

Wind Turbine Selection and Techno-Economic Assessment of Wind Power Generation in Kassa, Guinea

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Abstract

This study aims to select a wind turbine suited to the wind conditions of Kassa, Guinea, and to assess its energy and techno-economic performance. NASA POWER and ERA5 wind data covering the 2020-2025 period, available at 10 m, were used to determine wind conditions at heights of 30, 50, and 100 m. Three commercial wind turbines, NPS 100C-24, EWT DW54-900, and the 2 MW ENERCON E-82 E2, were evaluated by combining their power curves with monthly Weibull distributions. The ENERCON E-82 E2 provides the highest absolute annual energy production, with an AEP of 1775.31 MWh/year for NASA POWER and 1989.60 MWh/year for ERA5, whereas the NPS 100C-24 exhibits the highest capacity factors, at 17.20% and 20.02%, respectively. The ENERCON E-82 E2 was selected for the techno-economic assessment because of its higher absolute AEP. After accounting for 10% losses, its net energy production reaches 1597.78 and 1790.64 MWh/year. The economic assessment yields LCOE values of 0.2502 and 0.2233 USD/kWh, NPVs of -2,561,884 and -2,356,009 USD, IRRs of -5.16% and -3.41%, and payback periods of 53.53 and 40.47 years, respectively. The sensitivity analysis confirms that energy production, CAPEX, and the electricity price strongly influence economic performance, but none of the scenarios investigated achieves economic viability under the conditions considered. These results demonstrate the importance of

the choice of wind data source and highlight the need for in situ measurements and more detailed local economic data to strengthen the assessment of Kassa's wind energy potential.

Keywords

Kassa, Wind Energy, NASA POWER, ERA5, Weibull, Wind Turbine, AEP, Capacity Factor, LCOE, Techno-Economic Analysis

1. Introduction

The development of wind energy relies on a sufficiently accurate assessment of the available resource and on matching the characteristics of the wind regime with those of the conversion systems under consideration. In this context, Spiru and Simona (2024) assessed the wind potential of a site by combining Weibull analysis with a comparison of six wind turbines rated between 1.5 and 3 MW. Their study shows that Weibull parameters, energy production, and capacity factor are key elements for comparing turbine performance and identifying a technology suited to local wind conditions [1].

Using a comparable approach, Faraz (2024) investigated the wind potential of Al-Jouf, Saudi Arabia, using a 21-year wind-speed series. The data were modeled using the Weibull distribution before six commercial wind turbines were evaluated. The study notably shows that turbine selection should be based on the turbine response to the statistical characteristics of the site's wind regime rather than solely on rated power [2].

Operating height is also an essential aspect of this approach. Aroua *et al.* (2024) carried out a techno-economic assessment of wind power generation at three sites in the Algerian Highlands by considering several commercial wind-turbine models. Their approach combines resource assessment, turbine characteristics, and energy cost to identify the configuration best suited to each site. This study confirms the value of directly linking wind conditions at the heights considered to the energy and economic performance of wind turbines [3].

The availability of representative data nevertheless remains a challenge in regions where ground measurements are insufficient. In this regard, Younous *et al.* (2025) used ERA5 reanalysis data at 100 m to establish a climatological characterization of the wind resource in Chad. Their analysis highlights substantial spatial, seasonal, and diurnal variations in wind and demonstrates the value of ERA5 data for preliminary resource assessment in an African context with limited measurement networks [4].

Beyond resource characterization alone, recent literature has placed increasing emphasis on wind-turbine selection. A 2025 study covering several Indian sites compared different methods for estimating wind parameters and several wind-turbine technologies. Turbine selection was based in particular on energy produc-

tion and capacity factor at different time scales, while LCOE was used to complement the energy comparison with an economic dimension. This approach illustrates the value of an integrated assessment of the resource, the turbine, and the cost of energy [5].

Recent studies also show that economic assessment cannot be separated from energy performance. Wang *et al.* (2025) examined methods for calculating the levelized cost of electricity for wind and solar systems and highlighted the influence of natural, geographical, economic, and temporal conditions on this indicator. Their analysis shows that LCOE is an important economic assessment tool, but its relevance depends on the quality of the energy and financial assumptions used [6].

Extending this approach, the viability analysis of a wind project may incorporate, in addition to LCOE, financial indicators for assessing investment profitability over the project lifetime. Techno-economic studies therefore jointly use energy production, investment and operating costs, discounted cash flows, and sensitivity analyses to assess the robustness of the results. A recent study of a low-wind-speed region in Egypt specifically combined Weibull distribution modeling, techno-economic assessment, and sensitivity analysis to examine the conditions for viable wind power generation [7].

This linkage between technical and economic performance becomes particularly important when several configurations must be compared. Recent analyses show that capacity factor directly influences the amount of electricity generated and, consequently, its cost. A 2024 study on technical wind-energy potential notably showed that variations in capacity factor can lead to significant changes in LCOE, underscoring the need to integrate energy and economic dimensions simultaneously when assessing a wind project [8].

In Guinea, and more specifically on Kassa Island in the Loos Islands archipelago off Conakry, studies devoted to the wind resource are still recent. Camara *et al.* (2026) conducted an initial comparative analysis of wind speeds from NASA POWER and ERA5 over the 2020-2025 period. Using mean bias error (MBE), root mean square error (RMSE), and Spearman's correlation coefficient, the study reported a mean MBE of 0.336 m/s, a mean RMSE of 0.783 m/s, and a mean Spearman coefficient of 0.324. It also revealed seasonal differences between the two sources, supporting their separate consideration in site energy assessments [9].

In a second study of the same site, Camara *et al.* (2026) further assessed the wind-energy potential of Kassa using NASA POWER and ERA5 data over the 2020-2025 period. The analysis characterized the wind regime at the 10 m reference height and determined the Weibull distribution parameters required for wind-resource assessment. These results, therefore, provide a basis for extending the analysis to heights corresponding to actual wind-turbine operating conditions [10].

A review of these studies reveals a methodological progression from the statistical characterization of wind resources to wind turbine selection and then to techno-economic assessment. The present study builds on the two previous stud-

ies conducted in Kassa [9] [10], reusing the reference data and parameters established at 10 m. However, it makes a distinct contribution, whose positioning relative to the two previous studies is summarized in **Table 1**.

Table 1. Positioning of the present study relative to previous studies conducted in Kassa.

Study	Data/Period	Main Approach	Contribution
Comparative Analysis of NASA POWER and ERA5 Reanalysis Data for Assessing Wind Energy Potential in Kassa (Guinea) [9]	NASA POWER/ERA5, 2020-2025	Statistical comparison of the two sources	Assessment of agreement and differences between NASA POWER and ERA5
Assessment of Wind Energy Potential in Kassa (Guinea) Using NASA Satellite and ERA5 Reanalysis Data [10]	NASA POWER/ERA5, 2020-2025, 10 m	Characterization of the wind regime and Weibull distribution	Assessment of wind energy potential at 10 m
Present Study (Wind Turbine Selection and Techno-Economic Assessment of Wind Power Generation in Kassa, Guinea)	NASA POWER/ERA5, 2020-2025	Extrapolation to hub heights, power curves, and techno-economic assessment	Wind turbine selection and techno-economic assessment of the selected configuration

This progression highlights the transition from comparing data sources and characterizing wind energy potential at 10 m to an assessment applied at hub heights. The specific contribution of the present study therefore lies in the comparative evaluation of commercial wind turbines using their power curves and in the techno-economic assessment of the selected configuration.

Accordingly, this study aims to select, among several configurations investigated, a wind turbine suited to the wind conditions of Kassa and to assess its energy and techno-economic performance. Based on wind characteristics established at the reference height of $z_1 = 10$ m, the corresponding conditions are determined at heights of 30, 50, and 100 m. Three commercial wind turbines: the NPS 100C-24, EWT DW54-900, and 2 MW ENERCON E-82 E2 are then evaluated by combining their power curves $P(V)$ with the monthly Weibull distributions corresponding to their hub heights. Mean electrical power, annual energy production (AEP), and capacity factor CF are used to compare the configurations. Finally, the selected wind turbine undergoes a techno-economic assessment based on CAPEX, OPEX, LCOE, NPV, IRR, and payback period (PP), complemented by a sensitivity analysis.

The remainder of the paper is organized as follows. Section 2 presents the study site, reference data, and the methodology adopted to determine wind conditions at hub heights, preselect wind turbines, assess their energy performance, and carry out the techno-economic analysis. Section 3 presents and discusses the wind conditions obtained at the different heights, the characteristics of the preselected wind turbines, their power curves and energy performance, followed by selection of the retained configuration, its techno-economic performance, and the sensitivity analysis. Finally, the Conclusion summarizes the main findings and presents perspectives for wind-energy exploitation at Kassa.

2. Materials and Methods

2.1. Study Site and Reference Wind Data

2.1.1. Location and Description of the Potential Wind-Turbine Installation Area in Kassa, Guinea

Kassa Island is located off Conakry, in the Loos Islands archipelago on the Atlantic coast of the Republic of Guinea. The reference site considered in this study is located at geographical coordinates 9.477°N and 13.749°W, identical to those used in our previous studies assessing the wind-energy potential of Kassa [9] [10]. Its insular location and exposure to the Atlantic Ocean make it an area of interest for wind-resource exploitation.

Building on these studies, which characterized the wind resource at the 10 m reference height, the present study focuses on assessing the resource at heights compatible with wind-turbine installation. Wind characteristics are therefore extrapolated to 30, 50, and 100 m in order to examine the vertical evolution of the resource and identify the conditions most favorable for electricity generation.

Figure 1 presents the topographic configuration of the area selected for potential wind-turbine installation.

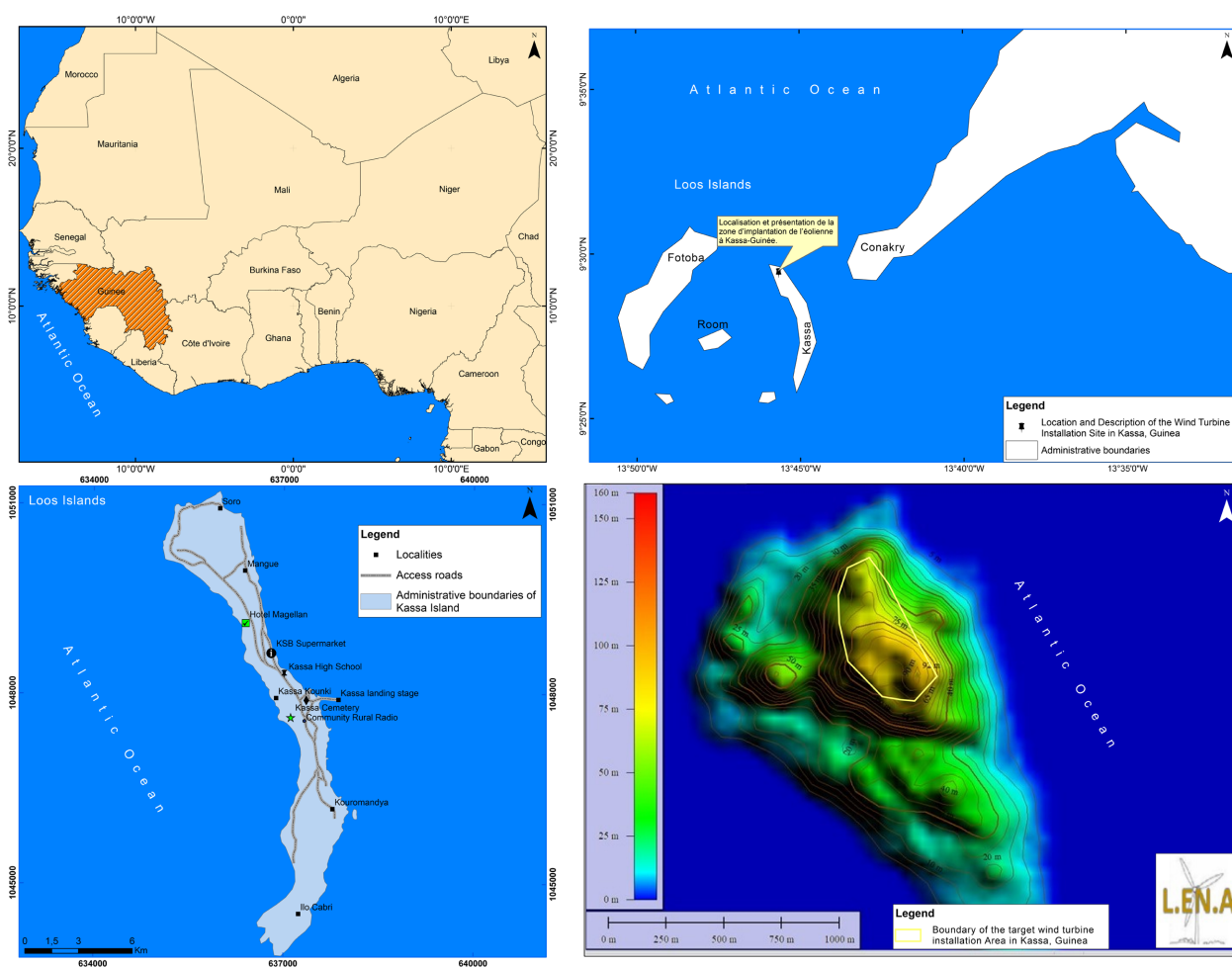


Figure 1. Location and topographic configuration of the potential wind-turbine installation area on Kassa Island, Guinea.

The island has contrasting relief, ranging from low coastal areas to sectors rising above 100 m, while the map scale indicates an extent on the order of one kilometer. The proposed installation area, outlined on the map, is located mainly in the central to northeastern part of the island and covers a relatively elevated sector. This location makes it possible to consider both the site's topographic characteristics and the variation of wind potential with height in the wind-turbine selection process.

Thus, unlike previous studies focused on characterizing and comparing the wind resource at 10 m, the present work uses those results as reference data to further assess the exploitable potential at different heights, then select wind turbines, estimate their energy production, and perform a techno-economic assessment of the retained configurations.

2.1.2. Reference Wind Data and Study Input Parameters

The wind data used in this study are obtained from the NASA POWER and ERA5 databases and cover the 2020–2025 period. They correspond to the Kassa site, located at 9.477°N and 13.749°W, and are considered at the reference height of $z_1 = 10$ m, in accordance with previous studies conducted at the same site [9] [10].

In a first study, NASA POWER and ERA5 data were comparatively analyzed in terms of wind speed and seasonal variability, establishing the main characteristics of the Kassa wind regime [9]. A second study expanded on this characterisation at a depth of 10 m by analysing the Weibull distribution and determining the shape parameter k and scale parameter c , as well as the corresponding wind power and energy characteristics [10].

The monthly Weibull parameters k_1 and c_1 used in the present study were previously determined at 10 m from monthly mean wind speeds and their corresponding standard deviations [10]. The high values of the shape parameter k_1 reflect the low relative dispersion of wind speeds around their monthly mean and should be interpreted in light of the monthly and aggregated nature of the data, which may reduce the apparent variability. They are therefore not representative of short-term wind variability.

In this study, the monthly average wind speeds V and the Weibull parameters k and c , determined at $z_1 = 10$ m, will serve as the input data for assessing wind resources at greater heights. These parameters will be extrapolated to 30, 50, and 100 m, separately for NASA POWER and ERA5, in order to preserve the specific characteristics of each data source.

The characteristics obtained at the different heights are subsequently used to assess wind power and energy, select and evaluate the energy performance of wind turbines, and finally conduct the techno-economic analysis of the retained configuration. This approach extends the results established at 10 m in previous work without repeating the processing already developed.

2.2. Method

2.2.1. Determination of Wind Conditions at Hub Heights

Wind data available at the $z_1 = 10$ m reference height are used to determine the

wind conditions corresponding to the hub heights of the wind turbines under consideration. For this purpose, the Justus and Mikhail model is adopted for vertical extrapolation of wind speed and Weibull parameters [11].

The wind speed V_2 at height z_2 is determined from the speed V_1 at the reference height z_1 using the power law given by Equation (1) [11] [12]:

$$V_2 = V_1 \left(\frac{z_2}{z_1} \right)^n \quad (1)$$

where:

- V_1 : wind speed at the reference height z_1 ;
- V_2 : extrapolated wind speed at height z_2 ;
- n : vertical wind-speed extrapolation exponent.

with:

$$n = \frac{0.37 - 0.088 \ln(V_1)}{1 - 0.088 \ln\left(\frac{z_1}{10}\right)} \quad (2)$$

The Weibull distribution parameters k and c are also extrapolated:

- The shape parameter k_2 height z_2 will be determined from k_1 , using Equation (3):

$$k_2 = k_1 \frac{1 - 0.088 \ln\left(\frac{z_1}{10}\right)}{1 - 0.088 \ln\left(\frac{z_2}{10}\right)} \quad (3)$$

where:

- k_1 and k_2 : are the Weibull shape parameters, corresponding to the heights z_1 and z_2 ;
 - z_1 : reference height of 10 m;
 - z_2 : extrapolation height of 30, 50, or 100 m;
 - $\ln$: natural logarithm.
- The scale parameter c_2 is obtained from c_1 using Equation (4):

$$c_2 = c_1 \left(\frac{z_2}{z_1} \right)^m \quad (4)$$

with:

$$m = \frac{0.37 - 0.088 \ln(c_1)}{1 - 0.088 \ln\left(\frac{z_1}{10}\right)} \quad (5)$$

where:

- c_1 : Weibull scale parameter at height z_1 ;
- c_2 : Weibull scale parameter at the new height z_2 ;
- m : vertical extrapolation exponent for the scale parameter;
- z_1, z_2 : heights considered.

In this study, $z_1 = 10$ m, and wind characteristics will be determined at heights z_2 of 30, 50, and 100 m, separately for NASA POWER and ERA5. The values of k_2 and c_2 obtained will be used as wind conditions at hub height for the pre-selection of wind turbines and the assessment of their energy performance.

Applying the same extrapolation formulation constitutes a modeling assumption that ensures consistent treatment of both data sources. However, it does not explicitly represent local variations in roughness, terrain, and exposure at the Kassa site. The wind speeds obtained at hub heights should therefore be regarded as modeled estimates associated with uncertainty that could be reduced through in situ measurements at the heights considered.

A comparison with ERA5 data directly available at 100 m would also provide complementary validation of the extrapolated wind speeds and may be considered in future work.

2.2.2. Wind-Turbine Preselection

Based on the wind conditions determined at the different hub heights, several commercially available wind-turbine models are preselected according to their suitability for the Kassa wind regime. Selecting a wind turbine suited to a site notably requires matching its technical characteristics and power curve to the available wind conditions [13].

The main parameters considered are:

- rated power P_n ;
- hub height;
- rotor diameter D ;
- cut-in, rated, and cut-out wind speeds V_{ci} , V_r , and V_{co} ;
- the power curve $P(V)$.

The rotor swept area A is determined using Equation (6):

$$A = \frac{\pi D^2}{4} \quad (6)$$

where:

- A is the wind-turbine rotor swept area, in m^2 ;
- D is the rotor diameter, expressed in meters (m);
- π is the mathematical constant pi, approximately equal to 3.1416.

This preselection identifies wind turbines that are technically compatible with the site's wind conditions for subsequent energy-performance assessment.

2.2.3. Assessment of Wind-Turbine Energy Performance

The energy performance of the preselected wind turbines is assessed by combining the manufacturer's power curve $P(V)$ with the Weibull distribution of wind speeds for each month and the corresponding hub height. This approach simultaneously accounts for monthly wind-resource variability and the actual operating characteristics of each wind turbine [14].

1) Evaluation of Mean Electrical Power and Electrical Energy Production

For each month m , the mean electrical power $\overline{P_{e,m}}$ is determined using Equa-

tion (7):

$$\overline{P_{e,m}} = \int_{V_{ci}}^{V_{co}} P(V) f_m(V) dV \quad (7)$$

where:

- $P(V)$: electrical power delivered by the wind turbine at wind speed V ;
- $f_m(V)$: Weibull probability density function for month m ;
- V_{ci} and V_{co} : cut-in and cut-out wind speeds of the wind turbine, respectively.

For each month, the Weibull distribution used in Equation (7) is defined by the parameters k_2 and c_2 extrapolated to the hub height of the wind turbine considered. Between two consecutive wind speeds on the manufacturer's power curve, the power $P(V)$ is determined by linear interpolation.

The duration of month m is determined using Equation (8):

$$t_m = 24N_{j,m} \quad (8)$$

where:

- $N_{j,m}$: represents the number of days in the month.

Thus, t_m is equal to 744 h for a 31-day month, 720 h for a 30-day month, and 672 h for February in a non-leap year.

The electrical energy produced during month m is then calculated using Equation (9) [15]:

$$E_m = \overline{P_{e,m}} t_m \quad (9)$$

where:

- E_m : electrical energy produced during month m , expressed in kWh;
- $\overline{P_{e,m}}$: mean electrical power produced during month m , expressed in kW;
- t_m : duration of month m , expressed in hours (h).

2) Evaluation of Annual Energy Production (AEP)

Annual energy production (AEP) is obtained by summing the monthly production values using Equation (10) [16]:

$$\text{AEP} = \sum_{m=1}^{12} E_m = \sum_{m=1}^{12} \overline{P_{e,m}} t_m \quad (10)$$

where:

- AEP: annual electrical energy production of the wind turbine, in kWh/year;
- E_m : electrical energy produced during month m , in kWh;
- m : month index, ranging from 1 to 12;
- $\overline{P_{e,m}}$: mean electrical power produced during month m , in kW;
- t_m : duration of month m , in hours (h).

with:

$$\sum_{m=1}^{12} t_m = 8760 \text{ h}$$

where:

- $t_m = 8760$ corresponds to the total number of hours in a non-leap year.

The annual mean electrical power $\overline{P_e}$ can therefore be expressed using Equa-

tion (11) [17]:

$$\bar{P}_e = \frac{1}{8760} \sum_{m=1}^{12} \overline{P_{e,m}} t_m = \frac{\text{AEP}}{8760} \quad (11)$$

where:

- $\bar{P}_e$: annual mean electrical power of the wind turbine, expressed in kW;
- $\overline{P_{e,m}}$: mean electrical power produced during month m , expressed in kW;
- t_m : duration of month m , expressed in hours (h);
- t_m : the duration of month m , expressed in hours (h); for $t_m = 8760$: this corresponds to the total number of hours in a non-leap year.

3) Evaluation of Capacity Factor (CF)

Finally, the capacity factor CF, defined as the ratio of actual annual production to the energy that would be produced if the wind turbine operated continuously at rated power P_n , is determined using Equation (12) [18]:

$$\text{CF} = \frac{\text{AEP}}{8760 P_n} \quad (12)$$

where:

- CF: wind-turbine capacity factor, dimensionless;
- AEP: annual electrical energy production of the wind turbine, in kWh/year;
- CF(%): capacity factor expressed as a percentage (%).

or, as a percentage:

$$\text{CF}(\%) = \frac{\text{AEP}}{8760 P_n} \times 100 \quad (13)$$

4) Determination of Equivalent Full-Load Hours

To complement the comparison of the energy performance of wind turbines with different rated powers, equivalent full-load hours (EFLH) will also be determined. They represent the equivalent number of hours during which a wind turbine would operate at its rated power to produce an amount of energy equal to its annual production [19]. They will be determined using Equation (14) [19]:

$$\text{EFLH} = 8760 \cdot \text{CF} = \frac{\text{AEP}}{P_n} \quad (14)$$

where:

- EFLH: equivalent full-load hours, expressed in h/year;
- AEP: annual energy production, expressed in MWh/year;
- P_n : rated power of the wind turbine, expressed in MW;
- CF: capacity factor, expressed as a decimal.

This indicator will allow the energy performance of the different configurations to be compared on a normalized basis, independently of differences in rated power [19].

The quantities, $\bar{P}_e$, E_m , $\overline{P_{e,m}}$, AEP, CF, and EFLH will therefore constitute the main indicators used to compare the energy performance of the preselected wind turbines.

2.2.4. Wind Turbine Comparison and Selection

The preselected wind turbines will be compared based on their energy performance and suitability for the wind conditions in Kassa. The main criteria considered will be annual mean electrical power $\bar{P}_e$, annual energy production (AEP), capacity factor (CF), equivalent full-load hours (EFLH), and the compatibility of the power curve $P(V)$ with the wind regime at the corresponding hub height [20].

Given the differences in rated power and hub height among the configurations studied, AEP will be used to assess their absolute energy production, whereas CF and EFLH will allow their performance to be compared on a normalized basis. The configuration selected for the techno-economic assessment will be determined by jointly considering these indicators and its suitability for the site's wind conditions.

2.2.5. Techno-Economic Assessment of the Selected Configuration

The techno-economic assessment is applied to the selected wind turbine to evaluate the viability of its installation at Kassa. It is based on:

- initial investment (CAPEX);
- operating expenditures (OPEX);
- net energy production;
- main economic performance indicators.

1) Determination of Initial Investment (CAPEX)

CAPEX includes wind-turbine acquisition and delivery costs, as well as expenses related to construction and installation [21].

The total purchase and acquisition cost is determined using Equation (15):

$$C_{aa} = C_a + C_t + C_m \quad (15)$$

where:

- C_{aa} : represents the total purchase and acquisition cost;
- C_a : wind-turbine acquisition cost;
- C_t : transportation cost;
- C_m : handling and delivery cost to the site.

The construction and installation cost is determined using Equation (16) [22]:

$$C_{ci} = C_{gc} + C_{mi} + C_{ee} + C_{ms} + C_r \quad (16)$$

where:

- C_{gc} : civil engineering cost;
- C_{mi} : assembly and installation cost;
- C_{ee} : electrical equipment cost;
- C_{ms} : commissioning cost;
- C_r : grid-connection cost.

The total initial investment is then determined using Equation (17) [23]:

$$\text{CAPEX} = C_{aa} + C_{ci} \quad (17)$$

This formulation determines the initial investment required to install the selected wind turbine at Kassa.

2) Determination of Operating Expenditures (OPEX)

OPEX includes annual expenditures related to operation, maintenance, repairs, and the possible replacement of certain installation components [24]. For year t , these expenditures are determined using Equation (18):

$$\text{OPEX}_t = C_{\text{exp},t} + C_{\text{maint},t} + C_{\text{rep},t} + C_{\text{remp},t} \quad (18)$$

where:

- $C_{\text{exp},t}$: represents the operating cost;
- $C_{\text{maint},t}$: maintenance cost;
- $C_{\text{rep},t}$: repair cost;
- $C_{\text{remp},t}$: cost of replacing components during year t .

The OPEX values thus determined are incorporated into the annual cash flows used for the project's economic assessment.

3) Determination of Net Energy Production

Net energy production is determined from the AEP of the selected wind turbine after accounting for technical losses and installation unavailability, in accordance with Equation (19) [25]:

$$E_{\text{net},t} = \text{AEP}_t (1 - \lambda_t) \quad (19)$$

where:

- $E_{\text{net},t}$: represents the net electrical energy produced during year t ;
- AEP_t : gross annual production;
- λ_t : overall rate of technical losses and unavailability.

This net energy constitutes the effectively marketable production used to assess the project's economic performance.

4) Assessment of Economic Performance

The economic viability of the selected configuration is assessed using energy revenues, LCOE, NPV, IRR, and payback period (PP).

a) Energy Revenues

Annual revenues are determined from the net electrical energy produced and the unit electricity price, in accordance with Equation (20) [26]:

$$R_t = E_{\text{net},t} P_e \quad (20)$$

where:

- R_t : represents revenue in year t ;
- P_e : unit electricity price.

b) Levelized Cost of Electricity (LCOE)

The average discounted cost of electricity generation over the project's economic lifetime is determined using Equation (21) [27]:

$$\text{LCOE} = \frac{\text{CAPEX} + \sum_{t=1}^N \frac{\text{OPEX}_t}{(1+r)^t}}{\sum_{t=1}^N \frac{E_{\text{net},t}}{(1+r)^t}} \quad (21)$$

where:

- r : is the annual discount rate, expressed as a decimal;

- t : year considered;
- N : economic lifetime of the project.

In this study, the reference annual discount rate is set at 8%, *i.e.*, $r = 0.08$. This value is used for the reference scenario of the economic assessment.

c) Net Present Value (NPV)

The project's discounted profitability is assessed using Equation (22) [28]:

$$VAN = -CAPEX + \sum_{t=1}^N \frac{R_t - OPEX_t}{(1+r)^t} \quad (22)$$

An $NPV > 0$ indicates that the project is profitable under the economic assumptions considered.

d) Internal Rate of Return (IRR)

The IRR corresponds to the discount rate for which NPV is zero, in accordance with Equation (23) [29]:

$$0 = -CAPEX + \sum_{t=1}^N \frac{R_t - OPEX_t}{(1+IRR)^t} \quad (23)$$

e) Payback Period (PP)

For an assumed constant annual net cash flow, the simple payback period is determined using Equation (24) [30]:

$$TR = \frac{CAPEX}{R - OPEX} \quad (24)$$

where:

- $R - OPEX$ represents the annual net cash flow.

These indicators jointly assess the cost of the electricity produced, financial profitability, and the investment recovery period.

The values adopted for CAPEX, OPEX, the overall loss rate, electricity price, and discount rate constitute the economic assumptions of the reference scenario. Their influence on the results will be examined in the sensitivity analysis to assess the robustness of the economic conclusions.

The economic model is expressed in constant values and does not explicitly account for inflation, taxes, financing arrangements, performance degradation, or residual value at the end of the project lifetime. These elements are outside the scope of the present assessment. The results should therefore be interpreted as a preliminary techno-economic assessment based on the assumptions considered.

5) Sensitivity Analysis

A sensitivity analysis will be carried out to assess the impact of the key parameters on the economic viability of the selected configuration. It will focus in particular on the AEP, the capacity factor CF, CAPEX, OPEX, the electricity price p_e , the discount rate r and the economic lifetime N .

Variations in these parameters are analyzed through their impact on the main economic indicators, namely LCOE, NPV, IRR, and PP. This analysis identifies the parameters to which project profitability is most sensitive and assesses the economic robustness of the selected configuration.

3. Results and Discussion

In accordance with the methodology presented in Section 2.2.1, wind characteristics were determined from the reference conditions at $z_1 = 10$ m and then extrapolated to heights of 30, 50, and 100 m for NASA POWER and ERA5. The monthly wind speeds at 10 m used as baseline data are taken from our previous comparative study conducted at Kassa using NASA POWER and ERA5 data [9]. The calculations considered wind speed as well as the Weibull parameters k and c required to characterize the wind-speed distributions used for wind-turbine assessment.

To keep the analysis focused on the objective of this study, the detailed results of extrapolating k and c to the different heights are not presented separately. The resulting values are directly incorporated into the monthly Weibull distributions $f_m(V)$, which are combined with the wind-turbine power curves $P(V)$ to determine monthly mean electrical power $\overline{P_{e,m}}$, followed by annual mean electrical power $\overline{P_e}$, annual energy production (AEP), and capacity factor CF.

The results are therefore presented according to the following analytical sequence: wind conditions at hub heights, wind turbine preselection, energy performance, selection of the retained configuration, and techno-economic assessment.

3.1. Wind Conditions at Hub Heights

The wind characteristics at the 10 m reference height, determined from NASA POWER and ERA5 data over the 2020–2025 period, are first recalled in **Table 2**. The monthly mean wind-speed values V_1 and the Weibull parameters k_1 and c_1 at $z_1 = 10$ m are taken from our previous studies conducted at the Kassa site [9] [10].

They constitute the reference data used in the present study for extrapolation to heights of 30, 50, and 100 m.

Table 2. Monthly wind characteristics at the reference height $z_1 = 10$ m according to NASA POWER and ERA5.

Month	NASA			ERA5		
	V_1 (m/s)	k_1	c_1 (m/s)	V_1 (m/s)	k_1	c_1 (m/s)
January	3.01	16.82	3.10	3.26	16.49	3.36
February	3.51	32.20	3.57	3.31	18.10	3.41
March	4.04	30.11	4.11	3.53	15.11	3.66
April	4.01	33.99	4.07	3.84	26.29	3.92
May	3.49	33.03	3.55	4.34	79.13	4.37
June	4.06	17.97	4.19	4.74	18.88	4.88
July	5.46	14.05	5.67	5.02	33.79	5.11
August	5.60	23.73	5.73	4.79	58.39	4.83

Continued

September	4.36	21.42	4.47	4.44	31.96	4.52
October	2.81	11.45	2.93	4.22	29.05	4.30
November	2.26	15.30	2.34	4.02	15.67	4.16
December	2.65	13.44	2.75	3.75	13.23	3.90

Based on the reference characteristics V_1 , k_1 , and c_1 at $z_1 = 10$ m, the corresponding parameters were determined at heights z_2 of 30, 50, and 100 m.

Table 3 presents the monthly mean wind speeds V_2 obtained for NASA POWER and ERA5.

Table 3. Monthly mean wind speeds V_2 at heights of 30, 50, and 100 m according to NASA POWER and ERA5.

Month	V_2 (m/s) at 30 M		V_2 (m/s) at 50 M		V_2 (m/s) at 100 M	
	NASA	ERA5	NASA	ERA5	NASA	ERA5
January	4.06	4.37	4.67	5.00	5.64	6.01
February	4.67	4.43	5.33	5.07	6.38	6.09
March	5.30	4.69	6.01	5.35	7.13	6.41
April	5.26	5.06	5.97	5.76	7.09	6.85
May	4.64	5.65	5.30	6.39	6.35	7.55
June	5.32	6.12	6.04	6.90	7.16	8.10
July	6.96	6.45	7.79	7.24	9.07	8.48
August	7.12	6.18	7.96	6.96	9.26	8.17
September	5.68	5.77	6.42	6.52	7.58	7.69
October	3.82	5.51	4.40	6.24	5.34	7.39
November	3.14	5.28	3.65	5.99	4.49	7.11
December	3.62	4.95	4.19	5.64	5.10	6.72

The results show a systematic increase in wind speed with height while preserving the seasonal variability specific to each source. The highest wind speeds are mainly observed between June and September. At 100 m, the monthly maxima reach 9.26 m/s in August for NASA POWER and 8.48 m/s in July for ERA5.

The k_2 and c_2 parameters, also determined at the same heights, are not presented in tables in order to avoid overloading the analysis. They are directly incorporated into the monthly Weibull distributions $f_m(V)$ used to assess wind-turbine energy performance.

3.2. Preselection and Technical Characteristics of Wind Turbines

Based on the wind conditions determined at heights of 30, 50, and 100 m, three commercial wind turbines were preselected: NPS 100C-24 [31], EWT DW54-900 [32] and the 2 MW ENERCON E-82 E2 [33]. Their preselection is based mainly on hub height, rated power P_n , rotor diameter D , swept area A , characteristic operating speeds V_{ci} , V_r , and V_{co} , and the power curve $P(V)$.

For the NPS 100C-24, the manufacturer's documentation specifies a rated power $P_n = 95$ kW, a rotor diameter $D = 24.4$ m, and a hub height of 30 m. The characteristic speeds used are $V_{ci} = 3.5$ m/s, $V_r = 12$ m/s, and $V_{co} = 25$ m/s. The documentation also provides the $P(V)$ power-curve data used for the energy assessment.

For the EWT DW54-900, the specifications used are a rated power $P_n = 900$ kW, a rotor diameter $D = 54$ m, and a hub height of 50 m. The characteristic speeds considered are $V_{ci} = 3.0$ m/s, $V_r = 13$ m/s, and $V_{co} = 25$ m/s.

For the ENERCON E-82 E2, the selected version has a rated power $P_n = 2000$ kW and a rotor diameter $D = 82$ m. Its 98 m hub height is approximated by the 100 m study height. The characteristic speeds considered are $V_{ci} = 2.5$ m/s, $V_r \approx 14$ m/s, and $V_{co} = 34$ m/s.

Table 4 presents the main technical characteristics of the preselected wind turbines.

Table 4. Main technical characteristics of the preselected wind turbines [31]–[33].

Characteristics	NPS 100C-24	EWT DW54-900	ENERCON E-82 E2
Hub height considered (m)	30	50	98 $\approx$ 100
Nominal power P_n (kW)	95	900	2 000
Rotor diameter D (m)	24.4	54	82
Swept area A (m ²)	467.6	2290.2	5 281
V_{ci} (m/s)	3.5	3.0	2.5
V_r (m/s)	12	13	$\approx$ 14
V_{co} (m/s)	25	25	34
IEC class	IIIA	IIIA	IIA

The three configurations therefore make it possible to examine wind turbines with different rated powers and hub heights corresponding to the 30, 50, and approximately 100 m levels considered in the study. Their energy performance is assessed from their $P(V)$ power curves combined with the monthly Weibull distributions corresponding to their respective hub heights. This approach determines, for each wind turbine, monthly mean electrical power $\overline{P_{e,m}}$, annual mean electrical power $\overline{P_e}$, annual energy production (AEP), and capacity factor CF. These

indicators are used to compare the configurations and select the wind turbine best suited to Kassa's wind conditions.

3.3. Wind-Turbine Energy Performance

3.3.1. Wind-Turbine Power Curves

The power curves $P(V)$ establish the relationship between wind speed V at hub height and the electrical power $\bar{P}_e$ delivered by each wind turbine. The V - $P(V)$ data used for the three preselected models are presented in **Table 5**.

Table 5. V-P(V) data used to establish the power curves of the preselected wind turbines [31]-[33].

$V(\text{m/s})$	NPS 100C-24 $P(V)$ in (kW)	EWT DW54-900 $P(V)$ in (kW)	ENERCON E-82 E2 $P(V)$ in (kW)
1	-0.6	0	0
2	-0.6	0	0
3	1.2	0	0
4	7.2	25	3
5	14.5	75	25
6	24.7	150	82
7	37.9	260	174
8	58.7	390	321
9	74.8	530	532
10	85.1	670	815
11	90.2	790	1180
12	94.7	860	1580
13	95.3	900	1810
14	95.1	900	1980
15	94.2	900	2050
16	92.9	900	2050
17	91.2	900	2050
18	88.9	900	2050
19	87.1	900	2050
20	84.1	900	2050
21	81.3	900	2050
22	78.6	900	2050
23	76.1	900	2050
24	74.3	900	2050
25	71.7	900	2050

In **Table 5**, for the ENERCON E-82 E2, although the rated power is 2000 kW, the manufacturer's power curve reaches 2050 kW at a wind speed of 15 m/s. The manufacturer's power-curve values were retained unchanged in the calculations. **Figure 2** presents the $P(V)$ power curve of the NPS 100C-24 wind turbine, illustrating the variation in generated power as a function of wind speed.

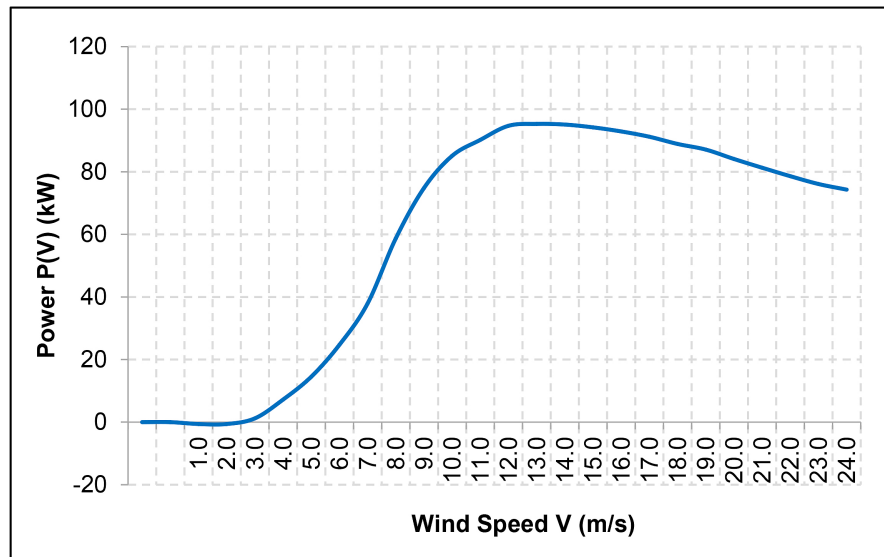


Figure 2. Power curve $P(V)$ of the NPS 100C-24 [31].

The power output of the NPS 100C-24 increases progressively with wind speed until it reaches a value close to its rated power. At higher wind speeds, the curve shows a slight decrease in delivered power.

Figure 3 presents the $P(V)$ power curve of the EWT DW54-900 wind turbine, showing the variation in generated power as a function of wind speed.

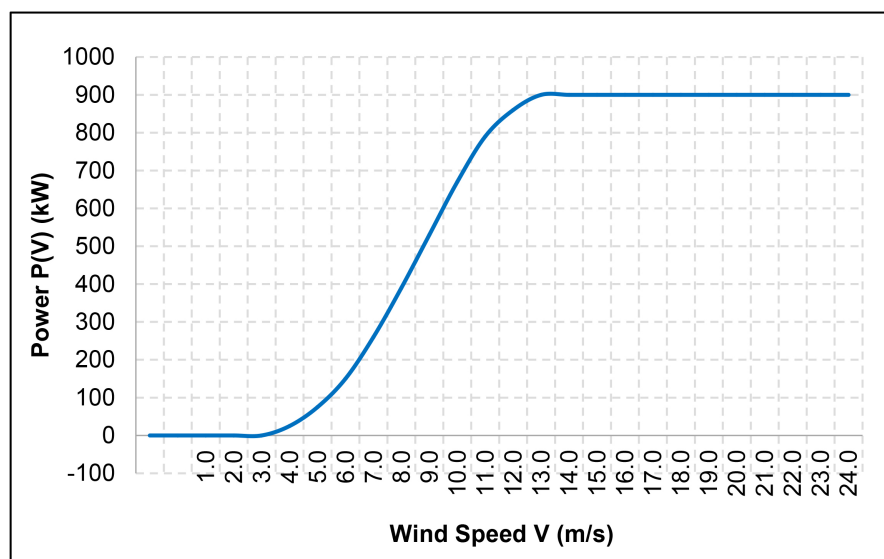


Figure 3. Power curve $P(V)$ of the EWT DW54-900 [32].

The power delivered by the EWT DW54-900 increases with wind speed until it reaches its rated power of 900 kW, after which it remains practically constant over the operating range considered.

Figure 4 presents the $P(V)$ power curve of the 2 MW ENERCON E-82 E2 wind turbine, showing the variation in generated power as a function of wind speed.

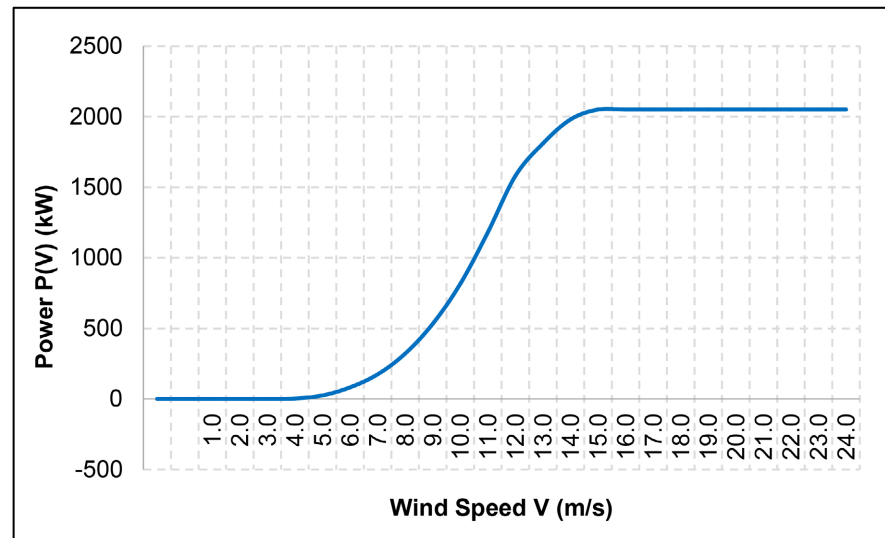


Figure 4. Power curve $P(V)$ of the 2 MW ENERCON E-82 E2 [33].

The ENERCON E-82 E2 curve shows a progressive increase in power with wind speed until the region corresponding to rated power is reached.

Figure 5 compares the $P(V)$ power curves of the three preselected wind turbines, allowing their respective performance to be assessed as a function of wind speed.

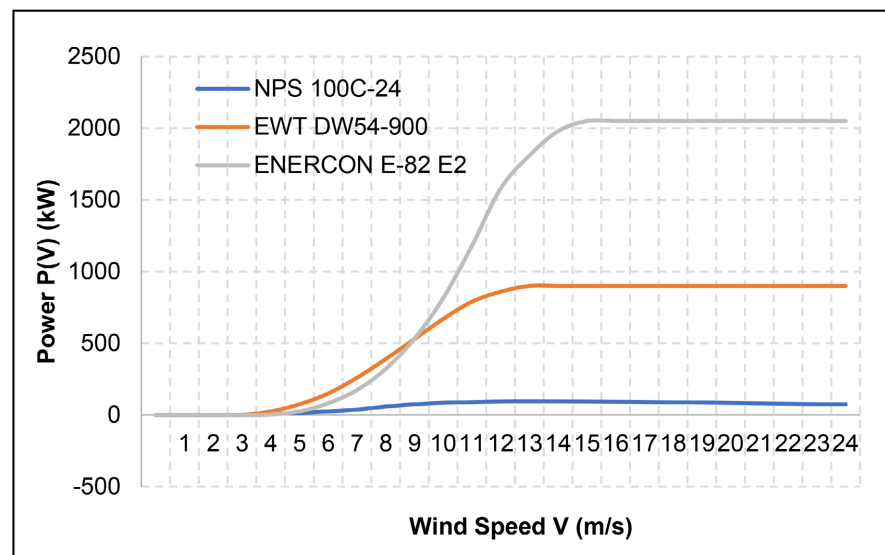


Figure 5. Comparison of the $P(V)$ power curves of the three preselected wind turbines. Source: prepared from manufacturer data.

Figure 5 highlights differences in the behavior of the three wind turbines as a function of wind speed. These differences result in particular from their rated powers and specific operating characteristics.

These $P(V)$ curves were combined with the monthly Weibull distributions corresponding to the hub heights considered in order to assess the energy performance of the three wind turbines under Kassa wind conditions.

3.3.2. Energy Production and Capacity Factor

For each wind turbine and each data source, the power curve $P(V)$ was combined with the monthly Weibull distribution $f_m(V)$ determined at the corresponding hub height to calculate the monthly mean electrical power. The resulting monthly energy production values were then aggregated over the year to determine the annual mean electrical power $\bar{P}_e$, annual energy production (AEP), capacity factor (CF), and equivalent full-load hours (EFLH), in accordance with the methodology presented in Section 2.2.3. The results obtained for the three preselected wind turbines using NASA POWER and ERA5 data are presented in **Table 6**.

Table 6. Annual energy performance of the preselected wind turbines according to NASA POWER and ERA5.

No.	Wind Turbine	Hub Height (m)	Source	$\bar{P}_e$ (kW)	AEP (MWh/an)	CF (%)	EFLH (h/an)
1	NPS 100C-24	30	NASA POWER	16.34	143.16	17.20	1506.95
			ERA5	19.02	166.63	20.02	1754.00
2	EWT DW54-900	50	NASA POWER	147.55	1292.55	16.39	1436.17
			ERA5	171.65	1503.68	19.07	1670.76
3	ENERCON E-82 E2	100*	NASA POWER	202.66	1775.31	10.13	887.66
			ERA5	227.12	1989.60	11.36	994.80

Note: *commercial hub height of the ENERCON E-82 E2: 98 m, approximated as 100 m in this study, in accordance with the adopted methodology.

The results in **Table 6** show that the performance of the three wind turbines differs depending on the criterion considered. In terms of absolute energy production, the ENERCON E-82 E2 has the highest AEP values, with 1775.31 MWh/year according to NASA POWER and 1989.60 MWh/year according to ERA5. However, its capacity factors are the lowest, at 10.13% and 11.36%, respectively, corresponding to 887.66 and 994.80 h/year of EFLH.

Conversely, the NPS 100C-24 exhibits the best normalized performance, with capacity factors of 17.20% according to NASA POWER and 20.02% according to ERA5, corresponding to 1506.95 and 1754.00 h/year of EFLH, respectively. The EWT DW54-900 occupies an intermediate position, with capacity factors of 16.39% and 19.07% and EFLH values of 1436.17 and 1670.76 h/year.

These results show that absolute AEP alone cannot serve as a selection criterion, given the differences in rated power and hub height among the three wind turbines. The comparison must therefore jointly consider absolute energy production, normalized performance, and the suitability of each power curve for the site's wind conditions.

Figure 6 compares the annual energy production (AEP) of the three preselected wind turbines estimated from NASA POWER and ERA5 data.

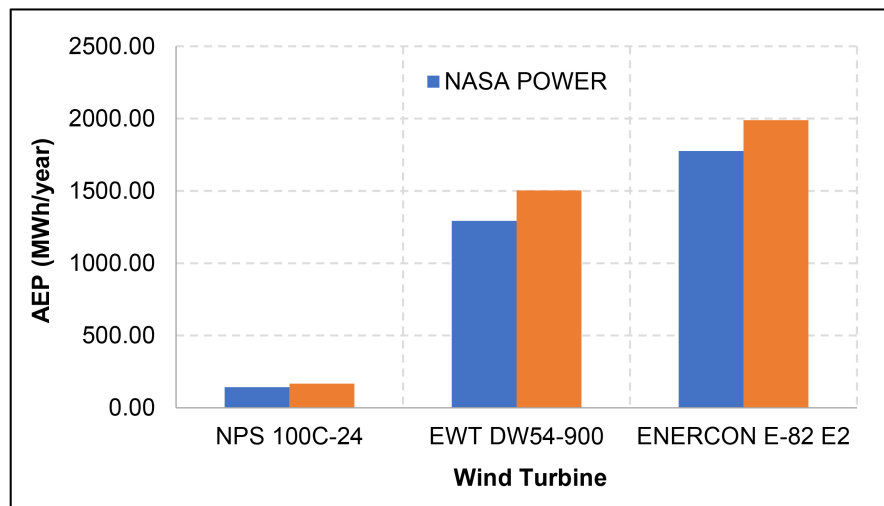


Figure 6. Comparison of annual energy production (AEP) of the preselected wind turbines according to NASA POWER and ERA5.

Figure 6 highlights substantial differences in AEP among the configurations studied. For all three wind turbines, the estimates obtained with ERA5 are higher than those obtained with NASA POWER, with the ENERCON E-82 E2 showing the highest annual production for both data sources.

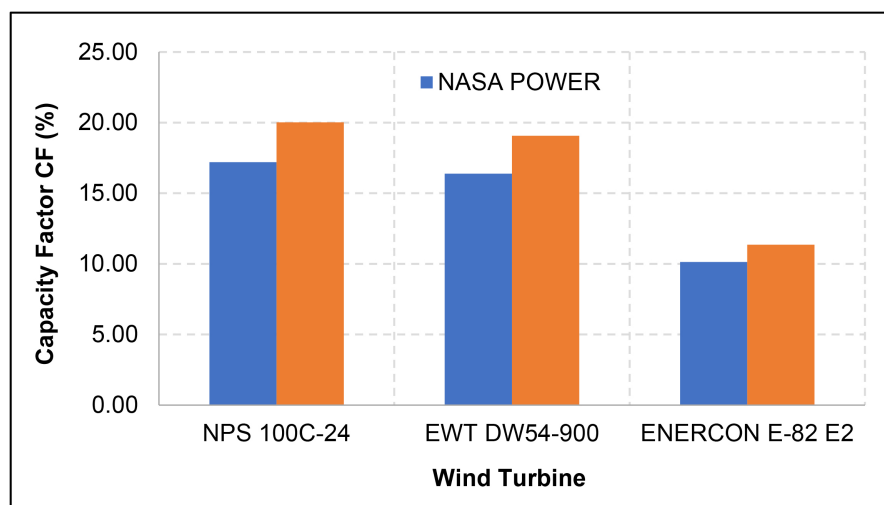


Figure 7. Comparison of capacity factors (CF) of the preselected wind turbines according to NASA POWER and ERA5.

Figure 7 compares the capacity factors (CF) of the three preselected wind turbines determined from NASA POWER and ERA5 data.

Figure 7 shows that the NPS 100C-24 has the highest capacity factors, at 17.20% for NASA POWER and 20.02% for ERA5. It is followed by the EWT DW54-900, at 16.39% and 19.07%, respectively, while the ENERCON E-82 E2 has the lowest values, at 10.13% and 11.36%. For all three wind turbines, the capacity factors estimated from ERA5 are higher than those obtained with NASA POWER.

3.4. Comparison and Selection Results for Wind Turbine

The comparison of energy performance reveals different results depending on the criterion considered. The ENERCON E-82 E2 has the highest absolute energy production, with an AEP of 1775.31 MWh/year according to NASA POWER and 1989.60 MWh/year according to ERA5. In contrast, the NPS 100C-24 exhibits the best normalized performance, with capacity factors of 17.20% and 20.02%, corresponding to 1506.95 and 1754.00 h/year of EFLH, respectively. The EWT DW54-900 shows intermediate performance.

Because the three wind turbines have different rated powers, their comparison cannot be based solely on absolute AEP. Normalized indicators, particularly CF and EFLH, allow production to be related to installed capacity. Each wind turbine is evaluated at the hub height considered in this study: 30 m for the NPS 100C-24, 50 m for the EWT DW54-900, and 100 m for the ENERCON E-82 E2.

Given the differences in rated power and hub height among the three configurations, these results do not allow any wind turbine to be identified as globally optimal based solely on AEP or capacity factor. Nevertheless, in this study, the 2 MW ENERCON E-82 E2 is retained for the subsequent techno-economic assessment because it has the highest absolute annual energy production among the three configurations studied and is consistent with the objective of evaluating higher-capacity wind power generation at the Kassa site.

3.5. Techno-Economic Performance of the Selected Configuration

The techno-economic assessment is performed for the 2 MW ENERCON E-82 E2, retained for further analysis because it has the highest absolute annual energy production among the three configurations studied. The assumptions considered are a CAPEX of USD 3,200,000, annual OPEX of USD 100,000, an overall loss rate of 10%, an electricity price of USD 0.10/kWh, a discount rate of 8%, and an economic lifetime of 25 years.

After accounting for losses, net energy production is 1597.78 MWh/year for NASA POWER and 1790.64 MWh/year for ERA5, corresponding to annual revenues of USD 159,778 and USD 179,064, respectively. The main results of the techno-economic assessment of the ENERCON E-82 E2 are presented in **Table 7**.

The results in **Table 7** show that, under the economic assumptions adopted, both scenarios exhibit unfavorable economic performance. The LCOE reaches USD 0.2502/kWh for NASA POWER and USD 0.2233/kWh for ERA5, values higher than the electricity selling price adopted in this study (USD 0.10/kWh). The NPVs

are negative, at –USD 2,561,884 for NASA POWER and –USD 2,356,009 for ERA5, while the IRRs are –5.16% and –3.41%, respectively.

The simple payback periods, estimated at 53.53 years for NASA POWER and 40.47 years for ERA5, greatly exceed the assumed economic lifetime of 25 years. Although the ERA5 scenario yields relatively more favorable indicators because of its higher estimated energy production, neither scenario achieves economic viability under the reference conditions considered.

Table 7. Energy and techno-economic performance of the ENERCON E-82 E2 according to NASA POWER and ERA5.

Nº	Indicator	NASA POWER	ERA5
1	Gross AEP (MWh/year)	1775.31	1989.60
2	Net energy (MWh/year)	1597.78	1790.64
3	Annual revenue (USD/year)	159,778	179,064
4	LCOE (USD/kWh)	0.2502	0.2233
5	NPV (USD)	–2,561,884	–2,356,009
6	IRR (%)	–5.16	–3.41
7	PP (years)	53.53	40.47

3.6. Sensitivity Analysis and Discussion of Economic Viability

A sensitivity analysis was conducted to assess the influence of the main parameters on the economic performance of the ENERCON E-82 E2. The variations considered concern net energy production (–20%, reference, +20%), CAPEX (+20%, reference, –20%), electricity price (0.08, 0.10, and 0.12 USD/kWh), and discount rate r (10%, 8%, and 6%). The other parameters are held constant for each scenario.

The results obtained are presented in **Table 8**.

The sensitivity analysis results show that the economic performance of the configuration studied remains unfavorable for all variations considered. Net energy production, CAPEX, and electricity price strongly influence NPV, IRR, and payback period. A 20% increase in net energy production improves the economic indicators and reduces the LCOE but does not result in a positive NPV under the conditions considered. Similarly, a 20% reduction in CAPEX improves economic performance without achieving profitability over the assumed economic lifetime.

Increasing the electricity price from 0.08 to 0.12 USD/kWh substantially improves NPV, IRR, and payback period without changing the LCOE. However, even at 0.12 USD/kWh, NPVs remain negative for both data sources. Changing the discount rate affects LCOE and NPV but does not alter IRR or payback period under the formulations adopted.

Overall, ERA5-based estimates yield relatively more favorable economic indicators than NASA POWER-based estimates because of the higher estimated en-

ergy production. Nevertheless, none of the sensitivity scenarios investigated achieves economic viability for the ENERCON E-82 E2 within the techno-economic variation ranges considered.

Table 8. Sensitivity analysis of the economic performance of the ENERCON E-82 E2 according to NASA POWER and ERA5.

Parameter	Variation	LCOE NASA	VAN NASA (USD)	TRI NASA (%)	TR NASA (years)	LCOE ERA5	VAN ERA5 (USD)	TRI ERA5 (%)	TR ERA5 (years)
Net energy	−20%	0.3128	−2,903,002	−9.41	115.02	0.2791	−2,738,303	−7.05	73.99
	Ref.	0.2502	−2,561,884	−5.16	53.53	0.2233	−2,356,009	−3.41	40.47
	+20%	0.2085	−2,220,764	−2.41	34.88	0.1860	−1,973,716	−0.82	27.86
CAPEX	+20%	0.2877	−3,201,883	−6.24	64.24	0.2567	−2,996,009	−4.57	48.57
	Ref.	0.2502	−2,561,884	−5.16	53.53	0.2233	−2,356,009	−3.41	40.47
	−20%	0.2127	−1,921,883	−3.77	42.83	0.1898	−1,716,009	−1.90	32.38
Electricity price	0.08	0.2502	−2,903,002	−9.41	115.02	0.2233	−2,738,303	−7.05	73.99
	0.10	0.2502	−2,561,884	−5.16	53.53	0.2233	−2,356,009	−3.41	40.47
	0.12	0.2502	−2,220,764	−2.41	34.88	0.2233	−1,973,716	−0.82	27.86
r	10%	0.2832	−2,657,393	−5.16	53.53	0.2527	−2,482,333	−3.41	40.47
	8%	0.2502	−2,561,884	−5.16	53.53	0.2233	−2,356,009	−3.41	40.47
	6%	0.2193	−2,435,837	−5.16	53.53	0.1956	−2,189,297	−3.41	40.47

These results also show that the ranges of variation considered do not reach the economic break-even point. The break-even values of the electricity price and CAPEX therefore lie beyond the ranges investigated. Uncertainty in the wind resource is partially represented by the $\pm 20\%$ variation in net energy production and by the separate use of NASA POWER and ERA5 estimates.

The use of monthly Weibull parameters is a limitation of this assessment because it does not fully capture wind variability at a higher temporal resolution. The results should therefore be regarded as a preliminary assessment to be strengthened with higher-resolution data before any investment decision.

Furthermore, the 2020–2025 period remains relatively short for characterizing long-term interannual variability in the wind resource. The present analysis could therefore be strengthened by a longer observation period and local measurements.

4. Conclusions

This study progressed from characterization of the Kassa wind resource to wind-turbine selection and assessment of its energy and techno-economic performance.

Based on NASA POWER and ERA5 data available at 10 m, wind conditions were determined at heights of 30, 50, and 100 m. The results show a systematic increase in wind speed with height, with monthly maxima at 100 m of 9.26 m/s in August for NASA POWER and 8.48 m/s in July for ERA5.

The comparison of the three preselected wind turbines: NPS 100C-24, EWT DW54-900, and ENERCON E-82 E2, shows different performance depending on the criterion considered. The 2 MW ENERCON E-82 E2 has the highest absolute annual energy production, with an AEP of 1775.31 MWh/year according to NASA POWER and 1989.60 MWh/year according to ERA5. In contrast, the NPS 100C-24 exhibits the best normalized performance, with capacity factors of 17.20% and 20.02%, corresponding to 1506.95 and 1754.00 h/year of EFLH, respectively. Nevertheless, in this study, the ENERCON E-82 E2 was retained for the techno-economic assessment because it has the highest absolute annual energy production among the three configurations studied.

After accounting for an overall loss rate of 10%, net energy production is estimated at 1597.78 MWh/year according to NASA POWER and 1790.64 MWh/year according to ERA5. Under the economic assumptions adopted, the LCOE is 0.2502 and 0.2233 USD/kWh, respectively, values higher than the assumed electricity selling price of 0.10 USD/kWh. NPVs are negative, at –USD 2,561,884 for NASA POWER and –USD 2,356,009 for ERA5, while IRRs are –5.16% and –3.41%, respectively. The simple payback periods, estimated at 53.53 and 40.47 years, exceed the assumed economic lifetime of 25 years. Thus, despite relatively more favorable results with ERA5, neither scenario achieves economic viability under the reference conditions considered.

The sensitivity analysis confirms that economic performance is strongly influenced by net energy production, CAPEX, and electricity price. However, none of the sensitivity scenarios investigated achieves economic viability for the ENERCON E-82 E2 within the techno-economic variation ranges considered. ERA5-based estimates remain generally more favorable than those obtained with NASA POWER because of the higher estimated energy production. These results also highlight the influence of the wind data source on the assessment of energy and economic performance. Finally, strengthening this assessment will require in situ wind measurements at hub heights as well as more detailed local economic data before any investment decision.

Author Contributions

This study was conducted through scientific collaboration encompassing study design, data processing and analysis, energy and techno-economic assessment, interpretation of results, and critical revision of the manuscript. Contributions were distributed among the authors according to their respective responsibilities and involvement in the different stages of the work. All authors have read the final version of the manuscript and approved its submission for publication. The table below presents the status and main contribution of each author to the study.

No.	Authors' Names	Contributions
1	Mohamed Ansoumane Camara	Study conception and coordination; definition of the research problem and methodology; supervision of analyses; wind-turbine selection and sizing; development of the techno-economic assessment; analysis and interpretation of results; drafting, revision, and final validation of the manuscript.
2	Kadiatou Aïssatou Barry	Support for scientific coordination; literature review; contribution to data processing and calculations; participation in the analysis of energy and techno-economic performance; preparation of tables and figures; contribution to manuscript drafting and revision.
3	Ouaïdou Emmanuel	Processing and analysis of NASA POWER and ERA5 wind data; contribution to extrapolation of wind characteristics to the different heights; calculation of Weibull parameters; participation in energy calculations, analysis of results, and manuscript drafting.
4	Souleymane Soumah	Contribution to the energy-assessment methodology; analysis of wind-turbine characteristics and their suitability for the Kassa wind regime; verification of calculations; interpretation of results and critical review of the manuscript.
5	Lamine Thiaw	Scientific and methodological expertise; advice on wind-turbine selection and sizing; critical review of energy and techno-economic assessment methods; scientific interpretation of results and critical revision of the manuscript.
6	Roger Marcelin Faye	Scientific supervision and senior expertise; methodological guidance; critical review of the scientific approach and techno-economic assessment; validation of result interpretation; in-depth scientific revision and contribution to final validation of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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