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Original Article

Feasibility Study of a Large-Scale & Wind Farm in Sujawal, Sindh Province of Pakistan through Two Economic Models: Levelized Cost of Energy (LCOE) & Cash Flow Model

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Abstract - *Pakistan has tremendous potential for wind power in Sindh province. The authors in this work studied the economics of a wind farm installation in Sujawal district, Sindh province. The technical aspects of the wind power plant are estimated using three years of wind data from 2016 to 2018 to evaluate the wind potential available there. Moreover, different wind turbine(WT) models are considered, to study the economics of the wind power project including; power output (P_{out}), capacity factor (Cf), and their annual energy production (AEP).*

Furthermore, the cost of energy generation ($/kWh), system payback period (SPB), and return on investment (ROI) of each wind turbine were calculated. For this purpose, two economic models have been utilized: The Levelized cost of energy (LCOE) and the Cashflow method. The financial analysis concludes that this site is suitable for the installation of a wind power plant. The wind project if installed in this district, will not only increase the generation of electricity but also bring new avenues for economic growth and produces employment. It will improve the quality of life of the local population.

Keywords - *Wind Energy, Levelized cost of energy (LCOE), Cash flow model, Net present value (NPV), System payback period (SPB), Return on investment (ROI).*

I. INTRODUCTION

Fossil fuels are contributing to carbon emissions due to which increasing climate change phenomenon is taking place, which leads to unpredicted climate patterns. All countries are switching to environmentally friendly and renewable energy sources (RES) to reduce their carbon footprint. Which previously were costly in a generation, but now their cost is decreasing due to advancement in these technologies. Among these renewable energy technologies, wind energy is an essential factor in achieving green and sustainable energy. It also increases the share in energy generation and reduces the dependency on fossil fuels [1], [2]. Wind energy can be utilized for commercial purposes wind farms and small wind turbines for distributed energy generation [3]. This technology relies on two determinants: the policies to encourage the production of this technology and the cost of this system [4].

The energy demand in Pakistan is increasing day by day because of the rise in population. To ensure energy security and improve the lives of people, Pakistan is diversifying the generation of energy. Pakistan has tremendous wind energy potential because of which many IPPs have obtained a letter of intent (LOI) [5]. These IPPs are mostly focusing Jhimpir wind corridor in the Thatta district of Sindh province. Despite this, the exploitation of enormous wind energy is below its level [6]. The Sujawal district also has wind potential for commercial applications. There are some prerequisites for the wind farm. Firstly, the site study is to be carried out. Secondly, there is a need for wind resource assessment. Thirdly, a feasibility study is required to obtain the cost-benefit relation. Fourthly, the installation of the wind power plant. In the last, operation and integration of wind farms into a national grid [7].

The critical stage in these processes is the wind resource estimation of the site. The accuracy of wind resource estimation depends on data quality. The collected data includes the 10 min mean wind speed (v), wind direction (dir), and air temperature (T_a) for the whole year. Wind mast measured data up to the height of 80m. This data is used to simulate WT models, each having a unique power curve. The annual energy generation of these WT is calculated[8]. Then comes the stage of the feasibility study, which is of much importance as it is a useful procedure for planning and design of a wind farm [9].

The economic analysis is carried out using cost-benefits estimation methods. There are many methods suggested in the literature to carry out a feasibility study of a wind project. These methods include factors like the capital cost (CAP_{cost}), costs of operation and maintenance (C_{om}), other variable and fixed costs, the life span (t) of a turbine, the capacity factor (C_f) of a turbine, their annual energy production (AEP) as inputs; and system payback period (SPB), return on invest (ROI) and cost of energy generation ($/kWh) as outputs. These financial inputs profoundly affect the cost of energy generation. This study uses two economic models; a Levelized cost of energy (LCOE) and a cash flow model.LCOE gives a price per unit generation in kilowatt-hour. The cash flow method represents all economic input factors, and it provides the cost-benefit relationship [10]-[14].

In this paper, the authors study the feasibility of a wind power project in the Sujawal site. Section II describes site characteristics and offers wind potential estimation for the proposed site considering different wind turbine models. Section III includes an economic analysis of wind farms for the proposed site using two revenue-expenditure models. In Section IV results and discussions are present, and in the last, the conclusion is given in Section V.

II. SITE DESCRIPTION AND WIND POTENTIAL ESTIMATION

A. Site description

Sujawal site, situated in Sujawal district of Sindh province, has an elevation of 17 m. There is a wind mast installed to record site characteristics. It has geographic coordinates 24.515563 Lat and 68.18865 Lon. Its total height is 80 m from its base. Its records include parameters like the wind speed (v), the wind direction ($_{dir}$), the air temperature (T_a), the humidity (h), and the air pressure (P_a). These parameters were recorded at an interval of ten minutes. The ten-minutes average data gets uploaded daily at Alternative Energy Development Board (AEDB) Pakistan and Global Wind Atlas official websites. The aerial view of the wind mast installed at the proposed site is shown in Fig. 1. Also, an aerial view of its anchors is shown in Fig. 2.

Fig. 1 Shows the aerial view of the wind mast installed at the proposed site

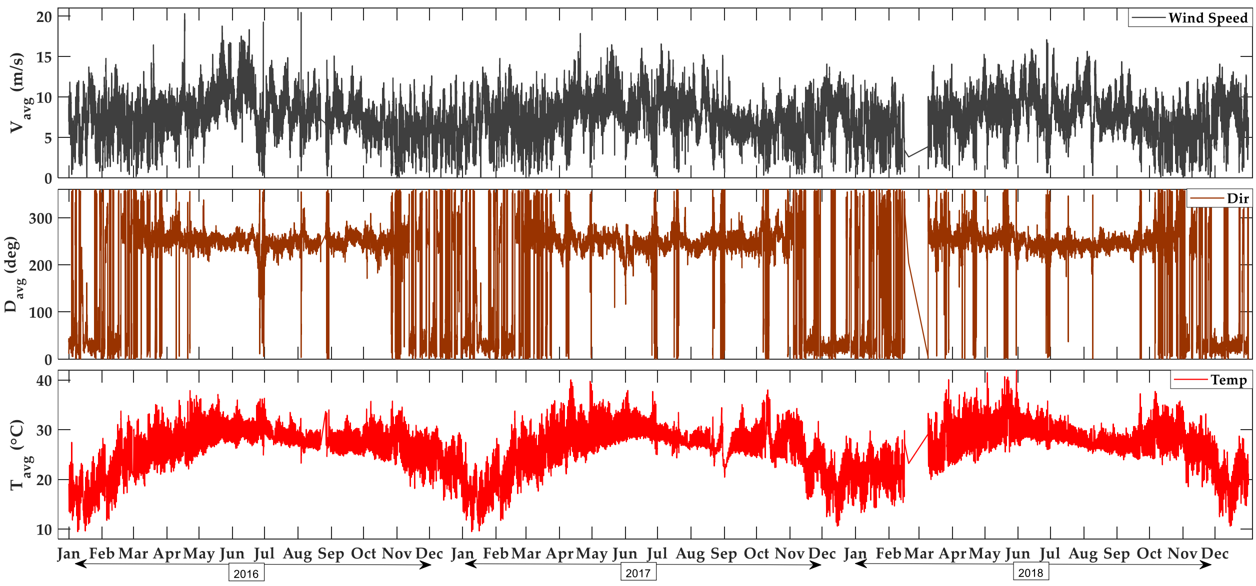

Fig. 3 Shows characteristics of the proposed site

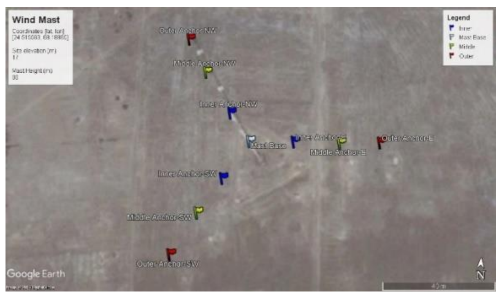

Fig. 2 Shows the wind mast with its anchors

B. Wind potential estimation

The specific parameters of the site and the technical properties of a wind turbine are two main factors in wind power production. The site parameters are wind availability (%), wind speed (m/sec), air temperature (°C), air pressure (mbar), Air Density (kg/m^3), wind power (W/m^2), and energy density (Wh/m^2). Moreover, wind speed frequency distribution (WSD) and wind frequency rose (WR) diagrams are given in Fig. 4 and Fig. 5, respectively. Also, the mean values for air temperature (T_a), air pressure (P_a), air density (ρ), wind speed (v), and wind power density (WPD) are in Table I.

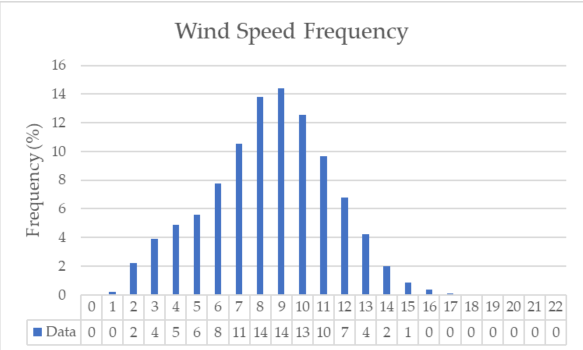

Fig. 4 Shows the wind speed frequency (WSD) of the proposed site

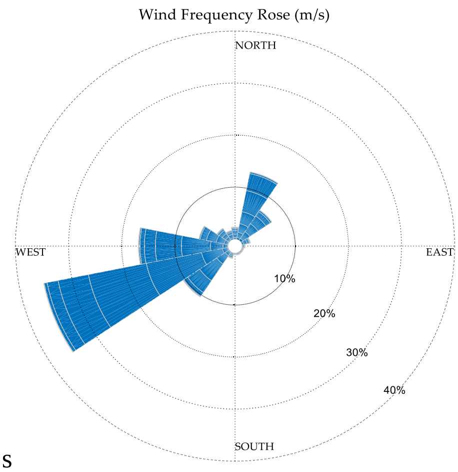

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Fig. 5 Shows the wind frequency rose (WR) diagram

Table 1. Gives details about different parameters of the proposed site

Time	Temp	Air pressure	Air density	Chub	Power density
3 years	26.20	1008.86	1.17	7.92	412.90
2018	26.74	1008.30	1.17	7.94	410.53
2017	25.81	1009.03	1.18	7.91	409.85
2016	26.06	1009.26	1.18	7.91	418.31

The technical specification of a wind turbine includes the rated power (P_R), the rated wind speed (V_R), the cut in (V_{in}) and cut out (V_{out}) wind speeds. The power curves of each turbine are in Fig. 6. The characteristics of all wind turbines are present in Table II. In this work, six wind turbines of different make use. Some of them are of 2MW or 2.05MW in rated power. The SANY SE, Vestas V90, Leitwind LTW, W2E, FWT 100, and Enercon E-82 has 2MW, 2MW, 2MW, 2.05MW, 2.05MW, and 2.05MW respectively. The cut-in wind speed at which wind turbine starts producing electrical power for each is 2.5m/sec, 4m/sec, 3m/sec, 3.5m/sec, 3m/sec and 2m/sec respectively. The rated wind speed is 10m/sec, 13m/sec, 11m/sec, 11.5m/sec, 11.5m/sec and 12.5m/sec respectively. Whereas the cut-out wind speed is 25m/sec for all except Enercon E-82.

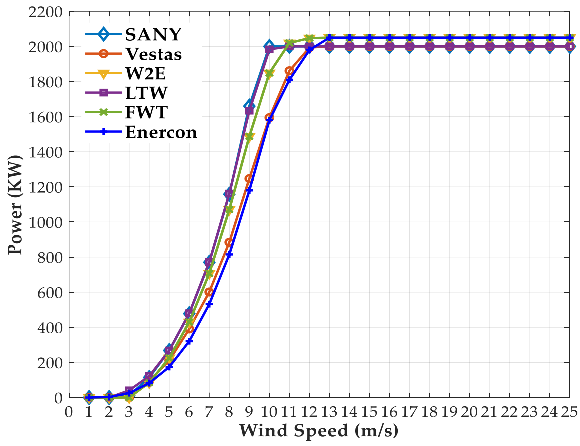

Fig. 6 Shows the power curve of the wind turbine (WT) considered in this study

Table 2. Characteristics of Turbines

WT	SE	V90	W2E	LTW	FWT	E2
P_R (MW)	2	2	2.05	2	2.05	2.05
H_H (m)	80, 85, 90	80, 95, 105	70, 85, 100, 117	80, 93.5	85, 100, 117	78, 85, 98, 108, 138
R_d (m)	102	90	100	101	100	82
S_A (m2)	8235	6362	7854	8012	7854	5281
N_B	3	3	3	3	3	3
V_{in} (m/s)	2.5	4	3.5	3	3	2
V_R (m/s)	10	13	11.5	11	11.5	12.5
V_{out} (m/s)	25	25	25	25	25	34

1) Capacity factor (C_f):

The wind data obtained through the wind mast is utilized to analyze the site parameters. The wind turbine power curve and capacity factor (C_f) determine the technical characteristics of a WT. The C_f of a WT is the ratio of the mean P_{out} to its P_R [15]. The C_f is found using equation (1):

$$C_f = \frac{e^{-(V_R/c)^k} - e^{-(V_{in}/c)^k}}{(V_R/c)^k - (V_{in}/c)^k} - e^{-(V_{out}/c)^k} \quad (1)$$

Where c and k are the Weibull scale and shape parameters. V_{in}, V_{out}, and V_R are the cut-in, cut-out, and the rated-wind speeds of a WT respectively.

2) Power output (P_{out}):

Thus, the power output (P_{out}) of a wind turbine (WT) is required to calculate the annual energy production of the turbine. P_{out} calculated with the help of equation (2) [16]:

$$P_{out} = P_R C_f \quad (2)$$

where $P_R$and $C_f$are the rated power and the capacity factor of the WT, respectively.

3) The annual energy production (AEP):

The annual energy production (*AEP*)in kWh of each WT is calculated from the equation given below:

$$AEP = 8760 P_{out} \quad (3)$$

Here 8760 represents the total number of hours in a year.

III. ECONOMICAL EVALUATION

A. The cost structure of large-scale wind farm

The study of the economics of a wind farm involves many parameters. These parameters affect the cost of electricity units generated with the help of a wind turbine. These parameters are different for different sites. Thus, the economic prospect of a wind power plant depends mainly on the site wind parameters. There is no fuel cost, but the capital cost of a wind farm is high. Also, there are other costs like the cost of civil works, interconnectedness to the grid, and transmission lines. The capital cost distribution of a wind farm is shown in Fig. 7.

Moreover, the cost structure of a large-scale wind farm consists of fixed and variable costs. The fixed costs are capital costs. The variable prices include the costs of operations and maintenance. Among them, the capital cost from fixed cost is of significance as the cost of wind turbines accounts for a large portion of the total investment whereas the WTs have a lifespan after which their efficiency decreases from rated power. Therefore, the wind turbine costs include its production, transportation, and the installation at site. The next significant cost is the cost of the grid connection, civil works, construction expenses, licensing procedures, operations, and control systems. The economics of a wind power project is in Fig. 8.

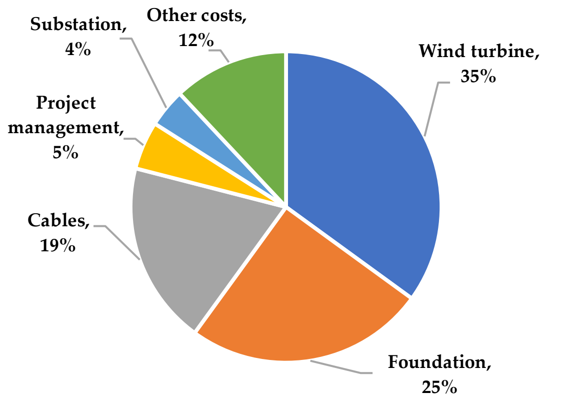

Fig. 7 Shows capital cost distribution for a typical wind power project [17]

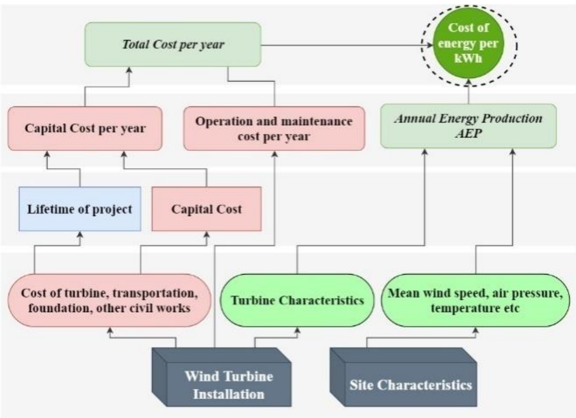

Fig. 8 Shows the economics of a wind farm

B. The Levelized Cost of energy method (LCOE)

The economic study of a wind farm includes the Levelized cost of electricity generation (LCOE) from wind power. LCOE is a primary determinant for the comparison of the cost of different power projects. For wind power, LCOE describes the sums of all expenses of a running wind power system throughout the life of the system with financial flows discounted to a current year [18]. The LCOE for a wind farm has the following main components: Capital costs, operations, and maintenance costs. The LCOE expenditures are further summarised in Fig. 9. The LCOE can reduce by reducing the cost of different components of the wind power project. It also includes the expected AEP. Currently, the cost of wind energy is reducing because of the improvement in the design of wind farms that as a result, increase the efficiency of a wind farm. Also, the LCOE is further decreasing because of the higher capacity factor obtained by increasing the turbine height and rotor diameter. The assessment of the wind farm requires careful estimation of all the parameters discussed above over its lifetime. It can be estimated using the equation (4) given below:

$$LCOE = \frac{Sum\ of\ Costs\ over\ Lifetime}{Sum\ of\ Electrical\ Energy\ Produced\ over\ Lifetime}$$

$$LCOE = \frac{CAP_{Cost}.FCR + C_{om}}{AEP}(cost/kWh) \qquad (4)$$

Where CAP_{Cost} is initial capital expenditures. Fixed charge rate (%) denoted by FCR.Operational expenses or cost of operation and maintenance (C_{om}).Annual energy production (AEP).

The FCR provides the total annual revenue required to pay the carrying charges during the life of a projectandrepresentedthrough equation (5). Where the discount rate (d), effective tax rate (T), and the present value of depreciation (PV_{dep}) are in percentage (%), and turbine lifetime (t) in years.

$$FCR = \frac{d(1+d)^t}{(1+d)^t - 1} x \frac{1-(T.PV_{dep})}{(1-T)} \qquad (5)$$

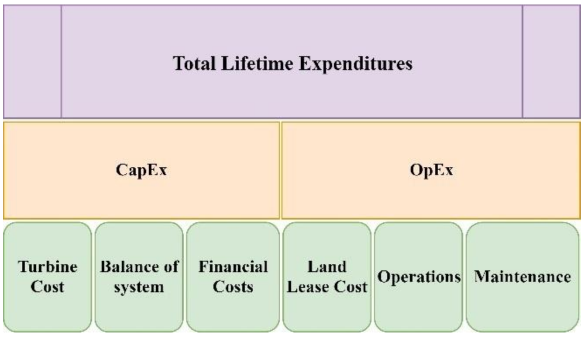

Fig. 9 Shows the total lifetime expenditure in Levelized cost of energy

C. Cash flow method

The industrial outline of a scheme consists of foretelling its profits plus losses and therefore, the viability of its investments. This study additionally presents valuable financial knowledge that if implied needed to ascertain better choice amid various technologies. So, models from those methodologies employed to wind power designs are submitted here. Numerous procedures are in the papers that can aid during the determination of the economy of a wind power project. Every method examines some factors. The cost throughout the project, yearly cash flows that cover benefits and liabilities, also the life of a project. The variance in money’s value across the period is as follows: Provided separate cash at a future cost (F_c) in the year (n), a present worth (P) with a discount rate (d), calculated by Equation (6):

$$P = F_c \frac{1}{(1+d)^n} \qquad (6)$$

So, it is a scheme investigated through implementing a cash flow model, where the yearly earnings and losses through the design life of n years signify the present value (P). This most simplistic model analyses the initial charge per kW installed, designated through C_i; constant annual cash flows associated with benefits (B_A), and operation and maintenance costs (C_{om}). At the end of the scheme, the salvage value (S) is the final income projected. A typical cash flow diagram presents in Fig.10.Where C_i is the cost of initial investment, B_A is financial benefits after selling of energy annually and, $C_{om}$is annually cost of operation and maintenance. Finally, additional benefits are supposed to be S.

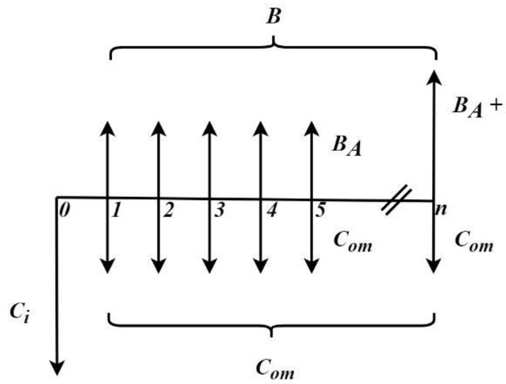

Fig. 10 Shows the typical cash flow of a wind farm

The net present value (NPV_T) of a wind farm is a standard budgetary parameter that provides to the growth of economic study, including resolution of its feasibility. Because of this two fiscal elements comprise the NPV_T of a wind power plant: the income, which contains the yearly savings through electricity selling $NPV(B_A)$ and a salvage cost NPV(S) by the end of the scheme; and the expenses, constituted initial investment C_i and annual operation and maintenance costs (C_{om}).

$$NPV_T = [NPV(B_A) + NPV(S)] - [C_i + NPV(C_{om})] \qquad (7)$$

The annual benefits (B_A) of the project are proportional to the AEP and represented as constant yearly cash flows. Therefore, the annual benefits (B_A) are calculated through Equation (8):

$$B_A = C_{kWh}AEP \qquad (8)$$

where C_{kWh} is the cost of kWh, and AEP is the annual energy produced.

The operation and maintenance costs $C_{omp}$are constant cash flows during the project lifetime and, in this work, are calculated as proportional to the initial investment costs C_i. We consider this proportionality to be 0.2% [19], [20]:

$$C_{om} = aC_i \qquad (9)$$

The salvage value (S) is calculated according to a straight-line depreciation of 10%. The annual depreciation (D_A) of a wind turbine with initial investment costs (C_i) expressed by Equation (10) [20], [21]:

$$D_A = \frac{C_i - S}{n} \tag{10}$$

Where n is the project lifetime. $De_n$is considered the Salvage value.

D. Payback Period

The payback period of a wind system is the period of an investment required to start savings and profits. Hence the long payback period is deemed to be not suitable for investment. The system payback period of a wind system is given by equation (11):

$$SPB = \frac{C_i}{(AEP.P_S - C_{om})} \tag{11}$$

Where C_i represents the cost of initial investment, *AEP* is the net annual energy production, P_s is purchase cost (according to NEPRA it is ~0.12 USD/kWh), and C_{om} is a yearly cost of operation and maintenance.

E. Return on investment

Return on investment (ROI) is a financial determinant that measures the amount of return on an investment relative to the investment cost in percentage. ROI is the ratio of benefits to the loss of the investment, calculated by using equation (12):

$$ROI = \frac{PVB - PVC}{PVC} \tag{12}$$

Where PVC is present value costs and PVB is present value benefits.

IV. RESULTS AND DISCUSSIONS

While using economic models discussed in section III, the following assumptions were:

- Investment costs denoted by C_i.
- The lifespan(t) of wind turbines to be 25 years.
- The cost of a wind turbine(C_T) is$1500/kW of its rated power (P_R).
- Other initial costs(C_{oi}) to be40% of C_T.
- Cost of operation and maintenance(C_{om}) as 20% of C_T.
- The inflation rate of service(i) is 5%.
- The rate of interest (d) is equal to 10% of the initial investment (C_i).
- The initial variable production cost is $0.015.
- Nominal variable cost escalation is 2%.
- Performance derating of the turbine is 10% per year.
- The scrape value (S) is 10%.
- All turbines are of the same rated power that is 2MW~2.05MW.

The capacity factor of a turbine according to the site characteristics is calculated using equation (1). For the calculation of the output power of a wind turbine equation (2) is used, whereas equation (3) is used to estimate the annual energy production of each turbine. The obtained values for each year and three years average capacity factor, annual energy production, power output, and cost of energy generation are in Table III.

Table 3. Annual and three years values about P_{out}, *AEP*, C_f, and *$/kWh*

WT	kW	GWh	C.F	$/kWh
2018				
SE	1191.57	10438.2	59.58%	0.0478
LTW	1188.17	10408.4	59.41%	0.0479
W2E	1132.87	9923.96	55.26%	0.0515
FWT	1132.87	9923.96	55.26%	0.0515
V90	1009.77	8845.63	50.49%	0.0563
E2	975.45	8544.90	47.58%	0.0598
2017				
SE	1264.31	11075.4	63.22%	0.0450
LTW	1261.10	11047.2	63.06%	0.0451
W2E	1204.37	10550.3	58.75%	0.0484
FWT	1204.37	10550.3	58.75%	0.0484
V90	1076.93	9433.91	53.85%	0.0528
E2	1039.03	9101.92	50.68%	0.0561
2016				
SE	1240.66	10868.2	62.03%	0.0459
LTW	1237.44	10840	61.87%	0.0460
W2E	1179.90	10335.9	57.56%	0.0494
FWT	1179.90	10335.9	57.56%	0.0494
V90	1053.02	9224.49	52.65%	0.0540
E2	1016.22	8902.05	49.57%	0.0574
Three years combine				
SE	3698.41	32398.1	61.64%	0.0462
LTW	3688.55	32311.7	61.48%	0.0463
W2E	3519.26	30828.7	57.22%	0.0497
FWT	3519.26	30828.7	57.22%	0.0497
V90	3141.78	27522	52.36%	0.0543
E2	3032.84	26567.7	49.31%	0.0577

The capacity factor of each turbine is calculated using equation (1). The LCOE method helps in the estimation of the cost of energy produced in $/kWh using equation (4). The capacity factor vs cost of energy generation by each turbine is in Fig. 11. The highest capacity factor of a turbine gives the lowest LCOE whereas the lowest capacity factor gives the highest LCOE. Which indicates that the SANY, Leitwind, W2E, FWT, Vestas and Enercon have a capacity factor of 61.64%, 61.48%, 57.22%, 57.22%, 52.36% and 49.31% respectively; with a LCOE $0.0462, $0.0463, $0.0497, $0.0497, $0.0543 and

$0.0577 per kWh each. The SANY and Leitwind turbines both gave the highest capacity factor and the lowest LCOE with a slight difference. Wind to Energy (W2E) and Fuhrländer (FWT) both have the same results in terms of C_f and LCOE, better than Vestas and Enercon turbines and stood second. While Vestas and Enercon have the lowest capacity factor and highest LCOE as compared with others. However, still, they both have a capacity factor and LCOE to be considered for installation of the wind farm at this site.

Along with this, the total expenditures vs total revenues graphs for each turbine are obtained using the cash flow model. Charts of the total spending vs total revenues are in Fig. 12. The entire expenses and revenues achieved during the expected life of the project are in million USD. Likewise, the cash flow vs cumulative net cash flow against the investment year for each turbine is in Fig. 13. Also, Fig. 14 shows the comparison among cumulative net cash flows of different turbines.

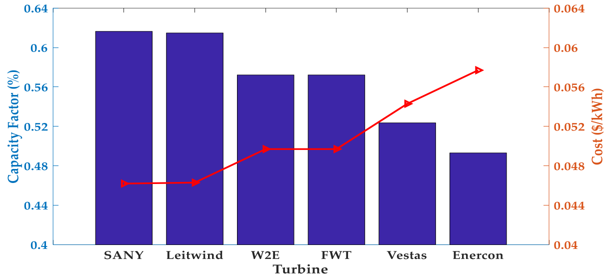

Fig. 11 Shows the cost vs capacity factor of different wind turbines

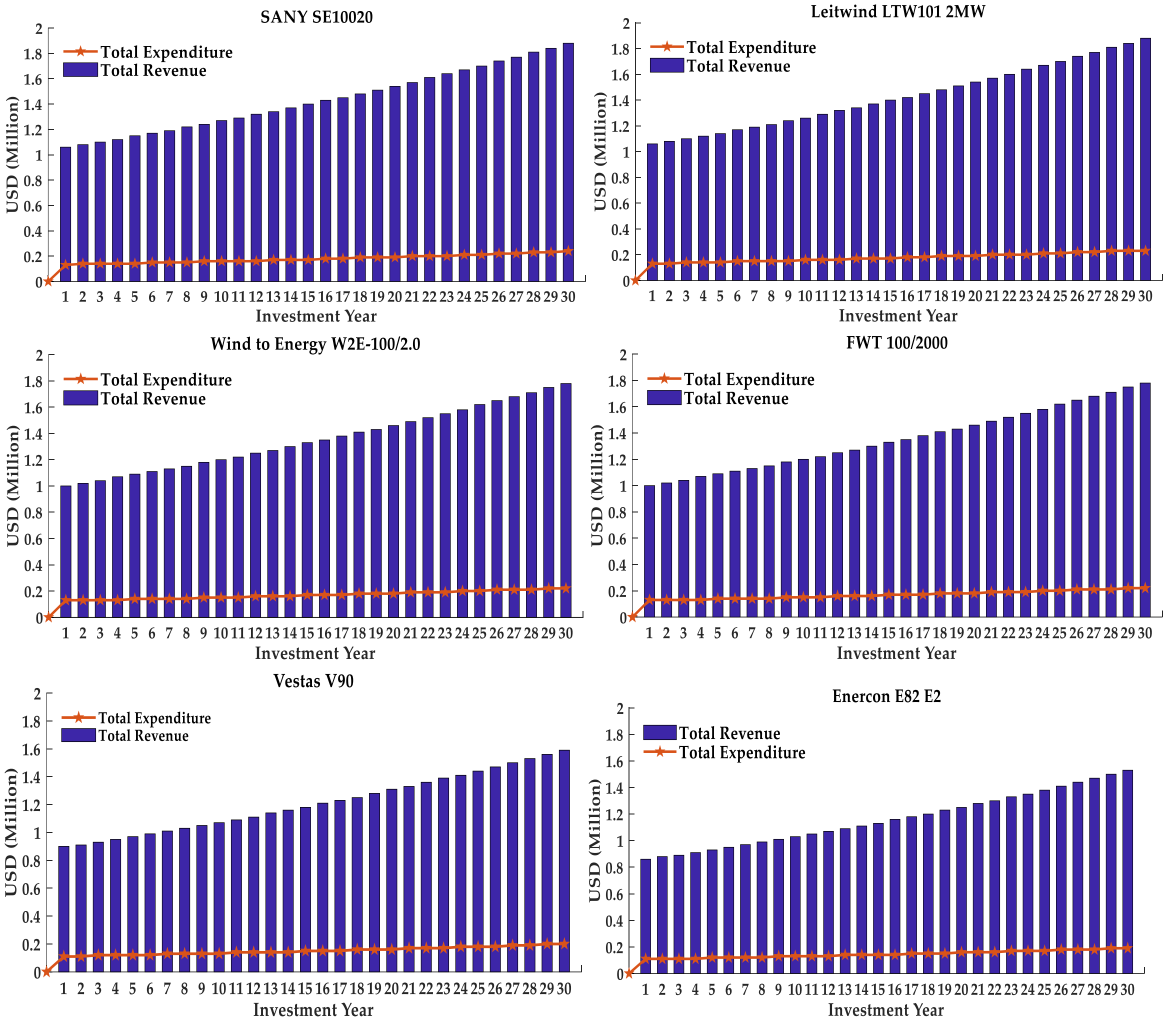

Fig. 12 Shows total revenues vs total expenditures of each turbine

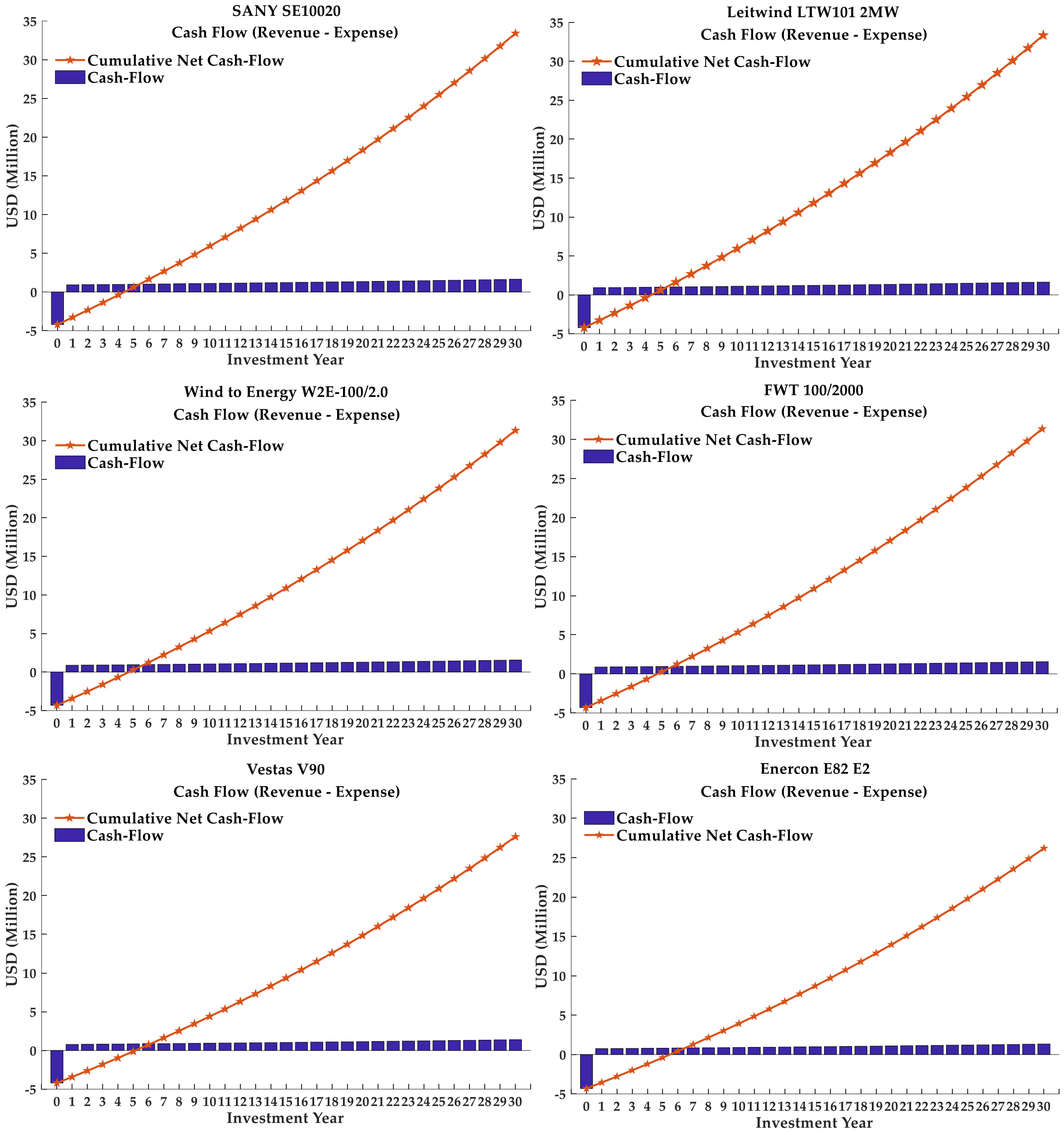

Fig. 13 Shows the cash flow diagram for each turbine over expected life of project

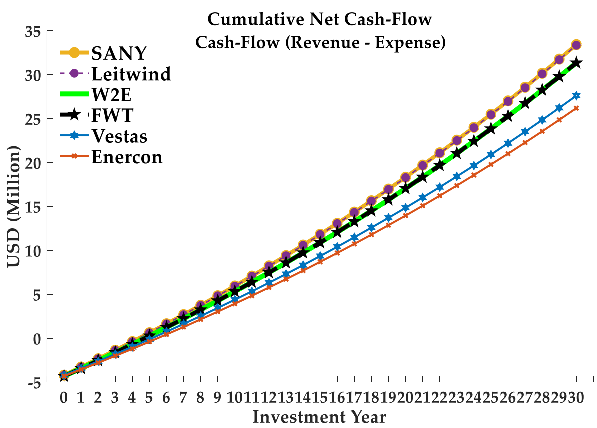

Fig. 14 Shows the cumulative net cash flow of all turbines considered in this study

The payback period analysis is done using equation (11). The SANY, Leitwind, W2E, and FWT gave the highest payback period means the investment will start generating revenues in the initial five years of the investment. Whereas the Vestas and Enercon turbines will start payback from the 6th year of the investment. Fig. 15 shows the payback period of each turbine installed at the proposed site. Similarly, the return on investment is highest for SANY and Leitwind, both with 24% of the investment. W2E and FWT both have 22% ROI. In the case of Vestas and Enercon, they each have 21% and 19%. Fig. 16 shows the rate of return on investment (ROI) for each turbine. Also, the net present value (NPV) for each turbine is in Table IV. The net present value (NPV) for SANY, Leitwind, W2E, FWT, Vestas and Enercon is $33416055,

$33345965, $31342884, $31342884, $27608386 and $26194430.

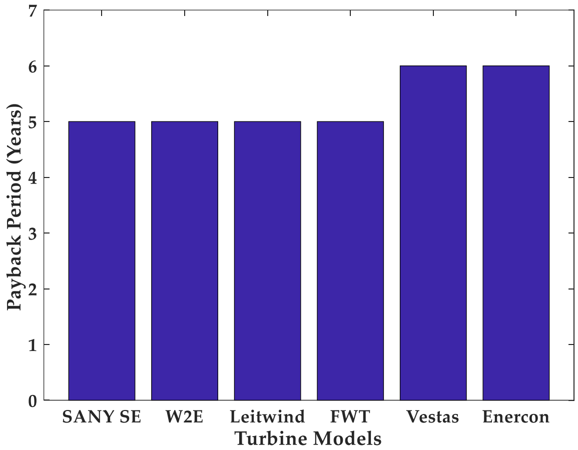

Fig. 15 Shows the payback period for each turbine

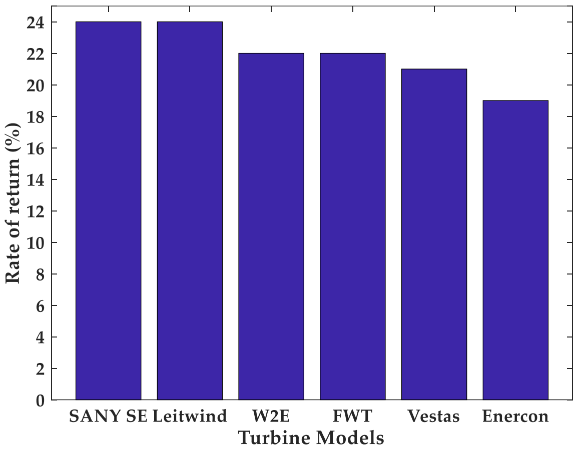

Fig. 16 Shows the rate of return against investment by each turbine

V. CONCLUSION

In this study, large-scale wind turbines are considered for the proposed site that their annual energy production is forecasted. The turbine characteristics should be considered according to the site characteristics for assessment of the wind potential at the studied site. The site has immense wind availability. Site characteristics; three years averaged temperature, air pressure, air density, hub height velocity and power density are 26.2 (ºC), 1008.86 (Pa or N/m^2), 1.17 (kg/m^3), 7.92 (m/s) and 412.9 (W/m^2) respectively. This study is carried out considering the six wind turbines of 2MW~2.05MW. The six turbines are SANY SE10020 (SE), Leitwind LTW101 2000 (LTW), Wind to Energy W2E-100/2.0 (W2E), Fuhrländer FWT 100/2000 (FWT), Vestas V90 (V90) and Enercon E-82 E2 2.0 (E2). The suitable site characteristics and the turbine characteristics are used to find the capacity factor (C_f), power generation (P_{out}), and annual energy production (*AEP*) of each turbine separately. Among six turbines SANY SE and Leitwind LTW have the highest C_f and AEP, followed by Wind to Energy W2E and Fuhrländer FWT. As compared to them, Vestas V90 and Enercon E2 both have low power factors and annual energy yields, but they are also suitable for installation at the proposed site. Their respective capacity factor is 52.36% and 49.31%.

For the feasibility study, two economic analyses were employed; the Levelized cost of energy and the cash flow model. LCOE is used to find the cost of energy generation in $/kWh. The cash flow model is used to study the cash flow and cumulative net cash flow throughout 30 years of project life. Along with this, the cost-benefits per year are estimated. Also, other factors like the net present value, the rate of return on investment, and the payback period are estimated. The AEP, Capital expenditures, operational expenditures, and other financing are inputs to the cost estimation models. These models were discussed in Section III (economic evaluation). Each input was further elaborated where the capital expenditures include the cost of a wind turbine, its transportation, foundation, installation, and share in the construction of a wind farm. While the operational expenditures were considered as a percentage of the capital cost discussed in Section IV. The three years average Levelized cost of energy (LCOE) for each turbine namely SANY SE10020 (SE), Leitwind LTW101 2000 (LTW), Wind to Energy W2E-100/2.0 (W2E), Fuhrländer FWT 100/2000 (FWT), Vestas V90 (V90) and Enercon E-82 E2 2.0 (E2) is 0.0462, 0.0463, 0.0497, 0.0497, 0.0543 and 0.0577 in $/kWh. This implies that the LCOE for each selected turbine is low and least for SANY SE and Leitwind LTW. Along with this, the cash flow model predicted revenues-expenditures in case of each turbine. The net present values (NPV) over the life of the project for stated turbines are $33416055, $33345965, $31342884, $31342884, $27608386 and $26194430. While the respective system payback period in years is 5, 5, 5, 5, 6, and 6, another economic factor, rate of return on investment (ROI) of these turbines is 24%, 24%, 22%, 22%, 21%, and 19%.

Because of these economic indicators, it concludes that this site has the potential for feasible wind energy generation. Such that the factors like costs-profits

Table 4. Gives detail about system payback period, rate of return on investment, and net present value

WT	Payback Period (SPB)	Rate of Return (IRR)	Net Present Value (NPV)
SE	5	24%	$33,416,055
LTW	5	24%	$33,345,965
W2E	5	22%	$31,342,884
FWT	5	22%	$31,342,884
V90	6	21%	$27,608,386
E2	6	19%	$26,194,430

(revenue-expense), cumulative cash flow (revenue-expense), the net present value (NPV), the rate of return on investment (ROI), and the system payback period (SPB), indicates this site is economical. SANY SE and Leitwind LTW turbines have the least LCOE, lowest payback period (SPB), and highest return on investment (ROI). It recommends that a large-scale wind farm installed in this region will increase energy generation and ensure energy security in Pakistan.

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REFERENCES

[1] Most afaeipour A.Productivity and development issues of the global wind turbine industry.JRenew Sustain EnergyRev., 14 (2010) 1048–58.

[2] Duran Sahin A.Progress and recent trends in wind energy progress in energy and combustion.Science., 30 (2004) 501–43.

[3] Tummala, A.; Velamati, R.K.; Sinha, D.K.; Indraja, V.; Krishna, V.H.A review on small-scale wind turbines. Renew.Sustain.Energy Rev., 56 (2016) 1351–1371.

[4] Liu, S.Y.; Ho, Y.F. Wind energy applications for Taiwan buildings: What are the challenges and strategies for small wind energy systems exploitation? Renew. Sustain. Energy Rev., (2016).

[5] Baloch, M. H., Chaudhary, S. T., Ishak, D., Kaloi, G. S., Nadeem, M. H., Wattoo, W. A., ... & Hamid, H. T., Hybrid energy sources status of Pakistan: An optimal technical proposal to solve the power crises issues. Energy Strategy Reviews, 24 (2019) 132-153.

[6] Baloch, M., Abro, S., Sarwar Kaloi, G., Mirjat, N., Tahir, S., Nadeem, M.,& Kumar, M., Research on electricity generation from wind corridors of Pakistan (two provinces): a technical proposal for remote zones. Sustainability, 9(9) 1611.

[7] National Wind Energy Coordinating Committee, Permitting Wind Energy Facilities — A Handbook, NWCC Siting Subcommittee, www.nationalwind.org, March., (1998).

[8] Hussain Baloch, M., Ishak, D., Tahir Chaudary, S., Ali, B., Asghar Memon, A., & Ahmed Jumani, T., Wind Power Integration: An Experimental Investigation for Powering Local Communities. Energies, 12(4) (2019) 621.

[9] De Oliveira, W. S., & Fernandes, A. J., Optimization Model for Economic Evaluation of Wind Farms-How to Optimize a Wind Energy Project Economically and Technically. International Journal of Energy Economics and Policy, 2(1) (2012)10-20.

[10] Hulio, Z.H.; Jiang, W.Site-specific technical and economic analysis of wind power potential and energy generation using Weibull parameters. world.Sci. Technol.Sustain.Dev 15 (2018) 35–53.

[11] Chadee, X.T.; Clarke, R.M. Wind resources and the Levelized cost of wind-generated electricity in the Carib bean islands of Trinidad and Tobago. Renew.Sustain.Energy Rev., 81 (2018) 2526–2540.

[12] Marian, A.; Sedaghat, A.; Mostafaeipour, A.; AkbarAlemrajabi, A.Exploring economy of small communities and households by investing in harnessing wind energy in the province of Sistan-Baluch restrain Iran.Renew.Sustain.EnergyRev., 74 (2017) 835–847.

[13] Cooney, C.; Byrne, R.; Lyons, W.; O'Rourke, F . Performance characterization of commercial-scale wind turbine operating in an urban environment, using real data. Energy Sustain.Dev., 36 (2017) 44–54.

[14] Sundell and, K.M.; Narayana, M.; Putrus, G.; Conlon, M.F.; McDonald, S.The cost of energy associated with micro wind generation: International cases studies of rural and urban in installations. Energy109 (2016) 818–829.

[15] Mohsin, M., Zhang, J., Saidur, R., Sun, H., &Sait, S. M. ., Economic assessment and ranking of wind power potential using the fuzzy-TOPSIS approach. Environmental Science and Pollution Research, 1-18 (2019).

[16] Abbes, M., &Belhadj, J., Wind resource estimation and wind park design in El-Kef region, Tunisia. Energy, 40(1) (2012) 348-357.

[17] Department of Trade and Industry, DTI. Study of the costs of offshore wind generation. A report to the Renewables Advisory Board (RAB) & DTI. URN Number 07/779; (2007b).

[18] Tazi, N., Chatelet, E., Bouzidi, Y., &Meziane, R., Wind farm topology-finding algorithm considering performance, costs, and environmental impacts. Environmental Science and Pollution Research, 25(25) (2018) 24526-24534.

[19] Grieser, B., Sunak, Y., &Madlener, R., Economics of small wind turbines in urban settings: An empirical investigation for Germany. Renewable Energy, 78 (2015) 334-350.

[20] Rodriguez-Hernandez, O., Martinez, M., Lopez-Villalobos, C., Garcia, H., & Campos-Amezcua, R., Techno-Economic Feasibility Study of Small Wind Turbines in the Valley of Mexico Metropolitan Area. Energies, 12(5) (2019) 890.

[21] Mathew, S., Wind energy: fundamentals, resource analysis, and economics (Vol. 1). Berlin: Springer., 1(2006)