MEMO

Final / Public

Subject:	Strategic advice floating LiDAR campaign BWFZ
Date:	6 March 2017
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CC:	
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1 Introduction

Within the Borssele offshore wind farm zone, RVO is performing a wind measurement campaign with floating LiDARs at the Borssele Wind Farm Zone (BWFZ). The primary goal of the campaign is to determine the wind conditions for this zone.

The 'Lot 1' floating LiDAR has been measuring on-site wind conditions since June 2015. A second floating LiDAR ('Lot 2') was also installed within the zone, during a relatively brief parallel campaign. The second campaign has already ended and that LiDAR buoy has been removed.

RVO is planning to end the Lot 1 measurement campaign and has asked Ecofys WTTS to perform a preliminary analysis of the wind measurements from that buoy. The objectives of this study are to determine:

i. Whether enough data is collected by the floating LiDAR at the BWFZ Lot 1 position to meet the initial goals for the measurement campaign; and
ii. Whether the LiDAR can be removed from the site.

In order to investigate the above objectives of the study, the wind data of the floating LiDAR has been analysed. This memo reports the findings of this analysis.

2 Measurement campaign detail

The Seawatch Wind LiDAR buoy (serial number WS149) was first deployed at a location within BWFZ in the Dutch North Sea on 11 June 2015. The LiDAR type installed on the floating buoy is ZephIR 300S. Wind measurements were recorded at 30 m and from 40 m up to 200 m at intervals of 20 m. The coordinates of the LiDAR are shown in Table 1 and the position over the BWFZ is shown in Figure 1. The measurement campaign is currently ongoing; however, this analysis covers the measurement period from 11 June 2015 through 14 February 2017.

Table 1: Location of Floating LiDAR Lot 1

Easting (ETRS89 Zone 31N)	Northing (ETRS89 Zone 31N)
502,392	5,728,440

During the above mentioned period, the measurement campaign has been experienced two major interruptions and a few minor interruptions, due to technical issues either related to the buoy or the LiDAR operation. These two longer events are shown in Table 2. Other than these events, there were no other major issues reported.

Table 2: Period of two major interruptions in the Lot 1 LiDAR measurements

Data gaps	Issue	Measurements heights affected
6th October 2015 to 12th November 2015	The Buoy stopped transmitting data	All heights
26th December 2015 to 12th February 2016	The LiDAR stopped working due to technical problem	All heights

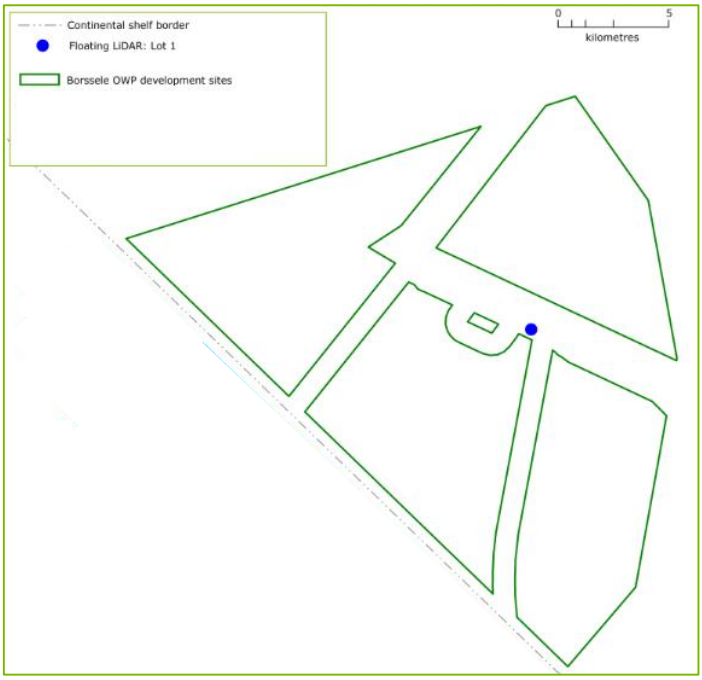

Figure 1: Location of floating LiDAR Lot 1 deployed at the Borssele offshore wind farm zone

3 Wind data analysis

This section investigates whether, since its starting date on 11 June 2015, enough data has been collected by the floating LiDAR at the BWFZ Lot 1 position.

3.1 Evaluation of data quality and quantity

Ecofys WTTS received the processed wind data set from Fugro in csv files, and is already processed by Fugro (including ZephIR internal filters). The Fugro data was published as 16 separate periods, covering a total period of 21 calendar months.

Ecofys WTTS performed preliminary quality checks of the collected data from the LiDAR, to identify records which were affected by equipment malfunction or other anomalies. No supplemental data filters have been applied by Ecofys WTTS, in order to maintain the same conditions as the pre-campaign verification of the LiDAR data.

Wind data availability was very similar at all heights. For the purpose of this memo, wind data availability is reported at 100 m, which was selected as a representative and relevant height as it is close to the expected hub heights for the site. Table 3 shows the wind data availability of the measured data at 100 m.

Table 3: Recovery rates for wind speeds at 100 m

Month Year	Data recovery rate [%]
Jun 2015*	58.4%
Jul 2015	96.6%
Aug 2015	98.9%
Sep 2015	99.5%
Oct 2015	16.0%
Nov 2015	56.3%
Dec 2015	80.4%
Jan 2016	0.0%
Feb 2016	57.9%
Mar 2016	97.7%
Apr 2016	97.5%
May 2016	96.8%
Jun 2016	97.9%
Jul 2016	90.8%
Aug 2016	93.8%
Sep 2016	99.1%
Oct 2016	98.7%
Nov 2016	98.0%
Dec 2016	88.3%
Jan 2017	97.3%
Feb 2017*	42.1%

* partial months

Table 4 shows the data availability per day for wind speed measurements at 100 m for the floating LiDAR Lot 1 position. The instances where no valid measurements were recorded are marked by red, and days with availability below 80% are in orange.

Table 4: Data availability if wind speed measurements at 100 m during the floating LiDAR measurement campaign

(red indicates no valid measurements record – orange indicates days with an availability of less than 80%)

	Data availability of wind speed measurements at 100 m [%] per day																													
Month- Year /Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jun-15											24	100	90	0	53	98	99	98	99	99	98	100	99	99	100	99	99	98	99	99	
Jul-15	30	99	94	98	100	99	100	99	100	100	99	100	99	99	99	88	99	100	99	100	99	99	99	99	99	99	100	97	99	99	100
Aug-15	99	99	99	100	99	98	99	100	100	98	99	99	100	99	100	99	99	99	99	100	98	90	99	98	99	99	99	100	99	99	100
Sep-15	100	100	91	99	99	99	99	99	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Oct-15	100	100	100	100	96	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov-15	0	0	0	0	0	0	0	0	0	0	0	40	100	100	100	100	100	98	99	100	100	22	37	99	99	99	99	99	99	99	
Dec-15	99	100	99	100	100	76	99	99	100	99	100	98	99	99	99	96	99	97	98	99	99	97	97	99	99	50	0	0	0	0	0
Jan-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb-16	0	0	0	0	0	0	0	0	0	0	0	44	99	100	63	97	99	99	99	98	99	99	99	99	99	97	98	94	99		
Mar-16	99	98	99	98	99	98	98	99	99	99	94	98	99	98	99	98	97	99	98	100	99	99	99	79	100	98	97	98	98	99	99
Apr-16	99	97	98	99	98	72	98	99	99	100	99	97	97	99	98	98	99	100	95	99	99	98	98	99	98	99	99	98	99	99	
May-16	86	97	99	99	98	97	99	99	98	98	99	99	98	88	98	95	99	98	98	100	98	99	99	98	99	98	74	98	99	99	98
Jun-16	99	99	97	99	99	98	97	94	98	98	99	98	99	99	98	97	98	99	98	98	94	97	100	99	97	99	98	99	99	98	
Jul-16	97	98	83	98	99	98	98	98	99	98	97	99	99	98	98	76	99	42	0	49	100	97	100	100	98	100	100	100	100	100	100
Aug-16	90	100	100	100	100	100	100	100	100	100	100	100	70	0	58	100	100	100	100	100	100	100	100	100	100	100	94	100	100	99	100
Sep-16	100	100	100	100	100	99	100	90	100	100	100	100	100	100	100	100	100	97	100	90	100	100	100	100	100	99	100	100	100	100	
Oct-16	100	95	99	100	100	99	100	99	100	99	100	100	100	95	100	100	100	100	100	92	90	99	100	100	95	100	100	100	100	100	99
Nov-16	100	100	92	100	100	100	99	100	100	100	100	99	65	100	96	100	100	99	100	100	100	100	90	100	100	100	100	100	100	100	
Dec-16	100	100	79	100	100	100	99	97	22	0	0	49	100	100	100	100	100	100	100	100	100	100	100	99	94	99	99	100	100	100	100
Jan-17	100	99	100	100	100	79	99	100	100	99	100	99	99	98	100	98	97	98	90	97	97	97	99	99	98	98	99	99	87	97	99
Feb-17	97	97	99	99	98	98	98	94	82	99	99	99	98	49																	

3.2 Estimation of long-term wind climate

One of the main objectives of this floating LiDAR measurement campaign is to estimate the long-term wind climate of the site.

To estimate the long-term wind climate, Measure-Correlate-Predict (MCP) methods are typically used, in order to extrapolate the short-term on-site wind data measurements to the long-term. In order to ensure independence from seasonal variations, especially if the extrapolation is performed using methods that do not use time series, such as Weibull-fit or Matrix methods, it is highly recommended that at least one year of concurrent measurements is available[*].

Wind data measurements at floating LiDAR Lot 1 can also be used for statistical extrapolation of 10-minute average wind speed to extreme wind speed value of a 50-year return period. Extreme wind speed value is one of the key input parameter for checking the wind turbine suitability at the sites of BWFZ. Again, for the estimation of extreme wind speeds, the measured wind data should cover at least a period of one year, notably capturing the high-winds period of the year. In the North Sea, high winds are mainly recorded during the winter period.

As per MEASNET guidelines[*], a measurement campaign for the purposes of wind resource assessment is considered to be incomplete if:

1) The measurement period at site does not cover at least 12 months of consecutive measurements; or
2) Within the available 12 months (at least) of consecutive measurements, the availability of the wind data after data filtering is less than 90%; or
3) The availability of the data filled by MCP methods based on further measurement data at the site is less than 95%.

From Table 3 and Table 4, it can be seen that there are 12 months of consecutive measurement with high availability from February 2016 to February 2017. The presented results are at a measurement height of 100 m, but the data availability was very similar at all heights. **The data availability at all heights is 96%, for the period of 14 February 2016 to 14 February 2017**.

In summary, the one year of consecutive wind measurements that has been measured, with high data availability, can be used to calculate the long-term wind climate at the site. Therefore, the main objective of the measurement campaign is met as of 14 February 2017.

[*] MEASNET, 'Evaluation of site specific wind conditions', Version 2, April 2016.

4 Conclusion

RVO has requested Ecofys WTTS to perform a preliminary analysis of the floating LiDAR Lot 1 wind measurements at the Borssele Wind Farm Zone (BWFZ). The main goal of this study is to determine whether enough data is already collected by the floating LiDAR Lot 1 and whether the initial goals for installing floating LiDAR Lot 1 are met, so that it can be removed from the site.

Based on the results presented in this report, it can be concluded that:

- By 14 February 2017, there are high-availability wind measurements at 100 m for 12 consecutive months. The length and availability of this dataset indicates that it will be suitable for a wind resource assessment of the site.
- The initial goals for installing the floating LiDAR are therefore met.
- The floating LiDAR Lot 1 can be removed from the site.