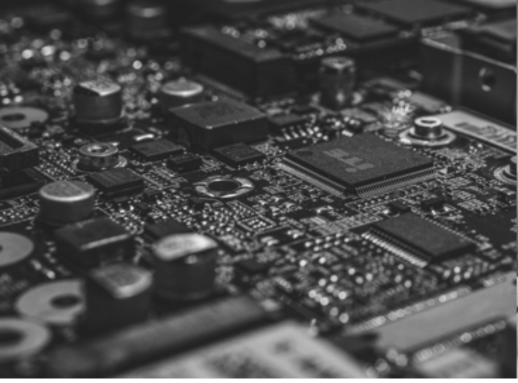

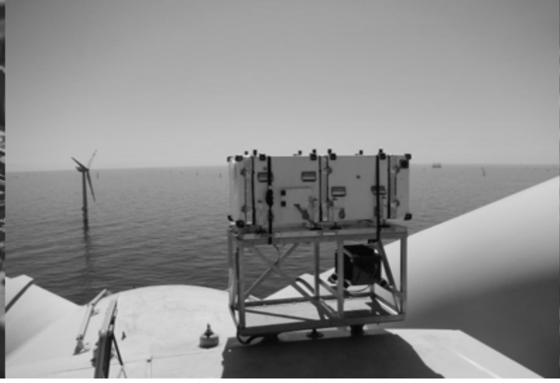

IEA Wind Task 32: Collaborative R&D Roadmap

Task 32 has created a worldwide network of wind lidar researchers who meet regularly to identify opportunities for the use of wind lidar, and mitigate the barriers to its adoption.

Wind lidar has many applications for wind energy that span all technology readiness levels. Task 32 connects many stakeholders including the research community, vendors, service providers, and end users with the aim of creating an active network for the exchange of information and experience.

About this document

This document provides an overview of our members' goals and the activities that we have already undertaken, and our plans for the future. They are intended to help stakeholders engage with the Task, provide feedback, and suggest new activities.

An overview of the technical background to these activities is provided in an article written by the Task 32 Advisory Board in 2018 [1] and in other references cited in the text.

It is expected that this document will be updated annually.

Feedback

Feedback about the activities described here should be directed to the Task 32 Operating agents. Contact details can be found on the Task 32 website.

List of Roadmaps

Task 32 has prepared roadmaps for several interrelated areas of wind lidar research and development:

The roadmaps include activities led by Task 32 (shown in bold text) and by other groups (lighter text).

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What are the conditions where we want to build wind turbines?

Wind lidar can be used to measure wind resources and design conditions on land and offshore.

How do we interpret lidar data in complex terrain and complex flows?

In complex terrain, data from wind lidars can differ from cup anemometers as they use different measurement principles. But, wind lidar may be more flexible in complex terrain than tower-mounted anemometers. Task 32 collects, collates, and disseminates experience in the use of wind lidar in complex terrain and flow situations and thus enables its successful use in future.

Roadmap 1: Wind lidar in complex terrain

Our goal

Understand how lidar data are related to point measurements, and how to use lidar to improve understanding of winds in complex terrain.

Activities

2013	Jan.	**Recommended Practice 15:** Ground-based vertically-profiling remote sensing for wind resource assessment *Advice for remote sensing in flat terrain [2]*
2017	Nov.	**Workshop 7:** Wind Lidar in Complex Terrain *Experience, challenges, and needs for wind lidar in complex terrain*
2019	Oct.	**Comparative Exercise:** Wind lidar in complex terrain *Focus on mean wind characteristics. Runs through end 2020.*
2019		*CFARS: Ongoing investigations into the use of models with wind lidar*

Deliverables

2021: Report on methods for correcting wind data in complex terrain

Outcome

Evidence-based assessment of methods to compare wind lidar data with cup anemometers

What are the opportunities and challenges when using lidar in cold climates?

Wind lidar have been used successfully in cold climates for many years. They have potential advantages over traditional met towers because they can be less prone to icing than traditional anemometers, and they are also easier to install in remote or hard-to-reach locations. There are also challenges with their use in cold climates such as keeping them ice- and snow-free, and of providing power supplies. Most of the challenges can be mitigated, meaning that there are clear opportunities for the wind energy community to exploit their advantages.

Roadmap 2 describes Task 32's steps to support the effective use of wind lidar for wind energy in cold climates.

Roadmap 2: Wind lidar for wind energy in cold climates

Our goal

Exploring the uses of wind lidar to support wind energy deployment in cold climates (together with IEA Wind Task 19).

Activities

2013		**Recommended Practice 15:** Ground-based vertically-profiling remote sensing for wind resource assessment *Advice for deploying and operating wind lidar in cold climates [2]*
2018	Oct.	**General Meeting:** 2019 *Identified potential opportunities and challenges for wind lidar in cold climates, including the need for a working group*
2020	Jan.	**Working Group:** wind lidar in cold climates *Form a group of stakeholders from Task 32 and Task 19 to drive activities.*

Deliverables

TBD

Outcome

Support the effective use of wind lidar for wind energy in cold climates

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How can we use wind lidar offshore, and how can we assess the performance of floating Lidar systems?

Floating wind lidar systems are cheaper and can be more flexibly used than lidar deployed to fixed platforms. For these and other reasons they have rapidly become the preferred tool for offshore wind resource assessment campaigns, and are also increasingly considered for alternative applications, e.g., power performance measurements.

Task 32 supported the development of an offshore wind community and the creation of relevant recommended practices, leveraging support from the Carbon Trust. Roadmap 3 describes our past and future activities in this area.

Roadmap 3: Floating lidar systems

Our goal

Support the commercialisation of floating wind lidar systems and the transfer of research experience into everyday practice

Activities

2016	Feb	**Workshop 1:** Floating Lidar
2018		**Recommended Practice 18:** Floating Lidar Systems [3]
2018	Nov.	**Workshop 13:** Floating Lidar Follow-up *Reviewed immediate and near-future needs for collaborative R&D*
2019	June	**IEC TC 88:** *Floating wind lidar proposed for standardisation*
2020	*Q1*	*Early-stage researchers start 3-year PhD programmes in EU-funded Innovative Training Networks Lidar Knowledge Europe (ITN LIKE) and FLOAting-Wind Energy netwoRk (ITN FLOAWER)*

Deliverables

2021: Possible update of RP18 on floating lidar systems

Outcome

Provide maximum input to the IEC TS 61400-50-4 initiative

How can we use lidar turbulence intensity data for site assessment and loads certification?

Wind lidar can provide data about the turbulence characteristics of wind [4, 5].

There is an ongoing discussion about the relationship between lidar-derived turbulence information and data obtained from a cup anemometer, and how a wind turbine or wind plant responds to turbulence. These are being explored by several groups and it is hoped that in 2020 a joint Working Group will be established between Task 32 and others to align our activities and communication with stakeholders (Roadmap 4).

In addition, Task 32 plans to evaluate how lidar can contribute to load verification beyond providing providing turbulence information similar to conventional measurements.

Roadmap 4: Turbulence intensity

Our goal

Ability to use wind lidar as part of a site assessment or wind turbine loads certification process

Activities

2015		**IEA Wind Expert Report:** Estimating turbulence statistics and parameters from ground- and nacelle-based Lidar measurements *Summary of methods and results [4]*
2018	Oct.	**Workshop 10:** Turbulence intensity measurements with lidars – applications to loads verification and site suitability *Identified barriers and solutions to the widespread application of lidar for these applications*
2019	*June*	*DNV-GL announce wind lidar turbulence Joint Industry Project (JIP)*
2019		*CFARS starts to explore the use of turbulence intensity data from lidar*
2020	Q1	**Working group on lidar Ti:** Working group with Task 32, CFARS, and DNV-GL JIP to coordinate activities, share results, and ensure stakeholder buy-in

Deliverables

2020 Q1: Joint roadmap with Task 32, CFARS and DNV-GL JIP

Outcome

Clearer understanding of methods to measure wind turbulence, how they relate to existing metrics, and how they relate to wind turbine applications

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How can we use lidar to better operate wind turbines and plants?

Wind lidar can measure the winds in and around operating wind turbines and wind plants with unprecedented detail. Several reports have identified this as a key enabling technology for reducing the cost of wind energy in future [6], and it forms a core part of Task 32's work.

How do we certify and optimize turbines that use lidar-assisted controls?

Wind Lidar can provide information about incoming winds that can be used to make wind turbine control decisions. Implementing lidar-assisted control systems brings new challenges related to optimising the wind lidar that are used for this application, and to optimising the turbine controller and structure for the new opportunities presented by the turbine.

Task 32 seeks to enable communication and collaboration between wind turbine OEMs, lidar vendors, certification agencies, and the research community to address these challenges (Roadmap 5).

Roadmap 5: Lidar-assisted controls

Our goal

To use wind lidar as an additional wind turbine/ wind plant sensor to improve wind turbine and wind plant control

Activities

2016 Jul. **Workshop 2:** Optimizing lidars for wind turbine control applications [7]

2018 Jan. **Workshop 8:** Certification of lidar-assisted controls applications [8]

2019 Oct. **Workshop 15:** Optimizing wind turbines using LAC using Systems Engineering methods
Joint workshop with Task 37

2020 **Workshop:** Lidars for wind farm control applications

Deliverables

2020 Q4: Research Plan on how to evaluate the benefit of lidar-assisted controls together with IEA Wind Task 37

Forecasting

Because of their ability to look upwind, wind lidar can be used to forecast the winds arriving at wind plants or wind turbines 10 minutes or more in advance. This can be used to forecast energy output or make wind turbine- and wind farm- level control decisions.

Task 32 and Task 36 (Forecasting) worked together to establish the opportunities and needs for such minute-scale forecasts.

Roadmap 6: Forecasting

Our goal

Identify the opportunities and needs for lidar-supported wind and power forecasting

Activities

2018 Jun. **Workshop 9:** Experience in very short-term forecasting
Joint workshop with Task 36

Outcome

2019: Summary of the different approaches to minute-scale forecasting and possible near-future developments published in *Energies* [9]

No further activities are planned in this area.

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How can we use lidar for performance verification?

Wind lidars can be deployed on the ground or on nacelles for temporary power performance testing, or integrated into the turbine for continuous monitoring. They can characterise the wind shear and veer across the rotor disk, and thus are very useful for detailed performance studies.

Task 32 supported validation of the uncertainty guidance in Edition 2 of the IEC 61400-121 Standard (2017) [10]. Since then the Task has looked at the use of nacelle-mounted lidar in complex terrain (Roadmap 7) and at using measurements in the wind turbine induction zone as input to a performance verification (Roadmap 8).

Nacelle-mounted lidar in complex terrain

It can be challenging to relate wind conditions at a turbine's location to a reference wind measurement, especially in complex (inhomogenous) wind conditions associated with complex terrain. Instead, it may be possible to use nacelle-mounted lidar to measure upwind of the turbine and use that data for power performance verification.

Roadmap 7: Nacelle-mounted lidar in complex terrain

Our goal

Enable the use of nacelle-mounted lidar for power performance verification

Activities

2017	*Start of development of IEC 61400-50-3 for nacelle-mounted lidar for wind measurements*
2020 Jan.	**Round Robin:** Comparison of nacelle-mounted lidar methods for power performance testing in complex terrain *Application of several methods and comparison of experience*
2020 Q4	**Workshop:** Comparison of nacelle-mounted lidar methods for power performance testing *Presentation and discussion of results from the round robin exercise*

Deliverables

2021: Proposal to IEC 61400-50-3 for nacelle-mounted lidar for wind measurements

Measurements in the induction zone of wind turbines

Current power performance standards require wind speed measurements for power performance verification to be taken at more than 2 diameters upwind. This is challenging with larger wind turbines.

Task 32's experience suggests that it may be feasible to use measurements closer to the rotor to estimate free-stream wind conditions as part of power performance verification (Roadmap 8).

Roadmap 8: Power performance verification using measurements in the induction zone

Our goal

Use of wind lidar to measure in the induction zone of a wind turbine and relate these to wind turbine power output

Activities

2018	**Round Robin:** Windfield reconstruction in the induction zone *Estimate of free-stream wind speed from a common data set*
2019 Jan	**Workshop 11:** Windfield reconstruction in the induction zone *Joint workshop with the Power Curve Working Group to present the results of the round robin*
2020	**Round Robin:** Windfield reconstruction in the induction zone with wind plant blockage *Extends the previous round-robin to consider the effects of flow blockage associated with other turbines in an offshore array*
2021	**Workshop:** Windfield reconstruction in the induction zone with wind plant blockage *Presenting the results of the round robin.*

Deliverables

Report on windfield reconstruction in the induction zone, summarizing results from the Round Robins and workshop

Outcome

More accurate power performance testing of wind turbines in operational wind plants

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How can we collaborate on hardware and software?

Wind lidar are traditionally expensive devices that have been heavily optimized for specific applications. This also applies to software, which have been designed for certain workflows. This makes it challenging to test new ideas for wind lidar - as a new device is needed - or to share results between groups.

Task 32's members have been developing the frameworks and tools needed to collaborate on device hardware and software, and the software used to analyse results (Roadmap 9).

Roadmap 9: Collaboration on wind lidar hardware and software

Our goal

Reduce the time and effort needed to design and test innovations in wind lidar device hardware and software

Activities

2017 Nov.	**General Meeting:** OpenLidar concept presented [11]
2018	*The e-windLidar tools repository on Github provides a central point to exchange and collaborate on tools*
2018 Oct.	**Workshop 12:** e-WindLidar *Identifies opportunities and challenges for collaboration on wind lidar device software and data processing software*
2020 Q1	*Early-stage researchers start in EU-funded ITN LIKE training network*

Deliverables

Reference lidar designs and campaign uncertainty estimates using the OpenLidar concept

Outcome

Frameworks, tools, and examples for collaboration on wind lidar hardware and software

These activities will allow us to develop new wind lidar devices and trial new applications, and estimate the measurement performance of wind measurements in advance. Software tools will also capture and share some of the community's knowledge, reducing our reliance on today's experts.

Other Activities

Task 32 offers its members a range of ways to exchange information and experience and disseminate their results to others.

Commitment to Open Science

Task 32 leverages public money from many countries. We therefore aim to make our results freely accessible. To support this goal, we regularly update the Task 32 website with news and results from the Task's activities. In 2019 we started a glossary on the website to capture some of the Task's knowledge and share it with others. We have also launched a Task 32 document repository where we collect material from our events and publish white papers.

Events

We hold around three workshops every year. These are focussed on one specific application and are intended to make progress on a clear question. Many examples of these workshops can be found in the roadmaps.

We also hold an annual General Meeting. The meeting is a mixture of presentations, discussion, and workshop sessions, and is attended by around 50 Task members from academia, industry, and government. The meeting includes results from the prior year's workshops and often triggers new activities. We will hold Task 32 General Meetings in Vienna in 2020 and Stuttgart in 2021.

Advisory Board Meetings

Task 32 is facilitated by Operating Agents who are in turn supported by a 12-person Advisory Board drawn from the Task. The advisory board provides a way for the participants, Operating Agents, and other Tasks to quickly respond to changing situations and keep the Tasks activities relevant.

Providing input to future versions

The Task 32 roadmap has been developed by the Task 32 Operating Agent and Advisory Board based on input from the Task's stakeholders. The easiest way to help set the Task's future direction is therefore to get involved with the Task. We welcome participants at our events from any of Task 32's member countries, and encourage observers from the rest of the IEA wind member countries. We'd love to hear your opinions about what we should be doing, or ideas for solutions that benefit the whole community. Please see the Task 32 website for information about our events.

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The International Energy Agency is an autonomous organisation which works to ensure reliable, affordable and clean energy for its 30 member countries and beyond. The IEA Wind Technology Collaboration Programme supports the work of 38 independent, international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues.

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task 32 lidar

IEA Wind Task 32 exists to identify and mitigate the barriers to the deployment of wind lidar for wind energy applications.

For more information: See the Task 32 website. **Author team:** Andrew Clifton (Task 32 Operating Agent, University of Stuttgart, Germany), David Schlipf (Task 32 operating Agent, Flensburg University of Applied Sciences, Germany). **Images:** Banner, left to right: Alexandre Debiève on Unsplash, SWE U. Stuttgart, Markus Spiske on Unsplash.