WHEN TRUST MATTERS

Floating offshore wind power performance measurements (FOWP)

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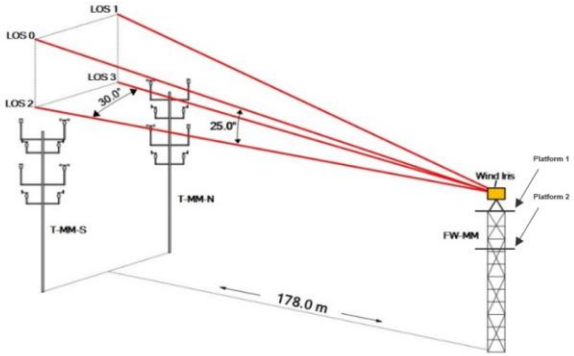
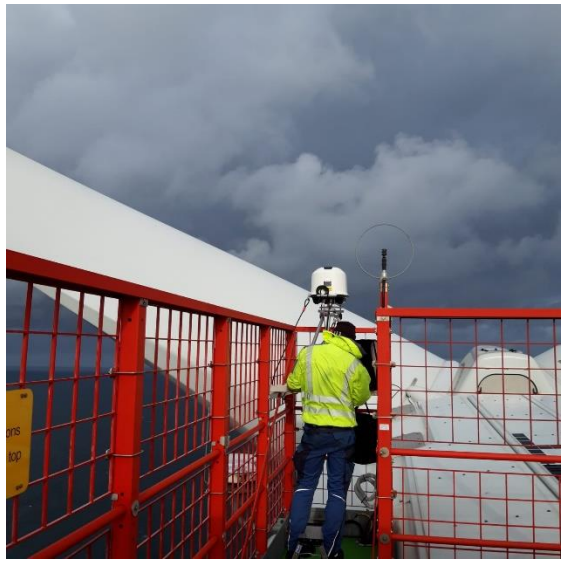
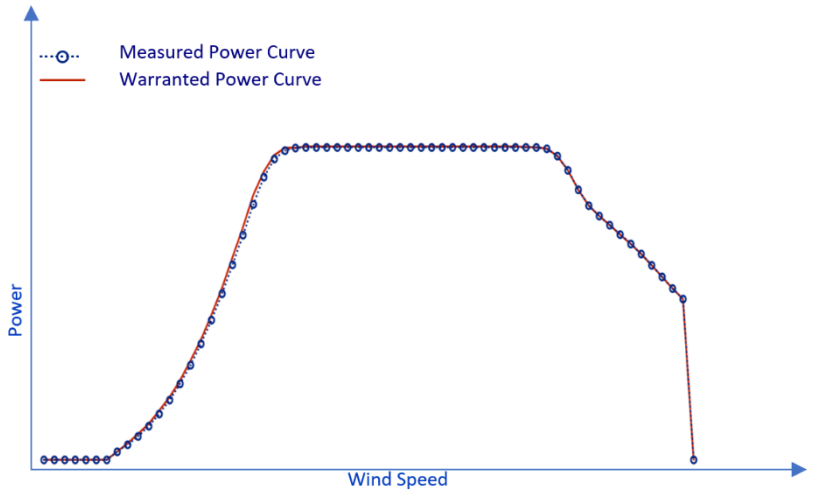
How does power performance work for bottom-fixed offshore wind turbines?







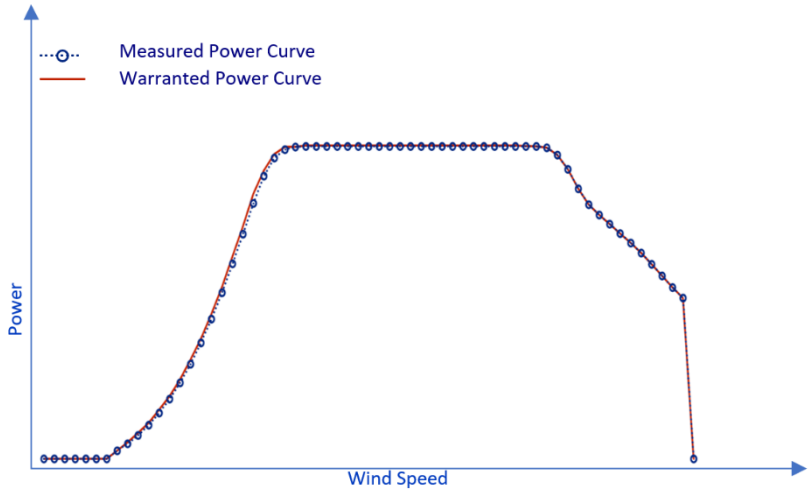
Nacelle Lidar Verification → Onshore Preparation → Offshore Installation → Power Curve Verification

How to measure the power performance of floating wind turbines?

Floating vs. Bottom fixed:

- (High) static inclinations depending on the wind speed
- More dynamics due to floating platforms

- **Implications on power production**
- **Implications on lidar measurements**



Floating offshore wind power performance measurements (FOWP)

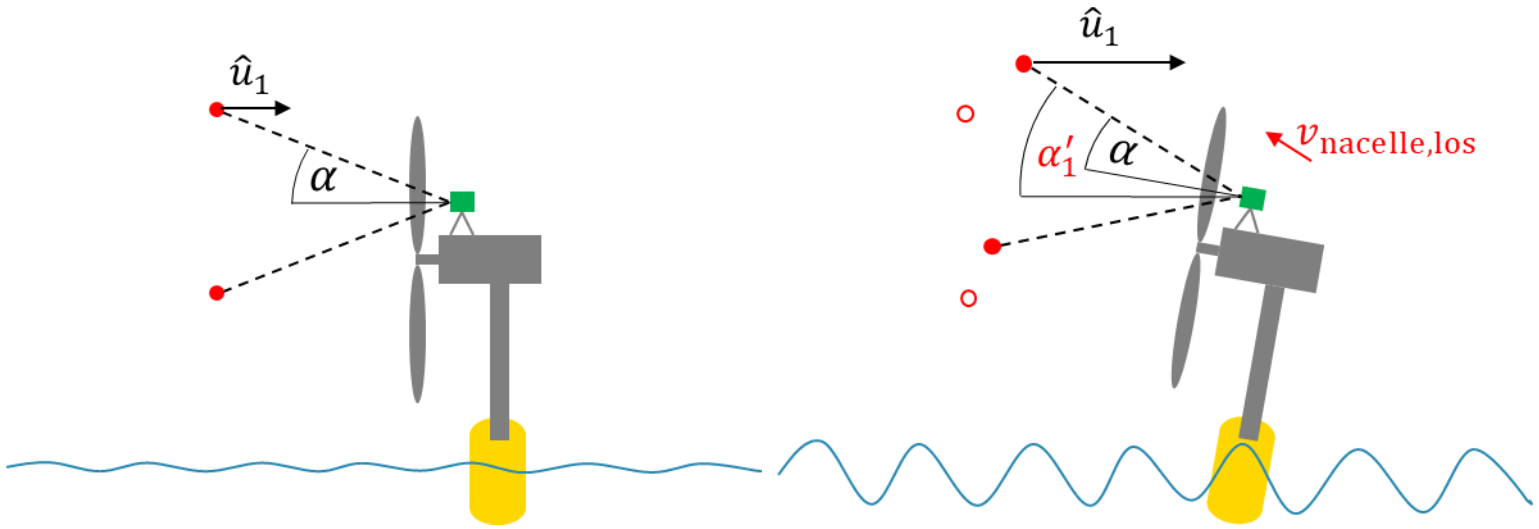
DNV and sowento have joined forces to deliver power performance testing and analysis for floating wind turbines

Our combined expertise will advance floating wind technology, enhance performance reliability, and reduce risks in this emerging industry.

How does power performance vary between floating and fixed bottom wind turbines?

Floating wind turbines are unique when it comes to their **motion envelope.**
As opposed to bottom-fixed turbines, the tower base is not attached to a fixed support structure like a monopile, but to a floating platform. The **platform moves in multiple degrees of freedom**, which leads to **static displacements and dynamic motions of the entire wind turbine**. These have an impact on the **overall power performance** of the floating wind turbine.

The impact of **the wave-induced pitch-motion**, which is the slow back-and-forth movement of the platform, and possible misalignments of the yaw angle, which is the direction the turbine faces, must be considered in a measurement campaign. With a wide range of floating concepts on the market it is crucial for OEMs, investors, developers, and owners to verify the performance of their turbines on a floating substructure.



What are industry pain points?

Floater manufacturer's view: Competition of Design Concepts

- Behaviour of the floating platform interacts with the aerodynamics of the turbine and power performance in several ways, e.g.:
  - Static floater behaviour (e.g. pitch depending on wind conditions and sea-state)
  - Dynamic motions (waves, frequency response of floater turbine ensemble)
  - Wind misalignment due to rotation (ocean currents, mooring concept)

Developer's view: Uncertainty of Performance

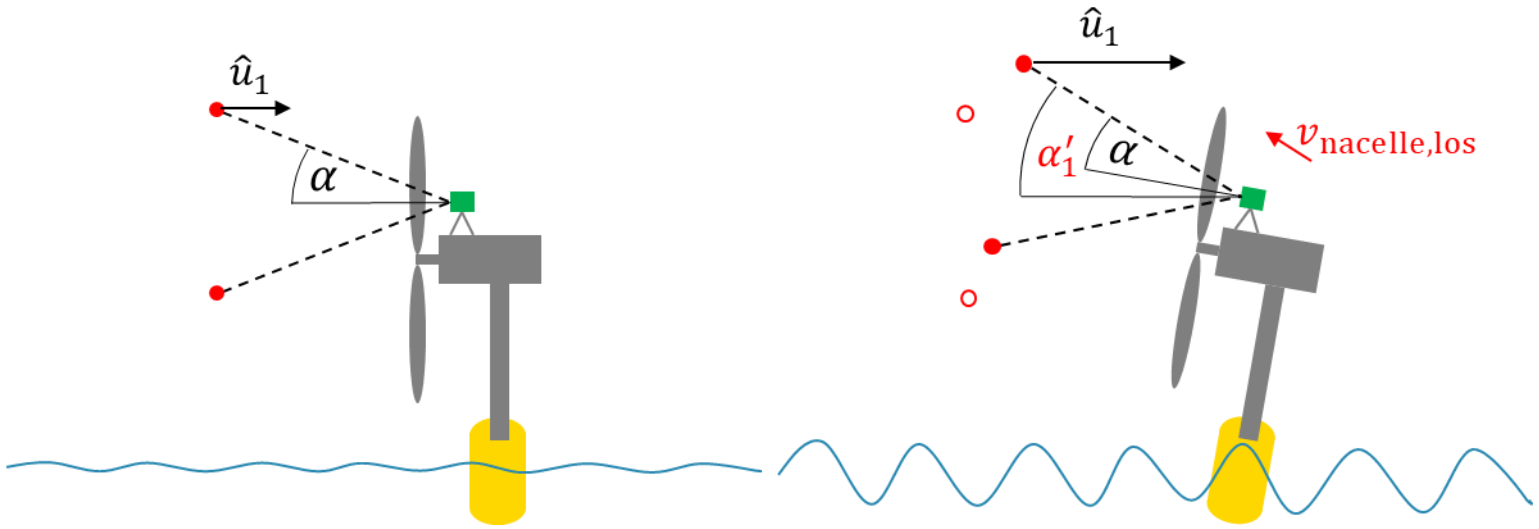
- challenges in accurately predicting performance due to the dynamic behaviour of floating platforms and varying site conditions.
- each uncertainty in power performance prediction translates into a financial risk.
- Building trust in floating concepts requires a dual approach: understanding the parameters that influence the power curve and providing experimental validation

Wind turbine OEM: Certification demands and structural integrity

- Type certification necessitates accurate performance measurements, especially for combined floater-turbine ensembles.
- The same applies to project-specific certification considering site conditions and turbine interactions.

How does DNV address this problem and what role does sowento play in it?

In offshore power performance measurements DNV typically **uses nacelle-mounted lidars,** which are aligned with the rotor and can measure the relative wind direction before the wind reaches the turbine. This can accurately determine the undisturbed wind speed at hub height in front of the turbine. As static offsets and motions dynamically affect the measurement location as well as the wind speeds recorded by the nacelle lidar device, a **correction of the measured wind speed is required**. By analysing the behaviour of the floater under expected met-ocean conditions, a suitable correction method must be established before the start of the measurement campaign to minimize uncertainties of the final results. Using modern measurement technology, **the motions of the floater will be quantified, and the assumption of the correction will be verified.**



How does DNV address this problem and what role does sowento play in it?

Pre-study / Floater Simulation

- The outputs of this analysis provide recommendations for a planning of the measurement campaign, which are vital to the success of the PPM campaign. These include, but are not limited to, NML positioning and adjustment as well as specifications for inertial measurement units.

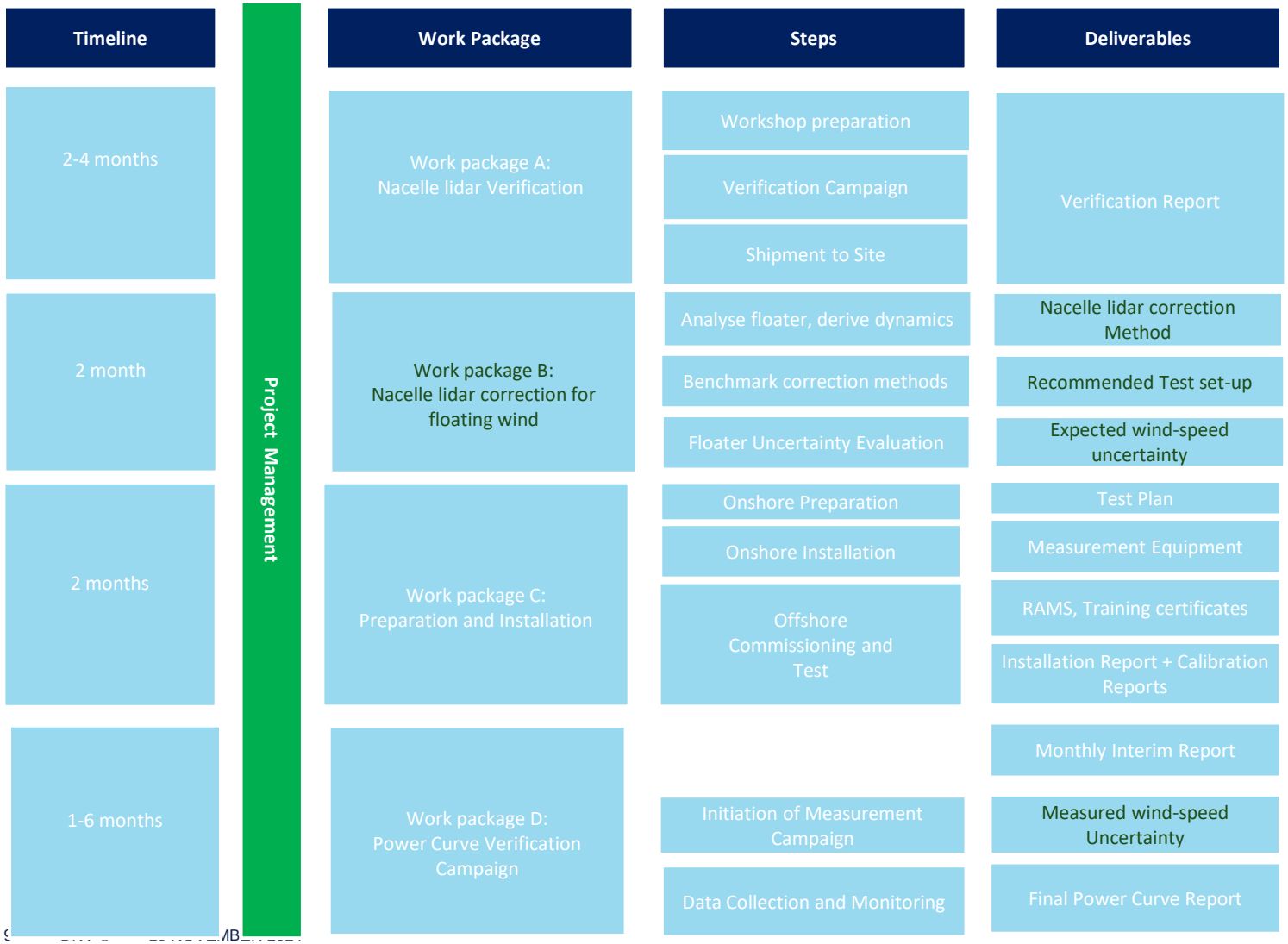
Post-processing of the NML Data:

- This involves deriving amotion-corrected and hub-height-interpolated windspeed

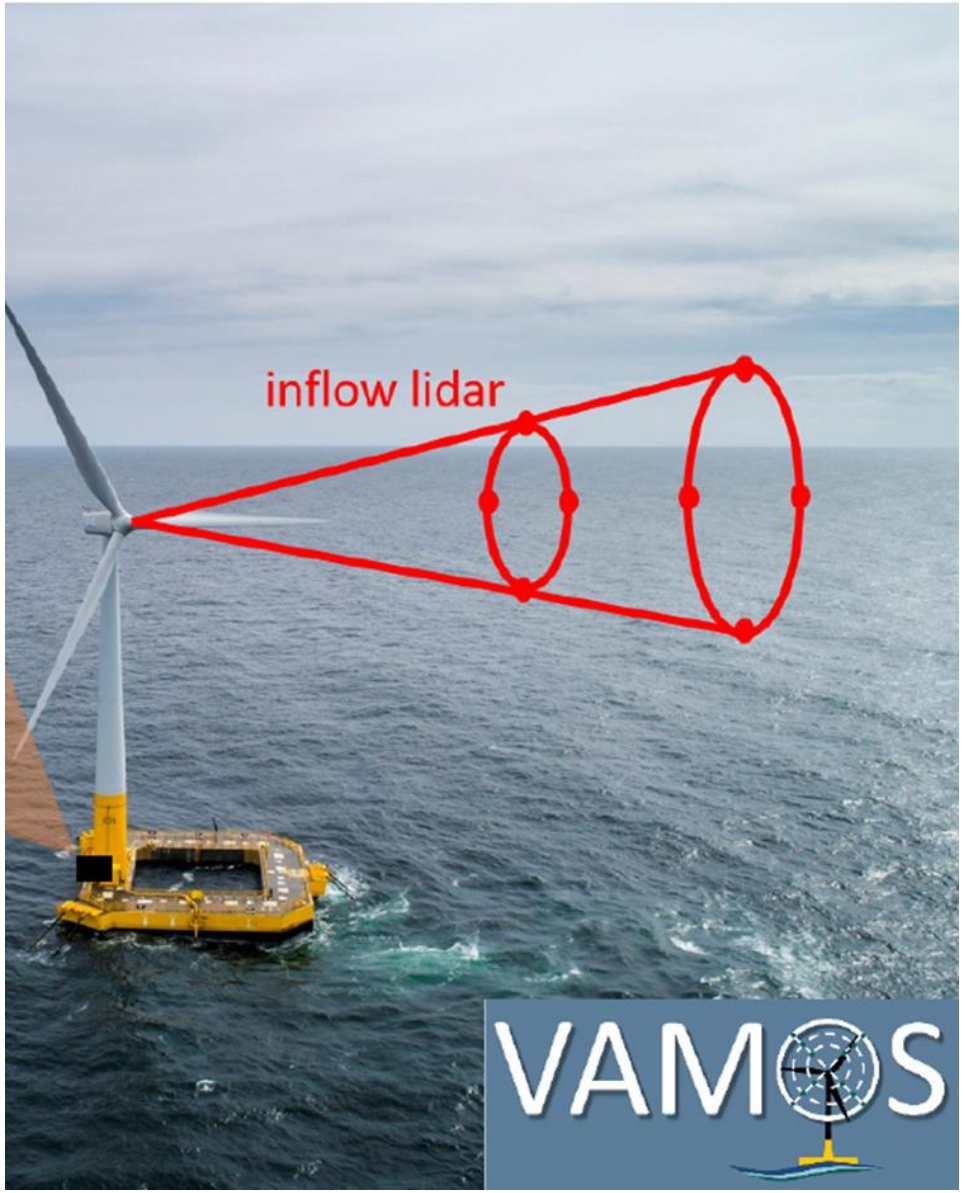
Deriving the uncertainties of the wind speed measurements:

- This is adopted from IEC 61400-50-3, butincludes additional required method uncertainties, suchas those due to wave-induced pitch and roll motions

Typical campaign workflow



Reference Project Sowento



Reference Projects DNV

Project	Location	WTG manufacturer	WTG model	WME type used
PPM	United Kingdom	confidential	5-6 MW	Nacelle LiDAR
PPM	United Kingdom	confidential	5-6 MW	Nacelle LiDAR
PPM & Nacelle LiDAR verification	Germany	confidential	8-9 MW	Nacelle LiDAR
PPM & Nacelle LiDAR verification	Denmark	confidential	8-9 MW	Nacelle LiDAR
PPM & Nacelle LiDAR verification	United Kingdom	confidential	9-10 MW	Nacelle LiDAR
PPM & Nacelle LiDAR verification	Belgium	confidential	8-9 MW	Nacelle LiDAR
PPM (only equipment provision & installation, except LiDAR)	United Kingdom	confidential	9-10 MW	-
PPM	United Kingdom	confidential	5-6 MW	Nacelle LiDAR
PPM	United Kingdom	confidential	5-6 MW	Nacelle LiDAR
PPM & Nacelle LiDAR verification	Germany	confidential	8-9 MW	Nacelle LiDAR
PPM & Nacelle LiDAR verification	Denmark	confidential	8-9 MW	Nacelle LiDAR
PPM & Nacelle LiDAR verification	United Kingdom	confidential	9-10 MW	Nacelle LiDAR
PPM & Nacelle LiDAR verification	Belgium	confidential	8-9 MW	Nacelle LiDAR

What are the unique benefits of the cooperation between DNV and sowento?

“DNV is a global leader in power performance measurement with nacelle lidar. For DNV entering the floating wind market is the next step to support an industry in maturing and to tackle uncertainty around floating wind at scale”
Mike Lüdde, Head of Section wind & Turbine Testing, DNV.

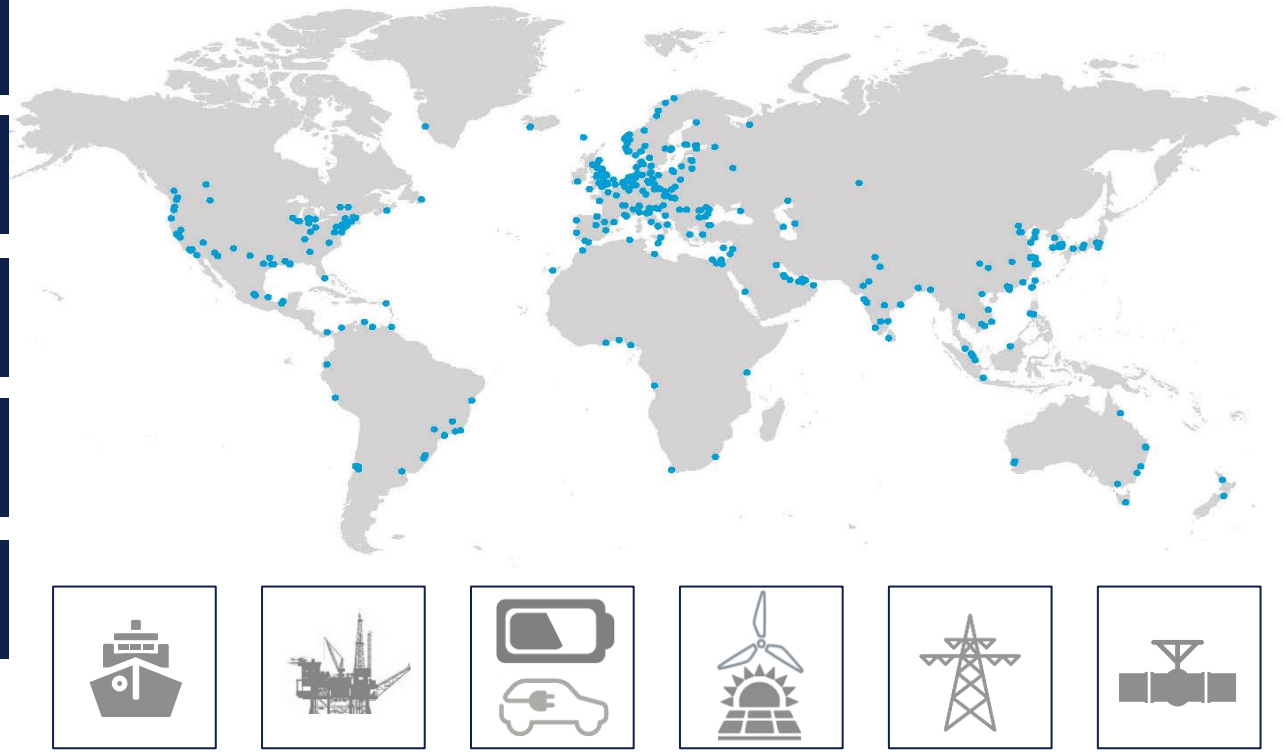
“sowento has been one of the early movers for real-time motion compensation of floating lidars and lidars installed on floating wind turbines” adds Steffen Raach, CEO of sowento. “We are happy to combine sowento’s proven solutions in floating wind and lidar applications with the high-quality measurement campaigns of DNV.”
Steffen Raach, CEO Sowento

DNV: a trustworthy partner across the complete value chain

We work with our customers …

- Energy end users
- Developers, owners and operators
- Governments, regulators and authorities
- Investors and banks
- Manufacturers

… across the entire energy sector …



… combining local presence & global expertise

- **12,000** employees
- **150+** years
- **100,000+** customers
- **100+** countries
- **5% R&D** of annual revenue