OWA Floating LiDAR Roadmap – Supplementary Guidance Note

List of abbreviations

Abbreviation	Meaning
FLS	Floating LiDAR System
IEA FL Recommended Practices	IEA Wind Expert Group Report on Recommended Practices for Floating LiDAR Systems
KPI	Key Performance Indicator
OEM	Original Equipment Manufacturer
OPDACA	Overall Post-processed Data Availability – defined in the OWA FL Roadmap
OSACA	Overall System Availability – Campaign Average – defined in the OWA FL Roadmap
OWA	Offshore Wind Accelerator
OWA FL Roadmap	OWA Floating LiDAR Roadmap

Introduction

This document is intended to provide supplementary guidance to users of Version 2.0 of the Carbon Trust's Offshore Wind Accelerator Roadmap for Commercial Acceptance of Floating LiDAR Technology (referred to here as the "OWA FL Roadmap") to ensure consistent interpretation and application of the document across the wind industry.

Version 2.0 of the OWA FL Roadmap included edits made throughout the document to make clarifications, updates, extensions and introduce new material compared to Version 1.0. This document is intended to be read alongside Version 2.0 of the OWA FL Roadmap and provide further discussion on how the roadmap should be interpreted, to avoid ambiguities and to encourage greater industry consensus in the use and application of the roadmap.

By its nature, the OWA FL Roadmap itself is not a standard and is not intended to fully prescribe the processes associated with the application of Floating LiDAR Systems within a trial or wind resource assessment campaign. To this effect, the authors believe the following documents considered together should provide the industry with sufficient guidance and best practice regarding Floating LiDAR Systems:

- The Carbon Trust OWA Roadmap for Commercial Acceptance of Floating LiDAR Technology[1], Version 2.0;
- This supplementary Guidance Note;
- IEA Wind Expert Group Report on Recommended Practices for Floating LiDAR Systems[2] (referred to here as the "IEA FL Recommended Practices").

[1] http://www.carbontrust.com/resources/reports/technology/floating-offshore-wind-roadmap

[2] IEA Wind, Expert Group Report on Recommended Practices, 18. Floating LiDAR Systems, First Edition 2017. O. Bischoff, I. Würth, J. Gottschall, B. Gribben, J. Hughes, D. Stein, H. Verhoef. https://community.ieawind.org/publications/rp

1. Key changes to the OWA Floating LiDAR Roadmap

Version 2.0 of the OWA FL Roadmap includes clarifications, updates, extensions and new material covering a number of topics. These are summarized in the table below and mapped to the relevant sections in the OWA FL Roadmap for ease of reference.

Relevant sections in OWA FL Roadmap	Topic
3.5.2, Appendix 1	Clearer definition of Stage 3 maturity pre-requisites – demanding increased reliability performance
3.2 (Important notes), 3.4.5, 3.5.5, Appendix 2	Consideration of wind measurement uncertainty
3.5.4, Appendix 3	Consideration of a risk based approach to pre-deployment verifications for Stage 3 systems
3.1	Treatment of design changes and impact on Type Verification
1.2	Clarity on who confirms a stage maturity milestone has been met
2	New section providing Health, Safety and Environment guidelines
3.6.4	New section providing guidelines for Site Acceptance Tests
Throughout	Links to current IEA FL Recommended Practices (and allowing for fixed LiDAR devices as a trusted reference source in verifications)

This supplementary guidance covers the following key topics:

- Stage 3 maturity pre-requisites
- Wind measurement uncertainty
- Risk based approach to pre-deployment verifications
- FLS type design changes

1.1 Stage 3 maturity and availability KPIs

At Stage 3 maturity, there is a large focus on more demanding reliability and availability performance of the Floating LiDAR System (FLS). In particular, the Stage 3 maturity prerequisites outlined in the OWA FL Roadmap demand that FLS Original Equipment Manufacturers (OEMs) present a body of evidence that demonstrates the capability of the particular FLS type to achieve higher levels of availability and reliability beyond that expected of Stage 2 devices and across a range of conditions.

Duration of trials and early commercial deployments

According to the OWA FL Roadmap, this will be evidenced through further successful trials as well as early commercial deployments as part of wind resource assessments covering a range of operational, site and metocean conditions. The number and length of trials and longer measurement campaigns required to fulfil this pre-requisite are summarized in the table at the end of Appendix 1 in the OWA FL Roadmap.

The following notes are made regarding trial duration for Stage 3 requirements:

- A "long" trial is defined as equal to or more than 3 months.
- A "short" trial can be less than 3 months (e.g. a pre-deployment verification).
- An "early commercial project deployment" should be at least 12 months and a continuous single campaign.

For the "long" trial, as long a duration as possible at or above the minimum 3 months is preferable and is recommended where possible. However, after careful consideration, a minimum of 3 months has been identified as a reasonable requirement to balance need for more evidence of performance against the practical and financial burdens on the FLS OEM to undertake verification trials against a trusted reference source. Consideration should also be given to the time of year that the long trial is undertaken and the duration that will be required in which to experience the greatest range of environmental conditions; for example, a trial taking place in winter months is likely to cover a greater range of environmental conditions in a given period than a trial during summer months.

Availability

Increased availability KPIs are defined in Appendix 1 of the OWA FL Roadmap for Stage 3 compared to Stage 2, to emphasize the more demanding expectations regarding reliability and availability levels achieved by Stage 3 FLSs. The following notes are made regarding these KPIs.

Post-processed data (OPDACA) vs. System availability (OSACA)

It is generally acknowledged that in the context of a wind resource assessment campaign for a formal energy production assessment, the most interesting metric for availability is the post-processed data availability.

However, the system availability KPIs have been retained from Version 1.0 of the OWA FL Roadmap to highlight that in the context of a trial, and especially for any new FLS OEMs, that focus is put on ensuring the system is able to operate and be available in an offshore environment.

97% overall system availability KPI threshold for Stage 3

Based on observations from FLS verifications to date, the higher level of 97% is considered achievable and reasonable for Stage 3 devices.

However, it is noted that the OWA FL Roadmap requires that FLSs also achieve this higher level of availability in early commercial project deployments as well as in FLS verification trials. It is acknowledged that, by their nature, trial scenarios are often more controlled than early commercial project deployments which will have other commercial drivers such as planned servicing and Operations & Maintenance strategies which have a direct impact on availability. When there is an issue with an FLS deployment and several days of measurements are lost as a result, that can significantly impact the overall availability.

To address this and to allow for some flexibility, the OWA FL Roadmap user's attention is drawn to footnote 9 in Section 3.5.2. It is the authors' intention that a suitably qualified and experienced third-party will make necessary adjustments to the reference availability KPIs to account for the chosen Operations & Maintenance strategy allowing for some scheduled maintenance. To encourage some consensus across the industry of the application of this discretionary flexibility in the context of Stage 3 availability KPIs, the following comments are made:

- This flexibility is only considered in the context of early commercial project deployments. Industry evidence to date supports that the higher availability KPIs are achievable in verification trial scenarios;
- It is suggested that flexibility is afforded to the assessment of the system availability KPI, as this will be most impacted by any outages related to delays in repairs associated with the maintenance strategy. Should the maintenance strategy be deemed less responsive than industry standard, then an adjustment can be made to account for this. The principle of attaining the higher availability KPI should still be retained achieved and this should be reviewed on a case by case basis by a suitably qualified and experienced third-party organisation;
- Given the importance of achieving high valid data coverage values in the context of commercial wind resource campaigns to support formal energy production assessments, it is suggested that no concessions are given to the overall postprocessed data availability and that this be maintained at 90%. In the context of performing a wind resource assessment it is noted that methodologies will be available to the wind analyst to improve data coverage levels through correlation analysis using on-site or off-site reference sources, however, it is considered that the principle of attaining the higher availability KPI should be retained in order to build industry confidence in the FLS's ability to achieve high data recovery rates.

1.2 Consideration of wind measurement uncertainty

Removal of indicative uncertainty ranges

Version 1.0 of the OWA FL Roadmap presented indicative ranges of wind measurement uncertainties expected for the different stages of maturity of FLSs. At the time of writing, the authors consider there is currently an insufficient body of evidence to support these indicative ranges.

Furthermore, since Version 1.0, the industry has gained and continues to gain an improved understanding of uncertainties associated with wind measurements from FLSs as evidenced through the significant number of FLS deployments globally as summarized in the Floating LiDAR Repository published by the Carbon Trust[3].

[3] Deployments of Floating LiDAR Systems, July 2018: https://www.carbontrust.com/media/676308/owa-floating-lidar-repository-aug-reissue2018.pdf

The key objective of the OWA FL Roadmap is to address reliability and availability of FLSs and current industry evidence suggests wind measurement uncertainty is not a driver of maturity. This is reflected in the OWA FL Roadmap's focus on the reliability of system, not accuracy, for Stage 3 maturity.

Therefore, in Version 2.0 of the OWA FL Roadmap, no indicative measurement uncertainties are presented, and a strong recommendation is made that case specific uncertainty calculations are performed for each deployment. Further discussion of this is given in Section 3.2 (Important notes), with guidance given in Appendix 2 to estimate FLS measurement uncertainties.

FLS offshore classifications

As discussed in Appendix 2.0 of the OWA FL Roadmap, there are 4 key components contributing to the overall uncertainty budget:

- Verification of the floating LiDAR unit (or of Lidar unit only / risk based);
- Classification of the Floating LiDAR System;
- Mounting arrangements (considered negligible for an FLS);
- Terrain non-homogeneities (considered negligible for an FLS).

The verification uncertainty is typically derived from the results of the Floating LiDAR System unit verification trial (offshore) or if accepting the risk of higher uncertainty of the LiDAR unit verification trial (onshore), only.

The classification uncertainty is therefore a key aspect of estimating the overall wind measurement uncertainty of an FLS and requires careful consideration. The OWA FL Roadmap refers to three ways to estimate the classification uncertainty for a specific application case which are outlined in the IEC 61400-1 design standard[4]:

1. By considering the FLS sensitivities to relevant environmental variables based on the observed ranges of conditions (least conservative);
2. By considering the FLS sensitivities to relevant environmental variables based on assumed ranges (based on solid experience or in terms of a conservative best-guess);
3. From the class number of the FLS type (most conservative).

Environmental variables for consideration in a classification are defined in the IEA FL Recommended Practices[5].

In the case of Stage 3 maturity, enough information should be available to perform the classification uncertainty estimation as described in Appendix 2.0 of the OWA FL Roadmap[6].

For other scenarios where this information is not available, it is advised to carry out this estimation as far as possible given available information, and to supplement the lack of data with expert judgement. It is the authors' experience that this pragmatic approach has been successfully adopted in many cases to date.

---

[4] "IEC Standard for Power Performance Measurements of Electricity Producing Wind Turbines", IEC 61400-12-1, Ed. 2, 2017.

[5] Section 7.6, IEA Wind, Expert Group Report on Recommended Practices, 18. Floating LiDAR Systems, First Edition 2017. O. Bischoff, I. Würth, J. Gottschall, B. Gribben, J. Hughes, D. Stein, H. Verhoef. https://community.ieawind.org/publications/rp

[6] http://www.carbontrust.com/resources/reports/technology/floating-offshore-wind-roadmap

1.2 Risk based approach to pre-deployment verifications

In Section 3.5.4 of the OWA FL Roadmap, the following best practice recommendation is made to bring additional confidence to the reliability and accuracy performance of the FLS data for Stage 3 maturity FLSs:

- 2-phase verification trial before an offshore wind resource campaign begins is recommended for lowest uncertainty. Alternatively, a single-phase verification trial (ideally offshore) in addition to a risk based approach as described in Section 6.2 of the IEA Wind Expert Group Report on Recommended Practices for Floating LiDAR Systems9 may be sufficient, see also Appendix 3.

A pre-deployment offshore FLS verification trial is considered the most robust and lowest uncertainty approach to performing a wind resource assessment. A pre-deployment verification provides traceability of measurement uncertainty back to a trusted reference source. As noted in Section 2.2, currently there is a lack of industry evidence regarding offshore classification trials, hence the pre-deployment trial is considered an important aspect of floating LiDAR wind measurement campaigns.

The authors consider it important to acknowledge that by their nature, FLSs are not considered to be "mass producible". As such, there is considered to be a residual risk that a unit (that has not been trialled) does not perform as well as another unit (that has been trialled), resulting from assembly.

However, the adoption of a risk based approach attempts to provide some concession on this point as the technology continues to mature. This approach also attempts to reduce the perception of pre-deployment verification requirements being onerous process to wind farm developers and FLS OEMs, whilst allowing the final user's appetite for uncertainty in the final wind data from the FLS to be factored in.

The OWA FL Roadmap effectively requires 3rd party experts, who will be the parties scrutinizing the floating LiDAR data in the context of formal energy production assessments, to acknowledge the requirement for pre-deployment verification for Stage 3 devices, and to justify whether an FLS verification or a (less onerous) LIDAR verification is most suitable to fulfil this requirement.

Some further commentary to aid the interpretation of the table included in Appendix 3 of the OWA FL Roadmap is provided below:

- The table mirrors Table 3 in the IEA FL Recommended Practices[7].
- Distinction is made between "fixed" and "not fixed" FLS Types. Currently, the majority of FLS devices currently available to the market are "not fixed".
- Mitigation measures are proposed to limit the risks associated with the FLS System Integration, the Dynamic Response of the Buoy as a function of set up (i.e. mooring arrangement) and with the Dynamic Response of the Buoy as a function of sea state.
- As described in Table 3 of the IEA FL Recommended Practices, even for a Commercial/Stage 3 FLS there is a residual risk that the FLS does not perform to the standards demonstrated previously if the environmental conditions experienced go outside

[7] Section 6, IEA Wind, Expert Group Report on Recommended Practices, 18. Floating LiDAR Systems, First Edition 2017. O. Bischoff, I. Würth, J. Gottschall, B. Gribben, J. Hughes, D. Stein, H. Verhoef. https://community.ieawind.org/publications/rp

those enveloped in verification (Scenarios S7 and S10), and this risk is therefore characterised in general as Medium. This is not intended to close the door on such scenarios however: for those seeking Low risk an expert assessment could conclude that the nature of the FLS or the small excursion outside the envelope justify a Low risk rating. Likewise it is possible to in theory assign a High rating given adverse circumstances, but in practice such a situation is very unlikely to arise.

- In all scenarios for Stage 2 maturity FLS types (S1 to S5), apart from a "fixed" system deployed within the envelope of environmental conditions experienced during previous trials (S6), an FLS Verification is always required in conjunction with an FLS Performance Sanity Check (as defined in the IEA FL Recommended Practices5) at the application site.
- For scenarios considering Stage 3 systems, this requirement may be relaxed to just a Lidar Verification Test (this can be onshore), to provide traceability to a known reference source to inform an uncertainty analysis, in conjunction with an FLS Performance Sanity Check to mitigate the risk of integration errors at the application site. It is anticipated that at this stage, Stage 3 maturity FLS types may have accumulated a significant body of evidence across a range of deployment conditions. In such case it is considered reasonable to assume that even in scenarios where the deployment conditions at the application site are more severe than the trial, there is sufficient evidence to apply the mitigations summarised in the "Dynamic Response of Buoy = f(Sea State)" column. In such a situation, this means that in practice, the analysis of the FLS' sensitivity to different environmental conditions as part of a classification trial cannot be fully relied upon and some expert judgement is required to extrapolate observations from trials within a certain envelope to the anticipated performance at an application site outside of that envelope.

The risk-based approach will therefore allow the FLS Verification trial to be omitted prior to a given deployment for a given unit if there is a sufficient body of evidence that the unit in question will perform as well as previous units, thus offering a real route to reducing the requirements for full sea trials for mature systems.

For the avoidance of doubt, the reader is encouraged to refer IEA FL Recommended Practices, Section 6.2, Note 257 for the full definition of the following terms used above:

- FLS Verification (i.e. an offshore trial);
- FLS Performance Sanity Check (i.e. likely to be a subset of activities from a Site Acceptance Test as defined in Version 2.0 of the Carbon Trust OWA Roadmap for Commercial Acceptance of Floating LiDAR Technology[8];
- Lidar Verification Test (i.e. Lidar is tested against a meteorological mast according to the guidelines in IEC 61400-12-1 Ed. 2 Annex L[9]).

1.3 Treatment of design changes and impact on Type Verification

As with any maturing technology, ongoing innovation and development should be encouraged. Therefore Version 2.0 of the OWA FL Roadmap includes a new section which outlines some

[8] http://www.carbontrust.com/resources/reports/technology/floating-offshore-wind-roadmap
[9] "IEC Standard for Power Performance Measurements of Electricity Producing Wind Turbines", IEC 61400-12-1, Ed. 2, 2017.

considerations for FLS design changes and the potential impact on previously achieved maturity stage Type Verifications.

The Roadmap sets out a clear process to follow in the case where design changes are made to an FLS to assess whether the new design would effectively be considered as a new FLS type and would require a further type verification for a period.

Due to the complex nature of FLSs, it is not possible to be fully prescriptive and cover all potential type critical design changes. Such a prescriptive approach is considered outside the scope of a roadmap document.

A process has been outlined in the OWA FL Roadmap whereby this can be considered on a case by case basis. In principle, the authors of the OWA FL Roadmap see this process working as follows:

- Aspects of the FLS design are changed as appropriate and necessary - an FLS design change is identified;
- Arguments are made for why that design change is not affecting the overall performance (considering both accuracy and reliability of the FLS);
- Have a suitably qualified and experience third-party confirm this assertion.

The authors also make the following additional comments:

- The FLS OEM will ultimately be in control of the design process and will evaluate the impact of the change (using a suitably qualified and experienced third-party where necessary and as outlined in the OWA FL Roadmap).
- Should the impact of the change on the performance and reliability of the FLS be considered negligible, such that it can be considered the same Type, then that mitigates the risk of any questions or challenges being made at a future date in demonstrating that sufficient due diligence has been undertaken to evaluate the impact of the design change and compare with all the prior verification work.

For example, for design changes that may impact the dynamic response of the whole buoy to various sea states, the authors would anticipate that a process similar to the evaluation steps outlined below may in principle be applied:

- What is the range of motion of the current FLS type design estimated from a dynamic model?
- How did that compare to the actual range observed in trials?
- From these observations, seek an expert view to opine on whether a significant change in response can be expected from the new design.

The authors intend that the process outlined in Section 3.1 of the OWA FL Roadmap should encourage good practice and promote an open and transparent process whereby industry stakeholders have the opportunity to understand the impact that critical design changes may have.

Important notice and disclaimer

Published in the UK: October 2018

Document history

Version	Date	Reason for Issue
1.0	09 October 2018	First issue accompanying Version 2.0 of the OWA Floating LiDAR Roadmap