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Wind Energy Resource Assessment and Feasibility Study of Wind Farm in Kaligandaki Riverbank of Mustang District

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Abstract

This study presents wind energy resource assessment and financial analysis of a 15 MW wind farm in Mustang for utility scale power generation. Hourly meteorological data at Kagbeni and Thini measured at 10 m and 20 m height from 2001 to 2005 have been analyzed and annual average wind speed and power density at 75 m above ground level at Kagbeni 8.05 m/s and 851 W/m^2 whereas the same for Thini are 6.99 m/s and 337 W/m^2 respectively.WAsP analysis showed that the wind speed and wind power density in the study area (20 × 20 km^2) varied from 2.72 m/s to 44.51 m/s and 0.23 kW/m^2 to 173.27 kW/m^2. Optimized layout of a 15 MW wind farm that comprised of twenty five S52 -600 kW turbines, developed by open Wind software yields annual gross energy 63.58 GWh, and net energy 41.66 GWh with capacity factor of 31.68 %. The economic analysis of the farm suggests that the unit energy cost stands on range NRs 4.57 to NRs 6.10 under different energy availability scenario to meet the project MARR of 16.1%. Based on the results, it is apparent that the wind resources at Mustang are suitable for harnessing wind energy especially for the purpose of utility scale electricity generation. Site accessibility is a major challenging factor to establish a wind farm currently.

Key words : WAsP, wind energy, wind farm

Introduction

Nepal, without proper wind energy resource assessment and detail technical analysis for the wind power development, already faced a bitter experience in the wind energy sector when initiative undertaken by the Nepal Electricity Authority (NEA) in 1989 to produce power through wind energy by installing two wind generators of 10 kW capacities, which got a jolt within three months of the project commencement (DANGRID, 1992). This act as a major barrier for the wind power development in Nepal and regarded as a wasteful resources and no one is interested in the investment in wind energy sector.

Solar and Wind Energy Resource Assessment (SWERA) project a first of its kind in Nepal was conducted by Alternative Energy Promotion Center (AEPC) in joint in-country partnership with Center for Energy Studies, Institute of Engineering, Tribhuvan University. SWERA has made attempt in wind energy resource assessment of the whole country specially focusing the buffered area within the grid connection and a separate study for the Annapurna Conservation Area(ACAP) with the limited wind data and this analysis shows that 3000 MW of electricity could be generated from wind energy with consideration of 10% of area within the boundary of 10 km from current national grid and with more than 300 W/m^2 wind power density in Nepal (SWERA 2008).

Except the study made by SWERA, there is no any other intensive study related to wind energy and its resource assessment in Nepal. SWERA report is only limited on the meso-scale energy estimation from the installed wind anemometers in different sites of Nepal. Government of Nepal has planned to produce 20 MW electricity from wind energy near by Kathmandu valley in its budget, AEPC is collecting wind data from various stations across the country. But a study focusing on any specific site for the potentiality and establishment of wind farm in specific location, its impact on grid integration has yet to be done. Similarly there is no study in the optimum energy production from the wind farm and its technical and economical evaluation of the wind farm in Nepal. In such a scenario a detail analysis in constructing the wind farm in the recommended site is very necessary and this study aims to annual energy production estimation from the specific site and detail technical and financial analysis in developing wind farm in the particular site.

Methodology

This study basically focuses on quantitative approach for the wind data analysis and energy resources assessment and qualitative analysis of the results obtained from the results of various software tools. Following methods and materials have been adopted during the study:

a. Literature review on the concerned subject.
b. wind data analysis: data collection, data validation and processing, presentation of results (wind rose, seasonal, annual, inter annual, monthly, etc. variation of the wind speed).
c. GIS study and site suitability.
d. Wind mapping for the site.
e. Turbine selection, siting and micrositing.
f. Energy production estimation.
g. Development of optimized layout of a wind farm.
h. Financial analysis.

Site Location

For the study purpose the site was selected in the mustang district. The focus area for this research has taken a matrix of 20×20 km^2 near the periphery of the following two wind mast station. These two sites are located near the bank of Kaligandaki riverbank. Thini wind mast is very near to the Jomsom, headquarter of mustang district whereas Kagbeni is 8.2 km northern to the Thini on the way to upper mustang.

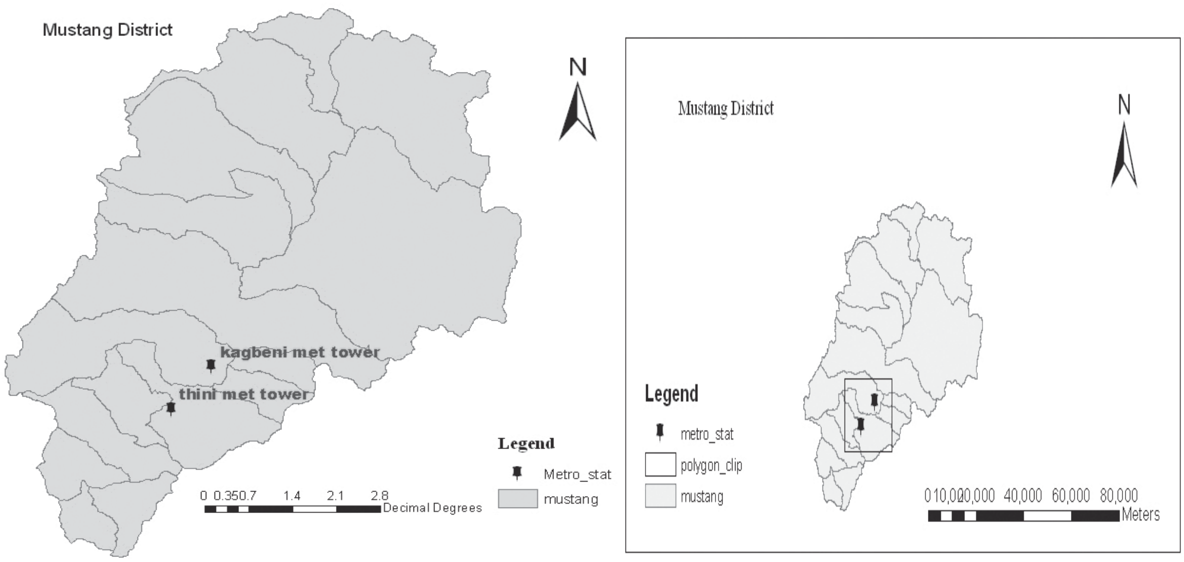

Fig. 1. study area location map

Results and Discussion

Data validation and recovery

In this study the data collected by AEPC from April, 2001 to December 2005 have been analyzed. All raw wind data were subjected to a series of tests and filters to weed out data that are faulty or corrupted. The gross percentage of data recovered (ratio of the number of raw data points received to data points expected) and net availability (ratio of data after filtration test to number of raw data points) are shown in Table 1.

From this result the data availability at Kagbeni at 20 m in 2005 and in Thini in 2001 are very less as compared to other years. Hence these data are discarded for the further analysis.

Table 1. Gross and net availability of wind data

Year	Kagbeni wind mast (m) (%)				Thini wind mast (m) (%)			
	Gross recovery		Net availability		Gross recovery		Net availability	
	10	20	10	20	10	20	10	20
2001	70.96	70.96	70.74	70.43	21.88	21.88	21.75	21.63
2002	80.92	80.92	80.25	80.38	84.75	81.39	84.32	77.27
2003	97.68	97.68	97.18	96.78	94.55	94.55	93.78	93.26
2004	98.21	98.21	97.74	96.85	98.42	98.42	97.33	97.28
2005	99.20	24.66	99.10	24.42	100.00	100.00	98.65	98.38

Wind speed analysis of Kagbeni wind mast station

The following graphs show the annual, monthly and diurnal wind speed variation at 10 m and 20 m height above ground at Kagbeni wind mast station. The figures (2, 3, 4, 5) show that the pattern of wind flowing in different years is same. June is the mostly windy month over all months in a year. Wind starts blowing strongly in the morning at 9 am and reaches to peak about 2 pm. This diurnal variation of the wind speed has great importance than other variation for detail analysis.

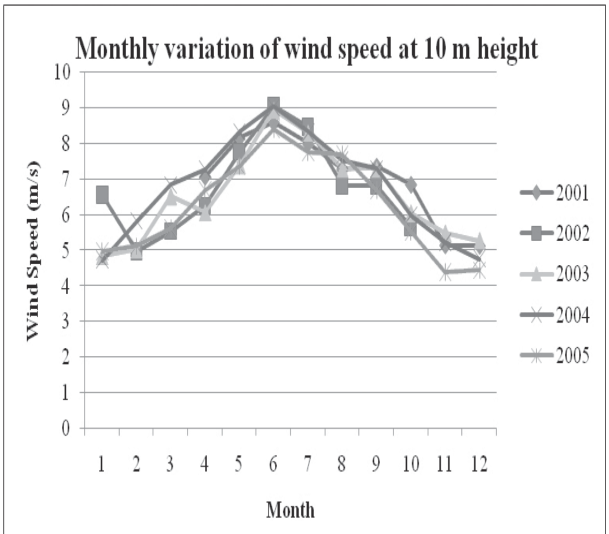

Fig. 2. Monthly variation of wind speed at 10 m height

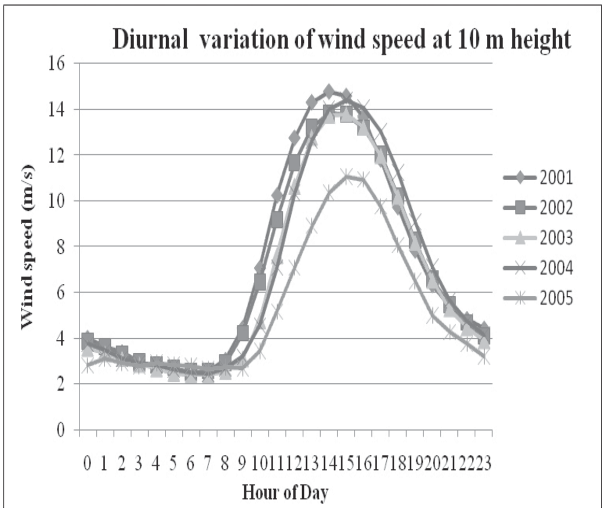

Fig. 3. Diurnal variation of wind speed at 10 m height

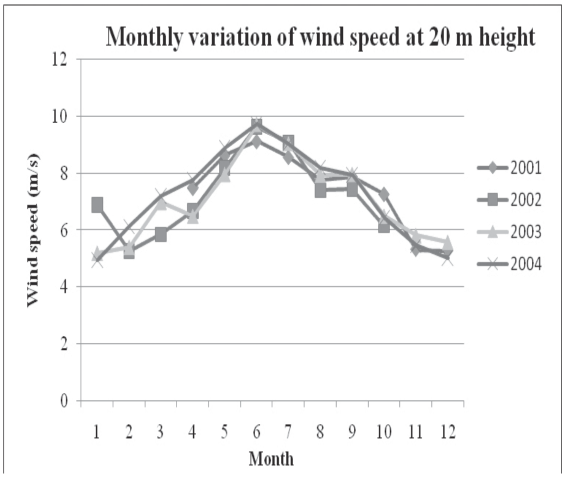

Fig. 4. Monthly variation of wind speed at 20 m height

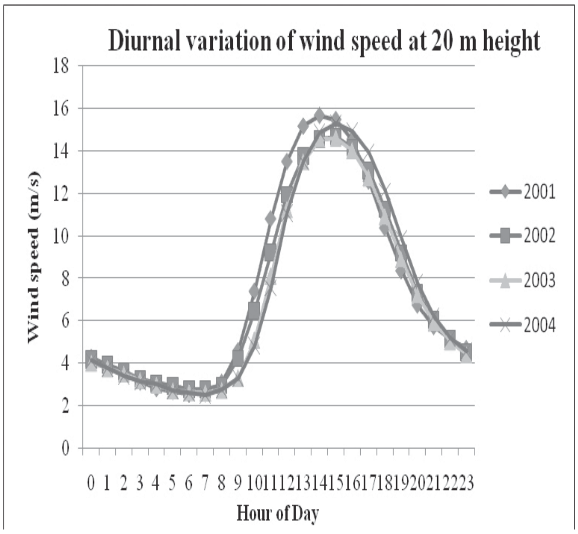

Fig. 5. Diurnal variation of wind speed at 20 m height

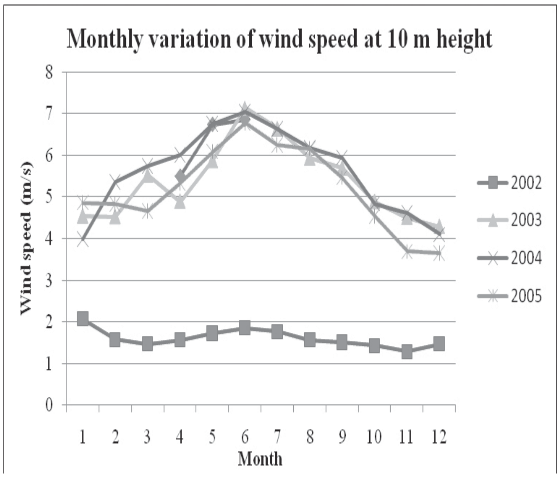

Fig. 6. Monthly variation of wind speed at 10 m height

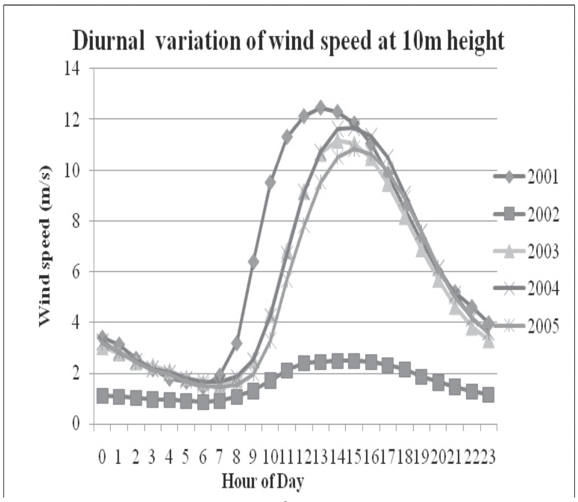

Fig. 7. Diurnal variation of wind speed at 10 m height

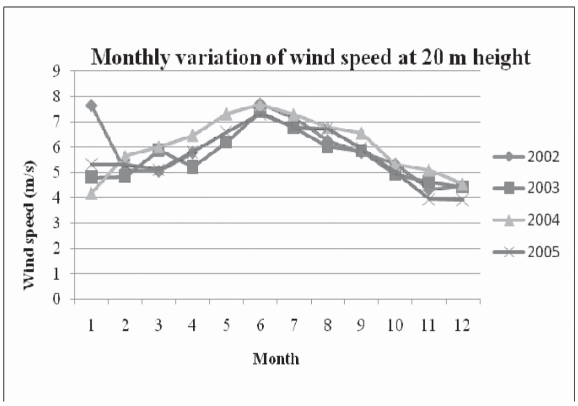

Fig. 8. Monthly variation of wind speed at 20 m height

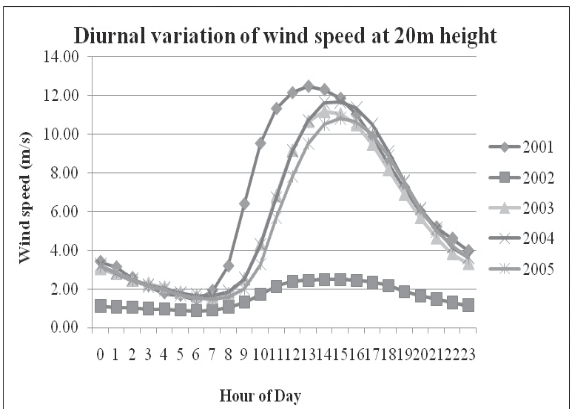

Fig. 9. Diurnal Variation of wind speed at 20 m height

Wind speed analysis of Thini wind mast station

The following graphs show the wind speed variation annually, monthly, diurnal, etc. in Thini wind mast station. In comparison to the Kagbeni wind mast Thini mast has a lesser windy. The wind speed at 10 m height in 2001 has found to be unrealistic as comparison to others years, but the cause behind it is unknown.

Result from WRPLOT

The average wind speed in hourly basis has been obtained from the arithmetic mean of the all hourly wind speed data but the direction is a vector quantity and thus direct arithmetic mean does not represent the true wind direction for the reference year. This reference year wind speed and direction is then loaded with WRPLOT software to obtain the wind rose for this year.

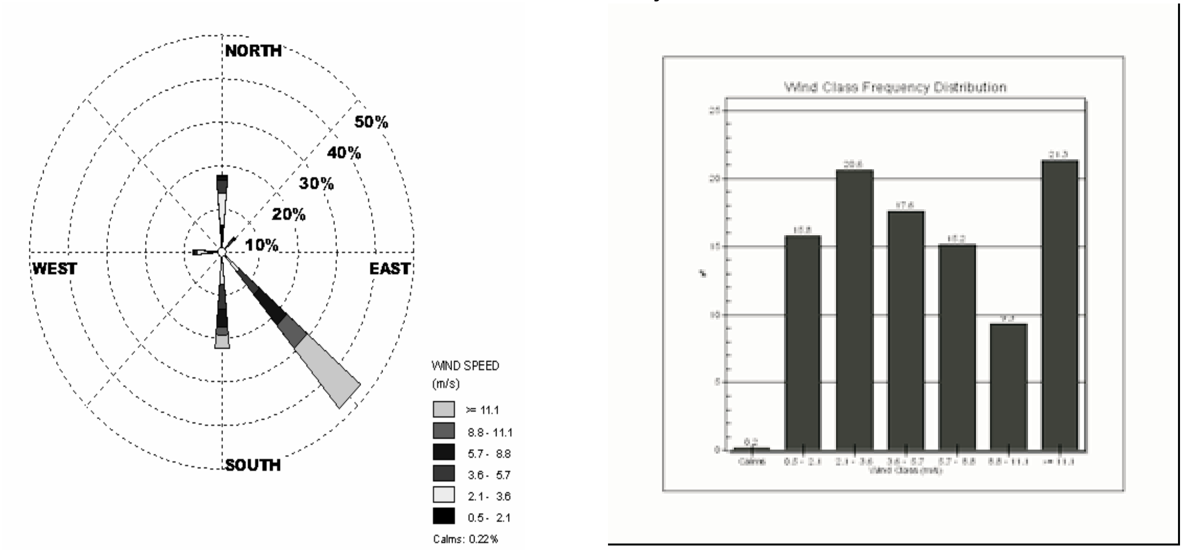

Fig.10. Wind rose and frequency diagram for reference year at Kagbeni

Fig. 10 shows wind rose diagram of Kagbeni wimd mast station. This wind rose shows the prevailing direction in Kagbeni is from the southeast direction. Wind blew from southeast about 45 % of the time and rest of the wind blows from north and south direction. This shows that the major consideration should be given to the south east direction wind speed in siting turbine.

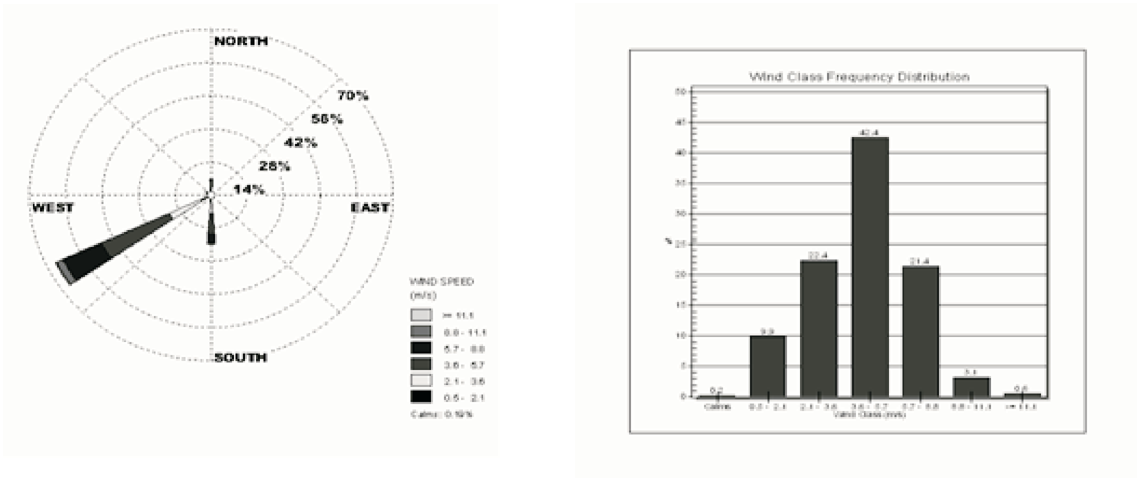

Fig. 11. Wind rose and frequency diagram for reference year at Thini

The rose diagram of the Thini wind mast (Fig. 11) illustrates that the major portion of the wind blows from the south west direction and small portion of wind blows from north and south direction.

Wind Resource Grid and Wind Map

With the help of WAsP , wind resource grid map of the site has been prepared and which shows the values of weibull parameters at all the grid points and thus a wind map for this site has been prepared showing the wind speed, wind power density ,shape and scale factor of the weibull parameters.

Wind resource grids have been prepared with the resolution of 150 m and total 4745 grid points, which contain the suitable area for wind farm as result obtained from GIS and site suitability analysis. The weibull parameters, mean wind speed and wind power density has been obtained and on the basis of their values, the wind mapping for site have been done. The map shows that the wind speed varies from 2.72 m/s to 44.51 m/s. WAsP is known to over predict the wind speed in complex terrains. Here also, the hills and mountains with steep slope has higher elevations, hence WAsP show higher wind speed in the slopy lands, but it may not be true in this case because the wind flow pattern in riverbank is mainly due to the cause of channelized flow.

The power density map prepared from WAsP in Fig. 12 show the distribution of wind power density in the study area. This varies from 0.23 kW/m^2 to 173.27 kW/m^2. The topography with higher elevation has higher wind speed and higher wind power density.

Open wind results

This software was used here for the optimization purpose of the wind farm. The total number of 25 wind turbines (S52-600 kW) were allocated for the installed capacity plant size of 15 MW. The wake loss was calculated from the Eddy Viscosity Model of this software. With 10000 numbers of iterations and to maximize the gross annual energy production from selected location, the optimization has performed with openWind. The gross annual energy production from the wind farm is 63.58 GWh and net annual energy production is 41.66 GWh with the array losses 1.30 % and average capacity factor of wind farm is 31.68 %. A sketch of the wind farm layout has been prepared with the two substations. Substation 1 collects the energy generated from 12 turbines whereas substation 2 collects power generated from next 13 turbines.

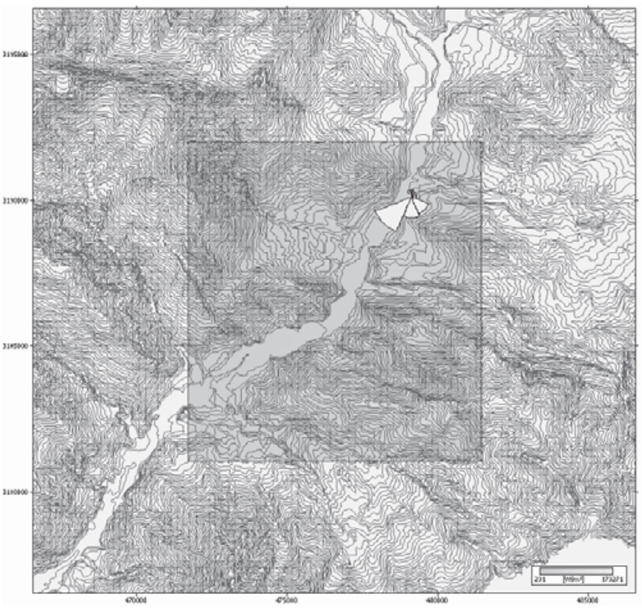

Fig. 12. Wind speed and power density map.

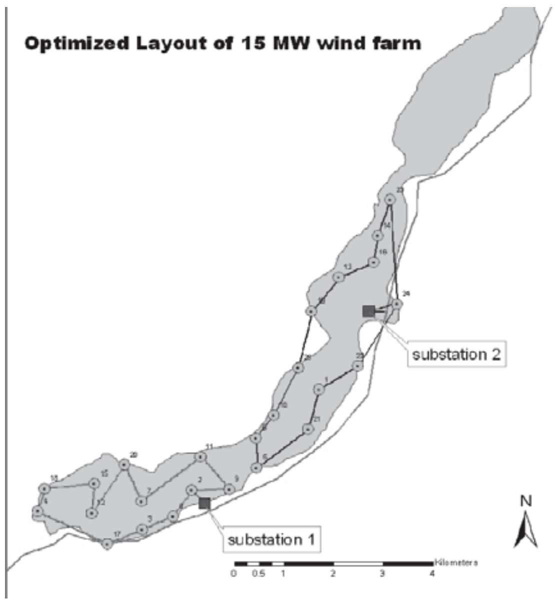

Fig. 13. Optimized wind farm layout

Financial analysis

The net available energy from wind farm is 41.66 GWh and gross energy is 63.58 GWh. Net energy is about 65.5% of the gross energy. Here, an attempt has been made for financial analysis, considering different losses scenario for estimation of NPV and IRR at different tariff rate by several cost considerations [4]. With the net available energy of 41.66 GWh and at different tariff rate, the NPV and IRR have been shown in Fig. 14, which shows that at the current electricity price at NRs 3.8, NPV of the wind farm has been found to be negative and hence this project is financially unfeasible to get MARR of 16.1%. Similarly, the NPV and IRR at different tariff rates are computed and increasing the tariff rate beyond NRs 6, the project seems to be financially feasible. Hence, the tariff rate plays very significant role for the financial feasibility of the project.

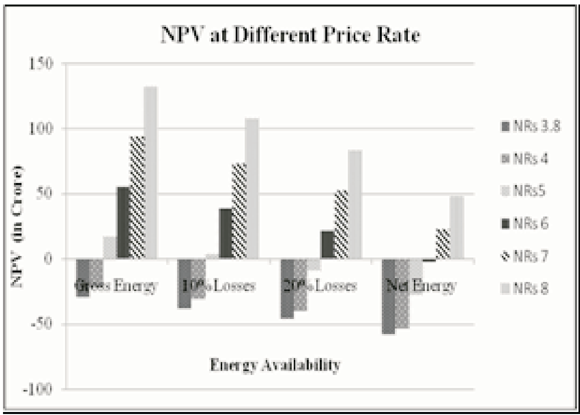

Fig.14. NPV at different tariff rate

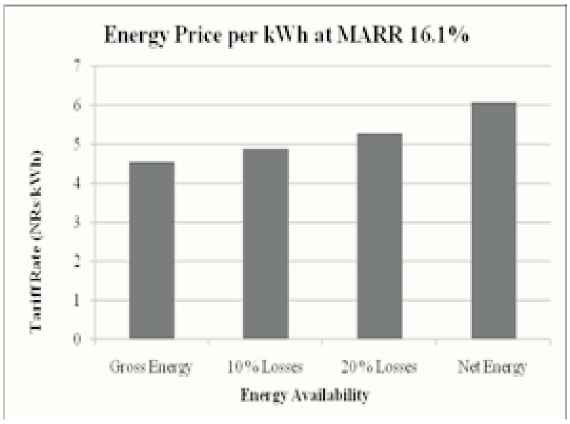

Fig. 15. Energy price per kWh at MARR 16.1 %

Average annual wind speed and power density at Kagbeni wind mast have been found to be 7.95 m/s and 852 W/m^2. Wind map in study site shows the variation of wind speed and wind power density on site varies from 2.72 m/s to 44.51 m/s and 0.23kW/m^2 to 173.27kW/m^2.

Optimized layout of a 15 MW wind farm that comprised of twenty five S52 -600 kW turbines, developed by openWind software yields annual gross energy 63.58 GWh, and net energy 41.66 GWh with gross capacity factor 31.68 %.

Preliminary analysis shows that the average cost per kWh of wind energy generated from wind farm would be NRs 4.57 to 6.10 under different energy availability scenario. The site is technically feasible for wind farming. However there is no possibility to develop such large scale wind farm at present because of site accessibility issues.

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