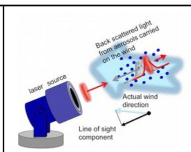
Name of organization	Wind Farm Analytics Ltd (with Renewable Advice Ltd, Fraunhofer UK Research Ltd)
Contact name	Dr Theodore Holtom

Summary:

This technology development seeks to commercialise a LIDAR (laser based) wind velocity measurement device having lasers housed within all three blades of large wind turbines.

The patent-granted innovation includes the convergence of three laser beams to measure three-dimensional wind velocity, advantageous in reducing wind velocity measurement error.

The look ahead cooperative beam scanning aspect enables full rotor wind velocity mapping for large wind turbine rotors, allowing increased wind energy to be harvested. The system also provides actionable alarms of incoming damaging wind-flow so that control systems may reduce the lifetime loads. This reduces operational costs and increases asset lifetime.



Project status:

The beam steering converging beam LIDAR prototype has been designed, built, tested in the laboratory, refined and successfully tested in the field. Under InnovateUK project 132710 the team has been working on demonstration that the laser beam steering LIDAR unit can be housed within the interior of a wind turbine blade and operating through a window in the blade's shell.

Blade specialist Renewable Advice has designed and manufactured solutions for achieving this safely without adversely affecting structural integrity or aerodynamic performance.

The team has also engaged with industry technicians including blade manufacturers, turbine manufacturers, turbine designers and turbine owner-operators who agree this is a valid approach from a structural as well as an aerodynamic standpoint. Industry engagement also shows agreement that whole rotor effects are significant to loads and power performance and that 3-dimensional wind velocity effects are significant.

The Technology Readiness Level reached is TRL 6 “system/subsystem model or prototype demonstration in a relevant environment”. A further project employing the system within a large wind turbine rotor will be required to reach TRL 7 “system prototype demonstration in an operational environment” and TRL 8 “actual system completed and qualified through test and demonstration”.

Description:

This patent-granted innovation includes the convergence of three beams to one or many programmable measurement positions in order to correctly reconstruct the three-dimensional wind velocity at those positions. Wind Farm Analytics has highlighted the mathematical fact that three independent velocity components are required in order to reconstruct wind velocity at a given point because wind velocity is a three dimensional vector.

Wind Farm Analytics has invented and patented the solution and built collaborations to develop this technology from concept to working demonstrator, with thanks to part-funding from InnovateUK and the UK taxpayer. The solution is based on operational wind industry experience and industry engagement. Project partners Fraunhofer UK Research and Renewable Advice have helped build prototype laser beam steering demonstrators and the blade embedding solution. All partners have participated in computer simulation and field testing.

Existing wind LIDAR devices all employ diverging beams (beams that do not intersect) where velocity components are combined from laser beam probes which have significantly diverse positions in space such as 100 metres apart. This leads to significant uncertainty in the measurement and ambiguity when using those devices. Whilst they certainly offer some benefit, employing diverging beam look ahead LIDAR devices mounted on the nacelle always suffers from one or many severe disadvantages such as ignoring the vertical component of wind velocity, assuming uniform flow across the whole rotor, ignoring the possibility of abnormal flow across the rotor, and other problems. Although diverging beam look ahead LIDARs are an improvement over traditional wind measurement instruments, anemometers and wind vanes situated in a poor location on the nacelle roof and behind the rotor, a converging beam LIDAR using three beams from within the three blades is a significant further step upward in improvement.

The blade window will be situated at approximately one third of the way along the blade on the pressure-side blade shell. This is a balance between the need to increase baseline separation of the three LIDARs, in order to improve three-dimensional velocity reconstruction, against the disadvantage of increased blade flexing toward the tip of a blade during operation.

The size of wind turbines has risen to an enormous scale already and the trend, as well as industry opinion, is that this can rise even further in future. Famously one wind turbine manufacturer has pointed out that a single blade is longer than 9 Routemaster London buses and has a blade root diameter wide enough that such a double decker bus could be driven inside. It has also been pointed out that a single blade can be longer than the entire wingspan of an Airbus A380 aircraft.

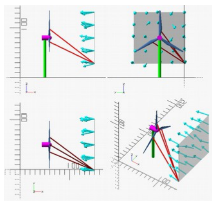
If one just thinks of a large tree with its branches and leaves moving in the wind then it is easy to visualise the variation of the wind field across an extended area. But the largest present day wind turbine diameters of 180 metres are approximately ten times the size of such a tree both vertically and horizontally! It becomes readily apparent for the need of modern wind turbines to account for wind variation across the entire rotor area, rather than just the single point hub height measurement which is used presently. There is definitely room for improvement!

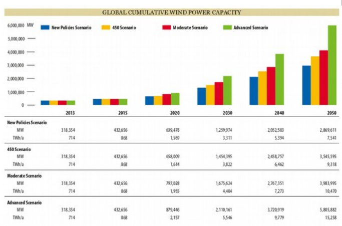
Innovative aspect:

A first major innovation is the successfully patented application of three converging laser beams applied to wind turbine LIDAR systems in order to reconstruct the three-dimensional wind velocity locally. A second innovative aspect is the full rotor three dimensional wind velocity mapping capability by use of three scanning beams.

LIDAR wind velocity measurement relies on the reflection of laser light from microscopic airborne particles and aerosols which are carried with the wind. The reflected laser light has an altered frequency depending on the relative velocity component along the laser beam line of sight, according to the Doppler effect. However velocity components perpendicular to the line of sight component are not resolved. This is why three converging beams are required in order to obtain the three velocity components of the wind velocity.

A third aspect is positioning the LIDARs inside the blades of large wind turbines including the employment of optical windows embedded in the wind turbine blade in order to obtain an increased baseline separation between the LIDARs whilst avoiding undue aerodynamic disturbance (because the window deviates minimally from the overall blade shape compared with mounting a LIDAR on the blade exterior).





	2013	2015	2020	2030	2040	2050
New Policies Scenario						
MW	318,354	432,656	639,478	1,259,974	2,052,583	2,869,611
TWh/a	714	868	1,569	3,311	5,394	7,541
450 Scenario						
MW	318,354	432,656	658,009	1,454,395	2,458,757	3,545,595
TWh/a	714	868	1,614	3,822	6,462	9,318
Moderate Scenario						
MW	318,354	432,656	797,028	1,675,624	2,767,351	3,983,995
TWh/a	714	868	1,955	4,404	7,273	10,470
Advanced Scenario						
MW	318,354	432,656	879,446	2,110,161	3,720,919	5,805,882
TWh/a	714	868	2,157	5,546	9,779	15,258

Global Wind Energy Council “modest growth” projections suggest the likelihood of 10000 large wind turbines per year every year for 30 years between 2020 and 2050. In case that the eventual product were sold for £100k this would imply a potential market size of £1 billion annually. The same industry outlook suggests global wind production rising from 868 TWh per annum in 2015 to 10470 TWh per annum in 2050. Based on our technology increasing production by 5% then this would imply increased renewable energy production of 523.5 TWh annually which would be a significant acceleration toward decarbonising the human energy system. This is a sound green tech investment targeting decarbonisation.

Benefits:

Our forward-looking blade-integrated LIDAR technology delivers:

- advance warning of damaging wind fields such as extreme gusts, extreme turbulence, extreme wind shear and other abnormal wind features which can be damaging to the wind turbine mechanical structure and rotating parts;
- look ahead anticipatory alarms to eliminate fatigue and damage from the wind turbine components lifetime;
- improved wind direction measurement across the entire rotor which gives rise to increased harvesting of wind energy, thereby increasing profit whilst simultaneously decreasing anthropogenic greenhouse gas emissions and other pollution;
- increased profitability expected to be in the region 5-10% improvement ; an 8 MW wind turbine operating with capacity factor 45% will produce 31536 MWh annually which is worth £2.2 million at an income level of £70/MWh; in this example the proposed LIDAR would provide increase in revenue between £110k - £220k annually;
- gains will scale - higher capacity factors are possible depending on location; income can be greater than £70/MWh depending on market; turbine capacity is also expected to increase from 8 MW today toward 15 - 20 MW by 2025;
- decreased human greenhouse gas emissions and other pollution thanks to increasing wind energy production;
- big data machine learning and human learning opportunities since the proposed sensor offers a wealth of wind inflow information not previously available to the wind industry, allowing classification of damaging incident wind fields;
- improved (cheaper) wind turbine design due to lower fatigue loads during its lifetime and improved turbine standard classifications taking account of full rotor wind conditions;
- improved turbine warranties and better designed insurance policies ensuring operation within design specification;
- lifetime data logging of the wind field on a per turbine basis can enable predictive maintenance by assessing which turbines have had a hard life and which turbines have had an easy life.