IMPACT OF WIND DISTRIBUTION ON ENERGY YIELD ESTIMATION

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About Us – Mott MacDonald

Company background

Renewable energy expertise

Mott MacDonald has been at the forefront of renewable energy, with over 100 years of experience in the energy sector. Our energy business spans across UK, Europe, Africa, the Middle East, India, Indonesia, Thailand, Singapore, Malaysia, Japan, Taiwan, Korea, Australia and the US.

Here at Mott MacDonald, we pride ourselves in working closely with our client, solving problems, supporting the successful delivery of projects, and staying at the leading edge of technological and commercial evolution.

Our energy key services:

- Technical advisory
- Owner's engineering
- Detailed design
- Project and programme management
- Digital and asset management

150+
global renewable energy deals supported to financial close in the last five years

240GWp+
renewable project experience

2000+
dedicated energy staff globally

300+
dedicated renewable energy staff in Asia

Over the last 10 years we have helped deliver:

70GW
of **hydro power** projects including **40GW in Asia Pacific**

50GW
of **solar power** projects including **28GW in Asia Pacific**

120GW
of **wind power** projects including **20GW in Asia Pacific**

30GW
of power transfer capability of Cables related projects

30GWh
of BESS projects including **20GWh ESS projects in Asia Pacific**

About Us – Mott MacDonald

Wind Energy Yield Assessment Services

Feasibility

Service	Details
Wind potential site identification and preliminary layout	Support project location identification and approximate capacity. Using GIS tools combine with publicly available wind maps (or Vortex maps) and other zoning or restrictions to identify available resource and capacity.
Pre-feasibility wind EYA	Support early-stage project development. When there is no measured data onsite, we propose a feasibility EYA. With publicly available wind data or Vortex data (purchased additionally)
Wind measurement campaign design	Design the wind measurement campaign of the site. Based on the terrain and land cover of the site, defining number and type of measurement devices to adequately represent the turbine locations/configuration
Indicative Wind Turbine Generator (WTG) layout and capacity	Using the unconstrained area of the site from the constraint map, we will populate indicative WTG locations that maximise the site potential.

Pre-construction

Service	Details
Campaign support	MM MOATA tool: Collects, displays and supports wind measurement data monitoring and analysis
Pre-construction EYA	Minimum of 1 year of measurements available onsite, both onshore and offshore
Layout optimisation	Maximise the yield resource by positioning WTG at most favourable locations from technical perspective
Site conditions assessment	According to the IEC 61400-1 standards
Site evaluation	Determine whether a site calibration is necessary according to the IEC 61400-12-1 and 12-5 standards

Operation & Repowering

Service	Details
Operational EYA	Available on 3 different methodologies: i) using 10-min SCADA data ii) using monthly production data on a WTG basis, and iii) using monthly production data on a wind farm basis
Operational monitoring-technical performance	Summarise our findings on energy differences between actual and forecast figures. Identify origin deviation due to wind resource variation
Repowering EYA	Use operational data from the existing WTGs to adjust the pre-constructional model for the repowering project

AGENDA

1. Introduction
2. Methodology
3. Case study and results
4. Conclusions
5. Q&A

Introduction

Common Misconception

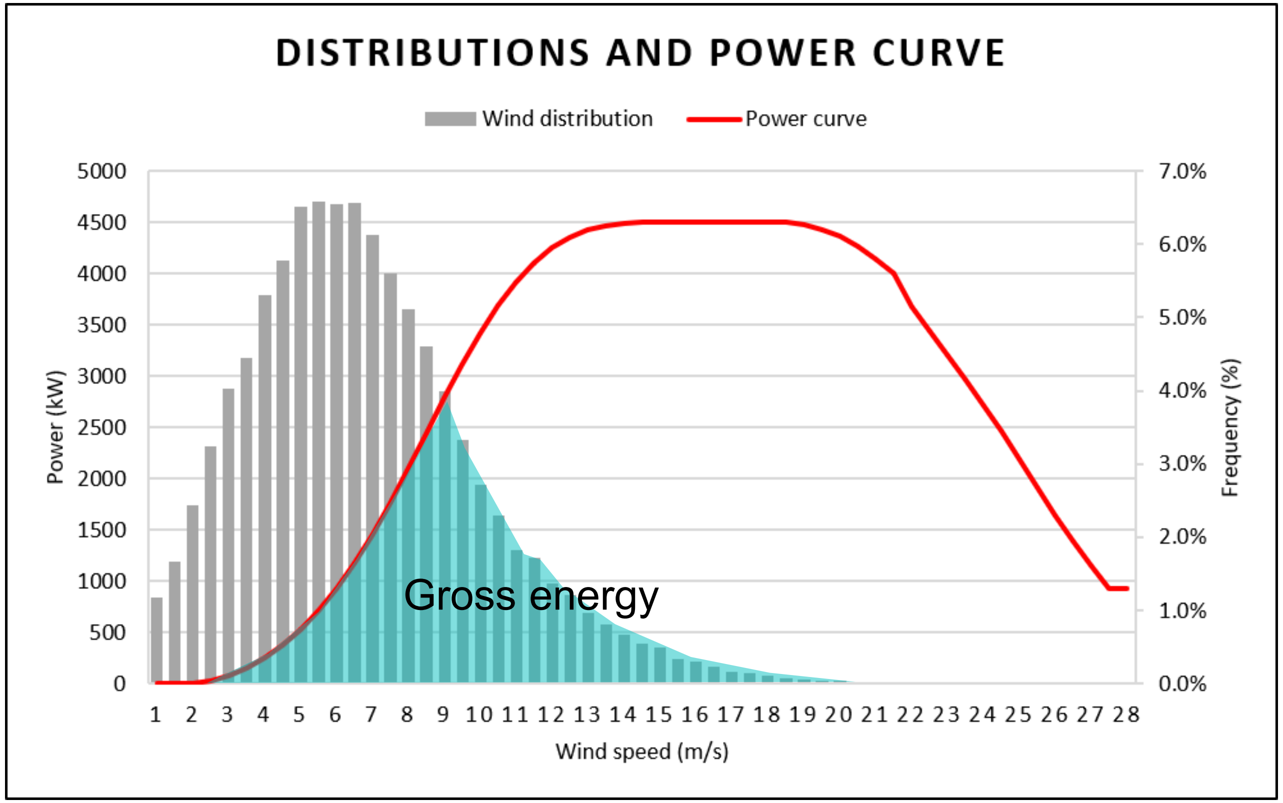
A common misconception about the energy yield for a wind farm is that "**a higher wind speed at windfarm sites can give a higher energy yield**".

The observed results suggest this is not always the case.

Energy yield estimation is not limited only to wind speed but the statistical "**Wind Frequency Distribution"** and other parameters.

Introduction

Why Distribution Matters



The statistical Wind Frequency Distribution captures the variability and representativeness of site conditions.
"Changes in wind distribution may cause significant energy yield differences"

Gross energy yield = the sum of each wind speed frequency x power output at each wind speed bin

Introduction

Case study from nearshore, onshore and offshore projects show that different wind distribution at a wind farm site can be caused by factors such as

- General terrain complexity and forestry
- Localised effect at the site-specific locations
- Period of wind measurement

We have investigated the impact of different wind distribution on the energy yield figures.

Methodology

Overview

Wind data analysis

Inputs:

- Wind data processing (screening, calibration, de-waking, reconstructing, etc.)
- Long-term correction
- Vertical extrapolation

Output: Long-term adjusted wind speed and distribution at hub height

Wind flow modelling

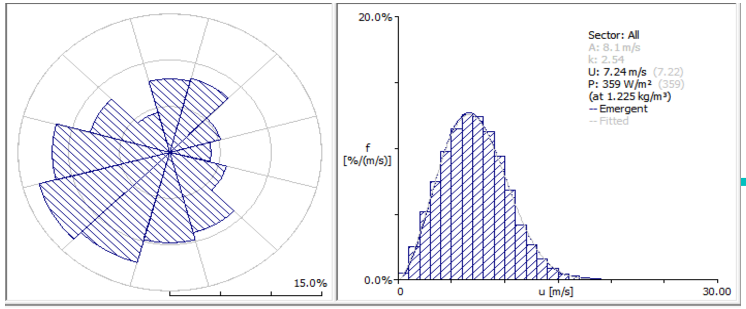
Inputs:

- Long-term wind distribution
- Power curve adjusted by site air density
- Topographic/roughness data
- Flow modelling parameters
- Layout configuration

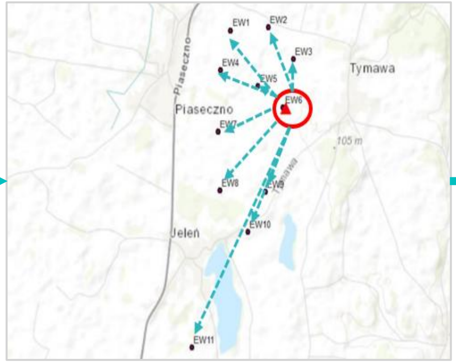
Output: Gross energy yield estimation

Result comparison

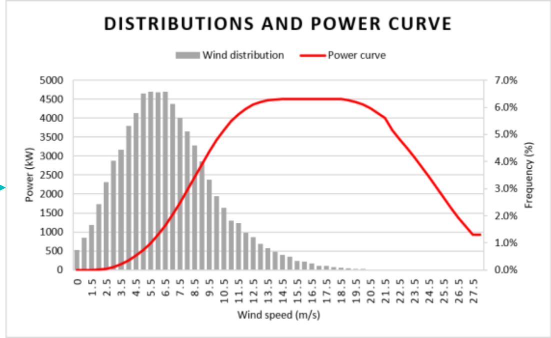
- Long-term wind speed
- Long-term wind distribution
- Gross energy yield figures



Long-term wind speed and distribution



Wind flow modelling



Gross yield at each wind turbine

Case study

Case 1: Impact of localised effect in *nearshore* wind project

Background

Nearshore wind project with forestry and hilly terrain present along the coastline.

3 measurement devices were installed in the project area (approx. 1 year of measurement each)

- 1 Onshore mast (60m): located at the coastline
- 1 Vertical LiDAR (40-200m): co-located with the onshore mast
- 1 dual scanning LiDAR ('DSL') (60m, 140m and 200m): located at coastline, measurement at offshore location

Observation

Different wind distribution is observed between the met mast and the co-located LiDAR. This difference is likely to be caused by localised effect, including forestry and nearby hills at the measurement location(s).

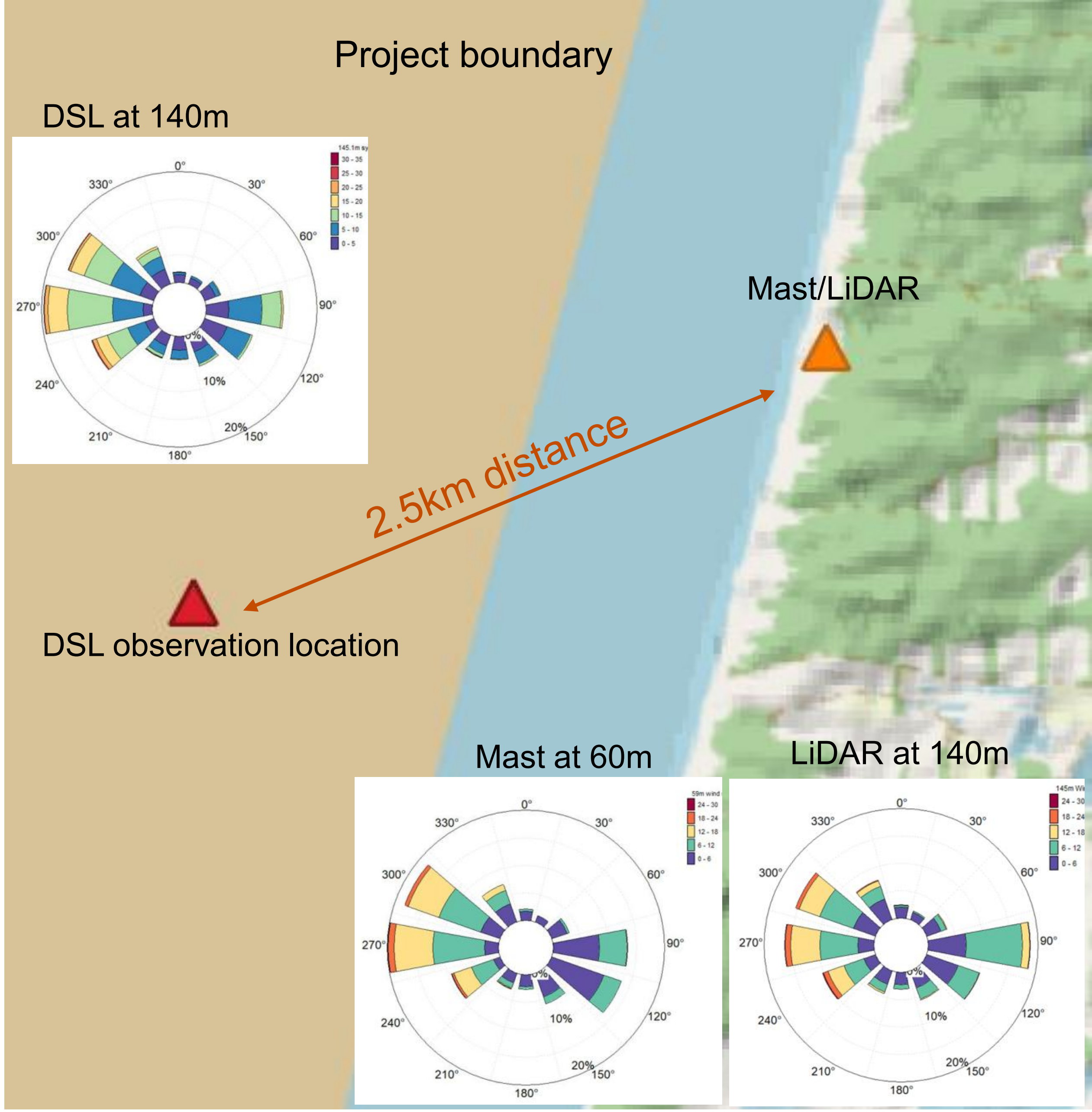
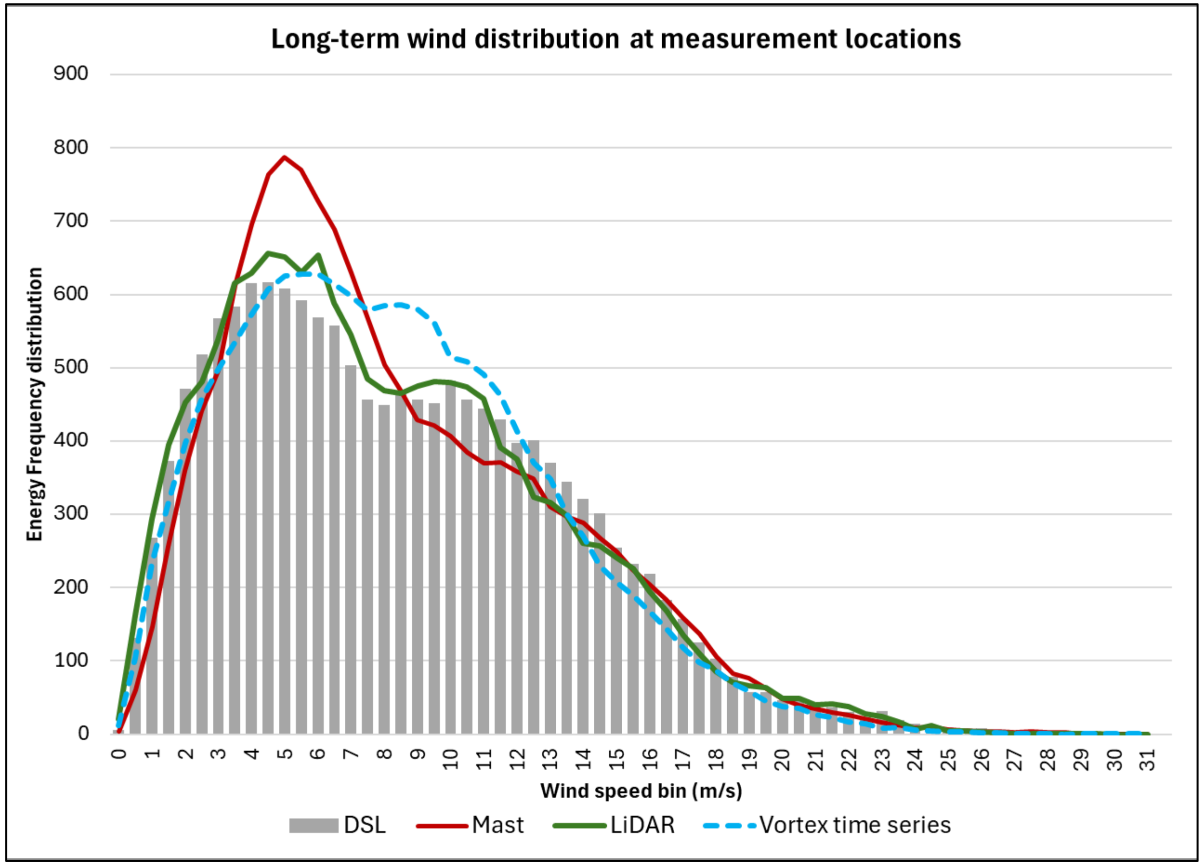


Figure 1: Long-term wind distribution at the measurement locations at hub height (140m), together with 30-year Vortex SERIES data



Results

Case 1: Impact of localised effect in *nearshore* wind project

% Difference from met Mast	LiDAR
Wind speed	-2% (lower)
Gross energy yield	+1% (higher)

% Difference from DSL	Met Mast	LiDAR
Wind speed	-1% (lower)	-3% (lower)
Gross energy yield	-5% (lower)	-5% (lower)

The shape of wind distribution at the met mast is significantly different from that at the DSL and LiDAR. The topographic effect from the hills and the tree effect in surrounding area may have caused the difference in wind speeds and energy yield estimates.

Case study

Case 2: Impact from localised effect in *onshore* wind project

Background

Project in forestry and complex terrain with 4 met masts installed across the site. The maximum elevation difference of approx. 250m among the met mast locations.

- M1: located in forestry area (>1 year of data)
- M2: located in forestry area (>1 year of data)
- M3: located in open area (>2 years of data)
- M4: located in forestry area (>2 years of data)

Observation

Variations in wind distribution is observed among different met mast locations. These differences are likely due to the terrain complexity and localised forestry effect at the specific location across the Project site.

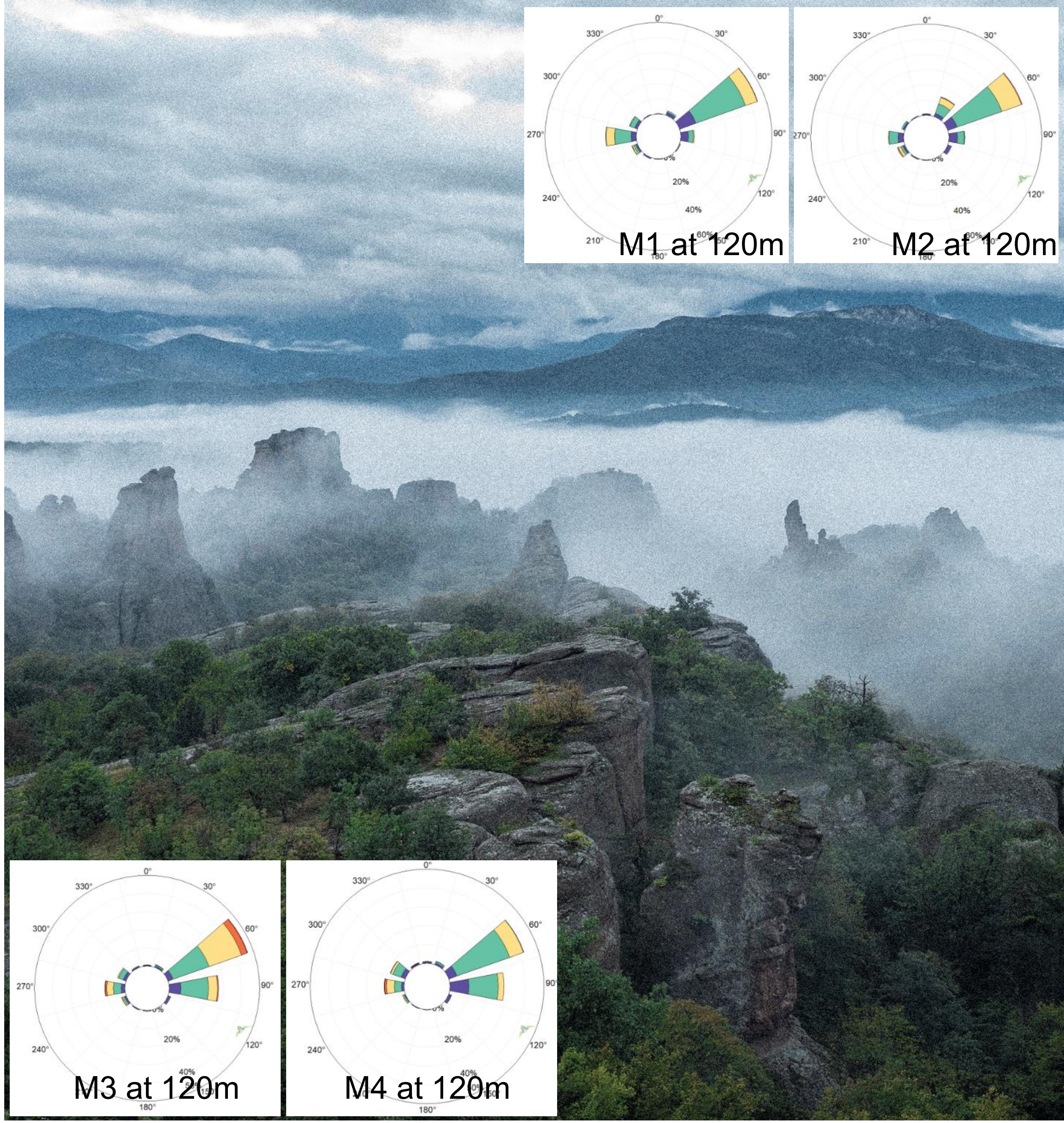
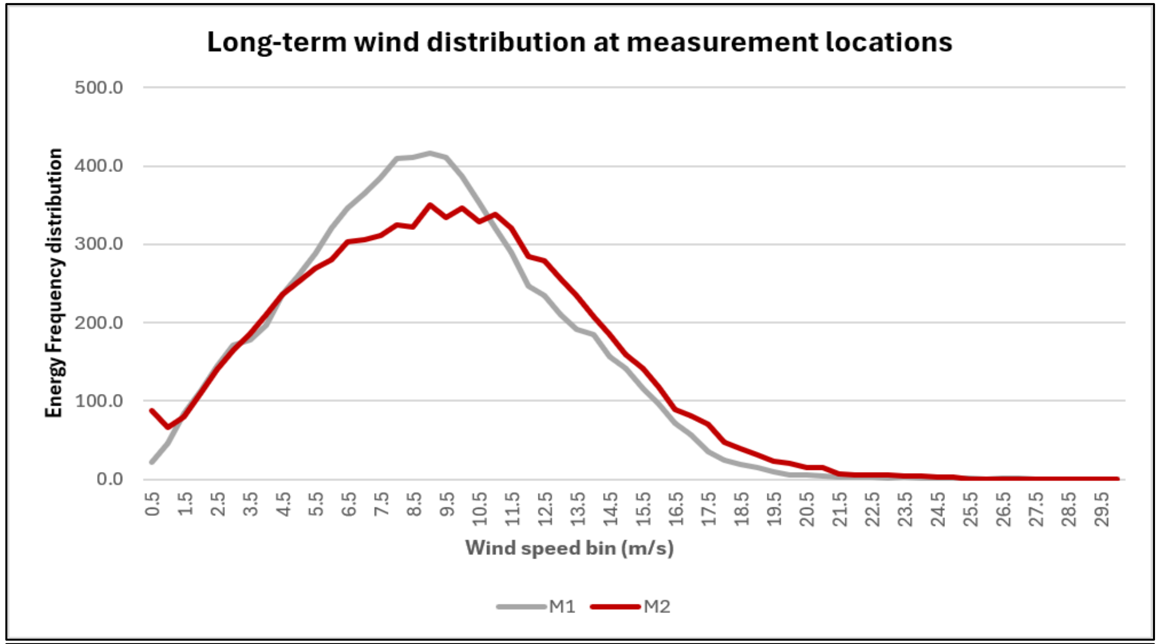
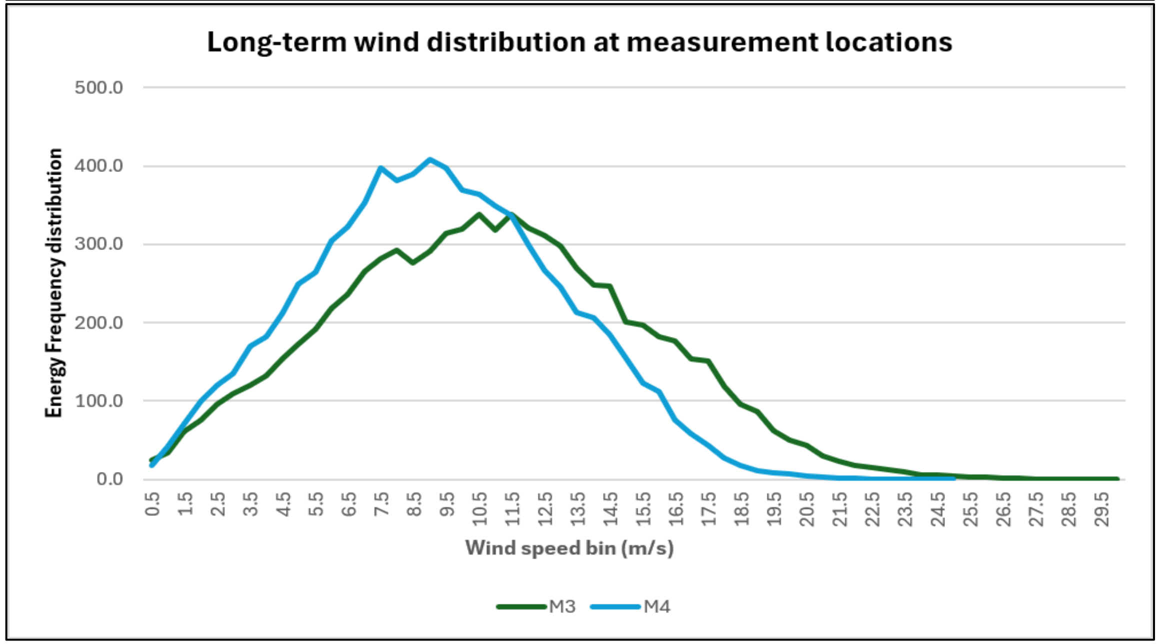


Figure 2-3: Long-term wind distribution at M1/M2 and M3/M4 locations at 120m hub height





Results

Case 2: Impact from localised effect in *onshore* wind project

% Difference from M1	**M2 (3km away from each other)**
Wind speed at mast	+5% (higher)
Gross energy yield nearest WTG to mast	+5% (higher)
Gross energy yield across the site	+58% (higher)

% Difference from M3	**M4 (5km away from each other)**
Wind speed at mast	-15% (lower)
Gross energy yield nearest WTG to mast	-9% (lower)
Gross energy yield across the site	-11% (lower)

The difference in shape of wind distribution is likely to be caused by the localised effects including general topographic and forestry effect.

This could introduce a huge difference in wind speed and distribution at different locations, and lead to very different energy yield estimates depending on mast association strategy.

Case study

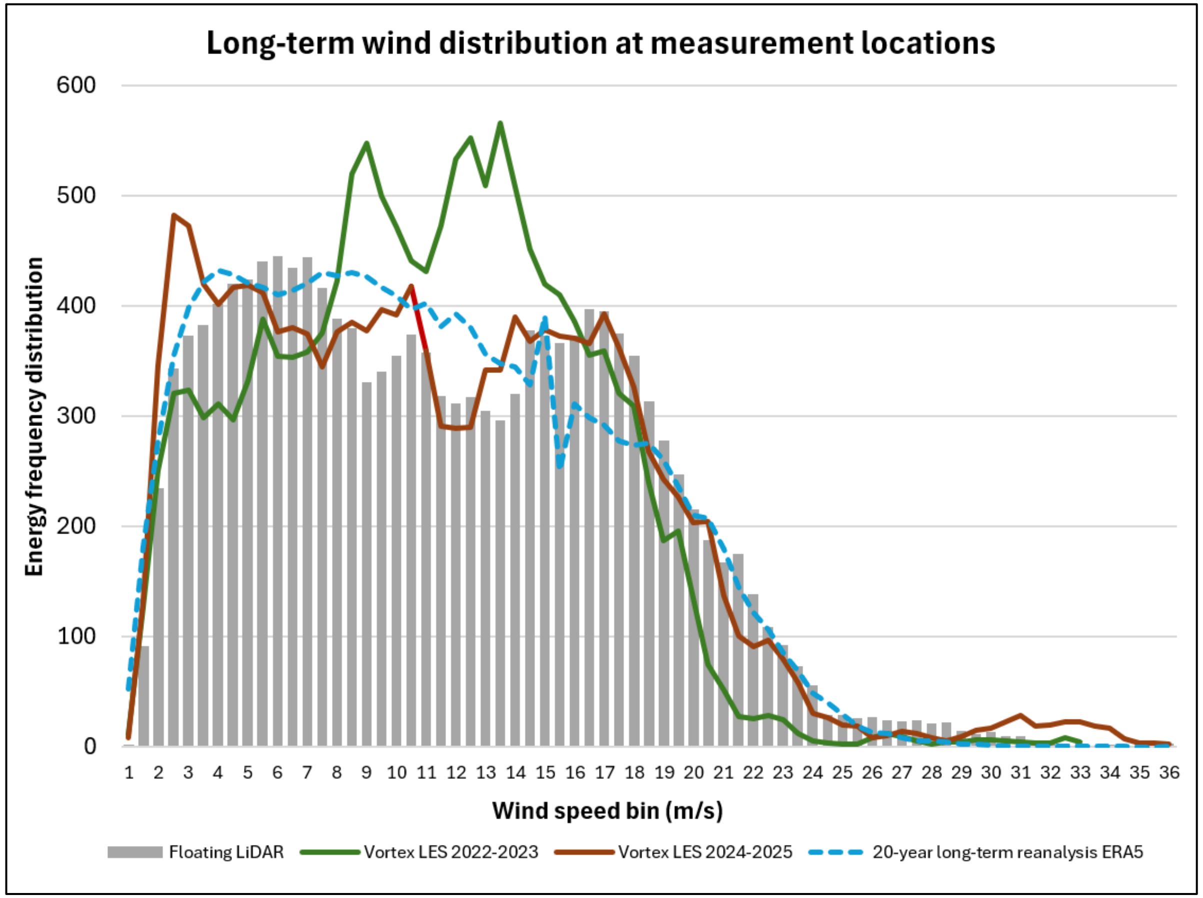
Case 3: Impact from measurement period in *offshore* wind project

Background
Offshore wind project with one Floating LiDAR 1-year measurement period from end of 2024 to end of 2025

Observation
Difference in wind distribution is observed when comparing between the modelled data (Vortex LES) in the period 2024- 2025 and from 2022 to 2023.

Source: OffshoreWIND.biz

Figure 4: Long-term wind distribution at Floating LiDAR at 150m hub height, together with long-term adjusted 1-year Vortex LES data and 20-year reanalysis ERA5 data



Results

Case 3: Impact from measurement period in *offshore* wind project

% Difference from Floating LiDAR (2024-2025)	Vortex LES 2022-2023	Vortex LES 2024-2025
Wind speed	-7% (lower)	-3% (lower)
Gross energy yield	+4% (higher)	-3% (lower)

From the long-term wind distribution comparison in different periods between 2022-2023 and 2024-2025, changes in wind distribution could potentially affect the predicted wind speed and energy yield.

The check on the available long-term measured and modelled dataset across the similar region has been done to ensure the representativeness of measurement period for further analysis. The wind distribution over 2022-2023 differs from 2024-2025 with the latter showing better consistency with the long-term wind regime in the region.

Although 1 year of measurement data are typically the minimum requirement for finance grade EYA in industry practices, extending the measurement period offers the benefit of better capturing long-term wind regime at the site and reducing the energy yield prediction uncertainty

Conclusions

Case study results

Wind frequency distribution – wind speed alone does not fully describe wind resource quality. Different wind frequency distribution could result in very different energy yield figure even with the same mean annual wind speed.

Case 1: Localised Effect
- Selecting measurement data that represent the site conditions is the key due to localised wind regime.

Case 2: Representative Measurement Location
- Considering the mast initiation strategy in order to account for different wind regime from each measurement.
- Considering additional measurement to capture the localised wind regime.

Case 3: Representative Measurement Period
- Considering the longest possible of measurement period to reduce uncertainty in long-term representativeness.

Conclusions

How to mitigate the risk in the future analysis

Do not rely on mean wind speed alone – always assess the wind speed together with wind frequency distribution, this is particularly relevant at early-stage of project development

Representative measurement (location) data – cross-check with on-site datasets, where available, to confirm site wind conditions

Mast initiation strategy – consider mast initiation strategy with caution where multiple site measurement locations are available

Measurement period– validate with long-term or relevant datasets to confirm typical wind conditions. Extending the measurement campaign, if possible, to better capture long-term wind regime at the site.

Q&A

THANK YOU