Prospects of Wind Farm Development in Algeria

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Abstract: This study utilized wind speed data over a period of almost 10 years between 1977 and 1988 from three stations, namely Adrar, Timimoun and Tindouf in order to assess the energy output for a 30 MW installed capacity wind farm at each site in Algeria, in terms of gross energy, renewable energy delivered, specific yield and wind farm capacity factor. The energy output analysis is done using three WECSs of rated capacity 600, 1000 and 2000 kW. The RETScreen model is used to perform the economical feasibility study of the wind farms at these locations. The study concludes that the wind farm consisting of 30 wind turbines of 1 MW rated power each is more feasible for all sites than using other WECSs. Finally wind park development at Adrar will avoid 45111 tons of greenhouse gases each year and about 1127775 of tons of GHG over the life time of the wind power plant. Similarly, at Timimoun and Tindouf a total of 900925 and 639475tons of GHG could be avoided from entering into the local atmosphere of these stations.

Key words: Wind farm, RETScreen model, Algeria

INTRODUCTION

An accurate wind resource assessment is an important and critical factor to be well understood for harnessing the power of the wind. It is well known that an error of 1% in wind speed measurements leads to almost 2% error in energy output. As we know that wind resources are seldom consistent and vary with time of the day, season of the year, height above the ground, topography and from year to year, hence should be investigated carefully and completely. According to Tennis et al.[1] the wind resource assessment powering a wind farm project is as fundamental to the project's success as rainfall is to alfalfa production. So, one who is interested in a wind farm development should know that how strong are the winds at the site of interest and how much energy will the wind farm produce in these winds. Potts et al.[2] performed the wind resources assessment of Western and Central Massachusetts using Wind Map software which is based on Geographic Information Systems (GIS). The authors utilized wind speed data from five locations and upper air data from one location as input to Wind Map software to produce estimates of wind speed at 50 meter. Brower[3] used GIS based tools to develop wind resource map for New Mexico using wind speed data from 67 stations and elevation data in the region. Rehman[4] presented the energy output and economical analysis of 30 MW installed capacity wind farms at five coastal locations in terms of unadjusted energy, gross energy, renewable energy delivered specific yield and plant capacity factor using wind machines of 600, 1000 and 1500 kW. In another study, Rehman[5] performed a detailed analysis of wind speed in terms of energy yield, effect of hub-height on energy yield, plant capacity factor, etc. for an industrial city situated on the northwest coast of Saudi Arabia. Rehman and Aftab[6] performed detailed wind data analysis for wind power potential assessment for five coastal locations in Saudi Arabia. Rehman et al.[7] computed the cost of energy generation at 20 locations in Saudi Arabia using net present value approach. Rehman and Halawani[8] presented the statistical characteristics of wind speed and its diurnal variation. The autocorrelation coefficients were found to match the actual diurnal variation of the hourly mean wind speed for most of the locations used in the study. Rehman et al.[9] calculated the Weibull parameters for 10 anemometer locations in Saudi Arabia and found that the wind speed was well represented by the Weibull distribution function. With growing global awareness of the usage of clean sources of energy, wind energy in particular, a lot of work is being carried out in different parts of the world, as can be seen from[10-23].

In Algerian context, a company of electricity, SONELGAZ, has used photovoltaic based solar energy to power the isolated villages and remote houses of

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south Algeria. These locations include Adrar, Timimoun (Tala Hamou-Moussa) and Tindouf (Gara Djebilet, Hassi Mounir, Draa el Khadra) as reported by Himri[24]. At present, the SONELGAZ Company is leading the way towards the development and utilization renewable sources of energy in the country in general and wind energy in particular as can be seen from Haddouche *et al.*[25] and SONELGAZ[26]. According to Elimax[27], Algeria is among 15 African countries (South Africa, Eritrea, Mauritania, cap avert, Algeria, Lesotho, Seychelles, Madagascar, Somalia, Djibouti, morocco, Chad, Egypt, Maurice, Tunisia) which have the good potential of wind energy.

This study utilizes the long term wind speed data for three sites, namely Adrar, Timimoun and Tindouf to investigate the economical feasibility of developing wind farms of installed capacity of 30 MW at these sites. The energy calculations and economic analysis were performed using the RetScreen Software.

WIND DATA AND SITE DESCRIPTION

The wind speed data were collected over a period of 8 to 10 years at three sites used in this study. The details of the sites are shown in Table 1.

Table 1: Geographical coordinates of the data collection stations used in the study

Location	Latitude (deg.)	Longitude (deg.)	Altitude (m)
Adrar	27°C 49' N	00°C 17' E	263
Timimoun	29°C 15' N	00°C 17' E	312
Tindouf	27°C 40' N	08°C 06' W	401

Fig. 1: Map showing the locations of the wind measurement stations

The meteorological measurements were made 10 m above ground level and registered every 3 h interval (viz. 0, 3, 6, 9, 12, 15, 18 and 21 h) at all the stations. The wind data measurement stations lie in the south west region of Algeria. The geographical locations of these stations are also shown in Fig. 1.

MATERIALS AND METHODS

The energy yield from a hypothetical wind farm of 30 MW installed capacity is calculated by RetScreen software using the annual average wind speed at hub height and the energy production curve of the wind turbine.

The estimation of wind energy is obtained by taking into consideration the effect of various losses like array, airfoil soiling, icing losses, down time losses and miscellaneous losses are shown in Table 2.

The pressure and temperature adjustment coefficients which effect the energy yield were also considered, are summarized in Table 2. A value of 0.16 for wind shear exponent was used in this study.

The gross energy production and wind energy delivered using wind turbines of rated power of 600, 1000 and 2000 kW are shown in Fig. 2.

It is observed that the maximum gross energy yield, without losses from Adrar, Timimoun and Tindouf was found to 109.371, 87.370 and 62.015 MWh respectively, is produced using the 1000 kW wind turbine. Wind energy delivered also follows the same trends.

Table 2: Wind energy related coefficients used in energy yield estimation

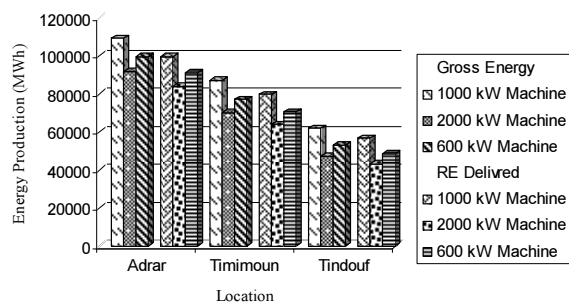| Value	Item
3	Array losses, (%)
2	Airfoil soiling and /or icing losses, (%)
2	Downtime losses, (%)
2	Miscellaneous losses, (%)
0.97	Pressure adjustment coefficient
0.97	Temperature adjustment coefficient
0.16	Wind shear exponent

Fig. 2: Energy production using different WECS

The highest values of the specific yield are obtained at Adrar for all the WECSs as shown in Fig. 3. The plant capacity factors obtained for all WECs at all the sites are shown in Fig. 4.

Higher capacity factor of 38 is obtained at Adrar while they fall between 30-22 at two other locations for a WECS of 1000 kW.

The RETScreen model also calculated the reduction of GHG as a result of using wind as a source of energy to generate electricity. The resulting values of GHG per year at all locations are resumed in Fig. 5.
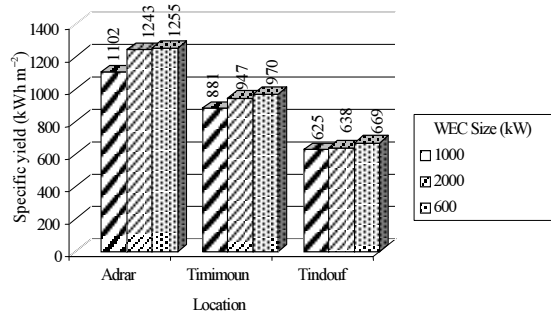
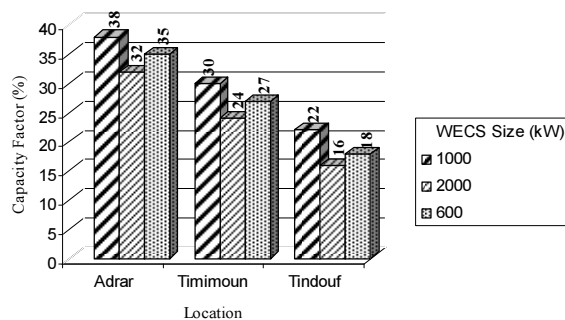Fig. 3: Comparison of specific energy yield from different WECS

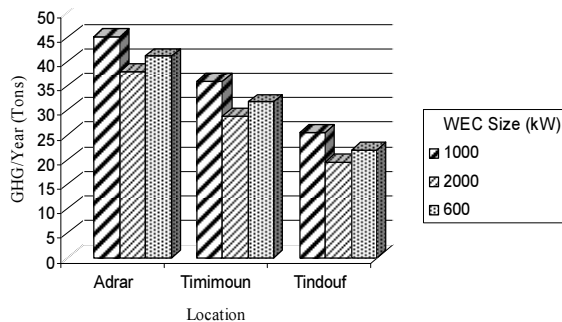Fig. 4: Comparison of plant capacity factor computed for each location

Fig. 5: Comparison of reduction in greenhouse gases per year

Using 30 WECSs of 1000 kW rated power at these sites (Adrar, Timimoun and Tindouf) will result in a reduction in greenhouse gases of 45 111, 36 037 and 25 579 tons each year respectively from entering into the local atmosphere thus creating a clean and healthy atmosphere for local inhabitants.

WIND ENERGY ECONOMICAL ANALYSIS

The Retscreen model is capable of performing a detailed economical analysis of the wind energy yield using some cost and interest parameters such as discount and inflation rates, GHG emission reduction credit, project life, energy cost escalation rate, etc. The inflation and discount rates of 2.5 and 12%, used in the present study, along with other cost parameters are resumed in Table 3.

The feasibility study on renewable energy equipment including the wind machine and tower, balance of plant, development, engineering, miscellaneous and operation and maintenance costs are shown in Table 4.

In all the calculations, the same values are used for all sites. As seen in this Table, the major cost of US $ 38 010000 correspond to a WECS of 600 kW machines and is about 77.1% of the total project capital cost.

The economic feasibility study is performed in terms of the pre-tax Internal Rate of Return (IRR) and Return On Investment (ROI), the after tax values, simple pay back period (SPP), Net Present Value (NPV), annual life cycle saving (ALCS), Year to Positive Cash Flow (YPCF) and benefit cost ratio (B-C).

The IRR for all the locations using three different types of WECS in shown in Fig. 6

It indicates that the project of 30 MW installed capacity for all types of WECS is feasible for all sites. For a WECS of 1000 kW size the pre-tax Internal Rate of Return (IRR) and Return On Investment (ROI) was found to be 62.7, 45.6 and 26.8% for Adrar, Timimoun and Tindouf sites, respectively. The after tax values were also found to be the same as pre-tax values of IRR and ROI.

Table 3: Summary of economic input parameters for cost analysis[28]

Value	Items
0.0950	Avoided cost of energy, ($/kWh)
0.025	RE production credit, ($/kWh)
10	RE production credit duration, (year)
2.5	RE credit escalation rate, (%)
5	GHG emission reduction credit, ($/$t_{co2}$)
21	GHG reduction credit duration, (year)
0	GHG credit escalation rate, (%)
5	Energy cost escalation rate, (%)
2.5	Inflation, (%)
12	Discount rate, (%)
25	Project life, (year)

Table 4: Cost breakdown of wind farm development elements (US$)

WECS cost items	600 kW		1000 kW		2000 kW	
	Cost	(%)	Cost	(%)	Cost	(%)
Feasibility study	195200	0.4	195200	0.4	195200	0.4
Development	770500	1.6	770500	1.6	770500	1.6
Engineering	610500	1.2	610500	1.3	610500	1.3
Energy equipment	38010000	77.1	37350000	77.6	36855000	77.4
Balance of plant	6000000	12.2	5593000	11.6	5593000	11.7
Miscellaneous	3715275	7.5	3628305	7.5	3587972	7.5
O and M costs	537531	-	537470	-	748442	-
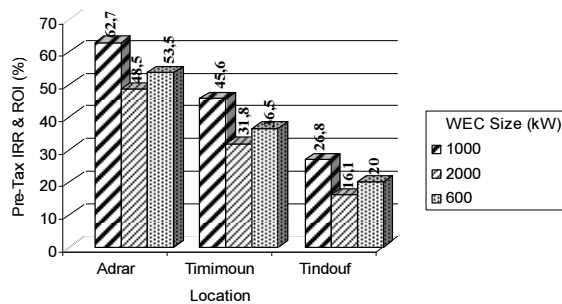
Fig. 6: Pre-tax Internal Rate of Return (IRR) and Return On Investment (ROI)

Fig. 7: Net Present Value (NPV) for discount 12%

Fig. 8: Comparison of Simple Payback Period (SPP) for Wind Park project using three different wind machines

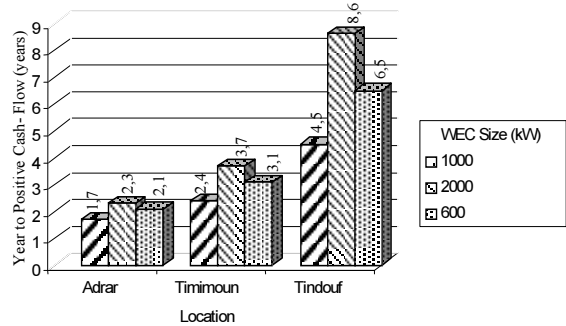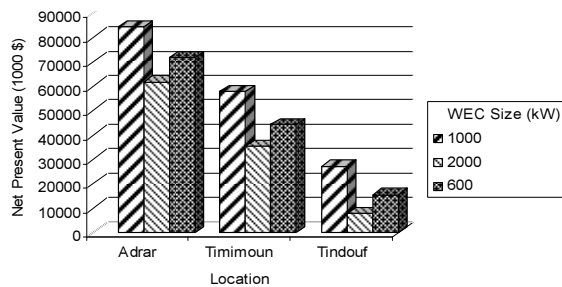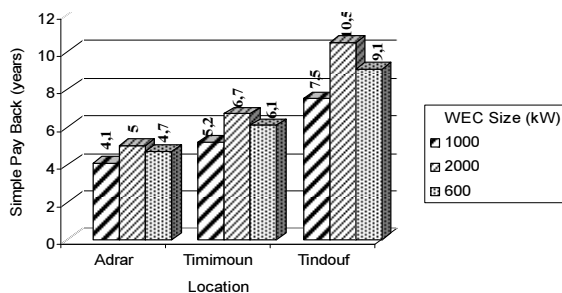Positive values of NPV demonstrate that the project is feasible. The NPVs calculated using the discount rate at 12%. As shown in Fig. 7.

Fig. 9: Number of Years to Positive Cash Flow (YPCF) for wind farms developed using three different types of WECS

The project is feasible for all sites and for all types of WECS considered. For 1000 kW machines the net present value for Adrar, Timimoun and Tindouf were found to be US $ 84 229 957, 57 781 209 and 27 300 034, respectively.

Shorter payback period means a desirable investment. Appositive case would be an indication that the annual costs incurred are higher than the annual savings generated. The SPPs calculated by the RETScreen model for all the wind parks are shown in Fig. 8.

Shorter SPPs are found for wind parks developed using 1000 kW wind machines. The minimum payback periods of 4.1, 4.7 and 5.0 years are found for wind park projects at Adrar corresponding to WECSs of 1000, 600 and 2000 kW rated capacity respectively.

At other locations, these periods were found to be of the order of 5 or more years. It's the same tendency for the YPCF as shown in Fig. 9.

The ALCS were found to be positive at all the locations for all the WECSs as seen in Fig. 10.

The B-C which is the ratio of the net benefits to costs of the project. Ratios greater than 1 are indicative of profitable projects. As shown in Fig. 11. The B-C values are found to be positive for all WECSs at all sites.
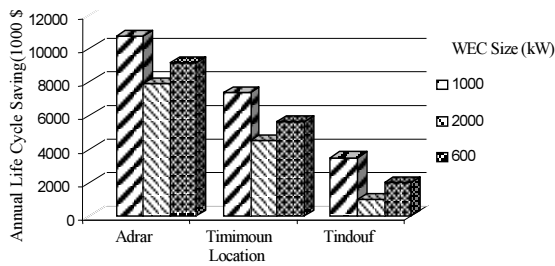
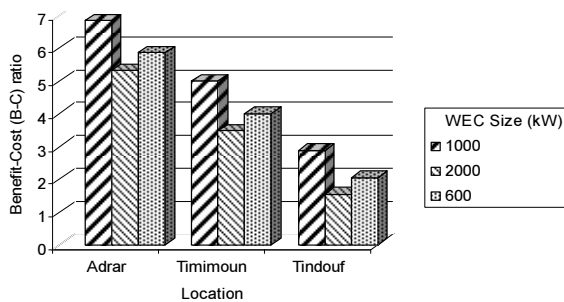Fig. 10: Annual life cycle saving (ALCS) for discount rate of 12%

Fig. 11: Comparison of benefit cost (B-C) ratio at all locations for discount of 12%

CONCLUSION

The economic analysis developed in this article shows that the wind farm consisting of 30 wind turbines of 1 MW rated power each is more feasible for all sites compared to the other WECSs.

The study found the following salient features as the outcome of the analysis:

- Wind farms of 30 MW installed capacity at Adrar, Timimoun and Tindouf, if developed, could produce 99 851, 79 765 and 56 617 MWh of electricity annually taking into consideration the temperature and pressure adjustment coefficients of about 6% and all other losses of about 10%, respectively

- It was noticed such a development at these sites could result into avoidance of 45 111 tons of greenhouse gases from entering into the local atmosphere of Adrar each year and about 1127775 of tons of GHG over the life time of the wind power plant. Similarly, at Timimoun and Tindouf a total of 900925 and 639475tons of GHG could be avoided from entering into the local atmosphere of these stations

- The plant capacity factors at Adrar, Timimoun and Tindouf were found to be 38, 30 and 22%, respectively

- The economical feasibility study made based on the assumed economical parameters from the literature, showed that the positive cash flow could be obtained in 1.7, 2.4 and 4.5 years at Adrar, Timimoun and Tindouf, respectively with corresponding benefit cost ratio (B-C) of 6.83, 5.00 and 2.89

ACKNOWLEDGEMENT

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