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Techno-Economic Feasibility of Wind Power Farms in India

Dipen Paul, Poorva Pitke, Purva Karmarkar

***Abstract**: Wind is a powerful and renewable source of energy that flows in every corner of the surface of the planet. As the world moves towards renewable and alternate energy sources, the potential of wind energy has been recognized and methods to use it to its maximum potential are being explored. India has been harnessing wind power over the years, but only lately, it has sent an ambitious target of achieving 60 gigawatts (GW) of wind installed capacity by 2022. The government has issued several tenders to invite private players or Independent Power Producers (IPPs) to develop wind energy projects. Many foreign investors and the Private Equity players have shown interest in investing in this growing renewable energy (RE) market in India. However, developing a wind project comes with lot many challenges as compared to any other RE project. These challenges range from land availability to seeking grid connectivity approvals and evacuation of the power. Along with this, the current reverse bidding process for the tariffs, have made the per unit tariffs to cost as low as INR 2.4. Hence, it is important to consider the technical and commercial feasibility of the project to function at these tariffs. This paper studies the current scenario of wind energy in the Indian market and analysis the potential for the development of wind projects. It also analyses the technical and commercial feasibility of the project by assuming a 300 MW project, having INR 2.5 as tariff, using Wind Resource Assessment (WRA) and Financial Model.*

***Keywords:** Clean Energy, Renewable Energy, Sustainability, Wind Energy, Wind Resource Assessment.*

I. INTRODUCTION

Sustainable development is said to rely on three pillars: the economy, society, and environment. However, there is another important factor that is a deciding factor is progress on sustainable development: energy. Sustainable development is intimately associated with the availability of energy. Higher the amount of energy available, the higher is the standard of living. Sustainable energy essentially means a continuous as well as energy-efficient supply which is beneficial to the environment as well as the society [1]. In a country like India, which has been facing the issue of lack of availability of sufficient energy supply from the conventional sources, a change in the way energy is produced is necessary to bridge this gap. Small Scale power generation has played a vital role in many rural areas in the country [2]. Hence, the development of alternative sources of energy like wind and solar energy is necessary for the Indian economy for both the supply side considerations as well as their environmental and social benefits [3]. Affordable renewable energy has become a key criterion for the long-term economic development of this country. India is fortunate to have strong wind currents that are needed for energy production in several regions across the country. Wind energy utilization is linked with several different criteria of localization and addressing it with a thorough study to ensure that it is tandem with infrastructure, socio-economic systems, and ecosystems are important [4]. India is blessed with a long 7500 km coastline and many hilly areas with high wind intensity, enabling a significantly large wind energy potential for the country. Hence, it can harness both Onshore and Offshore wind energy. India first tapped into this rich source for energy in the 1980s. However, development in this sector did not gain momentum until the mid-2000s. Over the last decade, wind energy has become the largest contributor to renewable energy capacity additions in India [5]. With the growing population, comes a higher demand for energy and resources resulting in an increased need to generate more energy (electricity). The world today is looking at green & clean power production and India aims at 175 GW installed renewable energy capacity by 2022 [6]. With wind energy to contribute 60 GW, the government has been issuing tenders for private developers to install wind energy projects. The current capacity of installed wind energy in India is 34.6 GW [7]. The following study is conducted to check the techno-economic feasibility of wind power generation in India for large projects. Before any project is set up, during the planning stage, the techno-economic feasibility assessment for any energy system is of utmost importance for a system to perform well at a given location. The study of a project is divided into two aspects: its technical aspect and the monetary or economic aspect. The technical aspect of a design refers to designing the project to optimize the parameters and to maximize output and efficiency. The economic aspect helps in understand the economic requirements and the use of finances for the given project [8]. The technical and commercial feasibility assessment of any technology starts with the evaluation of all the technical parameters and their appropriateness followed by the commercial or financial capability and other financial benefits and incentives of that technology for it to get efficiently distributed. This study has to be carried out during the planning stage itself to not only understand the practicality of the planned project but also to get optimum benefits from the finances, land, technology and wind power available at the chosen project site. This study has been carried out using Wind Resource Assessment (WRA) as a method to analyze the techno-commercial feasibility of a 300 MW sample wind project to develop a financial model for the project and infer the techno-commercial viability of the same.

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* Correspondence Author

Dipen Paul*, Assistant Professor Department of Management, Symbiosis International (Deemed University) Pune, India.

Poorva Pitke, Assistant Manager, Department of Mechanical. Symbiosis International (Deemed University) Pune, India.

Purva Karmarkar, Department of Environmental Science, Symbiosis International (Deemed University) Pune, India.

II. OBJECTIVES

The technical and economic aspects of any project are interlinked, and the best combination of both the factors should be calculated and used for the project. The technical feasibility for a particular wind farm can be analysed by studying the wind flow and wind potential data in India. Based on the obtained generation number from the technical feasibility, the commercial viability can be assessed. It can be calculated by running a financial model based on the obtained generation number.

The objectives of the study are:

1) To analyse the technical and commercial viability of an onshore wind project in India.
2) To determine the optimal returns based on the generation numbers obtained from running a model for an assumed wind project in India, and to analyse if the returns will invite more IPPs and investments in this sector.
3) To analyse if the low tariffs, resulted from the competitive bidding, can sustain and be commercially viable, leading to an increase in wind capacity in India, in the upcoming years.

III. METHODOLOGY

The Wind Resource Assessment (WRA) technique was used in this study to calculate the capacity of the project and a financial model was used to study the economic feasibility of the given project. The methodology for this study can be given as follows:

1. Wind Measurement and Data Collection: Meteorological data for the particular site or location is collected from the installed tubular towers by the National Institute of Wind Energy (NIWE). The data like, ground elevation, wind speed, turbulence, wake effects are collected for past years.
2. Validation of the Data: To eliminate any error and inefficiency in the data collected and in order to ensure more accuracy, the following formula is used to correct the wind speeds:

   $$V_{corrected} = V_{observed} / (0.095* TI + 0.992)$$

   The inefficiencies and errors in the data are mostly due to human error, equipment failure or mast shadow effects [14, 15].
3. Wind Resource Characteristics: The characteristics that are recorded include the annualized average and seasonal average wind speeds, data recovery, Weibull parameters, air density and wind power density, shear exponent, turbulence intensity [16].

   The annualized mean speeds take into consideration the repeated months in the data record and weigh each calendar month by its number of days. The wind shear exponent represents the rate of increase of the wind speed with the height above ground in accordance with the power law. The fluctuations in the wind speed are measured by the intensity of turbulence measures which are recorded at 10-minute intervals by the anemometer [17]. The Weibull function is an analytical curve which shows the wind speed in terms of frequency distribution and the observations in specific wind speed range [18].
4. Hub Height: Extrapolation is done to the mean wind speed at each mast to the actual or anticipated hub height, using the power law equation. The hub heights used today are 120 m [19].
5. Estimation of Long-Term Energy Production: Energy production over the long term or for the entire project life, are estimated using CFD software. This helps realizing the revenue generation that can be expected from the project and the economic viability of the project can be determined [20].
6. Uncertainty Analysis: There are elements of uncertainty linked with the wind speed and energy production estimates that are calculated from the above study. The uncertainty is defined as the standard error for a normal probability distribution. All uncertainties are computed as weighted averages based on the number of turbines associated with each of the mast [21].
7. Calculation of WRA: The Wind Resource Assessment was carried out in the following way [22]:

8. Calculation of Financial Parameters

a. Internal Rate of Return: The Internal Rate of Return gives the Return on Investment for any project. It calculates only the internal factors of a project to estimate the cost and return period for any project. It can be calculated using the following formula [23]:

$$IRR = [Cash\ Flows/(1 + r)^t] – Initial\ Investment$$

b. Net Present Value (NPV): Calculation of NPV gives a comparison of the cash inflows and outflows of a project and helps in the estimation of projected profit or loss from a project. For this study, NPV was calculated using the following formula [24]:

NPV = Present Value Cash Inflows / Present Value Cash Outflow

c. Debt-Service Coverage Ratio (DSCR): DSCR explores the ability of an entity to generate enough income to cover its debt payments. The higher the ratio, the more profitable is the project. DSCR was calculated using the following formula [25]:

DSCR = Net Operating Income / Total Debt service

On the basis of the findings of the parameters given above, the capacity and feasibility of the project were studied and the profitability of investing in this project was analysed.

IV. CURRENT SCENARIO OF WIND POWER POTENTIAL IN INDIA

India has a tremendous potential to harness Wind Energy. It has a large coastline, making states like Tamil Nadu, Karnataka, Gujarat, Andhra Pradesh to have the potential of more than 4 GW, Gujarat itself having huge potential of more than 5 GW.

Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka are High wind states [26]. Wind projects have been developed in these states for years. The intensity of wind differs from time to time and from season to season. It also differs across different regions. Apart from this, wind projects demand the availability of several acres of land, at the right location of desired wind speed.

This has been the biggest challenge that the entire world is facing when it comes to wind energy. Pertaining to this challenge, the high wind states, except for Gujarat, have utilized all the available wind locations, which give a favorable plant load factor. The other challenges like evacuation facilities etc. also make the commercial viability of the projects on certain locations, doubtful. This has led to a saturation of potential in high wind states, except for Gujarat, with states like Madhya Pradesh, Maharashtra and Rajasthan being the major focus to develop the wind energy projects. Maharashtra, Madhya Pradesh and Rajasthan are Medium Wind states but the wind potential has been saturated for almost all of them [27]. Lack of sufficient land and saturation of the available land have proven to be a major hindrance to the expansion of wind energy projects. Wind energy is intermittent and variable in nature of wind energy. In spite of this, it can be tapped to generate electricity for meeting a part of the population's energy demand [28].

The below table shows the potential of the states, considering the hub height 100 m Above Ground Level (AGL) [29]. The magnitude of the wind potential has also been mentioned, based on the mean wind speed at 100 m AGL, in that particular state. Gujarat has the highest wind energy potential, given to its longest coastline. The installed capacity as of September 2018 has also been mentioned, to derive the percentage of used potential and to indicate the available potential. India has a high concentration of wind and tremendous potential to harness this resource. However, there is a disparity in the availability of wind across different regions in the country. Apart from the mentioned states, other sites have negligible wind potentials. As mentioned above, the various challenges and issues have made the potential to develop more wind projects and harness more wind energy, saturate. Hence, with the new technology, the hub heights now installed are 120 m to 140 m AGL [30]. This increases the potential, making it viable to develop more wind energy projects in India. The following table gives a better understanding of the state-wise wind energy potential in India [31]:

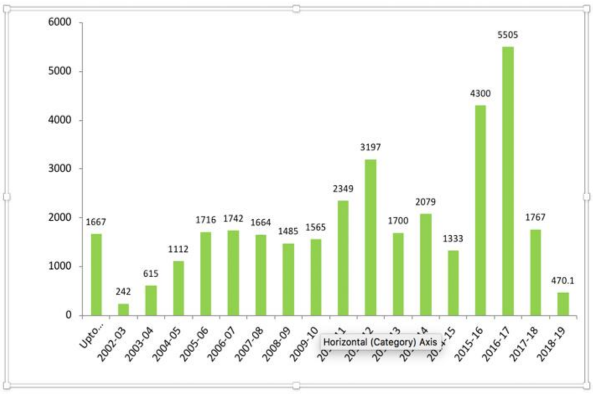

Fig. 1. Wind Energy Capacity Addition

Table- I: Wind Potential - State Wise

State	Potential (MW)	Magnitude of the Potential	Installed Capacity (MW) As on 30.09.2018	Percent Utilisation (%)
Rajasthan	5050	Medium	4301	85.17
Maharashtra	5961	Medium	4784	80.25
Gujarat	35071	High	5803	16.55
Madhya Pradesh	2931	Medium	2523	86.08
Andhra Pradesh	14497	High	4020	27.73
Karnataka	13593	High	4568	33.61
Tamil Nadu	14152	High	8335	58.90
Uttar Pradesh	1206	Low	Not utilised	0.00
Jammu & Kashmir	5685	Medium	Geo-political issues. Not favourable for developing projects	
Others	NA	Negligible	128	

V. TECHNICAL FEASIBILITY

To analyse the technical feasibility of a particular site or location, where the wind project is desired to be developed, a Wind Resource Assessment (WRA) is conducted.

The Wind Resource Assessment (WRA) is the most vital part of setting up a wind project. It provides information on wind speeds, wind strengths, turbulence factors, and the energy content resulted from them [32]. WRA also enables the appropriate selection of wind turbines, which can ensure maximum generation in that particular location. Also, WRA helps to arrive at annual generation numbers, making it able to predict the revenue generation and the returns. This helps the investors to decide whether to go ahead with the investment and also what returns to expect on the money they invest [33]. To arrive at the generation numbers and analyze the performance of the wind project, over a period of time, there are many software or models based on Computational Flow Dynamics (CFD) or on the boundary layer theory. These models take into account factors like elevations, wind measurement mast, sensor heights, wake effects etc.

VI. OBSERVATION AND RESULTS

Using the methodology as mentioned above and considering the current scenario of wind power in India, analysis was carried out for a 300 MW wind project,

located in Gujarat, having bid tariff as INR 2.50. It has been observed in the past years that the wind energy tariffs have been falling. Taking this into account, a low tariff is considered to analyse if the falling tariffs in today's scenario are commercially viable or not. The data that is used has bene assumed in an appropriate manner for the study. A thorough study of the wind characteristics was carried out using WRA and running wind assessment model. The data obtained is as follows:

Table- II: WRA Output

Parameters	
Measurement Height (m)	100
Mean Wind Speed (m/s)	7.01
Annualized Speed (m/s)	7.01
Data Recovery (%)	100
Annualized Wind Shear Exponent* (Heights)	0.201
Turbulence Intensity @15 m/s Speed Bin	0.039
Annual Weibull Parameters (A/k)	7.97 m/s / 2.93
Annual Prevailing Wind and Energy Direction	WSW / WSW
Energy-Weighted Air Density (kg/m³)	1.152
50-m Wind Power Density (W/m²)	180
80-m Wind Power Density (W/m²)	240

*Only Speeds > 4 m/s used in calculation

Running the WRA model gave the above data. This data is used to understand the wind characteristics in the chosen study area. The study of these characteristics helps in choosing the appropriate wind turbines amongst the available options to study further. Based on the above-obtained data, the generation numbers are estimated and a wind turbine of 2.5 MW/ machine is selected for the study. For a 300 MW project, it is calculated that 120 turbine machines shall be required [34].

Table- III: WRA Output

	Details
Rated Capacity	300 MW
Turbine Model	(2.5-MW) 131-m Rotor Diameter
Hub Height	120 m
Number of Turbines	120
Array-Average Free-Stream Speed	7.10 m/s
Gross Annual Production	900.5 GWh/yr
Plant, Wake, and Total Losses	Plant – 12.8%; Wake – 8.4%; Total – 20.1%
Net Annual Production	724.7 GWh/yr
(Plant Load factor)	-41.00%
P90 Production (Years 2-20)	630.5 GWh/yr
(Plant Load Factor)	-37.50%
P90/P50 Ratio	0.87

The gross annual generation of 900.5 GWh/year is estimated. The Net Annual Production for P50 (average annual energy output) is 724.7 GWh/year. Plant Load Factor (PLF) calculated is 41.%. The energy output at P90 is estimated to be 630.6 GWh/year. These parameters give an idea about the technical aspects of the wind turbines. These technical parameters are further used as an input for developing and running a financial model to calculate the economic value of the turbines in terms of Internal Rate of Return (IRR) and equity IRR. These values can then be used to study the feasibility of wind projects. For all the financial calculations, values corresponding to P50 are considered.

VII. FINANCIAL ANALYSIS

Project Capacity, Performance Detail & Expenses:
For any project, along with technological feasibility, understanding its financial feasibility is very imperative. Table 4 studies the capacity and performance of the project understudy to get a better understanding of the project details and the ensuing expenses for setting up and running the plant. For a project with a capacity of 300 MW and an estimated life of 25 years, the total project cost is estimated to be INR 1459 Cr. The Operation and Maintenance (O&M) cost is projected to be 1.5% of the project cost. A capacity utilization factor of

Table- IV: Project Details and Performance Parameters

CAPACITY			
Plant Capacity		300	MW
CAPITAL COST			
Capacity of WTG		2.50	MW / WTG
Unit EPC Cost	Rs.	11.50	Cr. / WTG
EPC Cost per MW		4.60	Cr. / MW
Land Cost	Rs.	5.00	Lacs per acre
Land Requirement		5.00	acres / WTG
Land Requirement per MW		2.00	acres / MW
Unit Land Cost	Rs.	0.1	Cr. / MW
Unit Development Cost	Rs.	4.70	Cr. / MW
Project Cost	Rs.	1410.00	Cr.
Additional Cost	Rs.	49.00	Cr.
Total Project Cost	Rs.	1459.00	Cr.
Project Cost per MW	Rs.	4.86	Cr. / MW
OPERATION & MAINTENANCE			
O&M Cost		1.50%	of Project Cost
Escalation in O&M Cost		4.00%	Annually
PERFORMANCE PARAMETERS			
Capacity Utilization Factor		41.00%	
Annual Performance Deration		0.53%	per year
Auxiliary Consumption		0.35%	
Project Life		25	Years
TARIFF			
Feed-In Tariff	Rs.	2.50	per kWh
VIABILITY GAP FUNDING			
Unit Viability Gap Funding	Rs.	0	Lacs per MW
Total Viability Gap Funding	Rs.	0.00	Cr.

41% is estimated along with an annual performance duration of 0.53% per year and auxiliary consumption of 0.35%. To understand the feasibility of a project of this scale, financial parameters are given in Table 5 as follows:

Table- V: Financial Parameters

Financial Parameters	
Parameter	**Value**
Debt Fraction	70% of Capital Cost
Moratorium Period	18 Years
Interest Rate of Loan	1 Year
Insurance Cost	0.10% of EPC Cost
Working Capital	1 month O&M Expenses + 2 month Energy Expenses
Interest on Working Capital	10% pa
Rate of S.L. Depreciation	4% for all years
Rate of accelerated Depreciation	80% pa
Corporate Tax	33.45%
Minimum Alternate Tax	21.34%
Discount Factor for calculation	10% pa
Depreciation	SL
Tax Depreciation	7.69%

Taking the parameters as given in Table 5 into consideration, the internal rate of return for the given project was calculated. It was found that Project IRR is 16.01% and the Equity IRR is 26.31% for the given project. From the financial parameters, the Net Present Value (NPV) and Debt-Service Coverage Ratio (DSCR) were estimated. The results for the same as are given in Table 6 below:

Table- VI: Results

Results	
Project IRR	16.01%
Project NPV	INR 587.71 Cr.
Equity IRR	26.31%
Equity NPV	INR 439. 83 Cr.
Average DSCR	1.84

The NPV for the project was found to be 587.71 Cr. And the Equity NPV was calculated to be. 4439.83 Cr. The DSCR was calculated and found to be 1.84. This indicates that the investment in this project will be profitable for investors with a good margin. This shows that the project is not only feasible but also a good investment as per the above calculations.

VIII. CONCLUSION

The Renewable Energy Market in India has a lot of Private Equity Investors interested in investing in wind energy projects. However, due to the high tariffs and installation and O&M costs, the wind energy market is not developing at its fullest potential. This study was carried out to

A detailed study of the wind potential of various states in India, WRA output, details and parameters of the project under study and its financial parameters was carried out.

From the above calculations, the Gross Annual Generation of the plant was projected to be 900.5 GWh/year. Financial analysis of the data showed that the IRR equity is 26.31% and the DSCR is 1.84. At the above-considered generation numbers and the lower tariff, the returns are favourable for the investors. An increasing number of investors are bound to be interested in investing in profitable projects such as these. Hence, this sector shall continue inviting more and more investments in this sector. India, therefore, has a good chance of achieving its target of 60 GW installed renewable energy capacity, by the year 2022.

However, effective implementation of large scale wind energy plants requires taking suitable policy measures taking into consideration the institutional barriers, local agreeability, and other collective factors. This calls for collective efforts from subject experts and policymakers for effective implementation of the projects to ensure maximum benefits to the environment, the economy as well as the society.

The extent of these parameters on the rate of investments should be explored through further study. Changes in other parameters and their effects on the costs and profitability of wind energy projects in India need to be studied further.

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AUTHORS PROFILE

Dipen Paul is an Assistant Professor in the Faculty of Management at the Symbiosis Institute of International Business which is a constituent of the Symbiosis International (Deemed University) Pune. He received his BE in Chemical Engineering and MTech in Energy Technology He has around 7 years of experience in the education sector and one year in the industry. His research interest areas are from the field of Renewable Energy, Alternative Energy and Sustainability

Poorva Pitke Education: B.E Mechanical, MBA (Energy & Environment) Currently working at Spring energy as Assistant Manager Projects: Involved in managing utility scale solar projects pan India

Purva Karmarkar Education: M.Sc. Environmental Science, MBA (Energy & Environment)