Final Report Summary - WINDSCANNER (WindScanner.eu - The European WindScanner Facility)

Executive Summary:
In 2014, the wind energy sector reached 128.8 GW of installed capacity in Europe (121 GW onshore and 8 GW offshore). In an average wind year, this would be equivalent to the production of 283.7 TWh of electricity, enough to cover 10.1% of the EU’s electricity consumption. The sector already employs 259,715 people. This remarkable performance has been made possible and will continue only with significant R&I efforts from industry, the research community and a decisive political support at national and European level. WindScanner.eu ERIC aims at making a significant contribution to these R&I efforts by promoting scientific excellence and strengthening the European Research Area (ERA).

WindScanner.eu ERIC will be a unique and mobile European scale research infrastructure, capable of scanning 3D wind fields with high precision in the atmospheric boundary-layer flow and turbulence. The facility will potentially enable the European wind energy society to experimentally investigate the complex flow and turbulence that create loads and cause fatigue on wind turbines and wind plants in operation.

Wind energy researchers and businesses across Europe will be able to use a new experimental research infrastructure for wind scanning. WindScanner.eu will define which wind turbines and turbulence aspects they are interested in, and the WindScanner.eu research facility will then be able to assist researchers and industry in designing optimal scan patterns and field tests accordingly. In these ways users from research institutions, universities and the wind industry will be relieved of quite a lot of the previous work with tall mast installations and can focus their efforts on the scientific and technological aspects of wind conditions.

During the WindScanner.eu preparatory phase the WindScanner.eu consortium has developed two sets of 3D space coordinated and time synchronized laser-based wind scanners, each set consisting of three synchronized scanners which are able to remotely measure wind speed and directions in huge volumes of airflow. When data from three scanners are combined, the investigators will obtain maps of the three wind components. The WindScanner facility will potentially allow European researchers via full-scale experiments in the
atmospheric boundary layer where 200 m tall or even taller turbines operate today to experimental evaluate hypotheses and numerical modelling of natural wind and turbulence properties. The WindScanner was admitted to the European Strategy Forum on Research Infrastructures (ESFRI) Road Map 2010 to be developed into a joint European renewable energy research infrastructure. Ten research institutions from seven European countries have taken part in the PP WindScanner.eu project consortium. The facility already has several showcases, e.g. a joint project with the innovative French company Nenuphar on horizontal axis wind turbines for deep-water floating offshore parks. Along the project two experiments (Kassel and Perdigao) were performed to fulfill few objectives of the project (new technology validation, staff training, database creation) but the results will also be used by other European projects such as NEWA as a key input in its program objectives. Moreover, the Windscanner.eu has been included in the EERA Joint Programme in the Research Infrastructures (RI) sub-programme as a virtual infrastructure. The WindScanner.eu e-Science Platform will comprise a collection of web-based tools accessible for the scientific community and represent a single point of entry for users where they can acquire necessary knowledge about the WindScanner remote sensing based wind measurement technology, learn how to operate it, present and interpret the acquired measurements and other data. During the Preparatory Phase it has been investigated how a proposed WindScanner Central Hub, to be located in Denmark, will be responsible for its development and implementation. See also www.windscanner.eu.

Project Context and Objectives:
In the following chapter it is described how the various scientific, administrative and legal objectives have been dealt with throughout the project period.

WP 1 – Organization, finance

The aim with Work Package 1 in the WindScanner PP project has been to develop a governance model and Business Plan for the establishment and operational phase of the WindScanner.eu facility, including a description of the governance and financial scheme.

The fact that the legal setup is intended to be based on the European Research Infrastructure Consortium (ERIC) has entailed that the Business Plan, including the governance structure and financial scheme has been specifically developed to adhere to the ERIC regulations.

The Business Plan developed in the end of the PP project is intended for stakeholders, national research funding agencies, business and industry as well as NGOs and policy makers concerned with wind energy, renewable energy, as well as basic and applied scientific research. Besides a governance structure and financial scheme, the Business Plan assesses the need and added value by setting up a WindScanner.eu ERIC, as well as detailing aspects related to the WindScanner e-Science and User Platform; data management of the research data generated by the National Nodes being part of the research infrastructure; scientific impact; the way towards implementation; KPI’s; and the critical risks for implementation. Thus, the document is intended to cover all elements that are currently assessed to be acute for the further establishment and operation of WindScanner.eu ERIC.

WP 2 – Legal issues

The objective of WP2 on Legal Issues has been to set up the necessary and expedient legal framework for the construction and operational phase of the WindScanner Research Infrastructure (RI). As already pointed out in the initial description of the project, this objective was anticipated to depend largely on the roles of the different partners, the mission of the project and the selected governance model as determined in WP1. Overall there have been several intersections with the tasks in WP1, and not just for this reason Task 2.1 was to establish an administrative and legal issues committee (ALC) that coordinated the works of both WP1 and WP2 in a joint way. The ALC was established as a forum to discuss and prepare legal and administrative questions.

The objective of Task 2.2 and 2.3 was to find the most appropriate legal options for WindScanner.eu. In particular, the objective of Task 2.2 was to map activities and stakeholders in a stakeholder matrix in order to get an overview of the future activities, and of Task 2.3 to compare different legal options and provide assessment criteria in order to find the most appropriate legal form for Windscanner.eu. Task 2.4 had the objective to deliver a clear picture of the appropriate path to be taken after the end of the WindScanner.eu Preparatory Phase (PP) project by determining the commitment of the partners, and Task 2.5 to ensure a framework of cooperation for the WindScanner project after the end of the PP.

WP 3 – WindScanner Technology & Innovation
The objective of the WP3 WindScanner Research and Innovation Work Package has been to prepare the WindScanner.eu lidar scientific instrument design and manufacturing process including mechanical design, optical design and also data acquisition and processing methodologies. Further, an important aim has been to prepare data analysis tools and presentation software in order for the consortium partners to start construction and operation of the joint WindScanner research Facility WindScanner.eu later on.

Innovation has been promoted via establishment of a “WindScanner Target Design Forum” among the stakeholders and participants for securing and promoting innovation, ideas and aesthetical design in future ground-based wind remote sensing and for promoting new wind turbine monitoring and control products spurred from innovation in equipment and software, enhanced prototype design and revisited manufacturing activities including field testing and quality assurance.

Dissemination of the PP WindScanner.eu projects accumulated know how, innovation products and opto-mechanical remote sensing design such as wind turbine integrated control products, technologies and methodologies, has been transferred to the WindScanner consortiums national and regional EERA partners for regional Pan-European dissemination and interaction with the end-users and stakeholders within the European wind energy research and industry communities.

WP 4 – EERA RI Nodal Coordination

The WindScanner.eu aims to be an open access and mobile research infrastructure that promotes measurement campaigns and dissemination of results. The measurements are done with a laser base technology measuring 3D inflow by means of LIDARS devises. The WindScanner project developed several aspects like the technology improving the LIDAR performance with synchronized control and also structuring the activities and organizing the partners to set up a virtual facility to European level.

Relevant efforts have been made to establish coherence for the implementation of the distributed WindScanner Facility at the seven new regional WindScanner National Nodes. In the same manner, coordination action were undertaken to create good synergy and optimal use of resources between the measurement requirements and measurement project developed by EERA and the WindScanner.eu facility. The EERA RI coordination group shall meet regularly to update the planning, provide contingency plans and share best practices. Among the stakeholders of the industry, IEA task leaders and EERA coordinators will play a dominant role.

Windscanner.eu makes sense as a European distributed facility because it is also supported by the National Nodes, which are taking place in each country from the partners participating at the project. Guidelines for structuring the National Node have been developed and shared among the project partners. Additionally, it was considered the type of training needed for the staff in the National Nodes. Staff assignment, education and training are a decisive part of the construction of both the central hub and the national nodes. This process needs a clear coordination to allow planning for the facilities development phases. The scheme should facilitate new learning interfaces between industry, researchers and students. The training done during the project was done by physical courses but it could also be done as virtual courses.

This includes establishment of a unique one-point-of-entry WindScanner e-Science and User Platform to facilitate a wide range of users from industry and the research community to use these unique 3D scanned wind field research data. This period of time for the project development was defined as the Preparatory Phase (PP), in which some activities were pointing towards the implementation of facility at European level as Windsacnner.eu and also at national level at the participating partners countries in the project as Windscanner National Node. Few partners encountered difficulties to obtain funds to support the activity neither financial support from their national administration. These issues have caused a delay in the original planning to move towards implementation and now, at the end of the project and Preparatory Phase, a transition phase has being proposed to continue with Windsascnner.eu until the National Nodes are ready to integrate their self into the implementation. In this regard, it is expected that National Nodes will be established all over Europe, each with portable rapid deployable short and/or long-range WindScanners, reflecting the objective to create a maximum of innovation impacts.

WP 5 – Open access

The foreseen WindScanner facility (WindScanner.eu) is a laser-based wind measurement system that can generate detailed maps of wind conditions in the proximity of a wind farm covering several square kilometres. The facility will rely on innovative remote sensing laser-based wind measurement devices called LiDARs.

In pursuit of the Commission's Europe 2020 Strategy and the SET-Plan strategy, the new European WindScanner facility will be established to spur, innovate and create accelerated synergies between existing European EERA JPWIND partners, much beyond the individual sum of existing national level R&D services. As a result, enhanced information exchange and innovation activities are envisioned among Europe's atmospheric research communities, the wind energy society and wind industry.

The WindScanner measurement technology enables innovative three-dimensional (3D) “view” of the wind flow in real-time, thus improving our fundamental understanding of the complex turbulent wind flow and its interaction with e.g. operating wind turbines.
current status of the initiative is the development and testing of short-range (10-300 m) and long-range (300-10,000 m) 3D scanning wind LiDAR systems for detailed surface and PBL research on- and offshore.

A new generation of WindScanner.eu equipment will be distributed to the 7 national nodes, including detailed manufacturing plans and test prototypes. The aim is to establish a distributed research infrastructure with regional nodes each possessing similar equipments. The current project in the framework of FP7 is aimed to prepare for the construction of a research infrastructure being an ERIC entity in terms of organisation, finance, legal, technology development, nodal coordination and open access. The project is organized accordingly.

The WindScanner.eu aims to be an Open Access distributed and mobile research infrastructure promoting the dissemination of results including innovation products and their exploitation. A distributed and mobile facility such as the WindScanner requires innovative methods and procedures to collect, process and distribute measured data. The database set-up should fit the requirements for storage of measurement data from the WindScanner.eu facility. The tasks around the validation, processing and storage of the data must be specified and organized. Analyses of measured data and the reporting of results must be defined. Access to the database must be provided and e-Science and networking arranged. The rules and arrangements of end-user support and dissemination are additional important issues to be well defined.

Project Results:

**Summary**

WindScanner.eu is not a “standard” FP7 Research project, but its purpose is to establish a joint European open access Research Infrastructure and an organization. It is the first time that a European Research Infrastructure is being established in the field of wind energy. As this FP7 funded WindScanner.eu project is a preparatory phase (PP) project, the results mainly relate to the legal structure; governance structure; financial scheme; data management that all have been developed in the PP project.

However, there have also been S&T results in the project all conducted in WP 3: WindScanner Technology & Innovation with the ambition to prepare the WindScanner.eu lidar design and manufacturing process for the future construction and operational phase of WindScanner infrastructure.

It is important to emphasize that 2 measurement campaigns conducted in Kassel, Germany and Perdigaö, Portugal, during the PP phase have given input to the overall technological results in the project. WP 5 has dealt with open assess issues and investigated how e-science solutions are foreseen to contribute to the operation of the WindScanner.eu infrastructure. All results conducted in the Preparatory Phase are described in this chapter.

**Administrative and legal issues**

One of the first main results was the establishment of the ALC as discussion forum for legal options and coordination of the business plan. The objective was to find the most appropriate legal options for WindScanner.eu: Task 2.2 mapped activities and stakeholders in a stakeholder matrix. The activities of Windscanner.eu were assigned to the node and the hub. Task 2.3 mapped different legal options and an assessment grid was developed. The main result of these two tasks was an overview and a comparison of existing legal entities. These legal options were assessed and the ALC presented the most appropriate ones to the steering committee. The steering committee decided that an ERIC would be the preferred option to follow up. Task 2.4 resulted in a Memorandum of Understanding, outlining the commitment of the partners in excess of the PP with the introduction of an interim phase before the intended implementation of a WindScanner RI. Deliverable of Task 2.5 is the draft statutes for the implementation and operation of the WindScanner.eu ERIC.

**Overview of the PP WindScanner.eu project by September 2015** generated and to the WindScanner.eu consortium disseminated research infrastructure WindScanners, innovation products, technology and examples of applications: Lover Panel left to right: Long-range WindScanner WLS4000S; Long-range WindScannerWLS200S(prototype); 6” telescope Short-range telescope WindScanner vers 2.0 3” upgraded telescope short-range WindScanner vers 1.2; Upgraded 2D inflow and wake scanning SpinnerLidar vers 1.2; 1” telescope small “Lidics” for turbine blade installation and for “touchless” open air anemometer calibration rigs (upper right).

**Scientific and technological preparation in the Preparatory Phase**

In WP 3 scientific & technological preparation of the research infrastructures collected suite of wind lidars, windscanners and multi-lidar based remote sensing measurement technologies have during the past three years of the PP project been generated, documented and disseminated constituting the experimental facility basis of the new European WindScanner.eu facility.

The new generated foreground IPR in form of new and upgraded WindScanner scientific instruments has all been consolidated and uploaded to the Consortium's joint accessible central server data processing and shared document depository.
The main scientific and technological results have been obtained from several pilot experiments that have been performed during the WindScanner Preparatory Phase project. These experiments include tests in the long range, short range and spinner lidar WindScanners. The added value of the data that the WindScanner provides becomes evident when the real measurements from the wind field surround an object of interest (like a wind turbine) is plotted, showing an image that up to now was not possible to obtain before. The measured wind field can be compared with predictions obtained from numerical computational fluid dynamic models for a specific experiment. In this way, the wind simulations can be validated against real measurements over a much larger volume of the atmosphere. This is a unique feature that opens the door to many new studies about the wind flow over large structures as well as wind resource assessment.

For the case of assessing the WindScanner capacities to operate in complex terrain conditions. Two pilot experiments have been organized. The first experiment was performed in Kassel, Germany, in summer of 2014. In this experiment 6 long range WindScanners, three version 1 and three version 2, have been tested. The measurements taken have been compared with the sonic anemometer measurements installed in a 200 m met mast. After applying appropriate filtering criteria for the wind velocity, as calculated indirectly from the WindScanner radial velocities, presents a good correlation with the sonic anemometer measurements installed. In figure 1, it is possible to see the experiment design.

A second pilot experiment in complex terrain was performed in Perdigão, Portugal, in spring of 2015. The Perdigão site is formed by two parallel ridges along the north-west to south-east direction. The ridges are about 4 km lengthwise, with 500-550 m high at their summit and are separated approximately by 1.5 km. On top of the south-western ridge, a 2 MW wind turbine is installed, approximately at the middle of the ridge. The location of the wind turbine as well as the 3 long range WindScanners are shown in figure 2. The long range WindScanners have been installed forming a nearly equilateral triangle, with one unit next to the wind turbine and the other two units in front on the north-eastern ridge, separated approximately 1.5 km. In the surroundings of the wind turbine, the 3 short range WindScanners as well as the 20 m high met mast have been installed.

Regarding the short range WindScanners, these were installed in a triangle around the wind turbine in order to measure the wind flow around the rotor. This means that the incident wind flow and the wind turbine wake have been the focus of interest. The electrical supply and the data transmission network were directly cabled from the control office container to each of the WindScanners.

Some of the objectives of the Kassel and Perdigão experiments included to verify the correct operation of the individual WindScanners, to verify the correct time and space synchronization of the measurements, to verify the private network operation, to assess several scanning trajectories and ranges. Additionally, a very relevant learning from the activities performed during the experiments, was the necessity of performing a proper equipment calibration. Firstly, a global system verification should be performed before transporting the WindScanners to the campaign site. At the arrival, a system calibration should be performed to assure that there were no misalignments during the installation process. After the measurement campaign, an additional calibration needed to verify the integrity of the components and settings.

For the long range WindScanner calibration, a procedure called hard targeting is followed in order to assess the angle deviations (offsets) from the internal scanner head readings and the actual position of physical objects in the surrounding region. In practice, several wooden sticks are installed around the WindScanner unit at least 80 m away. Behind the stick position, there should be a clearance of at least 20 m from any possible big obstacle, for instance a forest. Whenever possible, the sticks should be installed at the cardinal positions in order to assess whether the inclinometer calibration remains unchanged. Also, one of them should be at the met mast orientation in order to assess the WindScanner offsets at the direction of interest. The exact position of each stick is sensed with a GPS.

After several refinements of the scanning angle limits and accumulation times, a satisfactory result is delivered. The location of the target in the lidar coordinates is collected and converted to geographical coordinates. Additionally, the azimuth and elevation angles are calculated. These results are compared with those obtained from the GPS measurements taken previously. The results are compared and the WindScanner angle offset shall not be higher than 0.01 since the expected accuracy is of 1 m or less in a range of 5 km. Otherwise, an offset correction has to be done to the WindScanner hardware or manually change the offset values considered in the
WindScanner control software. The main components of the hard targeting procedure are shown in figure 3.

Since each experiment can have different objectives, for instance, compare the WindScanner measurements versus anemometers installed in a met mast, assess the wind resource over the edge of a hill, sense the inflow and wakes around a wind turbine, etc., different sensing trajectories might be needed. For that purpose, a careful planning of the trajectories design is required. The programming of the trajectories can take a considerable amount of time, depending on their complexity. For that reason, it should be programed well in advance before transporting the WindScanners to their measurement campaign site. Several default trajectories have been integrated in the control software, but any trajectory can be performed. Currently, the trajectory programing is a task that is been automatized in order to facilitate the final user the performance of advance experiments.

E-science platform and measurement campaigns in WindScanner.eu
The WindScanner measurement technology enables innovative three-dimensional (3D) “view” of the wind flow in real-time, thus improving our fundamental understanding of the complex turbulent wind flow and its interaction with e.g. operating wind turbines. The WindScanner.eu project aims to be an Open Access distributed and mobile research infrastructure promoting the dissemination of results including innovation products and their exploitation. WP5 (“Planning and Scheduling of Open Access”) included tasks around the specification and organization of the validation, data flow, processing, storage and central access to the data. Analyses of measured data, the reporting of results and the rules and arrangements of end-user support and dissemination are important issues to be well defined.

A report entitled “Establishment of methodologies for data quality assurance and exchange” is the deliverable of task “Open Access, e-Science and Networking study” of WP5. It aims at (i) collecting the user and technical requirements of the e-Science platform, (ii) present the State of the Art and describe related projects in Data Research Management or e-Science financed by EU, in the USA and in Australia, (iii) survey possible technologies and propose and discuss possible architectures to support the open-access e-Science facilities to be deployed. Therefore, the scope is: (i) to identify and describe the requirements of the Open Access platform, and (ii) to serve as basis for the other WP's tasks.

The growing tide of data to be collected by LiDAR sensor based WindScanners and its rising importance demand a solid e-infrastructure that can support the entire data workflow process: collection, processing, visualization, searching and long-term preservation.
It concerns all groups of users, those who want to keep i) the raw data, ii) the visualization of results and iii) the end results, e.g. publications, digital data or graphics. Apart from the computational needs, an e-Science platform needs to store and provide access to researchers to data from multiple campaigns from several sites. Thus, the platform must provide elastic storage to accommodate the growing amount of data produced by devices, plus the data produced by researchers themselves.

The D5.5 report is the first deliverable of the WP5 of the WindScanner.eu Preparatory Phase project, that starts the discussion around “Planning for Open Access”. The results herein presented (for example about user requirements or the proposed architecture) are preliminary and further discussions will take place in the near future, in other WP tasks, that may lead to different and more accurate results. Furthermore, since WindScanner.eu is a future facility that hasn't been defined and described in all details yet, there is a danger that the details presented in the report will not match the final structure and setup of the actual facility. Nevertheless, it is our understanding that the choices surveyed and illustrated in detail in this report, will provide a good understanding of the kind of problems and decisions that must take place in the future.

Given a centralized architecture for the e-Science platform, the Hub resides at a Central node where a ‘supervising’ institution screens and distributes data with different confidentiality levels, from open access for researchers to confidential regarding data from, for instance, turbine manufacturers. Data may be requested to be encrypted preventing unauthorized usage but, this way, it will be outside the scope of the e-Science platform and cannot be used by researchers.

The methodologies for data quality control will be taken place before the upload of data (and metadata) to the platform, in order to validate the data against an agreed format before storing these data for long term persistence.

The access to the platform to upload datasets and metadata, to upload research objects or to upload procedures, is prepared to be done via Web Applications to be developed or by assorted computer programs. Both Web applications and programs use the same set of defined Web Services with specified formats (an API), that enforces the verification of access privileges. The internal architecture, comprising the interfaces for communication between the different nodes and external applications that interact with the platform is
foreseen as a set of cohesive Web services following the RESTful architectural style. By following this approach, Web applications (to administrate the platform, to provide the e-Science services, to upload data, and so on) will easily be developed on top of the standard API, as well as Mobile applications. Moreover, the Hub central node, where all Business Logic will be deployed, may later on be integrated with other unanticipated nodes in a Service-Oriented Architecture (SOA).

Given the envisaged functionalities identified and characterized and the architecture proposed, a set of technologies must be analyzed. A set of choices over the current technologies is proposed in order to validate the putative approach and give a better insight on the kind of problems that will be faced in the future implementation of the research infrastructure. As the trade-offs will change soon the choices must be revisited before the platform is to be put in place.

Defined in work package 5 of the WindScanner.eu project is the task to setup requirements for the “WindScanner.eu database. It will enable the consortium partners to share measurements, best practices, data processing steps and findings. The relevant deliverable describes the requirements for a decentralized database network to share data of high value. Tools are presented to create data filters and guarantee data quality at a central place. This shares efforts and helps any data analysis to efficiently do analysis without the need for default filtering or validating the data themselves.

The WindScanner.eu database requirements go further than “just” sharing data. It will enable its users to store measurements, do post processing and generated reports at a local level thus sharing the work with all the levels above. The database part of the WindScanner e-Science platform. From there users will browse the content of the WindScanner database, taking a step closer to the measurements with every click.

Every participant of the WindScanner.eu consortium will have at least one WindScanner database in the WindScanner database network. It will enable the participant to share data, metadata and post processed data for other participants. For scalability in performance, databases can be added to the network to split the load of a highly used database. If partners join or leave the consortium databases can be added or changed of owner without much technical effort.

Not all requirements are in this document. The requirements in this document are based on best practices and try to cover the needs of the current consortium partners. For a WindScanner database the following major requirements and their rational are identified.

- Independent data repository. Database managers have a measure of autonomous management. This distributes responsibilities across the WindScanner database network giving a minimal day-to-day effort from the consortium itself.
- Support for multiple data sources. A database can register on data files, files on any network or signals from other WindScanner databases. The latter is the key requirement for transparent data sharing.
- Mapping of every measurement to metadata, reports, experiments and campaigns. A measurement is done for a reason and that is deductible from the database.
- Ability to read local data files. This keeps the raw data from the database avoiding a performance penalty when scan rates scale up. This essentially makes it a two-tiered database.
- Programmability. A database is able to do post processing locally by user functions. Converting, filtering or combining signals to create a new one.
- The option to store intermediate results. To generate an overview of signal behavior and quickly find points of interest.
- A store for data validation records. If the quality of measurements cannot be guaranteed to a certain level, they are flagged.
- A store for traceability. Every measured sample is traceable to how it's measured, its measurement conditions and its origin.

User access is granted on a, per campaign, per signal and per time span basis or signal can be publically accessible. A measurement campaign proposal will define access per signal so not all signals are shared by default.

By using existing and proven technologies, like cloud web services, open source software WindScanner.eu database support is guaranteed for a long time. In essence, all source code is available so we can rebuild or freeze software dependencies. The WindScanner access committee appoints local or on site database managers. They will guard local database integrity and quality.

Management and data quality in the WindScanner.eu database network is distributed over all partners in the network. This helps to create short management lines and get fast operational decisions.

The WindScanner.eu consortium is setting up a platform to share data from scanning LiDAR systems but it could be the first step in openly sharing and analysing data from experiments in the whole wind energy field. Part of the E-Science work in WindScanner.eu has been to describe, how measurement campaigns within the future WindScanner.eu Research Facility might be carried out.

It is not intended that the future RI owns or leases WindScanner hardware, thus the necessary hardware to perform the campaign have to allocated from the different National Node members. To support the WindScanner Hub regarding the hardware allocation and dealing with client requests, this document recommends establishing a permanent “Campaign Committee” which keeps track on the WindScanner hardware and the activities of the members. The Campaign Committee should consist of experienced National Node
members and perform the feasibility check of future campaigns and supports the Client regarding the full proposal. The time schedule of the desired campaign depends on the availability of the WindScanner hardware. Other members of the RI get involved in the campaign by providing the hardware and staff. Members involved in a campaign establish the "Campaign Team" which prepare and execute the campaign. This temporary establishment also performs the first data analysis and keep track on the running campaign and the progress of the measurements. The Campaign Team also consists of staff from the Client and should meet on a regular base during the installation and the running measurements.

Another scenario addresses RI internal campaigns, involving two or more National Node members. These RI internal campaigns, like the Kassel-Experiment require much less preorganization and a letter of interest or a full proposal might not be necessary. However, documents describing the planned campaign might help during the later planning and preparation.

Despite the organizational aspects, this document also gives technical solutions for the data and grid connections of the current WindScanner hardware. These information help to evaluate the necessary effort to prepare the campaign and gives practical solutions which have already been applied with success. However, the WindScanner technology is still under development and those technical solutions only cover the current state-of-the-art. New innovations and development might influence the amount of necessary staff to deploy the measurement systems or the power consumption significantly.

Based on literature review and the Kassel-Experiment case study recommendations are made for general and future WindScanner related measurement campaigns measuring from different directions within intersecting measurement volumes. The WindScanners should be installed in a way that maximizes the measured frequency shift (see also section 4.3 of WP 5.3) resulting from the different wind speed components (x (West to East), y (South to North), z (downward to upward)). This is especially of advantage when one of the components is small, which is often the case for the vertical wind speed.

To ensure a high accuracy of measurement the beam pointing uncertainty has to be as small as possible. This is a challenge when measuring with a long range scanner at a faraway point. To tackle this task, an exact leveling of the devices is required. During the preparation of the campaign the systems should be calibrated for their internal electronic inclinometer using an accurately determined position (e.g. with differential GPS) of reference poles at a distance of about 100 m. The scan head is consecutively directed at the two poles in an azimuth angle sweep. From the carrier to noise (CNR) back scatter ratio one can measure the position of the top of the reference markers (hard targeting) and derive the offsets between their expected position and their actual position. The offsets are used to correct the scanner head hardware or can be introduced into the scanner head control software. When the WindScanner is deployed in the field these offset values can be used to verify the proper leveling.

After the installation of the WindScanners on a stable underground the first task is a rough orientation and leveling. Afterwards the optical alignment has to be verified using a metallic template with a small hole drilled in the middle and a thermally responsive plastic sheet to check that no misalignment of the optics has occurred during transportation and installation. The fine leveling should be done with a hard target mapping (CNR mapping) approach. CNR performs a circular scan at the horizontal plane in order to identify the presence of obstacles (strong back scatter) around the WindScanner. For this purpose DTU has developed a software called "CNR mapper" which visualizes the positions of hard targets measured by the CNR back scatter ration of a WindScanner.

The CNR mapping approach is basically the same as for the inclinometer calibration. The scanner head position and the position of several wooden reference markers (three are recommended) at a distance of about 100 m around the WindScanner are determined using differential GPS. There should be no further obstacles within 20 m behind the reference markers. Whenever possible, the reference markers should be installed at the cardinal positions in order to assess whether the inclinometer calibration has remained unchanged. The WindScanner allows to choose between three pulse durations, which represent the pulse length and influence the sensing range. The short pulse lasts 50 ns and has a probe length of 10 m, recommended for a sensing range of 1 km and should be chosen for the mapping. The results of the differential GPS concerning the position of the reference markers and the WindScanner head position should be verified with a theodolite. The theodolite also has the additional advantage of exactly determining the position of distant targets.

The information on the position can be used in order to control the WindScanner head to find the target reference markers. The measured location of the target in the lidar coordinates has to be converted to geographical coordinates. Additionally, the azimuth and elevation angles have to be calculated.

The results have to be compared with those obtained from the GPS measurements taken before. The determined WindScanner angle offset should not be higher than 0.01° (less than 1 m deviation in 5 km distance). Otherwise, the leveling has to be changed or offset values have to be integrated in the WindScanner control software.

A measurement should give an estimation of the beam pointing accuracy using the approach of a probability cube.

To keep the quality of the results high, a quality control of the data is required. However it is always difficult to carry out a quality control without an independent reference. Therefore to check the quality of the measured radial velocity of the scanner it is advisable to install a reference mast with a calibrated free stream 3-D ultrasonic anemometer.

Possibilities of quality control of the WindScanner data are limited. Implausible values or spikes in the measurement data can be
detected by manual screening of the data or automated boundaries, which have to be defined with care and were not possible to be
generalized yet.
The CNR value can be used as a quality measure. Upper (e. g. -8 dB) and lower CNR limits (e. g. -27 dB) should be defined. Additionally,
the CNR values at different distances should be compared to detect obstacles e.g. the guying of a reference mast. A similar analysis
should be carried out for the radial wind speeds which might show implausible results in case the measurement is disturbed by an
obstacle in the line of sight. In the future also other parameters such as spectral broadening could be considered.
The combination of different radial wind measurements requires the measurements points (volumes) of the different WindScanners to
intersect as well as possible. Therefore a spatial selection of these measurement values has to be done. Additionally temporal
synchronicity should be checked, in particular for turbulence analysis with high temporal resolution.
The construction of the 3-D wind vector from line of sight measurements from the different systems requires that all data is
transformed to the same coordinate system. Afterwards a vector construction of x,y,z (u,v,w) is done and the wind speed is calculated.
Based on the results of the wind vector construction ten minute statistics (mean, maximum, minimum and standard deviation of the
wind speed and direction) can be calculated.

Developing the e-Science and user platforms is a long-term and multi-disciplinary project that will involve a diverse group of people. In
order to achieve success, it is of particular importance to split the entire work in subtasks. These subtasks will address necessary
hardware and human resources, development of the back-end and front-end of the platforms, and communication of the platforms with
the WindScanners and WindScanner measurements database.
From the given descriptions of the tools, it is important to define a set of inputs for each tool, and what outputs the tools will generate.
Since most of the tools are interlinked; while some tools are foreseen to communicate with the WindScanners and WindScanner
measurements database, the structure of the inputs and outputs of the tools need to be well defined. Afterwards, the interface for each
tool should be designed with simplicity and ease of use in mind in order to provide users with a seamless interaction with the user
platform.

The above-mentioned descriptions and definitions are sufficient to start developing the back-ends of the platforms, which basically
represent the e-Science tools. Certain tools already exist (e.g. the Blog) and they need a minimum of adaptation to suit the needs of the
platforms. Some tools require low resources to be developed (e.g. the e-Logbook).
Other tools require large resources (e.g. the Data grabber) and even can be seen as research projects (e.g. the WindScanner locator).
Nevertheless, these tools can be developed with a modular approach by subdividing the entire tool into smaller, independent and
completely functional modules that can be integrated in the platforms.

Since the data exploration tools are the most critical to develop, due to the present need of full scale measurements for models
validation (see the New European Wind Atlas project description), we recommend developing them first. In connection to the data
exploration tools it is important to point a database proof of concept has been established during the PP phase, which show the project
participants the feasibility and possibilities of the suggestions made in D5.1. This work can now be used to take the next steps and
create a working demo version of the e-Science and user platforms for end users. If the demo site is accepted we can focus on the final
design and implementation.
Overall, the contents and functionality of the e-Science and user platforms are foreseen to evolve, expand and adapt over the course of
the platforms’ usage. Therefore, it is not a prerequisite to develop all the features of the platforms all at once in order to have a
functional prototype of platforms.

The main obstacle in the development and major applications of the e-Science and user platforms is reluctance of users to interact
with the platforms. However, with the proposed philosophy of the platforms, we believe that well-established experts and key persons
will use and contribute to the platforms, which consequently will give a necessary momentum for the widespread usage of the e-
Science and user platforms

Potential Impact:
Summary

WindScanner.eu ERIC will potentially have a direct impact at three levels:
1) Scientific – by providing unique advancements within remote sensing-based meteorological measurements.
A new world-class research centre of excellence will be established, fostering human resources in the form of trained researchers.
WindScanner.eu elevates the cooperation between national research organizations from ad-hoc participation in joint projects to
collectively planning and implementing a new joint strategic research programme.
The outcomes of the joint, strategic collaboration. Enhancing and optimising EU energy research capabilities through alignment, knowledge sharing, more open access to research and development of the user community, expanding the number of partners involved in the Wind Energy. Before establishing the WindScanner.eu Research Infrastructure is designed to provide detailed insight in flow and turbulence fields at selected regional sites. The technological development envisaged helps reducing uncertainties associated with single turbines and entire wind farm's wake predictions. Wind data available from the future RI will also enable better model predictions of wind conditions and wind resource mapping.

Below, we provide a brief analysis of each of these three impacts.

2) Societal – by contributing to the realization of the SET-Plan goals.
At societal level, there are several stakeholders who benefit from the project's implementation and operation, since the scientific progress envisaged in the Preparatory Phase of WindScanner.eu will lead to better exploitation of wind energy. Thereby WindScanner.eu enhances the societal and political progress, including social well-being and the environmental impacts by mitigating climate change.

WindScanner.eu contributes to the realization of the SET-plan goals, including the European Wind Initiative (EWI) and the European Energy Research Alliance for Wind Energy.

3) Economic – by increasing European industry competitiveness.
WindScanner.eu stimulates technologically created innovation via exploitation of IPR and development of spin-off products for the wind energy industry. The WindScanner.eu Research Infrastructure is designed to provide detailed insight in flow and turbulence fields at selected regional sites. The technological development envisaged helps reducing uncertainties associated with single turbines and entire wind farm's wake predictions. Wind data available from the future RI will also enable better model predictions of wind conditions and wind resource mapping.

Below, we provide a brief analysis of each of these three impacts.

Scientific Impact
WindScanner technology provides a new insight into the complex wind field and turbulent features of an atmospheric boundary layer, where wind energy is being harvested. The increase in at least 3 orders of magnitude on high-quality, non-disturbed real flow cannot be replaced by any in-situ array of instruments, thus providing unique sets of real scale data on a larger volume.
Numerous CFD studies assisted by several wind tunnel scale model studies of turbine represent the state-of-the-art experimental research infrastructure to investigate turbine-wind interaction. However, none of these state-of-the art research facilities provide full 3D wind fields, in space and time measurements of the fully developed atmospheric boundary-layer flow and turbulence, embedded with large scale coherent structures and thermal stratification effects.
Attempts to measure full-scale 3D wind field structures include steerable unmanned aircrafts (UAS), tethered balloons, multiple array met-towers, and even a recent study of large scale flow structure in the wake zone of a 2.5 MW wind turbine, investigated experimentally via Particle Image Velocimetry measurement techniques during natural snowfall. Also multiple, time synchronized, but not space synchronized, wind LiDARs have recently been demonstrated to be able to measure the 3D wind velocity vector in one point in space.
Therefore, when fully operational, the new WindScanner.eu ERIC will offer the attractive and obvious advances of remote sensing-based meteorological measurement techniques. The results obtained will significantly increase the ability to conduct high-impact research for scientists.

From an instrumental point of view the WindScanner technology may be considered a game changer but it is still yet too soon to establish any sound metrics related to the full application of this technology.
Overall, by setting up efforts to jointly address grand scientific and technological challenges (e.g. measure and understand the three-dimensional and time varying wind field), the WindScanner.eu ERIC will work as a common platform for knowledge transfer that can reach out to both scientists and industries in different sectors, increasing the European research added-value and consolidating Europe's leading position of excellence in wind energy research.

Contribution to the realization of ERA
In order to create a genuine ERA, greater coordination between national and EU research activities is needed. A main objective of the WindScanner.eu ERIC is to support the realisation of the ERA through the reduction of fragmentation and increased coordination, in order to create a single more efficient research area where there is no unnecessary duplication of effort and where the needed critical mass is achieved at a scale unattainable solely at national level.
Furthermore, previous experience has demonstrated that there is a need for new strategic partnerships, where partners agree on common priorities and longer term strategies. The WindScanner.eu ERIC will underpin such a partnership approach focused on strategic alignment of the partners R&D efforts in this field of research and joint planning that could provide a more integrative approach to research, education and innovation activities. The creation of lasting cooperation between WindScanner.eu Partner Countries will have longer term, broader benefits with an equally important impact on the realisation of the ERA and on the implementation of a competitive and dynamic knowledge-based economy targeted by the Lisbon Strategy.
The WindScanner.eu ERIC will also be promoted together with the European Energy Research Alliance (EERA) Joint Programme on Wind Energy. Before establishing the WindScanner.eu ERIC the +40 partners in EERA JP Wind will be involved in the further development of the user community, expanding the number of partners involved in the WindScanner.eu Preparatory Phase project.

The main objective of EERA is to accelerate the development of new energy technologies in support of the SET-Plan by strengthening, expanding and optimising EU energy research capabilities through alignment, knowledge sharing, more open access to research and joint, strategic collaboration.
The outcomes of the WindScanner.eu ERIC facility, derived from an effective joint cooperation between European countries and
national research programmes, will thus contribute to the EERA objectives, promoting European research excellence in the field and contributing to the development of the European Research Area.

Societal Impact
The EU binding target of increasing renewables share by 20% in 2020 and Europe's commitments to cut the GHGs by 80-95% in 2050 makes wind energy an important player in the future energy mix. WindScanner.eu ERIC aims to leverage the long term European wind energy research potential, which will ultimately translate into attaining the demanding European ambitions for wind energy generation in the future (installed capacity is expected to increase by 64% in 2020 compared to 2013 levels).

Moreover, the WindScanner.eu ERIC will contribute to the realization of the SET-Plan goals by establishing a new and truly distributed European facility that will contribute to an optimized design and operation of large-scale turbines and an effective wind farms' siting, by providing unique data on turbulent wind flow and its interaction with wind turbines. Ultimately, this will lead to better located, more efficient, stronger and lighter wind turbines, thus reducing the cost of renewable energy, which in turn is expected to accelerate the penetration of wind energy in the EU and increase employment in the sector, benefitting the European economy by attracting the best professionals to the world-class research and technology environment created by the new RI.

Finally, the creation of a new European Research Infrastructure will benefit all Member States by strengthening and extending cross-border cooperation and making a more efficient and effective use of national resources and capacities, overcoming the fragmentation of the European research base currently recognized as a major impediment for further European development. WindScanner.eu ERIC will, therefore, reinforce European Research Excellence, by enabling trans-national research and innovation; exploiting synergies; and strategically aligning different sources of national, European and private funds.

Economic Impact
Research and innovation play a crucial role in the sustainable growth of productivity. Europe's future economic growth and jobs will increasingly have to come from innovation in products, services and business models. Due to its vital contribution to increasing Europe's competitiveness, innovation is at the core of Europe's 2020 strategy.

Even though the European wind industry is now at a competitive stage – being established as a driver for economic growth over the next twenty years – further development cannot be left entirely to the industry, which, in the current economic climate, tends to focus on incremental improvement and further upscaling of existing concepts, whereas new concepts and innovations are needed to drive down the costs. To realize this, a joint strategic, research effort is needed. WindScanner.eu ERIC will help mobilizing national resources for the development of the research advancements needed to keep Europe in a global leading position.

The WindScanner.eu ERIC facility will offer open access collaboration with all wind energy engaged atmospheric boundary-layer researchers and experimentalists, including the wind energy industry throughout Europe and Overseas. Research and spin off wind lidar products will assist wind energy integration, on and offshore, and, ultimately, help lowering the cost of wind energy. The innovative products and services derived from WindScanner.eu RI will be disseminated and exploited throughout Europe, contributing to the creation of growth. Furthermore, implementing the RI with its Nodes distributed in different regions will certainly bring new job opportunities and perspectives for researchers, engineers, administrative and related staff in these regions as a result of increased scientific and economic activity. Jobs will be created during the implementation and operational phases, a proportion of which will be highly skilled, in connection to the establishment and build-up of the hub and the National Nodes. Therefore, WindScanner.eu ERIC RI will spur economic development and innovation, generating opportunities to increase Europe's knowledge-based industry competitiveness.

Overall, besides the major impact on the European Research Area (previously described), it is expected that Europe will benefit economically from the new WindScanner.eu ERIC. The specific economic impacts expected are summarized in the following:

- Development of instruments for specific applications – i.e. licensing deals; WindScanner.eu ERIC will foster the development and commercialization of newly developed technologies, in cooperation with industry, increasing its competitiveness;
- Reduction of loads on wind turbines – increase in units longevity, decrease in the amount of matter thus creating lighter (and cheaper) wind turbines;
- Technological edge on wind engineering helping to optimize the design and performance of equipment and structures – improve innovation and competitiveness of European wind engineering;
- Decrease on the use of Meteorological Towers – lowering the environmental impact of wind resource assessment studies – reduction on the need of spatial distributed measuring tower network, thus reducing man-power and installation set-backs related to tower mounted instruments.

Dissemination

During the WindScanner Preparatory Phase Project, several dissemination activities have taken place. The main activities were focused on explaining the new WindScanner Technology to the potential consortium members. Furthermore, these meetings had the purpose of introducing the potential use and added value of the WindScanner technology to stakeholders. The objective is to gather the support
from the national administration to include the WindScanner in the national Roadmap. Additionally, workshops and Open Days have been held to include a broader audience, especially the industry as a main beneficiary of the output from the WindScanner measurements. Some of these events were coordinated with the pilot experiments in order to show to the public the operation of the systems and the capacity to sense the three dimensional wind field.

National and European stakeholder meetings
A number of WindScanner stakeholder meetings have been held during the PP phase, including national stakeholder days in Germany, the Netherlands, Spain, Portugal and Denmark. Furthermore, a couple of stakeholder events have been held involving several of the WindScanner.eu partner. The purpose of organizing such Annual Stake Holder Meetings is to share the latest developments of the WindScanner technology, together with the results of the ongoing pilot experiments. The results of the pilot experiments are used to exemplify the added value that true 3D measurements of the wind field can bring to the wind energy industry.

The Annual Stake Holder Meeting is an event where the networking at national and at European level can catalyze the proposal of new experiments to be performed and new possible applications for the WindScanner technology.

The first one was held in Amsterdam at the premises of ECN on 22 April 2013. In order to boost the networking aspect, the last stakeholder meeting is going to be held at the EWEA 2015 conference, where the main parties of the wind energy industry and policy makers are gathered. In this way, a high visibility for the WindScanner.eu consortium and the current state of the device development is guaranteed.

Throughout the Preparatory Phase the WindScanner.eu project webpage has been an effective tool to disseminate results and show progress in the project. The webpage will continue in the interim after the Preparatory Phase.

Exploitation
The WindScanner systems are scheduled to perform measurement campaigns during the New European Wind Atlas (NEWA) project, which includes a selection of sites around Europe, including Denmark, Germany, Spain, Portugal and Turkey. The different sites have been selected in order to represent different mesoscale and microscale properties, i.e. terrain conditions, roughness, forested regions, predominant mesoscale wind direction, coastal or inland regions, etc. To outcome of these measurement campaigns will include a large database that will be shared with the consortium members and other potential users under the e-Science platform. Further both short-range scanner as well as long range scanners are being used in national projects and measurement campaigns. This is the case for the Danish project RUNE, which aims at reducing the uncertainty of near-shore energy estimates from meso- and micro-scale wind models. The tools are onshore scanning lidars combined with ocean and satellite information.

List of Websites:
www.windscanner.eu

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Related documents

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