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ModellingThe Performance Of Wind Energy Conversion System At Potential Wind Farm Sites In Kerala

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Abstract:-Due to the energy crisis and growing environmental consciousness, the global perspective in energy consumption is shifting towards sustainable resources and technologies. Hence wind energy is going to be a major source of the global energy demand from renewable and sustainable resources. India ranks fifth in the world in terms of global wind power capacity. Though Kerala has an estimated wind power potential of 1000 MW at 50 m level, the installed capacity in the state is only 32 MW. Hence, the power base of the state can be strengthened by exploiting the available renewable energy resources. Seven sites from different districts are selected for analysis. The Wind Energy Resource Analysis (WERA) program is used for analyzing the wind energy potential and estimating the performance of a Wind Energy Conversion System (WECS) at the site. For wind energy economics analysis the Eco-REN software is used .Different input parameters like rated power, capital investment, life span, capacity factor, operation and maintenance cost, discounting rate and electricity cost are used to produce the outcome. Among the selected sites, Kanjikode is most suitable to install wind turbines with minimum capital investment and with a payback period of 2-5 years.

Keywords:-Wind velocity,WERAmodel,ecoRENandcapacity factor.

I. INTRODUCTION

It has been identified that the excessive use of energy - which is mainly derived from fossil fuels today - can cause irreversible environmental ill effects. On the other hand, these energy resources are running out at a frightening rate. With this energy crisis and growing environmental consciousness, the global perspective in energy generation and consumption is shifting towards sustainable resources and technologies. Judicious use of the available conventional energy forms, along with the utilization of new and renewable energy resources are the viable ways towards a sustainable and secure energy future.

With its global installation of over 235 GW (EWEA, 2012), wind is emerging as the fastest growing energy source in the world. Wind power could register an annual growth rate of over 25 per cent for the past seven years and several Multi-Megawatt projects-both on shore and offshore-are in the pipeline. India ranks fifth in the world in terms of global wind power capacity. Though Kerala has an estimated wind power potential of 1000 MW at 50 m level (ANERT 2012), till date, the installed capacity in the state is only 32 MW. Performances of these installed systems are very impressive with the plant load factor ranging from 21.92 to 31.9 per cent.

Keeping these in view, an investigation titled "Modeling the performance of Wind Energy Conversion System (WECS) at potential wind farm sites in Kerala" has been formulated and undertaken. The major objectives of the projects are:

1. To characterize wind resource available at the some potential wind farm sites in Kerala.
2. To simulate the performance of different wind energy conversion systems at these sites using WERA model.
3. To analyse the economics of Wind Energy Conversion Systems at these sites with the economic model "ecoREN".

II. MATERIALS AND METHODS

A. Materials

1) Wind Resource Analysis

For a concrete wind energy resource analysis, seven sites from Kerala state (Fig.2.1) were initially identified and wind data collected by Mani, A (1994) has been taken as the indirect yardstick for this program. Among these sites one station comes under strong category (20-25kmph) and four sites under moderate category (10-15kmph) and the remaining one under light category (<10kmph).

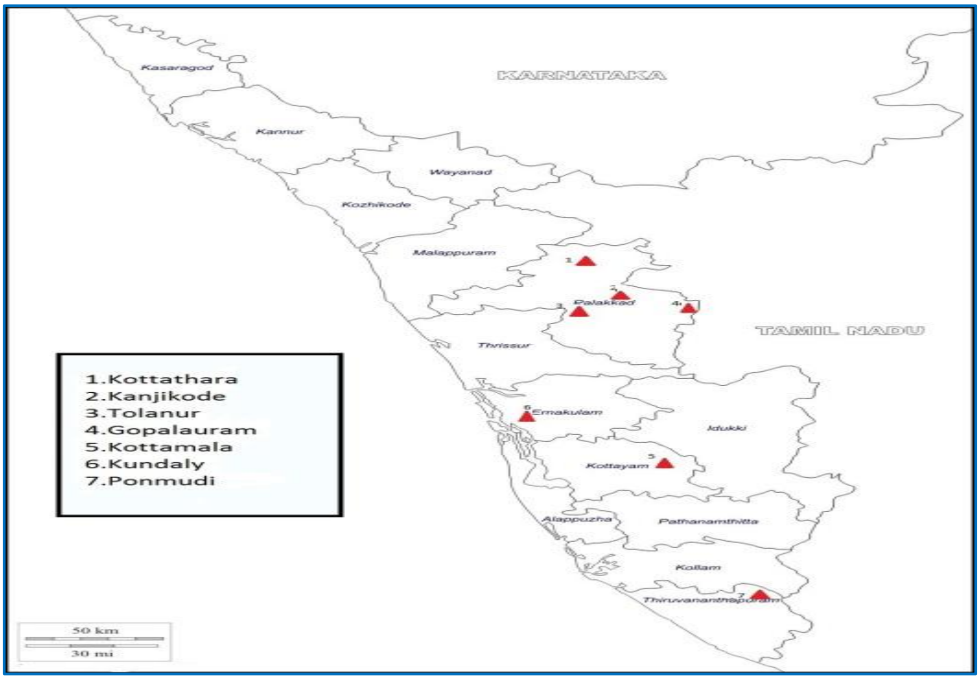

Fig. 2.1: Selected sites for wind analysis

2) Presentation and interpretation of wind data

The wind data available at these meteorological stations have been logged from different sensor heights (10m and 20m) as per the recommendations of the World Meteorological Organization (WMO). In wind energy calculations, the velocity available at the rotor height (100m) can be obtained by extrapolating to other heights on the basis of the roughness height of the terrain. Following data were recorded: 1) Hourly mean wind seed, 2) Peak wind seed and the time of occurrence on a monthly basis, 3) Duration of the longest lull 4) Frequency distribution for wind speed and direction for each month.

B. METHODS

1) Determination of proposed rotor height

Due to the boundary layer effect, wind speed increases with the height in a logarithmic pattern. Frequency distribution of wind data can be statistically analysed by the Weibull distribution and for this distribution,

$$f(V) = \left(\frac{k}{C}\right)\left(\frac{V}{C}\right)^{k-1} e^{-\left(\frac{V}{C}\right)^{k}} \text{ ………………………….. (3.1)}$$

$$F(V) = \int_0^{\infty} f(V)dv = 1 - e^{-\left(\frac{V}{C}\right)^{k}} \text{ ……………………. (3.2)}$$

Where:

k - Weibull shape factor

C - Weibull scale factor

If the wind data is available at a height Z and the roughness height is Z_0, then the velocity at a height Z_R is given by

$$V(ZR) = V(Z)\frac{ln\left(\frac{Z_R}{Z_0}\right)}{ln\left(\frac{Z}{Z_0}\right)} \text{…………………. (3.3)}$$

Where V (Z_R) and V (Z) are the velocities at heights Z_R and Z respectively.

$$V(Z_R) = V(Z)\frac{ln\left(\frac{Z_R}{Z_0}\right)}{ln\left(\frac{Z}{Z_0}\right)} \text{or} \frac{V(ZR)}{V(Z)} = \frac{ln\left(\frac{Z_R}{Zo}\right)}{ln\left(\frac{Z}{Z_0}\right)}$$

Then,

$$Z_0 = e^{\frac{\left(\frac{V(Z_0)}{V(Z)}lnZ - ln\,Z_R\right)}{\left(\frac{V(Z_R)}{V(Z)}-1\right)}} \text{ ……………….. (3.4)}$$

Using wind data at 10 m and 20m for all the sites, Z_o for all the months for a station can be determined by this equation.

2) Effect of proposed tower height on the velocity

Wind velocity increases with height due to wind shear. Rate at which the available power increases with height depends on the surface roughness of the ground.

3) Effect of tower height on the capacity factor

In tune with the increase in velocity, capacity factor of the turbine also improves. Apart from the increase in wind velocity, better matching between the wind spectra and the turbine also improves the capacity factor.

4) Effect of tower height on the cost

Towers account for around 20 per cent of the total systems cost. At present, cost of every additional 10 m of tower is approximately Rupees 7.5 lakhs. This means that, while we increase the tower height from 10 and 20 m to 100 m, the system cost would shoot up to manifold. This additional cost can be justified by the improvement in system performance.

5) Simulation of the wind data performance using "WERA" model

The Wind Energy Resource Analysis (WERA) program is based on the Analysis of wind regimes and performance of wind energy conversion systems. WERA can be used for:

(1) Analyzing the wind energy potential at a given site.
(2) Estimating the performance of a Wind Energy Conversion System (WECS) at the site.
(6) Economics of wind energy conversion systems

Economic issues of wind energy systems are multidimensional and this has to be obtained by using the software Eco-REN

C. Factors influencing the wind energy economics

1) Site specific parameters

Energy available in wind spectra is proportional to the cube of the wind speed. Hence, the strength of the wind spectra available at the project site is one of the critical factors deciding the cost of wind generated electricity. Cost of land, installation charges and labor wages vary from place to place. Expenditure on foundation depends on the strength of soil profile as well as the extreme loads expected at the site. In case of grid connected systems, a major concern would be the distance from turbine to existing grid as the cost of developing additional transmission network should also be taken into our calculations. Transportation also affects the expenditure. As the wind velocity increases with height, taller towers generally produce more power and hence also the cost. Local climatic conditions like high turbulence also influence the wind energy economics. Further, presence of corrosive and other harmful substances in the atmosphere reduces life span of the turbine. Frequent maintenance may be necessary due to these factors, which in turn would increase the system's operational and maintenance costs.

2) Machine parameters –Effect of cost reduction through scaling up

Cost of the wind turbines can be considerably reduced by scaling up the system size. Thus, transition of wind energy technology from small units in the earlier days to the MW capacity machines today, has resulted in reducing the cost of wind-generated electricity.

3) Wind Economics analysis using the computer programme "EcoREN"

One of the major factors limiting the wide spread acceptance of many renewable energy technologies is the high generation cost. However, with today's technology and institutional support, wind energy is economically competitive with other conventional sources like coal and natural gas. For the convenient tool for wind energy economics analysis, **Eco-REN** software is used**.** It is a decision **s**upport system for the economics appraisal of renewable energy projects. This is developed under the Energy Resource Programme University of Brunei Darusslam, based on the models of Sathyajith Mathew (2006).

III. RESULTSAND DISCUSSIONS

A.Wind Resource Analysis

Wind velocity and hence wind power is affected by the surface roughness of the ground, wind shear, wind turbulence, acceleration effect and time variation. These parameters will help to detect economically viable and technologically feasible wind energy conversion systems for that location. Geographical details and wind classification of these sites in Kerala are given in Table 3.1.

Table 3.1 Details of the sites selected for wind farm resource analysis

Sl.No	Location of site	Latitude (˚N)	Longitude (˚E)	Altitude > MSL (m)	Wind classification	Wind speed (km/h)
1.	Kanjikode	10.47	76.49	130	Strong	22.3
2.	Kottathara	11.65	76.02	529	Moderate to strong	19.4
3.	Ponmudi	8.36	77.00	912	Moderate to strong	18.1
4.	Kottamala	10.85	76.27	700	Moderate to strong	18.7
5.	Tolanur	10.70	76.50	114	Moderate to strong	15.9
6.	Gopalapuram	13.25	80.15	105	moderate	14.7
7.	Kundly	10.49	71.68	95	Light	9.1

1) Effect of wind velocity over time variation

Fig 3.1 shows the variation of wind velocity over time of the Kanjikode site. From the graph the maximum wind velocity is obtained in the month of June to August and minimum velocity is obtained at the month of October and November.

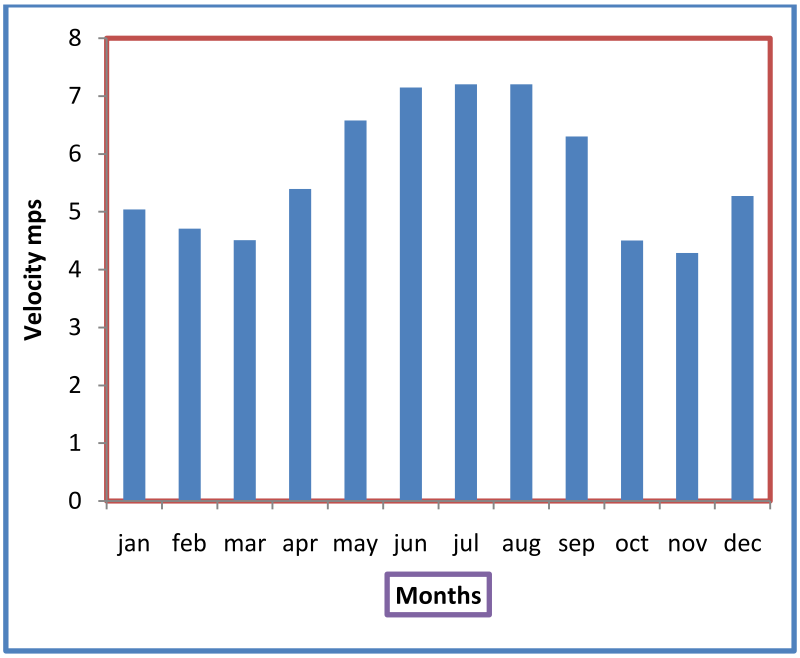

Fig. 3.1:variation of wind velocity over time of Kanjikode site

The wind data collected from the seven selected sites were graphically plotted with the probability distribution curve. Weibull distribution is used to study the wind characteristics. The wind characteristic of these sites described by probability density and cumulative distribution function of the prevailing wind spectra in one location are shown in Fig. 3.2.

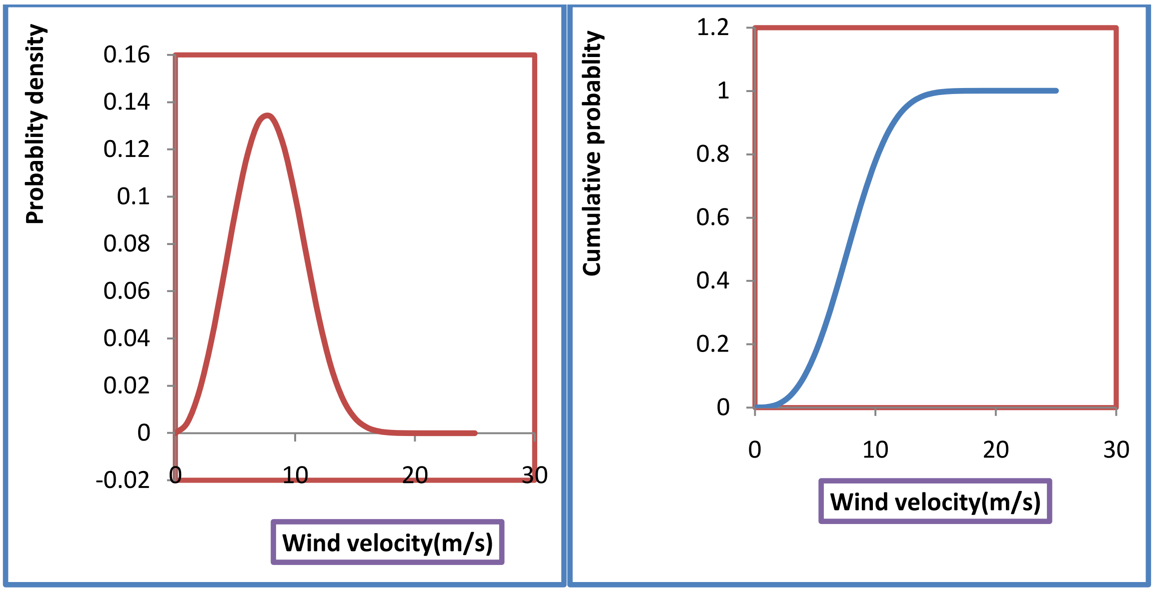

Fig.3.2:Probability and cumulative distribution curves at Kanjikode

Peak of the probability density curve indicates the most frequent wind velocity at the regime. Similarly, the cumulative distribution functions indicate the fraction of time for which the velocity is above a given value in the regime. Indication on the time for which a given turbine is functional could be deduced from the cumulative distribution function. Weibull distribution curves of these sites showed the wind energy content of the locations. Maximum energy density is found to be at Gopalapuram (0.16kW/m^2) and minimum at Tolanur and Kottathara (0.1kW/m^2).

2) Variation of wind velocity on the power

The wind velocity is the one of the major component which affects the power generation from the wind turbine. The wind velocity of a location mainly depend on the topographical features of the land such as the obstructions, surface friction etc. The generation of power is proportional to the cube power of wind velocity (Fig 3.3).

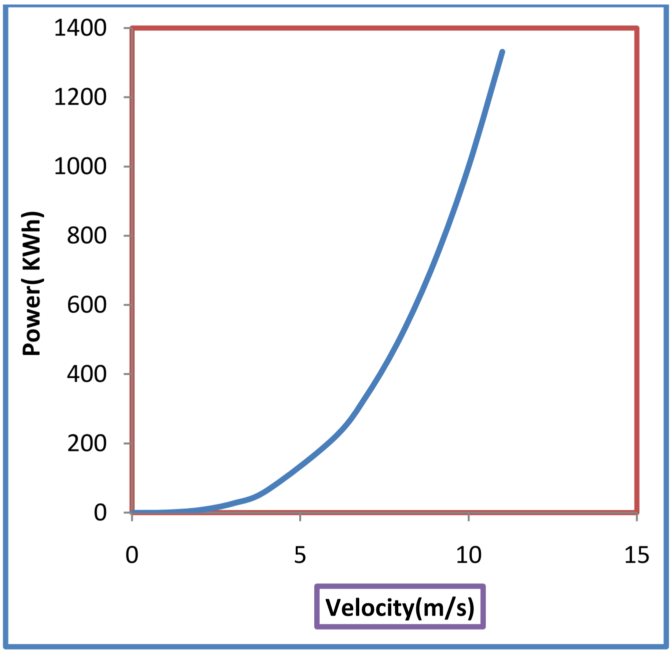

Fig.3.3:Variation of wind velocity on the power

3) Estimation of wind velocity at different locations at 100m height V (Z_R)

The wind velocity for 10m and 20m height are to be converted to corresponding values for 100m height. Both the velocity at 10m and 100m are graphically represented in Fig. 3.4.

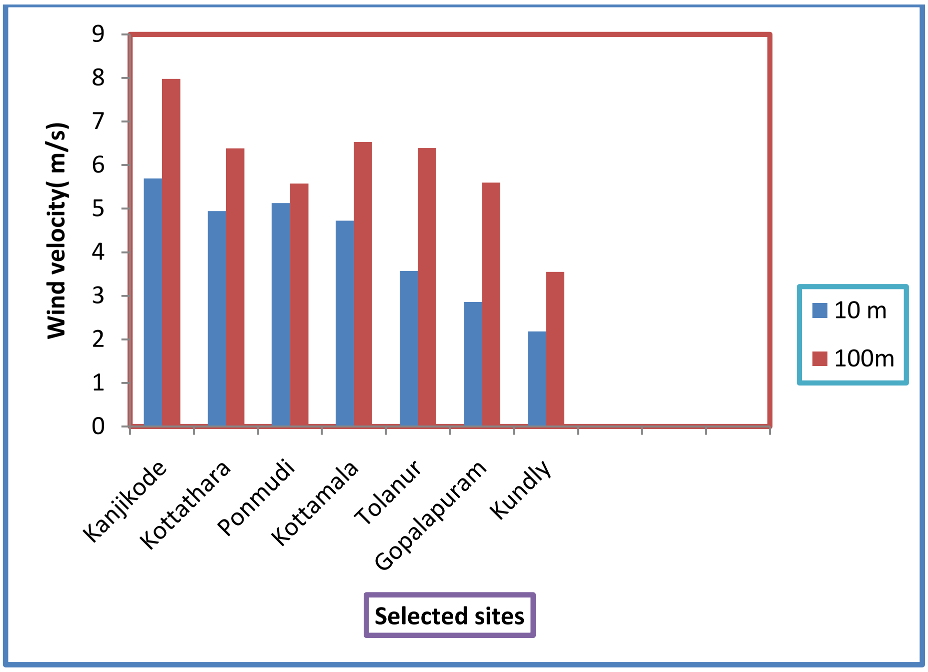

Fig. 3.4:Wind velocity at different height of selected sites.

4) Variation of capacity factor on the tower height

The capacity factor reflects how effectively the turbine could harness the energy available in the wind spectra. In tune with the increase in wind velocity, capacity factor of the turbine also increases (Fig 3.5). Apart from the increase in wind velocity, better matching between the wind spectra and the turbine also improves the capacity factor. When we compare both 10m and 100m, we can perceive a clear distinction of 40-60 % hike in capacity factor. A capacity factor of 0.4 or higher indicates that the system is interacting with the regime very efficiently and it is well understood after 90m of tower height.

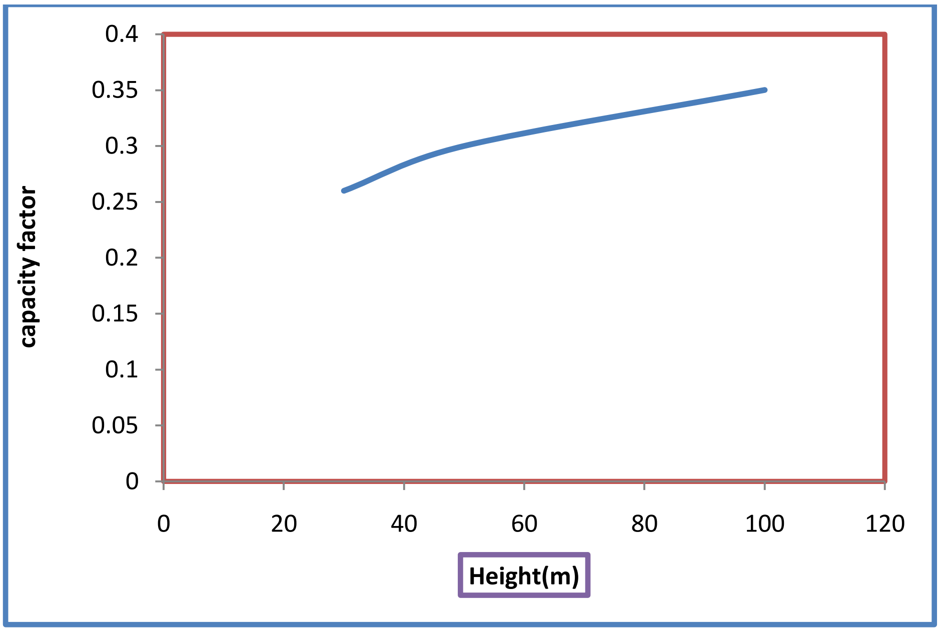

Fig. 3.5: Variation of capacity factor on the tower height.

B. Wind Energy Resource Analysis at the Selected Sites Using WERA model

The energy potential of wind spectra available at 7 prospective sites were analyzed using the WERA model. The Weibull parameters k and C are displayed along with mean wind velocity and standard deviation of seven sites in Table 3.2.

Table 3.2 Wind characteristics of the selected sites

Location	Mean velocity(m/s)		S D (σV) (m/s)		Weibull shape factor (k)	Scale Factor (C)
	10m	20m	10m	20m		
Kanjikode	5.69	6.19	2.08	2.12	3	8.73
Kottathara	4.94	5.38	2.29	2.47	1.8	7.86
Ponmudi	5.12	5.26	2.91	2.88	1.4	6.08
Gopalapuram	2.88	3.55	1.35	1.57	3	7.27
Kottamala	4.72	5.26	2.49	2.07	2.1	7.68
Tolanur	3.57	4.28	2.15	2.21	1.3	8.15
Kundly	2.18	2.51	1.57	1.86	1.3	4.38

In order to simulate the performance of the turbines for the seven sites the WERA wind turbine module was used. Technical specifications of the turbines in terms of cut-in, cut-off and rated velocity along with rated capacity were punched in to turbine specification forms of the programme.

C. Wind Economics analysis using the computer programme "Eco-REN"

Economic analysis of every energy resource is mainly focused on its beneficial side in future. As the capital investment required for WECS is proportional to the rotor area, this will increase the unit cost of energy produced. Wind economics study is more convenient and accurate by using the computer programme "Eco-REN". Different input parameters like rated power, capital investment, lifespan, capacity factor, operation and maintenance cost, discounting rate and electricity cost are used to produce the outcome. We acquire the output in the form of Net present value, Benefit cost Ratio, and Payback period. From this output, the liability of the wind energy consumption of the particular location can be interpreted.

IV. CONCLUSION

Today, fossil fuel based power plants, contributing more than seventy per cent to our energy needs. These plants pollute the atmosphere with harmful gases and particulates. As per the estimates of the International Energy Agency (IEA), 23683Mt of CO has been released to the atmosphere by the power sector during 2010. With the increase in energy demand, level of environmental pollution caused by the power sector is expected to increase further in the coming years. Hence a clean energy policy has to be evolved for the sustainable world. Renewable energy sources do not pollute the air or water with harmful gases and materials, nor does it generate hazardous wastes. Being a non depletable source, extracting energy from wind does not pose the threat of over exploiting the limited natural resources. Wind is considered as one of the cleanest sources of energy available today.

The wind regime analysis of seven selected sites was done. The WERA model has been validated using wind data of selected sites. Economics of wind energy conversion systems at these sites was estimated using 'Eco-REN' software. Based on economic viability, the 3MW turbine was finally selected for the wind farm activity. The maximum energy yield is estimated as 8437421 MWh for wind site at Kanjikode with minimum capital investment and with a payback period of 2-5 years. Then from this study, it is concluded that Kanjikode is more preferable for installing wind turbines.

REFERENCES

[1] AnnaMani.1994.WindEnergyResourceSurveyinIndia.Vol.I.Allied Publishers Limited,New Delhi: 419-472.

[2] AnnaMani.1994.WindEnergyResourceSurveyinIndia.Vol.II.Allied Publishers Limited,New Delhi: 419-472.

[3] AnnaMani.1994.WindEnergyResourceSurveyinIndia. Vol.III.Allied PublishersLimited,NewDelhi: 419-472

[4] Mathew, S., AnilKumar, V.R. and Rao, M.D. 2004. Performance analysis of WECS usinWERAmodel.Proceedings of 8th World Renewable Energy Congress, Colorado, USA.

[5] Mathew, S.2006.Wind Energy-Fundamentals, ResourceAnalysisand Economics.Springer Publication, Germany: 1-233

[6] MNRE (2012). Retrieved fromhttp://www.mnre.gov.in/mission and-vision-2/achievements