Site description

Evaluation of the location's specific factors that influence the energy calculation for the described site was made using topographic maps and aerial photos. The location of the wind park can be observed on the attached map. The coordinates of the reference point used to define the wind potential [UTM WGS84 Zone 35 coordinates system] are stated in the following table:

Reference points	East [m]	North [m]	Height [a.s.l.]
Site point	583.773	4.936.293	91m

Fig 1: Main point location, GPS coordinates

The area of interest is located in the south-eastern part of Romania, Dobrogea region, in the vicinity of Topalu village.

Fig. 2: Topalu Site

Wind monitoring equipment

For a detailed analysis of local wind parameters, one measuring mast was used. The 85 meters meteorological mast was built using Thies and Ammonit equipment.

For this study, the client provided the measured wind data along with all the necessary documentation, including the installation reports, calibration certificates and monthly data verification reports.

Documentation verification and wind data validation was done by Wind Power Energy team.

Fig. 3: Topalu 85 mast location

Data source	Reference point [UTM WGS 84 zone35]	
Topalu 85	584.282 [E]	4.935.157 [N]

Fig. 4: Met Masts, GPS coordinates

Other data sources

Available for this site were long term data from Vortex. WPE team chose this data because it was the closest, it has good availability and had returned good results in the previous projects in which it was used. The data was generated using ERA5 data source, for a period of 20 years. The reference point for the generated data is presented in the table below.

Data source	Reference point [UTM WGS 84 zone35]	
Vortex	584.282 [E]	4.935.157 [N]

Fig. 5: Vortex point, GPS coordinates

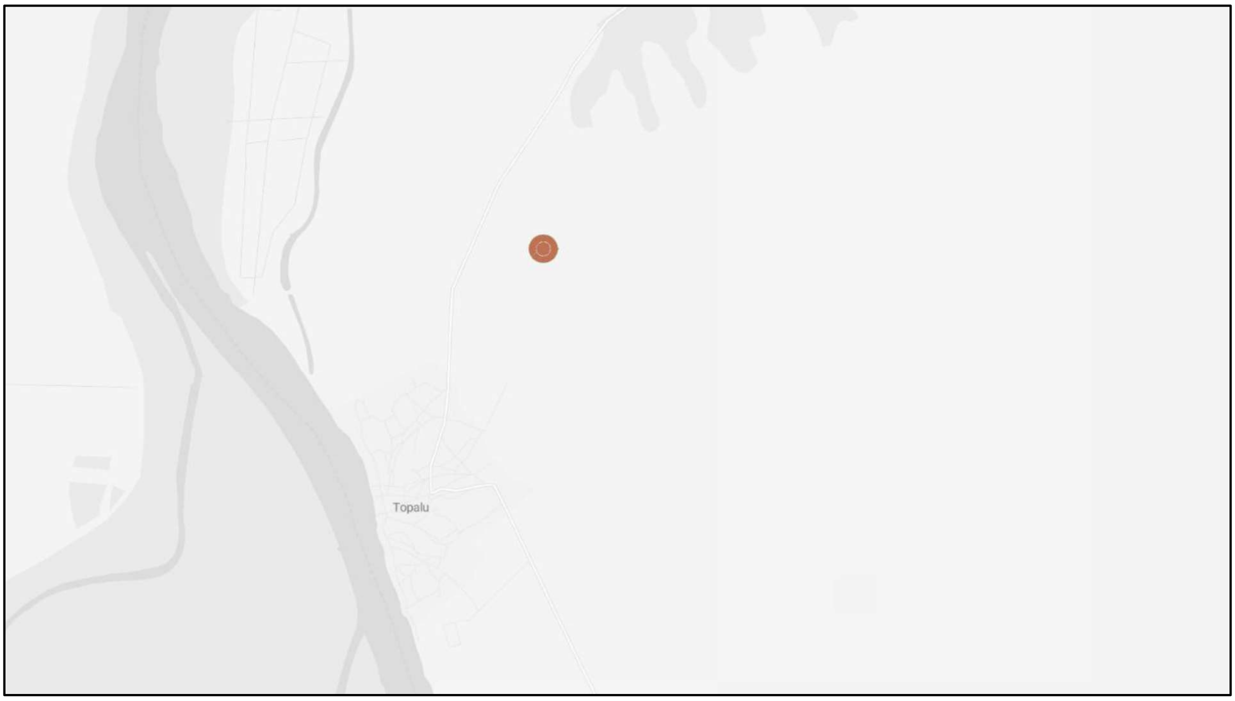

Fig. 6: Vortex data source

Vortex uses a computer cluster to run a non-linear flow model (WRF) that scales large atmospheric patterns (NCAR-NCEP, ECMWF and NASA) down to fine spatial resolutions (SRTM), generating modelled wind resource data suitable to be used where and when no measurements are as yet available.

Roughness

The roughness factor defines terrain elements that influence the laminar air flow, and that is situated at a relative distance from the reference point (meteo masts). In this case, using the satellite data, and analyzing the terrain in the area, a roughness map for an area of approximately 200 km^2 has been created. The map was then used in WindPro 3.6 to identify the way in which the wind profile is modified by its passing over those extents.

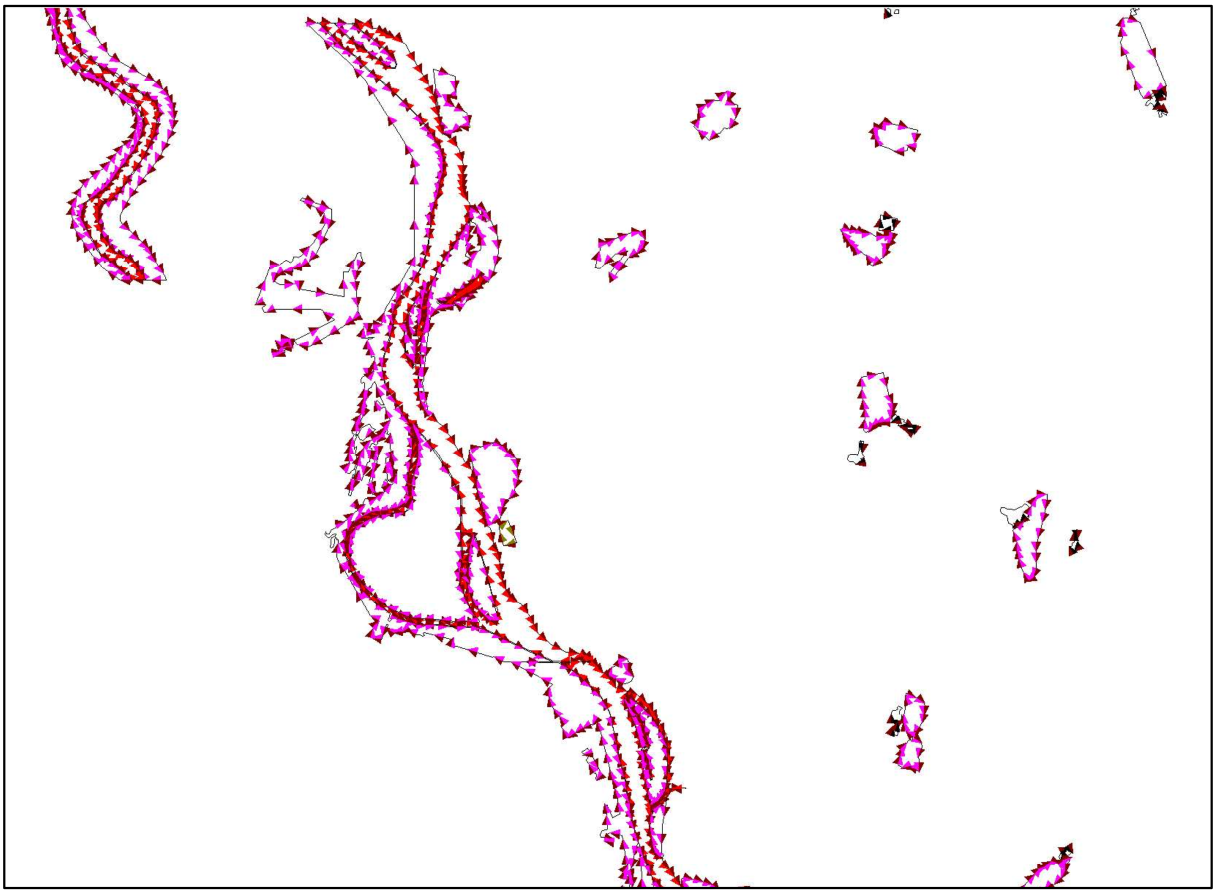

Fig. 7: Roughness Map

The region is mostly used for agriculture purposes. The agricultural areas are interrupted by trees outskirts and small forests. There are small villages and some houses along the main roads. No major obstacles were observed.

Orography

The orography of any region is a result of the action of internal (isostatic movements) and external (climate) factors on the terrain. Topalu area is characterized by the existence of a plateau with a medium altitude of 78m, bordered by a SE-NW oriented slope, with medium sloping. The slope is fragmented by several valleys. The arid climate with strong winds also influences the evolution of the orography. Most of the valleys don't have a temporary character, hydrous erosion being present only during rain. The area of interest is mostly used for agriculture. West from the site at ~ 2.5km is the river Danube. Thus, we can say that the relief has a moderate influence on the site energy production.

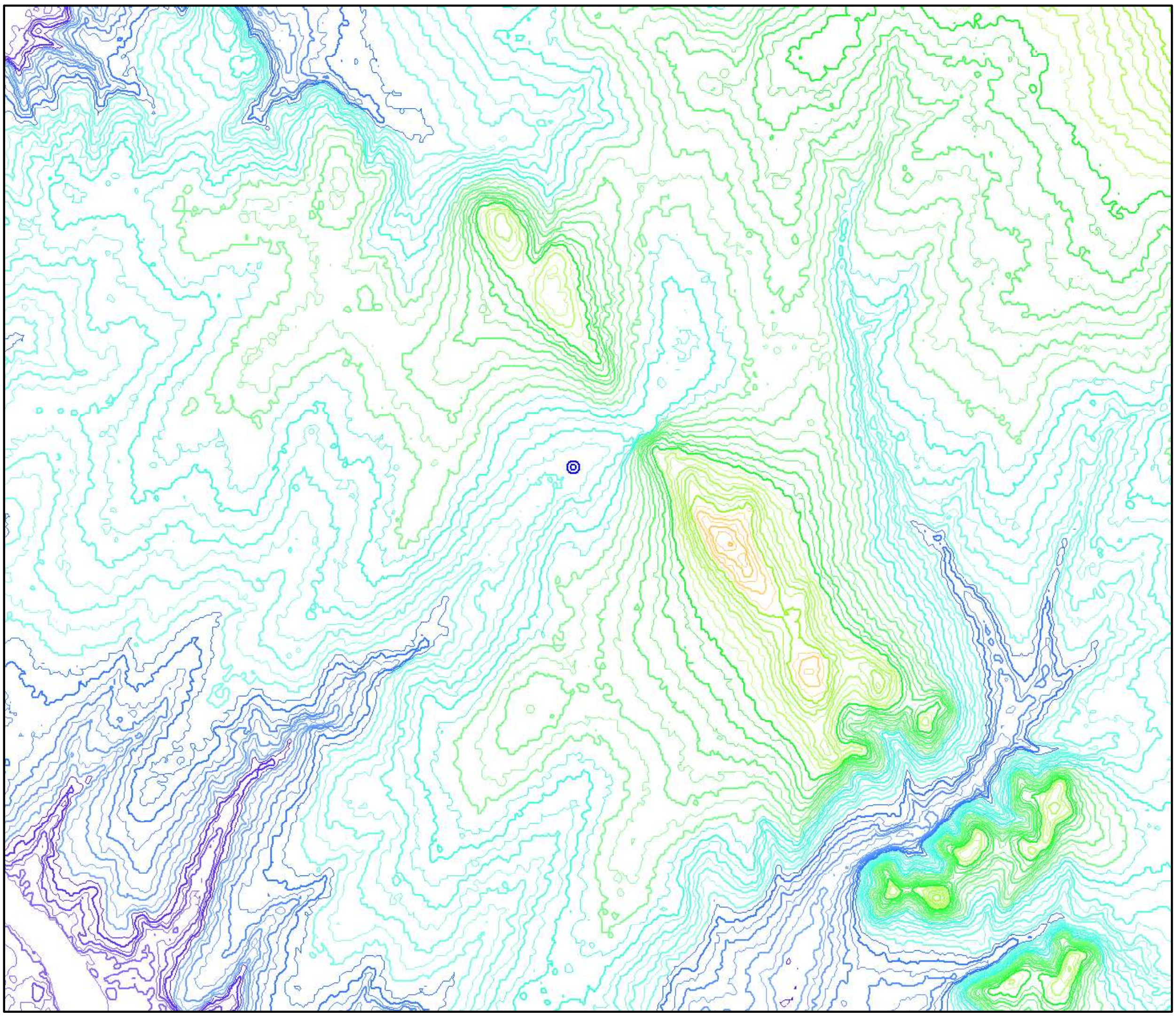

Fig. 8: Height Contours Lines Map

Methodology

Measured wind parameters

Topalu 85 Mast

Wind speed (mean and standard deviation) and wind direction were recorded for a 15.4 months period (September 2008 – December 2009) for Topalu 85m Mast.

The mast was equipped with 4 classic cup anemometers and 2 wind vanes. Air temperature, humidity and pressure were also measured. The configuration of the mast is presented in the table below.

Recovery rate was 99.8% at 85m for the recorded data. There was no equipment problems declared or extreme meteorological events during this period.

The availability was affected by missing data and icing. The unplausible data was filtered out. No other issues or extreme meteorological events were detected for the analysed period.

Sensor	Height [m]	Availability [%]	Availability (After filtering) [%]
Cup anemometer	85	99.8	99.6
Cup anemometer	71	99.8	99.4
Cup anemometer	51	99.8	99.6
Cup anemometer	30	99.8	99.8
Wind vane	71	99.8	99.8
Wind vane	51	99.8	99.8

Fig. 9: Sensor configuration and availability

The data logger samples wind speed and direction once every second. These are then combined into 10-minute averages, and along with the standard deviation for those 10-minute periods, are put into a binary file. These binary files are exported to text files by the data logger.

Preliminary to data loading in WindPro 3.6 software, all wind data were subjected to a series of tests and filters to weed out data that are faulty or corrupted.

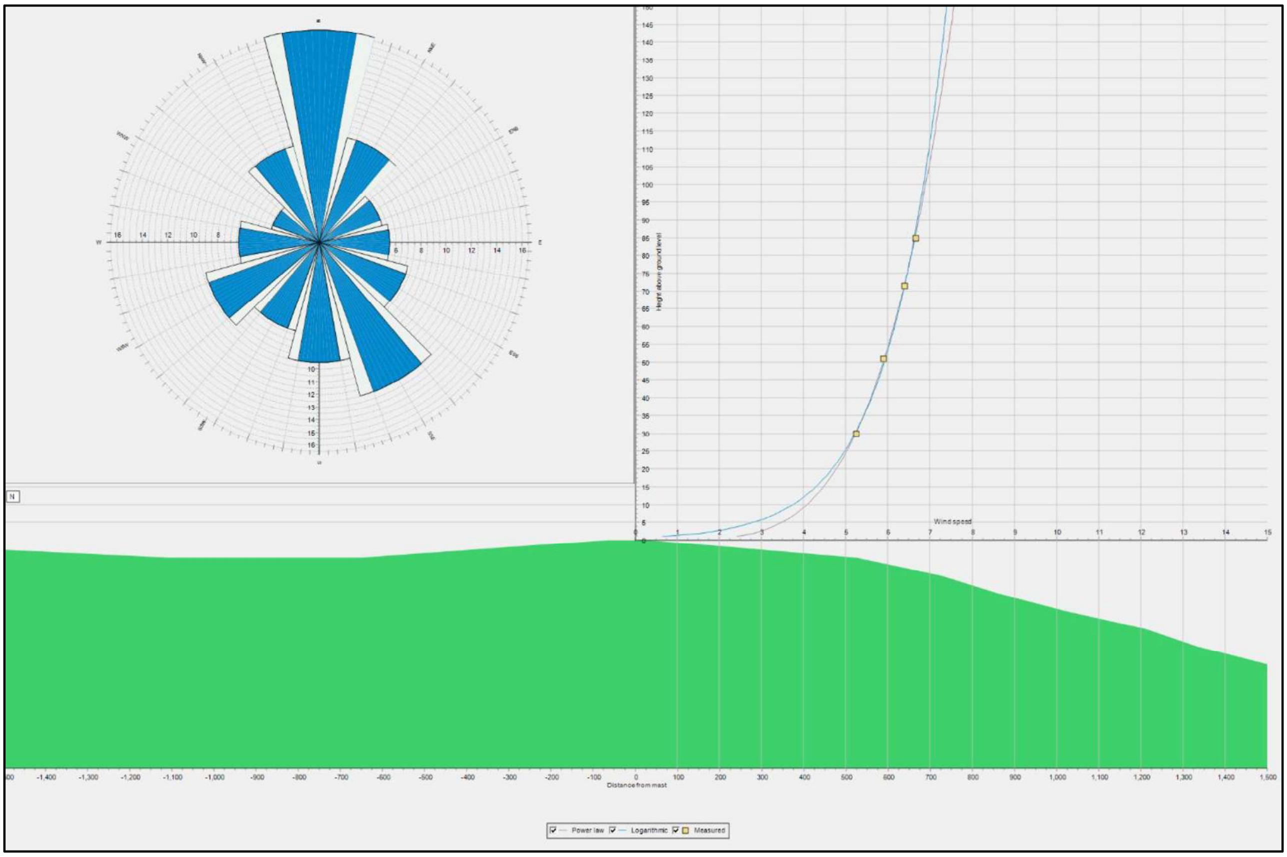

Fig. 10: Wind profile and wind rose for Topalu 85 mast

The wind speed as recorded at all the levels are presented in **Annex 2**.

Height [m] [a.g.l.]	Mean wind speed [m/s]
85	6.56
71	6.31
51	5.83
30	5.26

Fig. 11: Recorded wind speed for Topalu 85 mast

Regarding monthly distribution of wind speed, the location is part from general South-Eastern Romania climate, with mean wind speed distributions oscillating from higher ones in cold period of the year, to relatively low wind speed in warm season.

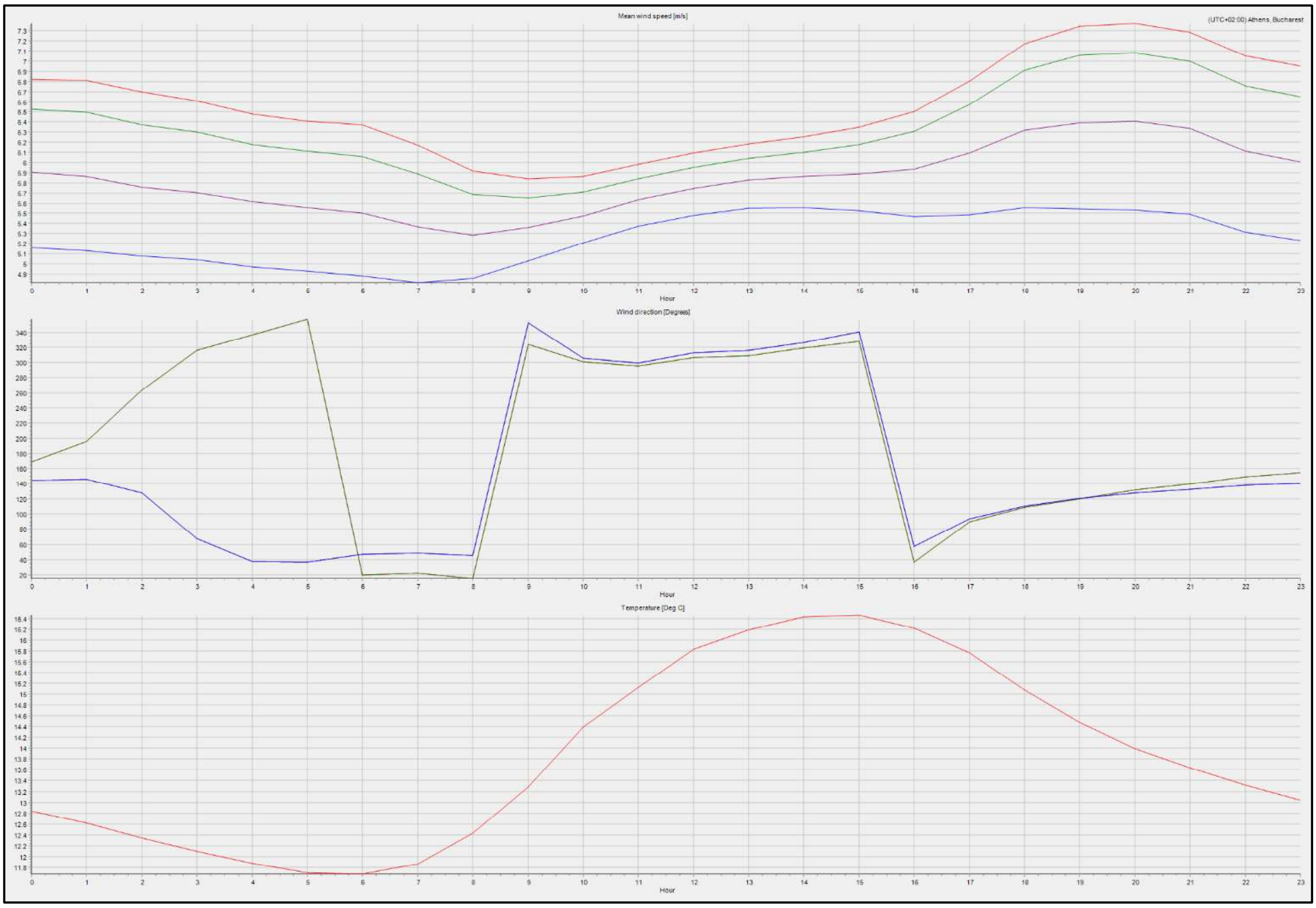

Fig. 12: Monthly variation of speed for Topalu 85 mast

Vortex long-term data

ERA5 data set

Wind speed and wind direction, temperature and pressure were estimated for a 20 years period (2002 – 2022) for the Topalu site.

Vortex's system core, WRF, is a sophisticated code that has been effectively employed to describe the physics and dynamics of atmospheric circulations with a significant degree of realism at a wide range of scales. WRF is neither a microscale nor large-scale model but is a one-in-all. WRF accuracy is based on the ability to portray the different mechanisms that interact at each one of the relevant atmospheric scales. The WRF model is the result of years of development by the atmospheric research community combined with additional experience from the extended use for weather forecast applications. The usual truncation, or simplification, of the equations that control atmospheric movements of air masses, is definitively small in WRF when compared to other lighter atmospheric codes. However, equally as relevant as this non-linear approach, is how the model includes other relevant factors such as radiation, thermal effects, air-sea-land interactions. In this sense, WRF is a modular model that can be adapted for different applications depending on the scale of the atmospheric movements, surface boundaries and thermal characteristic of the air masses, etc.

This product was chosen because of the good correlation and overall integrity of the model.

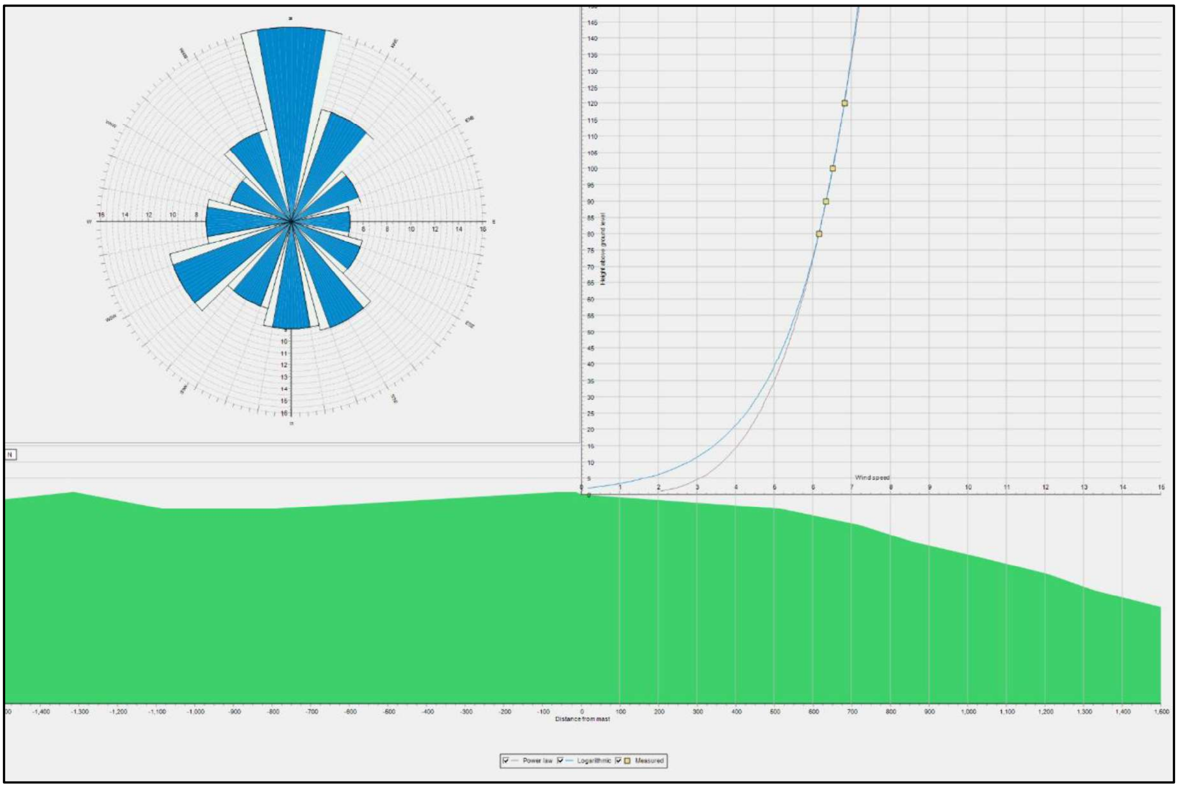

Fig. 21: Wind profile and wind rose for ERA5

Uncertainty degree of measured wind data

No service reports were available for the data from the beneficiary, and so the data gaps to be analysed through personal investigation and research methods.

Beside the data availability, the quality of the measured data depends on the anemometer's characteristics, the influences caused by the equipment installation and the terrain configuration. In the following table uncertainties estimated for each analysis phase of the installed anemometers are indicated as uncertainties in relation to the energy production calculation, which is estimated as being 1.4 bigger than the wind speed uncertainties.

Uncertainty of the parts of the analysis and calculations				
Wind statistic				**5.93%**
	Wind measurement			5.11%
		Anemometer calibration		1.00%
		Anemometer characteristics		1.50%
		Installation equipment's influence		2.90%
		Data recording		3.20%
			Availability	1.00%
			Recording frequency	0.50%
			Data recovery	3.00%
		Terrain effects (turbulence, wind shear)		2.06%
			Roughness and orography	1.30%
			Obstacles	1.60%
	Representation of the period			1.00%
	Long term correlation (Index consistency, 100% level, transfer to the future)			2.00%
	Site calibration (terrain modelling)			2.00%
Wake model/ wind farm calculation				**2.50%**
Integrity of the model (wind in hub height, transfer to the sites)				**3.00%**
WTG power curve				**10.00%**
Total uncertainty				**12.26%**

Fig. 24: Uncertainties table

Total uncertainty is considered as being the square root of the sum of squares of all individual factors. Uncertainties can be evaluated in detail, as follows:

- The anemometer calibration uncertainty results directly from the calibration reports and can be calculated with standard deviations of each recorded value. A simplified mean value for the measured uncertainty was chosen.
- The anemometer characteristics uncertainty describes the link of a certain type of anemometer with an ideal anemometer, regarding its behaviour due to wind profile and inertia. First Class Thies type anemometer belongs to high class quality with high performances in turbulent wind conditions. A small uncertainty is justified.
- The terrain influence is small, being indicated by the turbulence distribution between the three heights. As the relief in the area can be characterised as easy tilted, this fact shouldn’t lead to important vertical components of the wind vector and thus shouldn’t influence the wind measurements.

MCP analysis

MCP is the abbreviation for Measure-Correlate-Predict techniques, which is widely in use for establishing a long-term wind statistic using limited wind data from the current site and long-term data from a more-or-less nearby site.

Because often the on-site measured wind parameters do not cover a long period in time, there is a certain financial risk to estimate the turbine energy production for an entire park lifetime (mainly 25 years).

To cover a part from this risk, it is necessary to have the above-mentioned long term corrected wind data, obtained mainly after several statistical operations between the measured wind data and another reference data that can be considered reliable for the same area. In this wind resource assessment, the lack of reliable local meteorological data from meteo stations was replaced with Vortex type data.

The Vortex dataset consists of ***u*** and ***v*** wind components at different pressure surfaces, surface temperature data and surface heat flux. As we had mentioned early, twenty years long term data was used (2002 to 2022). In the following chart concurrent data only was analysed.

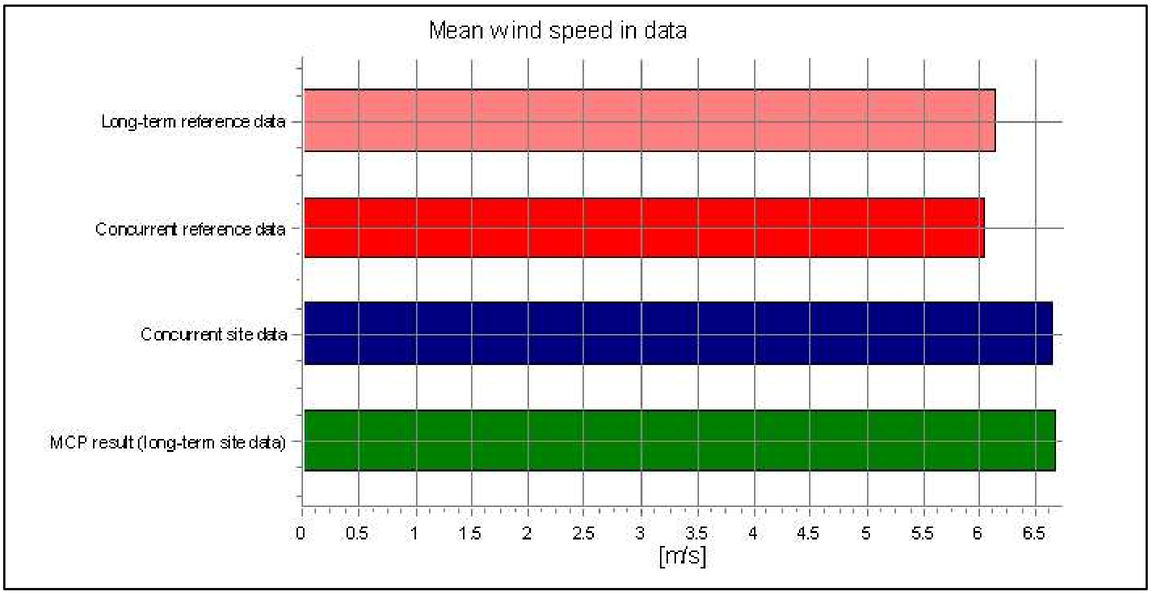

Fig. 25: Concurrent wind data at Topalu mast and at Vortex point

There are several methods to obtain a long term corrected wind data for site location. WindPro software can perform four MCP type analyses, their final result being dependent on several factors. It remains at user's attitude which method should be performed.

For the Topalu site, WPE team correlated the 85m anemometer from the Topalu 85 mast with 80m level from Vortex. Good correlation coefficients were obtained. After establishing a decent match between the local measurement and long-term reference data WPE team proceeded to creating a relevant wind statistic using the Matrix method. The final results of this MCP calculation will be represented by a long-term corrected meteorological data file, which will be used in an on-site WAsP analysis.

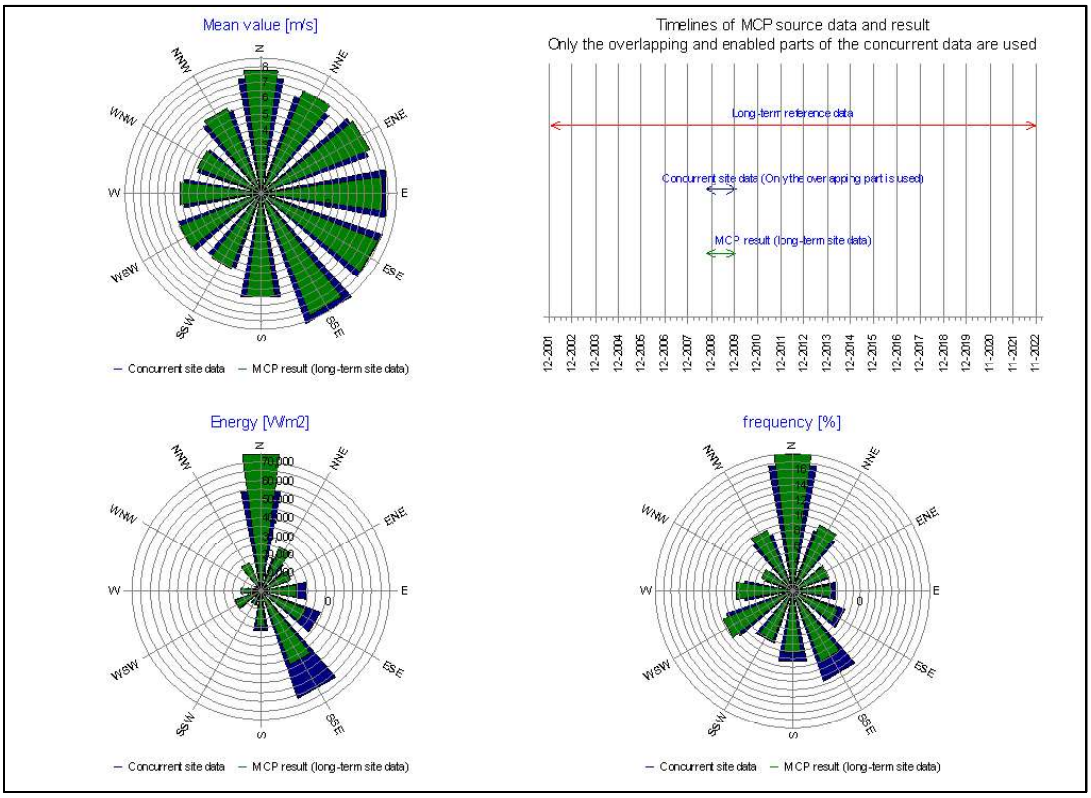

Fig. 26: Predicted Energy and Frequency

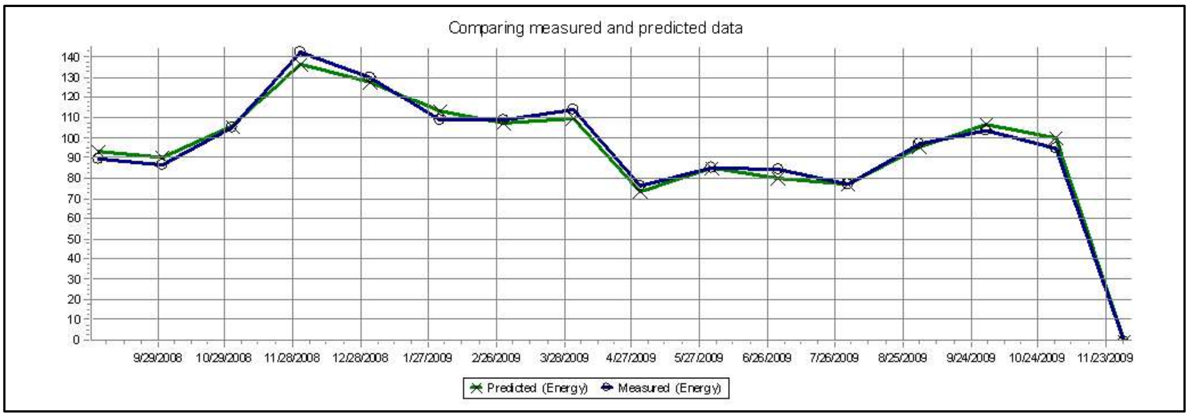

Fig. 27: Predicted Energy and Measured Energy