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Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879

# Feasibility Study of a 50 MW Wind Farm Project in Pakistan

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**ARTICLE INFO**

***Article history:***
Received 15 April 2020
Received in revised form 26 June 2020
Accepted 9 July 2020
Available online 15 August 2020

***Keywords:***
Renewable energy; wind energy; carbon emission; energy financial analysis; Pakistan

**ABSTRACT**

Wind energy is the most developed source of renewable energy, because of advanced technology, low operational cost, and less environmental impacts as compared to fossil fuels. Due to the electricity load shedding and high carbon emissions, Pakistan direly needs a clean and economical energy source. Pakistan has enormous wind potential, especially in remote areas of Sindh, which can cover the energy demand of the local communities. This paper aims to study the feasibility of the 50 MW wind project in four different geographic locations of Sindh province in Pakistan. The selected sites are technically and financially analyzed in renewable energy technology (RETScreen) software. Financial analysis is also carried out according to the renewable energy policy of Pakistan with the values of the discount rate, debt ratio, and inflation rate. The results showed that all sites are technically and economically feasible, but Hyderabad is the most favorable site with the highest capacity factor of 41.8% and lowest simple and equity payback periods of 7.4 years and 4.9 years, respectively, as compared to the other sites. So, it is concluded that wind energy is the most suitable option as technically and financially in the remote areas of Sindh province in Pakistan.



## 1. Introduction

Energy is an essential part of life and for the growth of the country's economy [1]. Countries are improving their energy demands to move towards energy-efficient renewable resources over the past decades due to the depleting fossil fuels, environmentally friendly, economical, and in ample form [2,3]. But developing countries are facing an energy crisis due to the exponential increase of population and majorly dependant on conventional resources [4]. The carbon dioxide emission is a serious problem that must be addressed, and the foremost thing is that the energy sector is the main

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https://doi.org/10.37934/arfmts.74.2.2742

contributor of that emission. So, there is a dire need for investigation and installation of different renewable energy resources, specifically wind and solar energy, to cope with the energy generation [5]. Solar and wind are used worldwide, but wind energy is verified as an economically suitable and reliable source of energy [6]. The advantage of wind power over other renewable energy resources is due to its advanced technology, simple infrastructure, easy installation and maintenance, long project life, minimum installation and maintenance time, and low-cost energy generation. It is highly used in renewable energy worldwide and plays an essential role in the energy sector [7].

Pakistan is at the 6$^{th}$ place all over the world in population with 222 million according to the 2017 census. Meanwhile, it is increasing at a rate of 2.4 percent per annum [8]. The energy demand in Pakistan is growing at a rate of 10-12% per year [9]. Pakistan majorly depends on thermal power plants for electricity production [10]. Due to this, Pakistan imports oil worth $ 14.5 billion every year for electricity generation. Wind energy production cost in Pakistan is US$ 0.056/kWh, which is nominal as compared to thermal plants [11]. According to the Pakistan Ministry of Energy (Power Division) report, Pakistan mainly depends on thermal (oil and gas) energy sources (see Figure 1), renewable energy generation is only 2% of the total energy. Pakistan is planning to increase the portion of renewable energy to 30% of the total energy by 2030 [12].

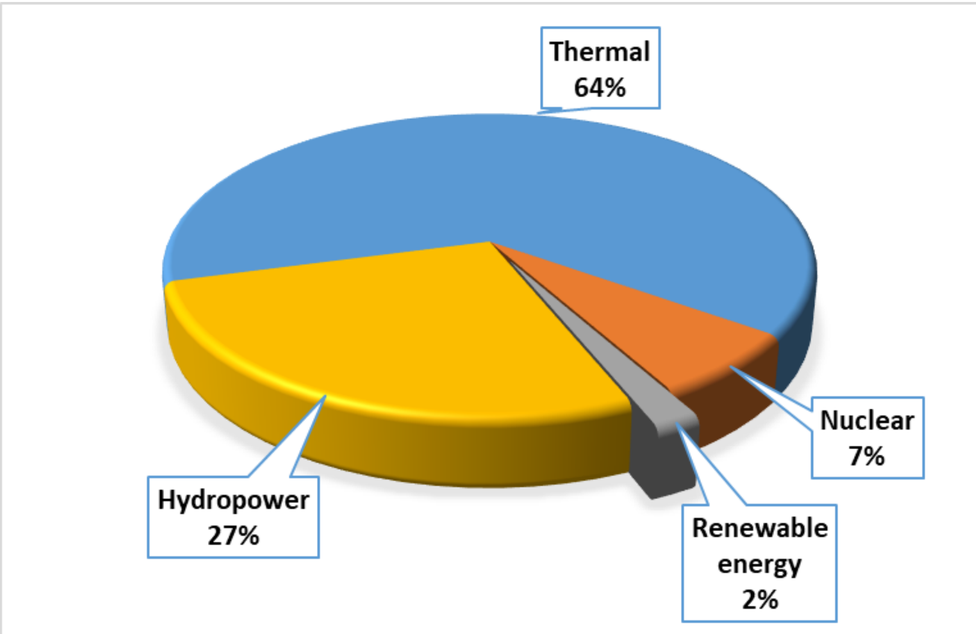


**Fig. 1.** Different energy sources share in Pakistan energy sector [13]

The report of emission forecast specifies that by 2030, the energy sector is the main contributor to the greenhouse gas (GHG) emission. In Pakistan's energy sector, a thermal source of electricity generation has always shared a significant portion of the total energy production of the country and also the major causes of GHG emissions. A report from European Commission shows the rising trend of the GHG emissions of Pakistan, given in Figure 2, which shows that from 1990 to 2015, $CO_2$ emissions have increased from 63081 to 174843 kton of $CO_2$ [14]. It specifies that this trend is the primary environmental concern and alarming situation for climate change.

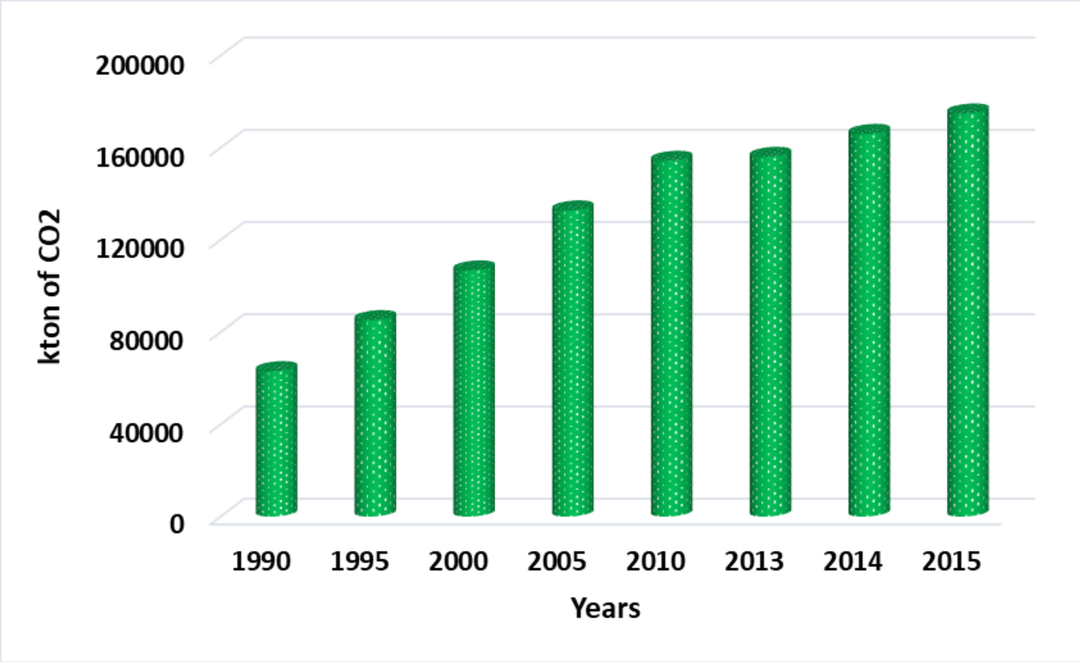


**Fig. 2**. $CO_2$ emission trend in Pakistan [14]

Pakistan has wind energy potential, especially in Sindh province. The country's diverse topography includes 1600 km of coastal line and hilly areas suitable for the installation of large wind turbines [15]. Currently, wind energy is one of the best solutions not only to compensate for the gap between availability and utilization demand but also to provide usable energy at a low price with an additional benefit of low carbon emission [16]. Currently, the wind contribution for electricity generation is by wind turbines, which amounts only 1302 MW (Figure 3).

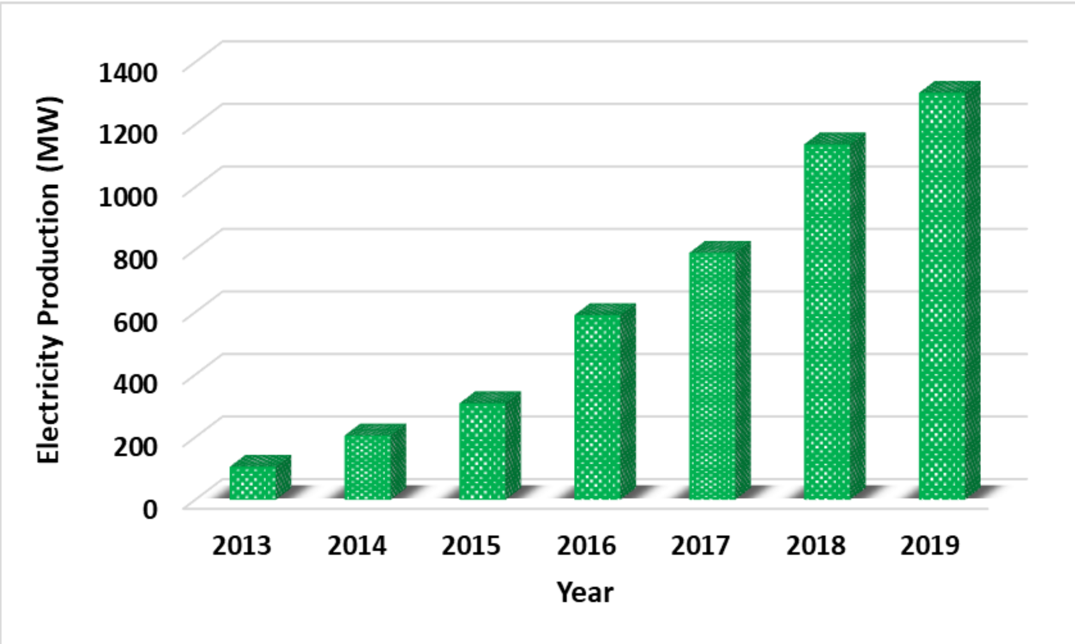


**Fig. 3.** Wind energy generation in Pakistan [13]

The utilization of renewable sources of energy is gaining escalation day by day due to their applicability to enhancements and environmental benefits. The current global renewable energy utilization is about 11,425 million tons (or equivalent), which are expected to be increased to 13,310 million tons by 2040 [17]. Wind energy is the most swiftly growing source of renewable resources. Its conversion system is both economically and environmentally friendly. It needs an understanding of wind situations at the site under study [18,19]. It can be utilized to meet the energy demand of the rural and off-grid areas of the country [20]. The present study is dedicated to providing the potential of wind energy production in different regions in the Sindh province of Pakistan.

The objective of the paper is to study the feasibility of a 50 MW wind farm project for remote areas of Pakistan. The purpose of the paper is to encourage renewable energy resources as compared to fossil fuel-based power plants. The enviro-economics analysis of selected sites has been examined by RETScreen software by using different parameters. The outcome of the government financing scheme of renewable energy has also been evaluated based on the viability of the purposed wind power plants on various sites. The final results of the project are influential not only for the administration of the country but also for the stable development of renewable energy sources of developing countries.

## 2. Methodology

The scientist, researchers, and engineers are working on different analysis techniques and technologies for the development of varying configuration of wind turbines under suitable and feasible working conditions. The RETScreen is one of the simple and best tools that provide clean energy analysis techniques for different clean and renewable energy technologies and gives information about the evaluation of energy production under variable conditions. In this software, all parameters could be defined by the user. The suitable sites can be selected from the global positioning system (GPS), which gives the monthly and annual variation of the wind speed in selected locations. The speed variation decides the monthly generation of power produced by the wind farm. This tool also estimates the total costs and savings. RETscreen could evaluate the many other factors like emissions reduction, financial viability, including the risk. In clean energy technologies, RETscreen provides a comparison between the base case and proposal case, which shows the probability of the practical approach of the project. By defining the input parameters, the RETscreen is capable of calculating the monthly and annual production of energy and the capacity factors of selected wind turbines. It can also provide an evaluation of the project's financial viability by highlighting the internal rate of returns (IRR), cash flow, and payback periods.

The internal rate of return and capacity factors are providing the quality, efficiency, and profitability of the projects. In the same way, net present value (NPV) shows the total amount added, which is required for the project investment. For a particular project, the internal rate of return (IRR) provides the value of the discount rate, which makes the NPV of all cash flows equal to zero.

The value of IRR decides the financial viability of the project, and its value should be greater or equal than organizational IRR value, which could justify the organization's investments. But in case of the negative or smaller value of IRR, the project could not be justified financially. The equity payback periods estimate the time duration in which the initial investment of the organization will return back. The equity payback periods involve cash flows and debt ratios. All the parameters used in the RETSecreen tool are the built-in mathematical expression, which is given below.

$$CF = \frac{P_{out}}{CP \times TP} \tag{1}$$

CP is the total installed plant capacity (kW), CF is the capacity factor (%), $P_{out}$ is the output power from the wind turbine, and TP is the number of time periods (%)

$$NPV = \sum_{T=1}^{t} \frac{NC_i}{(1+d)^T} - NC_t \quad (2)$$

$NC_t$ = Total net cash (US$), $NC_i$ = Net cash inflow (US$), d = Discount Rate (%), T = Number of time periods (%), t = Time (s)

$$IRR = NPV \rightarrow 0 \quad (3)$$

IRR = Internal rate of return (%), NPV = Net present value (US$)

$$PBP = \frac{I}{NC_p} \quad (4)$$

PBP = Payback Period, $NC_p$ = Net periodic cash flow (US$)

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

GHG = Green House Gas, E = Energy Supplied Annually (kWh/year).The systematic diagram based on optimizations analysis of the proposed system is shown in Figure 4.

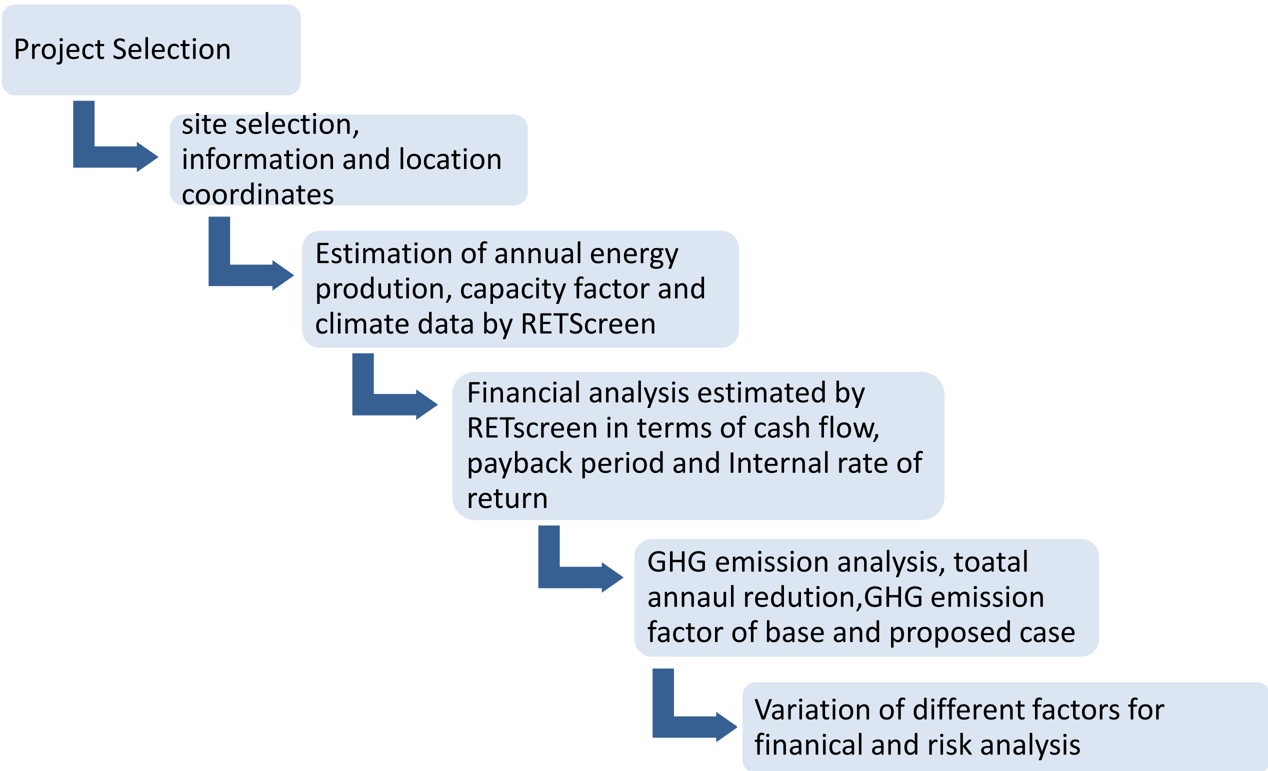


**Fig. 4**. Schematic flow chart of RETScreen

## *2.1 Site Specifications*

The selected sites are shown on the regional map of Pakistan (Figure 5). For the proposal case, the selected sites are Jamshoro, Tando Muhammad Khan, Nooriabad, and Hyderabad. Geographically these sites are in the wind corridor of Sindh province, where many areas are suitable for wind turbine

*Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*
Volume 74, Issue 2 (2020) 27-42

power generation. The Arabian sea gives importance to Sindh province; that's why the wind speed for selected sites throughout the whole year can be considered for the wind farm. The geographical states for selected sites can be seen in Table 1. The month-wise change in wind speed helps to estimate the monthly wind turbine power generation and finally gives the annual power generation. This monthly variation at 10m height for each site is shown graphically in Figure 6. The highest peak in the graph shows the maximum wind speed (4.5m/s) for Jamshoro and Hyderabad, and the lowest peaks show the minimum wind speed (2.5m/s) for Nooriabad. At 10m height, the annual average wind speed values for Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad are 3.5, 3.3, 3.5, and 3.5, respectively.

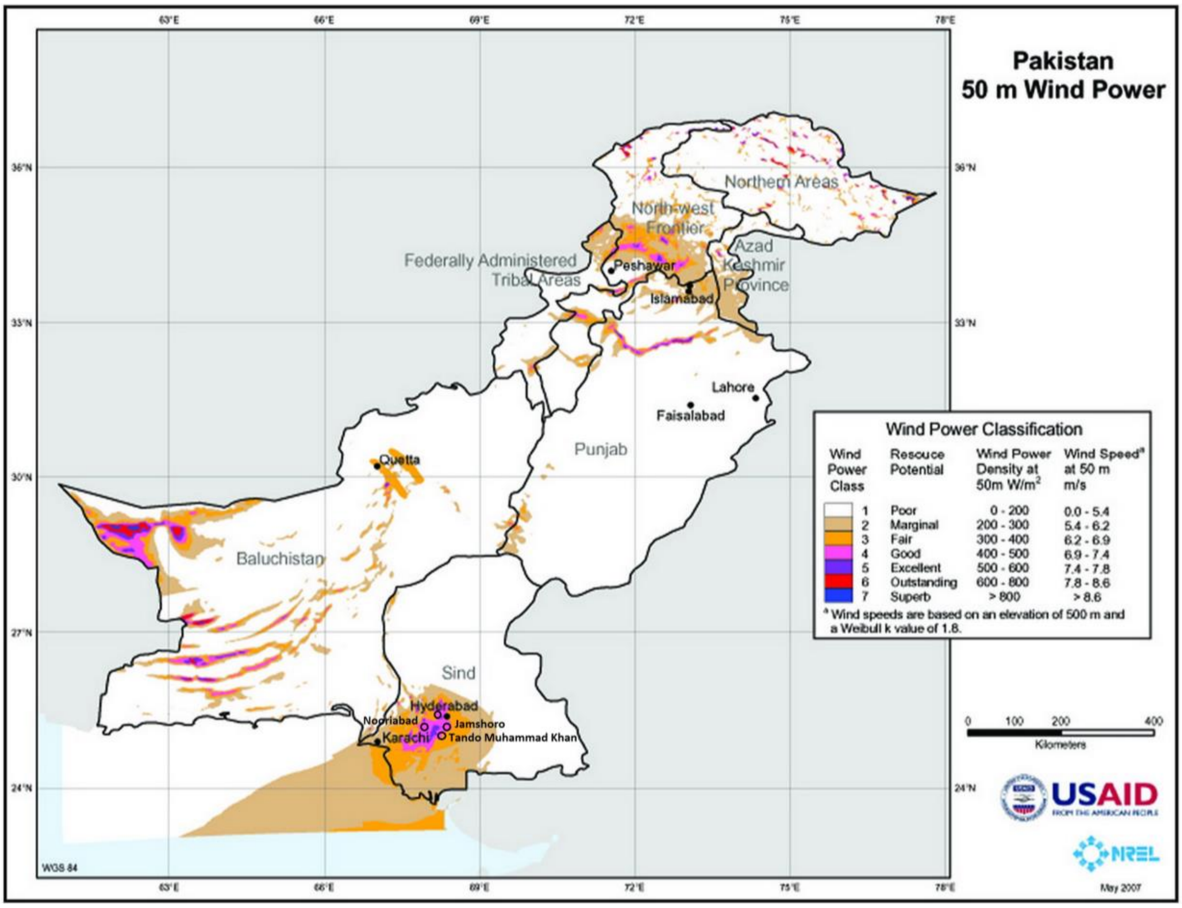


**Fig. 5.** Selected sites on Pakistan wind map [21]

**Table 1**
Selected wind sites for project

| Parameters | Tando Muhammad Khan | Jamshoro | Nooriabad | Hyderabad |
|---|---|---|---|---|
| Latitude(˚N) | 25.47 | 25.42 | 25.15 | 25.67 |
| Longitude(˚E) | 68.13 | 68.21 | 67.83 | 68.20 |
| Elevation (m) | 115 | 126 | 147 | 155 |

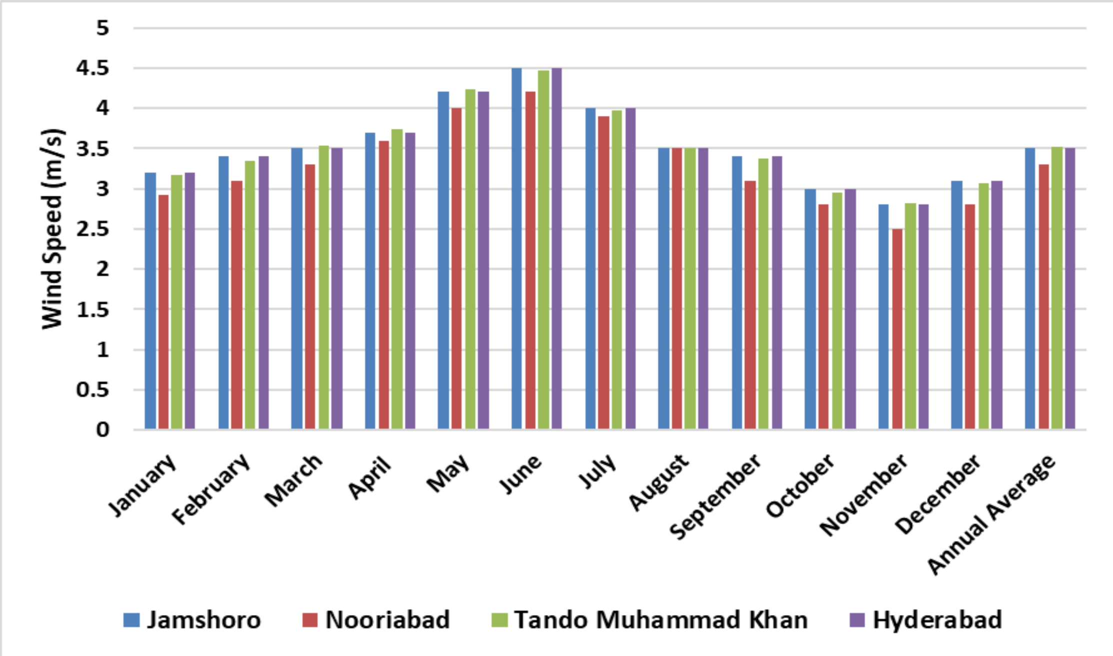

**Fig. 6.** Monthly wind speed of all sites

## *2.2 Wind Power System Description and Design*

The swept area and the kinetic energy of the wind are two essential parameters for calculating the power output of wind turbines.

$$P_w = \frac{dE}{dt} = \frac{dm_a}{2\times dt} {V_w}^2 \tag{6}$$

where, $t$ = time, $V_w$ = wind velocity of wind, $m_a$ = *mass* flow of air. As

$$dm_a = A_b \times \rho_a \times ds \tag{7}$$

where $ds$ = distance, $A_b$ = swept area, $\rho_a$ = density of air. By putting the value of $dm$ in the first above equation.

$$P_w = \frac{ds}{2dt} A_b \times \rho_a \times {V_w}^2 \tag{8}$$

$$P_w = \frac{1}{2} A_b \times \rho_a \times {V_w}^3 \tag{9}$$

A power coefficient ($C_p$) has to be introduced in the above equation because wind turbines cannot convert 100% wind energy into output power. The value of the power coefficient can be varied from 35 to 45%[22].

$$P_w = C_p \times \frac{1}{2} \times A_b \times \rho_a \times {V_w}^3 \tag{10}$$

If the values of wind velocity and swept area of the turbine increase, the output power ($P_{out}$) will be increased, RETScreen provides the multiples designs and models of the wind turbine. By using the input parameters from the RETScreen, the best configuration of the wind turbine is selected, which gives maximum annual output power. All the specifications of the selected wind turbine are given in Table 2. The working wind speed of the selected model (W2E100/2000-100m) is 3 m/s, and the cut-out speed is 25 m/s. The selected wind turbine has 2MW rated power capacity, and its rotor diameter is 100m.

**Table 2**
Selected wind turbine specifications [22]

| Parameters | Unit | Value |
|---|---|---|
| Turbine Manufacturer | Wind to Energy | - |
| Model | W2E100/2000-100m | - |
| Power capacity per turbine | MW | 2.0 |
| Rotor diameter per turbine | m | 100 |
| Swept area per turbine | $m^2$ | 7854 |
| Hub height | m | 100 |
| Number of turbines | - | 25 |
| Shape factor | - | 2 |
| Power coefficient ($C_p$) | % | 40 |
| Array loses | % | 3 |
| Airfoil loses | % | 2 |
| Miscellaneous losses | % | 6 |
| Availability | % | 98 |

The proposed case has installed capacity of 50 MW with 25 wind turbines. The 50 MW is selected due to the renewable energy policy of Pakistan because the government provides the financing scheme for renewable energy up to 50 MW plants [23]. The power energy curve for the selected turbine shows the available power within the range of the turbine. The power energy curve of wind turbines for the proposed case can be shown in Figure 7.

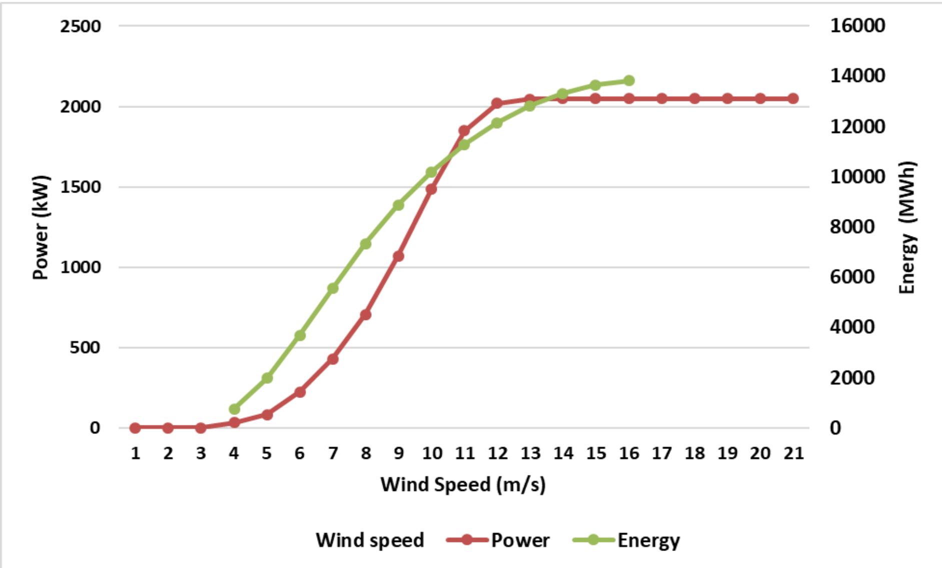


**Fig. 7.** Energy and power curve of selected wind turbine

## 3. Results and Discussion

It has already mentioned that as the wind speed and swept area of wind turbines changed, the output power will be changed. The monthly variation in the wind speed for each site gives the total annual energy production exported to the grid, which is shown in Table 3. Hyderabad has maximum electricity exported to the grid due to the highest wind speed and elevation among other sites. The results are shown graphically in Figure 8.

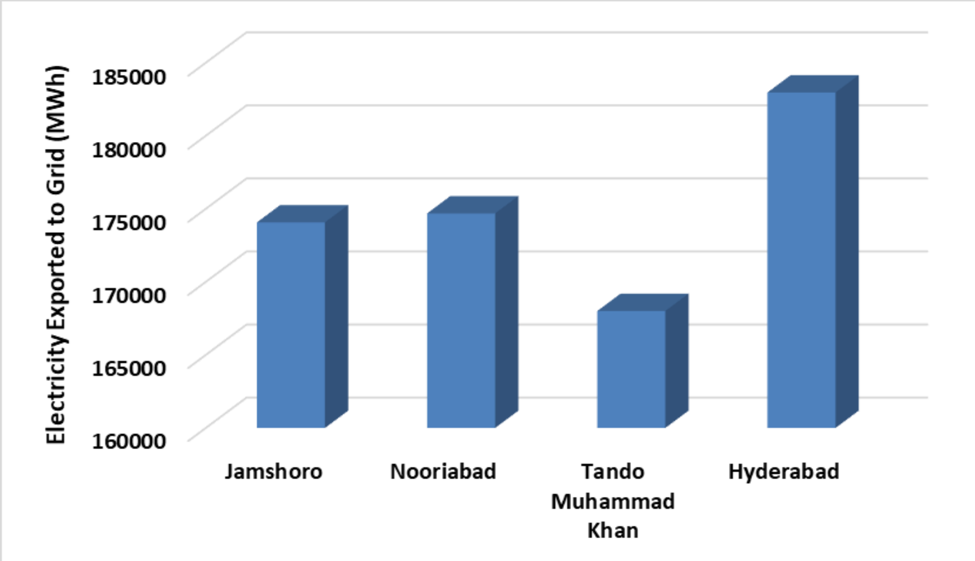


**Fig. 8.** Annual power exported to the grid for all sites

**Table 3**
Monthly power exported to the grid for all sites (MWh)

| Months | Jamshoro | Nooriabad | Tando Muhammad Khan | Hyderabad |
|---|---|---|---|---|
| January | 15357 | 15370 | 14822 | 16141 |
| February | 13722 | 13739 | 13244 | 14423 |
| March | 14862 | 14919 | 14344 | 15622 |
| April | 14145 | 14218 | 13652 | 14868 |
| May | 14462 | 14533 | 13958 | 15201 |
| June | 13938 | 14015 | 13452 | 14650 |
| July | 14457 | 14530 | 13953 | 15195 |
| August | 14530 | 14603 | 14024 | 15272 |
| September | 14121 | 14192 | 13629 | 14842 |
| October | 14706 | 14756 | 14193 | 15457 |
| November | 14503 | 14526 | 13997 | 15243 |
| December | 15265 | 15280 | 14733 | 16044 |
| Annual Average | 174069 | 174683 | 168003 | 182960 |

The RETScreen estimates annual electricity, which is exported to the grid for sites which are maximum and minimum for Hyderabad and Tando Muhammad Khan, respectively. The annual estimated electricity exported to Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad is 174069, 174683, 168003, and 1829960 MWh, respectively. The capacity factor of each site calculated by the RETScreen is shown in Figure 9. The Hyderabad has maximum, and Tando Muhammad Khan has a minimum value of the capacity factor. The capacity factor for Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad is 39.7, 39.9,38.3, and 41.8%, respectively.

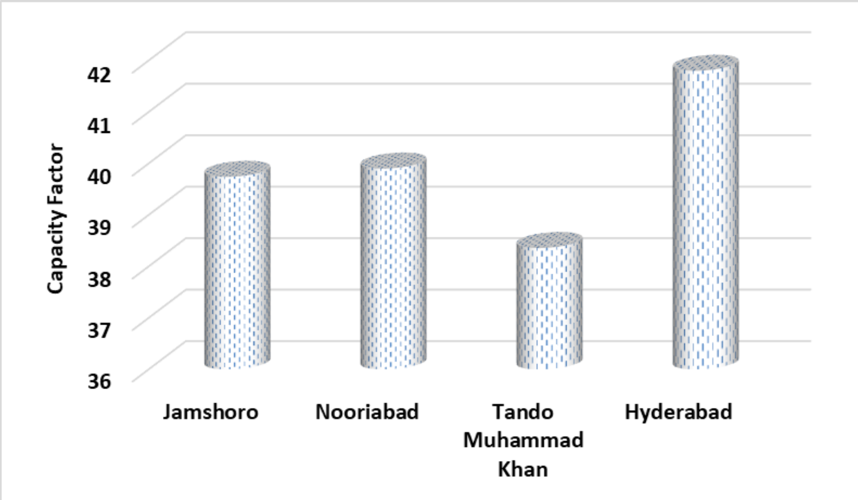


**Fig. 9.** The maximum achieved capacity factor for all site

The discount rate for any renewable power technology is 6%, which is fixed by the Pakistan government [23]. Thus, the discount rates for all sites are taken 6%. All financial parameters, like interest rates and project life for the selected sites are given in Table 4. The RETScreen also calculates the cash flows, which are given in Figure 10 to 13. The cash flows decide the equity and simple payback years periods. The simple payback periods for Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad are 8.6,7.7,8.3 and 7.4, respectively. Similarly, the minimum equity payback periods for Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad are 5.9,5.2,5.6 and 4.9, respectively. The simple and equity payback years of different sites are shown in Figure 14. The estimated values of IRR assets and IRR equity for each site can be seen in Figure 15. All the leading financial parameters are showing that the proposed case is financially feasible and acceptable.

**Table 4**
Financial values

| Terms | Unit | Value |
|---|---|---|
| Inflation Rate | % | 06 |
| Discount Rate | % | 06 |
| Project Life | Years | 25 |
| Debt Interest Rate | % | 06 |
| Debt Term | Years | 12 |
| Debt Ratio | % | 51.8 |
| Reinvestment Rate | % | 2 |

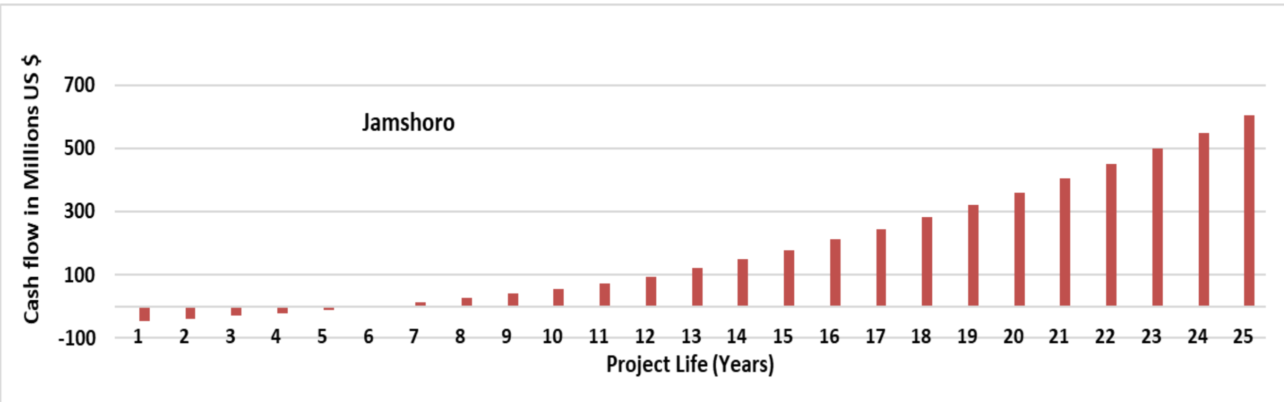


**Fig. 10.** Cash flow of Jamshoro

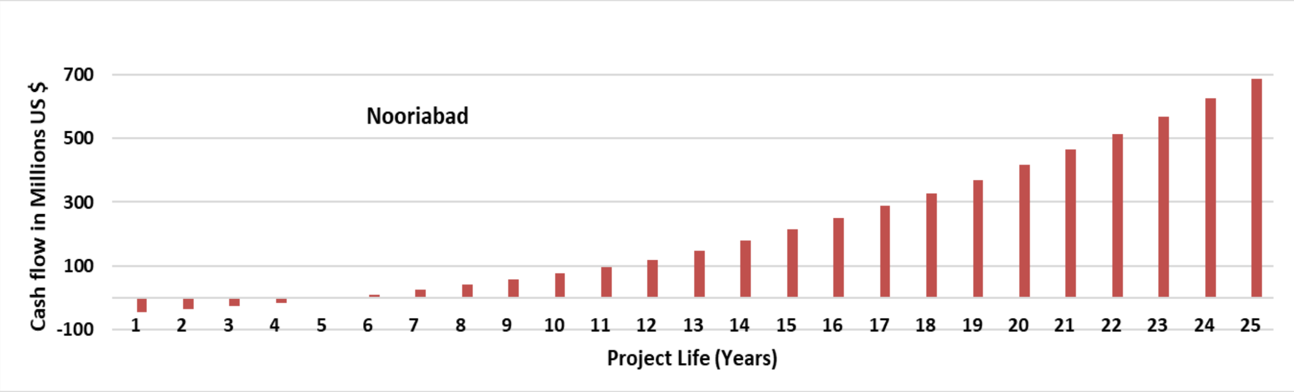


**Fig. 11.** Cash flow of Nooribad

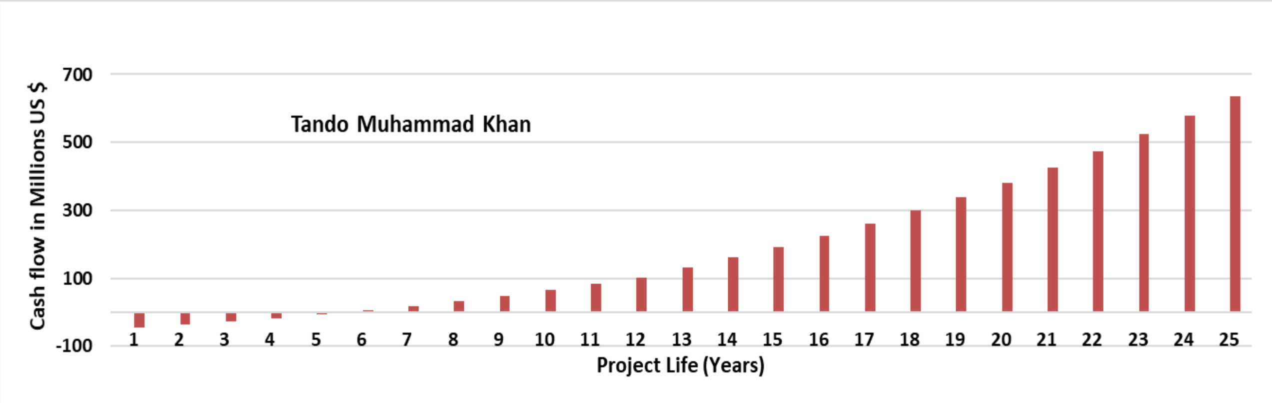


**Fig. 12.** Cash flow of Tando Muhammad Khan

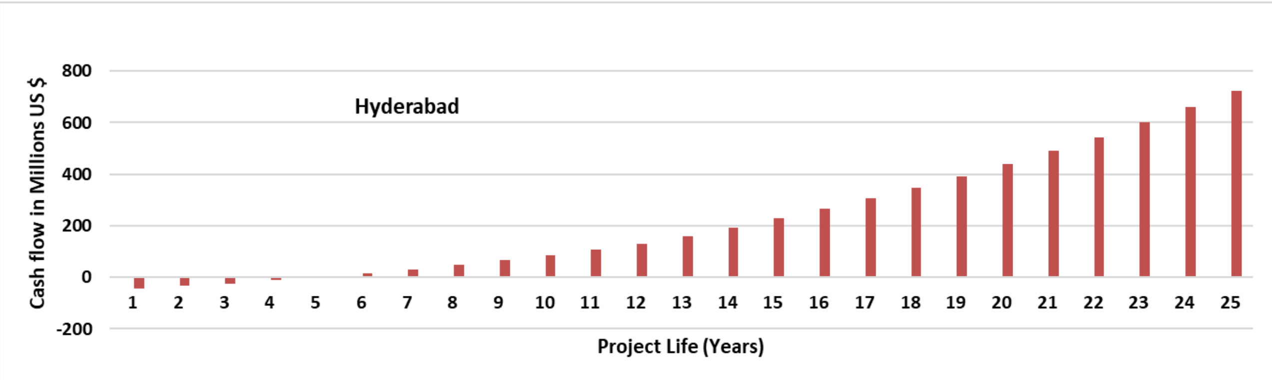


**Fig. 13.** Cash flow of Hyderabad

The wind energy farms will contribute to the reduction of GHG emissions when it is compared with the conventional power resources. The impact of the net annual reduction of GHG emissions for all sites is shown in Table 5. The net annual reduction of GHG emissions for Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad are 71324.1, 77489.1132, 77489.1132and 86308.9313 $tCO_2$ respectively. Furthermore, the average cuts in GHG are equivalent to 24594.5, 25415.6, 26720.3, and 29761.7 tonnes of waste recycled for Jamshoro, Nooriabad, Tando Muhammad Khan and Hyderabad respectively. This GHG emission reduction can help in an offer of a free harmful emission environment.

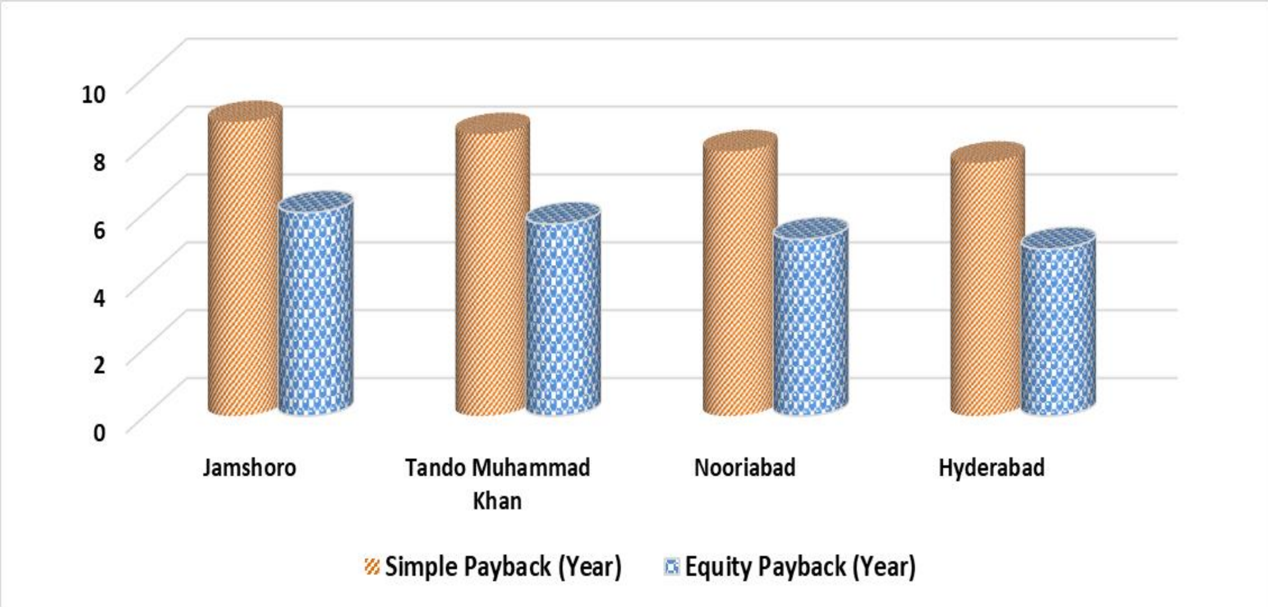


**Fig. 14.** Simple and equity payback years of sites

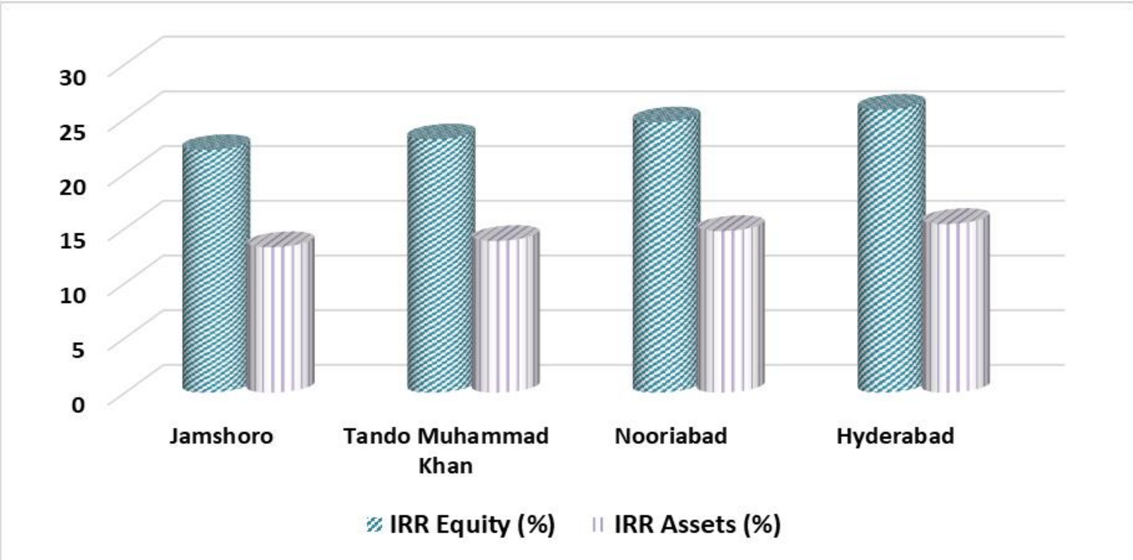


**Fig. 15.** IRR equity and assets percentage

**Table 5**
Net annual reduction of GHG emissions for all sites

| Locations | Net Annual Reduction of GHG Emission (tCO2) | Cars and Light Trucks not used | Hectors of Forest Absorbing Carbon | Peoples Reducing energy use by 20% | Tonnes of Waste Recycled |
|---|---|---|---|---|---|
| Jamshoro | 71324.1 | 13063 | 16210 | 71324.1 | 24594.5 |
| Tando Muhammad Khan | 73705.4 | 13499.1 | 6778.9 | 73705.4 | 25415.6 |
| Nooriabad | 77489.1 | 14192.1 | 17611.2 | 77489.1 | 26720.3 |
| Hyderabad | 86308.9 | 15807.4 | 7938.1 | 86308.9 | 29761.7 |

### 3.1 Risk Analysis

The instability of the project is solved by analytical access, which is given by risk analysis. That possibility which decreases the feasibility of project losses would be examined here. The risk analysis provides the distribution of the possibility and the level of danger for any result of the project. The risk analysis does the risk of 10% by using RETScreen.

Using RETScreen, the risk analysis gives the outcomes are shown in the figures, which are given below. The possibility of thermos-economic for the project, which is proposing has distinct impacts due to several factors like debt, initial cost, and operational, and management cost, and this can be noticed in Figure 16 and 17. The operating and management (O&M) and the initial cost have a more substantial effect on the project of the wind farm, which is proposing because these costs have an adverse impact. The distribution of IRR and payback outcomes are illustrated in Figure 18 and 19. The loss risk is much minor as compared to benefit, which is shown by the possibility of IRR distribution and the payback period using the estimation of risk analysis. There are two values of 23.4% to 24.8% in between the IRR equity is large. The cost of payback is higher for years, which are less than five years, and the value of payback decreases after five years.

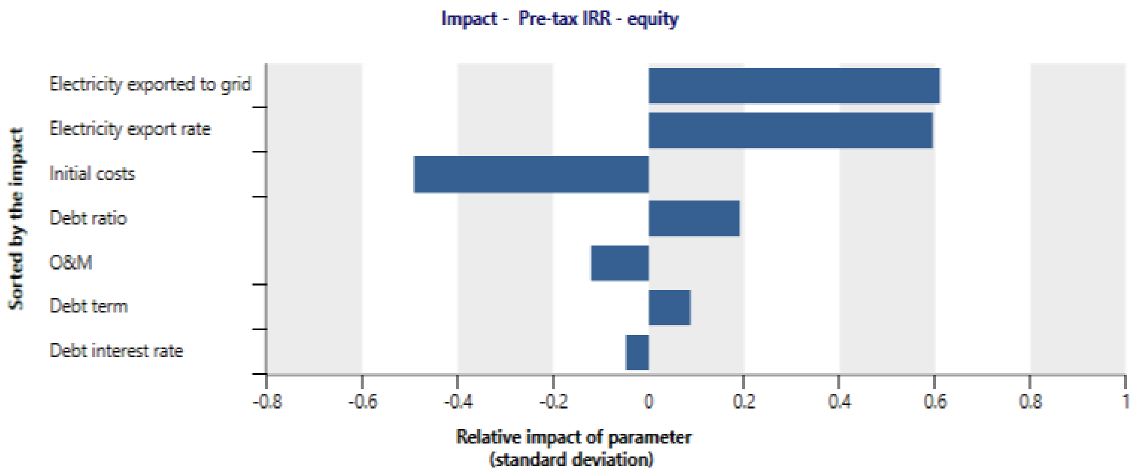


**Fig. 16.** Risk impact on IRR

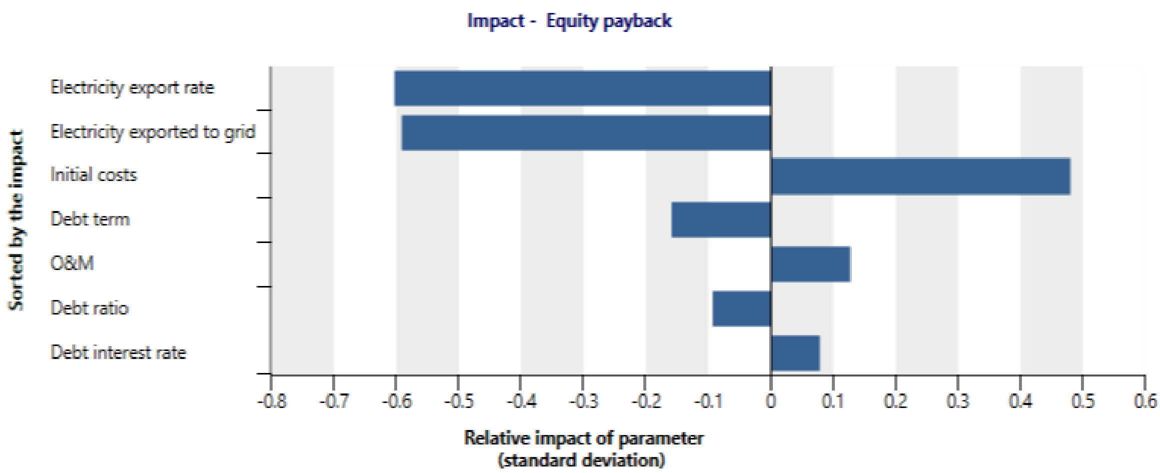


**Fig. 17.** Risk impact on equity payback year

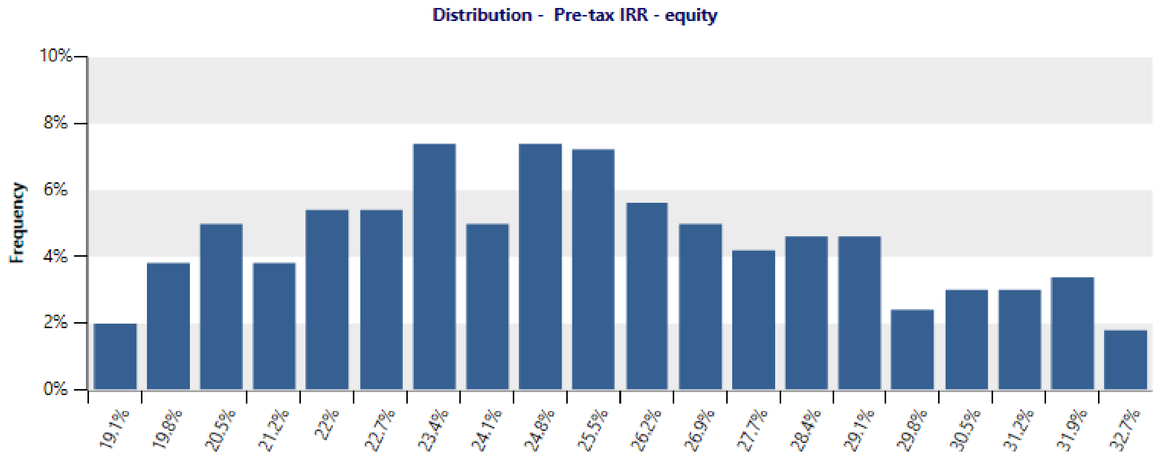


**Fig. 18.** Risk distribution of IRR

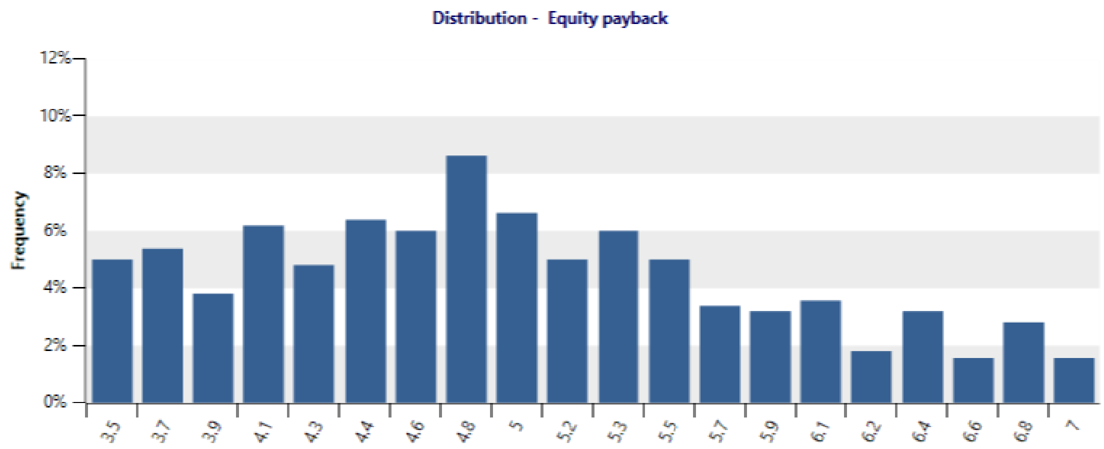


**Fig. 19.** Risk distribution of payback years

## 4. Conclusions

This paper highlights the technical and feasibility of power generation from a wind farm of 50MW and considered as a proposed case in RETScreen modelling. The four different sites Jamshoro, Nooriabad, Tando Muhammad Khan, are selected from the Sindh province. Their climate and geographical data show these sites can be taken for the instalment of a wind farm of 50MW. Moreover, there are the following findings of this feasibility study of the 50 MW wind farm project in Pakistan.

i. In the first step of RETScreen analysis for the wind farms, the climates' input parameters are used to estimate the monthly and annual power generation for selected sites. The annual power generation named as annual estimated electricity exported to the grid is 174069, 174683, 168003, and 1829960 MWh for Jamshoro, Nooriabad, Tando Muhammad Khan and Hyderabad, respectively.
ii. The estimated capacity factors for the selected sites are 39.7, 39.9, 38.3, and 41.8% for Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad, respectively. The energy analysis results show that the proposed case is acceptable for the required energy generation.

iii. After an acceptable energy analysis, the next step to check the financial feasibility of the proposed case. The simple payback periods for Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad are 8.6, 7.7, 8.3, and 7.4 years, respectively.
iv. The minimum value of equity payback periods is 5.9, 5.2, 5.6, and 4.9 for Jamshoro, Nooriabad, Tando Muhammad Khan, and Hyderabad, respectively.
v. The RETScreen analysis for the proposed case of wind farm estimates the reduction of GHG emission. The results show that there is a remarkable reduction in all sites. The estimated net annual reduction of GHG emissions for selected sites is 71324.1, 77489.1, 77489.1, and 86308.9 $tCO_2$ for Jamshoro, Nooriabad, Tando Muhammad Khan and Hyderabad respectively.
vi. The use of this wind energy will not only contribute to the economic development of the country but also save the environment from greenhouse gas emissions. Moreover, in the financial analysis, it is indicated that the state bank of Pakistan financing schemes played a significant role in the development and promotion of renewable energy projects in Pakistan.
vii. Public-private partnerships can be established on a long-time basis for the new investor. Different types of policies, promotions, and subsidies are mandatory to overcome the hurdles to the progress of renewable energy technologies in Pakistan.

**Acknowledgment**
The authors would like to acknowledge the Ministry of Higher Education (MOHE) of Malaysia [Fundamental Research Grant Scheme (FRGS) -203.PMEKANIK.6071444] and Universiti Sains Malaysia (School KPI grant) for financial support toward this study.

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