
Certification





"Remote sensing data certainly contributes to decision-making. It increases certainty, which in turn increases leverage, which in turn increases equity returns."

Liam Smith Investment Principal, Actis

Industry-leading warranties and support options

Leosphere, a Vaisala company, offers the best warranty in the industry, as well as robust standard and premium service levels. For example, for the WindCube vertical profiler, we provide a 15-day case duration for workshop repairs, and our premium on-site repair option provides guaranteed mean time to repair.

Support extends to ongoing training, including convenient online refreshers through our e-learning platform. These anticipate frequent questions and ensure you get the most from your WindCube investment.

For the WindCube vertical profiler, we also offer a validation continuity warranty, which enables users to maintain

IEC-compliant validation during repair or maintenance, as well as a pre-validated, off-the-shelf purchase option that can save up to two months of deployment time. Existing customers can efficiently upgrade to the latest enhanced and certified WindCube units, with warranty extension included.

Leosphere, a Vaisala company, is able to offer these options because our technologies are so reliable, and because we have invested in a global support infrastructure that is unlike any other lidar provider. This provides value well beyond accurate wind data, since when you select WindCube lidar, you also gain the trustworthiness and peace of mind that only we can provide.

Delivering value every step of the way

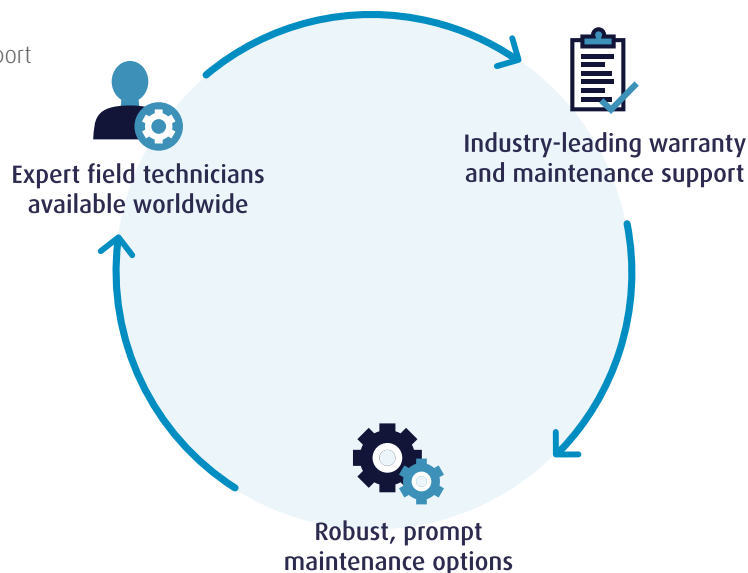
Leosphere, a Vaisala company, provides the most comprehensive solutions and service available, no matter where you are. In addition to our two factories, we maintain seven global service centers, and offer a variety of solutions that make deploying and operating lidar even simpler.

Easy, reliable global solution: Robust support offerings

- Extensive training, including online training refreshers, on-site or remotely
- Full maintenance capabilities that maximize operation continuity
- Installation and system integration support
- Technical and scientific support

Innovative lidar solutions from a one-stop shop: Turnkey offerings

- Standalone power supplies
- 4G remote communication
- Security fencing
- Data analysis software



VAISALA

A parent company worth celebrating

In 2018, Leosphere became a part of Vaisala, a global leader in observation technologies. Vaisala has strategically chosen to integrate Leosphere's capabilities while retaining its identity and the integrity of its solution set.

Together, these scientific giants comprise the most capable observation-technology company in the world.

The value of the partnership goes beyond technology and thought leadership.

Today, Leosphere leverages Vaisala's existing global network, drastically enhancing its reach, efficiencies of scale, service provision, and nimbleness.



**80+ years
of experience**

in environmental measurements
and monitoring



1,900+ professionals

and a large distributor network



13% of net sales

invested in R&D



**Organizational
charter**

to minimize the impact of
climate change



Pulsed lidar technology in depth

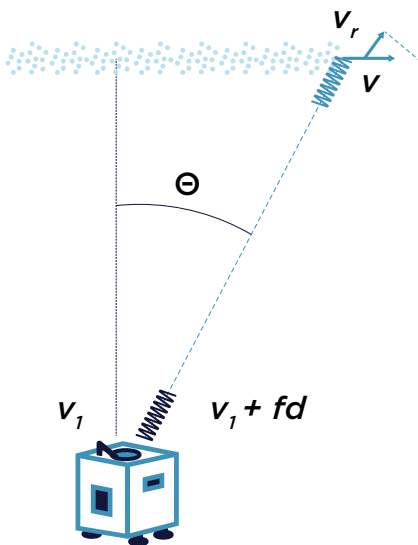
Not all lidar is created equal

You will see two primary lidar types in the marketplace: pulsed lidar and continuous wave (CW) lidar. Over decades of research and deployments, Leosphere, a Vaisala company, has relied on pulsed lidar technology for a variety of reasons, some of which are explained below.

Pulsed lidar requires high-level skills and methodologies, but it is the best technology to use. Its strengths are highly correlated to the specific needs of wind energy.

Principles and functionality

All lidar types share several key principles. Lidar (an acronym for Light Detection and Ranging, much like "radar" is an acronym for Radio Detection and Ranging) sends light beams into the atmosphere, which are reflected and returned by particulates moving with the wind. Using the Doppler Effect, the lidar unit analyzes the frequency of those reflections and computes a highly reliable wind speed.



Pulsed lidar's strengths are highly correlated to the specific needs in wind energy.

Benefits of pulsed lidar and WindCube technology

Measures multiple heights simultaneously, providing the full wind profile with no compromises in temporal resolution or accuracy	✓
Multiple heights produce much more data, more quickly (10 heights = 10x faster and 10x more data, for example)	✓
Provides spatial resolution that is constant throughout the entire wind profile	✓
Measures greater height and distance ranges, with constant accuracy	✓
Uses only 5 laser beams, which operate without moving mechanical parts	✓
Can use a unique hybrid wind reconstruction algorithm that combines scalar and vector data for the highest possible accuracy and reliability	✓
Maintains constant accuracy no matter the weather or cloud/aerosol layers	✓
Easy to position almost anywhere because its few (5) laser beams can easily be oriented to avoid obstacles	✓
Provides accurate wind direction over a 0-360° range; not vulnerable to possible 180° error	✓
Can use a 5 th (vertical) beam for direct, accurate measurement of vertical wind speed and flow angle	✓
Maintains high data availability and sample rates in a wide range of conditions	✓
Data recovery not affected by strong wind shear or wind turbulence intensity	✓
Uses 50% less power on average	✓

The WindCube suite

WindCube is the most trusted and widely used lidar in wind energy. Repeatedly validated and extraordinarily flexible, it has helped evolve each of these industries substantially.

WindCube is a technologically mature series, refined over multiple generations and capable of meeting future needs. It is recognized by name and trusted by financiers and other key stakeholders worldwide.

WindCube technologies span all major wind energy use cases. They are all easily integrated and interchangeable depending on your specific needs. They are mobile, small, and nondisruptive to landscapes and environments, and they measure across the entire rotor sweep of even the largest turbines, both onshore and offshore. They can be used temporarily and are easy to repurpose after their initial job is done. And they provide exceptional value and cost-effectiveness over long service lives.



WindCube:
The most accepted,
trusted ground-based lidar

- Deploy quickly for immediate measurement
- Place on any site with little or no permitting
- Small footprint, mobile, discreet
- Reliable remote operations, low power consumption
- Redeploy to other locations as desired

“The cost benefits are a big factor; it’s much more economical to get wind speed data [with remote sensing rather than met masts] and a thousand times easier.”

Nathan Lehman

Energy Analyst, Apex Clean Energy



WindCube®

The most trusted and tested vertical profiling lidar

WindCube is the industry standard vertical profiling lidar. It measures the complete wind profile at 20 simultaneous heights, with no compromise in data availability or accuracy across heights, and it provides the highest measurement accuracy on both simple and complex terrain. It can be positioned almost anywhere, temporarily or permanently, and it covers the entire rotor sweep of today's larger turbines, measuring up to 300m. WindCube also features breakthrough hybrid wind reconstruction capability, which integrates scalar and vector averaging to further reduce uncertainty and increase reliability.

WindCube data has been validated by hundreds of independent studies and meets or exceeds all international standards and guidelines. For complex terrain, it uses a highly evolved Flow Complexity Recognition (FCR) algorithm, which is integrated within WindCube and validated by formal studies. Its unique fifth (vertical) beam provides direct, accurate

measurement of vertical wind speed and flow angle. For very complex terrain, WindCube uses industry-leading CFD-based correction solutions.

Compared with other lidar, WindCube is simpler to locate thanks to its fewer beams. It is also cheaper to use because it uses less power (on average) than other solutions; cost-efficient power supplies further simplify operation. Like any Leosphere, a Vaisala company, solution, it benefits from the fastest and most local support available, and WindCube is the only lidar that can be fully maintained on-site, by one field technician. Support for WindCube includes a suite of standard and premium offerings, which ensure optimal time-to-repair and operational continuity anywhere in the world.

Wherever it is located, WindCube is the most trusted solution for optimizing financial performance, increasing efficiency, and maximizing energy output.

"We're pushing for remote sensing devices to provide investors with more confidence. The lidar device delivers cheaper, faster, and safer resource assessment campaigns."

Philippe Pontbriand

Energy Resources Director,
RES Americas, Inc.



WindCube®

Fleet Manager

Insights

Modern, cloud-based fleet management software for WindCube lidar

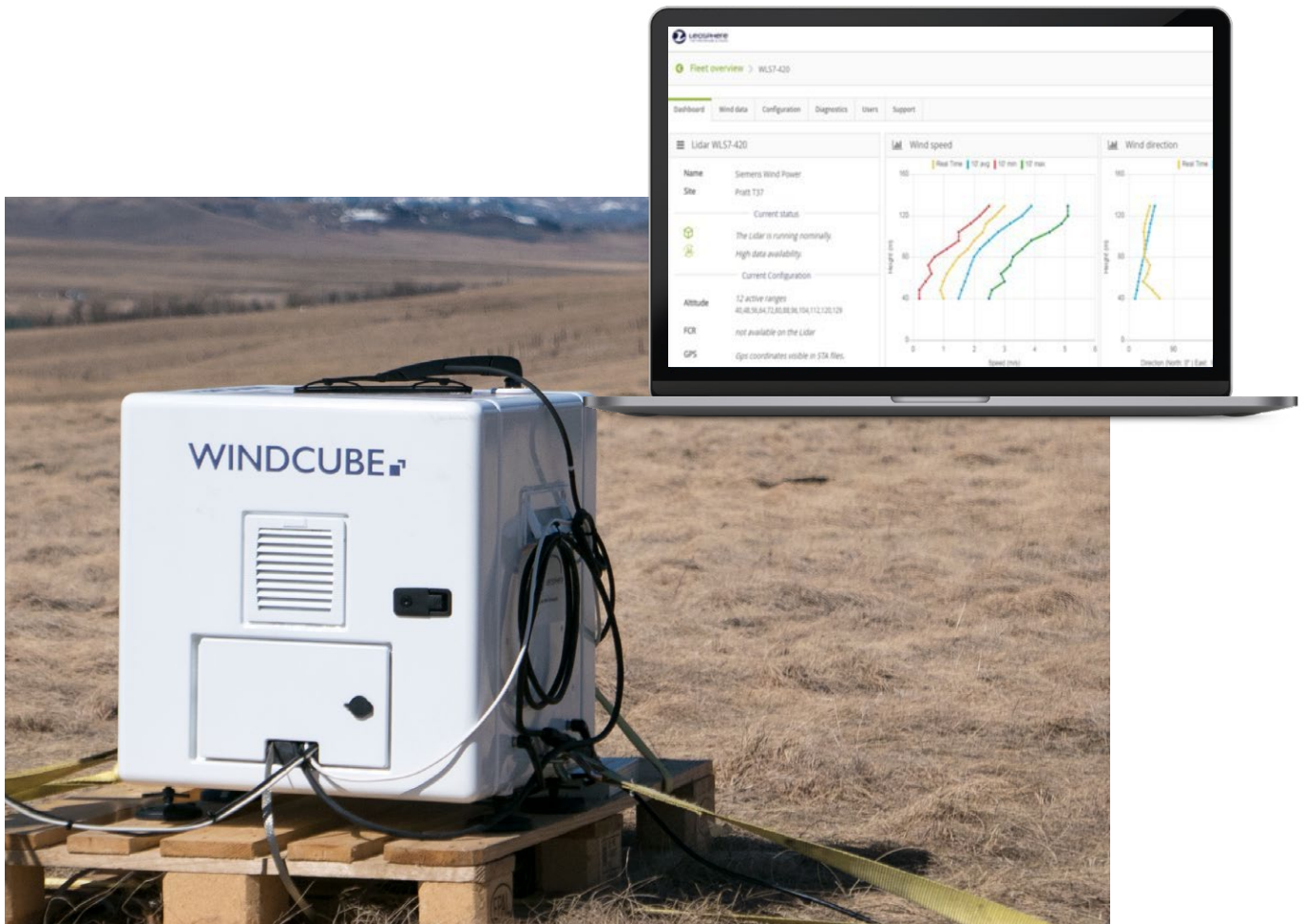
WindCube Insights — Fleet software allows users to monitor, assess, and manage their WindCube vertical profiling lidar fleets from a modern, easy-to-use interface.

The software is appropriate for all campaign types and fleet sizes,

from a single buoy-mounted unit positioned offshore to a large network of lidar units onshore.

The intuitive, cloud-based system provides accurate and transparent system performance data and reporting,

quick access to the right data in the right formats, and modern permissions and sharing features that allow organizations to customize how different stakeholders leverage the tool.



WindCube®

Scan

Full, 3D wind awareness and outstanding flexibility

WindCube Scan reliably and affordably provides accurate wind mapping and wake analyses that are indispensable to onshore and offshore projects.

The industry's tool of choice for reducing spatial uncertainty, it is valuable at any stage of a wind farm project, from prospecting to operation. WindCube Scan is suitable for short-term rental, changing placements during development campaigns, or long-term operations.

Each system is fully configurable for several uses, including monitoring, atmospheric cross-sectioning, and wind profiling.

Capable of measuring at ranges up to 19.5km, it can also measure multiple turbine locations at once, creating huge efficiencies in operational assessment.

Also, multiple WindCube Scan systems can easily be synchronized together for dual-lidar applications.

“Reducing the vertical and spatial uncertainty factors and being able to measure at higher heights in general is a significant advantage for us, considering the higher hub heights of modern wind turbines.”

Nicolás Briceño

Analyst, Wind and Solar Energy, Innergex



WindCube® Nacelle

Long-range wind detection, Power Performance Testing, optimization, and turbine control capabilities

Suitable for any turbine type and rotor diameter, WindCube Nacelle provides a complete picture of the wind profile at an exceptional range from 50 to 700m. By measuring 20 distances simultaneously each second, it provides outstanding data quality and availability — making it the routine choice for contractual performance testing in turbine supply agreements.

WindCube Nacelle is the result of more than 10 years of experience in nacelle-mounted lidar, as well as more than 300 field deployments. It is the only nacelle-mounted lidar that enables long-range Power Performance Testing (PPT) on any wind turbine, whether

onshore or offshore. Its accuracy and versatility have made Leosphere, a Vaisala company, a contributing expert to industry guidelines and standards for PPT.

WindCube Nacelle provides a wide range of data, including shear, veer, turbulence, and rotor induction effects. When paired with WindCube Insights — Analytics software, it enables previously unheard-of power curve calculations and analyses using a fast, simple, IEC-compliant, cloud-based tool.

WindCube Nacelle also offers a turbine control capability, which can be factory integrated into a manufacturer's turbine.

This allows users to adopt groundbreaking Lidar-Assisted Control (LAC) practices, enhancing turbine efficiency, protecting equipment, and reducing levelized cost of energy.

By fully characterizing the incoming wind field hundreds of meters ahead of the rotor plane, the system also enables anticipatory control optimizations for changing conditions. This can result in significantly extended wind turbine design limits, reduced loads and costs, improved safety and resilience to extreme events, and increased energy capture.



WindCube®

Analytics Insights

Revolutionary software for Power Performance Testing and data analysis

WindCube Insights — Analytics allows operators to perform quick, simple, transparent analysis and reporting, with IEC-compliant filtering, AEP calculation, and uncertainties reporting. By simplifying data handling activities, users are free to focus on the most essential performance analysis and optimization work.

Since PPT is a very strict process, this tool provides users with transparent validations and even lists which IEC standards are relevant while in use. It allows for the

upload of WindCube Nacelle and SCADA data with a simplified data synchronization process, and a variety of standardized lidar and turbine data filters are available and fully configurable to prepare the data set.

In addition, the software allows users to access systems and data — whether they have one system or many — for real-time visibility into campaigns. It provides intuitive system insights, secures business-critical data, and allows users anywhere, anytime access.

Simple to learn and user-friendly, WindCube Insights — Analytics offers customizable, real-time alerts and notifications providing enhanced system performance and reduced response times. It is extendable from one campaign to full fleet management, so it can grow with users' operations without new procurements.



WindCube®

Offshore

Ruggedized vertical profiling lidar for the harshest deployments

WindCube Offshore equips the WindCube vertical profiler with a robust casing for integration into floating buoys and other harsh offshore locations, such as lighthouses, substations, and vessels.

With offshore wind development accelerating, this is a timely innovation for consistent, reliable, and accurate data in places where collecting such data used to be impossible.

“We have deployed various WindCube devices across our offshore portfolio. The deployments have added value to all the projects, and Leosphere, a Vaisala, company, has provided great support and service.”

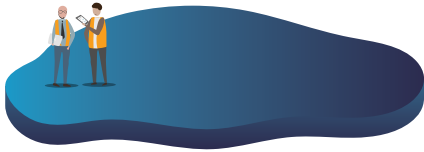
Stephen McKeown

Offshore Resource
Assessment Team Manager,
SSE Renewables



Photo: Blyth Accurasea EOLFI

Key applications summary

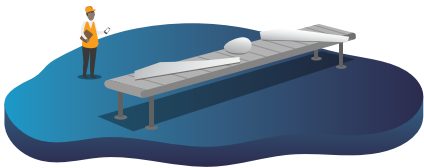


Project developers

Wind resource assessment: Provide quality data and bankable due diligence in almost any terrain and weather conditions, onshore or offshore

Optimizing wind farm layout and turbine choice: Inform turbine choice, optimizing important cost and risk factors

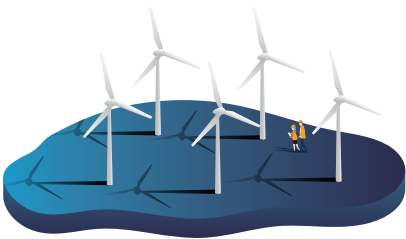
Wind monitoring: Ensure real-time wind awareness for successful construction and deployment



Manufacturers

IEC-compliant turbine testing, validation, and prototyping: Verify product performance or upgrades in real-world environments

Feedforward Lidar-Assisted Control: Bring new LAC functionality to market efficiently and cost-effectively



Wind farm operators

Reliable contractual and operational PPT: Power curve data and compliant analysis

Nacelle instrument verification: Yaw misalignment and transfer function

Permanent monitoring of site conditions: Meeting grid operator reporting requirements, conducting wind monitoring for maintenance or upgrade operations



Research and development

Blockage effect and wake studies

Wind farm control

Optimization of offshore wind farm layout



Conclusion

The WindCube suite is the most accurate, widely deployed, validated, and recognized lidar technology on the planet. For any particular wind energy application — or a combination of applications — it is the most refined and trustworthy option. And it just keeps getting better.

But when you choose Leosphere, a Vaisala company, you don't just get the

best lidar. You get the value of the only provider anywhere with the resources, robust service plans and infrastructure, and turnkey options to take you into the future with certainty.

And in the ever-changing field of wind energy, certainty is a valuable resource.



windcubelidar.com

