DUE DILLIGENCE OF

52 MW LOS COCOS II WIND FARM PROJECT

IN DOMENICAN REPUBLIC

GROUP 7 D

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1. ABSTRACT

The Objective of this report is to provide a due diligence assessment of the 52 MW grid-connected wind farm project in Dominican Republic developed by Cobra Energy with detailed analysis on the design plan and a thorough evaluation of the technical and economic since its commissioning in 2019.

We have divided the assessment in four parts: (i) Market analysis of wind and electricity in Dominic Republic, (ii) Regulatory framework and authorization procedure for wind farm installation in Dominican Republic, (iii) Resource assessment and technology analysis (iv) Economic analysis of the project.

In the technical analysis we have evaluated the operation of the used wind turbine and the annual energy production by taking accurate and reliable wind data on-site over a 36-month period between 2002 and 2005, using three 30-meter masts located across the project site whose evaluation was carried out by the Danish research centre, RISØ10. Followed by this we have compared this data with NASA MERRA-2. An assessment of operational efficiency is provided, validating the anticipated energy output.

We initiated the longitudinal analysis of the project by commencing with a financial assessment. Subsequently, we derived profitability ratios to evaluate the project's performance from the viewpoints of shareholders, stakeholders, and the overall company. This was followed by a thorough liquidity analysis of the company.

The subsequent phase involved conducting a benchmark analysis, comparing the profitability of the wind plant with others situated in Dominican Republic. Ultimately, the suggestions outlined in this report aim to assist us in achieving your primary goal of making long-term investments in the most tax-efficient manner. By adhering to these recommendations, investors can establish a high-quality, adaptable ISA, implementing a customized investment strategy crafted for robust long-term growth. Regular reviews will be conducted to ensure the policy's continued suitability. This approach is designed to optimize returns on investment, instilling confidence in the attainment of our long-term investment objectives.

2. INTRODUCTION

Caribbean countries are highly dependent on oil and gas for their energy needs and Dominican Republic is not the exception to this. The main energy source in the Dominican Republic is imported oil and its derivatives. They contribute 75% of the total primary energy supply. Energy proceeding from national production represents only 16% of the supply and basically comes from firewood (7%), bagasse (4%) and hydro (3%).

The development of wind energy in the Dominican Republic is fundamental for the diversification and sustainability of the energy sector and the reduction of greenhouse gas emissions. In the Dominican Republic, the SENI is composed mainly of fossil fuel fired power plants with little renewable electricity generation. Thus, the project will reduce the country's fossil fuel imports and diversify the sources of electricity generation, an important achievement for the transition away from fossil fuel electricity generation and for the reduction on the dependence on foreign energy sources.

The project site is located between the towns of Juancho and Los Cocos, in the province of Pedernales, approximately 40 km southwest of the province of Barahona, and east of Haiti. The proposed wind farm lies on a ridge of elevation between 10 m and 100 m.

The project involves 26 wind turbines, each with a capacity of 2 MW. The total installed capacity of the proposed project activity is 52 MW with net electricity generation of 157,189 MWh per year. The electricity generated by the project is supplied to the National Interconnected Electricity System (SENI2), displacing approximately 112,489 tonnes of CO_2 emissions per year from electricity generation at fossil fuel fired power plants.

The project developer is Empresa Generadora de Electricidad HAINA S.A. (EGE HAINA) and wind farm is constructed by COBRA Energy, a Spanish company, with more than 60 years' experience in the electricity sector. Based on the detailed assessment by EGE Haina from 2009 to 2012. Two wind turbine models were considered, Gamesa G90 and G97, each 2 MW, at a hub height of 78 meters. The layouts considered are shown in Figure 1. The selected configuration of the wind farm consists of two long rows and two short rows of wind turbines in a northwest-southeast direction.

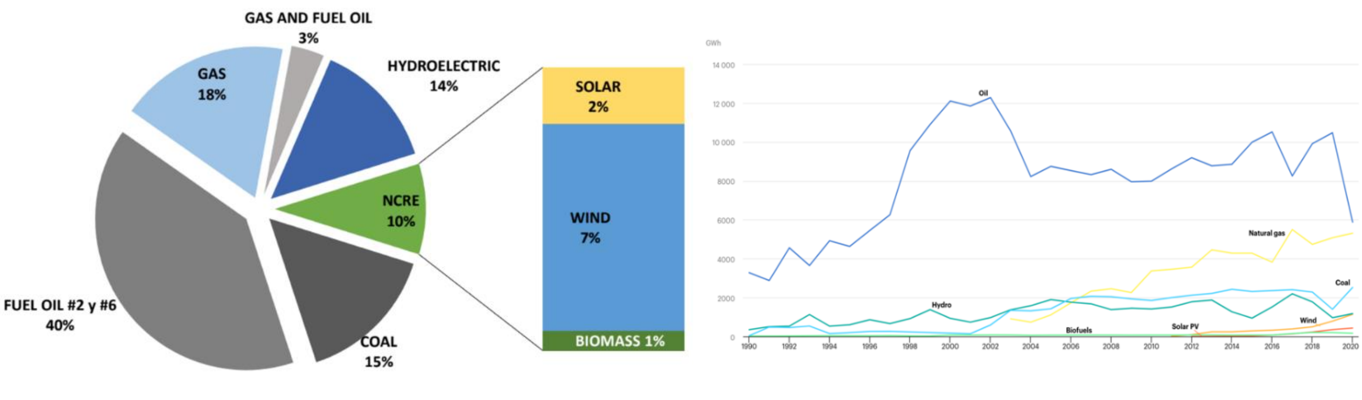
FIGURE 1 : ACTUAL WIND TURBINES SITTING TAKEN FROM GOOGLE EARTH

3. MARKET ANALYSIS

Dominican Republic has adopted a law on incentives for the development of renewable energy sources, which aims to increase the diversity of energy sources, reduce dependence on imported fossil fuels and stimulate investment in renewable energy.

As of 2020, the country's installed electrical capacity was 4921 MW, with fossil fuels accounting for 75.39%, followed by hydro (12.66%), wind (7.52%), solar (3.81%) and biofuels (less than 1%). Installed electrical capacity in the Dominican Republic increased by more than 52% between 2010 and 2019.

FIGURE 2: PERCENTAGES OF ELECTRICITY GENERATION IN DOMINICAN REPUBLIC BY ENERGY SOURCE



a) Percentage of grid installed capacity by energy source as September 2019

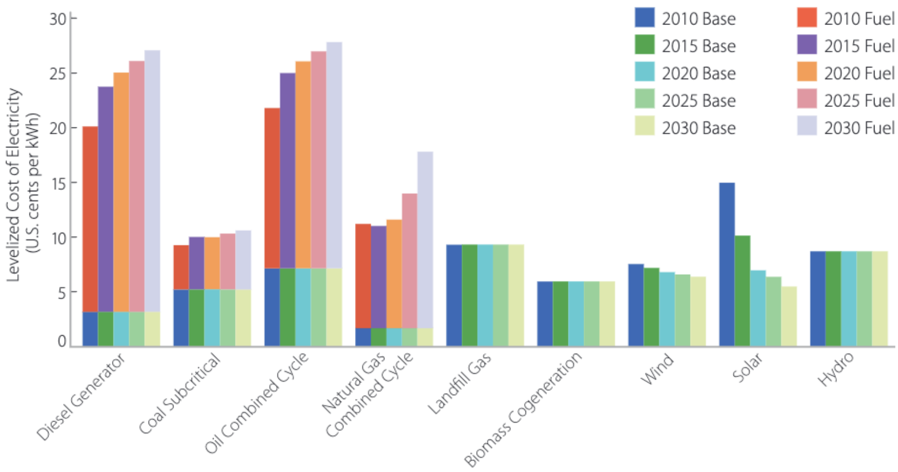
b) Electricity generation by source, Dominican Republic 1990-2020

3.1 ELECTRICITY COST IN DOMINICAN REPUBLIC MARKET

The LCOE for the various electricity generation options for the Dominican Republic shows that when the costs of capital, O&M, and fuel are factored in, renewable energy technologies already are competitive solutions for the country. Although most conventional technologies tend to have lower overnight capital costs than renewables, their ongoing fuel costs make them a much more expensive option over their lifetime.

Based on these assumptions, Figure 3 projects the LCOE for various electricity generation technologies in the Dominican Republic to 2030. Biomass cogeneration, wind, and hydropower are the cheapest generation technologies available for new projects in the country, at less than one-third the cost of electricity from diesel generators and one-fourth that from oil combined-cycle. Wind power is widely feasible in many good locations and is a competitive alternative to coal or natural gas.

FIGURE 3: DOMINICAN REPUBLIC LCOE PROJECTION TO 2030, BY TECHNOLOGY



Factors behind the decline in the global weighted average LCOE include:

3.1.1 Turbine technology improvements:

With the increase in turbine sizes and swept areas, the process of optimising the rotor diameter and turbine ratings, i.e. the specific power, has led to increased energy yield and thus project viability for the asset owner, depending on site characteristics. Consequently, this has increased energy yields, reduced O&M costs per unit of capacity and driven down LCOEs (Lantz et al., 2020).

3.1.2 Economies of scale:

Larger projects help to amortise project development costs and O&M costs while creating greater purchasing power for all aspects of the project. Meanwhile, larger turbines help reduce installation, given the reduction in the number of turbines required for a project due to higher turbine ratings.

3.1.3 O&M costs:

Improved O&M practices have also contributed to lower O&M costs. More players have been entering the O&M servicing sector for onshore wind, which is increasing competition and driving down costs (BNEF, 2019, 2020a).

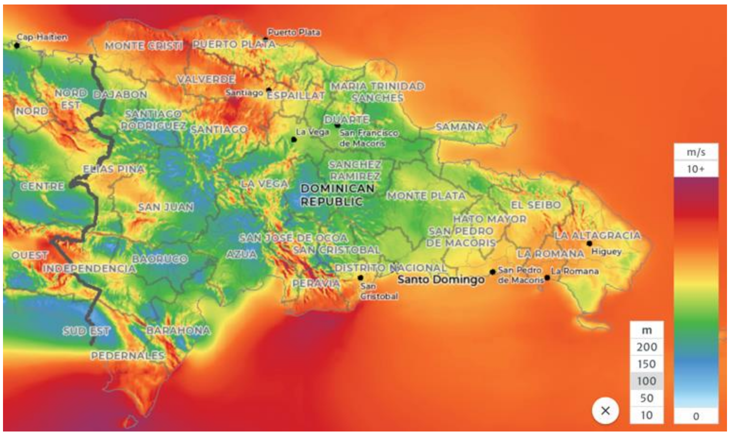
3.1.4 Competitive procurement:

The shift from feed-in-tariff support schemes to competitive auctions is leading to further cost reductions. This is because this shift drives competitiveness across the supply chain, from development to O&M and on both a local and global scale. For turbine manufacturers, the supply chain has also moved to support regional hubs and countries, minimising labour and delivery costs and further improving competitiveness.

3.2 WIND ENERGY POTENTIAL

3TIER's wind resource map for the Dominican Republic indicates that the country has strong wind potential that is suitable for wind power development. 3TIER also conducted more granular analysis for six zones: Pedernales, Baní, Montecristi, Puerto Plata, La Altagracia, and Samaná (as shown in Figure 4). The data, which reflect mean data for several points assessed in each zone, were chosen not to represent actual wind farms, but rather to best characterize the entire wind zone. According to the analysis, 214 of the 494 assessed grid points have capacity factors at or above 20%, and 78 have capacity factors at or above 30%.

FIGURE 4: DOMINICAN REPUBLIC WIND POTENTIAL AND WIND FARM DISTRIBUTION



a) *Wind speed map at 100 m Height*

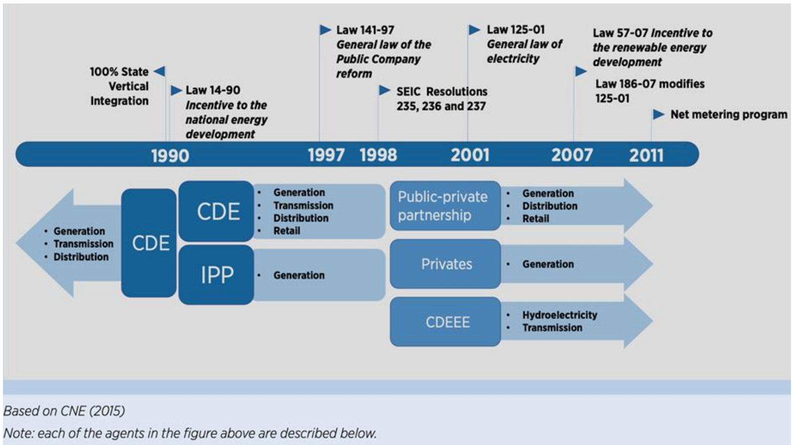
b) *The Dominican Republic plants distribution*

The Dominican Republic currently has two commercial-scale wind farms in operation. The first is Quilvio Cabrera, an 8.25 MW installation that was built in 2011 and is in the province of Pedernales in the southwest of the country. On a neighboring piece of land is the Los Cocos Wind Farm, which consists of two phases: Phase 1, completed in 2011, and Phase II, completed in 2013. In 2012, Los Cocos had a capacity factor of about 30%, above the level deemed necessary for a commercial project to be economical; however, integration with the grid has not been easy, as grid operators struggle with voltage regulation. A third wind park, Larimar, will be in the province of Barahona just to the north of Quilvio Cabrera and Los Cocos. These two provinces are home to the country's strongest wind potential.

4. REGULATORY FRAMEWORK ANALYSIS

The structure of the power sector in the Dominican Republic is the result of a reform process that started in the late 1990s. Until then, the state- owned Dominican Electric Company (Corporación Dominicana de Electricidad) (CDE) was in charge of electricity generation, transmission, distribution and retail. Only a few private companies participated in the generation business through Power Purchase Agreements (PPAs).

FIGURE 4: TIMELINE FOR THE MAIN INSTITUTIONAL AND LEGISLATION CHANGES IN THE POWER SECTOR OF DOMINICAN REPUBLIC UP TO 2011



Besides the legislation and main regulatory conditions, a set of technical rules have been developed by CNE (National Energy Commission), the Electricity Superintendency (Superintendencia de Electricidad) (SIE) and OC-SENI are enforced to allow the secure and efficient operation of the interconnected system. These technical rules include the connection code for generators, distribution systems and non-regulated consumers and the rules for the connection of distributed generation.

4.1 POLICIES ON WIND ENERGY

The main legislative instrument promoting renewable energy in the Dominican Republic is Law 57-07 on Renewable Energy Incentives and Special Regimes, enacted in 2007. Some of the policies which have been regulated are mentioned below:

4.1.1 SITE SELECTION LIMITATION

The CNE will determine in advance the areas that cannot be used for wind and photovoltaic developments, in order to avoid damage to protected or especially vulnerable areas, the occupation of land with destinations of greater value for people or the national economy, the generation losses associated with natural phenomena or unstable network points. To do this, the CNE will create a list of:

i. Excluded protected natural or landscape areas.
ii. Areas considered urban or soon to be urbanized.
iii. Areas excluded for industrial or agricultural/livestock reasons, tourism or some other high national interest.
iv. Areas excluded due to high statistical incidence of hurricanes, with great destructive effects caused by them.
v. Areas excluded due to instability or insufficiency of the electrical network.

4.1.2 ANALYSIS OF WIND AND ENERGY RESOURCES

- The technical studies of wind resources must be prepared by a company or entity with recognized technical capacity, previously authorized for this purpose by the CNE, whose studies comply with national and international standards.
- The measurement campaign will have, as a minimum, the following characteristics:
  i. It will include a period of no less than one year, with data availability greater than 80%.
  ii. The measurement towers will have a minimum height above ground level of 50% of the hub height of the planned wind turbines. The data from a tower at the hub height, located in a place representative of the average wind of the site, or failing that, the correlations between the measurement and the hub height of the planned wind turbines will be considered necessary.
  iii. The anemometers will be calibrated, and their calibration certificate will be presented, by an entity recognized for this purpose by the CNE.
  iv. Ten-minute averages of wind speed and direction will be recorded.
  v. In complex (mountainous) terrain, all wind turbines will be less than 4 kilometres from a measurement station.
- The wind resource study will have the following characteristics:
  i. Data measured at sites will be used for park energy production calculations.
  ii. Power curves of the proposed wind turbines, corrected for density, will be used to calculate park energy production.
  iii. The positions of the wind turbines and measurement towers used will be identified with geographical coordinates (UTM with its zone and projection).
  iv. Advanced cartography and adequate scale will be used.

4.1.3 WIND TURBINE CERTIFICATION

Wind turbine will be defined according to the regulations listed below and accompanied by the wind turbine certification documents:

i. IEC 61400-1 (2007-03): Design requirements.
ii. IEC 61400-2 (2006-03): Design requirements for small wind turbines wind turbines).

iii. IEC 61400-11 (2006-11) Ed. 2.1: Acoustic noise measurement techniques.
iv. IEC 61400-12 and IEC 61400-12-1 (2005-12): Power performance measurements of electricity producing wind turbines.
v. IEC 61400-21 (2001-12): Measurement and assessment of power quality characteristics of grid connected wind turbines.
vi. IEC/TS 61400-13 (2001-06): Measurements of mechanical loads (Measurement of mechanical loads)
vii. IEC/TS 61400-23 (2001-04): Full-scale structural testing of rotor blades.
viii. EN 50308:2004: Wind turbines – Protective measures – Requirements for design, operation and maintenance.
ix. IEC 61400-25-1 (2006-12): Communications for monitoring and control of wind power plants – Overall description of principles and models.
x. IEC 61400-25-3 (2006-12): Wind turbines – Part 25-3: Communications for monitoring and control of wind power plants – Information exchange models Information exchange models).
xi. IEC 61400-25-5 (2006-12): Communications for monitoring and control of wind power plants – Conformance testing.
xii. IEC 61400-SER (2007-03): Wind turbine generator systems.

4.2 ENVIRONMENTAL IMPACT

Wind power is one of the cleanest forms for generating electricity. However, since Los Cocos II comprises x02 26 MW wind generators, HAINA submitted a variation on the Environmental Impact Declaration (EID) to the Ministry of the Environment and Natural Resources. The following is a summary of the impacts identified in the EIA report for the construction and operation phases of the project:

- Change in drainage patterns (moderate impact)
- Activation of erosive process (moderate impact)
- Alteration of the soil properties (low impact)
- Alteration of landscape (significant impact)
- Alteration of air quality by the emission of gases and particulate material during construction phase (low impact)
- Increase in noise levels during operation of the wind farm (significant impact)
- Loss of vegetable cover (moderate impact)
- Reduction of available habitats and species (moderate impact)
- Increase in local employment and economic activity during construction and operation (significant impact)
- Payment of taxes to the State during operation of the project (significant impact)
- Increase in the income levels of the community during operation of the project (significant impact)
- Increase in the demand of goods and services during construction and operation (significant impact)
- Improvement in life quality of the community during operation of the project (significant impact)
- Alteration of water quality during construction (moderate impact)

The results of the environmental evaluation showed the necessity of develop and implement an environmental management and mitigation program which includes measures and actions to address the negative impacts of the project.

5. RESOURCE ASSESSMENT AND WIND TURBINE COMPARISON

The initial step in choosing a site for a wind farm involves assessing the wind potential in the region. To evaluate the wind speed potential at a specific location, the wind speed frequency distribution holds crucial importance. Various distribution functions, such as Weibull, Rayleigh, Lognormal, etc., are commonly employed to depict the wind speed frequency curve. Among these, the 2-parameter Weibull distribution is widely utilized to gauge the effectiveness of wind potential.

5.1 DATA ACQUISITION AND EXTRAPOLATION

Wind speed data for the past 10 years was obtained from the NASA MERRA-2 global dataset [9], specifically recorded at heights of 10 meters and 50 meters. The vertical extrapolation of this data was conducted at the turbine hub height, utilizing the power-law Equation [10].

$$v_z = v_0 \left(\frac{h_z}{z_0}\right)^{\alpha} \tag{1}$$

Where v_0 is measured wind speed at reference height z_0 and v_z is extrapolated wind speed at hub height h_z. The power law exponent α is evaluated at each wind speed at reference height of 10m and 50m using below equation. Subscript 1 and 2 correspond to 10m and 50m height respectively.

$$\alpha = \frac{\ln\left(\frac{v_2}{v_1}\right)}{\ln\left(\frac{z_2}{z_1}\right)} \tag{2}$$

5.2 WEIBULL DISTRIBUTION

To characterize the wind regime for the entire lifespan of the wind farm, various methods have been examined. These includes; (i) standard deviation method, (ii) Wasp method, and (iii) power density method, which are employed to assess the shape factor k and scale factor C for the Weibull probability density function.

$$f\,(v) = \left(\frac{k}{C}\right)\left(\frac{v}{C}\right)^{k-1} \exp\left(\left(-\frac{v}{C}\right)^{k}\right) \tag{3}$$

5.3 STANDARD DEVIATION METHOD

The shape factor k for this method is determined by utilizing the average wind speed and standard deviation, as defined by the following equation:

$$k = \left(\frac{\sigma}{\overline{v}}\right)^{-1.086} \tag{4}$$

Where the average wind speed and standard deviation is defined by below equations.

$$\overline{v} = \frac{1}{N}\sum_1^N v_i \tag{5}$$

$$\sigma = \sqrt{\frac{1}{N-1}\sum_1^N (v_i - \overline{v})^2} \tag{6}$$

Meanwhile, the scale parameter C is calculated using the following equation for all methods, including the Standard Deviation method, Least Square Method, and Power Density Method:

$$C = \frac{\overline{v}}{\Gamma\left(1+\frac{1}{k}\right)} \tag{4}$$

5.4 WASP METHOD

The WAsP method is governed by two primary conditions: (i) the equality of average power density for both the fitted and observed distribution, and (ii) the equivalence in the proportion of values above the mean observed speed for both distributions. Consequently, the scale parameter C is defined as follows:

$$C = \left[\frac{\sum_1^N {v_i}^3}{N\Gamma\left(1+\frac{3}{k}\right)}\right]^{\frac{1}{3}} \tag{5}$$

Whereas the shape factor is determined using proportion of wind speed that exceed the v_m.

$$X = 1 - F(v_m) = \exp\left(\left(-\frac{v_m}{C}\right)^{k}\right) \tag{9}$$

$$-\ln(X) = \left(\frac{v_m}{C}\right)^{k} \tag{10}$$

Where k can be determined using Goal Seek in Excel with combination of above two Equations

5.5 POWER DENSITY METHOD

This method is one of the most straightforward approaches for determining Weibull parameters. The following relations are employed to ascertain the shape factor k:

$$E_{pf} = \frac{\overline{v^3}}{\overline{v}^3} \qquad (11)$$

$$k = 1 + \frac{3.69}{{E_{pf}}^2} \qquad (12)$$

5.6 METHOD ACCURACY CHECK

The Root Mean Square Error (RMSE) for each method was computed with respect to the measured data to assess their accuracy. The method exhibiting the lowest RMSE error was selected for subsequent calculations of Energy Yield from the wind turbine.

$$RMS\ error = \sqrt{\frac{1}{n}\sum_1^n (f(v)_i - f(v)_{measured_i})^2} \qquad (13)$$

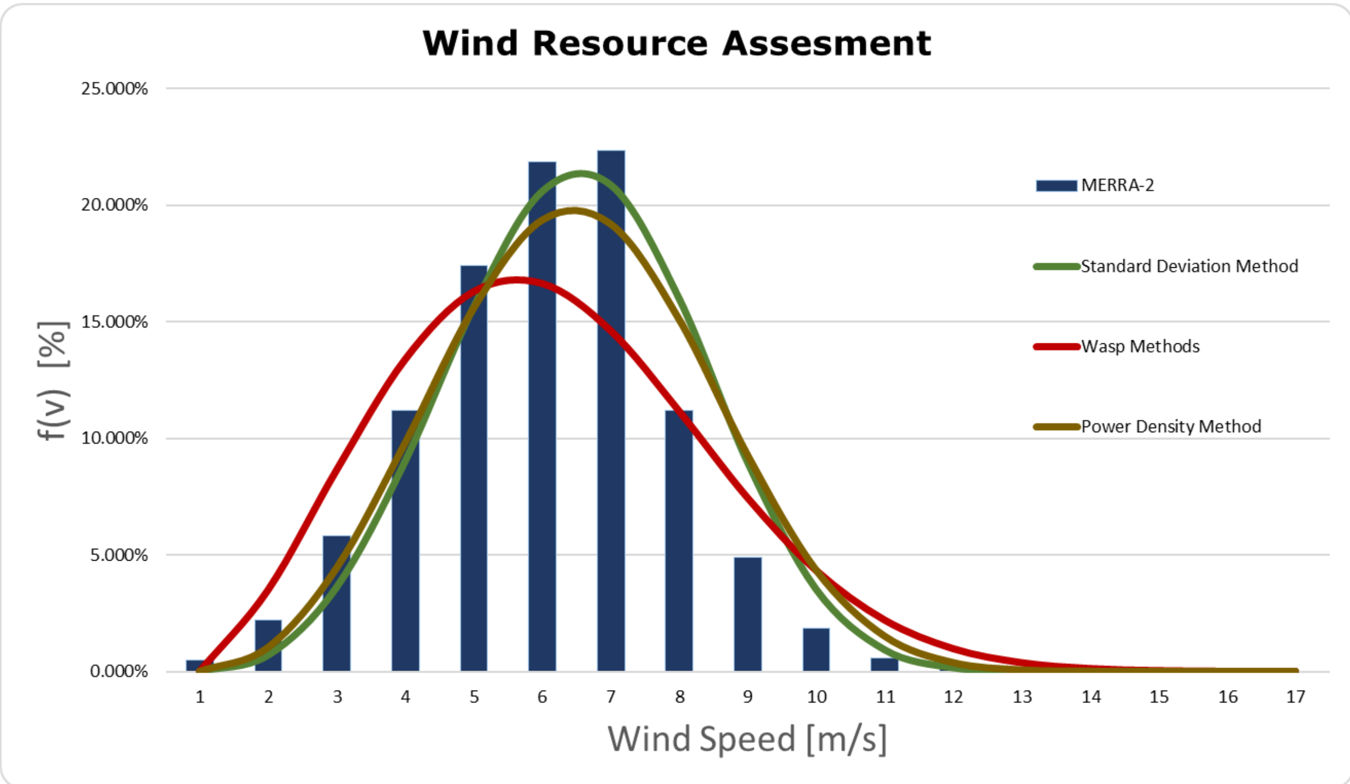
The estimation of Weibull parameters using above three methods and RMS error from NASA MERRA-2 wind speed data is shown in Table below.

TABLE 1: ESTIMATED SCALE AND SHAPE FACTOR AT 80-M HEIGHT AND ACCURACY

	Shape factor k	Scale factor C	RSME (%)
Standard Deviation Method	3.42	6.15	0.155%
Power Density Method	3.14	6.17	0.167%
WAsP Method	2.40	5.80	0.297%

It is evident from above results that the Standard Deviation method provides with least RSME and best fitting curve for the measured data. This can also be seen in the figure below.

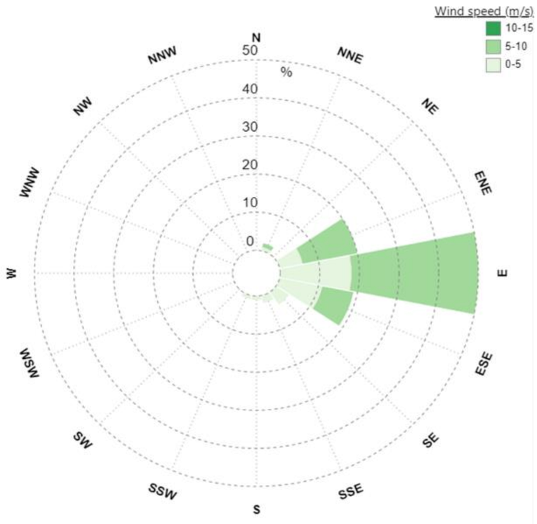
FIGURE 5: ACTUAL AND FITTED DISTRIBUTION OF WIND SPEED WITH DIFFERENT METHODS



4.7 WIND DIRECTION

A wind rose serves as a visual aid utilized by meteorologists to provide a concise representation of the typical distribution of wind speed and direction at a specific location. At our site, the prevailing wind direction is predominantly toward the East.

FIGURE 6: WIND ROSE DIAGRAM



4.8 ANNUAL VARIATION ASSESSMENT

Additionally, we must examine the annual variation of the mean wind speed to assess the availability of sufficient wind for power generation from the wind turbine generators (WTG) in the upcoming period. This analysis will be instrumental in the management and planning of the wind farm during its future operation. The linear regression method has been employed to analyze the trends in wind speed.

4.8.1 LINEAR REGRESSION METHOD:

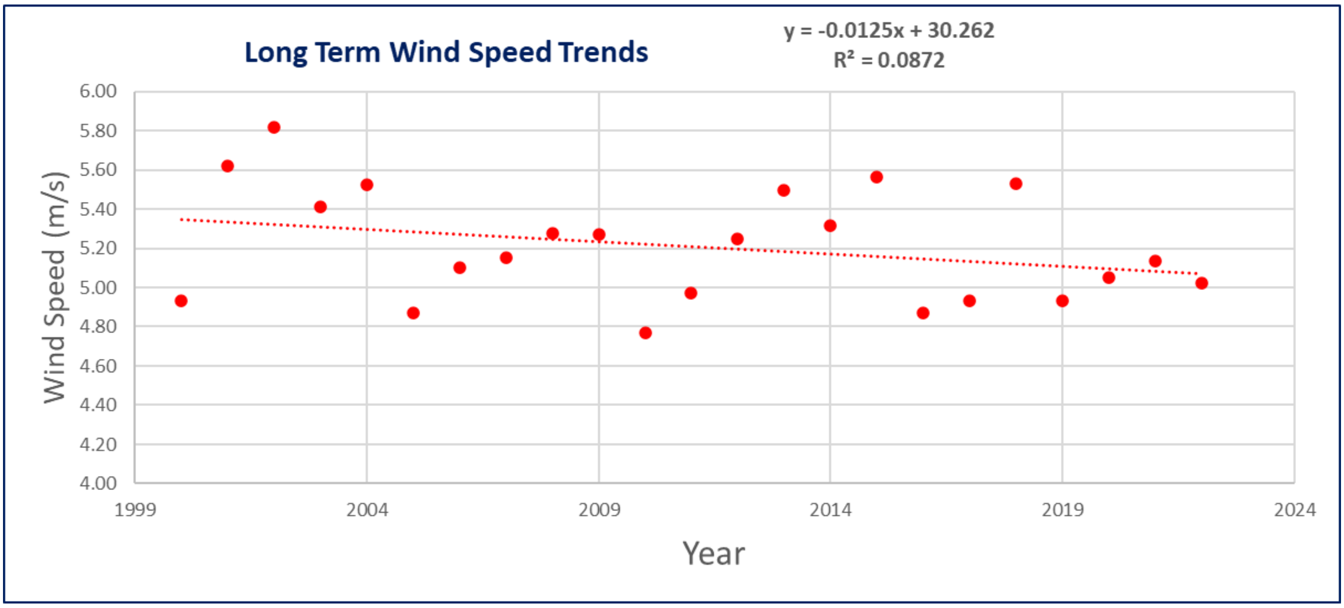
The wind data, spanning from 2000 to 2022, has been extracted from the NASA MERRA-2 global dataset. Annual wind speed calculations were performed, and the data was plotted over the years. The best regression line coefficients (A and B) and the corresponding coefficient of determination values (R^2) were determined. The trend categorization, whether increasing, decreasing, or showing no trend, is based on the regression coefficient 'A'. [11]

TABLE 2 : LINEAR REGRESSION COEFFICIENTS

Regression coefficient A	Regression coefficient B	R^2
-0.0125	30.262	0.0872

It is evident from the analysis that there has been a notable decrease in the trend of mean annual wind speed, approximately amounting to 0.00125 m/s, observed over the past 22 years.

FIGURE 7: LONG TERM WIND SPEED VARIATION TREND



4.9 WIND SITE CLASSIFICATION

The design and choice of a wind turbine for a particular site are heavily influenced by the assigned wind class. The criteria for determining a wind class for a specific site are outlined in the International Electrotechnical Commission standard IEC 61400 [12]. A wind turbine designed for a specific wind class is engineered to withstand wind disturbances characteristic of that site class and endure extreme conditions throughout its expected lifetime. Wind classes are categorized based on two main parameters: average wind speed and turbulent intensity. Class A designates a site with high turbulence intensity, while Class B designates a site with low turbulence intensity.

TABLE 3: MAIN PARAMETERS FOR WIND TURBINE CLASSES

	CLASS I	CLASS II	CLASS III	CLASS IV	CLASS S
V_{ref} [m/s]	50	42.5	37.5	30	Specified by Designer
V_{av} [m/s]	10	8.5	7.5	6	
A I_{15}	0.18	0.18	0.18	0.18	
B I_{15}	0.16	0.16	0.16	0.16	

Here V_{av} is annual average wind speed at turbine hub height and I_{15} is turbulence intensity at reference speed of 15 m/s.

Given that the average wind speed at the hub height of 120m for our site is 5.5 m/s, which falls below the threshold for class IV (with an average wind speed of 6 m/s), it is advisable to choose class IV for the design and selection of the wind turbine. This selection ensures that the wind turbine is appropriately matched to the wind conditions of the site, promoting safe and efficient operation throughout the lifetime of the plant.

$$TI = \frac{\sigma}{V_{avg}} \tag{14}$$

With a turbulence intensity (TI) value of 0.323 at the hub height of 120m and an average wind speed (V_{av}) of 5.5 m/s, the site is categorized as having high turbulence intensity, denoted as "A." Consequently, our site falls into the IEC Class IV A category according to the guidelines outlined in IEC 61400-1.

4.10 WIND TURBINE COMPARISON

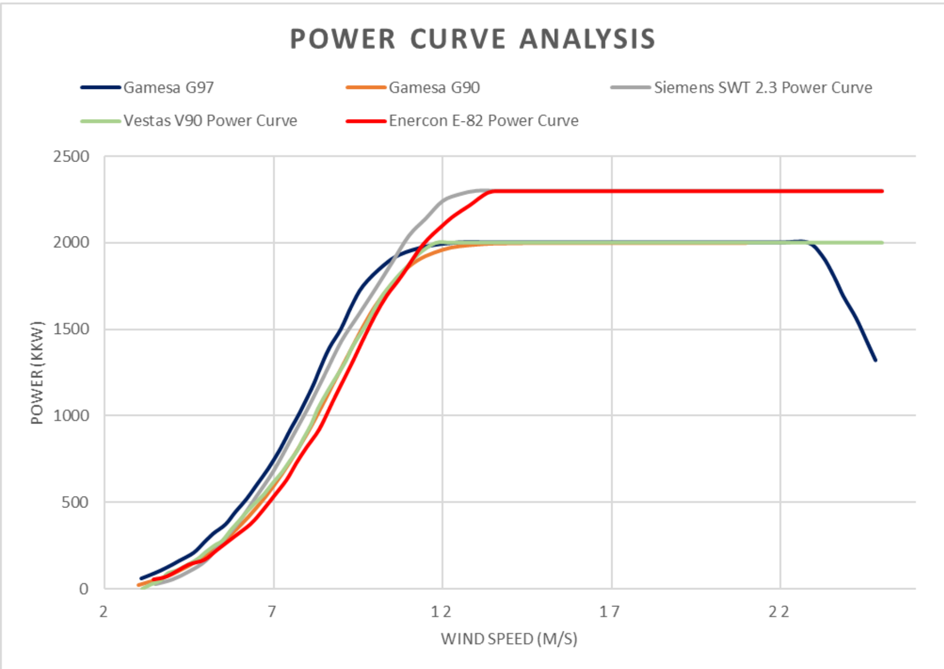
Different turbine models are being assessed based on their Annual Energy Production, considering a rated power range between 2 and 2.3 MW. The evaluations are conducted at a hub height of 120 meters for all turbine models. The technical specifications for our turbines, Gamesa G90 and G97, are detailed below [13].

TABLE 3 : TECHNICAL SPECIFICATIONS OF SELECTED TURBINE

WIND CLASS	IEC IV A / IEC S	**HUB HEIGHT**	78 m
RATED POWER	2.0 MW	**ROTOR DIAMETER**	90 m (G90) 97m (G97)
CUT-IN SPEED	3 m/s	**TYPE**	Three bladed horizontal axis
CUT-OUT SPEED	25 m/s	**TRANSFORMER**	138/34.5 kV

The power curve of various turbine models, sourced from publicly available data, is depicted in the figure below.

FIGURE 8: POWER CURVE OF DIFFERENT TURBINES WITH RATED POWER 2-2.3 MW

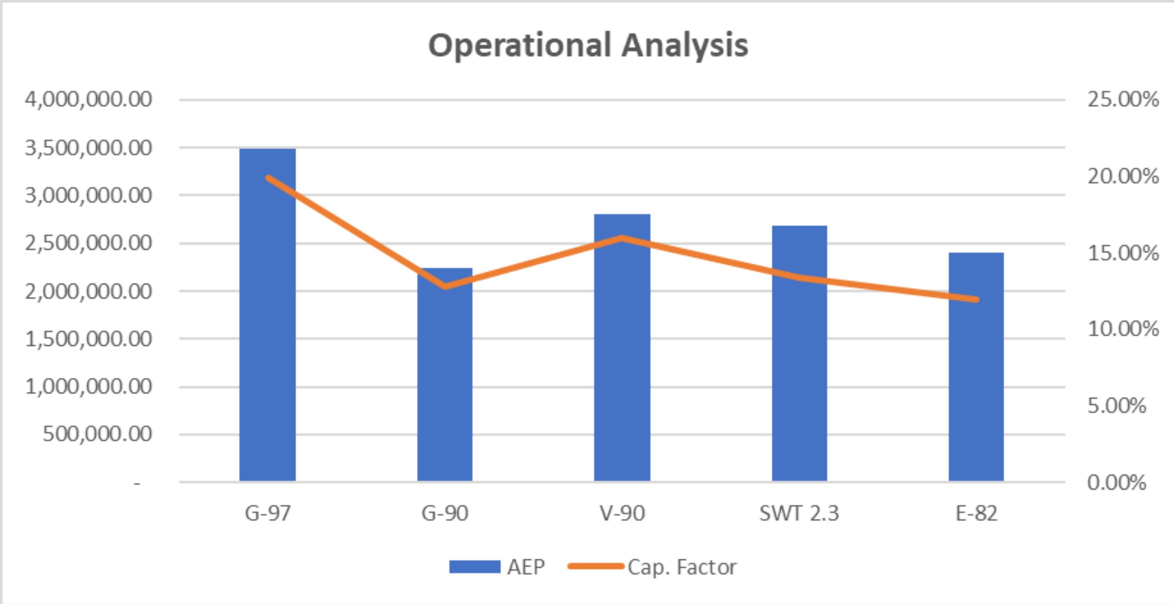


The assessment of annual energy production for all five models is conducted without factoring in any auxiliary and wake losses. The results indicate that the Gamesa G97 achieves the highest annual energy yield. Consequently, we can infer that the selected turbine model stands out as the best among others with comparable rated power.

TABLE 4 : AEP AND CAPACITY FACTOR WITH DIFFERENT MODELS

	AEP (kWh) - No Losses	CAPACITY FACTOR
GAMESA G-97	3,486,156	19.90%
GAMESA G-90	2,247,432	12.83%
VESTAS V90	2,805,261	16.01%
SIEMENS SWT 2.3	2,688,999	13.35%
ENERCON E82	2,400,641	11.92%

FIGURE 9: AEP AND CAPACITY FACTOR WITH DIFFERENT MODELS



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