

# The European WindScanner Facility WindScanner.eu

Scientific Synopsis

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## WindScanner.eu

### Introduction:

The facility is a unique, distributed research infrastructure that will provide fundamentally new knowledge about the wind and will lead to more efficient, stronger and lighter wind turbines. Exploiting recent advances in laser wind measurement techniques, mobile 3-D remote sensing wind scanners will be deployed by seven large energy research institutes across Europe. This will provide an important catalysis to the future cooperation and integration of the European wind energy research infrastructures.

The RES directive demands a high rate of deployment of renewable energy, to which wind is expected to contribute significantly. This demand corresponds approximately to the installation of one large turbine every hour for the next decade. WindScanner contributes to the realization of the SET-plan goals by establishing this new and truly distributed European facility. With a central node in Denmark, the core consortium consists of seven partners from the European Energy Research Alliance (EERA). Researchers and industry will have open access to the WindScanner infrastructure, accelerating technological innovation, exchange and synergy between the European R&D institutes and the wind energy industry.

It is a scientific challenge to measure and understand the three-dimensional and time varying wind field as it passes through and interacts with the huge rotor of a modern wind turbine. Using traditional wind measurements made by anemometers mounted on meteorological masts, it is practically impossible to acquire the necessary 3-D wind information. Our present comprehension of the turbulent wind flow and its interaction with wind turbines is correspondingly limited. Measurements with the WindScanner will have a lower uncertainty than alternative wind tunnel scale testing or computer modelling.

WindScanner is based on remote sensing measurement concepts using portable and easy deployable wind lidars and wind scanners. The new measurement technology will be disseminated and operated at both national and regional nodes, and interconnected throughout Europe via fast, scientific computer networks.
The results obtained will foster improved computer models and permit a more optimal design of wind turbines. Ultimately, this will lead to better located, better wind turbines thus reducing the cost of renewable energy.

## RI WindScanner.eu

At present, when deciding how and where to site wind turbines, engineers are forced to rely on a combination of guesswork, modelling and limited data gathered from meteorological towers – some more than 100 meters high. Though costly to erect and maintain, these towers can only provide data from a small number of anemometers and other instruments. Such limited data also apply only to the specific locations where the instruments were mounted. These locations may not actually be within the turbine's wind envelope, and the tower itself induces some unavoidable distortion of any oncoming wind flow.

With turbine rotors, now spanning diameters of 120m and more, it is obvious that measurement of the wind speed at a single or few measurement points along a narrow vertically mounted tower is of limited value.

Our envisioned new Research Infrastructure (RI) has been proposed under the auspices of the European **Energy Research Alliance (EERA)** for wind energy. It introduces a unique new experimental research methodology for full-scale measurements of the detailed 3D structure of wind flow around static or rotating objects, including wind turbines.

The primary goal of the new wind scanning experimental facility is to gain further fundamental understanding of the basic aerodynamics and structural fluid dynamics for a wind energy system. Today's wind energy research programs encompass fundamental fluid mechanical disciplines, the results of which are of the highest importance for enhanced understanding to further improvements in the construction and deployment of durable and effective wind turbines, both on and offshore.

## WindScanner.eu and ESFRI

The field-deployable windscanners are based at each EU partner distributed throughout Europe. Built from sets of portable laser Doppler wind profilers, the windscanners can sense the 3D wind vector field at distant points at rates up to 500 Hz.

This will enable measurements of 3D wind fields around large individual wind turbine rotors or within or behind wind turbine arrays and parks, both on and offshore.

## Experimental Atmospheric Boundary-Layer Research

Atmospheric turbulent flow is

- Non-stationary (changes with time)
- Inhomogeneous (varies in 3D space)
- Influenced by the terrain
- Affected by the rotation of the Earth
- Changed by heating and cooling of the surface

None of these physical effects can yet be modelled reliably by wind tunnels or Computational Fluid Dynamics (CFD).

## Joint European experimental research facility WindScanner.eu

In light of the complex nature of atmospheric turbulent flow, we propose the establishment of a new and distributed experimental network around the proposed RI WindScanner.eu facility.

Only via large, coordinated experimental research efforts, with extensive focus on atmospheric boundary-layer meteorological field experiments, will we be able to gain a new and comprehensive understanding of the nature of the atmospheric turbulent flow spanning all the different length and time scales relevant to wind energy research.

Our proposed novel RI, with its new measurement techniques, will radically improve our ability to scan and measure the complex three-dimensional structure of wind fields in the real atmosphere, and consequently, improve our fundamental understanding of the complex geophysical flows characteristic of the turbulent wind fields surrounding wind turbines in the atmospheric boundary layer.

The main aim of the WindScanner is to provide new data and new insight that can by used to improve computer models used for designing and siting of wind turbines.

WindScanner.eu is a distributed European research facility, consisting of sets of mobile 3-D remote sensing stations that can be copied and established across Europe. Since all the WindScanner lidars are distributable and mobile; measurements are by no means limited to research facilities only.

The WindScanner measurement technology is based on single (for homogeneous flow) or alternatively a tri-axial configuration (3D mapping). One to three laser beams are fired upwards and reflected by particles in the moving air. The Doppler Effect shifts the reflected laser beam's wavelength slightly and from this, the speed and direction of the wind vectors is deduced.

The Lidar (light detection and ranging) technology is already well-established in fields such as archaeology, biology, meteorology and the military. This “light-based radar technology has been used to measure the distance from the earth to the moon within millimetres, and to check vehicle speeds. Wind lidars were even used at the 2008 Olympics in China to gauge wind speeds during the yachting events.

Durable and sturdy wind lidars are now commercially available, built from standard fibre-based telecommunications components. This has brought down their size, power consumption and cost (available for around €200,000 each, perhaps less). To be used as scanners, commercial wind lidar must be equipped with steerable scan heads, a technology that has been developed and patented recently by Risø DTU.

## Envisioned Applications and Tasks

| Visions for WindScanner.eu **include, to:** |
|---|
| • cover all relevant terrain types that affect wind fields. A number of existing wind energy test sites in Europe have been identified as 'home bases' for hosting WindScanner facilities.<br><br>• become a Pan-European extension of a recently (2010) granted Danish large-scale RI facility, WindScanner.dk.<br><br>• do away with the need for towers, by using transportable ground-based equipment to produce detailed 3D pictures of air movements. This will allow turbines to be built at locations that will maximise their output, as well as help optimise the design of turbines themselves.<br><br>• take wind patterns into account when planning and designing bridges, buildings and other large structures that may be impacted by strong winds. |

| **Climate zones and terrain types Onshore:** |
|---|
| Applicable climatic zones range from subtropical to arctic, and ocean to continental<br><br>1) open flat land,<br>2) rural/agricultural<br>3) urban and suburban areas, along with their extended downstream fetch<br>4) coastal areas, including bluffs, mesas, and other discontinuities<br>5) forested areas,<br>6) hilly and mountainous terrain, including crests, canyons, and downslope bores<br>7) … |

| **Offshore** |
| --- |
| Offshore windscanners will be installed and operated at offshore platforms, monopoles or wind turbine pylons, and on pointing-stabilized platforms or gyros on floats, rafts or boats.<br><br>We propose at first to focus our studies on the new Joint EU offshore park Krieger's' Flat, located offshore "under the horizon" between Sweden, Germany and Denmark, near German FINO-2 (3) platforms, pt. owned by the German Government - and include this and some new jack-up platforms around it, for extensive offshore WindScanner measurement campaigns.<br><br>The ongoing EU FP7 NORSEWInD project, where Risø DTU is partner and work package leader for RTD data is today available from ordinary non-scanning wind lidars, operated over the North Sea 2009-2010. The research infrastructure can later supplement these investigations with detailed mapping of the offshore turbulence.<br><br>The scientific questions addressed off shore will focus on turbulent shear created by individual turbines and turbine parks in order to assess the potential impact on additional turbines to be erected in the vicinity. It is essential to understand these issues in order to estimate the profitability of very large future offshore wind parks. |

| **Wind LIDARs already developed or under development (2009) at the existing Danish national RI**<br>Windscanner.dk**:** |
| --- |
| • Two prototype continuous wave wind lidar (range 0 - 150 m) - scan rate 50 Hz.<br>• One standard wind profiler (ZephIR Unit 2 - range 10 - 150 m)<br>• One extended range ZephIR (U107 Range 20m - 200 m)<br>• One Control-ZephIR for nacelle (spinner installation (range 20- 200m))<br>• One standard Pulsed wind Lidar (WindCube) WLS7 range 40- 300 m<br>• One Long-range pulsed wind Lidar (WLS70 range 50m - 1.5 km)<br>• Two 3-D three-axis fast scanning cw-based windscanners w/ scan-volume 250m x 250m x 250m and with lidar scan rates up to 500 Hz.<br>• One 3-D three-axis long-range pulsed (WLS200- based) WindScanner w/ scan-volume 5 km x 5 5 km with scan rate of the order of 1 -10 Hz. |

| **Envisioned new Research opportunities to be shared within RI**<br>WindScanner.eu |
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1. Detailed characterization of the dynamic inflow to a wind turbine for improved prediction capability of power production, loads and structural dynamics.

2. Characterization of wake turbulence generated for improved understanding of fatigue loads and power production in wind turbine parks.

3. Extreme and normal structural load mitigation and power optimization from development of nacelle-mounted forward-looking wind lidars.

4. Characterization of flow and turbulence over hilly and forested terrain, hence improved atmospheric flow models.

5. Research on turbulent flow in areas with significant temperature gradients.

6. Research on turbulent flow around full-scale civil engineering structures, such as buildings and bridges.

7. Remote on-line laser systems capable of scanning on-coming turbulent wind fields both up and downstream of large scale turbines (involves European R&D teams and industrial suppliers)

8. Complete extended system to be developed at the existing Wind Test facility in DK (Høvsøre) on the west coast of Denmark

9. More mobile units to be used at other European sites, wind farms (i.e. the Dutch medium scale wind farm facility) and off-shore locations (owned and operated by European partner teams, e.g. Dong Energy)

10. Combined capabilities for remote and in-situ sensing of the wind turbine response to the turbulent field (Involves R&D in sensing technology by European partner teams)

11. Facilities for development and testing of active response technology for the dynamic control of large scale wind turbines exposed to turbulent wind fields and wakes (R&D by European teams including wind turbines manufacturers)

12. Development of algorithms to provide on-line digital representations of the wind fields to optimize the laser sampling technology (R&D by European teams, typically university based)

13. Development of aeroelastic algorithms to describe wind turbine responses and to develop dynamic control strategies (R&D by European university-based teams and teams including turbine manufacturers and owners)

14. Interface facilities to the development of component and partial system solutions incl. drive trains and coupling to power grid. (R&D by European teams incl. wind turbine manufacturers and owners).

15. Wind turbine structural load measurements - Remote sensing of wind turbine structural

load responses are now possible by videogrammetry scanning of wind turbine blade and tower deflections. Windscanner.eu will investigate combined deflection measurements on rotating turbines with wind scanning.

16. Wind turbine integrated Windscanners - Collaborative and extensive R&D is at the moment ongoing between wind lidar and wind energy industry and research institutes with aims to integrate state-of-the-art wind lidar's (pulsed and cw) directly into wind turbines ( spinners and blades) for enhanced productivity, steering and control. Development of studies in highly complex terrains for turbulent flow determination. Study in a selected wind farm in operation in the centre of Portugal with high turbulence occurrences, intense stratification and strong complex mountain-valley breeze circulations. Installation of Windscanners and/or wind lidar's in the area of the wind farm together with wind mast for data correlation.

17. Experimental studies atmospheric flow and turbulence in highly complex terrain for model evaluation.

18. Many more activities to be added …

For further description and references cf. the recent reference list at www.windscanner.dk

Further info:
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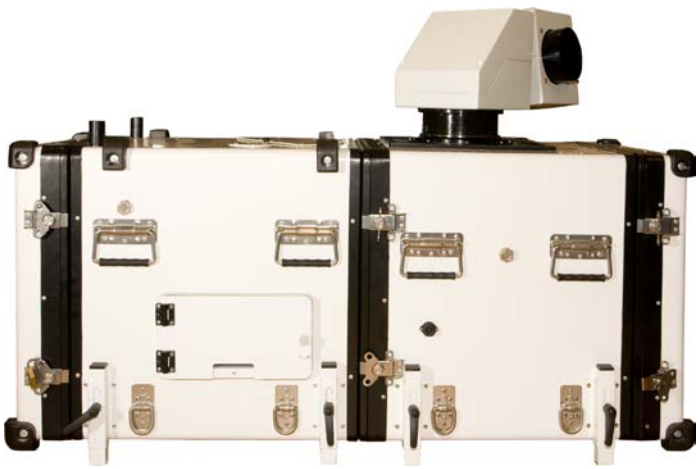
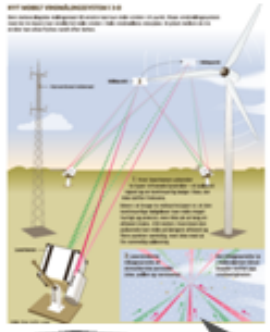
Short Range WindScanner 2010:


Long-Range WindScanner 2010:



# **Windscanner** - from idea to ESFRI RI RoadMap 2010:

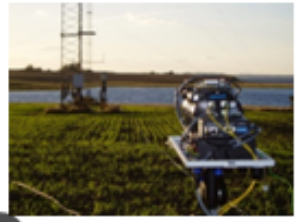


*WindScanner.dk*
*2010-2013*

*SpinnerEX*
*2009*

*MusketeerEX*
*2007/2008*

*First CW lidar*
*2004*



**ESFRI Road Map 2010**

RI focus

Scientific focus

Technical focus

RISØ DTU; CENER; ECN; CRES; Fraunhofer IWES; SINTEF; LNEG/INETI