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Feasibility Study of Wind Farm Using RETScreen Model: A Case Study of Al-Razaza Site, Iraq

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Abstract

In recent years, interest in renewable energies has increased due to their clean, renewable, and inexhaustible characteristics. Iraq faces a significant challenge in the shortage of electric power. The green economy, especially in renewable energy, has become one of the world's main pillars, especially after the remarkable rise in greenhouse gas emissions (GHG) from fossil fuel combustion for electricity production. This study evaluates wind farm feasibility, assessing costs, revenue, and financial viability. It identifies potential hazards and difficulties, enabling developers to develop strategies to mitigate risks during project creation and operation. This paper aims to undertake a feasibility study to assess the viability of constructing a wind farm with a capacity of 340 megawatts at the Al-Razaza location in Karbala province. The study site utilized authentic data from the meteorological tower installed on the premises. The data employed spanned three years, encompassing a comprehensive and integrated dataset for the study. RETScreen, a powerful model renowned for its energy efficiency analysis and sustainable decision-making capabilities, was employed. Through the application of RETScreen, a meticulous assessment and analysis of the intricate project components were facilitated. A study of risk analysis was conducted to ascertain the impact of various parameters on the payback period of the project. The findings showed that the capacity factor of the wind farm is 22.3%, which is relatively low, the simple payback period is 10.3 years, and the energy production cost is 0.059$/KWh.

Keywords: Wind farm, Feasibility study, RETScreen, Financial viability.

دراسة جدوى لمزرعة الرياح باستخدام نموذج RETScreen : دراسة حالة لموقع الرزازة، العراق

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الخلاصة

في السنوات الأخيرة، زاد الاهتمام بالطاقات المتجددة بسبب خصائصها النظيفة والمتجددة وكونها غير ناضبة. يواجه العراق تحديًا كبيرًا في مواجهة نقص الطاقة الكهربائية. أصبح الاقتصاد الأخضر، ولا سيما في مجال الطاقة المتجددة، أحد الركائز الرئيسية في العالم، لا سيما بعد الارتفاع الملحوظ في انبعاثات غازات الدفيئة الناجمة عن احتراق الوقود الأحفوري لإنتاج الكهرباء. تقوم هذه الدراسة بتقييم جدوى مزرعة الرياح، وتقييم التكاليف والإيرادات والجدوى المالية. ويحدد المخاطر والصعوبات المحتملة، مما يمكّن المطورين من

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تطوير استراتيجيات للتخفيف من المخاطر أثناء إنشاء المشروع وتشغيله. تهدف هذه الورقة إلى إجراء دراسة جدوى لتقييم جدوى إنشاء مزرعة رياح بقدرة 340 ميغاواط في موقع الرزازة في محافظة كربلاء.. استخدمت بيانات حقيقية من البرج الانوائي المثبت في الموقع. امتدت البيانات المستخدمة لمدة ثلاث سنوات، وتشمل مجموعة بيانات شاملة للدراسة. تم استخدام موديل RETScreen وهو موديل نمذجة يشتهر بتحليل كفاءة الطاقة وقدرات لصنع القرار. ومن خلال تطبيق موديل RETScreen تم إجراء تقييم وتحليل دقيقين لمكونات المشروع المعقدة. تم دراسة تحليل المخاطر للتأكد من تأثير العوامل المختلفة على فترة الاسترداد للمشروع. أظهرت النتائج أن عامل قدرة مزرعة الرياح هو 22.3%، وهو منخفض نسبيا، وفترة الاسترداد البسيطة هي 10.3 سنوات، وتكلفة إنتاج الطاقة 0.059 دولار/كيلوواط ساعة.

1. Introduction

The trend towards investing in renewable energy sources is a solution to compensate for the energy shortage. It is consistent with the world's trend toward reducing greenhouse gases (GHGs) and one of the goals of sustainable development [1], [2]. Iraq is among the nations that have begun to engage in green power for various uses, including irrigation, by establishing hybrid systems in southern Iraq [3]. Wind energy technologies have witnessed significant development over time. It has been very rapid in recent years, whether in terms of the efficiency of these technologies or their size, and it does not seem that they will stop. According to [4] [5], considered one of the energies that have witnessed a significant annual growth rate of 3.62%, it is expected to grow in 2023–2028. Investing in wind energy resources is necessary. Start by evaluating these sources and indicating the possibility of installing wind farms according to the recorded data (meteorological masts or remote sensing instruments) and the economic and technical feasibility study [6],[7]. Investments, returns, and external factors, including legalizations and risks, are all laid out in the feasibility study [8]. The evolution of software technology has led to numerous applications for conducting economic feasibility assessments through intricate calculations, the most prominent of which is the RETScreen Model [9]. The RETScreen Model is one of the programs that specializes in preparing feasibility studies for all energy projects (renewable and non-renewable). Its distinctive and flexible characteristics include its ability to conduct all financial calculations for the project and indicate the viability and growth potential [10],[11].

Numerous research and feasibility studies have been conducted on many specific energy projects. This study must be completed before carrying out the project to show the suitability of the project from an economic point of view and whether it is profitable or not. These studies play an essential role by providing specialists with a technical and economic vision of the project's returns and investments and contributing to a deeper understanding of the financial concepts required by the project.

Research suggests constructing an offshore wind farm in the Turkish seas, with a potential site in the Aegean Sea. A windPro software technical assessment calculates the potential annual energy yield while addressing infrastructure challenges and proposing remedies for advancing offshore wind farm projects [12]. A novel approach explores the technical feasibility of a 10 MW wind farm in Morocco, using multidimensional analysis techniques and a geographic information system to evaluate potential energy generation possibilities. [13]. Some research used analysis and evaluation methods that included three types of analyses for establishing wind energy facilities in the coastal region of South Purworejo, Indonesia: scenario-based economic analysis, risk analysis, and sensitivity analysis [14]. As a robust model, the RETScreen Model has been utilized to evaluate the economic feasibility of a 600kW wind farm project in Myanmar, focusing on the potential and financial viability of establishing a small-scale wind farm integrated with an isolated grid [15]. Wind speed data measured every 10 min at various heights of 10, 30, 50, and 52 m was used to conduct a preliminary economic feasibility assessment of a wind power project at the Al-Shehabi site (Wasit, Iraq). RETScreen was utilized to analyze the potential profitability of a future wind farm [16]. RETScreen evaluates Libyan [17], Chongming's energy system [18], and Sindh wind farms' economic viability. The software calculates energy production and wind power capacity, showing that renewable energy and natural gas-fueled CHP systems maximize profits. The software considers Pakistan's renewable energy policy, debt ratio, inflation, and discount rate to assess the financial viability of a 50 MW wind project in four Sindh provinces [19]. The analysis was conducted on the Taşlıçiftlik Campus in Tokat province, utilizing the RETScreen analysis program. An investigation was conducted on wind power. The system consisted of two turbines with a total power output of 100 kW, each subjected to cost, financial, and risk analysis [20]. The literature contains numerous studies on wind energy. The study incorporates many approaches to estimate the prevalence of wind energy projects [21], enhance the design of wind farm layouts [22], and examine the distribution and measurement of wind power in different geographical areas [23]. A collaborative effort has been undertaken by multiple academics [24],[25] to assess the potential and utilization of wind power. In order to effectively tackle the obstacles associated with wind power technology, it is imperative to do site-specific investigations to assess the feasibility of wind power technology [26].

On-shore wind turbines significantly contribute to the global energy mix worldwide due to their superior benefit-to-cost ratio. These turbines offer improvements in net present value, payback period, and levelized power cost [27]. Investments in feasibility studies are assessed by considering net annual energy production (AEP), purchased energy prices, and capital costs [28]. The practicality of offshore wind farms has been the subject of extensive research [29], encompassing investigations into several aspects such as site selection, cost estimation, and profitability analysis. Several studies have been conducted in countries such as Puglia, Korea [30], Nigeria [31], and Turkey. These studies employ mathematical models, cost estimation, and economic analysis to ascertain offshore wind farms' optimal site, energy cost, and payback period.

Numerous extant review papers have examined the obstacles associated with the widespread adoption of wind energy, including its economic viability [32], [33], [34], as well as the technical and sociological considerations in urban areas [35,36]. Assessing the viability of renewable energy technology involves utilizing various analytical methods, techniques, and software in commercial enterprises and research investigations. The fields of engineering economics [37], linear programming [38], and artificial intelligence (AI), which focuses on the development and implementation of intelligent software and machines [39], [40], and [41], have been extensively studied. Additionally, several software applications have been developed for the evaluation of renewable power projects, including WAsP [42], WindHygen [43], and MATLAB [44],[45]. RETScreen is a widely used tool for evaluating the techno-economic viability of renewable energy projects. The feasibility assessment of hybrid power systems, which involve combining several resources for power generation or energy conversion devices to overcome each other's limits, has been addressed by HOMER (Hybrid Optimization Model of Electric Renewable) [46], [47]. Additionally, several software packages were developed to assess the environmental and economic impacts of energy activities, including the Long-range Energy Alternatives Planning System (LEAP) [48] and the New Earth 21 Model (NE21) [49]. This study aims to employ the RETScreen Model to prepare valuable insight and an economic feasibility study for installing a wind farm in the Al-Razaza area in Karbala province.

2- Description of the site.

The planned wind farm is near Al-Razazah Lake, Karbala province. The coordinates 32 41.346 N and 43 54.469 E of the farm refer to the exact coordinates of the meteorological tower installed near Razaza Lake. The province is located 108 km southwest of Baghdad, the Iraqi capital, on the desert edge west of the Euphrates. It is bordered to the north by Anbar Province, to the south by Najaf Province, to the east by Hilla Province and a section of Baghdad Province, and to the west by the Levant Valley and the lands of the Kingdom of Saudi Arabia. Karbala Province is dominated by a desert climate, where temperatures rise relatively in the summer and may sometimes reach about 45 C at about midday. In the winter, the temperature drops to zero degrees in some winter nights. As for rain, the city is affected by the desert climate because it is exposed to the desert and the sedimentary plain from the east.

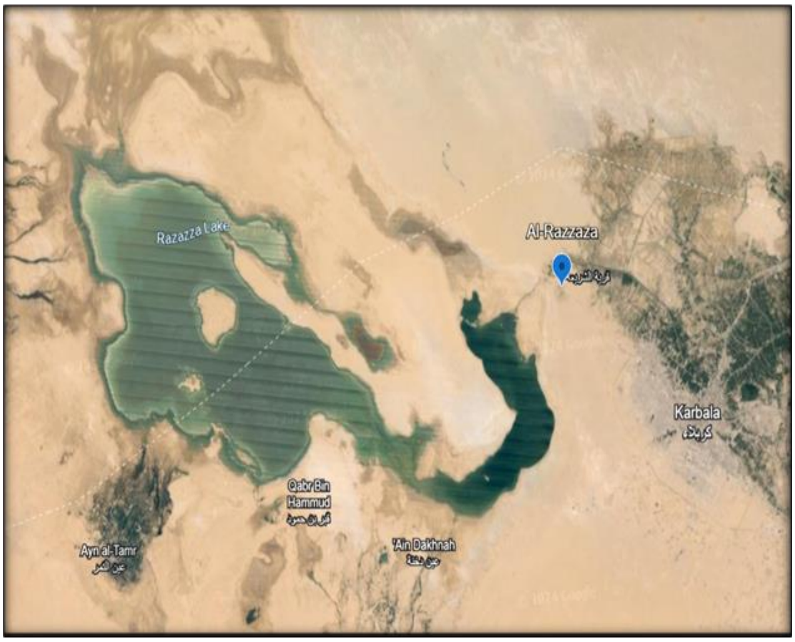


Figure 1: Study area

3- Materials and methods

The study adopted the methodology of the RETScreen Model in evaluating energy projects. This methodology consists of several basic steps, Figure 2 [50].

Figure 2: RETScreen model flowchart [15]

The steps begin with setting and site conditions, then selecting the energy model to be evaluated, such as wind power, in our study. Site data, such as meteorological data, area elevation, and electrical grid connection method, were entered into the program to assess technical viability. The second step includes the cost analysis of the project. It also analyses the project's emissions and financial impacts, including the project's initial investment costs, operation and maintenance costs, the expected financial return, and the payback period of capital investment. The last step includes the anticipated risks in the event of an increase or decrease in one of the factors affecting the project. RETScreen compares two technologies. The first is a conventional technology representing the "base case." The second aspect pertains to clean technology, specifically wind energy, which is being considered as a proposed case in our study. The program can calculate the proposed wind farm's annual power output and capacity factor (CF) based on the inputs.

Furthermore, it can compute all metrics about the project's economic feasibility. The Net Present Value (NPV) is a financial metric that quantifies the present value of an investment's cash inflows and outflows. It was commonly used to evaluate a project's profitability, suitability, and efficacy. CF and Internal Rate of Return IRR are used to determine these values. The following is the mathematics formula the RETScreen tool utilizes as its parameters.

$$CF = \frac{P_{out}}{CP \times t} \quad (1)$$

Where *CP* denotes the wind turbines' rated output, *t* is the time (hours).

NPV calculates net cash flow R_t at a specific discount rate *i* and time *t*. It is an essential aspect of project viability [16].

$$NPV = \sum_{t=1}^{T} \frac{R_t}{(1+i)^t} \quad (2)$$

The internal rate of return *(IRR)* is a discount rate utilized in a discounted cash flow analysis to equate all cash flows' net present value (NPV) to zero. The formula employed in computing IRR is identical to that utilized in calculating NPV [16].

$$IRR = NPV \to 0 \tag{3}$$

The payback period (PBP) is given by;

$$PBP = \frac{1}{NC_p} \tag{4}$$

$GHG\ reduction$ given by,

$$GHG\ reduction = (GHG_{base} - GHG_{proposed}) \times E \tag{5}$$

3-1. Wind data description

The wind resource at a prospective location was measured by installing meteorological masts before constructing a wind farm. The Renewable Energy Directorate within the Ministry of Science and Technology has established a meteorological mast at a designated location. The tower's height is 52 m, and it carries sensors at 10, 30 and 50 m. Sensors include horizontal and vertical wind speed, wind direction, solar radiation intensity, pressure, temperature, humidity, and precipitation amount. The data was measured over some time (10 min) and recorded in the tower's data logger. The data employed spanned three years, encompassing a comprehensive and robust dataset for the study.

Table 1: Monthly climatic data of the Al-Razaza site

Month	Relative humidity %	Precipitation mm	Daily solar radiation horizontal kWh/m^2/day	Atmospheric pressure kPa	Wind speed m/s
Jan	55.6	43.56	2.96	100.7	3
Feb	44.2	27.85	3.91	100.5	3.4
Mar	36	28.62	4.86	100.2	3.9
Apr	28.8	20.88	5.73	99.9	4
May	20.9	7.53	6.77	99.5	4
Jun	16.3	0.33	7.94	99	4.7
Jul	15.8	0.22	7.37	98.7	4.9
Aug	16.7	0.08	6.92	98.9	4.5
Sep	18.9	0.73	5.82	99.4	3.5
Oct	26.9	12.63	4	100.1	2.8
Nov	41.4	23.68	2.95	100.5	2.9
Dec	53	30.46	2.64	100.8	3.4
Annual	31.2	16.57	5.16	99.8	3.7
Altitude			10 m		

3-2. Wind Energy System: Explanation and Layout

Wind turbines harness the wind's kinetic energy and transform it into electricity via blades rotating at varying speeds. The amount of energy converted depends on the wind speed and turbine area. Therefore, knowing the anticipated power and power generation of each wind turbine is essential for evaluating the financial viability of wind farms.

The Vestas V136-3.45 MW wind turbine proposed in this study is a type of turbine that operates in areas with low and moderate wind speeds. The turbine specifications are shown in Table 2, and the power curve is illustrated in Figure 3.

Table 2: The specifications of the proposed Vestas turbine [51].

Wind Turbine Characteristics	Value
Power capacity per turbine	3.45
Turbine Model	Vestas V-136
No. of turbines	10
Wind farm capacity	34.5 MW
Wind turbine Hub height	149 m
Wind turbine Rotor diameter	136 m
Wind turbine Swept area	14527 m^2

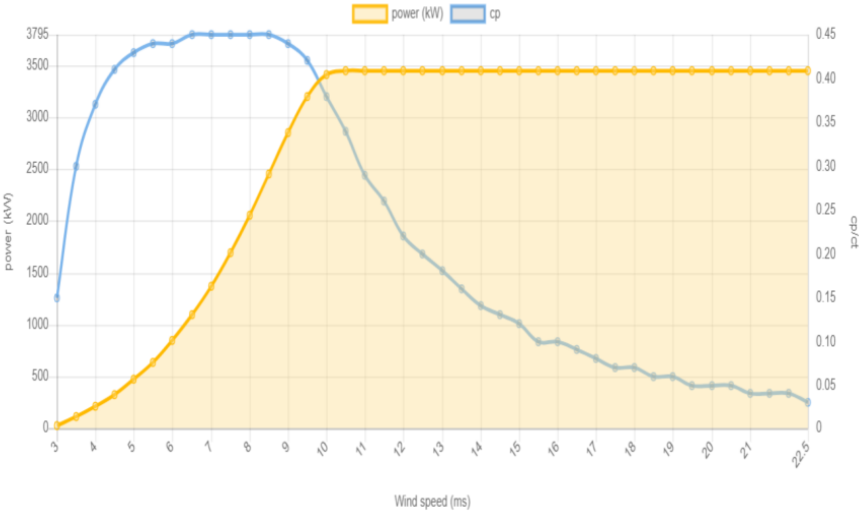


Figure 3: V-136 wind turbine power curve [50]

3-3. Losses

The study considered the losses associated with arrays, airfoils, and miscellaneous factors. The losses of the array were subject to the influence of various factors, including turbine spacing, orientation, site characteristics, and topography. According to [52], a cluster of well-designed turbines containing fewer than 8 to 10 units is expected to experience array losses of less than 5%. In contrast, a single turbine installation is anticipated to have 0% array losses.

Table 3: Wind farm losses.

Losses	value
Array losses	3%
Airfoil losses	2%
Miscellaneous losses	2%
Availability	95%

3-4. Financial parameters

Table 4 shows that the financial parameters chosen for the various research models are acceptable. The inflation rate in our study is 2%, and a discount rate of 3% was chosen since it is within the acceptable range and the other parameters are as in [16].

Table 4: Financial parameters [16]

Input parameters	Selected value %	Acceptable range %
Feasibility study	1.0	Less than 2
Project Development	3	1 to 8%
Engineering cost	5	1 to 8%
Power System	71.3	67 to 80%
Balance of System &	19.8	17 to 26%
Miscellaneous	2	1 to 4%
O & M/ parts of labour	3	15%
Inflation rate (i) (%)	3	2 to 3%
Interest rate (%)	8	
Fuel cost escalation rate	2.5	
Discount rate (%)	4.85	3.0 to 18.0%
Debt ratio (%)	60	50.0 to 90.0%
Debt interest rate (%)	8	-
Debt term ((year))	10	-
Project life ((year))	20	20 to 30 years
Turbine availability	98%	98%

4- Results and discussion

The data collected from a site was analyzed and illustrated in Figure 4, which depicts the wind speed histogram. As seen, the maximum wind speed recorded in (Jun, Jul, and August) months and the annual mean wind speed is 3.7 m/s at a height of 10 m.

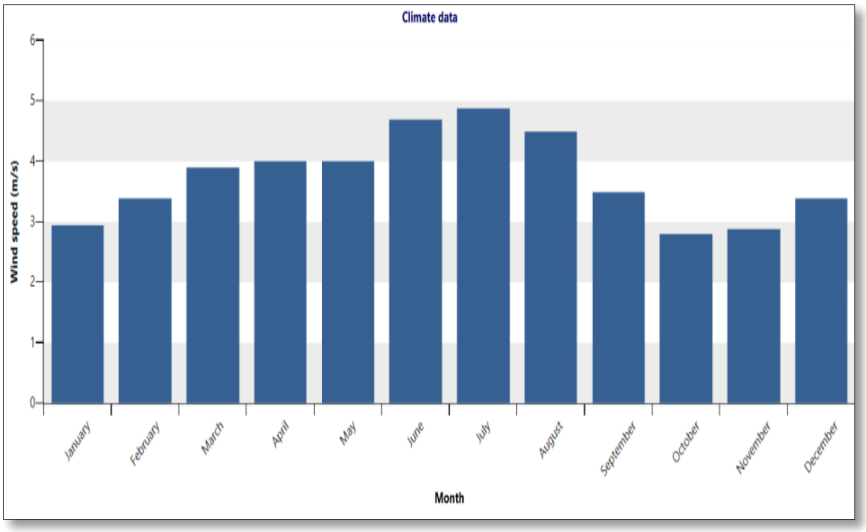


Figure 4: Wind speed histogram

Figure 4 depicts the relative humidity (%) for the recorded data; the high values can be recorded in the (Jan and Dec) months, while the months (Jun, Jul, and Aug) register the lower values.

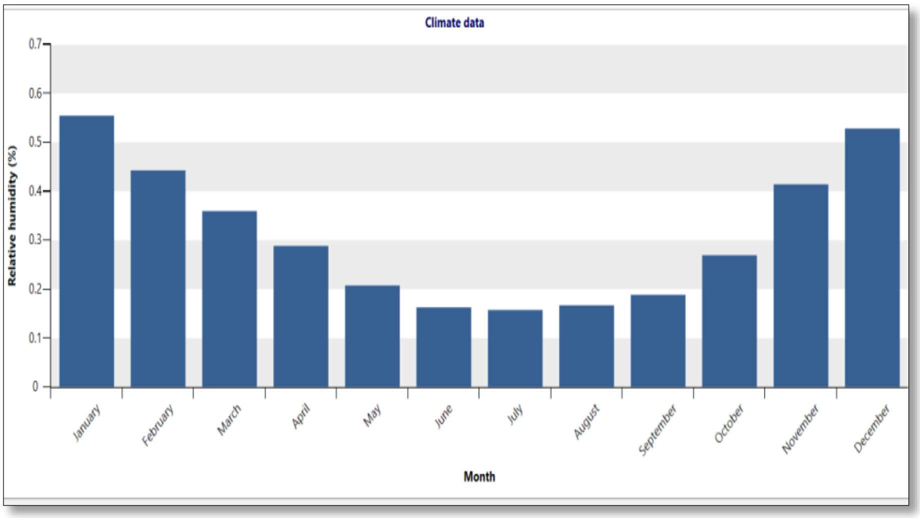


Figure 5: The relative humidity (%)

Figure 6 depicts the amount of precipitation; the Jan month witnessed increasing precipitation, reaching 44 mm, while it was absent in the (Jun, Jul, and Aug) months.

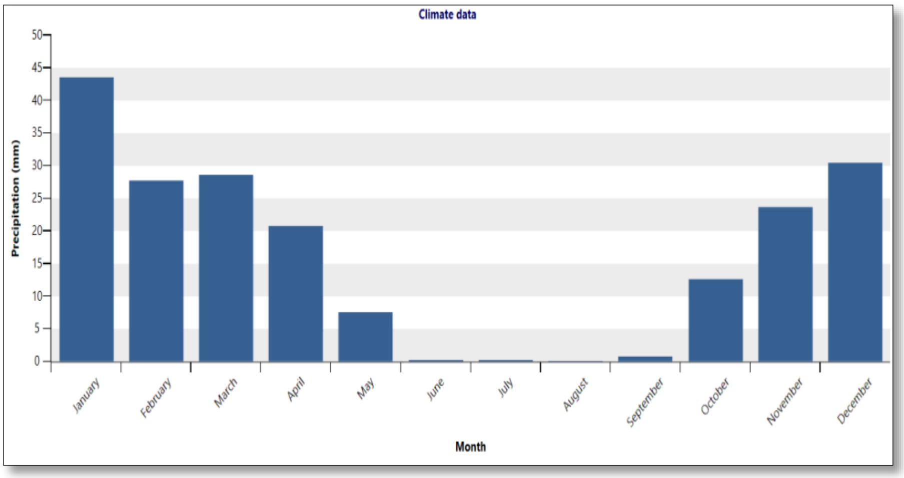


Figure 6: Precipitation (mm)

Figure 7 depicts the daily solar radiation-horizontal; it can be seen from the figure that the solar radiation increases in the summer season and decreases in the rest of the months.

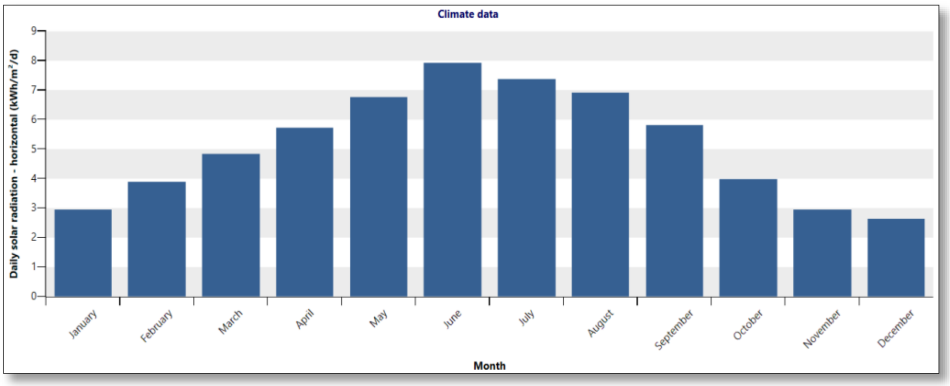


Figure 7: Daily solar radiation-horizontal(kWh/m^2/d)

The model estimates the yearly net decrease in GHG emissions resulting from enacting the suggested case. The calculation incorporated the annual emissions from the reference and alternative cases. The analysis determined that the project resulted in a remarkable 93% reduction in emissions; the Gross annual GHG emission reduction is 61,290.2 tCO2, equivalent to 26,334,691.4 L of gasoline not consumed, Table 5 and Figure 8.

Table 5: GHG emissions

GHG emission reduction	Reduction amount
Base case	65,903.4 tCO_2
Proposed case	4,613.2 tCO_2
Gross annual GHG emission reduction	61,290.2 tCO_2

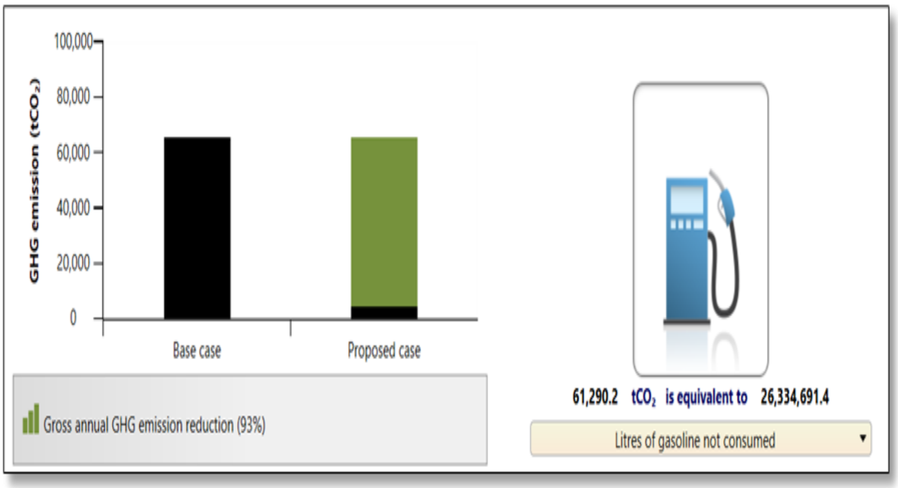


Figure 8: GHG emission (tCO_2)

Table 6 presents the annual energy production, revenue generated from electricity exports, and capacity factor of the proposed system as it is transmitted to the grid from the Razaza site. The values were determined based on the simulation result obtained from RETScreen for the Vestas 3.45MW wind turbine. The capacity factor exhibited a value of 22.3%, which is relatively low.

Table 6: Annual energy production, revenue generated from electricity exports, and capacity factor of the proposed system

System Summary	value
Capacity factor	22.3 %
Initial costs	40,000,000 $
O&M costs (savings)	40$/kW-year
Electricity export rate	0.10 $/kWh
Electricity exported to the grid	67,849 MWh
Electricity export revenue	6,784,897 $
Gross energy production for each turbine	7,666 MWh
Specific yield	467 kWh/m^2

Figure 9 shows the yearly cash flows ($), which refers to the estimated annual amount spent or earned during the project's lifespan. The project's first year of operation begins in year 1, whereas the equity is expected to occur in year 0.

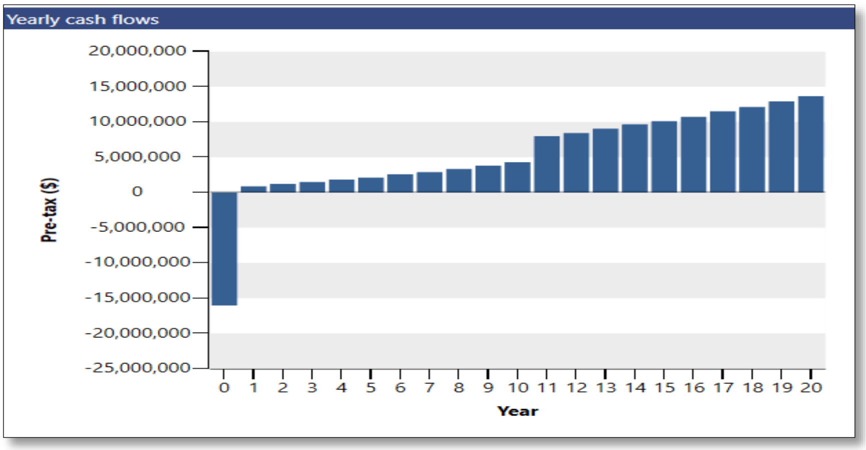


Figure 9: Yearly cash flows

The diagram depicted in Figure 9 displays the cumulative cash flows ($) that have accrued since Year 0. The term refers to the projected total amount, calculated annually, expected to be expended or acquired during the project's term.

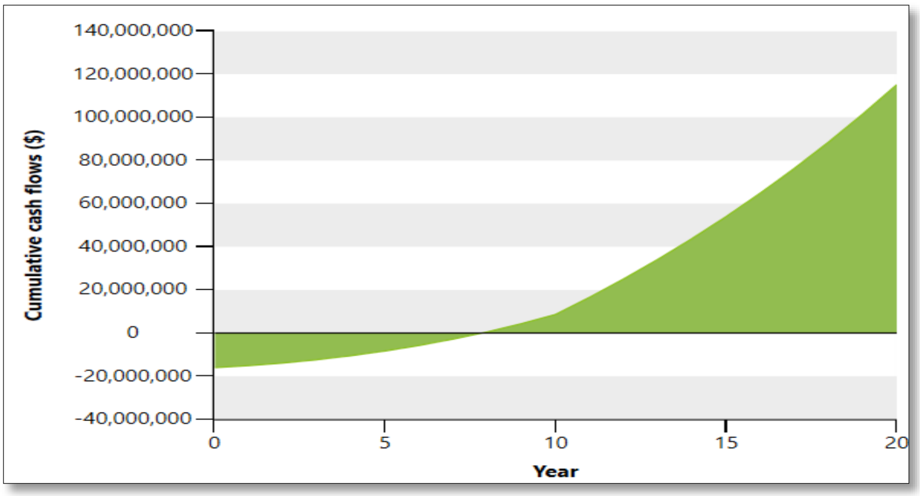


Figure 10: Cumulative cash flows ($).

Table 7 The financial viability of a project through various economic indicators. These indicators provide insights into the project's profitability and the period needed to repay the initial expenditure. The equity payback is 7.8 yr., the simple payback is 10.3 yr., and the Energy production cost is 0.095 $/kWh.

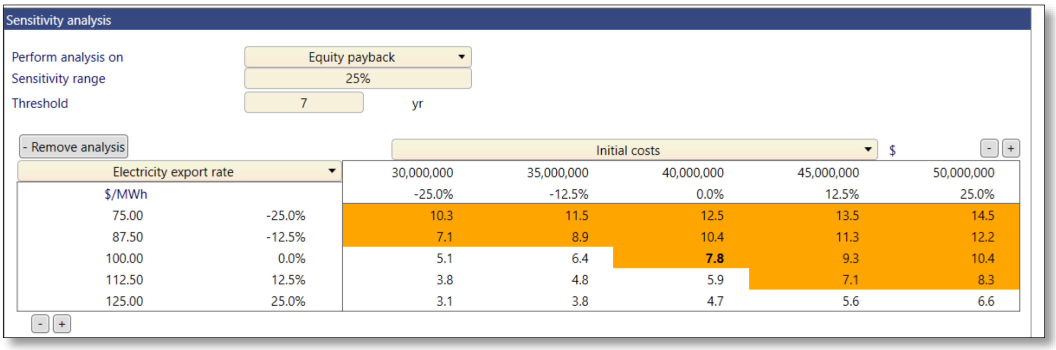
Table 7: Financial viability

Financial metrics	value
Pre-tax IRR- equity	19%
Pre-tax IRR- assets	9.4%
Simple payback	10.3 yr.
Equity payback	7.8 yr.
NPV	70,896,090 $
Energy production cost	0.095 $/kWh

The sensitivity and risk analysis tables provide valuable insights into the impact of the changes in the initial cost and O&M cost on the equity payback of the project. The tables assess the project's financial performance by considering different scenarios of cost variations.

Table 8 of the model output illustrates the duration necessary for a facility proprietor to recover their initial investment (equity) from the project's generated cash flows.

Table 8: Sensitivity Analysis performance on Equity payback



Perform analysis on	Equity payback
Sensitivity range	25%
Threshold	7 yr

Electricity export rate		Initial costs $				
		30,000,000	35,000,000	40,000,000	45,000,000	50,000,000
$/MWh		-25.0%	-12.5%	0.0%	12.5%	25.0%
75.00	-25.0%	10.3	11.5	12.5	13.5	14.5
87.50	-12.5%	7.1	8.9	10.4	11.3	12.2
100.00	0.0%	5.1	6.4	**7.8**	9.3	10.4
112.50	12.5%	3.8	4.8	5.9	7.1	8.3
125.00	25.0%	3.1	3.8	4.7	5.6	6.6

Table 8 evaluates the effect of a 12.5% increase or decrease in the initial cost on the equity payback period. If the initial cost increases by 12.5%, the table demonstrates the corresponding change in the equity payback period. It estimates the extended time required to recoup the initial equity investment due to the higher upfront costs. If the initial cost decreases by 12.5%, the table illustrates the potential reduction in the equity payback period. It shows the accelerated timeframe for recovering the initial equity investment due to lower initial costs. Figure 11 presents the risk assessment on the (NPV) metric, representing the aggregate of all expected cash flows discounted at the present-day currency's discount rate. The Electricity exported to the grid has the highest positive impact.

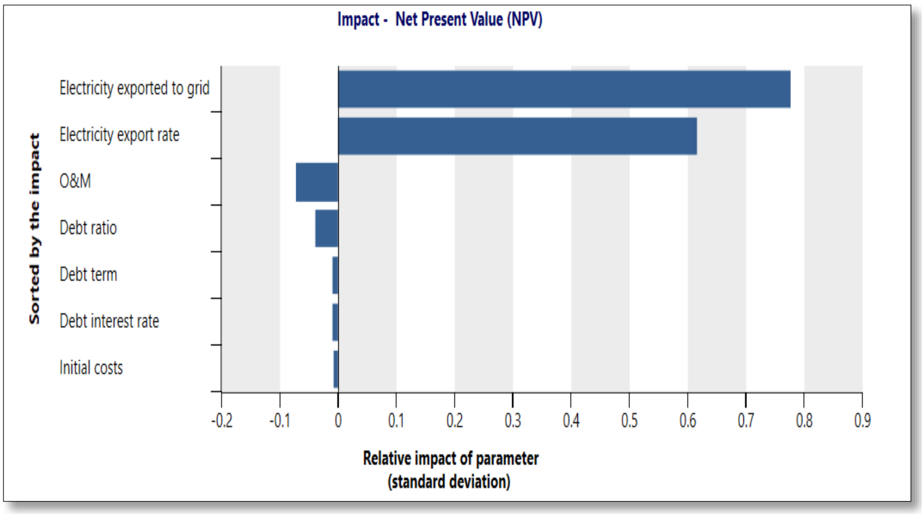


Figure 11: Risk assessment conducted on the (NPV) metric

The potential for equity payback is illustrated as an indicator of risk in Figures 12 and 13. The equity payback metric is deemed more precise in evaluating a project's long-term viability, as it determines its leverage and cash flows from its inception. It can be concluded that the electricity exported to the grid has the highest negative impact.

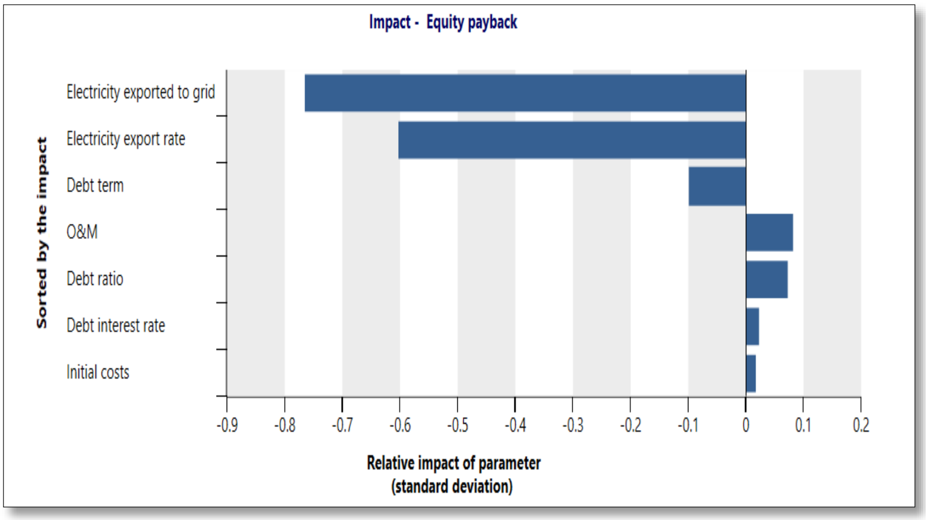


Figure 12: Risk assessment conducted on the (Equity payback) metric

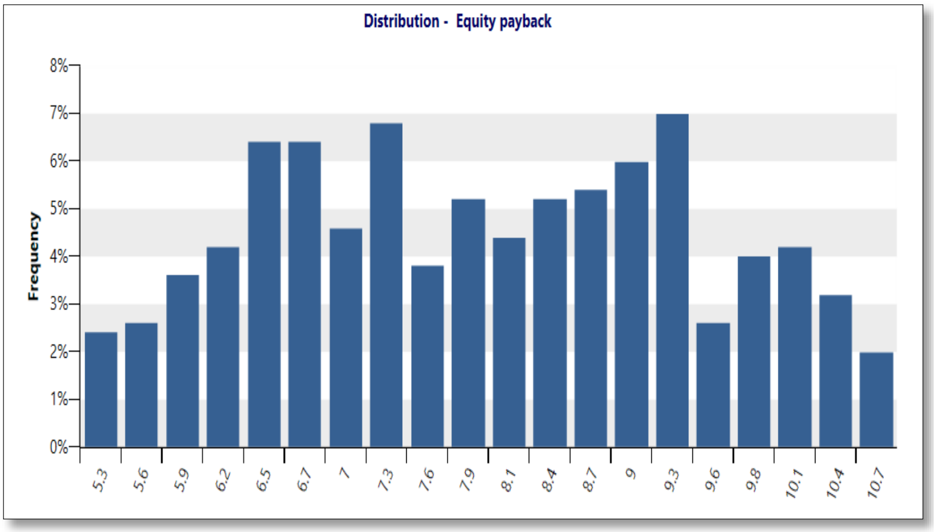


Figure 13: Frequency distribution of Equity payback

5. Conclusion

RETScreen is a widely used and appropriate software that evaluates many factors, such as energy generation, costs, financial viability, and environmental impact, to evaluate the feasibility of a renewable energy project. The framework provides a comprehensive study considering crucial elements like economic parameters, technology specifications, and other relevant factors. This study conducted a feasibility analysis using the RETScreen Model for constructing a 340 MW wind farm in the Al-Razaza region of the Karbala province. All economic signs point to the site needing to be more viable. Greenhouse gas emissions might be lowered, and the planned farm could produce an additional 67,849 MWh of electricity. The farm only operated at a capacity factor of 22.3%. The pre-tax internal rate of return (IRR) on equity was 19%, while the simple payback was 10.3 years or almost half the project's lifetime. The findings indicate that the suggested location is not financially viable and does not fall within the profitable range. The results obtained from this case study serve decision-makers and policymakers who are interested in the energy sector.

6. Acknowledgment

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7. Disclosure and conflict of interest

"Conflict of Interest: The authors declare no conflicts of interest."

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